African Primates 14: 55-60 (2020)

Brief Communication:

A Population Survey of Golden Monkeys and L'Hoest's Monkeys in Gishwati Forest, Rwanda

Sophia Siegel, Olivia George, Autumn Ellisor, Keith S. Summerville, and Michael J. Renner

Department of Environmental Science and Sustainability, Drake University, Des Moines, Iowa, USA

INTRODUCTION

This study was conducted to estimate the population sizes of the golden monkey (*Cercopithecus mitis kandti*) and L'Hoest's monkey (*Allochrocebus lhoesti*) in Gishwati Forest, which is located in the Rutsiro District of the Western Province of Rwanda (Figure 1). The forest comprises one of the two separate segments of the new Gishwati-Mukura National Park (Parliament of Rwanda 2016). The Gishwati Forest segment of the park is an irregular shape, ranging from approximately 1°48'S to 1°50'S and 29°21'E to 29°26'E and encompassing 1837 ha (Figure 2). Gishwati is part of the Congo-Nile forest complex and was separated from Mukura and Nyungwe forests through habitat loss. Its area has been significantly reduced due to deforestation and, in 2002, represented only 2% of the area covered by the forest in the 1970s. Effective protections for this forest system have been in place since 2007 (Nyandwi & Mukashema 2011; Forest of Hope Association 2017).

Gishwati Forest is a montane rainforest, with undulating hills, heavy rains, and dense vegetation from floor to canopy. For researchers, this complicates both travel through the forest and detection of monkeys. The park is home to at least three primate taxa: eastern chimpanzee (*Pan troglodytes schweinfurthii*), L'Hoest's monkey, and the golden monkey, all of which are listed as threatened by the IUCN: the eastern chimpanzee and the golden monkey are both endangered (Plumptre *et al.* 2016; Butynski & de Jong 2020;) and the L'Hoest's monkey is listed as vulnerable (Ukizintambara *et al.* 2019).

This study is intended to contribute basic information necessary for the effective management of primate species in Gishwati Forest. Such information can also be used to inform efforts already underway to develop ecotourism as a revenue source for the region – in a manner consistent with conservation.

Ecologists have developed a variety of methods for estimating population size in primates. Generally, methods are either plot-based or transect-based, depending on the level of rough terrain, ability to sight individuals in space, and behavior of the species in question. Plot-based estimates report population size in number of individuals per unit area; transect methods report population size as effort-estimates (i.e., number of individuals seen per unit time) or as projections from distance sampling. Distance sampling involves observers recording the number of individuals seen as well as the perpendicular distance of the observations from the base transect (Whitesides *et al.* 1988). This allows a more spatially-complex sampling regime in rough terrain as opposed to counting those individuals directly encountered on a transect (Buckland *et al.* 2001).

Distance sampling has been used in multiple studies of forest primates; other methods less frequently (Brockelman & Ali 1987; Marshall *et al.* 2008; Leca *et al.* 2013; Mangama-Koumba *et al.* 2016). Each type of analysis involves certain assumptions; in challenging terrain such as Gishwati, the degree to which those assumptions are met varies. As a result, population estimates based

Correspondence to: Michael J. Renner, Department of Environmental Science and Sustainability, Drake University, 2507 University Ave., Des Moines, IA 50311, USA; E-mail: michael.renner@drake.edu.

Figure 1. (A) Golden monkey (*Cercopithecus mitis kandti*) and (B) L'Hoest's monkey (*Allochrocebus lhoesti*) in Gishwati Forest, Rwanda. Photographs by S. Siegel and M.J. Renner, respectively.

on different methods are of varying and sometimes unknown – and perhaps unknowable – quality, and so the use of multiple methods is warranted.

METHODS

The study area included the core (i.e., least disturbed) section of Gishwati Forest, ranging from approximately 1°48'S to 1°50'S and 29°21'E to 29°23'30"E. The remaining area of the Gishwati segment of the park was badly degraded prior to the initiation of current protections and is being reforested; the work of acquiring and reforesting these lands began in 2007. To date, anecdotal reports and a brief, unpublished survey (Tuyisingize, pers. comm.) indicate only sporadic primate sightings in the reforestation area.

