Proposed methodology for Faunal Biodiversity Assessment for us in Papua New Guinea's National Forest Inventory (sponsored by the FAO of the UN)

Friendly Fantail. Photo: Nick Leseberg

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1. **Context**

Deforestation and forest degradation, through agricultural expansion, conversion to pastureland, infrastructure development, destructive logging, fires etc., account for nearly 20% of global greenhouse gas emissions, more than the entire global transportation sector and second only to the energy sector (Field, Barros et al. 2014). Reducing Emissions from Deforestation and Forest Degradation (REDD) is an effort to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development. "REDD+" goes beyond deforestation and forest degradation, and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks.

Papua New Guinea (PNG) has one of the most significant areas of largely-intact tropical forest in the world, although these forests appear to be facing acute and imminent threats. Forests are also a vital resource for the local population particularly in the remote rural areas of PNG, providing food, fibre, building materials, and support a variety of wildlife and ecosystem services. PNG has been a leading proponent of REDD+ at the international level, and was one of the original REDD+ "pilot" countries. REDD+ activities to date have focused on supporting effective stakeholder engagement, including through the development of guidelines for Free, Prior and Informed Consent (FPIC) and on developing technical elements of the country's national forest monitoring system. A Multipurpose National Forest Inventory (MNFI) for PNG is currently being designed with the support of the UN Agency for Food and Agriculture (FAO) and other international Agencies (JICA, AUSAID, etc.), and will collect the forest data to feed the

National Forest Monitoring System that PNG is required to establish in order to participate in a future REDD+ mechanism (UN-REDD PNG 2011).

Whereas traditional forest inventories are largely centred on the appraisal of timber resources, current inventories are evolving toward multipurpose resource surveys by broadening their scope in several directions, aiming to incorporate the multiple values (products and services) that forests provide, including those related to biodiversity (Marchetti, Sallustio et al. 2012). PNG's NFI project aims to combine inventory activities for carbon and GHG measurement with other significant features such as biodiversity and cultural features in addition to timber volume (UN-REDD PNG 2011).

Here we propose a rapid faunal assessment methodology that can be combined with proposed inventory activities centred around rapid carbon and flora assessments. We first provide context of the proposed methodology by briefly describing the biogeography of PNG in context of its fauna. We then summarise standard techniques for surveying fauna in tropical environments and then provide our survey technique given the known limitations in terms of time per site. We also propose how the data should be managed and what types of analyses can be conducted based on the data collected.

2. Biogeography of Papua New Guinea

Papua New Guinea hosts a highly diverse vertebrate fauna including some 270 species of mammal, 866 birds, 264 reptiles and 367 amphibians, with many species of amphibians and reptiles still being described (Kraus 2008; Kraus 2009; Oliver, Richards et al. 2012; Günther 2013). Scientific expedition such as Conservation International's rapid assessment of the Nakanai and Muller Ranges in 2009, continue to discover new species and extend known distributions. Many of PNG's species, despite the close proximity to Indonesia, are most closely related to Australian taxa (Allison, Keast et al. 1996). During historic glacial maximums, the fall in sea level enabled dispersal and many terrestrial species, except for across the deep water in the Lombok straight (Mayr 1944). This biogeographic boundary known as the Wallace line divides PNG from the Indonesian archipelago and defines the regions faunal diversity (Mayr 1944; Vane-Wright 1991).

Within PNG, variation in species diversity occurs over a range of habitat types and altitude gradients (Heads 2006). A central mountain range running down the spine of New Guinea forms peaks as high as 4509 meters with a snow line as low as 3600 meters, despite PNG's proximity to the equator. This mountain range defines the regions biogeography, dividing the north and south of the country and creating an altitudinal gradient (Figure 1). Species distribution data of PNG is generally poorly known (Beehler and Swartzendruber 1993; Sekhran and Miller 1995), however, some regional trends have been identified. Birds of paradise, bowerbirds, marsupials and amphibians are typically most specious on the central range (Flannery 1995; Heads 2001; Heads 2002; Heads 2002), snakes are most specious in the southern lowlands and coastal habitats of the Fly region (Heads 2002), while high diversity across multiple taxa also exists on the Huon peninsula.

