FINAL REPORT

Project: Initial density estimates for 10 rare and endangered birds in a relativeiy undisturbed lowland tropical forest

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บทคัดย่อ

การประเมินความหนาแน่นของประชากรสัตว์ป่าเป็นข้อมูลที่มีความสำคัญและเหมาะสมสำหรับการจัดการสัตว์ป่า การประเมินความหนาแน่นของสัตว์ป่าที่อยู่ในภาวะถูกคุกคาม ใกล้สูญพันธ์ หรือหายากในประเทศไทยและในพื้นที่ศึกษาแห่งนี้นั้นถือว่ามีน้อย ดังนั้นจึงได้ทำการศึกษาและประเมินความหนาแน่นของประชากรนกที่อยู่ในภาวะถูกคุกคามทั้งระดับชาติและระดับโลก รวมทั้งนกที่หายาก 14 ชนิด ที่ป่าบาลา ซึ่งเป็นส่วนหนึ่งของเขตรักษาพันธุ์สัตว์ป่าฮาลาบาลา ที่ตั้งอยู่บริเวณชายแดนไทย-มาเลเซีย และเป็นป่าที่ราบต่ำอีกผืนหนึ่งที่ยังเหลืออยู่ในประเทศไทย ชนิดที่ทำการศึกษาคือนกหว้า (*Argusianus argus*) นกเงือกเก้าชนิดได้แก่ นกเงือกเงือกหัวแรด (*Buceros rhinoceros*) นกกก (*B. bicornis*) นกชนหิน (*B. vigil*) นกเงือกดำ (*Anthracoceros malayanus*) นกเงือกปากดำ (*Anorrhinus galeritus*) นกเงือกหัวหงอก (*Aceros comatus*) นกเงือกปากย่น (*A. corrugatus*) นกเงือกกรามช้าง (*A. undulatus*) นกเงือกกรามช้างปากเรียบ (*A. subruficollis*) และกลุ่มนกที่ยังไม่รู้จักดีคือเหยี่ยวหงอนสีน้ำตาลท้องขาว (*Spizaetus nanus*) นกแต้วแล้วยักษ์ (*Pitta caerulea*) นกแต้วแล้วแดงมลายู (*P. granatina*) และนกคอสามสี (*Eupetes macrocerus*)

ทำการสำรวจโดยใช้วิธี Variable-width line transect เพื่อประเมินความหนาแน่นของประชากรและการกระจายของกลุ่มนกเป้าหมาย กำหนด 11 transect เพื่อสำรวจเดือนละครั้ง เป็นเวลา 16 เดือน (มกราคม 2544-เมษายน 2545) เส้นทางที่ทำการสำรวจประกอบด้วยทางเดินเท้า ทางทำไม้เก่า และถนนลาดยาง จากการสำรวจพบนกกลุ่มเป้าหมายทั้ง 14 ชนิดนี้ 1,531 ครั้ง จำนวน 2,559 ตัว ในช่วงเวลาดังกล่าวสามารถประเมินค่าความหนาแน่นได้เพียงเจ็ดชนิด อาจเนื่องมาจากขนาดพื้นที่ศึกษาเล็กเกินไป และประชากรของนกนั้นๆ มีน้อยมาก ค่าความหนาแน่นของนกแว่นคือ 0.2 ตัว/กม^2 (0.06-0.61, ค่าความเชื่อมั่นที่ 95%) ค่าที่ได้นี้เป็นค่าที่ต่ำกว่าที่ประเมินไว้ซึ่งอาจแตกต่างกันถึงเจ็ดเท่า ทั้งนี้อาจเนื่องมาจากความยากลำบากในการสำรวจและการประเมินในแต่ละครั้งส่วนใหญ่ได้จากการฟังเสียง ค่าประเมินความหนาแน่นของนกเงือกหัวแรดและนกชนหินคือ 2.31 (1.57-3.39) และ 0.99 (0.49-2.03) ตามลำดับ เป็นค่าที่มีความใกล้เคียงหรืออาจสูงกว่ารายงานจากพื้นที่อื่นเล็กน้อย ค่าประเมินความหนาแน่นของนกกกคือ 0.18 (0.10-0.31) นกเงือกปากดำ 0.38 (0.20-0.73) นกเงือกปากย่น 0.09 (0.04-0.19) และนกเงือกกรามช้างคือ 0.88 (0.52-1.48) ทั้งหมดเป็นค่าประเมินที่ต่ำกว่ารายงานจากพื้นที่อื่นในบริเวณนี้ ถึงแม้ว่าไม่สามารถประเมินความหนาแน่นของนกเงือกดำ นกเงือกหัวหงอกและนกเงือกกรามช้างปากเรียบได้ แต่การศึกษานี้ได้ชี้ให้เห็นว่านกเหล่านี้มีความหนาแน่นของประชากรต่ำ (< 0.1 ตัว/กม^2)

นอกเหนือจากขอบเขตของการศึกษานี้พบว่า หากสมมุติว่าค่าที่ประเมินนั้นไม่มีความโน้มเอียง เหตุผลที่ค่าประเมินมีความแตกต่างจากพื้นที่อื่นอาจเนื่องมาจากความแตกต่างของแห่งอาหาร รวมถึงการรบกวนจากมนุษย์ด้วย ซึ่งยังคงต้องมี*การศึกษ*าวิจัยต่อไป สำหรับนกอีกสี่ชนิดที่มีข้อมูลไม่เพียงพอสำหรับการประเมินนั้นคาดว่ามีความหนาแน่นของประชากรต่ำมาก (<< 0.1 ตัว/กม^2)

