Hawaiian Hoary Bat Guidance for Wind Energy Project Habitat Conservation Plans

Endangered Species Recovery Committee
and
State of Hawaii Department of Land and Natural Resources
Division of Forestry and Wildlife

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DOCUMENT DISCLAIMER

This document is not written to be, nor is in any way intended to serve as a policy or rule making instrument. The guidance put forth in the following sections is based on current best available science and data (as of the date posted on the cover page) and input from the Endangered Species Recovery Council (ESRC). This should be considered a "living" document that will be revised as data and results of future studies become available. The methods for monitoring Hawaiian Hoary Bats described within are suggestions to which applicants are not bound. Applicants are welcome to create their own monitoring methods and / or protocol, but such deviations from the guidance provide here will need to be fully justified within draft Habitat Conservation Plans and mitigation plans.

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I. INTRODUCTION

PURPOSE

The Hawaiian hoary bat (*Lasiurus cinereus semotus*) is listed as endangered under state and federal law. The operation of wind turbines in Hawaiʻi may result in "take" of the Hawaiian hoary bat. Under state law, take of endangered species is prohibited but may be permitted by the Board of Land and Natural Resources (BLNR or "the board") under certain conditions if the take is incidental to, and not the purpose of, the execution of an otherwise lawful activity, and when accompanied by an approved Habitat Conservation Plan (HCP). The Department of Land and Natural Resources (DLNR), Division of Forestry and Wildlife (DOFAW) provides technical assistance to project developers and landowners in developing, reviewing, and monitoring HCPs and oversees compliance. As endangered species in Hawaii are also protected by the Federal Endangered Species Act (ESA), DOFAW works with the US Fish and Wildlife Service (USFWS) to develop a single HCP for each project.

The Endangered Species Recovery Committee (ESRC) was established under Hawaii Revised Statutes, Chapter 195D (HRS 195D) in section 195D-25 (§195D-25) to serve as a consultant to the BLNR on matters relating to endangered, threatened, proposed, and candidate species. The ESRC's required duties include the review of all applications and proposals for HCPs and Incidental Take Licenses (ITLs), for which they recommend approval, amendment or rejection to DOFAW and BLNR. The Committee is tasked with reaching a decision based on a full review of the best available science and reliable data, while taking into account the cumulative effects of the actions proposed by HCP applicants on the recovery of the affected endangered, threatened, proposed, or candidate species. The ESRC is also required to consult with persons possessing expertise in areas or subject matter the Committee may deem appropriate and necessary to exercising its duties.

Wind project applicants for new HCPs, or major amendments of existing HCPs, must develop and receive approval of their HCP or amendment to secure an ITL from the BLNR. This guidance document intends to provide information or examples (and specific recommendations where necessary) from studies or previous applicant experiences that will assist applicants to meet the requirements of HRS 195D and facilitate HCP review by DOFAW and USFWS and approval by the ESRC and the BLNR. A key goal of this document is to provide consistency and transparency for these actions.

A complete account of the requirements for the issuance of an ITL under state law is provided in HRS 195D. This document does not serve as a comprehensive guide to all of these requirements and is not intended to be a set of specific requirements that need to be followed. It is understood that portions of this document may not be applicable for all situations and alternate methods or procedures may be proposed by HCP applicants with detailed justification. The guidance provided here may likewise change based on in-progress or future research on the Hawaiian hoary bat and does not supersede a detailed analysis of take, avoidance or minimization measures, or mitigation under state (or federal) criteria. This document most importantly does not constitute state (or federal) rule-making.

A concise checklist of HCP requirements pursuant to HRS Chapter 195D is provided in Appendix 3. Specific requirements in HRS 195D for approval of an HCP include the following actions or provisions:

1) An HCP describes all the proposed activities of a project in sufficient detail to allow the DOFAW to evaluate the project's impact on the particular ecosystems, natural communities, or habitat within the planned project area (§195D-21(b)(2)(B)).

2) An HCP contains Contain objective, measurable goals, the achievement of which will contribute significantly to the protection, maintenance, restoration, or enhancement of the ecosystems, natural communities, or habitat types; time frames within which the goals are to be achieved; provisions for monitoring (such as field sampling techniques), including periodic monitoring by representatives of the department or the endangered species recovery committee, or both; and provisions for evaluating progress in achieving the goals quantitatively and qualitatively (§195D-21(b)(2)(G)).

3) The HCP shall provide for an adaptive management strategy that specifies the actions to be taken periodically if the plan is not meeting its stated goals (§195D-21(b)(2)(H)).

4) Minimization and mitigation of impacts:
   a) The HCP applicant, to the maximum extent practicable, shall minimize and mitigate the impacts of the take (§195D-4(g)(1)) to species of concern; and
   b) The HCP shall identify the steps that will be taken to minimize and mitigate all negative impacts, including without limitation the impact of any authorized incidental take, with consideration of the full range of the species on the island so that cumulative impacts associated with the take can be adequately assessed (§195D-21(b)(2)(C)).

5) Determination and establishment of likely impacts:
   a) The HCP will contain sufficient information for the board to determine with reasonable certainty the likely effects of the plan on any endangered, threatened, proposed, or candidate species in the project area and throughout its habitat and/or range (§195D-21(c));
   b) The HCP will identify the impact of any authorized incidental take, with consideration of the full range of the species on the island so that cumulative impacts associated with the take can be adequately assessed (§195D-21(b)(2)(C)); and
   c) The HCP will take into consideration the full range of the species on the island so that the cumulative impacts associated with the take can be adequately assessed (§195D-4(g)(5)).

6) Provision of benefits:
   a) The HCP will increase the likelihood that the covered species will survive and recover (§195D-4(g)(4));
   b) The cumulative impact of the project activity, which is permitted and facilitated by the license, will provide net environmental benefits (§195D-4(g)(8)); and
   c) The HCP will be designed to result in an overall net gain in the recovery of Hawai‘i's threatened and endangered species (§195D-30).

7) Avoidance of specific impacts:
   a) Requested take will not be likely to cause the loss of genetic representation of an affected population of any endangered, threatened, proposed, or candidate plant species (§195D-4(g)(9)); or
   b) The cumulative activities within the areas covered by the HCP will not reach the level that they cannot be environmentally beneficial (§195D-21(c)(1)); or

c) Implementation of the HCP will not be likely to jeopardize the continued existence of any endangered, threatened, proposed, or candidate species identified in the plan area (§195D-21(c)(1)).

Ultimately, this document is intended to assist applicants for new HCPs, or amendments to existing HCPs, by providing guidance based on best available information using existing research or science and applicable knowledge. A key goal of this document is to provide consistency and transparency for proposed project actions.

NEED

The state of Hawai‘i has established ambitious renewable energy goals with the adoption of Act 97 in 2015. This act requires “each electric utility company that sells electricity for consumption in the State” to establish a renewable energy portfolio standard of 100 percent of its net electricity sales by 2045. Onshore and offshore wind energy generation is expected to be a significant contributor for meeting Hawai`i’s renewable energy goal. Eight wind energy facilities were constructed between 2006 and 2012 and became operational with a cumulative capacity to provide approximately 200 megawatts (MW) of renewable energy for Hawai‘i. These eight facilities generated nearly 5% of the State’s electrical energy in 2019[1]. A ninth wind farm located in Kahuku on O‘ahu with a 24 MW generation capacity began operation in 2020.

The most recent solicitations issued by Hawaiian Electric in 2019 for new dispatchable renewable energy generation on the islands of O‘ahu, Maui, Moloka‘i, Lāna‘i, and Hawai‘i did not result in the selection of any wind energy projects for negotiation or development. Selected instead were several grid-scale solar photovoltaic (PV) plus battery and standalone energy storage projects on O‘ahu, Maui, and Hawai‘i. In June 2020, however, Hawaiian Electric issued a request for information from proprietors on O‘ahu, Maui, Moloka‘i, and Hawai‘i pertaining to lands that could be available for future renewable energy projects, including grid-scale wind.[2] In 2021, the State of Hawai‘i’s electric utilities (KIUC, HECO, MECO, and HELCO) individually and collectively met the interim statutory mandate of 30% renewable energy by 2020 under HRS 269-92 with a statewide collective Renewable Energy Portfolio Standard (RPS) of 36.3%. (pers. comm., C. Black, Hawai‘i State Energy Office). Numerous additional grid-scale renewable energy projects will be needed to reach the next interim targets of 40%, 70%, and 100% by the end of 2030, 2040, and 2045, respectively, along with widescale installation of rooftop solar PV and significant energy use reductions (pers. comm., C. Black, Hawai‘i State Energy Office).

Monitoring to date at wind energy facilities in Hawai‘i has shown that turbine operation during nighttime hours results in take of Hawaiian hoary bats, and that the numbers killed were higher than expected during the initial review of applications for incidental take of the species. Between 2014 and 2017 several authorized wind projects exceeded approved take levels. Based on fatality monitoring, applied statistical modeling, and considerations of indirect take that assumes additional losses through take of pregnant females, estimated take of Hawaiian hoary bats as of September 30, 2021, is 214 individuals (108 on O‘ahu and 106 on Maui) for currently permitted HCPs in Hawaii. Total allowed take under the conditions of these HCPs is 524 bats (296 on O‘ahu and 228 on Maui).

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[1] https://energy.hawaii.gov /wp-content/uploads/2020/11/HSEO_FactsAndFigures-2020.pdf

[2] The results of that request can be found at https://www.hawaiianelectric.com/clean-energy-hawaii/selling-power-to-the-utility/land-rfi

All projects that result in incidental take under HRS 195D must possess an approved HCP and associated ITL that specifies their permitted level of take. State law is violated when take occurs without a valid ITL. An HCP integrates development activities with species conservation and must be designed to ensure that licensed activities do not reduce the likelihood of survival and recovery of at-risk species. This is accomplished through the establishment of impact avoidance and minimization measures, as well as mitigation efforts to offset take, all of which are laid out in an HCP. Mitigation required under HRS 195D must a) be consistent with established recovery goals, b) provide a net environmental benefit, and c) increase the likelihood that this species will survive and recover from its reduced state.

Development of an HCP for the Hawaiian hoary bat is difficult because of a lack of published data pertaining to the ecology and life history of the species. These data are essential for designing an HCP that meets the requirements of HRS 195D. Among the six HCPs that have been approved for take of Hawaiian hoary bats by wind energy projects, the guidance provided, and the terms and conditions approved for essential components of each have varied considerably. Approved mitigation, minimization, and monitoring requirements, for example, have changed among HCPs as data pertaining to the ecology of Hawaiian hoary bats have become available. The scale and cost of mitigation has therefore been inconsistent, adding to the challenges faced by applicants seeking to develop HCPs that will meet the requirements for approval by the state. These challenges are unparalleled among the numerous endangered species for which incidental take is currently authorized or requested in Hawaiʻi. They are also a clear indication of the need for consistent guidance developed for Hawaiian hoary bats through a scientifically rigorous and publicly transparent process.

PROCESS

The ESRC, advisory to the BLNR and DLNR for HCP approval and management, has acknowledged the challenges and inconsistencies regarding HCPs and the Hawaiian hoary bat. At the request of the ESRC, a Hawaiian hoary bat workshop was held April 14 and 15, 2015, in Honolulu, Hawaiʻi to discuss issues related to the species' conservation with particular reference to guidance for agencies and applicants seeking to develop and secure approval of HCPs. Workshop participants included bat researchers from DOFAW, U.S. Geological Survey (USGS), U.S. Forest Service, University of Hawaiʻi, and U.S. Fish and Wildlife Service (USFWS), as well as government regulators, consultants, stakeholders, and the public. A second workshop was held on March 5 and 6, 2020, that included updates from research conducted in Hawaii and results and observations from operational experience at wind projects in the state. Researchers with experience at U.S. mainland wind projects also attended this second workshop and provided valuable information and perspectives. For details on the agenda and presentations at the workshop see the ESRC website[3].

Further input on a previous draft of this revised guidance document was provided by written comments from researchers, government regulators and members of the public. These comments and additional oral input were discussed during two ESRC meetings in 2020.

The current draft in hand, which is an update of the 2015 guidance document, was developed from the outcome of those workshops and ESRC meetings and new research, and is meant to serve as a "living document". The intent is that this draft will be revised and updated by DOFAW staff (with ESRC review and input) every five years, or as significant advancements are made in the

[3] https://dlnr.hawaii.gov/wildlife/esrc/meeting-archives/

understanding of Hawaiian hoary bat ecology and management. This guidance document is based on the best available science and may include peer reviewed papers, preliminary reports, and anecdotal data. It is recommended that this document be supplemented with other guidance, in particular the U.S. Fish and Wildlife Service HCP Handbook (USFWS 2016). The 2021 revision of the Hawaiian hoary bat guidance document includes the following additions and modifications from the original 2015 document, along with numerous lesser changes:

- A revised Section III, Assessment of Take and Impacts for HCPs;
- Additional discussion to Section IV, Hawaiian Hoary Bat Take Avoidance and Minimization Measures, and Section V, Mitigation;
- Updates pertaining to research on Low Wind Speed Curtailment;
- A new Section VI, Adaptive Management;
- A summary of research initiatives currently underway in Appendix 1; and
- A checklist of HCP requirements pursuant to HRS 195D in Appendix 3.

A key element for continued status evaluation of the Hawaiian hoary bat, and subsequent updates to this guidance document, are annual reports provided by ITL-holders. Given the importance of these documents, uniformity of reporting is essential; a template is therefore provided for annual reports in Appendix 2.

II. BACKGROUND

ECOLOGY AND STATUS OF THE HAWAIIAN HOARY BAT

The endemic Hawaiian hoary bat, known locally as the ʻōpeʻapeʻa, is currently considered a subspecies of the North American hoary bat (*Lasiurus cinereus*). There is much debate regarding species level taxonomy of the Hawaiian hoary bat (e.g., Ziegler et al. 2016, Novaes et al. 2018, Teta 2019, Pinzari et al. 2020). Recent molecular studies indicate that hoary bats likely colonized the Hawaiian Islands through multiple events and suggest that two distinct subspecies of hoary bat may be present in Hawaii (Baird et al. 2015, Russel et al. 2015, and Baird et al. 2017). Local researchers and authorities, however, recognize the Hawaiian hoary bat as a single species (i.e., *Lasiurus semotus*) that is endemic to the Hawaiian archipelago (pers. comm., M. Gorresen and C. Pinzari). Although federal and state regulatory agencies may revise their listing determination in the future in light of new information, at the present time only one population of bat is considered present in Hawaiʻi. The laws of both agencies list the Hawaiian hoary bat as an endangered *subspecies* (NatureServe considers it "Imperiled") and it will therefore be considered as such in this document. In April 2015 the Hawaiian hoary bat was officially designated as the state terrestrial mammal (Senate Bill 1183), and is the only extant native terrestrial mammal in the Hawaiian Islands.

Data pertaining to Hawaiian hoary bat ecology, life history, and population limits are limited owing largely to its cryptic and solitary nature. Hawaiian hoary bat breeding has been documented on all of the main islands except for Niʻihau and Kahoʻolawe. Recent studieson the island of Hawaiʻi suggest that hoary bats there roost The most widely used maternity roosting tree speciesprimarily in woody vegetation exceeding 15 feet in height (Montoya-Aiona et al. 2020). Specifically, they found that for the 13 bats visible at perch sites, theyperch height ranged from 5 to 24 m (mean = 14 m) and mean forest stand canopy height ranged from 11 to 44 m (mean = 23 m).

Hawaiian hoary bat diet consists primarily of nocturnal flying beetles and moths (Jacobs 1999, Todd 2012, and Pinzari et al. 2019). Bonaccorso et al. (2015) found that Hoary bats in Hawaii may use several distinct core use areas while foraging, each with a mean size of approximately 25.5 hectares (63 acres) with little to no overlap areas. An individual bat may travel as far as 11 to 13 kilometers (6 to 8 miles) one-way per night to forage (Jacobs 1994 and Bonaccorso et al. 2015). Additional discussion on core use area is provided in Section IV B. These descriptions may not be applicable for all the Hawaiian Islands.

The population status of the Hawaiian hoary bat is unknown and it is generally accepted that it is currently not feasible to determine an actual population estimate for a single island or the entire state. Understanding population status and specific habitat requirements of the species was identified as a primary data need for recovery of the species (USFWS 1998 and Gorresen et al. 2013). Occupancy modelling and genetic studies for the bat have been conducted to develop population indices and effective size estimates. effective population, however, does not necessarily equate to true population size (Gorresen 2008 and Gorresen et al. 2013). Although population estimates for the Hawaiian hoary bat are not currently available, one acoustics study suggests that bat numbers on the island of Hawaiʻi may be stable and potentially increasing (Gorresen et al. 2013). An exploratory population viability assessment (PVA) has been conducted to assist in evaluation of take impact has been conducted and is described in Section III.E.

Additional information on the ecology and status of the Hawaiian hoary bat can be found in the recent Programmatic Environmental Impact Statement for four wind projects in Hawaii (USFWS 2019).

Overview of Bats and Wind Energy

Increasing development of wind energy facilities has led to hundreds of thousands of bats killed each year nationwide due to collisions with wind turbines. As a result, wind power has become a significant threat to the continued survival of these species (Cryan 2011).

Bat mortality at wind facilities is well-documented throughout the U.S., most involving migratory tree-roosting species such as silver-haired, hoary, and eastern red bats (Johnson and Strickland 2003, Kunz et al. 2007, Arnett et al. 2008, and Cryan 2011). Arnett and Baerwald (2013) estimated that 650,000 to 1,300,000 bats were killed at wind facilities in the U.S. and Canada from 2000 to 2011. Hoary bats accounted for the highest proportion of fatalities at most continental U.S. wind energy facilities, with a national average of about 50 percent (Cryan 2011). As noted in the Introduction (Section IB), fatalities of the Hawaiian hoary bat are low compared to mainland fatalities, but they do occur within and potentially affect a likely small population of bat. Most fatalities at mainland facilities occur between July and September during fall migration, with another smaller peak of fatalities documented during spring migration (Cryan 2011).

Bat fatality rates vary by facility with a national average estimated as approximately 12.5 bats per MW per year (Arnett et al. 2008). It is unclear what precisely is driving these fatalities but factors that may influence bat mortality at wind facilities include bat distribution, behavior (e.g., attraction to wind turbines), weather, turbine height, habitat degradation or loss, and/or facility siting near certain topographic or landscape features (e.g., proximity to forest or wetlands). Studies have indicated that tree-roosting bats may be attracted to turbines, potentially due to their resemblance to tall trees, and/or the expectation of resources, such as insect prey or potential mates (Kunz et al. 2007, Cryan et al. 2014, and Gorresen et al. 2015c). Foo et al. (2017) provided evidence that some species of bats (including hoary bats) do forage at wind turbines. Insects often amass on the downwind sides of natural and artificial windbreaks and tend to increase in number and density with wind speed (Lewis 1965 and 1969). At a wind project in West Virginia, Horn et al. (2011) found that weather patterns and nightly availability of insects may be reliable predictors of bat abundance. Other research has shown bats at wind turbines engaging in flight patterns that resemble those of bats swooping down to drink water, suggesting that bats perhaps perceive the smooth surface of the turbine as resembling water (McAlexander 2013).

Hawaiian Hoary Bats and Wind Energy in Hawai‘i

Records of take suggest there may be a seasonal pattern for Hawaiian hoary bat fatalities at wind facilities, although this pattern is not as pronounced as on the continental U.S. (Figure 1). Studies indicate that the Hawaiian hoary bat completes a seasonal altitudinal migration within a time frame similar to bats in North America (Gorresen et al. 2013; Bonaccorso et al. 2015), but there are still many questions surrounding timing and whether bats migrate on all islands regardless of maximum elevation, or if they migrate to a lesser extent or not at all on islands with lower elevations.

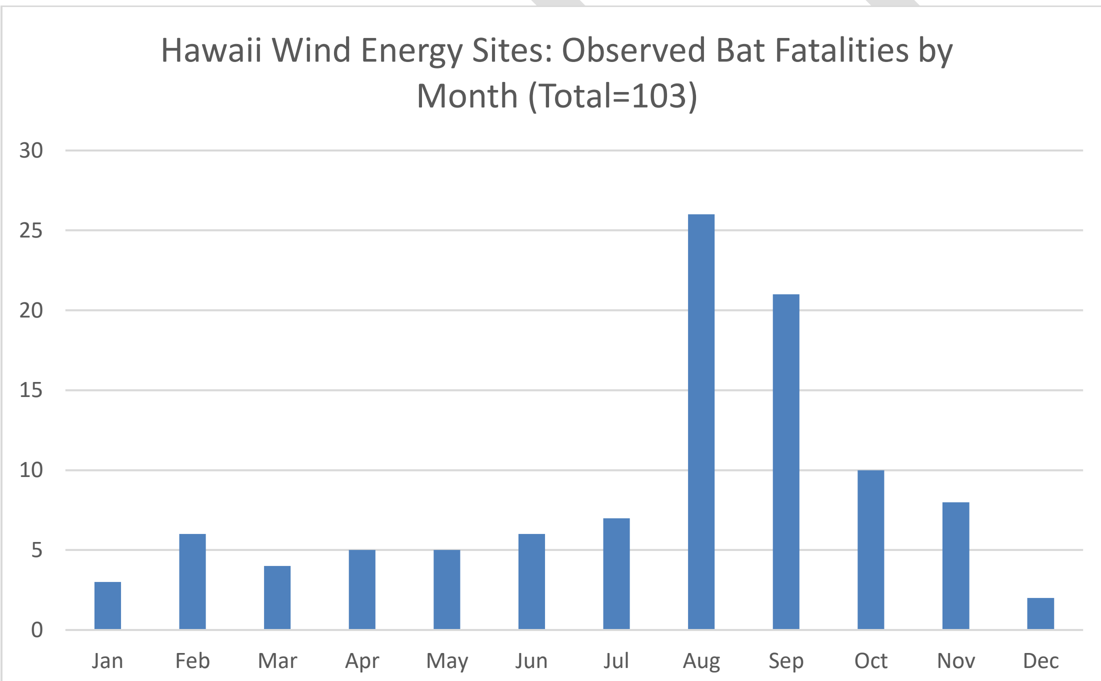

Figure 1. Observed bat fatalities by month across all wind facilities with approved ITLs in Hawai‘i as of December 31, 2021. The breeding season is reported from April – August with dependent pups possible through September 15 (see Appendix 4).

III. ASSESSMENT OF TAKE, IMPACTS, AND MONITORING FOR HCPS

Overview

Pursuant to statutory requirements in HRS 195D, HCPs should include measures to employ the best available science and methods to determine the number of individuals of a covered species expected to be taken during the term of an ITL. This is necessary to establish a credible estimated maximum take limit for a given license. An HCP would describe appropriate, quantitative field methods to monitor the wind project for all observable take and subsequently employ appropriate analytical techniques and statistical models to calculate the projected or estimated number of individuals of each covered species taken annually and during the full permitted term of the ITL. To assess potential effect of take on the Hawaiian hoary bat, the requirements of HRS 195D necessitate field surveys and monitoring of the species and employment of the best available science to assess the full extent of impacts of take in the project area, on the project island, and throughout the bat's range. Resolving these impacts, including cumulative impacts, must result in net recovery benefits for the species and should not cause the loss of genetic viability or jeopardize the continued existence of any endangered species. Guidance on the development of these measures for HCPs is provided in this section.

HCP applications or amendments that potentially impact Hawaiian hoary bats typically address strategies for bat surveys and related habitat features, particularly food resources, in four types of situations.

1. ***Pre-construction presence and activity survey.***

An initial survey is conducted to determine the presence and level of hoary bat activity occurring within proximity of the proposed wind farm project area. Information gained from this initial survey can be used to determine the level of incidental take (i.e., number of bats) to be requested for the proposed project or HCP modification. If pre-construction monitoring for Hawaiian hoary bats is not conducted it should be assumed that the species occurs in the area and therefore be included as a covered species for the HCP and ITL.

2. ***Post-construction activity monitoring.***

Regular monitoring is conducted to provide information on the level of use and seasonality of hoary bats at a project site in relation to the pre-construction surveys for the species. Although a study of mainland bat species found no correlation between pre- and post-construction activity at wind farms (Solick et al. 2020), which reflects observations at some Hawaii wind projects, comparison of post- to pre-construction baseline survey data in that study did indicate that the addition of towers and turbines to a site served as an attractant, and this likely also applies for Hawaiian hoary bats. Such information would potentially be helpful for evaluating whether modification to turbines in a given area could minimize take. Post-construction activity monitoring can also be used to assess the effectiveness of bat deterrents or other minimization strategies at the site. Collecting monitoring data in a consistent format and manner that facilitates their inclusion in an island-wide or regional assessment and analysis of Hawaiian hoary bat population status and trends will greatly add to an understanding of the species' demographics.

3. ***Post-construction fatality monitoring.***

Detailed surveys conducted regularly are necessary to detect Hawaiian hoary bats and / or avian species that may be injured or dead within a specified search area around wind farm structures. These surveys can be completed using either human or canine searchers, but preferably the latter. Routine post-construction fatality monitoring will be informed and adjusted based on the results of carcass retention (CARE) and searcher effectiveness (SEEF) studies that are periodically and concurrently conducted within search areas. The observed fatalities from these surveys are used in statistical modelling to calculate direct incidental take of hoary bats relative to permitted annual and total take for the project.

4. Mitigation site monitoring.

Monitoring at a project mitigation site provides quantitative data on the use of that site by Hawaiian hoary bats and allows agencies to determine the effectiveness of the mitigation strategy and restoration actions (i.e., providing more suitable habitat for bats). Monitoring at a proposed mitigation site involves three components. First, baseline hoary bat activity is assessed to determine whether bats are present and at what activity level prior to initiating mitigation actions at the site. Data collected from these initial surveys will also be used to assess continued use of the site by bats as a result of mitigation actions. Secondly, insects are sampled to assess the initial and subsequent levels of potential hoary bat food resources at the site in relation to any changes in habitat or water availability resulting from mitigation actions. Finally, a monitoring program designed and implemented to assess the response of the mitigation target (the focus of the mitigation in an HCP; e.g., restoration of degraded habitats to native forest cover and diversity) to the restoration actions. It should be noted that all monitoring data gathered will be incorporated as needed into island-wide or regional assessments of the status and trends of the Hawaiian hoary bat.
More details on sampling and analysis methods for these different types of monitoring are discussed in Sections III.D and V.C.

TAKE CALCULATIONS

To obtain an ITL, wind energy HCP applicants must identify a maximum take limit at their project site. For newly proposed sites or sites with minimal or no existing Hawaiian hoary bat monitoring data, an example process for determining the appropriate requested take is as follows:

1. Use information from the most comparable wind energy site(s) that are currently permitted and for which take data are available as a baseline.
2. Adjust the estimated take level based on specific conditions at the newly proposed site, including but not limited to: a) the size of turbines and rotors (including tower height and maximum height of blade); b) local recorded wind speeds; c) results of local or regional Hawaiian Hoary Bat studies; d) site-specific monitoring; and e) ecological and landscape level considerations.
3. Adjust the estimated maximum take (with justification) based on the implementation of any proposed avoidance and/or minimization measures for bat take.

