OPEN ACCESS

October-December 2021
ISSN 2006-9847
DOI: 10.5897/JENE
www.academicjournals.org

ACADEMIC JOURNALS
expand your knowledge

About JENE

Journal of Ecology and the Natural Environment (JENE) provides rapid publication (monthly) of articles in all areas of the subject such as biogeochemical cycles, conservation, paleoecology, plant ecology etc.

The Journal welcomes the submission of manuscripts that meet the general criteria of significance and scientific excellence. Papers will be published shortly after acceptance. All articles published in JENE are peer-reviewed.

Indexing

The Journal of Ecology and The Natural Environment is indexed in:

CAB Abstracts, CABI's Global Health Database, Chemical Abstracts (CAS Source Index) Dimensions Database, Google Scholar, Matrix of Information for The Analysis of Journals (MIAR), Microsoft Academic

JENE has an h5-index of 10 on Google Scholar Metrics

Open Access Policy

Open Access is a publication model that enables the dissemination of research articles to the global community without restriction through the internet. All articles published under open access can be accessed by anyone with internet connection.

The Journal of Ecology and The Natural Environment is an Open Access journal. Abstracts and full texts of all articles published in this journal are freely accessible to everyone immediately after publication without any form of restriction.

Article License

Article Copyright

When an article is published by in the Journal of Ecology and The Natural Environment, the author(s) of the article retain the copyright of article. Author(s) may republish the article as part of a book or other materials. When reusing a published article, author(s) should;

Cite the original source of the publication when reusing the article. i.e. cite that the article was originally published in the Journal of Ecology and The Natural Environment. Include the article DOI Accept that the article remains published by the Journal of Ecology and The Natural Environment (except in occasion of a retraction of the article)
The article is licensed under the Creative Commons Attribution 4.0 International License.

A copyright statement is stated in the abstract page of each article. The following statement is an example of a copyright statement on an abstract page.
Copyright ©2016 Author(s) retains the copyright of this article.

Self-Archiving Policy

The Journal of Ecology and The Natural Environment is a RoMEO green journal. This permits authors to archive any version of their article they find most suitable, including the published version on their institutional repository and any other suitable website.
Please see http://www.sherpa.ac.uk/romeo/search.php?issn=1684-5315

Digital Archiving Policy

The Journal of Ecology and The Natural Environment is committed to the long-term preservation of its content. All articles published by the journal are preserved by Portico. In addition, the journal encourages authors to archive the published version of their articles on their institutional repositories and as well as other appropriate websites.
https://www.portico.org/publishers/ajournals/

Metadata Harvesting

The Journal of Ecology and The Natural Environment encourages metadata harvesting of all its content. The journal fully supports and implement the OAI version 2.0, which comes in a standard XML format. See Harvesting Parameter

Memberships and Standards

Academic Journals strongly supports the Open Access initiative. Abstracts and full texts of all articles published by Academic Journals are freely accessible to everyone immediately after publication.

Crossref is an association of scholarly publishers that developed Digital Object Identification (DOI) system for the unique identification published materials. Academic Journals is a member of Crossref and uses the DOI system. All articles published by Academic Journals are issued DOI.

Similarity Check powered by iThenticate is an initiative started by CrossRef to help its members actively engage in efforts to prevent scholarly and professional plagiarism. Academic Journals is a member of Similarity Check.

CrossRef Cited-by Linking (formerly Forward Linking) is a service that allows you to discover how your publications are being cited and to incorporate that information into your online publication platform. Academic Journals is a member of CrossRef Cited-by.

Academic Journals is a member of the International Digital Publishing Forum (IDPF). The IDPF is the global trade and standards organization dedicated to the development and promotion of electronic publishing and content consumption.

Contact

Editorial Office: jene@academicjournals.org

Help Desk: helpdesk@academicjournals.org

Website: http://www.academicjournals.org/journal/JENE

Submit manuscript online http://ms.academicjournals.org

Academic Journals
73023 Victoria Island, Lagos, Nigeria
ICEA Building, 17th Floor,
Kenyatta Avenue, Nairobi, Kenya.

Editors

Dr. Abd El-Latif Hesham
Genetics Department
Faculty of Agriculture
Assiut University
Assiut,
Egypt.

Dr. Ahmad Bybordi
Soil and Water Research Department
East Azarbaijan Research Centre for Agriculture and Natural Resources
AREEO, Tabriz,
Iran.

Dr. Marko Sabovljevic
Dept. Plant Ecology
Faculty of Biology
University of Belgrade
Belgrade,
Serbia.

Dr. Sime-Ngando Télesphore
CNRS LMGE, UMR
Université Blaise Pascal
Aubière Cedex,
France.

Dr. Ram Chander Sihag
Zoology Department,
CCS Haryana Agricultural University,
Hisar, India.

Table of Contents

Vol. 13(4), pp. 100-109, October-December 2021
DOI: 10.5897/JENE2021.0910
Article Number: F6EA32167840
ISSN 2006-9847

http://www.academicjournals.org/JENE

Journal of Ecology and The Natural Environment

Full Length Research Paper

Economic valuation of tourism of the Sundarban Mangroves, Bangladesh

Mohammad Nur Nobi[1], A. H. M. Raihan Sarker[2*], Biswajit Nath[3], Eivin Røskaft[4], Ma Suza[5] and Paul Kvinta[6]

[1]Department of Economics, University of Chittagong, Chittagong - 4331, Bangladesh.
[2]Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong- 4331, Bangladesh.
[3]Department of Geography and Environmental Studies, University of Chittagong, Chittagong- 4331, Bangladesh.
[4]Department of Biology, Norwegian University of Science and Technology, NTNU, Trondheim #7491, Norway.
[5]Department of Social Sciences, Wageningen University, PO Box 8130, 6700E Wageningen, The Netherlands.
[6]573 Cameron Street SE, Atlanta, Georgia 30312, United States.

Received 5 August, 2021; Accepted 20 September, 2021

The Sundarban Reserve Forest (SRF) of Bangladesh provides tourism services to local and international visitors. Indeed, tourism is one of the major ecosystem services that this biodiversity-rich mangrove forest provides. Through a convenient sampling technique, 421 tourist respondents were interviewed to assess their willingness to pay for the tourism services of the Sundarban, using the Zonal Travel Cost Method (ZTCM). The estimated annual economic contribution of tourism in the Sundarban mangroves to the Bangladesh economy is USD 53 million. The findings of this study showed that facilities for watching wildlife and walking inside the forest can increase the number of tourists in the SRF. The findings also show that the availability of information like forest maps, wildlife precautionary signs, and danger zones would increase the number of tourists as well. Thus, the government of Bangladesh should consider increasing visitor entry fees to fund improvements and to enhance the ecotourism potential of the Sundarban mangroves.

Key words: Bangladesh, economic valuation, mangrove, Sundarban, tourism service.

INTRODUCTION

Ecotourism is a large and growing component of international tourism, which provides a means of earning foreign exchange and offers a less destructive use of resources (Honey, 2008). Additionally, ecotourism encourages the preservation of traditional customs, handicrafts and festivals that might otherwise be allowed to wane. In this regard, ecotourism creates civic pride (Buckley, 2009). Generally, protected areas are very important components of the ecotourism industry, as they occupy some of the most interesting landscapes. Ecotourism is increasingly becoming an important part of sustainable development because of the potential for contributing to local and national economic development, while providing incentives for nature and biodiversity

*Corresponding author. E-mail: dr.raihan.sarker@cu.ac.bd. Tel: +8801609479381.

conservation (Zacarias and Loyola, 2017).

The Sundarban Reserve Forest (SRF) of Bangladesh is a dynamic ecosystem that provides a variety of services, such as (1) provisioning (e.g., typical forest products, fisheries, etc.), (2) cultural (e.g., tourism, worship, educational research, etc.), (3) regulating (e.g., protection from cyclones, storm surges, floods, climate regulation, pollination, etc.), and (4) supporting (e.g., nursery and breeding ground of fish, nutrient cycling, habitat for biodiversity, etc.) services (Barbier, 2007; Giri et al., 2007; Kathiresan and Rajendran, 2005; Walters et al., 2008). Among the non-extractive services that mangrove forests offer are tourism services, which have great potential to benefit everyone in Bangladesh, its 163 million citizens and foreigners alike (BBS, 2019). The landscape of the SRF and its position as a tiger habitat make it a singular tourist attraction (Guha and Ghosh, 2011). The number of visitors to the Sundarban has been increasing day-by-day, and the region offers scenic beauty as well as wildlife-habitat, and traditional cultural and religious events, such as the Rash Mela and Ban Bibir Mela (that is, traditional worship of the local Hindu communities) (BFD, 2012; Hai and Chik, 2011).

There is a widespread notion that mangrove ecosystem valuation exercises might help decision makers which appreciate the value of the ecosystem services to the society and the anticipated cost of their imminent loss (Laurans and Mermet, 2014). Economic valuation in particular is often expected to be a useful tool to support conservation policy decisions and governance (Bateman et al., 2011). In this context, the USAID's CREL project with Winrock's JDR 3rd Scholars Program supported this research study to estimate the values (in monetary terms) of the tourism services of the SRF. A number of previous studies have been conducted on the economic valuation of the SRF, and these studies did not use primary data based on tourist surveys (Haque and Aich, 2014; Uddin et al., 2013). Therefore, the goal of this research was to provide an estimate of the economic valuation associated with the tourism services of the SRF of Bangladesh by using primary data collected through field surveys. Additionally, the specific objectives of the study were to understand the following: (i) the status and recreational behaviour of visitors, and (ii) the perceptions of visitors towards (a) the recreational activities and physical tourism services available in the SRF, and (b) the improvement of existing tourism services in the SRF.

MATERIALS AND METHODS

Information about the study site

The SRF is situated along the coastline of the Bay of Bengal in the south-western region (that is, Khulna division) of Bangladesh. It was declared a World Heritage Site by UNESCO in 1997. The total area of the forest is 603,000 ha and consists of three wildlife sanctuaries: Sundarban West (119,718.88 ha), Sundarban East (122,920.90 ha) and Sundarban South (75,310.30 ha) (BFD, 2021). The present study was conducted in all existing forest ranges of the SRF, as defined by the Bangladesh Forest Department (BFD), such as (i) the Burigoalini Forest Range, (ii) the Khulna Forest Range, (iii) the Chandpai Forest Range, and (iv) the Sharankhola Forest Range (Figure 1).

Questionnaire development, data collection, and analyses

Primary data was collected from the field directly through face-to-face interviews. Secondary data was collected from published books and journals and from unpublished sources like the reports of the BFD and information from different tour operators regarding the number of visitors and revenue earned from tourism. Data was collected from all tourist spots in the Sundarban Mangrove Forest from November, 2018 to April, 2019. A semi-structured questionnaire was used to collect information about the visitors' biographic information, visit preferences, reasons for preferring the Sundarban, selection of tour packages, opinions on existing tourism facilities and services, suggestions for improvement, and willingness to pay higher prices for improved quality of services provided by various tour operators.

During the study, a convenient sampling method was used in collecting primary data. Reaching the tourists on site at the tourist spots was convenient for the researchers. Usually, tourists visited in the Sundarban by ships provided by tour operators. In connection with this, research assistants for this study accompanied the tourists on these ships. The tourists were interviewed while returning from several Sundarban tourism spots. A total of 421 visitors (both local and foreign) were interviewed face-to-face. Day-visitors were also included, most of whom start from Karamjal. Thus, they were interviewed at that particular place.

Various Sundarban tour packages are offered by the tour operators. This study identified the packages through a Focus Group Discussion (FGD) with the established tour operators. All of the collected data (that is, primary data, secondary data and FGD information) was sorted for the purpose of quantitative and qualitative analyses. People who visit the Sundarban mangroves go for either tourism reasons or spiritual reasons. In this study, the responses of tourists only were considered.

The responses of spiritual pilgrims were excluded from the analysis. After processing and generating the data, visitors were categorized into seven major zones, based on their origin. Since there are seven divisions in Bangladesh, the tourists were categorized into one of these seven zones. The number of tourists in each zone was then divided by the total number of tourists to calculate the percentage share of each zone. The potential number of the visitors was measured based on the threshold level of income (minimum BDT 9158 or USD 117.42 to BDT 14092 or USD 180.69), which is the minimum income of the sampled visitors. The population of a zone having income above threshold level of income were considered as the potential number of tourists for that zone. Analyses were performed using SPSS version 20.0 (SPSS, Chicago, USA) and STATA 11. The study evaluated the differences in socio-economic condition, recreational behaviour, and tourists' attitude using one-way ANOVA and Chi-square (χ^2) tests. The level of significance was set at $p \leq 0.05$ and $p \leq 0.10$.

Calculation of the valuation of tourism service

The travel cost method (TCM) was applied for the valuation of tourism services in the Sundarban mangroves of Bangladesh. Gradually, TCM has become a widely used valuation technique for protected areas, national parks, sanctuaries, and forests. This method of valuing tourist spots, based on a tourist's willingness to pay, was developed by Harold Hotelling in 1949 when he used it to value U.S. national parks (Hotelling, 1949). There are two types of

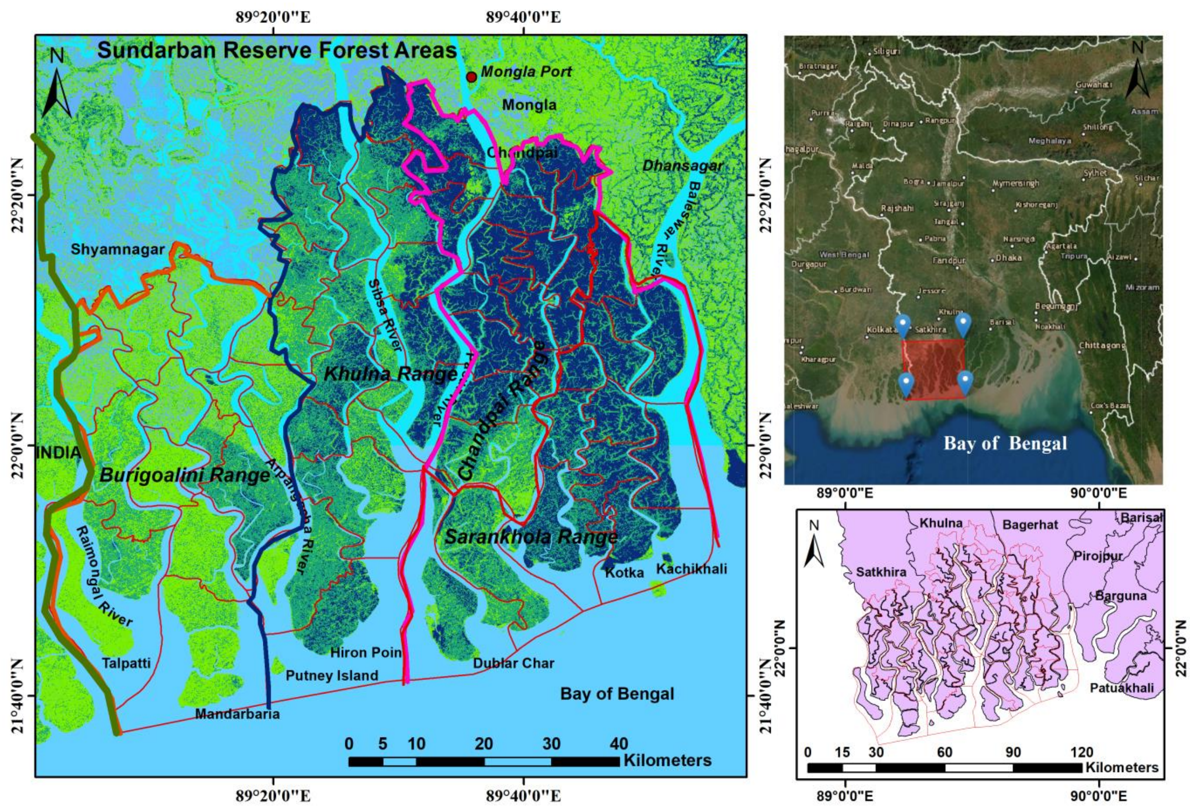

Figure 1. Location of the study area. Study sites have four forest range: Burigoalini Forest Range, Khulna Forest Range, Chandpai Forest Range and Sarankhola Forest Range shown in left panel. In this panel, base image used NASA SRTM DEM v3 acquisition from USGS Earth Explorer website: Image resolution: 1-Arc seconds: 30 meters; In Right Panel: Top image: Google Earth Pro view highlight SRF areas with transparent red box; and Bottom right: SRF location shown over District Map of Bangladesh as zoom view. The Sundarban Forest Compartment boundary and district boundary shape files are taken from Bangladesh Forest Department for JRD 3rd Scholar Project and DIVA-GIS web platform (https://www.diva-gis.org/gdata), respectively.