The established forest of Gishwati was demarcated from the areas where reforestation began in 2007, and the forest core area was determined using Arc GIS Pro 10.4 (ESRI 2019). In the established forest, we used transects 200 meters (m) apart on a north-south line from border to border of the forest. In total, 19 straight transects were plotted, each of

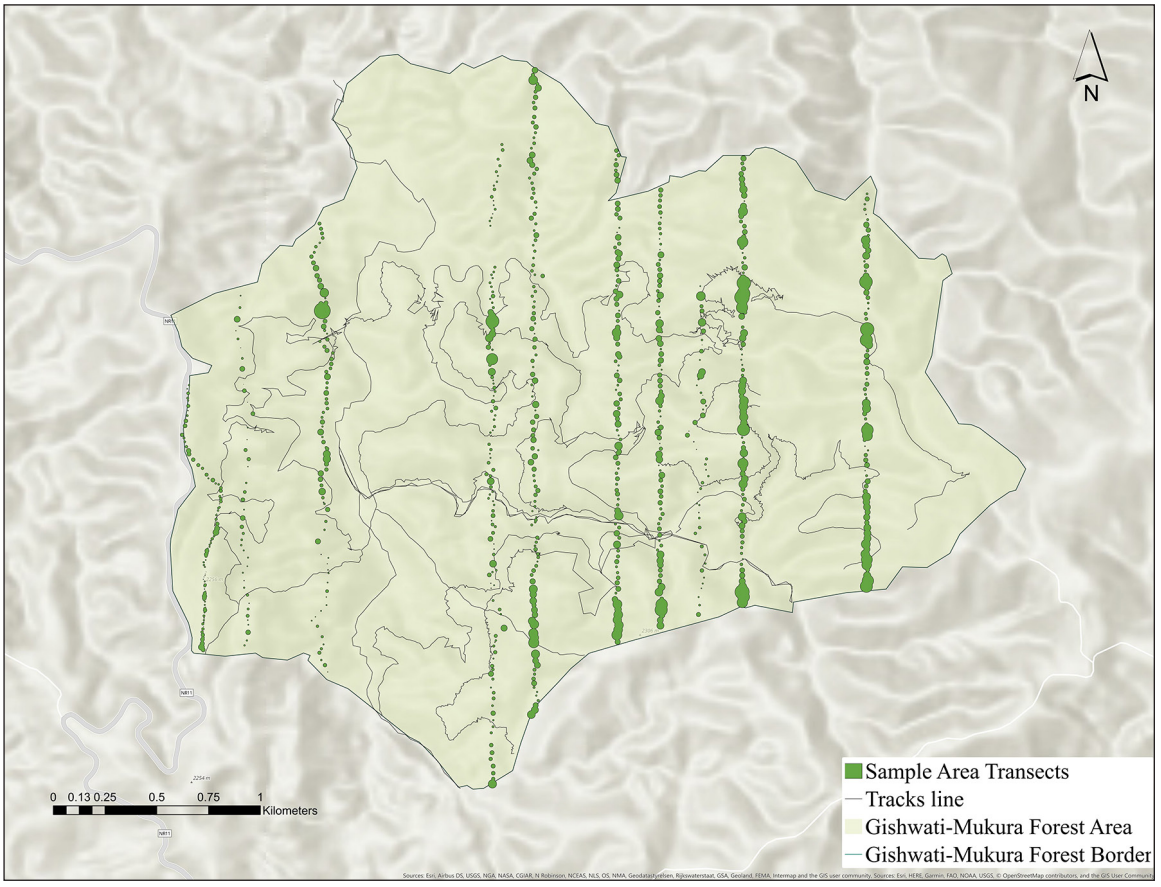

Figure 2. Gishwati Forest (least-disturbed segment), with transects and sample areas marked.

different length due to the irregular boundaries of the preserve, spanning different habitats and elevations. Transects were sampled in a random order to prevent oversampling of any given region of the forest. Ten total transects were sampled (total length 19.79 km) during June and July of 2019 (see Figure 2). There were 33 days of field observations by teams of two to five individuals, a total of 107 person-days.