It is recommended that a requested take limit for existing wind energy facilities, with at least several years of monitoring data, be determined using the Evidence of Absence (EoA) modelling (see description below) then adding an estimate of indirect take following the guidance as discussed below. If at all possible, it is best to use Hawaiian hoary bat data to model take for the species. If these data are not available, however, demographic data from North American hoary bats or another surrogate species can be used when deemed appropriate. Regardless of prior history at any proposed wind facility site, it is recommended that requested take levels be thoroughly justified with detailed documentation.

The EoA model was developed by statisticians at USGS (Dalthorp et al. 2017, or as updated) specifically to determine levels of take. Use of EoA is recommended by DOFAW and USFWS and is employed by all wind energy projects currently holding permits in Hawai‘i. EoA is designed to determine if take is likely to exceed a given threshold and accounts for both observed and unobserved takes. The model factors in the spatial distribution of carcasses encountered during mortality monitoring at wind farms to estimate the portion of carcasses landing outside the searched area, and additionally includes correction factors for searcher efficiency and carcass removal estimates based on field trials (see Section II C for detailed information on fatality monitoring). The model then employs this information to calculate a maximum credible number of fatalities at a project site. Both DOFAW and USFWS specify the use of an 80% credibility level for a conservative estimate of maximum take for a site over a specified time frame. If, for example, 25 bats are the direct take calculated by EoA at the 80% credibility level it can be stated with 80% certainty that the amount of direct take is 25 bats or less for a given period.

When using EoA to calculate take, a *rho* value (ρ) can be used if warranted. *Rho* is a relative mortality rate that is used to adjust for operational changes if the level of effect is known or can be determined. A $\rho = 1$ is typically used for a 1-year period that exhibited typical operating conditions and when there is no reason to suspect mortality rates varied systematically between years. If a project expands by 20%, however, the ρ would be 1.20 for the future (relative to the original project) because the site is now 20% larger. Alternatively, if minimization measures intended to reduce fatalities by 30% were implemented, ρ would be 0.7 for the period over which the measures were implemented. For instance, studies on the mainland have shown that raising the cut-in speed and/or feathering of turbine blades may reduce fatalities of some species of migrating bats. A *rho* value may therefore be used for those instances when higher cut-in speeds are deployed to inform the EoA model, as the rate of fatalities under this avoidance and minimization regime is expected to be less. The model will therefore address this change by reducing the take estimates for that relative period of time. The primary difficulty with employing ρ is determining the correct or most appropriate value use for it (i.e., the level of effect of the operational changes at a site).

The effectiveness of raising a facilities cut-in speed to decrease take of bats in Hawai‘i is not currently known. The Hawaiian hoary bat may occur in proximity to wind turbines year around and may behave differently towards them relative to hoary bats on the North American mainland. The risk of employing a *rho* value below 1 is that fatality estimates may be decreased when no reduction in fatalities may have occurred in reality. The unobserved take is always relative to the observed take and the detection probability. Extremely low numbers of observed fatalities and annual variability therefore make it difficult to determine if a reduction (or increase) in take is the result of the avoidance and minimization actions or is simply due to stochastic variation at a site between years. All wind projects initially use a $\rho = 1$. If additional minimization measures are implemented (e.g., raising the cut in speed or employing deterrents), the *rho*-value is kept at 1 as a precaution until tests on assumed weights indicate that there may be a difference in fatality rates because of these measures. Several years of deploying the minimization action may be required before any difference in fatality rates can be supported by the test of the *rho*-value. If the tests do confirm a change in the fatality rates between periods, beyond a reasonable doubt, a *rho*-value can be implemented retroactively for the periods in which the minimization action was deployed (if approved by DOFAW and USFWS). The tests can be rerun to determine if the *rho*-value continues to be reasonable. Note, however, that the actual *rho*-value is not calculated by the model and may never truly be determined. The best that can be done is to continue testing of the *rho*-value being used to determine if it is reasonable and acceptable.

It is recommended that annual reports provide outputs from the EoA model and include a graphical representation of estimated and projected take over the authorized life of the ITL (Figure 2). Indirect take recommendations have been provided by the Wildlife Agencies in a separate guidance document (Appendix 4). Demographic data to calculate indirect take for Hawaiian hoary bats are currently limited but the best available data are used.

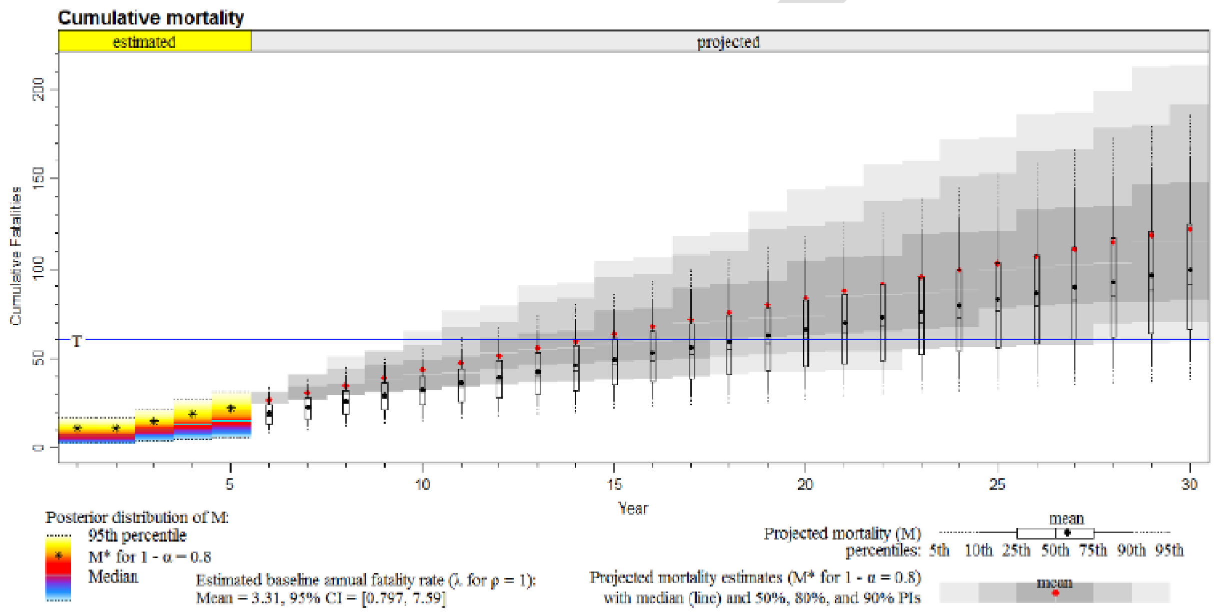

Figure 2. Example of a graphic representation of estimated take from Evidence of Absence modeling that is recommended for annual reports. In this example the blue line is the permitted take.

Fatality Monitoring

The determination of the numbers of Hawaiian hoary bats taken under an ITL is essential for compliance with legal requirements under HRS 195D.

The obligations of the license holder under an HCP include monitoring the impacts caused by a project's activities to ensure they are in compliance with authorized take limitations. A post-construction monitoring plan is designed for wind farms by the licensee/permittee and must be approved by DOFAW and USFWS. The calculation of a detection probability depends on the following: a) the method and frequency of monitoring, and the size of search plots; b) the number of turbines at a wind farm; and c) the monitoring period. These variables are project-specific and are based both on carcass persistence at the site and the effectiveness of the searcher.

Fatality monitoring may not detect all bats killed or wounded at wind farms as some individuals may: 1) fall outside the searched area; 2) be removed by scavengers before being detected; 3) deteriorate beyond recognition prior to detection; or 4) remain undiscovered by searchers even when present.

Current protocols involve routine searches within a specified distance from the turbines at the site. The use of canine searchers is encouraged to increase the efficiency of searches for carcasses, to improve estimates of take, and to allow for better estimates of the maximum distance of bat fallout relative to turbine locations (Smallwood et al. 2020). Peer reviewed research results (e.g., Hull and Muir 2010) and other scientifically valid findings can be used to determine fall-out patterns for fatalities and to define the search radius. Other important considerations to include are the maximum height of blade tip, wind direction and/or the quantile estimates of Hull & Muir (2010).

A 20% buffer can be added to the outer extent of search areas around turbines and searched during the initial few years of monitoring to ensure coverage is adequate. This is especially important at project sites with high winds. Hein (2017) and others (M. Huso, pers comm, Dec 2020) show that bats struck by blades during high winds fall farther distances from turbines. This has implications for fatality searches at Hawaiʻi wind energy facilities operating under a low windspeed curtailment regime. As blades are only spinning at higher wind speeds under such regimes, bats would on average be expected to fall further from turbines.

Search area selection is especially important at wind farms with few mortalities. Searching at least some areas out to the maximum likely fall distance may help to yield good estimates of mortality. This can be accomplished by searching roads and pads with some buffer placed around them (M. Huso, pers comm, Dec 2020) as roads and pads by themselves are likely inadequate. Maurer et al. (2020) investigated the methods necessary to estimate the proportion of turbine-caused bird and bat mortality within search areas. They concluded that estimates based only on data collected on roads and turbine pads should be avoided when few carcass presence is expected to be low and precision of mortality estimates is necessary (Maurer et al. 2020).

Independent searcher efficiency (SEEF) and carcass removal (CARE) trials should be conducted concurrently with fatality monitoring searches to estimate both the probability that a carcass persists until the next search and the probability that it is then discovered by a searcher. The details of these trials should be included in an HCP. Relevant issues to discuss should include how and when trials will be conducted at a specific site during the year, and what procedures will be employed to assure SEEF trial independence. Treatment of handling of carcasses found either during fatality monitoring or incidentally should follow the most current standardized protocol provided by the agencies (Appendix 5). Canine-assisted searches have been demonstrated to be the most cost effective and efficient approach to carcass searching; SunEdison (2014, 2015) found 80-90% of bats and 97-100% of birds during trials. The use of dogs for searches is therefore recommended to provide the best estimates for all Hawaiian hoary bat fatality monitoring and SEEF trials.

HRS §195D-4(g)(3) specifies that the applicant will cover all costs to monitor for species mortality. Employment of an independent, qualified third-party that is approved by the agencies to conduct the SEEF and CARE trials would help ensure transparency and avoid any conflicts of interest. For consistency and efficiency of statewide monitoring of Hawaiian hoary bat HCPs, DOFAW may instead prefer to procure appropriate monitoring services through a request for proposals process consistent with state procurement rules, the cost of which would be covered by the applicant.

Downed wildlife reports for bats should follow the recommended format and content laid out in the most recent Downed Wildlife Protocol per Appendix 5. The Protocol is subject to revision based on discussion with wind facility operators but the information recorded for bat fatalities currently (as of the date of this document) include wind speeds, wind directions, temperature, precipitation, moon phase, and turbine rotor activity for the interval between the date the fatality was found and the date of the previous fatality search and also for the time period before spanning the last two search periods (Appendix 5). Inclusion of acoustic detector results (including temporal aspects and call types) for bats in downed wildlife reports annual reports will also aid the evaluation of fatalities or trends thereof. Other important data to include in reports are the location of any open water in the wind facility project area, including manmade sources such as watering troughs because of their potential to attract bats; ungulate grazing activity or other relevant land uses in the project area because of their potential relationship to bat activity (Todd et al. 2016); and operational status during the search period of bat deterrent devices, if applicable.

Video imagery could uncover many interactions between bats and wind turbines which would be valuable information. This method, however, it is not currently considered an effective substitute for regular carcass searches at wind energy facilities. As field of view from thermal and infrared cameras is limited, multiple cameras would be required to adequately monitor each turbine. Documenting rare events, such as bat strikes at wind turbines in Hawaiʻi, would furthermore require the review of many hours of data. This would very likely result in a lag of time between the occurrence of the actual event and its identification or documentation. Owing to such potential lag times associated with the use of imagery, it is unlikely that carcasses would be found in a condition that would facilitate the confirmation of sex or collection of other necessary information.

POST-CONSTRUCTION BAT ACTIVITY MONITORING

To obtain information on Hawaiian hoary bat occurrence, level of use, and seasonality of activity at a project site, regular monitoring at the site is recommended throughout the permit period. Such information can also be compared to pre-construction monitoring data to determine if the addition of towers and turbines to the site serves as an attractant for bats and may be used to assess the effectiveness of deterrent or minimization strategies.

The following guidelines on monitoring serve as an example for designing an HCP, and include a detailed description of the experimental design to be employed for monitoring Hawaiian hoary bat activity in a project area. The description specifies the number and types of detection devices to be used, the spatial deployment of such devices, and the statistical approach to be employed for analyzing the acquired data. At a minimum, monitoring data would be collected using acoustic sampling devices. While not desirable for fatality monitoring, data can be collected with via thermal imaging devices, which can potentially provide more accurate assessments of bat presence and activity. As an example, Gorresen et al. (2020) conducted a detailed study at a wind facility in Hawaii using both thermal imaging and acoustic monitoring. Acoustic data were collected in a manner that allowed the facility to serve as an additional sampling location, which could be included in an island-wide or similar regional assessment of status and trends of Hawaiian hoary bats.

5. Monitoring Objectives

Design of post-construction monitoring of Hawaiian hoary bats at a project site can address two primary objectives:

1) To assess the presence and seasonality of bat activity in the vicinity of the project site and whether this activity has changed from preconstruction monitoring; and
2) To secure bat presence and activity data for the project site as part of an island-wide or regional occupancy assessment for the species.

6. Monitoring Methods

Monitoring of Hawaiian hoary bat activity at the project site throughout the permit period would provide data useful to evaluate their status and trends. Intensive monitoring after the initial years of a project could be scaled back if a reduced level of monitoring is demonstrated to maintain acceptable statistical power to track temporal trends in bat activity throughout the permit period and to evaluate interactions of bats with wind turbines. This will allow for the development of methods that more accurately document downed wildlife incidents and to evaluate the adjustment of low windspeed curtailment protocols.

The use of at least a 0.10 (90%) *alpha* level for testing differences in sample results is one approach to statistically analyze collected data. A power analysis for each of the assessment variables will facilitate evaluating the strength of the chosen statistical tests, particularly when no difference is detected when comparing results from different times or sites. Effective monitoring may also provide information regarding correlations to other factors that will better inform management decisions. Activity monitoring at both turbine nacelle and ground levels would be most effective.

Acoustic Sampling

Acoustic monitoring conducted at 5-10 randomly selected locations distributed across a project site can provide reasonable coverage of the site. Acoustic units typically employ an ultrasonic microphone mounted on a 10 ft pole and a data logger to record data. Probabilistic sampling of detector locations can allow one or more of these detector sites to be combined with island-wide or multi-island studies given that those efforts incorporate a similar sampling design. Additional detectors mounted on turbine nacelles increases the effective range of detection. Mid-priced acoustic devices (e.g., Wildlife Acoustics SM4BAT-FS) are currently widely used in Hawaii bat research. Lower cost units (e.g., AudioMoth[4]), however, are available that are capable of applying open-source software for on-board processing, alternative direct recording of acoustic/ultrasonic signals, and that make sampling designs feasible with greater spatial replication.

Primary metrics for acoustic sampling include presence, activity levels (within- and between-nights) and feeding activity ("feeding buzzes"). Secondary metrics include detection rate by time of night, data to determine spatial and temporal autocorrelation of detections, cumulative time of detection within-night and temporally (e.g., seasonal), and intervals between detections. The major limitations of acoustic sampling include imperfect detection due to cryptic vocalization behavior and a limited detection range (generally less than 30 m).

Sampling by Thermal Imagery

Recent advances in the availability, cost, and sensitivity of thermal imaging cameras make this approach to sampling more feasible as a tool for detecting Hawaiian hoary bats and quantifying their activity at a project or mitigation site. A major advantage of thermal imaging over acoustic sampling is the detection range for bats may extend as far as 130 m from the camera, depending on the focal length of the lens used. Thermal infrared and near-infrared cameras have been used in three studies at wind facilities on the continental U.S. and in Hawaii to observe interactions between bats and wind turbines at night (Horn et al. 2008, Cryan et al. 2014, Gorresen et al. 2015c, and Schirmacher 2020). Thermal imaging provides more detailed information about bat behaviors compared to other monitoring techniques. During a USGS six-month video surveillance study at the Kawailoa Wind Farm on Oahu, over 3,000 bat events were observed in almost four thousand hours of captured video.

[4] https://www.openacousticdevices.info/

This represented nearly 75% more detections than those obtained through concurrent acoustic monitoring. Bat interactions documented included “chasing” turbine blades, investigating turbine nacelles, foraging near turbines, and some additional unexplained behaviors.

Mid-priced thermal cameras are commercially available (*e.g.*, Axis Communication Q19 series[5]) and significant progress has been made in terms of analyzing thermal image data, allowing this information to more efficiently serve as a tool for quantifying bat activity. New data management and analysis methods are being developed by the USFWS to improve motion-detection, tracking, and target classification using open-source Python-based algorithms.

Field management and data processing requirements are moderately intensive for the application of thermal imagery and may currently limit its suitability for long-term studies (e.g., documenting bat behavior at turbines that may be months in duration). Thermal cameras, however, are generally suitable for high-mobility, short-term sampling (<1 week) when units are battery powered.

Primary sampling metrics acquired through the use of thermal imaging include bat presence, activity levels (within- and between-nights), and identification of flight paths, which can be indicative of feeding activity. Secondary metrics of this method include determining bat flight path characteristics (straight, curved, erratic) and proximity to turbine, contact with turbine structure (e.g., bat exploratory activity or blade strikes), determining the maximum number of concurrently present bats, and other interactions indicative of social behavior between individual bats.

Thermal sampling from one hour before sunset to one hour after sunrise with cameras deployed throughout the night will yield the most effective monitoring data. For repeated long-term monitoring, sampling could be limited to periods during the year when detection probability is highest (e.g., during Hawaiian hoar bat pregnancy and lactation periods).

Given the rapid advancements in technology, project proponents can keep pace by routinely adopting the latest available methods and techniques for monitoring bat activity at their wind projects. This will facilitate a better understanding of the impacts of their projects on Hawaiian hoary bats, and potentially reduce the impacts to the species by adjusting wind-speed curtailment protocols based on monitoring results. Research into developing new monitoring technology may be very beneficial, particularly for analyzing bat interactions with wind turbines, evaluating the effectiveness of deterrents or avoidance techniques, and developing methods to more accurately capture downed wildlife incidents.

Other Monitoring

In addition to acoustic or thermal bat activity monitoring at the project site, monitoring other weather-related variables such as temperature, wind speed, wind direction, or changing barometric pressure may also aid in identifying patterns of observed mortality (Baerwald and Barclay 2011), and to inform wind speed curtailment decisions. Gorresen et al. (2017) found that moon phase may also be important as it may affect how much Hawaiian hoary bats use echolocation.

Impacts of Take

HRS 195D requires that HCPs include four components related to impacts to covered species: 1) mitigation measures for individuals of a species impacted by a project’s actions; 2) actions that will

[5] https://www.axis.com/en-us/products/axis-q19-series

increase the likelihood the impacted species will recover; 3) sufficient information to determine with reasonable certainty the likely effect of a project on a covered species in the project area and throughout its range; and 4) an adequate assessment of the cumulative impacts associated with the take. The preferred approach to meeting these requirements is to implement mitigation actions designed to offset take of the affected population through enhancement of survival or reproductive success, or both. It is important to monitor the results of these mitigation actions to allow for quantitative confirmation of success. The effect of take on the population may be determined with reasonable certainty when the impacts of mitigation can be quantitatively measured with confidence. For the Hawaiian hoary bat, however, this approach poses significant challenges because of practical and technical limitations associated with quantitative assessment of any demographic and population level benefits of mitigation.

Since, as noted, it may not be possible to determine with reasonable certainty the impacts of take and the positive effects of mitigation actions on take, it is appropriate to explore other approaches to determine how take and mitigation may affect the covered species. Population models, for example, serve as an additional tool to aid planning and may be used to predict the impact of a given level of take at the population level. These models may be used to identify levels of take that are likely to cause a population decline. They may also be used to guide HCP planning by allowing the applicant or regulatory agency to establish a take limit that is not likely to negatively affect a population in the event that the effectiveness of mitigation is not known. Population models have been used to examine the potential population impacts of take of several mainland species (Frick et al. 2017). These specific models were used to predict population responses to mortality resulting from take by wind turbines and to assess the sensitivity of model inputs on the outcomes of the simulations (Frick et al. 2017).

Demographic and vital rates data necessary to inform population models are lacking and imprecise for the Hawaiian hoary bat. Models for the species are therefore likely to be considerably less robust than those reported by Frick et al. (2017) for mainland species. While a lack of data limits the predictive ability of population models, useful results and insights may still be gained from their development. A Task Force requested by the ESRC conducted preliminary, exploratory population viability analyses (PVA) using Vortex in 2021 to identify the following: 1) specific population dynamics parameters necessary to conduct an acceptable PVA; 2) meaningful parameters that should be prioritized for research; and 3) general trends or outcomes that could inform discussions on the impacts of wind projects on the Hawaiian hoary bat. These PVAs used plausible values for demographic parameters based on the best available data at the time. They explored Hawaiian hoary bat populations examining how these impacts would differ depending on the starting size of a population, whether suitable habitat was limited, and whether a population was stable, increasing, or decreasing at the onset of take. While these models are not meant to predict the outcome of take for any given application, they do suggest what scenarios are likely under certain circumstances. A detailed account of those exploratory efforts is provided in Appendix 6.

Based on the preliminary models explored by the ESRC Hawaiian hoary bat Task Force, the following conclusions are provided:

1. Additional research is needed to improve estimation of life history and demographic variables that can inform population models.
2. Additional efforts are needed to explore population models for the Hawaiian hoary bat that employ alternative assumptions and approaches.

3. As a precaution (until further data are available), using relatively conservative assumptions regarding Hawaiian hoary bat populations would be the best approach for an assessment of cumulative impacts of take. Based on the model, and using the precautionary principle, the following assumptions are prudent until further information and data are available:

   a. Hawaiian hoary bat populations on the island of Hawaii appear to be stable or slightly increasing (i.e., a 0 to 1% annual population increase as found by Gorresen et al. [2013]). Population status and trends on other islands are not known at present,

   b. Compensatory reproduction is not occurring (no studies have shown this to be the case), and,

   c. An annual rate of take that exceeds the annual rate of increase of a population is likely to cause a decline in the population. For example, if the pre-project population is thought to increase by one percent annually, the take of more than one percent of the population annually would likely cause a declining population. Similarly, if a population is stable, any take would likely result in a comparable population decline.

4. Although definitive populations have not been determined, a precautionary approach is to assume that the Hawaiian hoary bat populations on Oʻahu, Maui, and Hawaiʻi are not more than 1,000, 1,500, and 5,000 bats, respectively, until data showing otherwise are available. These estimates are based on the best professional judgement by the ESRC Hawaiian Hoary Bat Task Force and extremely limited information, including occupancy data and relative bat activity levels on Oahu, Maui, and Hawaii. An acoustic based study by the consulting firm Western EcoSystems Technology shows a patchy distribution of bats on Oahu, with major areas of occupancy in the northern Koolau Mountains and Mount Kaala (Starcevich et al. 2020, 2021a). The majority of Oahu otherwise appears to have patchy and low levels of occupancy with activity levels frequently 10 percent or less of those seen on Maui and Hawaii (Starcevich et al. 2020, 2021a, 2021b). This information suggests Oahu supports a lower population level than the other two islands.

5. Cumulative levels of take that exceed the annual rate of growth of the assumed population sizes for each island should not be authorized unless the predicted net benefits to Hawaiian hoary bat recovery outweigh the potential losses from take.

Additional details of the exploratory models employed are provided in Appendix 6.

USE OF TIERS

The BLNR and the USFWS approved six HCPs for wind energy projects between 2006 and 2018 that included authorization for the incidental take of Hawaiian hoary bats. During development of these HCPs, a high level of uncertainty existed regarding the levels of modelled or projected take for bats and the effectiveness of the projects approved as mitigation for take was unknown. There also existed an expectation that the results of ongoing research on Hawaiian hoary bats would provide improved guidance for HCP development and implantation. The approved HCPs, therefore, structured take levels for bats into sequential tiers, each with associated plans and conservation measures. This tiered approach was intended to provide the HCPs with flexibility to implement the appropriate suites of conservation measures in the face of unknown take probabilities and uncertainties regarding the effectiveness of the minimization measures to be employed. It also allowed for revisions to HCP implementation as new information became available as a result of ongoing research.

The ESRC acknowledged the rationale and utility of this approach for early HCPs. The use of tiers to guide an incremental approach to the implementation of conservation measures, as part of an otherwise effective and compliant HCP that authorizes an appropriate level of take, may serve a functional purpose. The use of tiers, however, may have negative outcomes, as discussed below. Incidental take licenses are intended to identify and subsequently authorize the amount of take that an approved activity is likely to have after take has been minimized to the maximum extent practicable. While tiers may theoretically serve as an incentive for the adoption of more effective minimization and mitigation efforts, tiers can also be a disincentive. This is of particular concern if the total authorized take requested by the HCP is not minimized (to the maximum extent practicable). The authorization of take levels that are either excessive or deflated is inappropriate. Underestimating a project's take negatively impacts endangered species, while overestimating take reduces the flexibility of future projects and unnecessarily burdens the current HCP, unless tiers are used to reduce financial assurances or expenditures. Moreover, if the requested level of take is higher than the take level that can be achieved by effective minimization the HCP may be inconsistent with statutory requirements to minimize take. Authorized take that is higher than can be achieved through minimization may also compromise regulatory provisions to ensure that the minimization measures are employed to the maximum extent practicable and that adaptive management is diligently applied to enhance the effectiveness of those measures.

Inappropriate use of tiers may include the following:

- The establishment of tiers that are unjustifiably low. If the initial tier levels are lower than the forecasted or actual take levels, the project may not be able to meet its statutory requirements during the permit period. The use of a tier, for example, that is well below the actual take will effectively delay the implementation of the mitigation measures that are ultimately required to compensate for that take, jeopardizing the effectiveness of mitigation, and placing the covered species at risk.
- Effectively creating a "pay as you take" situation. Establishing tiers that simply keep pace with estimations of take are likely to result in tiers triggered late in the permit period. These late triggers will have limited mitigation options and may result in the selection of less desirable conservation actions. Habitat restoration, for example, may take over a decade to be realized. Tiers that are triggered within a decade of permit expiration will likely be unable to use restoration as a mitigation tool.

If tiers are used, an informal determination by the State Attorney General's Office is that HRS 195D requires that funding assurance be provided for the full amount of take requested and is interpreted to mean that mitigation for tiers triggered late are to be completed by the end of the license term.

IV. HAWAIIAN HOARY BAT TAKE AVOIDANCE AND MINIMIZATION MEASURES

Overview

State law requires that any incidental take authorized as part of an approved HCP be minimized and mitigated to the maximum extent practicable (§195D-4-(g)(1)), and that any approved HCP identifies the steps that will be taken to minimize take (§195D-21(b)(2)(C)). An HCP submitted for approval, therefore, must contain a description of all measures that will be employed to minimize take and an analysis that illustrates how those measures constitute the maximum practicable extent of minimization. .

