Primate Conservation 2018 (32): 133-139

Nest Ecology and Conservation of Western Chimpanzees (*Pan troglodytes verus*) in Gola Rainforest National Park, Sierra Leone

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Abstract: A nest survey of western chimpanzees (*Pan troglodytes verus*) was conducted in Gola Rainforest National Park (GRNP) and the surrounding community forest in eastern Sierra Leone. The aim was to investigate chimpanzee nest ecology with a focus on nesting tree species selection. Field data were gathered between September 2015 and June 2016 during a nest census along 89 transects covering 158 km—104 km within the protected area and 54 km outside. We documented a total of 96 nests in 54 nest groups. Chimpanzees preferred to nest in areas of primary forest with low or no undergrowth. Twenty-two tree species were used for nesting trees. Tree selection was not random, with chimpanzees showing preference for a subset of tree species. *Heritiera utilis*, a common timber tree, was the species most selected, with 23% of all nests. The top six tree species accounted for 70% of all nests encountered. Chimpanzees showed a preference for nesting within the boundaries of the protected area and, on average, nested at a higher elevation (20.4 m above ground) than has been found in other studies in West Africa. Our results indicate that *P. t. verus* in our study area tended to avoid the human-disturbed community forests. These findings will be useful to inform conservation practices both inside and outside the park, as well as community forestry and law enforcement initiatives.

Key Words: Chimpanzee, nest site selection, tree choice, conservation, protected area

Introduction

The Gola Rainforest National Park (GRNP) is the largest remnant of lowland moist evergreen rainforest in Sierra Leone (Lindsell and Klop 2013). Research spanning more than 20 years has confirmed the outstanding conservation value of the GRNP both nationally and regionally. The Park hosts 47 species of large mammals (including many endemic and threatened species such as pygmy hippopotamus, western chimpanzee, Diana monkey, western red colobus, Jentink's duiker, zebra duiker and forest elephant: Lindsell *et al.* 2011) and about 330 bird species, 18 of which are threatened or near-threatened (Klop *et al.* 2008). Recent surveys have also recorded up to 41 species of bats (Weber and Fahr 2011), over 500 species of butterflies (Belcastro and Larsen 2006), and 31 species of fishes (Payne *et al.* 2009). Botanical surveys have identified close to 1,000 plant species, including well over 300 species of trees and 599 regional endemics (Klop *et al*. 2008).

The Upper Guinean forest is one of 35 worldwide biodiversity hotspots (Myers *et al.* 2000) and also one of the two highest priority sites for conservation of primates in the world due to the high rates of deforestation and human population growth (Mittermeier *et al*. 1999). The western chimpanzee (*Pan troglodytes verus*) was recently upgraded to Critically Endangered on the IUCN Red List, following widespread population declines driven by habitat loss and fragmentation, poaching and commercial agriculture (Humle *et al*. 2016). *Pan t. verus* is already rare or close to extinction in four of its nine range countries (Burkina Faso, Ghana, Guinea-Bissau, and Senegal). These countries have suffered a drastic reduction in their remaining forest cover and have inadequate protection measures in place for the chimpanzees' remaining habitat (Kormos *et al.* 2003). A recent study that included data collected in GRNP, quantified the decline of Western chimpanzees at 80% over the last 24 years (Kühl *et al*. 2017).

There has been a vast decrease in suitable habitats for chimpanzees and other African apes in the last decade (Junker *et al.* 2015) and most remaining habitat is highly fragmented and immersed in an agricultural and agro-forestry mosaic surrounded by a growing human population (Campbell *et al.* 2008). Chimpanzees are known to be highly vulnerable to habitat fragmentation due to their low population densities, low reproductive rates and relatively large home ranges