TCM, namely, the Individual Travel Cost Method (ITCM) and the Zonal Travel Cost Method (ZTCM). The ITCM is used when data is collected from individual tourist levels, and the ZTCM is used when data is collected from secondary sources. Defining the travel zones, the ZTCM is used for an identical recreational site. If secondary data sources such as recreational permits or fees are limited, the ZTCM is very useful (Loomis et al., 2009). In this study, the proportion of primary data was used for each zone to convert the secondary data by those proportions in order to use the ZTCM in estimating the value of tourism services of the Sundarban mangroves. The ZTCM is considered as one of the simplest and least-expensive methods for valuation of tourism service (Saraj et al., 2009). The main benefit of this method is the inclusion of the cost of time and travel that people incur for a visit, which exhibits as the price of travel to a site. Thus, ZTCM helps to estimate the willingness of tourists to pay based on their number of visits as a demand schedule with different prices. It also assumes that the cost for one individual to visit a recreation location from a specific zone is the same for all other individuals from that same zone (Emiriya, 2013), although there is heterogeneity among the population and variation in travel cost.

To get the actual number of visitors of different zones, the sample proportion (primary data collected during 2018-2019) was used to divide the actual number of visitors for 2018 into seven divisions. Then, these estimated numbers of visitors for 2018, categorized into seven zones, were used to estimate the zone-wise travel cost. The total number of visitors in 2018 for each zone was divided by the potential number of visitors of that zone to calculate the zone's visitation rate (*Vi*). The potential number of visitors refers the population with enough income to visit a place. The income distribution of the respondents was used to identify the potential number of visitors. From the income distribution of the respondents, which is found in the descriptive statistics, minimum income level of the respondents of each zone was identified. The threshold income level of a particular zone indicates people in that zone with the minimum income level or above, as these are the people who can afford to visit the Sundarban mangrove forest. For instance, the income of the top 5% of the population in Dhaka Division remains above that division's threshold level of income, and thus those people are considered as potential visitors to the Sundarban. The potential population of tourists was identified from the *'Household Income Expenditure Survey 2011'* (BBS, 2011) and categorized by zones following the administrative boundaries of the seven divisions in Bangladesh.

The number of visitors to a recreational area and the distance visitors travelled is used in the ZTCM to calculate the *'price'* that the visitors pay to visit the site (King and Mazzoatta, 2000). The ZTCM counts how many people travel from different distances or zones from the park and estimates the cost of the various distances. By adding the number of people and their associated travel costs, the

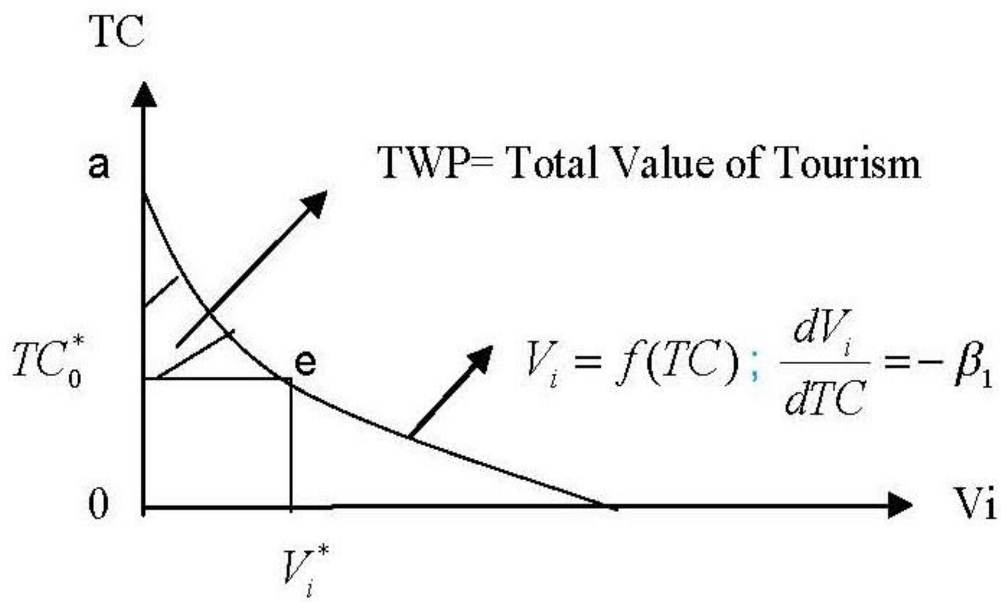

Figure 2. Visit-generating function (*Vi*).

total price that tourists pay to visit the site can be calculated. Thus, it is important to know the visitors' zone of origin to determine the visitation rate. This visitation rate considers cost of travel from the origin to the recreation site, and the income or demographic characteristics of the respondents (Das, 2013).

The visitation rate (*Vi*) was estimated as the visit-generating function (*VGF*) on costs of travel and others demographic variables (Nobi and Nahar, 2013). The visit-generating function was considered as the demand function for the visit, where *VGF* is the dependent variable and the travel cost (that is, price of visit) is the core explanatory variable along with other explanatory variables, such as whether the tourist is alone or in a group, whether the tourists uses at least one way by air or not, whether the tourist is from Khulna or some other division of Bangladesh, and whether the tourist is part of a package tour offered by tour operators. After the estimation, the price elasticity was calculated from the demand function for visitation to calculate the tourists' willingness to pay (WTP) for different zones. The total willingness to pay was then calculated by adding the WTP for different zones, which resembles the total value of tourism service of the SRF.

The visitation rate (*Vi*) of the visit-generating function is inversely related to the travel costs (Figure 2). This means that as the travel costs decrease the demand for tourism increases. The area under the *VGF* (that is, demand function for visit) shows the total economic value of tourism service. Subtracting the total costs of travel (that is, total costs = average travel costs × number of visitors) from the total value of tourism provides the net value of tourism, which is the consumer surplus (*CS*) and the contribution of tourism service to the national economy. According to Figure 2, area *aeTCo* is the net value for each zone in terms of willingness to pay. Finally, the total value of the tourism service of the Sundarban mangroves was calculated by adding the consumer surpluses of all zones.

The econometric model of the zonal travel cost method (ZTCM)

Adopted from Clawson (1959) and with a modification according to Torres-Ortega et al. (2018), the econometric model of the ZTCM is as follows:

$$V_i = f(TCost_i, Alone, Air, Khln, Package) \quad (1)$$

$$V_i = \alpha + \beta_1 TCost_i + \beta_2 Alone + \beta_3 Air + \beta_4 Khln + \beta_5 Package + \varepsilon) \quad (2)$$

$$V_i = \frac{Total\ number\ of\ visit}{Total\ population}$$

where *Vi* stands for visitation rate, which is the dependent variable that is calculated by dividing the zonal number of visitors by their total population. The explanatory variables are *TCost*, the travel cost of zone *i*; *Alone*, a dummy variable with a value of either 1 (the specific visitor is alone) or 0 (the visitor is in a group); *Air*, a mode of travel used by visitors from any destination to Jessore (the nearest airport to the SRF); *Khln*, a dummy variable representing zone, where 1 indicates the visitor is from Khulna Division and 0 indicates all other divisions; and *Package*, a dummy variable where the value 1 indicates the visitor is in a package tour and 0 indicates no package tour. β_0 is a constant variable and ε is the residual. It is notable that *Vi* is a dependent variable, while $TCOST_i$, *Alone, Air, Khln* and *Package* are independent variables in the model estimation. Holding other things constant, *VGF* (*Vi*) is inversely related with travel costs of the zones. Thus, the slope coefficient of travel cost (β_1) of this *VGF* is used to calculate the value of tourism service; the *CS* of tourism in the Sundarban mangroves.

Theoretical framework for calculating the areas of tourism locations

After calculating the tourism value, it was divided by the total number of visitors to get consumer surplus per visit. It is also divided by the total area of different tourism locations that the tourists visit in order to determine the tourism value per hectare of the SRF. In every tourist spot, visitors usually go to one side of the river in the Sundarban. Table 1 depicts the distance in km that the visitors walk, which has been calculated by using GIS (that is,

Table 1. Tourist coverage at some selected tourist spots in the SRF of Bangladesh.

Tourist spots	Compartment (Tourist spot) no.	Distance (km)	Area in half of circle (km^2)	Area (ha)
Katka (including Jamtala sea beach)	7	6	56.6	5654.9
Kachikhali	6	2	6.3	628.3
Harbaria	26	4	25.1	2513.3
Kalagasia	46	3.5	19.2	1924.2
Karamjol	31	5	39.3	3926.9
Nilkamal	44	2	6.3	628.3
Dubla, Meherali, Alorkol, and Majherchar	45	15	353.4	35342.9
Total	-	37.5	506.2	50618.9

∏=3.14159 and 1 km^2 = 100 ha.

Geographic Information System) technology where the visitors walk around. While measuring the favourite area for each tourist spot, one side of the river where visitors usually walk around in each tourist spot was considered. The estimated area for each of the seven tourism locations is shown in Table 1. Finally, to estimate the value per hectare of tourism service in the Sundarban mangroves, the total estimated value of tourism (in terms of WTP) was divided by the total area of Sundarban mangroves visited by tourists.

RESULTS

Socio-economic and demographic profiles of visitors/tourists

Among the visitors (n = 421), the majority were (n = 369, 87.6%) local, while the remaining (n = 52, 12.4%) were foreigners, who came from the outside of the country, especially from USA (4%), the UK (2.1%), and Germany (1.9%). During the study, it was observed that a considerable number of foreign visitors also came from a variety of other countries, that is, Australia, Brazil, Canada, Croatia, France, India, Nepal, Netherland, Singapore, Sri Lanka, and Italy. Among local visitors (n = 369), the highest numbers were estimated from the Dhaka division (41.2%) followed by Khulna division (39.8%), with the remaining from the Rajshahi (6.8%), Chittagong (6.2%), Rangpur (3.0%), Barisal (2.2%) and Sylhet (0.8%) divisions. The proportion of males was higher than females, and visitors mostly included young, middle aged, and elderly (Table 2).

Table 2 shows the socio-economic and demographic profiles of visitors. More than two-thirds of the respondents were highly educated (having graduate degree or above), and the number of these kinds of visitors was greater among foreigners than among local visitors. This study also identified the marital status of the tourists. The majority of local visitors were married, with the remaining being unmarried, divorced or widowed. The profession of the respondents was also varied. The majority of tourists were students. The average household size of the visitors was 4.5 persons (± 2.49), and the household size significantly varied between the types of visitors (*that is,* local: 4.83 ± 2.45 persons per household, foreigner: 2.21 ± 1.40 persons per household, F = 51.44, df = 1, and p = 0.0001). The average income of local visitors was approximately BDT 66,000/month or USD 846.26.

Recreational behaviour of visitors

More than four-fifths of the visitors (n = 421, 81.2%) said that they visited the Sundarban mangrove forest for the first time, while 18.8% were the repeat visitors, and their responses varied significantly between the types of respondents (χ^2 = 6.57, df = 1, p = 0.01). Among the repeat visitors, 20.6% of locals and 5.8% of foreigners were visiting the area for the second time. About 90.5% of the visitors reported that they came under a tour package, and their proportion varied significantly between the types of visitors (χ^2 = 3.96, df = 1, p = 0.047). More than two-thirds of the visitors (67.9%) said that they learned about the SRF from their family, friends, and relatives, while the remaining visitors mentioned media (9.7%), organizational websites (7.6%), social networks (7.6%), advertisements of tour operators (5.7%), government websites (1.0%), and newspapers, books, etc. (0.5%).Their responses varied significantly between the types of visitors (χ^2 = 41.68, df = 6, p = 0.0001). This study also revealed that a significant number of visitors (87.4%) travelled in groups, while 12.6% were visiting alone. Their responses varied significantly between the types of visitors (χ^2 = 30.92, df = 1, p = 0.0001).

More than half of the visitors (59.1%) mentioned that the Sundarban mangrove forest areas were the only destination within the region they visited on this trip. A majority of the visitors (84.1%) reported that they visited the Sundarban for recreation, while 12.4% visited for spiritual purposes, 3.5% came for study purpose, and 1% for business purposes. The purpose of visit varied significantly between the types of visitors (χ^2 = 15.14, df =

Table 2. Socio-economic data, obtained from interviews of visitors in Sundarban included in the study and χ^2 tests of independence between types of visitors.