HCPs are typically long-term endeavors that require commitments on the part of both the licensees/permittees and government agencies. While these required commitments help provide assurances and predictability, they can also reduce the incentive for undertaking additional or alternative actions that may be beneficial to endangered species. An effort is required to find mutually agreeable pathways to incentivize the incorporation of additional conservation actions as ongoing and future research discovers new ways to avoid, minimize, and/or mitigate impacts of wind projects on bats.

This section provides guidance for the inclusion of selected considerations, practices, or tools that may be employed to reduce take resulting from the operation of wind turbines. The basic principles to be considered for avoidance and minimization are as follows:

Ceasing operations and feathering of rotors from one-half hour before sunset to one-half hour after sunrise will avoid most take of Hawaiian hoary bats.
Minimization of take to the maximum extent practicable includes a range of alternative actions (with an evaluation of projected take) that are supported with relevant data and scientific reasoning.

AVOIDANCE AND MINIMIZATION EFFORTS ARE SUPPORTED WITH A ROBUST ADAPTIVE MANAGEMENT STRATEGY TO ENSURE THAT CHANGES AND ADJUSTMENTS ARE EMPLOYED TO INCREASE EFFECTIVENESS WHEN MINIMIZATION TARGETS ARE NOT BEING MET OR WHEN NEW TOOLS AND METHODS BECOME AVAILABLE.PROJECT SITING

Geographic siting of the wind turbine facility is an important variable to consider during the planning phase of a wind energy project. Records available for Hawaiian hoary bat strikes by wind turbines in Hawaiʻi suggest significant differences among sites. The environmental correlates or causes of these differences, however, are currently not well understood. Additional research is needed to understand why some sites result in higher take so that predictive models can be developed at landscape scales to guide siting decisions. Pending improved decision-making tools, the optimal approach should include the evaluation of various locations and turbine layout configurations, which includes detailed documentation of the advantages and disadvantages of each when considering the potential effect on Hawaiian hoary bats. Some of the factors to consider when siting wind energy projects include the following:

- Wind characteristics, including a determination of how much a facility can minimize incidental take of bats through curtailment.
- Proximity to habitat suitable for listed endangered species including Hawaiian hoary bats.
- Results of monitoring to assess the presence, activity, and use of the potential project areas by bats and other listed species based on prior research and project-specific monitoring. For bats, and effective approach would include acoustic monitoring of a minimum of one year in all months, and supplemental thermal imaging during high activity months.
- Topographic and habitat features that may be suitable for Hawaiian hoary bats.
- Land use adjacent to the proposed project area, including ranchlands used for grazing animals (see additional discussion below) and proximity to federal, state, and private reserves and conservation areas.
- Future land use plans in the vicinity.
- Restoration in the area that could attract bats.
- Vegetation types.

- Presence of water features, including those associated with ravines.
- Climate records.

There are concerns that pertain to the foraging behavior of Hawaiian hoary bats. Cattle grazing and the resulting manure attracts dung beetles (Coleoptera) and beetles comprise a large portion of the Hawaiian Hoary Bat diet. Anecdotal evidence suggests that the presence of dung beetles in the vicinity of a wind energy facility may serve as an attractant and draw in foraging bats, putting them at risk of colliding with turbine blades. A review of bat fatalities at the Auwahi wind energy facility on Maui, however, did not find a relationship between fatalities and grazing (Auwahi Wind 2019). USGS is not currently investigating further the possibility of a link between grazing and bat activity but will do so on request of the ESRC.

TURBINE SPECIFICATIONS

Bat foraging behavior may be influenced by wind turbines themselves owing to 1) an attraction of insects to turbines, 2) the turbines serving as perceived insect source, regardless of insect availability, or 3) an attraction of bats to turbines for various other potential but unproven reasons. Turbine design may help reduce their attractiveness to bats and important or pertinent features include a) turbine manufacturer, b) turbine height, and c) rotor size and sweep area.

Barclay et al. (2007) found that bat fatality rates in North America were relatively low at turbines less than 65 meters high (i.e., short) but that fatalities increased exponentially with increasing turbine height (Figure 3). The range of tower heights examined varied from 25 to 80 meters (Barclay et al. 2007). The highest bat fatality rates occurred at turbines with towers 65 meters or taller, leading to the hypothesis that higher towers elevated turbines to altitudes at which more bats migrated. It is not clear if Hawaiian hoary bats fly at high altitudes when they move from site to site and could be similarly impacted.

More recently, Zimmerling and Francis (2016) found no relationship between turbine height and bat fatalities for a narrow range of turbine heights they examined, which only varied by 37 meters (range = 99 – 136 meters). Importantly, however, Zimmerling and Francis (2016) defined turbine height by the maximum height of the blades, whereas Barclay et al. (2007) examined just the tower height. On O‘ahu, this narrow range would only capture the Kahuku wind farm turbines at 127 meters including the blades. The turbines at the Kawailoa wind farm, including blade length, are 150 meters high while those at the Na Pua Makani are approximately 173 meters high, both notably above the range examined by Zimmerling and Francis (2016).

Barclay et al. (2007) did examine rotor diameter (not turbine height that included rotor) but did not find a correlation between mortality and turbine rotor diameter. A series of studies at the Fowler Ridge wind farm (Good et al. 2011, 2012, 2018, 2019, 2022) further looked at the impact MW usage had on bat fatalities. The study showed there to be a correlation of bat fatality to MW. Huso et al. (2021) further investigated into the hypothesis of proportionality between turbine height to bat fatality and found that height, does not significantly contribute to bat fatality rates. It was found that energy production, along with turbine location, is the stronger determinant of wildlife mortality. Furthermore, Good et al. (2022) has continued to compare bat fatality among the different turbine types located within the Fowler Ridge wind farm, and began to classify turbine type by MW ratings. This differs from their earlier studies (Good et al. 2011, 2012, 2018, 2019) where there was no specified definition to classify turbine type. i however, found higher bat mortality at Siemens and Clipper turbines than at GE and Vestas turbines, which had smaller rotors. One potentially confounding factor was turbine type (e.g., Good et al. 2011). While all three turbines were of the same nacelle height, the turbines were produced by different manufacturers. Good et al. (2011; p. 69) stated that "Observed bat casualty rates were not equal between turbine types, with higher bat casualty rates observed at turbines with greater rotor diameters. This pattern was potentially a function of increasing rotor swept area, and bats may have had an increased probability of colliding with turbines that had greater rotor swept areas." However, it is not known if one turbine type may have emitted more sounds or had other characteristics that may have potentially attracted bats. The authors go on to say that "differences in bat fatalities between turbine types are most likely explained by differences in rotor swept areas" (Good et al. 2011; p. 69). Subsequent years' data also seem to show a relationship between rotor size and bat mortality (Figure 4).

Follow-up studies in 2017 and 2018 (Good et al. 2018 and 2019) provided additional data that show a pattern of turbines with increased rotor size progressively killing more bats (Figure 4). Feathering of rotors when not generating power is recommended as a standard minimization action for all wind projects.

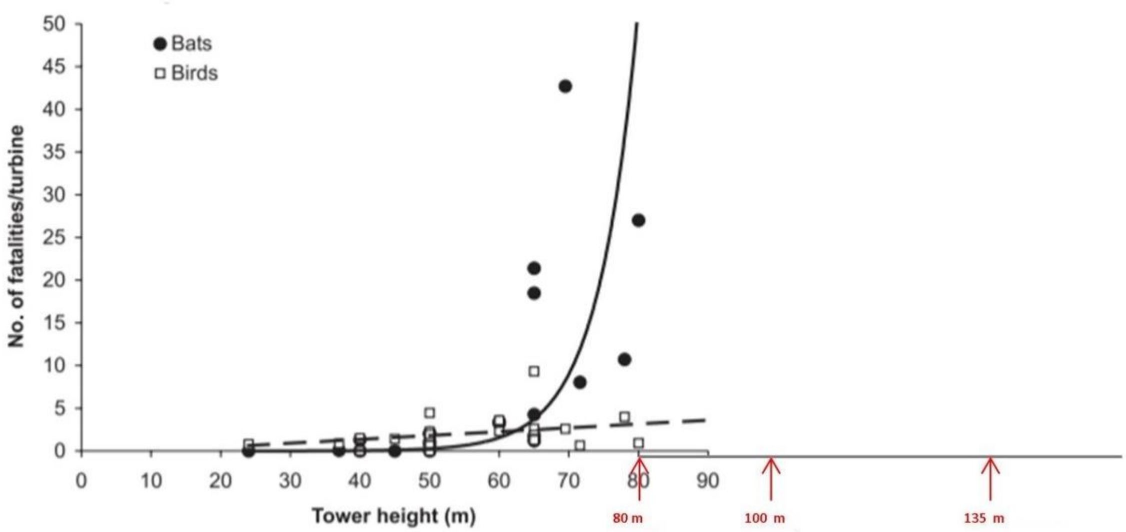

Figure 3. Adapted from Figure 1 in Barclay et al. 2007 and modified to show examples of tower heights for wind farms on O'ahu.

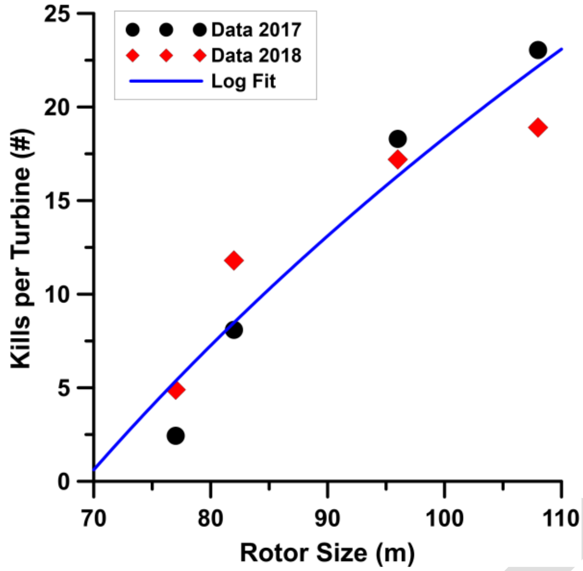

Figure 4. Rotor size and associated bat fatalities. Fatalities over two years for four different rotor sizes (from four different manufacturers) employed at the same nacelle height and under the same experimental treatments. Data from Good et al. (2018 and 2019). Data from 2017 had a significant regression (p=0.0155; r2=0.969), 2018 was not significant (p=0.0746; r2=0.856), and the average over years was also significant (p=0.0330; r2=0.9351).

Although better than any other study known to date, the design of these two studies was again not able todid not allow for the differentiatione between rotor size and manufacturer. Additionally, while conducted at a single wind project neither of the Good et al. (2019 and 2022) studies could eliminate potential geographic bias since turbines were arrayed in a clumped distribution. These studies have also been criticized for using smaller search areas at sites with larger turbines and this may have led to biased results by inflating mortality at larger rotors (unpublished verbal statements). However, no publications showing an instance of such bias were found. Additional studies are needed that include comparing the impacts of different rotor sizes from a single manufacturer and from sites where turbines are more randomly distributed across the landscape. In general though, based on evaluation of these data (e.g., Good et al. 2018 and 2019), estimated take is likely to be greater for turbines with larger rotors in Hawai‘i. It should be noted that rotor diameter in Hawai‘i’s HCPs span a greater range than those in both Good et al. (2018 and 2019) studies; varying from 70 m at KWP I and II to 96 m at Kahuku, 101 m at Kawailoa and Auwahi, and 130 m at Na Pua Makani.

Turbine Operations

This section addresses specific aspects of the operation of turbines that are necessary and important to avoid and minimize take of the Hawaiian hoary bat.

7. Curtailment

Operational adjustments that curtail the time during which turbines are rotating may reduce the number of bats struck by those turbines. Timing of curtailment may be designed to take advantage of known factors that may influence the probability of bats striking particular turbines. Factors can include time of night, weather, wind speed, location and / or wind farm, or seasonality of bat activity. Hawaiian hoary bats are nocturnal so curtailment of turbines during nighttime hours is likely to reduce take. Feathering of rotors when not generating power would be a standard minimization action for all wind projects. Additional factors to guide curtailment are discussed below.

8. Low Wind Speed Curtailment

Low wind speed curtailment (LWSC) is a twofold strategy of 1) raising the wind speed threshold at which the blades are allowed to begin spinning and generating electricity (i.e., the cut-in speed) and 2) feathering turbine blades (i.e., positioning the blades parallel to the wind) to slow or stop their rotation. Under LWSC, wind capable of producing energy is available but is not being converted to electricity that is supplied to the grid. Curtailment can be imposed on a wind energy facility by the receiving utility company if the grid has reached capacity. Curtailment can also be implemented by the wind facility operator to minimize the risk of incidental take of bats. For the purposes of this guidance document we use the term LWSC to refer to the latter, a facility operator-imposed curtailment of blade rotation. Although LWSC reduces energy output, there is strong scientific evidence that bat fatalities (especially of migratory species) are reduced on the U.S. mainland when LWSC is implemented compared to bat fatalities at facilities with no LWSC (e.g., Baerwald et al. 2009, Good et al. 2011 & 2012). Curtailment is currently the primary minimization measure implemented by wind energy facilities in the U.S., including those in Hawai‘i.

Various studies in the U.S. and Canada have attempted to assess the relationship between wind turbine cut-in speeds and the number of bat fatalities. Results from studies conducted across numerous ecosystems and facilities have consistently shown a decrease in bat fatalities of over 50 percent once cut-in wind speeds are equal to or greater than 5.0 meters per second (m/s). Based on these and other published data, curtailment with feathering has been implemented at all wind facilities with federal and state incidental take permits and licenses in Hawai‘i either from the outset of operation as a minimization measure, or as an adaptive management response to higher than expected levels of take. What follows is a summary of LWSC on the U.S. mainland.

Baerwald et al. (2009) conducted a study during the peak period of migration (August 1– September 7, 2007) for hoary bats (*Lasiurus cinereus*) and silver-haired bats (*Lasionycteris noctivagans*) at a wind energy installation in southwestern Alberta, Canada. These two species of bat accounted for the majority of turbine-related fatalities at the facility. Three turbine treatment groups were tested: control turbines, treatment turbines with an increased cut-in speed (5.5 m/s), and experimental idling turbines with the blades manipulated to be motionless during low wind speeds. After the two experimental treatment results were combined and compared to control turbines, Baerwald et al. (2009) concluded that the experimental turbines exhibited lower fatality rates for each species.

The Fowler Ridge wind facility in Indiana has conducted numerous pertinent studies on LWSC. These studies have reported statistically significant reductions in bat casualty rates (bats per turbine per season) for sets of turbines curtailed at 3.5 m/s, 5.0 m/s, and 6.5 m/s, respectively (Good et al. 2011) and at 3.5 m/s, 4.5 m/s, and 5.5 m/s (Good et al. 2012). The studies have also demonstrated the value of feathering turbine blades when they are not generating power (Good et al. 2012). When comparing LWSC at both 5.0 m/s and 6.5 m/s, Casselman and Pinnacle wind farms (in Pennsylvania, and West Virginia, respectively) did not find a statistically significant difference from curtailing at 6.5 m/s versus 5.0 m/s (Arnett et al. 2010 and Hein et al. 2014). However, Hein et al. (2013 and 2014) proposed that a lack of wind speeds between the 5.0 m/s and 6.5 m/s treatments may have made it difficult for the Casselman and Pinnacle studies to show differences between treatments. In contrast, the Fowler Ridge study a robust set of wind speeds that allowed for differentiation between treatments, with the 5.0 m/s and 6.5 m/s treatments operating 21.6% and 42% less, respectively, than the fully operational turbines.

Young et al. (2011) found that feathering to reduce the rotational speed of turbine blades at or under the manufacturer's cut-in speed of 4.0 m/s significantly reduced bat fatalities. Young et al. (2013) observed a 62% reduction in bat fatalities when feathering was implemented at 5.0 m/s and below. This study, however, was a comparison made across two years—2011 (no feathering) and 2012 (with feathering)—and assumes that other factors that may influence bat fatalities were the same across years. In the feathering study at Fowler Ridge, Good et al. (2012) found that turbines feathered at 3.5 m/s, 4.5 m/s, or 5.5 m/s had significantly fewer fatalities than turbines that were not feathered and that fatalities decreased with each feathering increment.

At the Casselman Wind Project, implementation of curtailment and blade feathering showed an average reduction in bat fatalities of 72% to 82%, depending on year, compared with no curtailment (Arnett et al. 2009, 2010 & 2011). Hein et al. (2014) reported a 54.4% and 76.1% reduction in bat fatalities from a base cut-in of 3.0 m/s for the 5.0 m/s and 6.5 m/s curtailment treatments, respectively; the two treatments, however, were not statistically different from one another.

Only Arnett et al. (2013a) experimentally increased cut-in speeds to 6.0 m/s, which then resulted in a 60% reduction in bat fatalities relative to turbines with a cut-in speed of 4.0 m/s. At Beech Ridge, West Virginia, Tidhar et al. (2013) reported a bat fatality reduction of approximately 89% when all turbines were curtailed at 6.9 m/s for the study. This reduction was based on a comparison with the Mount Storm and Mountaineer facilities, at which turbines were not curtailed. The Tidhar et al. (2013) study was not a comparison with other turbines at the Beech Ridge site, nor were other cut-in speeds evaluated. When comparing bat fatalities at turbines set to a cut-in speed of 3.0 m/s at wind farms in California and Nevada (USFWS Administrative Region 8), Arnett et al. (2013b) found a 34.5% reduction in bat fatalities at 5.0 m/s and a 38.1 reduction at 6.0 m/s during the first four hours after dark; neither of these, however, were statistically significant. It should also be noted that Good and Adachi (2014) reported that the effectiveness of curtailment speeds can depend on the deceleration and acceleration profile of the specific turbine model.

Cryan et al. (2014) investigated the influence of wind and blade rotation speeds on bat approaches to turbines at facility in northwestern Indiana using thermal video-surveillance cameras supplemented with near-infrared video, acoustic detectors and radar. Bats approached less frequently when turbine blades were spinning rapidly and the prevalence of leeward versus windward approaches to the nacelle increased with wind speed at turbines with slow-moving or stationary blades (Cryan et al. 2014). Cryan et al. (2014) found that leeward approaches to turbines declined when the blades were rotating and observed tree-roosting bats that showed a tendency to closely investigate curtailed or feathered turbines, and at times linger for minutes to hours. This observation suggests the possibility that bats are drawn toward turbines in low winds and sometimes remain long enough to be put at risk when wind picks up and blades reach higher speeds. The frequency of intermittent blade-spinning wind gusts within such low-wind periods might therefore be an important predictor of fatality risk to bats. In other words, fatalities may occur more often when turbine blades are transitioning from potentially attractive (stationary or slow) to lethal (fast) speeds.

Wind turbines that employ a curtailment regime typically use a 10-minute rolling average to determine mean wind speed and trigger rotation, feathering, or curtailment. Schirmacher et al. (2018) evaluated the effect of increasing the length of time from 10 to 20 minutes used for determining the average wind speed. The premise behind increasing the rolling average to a longer time period is to decrease the number of turbine starts and stops, and therefore potentially decreasing the number of bat fatalities. The results suggested that a 20-minute rolling average might reduce bat fatalities but was not statistically definitive. Schirmacher et al. (2018) also reported fewer bat fatalities when wind speed thresholds (trigger levels) were recorded by meteorological tower anemometers located elsewhere at the wind farm, rather than mounted on the turbine themselves. An approach that might best minimize risk (when software is available to perform these actions) to bats would be to; (1) use a rolling 20-minute average of wind speed to determine when curtailment threshold speeds are met so turbines can be spun up, (2) use a 10-minute rolling average to trigger the spinning-down of turbines when wind speed drops below threshold levels, and (3) validating that wind speeds estimated by turbine mounted anemometers are accurate (this validation could be accomplished with a comparison to wind speed data collected at an adjacent meteorological tower).

9. Summary of Curtailment of Wind Turbines

The effect of cut-in speeds higher than the 6.5 m/s are difficult to assess in Hawaiʻi because of the following:

1. The large uncertainty associated with estimating fatalities for rare events;
2. The lack of surrogate species that can be used in Hawaiʻi for estimating take of Hawaiian hoary bats and demonstrating real treatment differences;
3. The lack of statistical power because of small project size and high site variability;
4. Unknowns surrounding Hawaiian hoary bat flight behavior;
5. Existing power purchase agreements already in place; and
6. The impacts of an increased cut-in speed on reduction in renewable power production.

Although no studies on the effectiveness of curtailment have been conducted in Hawaiʻi, there is sufficient evidence from the research conducted across multiple ecosystems in the continental U.S. that support its use as a minimization measure. An overall comparison of curtailment results shows that there is a general increase in benefit (i.e., a decrease in mortality) as curtailment wind speed increases (Figure 5). Paired results from mainland studies are summarized in Figure 6.

Based on these findings, it is recommended that LWSC be implemented in wind facility minimization strategies to the maximum extent practicable. This would include a detailed description of all considerations used (including economic) to develop a cut-in speed for curtailment. Mainland wind energy site studies indicate that a cut-in speed of 6.5 m/s may be the most effective, based on studies cited in the previous subsection.

With a minimum cut-in speed of 6.5 m/s, a reduced take request (relative to using an Evidence of Absence model rho-value of 1) may be justified with a detailed rationale. Regardless, given the status of the hoary bat in Hawaiʻi and the findings of available studies, a minimum implemented cut-in speed of 5.0 m/s is essential, with higher cut-in speeds up to or exceeding 6.5 m/s necessary when the cumulative take of bats poses a risk to island populations. The higher curtailment speeds have already been implemented by several wind projects in Hawaiʻi as part of adaptive management actions aimed at reducing higher-than-anticipated rates of take. Important aspects of LWSC includes the collection, analysis, and reporting of data on the effectiveness of curtailment practices in annual reports. Further evaluation and reporting are necessary for periods when equipment was not operational or the operation did not meet HCP requirements. If available, as deterrence technology becomes more effective, the need for curtailment efforts may be reduced.

Curtailment procedures and triggers for increasing curtailment are included below in the adaptive management section of this guidance document. The inclusion of details for these procedures is recommended for inclusion in all HCPs.

Unlike the seasonal-related vulnerability associated with migratory bats on the U.S. mainland, Hawaiian hoary bats may be active around turbines at Hawaii-based wind farms year-round. Curtailment is therefore important year-round at wind facilities in Hawai‘i, unless it can be clearly shown that bats are less active at a particular site during certain months and no takes have previously occurred in those months.

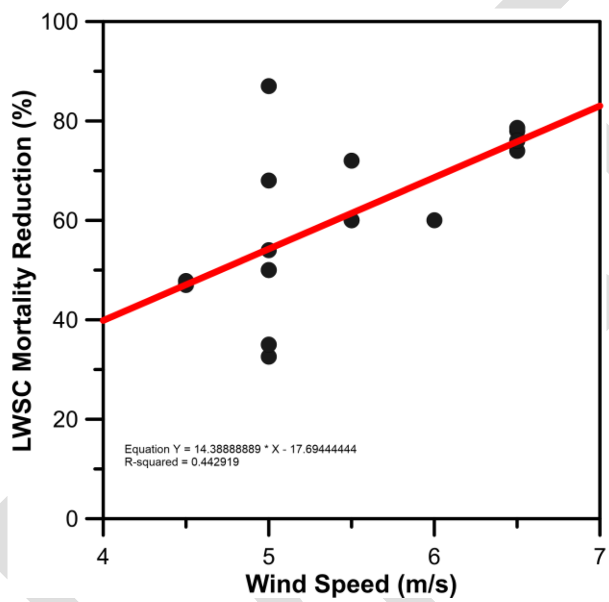

Figure 5. The relationship between curtailment wind speed and bat mortality. There is a general increase in mortality reduction as curtailment wind speed increases.

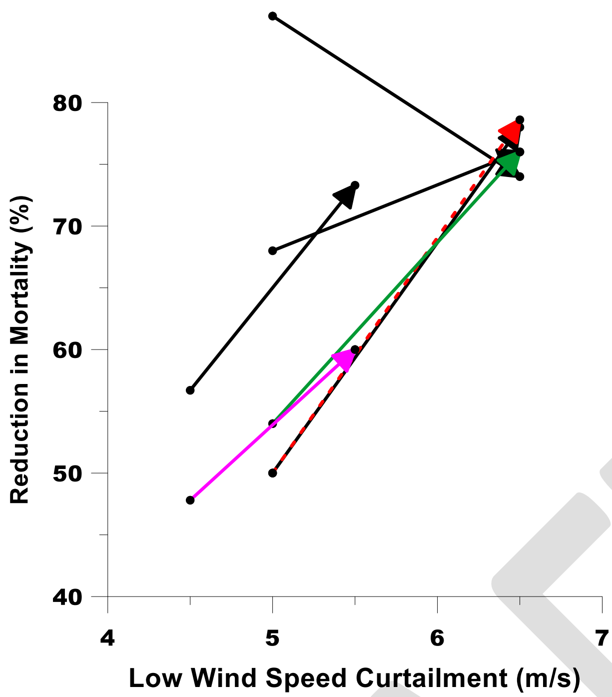

Figure 6. Project trends for eight mainland U.S. studies with incremental increases in LWSC. Seven of the eight studies showed increasing trends as LWSC increases. One study did not.

10. Summary of Other Operational Factors

Other important operational factors that may affect bat mortality and are recommended for inclusion and analysis in HCPs are:

- Turbine manufacturer and size details.
- Turbine behavior prior to reaching cut-in speeds, including specific cut-in speeds, acceleration, deceleration, free-wheeling rates, and feathering procedures.
- Criteria used to determine that wind speed has reached cut-in speed to include wind speed measurement location and trigger (see Section IV. D. above).
- Daily times of cut-in/cut-out and average daily time in feathering mode by season for turbines already in operation.
- Wind speeds and relationship to bat activity as measured by acoustic or thermal sensors.
- Siting considerations as specified above in Section IV. B.
- A discussion of minimization of Hawaiian hoary bat take through optimizing turbine manufacturer, rotor size, turbine power output, and number of turbines needed to reach the power production target.

A thorough analysis of previous take is recommended for existing wind energy projects that have experienced take of Hawaiian hoary bats. This will aid in determining or identifying any patterns that might be affecting take, which could provide opportunities for minimization. These include the information specified previously in Section III.C. to be included in Downed Wildlife Reports :

BAT DETERRENCE TECHNOLOGY

Bat deterrence technology refers to any device, feature, or modification that uses some means (usually visual or acoustic) to reduce the numbers of bats that are struck and killed by wind turbine blades. Promising, cost effective technologies currently in research and development include ultrasonic acoustic and ultra-violet (UV) light deterrents. Deterrence provides an alternative approach to reduce take that may not require curtailment of operations and associated impacts to energy production. While a number of new technologies have emerged that are designed to deter bats from coming in close proximity to turbines, additional testing and development are needed to inform planning and deployment for the Hawaiian hoary bat.

