Toward a standardized protocol for rapid surveys of terrestrial bird communities

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CORE STANDARDIZED METHODS

FOR RAPID BIOLOGICAL FIELD ASSESSMENT




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BIRDS

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TOWARD A STANDARDIZED PROTOCOL FOR RAPID SURVEYS OF TERRESTRIAL BIRD COMMUNITIES

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Introduction

Birds are found on all continents, throughout the oceans, and in virtually all terrestrial and aquatic habitats – there are few places on Earth where birds do not regularly occur. They play important roles in many ecosystems and contribute to ecological processes such as pollination, seed dispersal, and biological control (e.g. Şekercioğlu 2006). Some species are important to local indigenous communities as sources of protein, contributing to food security. Recreational bird watching is a rapidly growing sector of the international tourism industry, and tourism revenue can provide an important contribution to local and regional economies. Tens of thousands of recreational birdwatchers have also become citizen scientists by uploading their observational records to global (e.g. eBird) and national (e.g. WikiAves) open access online portals and data sharing networks.

Birds are ideal subjects for rapid biodiversity surveys. They are perhaps the best known group of organisms in terms of their taxonomy, biology, ecology, biogeography, and conservation status. Most species are diurnal and easy to identify under field conditions relative to other taxonomic groups, and nearly complete species lists can be produced during a rapid survey. The limited time and effort required for post-survey data processing allows for rapid data analysis. Birds are amenable to a variety of standardized survey methods (Bibby *et al*. 2000) and are highly cost-effective to sample (Gardner *et al*. 2008, Kessler *et al*. 2011). They are widely recognized as indicators of ecological integrity due to their habitat specificity and rapid responses to human impacts from local to regional scales (e.g. Furness and Greenwood 1993, Niemi and McDonald 2004). The global conservation status of all species is updated at regular intervals and many represent species of conservation concern (13% of extant species; BirdLife International 2013). Consequently, priority areas for biodiversity conservation have often been identified largely based on birds (e.g. the Endemic Bird Area – EBA – and Important Bird Area – IBA – frameworks of BirdLife International).

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A variety of resources exist to facilitate the identification of birds by both sight and sound. A similarly wide range of methodological approaches have been developed to count birds and quantify abundance and community composition (Bibby *et al*. 2000). However, not all of these approaches are suitable for rapid surveys because they are too time- or labor-intensive. In addition, different rapid assessment surveys have used different methods, limiting the comparability of results across surveys. The scope of this chapter therefore is to recommend a core set of standardized sampling protocols for rapid assessments of terrestrial bird communities that can be applied under most conditions worldwide.

General Approaches to Surveying Birds

Established methods can be broken down into four general categories: (1) audiovisual methods; (2) sound recording (acoustic documentation); (3) mist netting; and (4) specimen collecting. Strengths and caveats of these methods are summarized in Table 1. The most commonly used audiovisual methods in the tropics are point counts, line transects, and the species-list method (e.g. Poulsen *et al*. 1997, Fjeldså 1999, Haselmayer and Quinn 2000, Herzog *et al*. 2002, 2005, Söderström *et al*. 2003, O'Dea *et al*. 2004, Abrahamczyk *et al*. 2008, Clough *et al*. 2009, MacLeod *et al*. 2011), owing their popularity to time- and cost-effectiveness. Sound recording is an integral part of these methods, as it provides documentation of a large number of species, and enables analysis and identification of unknown vocalizations after surveys are completed. In many tropical environments, especially forest habitats, most bird species are much more often heard than seen. The recent development of automated sound recording technology (Brandes 2008) is likely to lead to an increased use of autonomous recording stations as a stand-alone method for documenting and monitoring tropical bird communities.