Socio-economic variables		Types of visitor (%)		Total	Statistics		
		Foreign tourist (n = 52)	Local tourist (n = 369)	(n = 421; %)	χ^2	df	p
Sex	Female	30.80	10.00	12.60	17.82	1	0.0001
	Male	69.20	90.00	87.40			
Age	Youth (18-30 years)	28.0	37.8	36.6	16.26	2	0.0001
	Middle age (31 to 50 years)	38.0	49.9	48.4			
	Old (above 50 years)	34.0	12.3	14.9			
Education	Below primary level/No. schooling	0.00	2.20	1.90	9.67	3	0.022
	Up to primary	1.90	0.50	0.70			
	Up to secondary	11.50	29.00	26.80			
	Graduate or above	86.50	68.30	70.50			
Marital status	Unmarried	40.40	31.20	32.30	31.54	3	0.0001
	Married	51.90	68.80	66.70			
	Divorced	5.80	0.00	0.70			
	Widow	1.90	0.00	0.20			
Occupation	Agriculture	0.00	1.90	1.70	24.91	8	0.002
	Business	19.20	24.70	24.00			
	Housewife	0.00	2.20	1.90			
	Journalist	1.90	0.50	0.70			
	Researcher	3.80	0.30	0.70			
	Student	25.00	44.20	41.80			
	Teacher	7.70	4.30	4.80			
	Technical profession	21.20	10.60	11.90			
	Others (GOs & NGOs)	21.20	11.40	12.60			

3, p = 0.002). The visitors used buses (62.0%), boats (26.4%), and a combination of air, bus, and boat (11.6%) to travel to the Sundarban, and their responses varied significantly between the types of visitors (χ^2 = 393.61, df = 2, p = 0.0001). More than 85% of visitors travelled to the Sundarban for a short duration only (3 to 7 days), and 63.7% of visitors covered tour expenses with their own income; 27.9% of visitors reported sponsorship, and 6.8% reported support received from family and friends.

Moreover, more than one-fifths of the respondents (21.4%) expressed dissatisfaction towards the overall recreational arrangements in the Sundarban areas, and their perceptions varied significantly between the types of visitors (χ^2 = 8.11, df = 1, p = 0.0001). When asked '*would you be willing to pay to conserve the environment and endangered species in the SRF?*' more than half of the visitors (51.3%) responded "yes." Among them, the proportion was higher for local (53.1%) than foreign (38.5%) visitors, and their responses varied significantly between the types of respondents (χ^2 = 3.92, df = 1, p = 0.05). More than half of the visitors (51.3%) wanted to see improvements in facilities required for watching wildlife (specifically birds, deer, and tigers), while 96.4% wanted improvements for walking facilities for going deeper into the forest, 45.6 and 49.4% requested improvement and facilities should increase to watch deer and bird, respectively, and 7.4% requested improved facilities for religious functions. Approximately 47% of visitors wanted to see improvement in information services (*e.g.,* forest maps, wildlife precautionary signs, danger zones, etc.). Among respondents who requested improvements in the recreation and information facilities, the proportion was significantly higher for local (76.2%) than foreign (44.2%, χ^2 = 23.14, df = 1, p = 0.0001) visitors. However, again when we asked, '*what is your opinion about forest entry fee?*' in response to this, more than half (52.7%) of the respondents said "reasonable"; and among them, the proportion was considerably higher for local (55.0%) than foreign (36.5%) visitors. Among them, the remaining respondents, 21.1% of the

Table 3. Estimated result of the visit-generating function.

Variable	Coefficients	Robust SE	T	P > t	[95% Conf. Interval]
$TCOST_i$	-0.00016*	6.5	-25.50	0.03	- 0.0003 - 1.8
Alone	487.94**	328.2	1.49	0.16	- 234.36 + 1210.24
Air	-23.15**	16.2	-1.43	0.18	- 58.86 + 12.56
Khln	58.31**	40.4	1.44	0.18	- 30.66 + 147.29
Package	34.99***	26.5	1.32	0.21	- 23.44 + 93.43
Constant	1.15***	20.6	0.06	0.96	- 44.14 + 46.45

Linear regression: Number of observation= 17, F (5, 11) = 3.70, Prob> F = 0.0328, R-squared = 0.6030, Root MSE = 45.969 *Indicates the level of significance below 5% level, ** indicates the level of significance up to 10%.
Source: Estimated from the sample data.

respondents mentioned “less”, 11.2% mentioned very less, 3.8% very high, and 11.2% high. Approximately 70% of visitors stated that the government should allocate more money to provide improved services, but also agreed to pay higher entry fees if government resources were not available for improvement of the facilities. Among the respondents, the proportion was significantly higher for foreigner (84.6%) than local (67.5%, $\chi^2 = 6.32$, df = 1, p = 0.01) visitors.

Estimation of the visit generating function

The estimated results are shown in Table 3. The visitation rate (the demand to visit) is negatively influenced by the travel cost from different zones, which is statistically significant (Table 3). However, the coefficients of the other variables of the visit generating function are insignificant. The result shows that the targeted variable travel cost ($TCost_i$) of different zones is inversely related with the visitation rate (V_i), which meets the properties of a travel demand function. All independent variables explain 60.3% of the variation in visitation rate with 17 observations. Though, the actual number of the sample observations is 421 but converting to different zones the observation turned to 17. Thus the number of observations here represents the zones which have been restructured by the mode of transports of the visitors of the seven divisions. The F-value is significant below to 5% level of significance refers that the model is a good fit.

Value of tourism services of the Sundarban mangroves

The slope coefficient of travel cost from visits generating a function was used to calculate the value of tourism service in the Sundarban mangroves of Bangladesh. The value of the tourism service in the SRF for different zones and their aggregation is summarized in Table 4. The analysis revealed that tourism as a whole in the SRF contributes about USD 53.14 million/year (Table 4) to the economy of Bangladesh.The total value of tourism was divided by the total visits (in the year 2018) to estimate the value of tourism per visit, and it was calculated as USD 577. The tourism service/hectare was also estimated by dividing the total value of tourism services by the total areas of seven tourism locations (that is, 50,619 ha), which provides USD 1,050/ha/year. After calculating the value per hectare of the tourism service in the SRF, the value of various tourism locations was calculated in order to determine the importance of individual tourism locations. It was revealed that a few tourist spots (that is, Dubla, Meherali, Alorkol, and Majherchar) constituted the highest value of tourism, compared to the other tourist spots (that is, Kotka, Karamjol, Harbaria, Kalagasia, Kachikhali and Nilkamal). The estimated value of each of the tourist spots is shown in Table 5.

DISCUSSION

The SRF contributes about USD 53.14 million/year to the national economy of Bangladesh, and it offers tremendous opportunities for developing ecotourism in terms of tourist attractions, economic benefits, employment, and ecosystem conservation (Alam et al., 2010; Hasan, 2012; Islam, 2008; Siddiqi, 2001). Haque and Aich (2014) studied the economic valuation of the ecosystem services of the SRF in Bangladesh. Applying the Delphi approach, the researchers considered nine support services, seven regulating services, five provisioning services, and three cultural services. Their estimate showed that the total value per hectare of the land of the Sundarban varied from USD105 to USD840 per year. Uddin et al. (2013) estimated the value of cultural services of the Sundarban based on the revenue collected by the Bangladesh Forest Department (BFD) only. According to their study, cultural services (that is

Table 4. Calculation of the tourism values of SRF for different zones.

Name of zones	Zonal travel cost (BDT)	Actual visits in 2018/10000	Potential visitors in 2018/10,000	Choke price* (BDT)	TWTP[1] (million BDT)
Barisal	13,203.4	19.3	42.4	133,787.4	60.3
Chittagong	26,517.8	16.1	135.8	127,014.4	167.9
Dhaka	14,018.4	34.9	227.8	232,247.8	980.8
Khulna	11,699.2	102.0	76.9	648,468.8	2590.5
Rajshahi	3,772.4	27.7	90.1	176,831.7	225.7
Rangpur	8,188.6	16.7	77.2	112,412.9	77.7
Sylhet	162,727.3	5.1	45.9	194,581.6	41.9
Total value	BDT 4,144.7 million (or USD 53.14 million)				
Mean CS	BDT 45000 (or USD 577)				
Value/ha	BDT 81880.3 or USD 1,049.75				

The calculation is based on estimated coefficient of VGF. *Choke price is the travel cost at which demand for visit from each of the zone comes to zero. It is calculated by dividing the intercept coefficient of the visit generating function by its slope coefficients. [1]Total Willingness to pay.
Source: Estimated from the sample data.

Table 5. Estimated value of tourism service of the different tourist spots of the SRF.

Name of the tourist spot (compartment no.)	Area (ha)	Value per year (million USD)
Katka included Jamtala sea beach (7)	5654.9	5.9
Kachikhali (6)	628.3	0.7
Harbaria (26)	2513.3	2.6
Kalagasia (46)	1924.2	2.0
Karamjol (31)	3926.9	4.1
Nilkamal (44)	628.3	0.7
Dubla, Meherali, Alorkol, and Majherchar (45)	35342.9	37.1
Total	50618.9	53.1

tourism) contributed on average USD42,000 per year from Fiscal Year 2001-2002 to 2009-2010. However, the Government of Bangladesh has already developed a travel guideline for the Sundarban mangroves; there is an urgent need to develop policy guidelines for the sustainable development of eco-tourism in the Sundarban. In this study, it is revealed that the higher proportion of visitors are literate and earn more than the average income level in the country based on 2010 Household Survey data (HIES, 2010). Since tourism expenditures have been found to be directly linked with family income (Abbruzzo et al*.,* 2014), household income has a positive impact on recreational behavior (Landry et al., 2012). It has been shown that visitors can afford to and are willing to pay higher rates to enjoy the amenity of the Sundarban. Visitors with higher incomes may be willing to pay more if the recreational quality of a park improves (Sarker et al., 2017). However, the added revenue generated from the forest service can be used to address some of the degradation challenges that the forest is facing (Brander et al., 2012, Brougham and Butler, 1981; Cavus and Tanrisevdi, 2002).

In this study, it is revealed that among the repeat visitors (we asked whether it is their first/second visit), the proportion of both locals and foreigners was very low, and almost half of them wanted to see the improvement (based on a question on what improvement they want to see) in information services such as forest maps, wildlife precautionary signs, danger zones, etc. Unfortunately, the government and private sector organizations have not yet developed well-organized, informative, and educational guides, signs, materials, or websites on the Sundarban tourism for visitors (BIDS, 2010). This is one of the major drawbacks for the growth of tourism in the Sundarban mangroves. Information regarding the natural and cultural significance of the Sundarban mangroves could motivate tourists to become aware of their ecological footprints, garner greater appreciation for the unique ecosystem, and enhance their experience (Budeanu, 2007). Trained tour guides could organize and lead tourists in more efficient ways to enhance their interest for further travel to the Sundarban. In this regard, the government should establish an “Ecotourism Training Centre” at Khulna and the surrounding areas of the Sundarban to ensure better customer service by producing skilled eco-tourism guides and creating employment opportunities in eco-tourism enterprises. The training centre should also provide orientation training to visitors before they enter the forest, regarding laws and regulations with respect to nature, environmental philosophies, biodiversity, conservation issues, etc., of the SRF.

However, this study shows that more than 20% of visitors expressed dissatisfaction towards the overall recreational arrangements in the Sundarban mangroves of Bangladesh. Visitors would like to see improvements in the facilities for watching tigers, deer, and birds, as well as improved walking facilities for going deeper into the forest. In this regard, more than two-thirds of the visitors also agreed to pay higher entry fees if government resources were not available for improving the facilities. Thus, the government of Bangladesh should consider increasing visitor entry fees to improve and enhance the eco-tourism potential of the Sundarban mangroves.

Finally, the BFD should facilitate and engage with landscape communities and stakeholders to develop a participatory community-based ecotourism strategy to ensure long-term local community benefit-sharing and promotion of activities run by local communities. A system should be developed in which increased ecotourism revenues collected by the BFD would be used for the protection and conservation of the Sundarban’s biodiversity, local livelihoods, and overall development. Further, the co-management committees can also be engaged to support the Sundarban’s ecotourism activities, which will ultimately help to achieve the specific UN sustainable development goals (SDGs) 2030.

Conclusion

The unique landscape of the SRF and its position as a tiger habitat make it a singular attraction for tourists. The direct economic contribution of tourism in the Sundarban is the entry fee of visitors charged by the BFD, along with other expenses related to travel, food, and accommodation charged by different service providers. Therefore, cultural services such as ecotourism contribute a significant amount of economic benefit to the national economy of Bangladesh. Moreover, the government must develop a system by which visitor entry fees, collected by the BFD, will be used for the protection and conservation of the SRF and local livelihoods, and for overall aesthetic development. Finally, the BFD should facilitate and engage with landscape communities and stakeholders to develop a participatory community-based ecotourism strategy to ensure long-term local community benefit-sharing and promotion of activities run by local communities. Though this research provides an in-depth visualization of ecotourism potential of the SRF in Bangladesh, which expected further research needs to be carried out in the coming days, especially when its importance will arise as demanded by the forest department.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

This study was carried out under the financial assistance provided by the JDR-Winrock-USAID.

REFERENCES

Abbruzzo A, Brida JG, Scuderi R (2014). Determinants of individual tourist expenditure as a network: empirical findings from Uruguay. Tourism Management 43:36-45.

Alam M, Furukawa Y, Akter S (2010). Forest-based tourism in Bangladesh: status, problems, and prospects. Tourismos 5:163- 172. Available at:https://mpra.ub.uni-muenchen.de/id/eprint/25212

Barbier EB (2007). Valuing ecosystem services as productive inputs. Journal of Economic Policy 22:177-229. Available at: www.jstor.org/stable/4502194. Accessed 5 August 2021.

Bateman IJ, Mace GM, Fezzi C, Atkinson G, Turner K (2011). Economic Analysis for Ecosystem Service Assessments. Environmental and Resource Economics 48:177-218.

BBS (2011). Report of the household income and expenditure survey 2011. Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Government Peoples Republic of Bangladesh.

BBS (2019). Report of the household income and expenditure survey 2019. Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Government Peoples Republic of Bangladesh.

BFD (2012). Bangladesh Forest Department. Available at: http://www.bforest.gov.bd. Accessed 20 October 2020.

BFD (2021). Bangladesh Forest Department. Available at: http://www.bforest.gov.bd. Accessed 24 August 2021.

BIDS (2010). A study of the principal market value chains derived from the Sundarban Reserve Forest. Dhaka: IPAC.

Brander LM, Wagtendonk AJ, Hussain SS, McVittie A, Verburg PH, de Groot RS, van der Ploeg S (2012). Ecosystem service values for mangroves in Southeast Asia: A meta-analysis and value transfer application. Ecosystem Services 1(1):62-69.

Brougham JE, Butler RW (1981). A segmentation analysis of resident attitudes to the social impact of tourism. Annals of Tourism Research 8(4):569-589.

Buckley RC (2009). Ecotourism: principles and practices. CAB International, Wallingford. 368 p.