Acoustic deterrents are devices that emit continuous high frequency sounds. Such deterrents have been in development and testing since 2006 and have exhibited generally positive results to date. A description of bat acoustics and acoustic deterrent technology is summarized in the proceedings to an Acoustic Deterrent Workshop held at the National Wind Technology Center, Louisville, CO, August 26, 2013[6]. These proceedings describe a fundamental impediment to acoustic deterrents, which is the short distance that acoustic signals broadcast at the necessary frequencies will travel. Attenuation due to higher humidity was also a noted issue with these types of deterrents. For Hawaiian hoary bats, Gorresen et al. (2017) documented the range of bat calls as a mean of 29.3 kHz with the 95th percentile of peak frequency at 38.1 kHz. Acoustic deterrent signals must be well above those frequencies to “jam” bat signals and deter the animals, rather than attract them to investigate the source of the sound. These frequencies are higher than mainland hoary bats and, consequentially, deterrent signals may be effective only over shorter distances, thus reducing their usefulness. Deterrent signals at effective strength that extend out as far as possible, ideally the full length of the rotor blades, would be the most effective.

During two trials at a wind facility in Pennsylvania, Arnett et al. (2013b) reported first year results of 21% to 51% fewer bat fatalities when deterrents were deployed and the second year results were 18% to 62% fewer fatalities. Weaver et al. (2019) found a 78% reduction in hoary bat mortality over two years for an acoustic deterrent system in Texas. This deterrent system was installed on all 30 turbines at the Kawailoa wind facility on O‘ahu in 2019, which was the first wind facility employing the use of commercial acoustic bat deterrents as a minimization strategy across the U.S. Since the deployment of the deterrent system at Kawailoa, only one Hawaiian hoary bat fatality has been found through the end of 2021, a major decrease from the 17 fatalities documented in the four years 2015-2018. The Auwahi wind project installed deterrents at its facility in June and July of 2020 and subsequently through December 2021 has recorded eight Hawaiian hoary bat fatalities during searches, the same number of fatalities recorded in the prior year period. These two facilities seem to show very different results from employment of a deterrent system and the reasons are not known at this time.

Prior to the deployment of acoustic deterrents at Hawaii wind projects, an acoustic deterrent study carried out in Hawai‘i was conducted at a macadamia nut farm on the island of Hawai‘i by Hein and Schirmacher (2013) using a broad-band signal comparable to the NRG Systems deterrents installed on Hawaii turbines. Hein and Schirmacher (2013) found a significant decrease in bat acoustic detections (a reduction from 3,814 calls to 10) when the deterrents were operating, with activity levels returning to pre-treatment levels immediately following the disuse of the deterrent devices. There was also no indication of habituation found in any of the studies (Hein and Schirmacher 2013).

[6] https://www.energy.gov/sites/prod/files/2015/03/f20/Deterrent-Workshop-Proceedings_Final.pdf

Additional current and ongoing deterrence research coordinated by the Bats and Wind Energy Cooperative and funded by various partners is summarized in webinar presentations given in March 2018[7]. Studies of the following were included:

- Rotor-mounted, Ultrasonic Bat Impact Mitigation System;
- Rotor-mounted Biomimetic Ultrasonic Whistle;
- Ultrasonic Acoustic Deterrent using a High-Speed Jet Device;
- Testing and Comparability at two facilities (Ohio and Texas) with various treatments; and
- Texturizing Wind Turbine Towers to Reduce Bat Mortality.

The following are relevant points made in presentations by NRG Systems at the 2020 Hawaiian Hoary Bat Workshop (Honolulu, Hawai‘i, 6 March 2020), the deterrent manufacturer used by Hawaii wind projects to date:

- Deterrent units have a lifespan of approximately ten-years
- It is assumed bats cannot become desensitized to the deterrents
- A study of 30 turbines in Illinois found that deterrents combining with 5 m/s low wind speed curtailment yielded:
    - 68% reduction in total bat fatalities
    - 57% reduction in the Eastern Red Bat fatalities, and
    - 71% reduction in the mainland hoary bat fatalities
- A study of 15 turbines in Texas found that using deterrents only yielded:
    - 50% reduction in total bat fatalities, and
    - 54% reduction in Mexican Free-tailed Bat fatalities, and
    - 78% reduction in mainland hoary bat fatalities

A recent study by Bat Conservation International (Schirmacher 2020) compared mortality reductions from both low wind speed curtailment and deterrents and was unable to detect a clear reduction in mortality from deterrents alone for any individual mainland bat species, including hoary bats.

Overall, the results for deterrent systems to date are mixed in Hawaii and on the mainland U.S. Additional studies and test systems are needed to determine the effectiveness of these systems.

Studies by Gorresen et al. (2015a and 2015b) conducted in the western U.S. and Hawaii were designed to determine if 1) dim UV light was perceptible to bats and 2) if bat flight behavior would be impacted by UV light. Gorresen et al. (2015a) demonstrated that multiple genera of bats can perceive dim UV light, at levels imperceptible to humans and many avian species. Gorresen et al. (2015b) conducted their study at the same macadamia nut farm on Hawai‘i Island where the aforementioned acoustic deterrent surveys took place (i.e., Gorresen et al. 2017). In the study acoustic detections per night at treatment sites declined by 44% compared to control sites, despite an increase in insect abundance which could have promoted more bat activity (Gorresen et al. 2015b). Thermal camera results also appeared to support the decrease in activity, although statistical results were not significant. These results were not supported in another study of UV deterrence (Cryan et al. 2022) at the National Wind Technology Center at the National Renewable Energy Laboratory in Boulder, Colorado in which no decrease in bat activity was detected when turbines were illuminated with dim UV light.

[7] Available at: https://awwi.org/webinars/status-and-findings-of-developing-technologies-for-bat-detection-and-deterrence-at-wind-facilities/

Lastly, although findings to date have been inconclusive, physical modifications to turbine towers and blades (i.e., surface texture) have also been evaluated in a preliminary study as a technique to make turbine towers less attractive to bats (unpublished research, Texas Christian University[8]).

Given the relatively high levels of take projected for Hawaiian hoary bats in Hawaiʻi, and the uncertainties regarding the effectiveness of mitigation to compensate for that take, the research, testing and deployment of effective deterrents are a high priority. This can be accomplished by 1) including the use of deterrents that have been shown to be effective in studies as part of all HCPs, and 2) investing in deterrent research to support the development and improvement of their effectiveness. Where deterrents are installed, therefore, it is important to report any periods when equipment is inoperable or malfunctioning. Funding should be aggressively pursued for opportunities to support development of deterrents, including application for state and federal grants, such as the HCP planning grants offered under the Cooperative Endangered Species Conservation Fund[9].

V. MITIGATION

OVERVIEW

HRS 195D requires that HCPs include mitigation measures that result in an overall net gain in the recovery of any species for which take cannot be avoided. The measures to be implemented to achieve those benefits must also be included in HCPs along with justification for how the proposed mitigation will achieve net recovery benefits. The net environmental benefit requirement is generally best achieved through implementation of conservation measures for which quantitative monitoring demonstrates that individuals of the covered species have been effectively added to the population, and that the number added exceeds the number removed through take. The conservation measures employed to achieve this end result may address any threats or limiting factors that affect the HCP covered species. The ultimate objective should be to increase survival or reproductive success above a known level that would be likely in the absence of mitigation.

Identification of mitigation actions to offset take of the Hawaiian hoary bat is challenging because many threats and factors that limit their population are unknown. Specifically, there are currently no data to infer (with statistical confidence) an effect on Hawaiian hoary bat population dynamics resulting from implementation of conservation measures to address a threat or limiting factor. These challenges are compounded by the limitations inherent in the tools currently available for measuring changes in Hawaiian hoary bat population demographics. Interim mitigation approaches therefore must be identified that comply with applicable sections in HRS 195D.

The discussion below provides guidance for the development of mitigation plans for the Hawaiian hoary bat in light of the challenges and uncertainties described above. The overall approach a) integrates the best available science and management practice to enhance efficacy, b) research to improve understanding of threats and limiting factors, c) biological monitoring to measure and track

[8] Available at: https://awwi.org/webinars/status-and-findings-of-developing-technologies-for-bat-detection-and-deterrence-at-wind-facilities/
[9] https://www.fws.gov/service/habitat-conservation-planning-assistance-grants

success, and d) adaptive management to improve effectiveness of mitigation as new information becomes available.

Mitigation Planning Framework

A framework for mitigation plans includes the following elements:

- Biological goals and objectives that establish specific, measurable outcomes. These should describe the targets that mitigation is expected to achieve and serve as the measures of success.
- Implementation plans that specify how the work will be accomplished to reach the mitigation targets; a schedule of work or activities should be included.
- Monitoring plans that establish the schedules of all activities designed to assess progress towards meeting mitigation goals and objectives. Targets should be time specific to provide a meaningful indication of whether the implementation is on track to achieve success.
- Adaptive management approaches that are based on the results of monitoring. These should describe alternative actions that will be implemented if mitigation targets are not being achieved by the proposed actions.

Additional guidance on compensatory mitigation is provided by the USFWS in their 2016 Endangered Species Act (ESA) Compensatory Mitigation Policy (81 Federal Register 248, pp. 95316-95348).

Mitigation Actions

Hawaiian hoary bats evolved in environments that include the native habitat complements of species composition, richness, and diversity. Recent data indicate that Hawaiian hoary bats can use at least some habitat that is comprised of non-native species for foraging, roosting, and/or breeding (see the USFWS 5-Year Status Review of the Hawaiian hoary bat conducted in 2021 [USFWS 2021] for examples. Use of native forest habitat as mitigation also considers the HRS 195D-4(g)(8)) requirement that HCPs provide net environmental benefit as well as an overall net gain in the recovery of the species. Native forest is optimal habitat for many of Hawai‘i’s native species and maintenance of ecosystem functions would therefore contribute to the requirement of net environmental benefit. Based on these assumptions and observations, the following components are important to include in a mitigation plan:

- An evaluation of how the proposed mitigation will protect or improve foraging, roosting, and breeding by Hawaiian hoary bats.
- The protection of currently suitable, predominantly native forest habitat that is threatened with loss or degradation.
- The restoration of degraded habitats to predominantly native forest.
- The inclusion or incorporation of non-native species or habitat features to provide recovery benefits to the Hawaiian hoary bat only when benefits have been demonstrated.
- An assessment of potential threats and how they will be addressed (i.e. predators, barbed wire)
- The consideration of net environmental benefits that support all native species.
- Monitoring the response of Hawaiian hoary bats (at the population level) to the employed mitigation action using the best available methods to determine occupancy, presence, distribution, or abundance.

- Inclusion of an iterative and structured process for the identification of and support for scientific research to improve the understanding of bat population dynamics, threats, and limiting factors to improve the effectiveness of mitigation efforts designed to provide recovery benefits.

Selection of mitigation projects may be informed based on the timing of mitigation in relation to take. Habitat restoration generally requires many years of effort before the creation of suitable habitat is achieved and may therefore not be appropriate as mitigation for shorter duration take authorizations.

The information provided below will ideally be revised on a 5-year basis, or sooner, as further research on Hawaiian hoary bats is completed and more specific management actions for the species are identified.

11. Habitat Restoration and Habitat Improvement

Biological Goals and Objectives

Habitat loss is one of the primary threats to the existence of many threatened or endangered species. Basic information, however, is currently lacking regarding factors that serve to limit the hoary bat's population in the Hawaiian Islands. Although the federal recovery plan for the Hawaiian hoary bat (USFWS 1998) assumed that habitat was a limiting factor, there are currently no studies that have documented this.

Strategic island wide habitat protection and restoration efforts aimed at maintaining the viability of native ecosystems that provide resources for Hawaiian hoary bats is the most desirable. HCP restoration efforts would ideally be coordinated island wide and with other organizations in order to provide habitat for bats that is well distributed across the island where take occurred, spans a range of elevations, and that complements the recovery of other Hawaiian species.

The goal of habitat restoration for Hawaiian hoary bats should be to restore habitat that is currently unsuitable for foraging, roosting, and breeding by the species to one that meets its biological and ecological needs. Hawaiian hoary bat breeding occurs only at elevations below 1000 meters (Menard 2001) and they generally prefer forest habitat for pup raising (Gorresen et al. 2013). Although both H.T. Harvey (2020) and Pinzari et al. (2019) have demonstrated that the species does forage in open areas and eats native and non-native insects, much is still unknown regarding the attributes that comprise suitable habitat for Hawaiian hoary bats. It can be argued that Hawaiian Hoary Bats are historically adapted to native vegetation in Hawaiʻi are and it is assumed that native cover is still an important component of current habitat requirements for recovery of this species, until peer reviewed science shows otherwise.

A model habitat restoration project would employ a landscape level strategy that results in restoration of native forest habitat that incorporates natural assemblages of forest canopy, understory, and ground cover plant species that exhibit appropriate species richness and diversity. Plant species used in such a restoration would optimally consist of known host plants of preferred prey for Hawaiian hoary bats, based on available information. Other restoration goals for healthy Hawaiian Hoary Bat habitat would include controlling habitat-degrading ungulates (e.g., by fencing), removing key invasive species, and planting or enhancing native vegetation as needed.

Several Hawaiian hoary bat mitigation projects to date have implemented habitat restoration efforts on native forest and wetland habitats (e.g. at the Waihou mitigation area on Maui (Auwahi Wind 2021) and the Ukoa wetland site on Oahu (Kawailoa Wind 2021). Although studies of activity and presence have shown that forested areas are positively associated with bat occupancy, the composition with respect to native-alien species for successful restoration has not yet been determined. A confounding factor in the determination of the best type of forest habitatmay be that the majority of remaining native forest occurs at high elevation (Gorresen et al. 2013). Studies by Grindal et al. (1999) and Brooks and Ford (2005) have found that the occurrence of open canopy forests interspersed with wetlands tend to be correlated with increased bat activity on the U.S. mainland. A study conducted by SunEdison in Hawaiʻi (SWCA 2011) suggests that ponds and wetlands could serve as important foraging areas for the Hawaiian hoary bat and observations of bats frequenting ponds has been documented during studies at a Auwahi Wind Energy restoration site on Maui (Auwahi Wind 2018).

USGS researchers have increased the understanding of Hawaiian hoary bat distribution, habitat use, prey consumption, and occupancy (Bonaccorso et al. 2015, Bonaccorso et al. 2016, Gorresen et al. 2013, Gorresen et al. 2015a, 2015b, and 2015c, Pinzari et al. 2014, Todd 2012, and Todd et al. 2016). These and other research findings are used to inform habitat-based mitigation actions to further benefit the bats and aid in identifying appropriate mitigation sites to support foraging, pupping, and roosting needs. Surveys, for instance, have been conducted in Kahikinui Forest Reserve and Nakula Natural Area Reserve on Maui (KFR-NNAR; Todd et al. 2016). Baseline information gathered during these surveys indicates that detection probabilities, mean pulses per night, percentage of nights with feeding activity, and acoustic detections are greater in recovering forest areas than in unrestored shrublands (Todd et al. 2016).

Gorresen et al. (2013) found a significant correlation between Hawaiian hoary bat occupancy and the prevalence of mature forest cover, indicating this should be a consideration for habitat management. Although abundant in habitat cover used by bats, this study also reported that the Koa (*Acacia koa*) tree was not significantly associated with bat occupancy (Gorresen et al. 2013). Gorresen et al. (2013) hypothesized this result may be the due to Koa providing little shade for bat day roosts, and with limited influence on overall prey availability and the local availability of a wide variety of other food sources that are used opportunistically by foraging bats.

In a study of foraging movements by Hawaiian hoary bats on Hawaiʻi, Bonaccorso et al. (2015) tracked 28 bats on the island's windward side (Figure 7). For this study, "foraging area" was defined as the area traversed by a bat as it searches for food and feeds as well as during its movements to and from day roosts and night roosts. The mean size of an individual bat's foraging area was 230 hectares (568 acres) with a mean core use area (CUA; the area where an individual at spends 50 percent of its time) of 25.5 hectares (63 acres); i.e., mean CUA equates to 4.49% of mean foraging area (Bonaccorso et al. 2015). Bonaccorso et al. (2015) found no significant differences in bat foraging area or core use area sized by sex or age. While adult bats, however, occupied mean core use areas of 19.64 hectares (48.5 acres), juvenile females occupied CUAs (mean = 12.2 ha or 30 acres) that were 22% smaller than those of juvenile males (mean = 56.7 ha or 140 acres). There was no overlap in CUAs among adult male bats and less than 8% overlap among all bats.

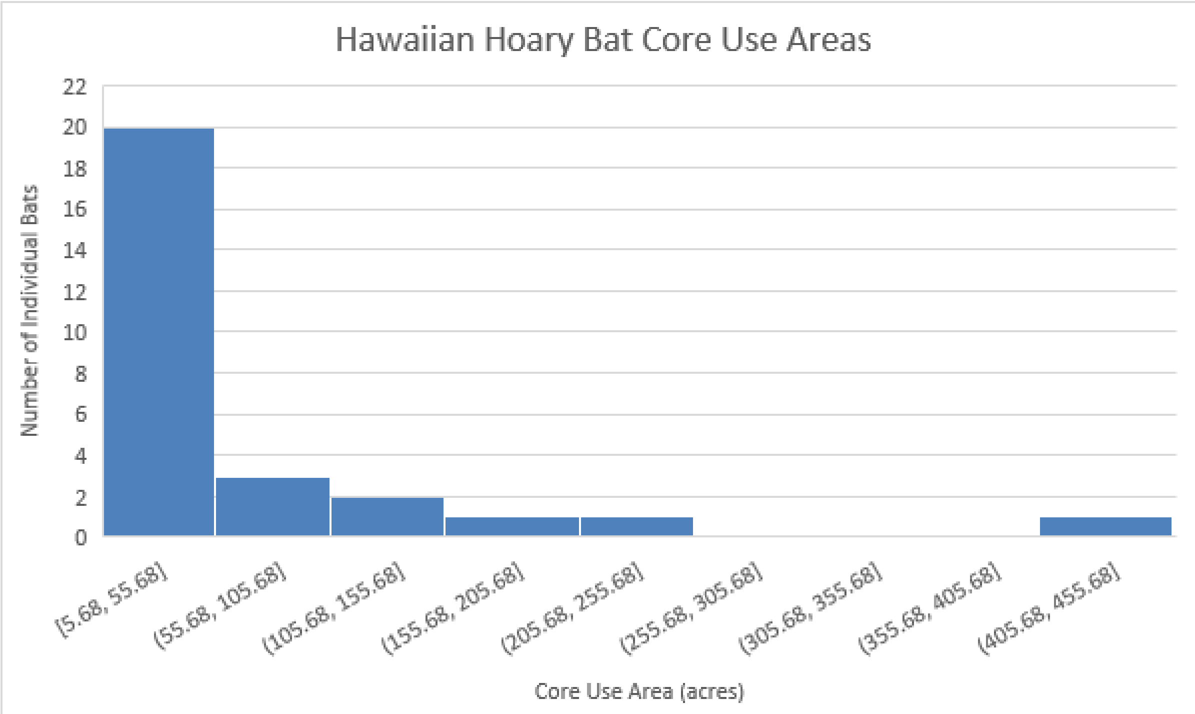

Figure 7. Bat core use area from 28 bats (both adults and subadults) on Hawaiʻi Island (Bonaccorso et al. 2015). The x-axis represents progressively higher range categories of 50 acres each.

H.T. Harvey (2020) conducted a study on Maui that included tracking bat movements. In an unpublished update to their study presented at a workshop addressing Hawaiian hoary bat issues[10] they found that bats occupied much larger CUAs (mean CUA for all bats of over 9,000 acres) and foraged over much larger areas (mean foraging area of over 40,000 acres). It is currently unclear how to reconcile the vastly different CUA sizes found in the two studies, although the H.T. Harvey (2020) study suggests that the CUAs on Hawaii Island included more native habitat that may have had a higher quality such that less habitat area was needed.

Federal and State agencies had previously used estimates of CUA sizes as a surrogate for the habitat needs of the Hawaiian hoary bat, which were then used to determine mitigation for the take of the species. The amount of habitat recommended to offset take of one bat has ranged from 20 to 40 acres, depending on the rationale in place at the time.

There are concerns of shortcomings with using the size of CUAs to determine the size of habitat mitigation areas for the Hawaiian hoary bat, the most significant of which is whether habitat can be a limiting factor to bat populations. If native forest habitat is not a key limiting factor for long term conservation of the Hawaiian hoary bat, habitat restoration as an offset to take generates a false assumption (or sense of security) that bat populations are benefitting from mitigation. If, however, habitat is a limiting factor, habitat restoration may be an important benefit to bat populations in Hawaiʻi. The secondary issue of concern then becomes the quantity of habitat needed to increase bat populations and what constitutes quality habitat.

[10] https://dlnr.hawaii.gov/wildlife/files/2020/10/HHBat.MauiForagingEcology.Johnston1.pdf

Until the H.T. Harvey (2020) study is better understood and results fully interpreted in a peer-reviewed document, the Bonaccorso et al. (2015) and Gorresen et al. (2013) studies provide the best information on habitat use by Hawaiian hoary bats.

Following Bonaccorso et al. (2015) as a starting point, two examples of habitat restoration that include a mix of foraging and roosting/pupping habitat (such as forest and forest edge habitat) are provided below that could serve as compensation for each bat take

a) Example 1: The typical unit of Hawaiian hoary bat take is one adult bat, which is considered an appropriate offset target. Bonaccorso et al. (2015) found that adult bats (Table 1) occupied a mean CUA of 48.5 acres (19.6 hectares). Bats spend at least 50% of their time and exhibit a high level of feeding activity within their CUA, which is therefore assumed to comprise high-quality habitat. The restoration of 48.5 acres CUA-quality habitat could be considered to add enough habitat value to provide for half or 50% of an adult bat's resource needs. Doubling this acreage might provide for an additional 50% resources and would equate to the creation of 97 acres of high quality, predominantly native habitat (i.e., CUA quality at an appropriate elevation with appropriate food or prey resources). While both native and non-native habitat cover types can provide resources for Hawaiian hoary bats, native forest restoration has a much greater potential of providing environmental benefits under 195D than non-native. Creating new, non-native forests could potentially preclude mitigation areas from contributing to the recovery of other endangered species.

b) Example 2: As noted above, the mean CUA on Hawaii Island covers an area of 48.5 acres (19.6 hectares). This second option would continue to restore a 48.5-acre CUA-equivalent with quality native habitat, but rather than doubling this area, would instead augment the core area with foraging habitat consisting of a mix of forested lowlands, shrublands, grasslands, and gulches. Table 1 shows that the size of an adult bat's foraging area is 511 acres (206.8 hectares) including the CUA (from data in Bonaccorso et al. 2015). The mean area for CUA and foraging would be 511 acres; 48.5 acres CUA and 462.5 acres non-CUA foraging. Unlike for the CUAs though, Bonaccorso et al. (2015) found that bat foraging areas overlapped to at least some. On-average, the overlap in foraging areas was approximately 50% of the entire foraging range (for the four adults in Table 3 of Bonaccorso et al. 2015).

Table 1. Twenty of the 26 bats in Bonaccorso et al. (2015) were adult bats. The sizes of the foraging and core-use area (CUA) kernels are shown below in hectares (ha). The average CUA was 19.6 ha (48.5 acres), the median size of CUAs was 8.3 ha (20.5 acres).

Bat	Sex/age	95% kernel foraging (ha)	50% kernel core-use (ha)	Long axis (m)	Tracking nights	Telemetry positions (n)	Month/year
631	♂/Adult	29.6	2.3	825	5	67	Aug.2005
467	♂/Adult	24.1	3.6	1,165	4	55	Oct.2006
756	♂/Adult	33.6	5.1	1,134	9	55	Dec.2004
514	♂/Adult	39.0	5.5	1,147	9	172	Aug.2005
782	♂/Adult	48.0	5.8	1,077	5	76	Oct.2005
70	♂/Adult	37.3	6.4	1,015	8	196	May.2010
99	♀/Adult	45.0	7.2	913	4	83	Nov.2005
694	♀/Adult	55.4	7.3	1,095	5	119	May.2006
19	♂/Adult	71.1	7.7	1,904	4	91	Nov.2005
630	♂/Adult	67.3	8.2	2,076	4	51	Sep.2005

Bat	Sex/age	95% kernel foraging (ha)	50% kernel core-use (ha)	Long axis (m)	Tracking nights	Telemetry positions (n)	Month/year
993	♂/Adult	104.3	8.4	1,843	6	87	Jun.2010
720	♀/Adult	73.7	9.3	2,644	4	32	Oct.2005
131	♂/Adult	94.3	13.1	1,029	4	32	Aug.2008
555	♀/Adult	126.2	17.2	8,833	3	30	Aug.2006
632	♀/Adult	146.0	20.0	2,218	6	56	Aug.2007
103	♀/Adult	139.2	21.8	1,304	4	39	Aug.2008
830	♂/Adult	124.0	25.0	4,650	4	71	Jun.2005
605	♀/Adult	626.3	59.8	7,177	8	72	Jun.2006
140	♂/Adult	1,593.0	72.0	17,911	7	62	Jan.2005
729	♂/Adult	657.7	87.1	11,327	12	56	Nov.2004
	Sum	**4,135.1**	**392.8**	**n/a**	**115**	**1,502**	
	Average	**206.8**	**19.6**	**3,564.4**	**5.8**	**75.1**	
	Median	**72.4**	**8.3**	**1,574**	**5.0**	**64.5**	

Based on that overlap, it is used to determine this second habitat mitigation option that includes an adjustment to the area needed for compensatory mitigation. One method to account for this overlap could be to provide compensatory mitigation for 100% of the average non-overlapping foraging area and only a per-bat proportional amount of the overlapping area – enough to reach the total cumulative amount of overlapping and non-overlapping foraging area. A project could provide 255.5 acres of non-overlap foraging area (511*0.5) which includes 48.5 acres of CUA quality habitat and 207 acres non-shared foraging habitat for each bat, plus 64 acres of shared foraging area (one-fourth of the foraging area with overlap ([511*0.5] ÷ 4) based on Bonaccorso et al. (2015) and using the four adult bats in this portion of the study). This option would provide for the creation of 48.5 acres of high quality predominantly native CUA habitat and an additional 271 acres (207 exclusive plus the 64 apportioned to each bat from shared habitat) with improved foraging opportunities in native or non-native lowland forest, grasslands, shrublands, and gulches. This option more closely matches observed habitat use by Hawaiian hoary bats on Hawaii Island and statements by an expert that a bat's full foraging range is likely important for its survival (F. Bonaccorso, pers. comm. 2011).