Mist nets were widely used during past decades for both bird surveys and specimen collecting, especially before the advent of modern field guides, affordable, portable sound recording equipment, and online audio reference libraries. Their time- and cost-effectiveness is considerably lower than that of audiovisual methods, and they are subject to a variety of biases, such as net avoidance, weather, habitat structure, and behavioral differences between species and among individuals of the same species (e.g. Jenni *et al*. 1996, Remsen and Good 1996). Nonetheless, under certain circumstances they should be considered as a supplemental method (see below). Specimen collecting is even more labor intensive than mist net surveys and therefore rarely suitable for rapid assessments. We assert, however, that there is a continued need for specimen collecting, especially in the tropics, where new species to science are still being discovered regularly. In regions poorly explored by ornithologists, specimen collecting is an essential tool to reveal cryptic biodiversity and document newly discovered taxa.

Core Standardized Methods

The most cost-effective way to survey the greatest proportion of bird species in a short period of time is to use a combination of audiovisual methods and sound recording. This combination of methods must also be sufficiently rigorous for comparative analysis and flexible enough to be adapted to specific conditions of different regions and ecosystems. Here we propose a set of efficient survey protocols that comply with these general prerequisites. We do not provide in-depth descriptions of particular methods and expect readers to have prior experience with these techniques (see Bibby *et al*. 2000 for detailed treatments).

Among audiovisual methods, 50-m radius point counts probably are the most widely used approach; points can be placed flexibly in any habitat type, are easily and precisely georeferenced, and their results can be analyzed quantitatively with a variety of robust parametric statistical techniques.

The 10-species or MacKinnon list technique is a rather new audiovisual method first proposed by MacKinnon and Phillipps (1993) that has been further developed since (e.g. Poulsen *et al*. 1997, Herzog *et al*. 2002, MacLeod *et al*. 2011). It is the logistically most flexible method but has limitations with respect to statistical analyses. Unlike point counts, consecutive 10-species lists are not necessarily spatially independent, and there is a greater probability of counting the same individual more than once. This method does allow, however, for estimation of relative abundances of species (and it is particularly suited for comparing abundances of the same species across sites; Herzog *et al*. 2002, Herzog 2008), and it is relatively robust with respect to potential observer biases and differences in experience (Fjeldså 1999, MacLeod *et al*. 2011). It also explicitly encourages the extensive use of sound recording (Herzog *et al*. 2002). Statistical analyses essentially are limited to construction of species accumulation (rarefaction) curves, both individual- and sample based, and curve extrapolation with confidence intervals (see Colwell *et al*. 2012), as well as the use of species richness estimators and similarity indices (Colwell 2013). Nevertheless, given that the main goal of rapid assessments often is a provisional estimate of overall species richness, relative abundances, and community composition, 10-species lists are an appropriate core survey method.

The importance of sound recording for documentation purposes and later identification of unknown vocalizations has already been mentioned. In addition to opportunistic sound recordings, standardized use of this method is crucial, particularly during the dawn chorus, at which time the greatest number of species vocalize almost simultaneously. In particularly species-rich habitats, the sheer diversity and abundance of sounds at dawn is likely to overwhelm even the most experienced observers. Obtaining clear recordings of the dawn chorus is the most efficient way to document the greatest possible number of species in most habitats.

Combining Core Methods into a Coherent Survey Protocol

Because each method has its own strengths, shortcomings, and biases, we recommend a combination of all three to generate robust, comparable data sets given the inherent constraints of rapid surveys. Note that the three core methods vary substantially in the required minimum level of observer expertise and experience with a given avifauna. Dawn chorus sound recording per se requires the lowest level of expertise and experience, and, although not ideal, vocalizations can be identified entirely by an expert after the survey is completed. 10-species lists are relatively robust with respect to potential observer biases and differences in experience, but do require at least intermediate knowledge of a given avifauna. Point counts, on the other hand, require high levels of expertise and experience and clearly is the most demanding of the three methods. In addition, in highly diverse tropical habitats they generally detect the lowest proportion of species and are the least amenable to comparisons of results among observers.