Budeanu A (2007). Sustainable tourist behaviour – a discussion of opportunities for change. International Journal of Consumer Studies 31:499-508.

Cavus S, Tanrisevdi A (2002). Residents’ attitudes toward tourism: a case study of Kusadasi, Turkey. Tourism Analysis 7(3-4):259-68.

Clawson M (1959). Methods of Measuring the Demand for and Value of Outdoor Recreation. Reprint, No.10, Resources for the Future, Washington DC.

Das S (2013). Travel Cost Method for Environmental Valuation. Centre of Excellence in Environmental Economics. Madras school of Economics. Dissemination paper 23:1-23.

Emiriya M, Robson M, Gombarago ENT (2013). An application of the individual travel cost method to Nyanga National Park, Zimbabwe. Research Journal of Economics 1(1):1-16. Available at:

http://www.researchjournali.com/view.php?id=174. Accessed 23 October 2020.
Giri C, Pengra B, Zhu Z, Singh A, Tieszen LL (2007). Monitoring mangrove forest dynamics of the Sundarban in Bangladesh and India using multi-temporal satellite data from 1973 to 2000. Journal of Estuarine, Coastal and Shelf Science 73(1-2):91-100.
Guha I, Ghosh S (2011) Valuing the land of tigers: what Indian visitors reveal. In: Haque AKE, Murty MN, Shyamsundar P (eds.) Environmental valuation in south Asia. New York: Cambridge University Press pp. 232-255.
Hai MA, Chik AR (2011). Political Stability: Country image for tourism industry in Bangladesh. Proceeding of the International Conference on Social Science, Economics and Art 2011. Hotel Equatorial Bangi-Putrajaya, Malaysia pp. 58-65.
Haque AKE, Aich D (2014). Economic valuation of ecosystem services in Bangladesh Sundarban Delta Vision 2050 – a first step in its formulation (volume 2) edited by Hussain MZ, published by IUCN Bangladesh Country Office, Dhaka.
Hasan A (2012). Package Eco-tour' as special interest tourism product-Bangladesh perspective. Developing Country Studies 2(1):1-9.
Honey M (2008). Ecotourism and Sustainable Development: Who Owns Paradise? Island Press, Washington, DC. 416 p..
Hotelling H (1949). Letter to National Park Service, In: An economic study of the monetary evaluation of recreation in the National Parks. U.S. Department of the Interior, National Park Service and Recreational Planning Division, Washington, DC.
Islam I (2008). Tourism in Bangladesh: challenges and opportunities, Business Column. The Daily Star. Available at: https://www.thedailystar.net/news-detail-39727. Accessed 24 August 2021.
Kathiresan K, Rajendran N (2005). Coastal mangrove forests mitigated tsunami. Journal of Estuarine, Coastal and Shelf Science 65(3):601-606.
King DM, Mazzotta MJ (2000). Contingent Valuation' in Ecosystem Valuation. Available at: http://www.ecosystemvaluation.org/contingent_valuation.htm. Accessed 24 August 2021.
Landry CE, Allen T, Cherry T, Whitehead JC (2012). Wind turbines and coastal recreation demand. Resource and Energy Economics 34(1):93-111.
Laurans Y, Mermet L (2014). Ecosystem services economic valuation, decision-support system or advocacy? Ecosystem Services 7:98-105.
Loomis JB, Hung LT, Gonza ´lez-Caba ´n A (2009). Willingness to pay function for two fuel treatments to reduce wildfire acreage burned: a scope test and comparison of White and Hispanic households. Forest Policy Economics 11(3):155-160.
Nobi MN, Nahar SB (2013). Valuing Foy's lake amusement park and its consumer surplus: an econometrics exercise. The Chittagong University Journal of Social Sciences 31:1-15.
Saraj BS, Yachkaschi A, Oladi D,Teimouri SF (2009). The recreational valuation of a natural forest park using travel cost method in Iran. iForest - Bio geosciences and Forestry 2(3):85-92.
Sarker AHMR, Roskaft E, Suza M, Al-Mamun MMA, Nobi MN (2017). Perceptions of the Quality of Nature-Based Tourism in Sundarban in Local and Foreign Visitors: A Case Study from Karamjal, Mongla. Environment and Natural Resources Research, Canadian Center of Science and Education 7(1):1-10.
Siddiqi NA (2001). Mangrove forestry in Bangladesh. Institute of Forestry and environmental Sciences, University of Chittagong, Chittagong P 201.
Torres-Ortega S, Pérez-Álvarez R, Díaz-Simal P, Luis-Ruiz JM, Piña-García F (2018). 2 Economic Valuation of Cultural Heritage: Application of Travel Cost Method to the National Museum and Research Center of Altamira. Sustainability, MDPI.
Uddin MS, de Ruyter van Steveninck E, Stuip M, Shah MAR (2013). Economic valuation of provisioning and cultural services of a protected mangrove ecosystem: A case study on Sundarbans Reserve Forest, Bangladesh. Ecosystem Services 5:88-93.
Walters BB, Rönnbäck P, Kovacs JM, Croma B, Hussain SA, Badola R, Primavera JH, Barbier E, Dahdouh-Guebas F (2008). Ethno-biology, socio-economic and management of mangrove forests: a review. Aquatic Botany 89:220-236.
Zacarias D, Loyola R (2017). How Ecotourism Affects Human Communities. In: Blumstein D, Geffroy B, Samia D, Bessa E (Eds.) Ecotourism's Promise and Peril. Springer, Cham, pp. 133-151.

Vol. 13(4), pp. 110-116, October-December 2021
DOI: 10.5897/JENE2021.0908
Article Number: F95301767886
ISSN 2006-9847

http://www.academicjournals.org/JENE

ACADEMIC JOURNALS
expand your knowledge

Journal of Ecology and The Natural Environment

Full Length Research Paper

Attacks on humans and retaliatory killing of wild carnivores in the eastern Serengeti Ecosystem, Tanzania

Franco P. Mbise

Department of Biology, College of Natural and Mathematical Sciences, University of Dodoma, P. O. Box 338, Dodoma, Tanzania.

Received 14 July, 2021; Accepted 27 September, 2021

Attacks on humans by wild carnivores are a serious problem, especially where communities and carnivores share the same landscape. When people are injured or killed, community members commonly retaliate by killing the carnivores. Awareness of how to minimize the risk of attacks is important and dependent on an understanding of the circumstances surrounding previous attacks and communicating them back to society. A total of 180 households were randomly selected from both the Maasai and Sonjo tribes. Findings from this study are based on the reported incidences among the Maasai and the Sonjo tribes living in the eastern Serengeti. Because the Maasai tribe lives close to the Serengeti National Park, they reported a higher frequency of human attacks than the Sonjo tribe over the last 50 years. Most of the human attacks occurred in the wet season during the daytime while herding livestock. Young males from both tribes responsible for herding livestock were more vulnerable to attack by wild carnivores. Lions (*Panthera leo*) were responsible for most of the reported human attacks, followed by leopards (*Panthera pardus*) and spotted hyenas (*Crocuta crocuta*). Currently, the trend in human attacks by carnivores is decreasing in both tribes. It was also established that in many incidences, carnivores escaped after attacking humans. Retaliatory killings for lions were most common among the Maasai, while retaliatory killings for hyenas were most common among the Sonjo. Factors associated with these retaliatory killings were as follows: both lions and hyenas feeding on a carcass, lions being fearless of humans, hyenas being frequently seen, and hyena's tendency to run and look back. These findings provide insight into the circumstances surrounding human attacks in the eastern Serengeti and the fate of these carnivores.

Key words: Attacks, injured, humans, killed, retaliatory killing, wild carnivore.

INTRODUCTION

Globally, attack on humans is a shocking phenomenon as it can lead to serious injuries and/or loss of human life (Löe and Røskaft, 2004; Packer et al., 2005; Quigley and Herrero, 2005; Thirgood et al., 2005; Gurung et al., 2008; Nyhus, 2010; Penteriani et al., 2016). Attacks on humans by wild carnivores exacerbate frustrations following

E-mail: francombise@gmail.com.

livestock depredation and may persist for a long time after the event (Löe and Røskaft, 2004; Quigley and Herrero, 2005; Thirgood et al., 2005; Røskaft et al., 2007). Human attacks provoke a strong response and are rarely tolerated by communities, who may call for immediate measures to address the problem animals (Packer et al., 2005; Gurung et al., 2008; Ikanda and Packer, 2008; Penteriani et al., 2016).

Application of different measures that are more applicable and relevant to people on the ground can reduce human attacks incidences (Löe and Røskaft, 2004; Nyhus, 2010), and governments are frequently willing to support such initiatives (Nyhus, 2010; Okello et al., 2014). However, understanding the timing and circumstances surrounding human attacks and/or mortalities will assist in the development of implementable strategies to reduce the likelihood of attacks (Löe and Røskaft, 2004; Packer et al., 2005; Kissui, 2008; Penteriani et al., 2016). Communities living with wild carnivores should be educated on how to reduce human-carnivore encounters and how to behave upon such encounters, especially when sharing the same landscape with these species (Löe and Røskaft, 2004; Woodroffe et al., 2005; Penteriani et al., 2016). According to the Wildlife Conservation Act of Tanzania, it is illegal to kill wildlife unless it is necessary (MNRT, 2013). Therefore, local communities are expected to report any human attack to the wildlife authority as soon as human attack occurs. Responsible authorities can either relocate problem animals to other areas or kill them. While the Tanzanian government has devoted much effort to promote tourism (Turner, 2015), it has failed to solve local problems related to wildlife (Vedeld et al., 2012).

Due to human population growth, development and technological advancements, wild carnivore populations are threatened and have been severely reduced worldwide (Nyhus, 2010). Human population expansion adjacent to African protected areas has led to carnivore habitats being destroyed and decline in prey abundance (Mbise et al., 2020). Here, carnivores encounter humans in anthropogenically modified landscapes, which may lead to human attacks and/or deaths (Löe and Røskaft, 2004; Ikanda and Packer, 2008; Penteriani et al., 2016; Pooley et al., 2017). Consequently, conflict escalates and eventually leads to retaliatory killing of carnivores (Packer et al., 2005; Ikanda and Packer, 2008). Thus, a proper management structure and policy to conserve wild carnivores is urgently needed (Pooley et al., 2017).

Retaliatory killing is a major threat facing wild carnivores worldwide (Treves and Karanth, 2003; Ray et al., 2005; Zimmermann et al., 2005; Ripple et al., 2014) and urgent intervention is needed at local levels (Kissui, 2008). For example, in Kenya, lion populations are declining because lions are frequently killed by local people co-existing with these species (Dickman, 2017). The retaliatory killing of carnivores can be accomplished either directly (e.g., spearing) or indirectly (e.g., poisoning) (Hazzah, 2006). Improving carnivore management is necessary because of their important ecological and economic role (Treves and Karanth, 2003).

In the areas where people and predators share the same landscape (Mbise et al., 2020), it is imperative to understand and assess the circumstances surrounding human attacks and what should be done to reduce human-carnivore encounters (Löe and Røskaft, 2004). Reducing human-attack incidences will foster a better co-existence between people and carnivores, which will ultimately reduce the carnivore's persecution. The study hypothesized the following: (1) More human attacks will occur on Maasai land than on Sonjo land because the Maasai will encounter a higher number of carnivores from Serengeti National Park (SNP). (2) Most human attacks will occur while herding livestock because herders sometimes lead livestock into areas of thick bush and forest seeking green pasture, which predisposes them to attacks. (3) Retaliatory killing of carnivores will be greater in the Sonjo areas than in the Maasai areas because of the more frequent use of poisons in the Sonjo community.

METHODS

Study area

The survey was conducted in the east of Serengeti National Park (SNP), in the Loliondo Game Controlled Area (LGCA) which lies between 1° 40′ S and 2 ° 50′ S and 35° 10′ E and 35° 55′ E (Figure 1). The main residents in the area consist of the Maasai and Sonjo tribes, and the population is increasing rapidly, leading to major habitat deterioration and change (Mbise et al., 2020). The human population in Ngorongoro district was 174,274 in 2012 and was projected to be 199,879 by 2017 (NBS, 2017). An increasing number of people and their associated activities will result in major habitat changes and compromise the future of wildlife species living in the area.

Data collection

Respondents were randomly selected and sometimes were met in the field, village centres or while visiting friends. Thus, mapping the location of each participating household to make a distribution map was not realistic. A total of 180 respondents from the Maasai (n = 90) and Sonjo (n = 90) tribes were interviewed from September to November 2016. People were asked about any reported and/or witnessed human attacks by wild carnivores in the vicinity of the village and how the attack occurred. The criterion to explain how attack occurred enabled to differentiate all reported events and therefore to ensure that each event was independent of one another. It was difficult for many respondents to remember the attack year, so this was excluded from the analyses. Respondents older than 18 years of age were interviewed because they have a broader experience and provide reliable information. The ages of respondents ranged from 20-76 years old. Only eight respondents were older than 68 years of age. Findings were therefore based on human attacks occurring over the past 50 years. The age categories for attacked victims were as follows: children (< 18 years), youth (18–35 years), adults (36–49), or elders (> 50 years).