<u>Incorporation of Other Habitat Features into Mitigation</u>

Wetlands have been used as mitigation sites for plant and animal species in Hawaii and elsewhere (for example for waterbirds and the Hawaiian hoary bat at Ukoa Wetland on Oahu as mitigation under the Kawailoa Habitat Conservation Plan). The results of restoration efforts at wetlands on the continental U.S. have documented increased bat activity at mitigation sties (Menzel et al. 2005). In Hawaii, only the HCP for Kawailoa Wind Farm on O'ahu includes mitigation for Hawaiian hoary bats through wetland restoration. Data collected by SunEdison demonstrated that bat activity rates measured through acoustic detectors are seven times higher at small irrigation ponds near the Kawailoa project site than at other nearby vegetated areas (SWCA 2011). It is not clear if these water features are increasing the number of bats that can successfully occupy the area, or if they simply represent sites where bats are concentrated while foraging over this landscape by the presence of the water feature and are thus easier to detect. Mitigation through restoration at the 'Uko'a wetland on Oʻahu is underway with the intent to provide increased bat foraging habitat. Monitoring efforts will aid in evaluating the efficacy of wetland management for Hawaiian hoary bat mitigation. Although no data to date have confirmed this, wetland restoration projects could provide important foraging habitat for Hawaiian hoary bats. Studies conducted by USGS at the Koloko-Honokōhau National Historical Park on the island of Hawaiʻi suggest that wetland habitats provide suitable insect prey for the Hawaiian hoary bat (Pinzari et al. 2014).

As noted at the beginning of this section, research suggests that Hawaiian hoary bats may use some non-native habitat. Habitat restoration or improvements could incorporate habitat features if justified by applicable scientific information and after assessment and consideration of any unintended effects. Examples of such habitat features may include the creation of edge habitat, forest canopy openings, water features, and may incorporate the use of particular tree species that possess special ecosystem attributes. These elements may be appropriate when included in an overall restoration plan consistent with the native habitat restoration or improvements discussed in Examples 1 and 2, above. Incorporation of these elements would be supported by a well-reasoned and detailed analysis of how the landscape would better support Hawaiian hoary bats and its likelihood of providing a net recovery benefit for the species given the level of take requested and net environmental benefits.

<u>Siting of Mitigation Projects and Legal Considerations</u>

It is recommended that mitigation be carried out on the island where take has occurred. It is also recommended to evaluate the proximity of the mitigation area to the wind turbine impact area and how this could negatively affect take.

Habitat restoration projects intended to serve as mitigation are most desirable and effective on lands for which those benefits will receive long-term or perpetual protection and management. When private lands are used for restoration, the documented commitment would preferably be a conservation easement that confers long-term or perpetual protection. If this is not feasible, a memorandum of agreement (MOA) with the landowner is warranted and should be pursued because

The use of public lands for restoration is recommended only when funding for restoration by an HCP will enhance and supplement public habitat restoration efforts, particularly in the case of acquisition or management of large tracts of land. HCP mitigation funds that replace or displace public funds available for the same type of work are discouraged. If restoration occurs on public lands, additional mitigation may be appropriate since no private land would need to be encumbered. A clear responsibility of the parties in a MOA with the public land manager would need to be in place prior to issuance of an ITL by DLNR.

The agencies and permittees should consider the establishment of island-wide in-lieu programs for Hawaiian hoary bat habitat restoration efforts. See the discussion below for further description.

12. Monitoring for Evaluation of Habitat Restoration/Improvement Success

Monitoring at a mitigation site would optimally facilitate future quantitative assessments of whether the project is on track to meet its mitigation goals. Mitigation site monitoring should be designed to address four objectives:

1) Assess the presence and seasonality of bat activity in the vicinity of the mitigation site prior to, during, and at the completion of mitigation.

2) Provide Hawaiian hoary bat presence and activity data for the site as part of an island-wide or regional occupancy assessment for the species;
3) Evaluate the initial and subsequent levels of potential Hawaiian hoary bat food resources (aerial invertebrates) at the site relative to changes in the habitat as a result of mitigation actions; and
4) Measure the response of the mitigation target (e.g., conversion of degraded habitats to increased native forest cover and diversity) to the restoration actions.

Measures of success and a detailed schedule of restoration actions and monitoring are key considerations for inclusion in the mitigation plan. Measures of success may include data that demonstrate an increase in Hawaiian hoary bat use of the mitigation area, such as increased presence, occupancy, or activity. Detecting a change in metrics may not be attainable with high levels of statistical confidence; this is a reasonable goal, however, and the limitations of analyses can be discussed in the monitoring plan. It is understood to be impracticable at this time to estimate the net recovery benefit of habitat restoration as the increased absolute number of bats occupying a core use area. The best measures of success, however, is the quantitative increase in one or more measures of Hawaiian hoary bat use of the mitigation area inferred with statistical confidence. It is recommended to use at least a 0.10 (90%) *alpha* level when testing for significance between sample results in statistical tests (pers. comm., J. Jacobi, USGS). Employing a power analysis is also prudent for each of the assessment variables to evaluate the strength of statistical tests, particularly when no significant difference is detected when comparing results from different times or sites.

It is important to monitor bat activity at the mitigation site throughout the permit period. Scaled-back monitoring after the initial years of a project can occur when the mitigation site is found to statistically maintain or increase bat activity through the permit period.

Acoustic sampling

Acoustic monitoring is recommended at 5-10 locations across a mitigation site using ultrasonic microphones mounted on a 10 ft poles attached to data loggers to record acoustic data (pers. comm., J. Jacobi, USGS). Mid-priced devices such as Wildlife Acoustics SM4BAT-FS are currently widely used. Lower cost units (e.g., AudioMoth[11]), however, are available that are capable of using open-source software for on-board processing, or alternatively, direct recording of acoustic/ultrasonic signals, which make sampling designs with greater spatial replication more feasible.

Primary metrics for acoustic sampling is Hawaiian hoary bat ‘presence’, which comprises bat activity levels (within- and between-nights) and feeding activity (noted by “feeding buzzes”); both would be measured by changes in detection rates over time. Secondary metrics include detection rate by time of night/daily, spatial and temporal autocorrelation of detections, cumulative time of detection within-night and over time (season), and interval between detections. Major limitations of acoustic sampling include imperfect detection due to cryptic vocalization behavior and a limited detection range (<30 meters). Given the latter, additionally employing thermal detectors to the site may be useful as they become more available and inexpensive, coupled with advances in analyzing thermal imagery.

[11] https://www.openacousticdevices.info/

Insect sampling

Insect diversity and abundance are greatly influenced by habitat structure and the composition of the plant community (Haddad et al. 2001). The availability and diversity of insects that represent food for bats is therefore expected to change during restoration of a mitigation site. The objectives of monitoring bat food resources in a mitigation area are to 1) determine baseline levels of key insect prey, and 2) assess trends in those or other important insects at the site over time.

The best methods for monitoring insects important to Hawaiian hoary bats employ the use of light traps and malaise traps (Matthews and Matthews 1971, Muirhead-Thomson 1991). Lights effectively attract night-flying insects and can be coupled with a trapping device to survey insect communities that are nocturnally active. Light traps are most effective at collecting flies, moths, beetles, hemipteran bugs and wasps (Kato et al. 1995, Scanlon and Petit 2008). As light traps draw insects from the surrounding environment, they are most effective when used away from competing light sources such as electrical outdoor illumination and the moon (Bowden and Church 1973).

Malaise traps are mesh, tent-like structures that intercept and capture insects that fly along or near the ground and are particularly effective at collecting flies, wasps and moths (Matthews and Matthews 1971, Townes 1972). Malaise traps compliment light traps because they are effective at collecting insect prey that may not be attracted to lights. Light and malaise traps deployed as pairs (i.e., 5-10 pairs spaced 5-10 m apart; close enough to represent similar habitat but far enough apart to minimize interference) across the mitigation area is recommended, but the number of trap pairs used depends on the size and complexity of the mitigation area. For example, an area planted only with koa of the same age would require fewer traps to assess insect communities than similar areas planted with a variety of plant species (Jeffries et al. 2006). Although precise placement of traps is not critical, light traps are most effective in areas that provide visual access of at least 20 m in all directions from the trap, while malaise traps work best placed in an area that provides uncluttered flight paths >5 m from the trap (Gressitt and Gressitt 1962).

A variety of light and malaise trap styles are commercially available. Commonly used examples include the Bioquip (https://www.bioquip.com/) Universal black light trap (Catalog #2851M) with standard collecting head (Catalog #2875H) and the Bioquip Townes style malaise trap (Catalog #2875DG) (Peck et al. 2008, Pinzari et al. 2019). Light traps are generally powered using a 12-volt sealed, deep-cycle battery that allows the trap to run throughout the night. A mechanical timer can be used to turn the light on at sunset and off at sunrise, saving battery power. Malaise traps in contrast do not require power and operate continuously throughout the trapping period.

Other good trap sampling practices include light traps and malaise traps operating 2-3 nights and 1-2 weeks, respectively, per sample period, with sampling conducted 3-4 times per year within the mitigation site (Pinzari et al. 2019). Placing traps in the same location during each sampling event is teh best approach to assess changes in an insect community over time (Pinzari et al. 2019). Using GPS units and/or flagging to identify trap locations will facilitate trap placement on subsequent dates.

The important measures for assessing insect prey in bat habitat are numbers of individuals and biomass (e.g., Scanlon and Petit 2008, Threlfall et al. 2012, Gonsalves et al. 2013). Bats appear to choose prey based on body size (Aldridge and Rautenbach 1987) and it is therefore important to determine the sizes of the insects that are collected during the monitoring effort. Insects are placed in three broad taxonomic groups in terms of their importance to bats: moths, beetles, and all other insects. Moths and beetles are the most important prey for the Hawaiian hoary bat (Jacobs 1999, Todd 2012, Pinzari et al. 2019), but insects such as flies, termites, crickets, and leaf bugs are also consumed. Insects and other arthropods that do not fly (e.g., immature crickets, wingless ants, spiders) should be removed from the samples since they are not available as prey for bats. Following proper procedures, insects are removed from light and malaise traps, identified as one of the three important taxonomic groups, placed into size classes (4-5 size classes), and counted. To best determine biomass, the samples should be oven-dried to constant mass and weighed to the nearest 0.1 gm (Gorresen et al. 2018). Samples may be saved for further analysis at a later time if desired. Examples of further study include searching for species that are rare or known to be particularly important prey for bats.

Habitat Recovery Monitoring

Monitoring selected habitat characteristics at the mitigation site will facilitate an assessment of the response of the mitigation target to the restoration actions. In many cases mitigation actions may be aimed at increasing cover and native species diversity in degraded habitats so these sites can provide for the essential resource needs of Hawaiian hoary bats, including roosting and pupping sites and reservoirs for increased food resources.

Changes in vegetation cover can be assessed periodically (e.g., annually, every five years, etc.) through image analysis or photo-interpretation of aerial or satellite photos. This method is generally suitable for quantifying changes in tree canopy cover, or extent of understory vegetation components such as grass or shrubs. More detailed vegetation sampling is conducted using vegetation plots (e.g., 20 x 20 m quadrat or 20 m radius) in which plant species are listed to provide information on species richness, and species cover is quantified using visual estimation or measured using point or line intercept methods (these and other sampling methods are described in Elzinga et al. [2001] and Mueller-Dombois and Ellenberg [2002]. One possible approach would based on these references include randomly establishing vegetation assessment plots throughout the mitigation area to document changes in species richness and quantity. The primary analysis metrics for this type of sampling are a) changes in the number of native species within different functional groups (trees, shrubs, ferns, etc.) and b) changes in cover by species and vegetation layer

13. Land Acquisition

The acquisition of land may be a desirable mitigation option when the benefits to the Hawaiian hoary bat within the acquired area can be determined with reasonable certainty. Consideration of the assessment of benefits may include (but are not limited to) land that presently supports bats, which may in some way be threatened in a manner that would render the habitat no longer suitable for bats. In this case, benefit is provided when the act of acquiring safeguards it from future development, protects existing habitat, and/or provides a clearly documented opportunity for restoration/creation of habitat.

When drafting proposals to acquire lands to serve as mitigation, good practice would be to include documentation that the habitat to be acquired currently supports bats. Such documentation might include a) the results of robust surveys that have documented the presence or occupancy of bats over the area for a specified time, b) the presence of suitable habitat such as intact native forest or other habitat types known to be used by Hawaiian hoary bats for foraging, roosting, or breeding, or c) other indicators of conservation value, such as size, location, proximity to protected public lands, or an overall beneficial landscape setting (i.e., nearby or adjacent preserved / protected quality habitat). Larger parcels are typically preferred over smaller parcels, but the location of a smaller parcel could make it more attractive as a mitigation site (e.g., the parcel’s proximity to another larger area that supports bats or is being restored to support bats).

It is recommended that the proposal includes documentation of the nature and urgency of threats to the lands and habitats to be acquired. Such documentation should illustrate that the subject lands are proposed for modification in the foreseeable future leading to the degradation or destruction of suitable habitat, and would result in the notable diminishment or absence of Hawaiian hoary bats on those lands.

The area (in acres) of suitable Hawaiian hoary bat habitat on land proposed for acquisition can be determined similarly to the approach used for habitat restoration or improvement described at the beginning of this section document section. If partnering with other entities for a larger land acquisition, the prorated share of funds provided for the mitigation would be used to calculate credit, unless a rationale for specific funding allocation is provided.

Proposals to acquire land as mitigation are recommended to be accompanied by documentation that ensures once a parcel of land is acquired, the habitat occurring on it will not be degraded or lose its suitability as bat habitat, in perpetuity. Such documentation may include records of transfer to conservation agencies, management plans, conservation easements, or other assurances. Also, planned activities or uses of the lands that are consistent with, and not detrimental to (e.g. timber harvesting, fencing with barbed wire, etc.), protection of bats and suitable habitat.

14. Research as Mitigation

At the April 2015 ESRC Bat Workshop and subsequently, experts recognized that current mitigation guidance for Hawaiian hoary bats is based on an incomplete understanding of the species' biology and recovery needs. Filling key information gaps was identified as a priority to better inform mitigation actions and reducing uncertainty in mitigation effectiveness. The Federal ESA Section 10(a)(2)(B)(ii) requires that the minimization and mitigation of the impacts of take be carried out "to the maximum extent practicable". The interpretation of this requirement by USFWS causes difficulty for the agency to support research as the best approach to fully offset the impacts of take "to the maximum extent practicable". Research is therefore not a preferred mitigation strategy for most species.

After thorough consideration by the ESRC, USFWS and DOFAW, research has been accepted in the past as a mitigation option for take of Hawaiian hoary bats in the near term due to the paucity of information on the species and the need for better management. Research as mitigation, therefore, has been and is still underway as of the date of this document.

While research is intended to result in a better understanding of the Hawaiian hoary bat and its recovery requirements, the benefit of research for the species is not readily assessed for any individual HCP; the level of effort required, therefore, cannot be determined without a monetary value assigned. In Hawaiʻi, Hawaiian hoary bat mitigation has varied extensively. The costs of research should ideally be similar to the costs of habitat restoration so that the value of the two are roughly comparable. Using 97 acres per bat as a recommended restoration acreage target in Method 1 described above under the Habitat Restoration and Habitat Improvement Section, the cost for research is estimated based on cost estimates to maintain and/or restore that amount of native forested areas and wetland habitats by the state and other partner organizations. DOFAW staff who developed the State of Hawaii "Rain Follows the Forest Initiative" estimated the costs to manage and restore key watershed areas (E. Yuen 2015 pers. comm.). These costs ranged from $35,708 - $68,415 per 40 acres depending on the condition of the forest and management needs, such as the amount of fencing and/or invasive species control required. The costs associated with management actions in the State of Hawaii Forest Reserves, Natural Area Reserves, and wetlands range widely with an average cost for 40 acres of $79,220.51 ± $47,366.45. Based on this high standard deviation and wide range in costs of the different managed areas described above, the figure of $50,000 to restore an area of 40 acres is currently considered to be a reasonable cost estimate. The calculated cost for research mitigation under this approach and using 97 acres per bat is $125,000 per bat.

For research to be credited as mitigation, research projects should be designed to gather information applicable to improving mitigation actions and planning during the life of the HCP or yield information for management of the Hawaiian hoary bat that better promotes its recovery. For instance, credit may be considered for research under habitat restoration or land acquisition mitigation for an HCP if research-quality data were obtained on topics in which research is needed; these topics or areas of interest are discussed below.

To identify the most desirable research questions and projects for Hawaiian hoary bats, the ESRC established the “Bat Taskforce” to conduct a thorough assessment of what data were needed for the species. This task force identified and prioritized these data needs, issued a request for proposals from entities qualified to carry out research on the species, reviewed, evaluated, and ranked all proposals received, and recommended to the ESRC which research proposals should be supported.

The Bat Task Force reported its findings to the ESRC in 2017 and included recommendations to support research projects totaling $4M in cost. These projects subsequently became a part of the mitigation plans for several HCPs that were pending approval at the time and were initiated in early 2018 with the expectation of continuing for 3-5 years. The ESRC reviewed the 2017 Hawaiian hoary bat research recommendations; Appendix 1 of this document presents the committee’s assessment of pertinent studies that will result in a better understanding of the Hawaiian hoary bat’s current status, limiting factors on its population, and management needs pursuant to HRS Chapter 92.

While recent studies (e.g. Pinzari et al. 2020) have produced valuable data on Hawaiian hoary bat status and ecology, several important informational gaps remain that are necessary to better understand limiting factors, abundance and population trends, and restoration needs to better conserve the species. The ESRC considers the following studies to be the highest priority to better offset impacts of incidental take on Hawaiian hoary bats:

- Development of effective methods for estimating Hawaiian hoary bat population size and trends at an island-wide or larger regional scale; [Appendix 1, Goal 1 (a)]. This would expand on recent research conducted by WEST on Oahu (WEST 2021a) and Maui (WEST 2021b) and would be part of an ongoing mitigation to other islands or regions on the islands of Maui or Hawaiʻi, and also extend the time-scale for these studies to better determine differential habitat use by the species and temporal trends in bat activity throughout the study area.
- Determining key demographic parameters for the species, including adult and juvenile mortality estimates, maximum age of bat reproduction, and average litter size; [Appendix 1, Goal 1 (b)]. Some of this information may be forthcoming in the final report of the 5-yr study by USGS.
- Determining if habitat restoration efforts result in increased bat occupancy. This could be completed by assessing trends in bat activity and insect food resource availability in similar adjacent habitats at different stages of forest regeneration. Such a study could be conducted, for example, in different age-class stands of forest at the Hakalau Forest Unit of the USFWS

Hakalau Forest NWR on Hawaiʻi Island, or in similar restoration forests in the Kahikinui area on east Maui; [Appendix 1, Goal 2 (a)].

The research topics and related priorities in Appendix 1 provide guidance for developing scientific studies that should benefit conservation and management of Hawaiian hoary bats. Studies focused on these topics may be considered for funding as part of incidental take mitigation or funded from other non-mitigation sources.

15. In-lieu Fee Approaches

Significant challenges and uncertainties exist when considering Hawaiian hoary bat mitigation. USFWS and DOFAW may therefore consider development of an in-lieu fee framework for an interim period of time as another option of mitigating for incidental take. As part of an in-lieu fee system, applicants deposit funds into an agency account to serve as their mitigation. The agencies then use these funds to develop and implement the recommended mitigation actions, as described above. This approach to mitigation has a number of advantages for species for which the success of compensatory mitigation is highly uncertain. Not only does this approach also simplify the process for applicants, whose mitigation will be deemed successful upon the deposit of the funds, but it enhances the ability of the regulatory agencies to direct the funds to specific needs (e.g., research and habitat management). HCPs may allow direct payments in this manner under State of Hawaii law pursuant to §195D-21(b)(1), if and when the mechanism exists.

An in-lieu fee program could increase the effectiveness of conservation and make it easier and more achievable for applicants to reach their mitigation offset needs. A required initial step in the process is a conservation plan.

VI. ADAPTIVE MANAGEMENT

Adaptive management is a required component of all HCPs and serves as a framework to address the uncertainty inherent in the conservation of a species covered by an HCP. The USFWS HCP Handbook (USFWS and NOAA 2016) outlines an HCP adaptive management strategy and program as follows:

- Define goals.
- Develop conceptual models to serve as hypotheses for how the system works and to identify key uncertainties.
- Evaluate management options.
- Develop a monitoring and evaluation program that can answer questions to reduce uncertainty.
- Implement management actions and monitoring.
- Evaluate information and incorporate it into decisions to improve system models, if needed.
- Use updated system models for directing future management and monitoring decisions.

An adaptive management framework is built on biological goals and objectives, monitoring, success criteria, and adaptive management triggers and strategy pathways. It allows for flexibility over time during the implementation of the HCP as new information is gained relative to calculated take and mitigation options, and uses monitoring and evaluation to adjust HCP management strategies.

Adaptive management is an essential component of an HCP that includes Hawaiian hoary bats because of a significant lack of data and specific conservation and recovery information pertaining to the species, This can result in uncertainties and / or risk to the species under an approved HCP. Inclusion of a "trigger" for specific actions in an HCP would make clear what actions would be taken under adaptive management, and when such actions would be put into place. The following list includes principles for sound adaptive management procedures:

- Inclusion of adaptive management triggers and responses, as a minimum, for the following: a) the overall rate of take; b) the rate of take within a tier if tiers are proposed; c) detection probability through CARE/SEEF monitoring; d) mitigation targets; and e) take minimization implementation rates (e.g., the percentage of time deterrence equipment is operational).
- Statement of a clear definition for both the triggers for proposed action, and the initial or default responses planned for exceedance of each trigger point (the use of a decision tree may in some cases be appropriate).
- Inclusion of a clear description of the range of adjustments to proposed management actions, which will be required as a result of any adaptive management provisions, and those that may be implemented.
- Specific consideration of additional curtailment and bat deterrence technology as responses to adaptive management trigger(s) for rate of take.

EoA modeling can be used to develop a metric for rate of take at a specific point in time to consider under adaptive management. Dalthorp and Huso (2015) describe a method that calculates a moving-average take rate that is tracked through the years. When the average take rate is clearly determined to be above the level permitted by the ITL, a short-term trigger is activated that can be used as a check against excessive take over the span of a few years, signaling that the long-term take limit is likely to be exceeded unless conditions change.

If the short-term trigger threshold is exceeded, HCP responses may include 1) curtailment with higher cut-in speed or other operating adjustments for wind turbines (if studies available at the time show those measures are likely to reduce take), 2) some form of deterrence if technologically feasible, or 3) some other specific means of minimizing take.

It is good practice is for HCPs submitted to agencies for consideration to include explicit and clear criteria for levels or rates of take that will trigger a response which is likely to be effective in reducing the rate of take in the foreseeable future. As Hawaiian hoary bats are almost exclusively nocturnal, a reasonable consideration for HCPs is whether to include trigger scenarios for which curtailment during all night-time hours is the most suitable response.

It is recommended that adaptive management include the provision that if authorized take is exceeded, turbines will not operate during times when the take of bats is possible.

Documentation of all adaptive management decisions is recommended in each HCP annual report and tracked to allow a thorough review of the full effect of all adaptive management decisions for an HCP. This should include results of monitoring, adherence to the schedule, and overall success, which will be reviewed annually with respect to the established success criteria in the HCP (A recommendation for HCP annual reporting isthe structure provided in the template provided by the agencies, found in Appendix 2.

VII. REFERENCES

Aldridge, H.D.J.N. and I.L. Rautenbach. 1987. Morphology, Echolocation and resource partitioning in insectivorous bats. *Journal of Animal Ecology* 56: 763-778.

Arnett, E.B., W.K. Brown, W.P. Erickson, J.K. Fielder, B.L. Hamilton, T.H. Henry, A. Jain, G.D. Johnson, J. Kerns, R.R. Koford, C.P. Nicholson, T.J. O'Connell, M.D. Piorkowski, and R.D. Tankersley, Jr. 2008. Patterns of bat fatalities at wind energy facilities in North America. *The Journal of Wildlife Management* 72: 61-78.

Arnett, E.B., M. Schirmacher, M.M.P. Huso, and J.P. Hayes. 2009. Effectiveness of Changing Wind Turbine Cut-in Speed to Reduce Bat Fatalities at Wind Facilities. 2008 Annual Report. Prepared for the Bats and Wind Energy Cooperative and the Pennsylvania Game Commission. Bat Conservation International, Austin, Texas, USA.

Arnett, E.B., M.R. Schirmacher, M.M.P. Huso, and J. P. Hayes. 2010. Effectiveness of changing wind turbine cut-in speed to reduce bat fatalities at wind facilities, final report. A final report submitted to the Bats and Wind Energy Cooperative. Bat Conservation International, Austin, Texas, USA.

Arnett, E.B., M.M.P. Huso, M. R. Schirmacher, and J.P. Hayes. 2011. Changing wind turbine cut-in speed reduces bat fatalities at wind facilities. *Frontiers in Ecology and the Environment* 9: 209–214; doi:10.1890/100103

Arnett E.B., G.D. Johnson, W.P Erickson, and C.D. Hein. 2013a. A synthesis of operational mitigation studies to reduce bat fatalities at wind energy facilities in North America. A report submitted to the National Renewable Energy Laboratory. Bat Conservation International, Austin, Texas, USA.

Arnett, E.B., C.D. Hein, M.R. Schirmacher, M.M.P. Huso, and J.M. Szewczak. 2013b. Evaluating the effectiveness of an ultrasonic acoustic deterrent for reducing bat fatalities at wind turbines. *PLoS ONE* 8: e65794.

Arnett, E.B. and E.F. Baerwald. 2013. Impacts of Wind Energy Development on Bats: Implications for Conservation. *Bat Evolution, Ecology, and Conservation*, pp 435-456.

Auwahi Wind. 2018. Auwahi Wind Farm Habitat Conservation Plan FY 2018 Annual Report. Prepared by Tetra Tech. https://dlnr.hawaii.gov/wildlife/hcp/approved-hcps/

Auwahi Wind. 2019. Auwahi Wind Farm Habitat Conservation Plan Final Amendment. Prepared by Tetra Tech. https://dlnr.hawaii.gov/wildlife/hcp/approved-hcps/

Auwahi Wind. 2021. Annual Report. https://dlnr.hawaii.gov/wildlife/files/2022/02/Auwahi-Wind-FY2021-HCP-annual-report_2021-09-03-compiled_final.pdf

Baerwald, E.F. and R.M.F. Barclay. 2011. Patterns of activity and fatality of migratory bats at a wind energy facility in Alberta, Canada. *The Journal of Wildlife Management* 75: 1103-1114.

Baerwald, E.F., J. Edworthy, M. Holder, and R.M.R. Barclay. 2009. A large-scale mitigation experiment to reduce bat fatalities at wind energy facilities. *The Journal of Wildlife Management* 73: 1077-1081.

Baird, A.B., J.K. Braun, M.A. Mares, J.C. Morales, J.C. Patton, C.Q. Tran. 2015. Molecular systematic revision of tree bats (Lasiurini): doubling the native mammals of the Hawaiian Islands. *Journal of Mammology* 96: 1-20.

Baird A.B., J.K. Braun, M.D. Engstrom, A.C. Holbert, M.G. Huerta, B.K. Lim, et al. 2017. Nuclear and mtDNA phylogenetic analyses clarify the evolutionary history of two species of native Hawaiian bats and the taxonomy of Lasiurini (Mammalia: Chiroptera). *PLoS ONE* 12: e0186085.

Barclay, R.M.R., E.F. Baerwald, and J.C. Gruver. 2007. Variation in bat and bird fatalities at wind facilities: assessing the effects of rotor size and tower height. *Canadian Journal of Zoology* 85: 381-387.