Dawn chorus recordings. We recommend conducting two to three 15-min stationary dawn chorus recordings each morning starting with the first vocalizations of diurnal bird species. Minimum distance between recording stations should be 200-250 m. Different stations should be sampled each morning. All stations must be georeferenced using GPS units. To standardize the recording procedure, we suggest the following protocol. Recordings should be made using a directional shotgun microphone (such as the Sennheiser ME-66) held at an angle of 20° above the horizontal or ground level in forest habitats (Haselmayer and Quinn 2000) and 0-10° in low-stature habitats such as grass- and scrubland. At the beginning of each recording the microphone should be pointed in the direction of greatest vocal activity; microphone direction is then rotated by 90° every 60 seconds until two full circles are completed after eight minutes. For the remaining seven minutes, microphone direction and angle may be changed at will to record newly vocalizing species, or to obtain clearer, louder documentation of species whose vocalizations may have been captured poorly during the first eight minutes of the recording.

Point counts. Following dawn chorus recordings, we recommend conducting 10-min (Fig. 1), 50-m radius point counts in early to mid-morning; stopping time will depend on bird activity, which varies with weather, season, and habitat. Minimum distance between point count stations should be 200-250 m; this is the maximum distance at which most forest bird species can be detected acoustically, and ensures spatial independence between points when a 50-m count radius is used. The same stations used for dawn chorus recordings may also be selected for point counts, provided they meet the minimum distance criterion. All birds heard and seen within 50 m of each point should be counted, and sex and age class noted if possible. If time permits, each station should be visited twice on different days at different times of the morning. We do not recommend estimating distances to unseen birds in tropical forest, due to the known incidence of high observer bias in distance estimates and the many variables affecting sound transmission through forest, which often make birds appear much closer or farther away than they actually are.

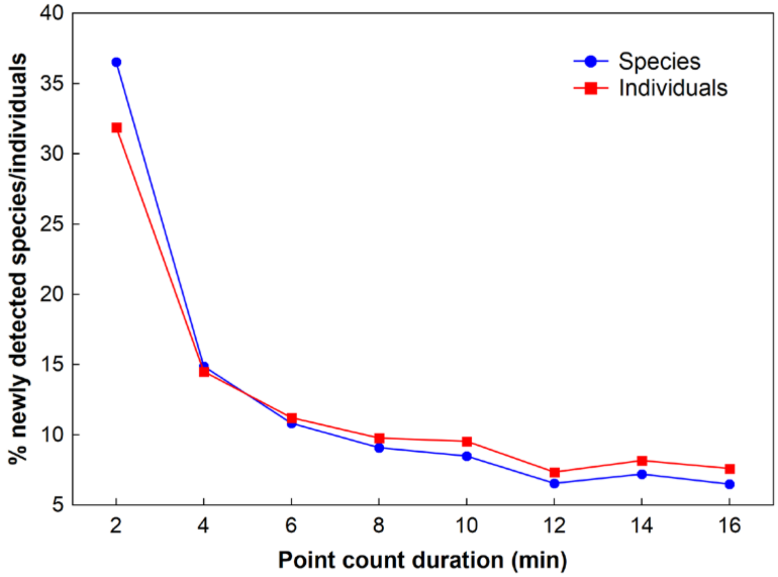

Figure 1
Percentages of newly detected species and individuals with increasing point count duration for eight 2-min intervals in semi-deciduous foothill forest of the central Bolivian Andes (dpto. Santa Cruz, Refugio Los Volcanes: 18°06'S, 63°36'W, 1000-1200 m; S.K. Herzog unpubl. data). Values are means of 172 counts (50-m radius) conducted at 12 stations between March 2003 and January 2004. The total number of detections per 16-min count ranged from 4 to 25 species (mean ± SD = 15.6 ± 4.6) and 7 to 48 individuals (mean ± SD = 24.7 ± 7.7). New species and individuals still were detected even during the last 2-min interval, but detection rates leveled off after 10 minutes for both species and individuals. On average, 80% of all species and 77% of all individuals detected during the entire 16-min point count were observed within the first 10 minutes.

10-species or MacKinnon lists. All individuals heard and seen between dawn chorus and point count stations as well as afterwards should be noted in consecutive order. A digital voice recorder (dictaphone) should be used during surveys and observations transcribed daily to a field note book outside survey hours. Species-list surveys should be carried out until at least mid-day to include peak hours of mixed flock activity. Stopping time will depend on bird activity, which varies with weather, season, and habitat. Surveys should be resumed in mid- to late afternoon until dusk. On at least 2-3 days per site, species-list surveys should also be conducted 1-2 hours prior to dawn and after dusk to detect nocturnal species. Detailed instructions for species-list surveys are given in Herzog *et al*. (2002), but some key considerations should explicitly be covered here. As with point counts, observations at distances of >50 m should be noted but excluded from analysis. It is crucial that provisional names be assigned to species not confidently identified by sight or sound at first (and later replaced with definite identifications). Ten-species lists should not actually be compiled in the field, but only later during data analysis and after all sound recordings have been reviewed and identified, so that birds recorded can be incorporated into the species lists. When longer time periods are spent in one spot or when resampling a given section of the study area, repeated counts of known territorial individuals should be avoided.

Obviously, it will occasionally be difficult to determine whether a bird has already been counted; when in doubt, it is best to adopt a conservative approach and omit a given observation from the analysis.

Data obtained during dawn chorus recordings and point counts can be combined with those produced by the species-list surveys per se to construct 10-species lists for the entire data set procured during a rapid assessment (see Fig. 2). All individuals detected by the three methods are simply listed in consecutive order and then broken down into 10-species lists, followed by the construction of species accumulation curves (sample-based rarefaction). These curves may also be constructed without dividing the total list of accumulated individuals into sub-lists (individual-based rarefaction). For dawn chorus recordings, in some cases it might be difficult to determine the total number of individuals when multiple individuals of the same species are vocalizing. In such cases, only the incidence (presence or absence) of each species on each 10-species list may be used for analysis (sample-based incidence data). Data can further be analyzed separately for each method, including both rarefaction curves (Fig. 3) and, in the case of dawn chorus recordings and point counts, parametric statistical comparisons between habitats or different rapid assessment localities.

The free software EstimateS (Colwell 2013) is readily available for rarefaction, curve extrapolation, and the computation of species richness estimators and similarity indices. Relative abundances of species of conservation concern and other key or indicator species can also be compared between habitats and localities for each method individually or the combined species-list data set (e.g. Herzog 2008, MacLeod *et al*. 2011). Sound recordings should be archived in a publically accessible repository or sound library (e.g. xeno-canto, Macaulay Library, British Library of Wildlife Sounds) so they are available for comparison and verification, contributing to an ever-increasing volume of available reference material.

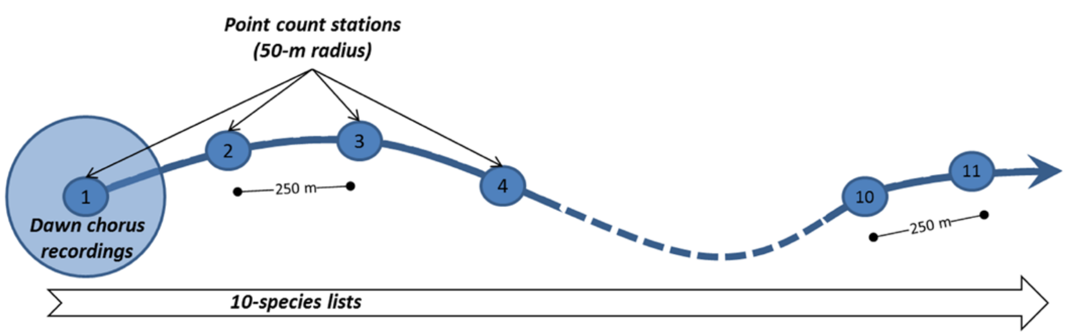

Figure 2
Schematic illustration of the combination of the three core methods into a coherent survey protocol. Daily surveys start with two to three 15-min stationary dawn chorus recordings followed by 10-min point counts until about mid-morning. All individual birds heard and seen between dawn chorus and point count stations as well as afterwards are noted in consecutive order, using opportunistic sound recording as deemed necessary. Data obtained by all three methods can then be combined to construct 10-species lists for the entire data set: all individuals detected are simply listed in consecutive order and then broken down into 10-species lists.

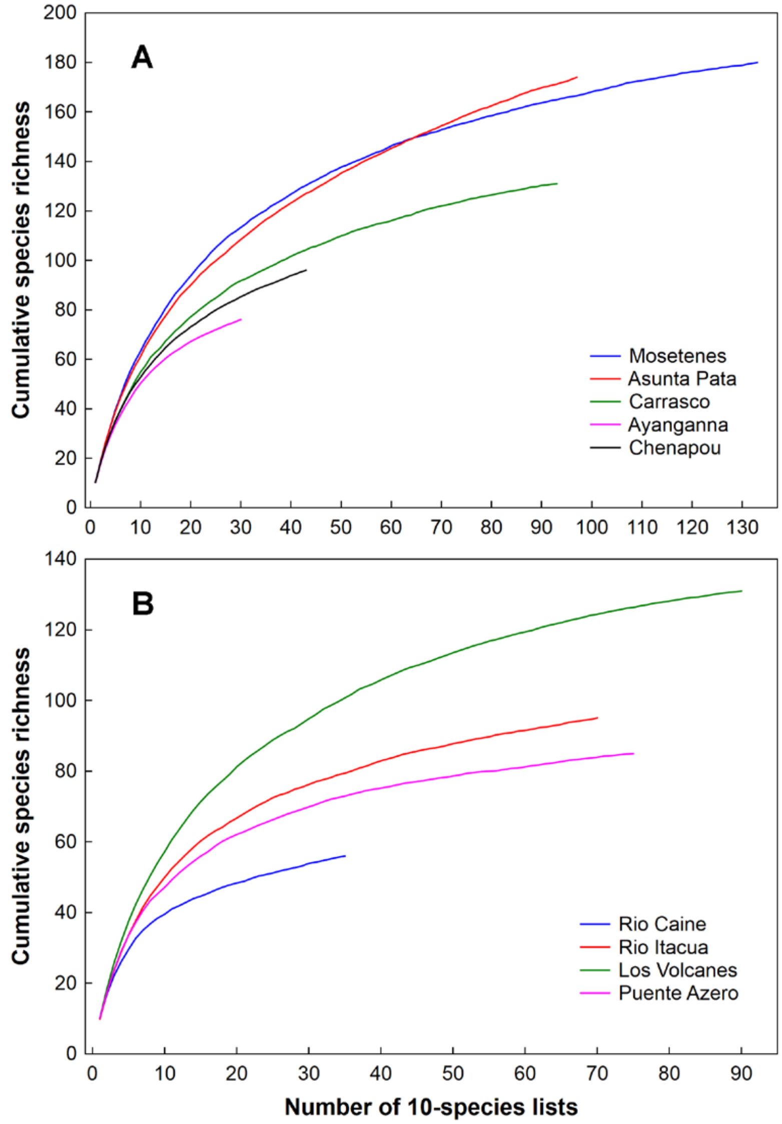

Figure 3
Examples of species accumulation (rarefaction) curves based on samples obtained by the 10-species or MacKinnon list technique. A: humid tropical forest localities in the northern Bolivian Andes (Mosetenes: 16°14'S, 66°25'W, 1180-1600 m; Asunta Pata: 15°03'S, 68°29'W, 1150-1500 m; Carrasco: 17°08'S, 65°35'W, 1180-1600 m; Herzog 2008) and on the Potaro Plateau in Guyana (Ayanganna: 05°18'N, 59°50'W, 700 m; Chenapou: 05°01'N, 59°38'W, 480 m; B.J. O'Shea unpubl. data). B: tropical drought-deciduous forest localities in the southern Bolivian Andes (Río Caine: 17°58'S, 66°51'W, 2100-2600 m; Río Itacua: 19°54'S, 63°31'W, 850-1000 m; Refugio Los Volcanes: 18°06'S, 63°36'W, 1000-1350 m; Puente Azero: 19°39'S, 64°03'W, 1100-1400 m; Herzog and Kessler 2002).

Sampling Effort and Site Selection

Before starting to survey birds, it is very important to consider habitat heterogeneity (spatial variations in topography, vegetation structure, and microhabitats within the same general habitat type) and diversity (total number of general habitat types) in the overall survey area. If possible, every general habitat type should be surveyed and analyzed separately to ensure comparability between different assessment sites with different degrees of habitat diversity. Ideally, habitat diversity along with the extent and spatial distribution of different habitat types should be determined beforehand using satellite images.
A single well-trained and experienced surveyor will often be sufficient to conduct rapid assessments with the combination of core methods outlined above. For particularly species-rich regions and habitats, however, a total of two surveyors are recommended.

Minimum survey effort will vary substantially between regions and habitats depending on overall species richness. We recommend a minimum number of ten point count stations in any type of habitat to account for natural and stochastic variability in the environment, and this sample size will usually be sufficient in areas with relatively few species, such as high elevation environments. In exceptionally species-rich environments, such as Amazonia and the eastern Andean foothills where several hundred species can be crowded into an area as small as 100 ha, ten point count stations will be insufficient. For such environments we recommend the use of at least 30 point count stations per habitat type. Elsewhere, 20 point count stations will probably suffice for most habitat types. Such numbers of point count stations require a fairly extensive trail system to ensure spatial independence between points. These considerations need to be taken into account when makeshift trail systems are established specifically for rapid surveys.

If available trail systems are inadequate, topography is highly complex, and/or the distribution of different habitat types is patchy at a fine spatial scale (e.g. patches of less than 300-400 m in diameter), point counts may not be an appropriate survey method. In these cases we recommend applying only sound recording and 10-species lists.

Establishing minimum recommended sampling effort for 10-species lists is less straightforward than for point counts. A 10-species list is defined neither by time nor space. Detecting ten different species may be accomplished in as little as 30 seconds, or it may take 30 minutes or even longer, depending on overall species richness at a site, season, weather, time of day, and observer skill, among other factors. As the main method for analyzing 10-species list is the construction of species accumulation curves, the number of newly detected species each day should be determined in the field as an approximation of sampling completeness. Computationally simple species richness estimators such as Chao 1 can also be used in the field for this purpose (Herzog *et al*. 2002). Overall, based on our experience in the Neotropics, three days of intensive species-list surveys by a single observer should be sufficient in areas with relatively few species such as high-elevation environments, whereas exceptionally species-rich environments may require as many as 8-10 days to record about 80% of the resident species.

A final consideration in mountainous areas is the elevational range covered by a survey. The greater the range, the stronger the influence of elevational species turnover on the number and proportion of species detected. Analogous to surveying different habitat types separately, different elevational zones in areas with wide gradients should be treated as separate habitats. We consider a range of 200-300 meters as a reasonable maximum for separating habitats by elevation.

Supplemental Methods

Line transects, in the strict sense, are straight lines along which the observer moves at a constant speed. In many tropical habitats, placing straight lines is logistically challenging, especially in mountainous regions. Therefore, the number of line transects surveyed will be lower than the number of point counts that can be covered in the same amount of time, leading to lower statistical power in quantitative analyses. Another issue with line transects is the requirement of constant observer speed, which is unrealistic, particularly in dense forest habitats, where birds often are partly hidden by foliage and mixed-species foraging flocks are common. This quite simply requires the observer to stop frequently for variable periods of time. Therefore, line transects rarely are a suitable core method for rapid surveys but may be used in open and/or species-poor habitats when logistically feasible.

Although mist nets are time- and labor-intensive, they do tend to detect a small proportion of species that might be overlooked using audiovisual methods (including rare, skulking, and quiet species). They also allow for photographic documentation of species and may provide additional information on age, sex, reproductive condition, molt patterns, and parasites that are not obtained by other methods. Therefore, they should be used as a supplemental method when time and human resources permit. At least two additional surveyors exclusively managing mist nets will be required to run a sufficient number of nets (10-15). All mist nets should be moved to new locations at least every other day to maximize capture rates.

The deployment of automated recording stations should be considered whenever funding permits, especially when only one surveyor is available. Within a survey site, this method provides documentation of vocally active birds simultaneously at several independent locations and at any time of day specified, enabling the surveyor to focus on point counts, 10-species lists, and/or opportunistic recording. Because automated recording can be conducted continuously, it can provide a vast amount of data with no observer bias, but also requires time-consuming analysis to identify individual sounds post-fieldwork. The recordings can act as a permanent repository of species present during the sampling period even if they are not analyzed until much later, and increasingly sophisticated analytical software may be able to automatically identify individual species in the future.

Drawbacks of automated recording stations currently include their relatively high cost and weight, and their recording quality is still inferior to that of standard hand-held digital recording equipment. They also suffer from problems associated with any electronic equipment in warm or humid locations – malfunctions can be common but may not be recognized immediately. Thus, recordings should be spot-checked daily to ensure that recorders are functioning properly. Animals such as ants and monkeys may also damage recording stations. Nonetheless, technological improvements and more affordable prices in the near future are likely to make the use of automated recording stations increasingly suitable for rapid assessment surveys.

Context-Dependent Sampling Considerations and Limitations

Point counts, 10-species lists, and sound recording are amenable to virtually any terrestrial habitat in the tropics and subtropics. However, the detectability of certain bird species can vary seasonally and bias results obtained by audiovisual methods at different times of the year. This needs to be taken into account when comparing data between sites. Ideally, rapid assessment surveys should be carried out in the season with the greatest overall activity and detectability of birds.

Standardized dawn chorus sound recordings are not always necessary. In comparatively species-poor habitats and those without a pronounced vocal activity peak at dawn (e.g. Amazonian white sand forest, certain grasslands, high-elevation forest), opportunistic sound recordings as part of the 10-species list technique are sufficient and often a better investment of time and effort than standardized dawn chorus sound recordings.

Rapid assessments are snapshot biodiversity surveys. They do not capture inherent natural variations in species richness and composition over time. Communities of highly mobile species such as birds are subject to not only seasonal, but also interannual and longer term variation, both naturally and as a result of anthropogenic pressures. Longer term variation in tropical bird community composition and richness is extremely poorly known due to the scarcity of long-term monitoring sites. Interannual and seasonal variation can be pronounced (e.g. Herzog *et al*. 2003, Latta *et al*. 2011), especially in areas with seasonal differences in climatic variables such as precipitation. The potential magnitude of seasonal variation in tropical bird communities must be taken into account when comparing results of rapid surveys from different areas.

Conservation Implications

As traditionally practiced, rapid assessments had the primary objective of identifying areas of exceptional biodiversity without regard to underlying processes and temporal change. Considering current rates of land conversion, rapid global climate change, and their synergistic, potentially detrimental effects on biodiversity (Travis 2003), this is an outdated approach. Today, rapid surveys should establish georeferenced baseline data using replicable sampling protocols that can contribute to long-term monitoring of both naturally and anthropogenically induced changes in particular areas at both the community and species level. This is especially important for a relatively large number of species of conservation concern as well as ecologically important functional groups such as seed dispersers and pollinators: using standardized sampling protocols during rapid surveys will help determine population trends and facilitate comparisons of abundance between sites, aiding in the identification of high extinction-risk species and priority areas for conservation.

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BOX 1: Equipment and supplies needed for rapid assessment bird surveys

Core Methods:

- Waterproof 8x or 10x binoculars
- Telescope (optional)
- Portable digital sound recorder (make sure the latest firmware version is installed) with corresponding memory cards and, if necessary, external speaker for playback
- Directional microphone with foam windshield and cables (at least 2-3 spare cables)
- Digital voice recorder (dictaphone)
- Field notebooks and pencils or pens with waterproof ink
- Field guides for bird identification
- Bird sound reference recordings in digital format
- GPS
- High-precision/professional altimeter
- Digital camera, 300-400+ mm telephoto lens

Secondary Methods:

- Mist nets and supplies used for bird banding (bird bags, spring scales, calipers, rulers, data sheets)
- Automated recording stations

TABLE 1. Overview of common ornithological survey methods, their strengths and caveats.

AUDIOVISUAL METHODS

Survey method	Strengths	Caveats
Point counts	• Thoroughly documented and tested method • High time- and cost-effectiveness • Points can be placed flexibly in any habitat type, are easily and precisely georeferenced • Results can be analyzed quantitatively with robust parametric statistics • Allows for relative abundance and density estimates of species	• Requires high to expert levels of observer expertise and experience • Tends to detect a lower proportion of resident species than other audiovisual methods
Line transects	• Thoroughly documented and tested method • Results can be analyzed quantitatively with robust parametric statistics • Allows for relative abundance and density estimates of species	• Transect placement is logistically challenging and time-consuming in many tropical habitats, especially in mountains • Lower time-effectiveness than other audiovisual methods, resulting in lower sample size and statistical power in quantitative analyses • Requirement of constant observer speed is unrealistic in many tropical habitats, especially forests, where most birds are hidden by foliage and mixed-species foraging flocks are common • Requires high to expert levels of observer expertise and experience
Species-list method	• Very high time- and cost-effectiveness • Logistically highly flexible • Generates data at all times during survey hours (no idle time while moving between survey stations) • Extensive sound recording is an integral component of the method (unlike point counts or line transects) • More robust with respect to observer bias and expertise than point counts or line transects • Allows for of relative abundance estimates	• Fairly recently developed method, less thoroughly tested than other audiovisual methods • Sampling units lack spatial independence, prohibiting use of robust parametric statistics • Statistical analyses limited to construction of species accumulation curves, curve extrapolation, species richness estimators, similarity indices

SOUND RECORDING (ACOUSTIC DOCUMENTATION)

Survey method	Strengths	Caveats
Manual recording	• Very high time- and cost-effectiveness in the field • Easy documentation of a large proportion of resident species • Recordings serve as acoustical voucher specimens, permits post-survey expert review of identifications • Dawn chorus recordings: most efficient way to document the greatest possible number of species in most tropical habitats; may be analyzed with robust parametric statistics	• Often requires time-consuming post-survey review of recordings to identify all vocalizing species • Equipment malfunctions may occur, especially in warm and wet environments
Automated recording stations	• Same strengths as manual recording, but less cost-effective (but equipment prices may drop) • Documentation of vocally active birds simultaneously at several independent locations and at any time of day specified • Provide vast amounts of data with no observer bias • Increasingly sophisticated analytical software may enable automatic species identification in the future	• Relatively high cost and weight of equipment • Recording quality is still inferior to that of standard hand-held digital recording equipment • Equipment malfunctions may occur, especially in warm and wet environments; animals (e.g. ants, monkeys) may also damage recording stations
Mist netting	• Tends to detect a small proportion of species that might be overlooked using audiovisual methods • Allows for photographic documentation of species • Provides additional information on life histories (e.g. molt, reproduction) not obtained by audiovisual methods • Requires only moderate bird identification expertise	• Very time- and labor-intensive • Requires substantial expertise extracting and handling birds • Detects only a small proportion of resident species in most tropical habitats • Subject to a variety of biases (e.g. net avoidance, habitat structure, interspecific behavioral differences) – unsuitable for statistical comparisons across survey sites
Specimen collecting	• Can be an essential tool to reveal cryptic biodiversity and document newly discovered taxa in poorly explored regions • Provides voucher specimens that can be subjected to post-survey expert review of identifications and made available for future research • Provides additional information on life histories (e.g. molt, reproduction) not obtained by audiovisual methods	• Very time- and labor-intensive • Requires special training in taxidermy, museum science, safe firearm handling • Requires additional research or collecting permits that are often more difficult to obtain • Weight and bulk of specimen collecting and preparation equipment and supplies, bulk of prepared specimens