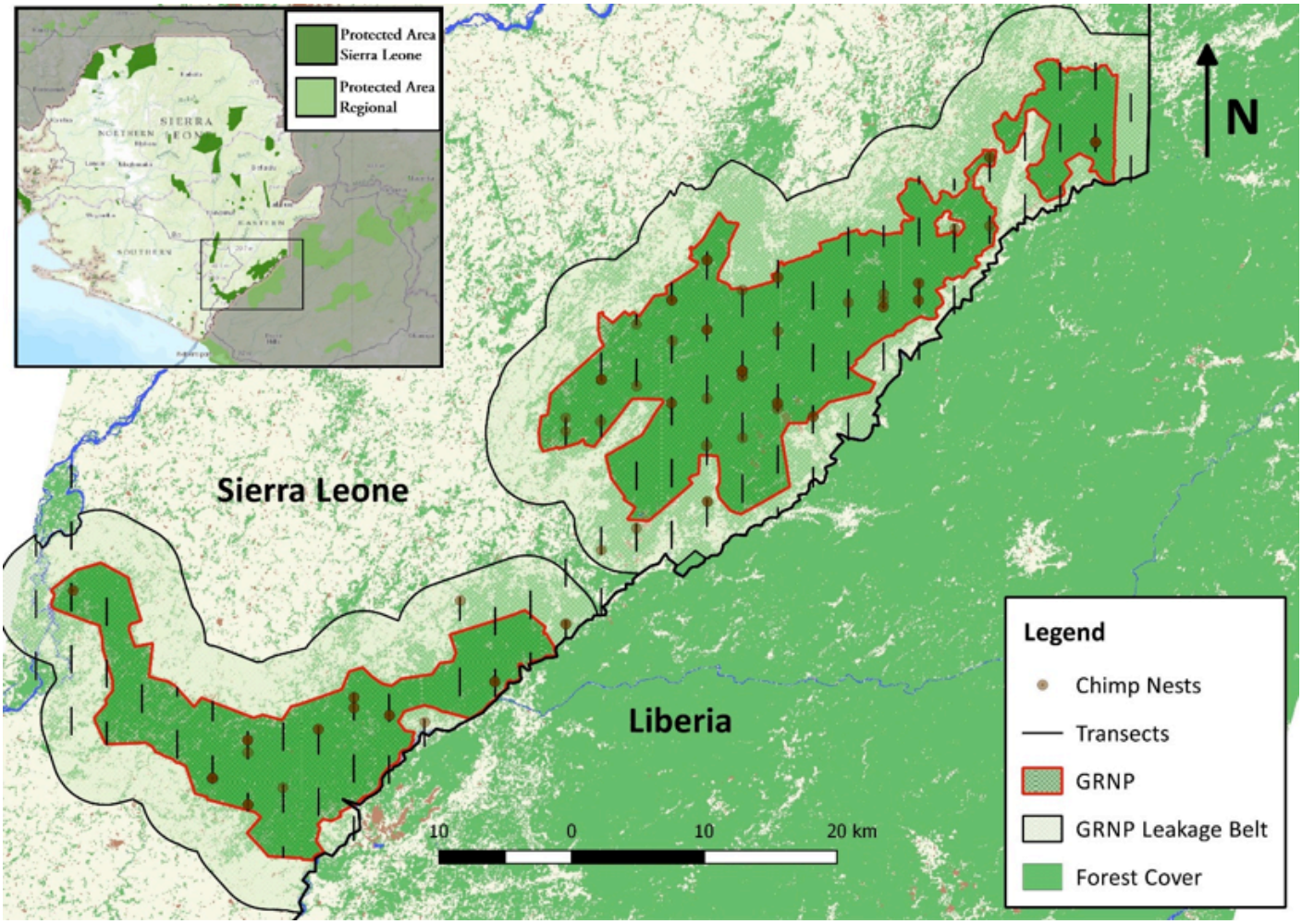

Figure 1. Gola Rainforest National Park (dark green) with the distribution of observed nests in and outside of the protected area. Darker points show locations with multiple nests. Inset shows GRNP location in Sierra Leone.

(Plumptre *et al.* 2010). In Sierra Leone, the western chimpanzee is found in a range of habitats, from savannah to semi-deciduous and tropical forests (Brncic *et al.* 2010). A national chimpanzee survey conducted in 2009−2010 produced a population estimate of 5,580 individuals (95% CI = 3,052−10,446) of which more than half were believed to be found outside of protected areas (Brncic *et al.* 2010) and at high risk. The effective protection of the remaining intact forests in the country is critical for preventing serious declines in the remaining chimpanzee populations (Brncic *et al.* 2010).