Observations were carried out five days a week between 0700 and 1700. When an impassable area was reached on the transect line, reconnaissance walks were used to avoid these barriers; researchers deviated from the transect line the minimum required distance to traverse the terrain, returning to the transect in as little distance as possible (Walsh & White 2016). Observers continuously scanned for primates while walking transects; in addition, they stopped every 20-30 meters to scan for monkeys. At each stop, the area was scanned 360 degrees, from canopy to the ground level. If no animals were spotted during a stop and scan, the visibility (i.e., the estimated farthest distance at which one could have reliably detected a monkey), was recorded using a rangefinder, perpendicular to the transect line to the east and west. When one or more monkeys were sighted, several variables were recorded with the waypoint in the GPS: species, number of animals (cohort size was counted from transect), sighting distance (SD) from observer to monkey, the angle of the group or individual from north, and the visibility (in meters). Monkey sightings were recorded regardless of behavioral state (active or napping).

Three estimates were derived from our data. One was calculated using Distance v 7.2 (Thomas *et al.* 2010). Only those observations made from the transect line were used. The perpendicular distance from the monkey to the transect was calculated trigonometrically using field data. Perpendicular distance, cluster size, and other information about the study site were used; a separate analysis was conducted for each species.

The second estimate was based on the number of individuals sampled within the entire area surveyed. This density-based analysis incorporates sightings from the transect and reconnaissance walk points that were taken during transect sampling, whereas the Distance software can generate estimates only from data taken on the transect line. We estimated the density of monkeys using polygons delineated in Arc GIS Pro 10.4 (ESRI 2019). Within each polygon, we searched for individuals continuously until we judged the probability of undetected monkeys to be very low; this time varied by vegetation conditions. Density was calculated as number of individuals per unit area (km^2), aggregated over all polygons.

The third estimate was calculated based on number of individuals sampled per unit effort (i.e., time spent observing). Observers spent approximately 148 hours walking the trails as they moved to and from the transect lines. Neither the distance-based nor density-based analyses could incorporate these trail sightings; thus, an effort-based analysis (sightings per hour of walking) was used to incorporate trail sightings.

RESULTS

We observed a total of 49 golden monkeys and 78 L'Hoest's monkeys across the surveyed transects. The two species represented 29 discrete occurrences in space; golden monkeys were observed in groups in 55% of the sightings, and L'Hoest's monkeys were observed in groups in 96% of the sightings.

We fit a uniform distribution, a log-normal distribution, and a negative exponential function to the data in Distance v 7.2 (Thomas *et al.* 2010). Only the negative exponential model fit the observation by distance data for the L'Hoest's monkey ($y = 0.3531e^{0.236x}$, $R^2 = 0.75$; $P < 0.01$). Using this negative exponential model, we projected that the population of L'Hoest's monkeys in Gishwati numbered 741 individuals (± 221 at the 95% confidence interval). Most individuals (86%) were detected within 20 meters of base transect, though some groups were observed at larger distances when the vegetation was less dense (see Figure 3). In contrast, no model was adequate to fit the golden monkey data, as individuals were observed only within a narrow band of distances along the base transect ($R^2 > 0.2$ for all models; $P > 0.50$). Though the projection models were not significant, the distance method estimated that the number of golden monkeys was near 70.

The density analysis assumes uniform dispersion of monkeys throughout the forest. For this analysis, both transect and reconnaissance walk points were used to determine the total area of the core forest of Gishwati Forest that was sampled (polygons generated using visibility data). Using this process of density estimation, we project that Gishwati forest contains 1327 L'Hoest's monkeys and 211 golden monkeys. This projection, however, assumes that individuals are proportionally allocated in space, an assumption that is unlikely to have been met.

Effort-based analysis incorporated only incidental sightings as observers used managed trails in the forest; during this time, observers were

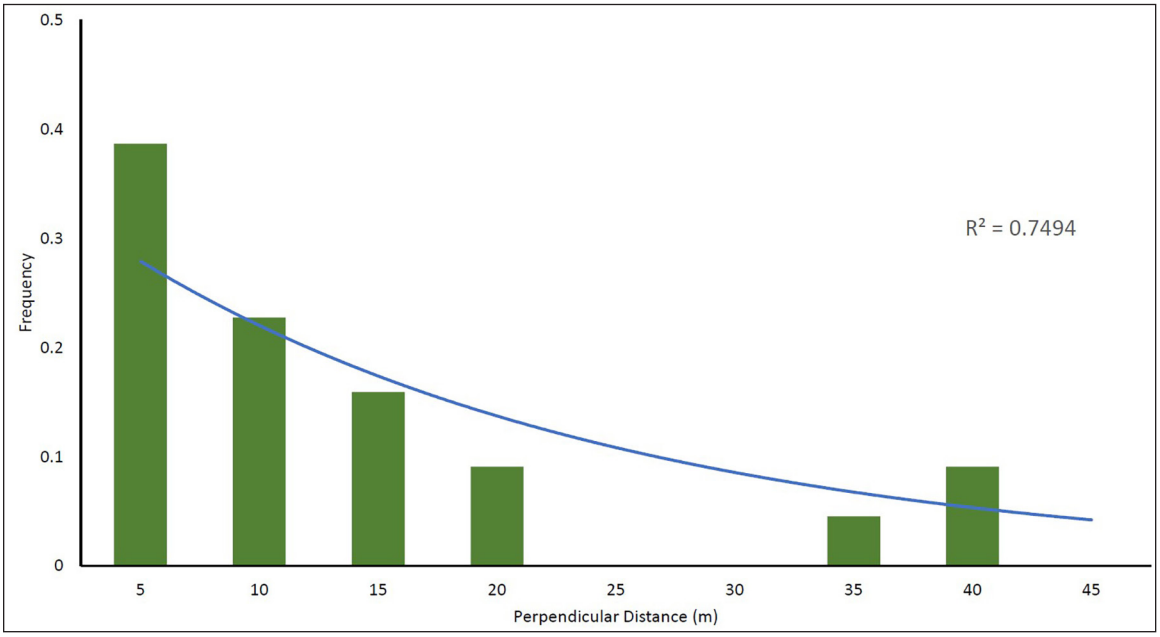

Figure 3. Detection probability of individual L'Hoest's monkeys. Sighting distances binned in 5-meter increments. An exponential line was the best fit for these data, including transect line data only (n=44), with an equation of y = 0.3531e^0.236x.

not explicitly scanning for monkeys. Approximately half of all sightings occurred on trails while en route to or from transect locations.

In approximately 148 hours of trail walks, seven cohorts of each species were seen from the trail, a total of 42 golden monkeys and 34 L'Hoest's monkeys, with variable group sizes. For each hour spent on the trail, the probability of seeing a cohort of monkeys was .0946 (P = 0.473 for each species). This would suggest that one would have to commute on the trails for an average of 10.6 hours to see a cohort of either species of monkey. However, sightings were more frequent in the morning; 12 of 14 sightings occurred during morning transits. If only morning sightings and effort (approx. 74 hours) are included in the analysis, the probability of a sighting nearly doubles (P = 0.162), with an average six hours of trail walking for a sighting to occur.

A summary of the results from two methods of population estimation and the effort-based analysis for the three population survey methods is shown in Table 1.

DISCUSSION

This paper reports three estimates for the population size of both golden monkeys and L'Hoest's monkeys in Gishwati Forest. Although the estimates are similar, the three methods may have been differentially impacted by both methodological and environmental factors. The distance sampling result likely underestimates the actual populations of both species, because the exponential decay in detection probability for L'Hoest's monkeys is mostly attributable to the density of the vegetation in Gishwati forest. The fact that the negative exponential function is the only viable model means that the topography, thickness of the vegetation, and limited number of encounters with primate groups renders the Distance-based projection more subject to error. In regions with such limited detections and high spatial and topographic heterogeneity, Distance sampling offers a lower-confidence estimation of population size. The error, however, is towards conservatism, suggesting that the actual population is higher than the model indicates. Conversely, the density-based result likely overestimates the actual populations of both species because it does not account for non-uniform dispersion (i.e., social grouping behavior). The effort-based result likely underestimates the number of monkeys that could be sighted per time in the forest because observers were not actively scanning for monkeys on trail walks when the data for this estimate were recorded. Taken together, these estimates provide a potential range of population size for the monkeys of Gishwati. The large reported standard deviations are partially due to the small sample size and limited temporal replication used in this study. The impact of dense vegetation on visibility is also uneven in this landscape, which also increases variability of observations. As a result, these population surveys

Table 1. Summary of population estimates and time-to-encounter estimates for three population survey methods at Gishwati Forest, Rwanda.

Method	*Species*	*Estimate*	*Confidence*
Distance	Golden monkey	70 individuals	n.s.
	L'Hoest's monkey	741 individuals	±221 @ 95%
Density Analysis	Golden monkey	211 individuals	n/a
	L'Hoest's monkey	1327 individuals	n/a
Effort-based (full day)	Combined	10.6 hrs per sighting	n/a
Effort-based (morning only)	Combined	6 hours per sighting	n/a

are preliminary and should serve as a basis for future work in Gishwati.

These estimates provide evidence that the population of L'Hoest's monkeys at Gishwati is of sufficient size such that it escapes an appreciable risk of genetic drift and stochastic elimination according to the 50-500 rule (Franklin 1980). The golden monkey population in Gishwati is above the risk threshold for genetic drift but, given limited sampling, it may well be vulnerable to extirpation due to stochastic environmental events. An additional factor that should be considered in managing these populations, not addressed in this study, is the possibility of monkey predation by the resident population of eastern chimpanzees. Although predation has not been observed at Gishwati, there is indirect evidence that the chimpanzee population at nearby Nyungwe Forest may hunt L'Hoest's monkeys (Fashing *et al.* 2007), and so we cannot rule out the possibility that it may occur at Gishwati.

Our population estimate based on counts of animal density assumed both 100% detection when an individual was within a polygon and a uniform distribution of individuals within the polygon. Because the majority of the individuals observed were seen in groups, we know that, at finer spatial scales, both species are aggregated in space. As noted elsewhere (Turner *et al.* 1989), aggregated dispersions at one scale can approximate uniform dispersions at larger scales as individuals respond to finer scale cues locally (e.g., behavior) and more general cues at landscape scales (e.g., distribution of food resources). Both species of monkey are generalist herbivores and opportunistic omnivores (Kaplin & Moermond 2000), so we suggest that it would be interesting and useful to map group locations across the core forest to better understand patterns of density in space. It would also facilitate improved recommendations for where visitors should explore if they wish to encounter these species.

These data, as well as anecdotal evidence from field observers, suggests that the Gishwati population of L'Hoest's monkeys is viable for carefully managed ecotourism. The people of the region are very supportive of forest protections but concerned about human-animal conflict and the economic impact of removing reserve areas from agricultural use (McGuinness & Taylor 2014). Moreover, the effort-based result suggests that morning trekkers would have a reasonable chance of sighting monkeys in the forest approximately once every six hours, which could probably be improved with experienced guides, additional study of daily activity cycles, and even a small habituation effect, which would be likely if forest visits by humans become more common.

In combination with existing estimates of the population of eastern chimpanzees (Chancellor *et al* 2012), these data supply baseline information that will be useful in the future management of these populations.

ACKNOWLEDGMENTS

We are grateful for the financial support of Drake University in making this project possible. The Forest of Hope Association, especially Madeleine Nyiratuza and Thierry Aimable Inzirayineza, provided logistical assistance. We would also like to acknowledge the assistance of Claude Ndacyayisenga and Celestin Pierre, students at the Center of Excellence in Biodiversity & Natural Resource Management at the University of Rwanda, who participated in part of the data collection.

REFERENCES

Brockelman, W.Y. & R. Ali. 1987. Methods of surveying and sampling forest primate populations. In *Primate Conservation in the Tropical Rain Forest*. C. W. Marsh & R. A. Mittermeier, eds. Alan R. Liss, New York. Pp.

23–62.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers & L. Thomas. 2001. *Introduction to Distance Sampling. Estimating Abundance of Biological Populations.* Oxford University Press, New York.

Butynski, T.M. & Y.A. de J*ong. 2020. Cercopithecus mitis* ssp. *kandti*. The IUCN Red List of Threatened Species 2020: e.T4236A92571626. https://dx.doi.org/10.2305/IUCN.UK.2020-2.RLTS.T4236A92571626.en. Downloaded on 18 November 2020.

Chancellor, R.L., K. Langergraber, S. Ramirez, A.S. Rundus & L. Vigilant. 2012. Genetic sampling of unhabituated chimpanzees (*Pan troglodytes schweinfurthii*) in Gishwati Forest Reserve, an isolated forest fragment in western Rwanda. *International Journal of Primatology* 33(2): 479–488.