Bonaccorso, F.J., C.M. Todd, A.C. Miles, and P.M. Gorresen. 2015. Foraging range movements of the endangered Hawaiian hoary bat, *Lasiurus cinereus semotus*. *Journal of Mammalogy* 96: 64-71.

Bonaccorso, F.J., K. Montoya-Aiona, C.A. Pinzari, and C. Todd. 2016. Winter Distribution and Use of High Elevation Caves as Foraging Sites by the Endangered Hawaiian Hoary Bat, *Lasiurus cinereus semotus*. Hawai‘i Cooperative Studies Unit Technical Report HCSU-068.

Bowden, J. and B.M. Church. 1973. The influence of moonlight on catches of insects in light-traps in Africa. Part II. The effect of moon phase on light-trap catches. *Bulletin of Entomological Research* 63: 129-142.

Brooks, R.T. and W.M. Ford. 2005. Bat activity in a forest landscape of central Massachusetts. *Northeastern Naturalist* 12: 447-462.

Cryan, P.M. 2011. Wind turbines as landscape impediments to the migratory connectivity of bats. *Environmental Law* 41: 355.

Cryan, P.M., P.M. Gorresen, C.D. Hein, M.R. Schirmacher, R. Diehl, M. Huso, D.T.S. Hayman, P. Fricker, F. Bonaccorso, D.H. Johnson, K. Heist, and D. Dalton. 2014. Behavior of bats at wind turbines. *Proceedings of the National Academy of Sciences* 111: 15126–15131.

Cryan, P.M.; P.M. Gorresen, B.R. Straw, S. Thao, and E. DeGeorge. Influencing Activity of Bats by Dimly Lighting Wind Turbine Surfaces with Ultraviolet Light. *Animals* 2022, 12:9. https://doi.org/10.3390/ani12010009.

Dalthorp, D., M. Huso, and D. Dail. 2017. Evidence of Absence (v2.0) Users Guide: U.S. Geological Survey Data Series 1055. 109 pp., https://pubs.usgs.gov/ds/1055/ds1055.pdf.

Dalthorp, D., and M. Huso. 2015. A framework for decision points to trigger adaptive management actions in long-term incidental take permits: U.S. Geological Survey Open-File Report 2015-1227. 88 pp., http://dx.doi.org/10.3133/ofr20151227.

Elzinga, C.L., D.W. Salzer, J.W. Willoughby, and J. Gibbs. 2001. Monitoring Plant and Animal Populations. Wiley-Blackwell, Hoboken, New Jersey, USA. 360 pp.

Foo, C.F., V.J. Bennett, A.M. Hale, J.M. Korstian, A.J. Schildt, and D.A. Williams. 2017. Increasing evidence that bats actively forage at wind turbines. *PeerJ* 5:e3985: DOI 10.7717/peerj.3985.

Frick, W.F., E.F. Baerwald, J.F. Pollock, R.M.R. Barclay, J.A. Szymanski, T.J. Weller, A.L. Russell, S.C. Loeb, R.A. Medellin, and L.P. McGuire. 2017. Fatalities at wind turbines may threaten population viability of a migratory bat. *Biological Conservation* 209: 172-177.

Gonsalves, L., B. Law, C. Webb, and V. Monamy. 2013. Foraging ranges of insectivorous bats shift relative to changes in mosquito abundance. PLoS ONE 8: e64081. https://doi.org/10.1371/journal.pone.0064081

Good, R.E. and K. Adachi. 2014. Fowler Ridge Research Summary. Western EcoSystems Technology (WEST), Inc. Bloomington, IN and Cheyenne, WY, USA.

Good, R.E., W. Erickson, A. Merrill, S. Simon, K. Murray, K. Bay, and C. Fritchman. 2011. Bat Monitoring Studies at the Fowler Ridge Wind Energy Facility Benton County, Indiana, April 13-October 15, 2010. Prepared for: Fowler Ridge Wind Farm. Prepared by Western EcoSystems Technology (WEST), Inc., Cheyenne, WY, USA.

Good, R.E., A. Merrill, S. Simon, K. Murray, and K. Bay. 2012. Bat monitoring studies at the Fowler Ridge Wind Farm, Benton County, Indiana. An unpublished report submitted to the Fowler Ridge Wind Farm by Western EcoSystems Technology (WEST), Inc., Cheyenne, WY, USA.

Good. R. E., A. Ciecka, G. Iskali, and K. Nasman. 2017. Bat Monitoring Studies at the Fowler Ridge Wind Farm, Benton County, Indiana: August 3 – October 12, 2016. Prepared for Fowler Ridge Wind Farm, Fowler, Indiana. Prepared by Western EcoSystems Technology (WEST) Bloomington, Indiana.

Good, R.E., G. Iskali, K. Nasman, and A. Ciecka. 2018. Bat Evaluation Monitoring Studies at the Fowler Ridge Wind Farm, Benton County, Indiana. August 1-October 15, 2017. Prepared for: Fowler Ridge Wind Farm. Western EcoSystems Technology (WEST), Inc. Bloomington, IN, USA.Gorresen, M.P., A.C. Miles, C.M. Todd, F.J. Bonaccorso, and T.J. Weller. 2008. Assessing bat detectability and occupancy with multiple automated echolocation detectors. *Journal of Mammalogy* 89: 11-17.

Gorresen, M.P., F.J. Bonaccorso, C.A. Pinzari, C.M. Todd, K. Montoya-Aiona, and K. Brinck. 2013. A Five-Year Study of Hawaiian Hoary Bat (*Lasiurus cinereus semotus*) Occupancy on the Island of Hawai‘i. Hawai‘i Cooperative Studies Unit Technical Report HCSU-041.

Gorresen P.M., P.M. Cryan, D. Dalton, S. Wolf, F.J. Bonaccorso. 2015a. Ultraviolet vision may be widespread in bats. *Acta Chiropterologica* 17: 193−198.

Gorresen, P.M., P.M. Cryan, D.C. Dalton, S. Wolf, J.A. Johnson, C.M. Todd, and F.J. Bonaccorso. 2015b. Dim ultraviolet light as a means of deterring activity by the Hawaiian hoary bat *Lasiurus cinereus semotus*. *Endangered Species Research* 28: 249–257.

Gorresen, P.M., P.M. Cryan, M.M. Huso, C.D. Hein, M.R. Schirmacher, J.A. Johnson, K.M. Montoya-Aiona, K.W. Brinck, and F.J. Bonaccorso. 2015c. Behavior of the Hawaiian Hoary Bat (*Lasiurus cinereus semotus*) at Wind Turbines and its Distribution Across the North Ko‘olau Mountains, O‘ahu. Hawai‘i Cooperative Studies Unit Technical Report HCSU-064.

Gorresen P.M., P.M. Cryan, K. Montoya-Aiona, F.J. Bonaccorso. 2017. Do you hear what I see? Vocalization relative to visual detection rates of Hawaiian hoary bats (*Lasiurus cinereus semotus*). *Ecological Evolution* 7: 6669–6679.

Gorresen, P.M., P. M. Cryan, and G. Tredinnick. 2020. Hawaiian Hoary Bat (*Lasiurus cinereus semotus*) Behavior at Wind Turbines on Maui. Hawaiʻi Cooperative Studies Unit Technical Report HCSU-093.

Gressitt, J.L. and M.K. Gressitt. 1962. An improved malaise trap. *Pacific Insects* 4: 87-90.

Grindal, S.D., J.L. Morisette, and R.M. Brigham. 1999. Concentration of bat activity in riparian habitats over an elevational gradient. *Canadian Journal of Zoology* 77: 972-977.

Haddad, N.M., D. Tilman, J. Haarstad, M. Ritchie, and J.M.H. Knops. 2001. Contrasting effects of plant richness and composition on insect communities: A field experiment. *The American Naturalist* 158: 17-35.

Hein, C.D. 2017. Bats and Wind Energy Development. NWCC Webinar, 18 July 2017. https://www.nationalwind.org/summary-synthesis-latest-knowledge-wind-energy-wildlife/

Hein, C.D., and M.R. Schirmacher. 2013. Preliminary field test of an ultrasonic acoustic deterrent device with the potential of reducing Hawaiian hoary bat (*Lasiurus cinereus semotus*) fatality at wind energy facilities. Unpublished report submitted to First Wind, Portland, ME, by Bat Conservation International, Austin, Texas, USA.

Hein, C.D., A. Prichard, T. Mabee, and M.R. Schirmacher. 2013. Effectiveness of an Operational Mitigation Experiment to Reduce Bat Fatalities at the Pinnacle Wind Farm, Mineral County, West Virginia, 2012. An annual report submitted to Edison Mission Energy and the Bats and Wind Energy Cooperative. Bat Conservation International, Austin, Texas, USA.

Hein, C.D., A. Prichard, T. Mabee, and M.R. Schirmacher. 2014. Efficacy of an operational minimization experiment to reduce bat fatalities at the Pinnacle Wind Farm, Mineral County, West Virginia, 2013. An annual report submitted to Edison Mission Energy and the Bats and Wind Energy Cooperative. Bat Conservation International, Austin, Texas, USA.

HSEO. 2020. Hawaiʻi's Energy Facts and Figures. 2020 Edition. Hawaiʻi State Energy Office, Honolulu, Hawaiʻi USA. https://energy.hawaii.gov/wp-content/uploads/2020/11/HSEO_FactsAndFigures-2020.pdf

Horn, J.W., E.B. Arnett, M. Jensen, and T.H. Kunz. 2008. Testing the Effectiveness of an Experimental Acoustic Bat Deterrent at the Maple Ridge Wind Farm. A report submitted to the Bats and Wind Energy Cooperative and Bat Conservation International. Bat Conservation International, Austin, Texas, USA.

Horn, J.W. E.B. Arnett, and T.H. Kunz. 2011. Behavioral responses of bats to operating wind turbines. *Journal of Wildlife Management* 72: 123-132

H.T. Harvey and Associates. 2020. Hawaiian Hoary Bat Research, Maui. Final Report. Prepared for Terraform Power, February.

Hull, C.L. and S. Muir. 2010. Search areas for monitoring bird and bat carcasses at wind farms using a Monte-Carlo model. *Australasian Journal of Environmental Management* 17: 77-87.

Jacobs, D.S. 1994. Distribution and abundance of the endangered Hawaiian hoary bat, *Lasiurus cinereus semotus*, on the island of Hawaiʻi. *Pacific Science* 48:193-200.

Jacobs, D.S. 1999. The diet of the insectivorous Hawaiian hoary bat (*Lasiurus cinereus semotus*). *Canadian Journal of Zoology* 77: 1603-1607.

Jeffries, J.M., R.J. Marquis, and R.E. Forkner. 2006. Forest age influences oak insect herbivore community structure, richness, and density. *Ecological Applications* 16: 901-912.

Johnson, G.D. and M.D. Strickland. 2003. Biological Assessment for the federally Endangered Indiana Bat (*Myotis sodalis*) and Virginia Big-eared Bat (*Corynorhinus townsendii virginianus*). Prepared for NedPower Mount Storm, LLC.

Kato, M., T. Inoue, A.A. Hamid, T. Nagamitsu, M.B. Merdek, A.R. Nona, T. Itino, S. Yamane and T. Yumoto. 1995. Seasonality and vertical structure of light-attracted insect communities in a Dipterocarp forest in Sarawak. *Researches on Population Ecology* 37: 59-79.

Kawailoa Wind. 2021. HCP Annual Report. https://dlnr.hawaii.gov/wildlife/files/2022/03/Kawailoa-HCP-FY2021Annual-Report_Revised13Dec2021.pdf

Kunz, T.H., E.B. Arnett, W.P. Erickson, A.R. Hoar, G.D. Johnson, R.P. Larkin, M.D. Strickland, R.W. Thresher, and M.D. Tuttle. 2007. Ecological impacts of wind energy development on bats: Questions, research needs, and hypotheses. *Frontiers in Ecology and the Environment* 5: 315-324.

Lewis, T. 1965. The effects of an artificial windbreak on the aerial distribution of flying insects. *Annals of Applied Biology* 55: 503-512.

Lewis, T. 1969. The distribution of flying insects near a low hedgerow. *Journal of Applied Biology* 6: 443-452.

Matthews, R.W. and J.R. Matthews. 1971. T he malaise trap: its utility and potential for sampling insect populations. *The Great Lakes Entomologist* 4: 117-122

Maurer, J.D., M. Huso, D. Dalthorp, L. Madsen, and C. Fuentes. 2020. Comparing methods to estimate the proportion of turbine-induced bird and bat mortality in the search area under a road and pad search protocol. *Environmental and Ecological Statistics* 27: 769–801.

McAlexander, A. 2013. Evidence that Bats Perceive Wind Turbine Surfaces to be Water. M.Sc. thesis, Texas Christian University, Fort Worth, Texas, USA.

Menard, T. 2001. Activity Patterns of the Hawaiian Hoary Bat (*Lasiurus cinereus semotus*) in Relation to Reproductive Time Periods. M.Sc. thesis, University of Hawaiʻi at Mānoa, Honolulu, Hawaiʻi, USA.

Menzel, J.M., M.A. Menzel, J.C. Kilgo, W.M. Ford, and J.W. Edwards. 2005. Bat response to Carolina bays and wetland restoration in the southeastern U.S. coastal plain. *Wetlands* 25: 542-550.

Montoya-Aiona, K., F. Calderon, S. Casler, K. Courtot, P.M. Gorresen, and J. Hoeh. 2020. Hawaii Island, Hawaiian hoary bat roosting ecology and detection 2018-2019: U.S. Geological Survey data release. https://doi.org/10.5066/P9R95UYT.

Mueller-Dombois, D., and H. Ellenberg. 2002. Aims and Methods of Vegetation Ecology (2 ed.). The Blackburn Press, Caldwell, New Jersey, USA. 547 pp.

Muirhead-Thomson, R.C. 1991. Trap Responses of flying insects: The influence of trap design on capture efficiency. Academic Press. London, UK

Novaes, R.L.M., G.S.T. Garbino, V.C. Claudio, and R. Moratelli. 2018. Separation of monophyletic groups into distinct genera should consider phenotypic discontinuities: the case of Lasiurini (Chiroptera: Vespertilionidae). *Zootaxa* 4379: 439-440.

Peck, R.W., P.C. Banko, M. Schwarzfeld, M. Euaparadorn, and K.W. Brinck. 2008. Aline dominance of the parasitoid wasp community along an elevation gradient on Hawaiʻi Island. *Biological Invasions* 10: 1441-1455.

Pinzari, C., F. Bonaccorso, and K. Montoya-Aiona. 2014. Hawaiian Hoary Bat Occupancy at Kaloko-Honokōhau National Historical Park. Hawaiʻi Cooperative Studies Unit Technical Report HCSU-051.

Pinzari, C., R. Peck, T. Zinn, D. Gross, K. Montoya-Aiona, K Brinck, M. Gorresen, and F. Bonaccorso. 2019. Hawaiian Hoary Bat (*Lasiurus Cinereus Semotus*) Activity, Diet and Prey Availability at the Waihou Mitigation Area, Maui. Hawaii Cooperative Studies Unit Technical Report HCSU-090.

Pinzari, C., L. Kang,L, P. Michalak, L. S. Jermiin, D.K. Price, and F.J. Bonaccorso. 2020. Analysis of genomic sequence data reveals the origin and evolutionary separation of Hawaiian hoary bat populations. *Genome Biology and Evolution* 12: 1504-1514.

Russell, A.L, Pinzari, C.A., Vonhof, M.J., Olival, K.J., Bonaccorso, F.J. 2015. Two tickets to paradise: Multiple dispersal events in the founding of the hoary bat populations in Hawaiʻi. *PLoS ONE* 10: e0127912. doi:10.1371/journal.pone.0127912.

Scanlon, A.T. and S. Petit. 2008. Biomass and biodiversity of nocturnal aerial insects in an Adelaide City park and implications for bats (Microchiroptera). *Urban Ecosystems* 11: 91-106.

Schirmacher, M.R., A. Prichard, T. Mabee, and C. Hein. 2018. Evaluating a Novel Approach to Optimize Operational Minimization to Reduce Bat Fatalities at the Pinnacle Wind Farm, Mineral County, West Virginia, 2015. An annual report submitted to NRG Energy and the Bats and Wind Energy Cooperative. Bat Conservation International, Austin, Texas, USA.

Schirmacher, M. 2020. Evaluating the Effectiveness of an Ultrasonic Acoustic Deterrent in Reducing Bat Fatalities at Wind Energy Facilities, Final Technical Report. Prepared by Bat Conservation International for DOE EERE – Wind Energy Technology Office. Report number DOE-BCI-0007036.

Smallwood, K. S., D A. Bell, and S. Standish. 2020. Dogs detect larger wind energy effects on bats and birds. *The Journal of Wildlife Management* 84: 852-864

Solick, D., D. Pham, K. Nasman, and K. Bay. 2020. Bat activity rates do not predict bat fatality rates at wind energy facilities. *Acta Chiropterologica* 22: 135-146.

SunEdison. 2014. Kawailoa Wind Power Habitat Conservation Plan FY 2014 Annual Report Year 2. https://dlnr.hawaii.gov/wildlife/files/2013/10/Kawailoa-Wind-Power-Year-2-FY-2014-Report.pdf

SunEdison. 2015. Kaheawa Wind Power I Habitat Conservation Plan Annual Report: FY 2015. https://dlnr.hawaii.gov/wildlife/files/2013/10/KWPI-HCP-Year-9-Annual-Report_9-1-15_Redacted.pdf

SWCA. 2011. Kawailoa Wind Power Final Habitat Conservation Plan. Prepared for Kawailoa Wind Power, LLC. by SWCA Environmental Consultants. October 2011.

Starcevich, L. E., J. Thompson, T. Rintz, E. Adamczyk, and D. Solick. 2020. Oahu Hawaiian Hoary Bat Occupancy and Distribution Study, Project Update and Second-Year Analysis. Prepared by Western EcoSystems Technology (WEST), Inc., Cheyenne, Wyoming, USA.

Starcevich, L. E., J. Thompson, T. Rintz, E. Adamczyk, and D. Solick. 2021a. Oahu Hawaiian Hoary Bat Occupancy and Distribution Study, Project Update and Third-Year Analysis. Prepared by Western EcoSystems Technology (WEST), Inc., Cheyenne, Wyoming, USA.

Starcevich, L. E., J. Thompson, T. Rintz, E. Adamczyk, and D. Solick. 2021b. Hawaiian Hoary Bat Distribution and Occupancy Study. Leeward Haleakala, Maui, Hawaii. Final Report. Prepared by Western EcoSystems Technology (WEST), Inc., Cheyenne, Wyoming, USA.

Teta, P. 2019. The usage of subgenera in mammalian taxonomy. *Mammalia* 83: 209-211

Tidhar, D., M. Sonnenberg, and D. Young. 2013. DRAFT 2012 Post-construction Fatality Monitoring Study for the Beech Ridge Wind Farm, Greenbrier County, West Virginia. Final Report: April 1 – October 28, 2012. Prepared for Beech Ridge Wind Farm, Beech Ridge Energy, LLC, Chicago, Illinois. Prepared by Western EcoSystems Technology (WEST), Inc., NE/Mid-Atlantic Branch, Waterbury, Vermont.

Todd, C.M. 2012. Effects of Prey Abundance on Seasonal Movements of the Hawaiian Hoary Bat (*Lasiurus cinereus semotus*). M.Sc. thesis, University of Hawai‘i at Hilo, Hawai‘i, USA.

Todd, C.M., C.A. Pinzari, and F.J. Bonaccorso. 2016. Acoustic Surveys of Hawaiian Hoary Bats in Kahikinui Forest Reserve and Nakula Natural Area Reserve on the Island of Maui. Hawai‘i Cooperative Studies Unit Technical Report HCSU-078.

Townes, H. 1972. A light-weight malaise trap. *Entomological News* 83: 239-247.

Threlfall, C.G., B. Law, and P.B. Banks. 2012. Influence of landscape structure and human modifications on insect biomass and bat foraging activity in an urban landscape. *PLoS ONE* 7: e38800. https://doi.org/10.1371/journal.pone.0038800

USFWS. 1998. Recovery Plan for the Hawaiian Hoary Bat. U.S. Fish & Wildlife Service, Portland, OR. 50pp.

USFWS. 2016. HCP Handbook. https://www.fws.gov/media/habitat-conservation-planning-and-incidental-take-permit-processing-handbook.USFWS. 2019. Final Programmatic Environmental Impact Statement Addressing the Issuance of Incidental Take Permits for Four Wind EnergyProjects in Hawai‘i. Pacific Islands Fish and Wildlife Office, Honolulu, Hawai‘i. July 2019.

USFWS. 2021. 5-Year Status Review for the Hawaiian Hoary Bat. Available at: https://ecos.fws.gov/docs/tess/species_nonpublish/3306.pdf

USFWS and NOAA. 2016. Habitat Conservation Planning and Incidental Take Permit Processing Handbook. December. https://www.fws.gov/endangered/esa-library/pdf/HCP_Handbook.pdf.

Weaver, S., I. Castro-Arellano, T. Simpson, and C. Hein. 2019. Testing ultrasonic acoustic deterrents for reducing bat fatalities at wind turbines in south Texas. Pp.101-103 In; *Proceedings of the Wind-Wildlife Research Meeting XII*. St. Paul, MN, November 28-30, 2018. Prepared for the Wildlife Workgroup of the National Wind Coordinating

Collaborative by the American Wind Wildlife Institute, Washington, DC. Susan Savitt Schwartz, ed. 148pp.

Young, D.P., Jr., K. Bay, S. Nomani, and W.L. Tidhar. 2011. Nedpower Mount Storm Wind Energy Facility Post-Construction Avian and Bat Monitoring: July-October 2010. Prepared for NedPower Mount Storm, LLC, Houston, Texas, by WEST, Inc., Cheyenne, WY, USA.

Young, D.P., Jr., C. Nations, M. Lout and K. Bay. 2013. 2012 post-construction monitoring study, Criterion Wind Project, Garrett County, Maryland: April-November 2012. Prepared for Criterion Power Partners, LLC., WEST, Inc., Cheyenne, Wyoming, USA.

Ziegler, A.C., F.G. Howarth, and N.B. Simmons. 2016. A second endemic land mammal for the Hawaiian Islands: A new genus and species of fossil bat (Chiroptera: Vespertilionidae). *American Museum Novites* 3854: 52 pp

Zimmerling, J.R. and C.M. Francis. 2016. Bat mortality due to wind turbines in Canada. *The Journal of Wildlife Management* 80: 1360-1369.

APPENDIX 1. HAWAIIAN HOARY BAT RESEARCH

RESEARCH PRIORITIES IDENTIFIED IN 2016

Although many studies have been conducted on HHB in Hawai‘i and similar species found in North America, there are many issues relating to the distribution, abundance, population trends, limiting factors, and needed management for this species for which information is lacking or poorly known. The following list of expanded or additional priority research questions has been compiled from the two Hawaiian Hoary Bat workshops held in 2015 and 2020, as well as from issues raised during discussions at ESRC meetings. General priority is listed in parentheses for each research topic. This list of research priorities is meant to guide HHB related research efforts that are conducted either directly or indirectly connected to existing or proposed HCP projects.

An ESRC bat task force was convened following the first bat workshop and the task force developed a request for proposal (RFP) for research projects based on the research priorities identified at the time and the funding available. Five proposals for research projects were selected based The components of those projects selected are shown in Table 1. Table 1 also adds several new potential research areas, as described in the research priorities below. The 5 projects selected in 2016 are further described, along with their status, in Section B of this appendix.