Chimpanzees select nesting trees based on certain physical and ecological characteristics of the tree, such as diameter at breast height (DBH), tree height and flexibility of the branches (Hernandez-Aguilar *et al.* 2013; Samson and Hunt 2014) and other environmental factors such as temperature and canopy exposure (Hakizimana *et al.* 2015). In certain forests this selectivity has been proven to be very high, with only a subgroup of all available tree species being used for nesting (Furuichi and Hashimoto 2004; Koops *et al*. 2012; Carvalho 2014). There have been no studies in Sierra Leone, and few across West Africa (Koops *et al*. 2012; Granier *et al*. 2014; Carvalho *et al*. 2015; Ukpong and Roberts 2015; Dutton *et al.* 2017) that have explored tree species preference and selection by *Pan t. verus*. Results from these studies indicate that chimpanzees have a preference for a restricted number of tree species for building their nests. It is not always clear what dictates such a preference, but a number of factors have been considered, including the biomechanics of the tree (Samson and Hunt 2014), predator avoidance (Baldwin *et al*. 1981), and the availability of fruiting trees (Furuichi and Hashimoto 2004; Carvalho *et al.* 2015). We believe that *Pan t. verus* will also show nesting tree preference in Sierra Leone, particularly for trees found more frequently within the national park (as opposed to the surrounding area) and species that provide a range of services (for example, fruit).

The Gola REDD+ project, the first sub-national REDD project in West Africa, received accreditation in 2015. As part of the REDD+ project area a buffer zone of 4 km was defined around the national park. Biodiversity and carbon loss (for example, 'leakage') was monitored in the buffer zone. The project was developed in conjunction with communities living in the buffer zone, with the intention of providing income from carbon credits and other livelihood interventions. A baseline chimpanzee survey was conducted in the GRNP and the 4-km buffer zone in 2009 (Fig. 1) and repeated in 2015-2016. In this study, we used the results from the most recent survey of 2015–2016. Our aim here is to describe western chimpanzee nesting ecology in the GRNP, with a

focus on nesting tree species selection and other environmental and ecological variables of site selection.

Methods

Gola Rainforest National Park

The climate in Sierra Leone is transitional between a continually wet tropical rainforest climate and a tropical savanna climate (Gabler *et al*. 2008). The GRNP is in the wet tropical climatic zone with an average rainfall of between 2500 and 3000 mm, with peaks in July and August. Before the turn of the 19th century, as much as 80% of the country was closed high forest, especially in the lowlands and the escarpment area, with savanna woodlands in the northern plateau region (Savill and Fox 1967). The National Park boundary is located between 07°18'2"N and 07°51'00"N, and 11°21'13"W and 10°37'40"W. The park is made up of three distinct forest blocks: Gola North, Gola Central and Gola South. The forests in the GRNP are an important catchment for the Moro, Mahoi, Mano and Moa rivers, providing water supply to local communities in the leakage belt and beyond.

Chimpanzee nest survey

The chimpanzee survey was conducted along 89 transects (total 159.4 km) between September 2015 and June 2016. The survey design replicated the one performed in 2008−2009 by Ganas (2009). A systematic survey design was generated using the software DISTANCE Version 5 (Thomas *et al*. 2010) to cover the entirety of the national park, as well as areas of community forest in the leakage belt so as to reduce the likelihood of transects with zero encounters (Ganas 2009). Each transect measured 2 km, running in a straight-line North to South, although some transects were truncated due to barriers such as rivers and international borders (Fig. 1). The distance between transects was 2.5 km. Two team members walked a few meters ahead of the team to navigate and open the transect. The transect cutting was kept to the minimum necessary to enable the observers to pass through. The rest of the data collection team walked at a slow pace (around 1 km every 2 hours) with the GPS, and searched for chimpanzee nests, other chimpanzee signs and observations and signs of human disturbance along transects. Nests encountered outside of transect walks were not taken into consideration. Each nest we recorded as one of four nest age classes—fresh, recent, old and decayed—based on descriptions given by Tutin and Fernandez (1984). For each nest we also recorded: the exact coordinates (longitude and latitude) and altitude with a handheld GPS device. Diameter at breast height (DBH) of nesting trees was taken with a DBH measuring tape, nest height and tree height with a laser ranger finder, and canopy cover was measured using a densiometer. A botanist accompanied the field team to identify the nesting tree species. Undergrowth density was defined by how far the team could see through the undergrowth vegetation (different options used were: Very open = view >15 m; Open = view 10−15 m; Closed = view 5−10 m; Very closed = view <5 m).

