Development of Mariana Fruit Bat Survey Protocols for Mariana Islands Surveys

Final Report – Rota Island Pilot Surveys

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Executive Summary

In preparation for the fruit bat surveys of the Northern Islands (planned for May-July, 2010) we tested methods for survey and assessment of Mariana fruit bat populations on Rota Island in February 2010. During this pilot work, we evaluated the feasibility and limitations of the most commonly-used population estimation methods for fruit bat colonies. We found all of the methods (departure counts, direct counts, photographic counts) to provide useful estimates of population abundances, but the "best" method (i.e., the method providing the most accurate data) for a particular roost was dependent on site-specific conditions. We, therefore, recommend that all methods be used to survey each roost in the Northern Islands. This will ensure collection of the best possible population size data and help to identify the most effective method for counting bats at each roost for future surveys.

The results of the pilot work illuminate the variance that can be expected in population size data from surveys of fruit bat colonies. Although we have only roughly quantified the variability found in the population estimates of the pilot study, it is clear from our work on Rota that the confidence limits of fruit bat population counts should be considered. Changes in weather, equipment used, observation angle and distance from the roost can affect count results, which emphasizes the need for careful planning and additional survey efforts in the Northern Islands to minimize error. We recommend conducting replicate counts, using multiple observers, and averaging the range of estimates to minimize the effects of error in the abundance estimate. Redundant counts will also help to quantify error in abundance estimates, making it possible to perform trend analysis and population viability assessment with the population data.

Preliminary results of the Rota pilot study revealed variance in counts among observers at the same roost and under the same conditions. Given the sensitivity of field methods to observer sampling error, it is important to include ways to minimize observer error in the field. During pre-survey planning, it is important to include time for observer training as well as sufficient time at each roost site for redundant counts, the use of multiple observers, and different survey methods.

In this report, we provide the methods and criteria we used to test fruit bat survey methodologies on Rota. We provide the resulting population data with interpretation and analysis. Based on our findings, we make recommendations for the Northern Islands fruit bat surveys and suggest a survey protocol to be used in the fruit bat surveys in the Northern Islands.

Introduction

The Department of Defense has contracted the U.S. Fish and Wildlife Service's Pacific Islands Fish and Wildlife Office to conduct avian, fruit bat, and natural resource surveys on the island of Pagan and throughout the Mariana archipelago. The primary objectives of these surveys are to assess natural resources on the island of Pagan and to assess Micronesian megapode (*Megapodius laperouse*) and Mariana fruit bat (*Pteropus mariannus*) populations throughout their range in the Mariana Islands.

The fruit bat assessment of the Mariana Islands will include population locations and abundance estimates for each island. To carry out the fruit bat assessments, it is important that a survey protocol first be designed and tested in the field for feasibility, efficiency, and effectiveness in providing the desired population location and abundance data. After design and testing of fruit bat monitoring methods, a standardized protocol can be developed for the upcoming archipelago-wide surveys. The standardized survey methods will support the recovery management and evaluation of the threatened Mariana fruit bat by generating monitoring data that can be tracked over time and among islands and by feeding back information to the Recovery Plan's adaptive management framework.

Objectives

The aim of this project is to develop a survey protocol for locating and estimating abundance of fanihi populations in the Northern Mariana Islands. To accomplish this, we established the following objectives:

- identify methods for fruit bat colony survey and population estimation
- test methods in the field on known fruit bat colonies
- evaluate methods based on feasibility of use given the constraints in the Northern Mariana Islands
- make recommendations to USGS and survey crew to support the planning for the fanihi surveys in the Northern Islands
- develop a survey and monitoring protocol for the fruit bat populations in the Northern Mariana islands to be conducted May-July 2010

Methods

We tested fruit bat sampling protocols from February 7, 2010 through February 16, 2010 on the island of Rota where fruit bat colony locations are known and personnel and infrastructure exist to support the efficient testing of methods in the field. Although Rota is an ideal location in many ways for field-testing fruit bat survey methods, the level of poaching is extreme. Consequently, the bats are very sensitive to human presence. When colonies are disturbed, they disperse from their roosting sites, and it may take months to years before they reoccupy former roosts. At the time of our fieldwork, there were three fanihi colonies that were stationary and accessible for observation: As Pupuengue, Palii, and Liyo.

We identified three standard methods used to estimate the population abundance of fruit bat colonies that would be appropriate for surveying the Northern Islands: exit counts, direct counts, and counts from digital photographs of the roost sites. Exit counts (also called departure counts) are performed in the late afternoon to early evening when the bats begin to depart from the roost site for evening foraging (Kunz et al. 1996; Eby et

al. 1999; Garnett et al. 1999; Worthington et al. 2001). Direct counts of the roosting colonies are performed in view of the roost site, commonly using binoculars or a spotting scope depending on the observation distance from the colony (Kunz et al. 1996; Eby et al. 1999; Garnett et al. 1999; Worthington et al. 2001). Digital photography of bats at the roost site is another way to perform a direct count. Using computer software, counts can be made from photographs, allowing the counter to zoom in as needed and to "mark" bats as they are counted (described in Boland 2009). All of these methods have been used to survey the fruit bat colonies on Rota, and the Rota Division of Fish and Wildlife has established observation stations and obtained the necessary equipment to perform surveys at the Rota colonies using these methods.