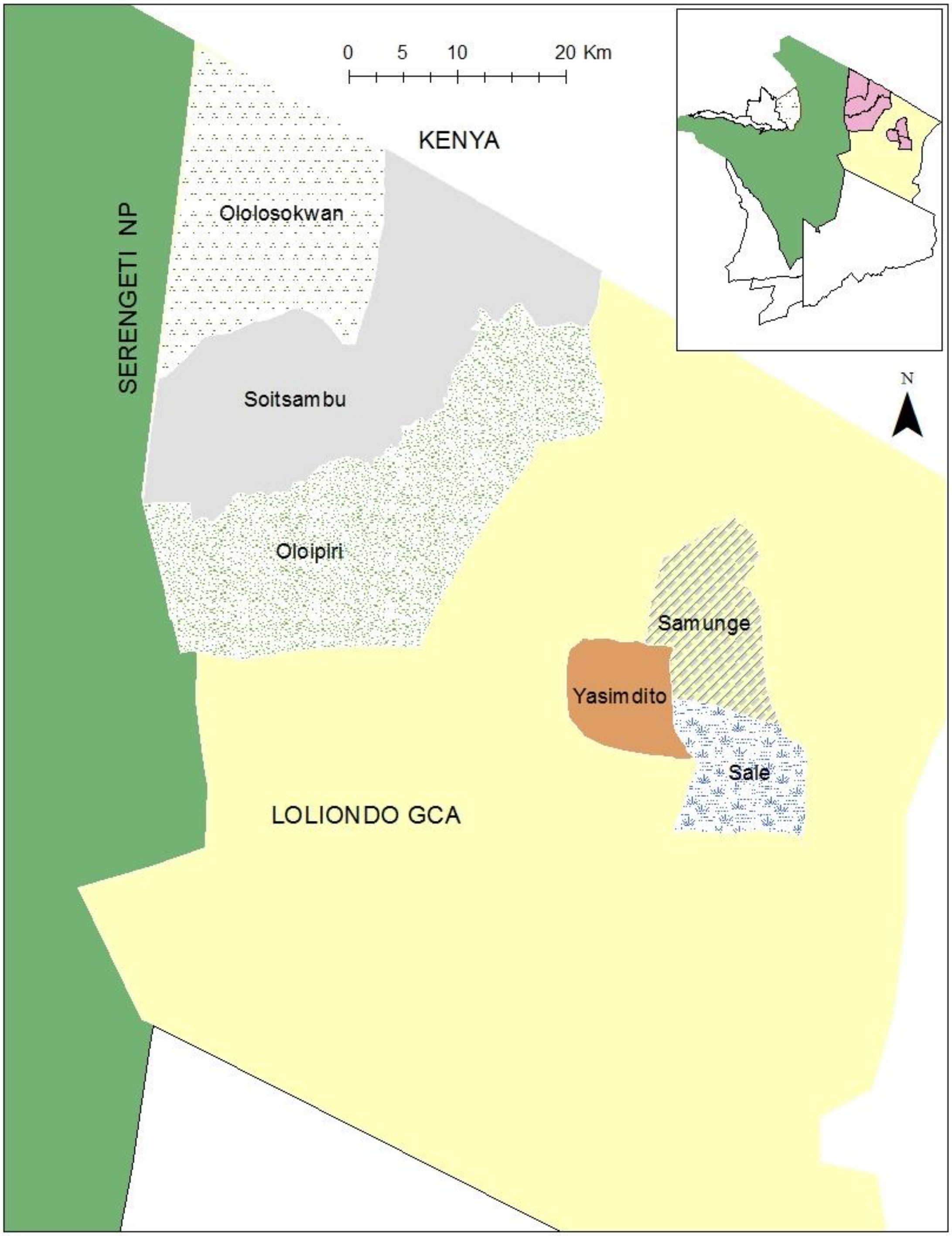

Figure 1. Map showing the villages included in this study in the eastern Serengeti ecosystem. Upper right; the green area is the Serengeti National Park and the pink area is the study area.

From each village, 30 respondents were interviewed. Therefore, in total we had 144 males and 36 females. The interview was administered in 6 villages, three from the Maasai tribe (Ololosokwan, Oloipiri, and Soitsambu) and three from the Sonjo tribe (Yasimdito, Samunge and Sale). Swahili, Maasai and Sonjo languages were used during interview, therefore, local translators were engaged to assist with the interview when vernacular languages were used.

The survey had open-ended and closed-ended questions for comparison purposes and for acquiring more details that were not captured by specific questions. Information obtained from respondents was based on age category (youth, adult, elder), gender (male, female), tribe (Maasai, Sonjo), and education level (never been to school, primary school, secondary school). The key

Table 1. Numbers of attacks on humans in relation to the attack time, the activity that the victim was involved in, and the season.

Tribe	Attack time {No. (%)}		Activity {No. (%)}		Season {No. (%)}	
	Day	Night	Herding livestock	Other activities	Dry	Wet
Maasai	66(93)	5(7)	54(76.1)	17(23.9)	15(21.1)	56(78.9)
Sonjo	20(87)	3(13)	20(87)	3(13)	6(26.1)	17(73.9)

*Other activities such as fetching water and searching for firewood and/or medicine

Table 2. Human attacks according to gender, age group and type of attack.

Tribe	Gender {No. (%)}		Age group {No. (%)}			Type of attack {No. (%)}	
	Male	Female	Children	Youth	Adult	No-fatal	Fatal
Maasai	64(90.1)	7(9.9)	0(0)	58(82.9)	12(17.1)	59(83.1)	12(16.9)
Sonjo	21(91.3)	2(8.7)	2(8.3)	14(58.3)	8(33.4)	20(87)	3(13)

questions were as follows: do you know anyone in this village who has been attacked (injured, killed) by wild carnivores? (yes, no), his/her age group? (child, youth, adult, elder), time of human attack? (day, night), where attack occurred? (home, pasture), what was the person doing? (herding livestock; other activities such as fetching water and searching for firewood and/or medicinal plants), human attack season? (wet, dry), carnivore species responsible for human attacks? (lion, leopard, hyena), carnivore's fate after the attack? (escaped or killed), and human attack and/or killing trend? (decreasing, stable or increasing). Furthermore, respondents were asked questions on factors associated with retaliatory killing and reasons behind the killing.

Data analysis

Chi-squared and logistic regression analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 24 (IBM, 2016). Chi-squared tests were used to determine significant differences between the Maasai and the Sonjo tribes. Logistic regression analysis was used to determine the predictor variable explaining the variation in incidences of human attack. The test was performed to assess the variation in the reported human-attacks in the two areas, with one dependent variable being the response (yes, no) and five independent variables (attack time, tribe, victim activity, attack season, and where attack occurred) being used. The variable "where attack occurred" refers to human attacks events occurring in the pasture or around home.

RESULTS

Carnivore attacks on humans

Attacks on humans occurred more frequently during the day than at night in both tribes, but the differences between the two tribes were not statistically significant (Pearson χ^2 = 0.804, df = 1, p = 0.370; Table 1). Furthermore, carnivores attacked humans in the Maasai tribal area significantly more than in the Sonjo tribal area (Pearson χ^2 = 51.301, df = 1, p < 0.0001). Most human attacks occurred while people were herding livestock rather than while performing other activities, and most of these human attacks occurred during the wet season, with no significant difference between the two tribes (activity; Pearson χ^2 = 1.232, df = 1, p = 0.267; season; Pearson χ^2 = 0.246, df = 1, p = 0.620; Table 1).

More males were attacked than females, and the number of attacked individuals in the Maasai tribal area did not differ significantly from those in the Sonjo tribal area (Pearson χ^2 = 0.027, df = 1, p = 0.87; Table 2). More youths than children or adults were attacked by wild carnivores, and the attack rates of different age groups differed between the two areas (Pearson χ^2 = 6.63, df = 2, p = 0.036; Table 2). More people were injured when attacked by wild carnivores than killed, and these frequencies differed significantly between the two areas (Pearson χ^2 = 51.44, df = 1, p < 0.0001; Table 2).

Almost all variables (attack time; B = 8.499, Wald χ^2 = 9.260, df = 1, p = 0.002; tribe, B = -14.971, Wald χ^2 = 8.933, df = 1, p = 0.003; victim activity; B = 3.232, Wald χ^2 = 7.712, df = 1, p = 0.005) were significant in explaining the variation on human attack incidences. Attack season was almost statistically significant (B = -5.579, Wald χ^2 = 3.638, df = 1, p = 0.056). Finally, the variable "where attack occurred" was not statistically significant in explaining the variation in human-attack incidences.

Wild carnivores

Overall, lions (*Panthera leo*) caused most of the human attacks, followed by leopards (*Panthera pardus*) and spotted hyenas (*Crocuta crocuta*). However, leopard attacks were more common in the Sonjo tribe than in the Maasai tribe (Table 3). The attack rates by the three wild carnivores (lions, leopards, hyenas) differed significantly

Table 3. Attack trends and predators responsible for human attacks in the Maasai and Sonjo tribes.

Tribe	Responsible carnivore {No. (%)}			Attack trend {No. (%)}		
	Lion	Leopard	Spotted hyena	Increasing	Stable	Decreasing
Maasai	55(77.5)	9(12.7)	7(9.8)	11(15.5)	12(16.9)	48(67.6)
Sonjo	2(8.7)	17(73.9)	4(17.4)	0(0)	0(0)	23(100)

Table 4. Retaliatory killing and reasons behind the killing.

Tribe	Killing responses -lion {No. (%)}		Killing responses- spotted hyena {No. (%)}		Reason for killing-lion {No. (%)}		Reasons for killing-spotted hyena {No. (%)}		
	Yes	No	Yes	No	Feeding on carcass	Fearless	Seen frequently	Run and look back	Feeding on carcass
Maasai	33(36.7)	57(63.3)	33(36.7)	57(63.3)	3(9.1)	30(90.9)	15(45.5)	10(30.3)	8(24.2)
Sonjo	3(3.3)	87(96.7)	50(55.6)	40(44.4)	1(25)	2(75)	15(30)	5(10)	30(60)

*Fearless – never run when they see humans.

between the two tribes (Pearson χ^2 = 11.04, df = 2, p = 0.004; Table 3).

The attack rates by lions and leopards differed significantly between the two tribes (p < 0.0001), while the attack rates by hyenas did not differ significantly between the two tribes (p = 0.3173; Table 3). Although both tribes claimed that the attack rates are decreasing, a significantly higher frequency of Maasai claimed that they were stable or increasing (Pearson χ^2 = 9.86, df = 2, p = 0.007; Table 3).

Retaliatory killing of wild carnivores

Most of those carnivores reported to attack and/or kill humans escaped afterwards; however, the difference was not statistically significant between the two tribes (Pearson χ^2 = 0.36, df = 1, p = 0.55). In both the Maasai and the Sonjo tribes, perception of respondents seemed not to be very eager to kill carnivores once they threatened and/or killed humans in their area, although the number of “yes” responses between the two tribes differed significantly (Pearson χ^2 = 24.33, df = 3, p < 0.0001; Table 4). Retaliatory killing of lions was most common among the Maasai, while retaliatory killing of hyenas was most common among the Sonjo (Table 4) (lions Pearson χ^2 = 31.25, df = 1, p < 0.0001, hyenas Pearson χ^2 = 6.46, df = 1, p = 0.01). Factors associated with these retaliatory killings were as follows: both lions and hyenas feeding on a carcass, lions being fearless of humans, hyenas being frequently seen, hyena’s tendency to run and look back.

The reason for killing hyenas was significantly different between the two tribes (Pearson χ^2 = 11.4, df = 2, p = 0.003; Table 4), while for lions, the difference in reasons was not significant (Pearson χ^2 = 1.64, df = 1, p = 0.201; Table 4).

DISCUSSION

This study reveals incidences of human attacks that have never been reported in the eastern Serengeti and provides insights into how such attacks occur and the characteristics of these attacks, including the time, season, people prone to these attacks, and the fate of these carnivores after attacking humans. Proximity to the park (Maasai) showed a higher rate of human attack than living further away (Sonjo) due to a higher number of carnivores coming from Serengeti National Park. Understanding the circumstances surrounding human attacks will provide insight into how to reduce such attacks. Awareness of how to reduce human-carnivore encounters and how to behave when such encounters occur will help the communities co-existing with carnivores avoid attacks that lead to serious injuries or death. Lions, leopards, and spotted hyenas were the main predators responsible for human attacks. Most of these attacks occurred in the wet season during the daytime while people were herding their livestock as opposed to doing other activities. Herding livestock is the responsibility of young males according to these tribes’ order of duties, and young males were in fact more susceptible to these attacks, as they sometimes pass through the risky habitats preferred by predators when searching for green pasture.

Carnivore attacks on humans

As found by Packer et al. (2005), human attacks occurred most frequently on males in both tribes because men are likely to do more outdoor activities, are more eager to kill carnivores and walk at night. More human attacks occurred in the Maasai community than in the Sonjo community most likely because the Maasai live closer to the Serengeti, which has a higher number of carnivores. Once human attacks occur, it is common for villagers to kill the responsible carnivore. In this study, those carnivores were normally lions, leopards and hyenas. There is a long history of wild carnivores attacking humans (Thirgood et al., 2005; Inskip and Zimmermann, 2009), and when such occur, they receive great attention and bring fear to the community (Røskaft et al., 2003; Thirgood et al., 2005; Nyhus, 2010). Attacks on humans typically occur in landscapes where humans and carnivores interact. As a result, promoting coexistence between humans and carnivores is the best approach to solving this problem; otherwise extinction will be the likely fate for many carnivore species around the world (Brantingham, 1998; Woodroffe et al., 2005; Nyhus, 2010).

Young people are responsible for herding livestock far from their home and sometimes look after livestock in risky areas (bushes and forests), which increases the risk of attack by wild carnivores. Once a herder notices the presence of a carnivore while herding livestock, they defend their livestock and/or try to scare away the carnivores. This behaviour further increases the chance of being attacked. Most of the attacks occurred during the wet season perhaps because the grasses are taller, making it harder to detect carnivores. In most incidences, carnivores tended to escape after attacking people. In the Loliondo Game Controlled Area, where human and livestock population is increasing at higher rates, the number of wild carnivores has declined in recent years (Mbise et al., 2018, 2020). As a result, the reported number of human attacks in the Maasai and the Sonjo communities has decreased compared to that in earlier years.

Responsible wild carnivores and retaliatory killings

Lions, leopards, and hyenas were the only carnivore species reported to cause human attacks. Predators attacking humans is a rare phenomenon, and the reasons behind most of these attacks may be due to a depleted prey base, an inability to hunt, old age, or behaviour learned from their parents (Packer et al., 2005; Ikanda, 2009; Nyhus, 2010). For instance, in a recent lion attack that occurred in 2016 at Ololosokwan village, one of the respondents claimed that the lion who attacked him in the pasture while he was looking for a lost sheep was an old male. However, it was the stealthy behaviour of leopards that was responsible for more human attacks in the Sonjo tribe compared to lions and hyenas. Additionally, on Sonjo land, forests are common and represent ideal leopard habitat.

Spotted hyenas were at higher risk of being poisoned following an attack on people. Kissui (2008) found the same for communities living around Tarangire National Park, Tanzania. Lion killings were also common because they do not fear people and appear during the day time (Kissui, 2008). This motivates locals to smear poison on carcasses, which ultimately kills lions and hyenas. The higher frequencies of retaliatory killing in the Sonjo tribe may contribute to a higher rate of carnivore decline in this area. The Maasai tribe, on the other hand, has a long history of coexistence with carnivores compared to the Sonjo tribe, although currently, their culture has started changing dramatically, which may threaten local carnivore populations. The Sonjo tribe, more frequently preferred the use of arrows coated with a poison sap from the bark of the Mroda tree *(Acokanthera* spp*.)* (Anonymous, 2016). To protect wild carnivore populations, there is an urgent need to find mechanisms for coexistence between local communities and carnivores (Mbise and Røskaft, 2021; Rasmussen, 1999). Illegal killing of carnivores can be either direct or indirect. For instance, leopards commonly suspend their kill on a tree, and locals take advantage of this by sneaking towards the carrion and putting poison on it, thus indirectly killing it. Using dogs to chase and directly kill leopards is sometimes risky because leopards habitually climb trees and can attack when approached.

