Group population and density estimates of pileated gibbons, *Hylobates pileatus*, in four protected areas in the Northern Plains Landscape, Cambodia

WCS
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Acknowledgements

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Executive Summary

Between 2016 and 2019, four protected areas in the Northern Plains Landscape were surveyed to estimate populations of pileated gibbon, *Hylobates pileatus*: Chhep Wildlife Sanctuary (CWS), Kulen Promtep Wildlife Sanctuary (KPWS), Preah Roka Wildlife Sanctuary (PRWS), and Phnom Tbeng Natural Heritage Park (PTNHP). Using listening posts and a call-based distance sampling methodology, population and density estimates were produced.

Table 1. Group population and density estimates of pileated gibbons, Hylobates pileatus, *in Chhep Wildlife Sanctuary (CWS), Kulen Promtep Wildlife Sanctuary (KPWS), Preah Roka Wildlife Sanctuary (PRWS), and Phnom Tbeng Natural Hertitage Park (PTNHP).*

Site	Survey area (km²)	Year	Group estimate (95% CI)		Group density (km²)
CWS	327.2	2017	443 (243–806)		1.35
KPWS	229.2	2017	258 (91–731)		1.13
PRWS	324.3	2019	242 (159–370)		0.75
PTNHP	143.6	2019	77 (42–139)		0.54
Total:	1024.2		1019 (650–1599)	Average:	0.99

These estimated group densities are similar to densities recorded at sites in Thailand in 2008.

Two sites in PRWS were surveyed in 2005, with estimated densities of 1.55 and 0.78 groups/km². The 2019 estimate of 0.75 groups/km² for this site suggests a decline in gibbon density over the past 15 years, although it should be noted that the 2005 surveys were limited in sample size, and the 2019 estimates are limited in their estimation of cue rate and lack of triangulation. Although CWS and KPWS were not surveyed in 2005, their estimated densities are close to the average density for sites surveyed across Cambodia at this time.

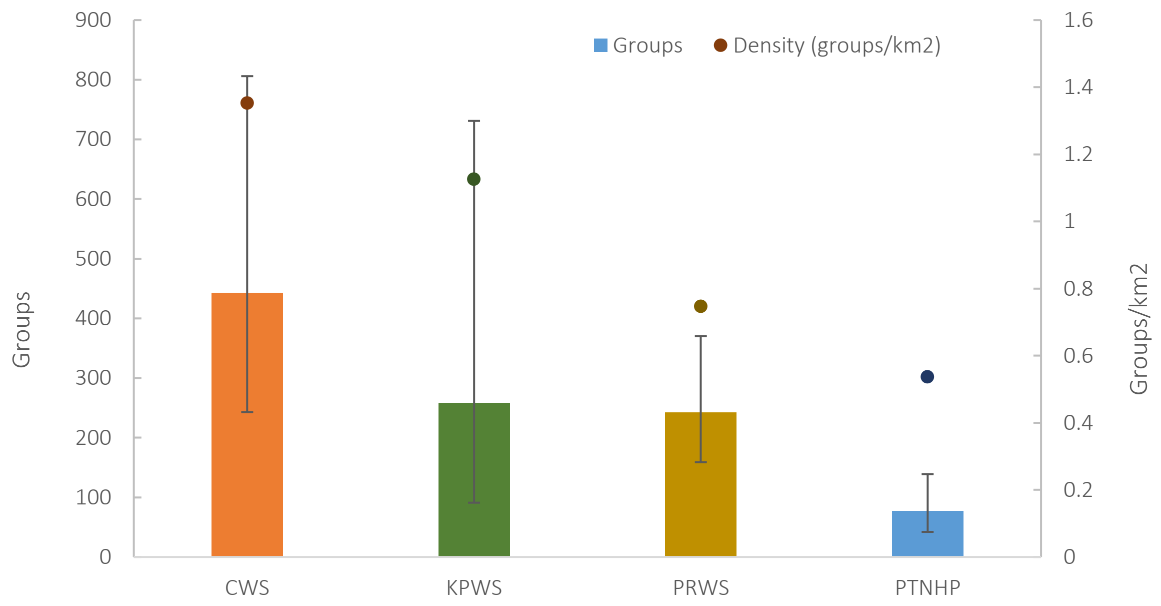

Figure 1. Group population and density estimates of pileated gibbons, Hylobates pileatus, *in Chhep Wildlife Sanctuary (CWS), Kulen Promtep Wildlife Sanctuary (KPWS), Preah Roka Wildlife Sanctuary (PRWS), and Phnom Tbeng Natural Hertitage Park (PTNHP). Error bars show 95% confidence intervals of the population estimates. No confidence intervals are shown for the mean group density estimates.*

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Background

Cambodia is home to two species of gibbons, the pileated gibbon, *Hylobates pileatus*, and the yellow-cheeked crested gibbon, *Nomascus gabriellae*, both Endangered on the IUCN Red List (IUCN 2020), both Rare under the 2002 Forestry Law of the Ministry of Agriculture, Forestry and Fisheries, and both listed on CITES Appendix I. The pileated gibbon is found west of the Mekong River, whilst the yellow-cheeked crested gibbon is found to the east. Both species prefer evergreen and semi-evergreen forests (Traeholt et al., 2006).

Pileated gibbons, nationally more abundant than yellow-cheeked crested gibbons, are found in significant numbers in two main blocks of forest: the Cardamom Mountains and adjacent areas in southwestern Cambodia, and the Prey Long forest complex in northern Cambodia (Rawson, 2010). Illegal logging and land encroachment represent the greatest threats to this species, with previously contiguous habitat becoming scarce and fragmented.

Pileated gibbons vocalize in pairs, with duets involving complex vocal interactions that can influence pair-bonding behavior (Brockelman & Schilling, 1984). Most duets and individual calls are distinct enough that a trained listener can distinguish between two different vocalizing groups (Traeholt et al., 2006).

Like most gibbon species, pileated gibbons are territorial and will defend a specific territory. "In Khao Soi Dao Wildlife Sanctuary, Thailand, groups roam an area of up to 34 ha and defend an area of approximately 26.6 ha against intrusion by other groups (Srikosamatara, 1984). Territory size is likely linked to food availability, as well as to group size and family structure. Their diet consists mainly of soft, fleshy fruit and figs, supplemented with leaves, flowers and insects (Srikosamatara, 1984).

Methods

Study sites

All study sites are managed by the Royal Government of Cambodia's Ministry of Environment, with financial and technical support from WCS.

Chhep Wildlife Sanctuary

Established in 2002 as Preah Vihear Protected Forest, Chhep Wildlife Sanctuary (CWS) is a 1,900.27 km^2 protected area in northern Preah Vihear Province, comprising large tracts of deciduous dipterocarp and evergreen forests, as well as seasonally inundated grasslands and small wetlands.

Kulen Promtep Wildlife Sanctuary

Kulen Promtep Wildlife Sanctuary (KPWS) was established in 1993 and covers 4,068.25 km^2. The area includes deciduous dipterocarp and evergreen forests, as well as Cambodia's largest swamp.

Preah Roka Wildlife Sanctuary

Preah Roka Wildlife Sanctuary (PRWS) was established in 2016 and covers 2,926.9 km^2. The area is used by the Kuy ethnic minority for resin collection and harvesting of non-timber forest products.

Phnom Tbeng Natural Heritage Park

Phnom Tbeng Natural Heritage Park (PTNHP) was established in 2016 and covers 252.69 km^2. The protected area contains evergreen and semi-evergreen forest and is a key area of the upper watershed of the Steung Sen River, a tributary of the Tonle Sap.

Data collection

In each protected area, expanses of evergreen forest representing suitable pileated gibbon habitat were identified using remote sensing data, and split into 1 km^2 cells. From the sum of these cells, a subset was selected for placement of listening posts (Table 2). KPWS and CWS were surveyed alternately from November 2016 to February 2017. PTNHP was surveyed between January and February 2019, and PRWS was surveyed between March and May 2019.

Table 2. Sampling sites with number of 1 km^2 cells defined, and number of listening posts assigned per site. A total of 8% of the study area was sampled, with two sites sampled in 2016–2017 and two in 2019.

Site	Cells	Listening posts	Percent sampled	Survey year
KPWS	229	18	8%	2016-2017
CWS	327	18	6%	2016-2017
PRWS	324	24	7%	2019
PTNHP	153	19	12%	2019
Total	1033	79	8%	

Within selected cells, listening post placement was determined by landscape features that maximized the chance of detection of gibbon calls, including elevation and ridgelines (Neilson, Nijman, & Nekaris, 2013).

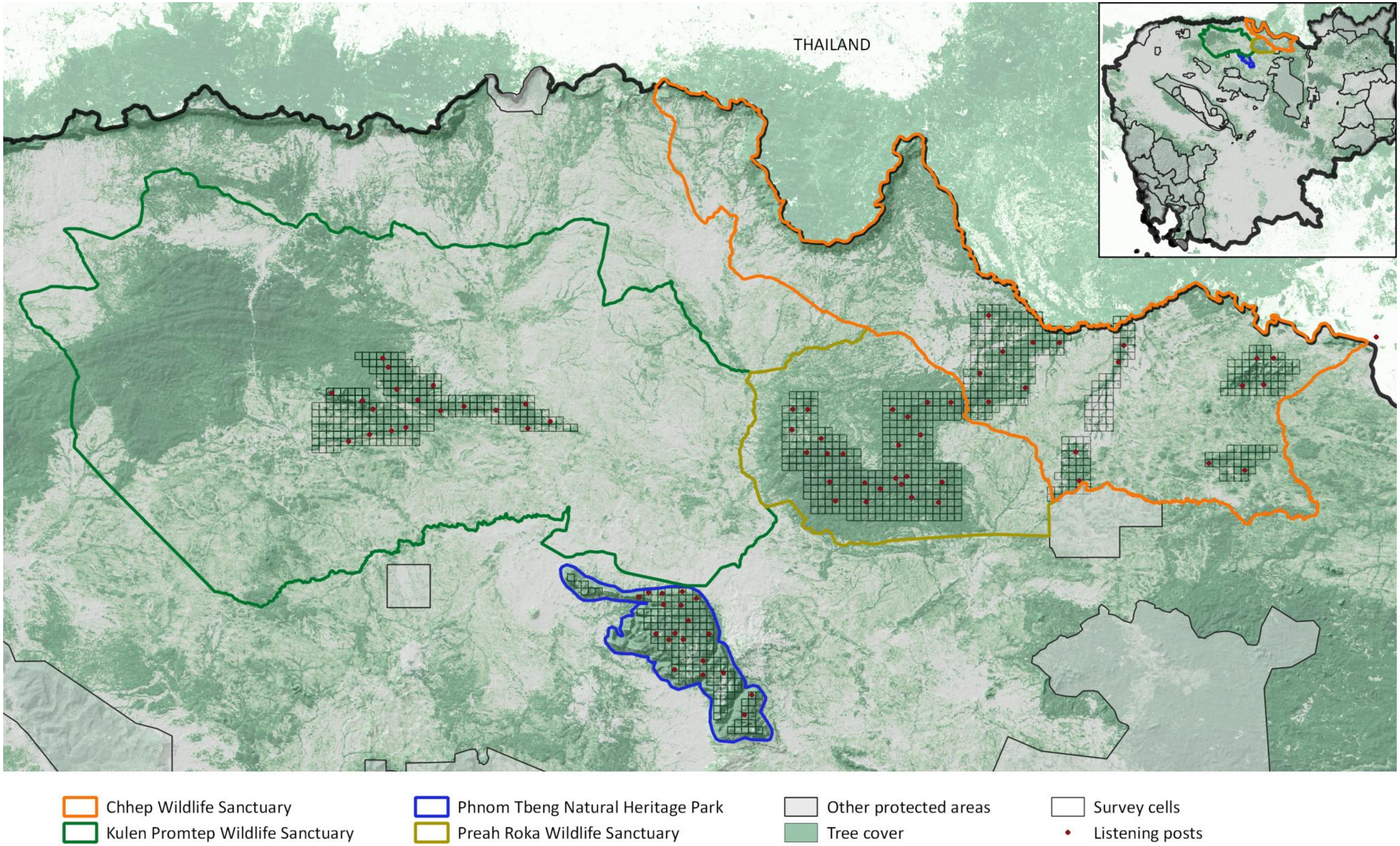

Figure 2. Location of the four study sites, survey cells, and listening posts in the Northern Plains Landscape of Cambodia.

Each listening post was visited by a team on three consecutive days, with three teams conducting surveys concurrently. Surveys took place between 05:30 AM and 11:30 AM, with data collection of listening post location, weather conditions, and elevation.

Each time the research team at a listening post heard a gibbon group calling, the date, start time and end time of the call, and estimated distance and bearing to the group were recorded. The estimated number of individuals calling was also recorded.

Data analysis

A point-count cue based distance sampling methodology was used, following Buckland et al. (2001; 2015). Analysis was conducted in R 3.6.2, using Distance 1.0.0 and mrds 2.2.1.

Cue rate estimation

Specific data on cue rates was not collected during the survey. No published cue rate and standard error was available in the literature, and comparison with published sources would be hampered by varying definitions of calls. In this survey, individual calls were not recorded; instead, call sessions were recorded, which could span up to 2.5 hours. To calculate cue rate from the data, non-zero calling sessions at less than 800 m from each listening post were extracted and averaged. The distance threshold of 800 m was derived from the histogram of radial distance from the listening post (Fig 3); it is highly probable that all available (cueing) groups within 800 m were detected by the teams.

This process gave a cue rate of 3.25 call sessions per listening post replicate (standard error 0.45, 20 degrees of freedom).

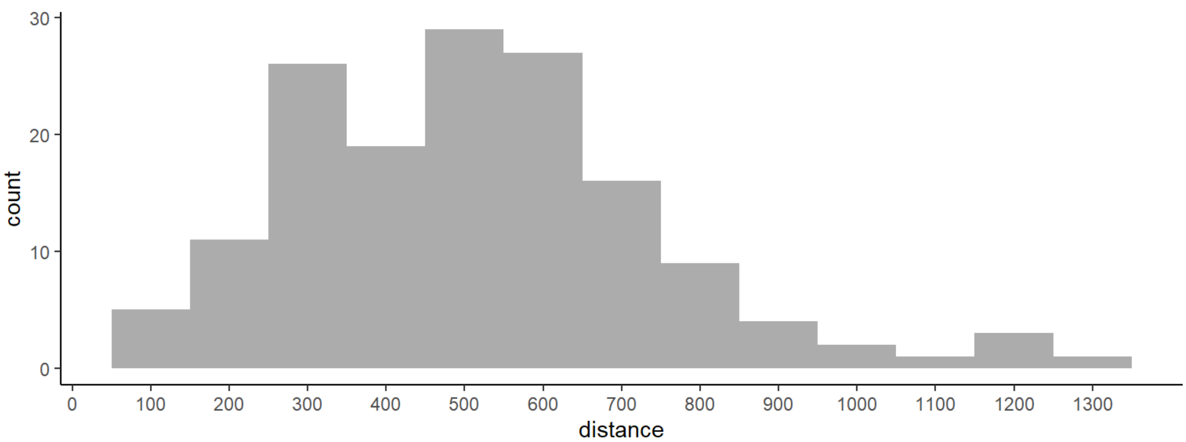

Figure 3. Histogram of distance from listening post of detected gibbon groups.

Group population estimates

Truncation

Data were left-truncated at 100 m, as at shorter distances unhabituated wild gibbon groups in areas with poaching are likely to show evasive behavior and move away from listening posts. Data were right-truncated at 900 m, based on the histogram shown in Fig 3. This retained 143 observations and discarded 10 (6.6% of observations).

Detection functions

A number of detection functions were fitted (Table 3. Models incorporating elevation were tested but failed to produce estimates.

Based on the assumption that all calling groups in close proximity would be detected, and selecting the lowest Akaike Information Criterion (AIC), non-significant Cramer-von Mises *p* values, and most acceptable model fit shown in the QQ plot (Fig 4), the hazard-rate detection function with site as a covariate was selected.

Table 3. Detection function models fitted. The df.hr.site model was selected, given the assumption of hearing all calls at short distances, low Akaike Information Criterion (AIC), and non-significant Cramer-von Mises p *(see Fig 4).*

Model name	Type	AIC
df.hr.site	Hazard-rate with site as covariate	1885.1
df.hr.null	Hazard-rate	1888.8
df.unif.cos	Uniform cosine	1888.8
df.hn.cos	Half normal cosine	1890.6
df.hn.site	Half normal with site as covariate	1891.7
df.hn.null	Half normal	1892.6

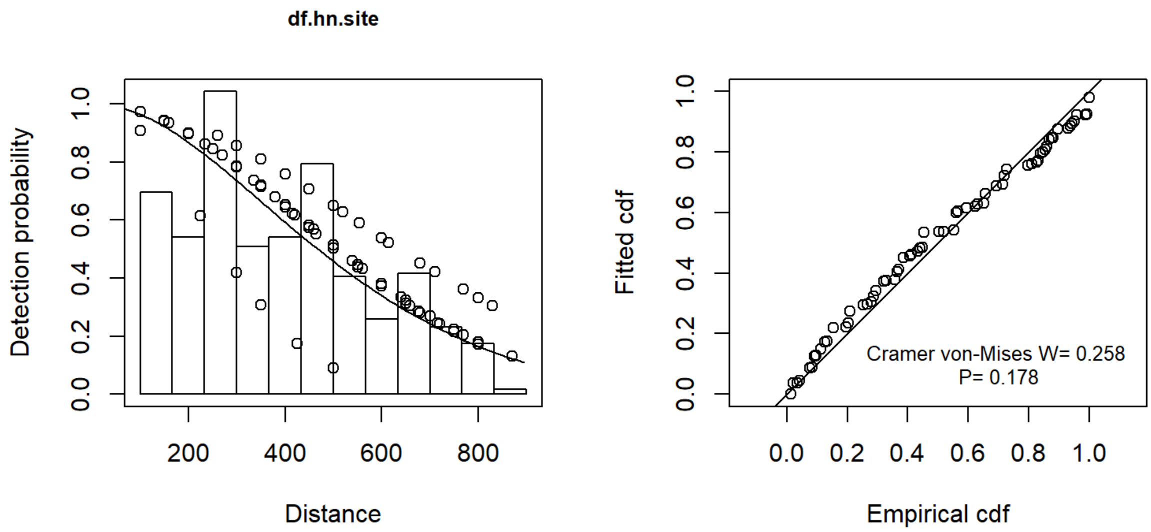

Figure 4. Model assessment plots for the selected model, hazard-rate with site as a covariate. Cdf = cumulative distribution function

Abundance estimation

Using the selected detection function and cue rate multiplier, the `dht2` function was used to estimate group abundance per site and for the total surveyed area.

