ENDANGERED SPECIES RECOVERY COMMITTEE (ESRC) MEETING
Hui ʻŌpe'ape'a Bat Workshop
March 5, 2020 Meeting Minutes

Meeting Location: University of Hawaiʻi at Manoa Campus Center, Executive Dining Room

MEMBERS: David Smith (DLNR), Jim Jacobi (USGS), Michelle Bogardus (USFWS), Melissa Price (UH), Loyal Mehrhoff (At-Large), Kawika Winter (At-Large), Lisa Spain (At-Large)

STAFF: DOFAW: Lauren Taylor, Koa Matsuoka, Afsheen Siddiqi, Lainie Berry, Marigold Zoll, Tiana Bolosan, Lindsey Nietmann

OTHERS: Darren LeBlanc, Lasha-Lynn Salbosa, Adam Vorsino, Rebecca Frager, George Akau, Rachel Moseley, Theresa Menard, Dave Young, Joel Thompson, Amanda Ehrenkrantz, Marie VanZandt, Marcos Gorresen, Kristin Jonasson, Kristina Montoya-Aiona, Corinna Pinzari, Bob Peck, Tom Snetsinger, John Ugland, Lily Henning, Matt Stelmach, Taylor Shimabukuro, Jason Preble, Ilana Nimz, Frank Bonaccorso, Karen Courtot

AGENDA

ITEM 1. Call to order. Introduction of Committee members and staff. Format and goals of the workshop.

ITEM 2. Regulatory status of the Hawaiian Hoary Bat. Incidental Take Licenses and permitted take to date: Lauren Taylor, Division of Forestry and Wildlife

LAUREN TAYLOR: Thank you everybody for coming and to everyone who is invested in Hawaiian Hoary Bats. My name is Lauren Taylor. I'm the Habitat Conservation Planning Coordinator for protected species for the State of Hawaii. The Hawaiian Hoary Bat Workshop is actually an ESRC meeting since we have quorum. I'm going to talk about the purpose of the workshop, the regulatory context, and why we're doing it. The purpose of this workshop is to guide the Endangered Species Recovery Committee in making recommendations for the endangered Hawaiian Hoary Bat in Habitat Conservation Plan development. The secondary purpose, because it is the mechanism that the recommendations will be provided to Incidental Take License applicants in the future, is to update the Hawaiian Hoary Bat Guidance Document. We've started a draft update for 2020. The original document was provided in 2015 and since then we've learned a lot about the bat so this is our time to collate that information and update the document.

I won't get much into the species itself since that is what this workshop is for, but I will mention a couple things that make the species unique. Beyond its ecological role, the species is one of only two native mammals in Hawaiʻi, and it also holds cultural significance. Although this isn't something that doesn't have to be reviewed for regulatory compliance in 195D, it is addressed in other laws like NEPA and HEPA. It's specifically mentioned in the Kumulipo in the 7th era so that places the bat in a historical context for Hawaiʻi. It's considered an ʻaumakua to some families here and the word ʻōpeʻapeʻa, the Hawaiian name for the bat, translates to the shape of a taro leaf or a sail.

So the Federal Endangered Species Act protected the bat before the State did. In 1970, it was listed as an endangered species under the Endangered Species Conservation Act of 1969. When that was replaced by the Endangered Species Act in 1973 it retained its endangered listing under that. In 1983, the State endangered species law came into effect and that's Chapter 195D, Hawaii Revised Statues; all ESA species are incorporated into the State endangered species list, and then we can also list additional species. So the bat was afforded additional protections at that time. In 1997, §195D was amended to include Habitat Conservation Plans. Our first Habitat Conservation Plan and associated Incidental Take License that permitted legal take of the Hawaiian Hoary Bat was issued in 2012. It is important to note that we do work closely with the U.S. Fish and Wildlife Service and we are required in the statute to coordinate as much as possible with the Federal HCP process and ideally come out with a similar Habitat Conservation Plan at the end, but in practice it doesn't always work out that way. So for the State we issue an Incidental Take License and what this allows is take, which I will define, of the Hawaiian Hoary bat that is incidental to, and not the purpose of, an otherwise lawful activity. It must be accompanied by a Habitat Conservation Plan. A Habitat Conservation Plan, or HCP, in order to be permitted: must to the maximum extent practicable minimize and mitigate the impacts of the take; shall increase the likelihood that the species will survive and recover; should consider the full range of environmental impacts of that take; and provide net environmental benefits. So the idea is that by allowing the incidental take of this endangered species it will be offset through the actions incorporated in the Habitat Conservation Plan and overall there won't be a loss in the recovery of the species by permitting this—otherwise we can't permit it.

We get a lot of questions about the word take, which sounds like a sanitized version of what is happening, which most of the time is death of the bat. The reason take is defined the way that it is is because it covers a wide range of species including plants and aquatic life, and there a whole suite of actions that we want to prevent that could harm the species. So take is a collective term. Take is defined as to harm, harass, pursue, hunt, shoot, wound, kill, trap, capture, or collect endangered or threatened species of aquatic life or wildlife or an attempt to engage in such conduct. In Hawaiʻi, we currently have six Incidental Take Licenses in effect for bat take at wind energy projects. Three on Maui and three on Oʻahu. For bat take they typically run from 20 to 25 years.

I also wanted to touch on why HCPs are an important component of incidental take, and not just because they're statutorily mandated. They also provide an avenue—we work very closely with the applicants for years developing these plans, the U.S. Fish and Wildlife Service, other agencies, and all the type of people who are here today—to resolve conflicts between endangered species protection and what would otherwise be a legitimate use of natural resources, such as the renewable energy goal the wind farms are trying to reach. They also contribute to endangered species recovery efforts because we're all working collectively at the same time with a broad overview of what take is happening through the islands. If we just issued licenses for take and there was no planning, or if we just issued fines and did not permit take, overall it wouldn't lead us to recovery or management of the species. They provide essential ecological information for the species. Especially for the bat, which is incredibly cryptic. The monitoring that occurs at the wind farms and the mitigation sites provides us with a lot of information about the species. So here's where we're at for fiscal year 2019; this goes through June 30, 2019, and the reason it doesn't go to date is because we calculate take with a model. There is observed take but then extrapolate that to a higher number for what we didn't observe, based on the assumption there was more bat take than what we saw. Since we haven't finished the full fiscal year 2020, this is just through fiscal year 2019. Since fiscal year 2019, the BLNR has approved two amendments for KWP II and Auwahi which would increase their permitted bat take but has not been included on these charts.

So why are we here with the ESRC? The ESRC is mentioned in §195D and they have a significant role in the approval of Habitat Conservation Plans for the State. This slide leads us to why we're here today. The ESRC is mandated to review all applications and proposals for Habitat Conservation Plans and Incidental Take Licenses and make recommendations, i.e. the guidance document, based on a full review of the best available scientific and other reliable data and in consideration of the cumulative impacts of the proposed action on the recovery potential of the species. They're going to make a recommendation to the Board of Land and Natural Resources whether or not a Habitat Conservation Plan and Incidental Take License should be approved and issued. They also may consult with persons possessing expertise in such areas as the Committee may deem appropriate and necessary in the course of exercising its duties. So what you'll see over the next two days is the very complicated nature of estimating impacts to bats and how to mitigate and minimize those impacts, and all the gaps in the knowledge of the species. So that's why we're here with this workshop, to provide the best, informed guidance that the ESRC can. So the format of the workshop: after each presentation we'll have time for a few questions. If you want to get into the details of the science that's a good time. The ESRC will also ask if there are public comments on each agenda item. Thank you for listening.

ITEM 3. Species ecology and current knowledge of the Hawaiian Hoary Bat. Biology and current taxonomy of the bat: Frank Bonaccorso, U.S. Geological Survey retired

FRANK BONACCORSO: I'm going to talk a little bit about the difference of opinion that currently exists in the world of mammalogy about what the name of the bat is. Then I just want to give you a real basic overview about some of the more important features of ʻōpeʻapeʻa ecology. *Lasiurus semotus*, ʻōpeʻapeʻa, the Hawaiian Hoary Bat: there is a consensus that the bat should be considered a full species and no longer a sub-species among mammologists. There are three recent sources to go to about the name of the bat although there are differences in the name of the genus. All of these sources recognize *Lasiurus semotus* as a full species. In 2019, the handbook for the Mammals of World, the last volume of the series was published. I contributed some writing but did it on sheep-tail bats and some of the flying foxes. But it is an incredible source on mammology. The editor is Don Wilson, one of the premier experts on bats. They recognize *Lasiurus semotus* as a full species. The database from the American Museum of Natural History also recognizes *Lasiurus semotus* as a full species under that same name. The difference of opinion though is from the Mammal Diversity Database, which is published by the American Society of Mammologists, and it divided the genus Lasiurus into three different genera, one of which includes a hoary bat which formerly was a sub-genus *Aorestes*. So they recognize it as a full species but they recognize it as under the genus *Aorestes* not *Lasiurus*. In my survey of bat biologists, the majority still prefer the name Lasiurus. So whatever ramnifications it has, science is recognizing it as a full species now.

DAVE JOHNSTON: Nancy Simmons of the American Museum of Natural History has data to support the genus Lasiurus for hoary bats as opposed to the genus *Aorestes*.

FRANK BONACCORSO: Yes, so there was a publication with an addendum discussing our present living species in Hawaiʻi on why they disagreed with the sub-division. Some folks describe the molecular resolution that went into dividing the Hawaiian Hoary Bat into three genera as a little minimal and weak. That opinion is held by some of the molecular biologists in our audience today. Overall, the important thing is that it's recognized as a distinct species.

Okay, some key points about the bat. Some general things that kind of drive the biology of the bat. The animal is an extreme habitat generalist. You can find them from flying over bays at sea level on up to the highest volcano peaks. Our USGS team worked high up in the Mauna Loa Forest Reserve and found bats actively foraging in the coldest months of the year in winter up to 3,600 meters. There are sightings from the peak of Mauna Loa, Mauna Kea, and Haleakalā as well. So our two islands that have the high volcanoes; they include habitat for the bat. It's thought of as a forest bat and it does roost in large shady trees, but it uses a number of habitats. I think Dave Johnston will talking about habitat specializations that he found on Maui. So it does use a variety of habitats. Over the last few years USGS alone has had over 500 point location acoustic detectors out. Almost all of those 500 plus detectors at one time or another—and many consistently—have found bats present. So they will go away from forest, particularly when they feed over open pastures. They do not really forage in forest with thick, closely packed trees and branches. They do need a bit of room to move. They are feeding generalists as well and it's the only bat currently living in Hawaiʻi. It has been for the last few thousand years so it has the complete niche of nocturnal aerial insects in which to exploit. I think that the work that's being done by both H.T. Harvey and by USGS with metabarcoding has turned up a large number of insects that we previously didn't know. Just using microscopic techniques has been such a biased technique, but we're finding that they eat primarily moths, and that's kind of true to the consensus from even earlier smaller studies. But a wide variety of beetles and *Himoptera* termites. So we don't have swallows or swifts among the bird world to kind of compete with that aerial crepuscular niche foraging on what bats eat. So that's something to remember as well.

In winter and summer in the foraging ranges on the Big Island where the research is proven both by acoustics and radio telemetry, they go up and down in elevation where elevation is available. What are they doing up at Mauna Loa, particularly in January and February, with snow on the ground at elevations of 3,600 meters? Well, lava tubes have a group of moths in the genus *Peridroma* that shelter in these lava tubes and in some cases in quite big concentrations. And one of the neat things is this is a cool resource for bats to come use when there's winter rains and storms down below and they pop up above the cloud inversion layer at night. And for a hoary bat flying 5 to 15 miles an hour that is not a challenge. So they're very active at the entryways of lava tubes that shelter these *Peridroma* moths including some cases in the upper elevation that have permanent ice in the bottom. The work that we published with USGS back in 2015 in the Journal of Mammology covered the home range and foraging movements of the animals in summertime, but I do want to caution that radio telemetry looks at it very briefly but because of the small size of the bat, which weighs around one ounce or 15 to 20 grams, the size of the battery and the size of the radio telemetry packaging you can put on a bat is limited. So you can look at their life by radio tracking them for a couple of weeks and the radios are generally glued on and then actually get groomed off and fall off. Sometimes it is before or after the battery gives out. So we have really narrow windows, and we do have a pretty good understanding of what's going on in lowlands of the Big Island. But we're less successful at knowing through radio telemetry studies what they're doing in the winter. We do know from acoustics that the bats, with microphones placed up high, that they are going up and down the elevational gradient. Perhaps in the future as GPS units become smaller it will become feasible to use for looking at longer time periods into detailed movements of the bat. For one instance on *Lasiurus cinereus*, the North American Hoary Bat, because they're about 30 to 40% bigger in body mass than our Hawaiian bats, which have become pygmies of the *Lasiurus* world.

Quickly moving through, it's important to consider pup rearing when you consider protecting habitat because virtually all reproduction of pups takes place at lowlands below 1,000 meters. As land becomes available, it's often more available in upland areas where forests are intact and people have developed. So it might be a challenge, but it's something to consider as you go through protecting the bat to find areas of lowlands where reproduction is occurring to protect. The movements of the bat, Dave I think is going to tell you about Maui and the studies H.T. Harvey has done. They found that bats move over bigger areas and foraging ranges are much bigger than in the rain forests of east Big Island. And this is perfectly logical. There should be a disparity in home range movements. I've radio tracked over a dozen species on three continents and a bunch of islands. They tend to use the smallest area that will support them. But if their needs are bigger seasonally or in different habitats, they will enlarge the amount of area that they move. One would think that insect productivity, abundance, and availability is a key driver. There are a number of studies that show order of magnitude differences in the foraging ranges and the core use areas of bats. So that's expected and I think we're finding that on different islands and different habitats, the bats are spatially using larger areas as to their needs.

Roosting for the bat, when they do rear pups they're really looking for big shady trees. Kristina Montoya with USGS is working on that on her Master's thesis and finding some great things about mother pup interactions, selection, and geometry of the trees in use. The roost trees themselves might not be limited in number but the location and the temperature is important. The temperature of the lowlands for the pups to develop and grow are relatively warm temperatures. And lastly I just want to again give a shout out to another USGS HCSU researcher Corinna Pinzari who's completed her Master's degree on the molecular genetics of the bat and has demonstrated that the major islands have genetically distinct populations with different haplotypes and different genetic traits that are unique to Hawaiʻi, Maui, Oʻahu or Kauaʻi. Okay, I'm going to stop there and give time for questions.

CHRIS TODD: The question about *Aorestes*. So *Aorestes* means to hover and float around and *semotus* means isolated. Just wanted to mention that.

JACOBI: This is for U.S. Fish and Wildlife Service and the State. Currently it's listed as a subspecies. Is there any movement towards recognizing full species and would that change any of the issues that are facing projects going through an HCP for bats in Hawaiʻi?

BOGARDUS: On the U.S. Fish and Wildlife Service side, no, we haven't done that internally yet. It could happen if that is proposed to happen. It would not have any bearing on the HCP process. The applicants would have to go through as if it was still listed as the same.

PRICE: So other than wind turbines, what do you think are the major causes of mortality for bats?

FRANK BONACCORSO: Mortality is an area that we need to understand better. So if one has looked at the food habits of some of the wildlife that you think might be predators like owls and feral cats looking through that literature, bats do not turn up in pellets of Barn Owls to my knowledge.

PRICE: They have on the mainland but not in Hawaiʻi. But there's very limited studies on owl diet in Hawaiʻi so it's possible they could be.

FRANK BONACCORSO: And arboreal rats could be a problem. Fire Ants if they spread could be a real problem. The most recent extinction of a bat in the world in the Christmas Island Pipistrelle, which were driven over the edge by Crazy Ants. It was a hole nesting species. We don't know anything really about pesticides and what health compromises that might cause. So it is an area that's difficult to investigate, but it's an important area.

PRICE: One follow up question on that. What are the major limits, in your opinion, to survive to maturity?

FRANK BONACCORSO: I don't have a quick answer to that maybe there's a biologist who will follow that will have a better idea. I don't know.

PRICE: What I'm trying to listen for here is what are the things that we can actually directly mitigate for to increase bat populations, and if we don't know other costs to mortality and we don't know what's limiting reproduction, then unless we have direct evidence that emaciation is a problem, that food limitation is a problem, those are kind of the plus/minus factors that I'm thinking about and I'd love to hear from people today.

WINTER: I have four questions. Is there a seasonal difference in the hours of activity?

FRANK BONACCORSO: Basically, the bat needs to fill its gut twice in the course of the night. And so they begin activity in most cases at dusk and are active for several hours depending on how well hunting is. If there's a rainstorm briefly moving through the bat will just find a tree and hang out until the rain passes and then go out again. Very light mist it might forage in. USGS does have data and it does vary at different sites. In the upper slopes in winter of Mauna Loa, foraging is very brief on the moth emergence when temperatures drop down to about seven degrees centigrade. The moths are either out or not active. We have strong correlation of the feeding activity by temperature and relationship to moth activity at the cold high elevations. But it can be quite variable and it's going to vary based on how experienced the bat is as a hunter. Younger bats theoretically are poor at tracking down insects and making the intercept through echolocation and take longer to feed. The time that the netting success is the greatest is during the fall period when the bats are fledging.

WINTER: Number two. So recognizing that this bat is recognized as a full species now, what are the major ecological and behavioral differences between this species and other hoary bat species?

FRANK BONACCORSO: So the North American Hoary Bat undergoes latitudinal migration. I'm talking on a continental scale from Canada down the Pacific Coast of North America into Arizona, New Mexico. And then the Western populations kind of do a big gyre inland and then back up into the Pacific Coast and Northwest. Whereas, Corinna's data have shown there's very little movement between the gene flow; between the island populations it is very low. They do as they move up and down in elevation and it's kind of counterintuitive that the high elevation activity is much more pronounced in wintertime, perhaps to get above the rainy storms that are a little more prevalent in the wintertime than in the lowlands. We don't know if the North American bat uses torpor, but Ted Weller and Paul Cryan a couple of years ago put GPS tags on the North American population and one bat went into torpor for about a month with no movement. So it did use torpor as a response to winter. We don't know if our bats, if they're going into torpor in winter. If there's a particularly prolonged stationary front where we get the rains for five or six days a bat's got to eat. But if it's raining for that time it's not good for foraging. Torpor is hibernation, essentially dropping a body temperature to conserve energy and remain inactive.

WINTER: So a closely related follow-up question to that is we're supposed to be looking at the best available data. There's obvious gaps in our knowledge for this species. So when applicants are applying continental proxy data, are there any particular red flags that we should be on the lookout for?

FRANK BONACCORSO: Yeah, sometimes the proxy data is not even another species of *Lasiurus* or even tree bats. Our bat like other species of *Lasiurus* does twin so its typical reproductive litter once a year are twin bats. That's got to have some impact on the life demographics of population and survivability. We don't know if they're more likely to successfully rear one pup most of the time or two pups. That's an important demographic. So you can I think get into some misleading sidetracks by using proxy data. We don't know how good, where's the good data that we can use. As you said, best scientific data available is what we've got to go on and it's a challenging bat. I've worked on a lot of bat species across the world. This one is as challenging as any bat that I worked on because it is a more or less solitary rooster and roosts fairly cryptically. Whereas, many other species of bat are hole nesters or cave roosters or live in human structures. So it's a real challenge and I can't tell you for sure what's good data to use as proxy and what's bad.