Efforts against the use of lethal control have so far been successful due to the ecological and economic benefits of wild carnivores (Treves and Karanth, 2003). However, there remains a great need to assess lethal methods that communities use to kill carnivores. Some killing techniques have serious effects on the carnivore population and the food web in general (Masenga et al., 2013; RCP, 2018). For instance, poisoning may target a specific carnivore species but result in the death of other untargeted animals such as vultures and other birds of prey (RCP, 2018). In conclusion, the two hypotheses out of three are supported by the study findings. Most reported human attacks occurred in the Maasai tribal area, and these attacks were more frequent while people were herding livestock than while doing other daily activities. However, retaliatory killings were most common in the Sonjo tribal area. The study recommends more effort to promote coexistence between carnivores and humans in this area, and zoning would be one of the alternatives to separate human activities from the preferred habitat of wild carnivores. Based on past incidences, more awareness of avoiding these human attacks should particularly be encouraged in herders.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

REFERENCES

Brantingham PJ (1998). Hominid–carnivore coevolution and invasion of the predatory guild. Anthropological Archaeology 17(4):327-353.
Dickman A (2017). The biggest threat to African lions isn't trophy

hunters, it's their lack of value to local people.*in* L. Butterfield, editor. Lion populations are at a tipping point. Oxford University, London.

Gurung B, Smith JLD, McDougal C, Karki JB, Barlow A (2008). Factors associated with human-killing tigers in Chitwan National Park, Nepal. Biological Conservation 141(12):3069-3078. doi:10.1016/j.biocon.2008.09.013

Hazzah L (2006). Living among lions *(Panthera leo)*: Coexistence or killing? Community attitudes towards conservation initiatives and the motivations behind lion killing in Kenyan Maasailand. Master thesis in Conservation and sustainable development. Unpublished. University of Wisconsin-Madison pp. 1-110.

IBM (2016). IBM SPSS Statistics for Windows, Version 24.0. IBM Corp, Armonk, NY, USA.

Ikanda D (2009). Dimensions of a human-lion conflict: the ecology of human predation and persecution of African lions *Panthera leo* in Tanzania. Doctoral thesis at the Norwegian University of Science and Technology, Trondheim, Norway.

Ikanda D, Packer C (2008). Ritual vs. retaliatory killing of African lions in the Ngorongoro Conservation Area, Tanzania. Endangered Species Research 6(1):67-74. doi:10.3354/esr00120

Inskip C, Zimmermann A (2009). Human-felid conflict: a review of patterns and priorities worldwide. Oryx 43(1):18-34. doi:10.1017/S003060530899030X

Kissui BM (2008). Livestock predation by lions, leopards, spotted hyenas, and their vulnerability to retaliatory killing in the Maasai steppe, Tanzania. Animal Conservation 11:422-432. doi:10.1111/j.1469-1795.2008.00199.x

Löe J, Røskaft E (2004). Large Carnivores and Human Safety. A Review. AMBIO 33(6):283-288.

Masenga EH, Lyamuya RD, Nyaki A, Kuya S, Jaco A, Kohi E, Mjingo EE, Fyumagwa RD, Røskaft E (2013). Strychnine poisoning in African wild dogs (*Lycaon pictus*) in Loliondo Game Controlled Area, Tanzania. International Journal of Biodiversity and Conservation 5(6):367-370. doi:10.5897/IJBC12.100

Mbise FP, Røskaft E (2021). Can conservation incentives promote willingness to coexist with large carnivores in the eastern Serengeti ecosystem? International Journal of Biodiversity and Conservation 13(3):77-85. https://doi.org/10.5897/IJBC2021.1490

Mbise FP, Jackson CR, Lyamuya R, Fyumagwa R, Ranke PS, Røskaft E (2020). Do carnivore surveys match reports of carnivore presence by pastoralists? A case of the eastern Serengeti ecosystem. Global Ecology and Conservation 24:e01324. https://doi.org/10.1016/j.gecco.2020.e01324

Mbise FP, Skjærvø GR, Lyamuya RD, Fyumagwa RD, Jackson C, Holmern T, Røskaft E (2018). Livestock depredation by wild carnivores in the Eastern Serengeti Ecosystem, Tanzania. International Journal of Biodiversity and Conservation 10(3):122-130. https://doi.org/10.5897/IJBC2017.1165

Ministry of Natural Resources and Tourism (MNRT) (2013). The Wildlife Conservation Act (Principal Legislation). Ministry of Natural Resources and Tourism, Tanzania.

National Bureau of Statistics (NBS) (2017). Human Population trend by the National Bureau of Statistics. Dar es Salaam, Tanzania. Retrieved from: https://www.nbs.go.tz/.

Nyhus PJ, Ronald T, Nyhus PJ, Dufraine CE, Ambrogi MC, Hart SE, Carroll C, Tilson R (2010). *Panthera tigris vs Homo sapiens:* Conflict, Coexistence, or Extinction. pp. 125-141 *in* P. J. N. a. R. Tilson, editor. Tigers of the World : The Science, Politics and Conservation of *Panthera tigris*. Elsevier Burlington.

Okello MM, Kiringe JW, Warinwa F (2014). Human-Carnivore Conflicts in Private Conservancy Lands of Elerai and Oltiyiani in Amboseli Area, Kenya. Natural Resources 5:375-391. doi:org/10.4236/nr.2014.58036

Packer C, Ikanda D, Kissui B, Kushnir H (2005). Lion attacks on humans in Tanzania. Nature 436(7053):927-928.. doi:10.1038/436791a

Penteriani V, Delgado MdM, Pinchera F, Naves J, Fernández-Gil A, Kojola I, Härkönen S, Norberg H, Frank J, Fedriani JM, Sahlén V, Støen OG, Swenson JE, Wabakken P, Pellegrini M, Herrero S, López-Bao JV (2016). Human behaviour can trigger large carnivore attacks in developed countries. Scientific Reports 6:20552. doi:10.1038/srep20552

Pooley S, Barua M, Beinart W, Dickman A, Holmes G, Lorimer J, Loveridge AJ, Macdonald DW, Marvin G, Redpath S, Sillero-Zubiri C, Zimmermann A, Milner-Gulland EJ (2017). An interdisciplinary review of current and future approaches to improving human predator relations. Conservation Biology 31:513-523. doi:10.1111/cobi.12859

Quigley H, Herrero S (2005). Characterization and prevention of attacks on humans. Pages 27-48 *in* R. Woodroffe, S. Thirgood, and A. Rabinowitz, editors. People and Wildlife: Conflict or Coexistence? Cambridge University Press, New York.

Rasmussen GSA (1999). Livestock predation by the painted hunting dog Lycaon pictus in a cattle ranching region of Zimbabwe: a case study. Biological Conservation 88(1):133-139. doi:10.1016/S0006-3207(98)00006-8

Ray J, Hunter L, Zigouris J (2005). Setting Conservation and Research Priorities for Larger African Carnivores. New York Wildlife Conservation Society 216 p.

Ruaha Carnivore Project, RCP (2018). Ruaha Carnivore Project: Deadly and depressing lions retaliation by pastoralists. Retrieved from: https://www.ruahacarnivoreproject.com/.

Ripple WJ, Estes JA, Beschta RL, Wilmers CC, Ritchie EG, Hebblewhite M, Berger J, Elmhagen B, Letnic M, Nelson MP, Schmitz OJ, Smith DW, Wallach AD, Wirsing AJ (2014). Status and ecological effects of the world's largest carnivores. Science 343 p. doi:10.1126/science.1241484

Røskaft E, Händel B, Bjerke T, Kaltenborn BP (2007). Human Attitudes Towards Large Carnivores in Norway. Wildlife Biology 13:172-185. doi:10.2981/0909-6396(2007)13[172:HATLCI]2.0.CO;2

Røskaft E, Bjerke T, Kaltenborn B, Linnell JDC, Andersen R (2003). Patterns of self-reported fear towards large carnivores among the Norwegian public. Evolution and Human Behavior 24(3):184-198. doi:10.1016/S1090-5138(03)00011-4

Thirgood S, Woodroffe R, Rabinowitz A (2005). The impact of human-wildlife conflict on human lives and livelihoods. Pages 13-26 *in* R. Woodroffe, S. Thirgood, and A. Rabinowitz, editors. People and Wildlife: Conflict or Coexistence? Cambridge University Press, New York.

Treves A, Karanth KU (2003). Human-Carnivore Conflict and Perspectives on Carnivore Management Worldwide. Conservation Biology 17(6):1491-1499. doi:10.1111/j.1523-1739.2003.00059.x

Turner R (2015). Travel and Tourism economic impact 2015 Tanzania. Pages 16-24. Harlequin Building, 65 South Street, London: Retrieved from; https://www.wttc.org.

Vedeld P, Jumane A, Wapalila G, Songorwa A (2012). Protected areas, poverty and conflicts: A livelihood case study of Mikumi National Park, Tanzania. Forest Policy and Economics 21:20-31. doi:10.1016/j.forpol.2012.01.008

Woodroffe R, Thirgood S, Rabinowitz A (2005). People and Wildlife: Conflict or Coexistence? Cambridge University Press, New York.

Zimmermann A, Walpole MJ, Leader-Williams N (2005). Cattle ranchers' attitudes to conflicts with jaguar Panthera onca in the Pantanal of Brazil. Oryx 39(4):406-412. doi:10.1017/s0030605305000992.

Vol. 13(4), pp. 117-124, October-December 2021
DOI: 10.5897/JENE2021.0906
Article Number: A53215868413
ISSN 2006-9847

http://www.academicjournals.org/JENE

ACADEMIC JOURNALS
expand your knowledge

Journal of Ecology and The Natural Environment

Full Length Research Paper

Structural characterization of over-exploited forest species: Case of *Garcinia kola* Heckel (Clusiaceae) in Côte d'Ivoire

Any Olivier Komenan*, Kouamé Kévin Koffi, Moussa Koné, Kouakou Laurent Kouakou, Kouakou Guy-Casimir Douffi and Irié Arsène Zoro Bi

Environment and Sustainable Development, Nangui Abrogoua University, Abidjan, UFR-Science of Nature (SN), Côte d'Ivoire.

Received 21 June, 2021; Accepted 14 December, 2021

The purpose of this study is to define the structural characteristics and spatial distribution of endangered *Garcinia kola* in Côte d'Ivoire, in order to ensure sustainable management of the species. The study was conducted in two natural growth zones (Affery and Biankouma) of the species and involved 94 trees with a minimum diameter of 10 cm measured at 1.30 m from the ground. The data collection method consisted of a mobile inventory within 100 m × 100 m plots. The study revealed that *G. kola* has an aggregated distribution. Both stands are dominated by medium class trees, [30-40 cm], [40-50 cm], [50-60 cm]. Modeling of all trees in each stand, divided into diameter classes according to the Weibull distribution, shows that *G. kola* has a low regeneration potential, with a shape parameter c = 2.41 and 1.74. In addition, basal area and tree density are very low. Sustainable management of this species therefore requires awareness of its domestication.

Key words: *Garcinia kola*, structural characterization, sustainable management, spatial distribution.

INTRODUCTION

Côte d'Ivoire lost nearly 84% of its forest cover between 1960 and 2000 (Koné et al., 2014). Anthropogenic activities (extensive agriculture, gold panning and uncontrolled exploitation of fuelwood and timber) due to rapid population growth are the main causes (MEDD, 2016). However, many plant species have become extinct or rarefied, mainly during the last century (Djaha and Gnahoua, 2014), among which is *Garcinia kola* Heckel (Clusiaceae). *G. kola* is one of the forest species of socio-economic interest much appreciated by local populations (Kouamé et al., 2016). About this species, all parts (from the top to the root) are used by man. Indeed, seeds are sought for their stimulating effects, aphrodisiacs, bad cholesterol cleaners and liver protectors (Iwu et al., 1999) Seeds are also used in drugs to treat multiple gastrointestinal and pulmonary conditions (Guedje and Fankap, 2001; Ebomoyi and Okojie, 2012). Thus *G. kola* is used as a remedy for the treatment of

*Corresponding author. E-mail: olivierkomenan@gmail.com.

diseases such as diarrhoea, laryngitis, gonorrhoea, headaches and gastritis: *G. kola* bark is also used as a purgative (Ajebesone and Aina, 2004). The pulp is also consumed. The supply of minerals, vitamins and amino acids contained in these fruits makes them complementary foods, sometimes essential, during the lean season for local forest populations. In addition, the plant has a market value inside and outside of Côte d'Ivoire (Koffi et al., 2015). The economic value of the seeds fluctuates from two to six USD per kilogram (Kouamé et al., 2016).

Yet, excessive demands for *G. kola*, are leading to depletion of the resource. This species is on the IUCN Red List of Threatened Species, as vulnerable (Cheek, 2004). To overcome this problem, it is essential to establish a good conservation strategy for this species. Indeed, to reach this goal a good description of its structure, the distribution of individual stem characteristics is necessary (Rabhi et al., 2016). However, scientific information on spatial distribution and the structuring of *G. kola* in Côte d'Ivoire still remains fragmentary. This information is very important because it allows the identification of potential areas where the species is abundant and thus guides the selection of areas where particular conservation measures for the species can be undertaken (Kebenzikato et al., 2014). It is why we are specifically studying, on one hand, the structure, as well as the analysis of dendrometric parameters, on the other hand, the spatial distribution of *G. kola* in two agro-ecological localities of Côte d'Ivoire. This approach will allow us to know the current conservation or disturbance status of the species and to consider better sustainable management strategies.

METHODOLOGY

Study sites

The study was carried out in two agro-ecological areas of Côte d'Ivoire for three years, from 2015 to 2018. One is in the west (Biankouma) and the other in the south (Affery). Figure 1 shows the geographical location of the study area. The choice of these areas was made after several prospecting studies with wholesale and field merchants. The surveys revealed that most of their supply of "petit kola" grains originated in these two areas. Biankouma is a department in the west of Côte d'Ivoire and is part of the Tonpki region, characterized by mountainous relief, ferralitic and hydromorphic soils. This locality is located at 635 km from Abidjan between 7˚44'00" North and 7˚37'00" West. During the year the temperature generally varies from 17 to 33°C with an average of 24°C. The rainfall varies between 1300 and 2400 mm per year and the vegetation consists mainly of humid forest.

Affery, the second study area, is located in the south of Côte d'Ivoire in the department of Adzopé, 101 km from Abidjan between 6°18'54'' North and 3°57'37'' West. Affery is located in a humid tropical climate zone. This climate gives it a relatively constant temperature which oscillates around 27.5°C with four seasons of uneven lengths. The annual rainfall is 1300 mm on average. The town of Affery is characterised by the presence of many hills whose average altitude does not exceed 100 m. They are separated by long valleys that look like precipices from which several marigots and rivers sometimes leave. The vegetation is dominated by tropical rainforest.