Reproducibility

An R Markdown analysis manuscript to reproduce the analysis is available from WCS on request.

Results

Total group population across the four sites is estimated to be more than 1,000 groups. CWS has the highest group density (1.35 groups/km^2), as well as the largest population, in part due to the largest area of available habitat. PTNHP has the lowest estimated group abundance, and the lowest density of groups.

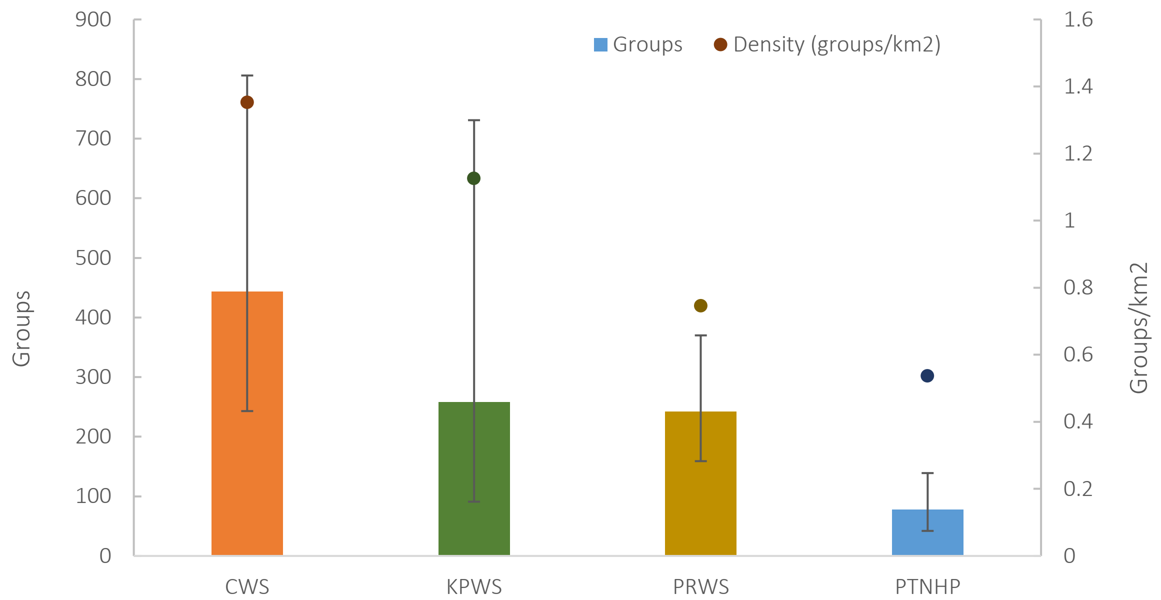

Figure 5. Group population and density estimates of pileated gibbons, Hylobates pileatus, *in Chhep Wildlife Sanctuary (CWS), Kulen Promtep Wildlife Sanctuary (KPWS), Preah Roka Wildlife Sanctuary (PRWS), and Phnom Tbeng Natural Hertitage Park (PTNHP). Error bars show 95% confidence intervals of the population estimates. No CIs are shown for the mean group density estimates.*

Table 4. Group population estimates of pileated gibbons, Hylobates pileatus, *in Chhep Wildlife Sanctuary (CWS), Kulen Promtep Wildlife Sanctuary (KPWS), Preah Roka Wildlife Sanctuary (PRWS), and Phnom Tbeng Natural Heritage Park (PTNHP). SE = standard error; cv = coefficient of variation; LCI = lower 95% confidence interval; UCI = upper 95% confidence interval; df = degrees of freedom.*

Site	Survey area (km^2)	Year	Group estimate (95% CI)	Group density (km^2)	SE	cv	LCI	UCI	df
CWS	327.2	2017	443 (243–806)	1.35	133.3	0.30	243	806	32.7
KPWS	229.2	2017	258 (91–731)	1.13	123.0	0.48	91	731	8.1
PRWS	324.3	2019	242 (159–370)	0.75	52.2	0.22	159	370	102.3
PTNHP	143.6	2019	77 (42–139)	0.54	22.8	0.30	42	139	27.8
Total	1024.2		1019 (650–1599)	0.99	225.6	0.22	650	1599	25.1

Discussion

These results show the Northern Plains Landscape holds an important complex of protected areas that support a significant, though fragmented, population of endangered pileated gibbons.