KRISTIN JONASSON: Frank, I was just wondering if you could expand on the difference between mainland and Hawaiian Hoary Bats in terms of their wing shape and body size and how that might affect their behavior in terms of echolocation frequency, if that's a little bit different.

FRANK BONACCORSO: So given that the mainland species is 30 to 40% heavier, a heavier bat now has a higher load to carry. Its bat flight dynamics are pretty similar to plane flight dynamics. So a heavier bat is less maneuverable, as is a larger bat in general. Hoary bats though, all of them are still pretty acrobatic. In fact, they catch their food in their tail membrane, which is a large membrane between the legs and with the tail running down the middle. They kind of do a basket catch in which they'll pursue prey and then when it gets to intercept the prey the bat will somersault and the tail membrane down here will actually capture and enclose the insect. As it's tumbling it actually may do two somersaults in the air as it's catching insects and transfer the insect to its mouth and then feed on the wing. During that process of tumbling and feeding it is probably why we get bats in collision with objects like barbed wire.

The wing shape itself... We have sent wing traces to Dr. Rick Adams at the University of Northern Colorado and he's going to be doing some detailed morphometric comparisons of hoary bats in the mainland and Hawai'i. Do you know?

KRISTIN JONASSON: I don't know the specific answer to that but my guess is they're adapted to slightly more cluttered places than a mainland hoary bat. Visually they look to be more similar to a Silver-haired Bat's wing shape and body size. Just keep in mind their echolocation frequency is a little bit higher which will affect their ability to detect things and for us to detect them.

FRANK BONACCORSO: Yeah their small size may be an advantage for using a bit more cluttered habitat than mainland bats. It's part of that whole island ecological release because there's no other bats they compete with. Okay one more.

BOGARDUS: Sorry, two quick ones. First is, can you speak to if we had any known mortalities and limiting factors of mainland hoary bats that we don't have evidence for here?

FRANK BONACCORSO: I don't believe there are any mortality studies of mainland bats... Michael would you like to answer that?

MICHAEL SCHIRMACHER: One thing that I noticed that might occur is aircraft collisions. There's papers on collisions with hoary bats. There's some papers you might find in Hawai'i. It kind of gets to the question about height of risk as well.

FRANK BONACCORSO: Otherwise it's wind turbine collision.

BOGARDUS: Last one, your statement about all pupping occurring below 1,000 meters… that has some pretty serious implications for the siting of mitigation projects if we're trying to influence pupping. Do you think that that's true on all islands and do you think our data on that is because of a limited size?

FRANK BONACCORSO: The line might be a little bit higher than 1,000 meters and we've got a pretty good number of bats that have been captured in the last 15 years. I'm reasonably confident that it's plus or minus somewhere in the area of 1,000 meters. That's the limit.

BOGARDUS: I know Dave found lactating and pregnant females are higher elevations but that doesn't necessarily mean…

FRANK BONACCORSO: A female can go on a two hour foraging bout and can definitely go higher than that. The question is the pups, which are dependent on the roost. Hoary bats in general, from day one, have such well-developed feet and claws that they're able to lock on to a branch and roost independently from females. So they're generally not carried on the breast like some of the other bat species. They are twins so it gives them a larger body mass to huddle together and retain heat. I think the key is up at 3,000 feet it's so cold even adult bats probably don't roost at extreme environments where they do forage. Thank you.

Diet and foraging behavior: Dave Johnston, H.T. Harvey & Associates

DAVE JOHNSTON: Thank you, I'm Dave Johnston. I'm actually a neophyte compared to Frank. I've only researched bats for about 30 plus years. But of those 30 years I spent most of my time working on the foraging ecology of bats. So I'm going to do just a short primer on foraging ecology of this species. I wanted to respond to the last question about pupping in the Hawaiian Hoary Bat and whether or not it's below 1,000 meters. If you look at models for a sister taxa that is the Western Red Bat, it very systematically breeds in certain minimum temperatures during summers. If you just look at that, it suggests temperature is critical for the pupping in this species. In this case western red bats make a latitudinal movement so that this species breeds or raises young only in the Central Valley of California and other areas where there are mean temperatures much higher than at any higher elevation. So very low elevation. Males are distributed all over the place – at many elevations and almost anywhere with trees and a good supply of moths. Females, who are in the business of raising young, require very specific habitats that are mostly temperature driven.

Okay, I want to just start out with some basics here and talk about optimal foraging theory. Basically, if you look at this as the profitability, that is the amount of net energy that a bat is going to obtain, it's going to be the energy content of that prey divided by the handling and searching time. So you can look at catches as something that the bat will want to forage on in a certain period of time and then when it's no longer profitable, they should move on to the next patch of prey, right? Because if they spent too much time just trying to get those last few insects, it's no longer going to be profitable. So this first section of time is a commute time to a prey source. At that point, the time here is the amount of time that that bat spends actually searching. So there's commute time, search time, and there's also handling time. So time in the patch is a combination of those. There are probably now 40 years of complex equations that model very specific situations. But this is just a way of looking at what the bat needs to do to find those patches, take advantage of them, and move on to the next patch. If the bat spends too much time or too little time it will not optimize its energy needs. So with that in mind (and I have to thank Frank for some of his comments about the size of that foraging area) the size of the foraging area can be very tiny if the bat is extremely efficient or if the bat is not efficient and at lower densities it's going to take a lot more search time and the foraging area may be a lot larger. I've worked on the foraging ecology of many species of bats and the wide variety of prey for some species; foraging behavior and handling time and effort for something like a scorpion is going to be very different than, let's say, a beetle.

I want to give you a few examples of the different sizes of foraging areas I've observed. In the Pinery, which is a provincial park in Ontario, Canada, I was with my major professor at the time and someone noticed bats coming out of a single lamp post. So the bats came out of the lamp post and they foraged on the moths and beetles that had been attracted to that lamp in the evening. They forged an area maybe 25 square meters, filled their tummies, and went back to home. Except home was, you know, a few meters away in the same lamp post. So this being a Little Brown Bat, *Myotis lucifugus*. Time-lapse photography of moths and beetles, by the way, if you take these pictures you can separate out moths from beetles just by the patterns. So I took this at about one second. And then these are actually lamps at one of our harbors here in Hawaiʻi. For various reasons, some lamps attract more moths and beetles than others. There's some great papers out from Europe on which lights attract which insects. Nonetheless, if you look at a typical foraging area for the same species, it varies from 5 to 15 hectares. So the little lamp post roost has a core use area of about 25 square meters.

Here's another example. I've also spent a number of years working on the Mexican Fishing Bat, *Myotis vivesi*. In the earliest study that we were doing radio telemetry in, we had a graduate student work out the home ranges or foraging ranges of different individuals. That occurred on Isla Partida Norte. This being about a kilometer and a half. It's about a mile long. So we worked out about six home ranges of this species. In the end, although her thesis describes all these home ranges the paper that we brought out let go of these because we realized that we only tracked about a quarter to a third of the bats. Some bats actually did systematically make these small home ranges, but we didn't feel comfortable with it and it wasn't a clean story. Five years later when we had data logging GPS units with very tiny batteries we had a whole different story. So this was a unique situation where the females, we put the GPS data loggers on the bats where they were roosting. We knew that they had to come back to their pups to feed every night. And so it gave us a unique situation where we could retrieve the path. That would not be very easy with hoary bats. Recatching hoary bats is darn near impossible. Bats are generally good learners by the way. Each one of these circles represents a one minute period of time. The distance from Isla Partida Norte to the coast here by hitting Bahia de Los Angeles is 30 kilometers. They typically go over a 100 kilometers a night many of them. Yes, a few have these tiny little ranges here; maybe they're inexperienced females. We don't know why, maybe they are compromised for other reasons, but this is the real story. So this is ecologically like a storm petrel and there are three species there that coinhabit this island. One is the least storm petrel at about 20 grams. *Myotis vivesi* is about 35 grams and then the black petrel with a weight of about 50 grams. So we have three completely different niches—each foraging on a different size of prey.

Okay, here's a quick summary of some of the dietary studies and the authors are in this audience here. But going back to Whitaker and Tomich, in the olden days when you collected the feces you put them in a petri dish and mashed it up with a little alcohol and then looked at the prey parts under a microscope. And then if you get good at this, you can figure out in some cases two species for things like beetles. Chris Todd in the back who has already spoken did this for his Master's. It earned me a ticket to Zimbabwe for five weeks because I was reasonably good at this and proficient. So we worked on a couple of papers in the 90s there. That is the old-fashioned way and DNA barcoding as you'll find today is so much better, but it's not easier and it also has its challenges and issues. But Whitaker and Tomich at the time found that beetles were the most prevalent prey. Moth scales in a bat's gut can last for days, maybe more than a week. Moths are difficult to separate out by species or even family so pretty much a moth is a moth that has scales. It's very difficult to separate out timewise because the gut hangs these particles up. I suspect that this earlier study was biased towards beetles simply because they have full parts that they could count. I wouldn't say that for sure, but I suspect.

Okay, moving forward. So Jackie Bellwood and Jim Pollard did this study and I used to make jokes to them about this because you're basically going out, and they took a vacation together to Hawaiʻi and they spent a week studying the diets of bats. And to me to spend seven days collecting data is just not enough to say much. However, the paper's actually really interesting because what they did is they went to an area with lights with lots of prey. They observed as many as eight bats at a time intercepting the same light source. So at one vantage point they could observe eight bats at a time and they watched a lot of interactions among the bats. Then they could also figure out what they are eating because when the bats would come in they would clip the insect wings off and the wings would fall to the ground and they can pick them up and then discern these by species. They found that the bats were eating primarily moths and that there were many more small flies and moths, much smaller than ten millimeters, but bats were preferring prey that were 16 to 20 millimeters.

Okay, Chris Todd again in the back came out with a really neat study trying to look at the availability of prey and what the bats were actually eating. Yes, he did it the old-fashioned way, which has advantages by the way—you can sometimes discern gender and things like that. You're not going to be able to do that with the DNA barcoding. But if you combine these two methods, sometimes you can separate out a species under the microscope and not by DNA barcoding and vice versa. How do they do that? Well in some cases the DNA barcoding will allow you to take something to genus or the genera level, but not necessarily species. If you have the right morphological character in a microscope, then you might be able to take that particular thing to distinguish species. Okay, I thought one of the interesting things that Todd did here was that at the low elevations bats were clearly eating more moths than beetles and this is proportional to the availability of these things. At the middle elevations bats were eating more beetles and at a higher percentage than were available. So different prey patches are going to have very different kinds of compositions and this I think would be pretty localized. But when we did our study, I tried to be very careful not to make generalizations. It'd be easy to with a few observations. But with only 11 bats, I think we're really limited to actually what we can say in some cases. To Chris's credit, he identified three moth families, which I have to say is really tough to do under microscope.

Corinna and the whole USGS team really came out with an amazing report last year, 2019, drilling down on a lot of the diets of hoary bats in Hawaiʻi mostly by DNA barcoding. From eight samples they got 24 moths and other insects to the species or genus level. What I thought was really unique was that they also collected caterpillars that they found on specific plants and then reared those out. For once, they can tell what the host species of a lot of these moths are because without that there's very little information on a lot of these. We found many of our moths were undescribed. Okay then finally, we analyzed 11 bats' guano with DNA barcoding and we followed the USGS team's protocol as much as possible in hopes that we could put their eight samples with our 11 samples which would make 19, which is a little more. It's still a small sample size. Chris, how many bats' diets did you look at?

CHRIS TODD: Sixty-eight.

DAVE JOHNSTON: I looked at 101 male Pallid bats for my PhD thesis. I got a handle on some things but not others. So 19 is good. It's better than eight or 11, but it's still a small fraction of what's going on because these are tiny snapshots. Now I put this up because there was quite a bit of discussion the last year or so about core use area and foraging range. This was taken from our study. You'll notice the bat on the left core use area here and that the foraging range is ginormous. But let's look at who that bat was and what it was doing where it was. This bat was a young female presumably foraging on its own for less than a few weeks. So it's late summer and this bat on the right is the mature male. He would travel some distance and went into this little gulch area here that was presumably chockfull with a high density of insects. It was very efficient at foraging. So what's the difference between these habitats? This was over the failed sugar cane fields. So mostly rural grassland and I suspect prey are very low density. Additionally, this bat is inexperienced. This bat on the right was experienced and it had found that sweet spot where it didn't need to forage except in a very small area. We found one bat at about 8,000 feet, so well over 2,000 meters, and we caught it very early in the evening at about nine o'clock and it was completely full. It had finished with foraging, presumably at a lower elevation, so it had come up in elevation to look for females.

I was amused at the comments that I heard from an earlier meeting where people were confused about the lanes cut into the wooded areas at the ʻUkoʻa wetlands. The lanes were cut into the wooded areas as a strategy to increase the foraging areas at this mitigation site for the Hawaiian Hoary Bat based on Meredith Jensen's work. She modeled the activity of mainland hoary bats along a gradient of the edges of forests. So where you had a fairly dense forest, in this case pines, and then you had a clearing like a meadow, river, or some other open geographic feature like that, she modeled bat activity and found that at about 12 meters away from the forest edge was an optimal distance for mainland hoary bats to forage at. She put microphones hundreds of meters into the forest and also out into the meadow but found that sweet spot was again, just 12 meters away from the forest. Knowing that and then spending some time at ʻUkoʻa wetlands -- where in a whole week of time, going out there every day, I found one dragonfly in a 100-acre wetland--that wasn't very many. Dragonflies are a predatory insect that feed on smaller insects. Bottom line is that I found very few insects. So I thought that if this site is going to be successful at mitigating for the take of bats, it needs to produce more prey. These lanes were not made to allow bats to access the interior of the wetlands; but rather, they were made to give more edge effects to the bat foraging area. So the prevailing trade winds come in this direction and so the idea was to make these lanes perpendicular to the wind direction. What you see in this slide was not my original plan. Some of these lanes were created sometime after I was involved with the project, but this layout may have been what was implemented, I'm not sure. So again these lanes were made to increase the amount of foraging area. The other measures I included were designed to increase the numbers of insects.

Okay, take home messages. These bats have a lot of plasticity showing a lot of behavioral flexibility. They can do a lot of different things in different situations. Prey availability is likely the driving factor in its distribution. This is not totally clear. I don't think we have enough solid data but generally, it looks like it might be true. We still need a lot more data before we can say yes. As Frank said, "Out of a lot of species out there, this species is a challenge." Thank you.

JACOBI: When looking at food resources, especially the beetles, is it necessary to take the effort to get down to the species level, or just keep it at those groups there, whether they're native or not?

DAVE JOHNSTON: I think if we're going to be in the business of designing habitats that provide prey for bats, there's some evidence that they select some moths over others. Again, because our sample size is really pretty low the most common moths were not found in any of our samples, which is interesting in itself. I wouldn't put a lot of weight on that though, because we only had 11 samples. I would advocate that, because if we're going to really restore habitat and design intact habitat that has these plants that provide habitat for prey species, I would advocate going down to the species level. A very common and widespread moth in some habitats like grassland was eaten far more than any other moth, and it's a grass specialist. So I would advocate identifying to the species level because then you can plant specific plants that you know will produce certain prey.

JACOBI: But it seems to be more of a size issue, right? Rather than the particular species because that species is all that's there but it's really the size they're selecting for feeding? The bats aren't distinguishing species, are they?

DAVE JOHNSTON: Based on some previous work, hoary bats definitely select some species of moths over others. The *Noctuids* often have defense systems. They can either hear the bat and then leave the area, or they taste bad, or they jam the sonar, or any number of things. But in support of doing a general assessment these are usually particular to genus and more generally in a family. In other words, some genera will usually have the same defense mechanism. So you don't want to be rearing a moth that's very successfully evading bats.

PRICE: Thank you Dave. I'm glad that you have so much experience in many places studying the foraging ecology. I'm curious if in Hawaiʻi in particular, but also you have knowledge of elsewhere, is there any evidence that bats are food limited? So for example, bats that have been in the hand with tracking studies—are they emaciated at all? Bats that have been found under wind turbines? Is there any evidence those are actually food limited and that's what is limiting population size?

DAVE JOHNSTON: You could look at this in a circuitous way. I think it would be difficult to actually directly assess this. At least on the islands here, I'm not in the business of looking at wind turbine fatalities. I've done a lot of that at solar projects and wind projects on the mainland. I caution against using correlations to figure things out because you know, you made a certain assumption there and without testing this we have to be very careful about correlations. Nonetheless in places like ʻUkoʻa wetlands, which looks like a great habitat, this is about a 100 acre area with a large wetland component, it should be chockfull of things for bats to eat but there are very few bats there. The bat detectors there were making detections of about one per week. That's a very low density. The density is, I have to tell you too, much higher in the Kawailoa Wind Farm habitat.

PRICE: I just want to make sure I'm understanding: there's no direct evidence you're aware of that bats are food limited and that's limiting population size?

DAVE JOHNSTON: I don't believe I would call it direct evidence. I think that it is a limiting factor to their occurrence, which is different to say that it limits their population. Those are two entirely different questions. So I would say, you know, you can make a nice correlation and I have other projects on the islands like harbors and airports suggesting the same very low density of bats and not much for the bats to eat.

JASON PREBLE: For these lanes that were put in, have you seen any increase in foraging or are there studies concerning edge effect and bat foraging that are good proxies for what you're hoping to see there?

DAVE JOHNSTON: I'm not a good resource to answer that question because I haven't visited that project in actually several years. I believe TetraTech is managing that project.

JENNA MASTERS: How much does a bat need to eat per night?

DAVE JOHNSTON: That depends entirely upon the sexual condition of the animal. So a lactating female will eat as much as her weight every night. A male may only eat order a quarter to a half. Again, depending upon its energetic needs. But just you know, a lot of people who do emergent surveys either at Hawaiian Hoary Bat roosts or at a large colony, people assume that the bats go out every night and so they make it count. Oh, yeah, well we saw two bats come out from this little neighborhood of hoary bats. Well, you're assuming that those bats go out every night when in fact they do not. I mean at some point the bat decides whether or not it's going to go out and forage or not. It may not go out because it's made the decision that it's not worth foraging. I won't put a reason on that. I'm just saying that that's probably the reason some bats don't go out every single night.

BOGARDUS: Other than insect availability, how would you define the resource needs?

DAVE JOHNSTON: Bats are very complex animals. There is not a quick answer. It has different needs over the course of the year. Its needs will change by season and by reproductive condition. So males and females have completely different needs and that has to do with mostly habitat and what that habitat provides, and the amount of resources that it needs and each of those habitats. So a male presumably could use much lower densities and get away with that, whereas a female might have to be much more efficient if she's lactating which is a heavy demand upon her resources. I don't know if I answered your question.

BOGARDUS: That was perfect, thank you. Last question, given the difficulty in capturing bats and especially the difficulty in recapturing bats, would you say that it is infeasible to determine how an individual bat's core range size changes over time in relation to, or in response to, changes in resource availability?

DAVE JOHNSTON: I wouldn't say it's impossible. GPS units are getting smaller. There are batteries that are much smaller today and they will continue to be much smaller in the future where we might be able to do a GPS data logger on the hoary bat in an area where we can recapture them. Like Ted Weller, basically he's found a swarming area where boy meets girl, I think in the fall, and it's pretty easy to capture a lot of bats there. I don't know of any sites here like that.