During our ten-day protocol development period, we surveyed each colony twice (on two different days), each time using all three methods of population estimation on the same day for comparison. We tested all three methods at each of the Rota colonies for effectiveness, efficiency, and feasibility for use in the Northern Islands surveys. We evaluated the population estimation methods using the following criteria: 1) detection rate, 2) sources of error in the estimate, 3) sensitivity to constraints in the field, 4) sensitivity to limited crew experience, 5) amount of time/effort needed for a "good" count, and 6) overall risk of failure given what we know about the field conditions and other factors in the Northern Islands.

Detection rate

According to the USFWS, the goal of the Northern Mariana Islands surveys is to establish the locations and population sizes of the fruit bat colonies on the lesser known Northern Islands. Therefore, the abundance estimates and especially the probability of detection resulting from the different survey methods are important criteria by which to evaluate and compare the methods available.

The success of a population estimation method is largely dependent on the method's detection rate, or the probability that individuals in the population will be detected and counted. Conceptually, detection rate is the number of individuals counted divided by the true total number of individuals in the population. Because the true population size is never known but remains the same for all survey methods at the same roost, we use the total number of individuals counted with each method as an index of the detection rate for that method.

Amount and sources of error/variability in estimate

In addition to the detection probabilities associated with each method, another measure of data quality is the amount of error and variability intrinsic to the survey method. There are likely to be many sources of variation and error in the population estimates derived from each of the survey methods. We identified the major sources of variance that would be the most likely to affect the quality of estimates in the Northern Islands surveys. For the purposes of this report and the protocol development, we do not calculate error, but rather provide a rough measure and a qualitative assessment of the role each type of error will play in each of the method's results.

Sensitivity to constraints in the field

In studying sources and magnitude of variance/error, we consider the impacts of each of the following on data quality: time available to conduct survey, distance from observer to fruit bat roost site/flight path, weather, number of observers, and magnification strength of observation equipment. Some of these error sources can be

mitigated through training and additional survey effort. We provide recommendations and the minimum requirements for each survey method.

Sensitivity to observer training

The variance in abundance estimates caused by differences in observers is a subset of the list of sources of error (above), but one that we felt warranted special attention, and therefore we list it in its own subsection. We examined variance in abundance estimates resulting from within and between observer differences. We did not test the impact that training and experience has on the quality of data yielded by an observer, however, we considered the potential impacts that limited observer experience could have on survey results and made recommendations accordingly.

Time/effort required

Because time is going to be managed tightly on the Northern Islands surveys, we recorded the amount of time each method took to prepare for and perform on Rota. Using empirical data from Rota as a baseline, we predicted the time that would be needed to perform high quality population surveys of fruit bats on the Northern Islands using each of the population estimation methods.

Overall risk of failure

Given what we know about the project constraints, field conditions, and bat roosts in the Northern Islands, we evaluated the risk of failure for each survey method to produce useful population size and location data.

Results (see tables at the end of this report):

Detection rate (Table 1)

Using counts as an index of detection rate, we compared detection rates of direct counts and exit counts performed on the same day at each of two roosts (As Pupuengue and Palii). We had to visit the Liyo roost by boat, so we could not perform direct counts at that roost. Colony counts from digital photographs are not included in the comparison.

We found that detection rates of the two counting methods (direct and exit) were different, and the method that provided the highest probability of detection depended on the roost site being surveyed. We performed paired surveys (direct and exit counts) on two different days at each roost, and the differences between counting methods were consistent for each roost site across both surveys. At the Palii roost, direct roost counts provided the highest abundance estimates/detection rates. We attribute this to the fact that our observation station for the direct counts was relatively close to the roost (~60-100m away), and we are confident that direct counts provided the best population size estimates for this roost. The exit counts for this roost are smaller, probably due to the fact that many bats do not leave the roost until later when it is too dark to count them, and because the exit count station is, by necessity, farther away from the roost than the direct count station.

The As Pupuengue roost, on the other hand, had higher exit counts than direct counts. This suggests that we are not getting a good view of all the bats in our direct counts of the roost, which is likely because our observation station was located far from the roost (~550m away). We also considered that it is likely that bats from other colonies that were roosting nearby were flying through our counting location during the departure time.

Amount and sources of error/variability in abundance estimates (Table 2)

In addition to differences in detection rates of survey methods, there are other sources of variability in count data that should be considered when designing a survey protocol and analyzing the resulting data. Although fruit bat roost fidelity is considered to be high, and we performed counts at each roost from the same locations using the same equipment and observers, the abundance estimates were different on the two different days we visited each of the roosts. This difference could represent actual changes in the numbers of individuals at the fruit bat colony, or it could reflect differences in the ability to detect individuals (e.g., using the same count method, detection rates could vary with weather, light conditions, movements of bats within the vegetation of the roost, etc.). Depending on how counts were replicated, differences in count data may also represent sampling error caused by differences in equipment capability, observer ability, and/or location of observation station.

We sampled fruit bat colonies using repeated counts with isolated changes in counting parameters to measure the variance in population size estimates that were potentially caused by each of the following: survey days, count methods, equipment, and observation locations. We measured variability within and between observers. We found that count results differed among all of these sampling scenarios, and we make recommendations (see Discussion) to minimize these sources of error/variance in the Northern Islands surveys.

Sensitivity to constraints in the field (Tables 3 and 4)

In the Northern Islands surveys, we expect to encounter all the sources of error/variance that we experienced on Rota (above). Given what we know about the constraints in the Northern Islands, we made a list of recommendations (Table 3) that should be followed to keep error/variance in abundance estimates to a minimum.

In the Rota pilot study, several factors dictated which survey methods could be used at each roost (Table 4). We suspect that location of observation stations and their distances from roosts will be the most important factors determining which count methods will provide the most reliable population size data in the Northern Islands. Therefore, we stress the importance of ample reconnaissance and scouting time to develop the best possible observation stations prior to performing any of the survey methods.

Sensitivity to observer training (Table 3)

Observer training is going to be especially important prior to the Northern Islands surveys. In testing the effects of observer error in our fruit bat population surveys on Rota, we found variance in the count data both between observers and within an individual observer. The between observer difference was surprising given the high level of experience for both observers. However, only one of the two observers was familiar with the Rota colonies and the particular equipment being used. The variance between observers decreased with time in the field; the second set of replicate surveys showed substantially less variance between observers. This is likely due to the establishment of a search image that was specific to the sites being observed and the techniques and equipment being used.

The same is true for within observer observations. We were surprised to see variability in an individual's repeated counts at the same roost on the same day. Some possible explanations may be due to changes in detectibility between counts, caused by

movements of bats or wind (which disturbs vegetation and jostles viewing equipment). Some of the difference between the repeated counts could also be due to within observer inconsistencies caused by changes in observer experience at the roost and/or observer fatigue. Intra-observer counting variance may be reduced with experience at a particular roost and time to rest between counts.

Based on these results, we make recommendations for the survey protocol in the Northern Islands to develop the identification skills and search images of observers, to standardize counting techniques among observers, and to minimize observer fatigue so that the survey can achieve the best possible count data.

Time/effort required (Table 5)

We recorded the amount of time it took to perform each counting technique. For surveys of lesser known fruit bat roosts, most of the time in the field is likely going to be spent conducting reconnaissance to identify the locations of the roost and suitable observation stations. Once these are known, the time to complete a count using any of the methods described will consist of hiking time to the observation stations plus counting time. The actual counting time takes 1-2.5 hours depending on the size of the roost and the proximity of the observation location. If demographic counts are possible, count time could increase by 1-2 hours, depending on size of the colony. Photography of roost sites in the field is fairly quick (<30 minutes), however, surveyors should expect a minimum of 5-10 minutes/photograph after the field survey activities to count the bats on a computer monitor.

Overall risk of failure to achieve useful population data

On review of our results, it is clear that no one survey method is clearly best for population surveys at all Mariana fruit bat roosts. The method most effective and feasible at each roost site is going to be dependent on the physical location of the roost and the availability and accessibility of observation stations. While exit counts may require the least amount of travel time to suitable vantage points, they are limited by lower detection rates and higher levels of variance in the estimate compared to direct counting methods. Direct counts, on the other hand, require much more effort to identify and travel to observer stations that are near to and in good view of the roost, which may not be possible on some of the islands with extremely rugged terrain.

Summary of fruit bat count methods and risk of failure to produce high quality data

	Detection rate	**Error**	**Time/ Effort**	**Robust to field constraints?**	**Robust to inexperienced observers?**	**Overall Risk**
Exit Count	**Partial****	**High**	**Low**	**Yes**	**No**	**High**
Direct Count	**Most*****	**Med.**	**High**	**No**	**No**	**Med.**
Photography	**Most*****	**Low**	**Med.***	**No/Yes***	**No**	**Med.**

* depending whether photographs are taken from the air or must be obtained by foot

** depends on weather, observation areas

*** depends on light conditions, observation angle/distance from the roost

Discussion and Recommendations for Northern Islands Surveys

The pilot testing of field survey methods on Rota was useful in identifying the feasibility and limitations of the most commonly-used population estimation methods for fruit bat colonies. We found all of the methods to be useful, but the "best" method (that providing the best data) for a particular roost site was entirely dependent on the location of the roost. Our results illuminated that variability that can be expected in count data, which emphasizes the need for careful planning to minimize error.

We outline a recommended survey protocol for the Northern Islands fruit bat surveys at the end of this report. Based on our experiences in Rota, we would also like to make the follow recommendations for the Northern Islands surveys.

Recommendations for Northern Islands Surveys (copy sent by email to U.S. Fish and Wildlife Service just after pilot work was completed on February 24, 2010)

BIOLOGISTS WITH FRUIT BAT SURVEY EXPERIENCE SHOULD BE PRESENT AT EVERY SURVEY

Experience in fruit bat population surveys is going to play a large role in the success of our surveys, both in the quality of our counts and in limiting disturbance to the bats, as well as with how we handle/troubleshoot problems in the field. As the only team members with substantial fruit bat survey experience, Julia and I are going to try to arrange our schedules so that both of us are at as many of the surveys as possible and at least one of us will be available for every survey.

LOCAL GUIDES/TECHNICIANS INCLUDED IN FIELD CREW

In addition to one or more experienced fruit bat biologists, field teams must include local collaborators that are experienced with working in the forests of the Northern Islands. The number of experienced local field technicians we can include will determine the success of our surveys and the quality of our data. In some cases, local guides/technicians will know the locations of roosts that have been occupied by fruit bat colonies in the past and will know from experience how best to access prime vantage points on these remote islands. They also have the experience and well-developed search images that will aid immensely in detecting fruit bat individuals among the Marianas vegetation.

Local field biologists will also play a crucial role in safety, as they will likely have the navigation and trail cutting skills needed to traverse the rough terrain of the Northern Islands. This is critical. It would be quite unsafe to put people who are unfamiliar with the terrain and unaccustomed to the weather into such remote and rough terrain. There are local guides and technicians available through the office of the Mayor of the Northern Islands and through the Saipan DFW office who are experienced and will ensure the safety, effectiveness, and efficiency of these surveys. Please contact Julia Boland, Laura Williams, or Curt Kessler for suggestions on potential crew.

TRAINING IN THE FIELD BEFORE SURVEYS START

Training is going to play a substantial role in the operation of the group as a team and in the quality of data that are collected. For the crewmembers who have not worked

in the Marianas and/or on fruit bat surveys before, training in the field is going to make a huge difference in their ability to contribute to the first surveys. Some supervised experience practicing survey techniques in the field will give inexperienced crewmembers a chance to become familiar with where fruit bat colonies roost, what the roosts look like, and how bat population sizes are estimated/counted. Field experience is also crucial for getting everyone up to speed on the sensitivity of fruit bat colonies to human presence. The crew needs to have an organized strategy for avoiding colony disturbance before the surveys begin. Fruit bat colonies can be very easily disturbed by the sight, smell, or sound of humans. If colonies are disturbed, they may flush, potentially causing injury or death to the animals. Young pups are especially vulnerable during disturbances as they are often dropped and either orphaned or killed. Also, once a roosting colony flushes, it could take several days to weeks before they are located again in one place.

Given the extent and importance of these Northern Islands fruit bat surveys, training in the field prior to the first surveys seems like an obvious starting point. We know that you have been thinking about the schedule already, Ernie, and we assume there will be a little time built into the beginning of the field schedule that provides for the crew to learn about the survey methods/schedule. We are hoping that the group will be sent to Rota for these pre-survey activities, so that we may efficiently conduct some practice surveys. Rota is a great staging place, because Julia has office space, a fabulous co-worker, and they know where the fruit bat colonies are located and the best places to observe them. Two days of practice in the field will give everyone a chance to do direct counts and exit counts on two different colonies, fill out the data sheets that go with each, and develop search images by doing practice picture counts in the office. Even more importantly, working together in the field will provide us with opportunities to discuss survey difficulties in the field as they happen and standardize everyone's reactions to these.

In addition to on-site training on Rota, we could also offer some pre-survey training for crewmembers to familiarize themselves with fanihi colonies and counting individuals at the roost site ahead of time. Julia and I took numerous photographs of fanihi at their roost sites on Rota. Once the crew is selected, we could send each crewmember an on-line packet with several photographs of fruit bats at a roost, which the crewmembers could practice counting and sending their final numbers back to us. We could send out the "answers" on photographs with each individual marked, so everyone could identify individuals they missed. This would give each person on the crew a chance to hone their skills of detecting individuals at the roost.

Support for this suggestion can be seen in the following excerpt from *Fruit Bat Monitoring Protocol, Pacific Island Network, Standard Operating Procedure (SOP) #2: Training Observers*
Version 1.00 (April 2008)

> ***Estimating Fruit Bat Numbers***
> Observer variability is often present when counting large numbers of fruit bats in a limited amount of time, especially when they are flying. …..Accuracy in number estimates may increase with more experienced observers……. Observer training and standardization may

> reduce this variability, which may be accomplished through the use of photographs, as well as during live field observations……Counting fruit bats in the field at both roost and viewshed sites (from land and boat) should also be utilized to estimate numbers. Practice counts at the large colonies …….. may be used to evaluate counting methodology.

SCHEDULE ENOUGH TIME FOR EACH ISLAND SURVEY

The largest part of our survey effort on any of the Northern Islands is going to be identifying the location of the roosting colony and getting to suitable observation sites. We are hoping that there will be some reconnaissance work on each island just prior to field surveys to identify the current location(s) of the roosting colony(ies). Hopefully, this is going to be done by helicopter, during which time some high-resolution photographs and thermal images will be taken at the roost as well. Having the exact location of the roost ahead of time will minimize the time the crew needs on the ground to do the surveys.

Even if the exact location of the roost is known, we will need a few days to cut trails to good observation locations. This will, of course, be entirely dependent on our initial landing location and base camp, the location of the roost, the type of terrain, and the crew's ability to cut trails.

Once the roost site and observation sites have been located, the crew may be able to conduct surveys in as little as two days (allowing for two exit and two direct counts per roost). This, of course, represents a best case scenario, and may need to be extended for a number of reasons (e.g. bad weather, bat sensitivity, etc.).

Specific recommendations for amount of time needed to survey each island are as follows:

1. Agrihan- ≥7 days. Large island with good potential habitat and no one has completed a thorough survey, Wiles et al. (1989) found 2 colonies on the E side and estimated 1000 bats, Johnson (2001) found 2 small 'groups' on the W side and estimated ~100 bats.
2. Asuncion- ≥4 days. Smaller island with possibly concentrated population of bats where forest is concentrated on the W side, Wiles et al. (1989) estimated 400 bats, Johnson (2001) estimated 600 bats with colonies in NW and SW regions.
3. Maug- 1 day with helicopter and, if need be, limited ground crew. Three small islets with forest andno bats seen by Wiles et al. (1989) or Johnson (2001).
4. Uracas- 1 day with only helicopter. No forest.
5. Pagan- ≥7 days. Wiles et al. (1989) found 2 colonies (NE/E side of island) and est 2500 bats, Johnson (2001) found at least two colonies (N and SE region of island) and est~1100 bats.
6. Alamagan- ≥4 days. No colonies located by Wiles et al. (1989) or Johnson (2001), however both suspect there are bats there.

7. Guguan- ≥5 days. Wiles et al. (1989) didn't find a colony but est. 400 bats, Johnson (2001) found a colony (300+ bats) roosting in the S region of the island two years in a row.
8. Sarigan- ≥5 days. no colonies found by Wiles et al. (1989), Johnson (2001) found two colonies (est. ~30 bats the E side and ~300 bats on the N side)
9. Anatahan- ≥3 days. Currently, not very much forest cover due to eruption of volcano.
10. Farallon de Medillina- 1 day with only helicopter. Very little forest.

MARIANA FRUIT BAT SURVEY PROTOCOL

OVERVIEW

This survey protocol is designed to achieve standardized population abundance estimates for the fruit bat colonies in the Mariana Islands. The protocol has been adapted from the survey methods used on Rota Island (developed by Julia Boland, CNMI Division of Fish and Wildlife) with special consideration of the surveys in the Northern Islands planned for May-July 2010. Based on findings in protocol testing and development work on Rota Island in February 2010, we have included redundancy in counts and counting methods to increase the accuracy of our abundance estimates and sampling for error and variance in the survey protocol to establish confidence limits around our estimates.

GOALS AND OBJECTIVES

1. Estimate population sizes of fruit bat colonies in the Northern Mariana Islands using standardized methods to support long-term population trend analysis, population viability assessment, and recovery planning and management.
    a. Perform direct, picture, and exit counts at each colony in the Northern Islands during the 2010 surveys.
    b. Use redundancy in counting methods, observers, and replicate counts to measure error and to determine the confidence limits around abundance estimates.
    c. Repeat surveys opportunistically on all of the Mariana Islands with fruit bats using these standardized methods whenever surveys are supported in the future.
2. Record demographic data at colonies that can be viewed directly and from a distance of <200m.
    a. Identify gender and age class (pup, juvenile, adult) for all individuals for which this is possible.
    b. Determine the proportion of individuals that can be identified to gender and age class compared to the total population to get indices of population dynamics (e.g. fertility rates, survival by age class, sex ratio at the roost, etc.).
3. Compare direct, picture, and departure counts to determine optimal site-specific population abundance estimation methods.
    a. Perform direct counts of all maternity colonies on all of the Northern Islands.
    b. Perform picture counts of maternity colonies that can be observed within 200m.
    c. Perform departure (exit) counts of maternity colonies where departure flyways are viewable.
4. Record information about fruit bat colony locations, travel logistics, and local experts to support future surveys.
    a. Record and map colony locations and observation stations.
    b. Record roost site characteristics.
    c. Provide directions to roost site, observation locations, and flight paths for departure counts.

d. Provide contact information for guides and other local information on the fruit bat colonies for each island.

SURVEY APPROACH

For each island in the Northern Islands, the survey will start with reconnaissance to gather all known information about the fruit bat colonies on the island. Once the crew arrives on the island, there will be scouting on foot to locate observation stations, followed by departure counts to verify roosting locations, and finally counts within direct view of the roost (i.e., direct counts, demographic counts, photographs).

To get an idea of the confidence limits around the population abundance estimates using these survey methods, we have suggested redundancy in the counting methods to provide measures of variance in the survey population data. We suggest performing at least two replicate surveys at each roost using each of the population counting methods to understand background variation in bat numbers. Surveyors should use all possible counting methods at each colony on the same day for comparison of abundance estimates among methods. Double counting should be employed in all survey methods by using multiple observers to count the same bats at the same time, which provides a measure of observer error.

The survey protocol was designed to maximize the data that can be obtained from population surveys non-invasively. As the Mariana fruit bats have been disturbed and hunted on many of the islands on which they roost, they may be sensitive to human presence. To minimize disturbance, we remind surveyors to be very cautious when approaching roosts, making sure to remain relatively out of sight and downwind of the colonies. If surveyors recognize bats becoming aware of or agitated by their presence, survey crew should back off slowly and try to find a better observation location. If the bats exhibit flushing from the roost, the crew should get GPS coordinates of their location and quickly retreat from the roost.

Reconnaissance (prior to survey)

1. Pre-survey research to determine historic fruit bat roosting behavior on an island.
    a. Review all trip reports and annual reports.
    b. Interview all biologists, guides and/or wildlife managers, who have traveled to the island and have made observations regarding the fruit bats and/or the terrain and geography of the island.
2. Determine current roosting location(s) and flight paths of fruit bats on the island (preferably within 2 days of the survey).
    a. Use helicopter and two observers to search the island for colony locations; one observer scanning with the FLIR (thermal imaging camera) and one observer scanning with the IS/10x binoculars.
    b. Interview local residents (and any recently visiting biologists/managers) to determine current knowledge of fruit bat colony locations, observation vantage points, and evening flight patterns.

Scouting on island (at the beginning of the survey)

1. Scout for roost locations and flight paths.
    a. Scouting should be performed on foot using binoculars and multiple teams.
    b. The first evening on the island, observations should be made of known roosting areas as well as any potential flyways or roosting habitat whose occupancy status is unknown.
    c. When roost locations are not known, multiple observation stations should be established with high and wide angle views of potential flyways or roosting habitat.
    d. When roost sites have been located during reconnaissance, count stations should be located with views in the direction of the roost.
    e. Record flight directions (to and from) and numbers of bats seen for all observation/count stations; this information can be used to search for roost sites on the following day.
2. Locate observation stations for direct and departure counts. Locations for all stations should be documented with GPS coordinates.
    a. *Direct count observation stations:* Once the approximate location of the colony roost site has been determined, trails should be made and mapped with GPS to suitable observation stations. Ideal observation stations are those in direct view of the entire roosting area, within 200m of the roost but not closer than 50m, and located downwind from the roosting colony.
    b. *Departure count observation stations:* Ideally, departure count stations should be located within 500m of a roost with an overhead view of the flyway. An overhead view of the flyway allows silhouettes of bats to be viewed as ambient light decreases. If the station is within 200m of a roost or flyway, it should be downwind of the roost or flyway to minimize potential disturbance to the bats.

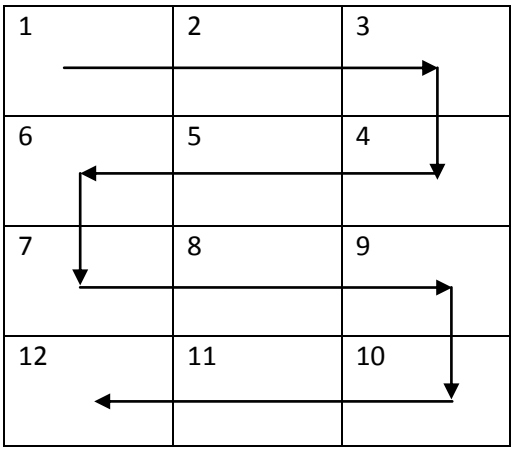
Fruit bat population counts (once the colony roosting site and observation stations are known)

1. Direct counts:
    a. Definition: a count performed from a station located with a direct line of view and, if possible, within 300m of the colony roosting site.
    b. Either a 20-60x spotting scope or 10x50 binoculars can be used if the observer is within 75m of the roost site. If the roost site is >75m from the observer, a spotting scope is required to perform the count.
    c. Direct counts will be performed in the early morning, just after bats have returned to the roost from foraging; this time of day is preferable because bats are still somewhat active (grooming, mating, settling in) and ambient temperatures are cooler and bats are less likely to be seeking shade below vegetation.
    d. To obtain the most accurate island-wide count of all colonial bats, direct counts will be performed at all existing colony roost sites on consecutive days (weather permitting).

e. Whenever possible, demographic data is recorded for as many of the individuals as possible (see Demographic counts, below).
f. Whenever possible, direct counts will be performed from multiple counting locations to determine the best observation station.
g. Direct counts will be performed at each observation station on two different days to provide a measure of variance in bat numbers and detection between days and give an average estimate of abundance.
h. Multiple observers (minimum 2 per direct count) will perform redundant direct counts (blind to the results obtained by other observers) to give a measure of observer variance and provide an average abundance estimate for the roost.

2. Demographic counts:
    a. Definition: a count of the number of males, females, and pups within a colony roosting site.
    b. Demographic counts will be conducted on colonies that can be viewed within 200m.
    c. Counts can be made in sequence with direct counts and should aim to start at sunrise when bats are active at the roost.
    d. A 20-60x spotting scope mounted on a tripod with a rotating head is used to scan the entire colony, regardless of the distance between observer and colony. The colony is scanned in a grid that matches the general shape of the occupied roosting area. The grid starts in the top (or bottom), left (or right) corner and moves from left to right then down, then right to left then down, then left to right, and so on. As the scope is adjusted to scan the next row, care must be taken to avoid overlap among or gaps between rows.
    e. Males and females will be identified by genitalia.
    f. Pups will be categorized into three classes as defined by their size, behavior, and dependence on their mother (adapted from criteria used by G. Wiles): 1)small- wings with a shriveled look, movement awkward, clinging entirely or almost entirely on to the body of their mother; 2) medium- larger, more physically adept/confident, and behaviorally more independent, they still cling to the female much of the time, but they also roost on the branch next to her; 3) large- approaching adult size and may roost several feet away and out of body contact from their mother for extended periods, but they still return to her to nurse and may roost side by side touching her.
3. Photographic counts:
    a. Definition: when a roosting colony is photographed and members of the colony are counted from digital pictures projected on a computer monitor.
    b. During helicopter reconnaissance surveys, photographs of the roost will be taken using both SLR camera and FLIR.
    c. On land, in view of the roost during direct counts, photographs will be taken with a 10MP (or greater) digital SLR camera with a 300mm (or greater) telephoto lens. The camera must be mounted on a tripod with a rotating head.

d. Photographs are taken of the roosting colony in a grid that matches the shape of the occupied roosting area. The grid starts in the top (or bottom), left (or right) corner and moves right then down, then right to left then down, then left to right, and so on. For example, if the roosting area is in the general shape of a rectangle, the picture grid could look something like this:



e. Photographs are downloaded and projected on a computer monitor using software that allows one to zoom into the picture and mark each bat as it is counted (e.g. Microsoft Paint).
f. At least 2 trained fruit bat surveyors should independently count the bats in the roost photographs to provide a measure of observer error and an average abundance estimate.

4. Departure counts (exit counts):
   a. Definition: when bats are counted as they depart the colony roost site in the evening.
   b. Departure counts will begin at least 1.5 hours before sunset and end when it is too dark to see.
   c. Departure counts will be performed with 10x50 binoculars.
   d. Departure counts should be performed for maternity colonies on the same day as direct counts at the roost for comparison.
   e. The number of teams of observers is determined by the number of flight paths of the bats. At a minimum, at least two teams should be stationed on opposite sides of the roost to count bats leaving the roost site.
   f. Each team should have at least 2 observers, who will perform redundant departure counts independently; this provides a mean estimate of the number of bats that departed the roost using that flight path.

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Table 1. Differences in detection rates between surveys methods at two roost sites.

Roost	Survey #	Count method	Abundance estimate	Distance from station
As Pupuengue	1	Direct	210	~500m*
		Exit	588	
	2	Direct	288	
		Exit	437	
Palii	1	Direct	1426	~60m
		Exit	1224	~350m
	2	Direct	1771	
		Exit	1193	

*Although distance from count station to roost inhibited the ability to obtain an accurate direct count of the colony at As Pupuengue, other factors, such as proximity to other colonies also contributed to the range of differences between direct and exit counts of this colony.

Table 2. How sources of variance affect total abundance estimate

Source of variance	**Found in all survey methods?**	**Size of error (% difference over mean est. abundance)**	**Summary of findings/additional notes**
Different survey days	Yes	2.5% - 24.9%	This represents the background variability in bat roosting behavior.
Counting method detection rate	Yes	14% - 64%	No clear best method. The counting technique that yields the largest abundance estimate depends entirely on the roost site, observation locations, and bat roosting and exit behaviors.
Observation location (distance from roost)	Yes*	82% - 84%	The farther the observation distance, the lower the number of bats that can be seen.*
Different weather/light conditions	Yes	24% - 36%	Weather can cause big changes in detection rates. Direct counts: bad light conditions, wind, and/or heat vents lower detection ability. Exit counts: clouds make it difficult to detect exiting bat silhouettes in the evening.
Equipment used ** (binoculars vs. scope)	Yes	38% - 82%	Spotting scopes tend to be preferable to binoculars because of the higher magnification. However, binoculars are most useful for identifying roost locations, scanning for bats away from the main colony, and during exit counts.**
Different Observers***	Yes	0% - 54%	Experience plays a crucial role in the ability of an observer to locate and count fruit bats. ***
Inconsistencies in the same observer	Yes	0% - 18%	Observer fatigue plays a substantial role in observer counting accuracy.

* Affects the direct counts and photographs more than exit counts

** Except when colony is small (N<100) and observer is very close (< 50m) to roost site

*** More pronounced with more distance, lesser zoom on equipment, and with greater difference in familiarity between observers

Table 3. How sources of variance can be minimized/mitigated by survey design.

Source of variance	**Occurrence likelihood in N. Islands**	**Minimum requirements to keep amount of variance low?**	**How should survey be designed to achieve best data?**
Different survey days	Yes	$\geq$ 2 replicates/roost (different days) with each count method	Repeat surveys over multiple days and take average values.
Counting method detection rate	Yes	Pre-survey training for all crew members. Best possible observation locations. Equipment with high zoom capability (suggested: 20-60x).	Use multiple counts and multiple methods to count each colony. Allow for enough time to find best observation locations, and to perform all count methods at each site.
Observation location (distance from roost)	Yes	Closest observation locations in good view of the roost. Suggested distances are Exit count $\leq$ 500m; Direct count $\leq$ 300m; Photographs $\leq$ 200m	Pre-survey reconnaissance for the location of the bats and potential observation vantage points. Allow enough time to identify, test, and travel to the best observation stations for counts.
Different weather/light conditions	Yes	Clear skies. Direct light (best earlier rather than late afternoon). Avoid backlighting of the roost from the observation station.	Encourage planning to view a roost during the optimal times given light conditions. Allow extra time to adjust surveys for bad weather conditions.
Equipment used (binoculars vs. scope)	Yes *	Best zoom capability. (suggested: 20-60x)	Have scopes with high zoom capability available at all times, but alternate with binoculars to identify entire roosting area.
Different Observers	Yes	Experience in fruit bat roost surveys is preferred. Minimum training for crewmembers lacking fruit bat survey experience: a) count fruit bats in $\geq$ 20 roost photographs; b) $\geq$2 days field training at known roosts.	Plan pre-survey training to begin the process of developing search images and counting techniques for fruit bats.
Inconsistencies in the same observer	Yes	Time to do a careful survey.	Plan redundancy in observers and ample time to conduct surveys to allow observers to relax between counting tasks.

Table 4. Summary of how available observation stations determine which survey methods can be used at each roost site on Rota

Roost Site	**Best Survey Method**	**Why?**	**Explanation**
As Pupuengue	Departure count	Nearest available count station was far (~400m from the roost site)	The roosting area was spread out along a steep cliff line. The area above the roost could not be accessed because it was upwind of the roost and areas below the roost had not yet been explored (as this colony had recently moved to the area).
Palii	Direct count	Count station was close (~60m above and downwind of roosting area)	We had access to an ideal count station with a view of the entire roosting area. Our departure count station was also suitable, but because so many bats do not exit the roost before dark, the exit count numbers are likely to be low.
Liyo	Photographic counts*	Roosting area is only viewable by boat.	Accurate direct counts with binoculars and spotting scopes are extremely challenging from a boat. The boat gets within 100 m of the roost, and the photographs provide clear images of roosting bats.

***** Photographic counts have not yet been calculated for comparisons to exit count data.

Table 5. Time, effort, and personnel required for survey methods

Survey Method	Equipment required	Minimum # personnel required	Time to observation point and set up	Time to conduct count
Exit Count	Binoculars	2-8*	Time to hike to areas in view of exit flights from roost	45 minutes – 2.5 hours*
Direct Count	Binoculars, Scope, Tripod	2	Time to hike to close vantage points for roost observation	10 minutes – 2 hours**
Photographic Count	Binoculars/Scope, Tripod, Camera	2	Time to hike to close vantage points for roost observation	10-20 min. to take photos, + 5-10 min./photo. to count using a computer; **

* Depends on the number of exit flight paths and exit behavior of the bats
** Total time depends on size of roost and proximity to the roost