Densities in CWS and KPWS are similar to those reported from the Cardamom Mountains, where 1–2 groups/km^2 were estimated in 2005. The CWS and KPWS densities are similar to the average density of all sites surveyed in this 2005 study, 1.23 groups/km^2 (Traeholt et al., 2006), and to those from Khao Yai National Park in Thailand in 2008 (1.03 ± 0.394 groups/km^2) (Phoonjampa & Brockelman, 2008).

During the 2005 surveys, two sites in PRWS were assessed and estimated to hold 1.55 and 0.78 groups/km^2, respectively. The 2019 data give a lower density estimate of 0.75 groups/km^2, suggesting a decline in gibbon density in this area over the past 15 years (Traeholt et al., 2006). Current densities in PRWS are similar to those estimated in Pang Sida and Tab Lan National Parks, and Khao Soi Dao Wildlife Sanctuary (0.66 and 0.67 groups/km^2 respectively), Thailand, in 2008 (Phoonjampa & Brockelman, 2008).

Limitations

Precision and accuracy of these baseline figures can be improved upon in future by using a robust spatially explicit capture-recapture (SECR) framework (Efford, Borchers, & Byrom, 2009).

Non-calling groups or individuals

As this cue-based distance sampling method can only count calling groups, groups and solitary indivduals that do not call are not counted. A more complete estimation of cue rate could account for this if enough groups or indivdiuals were included in the study.

Individual abundance estimates

Whilst a value for group size can be used as a multiplier to estimate individual abundance, no current mean group size data are available for these sites. Estimation of individual populations would be possible with additional data collected on group size in each location.

Extrapolation of estimates beyond sampled area

Extrapolation of group abundance beyond the survey area is not recommended, as the survey area included all habitat assessed to be suitable for pileated gibbons.

Cue rate estimation

To provide a more robust estimate of cue rate, a dedicated cue rate study should take place at the same sites and during the same season as the distance sampling data collection.

Distance and bearing estimates

As listening posts had no spatial/temporal overlap, triangulation to improve accuracy of distance and bearing estimates was not possible.

Conclusion

The significant populations of endangered pileated gibbons in the four survey sites demonstrate the importance of the Northern Plains Landscape for ongoing gibbon conservation efforts, along with the Cardamom Mountains and Prey Lang landscape (Rawson, 2010). Direct law enforcement efforts, community development support, and responsible ecotourism opportunities can all play a role in maintaining and increasing the populations of this imperiled species.

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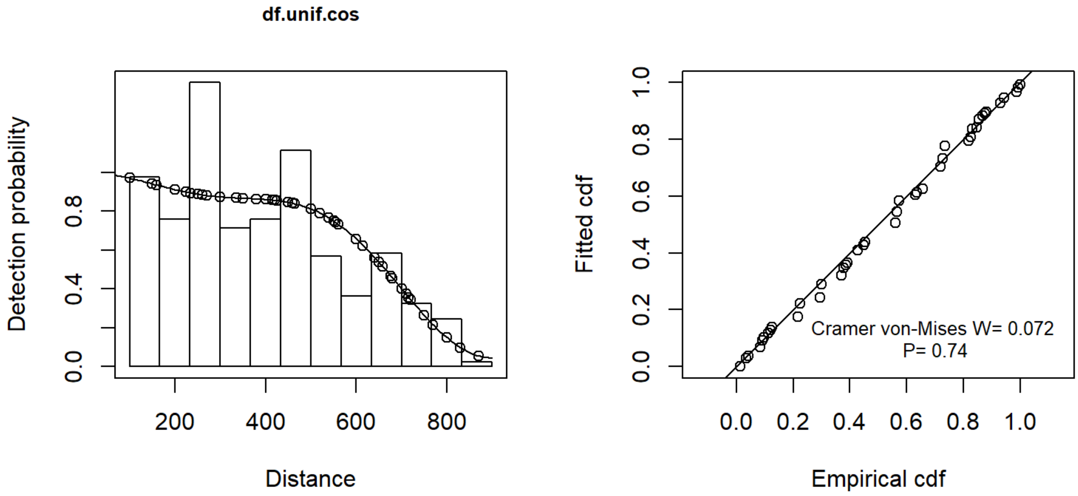
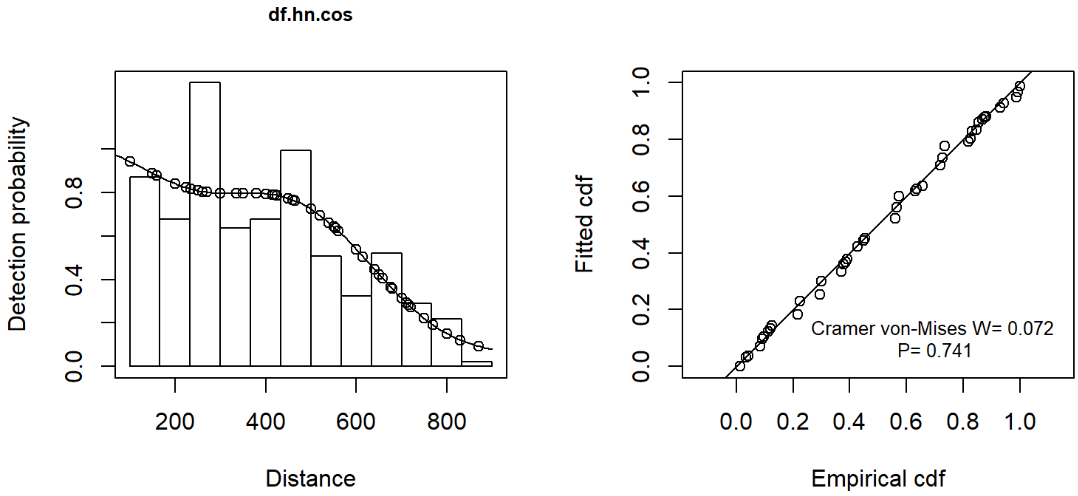
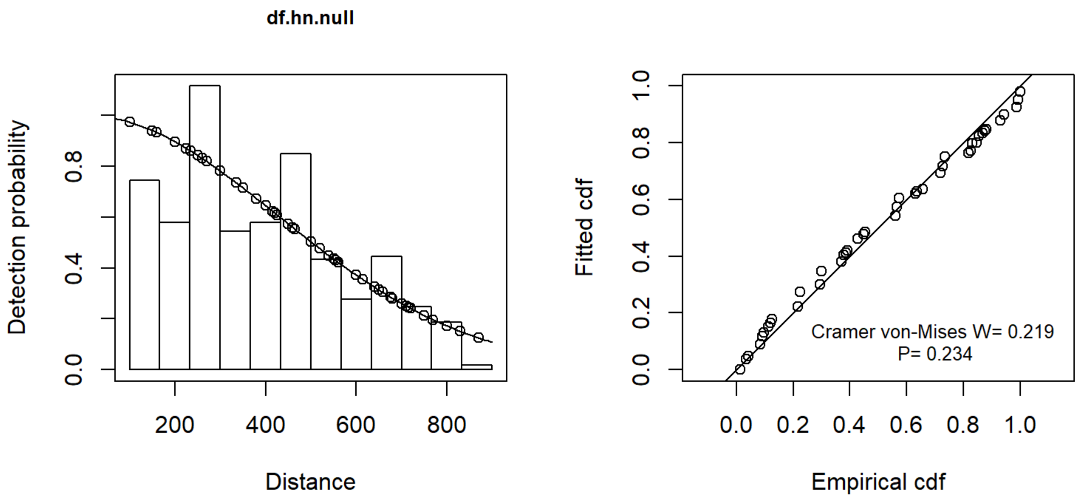
Appendix



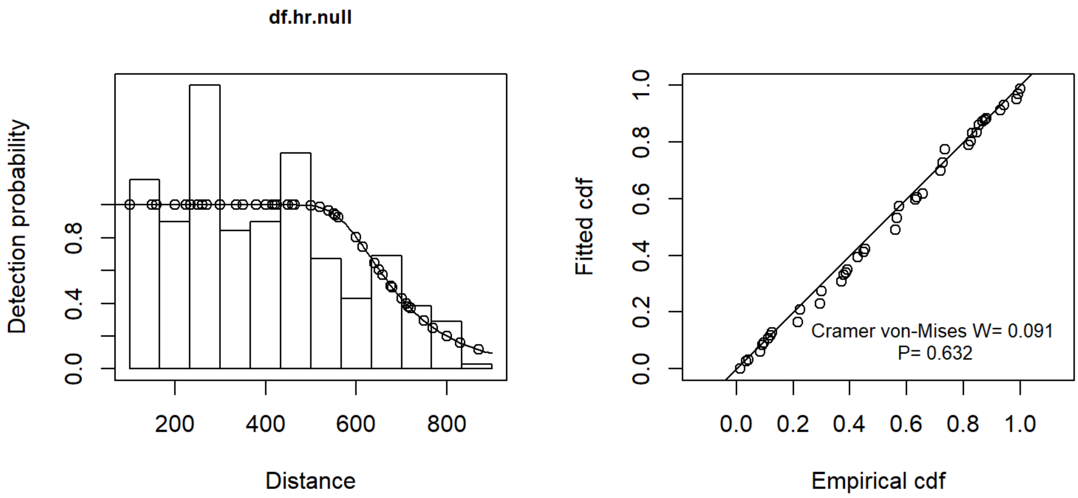
Uniform model with cosine adjustment. The fitted detection function (left) and goodness of fit QQ plot (right).