ITEM 4. Updates on ongoing research. Hoary bat ecology project: Marcos Gorresen, U.S. Geological Survey- Hawai'i Cooperative Studies Unit

MARCOS GORRESEN: My name is Marcos Gorresen. I work with the Hawai‘i Cooperative Studies Unit at UH Hilo. I'll be giving the intro slides to the ongoing studies we have going on on the Big Island. These projects are ongoing so these are status updates and very basic results. There's not a lot of interpretation involved. There will be follow-up presentations by Kristina Montoya on roosting ecology of the bat and by Corinna Pinzari on diet and genetic work that is underway. So these are the research topics we will be presenting now: our current mist netting effort and bat capture and tracking results, and then the other talks on the roost ecology and genetic diet.

So we completed our second year of a three year study on Hawaiian Hoary Bat ecology on the east side of the Big Island. We have eight sites that are kind of our fixed sites that we've been sampling on a recurring cycle, three times per year. They're generally dividing some upland sites and lowland sites shown here and we visit these sites three times a year. On each visit, we will sample for at least three nights netting bats and we have concurrent insect sampling that takes place in the same week. So our capture effort to date has involved 125 net nights of which we've caught 65 bats up to the end of 2019 and a little bit more in the last couple months. This has amounted to over 2,000 net hours. You can see the capture rate here is quite low because these are very difficult animals to capture. We use these triple high nets in some cases. Also, other lower height nets for catching bats that are coming down towards the ground and use of canopy openings or roadways in the forest. Sometimes in open terrain as well. So we do four insect light trappings on two of those nights and it's concurrent with netting nights. And we also get guano samples when we capture bats. Here's some tallies of results we did last year. Here's our capture as of 2019 with 65 bats. They're divided fairly unequally between the females and the males. What we do is we collect information both on the age as well the sex but also collect samples on the guano. We hold the bats in bags for a short period of time and we get a guano sample about two-thirds of that time.

We also take tissue samples for genetic work like fur clippings because we radio tag these bats so we need to take a little bit of fur off their backs to put the bat tag on. Fur samples are retained for future analysis. We collect wing photos so we can handle some of the morphometric questions. We collect a lot of standard metrics on all these bats like time captured, weight, size metric in in the forearm, age, sex, and reproductive status. Then these bats are colored banded so we can re-identify them at their roost or if they're recaptured.

So of the 65 bats, actually 67 as of February, there's been five recaptures. There's some discussion of GPS tags that will eventually make them possible for Hawaiian Hoary Bats and will allow us to get a handle on these long range movements over a long period of time. But it's totally dependent on being able to recapture the bat and download data. So you can see that five bats out of 67 is a low recapture rate. On these five bats we did get some information on the time between capture and you can see a couple of these bats have been captured a year later and close to the initial site. Their body mass seems to hold pretty well. It goes up on a seasonal basis between March and July for a male. So here's a breakdown of the 65 bats captured over the last couple of years at the eight sites. There's also some opportunistic sites; we also sampled at intervals between sites and they occur throughout the same area.

You can see there's a male bias in the capture rates. At this point we don't know if this is representative of capture or a true reflection of the population. This is a small sample so it's very hard to start generalizing and we're not going to do that until we're finished with one more year of bat netting and analysis of data. So here's a breakdown of sex by time of year. It does reflect the male bias and you can also see there's seasonal peaks in both capture rates as a whole and for capture rates of females. Here's some information on reproductive status of captured bats. You can see there are a lot of holes for the lactating females. That's all I have for now. Kristina and Corinna will pick up with follow up presentations.

KRISTIN JONASSON: I was wondering how much you're factoring in acoustic lures into the bias for capturing more male bats?

MARCOS GORRESEN: Right, so Corinna uses playback of a variety of calls and it does seem to attract male bats more. However, the acoustic lures are only used on one corner of the net area so there are a lot of other net areas that are available that are not exposed to acoustic lures.

PRICE: Of the 65 bats that you had was there any evidence of them being emaciated or showing food limitation?

MARCOS GORRESEN: No, all the weights seemed to be in the range that we use to indicate healthy bats.

KRISTIN JONASSON: To speak to the emaciation of bats, they're probably using torpor, their daily energy saving strategy to turn off the engines, and they would probably not get to that emaciated state; but they'll stop being able to grow and do things. You wouldn't see that state of emaciation, but you might see moms who might take longer to nurse their pups or something like that. Or they might not reproduce at all.

CORINNA PINZARI: I'd like to add that there are other ways to assess the health.

MARCOS GORRESEN: What Corinna said is there are other ways of assessing bat health but we can't really do that in the field. We can take tissue samples but we don't take blood samples. These are just field captures and a quick release.

MEHRHOFF: You had five recaptures out of 65; were you able to come up with a population estimate from that?

MARCOS GORRESEN: We're getting there. We have one more year.

MICHAEL SHIRMACHER: Two out of the ten females were non-reproductive in July. Does that seem like a high number of reproductive females?

MARCOS GORRESEN: It's really hard to generalize on this kind of sample size. I would say the fact that there are some females that are non-reproductive at this time of year, I would say they just didn't get what they needed that season. I can't get any further than that.

THERESA MENARD: I just had a comment that I had a skewed sex ratio when I was studying the Hawaiian Hoary Bat based on Tomich's capture records which were from shooting bats, so there wouldn't the same problem with the male bat being attracted by the lures.

Roost metrics and surveys, and fidelity: Kristina Montoya-Aiona, U.S. Geological Survey

KRISTINA MONTOYA-AIONA: Hello, I've been with the USGS bat project since 2010. I've worked on everything from acoustics to high elevation foraging surveys. Now I am taking the lead on some of our roost work that we're doing on the Big Island. In my spare time, I'm also a Master's student at UH Hilo working on roosting ecology and behavior ecology of the Hawaiian Hoary Bat. So to follow up on Marcos' presentation, this is the roost aspect of what we're trying to get from those 65 captures. So the objectives of this are to identify and characterize roost habitat, locations, and roost tree attributes, and then try and get some measure of fidelity, like how long bats are using roosts, if we can get to that.

These are a lot of the methods that we use. We have an amazing team that tracks the bats and captures them and does a lot of this work. So from capture and taking bat specific metrics and radio tagging them we radio track and use thermal imagery if we're lucky. That's what a bat looks like on a thermal imager in a very large tree. We use binoculars and scopes to try and find them in trees and when we can get to that tree level and we do a bunch of metrics and monitoring we get everything that we can from that specific roost tree. This is the end goal for roost work. That is what a bat looks like in an Ironwood. It's a unique search image.

For tracking we captured 65 bats this past year. We put radio tags on 61. There was a small subset that was not suitable to tagging likely because they were underweight relative to the weight of the radio tags, particularly the juveniles. So we tracked 38 bats to 55 roost stands. Then 18 of those we were able to track to a smaller level to an exact roost tree, which is great. Then within those roost trees we were confidently spotting bats at 14 of the roost perches. That's the exact roost location in the tree. And so to get an idea of the level of effort it takes to get to that we had 486 tracking events. If you do that times two personnel, which is a bit of an underestimate, we usually have two teams of two personnel times eight hours a day, which is also sometimes an underestimate because we can be tracking 12 to 14 hours a day. But if you underestimate it and divide it by the 52 roosts that's about 150 personnel hours per roost which is an incredible amount of effort to get to these roost trees and roost stands. So this is what it looks like on a map. The larger blue is the roost stand and the orange is the roost tree. This is a little bit concentrated in the lowlands and I kind of want to qualify that by on the east side of Hawaiʻi Island in the lowlands there are lots of roads and hiking trails and we are able to more efficiently and effectively track in those lowland conditions. In the uplands, it's a lot of contiguous forest and it's very difficult to track in those conditions. And so I don't want the takeaway here to be that bats are not roosting in the uplands. They're just quite a bit more difficult to track in those conditions.

So of those 24 roost trees that we've identified these are the species that we've seen bats in. ʻŌhiʻa is the only native tree so far that we have identified bats in, but these are all larger trees. The foliage is quite different between these so that's an interesting thing. This is data from the first two years and I'm really interested to see what we get this year. Our tracking methods and our team and everything is like a well-oiled machine now, so I'm hoping to get a lot more data this year. So we look at just some basic metrics of the roost tree. The height, there's quite a range of heights. The mean is 21 meters tall and tree canopy cover, there's quite a range with somewhere in the middle of 43%. When we look at where the bat is in the tree at the perch there's also a bit of a range but the mean was about 14 meters off the ground in the tree. Again, canopy cover was at about 55%. Then where is it in the tree and does this have some kind of thermalregulation? You know, why would they choose this southward and westward aspect? So this is a small sample size because we were only able to identify 14 perches in the 24 trees. So I think this is interesting. I don't know what it tells us quite yet, if there's a selection for you know, the southwestern sides of trees. I'm excited to get more data and see if there really is some kind of selection happening there. Also, if it's seasonal, because I would expect that to fluctuate a little bit seasonally.

So when you look at the larger forest stand metric there's a bit of a range. The mean canopy height is 24 meters and then cover classification, we had 25 forest stands that were in closed canopy. The next highest, we had 12 stands that were in very scattered, which is less than 5% canopy cover. So that's also quite interesting. So some of the ways that we get at these stand metrics. We use pictometry, which is awesome. We do a lot of ground-truthing but there's also something to be said about getting this eagle eye view of a larger stand. These stands are very difficult to maneuver and in some cases are actually pretty dangerous. So what this allows us to do is when we track a bat to a roost tree, we have our XY value and then we put in pictometry, a 50 meter radius buffer around that XY, that's our centroid. Then we're able to get all kinds of stand metrics that are around that roost tree. In some cases, where we weren't able to track to an exact roost tree we used our points and our bearings and we use a program called LOAS which is "Location of a Signal". It uses a really cool algorithm and estimator that determines where approximately that signal would be coming from given your triangulation or your points and your bearings. In that case, we use that estimated XY for the estimated stand area. And again, we put a 50 meter buffer around that estimated XY and we do the same sorts of stand measurements for that. So pictometry gives us both orthogonal and oblique images and it gives us both community level and then neighborhood level. So here we get this zoomed out view. This is off of Stainback Highway. So I think in the 60s, they planted a bunch of timber trees. So it's kind of interesting that you can see the way that they planted things. There's forest edges and roads and power lines. That also allows you to get to these neighborhood levels.

So this is a whole lot of eucalyptus. So it lets you get a finer detail and this would be closed canopy. In this example we can get edge canopy cover and a bunch of measurements that would be much more difficult to get in the middle of that. It also has oblique views so you can scan around and see these different views of it. So we're able to get measurements of trees that are within that stand and we can get a measure of mean canopy height that is surrounding our roost tree.

So back to our bats that we've been tracking. We had nine bats that we were able to confirm multiple roosts for. This is interesting on a couple of levels. First, there's a little bit of a difference in our capture site and where their roost trees are. So this particular bat was captured close to Hilo Bay and then we tracked it to two separate roost areas, both about two kilometers away. The next one was captured and located very close to the capture site in two different roost areas. This one was in a macadamia nut orchard in the lowlands. So sometimes these bats that we get multiple stands for, it's because they're easier to track. It doesn't quite mean that all the lowland bats had multiple stands. It's very likely that upland bats do as well, it's just hard to track them. This one, all of its roost locations were actually very close to each other. Then you get to some interesting ones like this one. This one was captured and then it has two roosts at 14.5 km and almost 21 km away from its capture location. So there's a lot of variability in what these bats are doing.

Maternity roosts are hard to come by for a whole variety of reasons. In 2019, we were able to identify three maternity roosts. One was a bat with one pup in a lychee tree. These were all captured later in the season so we didn't get any idea if the ones that had just one pup when we identify them, if they did birth two pups and for some reason lost one at some point, or if only one pup was born that year. These are just too late in the summer for us to know what happened there. When we get to the maternity roost we set up thermal cameras and acoustics, if possible, because we want to get at emergence, like are the mom and pups leaving together to forage or are the pups still sitting at the roost? If we run continuous acoustics, are there any identifiable calls that we can pick up during the day and is there any communication between the mother and pups during the day? So this is what an emergence looks like and these are just still shots.

So, you know, that's a limitation of the thermal sometimes in the lowlands. It gets hot during the day so we get a lot of video that we can't see where they're at until the tree starts cooling down. Departure ranged from 53 minutes before sunset to 20 minutes after sunset. So there's a little bit of range. For arrival, when they're coming back to their roost, the range was from 41 to 11 minutes before sunrise. We also wanted to see if there's any predation at these roosts and we did not observe any in our video.

For acoustic recordings, less than 5% of call files with bats were during the daytime and those were right around sunrise and sunset which is likely calls of them leaving the roost and coming back to the roost. We didn't pick up any midday recordings of bats making any echolocations at the roosts. Which is sort of expected. They don't use echolocation to talk to each other at the roost so it's not something that I expected. That's sort of where we are right now. I hope to get more maternity roosts this year. And go really hard at monitoring them when we do get them, because they are few and far between and it's a really special thing when you can monitor them. Thank you.

PRICE: So with the 61 that you were tracking, even if you can track them down to the roost, can you just talk a little bit about what your data can say towards survival and mortality? So re-sights over time and how many just disappeared from the area, that kind of thing.

KRISTINA MONTOYA-AIONA: That's a really good question. I think a lot of the ones that sort of fall off the radar or when we release them we never find them again, some of that is a function of having the bats groom off the radio tracker one night. Some of it is also a function of losing bats in forest that we can't track it in. A lot of the bats that we lose are up in the higher elevations. It's likely interior and we just can't get there. As far as survival and not being able to track them. I can't speak to the survivability.

PRICE: Maybe just what percentage did you never detect again after detecting them the first time? Not counting the ones that broke it off.

KRISTINA MONTOYA-AIONA: I would say about 30%.

WINTER: I had a question about roost trees. I'm curious how roost trees are in comparison to the trees around them.

KRISTINA MONTOYA-AIONA: Off the top of my head there doesn't seem to be something particularly special about this tree in the stand of eucalyptus. The lychee trees I think are special cases. We monitored these lychee trees since 2004, right Frank? So actually that mother and pup in the lychee tree, she was not captured or tracked back to that tree. That's a tree that I check all the time. It's in someone's garden in an agricultural area. So I think there are special cases like those lychee trees where there's something about those trees that is particularly helpful for bats.

WINTER: Do they go back to the same branch every time or just the same tree?

KRISTINA MONTOYA-AIONA: There's a lot of within-tree branch switching.

DAVE JOHNSTON: One of the landowners, where you've observed a roost, lived on his property since he was a young man, over a 50 year span. He pointed out several trees, some which were banyans which later fell down, where he observed bats coming in and out of anecdotally over his 50 years. So there seem to be some traditional trees that are frequently used. Also you found up to how many bats using one tree? They're not really a colony because there may be up to three, four bats in a single tree, but they are in widely displaced parts of the situation.

KRISTINA MONTOYA-AIONA: Again that's in the lychee situation. These lychee trees are very old and very big. The bats that I've seen, when there's been more than one they are in distinct, separated areas. There doesn't seem to be any interaction between them.

SPAIN: Given all your time in the field and working in lowland East Hawai‘i, are you guys finding fire ants at any of the sites where you're finding roosting trees?

KRISTINA MONTOYA-AIONA: So this is something that we note on our data sheets. There's a few areas where there's been fire ants and they don't seem to bother the bats as much as they bother us. I had been in some really invaded fire ant areas and the bat is still roosting in that tree.

DAVE JOHNSTON: Do you know what species of eucalyptus the bats are using because *Eucalyptus robusta* is very dense as opposed to the other eucalyptus species that are commonly used by the mainland hoary bats in California?

KRISTINA MONTOYA-AIONA: They've been found in all different types of eucalyptus that are planted off of Stainback Highway. I would have to look at the numbers to know if there's some sort of like, they're found more in one over another. I don't know off the top of my head.

JACOBI: Thanks for the presentation. But as you said you got a very small sample size. I guess my question is how much more effort will it take to get to where we have some confidence in being able to really describe these roost habitats and come up with something that can be tied into a management strategy?

KRISTINA MONTOYA-AIONA: I'm hopeful that this year we at least double our numbers. We have a great crew that can do that. For management, the takeaway is that foraging habitat and roosting habitat might not be the same thing.

JACOBI: So is there any indication that you see that roosting habitat may be limiting?

KRISTINA MONTOYA-AIONA: I don't know if I want to commit to that.

JACOBI: I'm just trying to get at some of the issues that may be really critical that we need to look at further or maybe if this is not really an issue, there are other things we should put our efforts towards.

KRISTINA MONTOYA-AIONA: I think maternity roosts are particularly interesting. I'll leave it at that.

Population genetics and genetic sexing: Corinna Pinzari, U.S. Geological Survey-Hawai‘i Cooperative Studies Unit

CORINNA PINZARI: My name is Corinna Pinzari and I'm a Research Supervisor with the Hawai‘i Cooperative Studies Unit out of the University of Hawai‘i at Hilo. I've been providing scientific support to USGS with various research projects including acoustic monitoring for the past 12 years. I recently earned a Master's degree from the TCBES program at UH Hilo. I completed thesis research on Hawaiian Hoary Bat population genetics there. The first part of my talk is about this diet metabarcoding that Dave introduced us to. I'm going to quickly go over some methodology of how we do it and share some current progress from the Hawai‘i Island study. We are halfway through the data so we don't have a ton of results yet to present. Then I'll give you an example of how we're looking at that data for Hawai‘i Island. We have done this study on a small scale last year on Maui which Dave talked about and I'll share the results from there.

Okay, so our objectives here were to look at bat diet composition and insect prey availability. You want to be able to look at that diet by age and by the sex of the bat and the reproductive season in which we have the sample from and the foraging habitat type that the bat was captured in. We also want to be able to look at the prey availability for bats at that site. We want to look at that by season and also by foraging habitat type. We're going to use meta-barcoding here to compare the bat diet contents to available prey and we want also to determine these prey-host plant associations. This is so that we can link insects that we find in diet to the host plants that people would like to use for restoring bat habitat. Bob Peck from HCSU will talk tomorrow about prey availability and how we're going to look at prey-host plant associations.

So meta-barcoding is very interesting to use for genetics and people have been doing this a lot for bats. It's kind of a new thing and it's still developing. So there's a lot of changes. Every time I check on the literature something else is coming up every few months. People are learning a lot about bats from exploring the diet in this way. So it's the extraction of environmental DNA from the bat guano and the process of high-throughput sequencing of taxonomically informative markers. The main advantage of this technique is you should be able to get to species level prey identification. That's the goal; it doesn't always happen but you can try to get close. They've been shown to provide more comprehensive results than just visual inspection of insect fragments alone by itself. You can also process four samples at one time. In some ways it can be considered expensive but the amount of data that you get out of it is pretty economical. Getting reliable, informative results with this system requires knowledge of the ecological study system. So you need to know what prey are available for bats to consume before you look at the guano contents. You need to have knowledge of analytical procedures that you're using to process these genetic samples. So what genetic markers are you going to use to detect prey items in guano? Is the local insect fauna genetically characterized so that you can ID to species? Or can you only get to order of insects? And can we make reliable matches between insects on the landscape and the insect parts that are left in the guano using this systematic approach?