จากการศึกษานี้มีข้อเสนอแนะสำหรับงานวิจัยในอนาคตคือควรใช้วิธีการทดลองที่ถูกต้องและแม่นยำให้มากกว่าที่ได้ทำมา และควรหลีกเลี่ยงการใช้เส้นทางและถนนสายต่างๆ ซึ่งมีความโน้มเอียงของข้อมูลมากกว่าวิธีการสำรวจแบบเป็นระบบหรือแบบสุ่ม

Abstract

Density estimates of wildlife are preferable to relative indices because they provide better data for wildlife management, however density estimates for many of the threatened species in Thailand and the region are lacking. Here we attempted to estimate the densities of 14[a] globally or nationally threatened or otherwise rare species in Bala, which is part of Thailand's HalaBala Wildlife Sanctuary on the Thai-Malaysia border and one of the few remaining areas of lowland forest in Thailand. Focal species included the Great Argus pheasant, (*Argusianus argus*), nine species of hornbills: Rhinoceros (*Buceros rhinoceros*), Great (*B. bicornis*), Helmeted (*B. vigil*), Black (*Anthracoceros malayanus*), Bushy-crested (*Anorrhinus galeritus*), White-crowned (*Aceros comatus*), Wrinkled (*A. corrugatus*), Wreathed (*A. undulatus*), and Plain-pouched (*A. subruficollis*), and less well-known species including: *Wallace's Hawk-eagle* (*Spizaetus nanus*),Giant Pitta (*Pitta caerulea*),Garnet Pitta (*P. granatina*), and Rail-babbler (*Eupetes macrocerus*). Variable-width line transect surveys were used to estimate the densities and distributions of the focal species. Once per month we surveyed 11 transects during a 16-month period (January 2001 - April 2002) using trails, old logging roads, and one paved road. A total of 1531 observations of 2559 individuals of the 14 species were made during the observation period. Density estimates were only possible for seven of these species due to insufficient sample sizes presumably due to low densities. The mean density estimate for Great Argus was 0.20 individuals/km^2 (0.06-0.61, 95% confidence interval) and was likely to have been a significant underestimate, perhaps by as much as a factor of seven due to the difficulty in sighting the bird and estimating its distance from the observer based on vocalizations. Estimates for Rhinoceros and Helmeted Hornbill were 2.31 (1.57-3.39) and 0.99 (0.49-2.03) respectively and were similar or slightly above densities reported elsewhere. Estimates for Great 0.18 (0.10-0.31), Bushy-crested 0.38 (0.20-0.73), Wrinkled 0.09 (0.04-0.19), and Wreathed Hornbills 0.88 (0.52-1.48) were generally below and often well below estimates from other areas in the region. Although density estimates for Black, White-crowned, and Plain-pouched were not possible our data suggested that their densities were also quite low (< 0.10 individuals/km^2) compared with elsewhere. Although not the focus of this research, reasons for differences between this and other areas (assuming that most of the estimates were unbiased) were likely the result of differences in food resources and perhaps levels of human disturbance, but require further investigation. For the other four species insufficient data was available to draw conclusions other than that the densities of these species is likely to be very low (<< 0.10 individuals/km^2). It is recommended that future studies apply a more rigorous sampling method than was used here, and that the use of preexisting trails and roads should avoided because they are more likely to produce biased estimates compared with systematic or random sampling.

[a] **The original proposal included 10 species, including Bat Hawk (*Macheiramphus alcinus*) and Large wren-babbler (*Napothera macrodactyla*). Both of these are present in Bala, but were never observed during the surveys so they were not mentioned in the report. Another six species including Great Argus, (*Argusianus argus*), Great Hornbill (*Buceros bicornis*), Bushy-crested Hornbill (*Anorrhinus galeritus*), White-crowned Hornbill (*Aceros comatus*), Wreathed Hornbill (*A. undulatus*), and Rail-babbler (*Eupetes macrocerus*) were added to the study because of their conservation status and their presence during the surveys.**

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Introduction

Relatively undisturbed lowland forest (< 200-m elevation) is now rare in the Sundaic region (Lambert and Collar 2002), particularly in southern Thailand where greater than 95% of the natural forest has been destroyed (Round 1988). Because lowland forest is so rare, many of Thailand's listed bird species reside in the remaining fragments of lowland forest (Round 1988). Although the presence or absence of threatened species is now fairly well documented for the remaining lowland forest and other forests of Thailand (Round 1988; Robson 2002), density estimates generally have not been done, particularly in Thailand (although see Marsden 1999; Anggraini et al. 2000 for surveys in the region). Without estimates of density from different areas of the Sundas, it will be more difficult to estimate the total population size of such species and therefore make estimates of their long-term probability of survival much less precise. Furthermore, without density data it is difficult to make predictions about habitat suitability because relative indices generally cannot be compared among sites due to potential differences in detectability (Karanth and Nichols 1998).

Here we proposed to estimate the densities of 14 threatened or otherwise uncommon species of birds in a lowland forest fragment. In addition, we attempted to use relatively inexperienced field workers to conduct the surveys. With the status of many forest bird species under such dire threats and the number highly trained tropical ornithologists limited, we believed that it was essential to utilize enthusiastic, but less experienced local personnel. Although conducting complete surveys of the entire avian community is particularly valuable, these generally can only be done by highly trained, highly experienced individuals because the species richness can be very high in lowland forests and most (> 85%) identifications have to be done by ear due to the density and height of the vegetation (Hamel et al. 1996; Rosenstock et al. 2002). Inexperienced observers however, can be trained to monitor a small number of species relatively quickly.

Methods

Focal species

We focused on nine species of hornbill and five other threatened/rare species (see Table 1 for species names and conservation status). Hornbills (family Bucerotidae) are particularly sensitive indicators of forest condition and human disturbance because they require large tracts of unfragmented forest with large fruiting trees for feeding and nesting, and they are large, which makes them targets for hunting (Poonswad 1998; Lambert and Collar 2002). The Wrinkled hornbill (the rarest of the hornbills in Thailand) and Plain-pouched are of particular concern because they are restricted to level lowland, evergreen forest (Lekagul and Round 1991). Of the other species, Wallace's Hawk Eagle is mostly restricted to evergreen lowland and lowland slope forests in Thailand, while Giant Pitta, is also restricted to lowland forests below 800 meters (Lekagul and Round 1991).

Study site:

The Bala forest, is part of the Thai, Hala-Bala Wildlife Sanctuary, on the Thai-Malaysia border (5°37' N, 101°08' E). The Sanctuary is 111.5 km^2 in area isolated from other forests by agricultural lands on the Thai side of the border (although the larger Hala portion of the Sanctuary lies approximately >7 km to the west) and a mix of forest and agriculture on the Malaysian side. Bala ranges in elevation from 50 to 960 m above mean sea level and is broadly classified as tropical lowland evergreen forest. Rainfall is considerable and averages and is moderately seasonal. During the first year of the study (2001) rainfall was > 4700 mm (see below). Bala has also been partly logged prior to the 1989 logging ban, but the details are unavailable at this time. However, with the presence of nine species of hornbills, the site still ranks as one of richest in the region (M. Kinnaird *pers. comm.*).

Survey methodology:

We used variable-width line transect surveys to estimate the densities and distributions of our focal species following the methods of Bibby et al. (1992). Once per month we surveyed 11 transects, which varied in length from approximately 3 to 11.4 km, during the 16-month period (January 2001 - April 2002). Transects were > 200 m from adjacent transects to minimize the double counting of individuals. All transects were surveyed 15 times, except for two transects which were surveyed 16 and 14 times. Most transects followed existing trails, old logging roads, including one paved road, in lieu of straight lines due to the density of the vegetation and the steep terrain. Consequently, due to the subjectively placed transects, density estimates could be heavily biased and should be interpreted with caution, such that the estimates should only be applied to the areas along the trails rather than the entire study area (Buckland et al. 2001; J. Nichols, USGS Wildlife Biologist, *pers. comm.*). Fortunately, we believed these trails covered a sufficient portion of the study area to be representative of most habitats in the forest, except for the northern-most section which was largely unsurveyed. The transects were marked every 100 meters and partly surveyed using GPS to assist in locating birds. Survey work was carried out by observers who had been working in the sanctuary for several weeks before starting the surveys and were familiar with focal species prior to the start of the surveys. Observers were rotated among transects to reduce some potential observer bias. Starting and ending points of the transects were reversed whenever possible to avoid biases associated with time of day. Observers also trained as a group to estimate distance both visually and aurally to reduce biases in such estimates.

On each transect, observers recorded (1) focal species (and sex when possible), (2) number of individuals, (3) detection cue (visual, vocal, or flying), (4) location of the observer on the transect, (5) estimated distance between observer and the focal species, (6) angle between the observer and the hornbill, (as well as true compass direction to estimate positions on the GIS maps), (7) and relevant notes related to the observation such as the presence of a "dancing ground" for Argus pheasants or fruiting figs or other large fruiting tree species for hornbills. Because the density estimate is a 'snap-shot' in time, birds that were observed flying (i.e., those flying birds that were not seen leaving the area near the transect), were not used to estimate the density following Buckland et al. (2001).

Analyses

Average density estimates for the sampled areas were developed using DISTANCE software (Thomas et al. 2002). In general, we followed the recommendations of Buckland et al. (2001) and used by others for estimating the densities of the same or similar species in the region (Kinnaird et al. 1996; Marsden 1999; Anggraini et al. 2000). For all species, birds were entered as clusters and distance data was grouped automatically by the software or into distance intervals if a better model fit could be obtained. Only visual observations were used because distance estimations on the aural observations were in some cases unreliable and generally did not fit available detection functions. In addition, it was recommended that visual and aural detections not be combined, as they would likely provide different detection functions (S. Strindberg, Wildlife Conservation Society, *pers. comm*). Cluster size was estimated using mean observed cluster size, otherwise size-bias regression (regression of cluster size against distance, to test whether larger cluster were more detectable at greater distances) was used when the regression was significant at $\alpha = 0.15$. Models were fit using the default settings which used the automated sequential selection and the Akaike's Information Criteria (AIC) stopping rule. One of three models were used to fit detection probability functions: uniform, half-normal, or hazard, using cosine-adjustment terms. We also found that truncating the furthest observations (usually between 10-15% of the right tail of the distribution) was often required to obtain results. On one occasion we left truncated observations directly on the transect to reduce "heaping" of observations due to rounding errors (Buckland et al. 2001). We chose models with the lowest coefficient of variation of the density estimate (following Kinnaird et al. 1996), or the lowest AIC function (when using different models, but the same distance intervals and other input parameters, following Buckland et al. 2001).

Results

Eleven transects were sampled approximately once per month for 16 months between January of 2001 and April of 2002. A total of 1531 observations of 2559 individuals of 14 species were made during the observation period (Table 2). The majority of all the observations were aural rather visual (75.5% versus 18.6%, and 5.9% observed flying). The majority of these observations (91.8%) were made by three observers working individually, while an additional 7.0% were made by these individuals working with one other observer, and the remaining 1.2% were made by a fourth individual.

The number of monthly detections varied considerably during the course of the year. Ignoring the first survey period which was spread over three months (January-March), the total number of individuals detected ranged from 112 during March of 2001 to 216 in February of 2002. In terms of trends in detectability, detections of Rhinoceros and Helmeted Hornbills were moderately correlated ($r = 0.60$, $p < 0.05$) as well as Wreathed Hornbills and Argus ($r = 0.53$, $p < 0.05$), while Wrinkled and Great Hornbills were negatively correlated ($r = -0.55$, $p < 0.05$). However, there was generally little correlation among the focal species in terms of detectibility during the year (Figure 1), such that there was no clear trend to suggest which months surveys might be conducted most efficiently. The Great

Argus was the only species that showed a noticeable periodicity in detection, such that the number of individuals appeared to peaked in August during a somewhat drier period, (Figures 1 and 2), however this was based on only one year of observation. There was also no significant correlation between the total number of observations and the number of visual observations, nor was there a significant correlation between total monthly rainfall and the total number of monthly detections (Pearson Correlation or Spearman Rank Correlation, $p > 0.05$; Figure 2).

Density estimates were only possible for seven of the 14 species due to insufficient sample sizes presumably caused by low densities (Table 2, see Table 1 for Scientific names). The density estimates from this study for Rhinoceros and Helmeted Hornbill were generally near or above densities reported elsewhere, whereas estimates for Bushy-crested and Wreathed Hornbills well below previous estimates, often by a factor of more than ten. Great Hornbills were also considerably lower in density than reported from India (Raman and Mudappa (*in press*), but nesting densities from northeast India 0.33 pairs/km^2 (Datta and Rawat *in press*) appeared to be similar to densities reported here. Other species, densities were highly variable, but were generally either similar or considerably lower than reported elsewhere (see Table 3).

As with Marsden (1999), the coefficient of variation of the density estimates was relatively large, and less than 20% only when the number of sample observations was greater than 80. Although, this sample size was only achieved for Rhinoceros Hornbill (Table 2), we found even with observations as few as 11, we were able to obtain estimates with a coefficient of variation of 36%, which was equal to or often better than previous studies with birds (Marsden 1999; Nelson and Fancy 1999). However, for other species where there was insufficient detections to provide estimates, we tried to incorporate simple spot-mapping methods and GIS maps using ArcView 3.1 in which we estimated a minimum number of individuals present in the study area (see below).

Although the number of detections for some species (Helmeted Hornbill, Great Argus, and Wreathed Hornbill) were either greater than or approximately equal to 80, most were aural rather visual. The aural observations were noticeably different from the distribution of visual observations and generally could not be incorporated into the analyses (presumably compounded by increased distance estimation errors) because we were not able to achieve adequate model fit.

In addition, the Great Argus estimate from distance sampling was likely to have been significantly underestimated. Based on highly simplified spot-mapping described above, 18 different territories were spot-mapped within 100 m of the trails/transects, which assuming that every individual present within this radius was detected and that distances of ≤ 100 m could be estimated accurately, translated into a crude estimate of 1.39 pairs /km^2, assuming one female per male. This estimate was more than ten times higher than the estimate obtained from distance sampling, though similar to estimates of Davison (1981) from west-central Malaysia. We attribute this difference to the fact that visual observations were quite rare for this vocal, but shy species. Although, we attempted to use distance interval categories to reduce aural distance estimation problems it was not possible to fit known models with DISTANCE software to the aural data for this species.

For White-crowned Hornbill, a maximum of four birds was observed at any one time, and on one occasion two pairs of birds were recorded in different locations simultaneously. For the study area, there appeared to be at least three distinct clusters, with one of the clusters possibly representing two breeding pairs and two others representing at least two other males. Thus, the minimum estimate for the study area was six individuals.

For the remaining species similar, highly simplified techniques were used. For Plain-pouched Hornbills, six independent observations were made of clusters between May 2001 and March 2002, with all the observations falling between the months of March and August suggesting that it bred in Bala, but moved out of the area during the non-breeding season. The maximum number of individuals observed at any one time was four, indicating the presence of at least four individuals. For the Black Hornbill, there were a total of three individuals observed, with at least one pair, and one additional male observed in widely separated locations, indicating the presence of at least three individuals. For Wallace's Hawk-eagle, there were four independent observations of this species during the study period, and it was likely that no more than two unique individuals were ever present. For Giant Pitta, there were only two widely spaced observations suggesting a minimum of two individuals. For the Malaysian Rail-babbler and Garnet Pitta, only one individual was observed during the study period.

Discussion

Because we were interested in the management of relatively rare or threatened species we believe that it is more useful to have unbiased estimates of density, rather than just presence/absence or relative abundance. However, distance sampling requires four primary assumptions: (1) animals on or very near the transect lines are detected 100% of the time, (2) animals are detected before they move (either naturally or in response to the observer), (3) distances to animals are known accurately, and (4) sampling transects or points are randomly located (Buckland et al. 2001).

Regarding assumptions, one and two, because hornbills are large and relatively vocal birds, detection probability close to the observer is probably relatively high as suggested by other studies with hornbills (Marsden 1999), but they may flush fairly easily depending on the human hunting pressure in the area (Marsden 1999, Curio *in press*). During this survey, there was some evidence of premature flushing for two species Great Argus which were particularly difficult to detect visually (only 5% of the observations were visual; see below) and possibly Great Hornbill. Such movements away from observers would tend to bias density estimates downward (Buckland et al. 2001), and may account for the lower than expected estimates for both of these species.

During our surveys it was difficult to achieve adequate confidence in our aural distance estimations (assumption three) because the hornbill and pheasant calls could potentially carry for hundreds of meters. If distances were under or over-estimated by as little as 10% on line transects, then the density estimate would have been under or overestimated 9-11% (Buckland et al. 2001). For surveys of whose calls travel long distances, aural observations are unlikely to be reliable unless extensive training is done by estimating distances from birds of known locations, and even if with extensive training it is not clear that accurate distance estimates can be obtained due to the wide variety of conditions which can alter human perceptions of sound (Waide and Narins 1988). However, others have found it possible to estimate distances by sound if limited to short-distances with highly trained observers (a maximum of 100 to 120m) (Gates, 1995; Marsden 1999). When accurate distance estimation is not possible, it is generally recommended to divide data into four to eight distance intervals (Buckland et al. 2001; Rosenstock et al. 2002). The number intervals should be large enough to keep the level precision of the detection function high, but not so large as to make distance estimation difficult and time consuming. For example, intervals bounded at 10, 25, 50, 100, 200, and > 200 m can be used, and this decreases risks of distance estimation errors provided that observations are grouped into the proper category (Rosenstock et al. 2002). It is also recommended to keep the last interval unbounded (such as > 200 m). Fortunately for our study, we had sufficient numbers of visual observation for six species to achieve reasonable estimates in the absence of reliable aural observations.

Also related to assumptions three and four is the use of straight-line transects. Straight line transects maybe preferable over points because they increase the probability of detection for uncommon/rare species and it is easier to estimate the distance from the animal to the transect line if the lines are straight (Marsden 1999), however in rugged terrain and/or dense vegetation, it often too difficult and/or time-consuming to cut straight transects. While, using trails or other curving transects is theoretically possible (Hiby and Krishna 2001), they are subject to significant bias and must be used with extreme caution. Furthermore, if curving transects are used then the observer must estimate the shortest distance from the animal to the nearest point on the path. This can be quite difficult if the observer does not know exactly where they are on the path and/or if they are not particularly familiar with the curves of the path, which is often the case in dense forest and/or rugged terrain. Also when using many different paths for surveys, it is important to insure that the paths/transects are sufficiently separated to reduce double counting. For example, Marsden (1999) recommended 200 m separation between point count locations in forested habitats and 400 m in more open habitats. GIS and GPS can help map out trails and mark observer positions relative to the trail's curves in areas were the path is winding and vegetation dense. However, the GPS estimates have to be accurate (< ± 5 m or depending on the width of the distance categories) to derive reliable density estimates.

Alternatively, point counts are probably logistically simpler and require fewer assumptions. Furthermore, point counts can be used along trails with less bias, if points are positioned 50 m perpendicular to the trails (Marsden 1999). Point counts also do not require the observer to record angles, which could be another source of error when estimating distances. The drawback of point counts is that it may require a large number of sample points (2000 points, *e.g.* Marsden 1999) to estimate densities of rare species, and for some very rare species or species with very low levels of delectability it simply may not be possible.

Specific recommendations for estimating densities and monitoring wildlife populations in Bala and elsewhere in Thailand

- Density estimates are preferable to managing wildlife, particularly threatened species, because population size is a key indicator in estimating long-term survival. Furthermore, without density data it is difficult to make predictions about habitat suitability because relative indices generally cannot be compared among sites due to potential differences in detectability (Karanth and Nichols 1998). In other words, because $\hat{N} = \frac{C}{\hat{p}}$ (where $\hat{N}$ = the estimated abundance, C = count of target species and $\hat{p}$ = the estimated detection probability), it is quite possible that if the detectability of a target species in a forest site with open vegetation is twice as high compared with densely vegetated site (where for example $\hat{p}$ = 1 versus $\hat{p}$ = 0.5), the animal counts would be exactly the same (C = 50, for example) but the true densities would be twice as high in the densely forested site ($\hat{N}$ = 100 versus $\hat{N}$ = 50).
- Thus, using unbiased sampling methods is critical to estimating the true density of target species. In addition, methods must be repeatable and comparable, such that long-term comparisons can be made. Once scientifically sound unbiased sampling methods have been established, changes in sampling protocol should not be made unless it can be shown that comparability and continuity can be maintained.
- For sampling species such as hornbills, sampling along roads and trails should be avoided because roads and trails are normally not set randomly nor systematically, and are therefore likely to sample an area in a way that may be difficult to understand, and more likely to provide biased estimates. For uncommon large mammals such as tiger, elephant, bear, etc. sampling along animal trails is often necessary to increase capture probabilities (Karanth and Nichols 1998), but this technique can estimate densities only when individuals can be recognized such that mark-recapture techniques can be utilized.
- Future surveys in Bala should avoid using the roads and pre-existing trails as in this survey because of the sampling problems it causes, particularly the road. It is therefore recommended that habitats of Bala be demarcated using GIS/Remote Sensing and sampled following some form of stratified random design, whereby different habitat types are sampled in proportion to their presence (e.g., if 10% of the area is classified as "lowland" forest and 15% disturbed forest then approximately 10% of the samples should occur in "lowland" habitat and 15% of the samples in "disturbed"). Furthermore, straight line transects are preferable to point counts because of the increased detection probability with such low-density species. Although long, straight lines may be difficult in this habitat, it seems possible that several short transects of 2 to 4 kilometers should

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be usable. However, if straight lines are not possible, then point counts are a viable alternative, but there is still the problem of getting to randomly placed points particularly if there is no existing grid or an extensive trail network. Although some researchers have used point counts located 50 m perpendicular to the left and right of trails (Marsden 1999; Marsden and Pilgrim 2003), this may still be biased and should be avoided if possible.

- Finally, due to limitations in time and resources, sampling should be designed to obtain the maximum amount of information for management purposes, with the least cost. Because the densities of target organisms are so low, it seems unlikely that density estimates would be possible on a monthly basis. However, sampling could be carried out more intensively during a single period of 2 to 4 weeks during a year and this should provide sufficient data for monitoring purposes. This would also have the added advantage of keeping within year variation in detectability to a minimum. The choice of a sampling period is problematic because different species are more easily detected at different months of the year, such that species such as Great Argus appear to be most detectible in August while hornbills appear to be most detectable either before nesting or after nestlings fledge. Choosing between these two periods may depend on other factors such as rainfall which may interfere with surveys or other factors such as the potential biases caused by sampling newly fledged juveniles together with adults. Densities of very rare species such as Giant Pitta probably cannot be effectively estimated through distance sampling, and may require other intensive methods such as spot mapping.

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Table 1. Focal species and their conservation status (source ARCBC 2003). Species occur in the order of Robson (2000).

Species	Conservation status (source & status)		
	CITES	IUCN Red Databook	Thai Red List
Great Argus *Argusianus argus*	II	-	Vulnerable
Rhinoceros Hornbill *Buceros rhinoceros*	II	-	Threatened
Great Hornbill *Buceros bicornis*	I	Near-threatened	Vulnerable
Helmeted Hornbill *Buceros vigil*	I	Near-threatened	Vulnerable
Black Hornbill *Anthracoceros malayanus*	II	Near-threatened	Threatened
Bushy-crested Hornbill *Anorrhinus galeritus*	II	-	Vulnerable
White-crowned Hornbill *Aceros comatus*	II	-	Vulnerable
Wrinkled Hornbill *Aceros corrugatus*	II	Near-threatened	Endangered
Wreathed Hornbill *Aceros undulatus*	II	Near-threatened	Vulnerable
Plain-pouched Hornbill *Aceros subruficollis*	I	Vulnerable	Threatened
Wallace's Hawk-eagle *Spizaetus nanus*	II	Vulnerable	Threatened
Giant Pitta *Pitta caerulea*	-	Near-threatened	Threatened
Garnet Pitta *Pitta granatina*	-	-	Threatened
Rail-babbler *Eupetes macrocerus*	-	-	Rare

Table 2. Summary of observations, detections, detection rates and density estimates for Bala Wildlife Sanctuary based on 16 months of observations (February 2001-April 2002).

	Observation type (number of observed clusters)				Detections & Detection rate			Density estimate (individuals / km^2)				
Species	Visual	Aural	Flying	Total	Average group size	Total no. of individuals detected	Individuals detected / km of transect surveyed	No. of clusters used for analysis	Estimate	Lower 95% CI	Upper 95% CI	%CV
Rhinoceros Hornbill	112	476	41	629	1.9	1191	1.17	93	2.31	1.57	3.39	19.2
Helmeted Hornbill	48	366	12	426	1.4	611	0.60	41	0.99	0.49	2.03	36.8
Great Argus	13	249	0	262	1.1	280	0.27	10	0.20	0.06	0.61	58.0
Bushy-crested Hornbill	14	24	3	41	4.2	174	0.17	14	0.38	0.20	0.73	32.2
Wreathed Hornbill	50	11	17	78	1.9	149	0.15	42	0.88	0.52	1.48	25.7
Great Hornbill	23	21	10	54	1.7	92	0.09	18	0.18	0.10	0.31	28.2
Wrinkled Hornbill	11	2	2	15	1.4	21	0.02	11	0.09	0.04	0.19	36.3
White-crowned Hornbill	6	4	0	10	1.8	18	0.02	-[a]	-	-	-	-
Plain-pouched Hornbill	3	0	3	6	2.0	12	0.01	-	-	-	-	-
Wallace's Hawk-eagle	2	0	2	4	1.0	4	< 0.01	-	-	-	-	-
Black Hornbill	2	0	0	2	1.5	3	< 0.01	-	-	-	-	-
Giant Pitta	0	2	0	2	1.0	2	< 0.01	-	-	-	-	-
Garnet Pitta	1	0	0	1	1.0	1	< 0.01	-	-	-	-	-
Rail-babbler	1	0	0	1	1.0	1	< 0.01	-	-	-	-	-
Total	286	1155	90	1531	1.7	2559	>2.50	-	> 5.03	-	-	-

[a] Insufficient number of detections to estimate density

Table 3. Density estimates (individuals / km^2) for Asian hornbill species found in Bala as compared with studies elsewhere in Eastern and South East Asia.

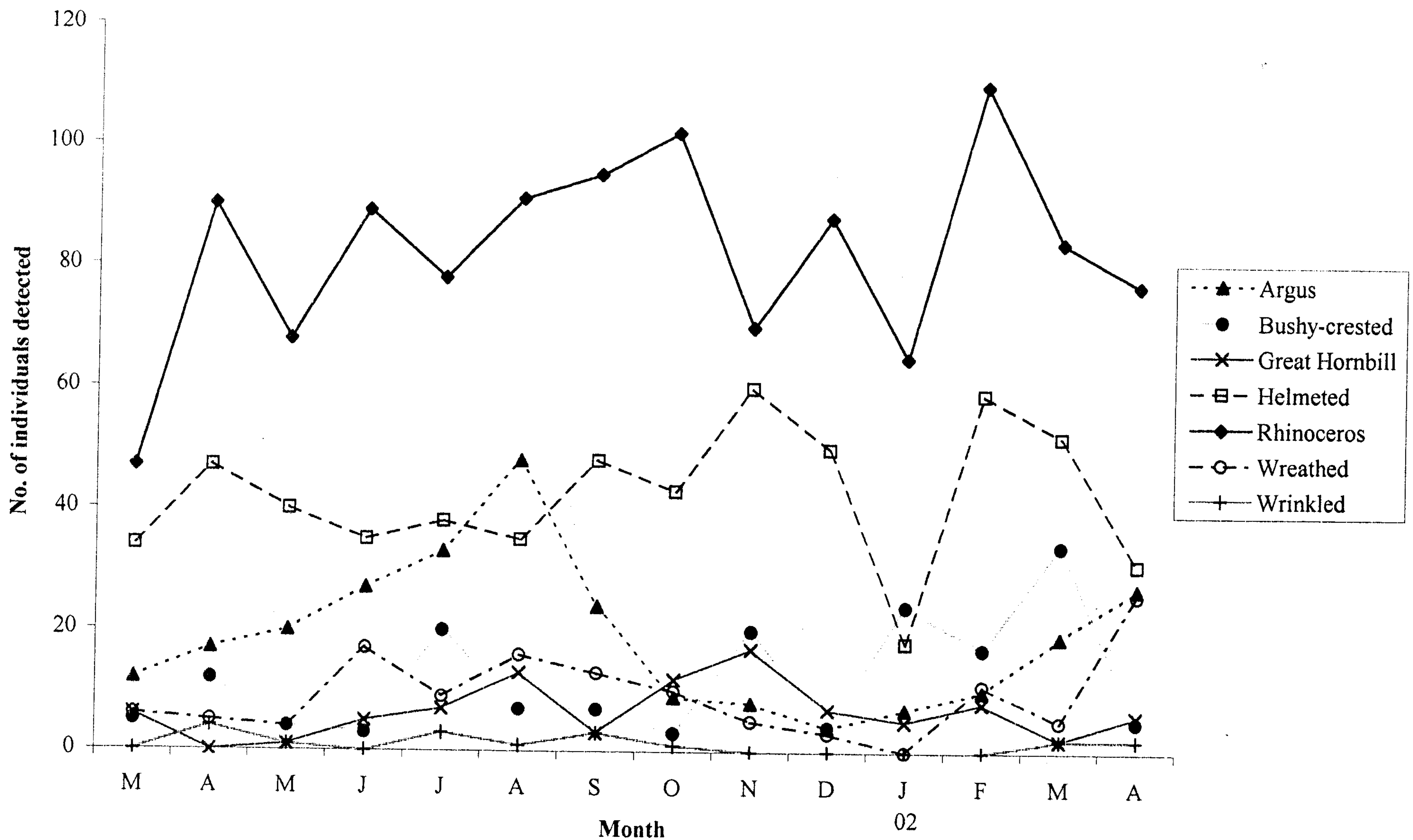
Species	Davison (1981) [W. central Malaysia]	Kemp (1995)[a] [Malaysia & Indonesia]	Angraini et al. (2000) [S.W. Sumatra]	Whitmore (1984)[b] [C. Malaysia]	Van Schaik Unplubl. Report[b] [N. Sumatra]	Leighton (1982) [E. Kalimantan]	Raman and Mudappa (in press) [S.W. Ghats, India]	this study [S. Thailand]
Great Argus	1.5-2.25	-	-	-	-	-	-	0.20 [1.39][d]
Rhinoceros Hornbill	-	2.8 (0.8-20)	2.60	0.5	3.11	1.10	-	2.31
Helmeted Hornbill	-	3.1 (0.25-16.7)	1.90	0.5	0.83	0.30	-	0.99
Bushy-crested	-	3.5 (1.25-5.8)	3.05	2.5	4.28	6.20	-	0.38
Wrinkled Hornbill	-	0.6 (0.10-0.7)	-	-	0.10	5-21[b]	-	0.09
Wreathed Hornbill	-	2.9 (0.8-6.7)	7.50	-	1.05	10-46[b]	-	0.88
White-crowned Hornbill	-	1.8 (0.5-3.1)	-	present[c]	-	4.20	-	< 0.10[e]
Black Hornbill	-	1.9 (0.5-4.0)	-	2.0	-	2.70	-	< 0.10[e]
Plain-pouched Hornbill	-	-	-	-	-	-	-	< 0.10[e]
Great Hornbill	-	-	-	-	-	-	3.4-9.55	0.18

[a] Median values (minimum and maximum) from studies referenced in Kemp (1995) other than those cited directly in this table.
[b] Values cited from Kinnaird et al. (1996)
[c] Present but densities not estimated
[d] Number in brackets is a density estimate based on spot mapping
[e] Insufficient detections for density estimates; based on encounter rates and spot mapping densities

Figure Captions

Figure 1. Number of individual detected of the seven most common focal species observed in the Bala portion of the Hala-Bala Wildlife Sanctuary between March 2001 and April 2002 (see Table 1 for scientific names and conservation status).

Figure 2. Total rainfall and total number of individual birds of the 14 target species detected between March 2001 and April 2002 in the Bala portion of the Hala-Bala Wildlife Sanctuary. (Rainfall data from the Waeng district meteorological station approximately 10 km from the study area).



120
100
80
60
40
20
0
No. of individuals detected
M
A
M
J
J
A
S
O
N
D
J
02
F
M
A
Month
Argus
Bushy-crested
Great Hornbill
Helmeted
Rhinoceros
Wreathed
Wrinkled

Figure 1

22

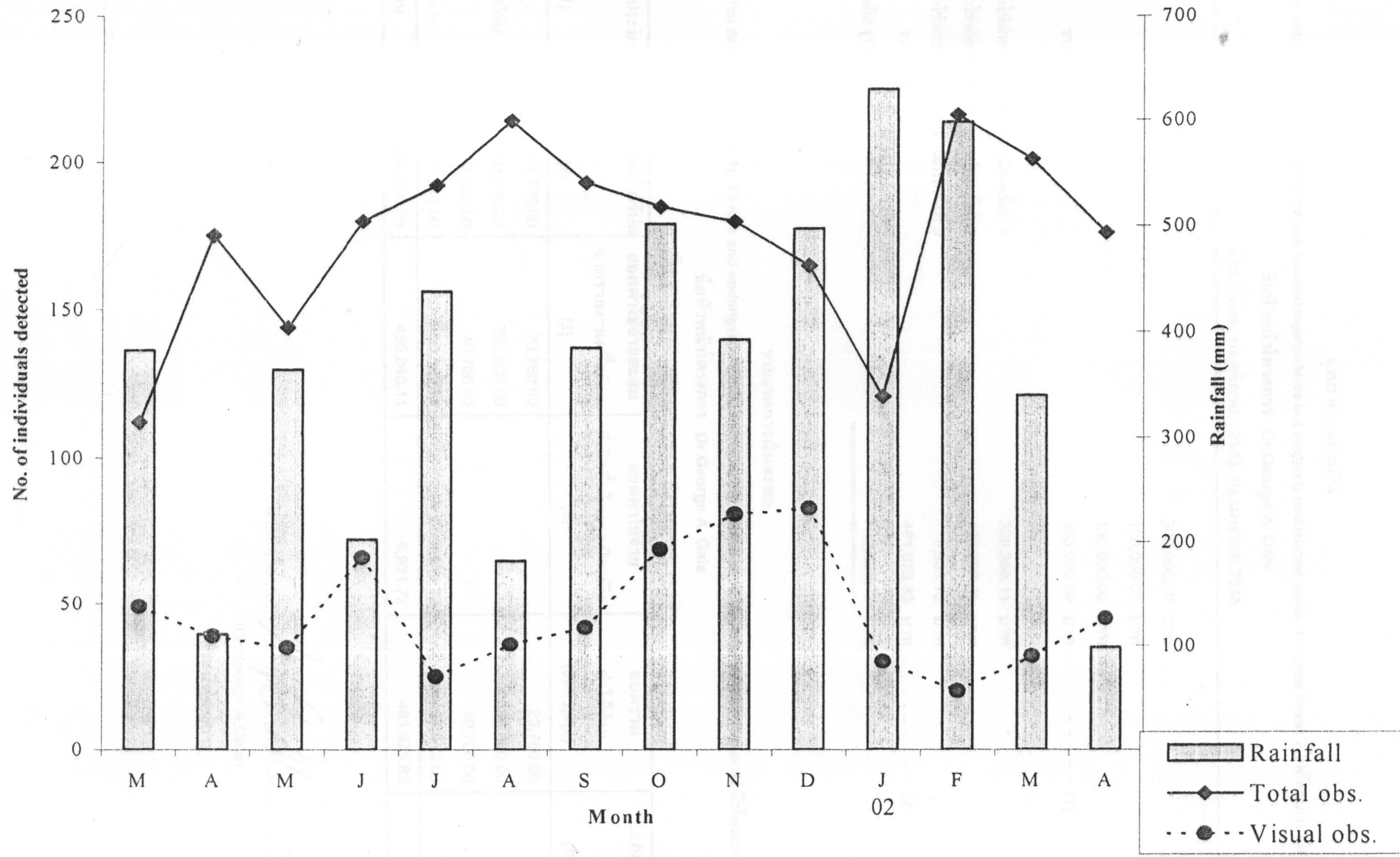

250
200
150
100
50
0
No. of individuals detected
700
600
500
400
300
200
100
Rainfall (mm)
M
A
M
J
J
A
S
O
N
D
J
F
M
A
02
Month
Rainfall
Total obs.
Visual obs.

Figure 2