Goal 1: Basic research
Conduct basic research to obtain information that will guide and assist conservation efforts. Objectives include:

a. **Document HHB population distribution and trends**. Conduct island-wide surveys on Maui and O‘ahu using replicable methods (e.g. occupancy analysis) to document distribution, annual trends, and seasonal changes in these populations. This information may inform efforts to evaluate risk associated with proposed actions in different areas, as well as inform management decisions for conservation benefit and provide baseline information needed to understand the potential role of habitat suitability in limiting populations of the bat. (1)
b. **Document demographic information**. Conduct research to determine basic demography, such as annual survival, mortality rates by age class, reproductive success, maximum lifespan, age of 1st breeding, % of breeding females, number of broods per year, mating system, etc. (1)
c. **Document home range and movements**. Conduct radio-telemetry experiments to better elucidate how nightly movements and home range may differ on different islands, in different habitats, or seasonally. This information can also help with identifying bat use for foraging, roosting, etc., in different habitat types and elevations. (1)
d. **Document genetic variability.** Collect genetic data to document variability, population structure, estimate effective population size, and provide information about population dynamics. Genetic information will also help with sex determination of damaged carcasses and to possibly differentiate different population groupings in different islands or regions of an island. (1)
e. **Conduct population modeling**. Obtain and use demographic information to develop population models, including population viability analyses. (1)

Goal 2: Identify limiting factors.
Understanding the factors that limit the survival and reproductive success of individuals, and therefore determine how this information relates to the distribution, abundance, and growth of populations, is essential for planning conservation actions designed to increase bat population sizes and create net recovery benefits. Potential factors that may limit bat populations include:

a. **Suitable habitat**. Bats require suitable habitat for foraging, roosting, and breeding. Studies indicate that bats use a wide range of habitats for foraging, but that mature trees may be important for breeding and roosting. Recent studies have documented aspects of habitat use for breeding and roosting, including tree species and architecture. However, some additional research is needed to improve our understanding of the definition of suitable habitat. Information resulting from habitat research will shed light on the question of whether or not bats are habitat limited. Findings that suitable habitat remains unoccupied would suggest that bats are not habitat limited, that habitat management and restoration would not necessarily result in net recovery benefits, and that other factors may be limiting bat populations. Objectives include, but may not be limited to:
   i. **Define suitable habitat.** Document aspects of habitat used for foraging, breeding, and roosting, including vegetation community structure, physical attributes, vegetation species used, and tree architecture. (1)
   ii. **Determine relationship of distribution to suitable habitat.** Document bat distribution and presence or absence in suitable habitat to determine whether suitable habitat is unoccupied. (1)
   iii. **Determine relationship of abundance to suitable habitat.** Determine whether aspects of suitable habitat are associated with demography and home range such that bat population densities or growth rates are associated with habitat features. (1)
   iv. **Conduct experimental treatments.** Conduct long term experimental studies (e.g. up to 20 years) in which bat occupancy or abundance is measured in treatment plots designed to increase suitable habitat. Research designed to employ this approach would be expected to require a study of considerable duration, given the long time frames inherent in habitat management and restoration efforts. Several habitat management projects are currently underway, in some cases in which Hawaiian Hoary Bat occupancy was assessed prior to the initiation of management efforts, that may provide opportunities for research consistent with the goals and objectives sought here. Applicants are encouraged to coordinate with current and potential licensees that may have opportunities for such long term research as part of their current mitigation requirements. (1)

b. **Food availability**

Populations may be limited if food resources are variable, scarce, or widely dispersed. Food limitation may impact survival and reproductive success to the degree that populations remain stable or decrease despite the availability of suitable habitat and lack of other threats. The following research objectives may contribute to a better understanding of food limitation.

i. **Identify diet**. Understand food habits by analyzing fecal samples to provide information on foraging ecology, nutritional needs, and population ecology. (1)

ii. **Document prey selection**. Determine which prey taxa are selected or preferred by comparison of diet to food availability. (1)

iii. **Food availability habitat type**. Abundance and seasonal trends of preferred HHB prey in different habitats. This research will help to identify foraging habitat use spatially and temporally. (1)

iv. **Determine relationship of home range to food availability**. Conduct studies in which food availability is measured within the home ranges of bats and determine whether a correlation exists. (2)

v. **Document relationship of food availability to survival and reproductive success**. Conduct studies in which food availability is monitored within and among years to determine whether survival and reproductive success are correlated with food availability. (2)

vi. **Conduct experimental treatments**. Conduct experimental studies in which bat demography, occupancy, or abundance is estimated in treatment plots designed to increase food availability. As with objective 2.a.iv. above, this research may require a study of considerable duration, and may be carried out as a part of a study pursuant to that objective, in order to explore the potential relationship between habitat suitability, food availability, and bat population dynamics. (3)

c. **Pesticides** Pesticide use in agricultural or other areas may place bats at risk to exposure, with resulting impacts on impact growth, survival, or reproductive success.

i. **Survey and analyze contaminate loads in bats.** (1)

ii. **Conduct surveys for chemical residues on bat prey**. (2)

iii. **Determine whether demographic variables are correlated with pesticide loads**. (3)

iv. **Determine whether high pesticide use areas are associated with low bat occupancy.** (3)

d. Predators

Predation may limit populations if bat pups or adults are subject to frequent predation events and high predator populations. Predator impacts on Hawaiian Hoary Bats are largely unknown. The following research may contribute to a better understanding of predatory relationships to bat populations.

i. **Bat breeding roost monitoring**. Conduct intensive monitoring at roost sites to observe the outcome of pups during the period they are non-volant. (1)

ii. **Investigation of potential predator's food preferences (e.g. barn owl)**. Analyze potential predators' consumed prey items through analyzing pellets, stomach contents, etc. (2)

Goal 3: Research and development

a. **Develop methods for assessing long term population trends**. Statistically robust methods for the detection of long term population trends are currently thought to be cost-prohibitive at relevant spatial scales. Efforts are needed to develop more cost effective methods to carry out state-wide long term population monitoring. (1)

b. **<u>Develop methods for the estimation of abundance</u>**. Methods for the estimation of bat population levels are currently not available. Efforts are needed to develop and implement such methods in order to inform population models that can be used to understand population status, risk, and sensitivity to incidental take and other threats. (1)

Table 1. Summary of Hawaiian Hoary Bat Research and Associated Goals and Objectives

Note: X indicates primary contributor, x indicates indirect contributor; red text indicates no primary contribution or incomplete information for either Oahu, Maui, or Hawaii island where geographic scope is important; blue text indicates a new research priority added subsequent to the 2016 RFP

Goals and Objectives	**Research Studies Funded by Wind Energy Projects starting after 2016**					**Other Studies Completed**
	Conservation genetics (USGS) [Complete]	Modeling foraging habitat suitability (USGS) [Complete]	Movement, roosting behavior, diet (USGS) [Ongoing]	Home range, movement, habitat util., diet, prey avail. (HT Harvey) [Complete]	Occupancy, distribution habitat use on Oahu (West) [Ongoing]	Various
Goal 1 Basic Research						
a. Distribution					X	x
b. Demography	x		x			x
c. Home range and movements			X	X		X
d. Genetic variability	X		x	x		X
e. Population modeling	x		x	x	x	X
Goal 2 Identify Limiting Factors						
a. Suitable habitat						
a.i. Define suitable habitat		X	X	X	X	X
a.ii. Relationship to distribution		X	X	X	X	x
a.iii Relationship to abundance		x	x	x	x	x
a.iv. Experimental treatments						x
b. Food availability						
b.i. Diet	x		X	X		X
b.ii. Prey selection		X	X	X		x
b.iii. Food availability habitat type						
b.iv. Relationship to home range			x	x		x
b.v. Relationship to success			x			
b.vi. Experimental treatments						
c. Pesticides						
c.i. Contaminant loads						
c.ii. Contaminants in prey						
c.iii. Correlation of loads-demography						
c.iv. Correlation of loads-occupancy						
d. Predators or Disease						
d.i. Bat reproductive success		x	x	x		x
d.ii. Bat predator food preference (cats, barn owls scat study)						
c. White-nose prevention plan						
Goal 3 Research and Development						
a. Population trend methods						
b. Estimate of abundance methods						
c. Deterrent research						X

Research Initiated in Response to the 2016 RFP

Five research projects were selected as meeting identified research needs as well as other scientific criteria and were recommended for consideration for funding to HCP (new or amended) applicants. Goals and objectives for each are described below and summarized in Table 1. The status of all five projects are noted below and in Table 1.

Hawaiian Hoary Bat conservation genetics [Complete]
Research components related to Objectives for Goal 1, Basic Research:
- Quantify levels of genetic variation and population structure throughout Hawaiʻi
- Determine if distinct population boundaries exist among islands
- Estimate effective population size(s)
- Determine sex of bats collected and carcasses

Modeling foraging habitat suitability of the Hawaiian Hoary Bat [Complete]
Research components related to Objectives for Goal 1, Basic Research:
- Echolocation, videography, and insect trapping
- Power analysis to estimate sampling effort for future studies of response to habitat restoration

Research components related to Objectives for Goal 2, Limiting Factors:
- Develop and test a technique that combines multiple sampling methods to specifically assess foraging habitat suitability
- Echolocation, videography, and insect trapping
- Power analysis to estimate sampling effort for future studies of response to habitat restoration

Hawaiian Hoary Bat conservation biology: movements, roosting behavior, and diet [Ongoing]
Research components related to Objectives for Goal 1, Basic Research:
- Home range size– seasonality; three annual cycles
- Habitat use– foraging, roosting, and breeding
- Roost fidelity and roost tree characteristics
- Mother-pup behavior at roosts
- Movement patterns and food availability
- Tissue and fecal collection bank– genetic, diet and pesticide studies

Research components related to Objectives for Goal 2, Limiting Factors:
- Habitat use– foraging, roosting, and breeding
- Roost fidelity and roost tree characteristics
- Movement patterns and food availability
- Insect prey-host plant associations
- Diet analysis– insect prey selection and availability using molecular bar-coding techniques
- Tissue and fecal collection bank– genetic, diet, and pesticide studies

Hawaiian Hoary Bat home ranges, seasonal movements, habitat utilization, diet, and prey availability (Maui) [Complete]
Research components related to Objectives for Goal 1, Basic Research:
- Determine home range and nightly and seasonal movements
- Evaluate foraging and roosting behavior
- Document the seasonal movements of bats

Research components related to Objectives for Goal 2, Limiting Factors:

- Define suitable habitat with acoustic sampling and radio-telemetry
- Assess risk of predation at maternity roosts through monitoring

Analysis of Hawaiian Hoary Bat occupancy, distribution, and habitat use (Oʻahu) [Ongoing]
Research components related to Objectives for Goal 1, Basic Research:

- Document distribution
- Estimate occupancy rates, detection probabilities, and covariate relationships
- Estimate seasonal changes in occupancy

Research components related to Objectives for Goal 2, Limiting Factors:

- Determine habitat suitability and characteristics to include vegetation community data, physical attributes, tree architecture, temperature, distance from water and forest, and other relevant variables
- Resource selection modeling

APPENDIX 2. HABITAT CONSERVATION PLAN ANNUAL REPORT TEMPLATE

APPENDIX 3. HCP CHECKLIST FOR REQUIREMENTS UNDER HRS 195D

Project Description and Covered Activities

☐ Project description
☐ Purpose and need: clear and detailed
☐ Specific discussion of power purchase agreements (PPAs) and implications for turbine operation details for wind energy
☐ Geographic plan area (includes mitigation areas)/Permit area (covered activities)
  ☐ Description and maps of both plan area to include mitigation program areas, and area covered by Incidental Take License/Incidental Take Permit. Include Tax Map Keys (TMKs).
  ☐ Permits/approvals required
☐ Description of covered activities that may result in take
☐ Alternative actions to the taking, as applicable (not an HRS 195D requirement but needed for an EA/EIS and Federal regulations)

Environmental Setting and Biological Resources

☐ Existing land use
☐ Ecosystem and vegetation for permit and plan areas
☐ Fauna for permit and plan areas

Covered Species

☐ Status and distribution of endangered, threatened, proposed, and candidate species (collectively covered species) with supporting studies
☐ Species description including life history
☐ Habitats/ccosystems used by the covered species
☐ Species use of the area
☐ Species in plan area that don't need coverage and why

Potential Biological Impacts and Take Assessment

☐ Anticipated take of each covered species
  ☐ Direct take; lifecycle considerations; breeding, feeding, shelter
  ☐ Specific causes or components of covered activities associated with take and duration of the take
  ☐ Evidence of Absence (EoA) and 80% credibility used for unobserved direct take
  ☐ Type of take (e.g., injury, mortality, harm, harassment)
  ☐ Indirect take (use USFWS guidance for Hawaiian Hoary Bats)
  ☐ Tiers if any and rationale
  ☐ Lost productivity
☐ Anticipated impacts of the take/effect analysis
  ☐ Resources required by species to fulfill lifecycle needs that may be affected by stressor
  ☐ Identify the resource need affected (breeding, feeding, shelter) by stressor
  ☐ Identify behavioral or physical response associated with each stressor (e.g., stress, displacement, lack of foraging ability, mortality)
☐ Cumulative effects: demographic consequence at population and species levels, both island-specific and Hawai'i-wide
  ☐ Identify all other authorized take for each species, both on the project island and Hawai'i-wide
  ☐ Demographic consequence at population and species levels, both island-specific and Hawai'i-wide
☐ Anticipated impacts of take on Critical Habitat

Conservation Program: Avoidance, Minimization, and Mitigation

☐ Biological goals
☐ Biological objectives

- ☐ SMART: ○ Specific ○ Measurable ○ Achievable ○ Result-oriented ○ Time-fixed
- ☐ Temporal and geographic scope of affected area (e.g., permit area, plan area)
- ☐ Uncertainties

☐ Conservation measures to avoid and minimize take
- ☐ Curtailment cut-in speed and justification
- ☐ Curtailment seasonal and daily timing and justification
- ☐ Details of turbine rotor speeds below manufacturer cut-in speed for the specific turbine models used
- ☐ Details of operation for the specific curtailment cut-in speed proposed: rotor speeds, rolling average times, and wind speed measurement location to stop feathering
- ☐ Deterrence research status and plans for the HCP
- ☐ Description of potential avoidance and minimization that will be employed under adaptive management

☐ Measures to mitigate unavoidable take
- ☐ Specific mitigation proposed including separate implementation plans
- ☐ Ensure HCP minimizes and mitigates impacts to the maximum extent practicable and provides reasoning for the determination
- ☐ Detailed, measurable mitigation success criteria during the permit term
- ☐ Net environmental benefit and recovery analysis
- ☐ Description of potential mitigation that might be employed under adaptive management

☐ A schedule for implementation of the proposed measures and actions

Monitoring and Reporting

☐ Avoidance, minimization, and observation training program for construction and operation staff

☐ Fatality monitoring
- ☐ SEEF and CARE trial specifics and justifications
- ☐ Bats to be sent to USGS for sex determination
- ☐ Third party monitoring and proctoring
- ☐ Notification requirements for downed wildlife and reference to state protocol

☐ Mitigation monitoring including analysis of success criteria and net benefit

☐ Migratory Bird Treaty Act (MBTA) monitoring and reporting

☐ Ecosystem, community, and habitat monitoring per requirement of 195D-21

☐ Reporting and meetings
- ☐ Annual report contents: all monitoring results, direct and indirect take for fiscal year, take since permit start, mitigation progress, adaptive management, minor amendments, expenditures
- ☐ Frequency of interim reports depending on complexity of the project and mitigation, e.g. quarterly
- ☐ Annual and interim reports to include an estimate of total direct and indirect fatalities
- ☐ Wind energy sites use 80% credibility limit to identify tier triggers (if any), and assess compliance with tier limits (if any) and the authorized take limit
- ☐ Annual reports include calculation of lost productivity
- ☐ Annual report recommendations
- ☐ Frequency of update meetings depending on complexity of the project and mitigation

Adaptive Management

☐ Adaptive management strategy
- ☐ Specific actions that may require adaptive management, e.g. take rate; new research or other information that shows that take minimization is available and practicable; mitigation success
- ☐ Triggers set for each action
- ☐ Specific analysis of defined objectives and success criteria, and process and timelines if triggers exceeded

Funding

☐ Budget includes monitoring, minimization, mitigation, contingency, funds for state compliance monitoring
☐ Description specifies that if a tier limit is reached mitigation for that tier must be fully funded and the next tier will not be authorized until mitigation is underway for that tier
☐ Funding assurance includes mitigation, contingency (or termed as adaptive management), and cost for state to take over management of mitigation if needed
☐ Inflation adjustments

Changed and Unforeseen Circumstances
☐ Changed circumstances
- ☐ Identify all changed circumstances (per USFWS regulations)
- ☐ Research or other information that shows an avoidance or minimization measure is likely to reduce take and is practicable
- ☐ Develop thresholds for clearly identifying when circumstances are changed versus unforeseen
- ☐ Develop responses for each circumstance: what will be the response to ensure goals and objectives are met if circumstance X happens to Y degree?

☐ No surprises description

Amendments
☐ In the event of a need for a formal amendment the applicant will work with the agencies to follow the most current agency regulations and policies
☐ Amendments
- ☐ Minor Amendment
  - ☐ Circumstances requiring a minor amendment, e.g. reduce take, increase mitigation
  - ☐ Procedures for a minor amendment
- ☐ Major Amendment
  - ☐ Circumstances requiring a major amendment
  - ☐ Specific trigger for when an amendment is needed when permitted take could be exceeded
  - ☐ Timelines for development of a major amendment

☐ Permit transfer (state ITL runs with the land)

APPENDIX 4. WILDLIFE AGENCY GUIDANCE FOR INDIRECT TAKE

Wildlife Agency Guidance for Calculation of Hawaiian Hoary Bat Indirect Take

In June 2016, the wildlife agencies discussed the possibility for standardizing the incidental take calculations for Hawaiian hoary bat for projects that have incidental take permits or incidental take licenses. As a result of that discussion we are recommending that proponents and their consultants consider using the following time periods and biological factors in their calculation of indirect take for observed Hawaiian hoary bat fatalities and for indirect take of unobserved Hawaiian hoary bats. Most of you will see very little change in the estimated take for your projects simply because the methods being used by everyone where somewhat similar. The only changes are really in the way the indirect is calculated and by the time the juveniles are converted to adults, there is only minor changes in total take estimation.

Calculation of Observed and Unobserved take will continue to be conducted with the Evidence of Absence software (Dalthorp et al. 2014 and Dalthorp and Huso 2015). The 80% credibility output will be used as a *general* guide for what the agencies are 80% confident has not been exceeded. This output plus the indirect take converted to adult bats will represent total take that we are 80% confident has not been exceeded. This total take at the 80% confidence level will also be used as the value to guide the triggering of the next tier level. The next tier level is currently triggered when 75% of the estimated take of the existing tier is reached or exceeded based on the output at the 80% credibility level plus indirect take.

Female Hawaiian hoary bats may be pregnant or supporting dependent young from April 1 through September 15 (Tomich 1986ab; Menard 2001; Uyehara and Wiles 2009; C. Pinzari, pers. comm. 2015). This is based on best science for the Hawaiian hoary bats or North American hoary bat surrogates and information in our files. The wildlife agencies understand that exceptions to this range can occur. However, the need to be conservative on the side of the species is primary. Second, the use of lactation to determine whether or not a female had dependent pups has been challenging, given the condition of the carcasses that are found. Thus, for these reasons, the Service recommends using April 1 through September 15 as a period in which a female bat taken may have been pregnant or lactating and will result in indirect take assessment on the direct take during this time period. This range would apply to all female observed carcasses. The determination of the sex of all carcasses found will be conducted through genetic testing by USGS.

The average number of pups attributed to a female that survive to weaning is unchanged and is assumed to be 1.8 which is based on Bogan, 1972 and Koehler & Barclay, 2000.

The sex ratio of bats taken through unobserved direct take will be assumed to be 50% female, unless there is substantial evidence to indicate a different sex ratio. Substantial evidence would need to be based on at least 10 or more bats.

The assessment of indirect take to a modeled unobserved direct bat take accounts for the fact that we do not know when the unobserved fatality may have occurred. The period of time from pregnancy to end of pup dependency for any individual bat is estimated to be 3 months. Thus the probability of taking a female bat that is pregnant or has dependent young is 25%, or 0.25.

The conversion of juveniles to adults has generally been 1 juvenile to 0.3 adults, though it has varied slightly from project to project. This was loosely based on the estimated survival of the little brown bat (*Myotis lucifugus*) which ranges from 20-48% (Humphrey & Cope 1976). The Service recognizes that this is a less than ideal surrogate for estimating Hawaiian hoary bat survival of a weaned pup to adult, but we have little other scientific evidence to base survival on, until it is established for the Hawaiian hoary bat. Thus, indirect take will be converted from juvenile to adult equivalency using the 0.3 conversion.

Based on the rationale presented above, the wildlife agencies recommend estimated total take be calculated as such:

Observed and Unobserved direct take calculated with Evidence of Absence and the output at 80% credibility used for calculating indirect take.

Indirect take assessed for females taken between April 1 and September 15:
The number of observed female bats taken between April 1 and September 15 x the average number of pups estimated at 1.8

Indirect take assessed for observed males taken at any time or females taken from September 16 through March 31 would be 0.

Indirect take assessed for unobserved take would be:
The estimated number of unobserved bats taken x the proportion of unobserved take that is female, which is assumed to be 0.50 x the proportion of the calendar year in which a female may be pregnant or have dependent young which is 0.25 x the average number of pups estimated at 1.8

Then to convert the indirect (juvenile) take to adults:
(Total indirect take based on observed take + Total indirect take based on unobserved take) x the conversion of juveniles to adults, 0.30.

Example using the above equations:

Observed take 5 bats. Assume Evidence of Absence output at 80% for the 5 observed bats is 13. This means 8 unobserved bats.

	Indirect take
2 of the observed bats were females taken between April 1 and September 15:	2 x 1.8 = 3.6
1 of the observed bats was a female taken between September 16 and March 31:	0
2 of the observed bats were males:	0
We assume 4 of the 8 unobserved bats taken were female:	4 x 0.25 x 1.8 = 1.8
Total indirect take of juveniles	3.6 + 0 + 0 + 1.8 = 5.4
Conversion of juveniles to adults	5.4 x 0.3 = 1.62
Total take based on 80% credibility basis:	**13 +1.6 = 14.6 rounded up to 15 bats.**

Literature Cited

Bogan, B.A. 1972. Observations on parturition and development in the hoary bat, *Lasiurus cinereus*. Journal of Mammalogy 53:611-614.

Dalthorp, D. and Huso, M. 2015. A framework for decision points to trigger adaptive management actions in long-term incidental take permits. U.S. Geological Survey Open-File Report 2015-1227**:**88.

Dalthorp, D., Huso, M., Dail, D., and Kenyon, J. 2014. Evidence of absence software user guide: U.S. Geological Survey Data Series 881, 34 pp. http://dx.doi.org/10.3133/ds881.

Humphrey, S. R. and Cope, J.B. 1976. Population ecology of the little brown bat, *Myotis lucifugus*, in Indiana and North-central Kentucky. Special Publication No. 4 of the American Society of Mammalogists. i-vii, 1-81.

Huso, M.S.P., Dalthorp, D. Dail, D. and Madsen, L. 2015. Estimating wind-turbine-caused bird and bat fatality when zero carcasses are observed. Ecological Applications 25:1213-1225.

Koehler, C.E. and Barclay, R.M.R. 2000. Post-natal growth and breeding biology of the hoary bat (*Lasiurus cinereus*). Journal of Mammalogy 81:234-244.

Menard, T. 2001. Activity patterns of the Hawaiian hoary bat (*Lasiurus cinereus semotus*) in relation to reproductive time periods. M.S. Thesis, Ecology, Evolution, and Conservation Biology Program, University of Hawaii, Manoa. 149 pp.

Pinzari, C. 2015. Observation of dependent Hawaiian hoary bat pup September 2-3, 2015 on the island of Hawaii. Email to Dawn Bruns, et al., USFWS and DOFAW personnel, September 3, 2015.

Tomich, P. Q. 1986. Endangered species information system species workbook. Part I - Species distribution. Unpublished U.S. Fish and Wildlife Service Report. Available at U.S. Fish and Wildlife Service, Ecological Services, Honolulu. 20 pp.

Tomich, P.Q. 1986. Endangered species information system species workbook. Part II – Species biology, Unpublished U.S. Fish and Wildlife Service Report. Available at U.S. Fish and Wildlife Service, Ecological Services, Honolulu. 38 pp.

Uyehara, K. and Wiles, G. 2009. Bats of the U.S. Pacific Islands. U.S.D.A. National Resources Conservation Service. Biology Technical Note 20. 34 pp.

APPENDIX 5. DOWNED WILDLIFE PROTOCOL 2019

Contact the agencies for the current version of the Downed Wildlife Protocol.

APPENDIX 6. EXPLORATORY POPULATION VIABILITY ASSESSMENTS (PVA) ON THE HAWAIIAN HOARY BAT V2.0

Introduction

Hawaiian Hoary Bats are listed as an endangered species at both the Federal and State levels. Because we lack good estimates of the numbers of bats found statewide and on individual islands, it has been difficult to assess population-level impacts of wind power projects on this species. Most early estimates of take at wind projects were significantly underestimated. Some recent estimates of cumulative take have ranged up to 30 or more bats per year, with the potential for increases in wind projects to result in a doubling or tripling of take in the future. These increased levels of take have been concerning to the ESRC. Hence, the ESRC's Hawaiian Hoary Bat Task Force was asked to explore the use of population viability analyses (PVA) to identify:

1. Specific population dynamics parameters that are needed to conduct an acceptable PVA,
2. Particularly impactful parameters that should be prioritized for research, and
3. General trends or results that might inform conservation decisions or provide management sideboards for wind projects.

A goal of the State endangered species statute is to ensure that projects will not jeopardize the continued existence of impacted species, are consistent with recovery plan goals, and will increase the likelihood of the recovery of those species. Currently, the 20-year old Federal recovery goal for Hawaiian Hoary Bats is to have stable or increasing populations on the islands of Hawaiʻi, Maui, and Kauaʻi. This recovery plan was written before it was known that Oʻahu had a breeding bat population.

General Methods

Population models are typically used to provide estimates of the likelihood of populations becoming extinct (e.g., probability of extinction), provide estimates of future population size, explore the impact of population parameters on model outcomes, and to compare the qualitative effects of different management options or regimes. Recent population modeling of hoary bats on the mainland provide an example of how to undertake modeling on the Hawaiian Hoary Bat (Frick et al. 2017, Friedenberg and Frick 2019).

Hawaiʻi-specific population parameters were used when available and a range of published parameters on other bats was used when Hawaiʻi data were not available. While data on Hawaiian Hoary Bats are indeed limited, there was more data available than expected. It should be noted, though, that particularly important data like juvenile and adult mortality estimates or population sizes are not currently available for Hawaiian Hoary Bats. Mortality data is available for some other bat species and data from those species were useable for at least exploratory modeling.

Vortex 10.3.60 (April 3, 2019) was used for all population modeling and sensitivity analyses.

Results

Sensitivity Analyses

Five model input parameters were subjected to sensitivity analyses in order to identify key research needs or to help inform the use of population models.

a. Adult mortality rates: ranging from 20-50 percent annual mortality. Model outcomes were very sensitive to changes in the value of adult mortality (see purple line in Figure 1).

b. Juvenile mortality rates: ranging from 30-60 percent annual mortality. Model outcomes were very sensitive to changes in the value of juvenile mortality (see green line in Figure 1).

c. Percentage of females breeding in the population: values based on estimates of 80% (from Tomich's captures of Hawaiian bats; see Menard 2001), 88% (estimate from Druecker 1972 on mainland hoary bats), and 90% (average of Tomich, Druecker, and Jones 1964 for Hawai‘i and mainland hoary bats). Model outcomes were very sensitive to changes in the percentage of breeding females (see red line in Figure 1).

d. Percentage of broods with only one offspring: values based on 8% (Koehler 1991), 4% (average of Koehler 1991, Druecker 1972, and Tomich for Hawai‘i and mainland hoary bats), and 0% (Hawaiian Hoary Bat estimate from Tomich; see Menard 2001). Model outcomes were less sensitive to changes in this value than the other parameters (see black line in Figure 1).

e. Maximum reproductive age was assessed by manually running a base PVA using 4 years (from Barclay; see Koehler 1991), 5 years (our best guess used in the baseline PVA), 6 years, 7 years, and 8 years of age. Model outcome appears to be sensitive to changes in this value, with a set PVA with a starting population of 1,000 bats resulting in populations after 20 years of 562, 1228, 1808, 2279, and 2626 bats for the five values.

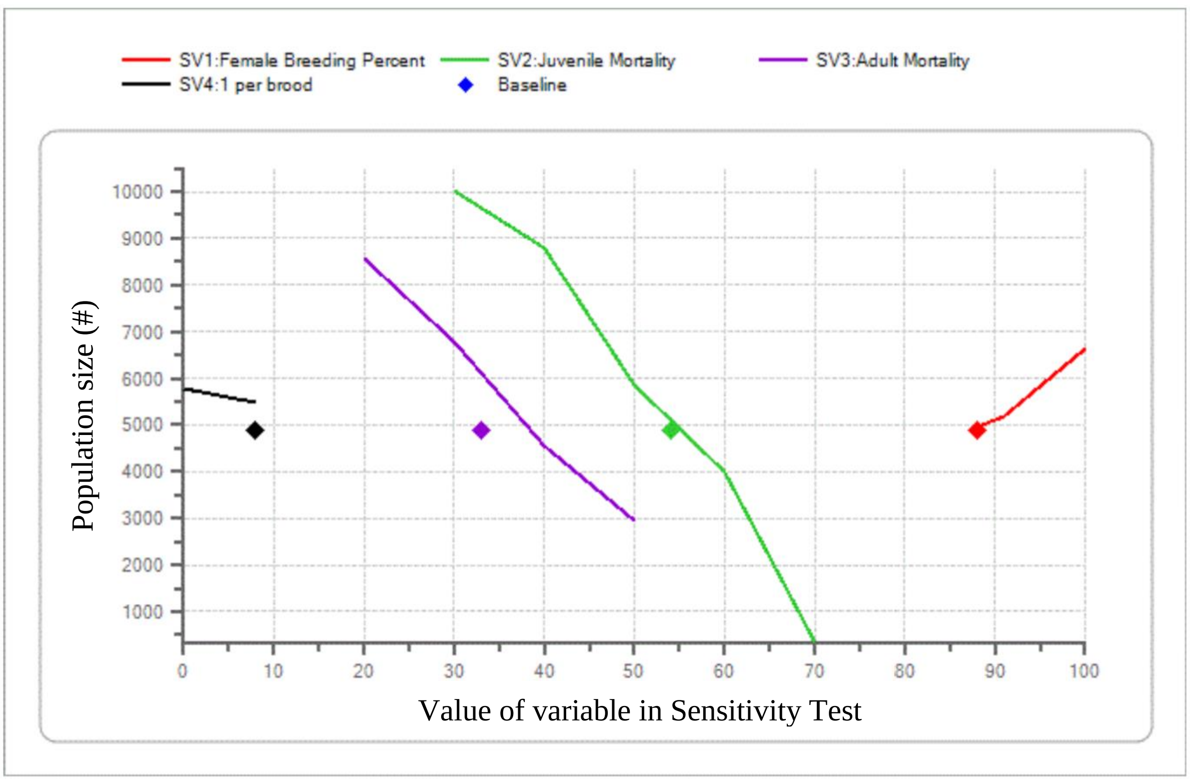

Figure 1. Output of sensitivity analysis for population parameters. The steeper the line, the more sensitive the variable to change. Parameters: percent of females breeding (red), juvenile mortality (green), adult mortality (purple), and the percent of broods with only one offspring (black).