So I'm going to go through this really cool imagery that I took and then modified from a publication in 2016. So first you have to select the appropriate DNA barcoding marker. In this case, we're just going to look at our arthropod specific primer. It's good for identifying Lepidoptera and Coleoptera in bat diet. Then you also have to select a barcode marker to detect your insect inside the guano and then you also need to build a DNA barcode reference library for your local site. So in pursuing this, I realized trying to ID insects without a reference library is hard. Hawaiʻi insects are not well represented on public barcode databases. People might have this data somewhere but it's not publicly available. So building a local one allows you to do higher taxonomic identification. The next step is you take the tiny guano samples and extract DNA and you also extract the DNA from the insects that you've identified. You run these through two different sequencing processes. And then you want to analyze the guano samples. You want to find out how many operational taxonomic units are within them. So it gives you an overall measure of diversity of insect taxa, and then you want to look at the sequence counts of those sequences inside the guano. That might give you an idea of the relative abundance of that taxa. Then you want to take that information and you want to compare it to your local library and your public databases to try to match what's in the guano to hopefully a species ID.

So current progress on this project. Not all bats want to give us this black gold. Even though we catch a lot maybe about half of them will give us some guano. It's a really small snapshot in their nightly behavior because we have such a little bit of guano caught at one particular time. We can only hold them for about half an hour so if they give us a guano sample in half an hour that's great, then we have to let them go. In this study so far, we've analyzed 35 individuals across those eight sites that we talked about earlier. We have 13 females here that have provided samples and 22 males. As for our prey library building, it's a pretty big library because it's covering a large geographic area. We started selecting insects that we want to extract DNA from and barcode. We sorted a lot of these contents on the availability that we're collecting at the sites to order and family and we're focusing on insects that have already been identified as being important in the diet like Coleoptera, Lepidoptera, and Diptera. Then we're also starting to collect caterpillars at sites on the Big Island pretty soon so we can try to make those host plant associations. Here's an example of a female bat that we caught last August at a low elevation native-exotic mixed sort of matrix habitat. This is in the area that Kristina was talking about with this special lychee tree. So here's a female bat feeding in that area. So in this pie, we have the prey availability that we sampled at that site and you can see the contributions of these orders. This is about a little over 2000 individual insects here counted across these different orders. You see the larger percentages of Coleoptera that might be available as well as Hemiptera, Lepidoptera, and Diptera. So we have one sample from this female who is feeding and probably mating in this area.

We look at the diversity. So how many different taxonomic items are in there? And we see high percentages of unique Lepidoptera and Diptera but smaller percentages of Hemiptera, termites and Coleoptera. But when we look at the sequence count most of this white is sequences from Coleoptera. So they're just dominating this diet sample. It's going to be interesting to tease out how and why this is different from this. This could be because they just eat a lot of huge beetles and that's really what's dominating that diet sample. So like I said before, we did a pilot study on Maui at a bat restoration site. This was our first opportunity to try to take a look and see how this will work in our system for our bats here. Here we're trying to link again the diet and what's available at a current restoration site. We're doing that by insect collection, catching bats, and looking at what's in their guano. So this is the info for that study. We found 42 unique prey taxa that are found in bat diets. Again, we only had nine bats. So it's not a large sample size. We had seven arthropod orders that were detected here. So we have termites, beetles, flies, moths, and crickets/grasshoppers. There were 32 families identified with 18 of those within Lepidoptera. So there's still an emphasis on moths here. We were able to make 13 species level IDs here. Some were made for native species but a lot of them were non-native species. We found overall that bat prey was available for bats at this restoration site.

So here is a few of the bats looking at the diversity in their diet. You can see that green is mostly Lepidoptera moths at this particular site where we captured bats above ponds, where at this site it seemed to work. It doesn't really work on Hawaiʻi Island, but it does work here on Maui. So what we found here is mostly moths, however, about seven kilometers away there was a fatality at the wind farm and we got to look at the bat carcass and I found there was guano that we analyzed. That was interesting because we see different a make up there with a lot more Coleoptera. We did find Coleoptera still being prevalent in female diets even here where it's mostly moths. But again, we only looked during June and November and it's a small sample size. Another way to look at this is how many of the bats were eating certain types of moth families. So we found that they are a lot of Crambidae, Noctuidae, and Geometridae. Some of these families were abundant too with the sequence count so they seem to be important contributions. A lot of them are also small. Then we went ahead and looked at the prey availability at a few locations within this restoration site. The take away from this mostly is that even on this small scale in our two that we looked at, the prey definitely changed of the types of moths that were there. Even in this small area of about 130 acres. We did see there was abundant moths in the families I just named in the diet and those moths were also abundant as prey at the site.

We were able to build a reference library for this small site at Maui. We barcoded 57 individuals here. We did find some overlap between our insects that were barcoded and our guano contents. So we were able to ID 11 families well this way and nine of those were Lepidoptera. One thing to note when you're looking at diet of bats is the contributions of native and non-native species. So we found 18 families that often have a lot of native representatives. We also found a lot of agricultural pests and introduced biocontrol agents. We found some army worms, seed bugs, moths introduced as biocontrol for *Lantana*, and a lot of Scarab Beetles.

So future on bat diets. It should be done on in other habitats and other islands. I don't think it's representative of the entire state. It depends on where the bat is feeding and we should be doing this in habitats that are going to be preserved for bats. I haven't seen anything about dry forest yet or the contributions of wetlands for bats. We should collect and save guano even if we can't afford to do anything with it right away. It's a great resource to keep and use later. We still have guano samples from O'ahu and Kaua'i. Another untapped resource are stomach contents of the bats from the wind turbines. We haven't looked at that yet. Although the carcasses are not in great addition there are enough at this point where you could go in and get stomach contents. Thank you.

JACOBI: Do the sampling methods for determining prey at this site mirror what you're finding in the guano? In other words, are there things missing in the guano, that you're not finding in the samples? Do we have adequate tools to do that?

CORINNA PINZARI: I would say yes. We are collecting, at least for Big Island stuff, a lot more different representatives of those other orders. Even though its focus is still on Lepidoptera and things like that. I think the type of insect sampling that we're doing in this study is a lot more thorough. So yeah, I think we're going to be able to identify more things that way.

JACOBI: Is there a different profile if the traps were above the canopy?

CORINNA PINZARI: Yes, there might be.

JACOBI: Second, as Kristina showed there is a quite a bit of movement of the bats. I think one of the challenges we have is being able to tie in the diet for where the bat is captured versus where it might be foraging and how to link those together.

CORINNA PINZARI: Yeah, some of the reasons for picking the eight sites across the elevation gradient is that we might be able to get at those questions. Because if we catch a bat at a lowland site and the guano doesn't match the site where it was captured it is possible it was feeding somewhere else first and where would that be? Do we have any sites that we looked at that make a better match?

PRICE: Diet studies are notoriously challenging especially for something that you can't watch eat. So this is great tool but one of the challenges I just want to be super cautious about is you don't know whether it's selective digestion or selected feeding. The sequencing bias: that's so gigantic of a difference I don't think it's sequencing bias. Can you just speak to how you would expect some of those parts to digest versus others and how that reflects what you saw in your samples?

CORINNA PINZARI: Yeah, we'll have to think a lot about how these different things digest. Because these are bigger beetles with harder parts and more of it is going to come out in the diet than the moth scales. So when we get to that stage of looking at these results and looking at this relative abundance we're really going to have to be conservative on that and address those sort of sequencing biases too.

MEHRHOFF: When you're looking at trying to assess prey and doing restoration targeting of prey, when you're doing surveys for that, can you get away with using one type of trap or do you need a light and a malaise trap?

CORINNA PINZARI: Bob Peck would say this but he's not here. He would say to use as many methods as possible. The light traps run concurrently with the netting is the best bet at looking at what's available at the time the bat is flying around when we're encountering it. Things like malaise traps they run day and night. So you're going to catch a lot of other things that maybe are flying around when the bats aren't eating. So to characterize the whole site, it would be great to have different traps, but the light traps are designed to look at the insects that are going to be available in that early part of the night.

MEHRHOFF: Thank you. The other question is are there growth curves for hoary bats from juveniles to adults?

CORINNA PINZARI: Not that I know of.

JACOBI: I've got one question. Is the information you're collecting on the barcoding the same methodology that is used on the Maui study, and are those samples compatible and is there a shared library that you're using?

CORINNA PINZARI: I don't know about the shared library part but the sequencing methods were exactly the same.

DAVE JOHNSTON: We actually tried to use the same protocol with the hopes of combining the two data sets. In the end if we publish this the reviewers probably will ask us to review the whole process at the same time which would cost more money and resources.

JACOBI: This is one of the things we on ESRC would like to see in terms of pulling all these data together so we have a better picture of what going on there. Hopefully there's that collaboration.

CORINNA PINZARI: That would good. This study was finished before Dave finished his.

Diet and metabarcoding: Corinna Pinzari, U.S. Geological Survey-Hawai'i Cooperative Studies Unit

CORINNA PINZARI: Sort of a big disclaimer here. There are not results for this yet because we're still not finished with this study. There are still a lot of things we need to analyze and sequence first. There's one manuscript so far that has been submitted to a journal. So I'm not going to have the numbers. Although I completed my Master's work it's still a student thesis and it would be better available science if it was published. When we received funding from the ESRC I was able to expand these ideas and geographic ranges for bat genetics. Instead of just trying to publish my thesis as is, the numbers changed a lot when I added more samples with this kind of methodology so I wanted to make sure we collected as many samples as we could and really be thorough with the opportunity that we had.

So I will quickly go over the conservation genetics work that we're doing and the progress that we've made. We do have one task that was completed so far and this was 2018 where we did sex determination of Hawaiian Hoary Bats so that we could ID carcasses that were found under wind turbines. I'll talk about that. The carcasses are really this untapped resource. Since bats are difficult to capture we should definitely be using the resources that we have in museums and these carcasses that we've already collected. This conservation genetics project was supposed to be able to tell us more information about the demographics of the bats and we want to know the genetic variability of bats on different islands. We want to know their population structure. Are these bats connected between islands or are they restricted to a single island? Then also look at population dynamics and look at effective population sizes. When we are able to get genetic information about bats we are able to connect the diet, prey selection, and population modeling.

It's happening in other study where we have a bat that we have genetic, diet, and roost information for so we have the whole suite of info about that individual. After doing a lot of acoustic work on bats here I can say that bats are widespread acoustically but we still don't have population numbers; we can't count them and can't tell if a vocalizing bat is male or female and as we've seen they're difficult to catch, locate, and find roosts for. So this is why we want to take a genetic approach to understand things about this species and their population. So we collected over 300 samples from representatives of Hawai‘i, Maui, O‘ahu and Kaua‘i. This is since 2005 when bat work really started. We have about 80 samples that have been contributed from wind facilities and that's a huge amount if you think about how almost a third of the samples are coming from that. It is an easier resource to get information from. We're using this to our sex genotyping study and also in the other DNA analysis studies. We have a huge state and it's not easy to go around and catch bats wherever you go. It takes a long time to determine where you can catch them. So we were able to get to some places, like we had 13 live bat captures on Kaua‘i. I think people have captured bats there before but I'm not sure if they have done that kind of effort. There was a few samples in Bishop Museum for Kaua‘i. Then we also were able to do collaborations to get samples. So when we were at Auwahi at the Waihou restoration site we have tissue samples from bats we caught there. Then Dave's project with H.T. Harvey contributed tissue samples from Maui as well which was really helpful. One thing I didn't get to do and I'm not sure if I will is Moloka‘i and Lana‘i. So I won't be able to say anything about those islands. This is just showing how those tissue samples are distributed. This has no relationship to how abundant bats are on these islands. It's all a function of just being able to sample and getting tissue resources from these places. So we have a lot of samples for Hawai‘i Island and quite a lot from Maui and about 50 or so for O‘ahu and about 15 for Kaua‘i.

We're looking at mitochondrial DNA at the CO1 marker to look at maternal diversity. We still have about a hundred bats to sequence for that. Those are being sent out and we're testing microsatellites that were used on North American Hoary Bats to look at population structure. We're going to test those and see if they work here because we don't have species specific ones to use. We're also working on looking at single nucleotide polymorphisms with Virginia Tech. We have that manuscript in submission now where we got to look at these diverse sites for 23 bats across Hawai‘i Island, Kaua‘i, O‘ahu and Maui. We're hoping to get a lot of information about that and hopefully that paper will come out. We're also working on sequencing 20 bats in this way so that our data will be available to everybody to do genetic work with. And assembling a reference genome for Hawaiian Hoary Bats in this library might be useful for other people doing population work or if they come and revisit the population after a certain amount of time, this would be baseline population information.

So getting to the sex determination study; these are some dead bats and they're pretty crusty and it's really hard to tell whether they were male or female. Sometimes the carcasses are just some skin and bones and so there's really not a lot of ways you can tell whether it's a male or female. We have a tropical environment and I know some of the wind farms are in more drier areas than wet areas but the carcasses decay very quickly. So after two days it's more difficult to determine the sex just by looking at the genitalia if it's there. Before we were able to use this method a lot of these carcasses were just unknown and you didn't know whether it was a male or female. So bats are sexually dimorphic here. The females are much larger than the males. So if you have a bat in hand and you can't tell the sex, you can't do morphometrics if you don't have any genitalia to look at because there's an overlap in size between juvenile females and adult males. So we tested this method for Hawaiian Hoary Bats that was used to sex North American Hoary Bats and it worked for us. We were able to amplify introns on the sex chromosomes and run a simple gel electrophoresis test. We did this on known individuals that we knew the sex of and if there was two bands present ,one for an X and Y, that was a male bat. If there was one bright band here it was a female bat. So we've been able to do this so far on about 80 bats which were wind turbine fatalities. I hope that's going to be helpful for people that are using it for population modeling or for take estimates and things like that. And then this is the information where you find that and we've been updating data releases with that sex information as carcasses are sent to us.

Lastly, we still don't know how to age bats. Loyal had a good question about development and we don't know how they develop. We don't know how to really age them past a juvenile. When we catch an adult we don't know if it's the first year adult or fourth year or a ten year and we don't really know how long they live either. So I think that's still an important thing to look at that, if we can establish some way of knowing ages in the population. There's a recent study for bats showing you can measure the methylation in tissues and you can look at that in relationship to age. You can also go ahead and look at the teeth and for wear and growth to try to establish if you can tell the age that way. I think with the current collection of carcasses, museum specimens, and tissue samples, we might be able to do that. This kind of genetic information is useful in population studies and viability analysis, but if we are able to get things like lifespan information that would be really important. We might be able to look at adult versus juveniles for the take that has happened at wind farms. We can also analyze the live capture data more and look at reproductive status and try to get more information from the bats that we do capture in hand. Lastly, we might want to work on developing microsatellites for this species. So I think that's an important thing to do and I think it can be done. Once you have genomic level data you can start testing different sites and that would be the next best thing to do after this current research is finished. Then you'll be able to look at male and female dispersal patterns too. Okay, thanks everyone. We have a lot of people to thank for this little segment of bat work.

PRICE: Okay so a couple of things. Your study using the SNPs is 23 bats on four islands and that's for population genetics for effective population size, which is something that I am really interested in seeing your outcomes on. I totally understand the cost issues and why you have more than 100 samples on your CO1, which is a like $5 a piece. Can you talk about potential for increasing sample size for calculating effective population size?

CORINNA PINZARI: Well, we are adding 24 more bats to the SNPs and then will try to calculate effective population size that way. But you can also use microsatellite data and you can also use the CO1 data that would be more for like historical population sizes. But microsatellite data has been shown and used in other bat species to look at population sizes.

PRICE: This is more of a general question. Was this funded through the ESRC work? Is the standard that we don't present the data until it's published or can it be presented before it's out in the peer-reviewed literature? Obviously, I would love to see this as soon as it's ready for public consumption, but it sounds like you have the data—it's just not peer-reviewed yet.

KAREN COURTOT: For USGS part of our practice is to go through fundamental science practices. The standard for USGS is that studies go through the peer-review process.

PRICE: So we have to wait for publication before we're able to use that on the ESRC for decision making?

LAUREN TAYLOR: You should be getting annual reports as part of the RFP requirements on the previous year's work. So there will be interim reports.

BOGARDUS: Those annual reports include information on the work that's being done but don't include raw data or preliminary analysis up until the point that it's published.

PRICE: One last thing completely unrelated. So you have 330 samples. There's a USDA study that came out this year looking at impacts of rodenticides and other pesticides that's amazing. They found detections of pesticides in one out of 20 bats in samples that they were given. Any potential to test for pesticides in the samples you were given?

CORINNA PINZARI: I knew that study was being conducted and I actually sampled in conjunction with them. In that way though they took a whole entire bat and ground it up. So I would say if you have got everything else you needed out of the carcass you can go ahead and do that but you also lose an entire museum specimen or other types of information. So yeah I guess if you designed a study where you didn't lose all of them. But there are carcasses and I don't see why they couldn't be looked at in that way.

WINTER: To follow up with the data questions. This is for Lauren. I thought that if it's a mitigation funded study we get to see the results whether or not it's peer-reviewed and that's in the agreement between DOFAW and the researchers. Is that not correct?

LAUREN TAYLOR: I'd have to look at the original RFP for this project. I don't know if USGS put a different condition in there. I wasn't here.

WINTER: My recollection is that this came up before and the ESRC should have all available data whether or not it's in peer-review. I know for a fact this has come up before. I just hope nothing is being withheld from us because we need this information to make decisions. I'd like to figure this out because if there's data out there that's being withheld then that's going to be an issue.

CORINNA PINZARI: I'm not sure I can speak on that.

WINTER: It's not for you. When it came up before the answer to me was it's supposed to be shared with us regardless of peer-review.

JACOBI: Responding both from the standpoint of USGS and ESRC, when we put the RFP together it was very clear in there that the data that is collected is not going to be proprietary and is going to be available for general use. There's nothing in there in terms of what the timing is. For USGS, as Karen mentioned, we do have a requirement where we have to go through peer-review before we can release the data. There are ways the information can be shared beforehand through a collaboration agreement. And that's something we would explore but believe me, we at USGS are doing everything we can to make sure we can facilitate getting that information available as quickly as possible. So we'll see what we can do in terms of working it out. It really sort of depends on what state the information is in in terms of whether it's available to be used.

PRICE: Just something to put a note on that. From an ESRC perspective, there's a conflict of interest. There's journals with a fast turnaround that'll get this thing out in a couple months. Then there's journals that you're going to wait six months and get an editor level decision that you need to send it to a different journal. Obviously, that's on the researcher to make the decision on which journal to submit to and there are very different review times. So just from an ESRC business perspective we want to get this out and if there's no timeline and they go through five journals trying to get into a high-end journal, from an ESRC perspective that's not in our best interest for decision making if we're funding the study.

LAUREN TAYLOR: Is this funding coming from the wind farms or is it mitigation money?

MEHRHOFF: It's in the table but we can touch on that later.

CORINNA PINZARI: Okay, thanks everyone.

(LUNCH BREAK)

(Joel Thompson and Dave Johnston agree to switch the order of their presentations within Item 4. Joel Thompson presents first, followed by Dave Johnston.)