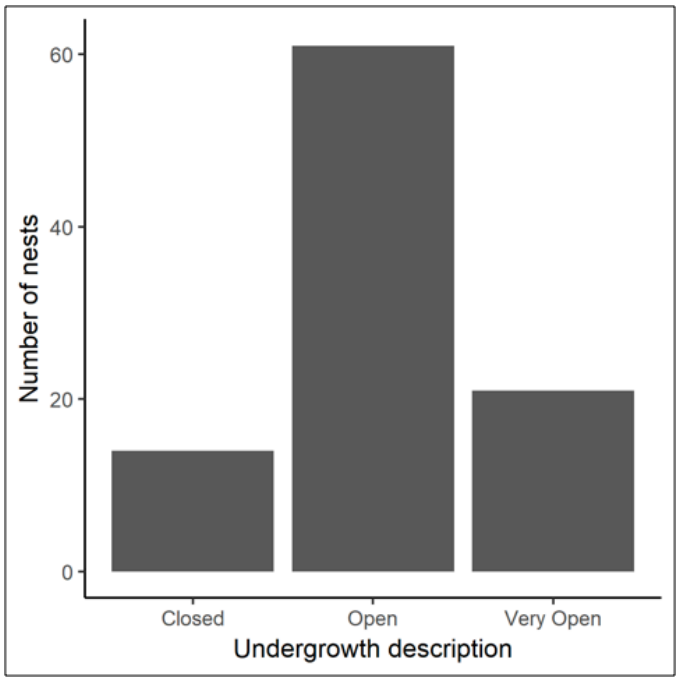

Figure 2. Plot showing the number of nests recorded in habitats with different undergrowth environments.

Analysis

All statistical tests were conducted in the statistical program R (R Core Team 2018). A G-test for goodness-of-fit was used to test if chimpanzees showed any preference within the sample of trees in which nests were found; the null hypothesis was that chimps nest randomly, without regard to the species of tree (Granier *et al.* 2014). The RVAideMemoire package (Hervé 2018) was used for the G-test. The expected values were calculated using overall tree availability in the park; these data were previously recorded from 693 plots placed along randomly distributed transects in the GRNP by Lindsell and Klop (2013). Univariate linear models were used to examine whether the height of the nest was related to tree height or DBH. Normality of residuals were checked with Q-Q plots.

Results

Ninety-six chimpanzee nests were observed and recorded for a nest encounter rate of 0.6 nests per km. The average nest group size was 1.66 (SE ± 0.1) nests per group with a maximum of 4 and minimum of 1 nest in each group. The survey effort outside of the GRNP boundary accounted for approximately 35% of the total (55 km surveyed outside compared to 104 km inside), but only had 7% of the nests. Most of the nests (93%) were found within the GRNP boundary (Fig. 1) indicating a preference for nesting in the protected area where the quantity and quality of forest cover is significantly greater than the agricultural matrix of the buffer zone. All nests encountered were found in either mature primary forest or degraded secondary forest, and no ground nests were found during this survey.