We also looked at how carrying capacity influenced modeling. Frick et al. (2017) set an upper bound on population growth at ten times the initial population size in order to strike a balance between unbounded and overly constrained population growth. We ran models with populations at two times, five times, and ten times carrying capacity. In general, the closer the initial population was to carrying capacity, the smaller its potential growth. Because we found no studies showing that Hawaiian Hoary Bats are habitat limited, we did not undertake extensive exploration of how creating new bat habitat could offset take. Carrying capacity and the impact of creating new habitat are complex modeling issues and need more intensive efforts.

Population Modeling

We started exploratory modeling using available Hawaiian Hoary Bat data, then augmenting that with data from other bat species. Five different models were initially used which spanned a range of different mortality rates in order to see which, if any, models produced stable or increasing populations. Those models (Figure 2) were:

1. Low adult mortality: resulting in a strongly increasing population (+5% annual growth).
2. Low to moderate mortality: resulting in a modestly increasing population (+3.5% annual growth).
3. Moderate mortality: resulting in a stable or slightly increasing population (<+1% annual growth).
4. Lowest mortality estimates for mainland hoary bats: resulting in a declining population (-1% annual growth).
5. Most likely estimated mortality for mainland hoary bats: resulting in a steeply declining population (-15% annual growth).

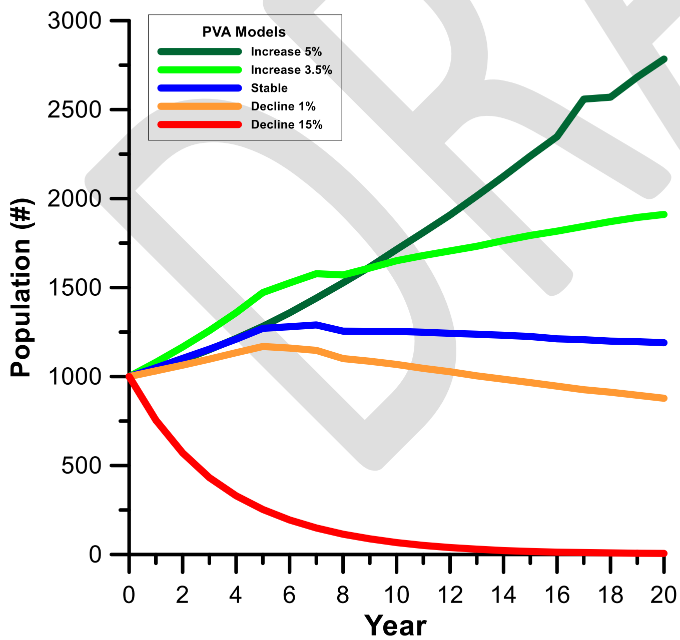

Figure 2. Population trends for an array of Hawaiian Hoary Bat PVA models without take. See text for explanations of models.

Gorressen et al. (2013; p.20) estimated a "stable to slightly increasing" population trend for a Hawaii Island population of Hawaiian Hoary Bats (Figure 3). This is the only published trend we know of for the Hawaiʻi subspecies.

The Task Force decided to focus on developing models that produced "stable to slightly increasing" population trends and assumed populations were not habitat limited. This is somewhat similar to what Friedenberg and Frick (2019) did, although they assumed stability only.

Three PVA models were produced under these narrowed conditions and run with a range of take levels to assess potential impacts to bat populations. When well documented data on Hawaiian Hoary Bats were lacking, parameters were used that were consistent with the literature for similar bat species (see Appendix 1A) and that produced a population trend that was stable or slightly increasing over a 20 year period (i.e., an increase of no more than approximately one percent (1%) annual growth). One PVA was developed to reflect a best guess model (Model A), another model used available Hawaiʻi data over mainland hoary bat data (Model B), and a third model pooled all hoary bat data from both Hawaiʻi and the mainland (Model C). The parameters used in each model can be found in Appendix 2A. A brief description of differences in the models follows.

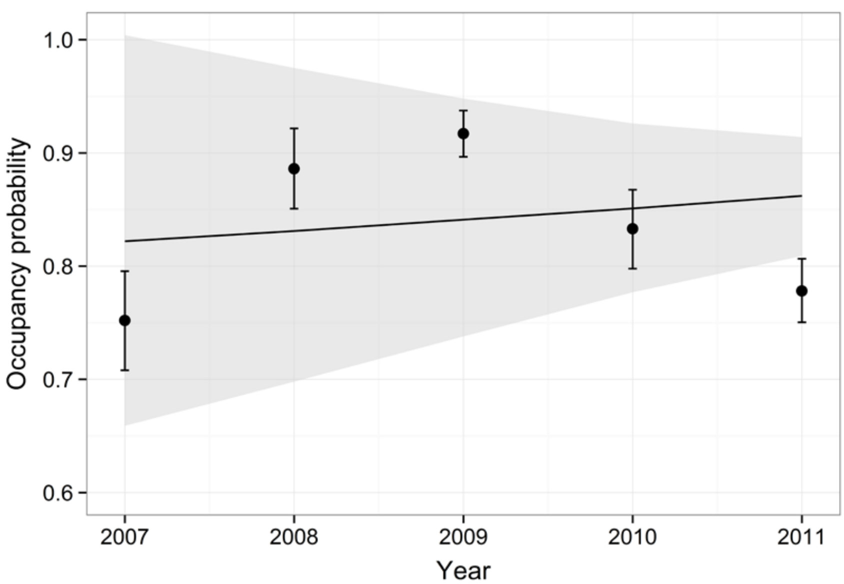

Figure 3. Trend in Hawaiian Hoary Bat occupancy on Hawaiʻi Island from 2007 to 2011 during the period of relatively high detection probability (June to October). Points depict mean annual survey area occupancy (± SE) for all survey areas. Mean trend (black line) and 95% CI (shaded band) were obtained from Bayesian log-linear regression of the annual estimates of occupancy for each survey area. From Gorressen et al. (2013; p. 18).

1. Model A: Best Guess. This model represents a collective best guess as to model parameters. This model produced a stable to slightly increasing population trend with the exponential rate of increase (r) = 0.0082 and the annual rate of change (lambda) = 1.0186. The annual take of up to 1% of the population seems to maintain a stable population. Annual take greater than 1% results in a declining population (Figure 4).

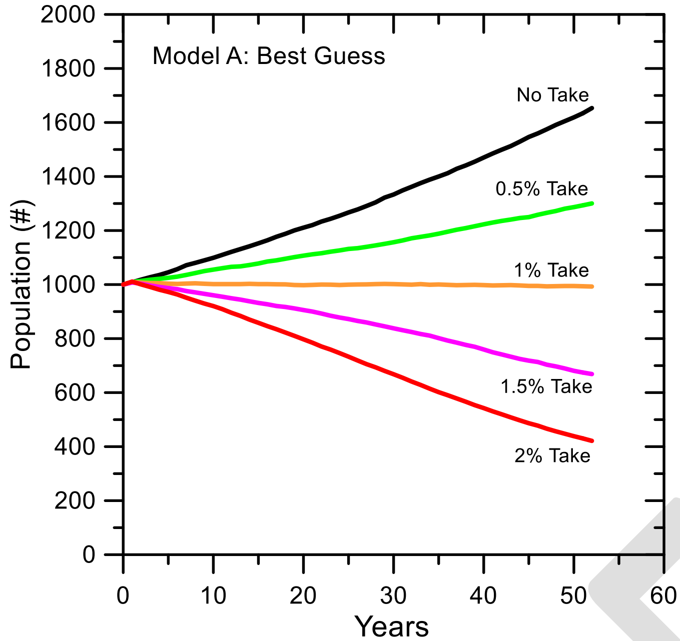

Figure 4. Population trend for Model A: Best Guess under different annual take regimes. Take begins in year 2 and continues to year 52.

2. Model B: Hawaiian Priority. This model prioritized Hawai'i data over mainland hoary bat data. This model produced a stable to slightly increasing population trend with the exponential rate of increase (r) = 0.0029 and the annual rate of change (lambda) = 1.0029. The annual take of 0.5% of the population results in a slightly declining population. Annual take greater than 0.5% results in a declining population (Figure 5).

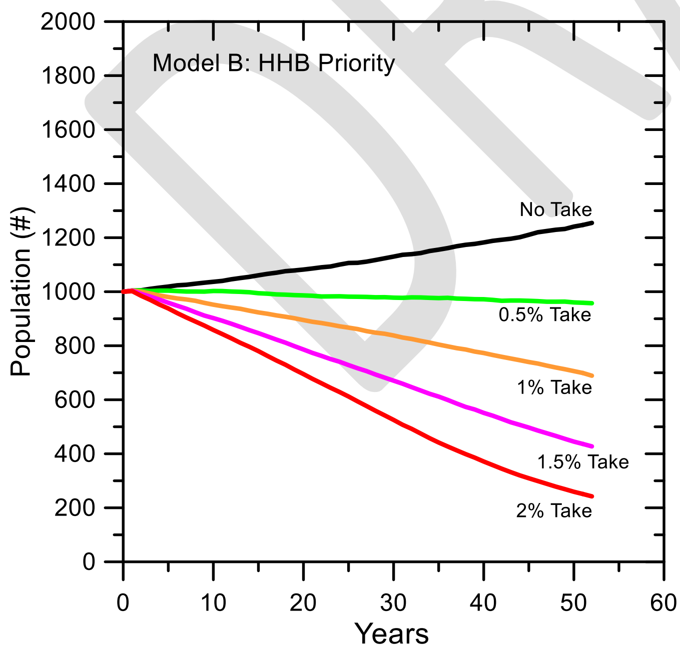

Figure 5. Population trend for Model B: Hawaiian Hoary Bat Data Priority under different annual take regimes. Take begins in year 2 and continues to year 52. This model uses Hawaiʻi data when it is available, even if other data is available.

3. Model C: Averaged Data. This model averaged all hoary bat data, from both Hawaiʻi and the mainland. This model produced a stable to slightly increasing population trend with the exponential rate of increase (r) = 0.0094 and the annual rate of change (lambda) = 1.0095. The annual take of up to 1% of the population seems to maintain a stable population. Take greater than 1.2% annually results in a declining population (Figure 6).

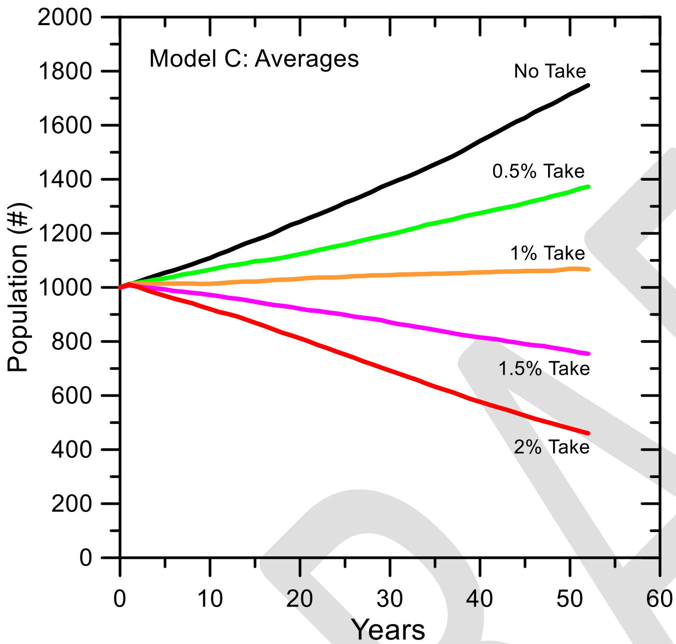

Figure 6. Population trend for Model C: Averages under different annual take regimes. Take begins in year 2 and continues to year 52. This model uses the average of Hawaiʻi and mainland hoary bat data when both are available.

We also looked at how population size and total annual take might factor into population trends. We used our Model A: Best Guess to explore how population size might interact with take and influence population trends. This model produces a stable to slightly increasing pre-take trend that is similar in scale to the trend reported by Gorressen et al. (2013) and showed very different outcomes to take levels based upon differing initial population sizes (Figure 7). While all populations showed some effects from take, larger populations (> 5,000 bats) showed much less impact than small populations.

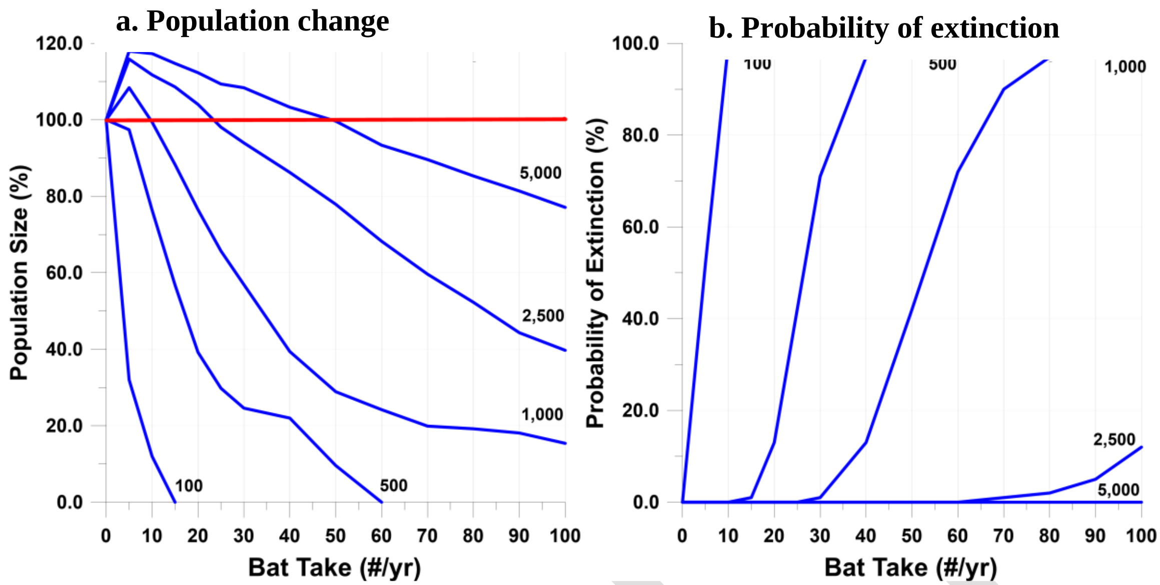

Figure 7. How mortality levels interact with gross take to impact population size and the probability of extinction at the end of 20 years of the specified level of take. A model producing a stable population showed different patterns of (a) population change and (b) extinction probability at various initial population sizes. Note that the point where take approximately equals one percent of the population size is the point where this model indicate that the population will drop below its pre-take population level (red line).

Summary: All three models started with population parameters resulting in slightly increasing populations (approximately a 0.4% to 1.0% annual growth rates). Under all three modeled scenarios, the annual take of bats has a negative impact on population growth; even a 0.5% level of annual take reduces population growth. When modeled annual take exceeded the annual growth rate, modeled population numbers declined.

<u>Preliminary Conclusions</u>

The exploratory PVA efforts provided some insights into research priorities as well as information that may inform conservation decisions. This is our first effort at modeling Hawaiian Hoary Bats; a much more sophisticated and more intensive modeling effort is needed before relying heavily on this effort.

Research priorities

It is well recognized that many important population parameters remain unknown for the Hawaiian Hoary Bat. From the perspective of Habitat Conservation Plans, the following research needs should be prioritized:

1. Determine the current bat population trend on Oʻahu.
2. Determine the current bat population trend on Maui.
3. Determine if past habitat restoration projects have increased bat populations.
4. Determine the size of bat populations on Oʻahu, Maui, and Hawaiʻi.
5. Determine if bat populations are habitat limited.
6. Determine adult bat mortality.
7. Determine juvenile bat mortality.
8. Determine the maximum age of bat reproduction.

Population modeling and take

These modeling efforts do not provide definitive determinations as to how much take should be allowed by specific wind projects. They do, however, provide information useful to conservation decisions and assessments on an island-wide basis. Specifically:

1. One study has estimated population trends for the Hawaiian Hoary Bat (Gorressen et al. 2013). That report stated that the study population on the island of Hawaiʻi was either "stable or slightly increasing." Similar studies on Oʻahu and Maui would help clarify the situation on those islands. Until field studies provide better data, modeling and impact assessment efforts should be consistent with this finding of no more than a 0 to 1 percent annual increase (in populations without wind project take).
2. No studies have shown that compensatory reproduction is occurring in Hawaiian Hoary Bats (or mainland hoary bats). The incorporation of compensatory reproduction in take modeling is currently not warranted.
3. To date, there are no studies that have shown an increase in Hawaiian Hoary Bat populations as a result of mitigation offsets. It is not prudent at this time to expect that habitat restoration will successfully offset large levels of bat take that might cause steep population declines.
4. In general, for models that are stable to slightly increasing and not limited by carrying capacity, an annual rate of take that exceeds the annual rate of increase of a population is likely to cause a decline in that population. For example, if a population has a one percent annual rate of increase without wind project take, a take level in excess of one percent would be expected to result in a declining population. For a stable population, all take would be expected to cause a decline in the population. Friedenberg and Frick (2019) came to a similar conclusion in their report. The significance of these declines would be dependent on the size of the population. If a population is declining prior to take, any take will further the population's decline.
5. These models indicate that projected levels of take may pose a relatively low risk to large Hawaiian Hoary Bat populations. For example, if the proposed annual take of bats for the island of Hawaiʻi was 10 bats/year and the bat population is expected to be over 5,000, there may be low risk to the population. Conversely, an island with under 1,000 bats may not be able to sustain the loss of 10 bats/year.
6. Population modeling can incorporate basic population parameters, take levels, habitat carrying capacity, and increases to carrying capacity via habitat restoration. These entities are all linked; they should not be assessed independently from one another. They should all use the same

population trend estimates, core use areas, carrying capacities, population parameters, and other assumptions. Similarly, efforts to estimate bat population sizes using the amounts of suitable habitat should incorporate inputs consistent with population models and observed population trends.

Literature Cited

Druecker, J.D. 1972. *Aspects of* Reproduction in *Myotis volans, Lasionycteris noctivagans,* and *Lasiurus cinereus.* Ph.D. dissertation, University of New Mexico, Albuquerque, New Mexico.

Frick, W.F., E. F. Baerwald, J.F. Pollock, R.M.R. Barclay, J.A. Szymanski, T.J. Weller, A.L. Russell, S.C. Loeb, R.A. Medelilin, and L.P. McGuire. 2017. Fatalities at wind turbines may threaten population viability of a migratory bat. *Biological Conservation,* 209: 172-177.

Friedenberg, N. and W. Frick. 2019. The Potential Population-level Benefit of Turbine Fatality Reduction Measures for Hoary Bats. *In* PNWWRM XII. 2019. Proceedings of the Wind-Wildlife Research Meeting XII. St. Paul, MN. Pp. 108-112.

Gorresen, M.P., F.J. Bonaccorso, C.A. Pinzari, C.M. Todd, K. Montoya-Aiona, and K. Brinck. 2013. A Five-Year Study of Hawaiian Hoary Bat (*Lasiurus cinereus semotus*) Occupancy on the Island of Hawaii. Technical Report HCSU-041.

Jones, C. 1964. Distribution and ecology of the bats of the Mogollon Mountains area. Ph.D. Dissertation. University of New Mexico. 116 p.

Koehler, C.E. 1991. *The Reproductive Ecology of the Hoary Bat (*Lasiurus cinereus*) and its Relation to Litter Size Variation in Vespertillionid Bats*. M.Sc. thesis, University of Calgary, Calgary, Alberta.

Lentini, P.E., T.J. Bird, S.R. Griffiths, L.N. Godinho, and B.A. Wintle. 2015. A global synthesis of survival estimates for microbats. *Biol. Lett*. 11: 20150371.

Menard, T. 2001. *Activity Patterns of the Hawaiian Hoary Bat* (Lasiurus cinereus semotus) *in Relation to Reproductive Time Periods*. M. Sc. Thesis, University of Hawai‘i, Honolulu, Hawaii.

Tuttle, M.D. 1995. The little-known world of hoary bats. *Bats*, 13: 3-6.

Appendix 1A. Required information to run Vortex modeling (Vortex 10.2.17.0, a stochastic simulation of the extinction process).

Model Input	Choice	Hawaiian Hoary	Mainland Hoary	Other Bats
Reproductive System				
• Choose one: monogamous, polygynous, hermaphroditic, long-term monogamy, long-term polygyny.	Polygynous			Assumed
• Age at first offspring females	1		Based on Druecker (1972): "Most males and female *L. cinereus [cinereus]* apparently mature sexually during their first summer." Druecker examined by sectioning reproductive tracts of 8 females (7 of 8 breeding).	
• Age at first offspring males	1	Tomich reported for *L.c.s.* (see Menard 2001 thesis Appendix B): "Do young breed in first season: it would seem so because of scrotal testes in this juvenile [2784 was caught 9-14-64]."	Based on Druecker (1972): "Most males and female *L. cinereus [cinereus]* apparently mature sexually during their first summer." Druecker examined by sectioning testes of 27 males (26 of 27 breeding).	

• Maximum lifespan	8		Tuttle (1995) article said about 6 or 7 years based on reproductive rates. Increased to 8 because of online sources giving higher estimates (like 14 years found online at http://www.worldlifeexpectancy.com/mammal-life-expectancy-hawaiian-hoary-bat).	
• Maximum number of broods per year	1	Well known to be 1. See Menard thesis.		
• Maximum number of progeny per brood	2	Tomich field notes (Menard thesis);	Koehler 1991; Druecker 1972.	
• Sex ratio at birth – in % males	50%		Koehler (1991): Thesis reported 10 females to 11 male pups for *L.c.c.*	
• Maximum age of female reproduction	5		Koehler (1991), p 7, said Barclay had 4 year old females. We added a year.	
• Maximum age of male reproduction	5		A guess based on females	
• Density dependent reproduction?	No			No documentation
Reproductive Rates				
% adults females breeding	80, 88, 95	Tomich dissected 15 *L.c.s.*: **80%** were breeding & 20% not (Menard thesis Appendix A).	Druecker (1972), p. 42, caught 8 females from April to June, of which 7 (**88%**) had embryos; the other one had no embryos but did have	

			sperm. Druecker cites Jones (1964) to report that 38 of 40 females in spring/summer were pregnant. (**95%**).	
SD in % breeding due to EV	5			Guess
Distribution of broods per year:				
0 Broods	0			
1 Broods	100%			We have never heard of breeding females having more than 1 brood per year.
Specify exact distribution (enter as percents)		Tomich dissected 4 pregnant *L.c.s.* and 100% had two embryos (Menard thesis Appendix A).	Koehler (1991) followed 13 families of *L.c.c.* and had 12 families with twins (92%) and 1 family with a singleton (8%). Druecker (1972) dissected 7 female *L.c.c.* and 100% had two embryos.	
1 Offspring	0,4,8%		As per Koehler 91	
2 Offspring	92,96,100		As per Koehler 91	
Mortality Rates				
Mortality from age 0 to 1	52,54,55			
SD in 0 to 1 mortality due to EV	5			
Annual mortality after age 1	33,34			Lentini (2015) study of several microbat studies concluded about 77% adult female bat survival (**23% mortality**) and 66% adult female survival

				(**33% mortality**) for species that produce more young.
SD in mortality after age 1	5			
Mate Monopolization				
% Males in breeding pool	20%			This low value didn't seem to matter too much since the population is polygynous.
Initial Population Size & Carrying Capacity				
Initial Population Size	100, 300,500,1000 ,2500,5000			1,000 was the base size
Carrying Capacity	1000,2000, 5000, 10000			10,000 was base size. Frick (2017): "We fixed a ceiling on population growth at 10 times the initial population size to account for carrying capacity and to balance between unbounded and overly constrained population growth."
Harvest				
First year of harvest	2			
Last year of harvest	52			Modeled 52 years …
Interval between harvests	1			
Number of females harvested	0-200			Base was 10 per year
Number of males harvested	0-200			Base was 10 per year

Appendix 2A. A comparison of variables for Model runs A, B, and C.

Input	Description	A	B	C
1	Populations: 1 island population	Same	Same	Same
2	Duration of 20 years to determine baseline trend (no take)	Same	Same	Same
3	Duration of 52 years to determine overall trends (take and no take)	Same	Same	Same
4	Take starts in year 2 and runs through year 52	Same	Same	Same
5	Extinction defined as no males or no females	Same	Same	Same
6	Reproductive system is polygyny, new mates each year	Same	Same	Same
7	Max age of survival is 8 years	Same	Same	Same
8	Beginning age of breeding is age 1	Same	Same	Same
9	Max age of breeding is age 5	Same	Same	Same
10	Sex ratio at birth is 50 - 50	Same	Same	Same
11	Reproduction is not density-dependent	Same	Same	Same
12	Correlation of environmental variation of 0.5 between repro and survival	Same	Same	Same
13	**Percentage of adult females breeding each year**	**88%**	**80%**	**90%**
14	Breeding environmental variation (SD) is 5%	Same	Same	Same
15	Percent of adult males breeding is 20%	Same	Same	Same
16	**Percentage of broods with 1 pup**	**8%**	**0%**	**4%**
17	**Percentage of broods with 2 pups**	**92%**	**100%**	**96%**
18	**Annual juvenile mortality**	**54%**	**52%**	**55%**
19	Juvenile mortality environmental variation (SD) is 5%	Same	Same	Same
20	**Annual adult mortality**	**33%**	**33%**	**34%**
21	Adult mortality environmental variation (SD) is 3%	Same	Same	Same
22	Initial population size is 1,000	Same	Same	Same
23	Carrying Capacity 10,000	Same	Same	Same
24	Harvest (e.g. take) ranges from 0 to 2%	Same	Same	Same
25	Model iterations: 5,000	Same	Same	Same

A **Best Guess Scenario**
B **Priority to Hawaiian Hoary Bat data**
C **Averaged data from all Hawai‘i and mainland hoary bat data**