O‘ahu bat occupancy and distribution study: Joel Thompson, Western EcoSystems Technology, Inc.

JOEL THOMPSON: I'm going to touch on certain topics today, but primarily talk through the O‘ahu islandwide occupancy study and where we're at this point. So we do have a preliminary analysis and I shared a report with the ESRC a week or two ago. So this is kind of a summary of that. So there may be folks who have had a chance to review and have some questions and then I'm going to follow up with a few tidbits on the little drone pilot study we did last summer. And then also touch on the leeward Haleakalā occupancy study, which we started this past summer, and do a little bit of comparison of how that looks compared to the referencing here on Oʻahu. So with that, many of you are familiar with the methods here, so I'll push through them.

This was a five year study with three to four years of fieldwork followed by analyses and final reporting. We're in about year two and a half of the project at this point. It was designed for island wide inference so we overlaid the island with a grid of 2.3 square kilometer cells based on understanding of bat ranges at the time and then we used the grid sample to get a spatially balanced sample of select sample sizes across the island. In this case the yellow dots represent the initial 100 sites we were targeting. So we can kind of go through these in sequence trying to ensure that we don't jump too far out of order so that we get our spatial distribution accordingly. We're using SM4 bat detectors. They're monitored year-round and checked every two weeks to two months, depending on where they're at and ease of access. A number of these are on the ridges and we fly to them every two or three months, but some of them are in highly urban areas so we check them more regularly to make sure they're still there and functional. We use Kaleidoscope Pro and Analyct to filter noise and do call review to identify calls and verify what the initial screening looks like and also to identify feeding buzzes and social calls as well. Of course, we started this several years ago and technology is always changing so we started seeing pretty large scale failures in the microphones last year and ended up having to switch partly at the recommendation of Wildlife Acoustics and partly because they don't even really provide that anymore and prices are a lot higher for the old technology. So cataloging windows were swapped out and microphone type was a covariate in the analyses as we move forward. Once we have more data we will be able to incorporate that better. So those were all swapped out at all the sites over the course of the summer.

The objectives of the study were to look at seasonal distribution and occupancy across the island. Initially there was a lot of discussion about what we should look at. We basically included every opportunity on the island to look at distribution across all landscapes. We had discussion originally about whether we should exclude some of the urban zones or what not and it was decided that we would sample everywhere to get this island wide inference. For distribution, we're really looking at where the bats are acoustically active when they're there and how often they're there based on seasons and how regular their frequency. So we're looking at those metrics based on the number of detections per detector night. So mean detections per night and then the proportion of nights that bats are actually active in an area. So that's more of the frequency of occurrence. The seasons we've been using were those defined by Theresa and Marcos' folks use on all the other studies; lactation basically through the summer, post-lactation, pre-pregnancy, and post-pregnancy. So I'll reference these seasons in the slides as we go through. And then for the occupancy analysis at this point, we've excluded the use of single season occupancy models. It's not really applicable to our data at this point.

So Leann has been using two multi-season models: one assumes detections are independent, and then a dynamic model that assumes detections are correlated. There are multi season models. They parameterize changes in occupancy as a function of extinction, colonization, and the probability of detection at the sites as well. She's done all her work in program Unmarked and program R using presence as well. We're looking at this point at three site level covariates, basically elevation at the site, percentage of tree cover in our grid cells, and human population density. This is our initial look at a few covariates and also looking at these seasonally and by month. So a brief review of occupancy analysis in general, the major assumption is that detections for a given site during different survey occasions are independent. So in this case we're out there every night and a key assumption is that the detection on Tuesday is independent of detection on Wednesday and we'll find that's not really true. So the correlation among the detections we've looked at using a joint count chi-square test which assumes independent detections. The first order Markov Model accounts for the correlation that actually exists there once you sub-sample. So we've looked at this using nightly data, which is very highly correlated. We've taken systematic random samples at 7, 10, 14 and 21 day intervals to look at what sort of distribution you need to get independent detections. We've looked at this separately by individual season.

So here's the distribution of all of the grid cells. The stars represent the actual detector locations within that grid. Our max is 87 detectors in the field. 85 of those are in our grid cells here. There was one at Hamakua ponds and one in Haleiwa at Erika's house. This was kind of a test sample that's in town and we continue to monitor those. So there are 85 within our sample and we've had a few that were lost due to debris and vandalism. We actually have got a couple sites that we ceased monitoring because we can't keep the detector out there, but overall vandalism hasn't been too severe. If we look at distribution of where the bat activity has been occurring—I'm going to have a lot of maps that are overlaid and will be flipping back and forth so you can see differences between the years—you'll see a lot of consistency. So from June 2017 when we first rolled out the first detectors through October of last year we had detectors at sites that were a little over a 100 days to 800 nights. Most of those are 600 to 700 nights in the field at this point. There's only been a few that had issues or were missing at times. We've collected over 12,000 bat detections ranging from 0 at some sites to an excess of a couple thousand at others, but the median is very low. So most sites we get very low numbers of calls. We've gotten at least one bat call at about 90% of the locations across the island.

So this map is for year one. If we look at year two it's very similar, but a little bit more widespread in terms of where we've got activity, including areas more down in the urban zone. By far and away the bulk of the activity is up in the northern part of the island. Again looking at that distribution of the average per detector you can see that the vast majority are well below one call per night with a few outlying sites where we're above one call per night. That's across all seasons. Some seasons there's much higher activity rates per night and we'll walk through that as well. So looking at annual detection rates in year one across the whole year it was anywhere from zero to a little over four calls per night. You can see where those were on the landscape with the highest detection rate up in the Waianaes with a handful of bat calls around the rest of the island. In year two, there were similar patterns to the previous slides but a little more distribution with low levels of activity around different parts of the island. The range was similar with zero to a little over five bat calls per night. Just looking at that kind of back and forth, year one to year two you see a little bit more broad use than year two, but that may actually be a function of not having as many detectors out early in year one. It was kind of a staggered deployment as we were gaining access to sites.

Overall, this is what the activity patterns looked like over the two years. You can definitely see high levels of use up at the Pūpūkea area on the North Shore and a much lower spread elsewhere. So this is the top 20 of out 87 sites in terms of number of detections. You can clearly see the three sites with consistently higher average detections per night and the bat activity that was more consistent...the proportion of detector nights that are there was across the full year; So in some seasons that's much higher. So if we look at distribution seasonally, over the course of the year we had detection rates that only went up to about four per night on average, but within some seasons that was much higher with up to 20 calls per night. Again those were in the primary areas that we see. The red cells represent sites that we didn't have a functioning detector out. These kind of rolled out over time. So you'll see the red cells diminish as we go through the season. We started in June during the lactation season so you'll see that as we progress here. There's a scale up here but really the size of the dot is just an indication of where there was more activity than the others. This is just to visualize relative use. So when we move to post-lactation we have more detectors out. There's a little bit of change in terms of level of bat activity. A little bit less here and more over here. Pre-pregnancy continues with higher levels of activity here but we see some retraction in levels of activity at other areas in the island. During the pregnancy period we were getting calls in a lot of places but again we were getting more calls in the higher use sites. When we look at the same series in year two there are similar patterns in terms of range of detection means during lactation in the North Shore and the Waianaes and similar post-lactation but a little more widespread in other places. Then it starts to retract again during the pre-pregnancy period and you're no longer seeing any activity down here in this region. During the pregnancy period it's even more contracted. I think that's important. We talk about distribution; in this case it's all based on vocal activity. We'll talk about that later but it could be bats are there but they're not being detected.

Now that we have two years of data these are the same seasons across years. We see again they're quite similar in terms of where the bats are relative to the amount of activity, consistent lactation period, and post-lactation period but we have a lot more detectors out down here than we did in the first year. Pre-pregnancy is similar both years. So that was all about the amount of activity on a given night. The frequency of bat activity in an area looking at basically the proportion of nights where there was some sort of activity was kind of a whole series of slides that are very similarly ordered, but you can see while the median was still quite low we had more sites that had bats there more regularly. They just had a low number of calls recorded. Across both years and all seasons detections maxed out at about 40% of nights. Again looking at it for just year one, the most frequent activity in the same areas were upwards of 30 to 50% of calls being recorded. In other areas, you might get a bat every one or two weeks or in some cases no bats at all. We don't see a lot of difference between the two years. When we look at them seasonally across years, as you would think, very similar patterns during the lactation period here. The post-lactation period had higher numbers with frequency of nights with calls. And then pregnancy seems to be the most restrictive on here in terms of acoustic activity.

So we've also been cataloguing feeding buzzes and social calls. As we would expect, areas where we have the most activity is where we've gotten more of these calls. There are a few exceptions, but in general, foraging calls are what we see in these places with some places more prevalent with social calls as well. I think there's only 39 out of 87 sites that actually have feeding buzzes recorded at them so it's more restrictive than just the calling activity in general. Maybe they are feeding but we're not detecting it. So before I go on to the occupancy part are there any questions?

JACOBI: You note there are limitations with the detectors. From your experience do you think this is a reasonable index of what is actually going on there and that you're not missing anything significant beyond your range? Obviously if bats are foraging in an area they're going to be feeding and doing feeding buzzes so that's understandable. Do you feel this is representative of the activity across the island?

JOEL THOMPSON: I feel like with the distribution of detectors we have it's relative but given the level of activity and the pattern we see in areas where we're consistently getting higher use, and the consistency across years, it changes within seasons but across the years it's been quite consistent. I feel like it's doing a pretty good job of showing some of those seasonal patterns.

JACOBI: The north and northwest sides of the islands seem to be where most of the activity is concentrated almost year round. Any ideas of what's causing that?

JOEL THOMPSON: Not really at this point. As we get more of the variables maybe we can tease that out a little bit more. There is a fair amount of variation even within some of the local areas; sometimes we seem to get a lot more consistent activity than others.

PRICE: Just curious, is there any possibility of looking at temporal patterns within a night? Like do they go up and down the mountain in the middle of the night? Is there any way to kind of tell that from the shift in your detections for a single night?

JOEL THOMPSON: I suspect there probably is. We're starting to sit on a gold mine of data. There is so much we can do with it. We're trying to get at the key questions first. Ideally, there are a lot more things we can do with it. The vectors are all synced up so we should be able to look at those patterns temporally over the night. But we don't have a ton of calls here on Oʻahu so some of those patterns might be hard to get. But in theory there is potential there.

PRICE: Are you guys looking at adding thermal?

JOEL THOMPSON: No, we are not at this point. So in our original scope we talked about doing something to look at abundance and relating acoustics to numbers. We did a drone study with thermal cameras last year and I'll touch on that in a bit.

MEHRHOFF: You talked about not having much activity compared to other islands. What is it compared to the other islands as far as activity per night?

JOEL THOMPSON: Well, when I get to the Leeward Haleakalā I have a side by side comparison.

THERESA MENARD: What are your thoughts on the reason for the range contraction during the pregnancy period?

JOEL THOMPSON: Puzzling. I mean, we're debating is it actual range contraction or are we just not detecting bats? We don't have quite enough data on transition periods from season to season yet because we're only part way through the study to really incorporate extinction and colonization rates. So we're modeling currently based on probability of detection, accounting for that, but we're not sure if that's the probability of detection or bats aren't there. So there's more nuance to that.

There's been evidence that they don't call all the time so is it the fact that they're not there versus not being detected?

JASON PREBLE: Are there certain hot spots in time or place where social calls are detected? That might give hints into breeding, for example.

JOEL THOMPSON: The social calls are very small in number. So I'm not sure we can make predictions there yet, but they're mostly overlapping with the same areas we're getting the bulk of activity. Same sort of hot spots.

CORINNA PINZARI: When you were reviewing your call files did you ever note if you could look at the call files and see if there was more than one bat echolocating during that recording?

JOEL THOMPSON: Right, so I think our first report last year we had included multiple bats and call sequences. But Donald had some follow-up discussions with others and they kind of came to the conclusion that that wasn't a very reliable source. And I forget it was one of the Anabat folks that does tons of analysis on acoustic data. So we actually pulled that back out but I think there is some indication that yes, there does seem to be calls that look like it. I mean he was calling them multiple calls to begin with.

CORINNA PINZARI: Yeah, I was just wondering if there was a way you could look for that.

JOEL THOMPSON: Right, I don't remember the details of why they decided that might not be a reliable signature of more than one bat, but I remember the discussion about it.

LAUREN TAYLOR: I have a question. There was a question asked by the ESRC last year about the habitat covariate modeling. Any updates on that?

JOEL THOMPSON: We'll touch on that in this part. We just have at this point not real habitat covariates as much as other covariates like population, tree cover, elevation—so we'll touch on that.

MATT STELMACH: Are you doing any weather tracking data associated with this as well?

JOEL THOMPSON: We have not done weather tracking data.

All right, well with that I have Leigh Ann on the phone. I'm going to walk through this but Leigh Ann if you hear me misspeak feel free to chime in and I'll put you up to the microphone. So we tested for independence amongst the data, and for all the seasons this chi-square test we see that we have to move to a 14 day interval during the lactation period before we get any sort of independence among the data. So at seven and ten day intervals we were still getting significant correlation among the data. So you can incorporate that and get good estimates out of your models. What we've done here, we got to a 14 day interval with the lactation period but we were able to use seven day intervals during the other seasons of the year. So our final set of data for analysis is a systematic random draw of our full data set based on the 14 day intervals during the lactation period and seven day intervals during the rest of the year modeling these by season. So that's important to note that while we're out there all the time, there's a lot of data that's not in many ways being used for this analysis in occupancy estimation at this point. So I just want to make sure that's clear to folks. She ran this at tighter intervals, but there were so many joins that it basically couldn't compute with so much correlation. I think we've seen that come out in some other papers about the correlation amongst data. So that's something that's kind of underlying these analyses. The site level covariates that were included were population per square mile, elevation, and percent tree class, and then a classification for those basically broken at the median. So a population being high or low above the median value versus the actual population per square mile for the grid cell because we're using a representation of our grid cell. Elevation was the main site elevation in each grid cell and the percent tree cover was a median and the classification of tree class. So modeling these with the detection probability modeled by season and the population per square mile classification, so the 0 or 1 high or low, generated the best model based on our two year data set. I can't say that won't change when we get more data, but at this point that's what we're looking like. That was quite a bit better than the second model but the second model used the same variables of seasonal difference in detection probability and population per square mile as well. So at this point it's kind of the underlying model for the data.

The actual occupancy rates by season were quite consistent across all seasons ranging from about 0.43 to about 0.45, whereas our detection probability varies among seasons from 0.25 to 0.5. Again, we're not sure exactly why they're not there or they're not calling—one or the other. If we look at those graphically over the two years, we have some data from the lactation period in our third year. We see that occupancy, when we account for imperfect detection across the island, has been quite stable to date. But our detection probability varies by season. So again, that's something that we still have to try to tease out. Why the detection probability is doing this and whether it's actual distribution or behavior. It's more of a biological question than a statistical question. So at this point our data suggest that things have been pretty stable early and it's a fairly wide distribution. Probability of detection varies across sites. Leigh Ann went back and kind of re-ran a power analysis to see what our data at this point look like and we still, with our samples and the 80-something detector range, have an appropriate sample to get a 20% relative precision based on our current estimates of occupancy and detection probability, given these seven and 14 day intervals. We still feel pretty good about the data with sample sizes and what not. So we'll continue on that approach and see if we see anything. Ultimately, at the end we could look at what it might take to see changes in that over time given these consistent and more robust values then we did a few years back with the power analysis. I guess insights at this point, we see very high temporal correlation amongst our data. So we're having to account for that in the models. It's a little problematic but there are ways of getting at it.

Distribution appears to be varying by season, but it's consistently more widespread during the lactation and post-lactation periods, then contracting or bats are going quiet during the other periods. There was actually somebody talking about torpor earlier. We tossed around the idea and maybe during the wintertime they're there and just not doing anything. Feeding buzzes and social calls were most prevalent in the highest areas of activity, as expected. Occupancy rates have been inversely associated with population density, but we didn't see any association with tree cover, percent tree cover, or elevation. In our areas of really high population density we're not really seeing a lot of bat activity compared to the more rural sites. The probability of detection varies quite a lot across seasons. While occupancy estimates have been quite consistent once we account for those detection probabilities we see a high degree of consistency among seasons across years. So from year one to year two and the lactation season we see pretty consistent numbers annually. As noted we're two and half years into the study so we have another year or two of data to collect that will increase our ability to look at incorporating other variables.

So Leigh Ann was having issues with some of the models converging. She incorporated more variables and whatnot and we're short on transition period data between seasons so ideally we get another complete sequence of transitions so those things will work out better. So we're looking at another year or two of data collection in the field followed by analysis and we'll probably talk more about where we go from here with that.

I'd like to propose we remove a few detectors. So in the earlier discussion, we wanted to look at distribution as a whole. So there's a few sites where the grid cells are almost entirely in the water. The detectors are right in the corner because we wanted some potential representation right down the beach but where we got two and a half years of zero detections. So just for resource purposes I'd like to drop about two or three of those sites. The data from the cell itself isn't going to be representative of the site. Then we had a couple detectors that we've been monitoring outside of our grid cells that at this point we can still use the data for all the data we have. We're going to reallocate those resources to the analysis or other things to be more compatible with figuring out some other issues. We want to continue monitoring the rest of the sites that we have for consistency and we don't expect to confound anything by moving things around within the study. Then we want more of these transition periods between seasons to try to get a better feel for extinction and colonization rates versus just probability of detection. Are the bats leaving the site or are we just not detecting them? So is that really range retraction shifting through the seasons or are they more or less stable and changing our ability to detect them? Leigh Ann's been doing a little bit more dabbling with a basing approach to see if she can get some better convergence with the models and incorporate the inclusion variables. So that's kind of where we're at and where we're going with this one. So with that I'll take questions on this part.

PRICE: So I have two comments and then a question. First of all, something I am super aware of is you spend a lot of time thinking about models and you've got a lot of background knowledge about the ifs, ands, and buts. To me it's really important when you're in a huge audience to be careful how you present your data. Each time I've seen this, I don't like seeing the first map showing your temporal deployment of your acoustic detectors to show the total number of detections for the year and not have it standardized in that map by detection nights. It's a misrepresentation because you didn't deploy all of those at the same time. So your later one shows that yeah, it holds true once you standardize it by detection nights. But just a point I don't like seeing that map shown because it's not standardized. Then kind of along the same vein. Just a minor wording thing, if you say distribution of calls instead of just distribution I think that's a whole lot more accurate. So like in our pig studies for distribution you have to be careful to say that's not necessarily representing the abundance of pigs in the area, it's the number of detections of a pig. And so in this case it's a detection of calls and I think that helps everyone understand we're not saying there aren't bats in areas where we don't get detections, we're just saying we don't get bat calls. Wording differences but I think it matters. Then I'm curious, because the meter height is heavily correlated within seven days periods does that mean they stick around in areas for seven days and that's why you get that high correlation? Just curious.

JOEL THOMPSON: I'm guessing once they're there they do tend to hang around, right, so if you've got a bat there one night you're more likely to have it there the next night so yeah it is very highly correlated. So I think sub-sampling takes you away from that more. Obviously, that's what is happening in the data to give it that independence. I think that's what some of the more recent studies are looking at. They're sampling once every week and going back repeatedly instead of monitoring detectors and then sub-sampling from the data sets. So if we had much lower numbers maybe we'd see less of that correlation because the bats are moving around but there are some areas where there is a lot of activity and the bats are there all the time.