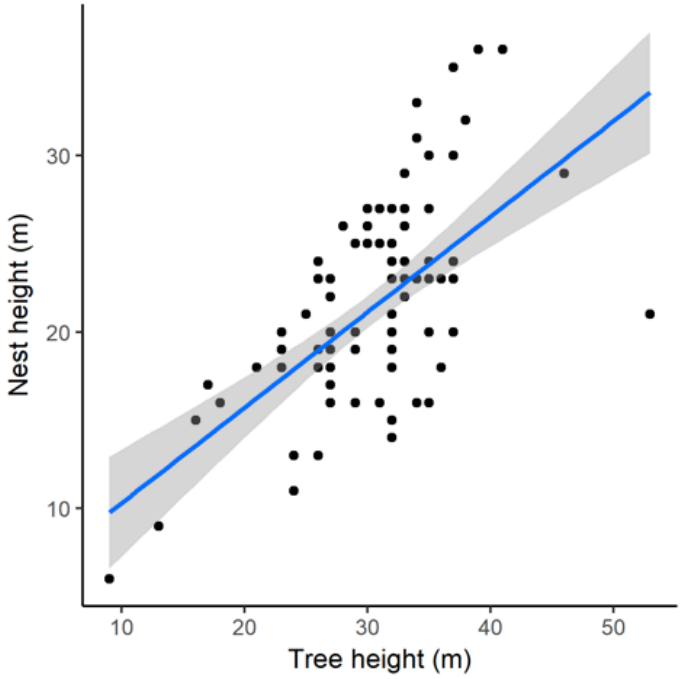

Figure 3. Scatterplot illustrating the relationship between nesting tree height and nest height for all observed nests (N = 96). A linear regression line with 95% confidence intervals is shown.

Chimpanzees tended to build nests in areas where undergrowth density was not too high. Of the 96 nests identified, 82 were built in either very open (21.9%) or open undergrowth (63.5%). The remaining 14 (14.6%) were found in areas with closed undergrowth (Fig. 2.). A significant relationship was found between tree height and nest height ($\beta = 0.54 \pm 0.07$, Adj-R2 = 0.36, DF = 94, $p < 0.001$; Fig. 3) but no relationship was found between DBH and the nest height ($\beta = 0.07 \pm 0.06$, Adj-R2 = 0.004, DF = 94, $p = 0.23$). Summary statistics are presented in Table 1.

The chimpanzees nested in 22 species of trees, and the top six species were used for 70% of all nests encountered. A higher proportion (27%) of observed nests were found in *Heritiera utilis* compared to other tree species. This proportion was even higher in fresh (35%) and recent-sleeping (34%) nest age classes indicating this tree is the most frequently used by chimpanzees in the area. Previous data collected throughout the GRNP in 2006 by Lindsell and Klop (2013) was used to assess tree preference by chimpanzees. Chimpanzees selected the nesting tree species in a non-random manner, independently of overall tree availability ($G = 44.5$, $df = 21$, $p = 0.002$). Some widely available tree species such as *Uapaca guineensis*, *Phyllocosmus africanus* and *Protomegabaria stapfiana* were only used for nesting on a few occasions.

Table 1. Summary of nesting tree height, DBH and height of all observed nests (N = 96).

	Range	Mean	SD.
Tree Height	9–53 m	30.0 m	6.3 m
Tree DBH	18–76 cm	32.6 cm	10.2 cm
Nest Height	6–36 m	21.3 m	5.6 m

Discussion

This is the first study to examine the nesting ecology of a western chimpanzee population in Sierra Leone. The results of this survey confirm that the protected area is important for the persistence of the chimpanzees—most nests encountered were within the bounds of the national park. The chimps may be using the GRNP as a safe zone, especially during the night when hunting is most prevalent (B. Barca pers. obs.). Through its designation and management, the park maintains a high level of mature, undisturbed forest, with ranger patrols covering close to 7,000 km per year serving as an active deterrent to hunting. Consequently, we assume that levels of poaching in GRNP are lower than other areas in the region that have no protection. The GRNP is an important landscape for western chimpanzees in the degraded forest mosaic of Sierra Leone and the wider Upper Guinean landscape. The GRNP forms a nearly continuous forested habitat with the newly gazetted Gola Forest National Park (GFNP) in Liberia, and is undoubtedly important for enabling connectivity between populations. In a recent review of western chimpanzee populations across West Africa, a team of experts (Kühl *et al*. 2017) stressed the need for more land to be designated as protected areas, especially in Guinea, Liberia and Sierra Leone, considered to be strongholds of the Critically Endangered *P. t. verus*. However, while it is promising that chimpanzees are present within the GRNP borders, the study of other aspects of their behavior (such as their diet, grouping and ranging patterns), would provide a more comprehensive understanding of their ecology, necessary for the development of a more targeted conservation plan.

