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RESEARCH ARTICLE

# Detection Patterns and Population Monitoring of Sympatric Hornbills in the Ebo Forest, Cameroon

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## Abstract

Forest hornbills are major seed dispersers, but dense vegetation, canopy use and species specific vocal behaviour make their populations difficult to monitor. These constraints are especially important in the Ebo Forest, where the Vulnerable Yellow-casqued Hornbill *Ceratogymna elata* occurs with a diverse sympatric hornbill assemblage under growing hunting and land-use pressure. We evaluated detection patterns and established a field-observation baseline for population monitoring of *C. elata* and co-occurring hornbills. Hornbills were recorded using 15-minute point counts at 98 survey stations in 2025. We quantified aural, visual, and combined detections, comparing the estimated detection distances and observed heights among common species. Additionally, retrospective aural- and visual-inclusive data subsets were analyzed to demonstrate the extent of survey coverage retained by each individual information channel. Hornbills occurred at 85 stations, yielding 186 species-by-station events, 413 individuals and 10 species. Aural-only detections comprised 58.6% of events, visual-only detections 28.5%, and simultaneous aural-visual detections 12.9%. A visual-inclusive subset retained only 41.4% of events, eight species and 54 occupied stations, whereas an aural-inclusive subset retained 71.5% of events, all 10 species and 69 stations. Detection distance differed among six common species (Kruskal-Wallis $H = 14.56$, $P = 0.012$). Observed height differed strongly among species ($H = 54.26$, $P < 0.001$), with large *Ceratogymna* and *Bycanistes* recorded higher than smaller hornbills. Population monitoring in the Ebo Forest should combine aural and visual records, repeated visits, observer training and acoustic validation. The present results provide a detection baseline and identify the observation biases that future, population size estimate, occupancy, density and community-based monitoring programmes must address.

**Keywords:** Acoustic Monitoring, Avian Detectability, Bucerotidae, Point-Count Surveys, Tropical Forest Monitoring

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# 1. Introduction

Tropical forests are undergoing rapid biodiversity loss, and large-bodied, slow-reproducing vertebrates are disproportionately vulnerable to hunting and habitat change. Forest hornbills are especially important because they consume diverse fruits, transport seeds across large areas and contribute directly to forest regeneration. In Cameroon's Dja forest, three *Ceratogymna* hornbills consumed fruits from 59 tree and liana species and dispersed seeds for approximately 22% of the known tree flora, demonstrating that hornbill decline can affect forest function as well as bird diversity (Whitney et al., 1998). Conservation decisions nevertheless depend on reliable observations, and observation is not equivalent to presence. The probability of detecting a bird varies with vegetation, distance, vocal activity, observer experience and species behaviour. When detection is incomplete, uncorrected encounter rates can misrepresent differences among species, sites or years (MacKenzie et al., 2002). Point counts remain widely used because they are rapid and non-invasive, but robust interpretation requires explicit attention to how birds enter the dataset: by sight, by sound, or through both channels (Ralph et al., 1995; Marsden, 1999).

African forest hornbills present a particularly difficult monitoring problem. Large *Ceratogymna* species track spatially and seasonally variable fruit resources, move over extensive areas and frequently occupy the upper canopy, whereas smaller hornbills use lower strata and may differ in call structure, calling rate and group behaviour (Whitney and Smith, 1998; Holbrook and Smith, 2000; Kemp, 1995). Consequently, species occurring in the same forest may occupy different visual and acoustic detection spaces. Long-term recordings have already shown that hornbill calls and wingbeats can reveal major seasonal changes that short visual surveys would miss (Rainey and Zuberbühler, 2007). The need for accurate monitoring is intensified by rapid declines of African forest hornbills. Long-term work in Ghana documented severe declines and local extirpations associated primarily with uncontrolled hunting and habitat degradation (Holbech et al., 2018). At the same time, broad comparisons of autonomous sound recorders and observer point counts show that acoustic sampling can expand temporal coverage and standardization, although recorders and human observers do not sample identical detection spaces (Darras et al., 2018; Kułaga and Budka, 2019).

Cameroon contains important populations of Central African hornbills (Whytock and Morgan, 2010), but quantitative baselines remain scarce (Whytock et al., 2016). Bird hunting in the Littoral Region is more substantial than market observations alone suggest: a social survey around the Ebo Forest estimated an average monthly consumption of 29 hornbills among a defined respondent group, illustrating how cryptic offtake can escape routine monitoring (Whytock et al., 2018). More recently, online-market and hunter-interview data showed that Yellow-casqued, Black-casqued and White-thighed hornbills dominate recorded hornbill products from Cameroon, with foreign demand strongly influencing targeted hunting (Su et al., 2024). International trade data further indicate accelerating exploitation of African hornbills and reinforce the need for standardized population monitoring (Tinsman et al., 2025). These threats make weak inference particularly costly. A count that ignores acoustic detections can underestimate occurrence, whereas a single-visit count that treats every encounter as abundance can overstate what the data support. Monitoring protocols must therefore maximize detection while maintaining a clear distinction among detection events, station occurrence, density and population size.

The Ebo Forest in Cameroon's Littoral Region supports a rich avifauna and several sympatric hornbill species, including the globally Vulnerable Yellow-casqued Hornbill (Whytock and Morgan, 2010; BirdLife International, 2025). The Ebo Forest is one of the largest remaining intact forest landscapes in the Cross-Sanaga-Bioko coastal forest ecoregion, yet it has no formal protected-area status and remains exposed to hunting and land-use change (Whytock et al., 2021; Djomo Nana et al., 2023). A repeatable monitoring system is therefore needed both for specialist surveys and for future participation by trained local monitors. This study asked four linked questions: (1) which hornbill species were recorded and how widely were they distributed among stations; (2) what proportion of detection events was aural, visual or simultaneously aural and visual; (3) how much survey coverage would be retained if monitoring relied on aural-inclusive or visual-inclusive records alone; and (4) how did estimated detection distance and observed height differ among common species? We predicted that acoustic information would dominate the dataset, that a combined aural-visual protocol would retain the most complete assemblage, and that large-bodied *Ceratogymna* and *Bycanistes* would be recorded higher than smaller hornbills.

# 2. Materials and Methods

## 2.1 Study Area

The study was conducted in the Ebo Forest in

Cameroon, Littoral Region, north of the Sanaga River and within the Cross-Sanaga-Bioko coastal forest ecoregion. The forest covers approximately 1,400-1,500 km² and forms one of the largest remaining lowlands to submontane intact forest landscapes in the region (Whytock et al., 2021). The surveyed landscape extended through lowland and submontane forest mosaics and was concentrated within the Nkam and Sanaga-Maritime administrative divisions. The Ebo Forest is characterized by undulating terrain, steep local relief, streams and river valleys. The Ebo Forest and Makombe river systems and numerous smaller tributaries dissect the landscape before draining toward the wider Sanaga-Wouri coastal network. Vegetation includes closed-canopy primary forest, secondary forest, disturbed forest and riparian formations. This structural complexity is relevant to hornbill surveys because canopy height, dense foliage and broken terrain simultaneously restrict visual contact and alter sound transmission. The Forest supports threatened primates, large mammals, endemic plants and a diverse bird community (Whytock and Morgan, 2010; Whytock et al., 2021). Although Ebo Forest was proposed for national-park status, formal gazettement was not completed. Parts of the landscape have subsequently been designated as Forest Management Units, increasing the urgency of establishing repeatable biodiversity baselines before access and land use change further (Djomo Nana et al., 2023). Exact hornbill detection coordinates are not presented because hunted species may face additional risk when sensitive localities are made public (Lindenmayer and Scheele, 2017). The geographic boundaries of the Ebo Forest study area, including the relevant forest management units and hydrological features, are illustrated in Figure 1.

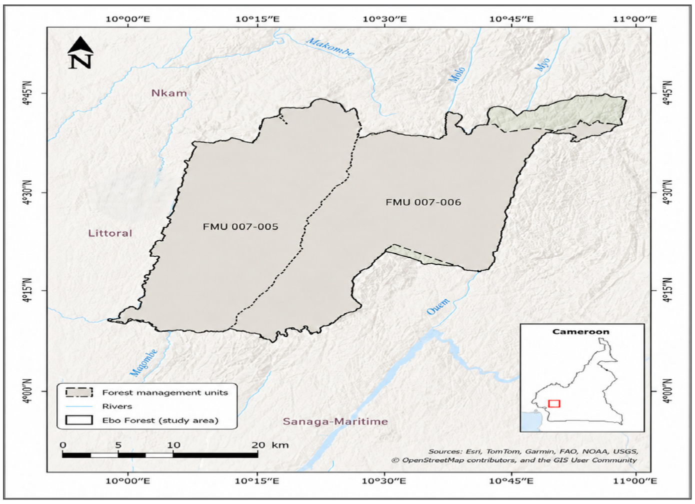


**Figure 1.** *Location of the Ebo Forest, Cameroon*

## 2.2 Field Survey Design and Access Routes

Field surveys were conducted during four months in 2025. Ninety-eight fixed point-count stations were distributed across the Ebo Forest to obtain broad landscape coverage. The spatial distribution of these sample points across the designated forest management units is illustrated in Figure 2. Stations were separated by at least 2 km to reduce the likelihood of repeatedly recording the same wide-ranging individuals at neighbouring stations. Field teams reached stations by existing logging roads, hunter trails and narrow forest paths; no new transects were cut. Hornbills encountered in while transiting between point count stations were not included in the present analysis, which is restricted to standardized point-count records.

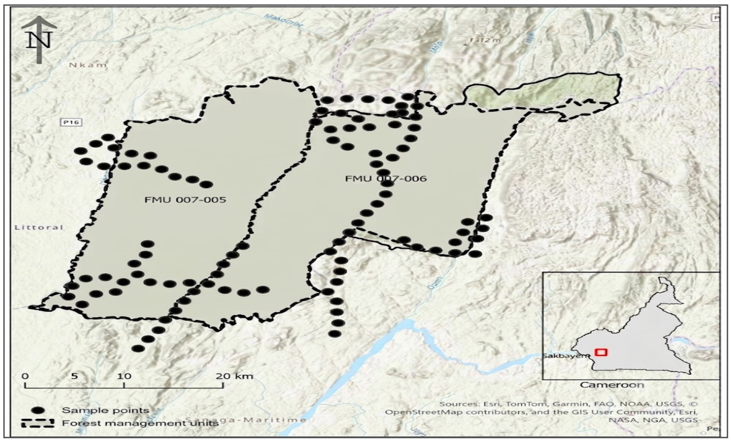


**Figure 2.** *Sampled point-count stations across the Ebo Forest, Cameroon*

### 2.3 Point Count Protocol and Recorded Variables

Each station was surveyed once using a 15-minute point count, consisting of 10 minutes of passive observation followed by 5 minutes of targeted playback. Surveys were conducted between 07:30 and 11:30 under favorable field conditions for both visual and acoustic observation. We recorded all hornbills detected within an estimated 500-meter radius and identified species according to Borrow and Demey (2014). For every encounter, observers recorded the species, number of individuals, estimated horizontal distance from the observer, estimated height above ground, and the detection method. The detection method was classified as aural, visual, or both (when an event involved simultaneous acoustic and visual confirmation). Aural detections included diagnostic calls, wingbeats, or other species-specific sounds. Because responses during the playback phase were not consistently recorded for every species, that specific phase was not analyzed on its own. Therefore, this study evaluates the overall value of acoustic information throughout the entire point count duration rather than testing the specific effectiveness of the playback technique.

### 2.4 Data Preparation and Survey Variables

We extracted all hornbill (Bucerotidae) records from the comprehensive bird dataset. Scientific names were standardized to current taxonomy, which included updating the historical name *Tropicranus albocristatus* to *Horizocerus albocristatus*. We defined a detection event as the recording of a single species at a specific station, with the number of individuals present recorded as the group size. We calculated station occurrence as the total number of stations (out of 98) where a given species was detected. Importantly, these survey variables describe observation frequency and spatial coverage; they are not estimates of absolute density or total population size. While all detected species were included in the overall descriptive summaries, statistical comparisons were restricted to species with at least 20 detection events to ensure robust results. Additionally, to explore the influence of body size on detection, we categorized *Ceratogymna* and *Bycanistes* as large-bodied hornbills, and *Lophoceros* and *Horizocerus* as smaller-bodied hornbills.

### 2.5 Statistical Analysis

We calculated the total number and percentage of aural-only, visual-only, and combined aural-visual events. To show how relying on different senses impacts survey results, we organized our data into three retrospective subsets: aural-inclusive (all records where birds were heard), visual-inclusive (all records where birds were seen), and combined (all records). We used these subsets specifically to test how much information would be retained under different sensory conditions; they do not represent separate field methods. For each subset, we calculated the retained number of events, individuals, species, and occupied stations. We used a Pearson chi square statistic (with a Monte Carlo permutation test based on 50,000 randomizations) to evaluate whether the detection method differed significantly among the common species. To compare the estimated detection distances and observed heights among common species, we used Kruskal Wallis tests. Additionally, we used two-sided Mann-Whitney U tests to compare the large-bodied and smaller-bodied hornbill groups. Statistical significance was set at $\alpha = 0.05$. All analyses were conducted in Python 3.13.5 using the NumPy (Harris et al., 2020) and SciPy (Virtanen et al., 2020) libraries.

## 3. Results

### 3.1 Survey Effort, Sampling Coverage and Hornbill Assemblage

During four survey months in 2025, 98 point-count stations were each surveyed once for 15 minutes, generating 1,470 minutes, or 24.5 hours, of standardized observation effort. Stations were separated by at least 2 km, and detections were recorded within an operational radius of 500 m. Given this spacing, the station buffers did not overlap, providing a nominal sampling footprint of approximately 77.0 km² $98 \times \pi \times (0.5\text{km})^2$. Hornbills were detected at 85 of the 98 stations, corresponding to a station-level detection rate of 86.7%. After standardizing species names, the dataset comprised 186 hornbill encounter records representing 413 individuals and 10 species. A comprehensive summary of detection methods, observation distances, and estimated canopy heights expressed as medians with interquartile ranges in parentheses for all recorded species is detailed in Table 1. The Black-casqued Hornbill *Ceratogymna atrata* was the most frequently recorded species, with 46 encounters involving 147 individuals. The White-thighed Hornbill *Bycanistes albotibialis* was recorded in 38 encounters, while the focal Yellow-casqued Hornbill *C. elata* was documented in 25 encounters at 24 stations, involving 53 individuals. By contrast, *B. subcylindricus* and *Lophoceros alboterminatus* were each recorded once, while *L. hartlaubi* was recorded in five encounters.

**Table 1.** *Hornbill detection events recorded at 98 point-count stations in the Ebo Forest.*

| Species | Events | Stations | Individuals | Aural | Visual | Both | Distance (m) | Height (m) |
|---|---|---|---|---|---|---|---|---|
| *Bycanistes albotibialis* | 38 | 38 | 61 | 15 | 19 | 4 | 40 (20-59) | 30 (25-35) |
| *Bycanistes fistulator* | 20 | 20 | 45 | 12 | 5 | 3 | 55 (34-78) | 32 (24-35) |
| *Bycanistes subcylindricus* | 1 | 1 | 2 | 1 | 0 | 0 | 100 | 24 |
| *Ceratogymna atrata* | 46 | 46 | 147 | 27 | 10 | 9 | 70 (42-100) | 32 (30-39) |
| *Ceratogymna elata* | 25 | 24 | 53 | 15 | 6 | 4 | 40 (25-100) | 40 (30-45) |
| *Horizocerus albocristatus* | 7 | 7 | 8 | 3 | 4 | 0 | 50 (30-60) | 14 (11-18) |
| *Lophoceros alboterminatus* | 1 | 1 | 1 | 1 | 0 | 0 | 30 | 27 |
| *Lophoceros camurus* | 21 | 21 | 38 | 18 | 2 | 1 | 50 (30-60) | 12 (8-16) |
| *Lophoceros fasciatus* | 22 | 22 | 52 | 13 | 7 | 2 | 50 (42-70) | 24 (20-29) |
| *Lophoceros hartlaubi* | 5 | 5 | 6 | 4 | 0 | 1 | 50 (35-50) | 25 |

## 3.2 Detection Methods and Survey Coverage

Acoustic information dominated the observation process. Aural-only detections accounted for 109 events (58.6%; 95% Wilson CI 51.4-65.4%), visual-only detections for 53 events (28.5%; 22.5-35.4%), and simultaneous aural-visual detections for 24 events (12.9%; 8.8-18.5%). Detection method composition varied among the six common species at the threshold of statistical significance ($\chi^2 = 18.15$, df = 10, Monte Carlo P = 0.050). The varying proportions of aural, visual, and combined detections for each species are illustrated in Figure 3. *Lophoceros camurus* was detected almost entirely through sound, whereas *B. albotibialis* had the largest visual component among the common species. Furthermore, the coverage comparison demonstrated the practical cost of relying on a single information channel, with the data retention rates for each sensory subset summarized in Table 2. An aural-inclusive subset retained 133 events (71.5%), 289 individuals, all 10 species, and 69 occupied stations. Conversely, a visual-inclusive subset retained only 77 events (41.4%), 193 individuals, eight species, and 54 occupied stations. The combined dataset retained all 186 events, 413 individuals, 10 species, and 85 occupied stations. The two species entirely absent from the visual-inclusive subset were *B. subcylindricus* and *L. alboterminatus*, as each was represented by only a single aural event.

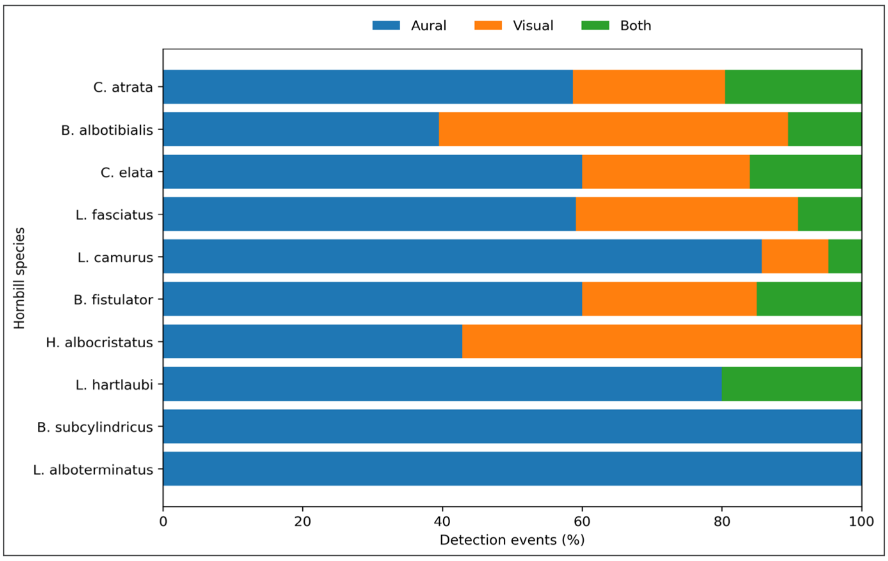


**Figure 3.** *Percentage of detection events classified as aural, visual, or simultaneous aural and visual for each hornbill species.*

**Table 2.** *Observation coverage retained by retrospective aural-inclusive, visual-inclusive and combined subsets.*

| Subset | Events | Events (%) | Individuals | Species | Occupied stations |
|---|---|---|---|---|---|
| Aural-inclusive | 133 | 71.5 | 289 | 10 | 69 |
| Visual inclusive | 77 | 41.4 | 193 | 8 | 54 |
| Combined aural and visual | 186 | 100.0 | 413 | 10 | 85 |

### 3.3 Vertical Stratification of Sympatric Hornbills

### 3.4 Species Differences in Detection Distance

Estimated detection distance also differed among common species (Kruskal-Wallis H = 14.56, df = 5, P = 0.012). The distribution of these estimated detection distances for each common species is illustrated in Figure 4, which displays interquartile ranges, medians, and individual outliers for the six hornbill species represented by at least 20 detection events. Median species values ranged from 40 m for *B. albotibialis* and *C. elata* to 70 m for *C. atrata*. However, body-size grouping did not explain this variation: large- and smaller-bodied hornbills both had a median detection distance of 50 m (Mann-Whitney U = 3892, P = 0.453). Detection distance was therefore species-specific rather than a simple consequence of body size.

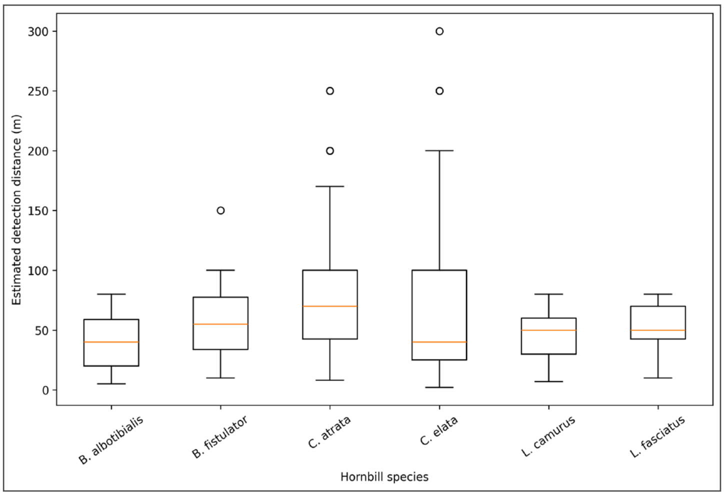


**Figure 4.** *Detection distances by hornbill species*

### 3.5 Species Differences in Detection Height

Observed height differed strongly among the six common species (Kruskal-Wallis H = 54.26, df = 5, P < 0.001). The distribution of these heights for each common species is illustrated in Figure 5, which displays interquartile ranges, medians, and individual outliers for all species represented by at least 20 detection events. The Yellow-casqued Hornbill had the highest median observed height at 40 m, whereas the Red-billed Dwarf Hornbill *L. camurus* had the lowest at 12 m. Large bodied *Ceratogymna* and *Bycanistes* were recorded at a median height of 30 m (IQR 26-40 m), compared with 18 m (IQR 12-25 m) for the smaller-bodied group (Mann-Whitney U = 5946, P < 0.001). Thus, the assemblage was vertically structured in the height at which observers encountered species.

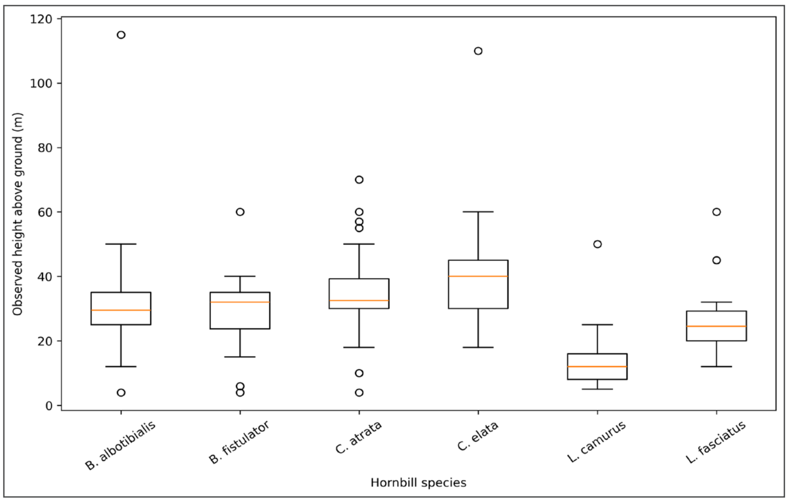


**Figure 5.** *Observed height above ground for the hornbill species*

# 4. Discussion

## 4.1 Overcoming Detection Bias in Canopy Frugivores

The clearest result is that hornbill monitoring in the Ebo Forest is fundamentally acoustic. Nearly three-fifths of all events were aural-only, while fewer than one-third were visual-only. A visual-inclusive subset would have retained only 41.4% of events and 54 of the 85 occupied stations. Visual-only counts would therefore produce a systematically incomplete picture of assemblage occurrence, even for large and apparently conspicuous birds. This pattern agrees with wider forest-bird research showing that dense vegetation strongly limits visual detection and that acoustic information makes a major contribution to inventories and monitoring (Darras et al., 2018; Kułaga and Budka, 2019). For hornbills, calls and wingbeats are not supplementary cues; they are core components of the sampling process. Rainey and Zuberbühler (2007) demonstrated that long term acoustic records could reveal large seasonal changes in African hornbill abundance, while Marsden (1999) showed that point-count distance sampling can be adapted to large parrots and hornbills. Our contribution is to quantify, across a sympatric Central African assemblage, how heavily routine field records depend on sound. The result should not be misinterpreted as evidence that playback increased detection. Playback responses were not consistently coded by survey phase, so this analysis cannot compare passive and stimulated periods. Its defensible conclusion is narrower and more useful: any future experiment designed to test playback must preserve phase specific detections, while any operational monitoring protocol must retain aural records.

## 4.2 Detection Distance Is Species-Specific, Not Simply Size-Dependent

Detection distance showed a markedly different pattern from observed height: whereas height scaled clearly with the large- versus small-bodied grouping used elsewhere in this study, distance did not. The species recorded at the greatest range was large-bodied, but the other two large-bodied species in the comparison were detected, if anything, at shorter range than several smaller-bodied ones. Body size is therefore a poor predictor of how far a hornbill can be detected, even though it strongly predicts the height at which one is encountered. This divergence is consistent with how detection distance actually arises for a predominantly aurally-detected assemblage: distance to a calling bird is governed by the acoustic properties of that species' specific call its amplitude, frequency, and repetition rate and by how the surrounding vegetation transmits that particular signal, not by the caller's body size (Marsden, 1999). Point-count distance sampling for parrots and hornbills has long been recognised as demanding precisely because species-specific detection functions, rather than a single guild-wide radius, are needed to model this variation reliably (Marsden, 1999). Hornbill species also differ substantially in call structure, pitch and delivery (Kemp, 1995), which offers a more parsimonious explanation for the pattern than any property of body size itself. This has a direct bearing on how the encounter data reported here should be used. Because distance was estimated in the field rather than measured, and because a single detection radius was applied across an assemblage whose species-specific detection functions evidently differ, raw encounter rates cannot be treated as directly comparable abundance indices across species a caution that applies equally to comparisons between habitat types or logging conditions elsewhere in this study, and one further reason why detection/non-detection rather than density was treated as the appropriate level of inference here. Passive recorders would not resolve this on their own: because recorders and human observers do not sample the same effective listening space, their detection distances would need independent calibration rather than being assumed equivalent (Darras et al., 2018; Sugai et al., 2019).

## 4.3 Detection Height Indicates Vertical Niche Structure and Survey Bias

The near two-fold difference in median encounter height between large-bodied (*Ceratogymna*, *Bycanistes*) and smaller-bodied (*Lophoceros, Horizocerus*) hornbills, with *C. elata* recorded highest among all species and *L. camurus* lowest, is consistent with the long-established relationship between bird-community structure and the vertical profile of forest vegetation (MacArthur and MacArthur, 1961), and it converges with direct movement evidence from a nearby Cameroonian forest, where GPS-tracked Black-casqued and White-thighed Hornbills the two large-bodied species most frequently recorded in the present study preferentially used taller, more vertically complex canopy (Russo et al., 2024). Large forest hornbills also depend on tall, large diameter trees for nest cavities (Kemp, 1995; Stauffer and Smith, 2004), a further pressure that could reinforce their association with the upper canopy independently of any immediate foraging decision. These height values are nonetheless better treated as an index of where birds were encountered than as a direct measurement of habitat use. Height was recorded as a field estimate rather than derived from a rangefinder or clinometer, and most detections of the large-bodied genera were aural rather than visual (see results; detection methods), so height for these species more often reflects an observer's estimate of call origin than a confirmed perch height. Acoustic detectability in closed-canopy forest is known to vary with habitat structure and survey conditions more broadly (Darras et al., 2018; Kułaga and Budka, 2019), so it is plausible that part of the height difference reported here reflects how acoustic detections are localized rather than a pure measure of vertical habitat use. This does not undermine the central pattern, but it means the absolute values should be read as approximate. For population monitoring, this vertical structuring has a direct practical consequence: a single ground-based observation points samples the forest column unevenly. Canopy specialists such as *C. elata* are, by their nature, easier to hear across the whole vertical profile than to see through intervening foliage, whereas low-canopy species such as *L. camurus* detected almost exclusively by sound in this study could be under-represented by any protocol that privileges visual confirmation, or by acoustic recorders deployed only near ground level, since microphone placement likewise samples the vertical dimension unevenly (Sugai et al., 2019). Occupancy and density models that treat detection probability as constant across an assemblage will tend to misrepresent species whose typical encounter height diverges most from the sampling point; vertical position is therefore a candidate covariate for detection sub-models in future occupancy analyses of this assemblage (MacKenzie et al., 2002).

### 4.4 Implications for Population and Community-Based Monitoring

The present survey provides a detection baseline, not an estimate of total population size. Its main value is to identify the design features required for a defensible long-term programme. First, fixed point-count stations should be revisited within seasons and across years, which is necessary to separate non-detection from true absence (MacKenzie et al., 2002). Second, observers should record detection mode, distance, height, time, group size, survey phase, weather and observer identity, measuring distance and height with a rangefinder or clinometer rather than a field estimate. Third, a verified reference library of calls and wing sounds should be used for training and periodic quality control. Fourth, passive acoustic recorders should complement, rather than automatically replace, field observers: recorders extend temporal coverage, while observers provide visual confirmation, group size and vertical-stratum information. Fifth, because detection height and distance both vary by species rather than simply by body size, future density or occupancy estimates should model these processes species by species and, where feasible, sample more than one vertical stratum for example an elevated platform, canopy walkway or drone mounted microphone alongside the ground station rather than assume a single detection function applies across the assemblage. These requirements are compatible with community-based monitoring when local participation is carefully structured. Knowledgeable residents can repeatedly visit fixed stations and recognize local wildlife cues, but data quality requires standardized training, supervised calibration and periodic expert validation (Danielsen et al., 2005). In the Ebo Forest, such a programme could connect local reporting to national conservation planning while avoiding the common error of treating raw encounter totals as population estimates. The urgency of this work extends beyond survey design. Hornbills in Cameroon face both cryptic local hunting and increasing international demand for casques and skulls (Whytock et al., 2018; Su et al., 2024; Tinsman et al., 2025). Monitoring must therefore be capable of detecting genuine change early enough to guide enforcement, habitat protection and community engagement. A protocol that misses most aural events would be poorly suited to that task.

### 4.5 Limitations and Next Steps

The study has four principal limitations. Each station was visited once, preventing estimation of detection probability. Distances and heights were field estimates rather than instrument-based measurements. Playback detections were not consistently separated from passive detections, so playback efficacy could not be tested. Finally, rare species had too few observations for inferential comparisons. These constraints mean that the results describe detection patterns and station coverage, not density, abundance or total population size. The next phase should use repeated point counts, phase-specific coding of passive and playback detections, calibrated distance measurements and paired passive acoustic recorders. Such a design would allow occupancy or density models to test whether detection probability varies with species, observer, season, habitat structure and survey method. The present paper provides the empirical foundation for that progression.

## 5. Conclusion

Reliable population monitoring is the foundation on which every subsequent conservation decision rests, yet for cryptic, canopy-dwelling forest birds this foundation is rarely examined critically. This study addressed that gap for one of the richest hornbill assemblages recorded in Central Africa. The Ebo Forest supports at least ten sympatric species, including the globally Vulnerable Yellow-casqued Hornbill, whose seed-dispersal role makes their conservation inseparable from the wider health of the forest. Our results show that how these birds are observed is not incidental to what is observed: detection was governed overwhelmingly by sound rather than sight; a purely visual protocol would have missed most encounters and many occupied stations outright; and species diverged sharply in both the height and the distance at which they were typically detected. Taken together, these patterns mean that a single, uncorrected encounter rate cannot be treated as equivalent across species, still less as a stand-in for abundance.This has an immediate, practical consequence for the Ebo Forest and for comparable tropical forest systems: a defensible long-term monitoring programme must combine aural and visual point counts, repeated visits, standardised observer training, explicit recording of playback response by survey phase, and acoustic validation, rather than rely on any single method in isolation. Structured in this way, the same protocol can be extended to well-supervised community-based monitoring, offering a realistic route to sustained data collection in a landscape where formal protection remains absent and where hunting and international trade pressure on hornbills are intensifying. The principle this study establishes is simple but easily overlooked: detection records are the raw material of population inference, not a substitute for it, and only a monitoring design that treats detectability as seriously as it treats the birds themselves can tell a declining population from one that has simply gone unheard.

### Ethical Considerations

The study used non-invasive field observations. No birds were captured, handled, marked or physically disturbed. Playback was limited to five minutes per station. Field access was undertaken with the knowledge and permission of local traditional authorities.

### Acknowledgements

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### Author Contributions

OM conceived the study, led field surveys, curated the data, conducted the analysis and drafted the manuscript. ETA, PF, JR, MDC and AIIT contributed to study design, interpretation, manuscript revision and supervision. RT, LK and DA contributed to interpretation and critical revision. All authors must review and approve the final manuscript before submission.

### Conflict of Interest

The authors declare no conflict of interest.

### Data Availability

A non-sensitive event-level dataset and the analysis script are available from the corresponding author. Exact survey coordinates and species-specific localities are withheld to reduce conservation risk to hunted hornbill species.

### Originality Statement

This manuscript is original, has not been published previously, and is not under consideration elsewhere. All co-authors must confirm the submission and authorship before the manuscript is sent to the journal.

## 6. References

1. BirdLife International. (2025). *Ceratogymna elata*. The IUCN Red List of Threatened Species 2025: e.T22682627A280610032. https://doi.org/10.2305/IUCN.UK.2025- 2.RLTS.T22682627A280610032.en
2. Borrow, N., & Demey, R. (2014). *Birds of Western Africa* (2nd ed.). Christopher Helm. Danielsen, F., Burgess, N. D., & Balmford, A. (2005). Monitoring matters: Examining the potential of locally-based approaches. *Biodiversity and Conservation*, *14*, 2507–2542. https://doi.org/10.1007/s10531-005-8375-0
3. Darras, K., Batáry, P., Furnas, B. J., Celis-Murillo, A., Van Wilgenburg, S. L., Mulyani, Y. A., & Tscharntke, T. (2018). Comparing the sampling performance of sound recorders versus point counts in bird surveys: A

meta-analysis. *Journal of Applied Ecology*, *55*, 2575–2586. https://doi.org/10.1111/1365-2664.13229

4. Djomo Nana, E., Ngansop Tchatchouang, E., Mandah Takor, C., Nkemny Nkengbeza, S., Mayumgo Kamga, C. L., Ngome Mesame, L., Suife Ndze, J., Nadine Tchudjo Tchuente, A., & Tchopwe, E. (2023). Saving unique, rare and threatened species in the Ebo Forest, Cameroon, under the imminent threat of logging. *Oryx*, *57*(6), 696–697. https://doi.org/10.1017/S0030605323001230

5. Gill, F., Donsker, D., & Rasmussen, P. (Eds.). (2026). *IOC world bird list* (v15.2). https://www.worldbirdnames.org

6. Harris, C. R., Millman, K. J., van der Walt, S. J., Gommers, R., Virtanen, P., Cournapeau, D., ... Oliphant, T. E. (2020). Array programming with NumPy. *Nature*, *585*, 357–362. https://doi.org/10.1038/s41586-020-2649-2

7. Holbech, L. H., Annorbah, N. N. D., Phalan, B., & Arcilla, N. (2018). Uncontrolled hunting and habitat degradation decimate and extirpate forest hornbills in Ghana, West Africa. *Biological Conservation*, *223*, 104–111. https://doi.org/10.1016/j.biocon.2018.04.039

8. Holbrook, K. M., & Smith, T. B. (2000). Seed dispersal and movement patterns in two species of *Ceratogymna* hornbills in a West African tropical lowland forest. *Oecologia*, *125*, 249–257. https://doi.org/10.1007/s004420000445

9. Kemp, A. C. (1995). *The hornbills: Bucerotiformes*. Oxford University Press. Kułaga, K., & Budka, M. (2019). Bird species detection by an observer and an autonomous sound recorder in two different environments: Forest and farmland. *PLOS ONE*, *14*, e0211970. https://doi.org/10.1371/journal.pone.0211970

10. Lindenmayer, D., & Scheele, B. (2017). Do not publish. *Science*, *356*, 800–801. https://doi.org/10.1126/science.aan1362

11. MacArthur, R. H., & MacArthur, J. W. (1961). On bird species diversity. *Ecology*, *42*, 594–598. https://doi.org/10.2307/1932254

12. MacKenzie, D. I., Nichols, J. D., Lachman, G. B., Droege, S., Royle, J. A., & Langtimm, C. A. (2002). Estimating site occupancy rates when detection probabilities are less than one. *Ecology*, *83*, 2248–2255. https://doi.org/10.1890/0012- 9658(2002)083[2248:ESORWD]2.0.CO;2

13. Marsden, S. J. (1999). Estimation of parrot and hornbill densities using a point count distance sampling method. *Ibis*, *141*, 327–390. https://doi.org/10.1111/j.1474-919X.1999.tb04405.x Morgan, B. J., Adeleke, A., Bassey, T., Bergl, R., Dunn, A., Fotso, R., Gadsby, E., Gonder, K.,

14. Greengrass, E., Koulagna, D. K., Mbah, G., Nicholas, A., Oates, J., Omeni, F., Saidu, Y., Sommer, V., Sunderland-Groves, J., Tiebou, J., & Williamson, E. (2011). *Regional action plan for the conservation of the Nigeria-Cameroon chimpanzee (Pan troglodytes ellioti)*.

15. IUCN/SSC Primate Specialist Group and Zoological Society of San Diego. Rainey, H. J., & Zuberbühler, K. (2007). Seasonal variation in hornbill abundance in a West African national park detected using analysis of acoustic recordings. *Bird Conservation International*, *17*, 235–244. https://doi.org/10.1017/S0959270907000731

16. Ralph, C. J., Sauer, J. R., & Droege, S. (Eds.). (1995). *Monitoring bird populations by point counts* (General Technical Report PSW-GTR-149). U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station.

17. Russo, N. J., Nshom, D. L., Ferraz, A., Barbier, N., Wikelski, M., Noonan, M. J., Ordway, E. M., Saatchi, S., & Smith, T. B. (2024). Three-dimensional vegetation structure drives patterns of seed dispersal by African hornbills. *Journal of Animal Ecology*, *93*, 1935–1946. https://doi.org/10.1111/1365-2656.14202

18. Sedláček, O., Vokurková, J., Ferenc, M., Nana Djomo, E., Albrecht, T., & Hořák, D. (2015). A comparison of point counts with a new acoustic sampling method: A case study of a bird community from the montane forests of Mount Cameroon. *Ostrich*, *86*, 213–220. https://doi.org/10.2989/00306525.2015.1049669

19. Stauffer, D. J., & Smith, T. B. (2004). Breeding and nest site characteristics of the Black-casqued Hornbill *Ceratogymna atrata* and White-thighed Hornbill *Ceratogymna cylindricus* in south central Cameroon. *Ostrich*, *75*, 79–88. https://doi.org/10.2989/00306520409485418

20. Su, S., Guetse, F., & Arcilla, N. (2024). A price on their heads? Assessing foreign demand as a driver of hornbill hunting in Cameroon. *Global Ecology and Conservation*, *51*, e02905. https://doi.org/10.1016/j.gecco.2024.e02905

21. Sugai, L. S. M., Silva, T. S. F., Ribeiro, J. W., Jr., & Llusia, D. (2019). Terrestrial passive acoustic monitoring: Review and perspectives. *BioScience*, *69*, 15–25. https://doi.org/10.1093/biosci/biy147

22. Tinsman, J., Woodward, A., Su, S., Skinner, D. H., Kemp, L. V., Abeh, A. D., Afiademanyo, K. M., Arcilla, N., Brouwer, K., Chaffra, A. S., Forzi, F., Guetse, F., Holbech, L. H., Ikome, D., Koutchoro,

A. M., Odoukpe, S. G. K., Orenstein, R., Nshom, D., Russo, N. J., ... Oswald Terrill, J. A. (2025). Intense international exploitation of African hornbills necessitates urgent conservation measures, including CITES listing. *Biological Conservation*, *308*, 111105. https://doi.org/10.1016/j.biocon.2025.111105

23. Virtanen, P., Gommers, R., Oliphant, T. E., Haberland, M., Reddy, T., Cournapeau, D., ... SciPy 1.0 Contributors. (2020). SciPy 1.0: Fundamental algorithms for scientific computing in Python. *Nature Methods*, *17*, 261–272. https://doi.org/10.1038/s41592-019-0686-2

24. Whitney, K. D., Fogiel, M. K., Lamperti, A. M., Holbrook, K. M., Stauffer, D. J., Hardesty, B. D., Parker, V. T., & Smith, T. B. (1998). Seed dispersal by *Ceratogymna* hornbills in the Dja Reserve, Cameroon. *Journal of Tropical Ecology*, *14*, 351–371. https://doi.org/10.1017/S0266467498000273

25. Whitney, K. D., & Smith, T. B. (1998). Habitat use and resource tracking by African *Ceratogymna* hornbills: Implications for seed dispersal and forest conservation. *Animal Conservation*, *1*, 107–117. https://doi.org/10.1111/j.1469-1795.1998.tb00018.x

26. Whytock, R. C., & Morgan, B. J. (2010). The avifauna of the Ebo Forest, Cameroon. *Malimbus*, *32*, 22–32.

27. Whytock, R. C., Buij, R., Virani, M. Z., & Morgan, B. J. (2016). Do large birds experience previously undetected levels of hunting pressure in the forests of Central and West Africa? *Oryx*, *50*, 76–83. https://doi.org/10.1017/S0030605314000064

28. Whytock, R. C., Morgan, B. J., Awa, T., Bekokon, Z., Abwe, E. A., Buij, R., Virani, M., Vickery, J. A., & Bunnefeld, N. (2018). Quantifying the scale and socioeconomic drivers of bird hunting in Central African forest communities. *Biological Conservation*, *218*, 18–25. https://doi.org/10.1016/j.biocon.2017.11.034

29. Whytock, R. C., Abwe, E. E., Mfossa, D. M., Ketchen, M. E., Abwe, A. E., Nguimdo, V. R. V., Maisels, F., Strindberg, S., & Morgan, B. J. (2021). Mammal distribution and trends in the threatened Ebo “intact forest landscape,” Cameroon. *Global Ecology and Conservation*, *31*, e01833. https://doi.org/10.1016/j.gecco.2021.e01833