BOGARDUS: Marcos, just to confirm, in the 2015 study that you did that looked at acoustic detections versus video detections, it was something like less than 10% of the bats that were there actually showed up in acoustic monitoring?

MARCOS GORRESEN: So we did a comparative study that looked at acoustics and thermal video just to see if bats were around turbines and not being picked up and to see what going on there. Is it cryptic behavior or faulty detector mics? So we did a follow up study to look at the correlation between acoustic and video monitoring. We found that about a third of the time we actually see and hear the bats on the different monitors. If you think about it the mics only have a range of about 30 to 40 meters and if bat zooms right through it you might get one call or no calls. So there is range limitation.

BOGARDUS: So just to follow up on that. Are the results that WEST is showing surprising to you?

MARCOS GORRESEN: So we did a study a couple years ago on the Big Island and we had very similar results. The detection probability was fairly low.

DAVE JOHNSTON: So how did you decide on the dates of sexual reproduction condition? So you have pre-pregnancy and pre- and post-lactation period. Because there is enormous overlap in the population how did you decide on the dates and what are they?

JOEL THOMPSON: We just used the dates that Marcos and others used.

DAVE JOHNSTON: But one will finish while another hasn't started. What I'm saying is that this doesn't happen by calendar year. There's a huge swath of overlapping times for those conditions.

JOEL THOMPSON: I mean we could pick any season I guess we wanted to to look at this by. We used this as somewhat biologically relevant. But we can look at it monthly or all sorts of different variations. We did the seasons using the published literature.

DAVE JOHNSTON: I would suggest just using summer or something like that because that suggests that you actually know the time they are actually pre- or post-lactating. This is a broad band of individuals that all have their own timing. You're inferring something that I think is an enormous assumption and that is that they actually do this all at the same time and they don't.

JOEL THOMPSON:I think these seasons have been used for other studies for comparability; that's why we started with this.

DAVE JOHNSTON: What are the dates then?

JOEL THOMPSON: They're presented in the paper. It's like mid-June through August, September to November, etc.

DAVE JOHNSTON: Okay, so I would just suggest showing maybe a percentage of the ones engaged in that activity for those times or something. Somehow provide the details of this animal's seasons. That's easy enough to do. So like 80% of the animals are lactating during this time based on the information that's available. Which is Big Island but nonetheless, otherwise I think you're just making a huge assumption. Another question I had was were you able to adjust for calls per minute to adjust for the fact that it could be one bat circling around an area?

JOEL THOMPSON: Yes.

DAVE JOHNSTON: Okay, thank you.

JACOBI: Joel, what are you expecting to see? Is it really more of a confirmation of the trend that you see or are you expecting the possibility of some variation that may be triggered by something like different weather patterns? That could be something that could be really changing the trends probably.

JOEL THOMPSON: Multiple years are great, right? Originally, I think we had planned for up to four years for the study. I would think that at this point given the consistency we're seeing across the years once we get a full three transitions between seasons then we move on from there and do more analysis, data mining, and power analysis to determine if doing another year of this sort of effort is effective versus a refined study plan over longer term monitoring.

JACOBI: So there are a lot of other sites that have been sampled over the years, not at the same time or whatever. Is there a way that that information can be pulled in to give a stronger picture of what's going on? Given the consistency that you're finding would they be valid points to add into the analysis?

JOEL THOMPSON: We've talked about that and I talked to Corinna and Marcos in the past about various sample sites. And I talked to Leigh Ann about this and most of them don't fall within our grids, so from the statistician side we're concerned about extrapolating that if it's not a part of the sample. But I think there's still potential to do that as we get to having the full data set.

MEHRHOFF: So in Marcos' 2015 study where he looked at five years of occupancy studies on the mainland and generated a trend on that, wo will you still be able to do that on the O'ahu one?

JOEL THOMPSON: Well that was kind of the underlying goal of this to start with. When we look at that I'm not sure we'll be able to get potential power of that in terms of the change with three or four years of data. Leigh Ann and Marcos have talked about that a fair amount looking back at that study. I think what we could do, looking back at that study, now that we have a big strong data set on detection probability and all these other parameters we could look at what it would take to get at that trend. We did a similar thing in 2015 and found we needed several hundred detectors to get at that trend but that was all based on scattering of data in terms of detection probability around all the islands. So that's one of the goals we should be able to get at if we can get a trend over the three years. Right now, our trend looks extremely flat.

MEHRHOFF: Thank you.

JOEL THOMPSON: So we'll just keep on chugging along here with a couple other little tidbits. So last year we talked a little bit about testing some drone sampling to try to get at numbers of bats. We've been working on doing this on the mainland for hoary bats in some areas. Dave Jones has kind of been leading that effort with some of our drone pilots and acoustics folks. Seemed like a great opportunity to test it here when I have one bat species to deal with. So we worked through the permitting issues last summer. We got access to a few sites to test this out. Ultimately, the goal would be to get some sort of abundance for an area using line transect sampling that we're all familiar with in other species. Then be able to maybe associate that with the acoustic activity in an area because there are certainly areas where if you can come up with a drone number that you can go sample flying. So for problems with the efforts…we kind of picked and chose our transects because you have restrictions on maintaining line of sight with the aircraft and what not at all times, and so we are kind of limited on where we can sample on O‘ahu. Especially, there's tons and tons of restrictions on where you can fly but ultimately our goal is to try to get at density correlating with acoustic activity. I want to throw a punch line that we're not there. But in this pilot study I think we did get some good steps forward.

So we spent a couple nights testing with Marcos from their sites on the Big Island that have fairly good numbers. We were varying lots of things in terms of how high to fly, angles to fly to get a good field of view for detecting bats. We saw a few bats not very many. Unfortunately, virtually all of them we saw were when the drone was either sitting on the ground and we were just tinkering with things or the drone was actually elevating; when we were actually flying transects over the orchards, I don't think that we ever saw bats. We've done a cursory review of all the videos just manually and have not picked anything up doing that either.

So I have a few clips from various things. So we did a bunch of testing over there and then we came over to O‘ahu and flew three of our grid cells up on the North Shore where we have had the majority of our bat activity. We spent four nights out there flying 15 or 20 transects per night depending on the number of transects and winds and other issues. We were able to get the drone to work great contouring flights across canyons so it would maintain consistent fly heights, and we wanted to make sure we were sampling a consistent volume of air space. So we got a lot of those kinks worked out so that worked quite well. Unfortunately, there's not a lot of bats on O‘ahu even though they seem to be widespread. They show up in places, but they're not flying everywhere.

JACOBI: How are you aiming your sensors?

JOEL THOMPSON: Mostly down and slightly forward. So we ended up flying most of our transects on Oʻahu at about 65 meters which left us probably a 30 meter space above canopy height because a lot of it was over pretty big canopy. And so I have a few little video clips. This is testing over on the Big Island. These are really short clips. You can see one bat zipping across. But just a representation of the thermal camera on the drone that we're using. In this case, this one comes in. There's actually a second object in this that you can't really see.

And then flying the drone transect when we come over to Oʻahu, this is up in the Pūpūkea area flying over dense canopy versus over in the orchards. In this case you see a bat right down here in the corner. So we only got one or two bats flying the transects. We did get a couple we think. So you can see it right down in here swinging around. So this is representation of a bat flying in or about canopy height at Pūpūkea. This one is super hard to see. In this case, that was debatable; I wouldn't guarantee it. For comparison here is an owl that you can see. It's much bigger than the others. So we flew about maybe a square mile in total. Assuming about a 50 to 60 meter transect width and 30 kilometers of transects. In Pūpūkea, we got maybe a couple bats. Not really inconsistent with your kind of back of the hand density estimates. But anyway, I think there's potential for this sort of thing to work. Maybe not on Oʻahu given all the issues and restrictions, but I think it's a potential opportunity. So we saw one bat here while we were waiting right at sunset to take off, but we didn't get it on film.

Leeward Haleakalā occupancy monitoring study: Joel Thompson, Western EcoSystems Technology, Inc.

JOEL THOMPSON: Okay, so last summer we started a similar study that we're doing on Oʻahu on the leeward side of Haleakalā. There's really no methods here. The methods are all the same as we're using here on Oʻahu. We have grid cells spread over the entire island. We subset it to the Haleakalā study area, but we did the whole island and sampled across it then pulled the samples from there in case we were ever to expand, it would be easy to do so. We've got 20 detectors out there, represented by the yellow dots on here, scattered around from down the shore up to the upper slopes. Same sort of set up with SM4 bat detectors. Most of them are in enclosures and we check them about every two months. So at this point this data has been July to mid-December. Just a quick comparison of what we've got on Oʻahu compared to what we've gotten so far on this study. We have about 20 detectors out there with a few months of data with 17,000 plus detections compared to our 12,000 over two and a half years on Oʻahu. We've got detections at all 20 sites and much higher levels of activity at all the sites. Total detections ranged from 115 to 3,000 hits at an individual detector. These all were deployed within two days. There was no staggering so they're pretty much equivalent in terms of nights out. Calls per detector night were variable with just below one to upwards of 30 calls per detector night. Right now, we have only summer and fall instead of lactation and post-lactation but July through December data. And we've got evidence of feeding activity at all 20 detectors and some of them were getting bat calls 90% of the nights so almost every one every night.

So far and away, there's a lot more activity at this particular area compared to island wide on Oʻahu. Even more so than many of our hot spots on Oʻahu. Looking at the distribution of those and the relative number of detections it seems widespread on this side up here. This detector is next to the National Park fence. This one is next to the fence of the Nakula Forest Reserve up there.

We found a similar trend to Chris Todd's older work there showing higher activity levels at higher elevations. With that said there's bat activity all across the lower slopes as well. Mean detections per detector night was 20 plus at some of the sites. In general, more than one per night even at the lower elevations. Looking kind of at the summer versus the fall seasons, there is a similar sort of distribution in terms of activity rates, proportion of nights with detections. The subset seems to be little bit more consistent. Maybe some sites are having higher numbers and the bats are there fairly regularly at all of these locations from the summer to the fall period. A few differences by season so far with a couple spots down here near Kaupo Store which had some activity but not as much later on. Generally speaking this upper eastern side is generally more consistent with higher levels of activity. So far it seems bats are pretty widespread across the area regardless of where we're at. It's greater and more frequent in the upper elevation areas consistent with past studies. We saw foraging activity are all 20 sites and much greater numbers than the same study design here on Oʻahu. With that, thank you to all these people.

JACOBI: So with the information on Oʻahu and Maui, how do you see this kind of information being able to inform siting of either a future wind farm or mitigation actions? How do you think this information can inform that kind of decision?

JOEL THOMPSON: I think the patterns in areas are a very useful thing to come out of this. Very site specific information seems to be more challenging because there is a fair amount of variation but as we get more clear patterns in the seasons maybe it can inform mitigation measures in areas with consistently higher activity or vice versa. So I think patterns over time would be the more useful information.

JACOBI: I would think you wouldn't want to do restoration at higher activity sites but at lower activity sites to enhance them.

JOEL THOMPSON: But you could use what's at a higher activity site to maybe try to restore the others. Maybe in an area of low activity it's harder to make bats in that area.

JACOBI: Thank you.

PRICE: You show that you're comparing all of Oʻahu to just a section of Maui. If you were to limit it just to comparing a similar habitat on Oʻahu to a similar habitat on Maui… I'm just saying that you're comparing the zeros on an entire island to a Maui sub-section that is very dry.

JOEL THOMPSON: I think there's a quarter of a magnitude of different activity levels on Maui given the differences between the habitats on each island. We have a little bit of activity but even over there on Maui the highest levels of activity are up high on the ridges versus down on the open slopes.

PRICE: So I'm trying to reconcile the information that you're getting at leeward Haleakalā and how many more detections you're getting there with Dave's work of extremely large home ranges and core use areas because of the perceived lack of resource availability so they have to go further. I'm having a hard time making those two things work for my head. Can anyone speak to that? What do you think is going on there?

DAVE JOHNSTON: I think that's a great question for after you learn more because they will have more information and it will be easier to put the pieces together.

Maui habitat use and foraging ecology: Dave Johnston, H.T. Harvey & Associates

DAVE JOHNSTON: Okay, so I think we're running a little late and this is combining really three studies into one talk because our work mirrors a lot of what USGS is doing on the Big Island. We looked at three things and our questions were: which habitats do bats use? How much land does a bat use? And what do they eat? Very simple questions that hopefully will help us learn how to manage the species. We decided on looking at Maui for a number of reasons, one of which was that it was riddled with roads for the most part. There are a number of roads in most of this area here below Haleakalā National Park. Here you see a grid like the WEST study. We used tessellated random sampling and based on what I knew of the species, I decided to try a 250-meter square. And so we did a test run to see if this would work. We did a power analysis and that first month it worked beautifully. We had very high probability of 0.0001 at alpha equals 0.05 that bat use was significantly different among habitat types. So here you can see the different backgrounds of these nine habitats, and we took forest woodland in lower elevations and forest woodland in upper elevations because the alien and non-native occurred fairly high up. This is above 2,000 meters. All this is mostly down scope. So this is the Haleakalā National Park here with a crest of around 10,000 feet. I don't have all the parameters here because it would take too long to go through all of the methods. I'm not going to give you great detail on the methods but you can ask questions after my presentation. We put up our bat detectors every other month, so bi-monthly. We put a bat detector in each of the nine habitats. We ran those for three nights in each habitat and then it was switched five times for each habitat. So there would be 45 nights per sample per habitat. In total, there are 315 sites and that means that each of these nine habitats have five detector sites for each month sampled. Well, that first month modeled beautifully. Wow, I couldn't have asked for anymore. So we went ahead and we set up a 250-meter unit polygon.

About January we're starting to look at the data and it was hard to model. So we started looking at different things that we could look at that may have confounded the data. The first one was rain. I didn't really know how to deal with that variable and it took us months to get good rain data and we finally did from five different sources. Then we used those rain data for the closest detector. Even that was a big job. But this is what those data look like. This is the calls per night on the y-axis here, and then this is the amount of rain. You can see this model when we controlled for rain by taking out detectors with just five millimeters of rain. Mind you, the problem with modeling rain on the islands is that you can have rain in the low elevation or just a certain area and it can be dry very nearby. So that's why we had to be really careful. That's why we used as many rain gauges as possible and they were all operated by NOAA. So in this figure you can see that calls per night were very high when the rainfall was less than five millimeters. As you increase rainfall, the number of calls drop considerably in all these cases. This is pretty dramatic.

Okay so this is what we looked at. And actually we looked at a lot more things than I'm going to have time to talk about here. We looked at temperature. Temperature models beautifully. We looked at moon phase and a number of other things. I'm going to just stick to habitats and activity for these three different studies. So we looked at these generalized linear models and they were fit by maximum likelihood of the negative binomial distribution. We tested four differences between months of each habitat and habitats within each month. For our radio telemetry work, we used a lot of the acoustic data to determine best places for us to mist net. And we used very large macro nets up to 30 feet high and a hundred feet long and we used acoustic lures to catch bats and I would say that it looks like acoustic lures bias for males. It's pretty obvious. Okay, and then we determined the 50% kernel and then the 95% kernel. So the immediate home range and then the foraging range. Then after seeing such a huge differences between our data and Frank and his USGS crew's data we decided to use the USGS methods for kernel analyses. So we used our data and then ran them through the same protocol published by USGS. For prey we used light traps that were put out bi-monthly in each of the nine habitats. I have to say we had more "bugs" than you can imagine. Tens of thousands of moths mostly. It was crazy. So we had to deal with a huge number of insects which are now going to the Bishop Museum, by the way.

I want to mention something about traps because Jim I think asked about traps. So I have done this for a long time—over 30 years—sampling insects to determine prey availability. The problem with malaise traps is, as was mentioned, they collect insects all the time, day and night. You can skew it a little bit if you use a timed light inside the malaise trap. But of the other two traps we explored, one was a stock trap. A stock trap is simply a sheet that's erect like a screen of flexible plastic and then a tray with alcohol in the body. And so this trap unfortunately biases for beetles; moths are rarely caught by these traps; they can be, but they are typically not. A fast flying beetle hits it and they drop to the ground, only they go into the alcohol trap. The third one is the light trap in which we used a light sensitive switch, or a temporal switch in cases where it was in the forest, so that it collected insects that were primarily flying at night. We wanted to look at what was available to the bat in the night and not during the day, right?

It's a problem to identify these moths and Matt Medeiros identified hundreds of moths. And in order to get these down to species you have to dissect the genitals, put those on a slide, and then compare those with sets. He has a number of undescribed species that he's found because of our sampling set. And each have a slide and so on. Okay, the statistics of the dry weights of insects per habitat month fit a negative binomial generalize linear model with a log-normal function and we used the estimated marginal means. We tested for differences between months and habitats using pairwise contrasts with a Tukey adjustment. I won't need to go through an explanation of DNA barcoding because Corinna did such a good job of explaining this earlier.

Like the study that USGS did on Maui, we also used the CO1 region primers and we also targeted the 16S region with primers from Epp et al. (2012). I want to make one response to discussion about DNA barcoding and identification and that is in some cases, you know, we all want a silver bullet, right? We have got DNA barcoding that will do it better than anything else. If you can combine technologies, you can often improve that. We have fecal samples that clearly show beetle parts based on the dark brown pieces and yet neither of these primers detected those and we got a hundred percent on our DNA extraction. But in the end we know some species, like the African dung beetle, were missed for some fecal samples. So by doing both fecal analysis by microscope and by DNA barcoding, you're going to be a little bit better than just the DNA barcoding. I'm not saying that DNA barcoding might identify nearly all, I'm saying you can do better by also doing both.

For our habitat analyses, these maps are similar to Joel’s although I didn’t draw in the grids here, and you can see this is the combination of 315 activity sites. We have maps of each of these habitats and I’m not going to show them all to you because we simply don’t have time to do that. But I just wanted to let you know we have those.

Okay, so we analyze these data both by calls per minute and calls per night. Why would we do it by calls per minute? Recording the same bat is the problem, right? So you can have one bat that is circling the microphone a few times and all of a sudden you’ve got three calls within let’s say a minute. But if you buffer that by only counting the minutes that have calls then you can take out two calls that were presumably by the same bat to make it only one. We did both. We converted everything to calls by night because that’s pretty much the standard here on the island. By taking the rainy nights out, that is by controlling for rain, our habitat datamodeled very nicely. So to our surprise we found that the habitat gulch, grassland, and low density development had the highest amount of activity. Now because there’s quite a bit of variance in some of those we wanted to be very conservative, rather than say there are statistical differences here. I wanted to make one point here. There’s a very interesting paper by Schleper (2018) who suggested that in some cases these low density development areas like we have in the communities of Makawao and Kula may have fairly high values of biodiversity. I think that’s what is happening here in the Upcountry of Maui. Because there are so many introduced tropical plants in the landscape and also many introduced insects, there are fairly high densities of insects and bat activity.