The chimpanzee groups in the GRNP constructed their nests at greater average heights than has been documented in similar studies across West Africa (Baldwin *et al*. 1981; Granier *et al*. 2014). In Sapo National Park in Liberia, for example, Anderson and fellow researchers (Anderson *et al*. 1983) found a median height above ground of 12 m from a sample of 67 nests, whilst observations made in the Taï Forest in western Ivory Coast, recorded the mean height above ground of nests to be 23.2 m from a sample of 683 nests (Kouakou *et al*. 2011). The 96 chimp nests we recorded in the GRNP were between six and 36 m, with a mean height of 21.2 m, above the average nest height in Sapo National Park and marginally less than the average height at Taï National Park. Hernandez-Aguilar *et al.* (2013) suggested that in Uganda elevated nest heights are a predator avoidance strategy. The relatively undisturbed GRNP, particularly Gola Central and Gola North, likely supports a number of potential chimpanzee predators such as leopards, but nesting high might also be a strategy to avoid hunting by humans, who in the past have targeted nesting sites at night. Avoidance of hunters and predators could also explain the lack of ground nests, as suggested by two other studies in Cameroon and Guinea Bissau that linked the possibility of high nests and lack of ground nests to increased human disturbance (Last and Muh 2013; Carvalho 2014). The topography and location of the nesting

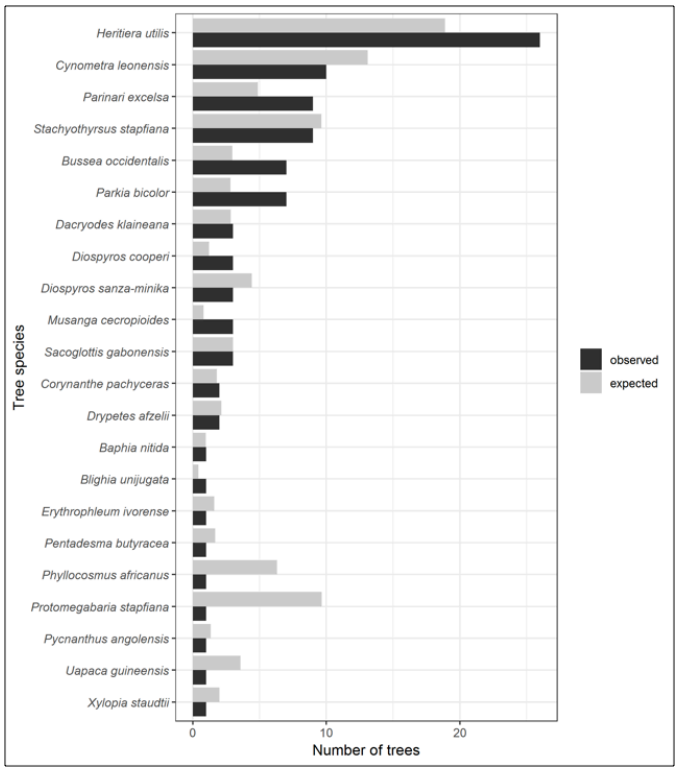

Figure 4. The observed nesting tree species (black) compared with the expected nesting tree frequency (gray).

trees, physical tree characteristics and tree species available are also considered important factors affecting the choice of where and at what height to nest.

Chimpanzees in GRNP showed a clear preference in their choice of nesting trees (Fig. 4). Selectivity in the choice of nesting tree species has also been reported from sites in Guinea, Uganda, and Tanzania (Furuichi and Hashimoto 2004; Stanford and O'Malley 2008; Koops *et al*. 2012). Previous studies have linked nesting tree selection to physical characteristics, with preference predominantly shown for mature tree species of dense forests (Baldwin *et al*. 1981; Pruetz *et al*. 2008; Hernandez-Aguilar *et al*. 2013). A study on nesting tree selection in Bwindi Impenetrable National Park in Uganda also found that certain physical attributes, such as height and age of the tree explained tree choice more than if these trees were producing edible fruits or not (Stanford and O'Malley 2008). In our study, the tree species preferred by chimpanzees also shared common morphological traits that may explain their selection. Physical characteristics noted by field staff during surveys included: flexible yet hard branches, shape of the crown (cone or spreading), branching pattern (inverted tripod), and fruit bearing. The tree species most avoided also shared some morphological characteristics, these were: stiff branches, very high crown and long trunk, open fork branching.

More research is needed to understand the movement patterns and habitat selectivity of the chimpanzees in the GRNP. An analysis of their diet, for example, might help explain if nesting tree choices are related to fruit availability (for example, Carvalho *et al*. 2015). Both *Heritiera utilis* and *Parinari excelsa*, two of the species used more frequently than expected, are known to bear fruits that are eaten by chimpanzees as well as humans. The tree most preferred, *Heritiera utilis*, is a valuable timber tree, and is categorized as Vulnerable on the IUCN Red List of Threatened Species as a result (Hawthorne 1998). It is native to the evergreen forests of West Africa, and the most abundant tree species in the GRNP (Klop *et al*. 2008). It is targeted by artisanal and commercial loggers outside of the National Park and for this reason is rarely found in the community forest (B. S. Turay pers. obs.). Similar to our findings, Carvalho *et al*. (2015) found that the most abundant tree, *Dialium guineense*, in their study area was the most preferred nesting tree by chimpanzees. Certain areas of the GRNP, particularly the southern block, have been selectively logged in the past, affecting the availability of certain tree species and possibly the distributions of chimpanzees and other primate species. Further studies are currently exploring the effects of logging and disturbance on chimpanzee behavior and feeding ecology.

These results provide some insights into the tree species (for example, *Heritiera utilis* and *Parinari excelsa*), forest characteristics (for example, trees >30 m in height), and habitat (primary forest, low undergrowth) that may be important to the conservation and persistence of chimpanzee populations across the transboundary Gola landscape, from Sierra Leone into Liberia and may help in identifying, for example, key areas outside of the national park that could serve as corridors between protected areas, or by sensitizing communities to the need to reduce artisanal logging of those tree species preferred by chimpanzees. The Gola REDD+ project is the first of its kind in West Africa and aims to reduce deforestation in this valuable remnant of Upper Guinean lowland evergreen forest, protecting habitats favored by the western chimpanzee and other endangered species (Lapeyre and Laurans 2017). Information from this and following surveys will help inform management plans with an aim to reinforce protection in community forests and provide alternative livelihoods to reduce encroachment into valuable primate habitats.

Serious declines in the western chimpanzee populations throughout its range (Kühl *et al.* 2017) indicate the need to increase protection and connectivity in the landscapes where they occur. Notwithstanding the high rates of forest loss nationally, Sierra Leone remains a stronghold for the species (Brncic *et al*. 2010; Kuhl *et al*. 2017) with chimpanzee populations persisting in degraded and agricultural landscapes (Brncic *et al*. 2015). Concerted efforts are underway to better understand the relationship between chimpanzees and humans living in such close contact and finding ways to avoid conflict in the future (Garriga *et al*. 2017; Hulme *et al*. 2018). As we learn more about western chimpanzees, we can use the findings to educate rural communities on the importance of conserving the remaining patches of community forest so the chimpanzees will be able to persist in the landscape for generations to come.

Acknowledgments

We would like to thank the efforts of the research and monitoring department of the Gola Rainforest National Park, and in particular our senior botanist Mohammed Swaray for training all staff on tree species identification. We are grateful for the support given to us by the 122 forest edge communities and the many community guides that spent time with us in the forest tirelessly searching for chimpanzee nests. We also acknowledge the work done by Annika Hillers who started the coordination and implementation of this survey in 2015. We would also like to thank two anonymous reviewers for their insightful comments. Finally, we would like to remember our late colleague Tamba Vandi, who dedicated his life to the protection of Gola Rainforest National Park and who is sadly no longer with us.

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Received for publication: 21 June 2018
Revised: 31 October 2018