ESRI. 2019. *ArcGIS Pro:* Release 10.4. Environmental Systems Research Institute, Redlands CA.

Fashing, P.J., F. Mulindahabi, J.B. Gakima, M. Masozera, I. Mununura, A.J. Plumptre & N. Nguyen. 2007. Activity and ranging patterns of *Colobus angolensis ruwenzorii* in Nyungwe forest, Rwanda: possible costs of large group size. *International Journal of Primatology* 28(3): 529–550.

Forest of Hope Association. 2017. *Guidebook: Gishwati-Mukura National Park.* Critical Ecosystem Partnership Fund, 24 pp.

Franklin, I.R. 1980. Evolutionary change in small populations. In *Conservation Biology: An Evolutionary-ecological Perspective.* M. E. Soule & B. A. Wilcox, eds. Sinauer, Sunderland MA. Pp. 135–149.

Kaplin, B.A. & T.C. Moermond. 2000. Foraging ecology of the mountain monkey (*Cercopithecus l'hoesti*): implications for its evolutionary history and use of disturbed forest. *American Journal of Primatology* 50(4): 227–246.

Leca, J.B., N. Gunst, A. Rompis, G. Soma, I.G.A.A. Putra & I.N. Wandia. 2013. Population density and abundance of ebony leaf monkeys (*Trachypithecus auratus*) in West Bali National Park, Indonesia. *Primate Conservation* 26(1): 133–144.

Mangama-Koumba, L.B., N. Yoshihiro, J.F. Mavoungou, E.F. Akomo-Okoue, T. Yumoto, J. Yamagiwa & B. M'Batchi. 2016. Estimating diurnal primate densities using distance sampling method in Moukalaba-Doudou National Park, Gabon. *Journal of Applied Biosciences* 99(1): 9395.

Marshall, A.R., J.C. Lovett & P.C.L. White. 2008. Selection of line-transect methods for estimating the density of group-living animals: lessons from the primates. *American Journal of Primatology* 70(5): 452–462.

McGuinness, S. & D. Taylor. 2014. Farmers' perceptions and actions to decrease crop raiding by forest-dwelling primates around a Rwandan forest fragment. *Human Dimensions of Wildlife* 19(2): 179–190.

Nyandwi, E. & A. Mukashema. 2011. Excessive deforestation of Gishwati mountainous forest & biodiversity changes. *Participatory Geographic Information Systems (P-GIS) for Natural Resource Management and Food Security in Africa.* ENDA Lead Africa, Dakar, Senegal.

Parliament of Rwanda. 2016. Law No. 45/2015 of 15/10/2015 Establishing the Gishwati-Mukura National Park, Kigali, Rwanda: Official Gazette No. 5 of 01/02/2016, pp. 44-90.

Plumptre, A., J.A. Hart, T.C. Hicks, S. Nixon, A.K. Piel & L. Pintea. 2016. *Pan troglodytes ssp. schweinfurthii* (errata version published in 2016). The IUCN Red List of Threatened Species 2016: e.T15937A102329417. https://dx.doi.org/10.2305/IUCN.UK.2016-2.RLTS.T15937A17990187.en. Downloaded on 18 November 2020.

Thomas, L., S.T. Buckland, E.A. Rexstad, J. L. Laake, S. Strindberg, S. L. Hedley, J. R.B. Bishop, T. A. Marques & K. P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. *Journal of Applied Ecology* 47: 5-14.

Turner, M.G., R.V.O. Neill, R.H. Gardner & B.T. Milne. 1989. Effects of changing spatial scale on the analysis of landscape pattern. *Landscape Ecology* 3:153–162.

Ukizintambara, T., W. Olupot & J. Hart. 2019. *Allochrocebus lhoesti.* The IUCN Red List of Threatened Species 2019: e.T4220A92345122. https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T4220A92345122.en. Downloaded on 18 November 2020.

Walsh, P.D. & L.J.T. White. 2016. What it will take to monitor forest elephant populations. *Conservation Biology* 13(5): 1194–1202.

Whitesides, G., J. Oates, S. Green & R. Kluberdanz. 1988. Estimating primate densities from transects in a West African rain forest: a comparison of techniques. *Animal Ecology* 57(2): 345–367.

Received: 4 August 2020
Accepted: 17 December 2020