So in the Calls over Time by Habitat figure, we’re going to start seeing very significant differences among habitats between months. We have enough data that we can separate this out by months. Here in the low density development, Grassland, and Gulch habitats, the last three months, May, June, and September, show a higher number of calls. This time period represents the warm part of the year or mostly what we call the breeding or maternity season. There are some other interesting stories. If you look at forest habitats and separate them out at a 2000 meter level, in the summer as we heard from others here, the lower forest below 2000 meters has relatively high amounts of activity compared to the upper forest, which had almost nothing. (And don’t forget each habitat is represented by 35 sites scattered throughout our study area. Each site had three nights of acoustic data, and each month comprises 5 sites.) Then we look at the winter data and the activity values reverse. The most activity in all habitats in January is in the upper forests which is exactly what is going on in Hawaiʻi based on USGS data. Are there a lot of caves up there around the upper altitude forests of Maui? I don’t think so. But there’s more to this story. There are a number of plants in bloom including primrose. There’s also a corresponding amount of insect activity up there and I think that bats are up there primarily for prey resources just as they are in Hawaiʻi. The resources on Maui though not wintering moths in caves like on Hawaiʻi; but rather, the upper forests of Maui likely provide aerial insects as available prey.
In the lower forest in the winter, there is almost no bat activity.

Okay, a little bit about our radio tracking. We caught 20 bats and 11 ranges were mapped. The mean number of days bats were tracked in fact was a little over five nights. Again, I’m not going to spend much time giving you a long list of the basic statistics because we simply don’t have time but in general most of the bats were males, a couple were females, and some were sub-adults or that year’s young. Okay, so I have this beautiful colored map on my screen. So here you see that this is the 50% core use area. These core use areas are pretty big compared to those on the Big Island. And now we're getting into the foraging ranges which are "ginormous." But when we start to pick this apart and look at individual bats, you can start to get a story. Although I hate to do that because we can't really work with an of 1, 2 or 3, I think it's useful to examine each individual bat. The maps showing are a combination of the H.T. Harvey and USGS methods. So the kernel analysis for bat 3 is probably the best example to show you differences. I'm going to use this one more than the others. So here in the figures of kernel foraging and core use areas, we show the calculated areas based on the H.T. Harvey method and the USGS method. They make the same foraging range, they just overlap each other. Perfect. But when you look at the core use area, the core use area for the USGS method makes these smaller because the smoothing parameter is a little different. So because of that, R shows a bigger core use area. This inner black, which are much smaller polygons around much higher densities of area rather than these more general ones. So what is the difference? About 25% area for some. For others the USGS method actually makes smaller core use areas and ranges.

To compare our telemetry data with our acoustic data, we looked at the number of telemetry fixes within habitats based on pooled data from the bats foraging. In other words, we took the base habitat map and then took those fixes and found exactly which habitat those fixes fell on. So this is a nice way to then correlate the telemetry data with our acoustic and diet data. There's something unusual about this. Low density development, grassland, and forest woodland (not gulch) had the highest numbers of telemetry fixes. Gulch had one fix out of 100. We had one fix on a gulch, so what's wrong here? So again based on the acoustic data, we found an enormous amount of activity in these gulches but when we look at the fixes none are in the gulch. What do you think is going on? If you're using an antenna and you're trying to get a fix on a bat that's inside a hole you're not going to detect it. It's when it pops up that you get a signal again. So let's test this hypothesis. We'll have to do that a little later, but in this slide of Detail of Bat 9 fixes over Habitat Types you can see that many of the woodland fixes are at the edges of the gulches. We didn't get fixes on 9 when it was in the gulches, we got fixes only when the bat was moving from one gulch to another. Otherwise, our telemetry data corroborate our acoustic data.

In this slide we show the number of telemetry fixes in habitat types per bat and by season. So over time, I grouped the bats and the habitats that they fall in based on their fixes. In the summer, we have mostly grassland here and this is low forest woodland. When we go to the fall we have similar habitats here but we start getting more low density development. But notice how similar the summer and fall habitats are. They're very, very similar. Bat six didn't have a little bit of this shrub but otherwise they're extremely similar. Going into the winter all of a sudden you have a specialist that only has fixes in the high altitude shrub. Bat seven is the one that is nearly all in high altitude shrub. Bat ten is 100% in low density development. So each of these three bats are doing something quite different which to me suggests that the resource availability may have changed in the winter. That's a hypothesis. Okay, and then spring. Look how closely the spring mimics the fall. But this shows that they're spending a lot of time in the forest woodland, but wait a minute, the acoustic data suggest otherwise. Okay, we'll tackle these one at a time. This is bat number nine and it's a mid-level bat. So it's in the spring. So it shows that this is using a lot of low elevation forest. If you blow that up and you start looking at these fixes they are adjacent to gulches. So I'm not saying that they're all immediately adjacent to gulches but most of these are. And based on the fact that the signal disappears in the gulch then by the time they reappear they're at the edge of the forest.

Bat nine was more likely foraging in the gulches and was detected when it crossed through low woodland from one gulch to another gulch.

Okay bat number two is really interesting to me because this is a pretty small range. As it turns out this has similar aspects to the ranges shown on the Big Island. It's got native and non-native forest. It also has a lot of gulches and at this point gulch and forest habitats are all kind of intertwined. I looked at this in great detail. It's got native and alien forest in these huge wide gulches. So at this point it becomes difficult to separate out what we want to really call these habitats. But I thought it was interesting that it was such a small range compared to some of the other ranges on Maui. The habitat number two used is, I'm guessing, not unlike some of what the USGS finds in the Big Island.

Okay, bat seven. This is the 10,000 foot contour mark up here. These are all high altitude fixes. Bat seven, if you recall, is the one that spends so much time in shrubland. I'm guessing that's where a lot of bugs are. You might think "but why not forest, why don't they use forest?" Let's look at that. I asked Kristin earlier how many pint jars of insects we had. We had well over a hundred and it took up a huge amount of space. But anyway, this figure shows the model estimates for insect dry weight by habitat. So what we did for each of these habitats each month was simply dry them to get the dry mass. This is often a crude measurement of prey availability. Can they eat all these insects? No, but at least it's some measurement that you can say "okay, insect abundance was what?" Again, forest woodland doesn't show up with very much insect mass. The pale blue bar shows insect dry weight for grassland is also very high. You can see developed low density is also very high. The biggest values for insect dry weight was actually agricultural vegetation, which is a much higher number than what we got for bat activity; it could be that some of those prey species in this agricultural areas aren't selected by bats. We don't really know. I'm not going to say why bat activity did not match with this particular habitat. Over here on the figure we have gulch, shrub, and sparse the vesicular basalt here. The two smallest average masses were from the forest woodland, lower and upper, which suggests that the reason the bat activity was so much greater in the low density developed and grassland habitats is because there aren't many insects found in the forests.

Alright, so looking at the DNA barcoding about two-thirds of their diet comprises moths. Beatles made up of a very small percentage and the second most important taxon was flies. They ate a lot of termites compared to availability. Then a certain number of grasshoppers which includes a small cricket and true bugs. And we don't have time to show separation of each individual. So that's why I'm showing the general here. Okay, in this slide I'm showing three very important species to the bats on that slope in Maui. This is the Tropical Sod Webworm. It's introduced. It's very common in grasslands. Six of the bats, that's a little over half, have this species in their diet. This second one, the Variegated Cutworm moth, isn't a specialist per se but it feeds primarily on fruits and vegetables. So it's a garden pest. And yes, it was found in the low density development, not too surprisingly. So five bats ate the variegated cutworm moth. Just slightly less than half. And then this last species is the Athetis moth, also introduced and a generalist. It's found in many habitats and it was also found in five of the bats. There are other species including the dung beetle that were also consumed but only four or three of those bats were eating some of those other insect species.

Okay summary. Bats in Hawai‘i are using different habitats. So on Maui we found the most bat activity was in gulches, low density development, and grasslands. Many of the insects they are eating are non-native, but they also eat native insects. The bat’s core use area and foraging range differ enormously among the two groups, Maui bats vs. Hawai‘i bats. One slide that I didn’t show because of time was a bat that was a mature male that went to one site. It has a core use area of 24 hectares or something like that. This was a very tiny core use area suggesting that this bat was very efficient at foraging. It was in a low density development area. It traveled about nine miles from its roosting to its foraging area. So even though it had a long commute time, once it got to that patch it was gold. Bats move up and down in elevation regularly. So one of our hypotheses was that the population just moved up to the crater and spent the winter there. No, it’s not like that. This bat can move very quickly, can roost at a lower elevation and can zip up elevation, forage there and then come back to roost. So where you catch the bat may not tell you much except you caught the bat at that site. Bats ate mostly moths and very few beetles and as I said before native and non-native. They appear somewhat selective and I say that because many of the most common moths were not consumed. But you know, I have to put in a cautionary statement that our sample size was 11. That’s not a very big sample set even though there was a huge proportion of these moths of the specific types in these areas that it would appear as though the bats are there. Then finally bats in each season do pretty much the same thing, except for the winter when each of those three bats did something completely different.

Okay, these are some discussion points that we might want to ponder, think about moving forward. I think that bats should be managed on an island by island basis. Their ecology may be different enough. Corinna just said that they are genetically different. So the islands each have different ecologies; why wouldn’t they respond in the amount of time that they have diverged genetically? The core use area and the foraging area may not be as important as the quality of the habitat. So we might want to start thinking for mitigation, can we move this habitat out over here where it can be very useful habitat for bats? And can we measure that? Yes, we can measure the use before and measure the use after. So that’s measurable. But to just decide on okay, we need to figure out what the core use area is and then that amount of land is what corporations have to purchase to mitigate for this: I’m not sure that that serves us well. Thirdly, bats foraged in very patchy habitats. Even though they had fairly large ranges we saw bats that selected very specific habitats that meant that they had to fly over other areas and they were frequently flying over forest. We could see them; with our view of mist nets below and a little skylight above us we watched bats fly overhead. So in those situations we didn’t catch many bats, but we saw bats. They weren’t down there, they were up there. Could they have foraged above the forest? Yes, there’s no way of saying that they didn’t do that except in most cases we just saw bats flying above us while we were trying to catch bats inside the forest. And finally, I think it would be more important to enhance a given habitat as opposed to purchasing a set forest or set habitat. These bats are complex enough that they need different habitats at different times of the year to some degree. But there are some basic habitats that they do need to forage. Thank you. I just wanted to say that over the 900 nights of detecting we had few nights that we didn’t have at least one bat call. Nearly all of our nights had bat calls. Some of our 315 sites had hundreds within those. So it’s fairly active and there is a good population of bats there.

PRICE: So out of the 11 bats, how many mortalities were there in the time of your study?

DAVE JOHNSTON: I'm not sure why we would detect mortality.

PRICE: Well you could track it down and see that it died.

DAVE JOHNSTON: We had no fatalities.

PRICE: I'm just trying to get at survival statistics.

DAVE JOHNSTON: I have a point about testing or having some metric to figure out whether bats are fit biologically or not. You might consider looking at the ratio of bats that are lactating versus non-reproductive females. That's the metric that would be reason enough to measure and could be standardized.

PRICE: Second, when you're presenting the prey data you presented as a proportion of the diet. But really is it sequences? Is it number of items detected in the fecal sample? What was it actually?

DAVE JOHNSTON: That's a really good question. They were weighted by frequency. They're not weighted by mass or volume. But to answer your question it was detection per fecal sample.

PRICE: By number of sequences.

DAVE JOHNSTON: We have a table that shows the number of sequences for each detection for each bat.

PRICE: That just gets at my thing that we have a huge variety of expertise in the audience. I've done fecal samples so I know all the if, and, and buts in the back of my head but when you're presenting it as this is the proportion of their diet, it's not accurate because it's the proportion of sequences that were detected. If I'm understanding what you're saying.

DAVE JOHNSTON: Correct, but it's pooled data. What I didn't show are individual bats. It's you know, how accurate is this? Well, you have to dig down and look at our table which shows how many sequences for each primer. I know it's not a 100% because one of the fecal samples clearly had beetles and that bat didn't have beetles in either sequence.

PRICE: I'm just asking when it's presented to the ESRC, if it's just labeled as percentage of sequences as opposed to presenting it as this is the proportion of diet then we can all filter that in our own heads. Then the final question is what is the distance of antenna in the forest versus the open habitat? So if you're in open habitats, you got your antenna and there's a bat two miles out. Are you going to detect it versus in the forest? Are you also going to detect it two miles out?

DAVE JOHNSTON: One of the really nice things about our study area is that if you look at the topography it is kind of cupped. So we started a lot of our telemetry work along Kula Highway going to Makawao up to Kula. The very nice thing about this site is that we can detect signals from the valley ten miles away and get clean signals. So we have the advantage of being on the bottom looking up and also being on the top and looking down. Anytime that all the signals were less than 15 degrees we omitted those fixes. We also omitted range maps; if we had less than 25 fixes we didn't use it. We would've had more but didn't use them. Those are good questions but in the actual report there's a lot of metrics in the methods. Both methods for kernel analysis are made so that people can duplicate exactly what we did.

CHRIS TODD: What the error or confidence around detecting a bat ten miles away?

DAVE JOHNSTON: It varied but we did get errors for each fix. So, I'd have to look that up but it was around 5 to 8% if I recall. It depends on each fix.

KRISTIN JONASSON: I was just going to say that ten miles was just one roost that we spent a lot of time getting down to but for most of the triangulations we were very close.

DAVE JOHNSTON: Right, this was the outlier.

CHRIS TODD: Next time it would be good to show on the map where the actual fixes were and the core use areas and the actual home ranges.

DAVE JOHNSTON: Yeah, we have all of those just without the habitat face and they're both USGS and H.T. Harvey methods. Then I also have a map of the habitat underlying the capture site and then each of those fixes. So those are all maps.

ITEM 5. Using a common habitat base. Designing studies to be comparable: Jim Jacobi, U.S. Geological Survey

JACOBI: I will make this quick. The purpose of this presentation really is to try and coalesce around a common habitat base for covariates in the study. I made the suggestion over a number of ESRC meetings for both bat studies and some of the other ones. And when I talk about habitat, I'm talking about plant communities. There have been a number of statewide land cover maps that have been produced. I've been involved in pretty much all of them, either as a producer or in the case of the NOAA C-CAP one as a user, and also a reviewer of their products and so forth. So I've got pretty intimate knowledge of each of those. The Hawaiʻi Gap Analysis is one that a lot of people have used. We produced that back in about 2004 to 2005 publishing 2006. That was sort of the standard we used; again, it's one of the statewide plant habitat community bases that we used. NOAA C-CAP is another one which is really quite good for agriculture and low elevation areas. It doesn't really get much detail in the upland areas and the forest areas and so forth and the areas beyond agriculture, but it's very useful for that lower portion of there. Land fire is another one that USGS put together and that one was initially based on a similar approach that we use for the HIGAP. Then we sort of calibrated to what their characteristics were that they were trying to map particularly looking at again fire vulnerability for different areas based upon the climate. Then finally most recently in 2017 as part of the Hawaiʻi carbon assessment we put together a land cover map that we used as the base for that. What we did basically on that one is take the starting point of the Hawaiʻi Gap Analysis and what lessons we learned from the land fire project incorporating in detail from the agricultural and the urban sections from the NOAA C-CAP into an updated version of the statewide one. I think from my perspective it is the most consistent to work with. So

I just want to do a real quick run-through of what that looks like. The carbon assessment was the big study that obviously looks at carbon sequestration resources in Hawaiʻi at a whole. Chapter 2 is where we covered the land cover portion of it. Chapter 3 we actually get into some of the climate change implications as it relates to how the plant communities could potentially change.

Basically, what we've done with this classification is have a system which is hierarchical. In the most detailed one you have the 48 units which are the detail and cover units and these are not only just the forest vegetation structure but also have dominant species in them. For example, you get koa forest, koa-'ōhiʻa wet forest, and equivalent things in the different habitats zones and so forth. Then those can be generalized into 27, what we call general land cover units, which don't include the dominant species in that but it really is breaking it by native forests, alien forests, native wet forest, alien wet forest, and so forth. I'll show some examples of that and you can also break those into more generalized biome units as we call them. Then finally the seven major land cover units, which I'll show you the example of, which are forest, shrubland, grassland, agriculture, and so forth and so it just depends on how you make the query on the units. These are just to show a representation of what they look like and hopefully if anybody is really interested in using this base, you know, I'll connect you up with these GIS files. But this is the general habitat units. It's not the detail one. This is the 27 as opposed to the 48. I couldn't really render the colors for the 48 because that's too much to show on here. But basically the green colors are the ones which are native dominated and the purples and so forth are the alien dominated ones. The biome units again, it's a whole lot less in terms of the detail on them. But it's fairly useful in terms of looking at things such as in this case here wet forest, wet shrubland, wet grassland, mesic forest, and so forth. So that's how it's broken down. When you get to the major land cover units there we're not even saying whether it's wet, dry, or mesic. It's just forest units, shrubland, grassland, agriculture, and so forth. Again, each of these you can break down into the detail or more generalized such as this.

Then finally based upon the species composition from the more detailed units we can come up with whether these are native dominated primarily, alien dominated completely, or whether they are a mix of native and alien species. This is one rendering of it. This is another color rendering that we've done. And again, this version was really based upon a previous effort. We had John Price and a whole bunch of us working together on putting this together looking at habitat status. We used this as one of the bases for looking at modeling species ranges across the state. The reason I like this color rendition is because it gets to the good, the bad, and the ugly as we like to call it. The good being the green and the ugly is the red where the earth has been turned. I mean literally it's agriculture lands or urban lands where it really has been changed. There obviously are some native species that are scattered in places like this like ʻilima and a few other things like that. It doesn't really render the coastline at all. That's a different realm and the scale doesn't show it here at all. But this is one we found is fairly useful in terms of looking at particularly trying to determine whether areas are restoration areas or management areas in terms of trying to maintain that tree cover as it is. Then finally this is one other map, which you've also included in that carbon assessment but again this is essentially adapted from the Price et al. work that we did previously.

This is one which I think people would find useful. It's a moisture zones map. And this goes beyond just simply looking at precipitation, which a lot of people had done. We developed this sort of empirically based upon vegetation and how that really related to precipitation and other characteristics. Then we did a real tough ground test on this in terms of is this real in terms of where things are. Some areas that really are important in my test cases here. If you look at the precipitation it goes just like this. But because you do have this swoop around there of mesic forest that really is caused by this fog interception that comes on that side there, that renders this forest as a lot wetter than it would show if you simply look at the precipitation. We're working to come up with a more objective way. Essentially it's going to be the same thing, but now that we have more climate variables, including cloud cover which is sort of the key that we needed in there, we can come up with a better modeling system to render this rather than the empirical way we did it previously. So these are sort of the bases that I think may be useful. Again, this is just a reference here and in terms of the carbon assessment probably the more important thing for you to remember is if you're interested in using this base here, contact me at jjacobi@usgs.gov. These are all published. These are all citable and they all have metadata documentation and so forth and I can connect you up. We do have a data release that goes along with the USGS one. But the way the USGS releases, it doesn't release it. It just basically gives you your basic shape file, your single one, and it doesn't get all the different variations that I'd be able to put in there. So if you contact me I can get you set up with all the layer files. With that I think I'll stop there and if there any real quick questions as I know we're running late.

MATT STELMACH: What is your suggestion for incorporating this into bat data analysis?

JACOBI: That's important because bats seem to be looking at many different kinds of habitats and so forth and I think this is something that I would like to see the analyses to see what does stick properly and what doesn't. This is to see whether there is any kind of relationship that we can work with.