Sampling and data collection

The data collection method consisted of a mobile inventory (Rabiou et al., 2015; Ouattara et al., 2016) within 100 m × 100 m plots (Habou et al., 2014). This method was used given the low apparent density of *G. kola* in the natural formations studied. It not only accounts for the structural heterogeneity of the stands but also allows for the enumeration of sufficient individuals to obtain a reliable estimate of density and demographic structure (Goba et al., 2019). Distances traveled were estimated using a GPS. A total of 300 plots were installed at each study site. In each plot, dendrometric measurements involved all georeferenced *G. kola* individuals with a diameter equal to or greater than 10 cm at a height of 1.30 m from the ground (dbh > 10 cm). The circumference of the trees was measured with a tape measure. This measurement was used to determine the diameter of each tree.

Data analysis

Analysis of the spatial structure of G. kola

Garcinia kola trees being slightly scattered, we used ArcGIS software to calculate the distances between the trees. The distances were calculated using the T-Square Sampling Procedure, described by Besag and Gleaves (1973). The method consisted of randomly selecting a number of points within the study area, each point is where *G. kola* were found. For each random point, two measurements were taken: the first measurement is the distance from the random position (x) to the nearest individual (y); the second measurement is the distance between (y) and its nearest neighbor (z) provided that the angle formed by xyz is greater than 90° (Figure 2). On the basis of the data from the T-square method, it was possible to test the hypothesis of a random distribution according to the formula implemented by Hines and Hines (1979):

$$H_T = \frac{2n(2\Sigma(xi)2+\Sigma(zi)^2}{\{(\sqrt{2}\,\Sigma(xi)+\Sigma(zi))\}^2} \quad (1)$$

where H_T= Hines statistical test to check if the data is random, n= sample size (number of random points), Xi= distance between random point and nearest individual, Zi= distance between the individual closest to the random point and its nearest neighbor, H_T =1.27, the distribution is random, H_T < 1.27, the distribution is uniform, and H_T > 1.27, the distribution is aggregated.

Dendrometric structure of G. kola

Trees distribution by diameter classes: The inventoried trees were grouped into diameter classes to produce a histogram of diameter structures. These classes were distributed as follows: 10-20, 20-30, 30-40, 40-50, 50-60, 60-70 and 70-80 cm. The histogram was used to display the structure of the population (Glèlè et al., 2016). Thus, for the trees of each locality (Affery or Biankouma), the diameter structure has been established Student's t-test for independent samples were used to compare the means of the different dendrometric parameters of *G. kola* in the different study area. There is a significant difference between sites at the 5% significance level. Three Weibull distribution parameters were used to represent the theoretical structure of woody stands. This distribution is based on the probability density function defined by Rondeux (1999) and is

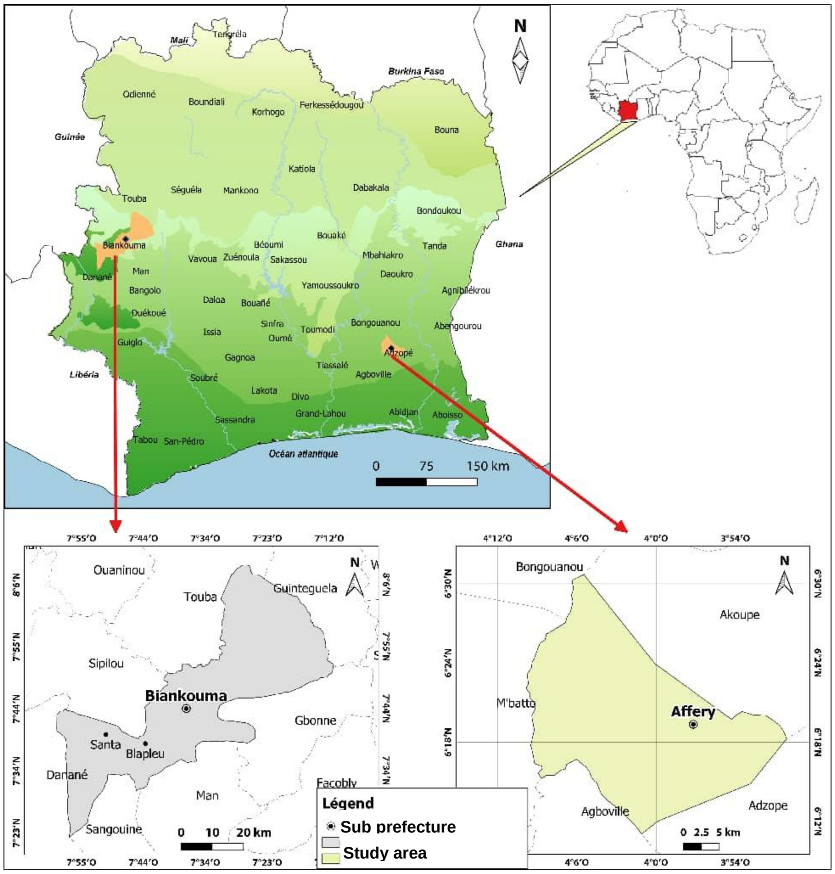

Figure 1. Location of study sites in Côte d'Ivoire, (A): location of Côte d'Ivoire in West Africa (B): location of Biankouma and Affery (C): location of surveyed sites.

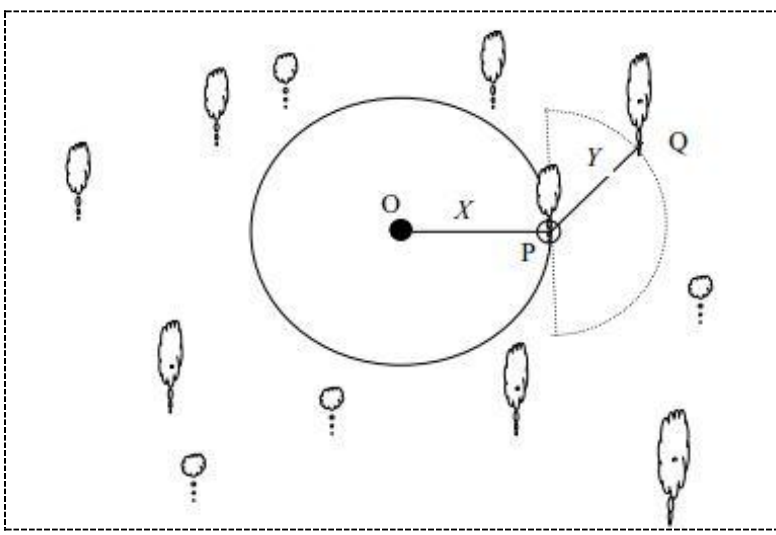

Figure 2. T-Square sampling procedure. From a random tree "O" in the study area, the distance Xi to the nearest individual "P" is measured. Distance *Xi* to the nearest individual P is measured. A second distance *Zi* from P is measured to individual "Q" closest to P, with the constraint that the angle OPQ > 90° (T-Square distance). The procedure is repeated for a series of *n* random points.
Source: Masumbuko et al. (2008).

Table 1. Interpretation of the Weibull distribution as a function of the value of the shape parameter « c ».

Value of parameter « c »	Interpretation
c < 1	The distribution is J-reversed, characteristic of multispecies stands with high regeneration potential
c = 1	The distribution is described as exponentially decreasing. This structure is characteristic of populations with a high potential for regeneration, but with a problem of survival during the transition between stages of development
1 < c < 3,6	The distribution is skewed positive or skewed right. This structure is characteristic of populations with low regeneration potential due to exogenous actions especially in small diameter classes
c = 3,6	The distribution is symmetrical; normal structure, characteristic of species populations with low regeneration potential due to exogenous actions or characteristics of the species
c > 3,6	The distribution is skewed negative or skewed left. This structure is characteristic of monospecific stands with a predominance of older, large- diameter individuals

Source: Glèlè et al. (2016).

presented under the function:

$$f(x) = \frac{c}{b}\left[\frac{(x-a)}{b}\right]^{c-1} exp^{\left[-\left(\frac{(x-a)}{b}\right)^{c}\right]} \quad (2)$$

where : x = diameter of the trees, f (x) = probability density value at point x; a = position parameter (in this study a = 10 cm for diameter) (Glèlè et al., 2016); b = scale; it is related to the central value of the diameters of the trees in the stand under consideration; c = shape parameter related to the considered diameter structure.

The structure of the groupings has been adjusted to the Weibull model because of its great flexibility and ease of interpretation (Bonou et al., 2009). This Weibull distribution can take several forms depending on the value of the shape parameter "*c"* (Table 1) related to the diameter structure (Kebenzikato et al., 2014). All analyses were performed with the software XLSTAT Ecology software version 2014.5.03.

To verify the significance of the adjustment, between the observed frequency of a diameter class considered and the theoretical frequency expected according to the Weibull function (Agresti, 2010), a log-linear analysis was performed (Caswell, 2001).

Basal area: The basal area was calculated by summing the land area of all trees in each sub-sampling unit defined within a plot. This value is usually expressed in m²/ha. The basal area calculated for 1 ha allowed an approximate extrapolation for all sites explored. Thus, an average basal area was determined for each study site. It is calculated by the following relationship:

$$G_{1,30} = D^2 \text{x} \frac{\pi}{4} \quad (3)$$

where $G_{1.30}$ is the basal area at 1.30 m from the ground and D is the diameter of a tree.

RESULTS

Spatial distribution by T-square sampling method

The Hines and Hines test applied, gives a H_T value equal to 3.37 to Affery and 2.49 at Biankouma (Table 2). Those values are higher than 1.27. Comparison of these values with the critical values listed in the Hines and Hines table reveals that there is a significant difference with the random distribution at α = 0.05. Therefore, the natural population of *G. kola* shows an aggregated distribution in Affery and Biankouma.

G. kola diameter class structure and Weibull distribution fit

Measurement of the diameter at 1.30 m from the ground of all the *G. kola* individuals sampled permitted their distribution into diameter classes. Figure 3 shows the results for each stand.

The majority (27.6%) of the trees in Affery were between 40 and 50 cm in diameter. Trees with a diameter between 30 and 40 cm are 25.2% while 12.2% have a diameter between 20 and 30 cm. The diameter classes [50-60 cm] and [60-70 cm] express, respectively 21.9 and 8.1% of the individuals. All these individuals belong to the middle stratum. Next, 1.7% of the individuals have a diameter between 10 and 20 cm and are considered to belong to the shrub stratum. Finally, the upper stratum is represented by the individuals with a diameter of more than 70 cm and concerns 3.3% of the trees surveyed.

Table 2. Parameters calculated for T-Square sampling in both stands.

Statistical parameter	Population	
	Affery (n =37)	**Biankouma (n =37)**
Surface area (km^2)	33.08	30.79
Σ (xi)	4166.11	4034.28
Σ (xi)^2	1313832.56	1250306.03
Σ (zi)	3281.32	4445.87
Σ (zi)^2	1210746.81	1514006.87
Hines and Hines test	3.37*	2.49*

n: number of random positions in the study area; H_T: statistical test of Hines and Hines; xi = distance between the random point and the nearest individual; zi = distance between the individual closest to the random point and its closest neighbor; * = $p<0{,}05$.

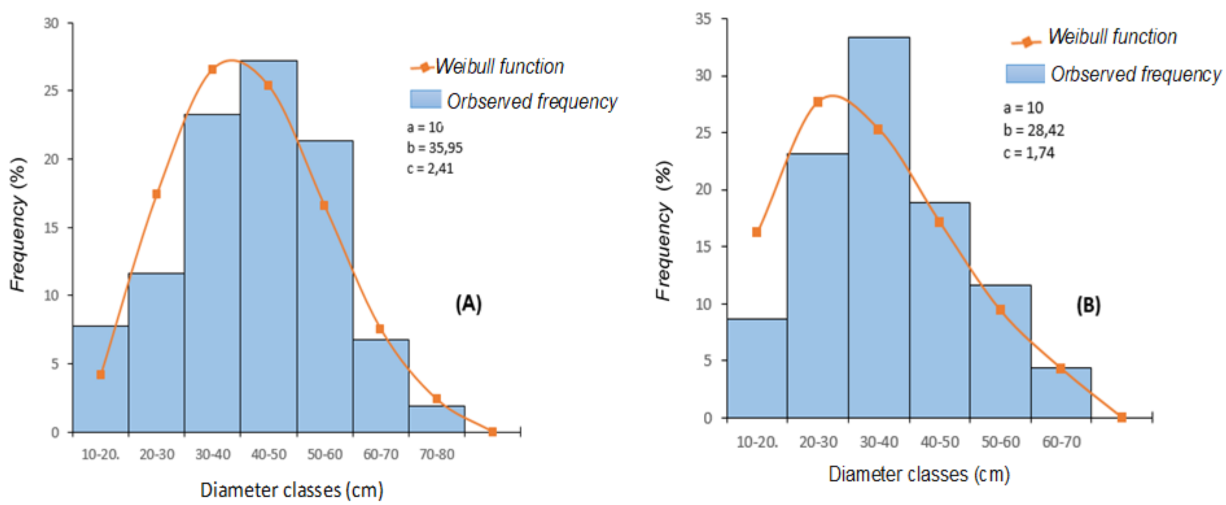

Figure 3. Tree diameter class structures of *Garcinia kola* with Weibull distribution adjustment (A) Affery and (B) Biankouma.

In Biankouma locality, the majority of trees (33.3%) have a diameter between 30 and 40 cm, while 23.18% of trees have a diameter between 20 and 30 cm. All these trees belong to the middle stratum, which is the most represented. The upper stratum is not represented because there are no individuals with a diameter greater than 70 cm. Between 10 and 20 cm in diameter there are 8.7% of trees.

The fit of the theoretical Weibull distribution to the observed diameter class distributions in the two stands is as shown in Figure 3. The two populations, (A) Affery and (B) Biankouma have a structure with a shape parameter c between 1 and 3.6 ($1 < c < 3.6$). This shape parameter is 2.4 for the *G. kola* population in Affery and 1.74 for the Biankouma population. These distributions are said to be asymmetric positive or straight asymmetric. Trees of average diameter classes are the most represented. The log-linear analysis performed shows a good fit of the Weibull distribution with the data of the observed distribution for diameter structures (p>0.05) at the 5% threshold.

Dendrometric characteristics of the two stands

The results of the analysis of variance on the dendrometric characteristics of the two *Garcinia kola* stands show significant differences (P<0.05) in mean diameter and basal area (Table 3). The comparative analysis of dendrometric characteristics shows that basal area and mean diameter are higher in the Affery population compared to the Biankouma population. The mean diameter and basal area of trees in Affery are 43.16 cm and 0.0048 m^2/ha, respectively, while in Biankouma they are 36.17 cm and 0.0026 m^2/ha. However, tree densities in the two populations are relatively close with less than 1 tree/ha. There is no significant difference (P>0.05) in tree density in the two populations. In Affery it is 0.0246 trees/ha while it is 0.0368 trees/ha in Biankouma.

