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A Comparison of Hylobatid Survey Methods Using Triangulation on Müller's Gibbon (*Hylobates muelleri*) in Sungai Wain Protection Forest, East Kalimantan, Indonesia

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Abstract Density estimates are a common tool for assessing potential changes in primate populations over time and for evaluating important habitat characteristics such as preferred food sources. There are several different methods for estimating the density and population of wild primates, though the accuracy of these methods across different habitats and species is difficult to assess. We calculated the density of the population of Müller's gibbon (*Hylobates muelleri*) in the pristine and regenerating forest in Sungai Wain Protection Forest in East Kalimantan, Indonesia from May to July 2012. We collected data on the location of bonded pairs and compared the results of two different density estimate methods: triangulation and point transect sampling using Distance software. The triangulation method yielded population estimates of $486.9 \pm \text{SD } 132.6$ individuals in the pristine forest and $274.3 \pm \text{SD } 179.0$ in the regenerating forest. Distance analysis produced population estimates of $580.5 \pm \text{CV } 20.6$ and $388.4 \pm \text{CV } 23.4$ individuals for the pristine and regenerating forest, respectively. The difference in the density estimates between methods was not significant. We hypothesize that point transect sampling overestimated group density based on the unusually high estimate,

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but further investigation into the accuracy of point transect analysis using Distance with respect to gibbons is needed. We conclude that triangulation remains an important tool for hylobatid surveys because of its efficacy in locating gibbon groups using acoustic detection.

Keywords Borneo · Distance sampling · Point transect · Triangulation

Introduction

Accurate population estimates of primate species are crucial in the assessment of important habitat characteristics and the changes in these characteristics over time. If completed often enough, density estimates will allow researchers to monitor fluctuations in a primate population following seasonal or anthropogenic effects. In addition, by monitoring the impact of habitat changes on specific populations, important habitats may be designated as priority conservation areas (Mitani 1990; Mittermeier *et al.* 1998; Plumptre and Cox 2006).

There are several methods of estimating primate density, the most common being line transects and distance sampling techniques (Buckland *et al.* 2010a; Lee *et al.* 2015; Lindsell *et al.* 2011; Plumptre 2000; Plumptre and Cox 2006; Thomas *et al.* 2010). In line transect sampling animals are recorded from systematically placed transects using a random starting point and data are analyzed using Distance software, which estimates the abundance and/or density of objects by establishing a detection probability function (Buckland *et al.* 2001; Thomas *et al.* 2010).

In addition to line transects, Distance software may also be used to analyze data collected using point transects, whereby an observer stands at a single location and records the distance to acoustic rather than visual cues (Buckland 2006; Buckland *et al.* 2010b). This technique is common in avian surveys because it is not necessary that the observer see the animal directly (Buckland 2006; Buckland *et al.* 2010b; Nijman 2001; Thomas *et al.* 2010). It has been argued that line transect methods are not ideal for hylobatids because gibbons tend to favor the upper canopy, live in small groups, and may flee quietly or hide on being approached by humans, rendering methods that rely on solely visual detection unreliable (Brockleman and Ali 1987; Mukherjee 1986; Nijman 2001; Nijman and Menken 2005). Therefore many studies have favored triangulation and associated formulae for gibbon surveys because they allow for efficient sampling over large areas and rely on auditory detection (Brockleman and Ali 1987; Buckley *et al.* 2006; Hamard *et al.* 2010; Nijman 2001; O'Brien *et al.* 2004). This method is appropriate for hylobatid surveys because gibbons vocalize regularly and can be heard over considerable distances, which allows for a large survey area (Mukherjee 1986; Neilson *et al.* 2013; Nijman 2004; Nijman and Menken 2005; O'Brien *et al.* 2004).

Müller's gibbons (*Hylobates muelleri*) are currently listed as Endangered because of a perceived decrease in population by >50% in the last 45 yr (IUCN 2013). They are found in southeastern Borneo, having recently been designated a separate species from the closely related northern gray gibbon (*H. funereus*) and Abbott's gray gibbon

(*H. abbotti*) (Chivers *et al.* 2013). Habitat loss; illegal trade; and, in the interior of Borneo, hunting, are the main threats to Müller's gibbons (Bennett *et al.* 1987; Geissman 2007). Sungai Wain Protection Forest is one of the few remaining primary coastal lowland forests in East Kalimantan and covers an area of *ca.* 100 km² north of Balikpapan, East Kalimantan (1°05'S and 116°49'E). In 1998 naturally occurring forest fires affected *ca.* 60% of the protected area. The remaining 40% was unburnt, and presently makes up the pristine core of the reserve (Fig. 1) (Fredriksson and Nijman 2004). Despite >15 yr of regeneration, the diversity and density of trees remains low, and the impact of these habitat characteristics on the density and distribution of primate species, including Müller's gibbons, within the reserve is unknown (Sastramidjaja, *unpubl. data*).

Distance analysis has only recently been used to estimate gibbon density (Hassel-Finnegan *et al.* 2008; Höing *et al.* 2013; Lee *et al.* 2015). Phoonjampa *et al.* (2011) used Distance software to establish the effective detection radius after discarding the furthest 5% of all distance estimates; however they did not use distance analysis techniques to generate a population estimate, relying instead the triangulation formula to estimate group density (Brockleman and Ali 1987).

The aim of this study was to provide a density estimate of Müller's gibbons in the pristine and regenerating forest in Sungai Wain Protection Forest. We also sought to compare the results of two different methods of data analysis: the triangulation formula

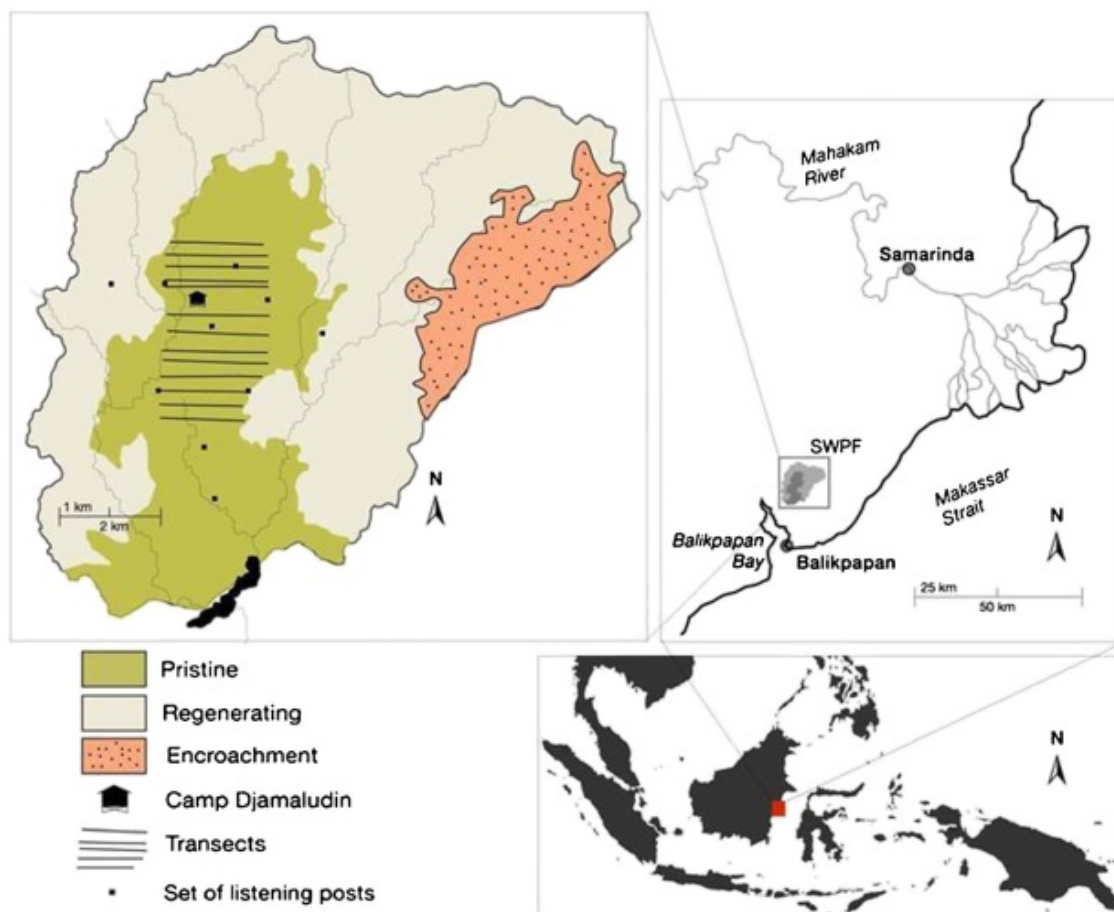


Fig. 1 Map of Sungai Wain Protection Forest in April 2012 showing the pristine and regenerating forest, transect grid, Camp Djamaludin, and the approximate center of 10 sets of listening posts used to collect data on pair-bonded calls of Müller's gibbons. (Derived from Bersacola *et al.* 2014.).

and *post hoc* point transect sampling using Distance software, to assess whether the results were comparable across methods.

Methods

Study Species

Müller's gibbons live in bonded pairs, which are characterized by an exclusive relationship between opposite-sex individuals (Fuentes 2000). They produce complex and sequentially organized duets that are dominated by females and can be divided into introductory, interlude, and great call sequences. The introduction phase features short repetitive notes by the female before being joined by the male for the alternating interlude and great call sequences (Haimoff 1985).

Study Area

Sungai Wain Protection Forest achieved protected status in 1983 after having previously been designated as a water catchment reserve for the Balikpapan oil industry in 1947 (Nijman and Menken 2005). Approximately 75% of Sungai Wain Protection Forest is dominated by lowland dipterocarp forest, with elevation ranging from 40 to 140 m above sea level (Cleary and Priadjati 2005). The forest includes five topographical types: 1) alluvial forest containing flat, noninundated areas featuring large trees and in close proximity to rivers; 2) swamp areas that are either inundated or show signs of inundation and feature a high density of small-diameter trees, rattans, and climbers; 3) high flat forest exhibited by a flat, elevated area away from rivers, often characterized by large trees; 4) slope forest with steep inclination; and 5) ridge forest occurring on the narrow tops of hills with crests or sides of longer chains. The forest is composed of slight to steep hills that are intersected by small rivers (Fredriksson and Nijman 2004). Rainfall patterns are inconsistent annually; however the wet season tends to fall between December and March while August to November are typically the driest months (Fredriksson and Nijman 2004). Sungai Wain Protection Forest experiences a mean monthly rainfall of 130 mm and temperature ranged from 25 to 36°C during the study period (BMKG 2015).

There are eight other primates species in Sungai Wain Protection Forest: long-tailed macaque (*Macaca fascicularis*), pig-tailed macaque (*Macaca nemestrina*), proboscis monkey (*Nasalis larvatus*), white-fronted langur (*Presbytis frontata*), red langur (*Presbytis rubicunda*), Bornean orang-utan (*Pongo pygmaeus*), Bornean slow loris (*Nycticebus menagensis*), and Horsfield's tarsier (*Tarsius bacanus*) (Bersacola et al. 2014; Russon 2009). There are a number of current management objectives in the reserve at present; however, most relevant to primate conservation are the continuous anti-poaching and anti-logging patrols as well as forest fire prevention (HLSW 2015).

Sungai Wain Protection Forest currently includes 40 km² of regenerating forest and 40 km² of pristine forest; the remaining 20 km² at the eastern border of the reserve has experienced illegal clearing since the 1970s for conversion to gardens (Fig. 1). Despite being damaged during the 1998 fire, this area still experiences encroachment today, including illegal logging. Though no published data exist, poaching also occurs in this

area in the form of setting snares to catch deer species and to prevent crop raiding by pigs (G. Fredriksson *pers. comm.* 2013). Government intervention and border patrolling units established in 2002 eradicated both poaching and illegal logging in the pristine core of the forest (Harrison 2011). Human movement in the pristine forest is limited to researchers and visitors and is subject to management approval (Gilhooly *pers. obs.* 2012).

Data Collection

We collected data from 10 sets of listening posts over 38 survey days from May 20, 2012 to July 16, 2012. Each set was composed of three listening posts arranged in a triangle located 300–500 m apart (mean 360.4 ± 68.8 , $N = 30$, range: 300–511). We trained two research assistants in triangulation methods before the start of data collection, and the same individuals collected data throughout the survey. Data collection began when all three researchers agreed on the distance and compass bearing of groups calling. We located one or two individuals at each listening post and recorded the compass bearing and estimated distance in 3-min intervals to each gibbon group. We recorded the exact time of each great call to corroborate group triangulation among all three listening posts. We collected data on the estimated distance to each group to differentiate between groups calling from a similar bearing. We did not attempt to identify individuals within a pair-bonded group using unique song characteristics.

To ensure we did not count lone males as a group, we included only groups for which a female's great call was heard, indicating a bonded pair (Cheyne *et al.* 2008). Each team was in place between 04:30 and 05:00 h, and data collection began when the first gibbon group started singing and continued until all groups had stopped for 30 min (Cheyne *et al.* 2008; Hamard *et al.* 2010). We did not restrict data collection to a single time slot because there is no peak calling period for Bornean gibbons and the triggers for them to start and stop singing appear to be behavioral rather than external (Cheyne 2008; Harrison 2011). Although gibbons may sing after 30 min of silence, this behavior represents <2% of all singing bouts and is often associated with a territorial conflict or interaction with another species (Cheyne *unpub. data*). By terminating data collection after 30 min of silence we were less likely to count groups twice because of undetected movement between calling trees. In addition, limiting data collection to a specific time slot does not take into account the changes in the audibility of a group over the course of one morning; an observer may hear a group for the first time long after the gibbons started calling. Excluding observations beyond a specific cutoff time would result in an underestimation of gibbon groups.