DAVE JOHNSTON: Just a short comment. When we're trying to model activity we looked at moisture. We looked at the 2012 paper and then tried to follow up with that and it didn't go anywhere.

JACOBI: Yeah, some things fit to those kinds of models and other things like bats seem to be, you know, sort of a special case in terms of how they work. But again contact me if you would like to get access to these data files. Thanks.

ITEM 6. Bats and wind energy. Synthesis of 15 years of research on bats and renewable energy: Michael Schirmacher and Kristin Jonasson, Bat Conservation International

KRISTIN JONASSON: I'm going to give a brief introduction to Bat Conservation International which is the organization that Michael and I are with. Then he is going to give you a much larger in depth background on what we've learned about bats and wind energy over the last 15 years. We're going to talk about some ideas about how we could assist with Hawaiian Hoary Bats, then a big background on the state of the science. So like some high-level research areas. This is all based on available publications, technical materials, and then we will go broadly over wind farm siting, minimization, deterrence, and what we've learned about bat behavior around wind turbines and how these paradigms have shifted over the last 15 years so that you guys aren't repeating some of the same thought processes that we've gone through historically. Then the final slide, I think there's some really unique opportunities for Hawai‘i because we do have these smaller islands with closed populations.

So basically our goal is to conserve the world's bats and their ecosystems to ensure a healthy planet. What's really exciting for us right now is that we are going to be announcing a new strategic plan the next month for the next five years and what that's really changed is we're reorganizing to be an on the ground organization, which we weren't before. Before we were more about informing people about bats. Now we have missions to find solutions and we would love to be a part of that. So broadly things we cover are endangered species interventions. This is largely more applicable to places where we have like one last roost of an endangered bat. So for example here, the Jamaican Flower Bat where the only known population lives in one cave, so securing the land rights to that cave and increasing capacity for the people in Jamaica to manage that cave and giving the tools to help the local people do that. We've also secured the last roost of the Fijian Free-tailed Bat. On a broader landscape, we do habitat restoration and protection of landscapes and that's not something we do with our organization alone. We have many partnerships. So this is planting agave in Mexico and the southern United States to increase the connective corridor for *Leptonycteris nivalis* which is a pollinator of agave. The final goal is to connect high priority research and development of scalable solutions. So that's the department that I'm in: the science team. So what's there is the UV light and part of our research is to help bats on the mainland affected by white-nose syndrome.

What Michael's going to present on is finding scalable solutions for wind energy. Briefly, I'm going to go through how we start thinking about these problems and how they apply to Hawai‘i. So really linking all the steps between what we want our strategy to be and what the outcome is. So there's an intermediate result and a threat reduction result and how we assure that we're making those connections along the way, so that we're not doing interventions and just hoping to get to the solution of our conservation target.

So in the example of minimization we want to have fewer turbines operating when bats are flying, hoping to reduce fatalities and get a sustainable level of take. But this means that we actually have to monitor that bats are flying when wind turbines are operating. It's not only population monitoring but figuring out what the population might be. We have some of these connections that we already have in the solid black lines and some of the connections that we really need. So we create habitat but how do we really know that it's having an effect on the bats? With that I'm going to hand it off to Michael.

MICHAEL SCHIRMACHER: So with BCI we've been doing research on bats and wind energy for 15 years. What I hope to bring here is that a lot of our work is on the mainland. You guys are the experts here but there are lessons that can be learned from what we've done and the processes we've taken. So that's what I hope to share. So the first thing I want to talk about is the avoidance and siting. I give this example first because you know, there's a lot of things that go into predicting risk and how to site turbines properly. By looking at the reward first you can see maybe where the value is. So these are actual sites here in Pennsylvania. So one on this forested ridge here with very mature forest. Half of the facilities are reclaimed mine areas. Half of it is in the forest and some of these numbers are probably going to blow you away. But this one site we found 120 bats per turbine per year, where this other one had 20 bats per turbine. There's no minimization strategy out there that can reduce fatalities at that level. So by looking at ways to basically avoid this impact initially, we can avoid some of these costly approaches of deterrents and operation minimization. Siting in areas of low risk is the most economical way to do it.

A couple different approaches to predict risk there using some pre-construction information or identifying it using post-construction fatality. Things have different spatial scales so regional landscape is probably not scaled for you. You seem to have variation between turbines. Can we identify that? Can we microsite these turbines and that can be extremely difficult because whenever you're doing these fatality surveys, basically you have to have detectability for each turbine in case there's something like a fox den nearby. This facility right here, the blue circles are all these ponds. The red circles are the turbines. So basically we won't be able to tell exactly if fatalities were higher in these or these. We did notice higher fatalities almost like the bats were commuting between there. So think about where these turbines are being sited and if there's certain habitats they might have to travel through to get somewhere else. This facility here is a post-construction survey where we had acoustic data at these locations prior to generating the site. This site here had a lot of edge habitat. So there's a lot of activity there. This one was open field, relatively low. This one was forested, relatively low. When the site was constructed we found an increase in activity here but we also found it here. Basically the theory is that by constructing these roads and cuts in the forest you're basically connecting all this habitat. So even though the site didn't have high activity it basically connected all these. Then you created a habitat for the bats.

So, challenges. We actually attempted to predict risk based on pre-construction data and we definitely have an issue with that confidence interval going below zero. When we looked at particular habitat type, we found three locations where we did have a good relationship and that was likely because the habitat didn't change. Here's something very interesting. We get to the point where you start cutting holes in the forest and bats start using it. We saw a species richness and activity bump. So the black represents the year after the cut. Basically, even at one and a half and 22 meters of sampling we just saw a spike in activity. Also, using post-construction fatalities to identify roosting areas or habitat. Previously, it's been difficult because a lot of the methods that we use and even the estimators out there are biased. So it makes it difficult to compare between sites and so you really have to account for that. The one good thing about Hawai‘i is everyone has come together and you have laws to make sure everyone is sharing data. It's very difficult to have operators share data on the mainland. Now that GenS's fatality estimator by USGS is supposed to be unbiased, we can use that to learn from all the facilities that are out there and where high or low kill sites may be based on habitat characteristics. We lack the data. The data we have—is it representative? There's a lot of issues that we face. Another issue here is rare events. It's hard to tell a high kill site if it's one versus two. So specific to Hawai‘i, post-construction fatalities basically identify these risky areas. And like I said, it might be a challenge here because you have a limited number of facilities. You also have these rare fatality events. There might be an alternative metric and so it was interesting to see how the activity Joel presented matched up with the facility that's up there. So it's a very small sample size but we start collecting this data and seeing where activity is higher and where maybe bats aren't commuting as far. This is suggesting that this is good habitat for bats and that might just be options of places to be concerned with. Also, changing the environment. If there's particular sites that you don't have to change the environment or are less than optimal they might make for a good site.

Then we get to what if bats were attracted to the turbines? Determining the spatial scale of attraction can maybe be helpful in that situation. For Hawaiʻi, one of the most important things is that you already have wind turbines out there so the risk is already present. Basically, there's impact reduction strategies and operational minimization where you change the operation of the turbine to reduce fatalities. There's ultrasonic acoustic deterrents and there's a few others under development. As a bat biologist, we work with the industry to come up with solutions and were able to get a better understanding of how turbines operate. So here's basically three different turbines with three different cut-in speeds or when they're actually generating electricity. Unless there's some information to indicate that electrical generation is what is driving fatalities it's when these blades are rotating that it is a risk to bats. So there's a term start up speed which is what I ask at every wind facility I go to. Cut-in speed is when it's generating electricity and that's important to the companies, but when the blades aren't spinning that's important to the bats. So understanding that there might be differences there. There's talk to eliminate that period of time where the turbines are actually operating but not producing any power. So operational minimization, basically trying to reduce or limit blade rotation during these periods of high risk. You know the effectiveness varies by a turbine's start up speed. Also the curtailment wind speed threshold that you are going with. The framework to cut in and cut out; that's also something to think about.

So how do I measure this wind speed? Is it a ten minute period or a 20 minute period? I've actually had facilities where it was in real time so the turbines were on and off all the time. It's actually something that's pretty important you get the details on that hysteresis. A gust of wind would inflate your average over that ten minute period. So you want to make sure that it's above that wind speed before you turn the blades. Operational minimization is like a wind speed threshold. Then you have informed or smart curtailment. So for blanket curtailment, we're actually working on a synthesis of all the operational minimization studies that are out there. Power loss can be influenced by a number of factors. You have the cubic effect where it's actually eight times the energy loss. This is a big one, carcass fall distribution and how that changes. Basically at the higher wind speeds bats are falling further from the turbines. So when you're doing a research project to test the effectiveness of curtailment, what curtailment is doing is limiting the amount of time for the risk of collision at these low wind periods. You're biasing when the chances are of actually having a collision. So if you're doing operational minimization studies or trying to assess the effectiveness you've got to have very large plots to be able to compare that. So some of the earlier work was likely biased to suggest curtailment is more effective than it is. Now we have a number of projects going on with 105 meter radius.

Then with hysteresis basically we tried to think through this and some of this is based on some work we did with USGS in Indiana, where the on and off of the turbine might also be a period of risk. Basically, how do we make sure that the wind is sustained before we start turning it on? So we tried to measure the wind speed over a longer period of time. So a 20 minutes rather than a ten minute average. It was interesting that we actually found the 20 minute average to lose less power than the ten minute average. Slightly related to this next thing which is the number of on and offs of the turbine. Basically after that it's wear and tear so it's a benefit for both the bats and the turbine. One thing I'll add is to make sure that the cut-out speed is that ten minute average.

So operational, we're looking at informed or smart curtailment. I like informed better because it's basically a blanket curtailment and the most cost effective strategy for 12 years. So the one in Europe here is the bat friendly curtailment algorithm. It's a predictive model and they have found a good relationship between acoustics and fatalities. They used that to come up with when to curtail and there's an estimated 83% reduction using that strategy. The timer study is real-time activity with a wind speed measurement component. So they basically have a detection of a bat and have the wind speed below 8 m/s to initiate curtailment. A very high reduction, but in very small plots you're only looking 40 meters around a turbine so that's one thing that goes against this project. Power loss is less than 3.2% per year. Just to kind of put it out there, DOE funded three smart curtailment projects. Basically another look at the timer study with these very large plots to see if it still produces these magnificent results. The best is that protection system. Basically using acoustic, thermal video, and fatality monitoring to see if we can build a predictive model and then implement that the following year. Then there's activity based informed curtailment and it's another predictive model.

So now moving on to deterrents. Basically, we want to generate ultrasound to create an uncomfortable air space that bats will avoid. So like us trying to have a conversation next to a very loud noise is very difficult. We basically move out of the area. This was first tested in 2007; actually prior to testing curtailment. It's a promising technology, but you understand it's relatively limited compared to curtailment. A lot of these devices are very specific to the technology that they use. BCI actually had a deterrent you know that used this broadband signal. The signature, the sound that is produced is very specific to the device. First off, look what you're going against. This is designed to beat white noise. One of the issues is the attenuation of ultrasound and just some approximations here. It depends on a number of factors. It's always going to be an issue as you get higher in frequency, you know, it can't travel as far. Signal characteristics deterrents, something we do on the mainland a lot, is we start getting a solution and everyone is like go after it. Then taking some time to actually understand why it works I think can be an effective way to do this. Basically what are the criteria that the signal needs to have? What intensity and how broad does the signal need to be? Does it need to overlap their fundamental frequency to be able to actually get this deterrence response? Basically we're just like, let's cover everything and play it loud. But there's actually a DOE funded project to look at this species-specific. There's also potential for habituation and you know, that could be greater for a resident species that experiences that noise more regularly. That's speculation.

Harsh conditions up there, you know. To be able to have an effective minimization strategy it has to work. Someone's going to have to go up and change that and I've worked on enough projects where we have a bat detector up there and we need to change out the battery and we can't get them to do it for a week. This is designed for reducing fatalities, but luckily you guys have monitoring strategies that should help to encourage them. Placement orientation and coverage: here are some examples from a project we did in Ohio where it seemed like they saw the orientation and devices cause an increase in fatalities for some species. Bat behavior—bats never do what we want them to do. Basically, there's two different deterrent devices that have high technology readiness level. So NRG systems, that uses piezoelectric transducers, basically vibration and whenever we were doing some of this research we had these transducers that weren't really waterproof. So we had a lot of failures that way, these just being plates. They got away from having those sensitive components exposed. So they use multiple subarrays to generate a broadband signal. With both of these technologies there's some gap in coverage at different frequencies. GE has a pneumatic powered ultrasonic jet. It's kind of an ultrasonic whistle. Both devices have significant effects. We're seeing reductions in some species like the mainland hoary bat, free-tail bats, but we're at no effect to significantly increase in fatalities for other species like the Eastern Red Bat, yellow bat. I will mention that a lot of the information that's available is stuff that we've done in the past. I think there's maybe some presentations later on some more updated information.

Alright, deterrent effect. So here's what you want to see. This is with 3D software. Basically, you know, we wanted to be able to determine where the bat was if it's effective. But then here's some situations I would call risky. You have bats that seem to be flying through the blades. These are rotating blades and they basically go back into them. We designed this software because we wanted to know where the bats were so that we could improve the orientation because we don't want to see stuff like this. For Hawai‘i, it's a good candidate for deterrents. You know with a significant reduction in activity. We did the study of macadamia nut farms and got good results. There's potential for designing it specifically for this species, which could be interesting. To be able to determine the effectiveness on an operating turbine is the priority. To able to determine a reduction in fatalities and ways to maybe improve the effectiveness is the orientation. Because for me and the available data I have it's unclear how effective it's going to be when you see this range of effects. We see great reduction in hoary bats. They're echolocating at 20 kilohertz. The sound travels further than 30 and 35 kilohertz. I'll present on some of this stuff tomorrow. But basically what I want to say is that one of the first projects we did was to understand and prove that fatalities were happening. So in 2003 to 2004 was the first behavioral study but after that it was abandoned because of the cost. We came up with the idea of curtailment and all our resources went into threat reduction. Now that we're trying to improve on the strategy and we're coming back to figure out why the bats are up there and when they're up there. USGS paved the way for this with low cost cameras and the development of software. It's been a grind to get to a place with 3D software and tools to be able to analyze those data in an efficient manner.

We can do a number of different things to look at the effectiveness of deterrents. The predictive model is based on the real-time risk and we know when they're flying through moving rotor blades. So what was the wind speed, temperature, and what was going on that day? You can start building this model over time to really see when risk is present and target that to determine the cause of fatality. That's the most efficient way to reduce these fatalities. Quantifying the impact with these rare species. You have the sample size to be able to do something. You have to find that relationship between acoustics and fatality. Opportunities, there's a lot of overlap between what we're facing and what you have here. But there's less confounding factors being here. So I think that there's a lot of value and I think you also bring in resources from other places because it's going to benefit both.

JACOBI: Thank you for your insight and help in all of this. One of the challenges I see here is that it's exciting to see these developments in some of the responses in the mainland hoary bat. The challenge is how will it work over here in Hawai‘i? And how do we evaluate that? I think the biggest concern I've got is that already some of the wind projects are starting to deploy deterrents since it's the first thing that's available. As they put that capital investment into doing that, how do we recognize whether that is actually making difference or not? More importantly if something better comes along the line then how do we justify them retooling to do that? Because again it's a second capital investment. So that's sort of the challenge that I see there in terms of how to balance on that tightrope.

MICHAEL SCHIRMACHER: It's definitely a challenge. Speaking to effectiveness, we ran some numbers with USGS data specific to a site to see how many samples do we have to do over what period of time – a power analysis. I do think it can be quantified. I think that it's not going to be as challenging as it was last time. We have software that's more efficient. After running the numbers it's manageable from what I've seen for some of our other projects where we have 18 turbines that we're sampling in 100 meter plots. The level of effort is manageable, but I do think it needs to be examined. If you're going to put something on your turbines it's up to them. I mean there's risks to putting something up there and not testing it.

PRICE: So with HCPs we have two things we need to consider. Minimizing take and making up for that take. When I look at the schedule today was supposed to tell me how we grow bats. I haven't really heard anything that shows me we can grow bats or at least prove that we can grow bats. Can you just speak to that from the work on the mainland?

MICHAEL SCHIRMACHER: Yeah. When you start getting to these migratory tree roosting bats it's very challenging. But what's nice is you guys got the islands. You have to put a lot of effort into getting that information, but I think it's more manageable here. I think you have a good start on figuring that out. Basically have a tiered approach for maybe using acoustic data from WEST to see where activity is high and concentrate your efforts on those areas to verify that it's not just one bat circling around. What the bat has here is what it needs during multiple seasons. Then you have other islands you have to deal with as well.

PRICE: That's also just monitoring. That's not telling you've increased reproduction or increased survival. There's nothing on the mainland that can tell us how to increase survival?

KRISTIN JONASSON: There's not the same incentive to make bats on the mainland. Right now what we're focusing on is if we can do continental scale population estimates and how that would be feasible.

FRANK BONACCORSO: I think it would be informative if you turn the design of the workshop around and you present. You have the scientist sitting there presenting on how to grow bats. Because our expectation is we present the research we've done and we're at a certain point, but we don't have the answers to the questions you're thinking about. But it would be great to turn it around so that we can try to brainstorm those questions.

JACOBI: We'll do that tomorrow.

UNKNOWN VOICE: One quick question. What size wind turbines are you using? What is the largest size that you were evaluating?

MICHAEL SCHIRMACHER: Probably a hub height of 100 meters and 2.3 megawatts. I'd have to look back.

UNKNOWN PERSON: Does the height vary for killing?

MICHAEL SCHIRMACHER: There's some information there. I think it should be reevaluated because there's a bunch of confounding factors where it's difficult to find a facility that has different height turbines. So one thing that we speculate is during a repower event where you're going to take some down and put some back up you can use that moment to leave some of the smaller ones up, put up some of the bigger ones, then you have that comparison at the same exact site. Or you could determine if bats are attracted to these turbines without the blades there.

DAVE JOHNSTON: This is a comment to the gentlemen in the front here. We've been looking at bat fatalities for the last eight years at Altamont Pass, the world's first wind energy area. So we have many old projects and new projects as they've been repowered. The new ones are 1.9 to 2.3 megawatts. Some of them are 100 meters at the nacelle. So to answer your question, the bat fatalities are 100 fold over the old projects. In nine years they didn't find any bats and during 15 years they have records of only two bats for the short old-school turbines. However, one of the issues with our data is that we use scent dogs which are enormously better at finding bats than humans.

MICHAEL SCHIRMACHER: Don't the smaller turbines have a fixed speed at which they operate? Aren't they always spinning really fast? I know there's some other differences with turbine height.

DAVE JOHNSTON: Well, I think the biggest other difference is the amount of area. So the much larger turbines have a huge area compared to the small turbines but that also balances out by the many more small turbines that you have. So a lot of moving parts. But Barclay's early prediction suggested that higher turbines would kill more bats and fewer birds and I have to say that's what it looks like.

MICHAEL SCHIRMACHER: It's very interesting to see the species that are colliding with aircraft are the same we're finding at wind turbines. Okay, thank you all.

ITEM 7. Wrap-up discussion. Overview of workshop presentations.

(Did not do due to time constraints.)