DISCUSSION

The study of the spatial structure of *G. kola* within the two

Table 3. Dendrometric parameters of *Garcinia kola* in Affery and Biankouma stands.

Population	Average diameter (cm)	Basal area (m^2/ha)	Density (tree/ha)
Affery	43.16	0.0048	0.0026
Biankouma	36.17	0.0246	0.0368
Probability (*P*)	0.001**	0.005**	0,809

Values followed by "**" are significantly different at the 5% cut-off (student t-test for independent samples); V=Coefficient of variation.

agro-ecological zones (Affery and Biankouma), revealed an aggregated distribution of trees. There are many possible explanations for the aggregated distribution in *G. kola*. Indeed, the aggregated spatial distributions of some tree species can be interpreted as reflecting variations in environmental characteristics (Dajoz, 2003; Silvertown, 2004). The habitats of the two agro-ecological zones (Affery and Biankouma) constitute favorable environments for the development of *G. kola*. They are wetlands with an average temperature of 30°C. According to Ntamag (1997), a relative humidity of 76.34% with temperatures between 21 and 32°C is favorable for the development of *G. kola*. In India, a study on *G. indica* reveals that precipitation and temperature are the main factors that favor the distribution of this species (Palkar et al., 2020).

Moreover, the distribution of the species is done according to the environmental conditions (Thammanu et al., 2021). Thus, the species would aggregate where environmental conditions are favorable for their development. The same would be true for *G. kola*. Furthermore, aggregation appears to be a consequence of the short distance at which seeds are dispersed (Hubbell, 2001). These observations for this species were confirmed by Dike and Aguguom (2010) in a forest reserve in Nigeria. The work of these authors revealed that the maximum distance of seed dispersal of *G. kola* is 8.42 m. Indeed, the limitation of dispersion results in an aggregated geographical distribution (Condit et al., 2000) often observable for tropical trees species (Seidler and Plotkin 2006). In addition, a study by Mcconkey et al. (2015), showed that 'small animals' often consume *Garcinia benthamii* fruits, but their ability to disperse seeds has not been evaluated. In contrast, elephants and gibbons are the main dispersal agents of *G. benthamii* seeds. In the present study, the presence of elephants was not reported, but informal exchanges with landowners confirmed the presence of monkeys in the sampled habitats.

However, the aggregated distribution could result from the scale of observation. Indeed, the spatial extent or scale could influence the observation of the spatial distribution of the species as small or large (Goreaud, 2000; Dungan et al., 2002). Komenan et al. (2019) obtained an aggregated distribution of *G. kola* using the Clark and Evans method. However, this method is sensitive to the effect of extent (Kumba et al., 2013), confirmation of the aggregated distribution was made using the T-square sampling procedure.

The study of the diameter structure reveals that trees belonging to the middle stratum dominate in both stands. Modelling of all the trees in each population, divided into diameter classes according to Weibull's law, shows a positive asymmetric or right asymmetric distribution. According to Husch et al. (2003), this distribution is characteristic of populations with low regeneration potential due to exogenous actions especially in small diameter classes. There is thus a problem of recruitment of young individuals in the classes of older individuals (Glèlè et al., 2016). This cannot be interpreted as a good conservation status of *G. kola* stands in its different habitats. Indeed, *G. kola* is subject to anthropogenic pressure, which compromises the viability of the species (Neuenschwander et al., 2011; Goné Bi et al., 2013). This pressure is linked to the fact that *G. kola* is multipurpose. The organs (seeds, roots, bark, branches and wood) are mainly used in pharmacopoeia and food (Guedje and Fankap, 2001).

The low or non-existent regeneration rate of *G. kola* in the wild may also be due to the seed's very hard pericarp, which delays germination (Agyili et al., 2007; Yakubu et al., 2014). The poor regeneration would also be due to the non-contact of the fruits with the soil and the failure to bury the seeds of the species in the soil to facilitate germination. The fruits fall and remain above the dead leaves and eventually rot. Dossa et al. (2019) found similar reasons for compromising natural regeneration in *Detarium senegalense* (Fabaceae) in dense forests. For this reason, there is reportedly a low rate of young individuals in both populations of *G. kola*, which justifies the low density of the species in these populations. This low density of all the trees confirms the precariousness and decline of *G. kola* populations in the areas under consideration and especially in its area of occurrence.

The average diameter and basal area of trees are higher in Affery than in Biankouma. There are several reasons explaining this difference. According to our study, individuals in the upper stratum with a diameter greater than 70 cm are represented in the Affery population, whereas none exist in the Biankouma population. In addition, trees in the Affery population are more in agrosystems and would benefit from protection and maintenance by field owners. However, in the

Biankouma locality, this species would be subject to greater human pressure.

Conclusion

The study of the spatial structure within the two populations showed that *G. kola* is a gregarious species. The structural characterization of two populations of *G. kola* in Côte d'Ivoire showed, on the one hand, a structure in diameter class dominated by trees in the middle stratum and, on the other hand, that the density of this species is very low. Therefore, the safeguarding of the rare individuals of this species is important to ensure their sustainable management. A study on the morphological variability of *G. kola* would help to achieve this objective.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

The authors express their sincere gratitude to the farmers and local administrators of the study area for their assistance during the field work.

REFERENCES

Agresti A (2010). Analysis of Ordinal Categorical Data. 2nd edition. New York, USA, Wiley 424 p.

Agyili J, Sacande M, Koffi E, Peprah T (2007). Improving the collection and germination of West African Garcinia kola Heckel seeds. New Forests 34(3):269-279.

Ajebesone PE, Aina JO (2004). Potential African Substances for Hops in Tropical Beer Brewing. The Journal of Food Technology in Africa 9(1):13-16.

Besag J, Gleaves JT (1973). On the detection of spatial pattern in plant communities. Bulletin of the International Statistical Institute 45:153-158.

Bonou W, Glèlè KR, Assogbadjo AE, Sinsin B (2009). Characterisation of Afzelia africana Sm. habitat in the Lama forest reserve of Benin. Forest Ecology Management 258(7):1084-1092.

Caswell H (2001). Matrix population models: construction, analysis, and interpretation, 2nd edn. Sinauer Associates, Sunderland, Massachusetts 722 p.

Cheek M (2004). *Garcinia Kola*. The IUCN Red List of Threatened Species. Available at: http://dx.doi.org/10.2305/IUCN.UK.2004.RLTS.T34715A9884648.en

Condit R, Hubbel SP, Baker P, Bunyavejchewin S, Gunatilleke N, Foster RD, Itoh A, Lafrankie JV, Lee HS, Losos E, Manokatan N, Sukumar RQ, Yamakura T (2000). Spatial patterns in the distribution of tropical tree species. Science 288(5470):1414-1418.

Dajoz R (2003). Précis d'écologie. Dunod, Paris 615 p.

Dike MC, Aguguom AC (2010). Fruits, seeds weights, flight patterns and dispersal distances of some nigerian rainforest tree species. ARPN Journal of Agricultural and Biological Science 5(3):56-64.

Djaha AJB, Gnahoua GM (2014). Contribution à l'inventaire et à la domestication des espèces alimentaires sauvages de Côte d'Ivoire. Journal of Applied Biosciences 78:6620-6629.

Dossa BAK, Gouwakinnou GN, Sourou BN, Houetchegnon T, Wedjangnon AA, Odjrado, BK, Ouinsavi C (2019). Caractérisation structurale des peuplements naturels de Detarium senegalense J.F. Gmel. (Caesalpiniaceae) au Bénin, Afrique de l'Ouest. Revue. Ramres 7:15-23.

Dungan JL, Perry JN, Dale MRT, Legendre P, Citron-Pousty S, Fortin MJ, Jakomulska A, Miriti M, Rosenberg MS (2002). A balanced view of scale in spatial statistical analysis. Ecography 25(5):626-640.

Ebomoyi MI, Okojie AK (2012). Physiological Mechanisms Underlying the Use of *Garcinia kola* Heckel in the Treatment of Asthma. African Journal of Respiratory Medicine 8(1):1-8.

Glèlè KR, Bonou W, Lykke AM (2016). Approche méthodologique de construction et d'interprétation des structures en diamètre des arbres. Annales des Sciences Agronomiques 20 _ Spécial Projet Undesert-UE: pp. 99-112.

Goné Bi ZB, Kouamé D, Koné I, Adou YCY (2013). Diversité végétale et valeur de conservation pour la Biodiversité du Parc National du Mont Péko, Côte d'Ivoire. Journal of Applied Biosciences 71:5753-5762.

Goreaud F (2000). Apports de l'analyse de la structure spatiale en forêt tempérée à l'étude et la modélisation des peuplements complexes. Thèse de doctorat en Sciences Forestières 362 p.

Guedje NM, Fankap R (2001). Utilisations traditionnelles de *Garcinia lucida* et *Garcinia kola* (Clusiaceae) au Cameroun. Plant Systematics and Phytogeography 71:747-758.

Habou R, Maârouhi I, Bakasso Y, Abdoulaye D, Moussa MB, Mahamane A, Saïdou IS, Mahamane S, Lykke AM (2014). Structure de la population de *Boscia senegalensis* (Pers) Lam. Ex Poir suivant la toposéquense dans la commune de Simiri (Niger). Journal of Animal and Plant Sciences 23:3657-3669.

Hines WGS, Hines RJ (1979). The Eberhardt statistic and the detection on nonrandomness of spatial point distributions. Biometrica 66(1):73-79.

Hubbell SP (2001). The unified neutral theory of biodiversity and biogeography. Princeton University Press 392 p.

Husch B, Beers T, Kershaw JJR (2003). Forest Mensuration. John Wiley and Sons, Inc., New York 443 p.

Iwu MM, Duncan AR, Okunji CO (1999). New Antimicrobials of Plant Origin. In: Janick, J., Ed., Perspectives on New Crops and New Uses , ASHS Press alexandria, VA. pp. 457-462.

Kebenzikato AB, Wala K, Dourma M, Atakpama W, Dimobe K, Pereki H, Batawila K, Akpagana K (2014). Distribution et structure des parcs à *Adansonia digitata* L. (baobab) au Togo (Afrique de l'Ouest). Afrique Science 10(2):434-449.

Koffi KE, N'guessan AK, Kouamé CN, Kouassi MK, Kahia JW (2015). Possibility of using the intermediate mature stage of Garcinia kola Heckel seeds to shorten the germination time. African Journal of Agricultural Research 10(52):4762-4769.

Komenan AO, Koffi KK, Gbotto AA, Kone M, Akaffou DS, Kouakou KL, Kouassi KI Zoro, BIA (2019). Morphological Diversity and Distribution of *Garcinia kola* Heckel (Clusiaceae) in Two Agro-Ecological Areas of Côte d'Ivoire. American Journal of Plant Sciences 10(10):1871-1887.

Koné M, Kouadio YL, Neuba DFR, Malan DF, Coulibaly L (2014). Évolution de la couverture forestière de la Côte d'Ivoire des années 1960 au début du 21e siècle. International Journal of Innovation and Applied Studies 7(2):782-794.

Kouamé NMT, Aké CB, Mangara A, N'guessan K (2016). Analyse de l'intérêt socio- économique des graines de Garcinia kola Heckel (Clusiaceae) dans la commune de Koumassi (Abidjan), côte d'ivoire. International Journal of Biological and Chemical sciences 10(6):2587-2595.

Kumba S, Nshimba H, Ndjele L, De Cannière C, Visser M, Bogaert J (2013). Structure spatiale des trois espèces les plus abondantes dans la Réserve Forestière de la Yoko, Ubundu, République Démocratique du Congo. Tropicultura 31(1):53-61.

Masumbuko NC, Mangambu MJD, Nyakabwa MDS (2008). Distribution spatiale de Syzygium guineense (willd.) dc (myrtaceae) dans le parc national de Kahuzi-Biega (secteur de nyamuhambazatshivanga) en zone de haute altitude, à l'est de la République Démocratique du Congo. Cahiers du CERUKI 36(1):59-63.

Mcconkey K, Brockelman W, Saralamba C, Nathalang A (2015). Effectiveness of primate seed dispersers for an "oversized" fruit, *Garcinia benthamii*. Ecology 96(10):2737-2747.

Ministère de l'Environnement et du Développement Durable (MEDD)

(2016). Plan d'investissement forestier de Côte d'Ivoire. Draft final. Abidjan, Côte d'Ivoire, Ministère de l'Environnement et du Développement durable 85 p.

Neuenschwander P, Sinsin B, Georgen G (2011). Protection de la nature en Afrique de l'Ouest: une liste rouge pour le Benin [Nature Conservation in West Africa: Red list for Benin]. Ibadan, Nigeria: International Institute of Tropical Agriculture 365 p.

Ntamag CN (1997). Spatial distribution of non-timber forest production collection: a case study of south Cameroon. Wageningen, Pays-Bas, Agricultural University (Department of Forestry) 65 p.

Palkar RS, Janarthanam MK, Sellappan K (2020). Prediction of Potential Distribution and Climatic Factors Influencing Garcinia indica in the Western Ghats of India Using Ecological Niche Modeling. National Academy Science Letters 43(6):585-591.

Rabhi K, Messaoudene M, Fortin M, Collet C (2016). Modélisation de la structure en diamètre des reboisements et des peuplements naturels de Cèdre de l'Atlas (Cedrus atlantica Manetti) du Djurdjura (Algérie). Revue Forestière Française 68(1):43-52.

Rabiou H, Diouf A, Bationo BA, Segla KN, Adjonou K, Kokutse AD (2015). Structure des peuplements naturels de *Pterocarpus erinaceus* Poir. dans le domaine soudanien, au Niger et au Burkina Faso. Bois et Forêts des Tropiques 325(3):71-83.

Rondeux J (1999). La mesure des arbres et des peuplements forestiers. Gembloux, Belgique : Les presses agronomiques de Gembloux 522 p.

Seidler TG, Plotkin JB (2006). Seed dispersal and spatial pattern in tropical trees. PLoS Biology 4(11):2132-2137.

Silvertown J (2004). Plant coexistence and the niche. Trends in Ecology and Evolution 19(11):605-611.

Thammanu S, Marod D, Han H, Bhusal N, Asanok L, Keetdee P, Gaewsingha, Lee S, Chung J (2021). The influence of environmental factors on species composition and distribution in a community forest in Northern Thailand. Journal of Forestry Research 32:649-662.

Yakubu FB, Bolanle OJ, Ogunade OJ, Yahaya DK (2014). Effects of water soaking and light on the dormancy of *Garcinia kola* (Heckel) seeds. European Journal of Agriculture and Forestry Research 2(2):17-26.

Related Journals: