DEVELOPMENT OF REMOTE TRACKING AND VOCALIZATION PLAYBACK METHODOLOGY TO STUDY THE NATURAL HISTORY OF TONGAN GROUND DOVE ON OFU AND OLOSEGA ISLANDS, AMERICAN SAMOA

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28 February 2019

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First-year Tongan Ground Dove, Mt. Tumu Trail, Ofu Island, 4 June 2018

Suggested citation:

Kayano, K., P. Pyle, and D. Kesler. 2019. Development of remote tracking and vocalization playback methodology to study the natural history of the Tongan Ground Dove on Ofu and Olosega Islands, American Samoa: The Institute for Bird Populations, Point Reyes Station, CA.

Cover photograph by Kimiko Kayano

EXECUTIVE SUMMARY

Islands tend to have fewer species but often those species are rare and unique, and extinction or extirpation often occurs and can result in disrupted ecosystems. The Tongan Ground Dove (*Alopecoenas stairi*; formerly placed in the genus *Gallicolumba*) is a furtive and little-known species that has a discontinuous and poorly-documented distribution on islands of central Polynesia. In certain locations it is also known as the Shy Ground Dove or the Friendly Ground Dove. The species is becoming increasingly rare and restricted to remote islands or undisturbed forest. The nominate subspecies, *G. s. stairi* is found on at least one islet of Independent Samoa, where rare, and on the small adjacent islands of Ofu and Olosega in American Samoa. The population in American Samoa was only discovered in 1976, at which time a size of just 100 individuals was estimated. Effective 24 October 2016, the U.S. Fish and Wildlife Service (USFWS) designated the Tongan (Friendly) Ground Dove population on Ofu and Olosega Islands as a Federally Endangered Species. This designation was based on habitat loss or degradation, predation by feral cats and rats, inadequacy of existing regulatory mechanisms, and other natural or man-made factors affecting a species with a small number of individuals and populations.

The biology and natural-history of the Tongan Ground Dove on Ofu and Olosega are currently unknown, further information being critically needed to manage and conserve this small and unique endangered bird population. Therefore, we undertook a pilot study in 2018 to develop optimal survey methods to monitor this species, including the use of vocalization playback (broadcast) monitoring, point-count and area-search methodology, and remote tracking methodology. The specific goals for this project were to 1) assess the best remote-tracking methodologies to use on Tongan Ground Doves; 2) assess whether or not playback methodologies can be employed to allow target capture and better population surveying; 3) obtain a preliminary population estimate using survey methodology; and 4) collect preliminary data on other natural-history aspects of Tongan Ground Doves on Ofu and Olosega Islands. The ultimate goal was to provide information which could be applied to the distribution, current status, and management of this population.

We concluded that broadcast surveys and point counts are ineffective means of attracting or monitoring Tongan Ground Doves in American Samoa. We conducted 113 area searches which resulted in a rough population-density estimate of 12.92 birds per km^2, with much higher densities recorded in lowland forest than in coastal strand or upland forest habitats. From habitat-specific densities we estimated a total population size of 249 individuals, including 145 ground doves on Ofu and 104 on Olosega. Our habitat-specific results are at odds with more captures recorded in coastal habitats per 600 net-hours of effort during our Tropical Monitoring Avian Productivity and Survivorship (TMAPS) program on Ofu and Olosega, suggesting that our area-search data are not yet robust enough to calculate adequate population densities and size estimates, especially given apparent patchiness in the distribution of the ground doves on these islands (see below). We thus consider these population densities and size estimations very tentative at this time, but recommend further use of area-search methodology in order to calculate better information on the population.

We were successful in capturing Tongan Ground Doves for application of tracking devises and in tracking several doves with the use of units consisting of both Ecotone GPS-UHF and VHF transmitter tags. The best capture methodology proved to be the setting up of continuous strings of nets at TMAPS stations near net lanes where ground doves had been frequently captured, monitoring nets consistently, and walking the lanes periodically to flush doves into the nets. We were able to track doves for up to two weeks, and overall, no deaths, injuries, or apparent adverse effects of any kind resulted to Tongan Ground Doves during our capture, harnessing, and tracking efforts. We obtained no tracking data from the two Lotek Satellite tags deployed on ground-doves nor the three tags that were activated and moved around experimentally, and conclude that the batteries for our unit contained insufficient energy and/or that transmissions from these tags were unable to penetrate the moist canopy when attempting to upload data to satellites.

However, the Ecotone GPS-UHF and VHF package effectively tracked five Tongan Ground Doves including three which reported enough locations for space-use analyses. Data from these three birds suggested that home-range sizes overlapped in a central area, in which the birds were initially captured, suggesting that the ground doves are not territorial, and that they do not hold exclusive access to any particular resource. With adequate time investment we anticipate that as many as 300-400 locations may be gathered from a single bird across the course of 2-4 weeks using an Ecotone GPS-UHF system, enabling a robust analysis of their movements relative to vegetation resources on the island (including remote-sensed databases). We recommend the gathering of more data in the future with Ecotone UHF/VHF packages.

A total of 97 incidental observations of tongan Ground doves indicated that they occur throughout all habitats of Ofu and Olosega islands but are most commonly found in thickets along the coastal plain of the islands and in forested areas, particularly those with talus slopes. A notable observation was of one on Nu'utele Island to the west of Ofu. Vocalizations of Tongan Ground Doves were heard on 16 occasions between 6 March and 9 October, with a peak number of calls heard in late May and early June, whereas no calls were heard during November-February despite targeted listening. A total of 25 recordings of ground dove calls were obtained, the best of which will be loaded on to the website http://www.xeno-canto.org for availability and further analysis. No Tongan Ground Dove nests wee located but courting individuals were observed in April-May and a family group including two adults attending two juveniles was observed on 31 May. These observations suggest that Tongan Ground Doves breed during the austral fall and winter (March-August), in keeping with the lack of breeding condition or activity detected for captured birds for the TMAPS project in November-March. No food items that could be directly identified were observed being eaten by Tongan Ground Doves; however, on two occasions the seeds of the native tree *Macaranga harveyana* were found in areas in which foraging doves were observed and foraging behavior was observed suggesting that they may flush insect or arthropod prey, including centipedes, ants, and a black beetle.

On 19 March 2018 a predated juvenile Tongan Ground Dove was found near one of the capture stations on Ofu. Potential predators of ground doves observed on Ofu and Olosega include cats, rats, and Barn Owls, with cats being observed in the area and thus the primary suspect for this juvenile. Many island species and populations are threatened by loss of habitat through the expansion of urban and agricultural areas by humans and associated introduced species. The

resident human population on Ofu and Olosega is declining, but increased urbanization is a continuing factor as people build more, and often larger, western-style homes and expand agricultural plots. As people encroach into the forest for development not only is critical habitat lost, but associated predators (such as cats and rats) expand their range as well. The introduction of house cats from such areas, some of which subsequently become feral or produce feral offspring, may perhaps be the greatest threat to the Tongan Ground Dove, which is vulnerable to cat predation due to its ground-dwelling habits. We recommend that awareness about the potential damage of cats to the Tongan Ground Dove be increased throughout the islands.

We have achieved the goals of this project to determine the best methodology to study the Tongan Ground Doves on Ofu and Olosega islands, American Samoa. We look forward to the chance to implement these methodologies in the future, increasing our sample size of area search data, refining our population estimates, applying more Ecotone UHF/VHF packages to do an in depth analysis of home-range sizes and habitat preferences at different times of year, and continuing to collect information on the vocalizations, habits, and nesting behavior of this endangered population.

INTRODUCTION

Islands tend to have fewer species but often those species are rare and unique. Extinction or extirpation often occurs and can result in disrupted ecosystems (Simberloff 2000). Island species are in particularly prone to extinction because of low population size, patchy distribution, poor dispersal abilities, and high habitat specificity (Terborgh et al. 1990, Turner 1996, Laurance et al. 1997). The increasing occurrence of cyclones can also impact bird species on tropical islands (Lovegrove et al. 1992, Craig and Beal 2001, Saracco et al. 2016, Helton et al. 2018). In order to create effective conservation strategies and successfully manage island species and ecosystems, targeted and well-designed studies need to be undertaken. Unfortunately, information about tropical birds lags far behind that available for the temperate zones, particularly in terms population size (Tobias and Seddon 2002).

The Tongan Ground Dove (*Alopecoenas stairi*; formerly placed in the genus *Gallicolumba*) is a furtive and little-known species that has a discontinuous and poorly-documented distribution on islands of central Polynesia, including those in Fiji, Tonga, Independent (Western) Samoa, American Samoa, and Wallis and Futuna (Pratt et al. 1987, Baptista et al. 1997, Birdlife International 2016, Gill and Donsker 2019). In certain locations it is also known as the Shy Ground Dove or the Friendly Ground Dove. The species is becoming increasingly rare and restricted to remote islands or undisturbed forest (Rinke 1991, Steadman and Freifeld 1998, Birdlife International 2016). In Fiji, Tongan Ground Dove populations appear to be declining due to habitat degradation and predation by mongooses and on other islands they are generally found in very small and/or declining numbers (Steadman and Freifeld 1998, Birdlife International 2016). On the island of Alofi the species appears to have been extirpated after 1985 (Thibault et al. 2015). The IUCN roughly estimates a global population of 2,500-10,000 individuals (Birdlife International 2016).

The nominate subspecies, *G. s. stairi* is found on at least one islet of Independent Samoa (Amadon 1943), where rare (Baptista et al. 1997, Friefield et al. 2001), and on the small adjacent

islands of Ofu and Olosega in American Samoa. The population in American Samoa was only discovered in 1976, at which time a size of just 100 individuals was estimated (Amerson et al. 1982); it has since been considered the most endangered bird population in Samoa (Watling et al. 2004). Prior to 2015, information on the American Samoan population was limited to anecdotal sightings of individuals. Only six observations were recorded between 1976 and 1986, in low coastal forests behind the village of Ofu and by the airport (Amerson et al. 1982, Engbring and Ramsey 1989). Between 1986 and 2015, Tongan Ground Doves continued to be observed sporadically, along Mataala ridge in 1995 (A. Tualaulelei pers. comm.) and near Sili village on Olosega in 1996 (H. Freifeld in litt.).The American Samoan Department of Marine and Wildlife Resources (DWMR) observed 23 and captured and banded ten ground doves near Sili in 2001-2004 and has made further sporadic observations through 2015 (Rosa 2007, USFWS 2016; A. Tualaulelei, pers. comm.). A report of one from Ta'u Island, if confirmed, may indicate occasional dispersal to this island (USFWS 2016).

In 2012, the Institute for Bird Populations (IBP) and the Department of Marine and Wildlife Resources (DMWR) initiated a Tropical Monitoring Avian Productivity and Survivorship (TMAPS) program in American Samoa in order to monitor forest bird species (Pyle et al. 2018). Long-term goals of this project are to provide annual indices of adult population size, post-fledging productivity, and adult survival rates in order to identify proximate and ultimate causes of population change. Data are collected at standardized capture stations during peak landbird breeding season in American Samoa, generally in November to March (Pyle et al. 2018). Birds are marked with standardized bird bands and extensive data are collected during both initial captures and recaptures, including biometrics, molt, fat loads, and age and sex (DeSante et al. 2017).

In November 2015-March 2016, the American Samoan TMAPS program was initiated on Ofu and Olosega islands and has continued during this (2016) and the 2017, 2018, and 2019 seasons (Pyle et al. 2018). Four capture stations were established on Ofu Island and two on Olosega Island (Figure 1). Stations were located at elevations of 5 to 477 m, in coastal strand (3 stations), lowland forest (2 stations), and upland forest (1 station) habitats, as defined generally by elevation (see Methods). During these four seasons (through February 2019) a total of 44 Tongan Ground Doves were captured, five of which were recaptured at least once. Capture data have enabled us to confirm age and sex determination criteria for this species in American Samoa (Pyle et al. 2017) and they have provided critical information on breeding condition, molt status, biometrics, and weights. For most captures, feather, blood, and/or swab samples were collected to investigate genetic differentiation, pathogens, and diet (Pyle et al. 2018). In roughly equivalent effort per station, most captures (33 in 86 days of banding) occurred in coastal strand habitat, with fewer captures (14 in 64 days) in lowland forest habitat and only one capture was recorded in 35 days of banding in the upland forest station. As part of TMAPS protocol, all bird species at a station were recorded on each day of operation. Tongan Ground Doves were observed during 36.4% of days at coastal stations, 27.3% of days at lowland forest stations, and 5.8% of days at the single upland forest station. Prior to initiation of this project, the vocalizations of Tongan Ground Doves on Ofu and Olosega islands were undescribed and breeding behavior or nests have not been documented.

Effective 24 October 2016, the U.S. Fish and Wildlife Service (USFWS) designated the Tongan (Friendly) Ground Dove population on Ofu and Olosega Islands as a Federally Endangered Species (USFWS 2016). This designation was based on four factors: (1) habitat loss or degradation due to agriculture, urban development, nonnative ungulates, and nonnative plants; (2) predation by feral cats and rats; (3) inadequacy of existing regulatory mechanisms; and (4) other natural or man-made factors affecting a species with a small number of individuals and populations (Rosa 2007; USFWS 2015, 2016).

Apart from these recent data from the TMAPS program, the biology and natural-history of the Tongan Ground Dove on Ofu and Olosega are currently unknown, further information being critically needed to manage and conserve this small and unique endangered bird population. Therefore, we undertook a pilot study in 2018 to develop optimal survey methods to monitor this species, including the use of vocalization playback (broadcast) monitoring, point-count and area-search methodology, and remote tracking methodology. The specific goals for this project were to 1) assess the best remote-tracking methodologies to use on Tongan Ground Doves; 2) assess whether or not playback methodologies can be employed to allow target capture and better population surveying; 3) obtain a preliminary population estimate using survey methodology; and 4) collect preliminary data on other natural-history aspects of Tongan Ground Doves on Ofu and Olosega Islands. The ultimate goal was to provide information which could be applied to the distribution, current status, and management of this population.

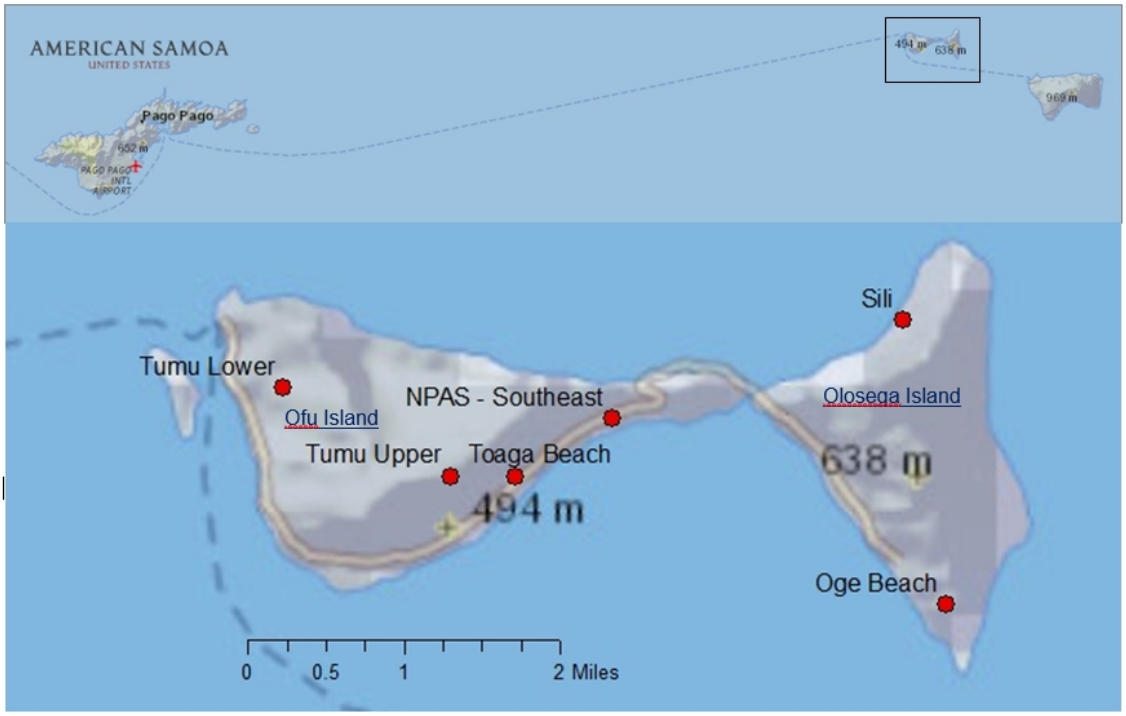


Figure 1. Ofu and Olosega Islands, American Samoa. Red dots indicate TMAPS stations (see text); Toaga Beach, NPAS – Southeast, and Sili are located in coastal strand habitats, Tumu Lower and Oge Beach are located in lowland forest habitats, and Tumu Upper is located in upland forest habitat (Pyle et al. 2018).

METHODS

The islands of Ofu and Olosega are part of the Manu'a Island group of American Samoa, which also includes the island of Ta'u. Ofu and Olosega are located at about 14.18º S, 169.62 º W and comprise about 7.5 km^2 (Fig. 1). The island of Ofu is connected to Olosega by a 100-m length concrete bridge which spans a narrow strait. The highest elevation is Mount Tumutumu on Ofu, at 495m. Habitat consists of steep rugged, forested mountain ridges surrounded by a thin strip of coastal strand, upon which most of the human population resides in small villages (Amerson et al. 1982). The climate is maritime and tropical, with distinct wet (December-March) and dry (April-September) seasons. Cyclones periodically hit the islands; during this project Cyclone Gita passed over American Samoa in February 2018. The breeding season for landbirds generally follows that of other subtropical populations in the Southern Hemisphere, with peak breeding occurring in November-March but low-level breeding occurring year-round (Banks 1984, Pyle et al. 2017). The lack of captures of Tongan Ground Doves in breeding condition during the TMAPS season in November-March suggests the possibility that this species shows peak breeding during the wet season in April-September (Pyle et al. 2017).

In order to facilitate descriptive locations and to keep track of general locations as well as to help with broadcast, point-count, and area-search surveys, we created grids with GPS-based points 250 m and 500 m apart (Fig. 2). We also divided the habitats into three categories as defined by elevation (see Fig. 4, below): Coastal Strand habitat (< 50 m elevation), Lowland Forest habitat (50-300 m elevation), and Upland Forest habitat (> 300 m elevation).

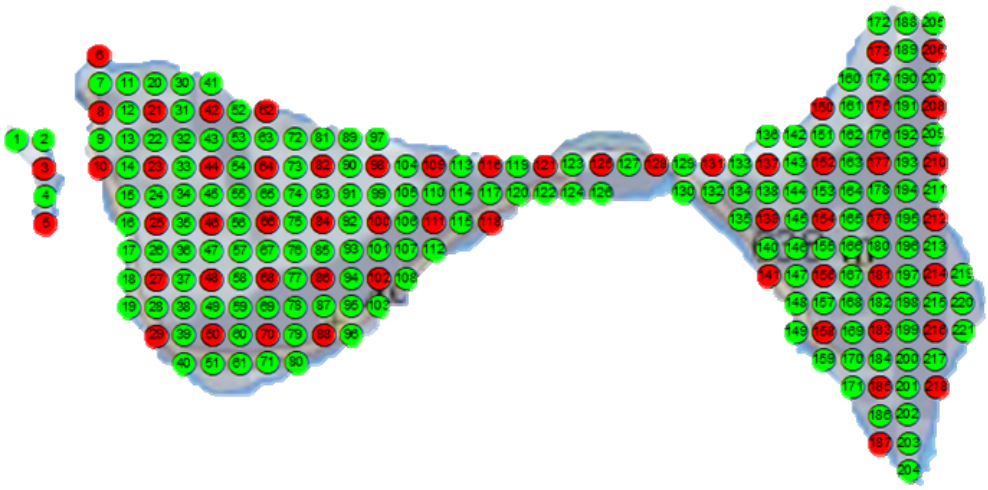
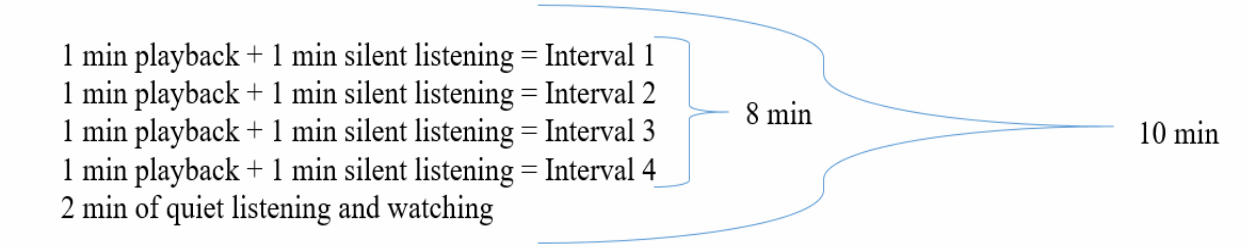


Figure 2. Grid systems used on Ofu and Olosega Island for randomized broad-cast survey, point-count, and area-search survey selection for detection of Tongan Ground Doves. Grid points are 250 m (green and red) and 500 m (red) apart.

Broadcast Surveys. Broadcast surveys were conducted to see if responses were observed, to obtain recordings of the vocalizations of Tongan Ground Doves on Ofu and Olosega islands, and to test the effectiveness of applying call playbacks for enhancing target capture and improving survey methods. Surveys took place at randomly selected grid points (Fig. 2) that were easily

accessible. Points were selected at 500 m distances on both Ofu and Olosega islands. When selected survey points were difficult to access due to the steepness and features of the terrain, we conducted them at the nearest accessible location. Surveys commenced as soon after dawn as there was enough light at the survey point, to be sure observers would be able to visually detect a Tongan Ground Dove if present. We used a FoxPro NX4 Digital Callers to broadcast the call of a Tongan Ground from Fiji (http://www.xeno-canto.org/278883), the only one available at project commencement. Each survey lasted 10min, with 4 intervals of 1 minute of broadcasted call and 1 minute of silent listening, using the following time intervals:



The Fiji recording of Tongan Ground Dove was initially played on the FoxPro at a preset volume (75% of maximum volume capacity) across all surveys regardless of background noise (see Results).

Point Counts. We conducted passive, 8-min point counts at randomly selected grid points (Fig. 2) that were easily accessible, following standard point-count methodology (Ralph et al. 1993, DeSante et al. 2017). We began conducting point counts once it was thought that ground doves were not responding to broadcast surveys (see above). We conducted stationary circular plot surveys of 8 min, during which auditory and visual detections were noted for every bird species present. Detection distances were categorized as <25m, 25-50m, 50-75m, or >100m from the observer and detected birds were placed in these distance-to-observer categories. To the best of our ability birds were noted only once at the distance of initial detection and were not double counted again during the survey.

Area Searches. Area searches were performed in order to calculate densities within each of our three broad habitat types on each of the two islands. Standardized area-search techniques were employed, in which areas of a given dimension are covered thoroughly and all birds (including ground doves) within the area are recorded (Ralph et al. 1993, Dieni and Jones 2002, Watson 2003, Dunn et al. 2006). Rectangular area-search plots of varying width, as dictated by vegetation and topography, were surveyed at randomly selected grid points (Fig. 2) that were easily accessible. Surveys were conducted by two observers for 20 minutes, in which time all birds detected within the survey area were recorded. Detections were categorized as visual or vocal only. Initially, traditional plots of 100m x 100m areas were considered; however, topography, vegetation, and behavior of the ground doves (not flushing until closely approached by the observer) caused us to switch to the more rectangular plots, or strip searches, for more effective ground-dove detection. All survey areas were 50 m in width, and lengths varied from 90 to 300 m in length as dictated by topography. The two observers walked in parallel through the area, 25m apart, to attempt complete sampling of all doves within the 50-m width strip. We assumed this methodology would result in the detection of all ground doves within the survey areas, and densities for population estimates were calculated accordingly.

Application of Tracking Devices. In order to apply tracking devices, Tongan Ground Doves were captured using 30 and 40mm mist nets, 12-m long, 4-tier nylon mist nets were erected at fixed net sites. Initially we attempted to target-net Tongan Ground Doves at known locations or following an observation but found that the disturbance caused by taking down and setting up nets kept birds away for long periods of time. When the broadcast surveys failed to yield results (see above) we began netting at TMAPS Stations Toaga Beach, Tumu Lower, and Sili (see Fig. 1) at and near net lanes where ground doves had been frequently captured. We had the most success at stations Tumu Lower and Sili, where we were able to erect a sequential line of 12 nets end to end as allowed by vegetation without the need for clearing. In addition, we set up nets near where ground doves were observed regularly. While checking nets, we walked a distance away and parallel to our net array first so that we would passively flush birds into the array before walking alongside the array. On several occasions ground doves on the forest floor would flush at our presence and fly right into the nets. Our conclusion based on the numbers of doves that were captured is that 40 mm mesh-size mist nets are more effective due to doves bouncing out of 30 mm nets more often Weather depending, we operated nets beginning at local sunrise for seven to eight morning hours per day, or until a ground dove was captured. Each captured Tongan Ground Dove was banded with a USGS numbered aluminum leg band and data collection occurred following the same protocols used for the TMAPS project (DeSante et al. 2017, Pyle et al. 2018), including the birds weight. Each captured ground dove was photographed to document age and sex.

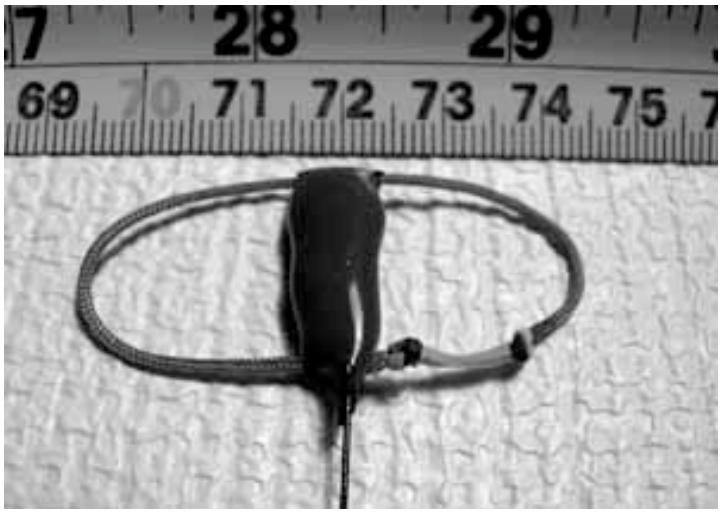


Figure 3. Example of a tag unit and leg-loop harness applied to Tongan Ground Doves

Tags were attached using a 1 mm nylon lower-back leg-loop harnesses which wrapped around the body and legs (Fig. 3). Harnesses were constructed using a modified version of the leg harness design, which incorporates a weak link that allows the transmitter to drop off (Kesler 2011). We sized harnesses using the allometric equation presented by Naef-Daenzer (2007), and added 3-5 mm based on field testing to obtain the best fit for each individual. Altogether the harness weighed approximately 0.6 gm.

Tracking Devices. The primary goal of this project was to evaluate the efficacy of two different types of equipment for marking and tracking the movements of Tongan Ground Doves. Specific technical objectives for the field season included: 1) to evaluate whether units could be safely deployed on Tongan Ground Doves; 2) to determine whether the systems can effectively collect location information in the insular Pacific forest conditions; 3) to determine whether the systems can relay onboard position information to data collection devices (satellite and hand-held base station); 4) to identify optimal operational settings for the units so that they collect the most useful data; and 5) to evaluate whether data collected by the units can be used in space-use and movement analyses. At the onset of fieldwork, we obtained 7 Lotek (Newmarket, Canada) Pinpoint Argos transmitters and 7 Ecotone (Sopot, Poland) Uria UHF transmitters along with an Ecotone receiver system. Both tag systems were used during fieldwork, and the deployments provided insights into their utility on insular systems.

Each Lotek and Ecotone unit was also equipped with a VHF transmitter (ATS Telemetry Systems, Isanti, MN). These small (0.9 g) transmitters were glued to the side of the other tracking units and allowed field personnel to use a hand-held antenna and track marked birds from distances of up to 2 km via a portable receiver with antenna. These tags transmit signals continuously for remote detection, and are recommended on each bird in case of transmitter failure or loss from the bird and to allow closer approach for further data collection as needed.

As a rule, tracking units including batteries and harnessing equipment should weigh no more than 5% of the total weight of a ground-dwelling bird such as Tongan Ground Dove (Gaunt and Oring 1999). Tongan Ground Doves captured in 2015-2018, as part of the TMAPS program, weighed between 118 and 197 grams (mean 149 grams; n =35), which allows for the application of tracking device weights of 5.9-9.9 grams. All tracking devices and harnesses together resulted in a total weight of 5.0-6.0 grams (see below), and in each case the weights of the birds were checked to ensure that the tags weighed no more than 5% (and often < 4%) of the total bird weight.

The Lotek units were designed for birds to collect one location per day, and then to upload those data to an array of earth-orbiting satellites, allowing for the retrieval of data without the need to recapture or relocate the ground dove. Each Satellite tag and battery weighed 3.5-4.0 grams, resulting in a total weight of about 5.0-5.5 grams with the addition of the harness and VHF unit. The Lotek units require pre-programming prior to deployment and conserve battery by collecting location data and then sending those data only after an extended period. We designed the system to collect data for 30 days (30 locations) and then attempt to send those data at the end of the period. These units have been proven to work on other species in other regions but their utility in forested habitats of insular Pacific Oceania is unknown. In addition to the application of Lotek tags on ground doves, a series of tests were performed on programmed tags moved around in the field. We employed the ARGOS Worldwide Tracking system (Collecte Localisation Satellites 2016) to track the Lotek tags.

The Ecotone Uria system is designed to collect location information at a scheduled rate, and then to send those data to a hand-held or stationary base station when it is encountered. Each tag and battery weighs 4.5 grams, resulting in a total weight of about 6.0 grams with the addition of the harness and VHF unit. The Ecotone system has the capability to collect up to 500 GPS positions

over the course of the field season, at predetermined intervals. The attached VHF transmitter (see above) allowed field personnel to locate and approach birds to within 100 m, at which point a hand-held base station was used to download data. The Ecotone system is reusable -- units can be recharged after recovery and redeployed if they are dropped from study subjects – and they can be reprogrammed after deployment to reconfigure the frequency of data collection and daily hours of operation.

Once tags were applied to Tongan Ground Doves they were tracked and followed throughout the life of the tag. Advanced Geographical Information System (GIS) software and analysis techniques were used to estimate home-range sizes and characterize habitat utilization by Tongan Ground Doves.

Incidental observations. During the course of this project, data and incidental information on all detections of Tongan Ground Dove and any other information related to the natural-history goals of this project were also recorded. In particular we were interested in obtaining location and habitat data for all observations, recorded vocalizations, and information on diet or any signs of breeding behavior. Areas where doves were repeatedly observed were searched for food and foraging behavior. When vocalizations were heard we attempted to approach the vocalizing individual to observed behavior under such conditions.

Kimiko and three volunteer technicians were employed for field work during January-October 2018. Each technician assisted with fieldwork for three months each. Pursuant with qualification reviews, Kimiko was permitted to capture and handle Tongan Ground Doves under the Fish and Wildlife Service List of Authorized Individuals for Endangered Species Act Recovery Permit TE-08598C-0 and US. Fish and Wildlife Service Bird-banding Laboratory (BBL) master permit BBL 22432 (with Pyle as master permittee). Requirements for this project included extensive experience handling, banding, collecting blood and other samples, and applying harnesses with electronic position tags. Prior to fieldwork (in December 2017), Kimiko received extensive training from Kesler in applying the tags to be used specifically for this project. During fieldwork, every effort was made to prevent any accidental injury or death of ground doves, following strict safety protocols for MAPS and TMAPS banding programs (DeSante et al. 2017). Protocols dictated that when birds exhibited signs of stress, they were to be immediately released. Doves in general are hardy birds and no captured individuals for this project showed undue levels of stress or injury prior to successful release.

RESULTS

Broadcast Surveys. We conducted 87 broadcast surveys between 6 March and 17 September 2018 for a total of 870 minutes (14. 5 hrs) of surveying. During these surveys we failed to confirm a direct response by Tongan Ground Doves to any of the broadcasts. At many sites noise from surf was moderate to substantial. Under such conditions we found that the FoxPro recorder broadcasting was often inaudible to human ears at >30 m distance at the preset standardized volume we had chosen. We thus experimented playing the recordings at higher volume levels but no ground-dove reactions were elicited. We also experimented by playing a recording of a Cooper's Hawk (*Accipiter cooperi*) and although other native Samoan birds responded, there was no detected response from Tongan Ground Doves.

Tongan Ground Doves were observed to be present on three occasions during or following broadcasts; however, these occurrences appeared to be incidental to the survey. On six occasions we broadcast calls with ground doves in view and none of these appeared to elicit any response to the broadcasts. On one occasion (6 March 2018) two Tongan Ground Doves were heard during a broadcast survey but it did not seem like they were interacting with the recording. We continued to broadcast the call at intervals but neither of the calling Ground Doves came closer while they were calling. Eventually both stopped calling though we continued playing the recorded call for several additional minutes in intervals.

We thus concluded that broadcast surveys were ineffective in monitoring Tongan Ground Doves or in target netting for application of transmitters. See results of incidental observations (below) for more information on vocalizing Tongan Ground Doves.

Point Counts. We conducted 15 point-count surveys between 30 March and 10 September 2018. We initiated point counts once it was thought that ground doves were not responding to broadcast surveys. We detected no ground doves during point counts and concluded that, due to low detection probability (difficult to observe from a stationary point and low frequency of vocalizations), point counts would be an ineffective method for monitoring Tongan Ground Doves.

Area Searches. After it was becoming evident that broadcast and point-count surveys were going to be ineffective for surveying Tongan Ground Doves, we initiated area searches, which have the added benefit of allowing us to estimate densities within each habitat type on each island, and thus an overall population estimate. A total of 99 area-search surveys were performed between 6 April and 4 October 2018. The total area of all area searches was 851,500 m^2 (0.8515 km^2), of which 474,500 m^2 was surveyed in coastal strand habitat, 252,000 m^2 was surveyed in lowland forest habitat, and 125,000 m^2 was surveyed in upland forest habitat. Among the two islands, 645,500 m^2 was surveyed on Ofu and 206,000 m^2 was surveyed on Olosega.

A total of 11 Tongan Ground Doves were detected at 10 of the 113 area-search stations; singles were observed except for two birds noted on one survey. All detections were of visual observations, and all detections were on Ofu. Among habitat types, 2 birds on 2 surveys were recorded in coastal forests, 8 birds on 7 surveys were detected in lowland forests, and 1 bird on 1 survey was detected in upland forest.

Assuming all ground doves were detected on each survey, a simple overall population density (birds per area surveyed) of 12.92 birds per km^2 were surveyed. Among habitats, 4.21 ground doves per km^2 were surveyed in coastal strand habitats, 31.74 ground doves per km^2 were surveyed in lowland forest habitats, and 4.85 ground doves per km^2 were surveyed in upland forest habitats. Roughly defining habitat based on elevation, coastal strand occurring at < 50 m, lowland forest at 50-300 m, and upland forest at >300 m in elevation, we calculated the total area of each habitat on Ofu and Olosega as 3.30 km^2, 6.96 km^2, and 2.82 km^2 for each of these three habitat types, respectively (Fig. 4). As such, the total number of Tongan Grounds Doves might be estimated as 14 in coastal habitats, 221 in lowland forest habitats, and 14 in upland forest habitats, resulting in a total population estimate of 249 ground doves. We cannot calculate these

estimates directly for each island since no birds were detected on area searches on Olosega. However, applying the rates per habitat to the total habitat areas on each island yields a population estimate of 145 birds on Ofu and 104 birds on Olosega. Several assumptions have been made in deriving these population estimates (see Discussion), so it should be viewed with appropriate caution at this time.

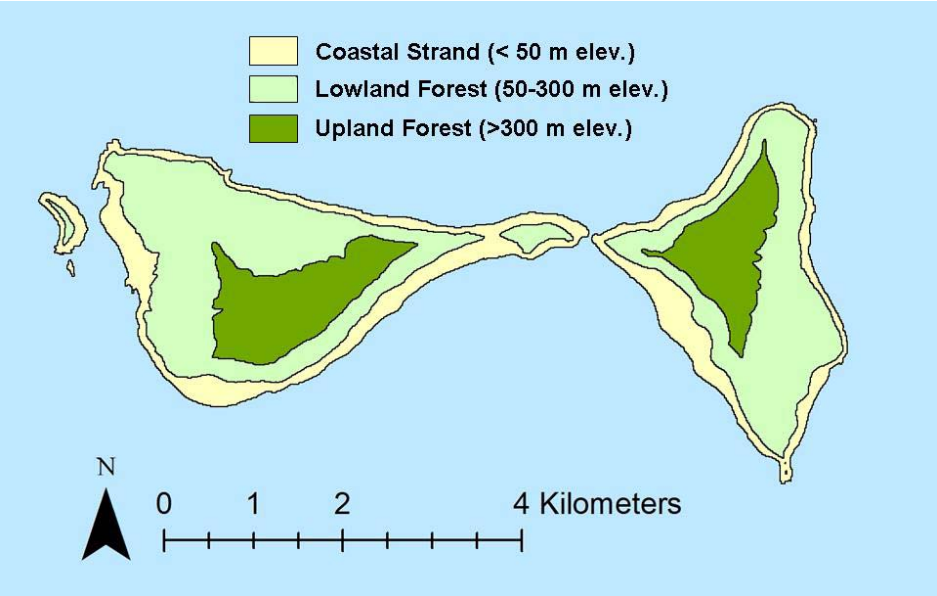


Figure 4. Habitat types by elevation on Ofu and Olosega islands. Total areas are: Coastal Strand 3.30 km^2 (1.98 on Ofu and 1.32 on Olosega), Lowland Forest 6.96 km^2 (4.06 on Ofu and 2.90 on Olosega), and Upland Forest 2.82 km^2 (1.59 on Ofu and 1.23 on Olosega).

Tracking Devices. Ten Tongan Ground Doves were marked with tracking equipment (Table 1), confirming our ability to mark and track birds, and to collect movement information from study subjects. These included data from 8 individuals that were marked with Ecotone GPS-UHF tags downloaded hand-held base stations, and two individuals that were marked with Lotek ARGOS tags designed to send movement results to earth-orbiting satellites. In addition, three other LOTEK tags were deployed and moved around or set at distance locales to test their functionality.

Conditions at the field site proved challenging for both sets of tags. The global positioning system tags used in this study rely on signals from the GPS satellite system, which are then used to triangulate the precise location of marked birds. The GPS signals are gathered with two short antennas that project from the anterior of both the Lotek and Ecotone units. Previous investigations suggest that high moisture environments, and settings with dense canopy cover can inhibit reception of the GPS signals, and require additional power in order for a unit to estimate its global position. During the 2018 trial, we evaluated GPS acquisition times and noted that they ranged generally between 30 and 50 seconds (orange line in Figure 5). Similar studies in more open and drier habitats report shorter data acquisition times, which allow extended battery life and longer unit lifespans.

Date	Band Number	Age	Sex	Weight	Tag Type	Tag Number
26-Mar-18	085413909	FPF	M	108.4	UHF	BCK13
23-Jun-18	125399090	FAJ	M	180.2	UHF	BCK14
12-Jul-18	085413910	DPB	F	143.5	UHF	BCK10
01-Aug-18	085413911	UPB	M	156.5	UHF	BCK12
06-Aug-18	085413912	FCF	F	152.2	Satellite	580
09-Aug-18	125399019	FPF	F	114.2	Satellite	583
15-Aug-18	125399020	FPF	F	126.2	UHF	BCK11
09-Oct-18	125399021	FPF	F	130.8	UHF	BCK15
31-Oct-18	125399022	FAJ	F	120.4	UHF	BCK13A
19-Nov-18	085413914	UPB	M	199.8	UHF	BCK16

Table 1. Tongan Ground Doves for which tracking devices were deployed. Age codes include first-year birds (FPF and FCF) and adults (FAJ, UPB, and DBP). Weights are in gms.

We obtained no tracking data from the two Lotek tags deployed on ground-doves nor the three tags that were activated and moved around experimentally. A challenge for any GPS-based tracking equipment deployed in forested systems in American Samoa will likely be with the battery required to acquire positioning satellite signals. The added battery needs require that GPS-UHF units either be larger and carry heavier batteries, or that researchers should expect fewer locations than might be obtained in other study conditions. Similarly, the energy required for satellite acquisition may have prematurely drained batteries on the Lotek ARGOS units to a point in which they were unable to transmit location information back to the earth-orbiting satellites. Alternatively, the Lotek Pinpoint units may also have been unable to penetrate the moist canopy when attempting to transmit back to the satellites.

Despite the moist environment and dense vegetation, the Ecotone GPS-UHF systems were used to effectively collect a substantial amount of information from the Tongan Ground Doves with the number of positional observations per bird ranging from 0 to 276 (Table 2). Deployments of Ecotone GPS-UHF units that resulted in fewer location records were caused by an inability of observers to relocate birds and download onboard data after unit deployment. Most data were downloaded when the target bird was in line of sight, often within 20 m range of the receiver. In some cases in which we were close to the bird according to the VHF signal we were unable to download data or data collection would cease despite continued proximity of the target bird. The VHF system facilitated relocations for several birds, however. Battery voltage declined at a rate that allowed detections for a at least 276 detections over 11 days (BLK 13; Fig. 5).

After release, 3 of the 8 individuals marked with Ecotone GPS-UHF equipment were tracked and movement data were downloaded (Tables 1-2; Fig. 6). No data were collected from 3 of the Ecotone GPS-UHF marked individuals that were not relocated following release. A minimum of 5 locations is needed to make a basic home range estimate, and many more locations are needed for more sophisticated analyses such as ecological studies of movement and habitat use/selection. Of the birds marked in 2018, three reported enough locations for space-use analyses (BCK13, BCK14, and BCK16; Fig. 7).

Unit	Locations	Date Deployment	Last Detection	Home Range
BCK10	0	12-Jul-18	12-Jul-18	--
BCK11	3	15-Aug-18	15-Aug-18	--
BCK12	0	01-Aug-18	01-Aug-18	--
BCK13	276	26-Mar-18	04-Apr-18	38.41
BCK13A	0	31-Oct-18	31-Oct-18	--
BCK14	73	23-Jun-18	27-Jun-18	19.62
BCK15	4	09-Oct-18	09-Oct-18	--
BCK16	17	19-Nov-18	23-Nov-18	2.88

Table 2. A summary Ecotone deployment data. Home range size in hectares (ha).

Home ranges for birds were estimated using the minimum convex polygon (MCP) method (Worton 1987) and the adehabitatHR v3.3.0 package (Calenge 2015). Home range size of each individual differed substantially, although there may be a low-biasing effect for birds with fewer locations. We plotted the minimum convex polygon home ranges for each of the three individuals on a visual spectrum image of the island using Google Earth (Fig. 7). Although the sample size is small, several key patterns are evident in these data. First, the home ranges of marked birds appear to be biologically reasonable in size, and their locations within the island align with the forest-associate behavior of ground doves. Notably, all three estimable home ranges overlapped in a central area, in which the birds were initially captured, which suggests that the TOGD are not substantially territorial, and that they do not hold exclusive access to any particular resource.

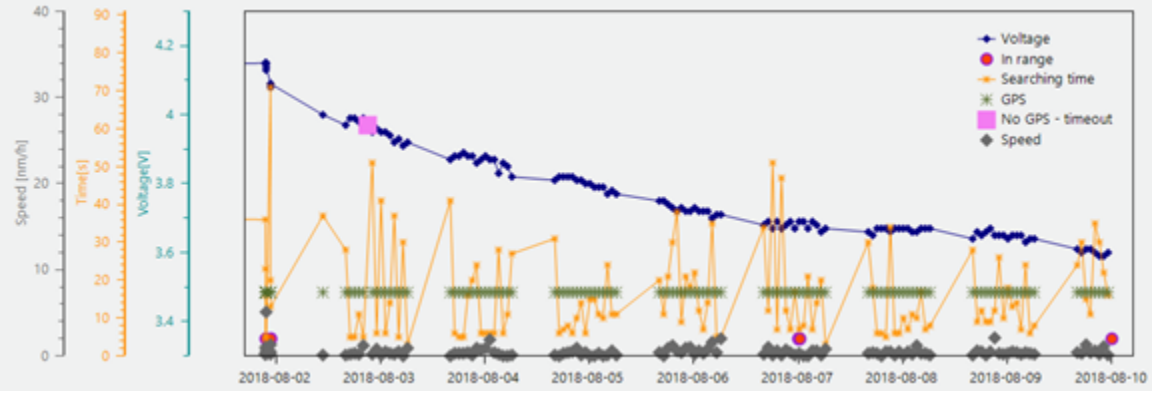


Figure 5. Data collection and transmission information for BCK13 deployment of Ecotone Uria GPS-UHF locator on Tonga Ground Dove in 2018. The blue line indicates the decline in voltage during the tracking period, the orange line indicates time required to search for earth-orbiting satellites sending GPS location information, and the green points indicate location observations.

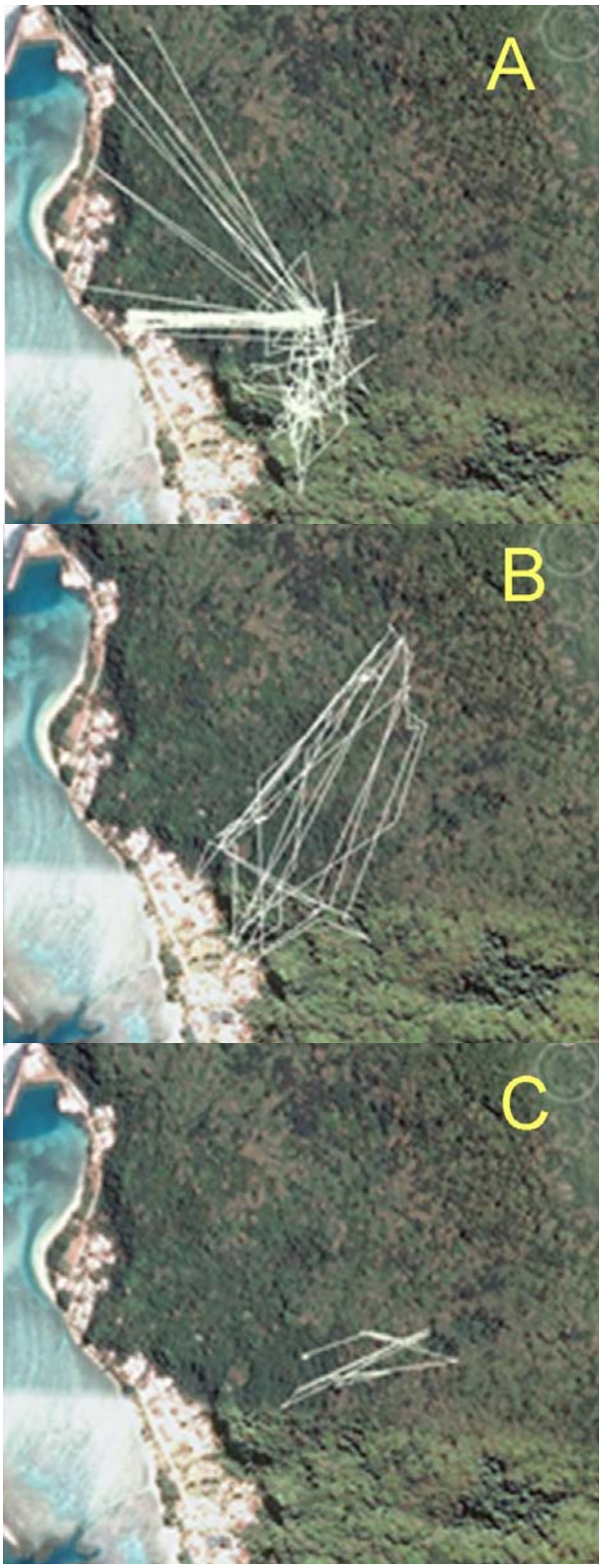


Figure 6. Movement paths of three Tongan Ground Doves, BCK13 (A), BCK14 (B), and BCK16 (C) on Ofu in 2018. See Tables 1 and 2 for deployment details.

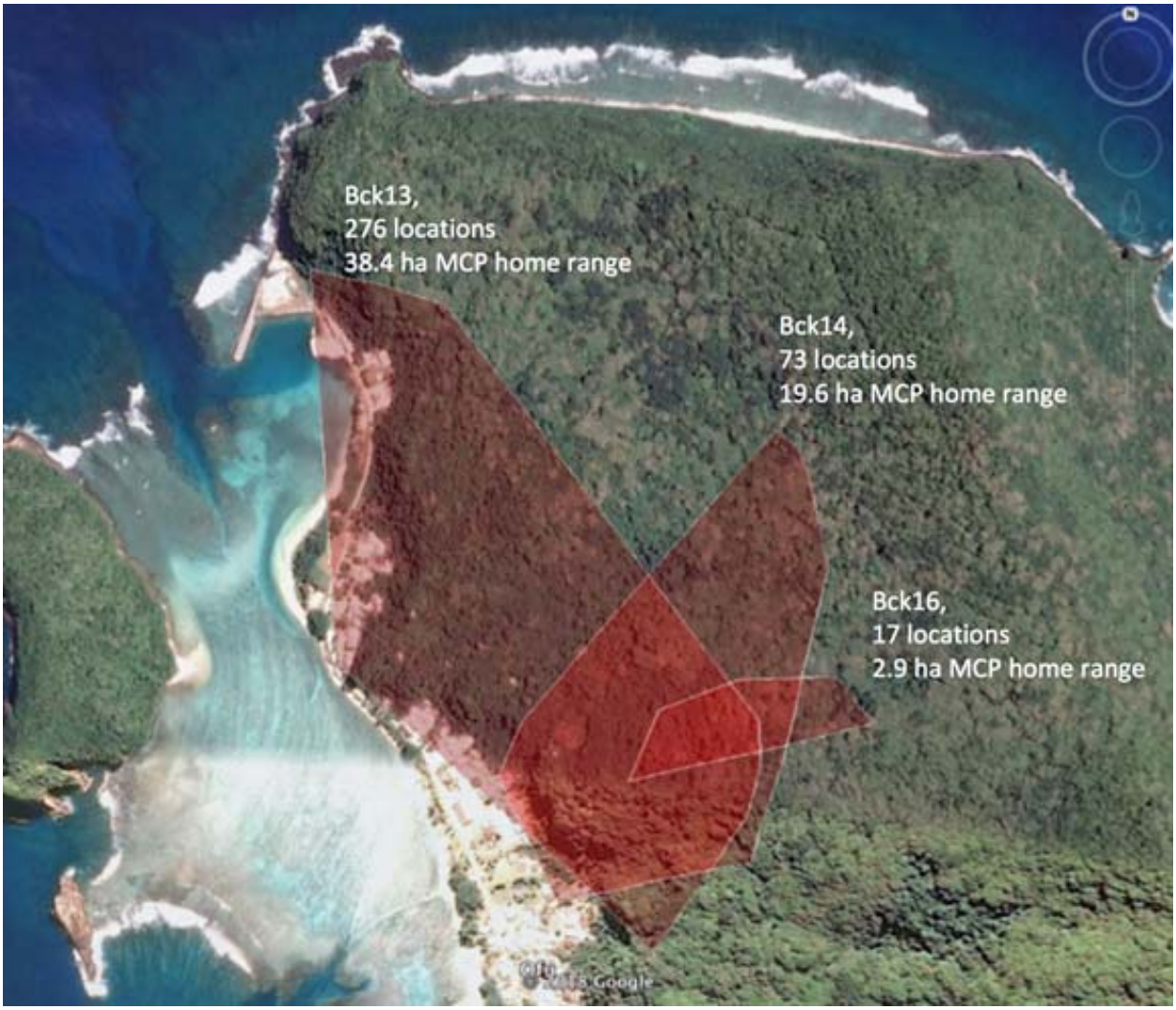


Figure 7. Minimum convex polygons representing the three home ranges. Each home range was derived from location data collected using a GPS-UHF tracking system in 2018.

Incidental Observations. During the course of fieldwork for this project, data and incidental information on all detections of Tongan Ground Dove and any other information related to the natural-history goals of this project were recorded. Figure 8 indicates all locations on Ofu and Olosega where Tongan Ground-Doves were encountered and recorded with GPS units. A total of 97 observations of Tongan Ground Doves were recorded at 71 locations, including 14 at capture locations for tagging, 12 during area searches, and 69 additional incidental observations. A majority of observations were obtained along the Tumu Trail in lowland habitat in the northwestern section of Ofu. Many additional observations on this trail were not marked with GPS coordinates and are not shown in Figure 8. The highest elevation for an incidental observations was at 287 m on the Tumu trail, although they have also been recorded and captured during the TMAPS season on Mt. Tumu at 487m elevation. Another notable observation was of one on Nu'utele Island to the west of Ofu on 9 June 2018. Nu'utele is 160-230m from the shore of Ofu (depending on the tide).

Tongan Ground-Doves were found in a variety of habitats on Ofu and Olosega, but primarily in shaded forests or thickets. In coastal habitats, they were often found in the vicinity of tamau (*Calophyllum inophyllum*) and/or hibiscus (*Hibiscus tiliacesu*) thickets or trees, and they were occasionally observed foraging in shaded areas with open understory and/or in areas where habitats were disturbed by human activity. In forested sections of the island, where they seemed most abundant, they were often found near steep densely vegetated slopes, or sometimes those with an open understory and exposed soil. But when flushed or during calling or mating activity they appeared most often to retreat to dense understory.

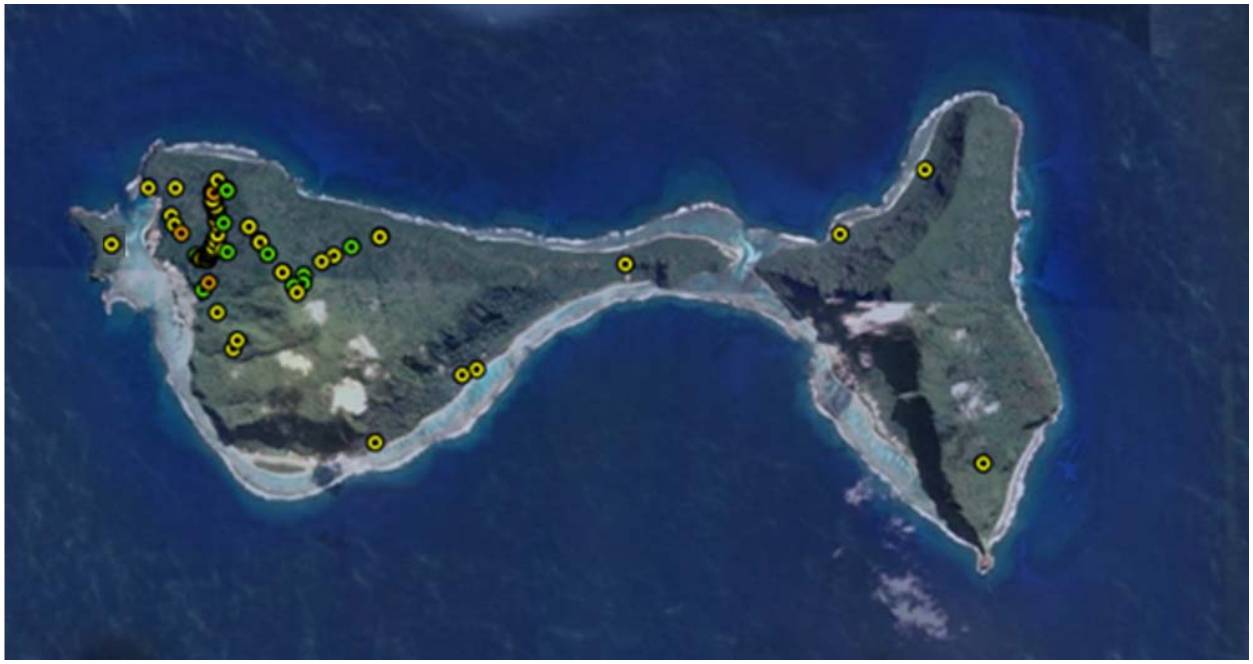


Figure 8. Locations for incidental observations of Tongan Ground Doves during the course of this study in which GPS point data were obtained. Green dots = observations during area searches; Orange = observations at capture stations; Yellow dots = incidental observations.

Most observations of Tongan Ground Doves were of birds within 4 m of the ground although individuals were observed as high as 13 m up in trees and flying over the canopy at 15 m height. Otherwise flights were short, most birds detected walking on the ground away from the observer or flushing for short distances of 15-20 m. When walking, the ground doves usually had their tails erected vertically in the manner of a rail. On one occasion a an adult male ground dove was observed walking on top of an old cement cistern, 4 m above the forest floor. A broadcast call to this bird elicited no reaction. On 19 March 2018 a predated juvenile was found feather near one of the capture stations. Potential predators of ground doves observed on Ofu and Olosega include cats, rats, and Barn Owls (*Tyto alba*), with cats being observed in the area and thus the primary suspect for this juvenile.

Vocalizations of Tongan Ground Doves were heard on 16 occasions between 6 March and 9 October, with a peak number of calls heard in late May and early June. Fourteen calls were heard on Ofu and 2 on Olosega. Despite targeted listening, no calls were heard during November-February, which accords with the lack of calls being heard despite targeted listening during three

TMAPS seasons. All vocalizations were of repeated low-pitched notes, at times consisting of <10 notes and at other times repeated for 25 or more times. A total of 25 recordings of the calls were obtained between 23 May and 5 June, during six calling episodes. Calls were heard more often during still periods, when overcast or after first light but before sunrise. But calls were also heard at all times of day and most recordings were obtained mid-day. Most calling birds were singles but two at once were heard on three occasions and three at once on one occasion. Multiple calls heard at once may have been of males counter-vocalizing.

The best recorded calls will be loaded on to the website http://www.xeno-canto.org for availability and further analysis. Compared to the one available call of Tongan Ground Dove from Fiji (http://www.xeno-canto.org/278883), the calls of this species in Samoa are slightly different, sounding a bit higher pitched, more double-noted, and not slowing down in cadence. Whereas the Fiji call could be transcribed as *whooh-whooh-whoowa-whoowa*..., slowing down in tempo, whereas the calls from Samoa might be transcribed as a monotonous *whouck-whouck-whouck-whouck*..., without change in cadence.

Tongan Ground Doves ceased to call when observers approached so recordings are faint, and no calling birds were directly observed. In addition, the calls were ventriloquial, direction and especially distance from the observer being difficult to determine. It was inferred that ground doves were at closer distances than originally estimated based on the volume and quality of the calls heard. Observers could get an estimated 15-20 m within calling birds before they ceased vocalizing. Understory was dense around apparent calling locations, further preventing visual observation of calling birds. All birds later flushed from calling areas that could be sexed were adult males and it is presumed vocalizations are restricted to this age/group as occurs in most other Columbiformes. On three occasions females also appeared to be present in the calling area, perhaps attracted to the males.

No food items that could be directly identified were observed being eaten by Tongan Ground Doves. On two occasions the seeds of the native tree *Macaranga harveyana* were found in areas in which foraging doves were observed and it is suspected that this may be a primary food source for the ground dove in American Samoa. On 27 September 2018 a ground dove was observed at the TMAPS site TOAG foraging actively. It was observed performing wing extensions and hops, repeatedly over 12 times, possibly to flush insect or arthropod prey. This individual foraged in area of about 5x5 m for 50 min. Its behavior also including pecking at the ground at rates of 10-22 pecks per minute. leaf-litter kicking, and at one time flinging a leaf away with its bill. Examination of this area following the bird's departure yielded centipedes, ants, and a black beetle.

No Tongan Ground Dove nests were located. Observed nesting and courting behavior including several instances of adult males and females together and one family group observation of a pair and two recently fledged juveniles. The family group was observed on 31 May 2018 in lowland forest habitat east of Ofu Village, Ofu, from 1000-1300 AST local time (AST). Two juveniles were observed together on a log, preening each other and occasionally fluttering their wings. One juvenile was larger and more fully developed than the other. An hour after first observation an adult male flew to the juveniles, began walking on the ground and scratching for food, and guided the juveniles to the area in which it was located. A fourth bird flew in, likely an adult

female. The two non-juveniles flew a short distance at which time calling by one of them (presumably the male) was heard and recorded. The male then returned to feed both chicks several times, interspersed with its scratching on the ground and kicking up leaves The juveniles exhibited fluttering of wings during this time and one tried to climb on top of the male. The male then flew off, leaving the juveniles which were monitored for another two hours without return of the adults. The location was revisited on 5 June at 0900. A very soft ground dove call (only 4-5 notes) was heard but no other activity was recorded.

DISCUSSION

The purpose of this pilot project was to determine the best methodologies for monitoring and further investigating the endangered population of Tongan Ground-Dove on Ofu and Olosega Islands. We concluded that broadcast surveys and point counts are ineffective means of attracting or monitoring this population. Area-search methodology was thus employed to obtain preliminary population densities of ground doves in different habitats, and resulted in a rough population-density estimate of 12.92 birds per km^2, of which 4.21 ground doves per km^2 were surveyed in coastal strand habitats (up to approximately 50 m elevation), 31.74 ground doves per km^2 were surveyed in lowland forest habitats (50-300 m elevation), and 4.85 ground doves per km^2 were surveyed in upland forest habitats (>300 m elevation). From these densities we estimated a total number of Tongan Grounds Doves in American Samoa of 249 individuals, including 14 in coastal habitats, 221 in lowland forest habitats, and 14 in upland forest habitats. We estimated populations of 145 ground doves on Ofu and 104 on Olosega.

Several assumptions were needed to derive these estimates, and other biases cause area-search based estimates to be imprecise (Verner and Milne 1990, Dunn et al. 2006). Our tracking evidence suggests that Tongan Ground Doves are not substantially territorial, which prohibits uniform density estimates for breeding birds due to the inclusion of wandering individuals in searches. Breeding birds may also wander over substantial distances, lessening the chance that they will be recorded at a given time and in a given breeding habitat (Dunn et al. 2006). Patchiness of distribution increases the chances that random survey location will be biased. Our results indicating higher densities of doves in lowland forest than in coastal habitats is at odds with more captures recorded in coastal habitats per 600 net-hours of effort than in lowland forests at TMAPS stations (Pyle et al. 2018). This may result from the specific locations of the mist nets relative to those of area searches in these habitats, or it may indicate that our area-search data are not yet robust enough to calculate adequate population densities and size estimates.

Our sample size of 113 area searches did not allow us to calculate confidence intervals around our mean density estimates, and our results thus should be treated as indices rather than island-wide densities until higher numbers of searches can be performed. For these reasons, our population densities and size estimations should be considered very tentative at this time. However, despite being very time-consuming (Dieni and Jones 2002), we recommend further use of area-search methodology in order to calculate better information on the population of Tongan Ground Doves in American Samoa. Even if treated as occurrence indices, we believe that this methodology, when combined with that of tracking data, will at least lead to relative abundances in different habitats with the accumulation of sufficient data.

Despite some challenges we were successful in both capturing Tongan Ground Doves for application of tracking devises and for tracking several doves with the use of units consisting of both Ecotone GPS-UHF and VHF transmitter tags. The best capture methodology proved to be the setting up of continuous strings of nets at TMAPS stations near net lanes where ground doves had been frequently captured, monitoring nets consistently, and walking the lanes periodically to flush doves into the nets. We concluded that 40 mm mesh-size mist nets are more effective than 30 mm nets for catching doves. We had no issues attaching 1 mm nylon lower-back leg-loop harnesses and successfully tracking doves for up to two weeks, indicating little adverse effects of the harnesses on the doves. Total weight of harness and tracking devices was 5-6 gms, well under the recommended 5% of individual bird weight in most cases. Overall, no deaths, injuries, or apparent adverse effects of any kind resulted to Tongan Ground Doves during our capture, harnessing, and tracking efforts.

We obtained no tracking data from the two Lotek Satellite tags deployed on ground-doves nor the three tags that were activated and moved around experimentally. We conclude that the energy required for satellite acquisition may have prematurely drained batteries or that transmissions from these tags were unable to penetrate the moist canopy when attempting to upload data to satellites. However, the Ecotone GPS-UHF systems were used to effectively track Tongan Ground Doves including three doves which reported enough locations for space-use analyses. Data from these three birds suggested that home-range sizes differed from each other but appeared to be biologically reasonable in size, and that their locations within the island align with the forest-associate behavior known for this species. All three estimable home ranges overlapped in a central area, in which the birds were initially captured, which suggests that the Tongan Ground Doves are not territorial, and that they do not hold exclusive access to any particular resource. This is a common behavioral pattern among Columbiformes in general.

Under optional conditions, and with adequate time investment tracking down marked birds after release (at least once every three or four days), we anticipate that as many as 300-400 locations may be gathered from a single bird across the course of 2-4 weeks using an Ecotone GPS-UHF system. The VHF transmitters facilitated relocations for several birds. These data indicate the strong potential for future projects to use similar tracking and field approaches to answer more sophisticated and important questions. For example, data collected from an expanded field effort could be used to relate the movements of Tongan Ground Doves to vegetation resources on the island (e.g., Whistler 1992 and remote-sensed databases) by evaluating data in the context of a map of the spatial extent of the vegetation types. Vegetation types that are used in proportions higher than anticipated (available in the study area) can be considered to have been "selected for", whereas others that were used in lower proportions can be considered to have been "selected against". We recommend the gathering of more data in the future with Ecotone UHF/VHF packages.

During the course of fieldwork for this project, data and incidental information on distribution, vocalization, habitat, and nesting behavior of Tongan Ground Doves in American Samoa were recorded. A total of 97 observations occurred throughout all habitats of Ofu and Olosega islands, with many observations obtained along the Tumu Trail in lowland habitat in the northwestern section of Ofu. A notable observation was of one on Nu'utele Island to the west of Ofu.

Vocalizations of Tongan Ground Doves were heard on 16 occasions between 6 March and 9 October, with a peak number of calls heard in late May and early June, whereas no calls were heard during November-February despite targeted listening. These are the first published descriptions of the calls of Tongan Ground Dove from American Samoa. Generally these calls sound similar to those of the calls from other areas of the species' range, described as a wavelike progression consisting of 18 to 65 repetitions (Beichle 1991), although the calls from Ofu and Olosega seem slightly higher pitched and more upslurred than those of Fiji (see above). A total of 25 recordings of ground dove calls were obtained, the best of which will be loaded on to the website http://www.xeno-canto.org for availability and further analysis.

No Tongan Ground Dove nests were located. Courting individuals were observed in April-May and a family group including two adults attending two juveniles was observed on 31 May. These observations on calling, courting, and fledgling birds suggest that Tongan Ground Doves breed during the austral fall and winter (March-August), in keeping with the lack of breeding condition or activity detected for captured birds for the TMAPS project in November-March (Pyle et al. 2017, 2018). No food items that could be directly identified were observed being eaten by Tongan Ground Doves; however, on two occasions the seeds of the native tree *Macaranga harveyana* were found in areas in which foraging doves were observed. One foraging bird was observed performing wing extensions and hops possibly to flush insect or arthropod prey, including centipedes, ants, and a black beetle noted in the vicinity. In other areas of its range, Tongan Ground doves have been reported to forage for seeds, fruit, buds, young leaves, shoots, snails, insects and caterpillars on the forest floor (Clunie 1984, Watling et al. 2004, Birdlife International 2016). Future analysis of fecal samples from our TMAPS program (Pyle et al. 2018) should shed more light on the diet of Tongan Ground Doves on Ofu and Olosega islands.

On 19 March 2018 a predated juvenile Tongan Ground Dove was found near one of the capture stations on Ofu. Potential predators of ground doves observed on Ofu and Olosega include cats, rats, and Barn Owls, with cats being observed in the area and thus the primary suspect for this juvenile. Polynesian rats (*Rattus exulans*) are suspected of affecting the Tongan Ground Dove in Tonga based on distributions of doves being lower or absent on islets of higher rat abundance (Rinke 1991), although the species appears to coexist with rats on the main island in Vava‘u (Steadman et al. 1999). Another potential threat to faunal populations of Samoa is the presence of "yellow crazy ants" (*Anoplolepis gracilipes*), known as invasive and having the potential to affect a wide variety of terrestrial flora and fauna including birds (Plentovich and Fejeran 2017). This species was found to be spreading on islets off Independent Samoa in 2006, where eradication attempts for ants and rats are being considered (Tye and Butler 2013, Birdlife International 2016).

Many island species and populations are threatened by loss of habitat through the expansion of urban and agricultural areas by humans and associated introduced species (Terborgh et al. 1990, Turner 1996, Laurance et al. 1997, Birdlife International 2016). In Fiji, Tongan Ground Doves have been observed departing areas with logging or planting activities within days of occurrence, and not re-inhabiting within five years after the cessation of human activity, perhaps due to changes in forest characteristics, food resources, or invasion by predators (Birdlife International 2016). The resident human population on Ofu and Olosega is declining, but increased urbanization is a continuing factor as people build more, and often larger, western-style homes

and expand agricultural plots. As people encroach into the forest for development (homes and agriculture), not only is the critical habitat lost, but associated predators (such as cats and rats) expand their range as well. The introduction of house cats from such areas, some of which subsequently become feral or produce feral offspring, may perhaps be the greatest threat to the Tongan Ground Dove, which is vulnerable to cat predation due to its ground-dwelling habits. We recommend that awareness about the potential damage of cats to the Tongan Ground Dove be increased throughout the islands.

Tongan Ground Doves in Ofu and Olosega seem to be widely dispersed across both islands but appear to have preferred microhabitat of shaded forested areas. Introduced pigs are also capable of severely impacting the islands' existing biota and damage from such pigs should be monitored and reduced as feasible. The occurrence of cyclones can also impact bird species (Lovegrove et al. 1992). Most recently, American Samoa was affected by Cyclone Gita in February 2018. Although Gita did not appear to affect the Tongan Ground Dove to a large degree according to our incidental observations, perhaps due to the species' sturdiness and ability to find cover near forest floors, large natural disasters such as cyclones could be detrimental in the future due to their small population, restricted range, and limited dispersal ability.

We have achieved the goals of this project to determine the best methodology to study the Tongan Ground Doves on Ofu and Olosega islands, American Samoa. We look forward to the chance to implement these methodologies in the future, increasing our sample size of area search data, refining our population estimates, applying more Ecotone UHF/VHF packages to do an in depth analysis of home-range sizes and habitat selection at different times of year, and continuing to collect information on the vocalizations, habits, and nesting behavior of this endangered population.

ACKNOWLEDGMENTS

We are extremely grateful to Samoan landowners and local residents of Ofu and Olosega for assistance and granting us permission to establish TMAPS stations and otherwise access their lands to track Tongan Ground Doves: the Lata family, Peter Ili and family, Misaalefua family, the National Park of American Samoa, John Utuga, Ricky Miasaalefua, Lata and Afuli (of Public Works), and the high chief Afe and other village chiefs of Olosega. Rangers and staff of the National Park that provided assistance include Carlo Caruso, Scott Burch, Bryan Harry, Tavita Togia, Kiolona Atanoa, and Loia Tagoni. We thank the U.S. Fish and Wildlife Service (USFWS) for providing funding through Wildlife Restoration (WSFR) Grants to American Samoa; Ruth Utzurrum of USFWS, Honolulu, assisted us by reviewing and making suggestions for improvements to the grant proposal. We also thank Annie Marshall and Colleen Henson of the USFWS, Honolulu, for help procuring Endangered Species Act Permit ((# TE08598C-0, Institute for Bird Populations, 12/22/2019) for our work with the Tongan Ground Dove, and Bruce Peterjohn and Danny Bystrak of the USGS Bird Banding Laboratory for authorizations (under Master BBL Permit 22423) to band and apply tracking devices to ground doves on American Samoa.

We thank DMWR Director Va'amua Henry Sesepasara and Deputy Director Selaina Vaitautolu-Tuimavave for approving the work for this project. We also thank other DWMR staff members

and biologists, including Mark MacDonald, Siaifoi Faaumu, Matthew Toilolo, Ailao Tualaulelei, Alice Lawrence, and especially Adam Miles for help with funding and logistics. IBP field biologists who took part in the TMAPS and/or Tongan Ground Dove projects during 2018 and provided assistance to Kayano included Hallie Daly, Kristi Fukunaga, Jaime McConachie, Andrew Motto, Daniel Roche, and Holly Marie Todaro. We are also indebted to Lauren Helton, Ron Taylor and Rodney Siegel of IBP for administrative, logistical, and technical support. This is Contribution No. 620 of The Institute for Bird Populations.

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