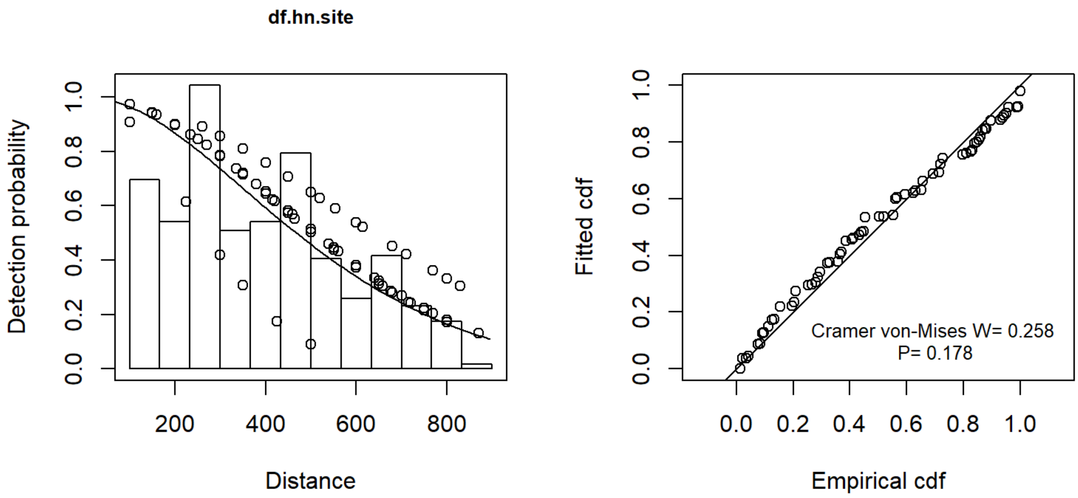
Half normal model with cosine adjustment. The fitted detection function (left) and goodness of fit QQ plot (right).



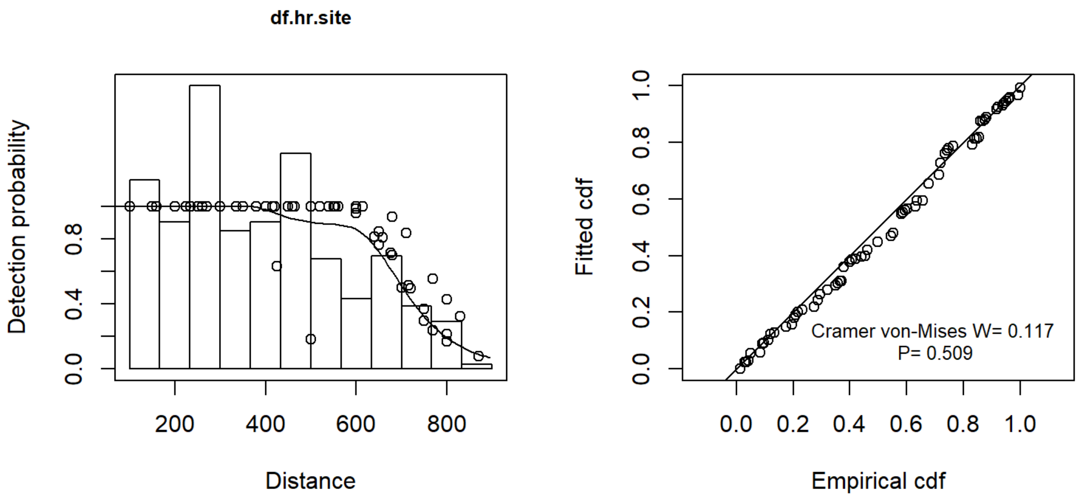
Half normal model with no adjustment. The fitted detection function (left) and goodness of fit QQ plot (right).



Hazard-rate model with no adjustment. The fitted detection function (left) and goodness of fit QQ plot (right).



Half normal model with site as a covariate. The fitted detection function (left) and goodness of fit QQ plot (right).



Hazard-rate model with site as covariate. The fitted detection function (left) and goodness of fit QQ plot (right).