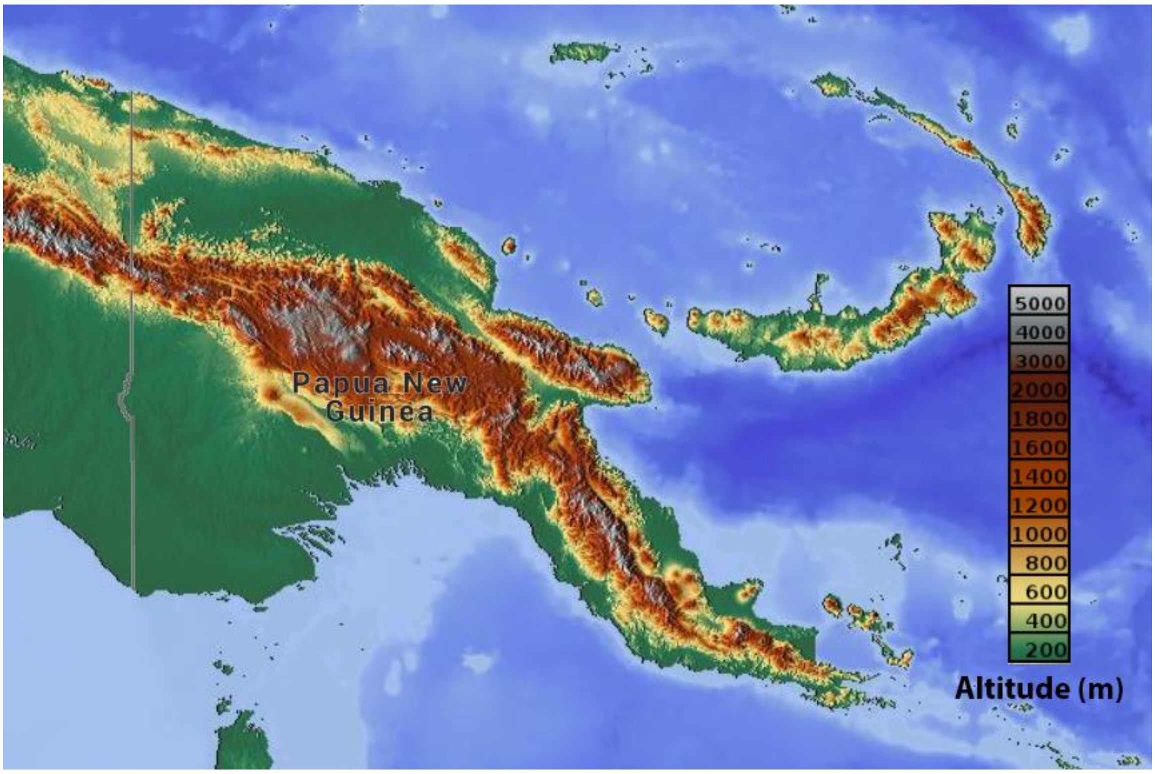


Figure 1. Terrain of PNG. Altitude in PNG is highly variable ranging from lowland savannah and forest to high altitude alpine habitats on the central range. The central range is the major geographic feature that defines PNG's biogeography; by creating an altitudinal gradient, and by separating the lowlands of the north and south.

Being in tropical latitudes, the climate in PNG is stable and warm with high rainfall of up to 10 000mm/annum making in a high proportion of rainforest except where maintained by fire (Bird, Haberle et al. 1994). The differentiation between rainforest and open habit is often a defining habitat characteristic of faunal diversity, for example PNG's bird species typically occupy forest of open habitat but seldom both (Beehler, Sengo et al. 1995; Pratt and Beehler 2015). Altitudinal variation in forest type can be divided into many categories (Sekhran and Miller 1995; Pratt & Beehler 2015), but in reality they vary across a continuum. These forests, as defined by Pratt & Beehler (2015) are: lowland rainforest, a floristically and structurally complex habitat at lower altitudes; hill forest, species rich but less diverse than lowland forest with tall emergents of *Aracauria*; and cloud forest, sitting in and above the cloud bank at altitudes above 2000 meters. At elevations above 3700 meters rainforest gives way to alpine shrubs and grassland as the altitude exceeds the snowline, which were historically lower during glacial maximums (Bowler, Hope et al. 1976). At lower altitudes and around the coast are also mangrove forest, seasonal monsoon forest, savannah and open woodland, and wetland and swamp habitats.

3. Choosing a suitable fauna biodiversity method

A strategic aim to of REDD+ activities is to reduce risk to biodiversity through prioritisation of sites with both high carbon value and high biodiversity benefit. The project aims to assess 1000 sites across PNG to gain understanding of biomass as part of a wider pilot study. To assess priority sites for conservation one would ideally obtain biodiversity measures assessing the species richness (total number of species), species diversity (type of species) and population sizes of all vertebrate species present at the site. To attain this information would require the adoption of variety of methods and assessment of the site at multiple time points. A comprehensive assessment would entail general fauna survey methods such as those used regularly in environmental impact assessments (Hyder, Dell et al. 2010). Each major group requires a variety of methods to be surveyed for effectively.

3.1 Amphibians and Reptiles

Both reptiles and amphibians are typically surveyed for using similar methods, however, the vocalisations of frog species lend themselves to acoustic methods. Reptiles and amphibians are often cryptic within their habitat and either need to be trapped or extensively searched in order to attain useful biodiversity information. Techniques most commonly used to survey for amphibians and reptiles are:

Pit fall trapping. This is a method that when used for vertebrates consists of a length of fence that directs animals towards capture devices, such as pipes, buckets and herp funnels. Recently, inclusions of downward facing camera traps have improved this method so that it records species the climb out of or are wary of pit falls. Typically, pit fall techniques are used to capture reptiles, amphibians and small mammals. Pit falling produces species diversity and population data via mark recapture studies or catch per unit effort. While being a commonly adopted method, pit falling does not necessarily provide a complete view of species present, typically biased towards specific taxa that enter traps more readily.

Active search. This consists of activities such as flipping, raking and spotlighting at night in order to find animals in their habitat. It is used primarily to capture and identify reptiles, frogs and small mammals. Compared to pit fall trapping it is a logistically simple method, however, provides species diversity data only and can be calibrated between sites in terms of unit effort (time and number of surveyors).