We selected the general location of the 10 sets of listening posts to cover the largest possible survey area, which largely limited us to the established transect grid in the pristine forest. Our survey was mostly restricted to the east, west, and south of camp because there was no constant trail maintained running north from camp Djamaudin (Fig. 1). We selected the location for the first set of listening posts based on its proximity to camp and lack of deep valleys that may have inhibited gibbon detection (Phoonjampa *et al.* 2011). We placed subsequent listening posts ≥ 1 km away from the next nearest set (mean 1.15 ± 0.2 , $N = 14$, range: 0.95–1.54). We selected the precise location of each listening post by prioritizing areas of high elevation and avoiding valleys where gibbon calls might be missed. It has been argued that this is more

important than ensuring that the distance between each listening post is uniform (Phoonjampa *et al.* 2011).

The proportion of a groups calling on any given day can vary depending on gibbon density and climatic conditions (Cheyne 2008; Maples *et al.* 1988). In addition, gibbons may not call every day even if no adverse climatic conditions are in effect (Brockelman and Srikosamatara 1993). Therefore, locations should be surveyed for a minimum of 4 d to ensure that all groups in the area are recorded (Brockelman and Ali 1987; Brockelman and Srikosamatara 1993; Cheyne *et al.* 2008; Hamard *et al.* 2010; O'Brien *et al.* 2004). We surveyed 9 of the 10 sites for 4 d, and the last for only 2 d because of time constraints. We considered all groups heard ≥ 500 m apart as separate groups and differentiated groups ≤ 500 m apart based on which calls were heard simultaneously (Brockelman and Srikosamatara 1993; Buckley *et al.* 2006; O'Brien *et al.* 2004). We used the intersection of the compass bearings from each listening post to compile a map of all of the groups heard during a single survey. We used these daily locations to calculate a mean of the global positioning system (GPS) coordinates to produce a single location for each group. We did not triangulate any groups for which we could not confidently assign a single location.

Data Analysis

Triangulation Formula We obtained density estimates (D) from the pristine and the regenerating forest using the formula

$$D = n / (p(m) \times E)$$

where n represents the total number of groups heard from a set of listing posts, $p(m)$ is the anticipated proportion of groups expected to sing over a period of m days, and E is the total effective listening area (Brockelman and Ali 1987; Cheyne *et al.* 2008). Independent data from this site were not available; we therefore calculated the correction factor $p(m)$ using calling data from the present study with the formula

$$p(m) = 1 - (1 - p(1))^m$$

where $p(1)$ represents the singing probability for any given day (total number of survey days (m)/total number of groups heard in the effective listening area) (Cheyne *et al.* 2008).

We defined the effective listening area (E) as the area in which at least two researchers at their respective listening posts could hear groups calling. We calculated this area using the effective detection radius (EDR) generated by Distance, and we used the same EDR for each set of listening posts (Cheyne *et al.* 2008; Phoonjampa *et al.* 2011). We drew the EDR around each listening post and measured the overlapping area in which at least two researchers should have heard groups calling. We included only groups that were identified by two or more listeners, or those that were observed directly near a listening post during data collection. We excluded from analysis groups that were located outside of the EDR or were heard by only one listener. Of the 10 sites surveyed, four were located entirely in the pristine forest, 5 included both pristine and regenerating forest, and 1 was located entirely in the regenerating forest. Despite the reduced survey effort, we include a density estimate for the regenerating forest given

that such habitat types have been shown to be nevertheless important for gibbon conservation (Lee *et al.* 2015). We calculated separate density estimates for the pristine and regenerating forest by measuring the total amount of each forest type in each effective listening area (E). We determined whether a group was located in the pristine or regenerating forest by plotting its estimated location into Google Earth Pro v. 7.0.3.8542, whose aerial image of Sungai Wain Protection Forest shows clearly the boundary between the two forest types.

Distance Sampling. In addition to the triangulation formula, we analyzed the same data using point transect analysis and Distance v.6.2 (Thomas *et al.* 2010). There are three main assumptions to distance sampling: 1) Objects on a line or point are detected with certainty; 2) objects are detected at their initial location; and 3) measurements are exact. In point transect surveys it is also important that 4) objects move independently of the points and 5) they are measured from a single location (Buckland *et al.* 2001; Thomas *et al.* 2010). Given that gibbons may call for >30 min per day and we surveyed each point for several days, our survey should have satisfied the first assumption that all objects on a point are detected. All researchers were in place before dawn and remained quiet and stationary thereafter. It is possible that gibbons may flee quietly when approached by humans and thus may have escaped undetected (Nijman 2001). However, because gibbons do not typically sleep in the same tree for two consecutive nights and we surveyed each site for 4 d, it is unlikely that a group was undetected for the entire survey (Reichard 1998). On a similar note, researchers being quiet and stationary at their listening posts should have ensured that groups were detected at their initial location, i.e., on waking up. It was not possible to ensure that all measurements were exact given the distance between the observers and the objects. Gibbons may move in the canopy and change direction as they call, creating a certain degree of error in estimating the compass bearing to the group (Haimoff 1985; Rawson 2010). However, such errors would have been random and without bias, and triangulation by two or more listeners over the course of several days should have reduced this effect. The assumption that objects move independently of the point transects can typically be satisfied by an adequate survey effort and the random distribution of data collection points (Thomas *et al.* 2010). The location of each of our listening posts was determined in part based on what would allow for a high degree of audibility, i.e., prioritizing areas of high elevation and avoiding valleys. Therefore the assumption that the location of data collection points was random was violated (Rawson 2010). Lastly, to satisfy the requirement that all objects were measured from a single point, we calculated the mean GPS coordinate of all three listening posts in each respective set and used this as the central point from which we measured the distance to each bonded pair. If only one listener identified a group close to its listening post we used the single distance estimate calculated in the field as the distance from the central point (Lee *et al.* 2015). We cannot be sure that no groups were missed at the central point on any given morning because listeners were never physically present at that location. However, surveying for several days should have reduced the likelihood that such groups went undetected.

We generated density estimates by running uniform, hazard rate, and half normal tests with different combinations of cosine, simple polynomial, and hermite polynomial adjustments after right-truncating observations beyond a probability of detection of 0.1 (Buckland *et al.* 2001). We entered each listening post as a single stratum and used each group as an individual observation. We entered the forest type the gibbons were located in as an additional parameter to allow for post stratification by habitat. In addition, we adjusted survey effort to account for the uneven distribution of strata between the two forest types. We weighted the analyses by total area surveyed in each strata and used the mean of the two habitat densities to generate a global estimate for the entire survey area (Lee *et al.* 2015). We also analyzed the regenerating data separately and left-truncated the data to correct for the lack of 0 m points in the regenerating forest. We used the lowest Akaike's information criterion (AIC) value to determine the most appropriate detection probability function (Akaike 1973).

Population Estimate We used the lowest value reported by Nijman and Menken (2005) of 3.3 individuals/group in Sungai Wain Protection Forest to generate a conservative individual density and overall population estimate in the pristine and regenerating forest. Although this group size estimate was derived from data collected following the 1998 forest fire and may not reflect current values, it has the advantage of being from the same site. We include the population estimate as a cautious extrapolation of previous research in Sungai Wain Protection Forest.

Ethical Note

We obtained all necessary permissions before starting data collection, including federal and local. As our methods required listening only, the impact of our research on surrounding fauna and flora was minimized.

Results

We plotted a total of 650 bearings between all 30 listening posts over 38 survey days. We identified 71 groups in the entire survey area and 64 groups in the pristine forest. We identified a mean of $6.0 \pm \text{SD } 1.5$ groups (range: 3–9) and recorded $67 \pm \text{SD } 15.9$ unique bearings from each set of listening posts (range: 30–88). We collected all data between 04:30 and 08:50 h, with a mean daily survey effort of $140.8 \pm \text{SD } 42.0$ min ($N = 38$, range: 63–245). We did not identify any groups calling after 30 min of silence. Parameters used to estimate gibbon density are provided in Table I. Density estimates generated by Distance and triangulation analysis methods are shown in Table II.

Triangulation

The effective detection radius was 814 m and produced a total surveyed area of 19.84 km², of which 14.97 km² were located in the pristine forest and 4.87 km² in the regenerating forest.

Table I Summary of the parameters used to estimate Müller's gibbon density in the pristine and regenerating forest in Sungai Wain Protection Forest from May to July 2012

Site	Number of groups heard <i>N</i>		Number of survey days <i>M</i>		Effective listing area (km ²) <i>E</i>	
	Pristine	Regenerating	Pristine	Regenerating	Pristine	Regenerating
A	6	—	4	4	1.98	—
B	6	—	4	4	1.98	—
C	6	—	4	4	1.99	—
D	6	0	4	4	1.12	0.87
E	6	3	4	4	1.27	0.72
F	5	3	4	4	0.89	1.09
G	6	—	4	4	1.98	—
H	7	0	4	4	1.65	.32
I	—	3	—	4	—	1.99
J	8	—	2	2	1.99	—

Calling probability ($p(1)$)=0.61, correction factor ($p(m)$)=0.98.

Distance Analysis

The 814 m effective detection radius for each point produced a survey area of 2.08 km² for each set of listening posts (total: 20.8 km², $N = 10$). There was a small degree of overlap between some adjacent sets of listening posts (mean $0.14 \pm \text{SD } 0.08$ km², range: 0.03–0.32). The total amount of overlapping area was 1.38 km² (7%). After the post stratification analysis we selected the uniform model with a simple polynomial adjustment as the best fit based on the lowest AIC value. The regenerating forest had the least reliable results based on the 95% CI (5.8–16.7), while the pooled estimate provided the most narrow 95% CI (11.9–19.0). The triangulation formula and distance analyses did not produce significantly different results (t -test: $t = 1.564$, d.f. = 4, $P = 0.193$).

A potential explanation for the high estimate generated by Distance is that one or more of the key assumptions to distance sampling were violated. The histogram generated for the pristine forest suggests that gibbon detection was imperfect. With a spike between 400 and 600 m, the detection probability did not decrease monotonically with increased distance from the point (Fig. 2). The uneven survey effort between the two forest types violated the assumption at all groups at 0 m were heard in the regenerating forest. Because only one 0 m point was located in this forest type, the detection probability increased with increasing distance, rather than decreased (Fig. 3). Analyzing the regenerating forest data separately with a left truncation of 250 m and an increased number of intervals provided a better fit in the resulting histogram, though the histogram still revealed significant clustering around the 400 m mark (Fig. 4). This approach also resulted in a wider 95% CI (2.19–20.03) and increased the group density to 6.6 groups/km².

Table II Density estimates (per km²) of Müller's gibbon generated by Distance and triangulation analysis methods in Sungai Wain Protection Forest from May to July 2012

	Group density			Individual density ^c			Population		
	All	Pristine	Regenerating	All	Pristine	Regenerating	All	Pristine	Regenerating
Distance ^a	4.6±11.6	5.1±13.1	3.0±23.3	15.0±11.6	16.8±13.1	9.8±23.4	531.11±17.3	580.50±20.6	388.4±23.4
Triangulation ^b	3.1±0.8	3.7±1.0	1.7±1.8	10.2±2.5	12.3±3.1	9.4±4.5	406.9±101.0	486.9±132.6	274.3±179.0

^a With coefficient of variation.^b With standard deviation.^c Using group size estimate of 3.3 individuals/group.

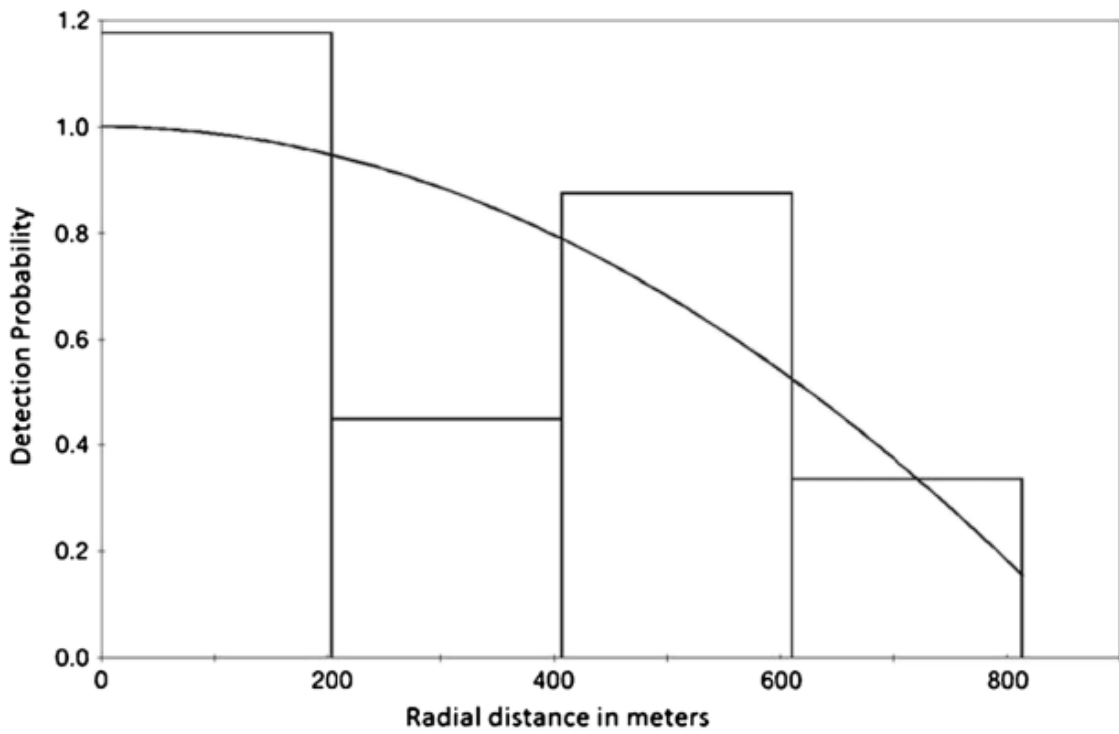


Fig. 2 Detection probability with a Uniform key function and simply polynomial adjustment for Müller’s gibbons in the pristine forest of Sungai Wain Protection Forest from May to July 2012.

Discussion

The difference in density estimates generated by the two methods demonstrates the potential for highly variable results using the same data set. Distance estimates were higher than the triangulation estimates for each of the pristine, regenerating, and pooled

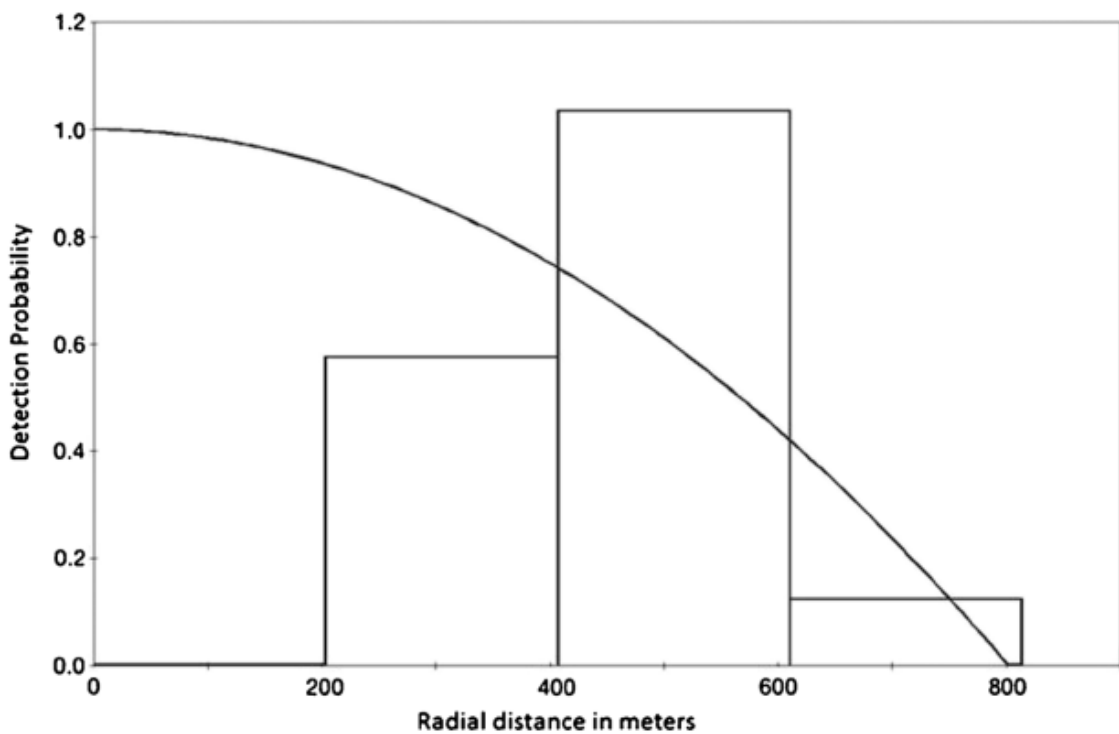


Fig. 3 Detection probability with a Uniform key function and simply polynomial adjustment for Müller’s gibbons in the regenerating forest of Sungai Wain Protection Forest from May to July 2012.

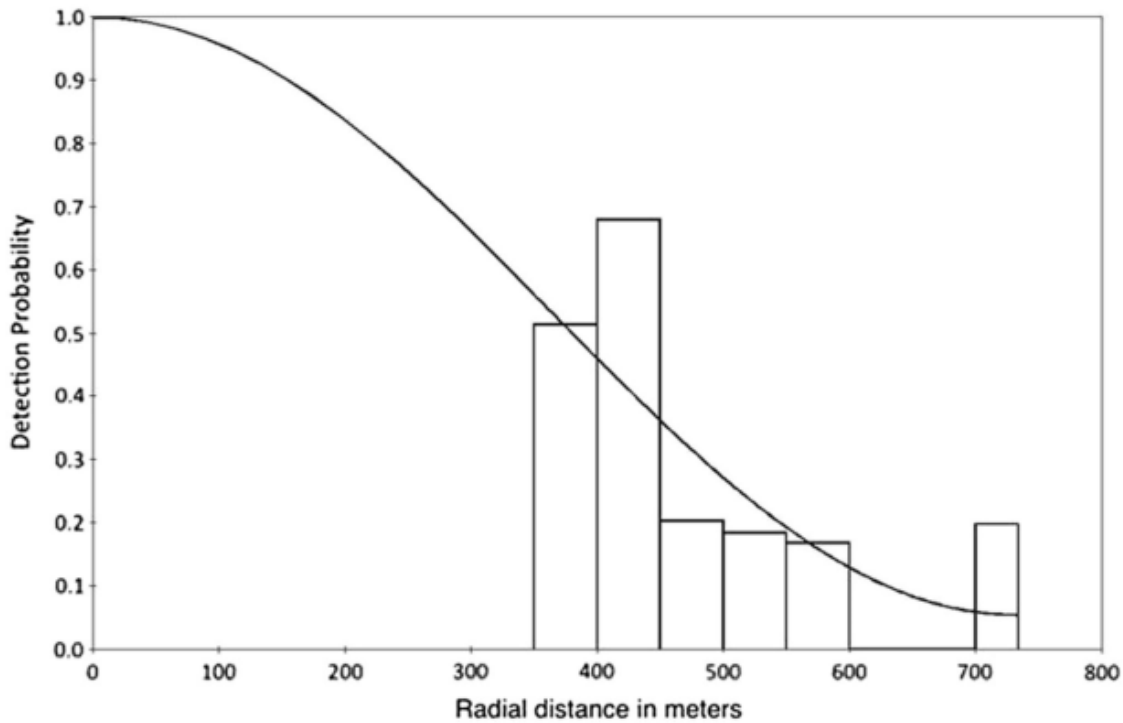


Fig. 4 Detection probability with a Uniform key function and simply polynomial adjustment and 250 m left truncation for Müller's gibbons in the regenerating forest of Sungai Wain Protection Forest from May to July 2012.

areas. Results were most similar for the pristine forest, while the regenerating forest produced the greatest discrepancy, distance analysis also produced a higher standard deviation than triangulation (distance, mean 4.2 ± 1.09 ; triangulation, mean 2.84 ± 1.03). Without data on the mean gibbon home range size in each forest type in Sungai Wain Protection Forest it is difficult to conclude which of the density estimates is the most accurate. If the distance generated estimate for the pristine forest was indeed the more accurate of the two, the resulting value of 5.1 groups/km^2 would be the highest value reported for any Bornean gibbon species (Buckley *et al.* 2006; Cheyne *et al.* 2008, 2012; Chivers 1984; Hamard *et al.* 2010; Leighton 1987; Marshall 2009; Mitani 1990; Nijman and Menken 2005; Robbins *et al.* 1991; Rodman 1978; Suzuki 1992; Wilson and Wilson 1975). It is possible that the presence of the surrounding regenerating forest has had a compression effect on the pristine area, resulting in higher than average densities of Müller's gibbons. Previous work in Sungai Wain Protection Forest reported higher densities of red langurs compared to those in similar habitat types, though this was attributed to differences in survey design between studies (Bersacola *et al.* 2014). Although it is not impossible that the group density of gibbons is as high as 5.1 groups/km^2 , we speculate that this is likely an overestimation based on the extremely high estimate generated.

The density estimates from the regenerating forest produced the widest measures of variability for both methods of analysis, which is likely a result of the reduced survey effort in this habitat type. Although these estimates may not reflect the true density of gibbons in the regenerating forest, they suggest that group density is lower compared to the pristine forest. Lower tree species diversity and density in the regenerating forest support these preliminary results (Sastramidjaja *unpub. data* 2012).

Although Distance is a highly sophisticated program and is capable of correcting for various parameters, it may not be suitable for hylobatid surveys. One of the potential weaknesses of point-transect sampling using Distance to estimate gibbon density is that a researcher is not physically present at the 0 m mark. Surveying each location for a minimum of four days should help to ensure that groups residing this location are not missed. However, depending on the topography of the terrain, it is possible that such groups may go undetected. A solution to this would be to have one researcher stationed at the 0 m point in addition to three collecting data from the listening posts arranged in a triangle. This would reduce the likelihood that groups might be missed; however, it would increase the number of trained researchers required. Future studies should weigh the additional costs of funding and training a fourth observer against the potential benefits of improved triangulation accuracy and point transect survey design.

Conclusions and Future Directions

We concluded that the density estimate for the regenerating forest was not reliable because of the small survey effort during our study. A survey in Sungai Wain Protection Forest that features a significant amount of effort in the regenerating forest will require a large amount of time spent camping rather than being based at Camp Djammaludin. Future studies will benefit from ensuring that the survey effort is proportional between different forest types to determine better how group density differs by habitat. We encourage future projects to use Distance in establishing the maximum listening radius in combination with the featured formula to determine a density estimate for hylobatids (Brockelman and Ali 1987; Phoonjampa *et al.* 2011). Distance is an important tool for surveying primate species because it can be used in different environments and allows for standardization between surveys across different habitats (Hassel-Finnegan *et al.* 2008). Having demonstrated that point transect and distance analysis can be used with triangulation data, we encourage future and perhaps even retrospective distance analysis of gibbon data from other sites to elucidate trends in the accuracy of this new method. More specifically, testing these methods against corroborated data on home range size and group density through long term research would be especially useful. Although our study suggests that point transect sampling may overestimate density, further investigation is necessary to understand fully the nature of these possible inaccuracies.

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