3.2 Mammals

Mammals are often difficult to survey due to their low density and cryptic nature. Consequently mammals are often needed to be trapped either with conventional means or with the use of remote cameras. Population estimates of more conspicuous species can be estimated using distance transects; however, the thick forests of PNG are likely to cause issues in delectability. Bats require a different set of methods to be captured, but their echolocation and social calls are unique to a species level and acoustic devices can be used to identify species in an area. Techniques most commonly used to survey for mammals are:

Cage and Elliot traps. These are baited cages or boxes triggered by a foot treadle used primarily to capture small to medium sized mammals. Capture data can be used to calculate species diversity and population data via mark recapture or catch per unit effort. Cage and Elliot trapping is a logistically demanding method which would entail approximately 50 traps per site to be opened over 3-4 consecutive nights in order to attain a high enough number of captures for population estimates to be generated.

Camera trapping. This is a method where remotely triggered cameras that can be programmed to take both still and video images are set and left in place for extended periods, normally for a period of weeks to months. Cameras are either positioned facing a cleared area, game trail or bait/lure to "capture" passing wildlife. The method is primarily used to survey for mammals, particularly species which are cryptic, low density or otherwise not easily trapped; however, the method is also useful for a variety of different vertebrate taxa. Camera traps are used to provide data on species diversity but can also be used for mark recapture studies to estimate population size for species with unique markings on individuals. When the method standardised it can also be used to attain relative measures of abundance. The method is also expensive, requiring numerous cameras per sites and large amounts of processing time to identify animals from photos.

Spotlighting transects. This method essentially distance transects conducted at night with the use of a spotlight. In the context of PNG the method would be primarily for arboreal mammals, but would also detect a variety of other nocturnal taxa including amphibians, birds and reptiles. Spotlighting transects provide data on species diversity and density when used with distance sampling calibration or proxy of unit effort with distance and time. They require numerous evenings of effort and repeat visits before species richness can be calculated due to the cryptic nature of target species.

Harp trapping and other bat capture techniques. These are manual capture techniques used specifically for microbat species. They provide data on species diversity and population data via mark recapture studies or catch per unit effort. They require numerous evenings of effort and repeat visits before species richness can be calculated due to the cryptic nature of target species and does not provide complete species coverage as the method often fails to high-flying species. The method is logistically demanding requiring multiple harps per site.

3.3 Birds

Bird survey methods use a skilled surveyor to identify birds by call and sight in the field. When conducted systematically observations can be used to generate detailed species richness and density data. Data can be collected over a short period of time, as short as a morning per site, and requires very little in terms of equipment. Birds can be surveyed for using a variety of methods, each of which has its strengths and weaknesses (Bibby, Burgess et al. 1992). Additional to conventional survey methods, birds can also be surveyed for using acoustic recorders and detailed population data can be attained through mist netting. Techniques most commonly used to survey for birds are:

Area counts. These are a standard, repeatable method that produces estimates of density and richness. In this method, the surveyor traverses a defined area of known size for an allotted time period, recording the number of each species encountered. Area counts are used frequently for Atlas protocols such as for Birdlife Australia's Atlas (Watson 2003). The variety of habitats in PNG, ranging from open grassland the closed rainforest make area counts a poor choice of method as ease of traversing and visibility will vary greatly between habitat types, biasing results.

Random walks. These are an informal protocol used solely to produce species lists. Duration of the survey is often variable and enables surveyors to freely travel an area without a predetermined route. Random walks are good for rapid accumulation of species presence data and hence species richness data. The surveyer can undertake a **MacKinnon listing technique** while undertaking a random walk. The method consists of a random walk in and around the proximity of the biomass subplots, avoiding activity from members of the biomass and flora survey teams. During the random walk the surveyor compiles a series of sub-lists where the first 10 species are in order they are encountered (Bibby 2004). Once 10 species have been identified the surveyor begins a new list (see appendix 2). Estimates of detectability and species richness can then be calculated by assessing the accumulation of species over concurrent lists. MacKinnon lists provide an independent estimate of species richness for comparison with point counts. MacKinnon lists are useful as they have been found to be a complementary method to point counts as mobile surveyors are likely to detect different species not easily identified by a stationary surveyor (Watson, Whittaker et al. 2005).

Line transects. This is a standard, repeatable method that produces estimates of both species density and richness. In this method, the surveyor follows a predetermined route, recording the number of each species encountered. Transects are either timed or time capped in order to standardise effort. Variations of the method include distance bands and distance sampling techniques in order to provide density estimates. Distance bands restrict the surveyor to a fix width either side of the transect from which birds are recorded (where transect length x strip width = area) whereas in distance sampling the surveyor records the distance to each individual (or individual group of) bird with an estimate of distance from the observer (either estimated within a band or calculated precisely, ideally with a device such as a laser rangefinder). The variety of habitats types in PNG makes line transects a poor choice of method as ease of traversing and visibility will vary greatly between habitat types, biasing results.

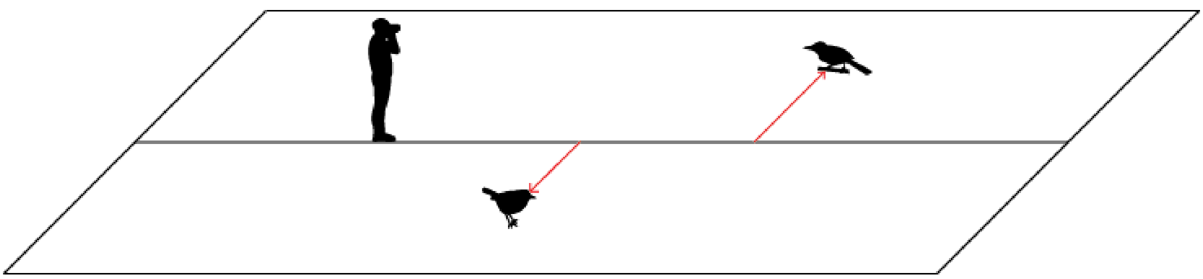


Figure 2. An example of a line transect. A method where the surveyor records all the birds they encounter along a predetermined transect. Birds are either recorded within

distance brackets, within a maximum strip distance either side of the observer, or using distance sampling (depicted) where the precise distance is recorded for each bird.

Point counts. This is a repeatable method that produces estimates of density and richness and used in many tropical countries as the standard methodology (Hutto, Pletschet et al. 1986; Bibby, Burgess et al. 1992; Bibby 2004). In essence a point count is a line transect that has no length. As such, density is estimated using the same techniques as transects (see above). Point counts are standardised to a fixed time, typically ranging between 5 and 20 minutes. They are an ideal for densely vegetated habitats where ease of traverse and detectability is low. A stationary observer is both advantageous as it reduces disturbance to birds and a disadvantage as the surveyor cannot use their movement to flush and record fleeing birds.

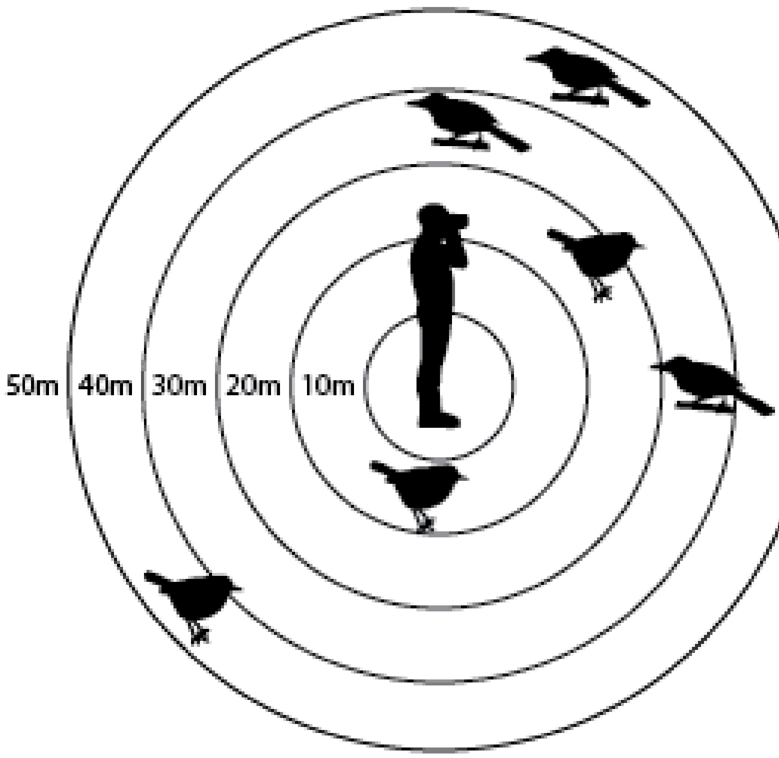


Figure 3. An example of a point count. A surveyor remains at a set point and records all birds encountered within a predetermined time frame. Here a distance bracketed method is depicted, where they surveyor records the distance to each bird or group of birds in 10 meter brackets. Recording distance information enables us to determine differences in detectability for each species at each site.

Catching and marking techniques. These are a standard, repeatable method that produces estimates of density and richness. They are ideal for long term monitoring as they provide detailed information about condition and population demographics, however are often biased towards specific community types (Wang and Finch 2002) and identify a relatively small proportion of species richness (Whitman, Iii et al. 1997; Wang and Finch 2002) compared to point counts. Catching and marking techniques are logistically demanding, labour and time intensive, and require the highest level of skill of the surveyor of any method. As such they are typically unsuitable for rapid assessments.

Acoustic monitoring. This is a relatively new survey method that utilises an acoustic recording device to generate a permanent record of calls at the study site. The method capitalises on the unique vocalisations of each species as an identifying characteristic (something surveyors already currently rely on in the field) and can be also used be used for bats and amphibians. Acoustic recorders are left at a site to record data for periods of few minutes to several months which is then collected and analysed using computer software. Current methods for analysis typically involve a skilled birder identifying the calls from a subset of the recording (Wimmer, Towsey et al. 2010; Truskinger, Towsey et al. 2015); however, as pattern recognition software improves it is likely that this process will become automated. While techniques are currently being developed to estimate density from acoustic data (Lambert and McDonald 2014), they cannot be broadly applied, making acoustic monitoring a species richness only method.

3.4 Why birds are the most appropriate surrogate taxon

A comprehensive vertebrate fauna assessment would entail the adoption of all of the above methods. Each site would require 4-7 days to survey effectively and need to be visited on numerous occasions (Hyder, Dell et al. 2010). Such a task would require a large number of independent fauna assessment teams and a large amount of equipment. Without a significant investment in training and building local capacity such a survey is clearly not possible. As the fauna survey teams are to be embedded with the existing project team who are conducting vegetation and biomass surveys and each site will be visited on a single occasion and only for 1-2 days, we propose the adoption of birds as a surrogate taxon for biodiversity assessment.

4. Proposed rapid survey protocol

4.1 Recognised Study Limitations

By coupling bird surveys to the existing biomass and flora surveys the methods are subject to a series of limitations. The most significant of which is the limitation of a single visit. Good estimates of species richness typically require in excess of 300 minutes of survey effort (Watson 2004), spread over numerous visits. Furthermore, the presence and abundance of birds varies in time and space (Holmes and Sherry 2001;

Maron, Lill et al. 2005). Typically, multiple visits are required to generate a good understanding of the populations and richness of species that utilise a site. Monthly visits over the course of a year are a reasonable amount of effort seasonal variability; however, several years of regular surveying is required to determine the true richness of species that occupy a site (Watson, Whittaker et al. 2005). Seasonal variability can be controlled for by visiting a site numerous times over the same seasonal period for all of the sites in the study; however, this would restrict biomass surveys to a dramatically shortened timeframe. A single visit with surveys conducted throughout the year limits any data to representing a snapshot of the sites richness (Fuller, Trevelyan et al. 1997) and prevents the ability to control for seasonal influences at an experimental level. It should be noted that this statement is true for all faunal groups and is not an inherent weakness as birds as a metric over alternative taxa.

Other limitations include increased disturbance at the site from the simultaneous presence of other people. This effect can be reduced by conducting bird surveys when other team members are away from the bird surveyor by ensuring on-site surveys are conducted early in the morning before the biomass and floral team have commenced work. Once on-site work has commenced bird surveys should take place in adjacent habitat and not in the proximity of other workers to avoid this bias.

4.2 Proposed Survey Protocol

We propose a survey protocol that utilises a series of complementary methods designed to collect best quality data within the existing limitations (Figure 4.). This survey protocol provides estimates of density, species diversity and species richness at the site for the given survey period. Our methods for species richness are also appraisable , meaning that the data collected can be used to estimate how comprehensive the species list is by looking at the change in rate of species accumulation with effort (LlorenteB 1993; Ugland, Gray et al. 2003; Colwell, Mao et al. 2004). Our survey protocol also requires minimal equipment, making access to walk in sites easier. These methods are:

A series of 10 minute, distance bracketed point counts. The surveyor will conduct up to 10 counts between the period 0-3 hours after sunrise for at least one morning. The points will be predetermined and positioned at minimum of 100 meters apart. The point counts should overlap any flora surveys and carbon inventories sites that are being conducted (but not at the same time). The surveyor will count and record the number of all species identified by sight and call as well as their distance (in 10 meter brackets, see Figure 3) from the observer (see appendix 1). Bracketed distance sampling is the most appropriate method for high density vegetation and most suitable for PNG. We have chosen this method as it provides a repeatable estimate of density and richness. The richness estimate is also appraisable by using the change in rate of accumulation over concurrent point counts.

MacKinnon lists are to be compiled each afternoon between the period of 3-0 hours before sunset for at least one afternoon. The method consists of a random walk in and around the proximity of the biomass subplots, avoiding activity from members of the biomass and flora survey teams. During the random walk the surveyor compiles a series of sub-lists where the first 10 species are in order they are encountered (Bibby 2004). Once 10 species have been identified the surveyor begins a new list (see appendix 2). Estimates of detectability and species richness can then be calculated by assessing the accumulation of species over concurrent lists. MacKinnon lists provide an independent estimate of species richness for comparison with point counts. MacKinnon lists are a complementary method to point counts as mobile surveyors are likely to detect different species not easily identified by a stationary surveyor (Watson, Whittaker et al. 2005). Including the afternoon period also provides an opportunity to survey for species active at different times of the day and maximises time spent collecting data. The combination of point counts and MacKinnon lists have been shown to be a powerful, cost effective method for rapid assessments (O'Dea, Watson et al. 2004) and therefore an ideal combination for the study needs.

Acoustic monitoring boxes. If financing enables this, we believe placing acoustic monitoring boxes will be invaluable as it creates a permanent record of calls that can be reviewed at will, maximising on the short time spent at the survey site. Recorders are to be set up as soon as reaching site and taken down just before leaving. For maximum effect, recorders must be set up for at least one dawn chorus and a full 24 hour period. Recordings are to be used to create an independent species richness list, but more importantly are to be used to assess the skill of each surveyor by providing an alternative site list as a comparison. This is critical as there is otherwise no potential for calibration between surveyors as each site will only be visited on a single occasion and by a single surveyor.

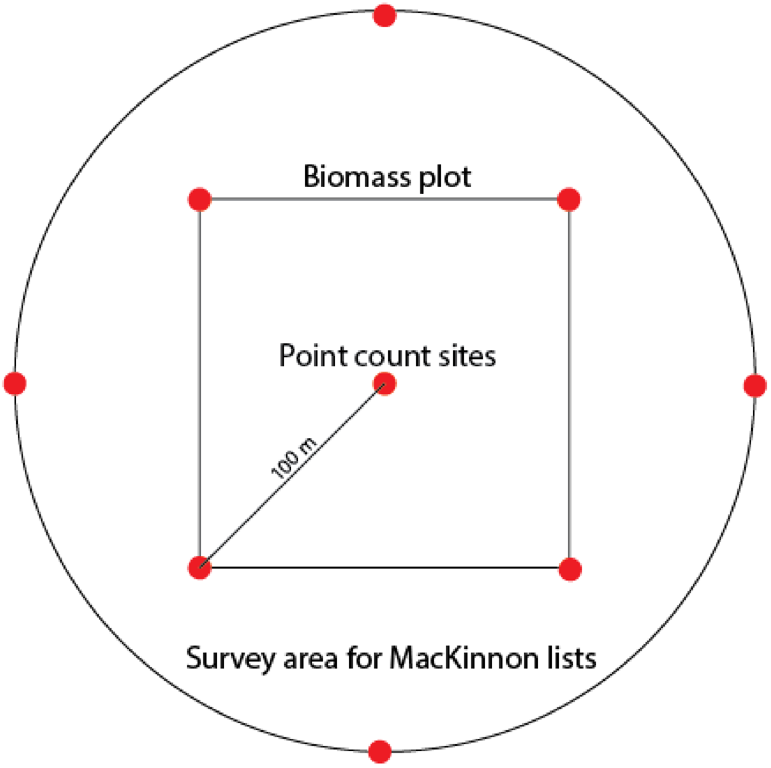


Figure 4. Site survey design. Where the box depicts the biomass plot, the red circles depict point counts and the black circle depicts the vicinity in which MacKinnon lists can be made. The surveyor travels to as many point counts as the terrain permits up to three hours after dawn and compiles MacKinnon lists in the afternoon season starting from 3 hours before sunset. The surveyor is to collect data from the central point count first, so to avoid biomass and flora teams who will be on site later in the day.

4.3 Pilot Study

It is likely that unforseen limitations will not be realised until surveys have commenced and that minor refinements to this method will improve data quality and practicality. As such, a short pilot study or review of the methods after a small number of surveys have been conducted is advisable. Should potential arise for follow up visits in the future, the existing survey protocol has been accordingly designed to be repeatable. Conforming to the protocol for follow up visits is critical for making the most out of the existing data. Follow up visits would open opportunities for camera trap surveys (primarily for mammals) and further acoustic monitoring, which should be investigated if the situation arises.

4.4 Materials and personnel

An expert surveyor familiar with the bird species in the region will be required for each survey crew. Given the likely extended duration of the surveys and likely scarcity of experts, expert surveyors should be utilised to train potential future surveyors to reduce potential of personnel shortages throughout the project. Members of each crew should be equipped with binoculars, a field guide (Pratt and Beehler 2015) and a device with a copy of call recordings. Clothing colour is known to influence bird behaviours such as distance to flush (Gutzwiller and Marcum 1997) and consequently can become a source of bias in surveys. As such surveyors are to wear clothes of neutral natural colours, such as olive, brown or khaki. Ideally, standard field apparel should be worn by all bird surveyors. The inclusion of 1-3 acoustic recorders for each team provides a large return in data for a relatively small investment in equipment. As the calls of PNG's birds have not been comprehensively documented, the inclusion of a shotgun microphone and recorder for each crew will help enable surveyors to record bird calls in the field so to improve this resource, which will in turn help improve future surveys. An example of the survey sheet used for recording data in the field is provided in the appendix 1 and 2.

5. Proposed Data Management

Over the span of 1000 sites our protocol will produce a large volume of data, in excess of 10 000 distinct lists. State of bird knowledge in PNG relative to other countries is poor (Beehler and Swartzendruber 1993; Sekhran and Miller 1995) and to date no Atlas style census program has been undertaken in PNG. Furthermore, citizen science programs such as eBird, an online data collection portal (http://ebird.org), have only generated sparse records of approximately 4000 eBird lists.

The data from this study would easily double the number of lists for the country and act as essentially the first complete atlas of birds of PNG. Given the current lack of knowledge of birds in PNG it is also important that this data is made open access so it can be used for a variety of strategic conservation planning problems (Faith, Walker et al. 2001) beyond the REDD+ ACTIVITIES+ program such as contributing to the planning of protected areas as part of obligations under the Convention for Biological Diversity (Ref to CBD) and contributing to the IUCN species and ecosystem Red List (Baillie, Hilton-Taylor et al. 2004; Rodrigues, Pilgrim et al. 2006). Entering this data will be a time consuming exercise and efficiencies need to be found in the way the data in managed. While a purpose built database could be made, existing infrastructure such as the creation of a custom eBird portal would provide both the capacity for efficient data entry and open access. The fee incurred is anticipated to be in the vicinity of US$10 000 (a quote for the finalised protocol can be provided upon request) for the creation of a custom eBird portal will be easily justified by time saved in the development of a data portal and time saved in data entry. Also, eBird is a state of the art electronic database (Kelling, Gerbracht et al. 2012; Sullivan, Aycrigg et al. 2014) with inbuilt data management and vetting devices that would not be available from the likes of a purpose built Access database. It would also prevent the need for double handling of data to be later formatted for an open access database. The data would also be hosted on eBird servers providing a backup and additional security against loss.

6. Possible Analysis and Application

The data collected from our survey protocol will be used to generate three different metrics that can be used to understand what is happening at site and habitat level. These three metrics are:

Species richness describes the total number of species that occupy the site. Richness will be used as a as the primary indicator of the condition of the site. Different habitats are likely to have different intrinsic species richness's. Comparisons in richness between habitat types can only be made after the data is correct for with habitat data collected by the flora and biomass teams. Site richness can be calculated two different ways. Species richness can be calculated by pooling all species identified from point counts, MacKinnon lists, acoustic boxes and other incidentals into an aggregated list. However, this is likely to be a subset of the total species richness at a site, as not all bird species will have been identified during the survey period. By using accumulative survey methods (concurrent point counts and MacKinnon lists), we can create a species accumulation curve (Figure 5) and predict actual species richness for the site and the proportion of species identified (Gotelli and Colwell 2001).

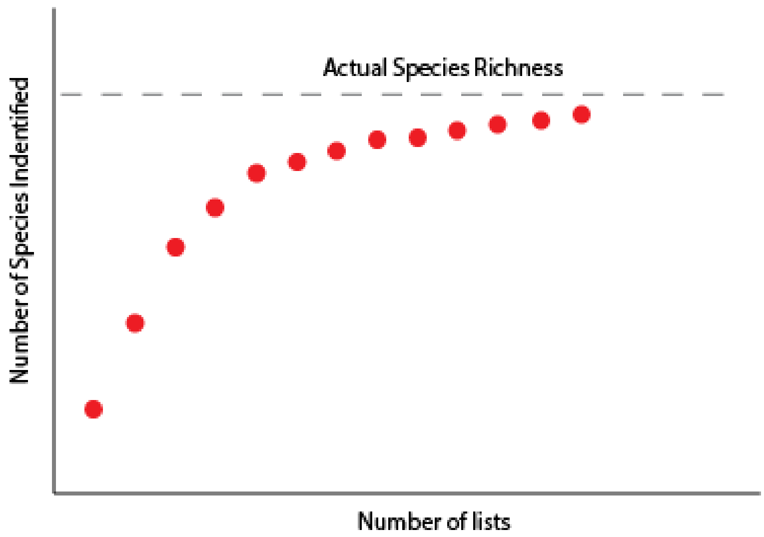
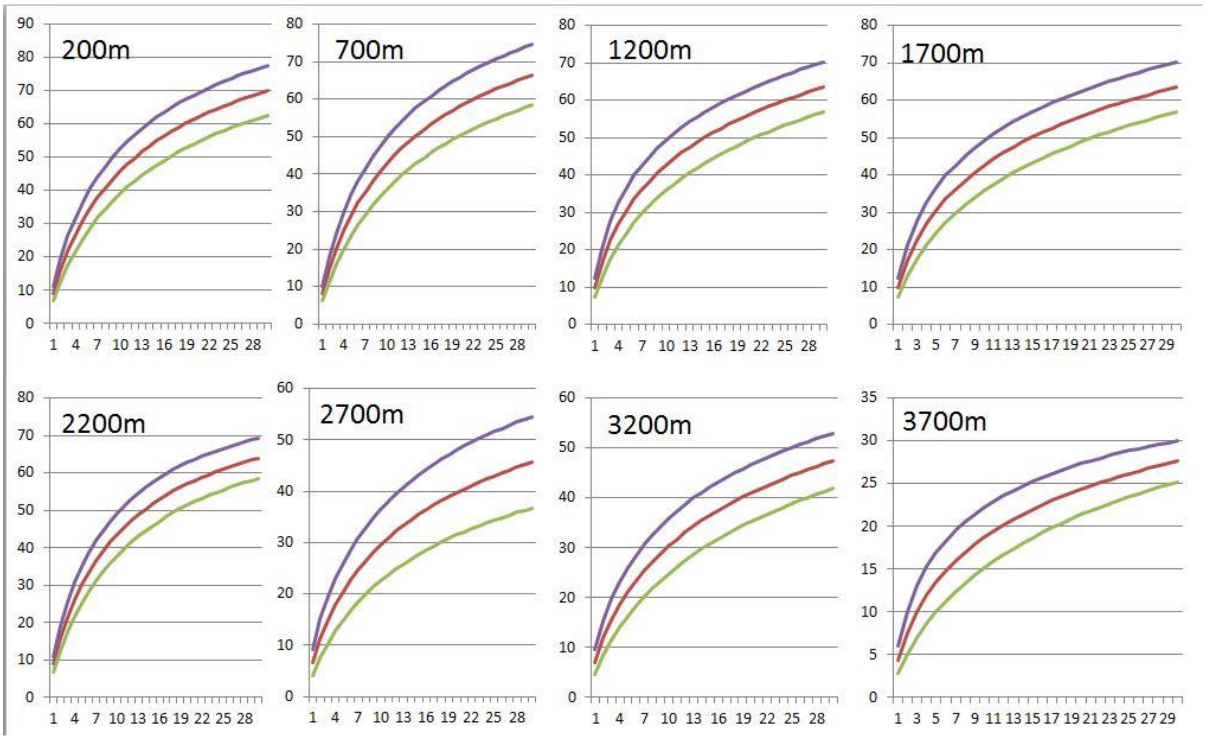


Figure 5. An example of a species accumulation curve. Each survey conducted provides a more complete understanding of the sites richness and diversity. With each additional survey the rate of accumulation slows as the known richness approaches actual richness. This curve varies depending on the total number of species and detectability and therefore must be calculated for each site. Modelling this curve for each site enables us to determine where on the curve the known total lies and estimate the actual value of richness at the site.



Species diversity describes the suite of species that occupy a site. The type of species that occupy a site can be used as a habitat and condition explanatory variable as well as an identifier for potential threat types that occur at the site (Bowman, Woinarski et al. 1990). This can be calculated this by pooling all species identified from point counts, MacKinnon lists, acoustic boxes and other incidentals into an aggregated list. Birds as a group do not always make good indicators, however, individual species of bird can (Sushinsky, Rhodes et al. 2013). The presence/absence of a species at a site can be used to indicate condition and the presence of threat types (Carignan and Villard 2002). Through our analysis we will identify potential candidates for indicator species.

Abundance/density estimates can be used to provide finer resolution of habitat condition and threats than diversity when using indicator species (as discussed above). Density estimates will be calculated uses the data from point counts. Density is estimated by comparing the number of birds seen at each distance bracket from the observer (Figure 6). Changes in each bracket are used to estimate the change in detectability with distance from the observer, which feeds back into density estimates for the species.

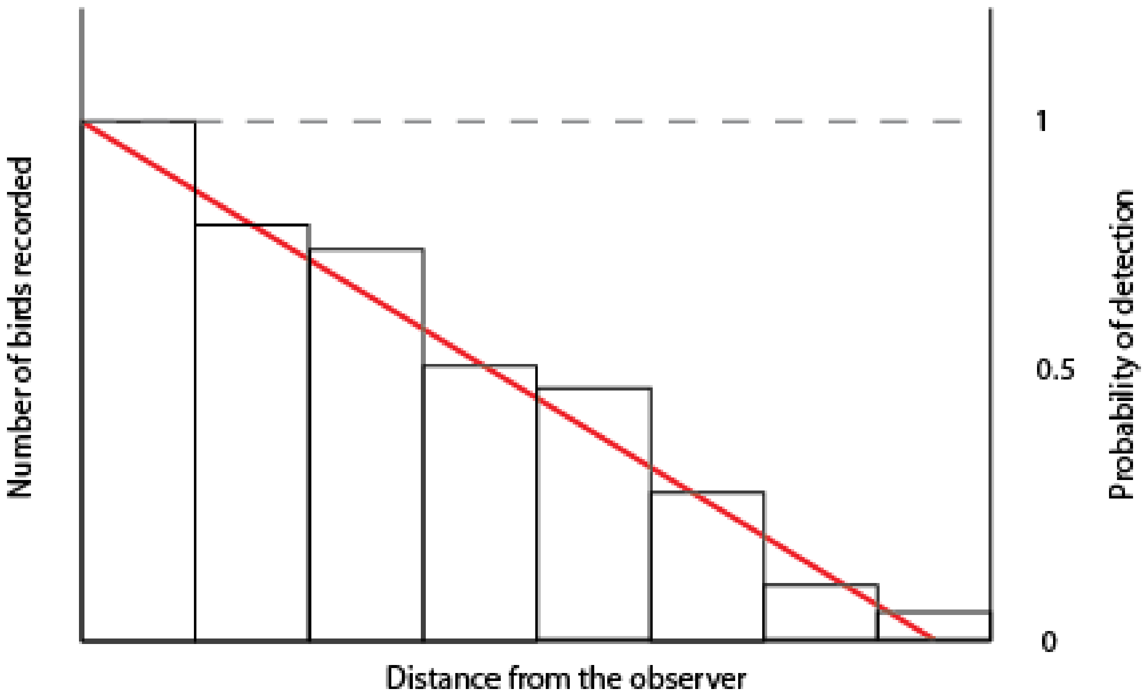


Figure 6. Depicts change in detection probability with distance, where the black bars depict the number of birds observed at each distance bracket and the red line depicts the modelled detection probability. The modelled detection probability is then use to calculate the density of said species at the site.

We propose that analysis will be conducted in partnership with the UQ Environmental Decisions Group as they have the resources and expertise to for this type of analysis.

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8. Appendices

Appendix 1.

10 minute Point count

Site ID		**Date**	
Surveyor		**Start time**	
Comments			

Species	**Detected**	**Site use**	**Distance from observer (m)**							**Notes**
	S/SH/H	**P/F/FO**	**0-10**	**11-20**	**21-30**	**31-40**	**41-50**	**51-100**	**100 +**	

Appendix 2.

MacKinnon list

Site ID		**Date**	
Surveyor		**Start time**	
Comments			

Time		**Time**	
	Species		**Species**
1		**1**	
2		**2**	
3		**3**	
4		**4**	
5		**5**	
6		**6**	
7		**7**	
8		**8**	
9		**9**	
10		**10**	
Time		**Time**	
	Species		**Species**
1		**1**	
2		**2**	
3		**3**	
4		**4**	
5		**5**	
6		**6**	
7		**7**	
8		**8**	
9		**9**	
10		**10**	
Time		**Time**	
	Species		**Species**
1		**1**	
2		**2**	
3		**3**	
4		**4**	
5		**5**	
6		**6**	
7		**7**	
8		**8**	
9		**9**	
10		**10**	