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Full Length Research Paper

Floristic assessment of semi evergreen forests of a peripheral site in Hadagarh Sanctuary, Odisha, India

Ashis K. Dash, V. P. Upadhyay* and H. K. Patra

Department of Botany (Environmental Sciences), Faculty of Science, Utkal University, Bhubaneswar-751015, India.

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Phytosociological study was carried out in the outer periphery region of Hadagarh Wildlife Sanctuary, Odisha, India. An attempt has been made to find out the characteristics of the vegetation community of the forests of the sanctuary. Analysis of the vegetation was done following the standard ecological methods widely adopted for such studies (quadrat method). A total of 68 plant species from 30 families were documented comprising of 14 species of tree, 42 species of shrubs and saplings and 12 species of herbs and seedlings. This study provides a baseline data for all such future studies as no previous ecological assessment about the forest vegetation of the sanctuary is available. In terms of Importance Value Index (IVI), *Azadirachta indica* with IVI value of 61.45 among trees was found most dominant followed by *Shroea robusta* (46) and *Schleichera oleosa* (37). Similarly most common plant species amongst shrubs and herbs were *Ageratum conyzoides* L. (IVI-40.08) and *Mimosa pudica* L. (IVI-45.67). The sanctuary has been under various anthropogenic pressures resulting in depletion of the vegetation. Near absence of saplings and seedlings of dominant forest trees is a matter of concern in the peripheral region of the sanctuary. The study revealed that, a suitable long term management intervention to step up regeneration of population in this area will go a long way in improving overall ecological and aesthetic value of the forests of the sanctuary area.

Key words: Importance Value Index (IVI), Santhal tribe, natural vegetation, traditional knowledge, strict enforcement.

INTRODUCTION

The concept of Sustainable development has received worldwide acceptance. Sustainable planning of ecologically important regions could not be taken up due to lack of sufficient data on structure and functioning of ecosystem. Hadagarh Wildlife Sanctuary is one such area containing diverse floral and wildlife composition but does not have much information about its phytosociological composition. The floristic composition and phytosociological attributes are useful for comparing one community with the other from season to season and from year to year under certain environmental stress factors (Singh and Weigand, 1994). Large number of animals and plants inhabit the earth in a variety of habitats and ecosystems (Wilson, 1992). Odisha is one of the richest biodiversity regions in Southeast Asia. Saxena and Brahmam (1996) reported 2,727 species of plants under 228 families and 1062 genera of which 2561 species are indigenous and 166 species are cultivated.

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

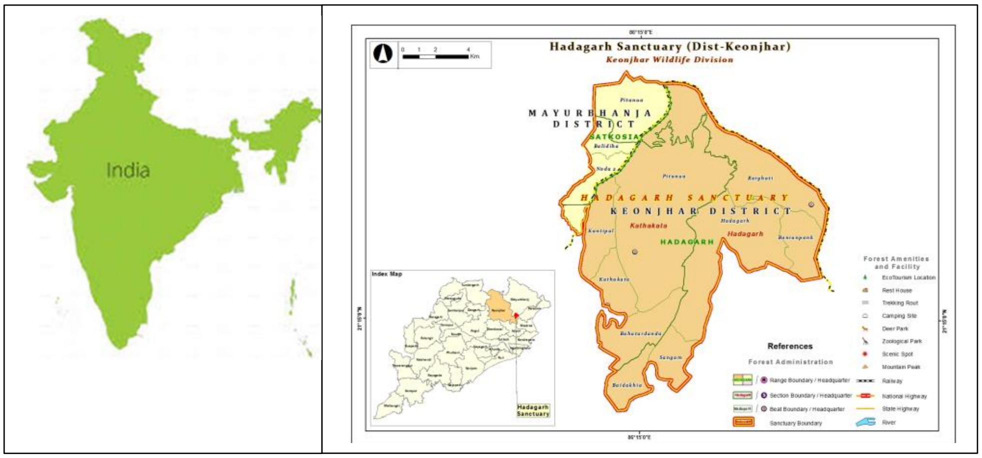

Figure 1. Odisha Wildlife Organisation (2020).

There is such a vast repositories of animals and plants found across the planet with a distinct biological co-relationship maintained and sustained by various adaptations vis a vis changing environment, inter dependence among the different life forms, sustained productivity and food chain/web relationships, nutrient cycling and energy flow etc. Phytosociology reveals the organization and structure of plant diversity which helps in determination of the distribution pattern of individuals among the species in a particular habitat therefore such analysis is important for understanding the functioning of any community (Warger and Morrel, 1976). Phytosociological status of Kuldiha Wildlife Sanctuary Odisha, India reveals that there is a big gap between the values of various structural parameters and tree species having very low values of IVI deserve more attention (Rout et al, 2018). Another study on Similipal Biosphere Reserve (SBR) listed 266 species of angiospermic plants represented under 72 families. Out of 266 plant species 115, 37, 103 and 11 are trees, shrubs, herbs and climbers distributed under 42, 22, 34 and 8 families, respectively (Mishra et al, 2008). Presence of high species richness and diversity, mean stand density and species rarity indicates the uniqueness and potentiality of SBR for conservation of ecosystem in its totality (Reddy et al., 2007). Forests in the peninsular India are decreasing at a fast rate, though the data on structure and functional dynamics of these forests (Parthasarathy and Sethi, 1997) are scarce. A few studies in Eastern Ghats of Tamil Nadu (Kadavul and Parthasarathy, 1999a, b; Chittiibabu and Parthasarathy, 2000; Natarajan et al., 2004) have been conducted reflecting the floristic composition of forests in the area. More studies in tropical forests are (Tripathi and Singh 2009; Hegde et al., 2011, Bajpai et al., 2012; Dangwal et al., 2012; Sahu et al., 2012; Verma et al., 2013; Sangma and Lyngdoh, 2014; Ahmed and Sharma 2014; Pradhan and Rahman, 2015; Knight, 2015; Sundarapandian and Subbiah 2015; Shahid and Joshi, 2016; Bajpai et al., 2017; Masens et al., 2017; Shiferaw et al., 2018). Sahu et al. (2010a) and Bhadra and Pattanayak (2016, 2017, 2019) have also studied tree Species Population Dynamics in the Tropical Dry Deciduous Forest of Gandhamardan Hills, Eastern Ghats, Western Odisha. Behura et al. (2016) highlighted the ecological significance of native species which are effective ecological tools towards conserving the biodiversity and enhancing the ecological services in a restored habitat. From various studies, it is seen that phytosociological characteristics of Western Ghats have been carried out over a period of time on the forest vegetation of the area whereas a few data are available about the forests of Eastern Ghats, particularly about Odisha. The phytosociological studies conducted in other parts of Odisha are by Sahu et al. (2007), Ekka and Behera, (2011), Behura et al. (2015) and Nayak et al. (2016) etc. Odisha accounts for about 45% of the forest area in the Eastern Ghats. Therefore, the present study was aimed at documenting the status of the present vegetation structure of Hadagarh Wildlife Sanctuary through a detailed phytosociological analysis of the forest ecosystem involving parameters like relative density, abundance, relative frequency, relative basal area and Important Value Index, which will be helpful to plan for a better management intervention to enhance the quality of forest ecosystem.

MATERIALS AND METHODS

Study area

The Hadagarh Wildlife Sanctuary spreads across the districts of Keonjhar and Mayurbhanj in the state of Odisha, covering an area of 191.06 Sq Kms (Longitude 86°10' to 86°22' E Latitude 21°23' to 21° 12 'N) which was notified vide Government notification dated 06.12.1978 (Figure 1) (Odisha Wildlife Organization, 2020. www. wildlife. odisha. gov.in). This area, therefore came under the status of a 'protected area' under the provisions of the Government from

Figure 2. A view of study area.

the date of its notification.

It lies in the catchment of Salandi River, one of the major tributaries of river Baitarani and is close to the Hadgarh Reservoir of Salandi dam. This region is rich in mixed deciduous forests and provides ideal habitat to variety of wildlife. The Baula area of sanctuary consists of two hills on either sides of the river and spreads across Satkosia RF of Mayurbhanj and Baula RF of Keonjhar district. The valley comprises of Hadagarh reservoir and its catchments. There are 16 villages, largely dependent on the ecological resources of the sanctuary. The demography of the area reveals dominance of backward classes and tribes like Santhals and Hos. Their regular day to day needs like firewood, grazing of domestic animals, timbers, medicinal plants etc are fulfilled from the resources available within the forests. Villagers' residing near the boundary allow cattle into the sanctuary, which is a common feature in the area. The relative humidity generally remains above 60%, maximum temperature 35°C during April-May and 6 degree Celsius during November –January of the year. Average rainfall ranges from 1718 mm to 2369 mm with 86 rainy days in a year. Cyclone with wind is frequently observed during September to December of the year (Management Plan of Hadagarh Sanctuary, 2011-2012 to 2020-2021).The study area comes under the district Kendujhar, Odisha. The District of Keonjhar is very often visited by calamities like droughts, floods, cyclone and other natural calamities. (District Disaster Management and Response Plan, Keonjhar, 2016).The forest type of this area has been categorised as Dry Peninsular Sal Forests and Northern dry mixed deciduous forests (Champion and Seth, 1968) (Figure 2). The sanctuary comes under Biogeographic classification of Deccan peninsula sub-division of Chotanagpur plateau. Sandy loam is the prominent soil type and Quartzite, Quartz, Schists, Laterite are the main rocks found in the area. (Management Plan of Hadagarh Sanctuary, 2011-2012 to 2020-2021).

Vegetation study

The sampling of vegetation was done for trees and shrubs only once for one year during summer (March –May) and for herbaceous vegetation and seedlings three times in a year i.e. for summer (March-May), winter (December-January) and rainy season (July-September). Similar observation continued for the 2nd year also. The data thus obtained were used for analysis of all structural vegetation parameters for phytosociological analysis.

Random sampling plots were identified for the study. The quadrat size was taken 10 x 10 m for trees, 5 x 5 m for shrubs and 1 × 1 m for herbs and seedlings. All the plants were classified into following three categories taking into account their girth class i.e. circumference at breast height (cbh) (i) Herbs and Seedlings (0-10 cm cbh) (ii) Shrubs and Saplings (10-30 cm cbh) and(iii)Trees - more than 30 cm cbh and a total of 20 quadrats were sampled for each strata of vegetation. The size and number of quadrats, collection of data from the quadrats were based on standard ecological methods of Misra (1968) and Kershaw (1973). Analysis was done for arriving at phyto-sociological parameters following the Philips (1959) and Curtis (1959) to compute density, basal area (BA), frequency, relative density (RD), abundance, relative frequency (RF), relative basal area (RBA) and Important Value Index (IVI).IVI was determined as the sum of the relative frequency, relative density and relative dominance for tree layer. The following formulae were used for calculation:

$$\text{Frequency} = \frac{\text{Number of quadrats in which species occur}}{\text{Total number quadrats under study}} \times 100$$

$$\text{Relative Frequency} = \frac{\text{Number of occurrences of a species}}{\text{Total number occurrences of all species}} \times 100$$

$$\text{Density} = \frac{\text{Total number of individuals}}{\text{Total number of quadrats under study}}$$

Table 1. Species, density, basal area, frequency, distribution pattern and Importance Value Index (IVI) of Tree species of a peripheral site of Hadagarh Sanctuary.

Name of Species	Local name	Denisity/ha	BA m^2/ha	Freq (%)	Abundance	RD	RF	RBA	IVI
Azadirachta indica A Juss.,Mem	*Neemba*	105	0.348	50	2.1	30.435	26.316	4.708	61.459
Shorea robusta Gaertn.f.Fruct	*Sal*	75	0.261	40	1.875	21.739	21.053	3.537	46.329
Schleichera oleosa (Lour.)Oken	Kusum	5	2.407	5	1	1.449	2.632	32.595	36.675
Tamarindus indica L.Sp.Pi	*Tentuli*	20	1.932	5	4	5.797	2.632	26.161	34.590
Naringi crenulata(Roxb.)M.Roem.	*Benta*	10	0.115	10	1	2.899	5.263	23.919	32.081
Lannea corromandelica(Houtt)	Jia	40	0.188	20	2	11.594	10.526	2.541	24.661
Strychnos nux-vomica (L.)	*Kuchila*	20	0.072	15	1.333	5.797	7.895	0.980	14.672
Eucalyptus tereticornis Sm.Spec	*Nilgiri*	20	0.304	5	4	5.797	2.632	4.118	12.547
Protium serratum(Wall.exColebr)	Rimili	10	0.013	10	1	2.899	5.263	0.182	8.344
Cassia fistula L.Sp.Pl	*Sunari*	10	0.001	10	1	2.899	5.263	0.007	8.168
Diospyros malabarica(Desr.)Kostel	*Kali Kendu*	10	0.017	5	2	2.899	2.632	0.235	5.765
Cycas circinalis L.var.orixensis	*Katha Bheru*	10	0.001	5	2	2.899	2.632	0.007	5.537
Acacia nilotica L.	*Babul*	5	0.054	5	1	1.449	2.632	0.737	4.818
Catunaregam spinosa(Thunb.)Tirveng.	*Kalei Kanta*	5	0.020	5	1	1.449	2.632	0.273	4.354

Total Indi.-Total number of individuals, BA-Basal Area, Freq-Frequency, RD-Relative Density, RF-Relative Frequency, RBA-Relative Basal Area, IVI-Important Value Index.

$$\text{Relative Density (RD)} = \frac{\text{Number of Individuals of the species}}{\text{Number of individuals of all species}} \times 100$$

$$\text{Abundance} = \frac{\text{Total number of individuals of the species}}{\text{Total number of quadrats of occurrence}} \times 100$$

Relative Abundance (RA) = Relative Frequency + Relative Density

$$\text{Relative Basal Area (RBA)} = \frac{\text{Total basal area of the species}}{\text{Total basal area of all the species}} \times 100$$

Finally, the Importance Value Index was calculated on the basis of the following formula Importance Value Index (IVI) = Relative Frequency + Relative Density+ Relative Dominance. Specimen were identified with the help of Working Plan (WP,2008,2017) of Keonjhar forest division, Flora of Orissa (Saxena and Brahmam,1994-1996), Botany of Bihar and Orissa(Haines,1921-1925) and herbarium of Botany department, Utkal University, Bhubaneswar, India.

RESULTS AND DISCUSSION

Analysis of vegetation reveals that 68 plant species from 30 families were available in the area with 14 species of tree, 42 species of shrubs and saplings and 12 species of herbs and seedlings (Tables 1 to 3). The species of trees, shrubs and saplings and herbs and seedlings belonged to 13, 29 and 9 families respectively. Importance value Index (IVI) is the measurement of ecological amplitude of species (Ludwig and Reynolds, 1988) which indicates one of the ability of a species to establish over an array of habitats. It gives composite information by taking into account the relative density, relative frequency and relative basal area. The frequency, abundance and density values are suitable for herbs and shrubs (Airi et al., 2000). IVI is an important information for all species. The vegetation characteristics of the area should be looked into through upper-story, middle- story and under- story vegetation for the purpose of a holistic assessment. The high importance value index of the species states its dominance and ecological success, its better power of regeneration and ecological amplitude in the area (Bhandari et al., 1999).

The dominant tree species having maximum RD and RF values were *Azadirachta indica followed* by *Shorea robusta* and *Lannea corromandelica* (Table 1).The IVI of *A. indica* was highest followed by *S. robusta*, *Naringi crenulata, Tamarindus indica and Schleichera oleosa*. Mishra et al., (2012) Shorea robusta was found as the dominant species in the SBR having IVI of 77.67 followed

Figure 3. View of a peripheral site of Hadagarh Sanctuary.

by *Terminalia alata* (16.13) and *Anogeissus latifolia* (13.43). Wendlandia sp. had IVI of 0.25 and was considered as the rare species of the reserve. All other tree species showed intermediate range of IVI Among the shrubs and saplings which occupy the middle storey vegetation *Ageratum conyzoides* exhibited highest IVI followed by *Combretum roxburghii*, *Holarrhena antidysenterica* and *Combretum decandrum* (Table 2).

The middle storey vegetation comprised of a good numbers of woody climbers and liana like *Combretum roxburghii*, *Smilax macrophylla*, *Cissampelos pareira*, *Ichnocarpus frutescens*. Similarly, analysis of herbs and seedlings (understory vegetation) (revealed *Cynodon dactylon* having the highest IVI followed by *Arundo donax, Mimosa pudica* and *Sida rhombifolia*. The plant species observed and encountered in the study belonged to 30 different families with most of the species belonging to Mimosaceae followed by Ebenaceae, Acanthaceae, Asteraceae, Combretaceae etc. It is important to note that majority of the families were represented by only two or less number of species. Though vegetation can be described in terms of a number of parameters including frequency, density and cover the use of any one of these quantitative parameters could lead to over-simplification or under-estimation of the status of the species (Kigomo et al., 1990; Oyun et al., 2009). Low ecological status of most of the tree species in the present investigation as evidenced by the IVIs, may be attributed to lack of dominance by any one of these species, suggesting positive interactions among the tree species (Mishra et al., 2012). In addition to the above findings, several cutting stumps were also observed indicating impact of anthropogenic activities in one of the forest vegetation in the area. Plant species like *Shorea robusta*, *Cassia fistula* have local economic importance. Similarly, plant species like *Diospyros ebenum*, *Acacia nilotica*. *Azadirachta indica*, *Strychnos nux-vomica*, *Andrographis paniculata*, *Alangium salvifolium* , *Holarrhena antidysenterica*, *Smilax macrophylla*, *Asoaragus racemosus*., *Xantolis tomentosa* etc have been used by the local population for years for preparation of medicines. Similar use of such plant species by people have been reported by various studies in India and abroad (Brahmam and Saxena, 1990; Girach, 1992; Sahoo and Mudgal, 1995; Mohanty et al., 1996; Brahmam et al., 1996; Aminnudin and n, 1996; Mehra et al., 2014; Bajpai et al., 2016; Rout et al., 2018). These plant species need urgent attention from the conservation point of view as their numbers are decreasing owing to factors like unsystematic and uncontrolled harvesting, grazing pressure from domestic animals and many other anthropogenic pressures (WP, 2008, 2017).

The population residing inside and adjoining area of the sanctuary have been dependent on the resources of this forest ecosystem which will have long term implications. This may be fairly attributed towards their lack of awareness on the issues concerning ecosystem services. Extensive use of natural vegetation in the sanctuary in the past has led to decrease in the provisioning services and increasing human demands has been the major case of deterioration in the condition of the natural habitats and increasing rarity of plant biodiversity (Giam et al 2010). The middle and lower storey vegetation showed presence of many saplings and seedlings of tree species like *Morinda tinctoria, Cassia siamea, Holarrhena antidysenterica*, *Azadirachta indica, Cesearia elliptica, Acacia nilotica*, *Diospyros ebenum*. These plant species need proper protection to grow as big trees. These plants are facing fierce competition in the ecosystem for space and sunlight due to threat from demands, weed species and other biotic impacts. As a result, there are a low percentage of old grown trees in the peripheral site.

Table 2. Species, density, basal area, frequency, distribution pattern and Importance Value Index (IVI) of Shrubs and saplings of a peripheral site of Hadagarh Sanctuary.

Scientific name	Local name	Frequency	R F	Density	R D	Abundance	RA	IVI
Ageratum conyzoides L.	*Poka Sungha*	62.5	14.164	1290	20.925	5.160	4.994	40.083
Combretum roxburghii Spreng.Syst	*Dhala Atundi*	55	12.465	1065	17.275	4.841	4.685	34.425
Holarrhena antidysenterica Wall.	*Kurei*	15	3.399	430	6.975	7.167	6.937	17.311
Albizia marginata(Lam)	*Beranga*	23.75	5.382	430	6.975	4.526	4.381	16.738
Combretum decandrum Roxb.Pl.	*Atundi (kala)*	12.5	2.833	355	5.758	7.100	6.872	15.463
Diospyros malabarica(Desr.)	*Kali kendu*	28.75	6.516	300	4.866	2.609	2.525	13.907
Strychnos nux-vomica (L.)	*Kochila*	18.75	4.249	290	4.704	3.867	3.743	12.696
Andrographis paniculata(Burm.f.)	*Bhuini Nimba*	10	2.266	235	3.812	5.875	5.686	11.764
Streblus asper Lour.	*Sahada*	26.25	5.949	165	2.676	1.571	1.521	10.146
Cesearia elliptica Willd.	*Khakada*	18.75	4.249	185	3.001	2.467	2.387	9.638
Morinda tinctoria Roxb.	*Achu*	7.5	1.700	150	2.433	5.000	4.839	8.972
Cissus guadrangula L	*Hada shankha*	18.75	4.249	155	2.514	2.067	2.000	8.764
Pergularia daemia(Forssk.)	*Utu rali*	7.5	1.700	145	2.352	4.833	4.678	8.730
Cissampelos pareira L.var.hirsuta	*Akandabindu*	10	2.266	150	2.433	3.750	3.630	8.329
Indigofera cassioides Rottl.	*Gilri*	18.75	4.249	110	1.784	1.467	1.420	7.453
Manilkara hexandra (Roxb.)	*Lal banduri*	17.5	3.966	100	1.622	1.429	1.383	6.971
Jasminum pubescens Wild.Sp.	*Bana malli*	12.5	2.833	115	1.865	2.300	2.226	6.924
Symphorema polyandrum Wight	*Badichang/Mahasindu*	10	2.266	115	1.865	2.875	2.783	6.914
Clerodendrum viscosum Vent.	*Gobra*	13.75	3.116	65	1.054	1.182	1.144	5.314
Woodfordia fruiticosa(L)	*Dhataki*	2.5	0.567	35	0.568	3.500	3.388	4.522
Paederia foetida L.Mant Pl.	*Gandhli*	5	1.133	40	0.649	2.000	1.936	3.718
Acacia nilotica L.	*Babul*	1.25	0.283	15	0.243	3.000	2.904	3.430
Diospyros ebenum Koenig	*Kendu*	1.25	0.283	15	0.243	3.000	2.904	3.430
Asoaragus racemosus Willd.	*Iswari jata*	6.25	1.416	35	0.568	1.400	1.355	3.339
Cassia siamea Lam.	*Chakunda(Desi)*	3.75	0.850	30	0.487	2.000	1.936	3.272
Diospyros montana Roxb.	*Halada*	6.25	1.416	25	0.406	1.000	0.968	2.790
Atalantia monophyla L.	*Narguni*	3.75	0.850	20	0.324	1.333	1.291	2.465
Glycosmis pentaphylla(Retz.)	*Dubuduba/Haumircha*	1.25	0.283	10	0.162	2.000	1.936	2.381
Ichnocarpus frutescens (L.)	*Suama Noi*	2.5	0.567	10	0.162	1.000	0.968	1.697
Impereta cylindrica(L)	*Dara gadi*	2.5	0.567	10	0.162	1.000	0.968	1.697
Alangium salvifolium (L..)Wang	*Ankula*	2.5	0.567	10	0.162	1.000	0.968	1.697
Thunbergia fragrans Roxb.var.hispida Gamble.	*Natka koli*	2.5	0.567	10	0.162	1.000	0.968	1.697
Protium serratum(Wall.exColebr)	*Rimili*	1.25	0.283	5	0.081	1.000	0.968	1.332
Xantolis tomentosa(Roxb.)	*Jyestha madhu*	1.25	0.283	5	0.081	1.000	0.968	1.332
Combretum decandrum Roxb.	*Kala Atundi*	1.25	0.283	5	0.081	1.000	0.968	1.332
Achyranthes aspera L.	*Apa maranga*	1.25	0.283	5	0.081	1.000	0.968	1.332

Table 2. Contd.

Smilax macrophylla Roxb.Fl	*Muturi*	1.25	0.283	5	0.081	1.000	0.968	1.332
Mimosa himalayana Gamble,Kew	*kirki koli kanta*	1.25	0.283	5	0.081	1.000	0.968	1.332
Grewia tillifolia Vahl,Symb	*Kulutha*	1.25	0.283	5	0.081	1.000	0.968	1.332
Flacourtia jangomas (Lour.Raeusch.Nom)	*Mambuli Kuli*	1.25	0.283	5	0.081	1.000	0.968	1.332
Shorea robusta Gaertn.f.Fruct	*Sal*	1.25	0.283	5	0.081	1.000	0.968	1.332
Sida rhombifolia L..Sp.Pl	*Bajramuli*	1.25	0.283	5	0.081	1.000	0.968	1.332

Total Indi.-Total number of individuals, A-Basal Area, Freq-Frequency, RD-Relative Density,RF-Relative Frequency,RBA-Relative Basal Area, IVI-Important Value Index.

Table 3. Species, density, basal area, frequency, distribution pattern and Importance Value Index (IVI) of Herbs and seedling species of a peripheral site of Hadagarh Sanctuary.

Name of Species	Local Name	Frequency	RF	density/m2	RD	Abundance	RA	IVI
Cynodon dactylon L.Sp.Pi	*Duba Ghasa*	23.75	13.768	2.175	30.000	9.158	21.936	65.704
Arundo donax L.	*baunsapatri grass*	31.25	18.116	1.575	21.724	5.040	12.072	51.912
Mimosa pudica L.	*Lajkuli lata*	33.75	19.565	1.250	17.241	3.704	8.871	45.678
Sida rhombifolia L..Sp.Pl	*Bajramuli*	16.25	9.420	0.438	6.034	2.692	6.449	21.904
Blumea lacera(Burm.f)	*Pokasungha*	13.75	7.971	0.438	6.034	3.182	7.621	21.627
Pachyrrhizus sp DC Rich.ex	*Sankha Saga*	13.75	7.971	0.388	5.345	2.818	6.750	20.066
*Andrographis paniculata(*Burm.f)Wall.ex	*Bhuin neemba*	15	8.696	0.363	5.000	2.417	5.789	19.484
Lygodium flexuosum (L.) Sw.J	*Mahajala*	8.75	5.072	0.225	3.103	2.571	6.159	14.335
Ageratum conyzoides L.Sp.Pi	*Bok sunga/ Deksingi*	3.75	2.174	0.100	1.379	2.667	6.387	9.941
Solanum insanum L.Mant.Pl	*Kanta Baigana*	5	2.899	0.113	1.552	2.250	5.389	9.840
Sida acuta Burm.f	*Sunakhadika*	5	2.899	0.113	1.552	2.250	5.389	9.840
Cassis oxidentalis L.Sp.Pi	*Kala Chakunda*	2.5	1.449	0.075	1.034	3.000	7.186	9.670

Total Indi.-Total number of individuals, BA-Basal Area, Freq-Frequency, RD-Relative Density,RF-Relative Frequency,RBA-Relative Basal Area, IVI-Important Value Index.

These species have shown good regeneration pattern in some of the areas of the study. Therefore, it is important that anthropogenic activities in this area like overgrazing, encroachments, illegal felling etc need to be curtailed suitable intervention (WP, 2008, 2017).

Despite having the status of a protected area of the country; the vegetation needs more attention from the habitat conservation point of view. The area needs management intervention for speedy regeneration of plant species. The phyto-sociological analysis reveals good generation potential of the habitat and the tree species having low IVIs , tree saplings and seedlings deserve due attention to ensure strict enforcement of the rules and better monitoring for enhancement of ecosystem stability of this protected area. For addressing forest management issues of the sanctuary, collection and analysis of long term ecological data by scientific baseline studies covering all structural parameters will be helpful to know the present state of ecological health of the ecosystem. Various forms of anthropogenic pressures have affected the habitat which include logging, illegal hunting, and other development challenges like mining in peripheral areas. The conservation efforts as per working (management) plan prescriptions have not so far yielded desired result. Therefore, for a sustainable ecosystem and community management and for reducing biotic pressure, the management methodology also needs to be modified for developing a Long Term Research Network to ensure improvement in. structure and function of ecosystem.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Ingestion of plastic debris affects feeding intensity in the rocky shore crab *Pachygrapsus transversus* Gibbes 1850 (Brachyura: Grapsidae)

Matheus Souza Ferreira de Barros*, Tereza Cristina dos Santos Calado, Alberis Santos Silva and Ewerton Vieira dos Santos

Laboratórios Integrados de Ciências do Mar e Naturais da Universidade Federal de Alagoas (LABMAR-UFAL), Brazil.

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The aim of this study was to investigate the plastic consumption by the rocky shore crab *Pachygrapsus transversus* and its effects in the species feeding activity. Specimens were collected monthly from August 2019 to January 2020 in a coral reef located in the north-eastern Brazilian coast, taken to the research laboratory, where they had their stomach removed, degree of fullness determined for each stomach and presence/absence of plastic debris assessed. Frequencies of occurrence of each degree of fullness were compared between sexes and contaminated/non-contaminated individuals. At total, 209 specimens were sampled and high levels of plastic contamination were detected: 47.4% of the sample had plastic fibres in the foregut. All contamination consisted only of nylon filaments, suggesting that irregularly discarded fishing equipment is the source. The frequencies of contaminated individuals among sexes did not differ. However, differences were detected in the comparison between degrees of fullness, demonstrating that there is significant influence of plastic ingestion in the stomachs volume. It is possible that the discrepant frequencies of occurrence of gut fullness were due to false satiation effects and blockage of the digestive tract provided by the fibres.

Key words: Pollution, decapoda, ecology, brachyura.

INTRODUCTION

Anthropogenic disturbances and pressures reduced the natural products in such a way that society has opted for plastic products for daily use purpose and it becomes a major component of human routine. The plastic material takes several decades to decompose and its waste is now considered a global problem. Due to these factors, natural and artificial ecosystems became vulnerable from natural and other hazards. These anthropogenic disturbance have adversely affected microbial activities, decomposition processes and nutrient cycling due to the fact that these processes depend on substrate quality and environmental factors (Pruter, 1987; Upadhyay et al., 1989; Bargali et al., 2018; Bargali et al., 1993, 2015, 2019; Andrady; 2011; Reisser et al., 2013; Lambert et al., 2014). In order to illustrate the scenario, since the mass production of plastics begun, in the 1950s, about 6.22

*Corresponding author. E-mail: matheus.barrosteu@gmail.com. Tel: +55 82 99976 1016.

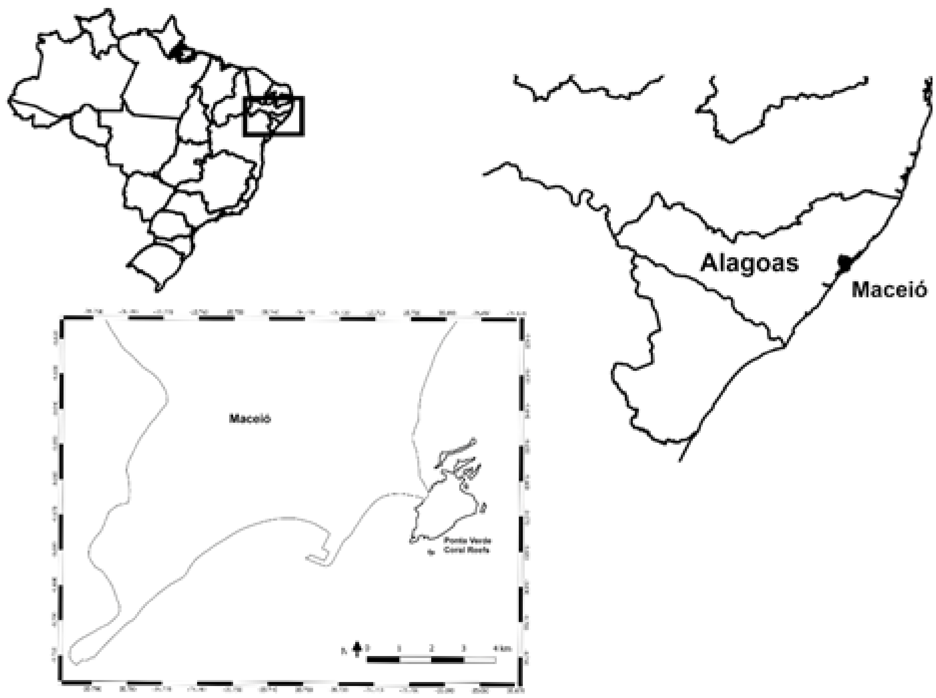

Figure 1. Location of the study site.

billion tonnes of plastic garbage had been discarded in the environment, with a majority being of single use goods (Geyer et al., 2017).

The accumulation of solid debris is a huge and growing concern for the conservation of marine biota. The less apparent impacts are primarily caused by the smaller particles of plastic, given that this material gradually decomposes in the environment. Microplastics tend to have increased availability to invertebrates in the base of the food web, which are commonly not affected by larger debris. Also, there is a higher probability of passive ingestion by planktivores (Browne et al., 2008; Fossi et al., 2012; Wright et al., 2013). Laboratory studies showed that many invertebrates are able to ingest plastic material (Wright et al., 2013; Cole and Galloway, 2015; Hall et al., 2015), although it is important to consider that the ingestion of this material is affected by the feeding dynamics of each taxon (Setälä et al., 2016). Impacts such as diminution in the overall body condition and feeding intensity following plastic ingestion were observed in a significant amount of studies (Murray and Cowie, 2011; Welden and Cowie, 2016; Bordbar et al., 2018).

The crab *Pachygrapsus transversus* (Gibbes, 1850) is a small brachyuran crab inhabiting consolidated substrata in several coastal regions in the Atlantic Ocean. It is known for having an omnivorous and generalist feeding strategy (Abele et al., 1986) and presenting importance in what comes to structuring communities as active grazers, controlling algae and sessile invertebrates abundance (Christofoletti et al., 2010). Thus, it is a key-specie to characterizing environments. Therefore, this study aimed to report data on plastic ingestion by the crab *P. transverus* and investigate impacts on the organism's feeding intensity under the hypothesis that ingested plastic material is able to decrease natural feeding rates by causing false satiation.

MATERIALS AND METHODS

The specimens were collected monthly by hand, at low tide, between August 2019 and January 2020, at the coral reefs located at Ponta Verde Beach, municipality of Maceió, Alagoas, Brazil (9°39'40" - 9°40'50" S and 35°41' - 35°42'W) (Figure 1), with a tidal amplitude around 2 m. Correia and Schlenz (1997) gave a brief description of this area, which is characterized by being a typical fringing reef, having the top of its platform constantly exposed to low tides and presenting a considerable amount of calcareous algae. Since it was composed of one slightly homogeneous rock, no sampling sites were adopted in this experimental design in order to assure independent sampling, considering that the studied crabs are fast moving, have high facility of dispersal and the area has no natural barriers around the rocky environment. Only crabs in the intermoult stage were captured. Right after capture, the specimens were put in a bucket containing ice in order to reduce enzyme activity, avoid any regurgitation and slow down the digestion processes (Figure 1).

In the research laboratory, the crabs were dissected and had their foreguts removed monthly in laboratory. Before analysing the gut content, the degree of gut fullness was determined visually by ranking with a score (¼, ½, ¾ and full). Although this estimation is slightly subjective, it is known that assessment of gut fullness in

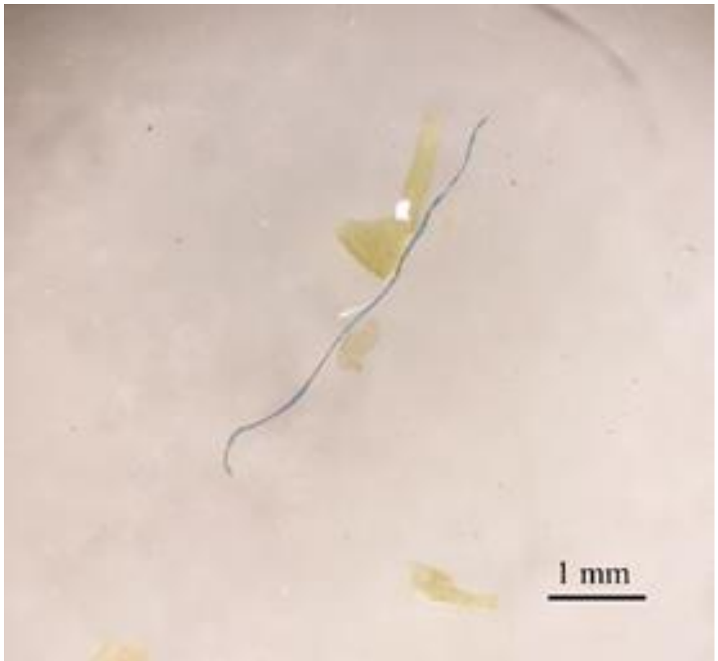

Figure 2. Nylon filament and algae fragment found in the stomach of *P. transversus*

decapod crustaceans can have an acceptable degree of reliability, since the stomachs of this organisms are not distensible as it is in fishes (Maller et al., 1983; Goes and Lins-Oliveira, 2009). The foreguts were then slit open in a volumetric petri dish containing distilled water and examined under a stereomicroscope with 400x magnification. The presence/absence of plastic material was then determined. Frequencies of occurrence of each level of gut fullness were compared between the contaminated and non-contaminated individuals by means of the Chi-square test (X^2) to address the hypothesis that the presence of plastic fibres in the stomach affects the feeding activity. Thus, to reject the null hypothesis, contaminated individuals should be significantly more frequent with empty or less filled stomachs. Also, the frequency of occurrence was compared between the two sexes. All analysis and graphing were realized by usage of GraphPad Prism 8 software version 8.0.01. The confidence level to reject null hypothesis was considered to be below 5%.

RESULTS AND DISCUSSION

A total of 209 specimens of *P. transversus* were sampled, being 102 males and 107 females. High levels of plastic contamination were detected in the sample: 47.4% of the individuals had one or more plastic fibres in the foregut. All plastic debris consisted of nylon filaments (Figure 2), enforcing the assumption that there is a single source of contamination in this particular site: irregularly discarded fishing apparatus. This is a common source of pollution by plastic debris (Ryan et al., 2009; Murray and Cowie, 2011; Reisses et al., 2013; Bordbar et al., 2018; Haward, 2018). The Chi-Square test demonstrated that there is a significant association between plastic consumption and degrees of fullness, indicating that fibres presence in the foregut can affect feeding activities ($X^2 = 65.18$, $p < 0.001$). The individuals that happened to ingest plastic debris had higher frequency of occurrence with empty and 25% filled stomachs (Figure 3). No significant differences in plastic consumption were detected between sexes ($X^2 = 1.33$, $p > 0.05$).

Plastic ingestion by decapod crustaceans is a big issue that may affect ecological processes, given that these organisms have a crucial importance in influencing the structure of benthic communities, diverse role in the food chain, behavioral plasticity and regulating trophic cascades (Cannicci et al., 1999; Branco et al., 2002; Boudreau and Worm, 2012; Barros-Alves et al., 2018). Also, this issue has the potential of negatively affecting commercial fishing (Possatto et al., 2011; Foekema et al., 2013). The direct and indirect impacts of plastic ingestion, such as false satiation and blockage of the digestive tract can also be sources of disturbance in life story traits and general health condition of crustaceans (Watts et al., 2015; Welden and Cowie, 2016; Bordbar et al., 2018; Jabeen et al., 2018), as well as in other groups of organisms (Lavers, 2016; Cardozo et al., 2018; Clukey et al., 2018; Forrest and Hindell, 2018).

Conclusion

It is clear that plastic consumption by *P. transversus* affected feeding activities in the studied specimens. We

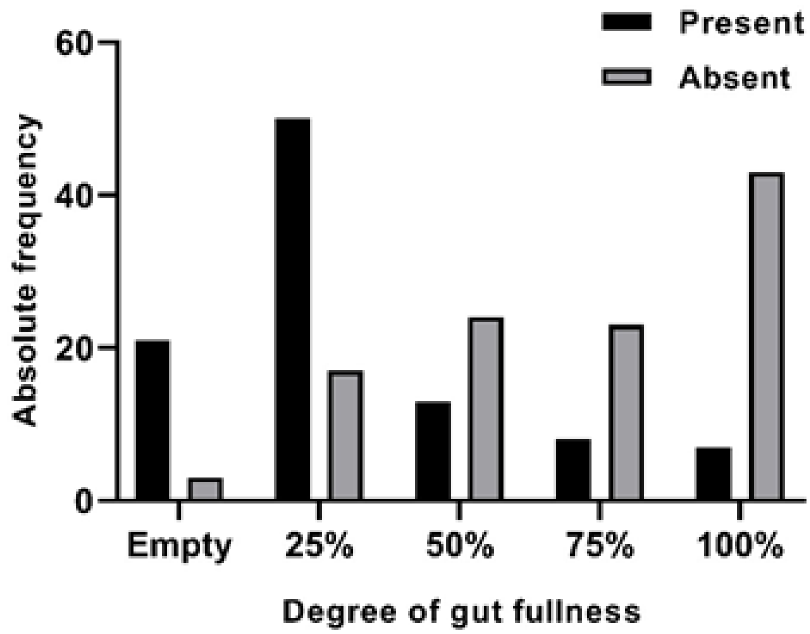

Figure 3. Occurrence frequency for each degree of fullness for individuals with present and absent plastic material.

hypothesized that the influence of plastic ingestion in the degrees of fullness is related to the false satiation or blockage of the digestive tract caused by the fibres. Also, plastic ingestion by decapod crustaceans should be a central issue when studying solid pollutants in the oceans, addressing the individual, population and ecosystem effects. The authors suggest that *P. transversus* can be used as indicator specie when it comes to monitoring coastal regions in a regional scale because of its high abundance and diverse diet.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Assessment of impact of ecological elevation on grass species' diversity in Yabello Rangeland, Southern Ethiopia

Yeneayehu Fenetahun[1,2,3], Wang Yong-dong[1,2]* and XU-Xinwen[1,2]

[1]State Key Laboratory of Desert and Oasis Ecology, Xinjiang Institution of Ecology and Geography, Chinese Academy of Science, Urumqi 830011, China.
[2]National Engineering Technology Research Center for Desert-Oasis Ecological Construction, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi, Xinjiang, China
[3]University of China Academy of Science (UCAS), Xinjiang Institution of Ecology and Geography, Chinese Academy of Science, Urumqi 830011, China.

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Elevation has great impact on species' diversity; it creates ecologically diverse vegetation. Studying species' richness patterns at different scales is very important both for ecological explanations and effective conservation design. In this study, grass vegetation data were collected using systematic sampling methods. 18 transects and 54 quadrants were laid, with 6 transects and 18 quadrants from each selected study kebele having 1 × 1 m^2 for grass. In each quadrant, the level of impact for each threatening factor was evaluated and a total of 26 grass species were recorded. The data were analyzed using SPSS and the average species' composition was assessed in relation to topographic variables. There was upper elevation observed in both richness and diversity of plant species compared to the others with significant P<0.05. Grazing intensity also has significant impact on both species' diversity, density and area coverage. This shows that the area heavily grazed had less diversity richness and coverage compared to the less grazed (p<0.001) area. From the data we can summarize that anthropogenic, topographic and climate factors were the leading causes of the overall shift of plant community structure in the study area.

Key words: Elevation, grazing intensity, grass composition, Kebele.

INTRODUCTION

Area topography and soil composition variation has great impact on plant type and richness, and all structures of plant community exist on that (Huston, 1994). For conservation and general understanding of ecological characteristics of a certain area, assessment of species type, composition and coverage is primary and key for the next step of rangeland management (Fetene et al., 2006; Muhumuza and Byarugaba, 2009). Different scholars related linkage of topography with plant diversity including: (i) decline with higher altitude; (ii) increase with higher altitude; (iii) bulge at mid-altitude; (iv) dip at mid-altitude; or (v) have no clear

*Corresponding author. E-mail: wangyd@ms.xjb.ac.cn.

relationship with altitude (Zhao et al., 2005). Rangeland plant species dynamics were influenced by climatic factors, topographical factors and also human interaction with different time and space. In rangeland area, slope variation had impact on type, composition, and the general status of rangeland in relation to its production potential and ecology (Angassa, 2014).

Former studies conducted in Borana rangeland, particularly at Yabello rangeland area mainly emphasized rangeland degradation excluding factors like topographic and anthropogenic influence, even if they have great impact on both diversity and density on the grass species of the study area (Acharya et al., 2011). For sustainable rehabilitation of degraded rangeland, gathering of basic information on the impact of such topographical factors is highly needed and this helps to reduce the rate of range land degradation. Assessing both composition and diversity of grass species in the study area is highly valuable to understate the current status of the area and to predict future conservation strategies and design (Feyera et al., 2014). In addition to the aforementioned factors, anthropogenic impact has become a major cause of range land degradation. This is due to changing the grazing land to other purpose like cultivated land, drought, shifting to plant species and imbalance between number of livestock and grazing land size (Leul et al., 2010).

Even though Yabello is the major semiarid rangeland area in the pastoral area of Southern Ethiopia, no study has been conducted on vegetation dynamic changes linked to diversity, richness and basal area cover regarding grass species in particular. Mainly ecological impact of elevation with regards to variation of herbage grass species has not been previously assessed. Therefore, the current study evaluated the impact of threating factors basically topographic and anthropogenic on the general vegetation pattern of the Yabello Rangeland. The local communities and rangeland stakeholders found in the study area played a great role in accomplishing the aim of this study through providing key information compared to the current and past and also through design intervention techniques for managing grass species existing in the study area. Therefore, this study investigated the effect of elevation on the vegetation species' diversity of Yabello Rangeland. The following basic questions were answered: (1) is there a visible variation on vegetation pattern linked to topography? (2) How do we identify the leading topographic variables that affect vegetation pattern in the rangeland of the study area.

MATERIALS AND METHODS

Study area

The study area included Dida Tuyura, Danbal-Waccu and Arero kebeles of Yabello district, Borana zone, Southern Ethiopia (Figure 1). The study was done in 2018. The area is 566 km from the capital city of the country, in the south direction and has area coverage of 5426 km^2; it is located between latitude 4°30′55.81″ and 5°24′36.39" in the north and between longitude 7°44′14.70″ and 38°36′05.35" in the east. The altitude is about 1000 to 1500 m; its maximum altitude is 2000 m. The area experiences a bi-modal rainfall features which is the 73% rainfall that occurs in March to May (long rainy season), and 27% rainfall that occurs in September to November (short rainy season) (Dalle et al., 2015). The potential evapotranspiration is 700to 3000 mm (Billi et al., 2015). The study area is dominated by savanna vegetation containing mixtures of perennial herbaceous vegetation. It is also confronted with the problem of bush expansion in the native savanna grass lands. Besides, the area is characterized by savanna grass land.

Sampling procedure and data collection

Collection of grass species data was done through purposive sampling techniques. 6 transects and 18 quadrants were laid from each selected study kebele; in total there were 18 transects and 54 quadrants in one growing season (From March to September, 2018) having altitude from 1000 to 1750 m. Vegetation data were collected from each sampling site. For grass species 1 × 1 m^2 quadrant size was used; identification and counting were done. For biomass determination based on the dry matter all available grass species were collected using hand cutting. They were oven dried at 105°C for 24 h. Basal area coverage of the site was also justified based on visual observation compared to the bare area (Angassa, 2014). From each plot composition of grass species was also calculated. From the total sampling quadrant, 26 grass species were identified. The rate of impact of each threating factor was also visualized within each sampling area. Grazing and human intensity were estimated based on direct field observation and during grass sample collection. Information was obtained from both direct interview and previous research work. The value of intensity was given by the following (Kebrom et al., 1997): 0=Non-grazing; 1=slightly grazing; 2=moderately grazing; 3=over grazing. Altitudinal variation includes 1000-1250 m.a.s.l (lower altitude), 1250-1500 m.a.s.l (middle altitude), and 1500-1750 m.a.s.l (upper altitude). Slope locations: 1, 2 and 3 for lower (0-30%), middle (31-60%) and upper (61-90%) position in a slope, respectively were assigned.

Data analysis

The data were analyzed using SAS statistical software version 9.1 (SAS Institute, 2001) and ANOVA (Analysis of variance). Composition and area coverage of the vegetation in the study area was estimated using the formula developed by Mueller-Dombois and Ellenberg (1974).

$$\text{Density} = \frac{\text{number of individual}}{\text{area sampled}} \quad (1)$$

Species' diversity existing in the study was calculated as follows (Shannon and Wiener, 1949):

$$H' = -\sum_{i=1}^{s} P_i \ln(P_i) \quad (2)$$

where H'=Shannon diversity indices, S=the number of species, Pi=proportion of individual species and InPi=log proportion of individual species.

Evenness of vegetation in the study sites was calculated as follows (Magurran, 2004).

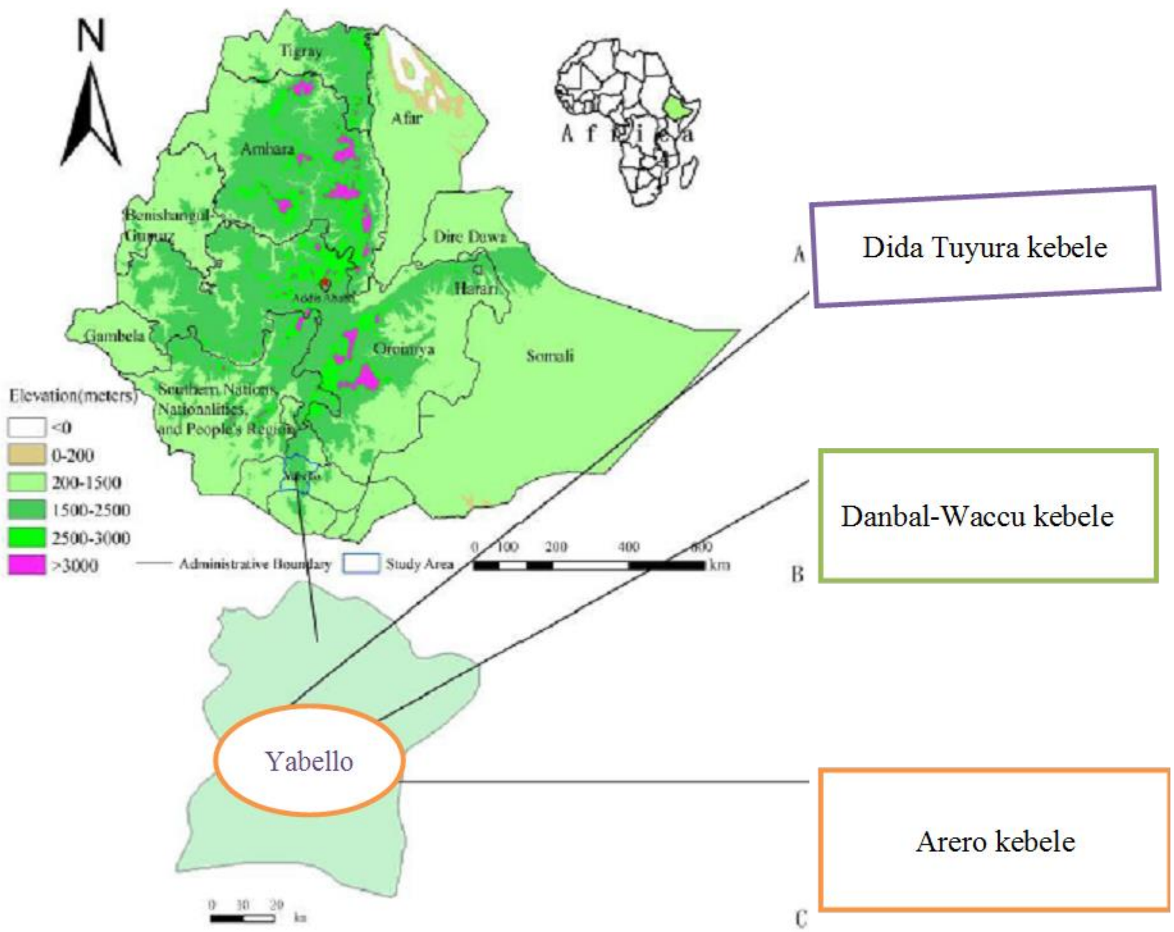

Figure 1. Map of the study site.

$$E = \frac{H'}{H\,max} = \frac{\sum_{i=1}^{S} Pi \ln pi}{\ln s} \quad (3)$$

where H' = Shannon diversity indices, S = the number of species, and Hmax = the maximum level of diversity possible within a given population. Pearson correlation analysis was used to correlate the environmental variables and diversity. Linkage of vegetation diversity with climate factors was assed though regression analyses method.

RESULTS AND DISCUSSION

Herbage grass species identified in the study site

All grass species were identified in each sampling plot using random harvesting techniques. The identified grass species were grouped as decrease (going to reduce), increase (likely to increase) and invaders (species that substitute the native species) based on the grazing intensity of the study site according to the succession theory (Tainton, 1986). From the study site, 26 grass species were recorded and both their scientific and local names were identified. The species and their average coverage of the study site are shown in Table 1. *Chloris roxburghiana* and *Chrysopogon aucheri* grass species had the highest average single species coverage of over 30% for all the sites and high abundance compared to other species. Of all the grass species recorded from the project area, 30.8% were categorized as highly desirable, 53.8% as desirable and 15.4% as less desirable. The ratio of grass species that were identified as highly desirable and desirable was high compared to less desirable grass species. This resulted from timely degradation of available forage on the study site as most grass species became highly desirable species over time. And also we understand that over grazing reduces ground cover and composition of herbage species in the study area. Among the threating factors mainly occurring in the study site drought and grazing intensity were the primary factors due to reduction of vegetation status in the study site over time (Alemayehu, 2006; Aynekulu et al., 2009). As shown in Table 1, only four grass species are highly dominate in all the study sites and this accounts for only 15.4% of the total recorded grass species. This indicates that almost all of the grass

Table 1. List of grass species identified in the rangeland in all elevation sites and their desirability.

List of species (Scientific name)	Local name	Family	Desirability	Composition status
*Chrysopogon aucheri**	Alaloo	Poaceae	HD	D
Dactyloctenium aegyptium	Ardaa	Poaceae	LD	LC
Xerophyta humilis	Areedoo	Poaceae	DS	C
Aristida kenyensis	Biilaa	Poaceae	LD	LC
Eragrostis capitulifera	Biilaa	Poaceae	DS	C
Harpachne schimperi	Biilaa	Poaceae	DS	C
Leptothrium senegalense	Biilaa diidaa	Poaceae	DS	LC
Melinis repens	Buuyyoo xirooftuu	Poaceae	HD	C
Themeda triandra	Gaaguroo	Poaceae	DS	C
Digitaria milanjiana	Hiddoo	Poaceae	HD	C
*Chloris roxburghiana**	Hiddoo luucolee	Poaceae	HD	D
Digitaria naghellensis	Ilmogorii	Poaceae	DS	LC
Panicum maximum	Loloqaa	Poaceae	HD	D
Bothriochloa insculpta	Luucolee	Poaceae	DS	LC
*Cenchrus ciliaris**	Mata guddeessa	Poaceae	HD	C
Pennisetum mezianum	Ogoondhichoo	Poaceae	LD	LC
Eragrostis papposa	Saamphillee	Poaceae	DS	C
Sporobolus discosporus	Saamphillee kootichaa	Poaceae	DS	C
Grewia tenax	Saarkama	Tiliaceae	DS	C
Grewia tenax	Saarkama	Tiliaceae	HD	D
Cyperus sp.	Saattuu	Cyperaceae	DS	LC
Cyperus bulbosus	Saattuu arbaa	Cyperaceae	LD	LC
Sporobolus pellucidus	Salaqoo	Poaceae	DS	C
Cynodon dactylon	Sardoo	Poaceae	HD	C
Heteropogon contortus	Seericha	Poaceae	DS	LC
Loudetia flavida	Seericha gaaraa	Poaceae	DS	C

HD= highly desirable, DS= Desirable, LD= Less desirable; D= Dominant (> 35%), C= Common (10-35%), LC= less common (<10%).

species are very sparsely distributed and in less amount. Those highly dominate grass species were recommended by the local people, and also previous studies have shown the high importance of rehabilitating degraded rangeland areas.

Species diversity and evenness

Impact of elevation difference on species' variation and composition

Altitudinal difference had great impact on diversity and density of grass species in the study site. The upper altitude had a significant variation index compared to middle and lower altitude gradient (Table 2). This is due to top-climatic factors like season, slope and elevation (Getachew et al., 2008). Altitude is the independent factor that affects both the environmental and grazing land sustainability. This is the major cause of the general vegetation pattern (Alemayehu, 2003) linked with other living and non-living threating factors (Otypkova et al., 2011; Tibebu and Teshome, 2015) and results of diversity and richness of grass species along with attitudinal difference. According to Sharma et al. (2009) and Bruun et al. (2006) as altitude increases, richness of vegetation declines as a result of harsh climatic condition in the upper altitude caused by restriction in species' expansion. Mid-latitude is used as threshold level to compare vegetation pattern (RDCT, 2015). And this makes them more sustainable due to their enhanced fitness at higher altitude compared to the rest (Ole et al., 2002). Based on the interaction of abiotic and biotic factors the vegetation pattern (diversity and evenness) may either rise or decline or at threshold in each topographic level. From this, we can understand that altitude variation is the primary determinate issue of vegetation patter in the grazing area of Yabello rangeland (Acharya et al., 2011; Ru and Zhang, 2012; Zhang et al., 2013). It is not only the topographical nature but also less human interface with vegetation on high altitude lead to increment of both diversity and composition

Table 2. Mean (±SE) of the general vegetation pattern in Yabello Rangeland.

Topographical variation	Composition	Variation	Evenness (J)
High altitude	16.28[a]	2.2 (±0.06)[a]	0. 79 (±0.02)
Middle altitude	12.21[b]	1.91 (±0.08)[b]	0.79 (±0.01)
Lower altitude	10.04[b]	1.87 (±0.07)[b]	0.82 (±0.02)
P value	<0.001	0.009	0.28
Slope gradients			
Lower	11.24 (0.84)	1.90 (±0.06)[a]	0.82 (0.01)
Middle	13.64 (0.90)	2.04 (±0.07)[b]	0.79 (0.01)
Upper	13.62 (1.87)	2.04 (±0.12)[b]	0.81 (0.01)
P value	0.13	0.33	0.42

Table 3. Mean± (SE) of livestock per household at Yabello Rangeland area.

S/N	Livestock species	Mean± (SE)/household
1	Cattle	9.41 ± 0.03
2	Goat	9.4 ± 0.33
3	Sheep	0.9 ± 0.08
4	Donkey	0.3 ± 0.33
5	Camel	0.11 ± 0.03

species compared to lower altitude (Yohannes et al., 2015). We can conclude that environmental issues are the bottleneck on the general vegetation pattern in Yabello Rangeland.

From the Table 2, we can see that topographical difference has no significant (P>0.05) impact on the vegetation distribution (evenness). This indicates that slope variation has no observable influence on vegetation (grass) distribution at Yabello Rangeland area. Even though it has slight variation among the three slope gradients, noticeably the top and middle have slightly highest species richness value of 13.6 compared to the lower (11.24) (Table 2).

Impact of grazing intensity on species' richness and diversity index

Livestock holdings and composition in the grazing site: Cattle ranked first in the dominancy of livestock composition (9.41±.03) in Yabello Rangeland followed by goat (9.4±0.33), sheep (0.9±0.08), donkey (0.3±0.33) and camel (0.11 ± 0.03), respectively. This shows uniformity in all the elevation levels (Table 3). This result is in agreement with Sisay (2006) who studied the qualitative and quantitative aspects of animal feed in different agro ecological areas of North Gonder. However, impact of livestock grazing intensity on both composition and variation of species is significant (P<0.001). It means that if the rate of grazing is high the overall vegetation pattern would decrease. There was higher type, composition and distribution at the place where there is no (nil grazing rate) disturbance (Table 4). From this, we can conclude that livestock grazing rate had great impact on the vegetation pattern of the Yabello Rangeland. And this result shows human and livestock settlement distance with vegetation general pattern has a direct effect. It means that the place where humans settle and livestock graze repeatedly has less vegetation in all aspect of its pattern compared to areas with less frequent grazing. Due to area variation with production, diversification of habitat and contacting determinant factors mainly anthropogenic factors like farming practice, firing, and over harvesting of forage have a direct impact on the grass species (Brinkmann et al., 2009; Maestre, 2004; Feyera et al., 2014). Generally, the observed vegetation variation linked to topographical difference shows the degradation level of the grazing site and its biodiversity composition (Gunnar and Ove, 2001; Oba, 2011; Tessema et al., 2011; Angassa, 2014). Some studies show that duration of livestock grazing at a certain grazing area highly impacts vegetation density and variation and this may cause sustainability of the plant community within the rangeland site (Amsalu, 2000; Hoshino et al., 2009). This result is also in agreement with Aynekulu et al. (2009)'s study conducted in Northern Ethiopia. The primary determinant factor of rangeland

Table 4. Mean (±SE) of general vegetation pattern with level of grazing intensity in Yabello Rangeland area.

Grazing intensity	Composition	Variation	Evenness (J)
Nil	17.84 (0.95)[a]	2.27 (±0.09)[a]	0.79 (±0.02)
Slight	13.37 (1.15)[b]	2.05 (±0.06)[ab]	0.81 (±0.01)
Moderate	9.09 (1.04)[c]	1.73 (±0.1)[c]	0.80 (±0.02)
Heavy	10.45 (0.60)[c]	1.88 (±0.07)[bc]	0.81 (±0.02)
P value	<0.001	<0.001	0.78

Table 5. Mean (±SE) of area coverage of grass species in different topographical elevation in Yabello Rangeland area.

Topographical variation	BA (m^2/ha)
Top altitude	10.15 (±0.60)[a]
Middle altitude	6.48 (±0.96)[b]
Lower altitude	6.40 (±1.38)[b]
P value	0.001
Slope gradients	
Lower slope	5.97 (±0.81)
Middle slope	7.81 (±0.96)
Upper slope	7.25 (±1.89)
P value	0.37

degradation is the combination effect of all agricultural expansion, drought, infestation of invasive plant species and climate change in general (Alemayehu, 2007).

Impact of elevation on basal area grass species coverage

Topographical elevation variation has significant impact (P=0.001) on the vegetation area coverage (Table 5). Elevation has a direct impact on the composition and density of vegetation in general and grass species in particular at the Yabello Rangeland. Our finding is in agreement with the study conducted by Markos and Simon (2015). The mean basal areas for lower altitude, middle altitude and upper altitude were 6.40 , 6.48 and 10.15 m^2/ha, respectively. The top elevation had more area coverage compared to the others (middle and lower), and density of grass vegetation had better performance when the elevations of rangeland increased as livestock and human interference reduced when elevation became higher. The study conducted by Markos and Simon (2015) shows that altitude variation affects the general abundance and area coverage of rangeland due to environmental variation within each attitude, like temperature, moisture, sunlight, etc.

Impact of grazing intensity on individual grass species density

The livestock grazing duration had a significant impact (P<0.001) on basal area coverage of grass vegetation and number of individuals within a study site. Rangeland site almost free from livestock grazing had great number of grass species within (382.30+26.04) (Table 6) compared to rangeland site that is degraded due to overgrazing, caused by both anthropogenic and climatic influence. This may occur in rangeland site located near human settlement, making it appropriate for continues livestock grazing.

Regeneration status of grass species across topographic variables

Livestock grazing intensity of rangeland also highly impacts the recovery of vegetation species and determines the composition of mature vegetation, intermediate and seeding stage of the existing grass species in Yabello Rangeland. As a result the most mature and intermediate stage vegetation/ha was observed

Table 6. Mean (±SE) number of individuals related to grazing intensity in Yabello Rangeland area.

Grazing intensity	Individuals/ha
Nil	382.30 (±26.04)[a]
Slight	211.68 (±15.81)[b]
Moderate	160.22 (±13.41)[c]
Heavy	142.72 (±14.97)[c]
P value	<0.001

Table 7. Mean (±SE) of mature grass, middle stage and seedlings of different grazing intensity in Yabello rangeland area

Grazing rate	Mature	Middle age	Seedling
Nil	1478.84 (±99.18)[a]	4100.00 (±393.21) [a]	3230.76 (±270.41) [a]
Slight	920.31 (±107.82)[b]	2362.50 (±205.92) [b]	1506.25 (±182.68) [b]
Moderate	552.27 (±58.52)[c]	1254.54 (±250.22)[c]	1081.81 (±138.05) [b]
Heavy	509.09 (±64.43)[c]	1109.09 (±154.99)[c]	1313.63 (±114.96) [b]
P value	<0.001	<0.001	<0.001

at the rangeland area where the grazing intensity is almost none or nil. From this, we can understand that grass rehabilitation time highly impacted the livestock grazing duration (Table 7). Disturbances such as intensive grazing, explanation of agricultural practice, infestation of invasive alien plant species and drought had great impact on the recovery of rangeland grass species (Leul et al., 2010). Also the anthropogenic activates also had a great impact on the recovery of grass spices in the rangeland area. This result is in agreement with the report done by Leul et al. (2015). All the recovery of vegetation in the study site is highly impacted by both climatic and human factors (Markos and Simon, 2015). According to the data reported by Adane (2011), the recovery and rehabilitation rate of rangeland vegetation is primarily influenced by topographical variation, site location, rate of grazing intensity, human interference in the rangeland and combination of all the determinant factors. Both livestock and human interference had a direct impact on rangeland vegetation growth, recovery rate, rate of degradation and development in general (Austrheim, 2002; Zhang et al., 2015; Sproull et al., 2015).

Recovery status of grass vegetation in the studied rangeland area is high in higher elevation compared to the middle and lower elevation (Table 8). This is due to favorable condition of living and non-living determinant factors observed at the higher elevation area. This helps to speed up the regeneration rate of the grass species found in the top elevation sampled area compared to other elevation (Melese and Wendawek, 2016). Abundant existing matured grass species were high at the upper elevation area compared to the lower elevation area. This is due to the high impact of livestock grazing intensity combined with other environmental issues. And in the upper elevation the grazing site is not more appropriate for livestock to graze frequently. This helps the existence of more mature grass species both in abundance and type. In addition, elevation also had impact on the rangeland moisture status. This has great influence on the recovery and rehabilitation status of the vegetation in the study area (Soromessa et al., 2004). The impact of human disturbance at higher elevation is lower compared to lower elevation. This resulted regeneration status of grass vegetation in the lower slope is slow compared to the higher one. This becomes the primary cause for the increasing trend of recovery and rehabilitation status of rangeland vegetation as elevation increases. The recovery status of grass species in Yabello Rangeland is highly influenced by both topographical difference, human and environmental factors. This result is in agreement with the data reported by Deribe (2006).

Relationship between grass species' patterns and environmental factors

In the study area, elevation variation and anthropogenic factors had impact on the general vegetation pattern and recovery status over time and space (Alexander and Millington, 2000). In Yabello Rangeland area,

Table 8. Mean (±SE) of mature grass abundance, sampling and seedlings/ha at different topographical sites in Yabello Rangeland area.

Altitudinal gradients	Mature/ha	Middle age/ha	Seedling/ha
Top altitude	1386.11 (±98.08)[a]	3605.55 (±346.45)[a]	2683.33 (±290.17)[a]
Middle altitude	721.05 (±75.95)[b]	1968.42 (±233.96)[b]	1384.21 (±169.21)[b]
Lower altitude	503.00 (±57.08)[c]	1080.00 (±142.94)[c]	1292.00 (±108.61)[b]
P value	<0.001	<0.001	<0.001
Slope gradients			
Lower slope	628.44 (±80.99)[b]	1379.31 (±170.86)[b]	1313.79 (±129.20)[b]
Middle slope	924.00 (±92.78)[a]	2484.00 (±310.73)[a]	2032.00 (±216.08)[a]
Upper slope	1237.50 (±194.45)[a]	3400.00 (±611.49)[a]	2250.00 (±519.27)[a]
P value	0.003	<0.001	0.01

Table 9. Impact of determinant factors (environmental variation, human interference and grazing rate) on the general vegetation pattern in Yabello Rangeland.

Variable	BA		Individual		H		S		J	
	r	p-value	r	p-value	r	p-value	r	p-value	r	p-value
Altitudinal gradients	0.44	<0.001	0.78	<0.001	0.44	<0.001	0.64	<0.001	-0.15	0.25
Slope gradients	-0.05	0.72	0.46	<0.001	0.21	0.09	0.28	0.03	-0.11	0.4
Grazing intensity	-0.3	0.01	-0.69	<0.001	-0.41	<0.001	-0.59	<0.001	0.09	0.48
Human	-0.3	0.01	-0.67	<0.001	-0.4	<0.001	-0.57	<0.001	0.08	0.5

r=Correlation coefficient value; BA= basal area; H= Shannon diversity index; S=species richness; J=evenness.

environmental factors such as slope variation, human daily activity and livestock grazing rate highly impacted the general pattern and rehabilitation status of grass species. Vegetation composition and variation had a direct linkage with elevation and human interference (Jin et al., 2013). The livestock grazing duration was inversely related with the abundance of vegetation on the rangeland site (r = -0.59, P < 0.001), but elevation (slope) variation was directly related with the number of individuals/ha (r = 0.46, P < 0.001). Human interference also had a negative impact on both existing number of grass species, abundance and diversity of grass/ha in the Yabello Rangeland site (r = -0.67, -0.4 and -0.57), respectively (Table 9). Elevation difference is the factor that highly impacted the grass species type in the Yabello Rangeland. Our result is in agreement with the data reported by Zhang et al. (2006), Muhumuza and Byarugaba (2009) and Chawla et al. (2008). Slope also has a significant impact on grass species vegetation in the study site. This is because as elevation varies, the humidity and temperature vary also. This result is in line with the data reported by Lovett et al. (2006), Zhang and Zhang (2007), Jin-Tun et al. (2016) and Virtanen et al. (2010). Range land basal area coverage with livestock grazing rate and human interference had a negative linkage (r = -0.3, P =0.01) and a direct linkage with altitude (r = 0.44, P < 0.001) (Table 9). Altitude and slope have an equally strong significant (p < 0.0001) effect on basal area of species (Markos and Simon, 2015). Although, the linear trend explains a significant amount of the variability in basal area on the altitude gradient (Carpenter, 2005). Altitude has strong correlation with species' richness and Shannon diversity index of grass; it has great impact especially on rangeland vegetation distribution (Zewde, 2014). Species' richness, Shannon diversity index and evenness all significantly correlated with elevation and grazing gradients. Grass species' composition, diversity and distribution pattern generally are significantly correlated with environmental gradients that exhibit heterogeneity over space and time, such as topography and grazing intensity (Brinkmann et al., 2009; Zhang et al., 2013). This was observed in the Yabello Rangeland area.

Conclusion

Declining of grass vegetation composition and variation Shannon grass species in the rangeland were the outcomes of the altitudinal variation and other topographic factors. Our result concluded that altitudinal difference has great impact on the general vegetation pattern of Yabello Rangeland area. Elevation variation, human activity and livestock grazing rate played a key role in herbage grass species' variation account. This is because with altitudinal gradients, human activity and grazing rate affect species' variation and density difference. It was concluded that decline in grass vegetation pattern had a direct effect on human daily activity, grazing intensity and altitudes in the Yabello Rangeland area, and this highly affected the growth, variation, composition and recovery rate and population structure of the grass species. Measures such as managing livestock grazing rate and human activity, monitoring rangeland diversity change, and effective management should be done in this rangeland area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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ABBREVIATIONS

ANOVA, Analysis of variance; **BA,** basal area; **J,** species evenness; **S,** species richness; **R,** correlation coefficient; **H,** Shannon diversity index; **SAS,** statistical software; **SE,** standard division; **MASL,** meter above sea level; **H max,** maximum level of diversity.

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Polymorphism of *Cyclops abyssorum mauritaniae* (Copepoda, Cyclopoidae) collected from Algeria water bodies

Safia Akli-Bidi[1*] and Sybille Maas[2]

[1]Laboratory of Dynamic and Biodiversity, Faculty of Biological Sciences, University of Sciences and Technology Houari Boumediene, BP 32, El Alia, Algiers, Algeria.
[2]Department of Biology, Faculty of Science, Ghent University, Ghent, Belgium.

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Three morphotypes A, B and C were isolated after description of *Cyclops abyssorum mauritaniae* populations obtained from 46 Algerian water bodies. These are described based on their morphometric characters. Morphotype A found in six localities characterized the east of Algeria, morphotype B was collected in the west of Algeria, while morphotype C was collected in High Mountain in the North. After dissection of certain males and females, measurements of the different parts of the body illustrated by drawings were made for each morphotype. The size of morphotype B is intermediate between A and C. The outer side of the second article of the fifth thoracic leg presents a small bump only in morphotype A and C. Morphotype C is characterized by the convexity of its third, fourth and fifth thoracics anterior margin. Other differences were observed on ornamentations of the antenna basis and the coxa of the fourth leg. This subspecies, with common occurrence in the Eastern Region of Algeria and rare occurrence in the northern and western parts of the country indicates that it is dispersed in Algeria from the East to the West and North.

Key words: Algeria, Copepoda, *Cyclops abyssorum mauritaniae*, distribution, polymorphism.

INTRODUCTION

Cyclops abyssorum mauritaniae Lindberg 1950 is a Southern element of the Holarctic genus *Cyclops* O.F.Muller 1776. In North Africa, *C. abyssorum mauritaniae* was first reported from Morocco by Lindberg (1950) and was met for the first time in Algeria in 1992 (Akli, 1992). In Tunisia it was reported later by Toumi et al. (2013). Three populations from the Middle and High Atlas (Dayat Ifrah, Aguelmane de Sidi Ali, and Lake Ifni) have been compared (Dumont and Decraemer, 1977).

In accordance with its eurytopy, the species has been recorded as tolerating a variety of environmental conditions, such as acidic waters (Røen, 1962) and alkaline waters (Morgan, 1972). In Algeria shallow dams, this species was usually observed after eutrophication (Bidi et al., 2014). According to Krajicek et al. (2016), eutrophication represents a recent dispersion caused by man. Many morphotypes of *C. abyssorum* have been

*Corresponding author. E-mail: safiabidi@yahoo.fr. Tel: 07 82 75 26 93.

described by different authors. Einsle (1975) found that the planktonic populations react quickly to the environmental conditions changes with a change of morphometry of the different parts of the body.

MATERIALS AND METHODS

Sampling

A total of 46 water bodies (Table 1 and Figure 1) were sampled in different parts of Algeria with one sampling per water body except for three localities (9, 10 and 18). Samples were collected using plankton net of 50µm mesh size. The samples were fixed in 5% formalin solution. Samples were collected by the author.

Dissection

For preparation, the organisms were first placed in small dishes containing a mixture of formalin water and glycerin. The water evaporated in 1-2 days and then specimens were dissected in the concentrated glycerin. The cyclopoids were examined in dorsal view. Total body length and length of antennules in relation to the cephalothorax were measured. Other measurements on the caudal rami, the fourth and fifth thoracic legs were made after dissection and followed by drawings for each morphotype of *C. abyssorum mauritaniae*. Cyclopoids were identified using the key of Dussart (1969) (Table 2).

RESULTS AND DISCUSSION

Three Algerian morphotypes A, B and C of *C. abyssorum mauritaniae* were identified. The morphotype A which characterises the East Algeria water bodies was the most abundant, collected at different altitudes (25, 600 and 1090 m) in lakes and wadis. Only two females of morphotype B was sampled in West Algeria, in wadi at 86 m altitude, while morphotype C was collected in lake in the High Mountain (1200 m altitude), in the North. According to Holynska and Wyngaard (2019), *C. abyssorum* G. O Sars, 1863 occur in both low and high-altitude habitats. Morphotype A (Figure 2a) is the most robust one (2.2-2.3 mm); size of morphotype B (1.9- 2.1 mm) is intermediate between A and C (1.7-2 mm) (Figure 2b and c). Tunisian (1.6-2.2 mm) and Algerian specimens of *C. abyssorum mauritaniae* have relatively big size compared to Morocco specimens of Aguelmane de Sidi Ali (1.4-1.74 mm) and lake Ifni (1.24-1.29 mm). From Dayat Ifrah one adult female was isolated, suggesting a more robust form than the animals from Aguelmane de Sidi Ali, with shorter furcal rami (Dumont and Decraemer, 1977). Algerian specimens' first antenna reaches the posterior margin of the cephalothorax; those from Morocco have the first antenna that reaches the half of the second thoracic segment; those from Tunisia exceed it. Morphotype C shows a habitus that is close to the material of Aguelmane Sidi Ali with convexity of its third, fourth and fifth thoracic anterior margin (Figure 2c). Furcal rami in morphotype C (Figure 3c) are slightly shorter (5.6 -6.9 times as long as wide) than of morphotype A and B (6 -7 times as long as wide) (Figure 3a, b). Morphotype A shows furcal rami (Figure 3a) with thickened ridge in the dorsal side which is close to that of Dumont material of Dayat Ifrah (Dumont and Decraemer, 1977).

Differences between these three morphotypes were observed in spinule ornamentation of the antennary basipodite. The antennary basipodite in caudal view (Figure 4a, c and e) is shown in both morphotypes' proximal spinules; on the lateral rim, it is composed of 6 long spinules slightly incurved in morphotype A, 8 spinules in morphotype B and 3 little spinules in morphotype C. Oblique row of spinules next to proximal row on lateral rim is composed of 7 elongated spinules in morphotype A, 4 spinules in morphotype B and 7 spinules in morphotype C. Longitudinal row along lateral rim is arranged in one curved row of small spinules (10 spinules) of equal size in morphotype A and one continuous row of spinules (7spinules) in morphotype C, in morphotype B, longitudinal row along lateral rim is absent. Frontal spinule pattern of antennary (Figure 4b, f) consists of group of oblique spinules (4) near the base in morphotype A and C. frontal basipodite antenna without spinules (3d).

In all morphotypes, formula of exopodite 3 (P1-P4) is: 3- 4- 3- 3; the endopodite 3 of the fourth leg is 2 to 2.5 times as long as broad. The internal apical spine is 2 times as long as the external apical spine (Figure 5a, b and c). Caudal spinule ornamentation of P4 coxopodite (Figure 6a, b and c) composed of intermittent row of spinules along distal rim is arranged differently in both morphotypes; (4+5) in morphotype A, (11+1) in morphotype B and (4+4) in morphotype C. Along proximal rim of P4 coxopodite, spinules are arranged in two rows with different size, consisting of 17 spinules in morphotype A, 22 spinules in morphotype B and 16 spinules in morphotype C. On lateral rim, a row of numerous fine spicules comb like exists only in morphotype A. The connecting plate of P4 carries two rows of long hair; it is an ornamentation which is identical to all the morphotypes. The outer side of the second article of the fifth thoracic leg presents a small bump in morphotype A and C (Figure 7a and c) with 4 to 5 small spines for morphotype A (Figure 7a) and 3 to 4 small spines for morphotypes B and C (Figure 7b and c).

Conclusion

In the 46 water bodies sampled, *C. abyssorum mauritaniae* existed only in eight localities with considerable morphological plasticity. Morphological characters of morphotype A are stable in all its localities; for morphotype C, any morphological differences in

Table 1. List of localities with altitude and dates of sampling.

S/N	Locality
1	Terni wadi (Tlemcen). 867 m. 18/01/1989.
2	Tafna source (Tlemcen). 800 m. 18/01/1989.
3	Sebkha (Oran). 110 m. 19/01/1989.
4	Lake of Gharabes (Oran). 109 m. 19/01/1989.
5	Swamp of Lamacta (Oran). 0 m. 19/01/1989.
6	Saida wadi (Saida). 980 m. 20/01/1989.
7	Dam of Oued El Fodda (Ech Chellif). 200-235 m. 7/11/1990
8	Chellif wadi (Ech Chellif). 86 m.3/04/1990.
9	Mazafran wadi (Tipasa). 12 m. 10/10/1990, 5/11/1990.
10	Chiffa wadi (Blida). 92 m. 8/6/1990, 9/11/1990.
11	Dam of Ghrib (Medea). 559 m. 5/11/1990.
12	Dam of Boughzoul. (Medea). 600 m. 6/11/1990.
13	Sebkha of Boughzoul. (Medea). 600 m. 6/11/1990.
14	Lake of Reghaia (Alger). 4-35 m. March, July 1989.
15	Dam of Hamiz (Boumerdes). 300 m. 15/05/1989.
16	Dam of Cap Djenet (Boumerdes). 121 m. June 1990.
17	Basins of Djurdjura (Bouira). 2308 m. 06/12/1989.
18	Black lake (Bouira). 1200 m. 16/05/1990, 5/06/1990.
19	Soummam wadi (Bejaia). 1 m. September, 1990.
20	Ziama Mansouria wadi (Jijel). 15 m. 25/11/1989.
21	Dam of Bordj –Bou-Arreridj (Bordj –Bou-Arreridj). 900 m. 21/11/1989.
22	Rhumel wadi (Constantine). 1090 m. 21/11/1989.
23	Boumerzoug wadi (Constantine). 506 m. 21/11/1989.
24	Charef wadi (Guelma). 621 m. 22/11/1989.
25	Benazouz wadi (Skikda). 17 m. 24/11/1989.
26	Ain Barbar wadi (Annaba). 900 m. 24/11/1989.
27	Seybouse wadi (Guelma). 0 m. 22/11/1989.
28	Dam of Cheffia (El Taref). 337 m. 22/11/1989.
29	Lake of Melah (El Taref). 60 m. 23/11/1989.
30	Lake of Oubeira (El Taref). 25 m. 23/11/1989.
31	Lake of Tonga (El Taref). 589-1061 m. 23/11/1989.
32	Blue lake (El Taref). 60 m. 23/11/1989.
33	Messida wadi (El Taref). 1 m. 23/11/1989.
34	Swamp (El-Harrach, Algiers). 0-178 m. 14/11/1990.
35	Bethah wadi (Annaba). 600 m. 24/11/1989.
36	Basins (Tasslemt, Tissemssilt). 900 m. 17/01/1989.
37	Swamp between Ain El Hadid and Rosfa (Tiaret). 911 m. 17/01/1989.
38	Basins (Tamezguida, Medea). 1604 m. 9/11/1990.
39	Sebkha between Hassi- Bahbah and Djelfa. 750-850 m. June.1990.
40	Dame of Blidet Amor (Touggourt). 93 m. 10/05/1990.
41	Segger wadi (Biskra). 87 m. 9/05/1990.
42	Lake of Ain Saadane (El Biodh Sidi Cheich, El Bayad). 744 m. 17/05/1989.
43	Source of Ain EL Hammam (Brezina- El Bayad). 849 m. 18/05/1989.
44	Dam of Sidi Okba (Biskra). 54 m. 9/05/1990.
45	Lake of Gue of Arsaouet ((El Biodh Sidi Cheich, El Bayad). 744 m. 17/05/1989.
46	Source of El Goleita (Brezina- El Bayad). 849 m. 18/05/1989.

samples taken at different time were found. These suggest that morphotypes character differences are not local neither temporal, and are due to fragmented dispersion of *C. abyssorum mauritaniae.* This subspecies

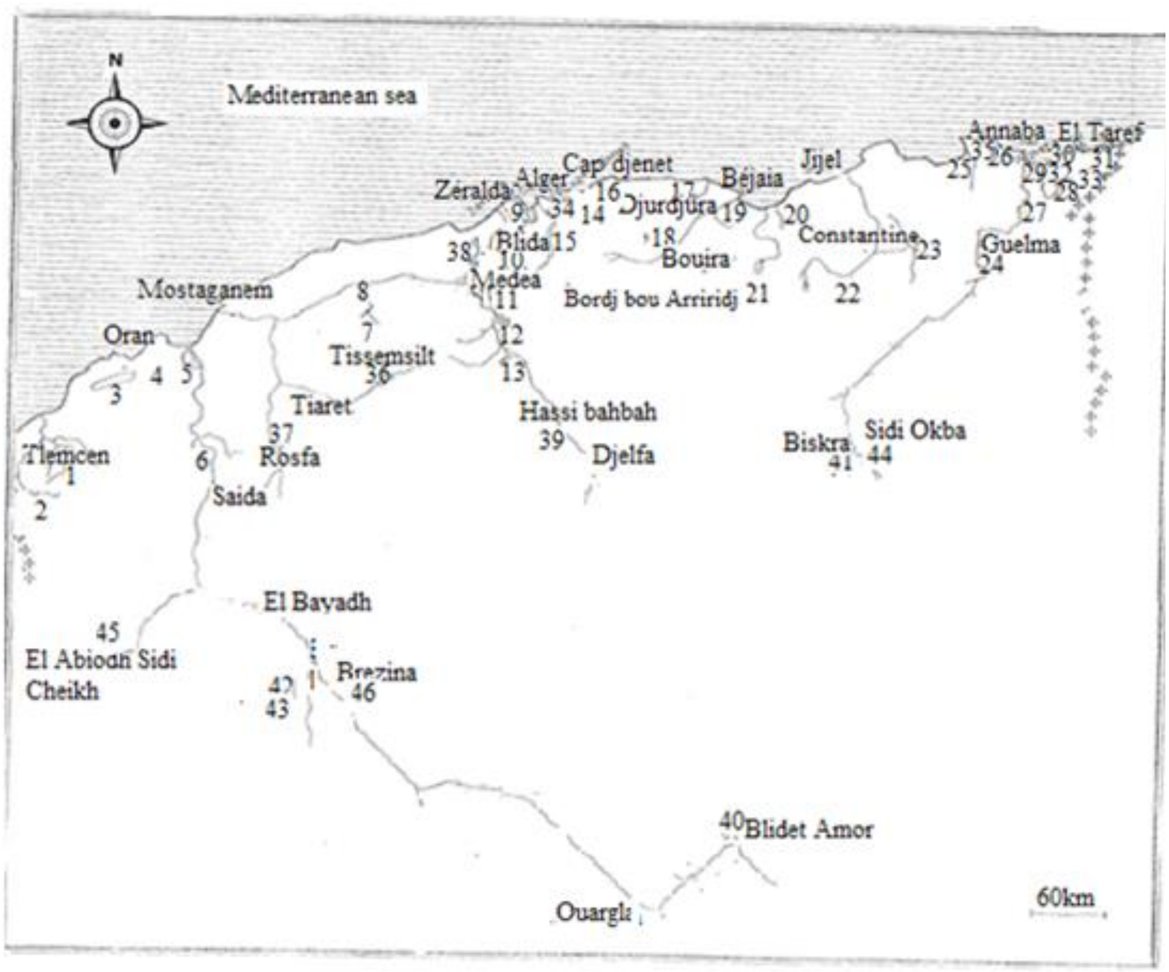

Figure 1. Sampled localities (numbers) in water bodies of Algeria.

Table 2. Material examined (Number(s) refer to the localities.

***Cyclops abyssorum mauritaniae* (Morphotype A)**	
22	Several males, several females.
23	Several males, several females.
24	Several males, several females, copepodites.
30	One female.
31	One female, copepodites.
35	Several males, several females
***Cyclops abyssorum mauritaniae* (Morphotype B)**	
8	Two females
3-*Cyclops abyssorummauritaniae* (Morphotype C)	
18	One male, several females

is well represented in the Eastern Region of Algeria and rare in the North and West regions, indicating that it originated in the East and began spreading to north and west Algeria taking different forms. *C. abyssorum*

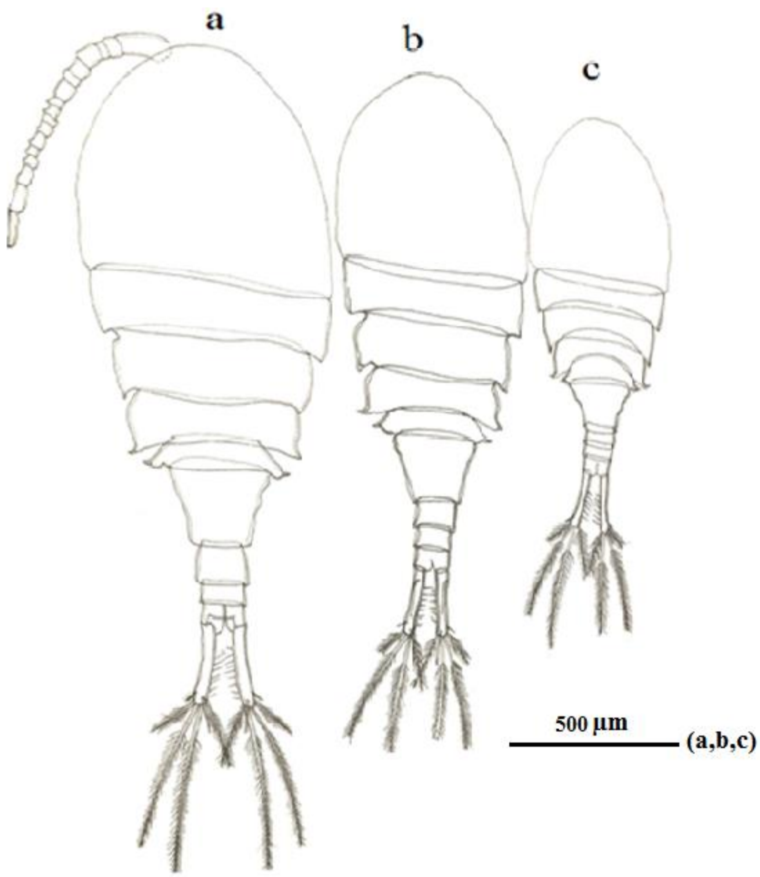

Figure 2. *C. abyssorum mauritaniae* Lindberg 1950. Habitus: a: morphotype A; b: morphotype B; c: morphotype C.

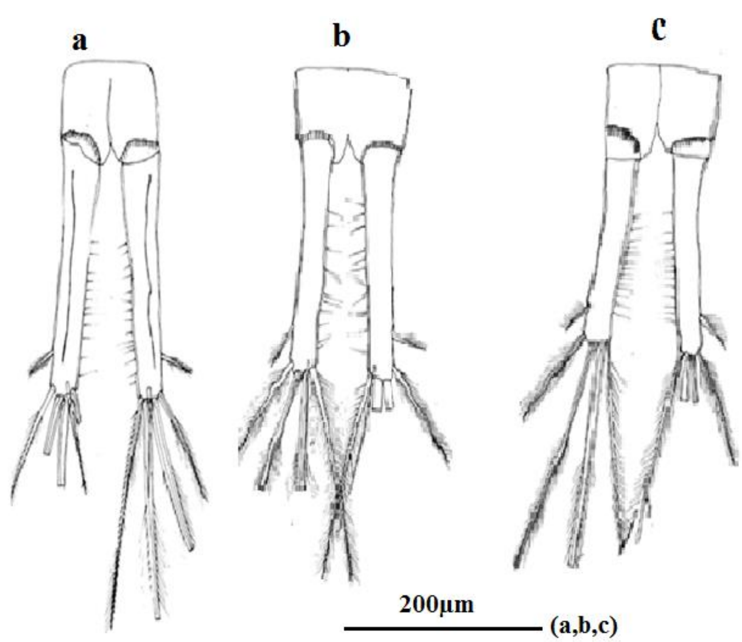

Figure 3. *C. abyssorum mauritaniae* Lindberg 1950. Furca: a: morphotype A; b: morphotype B; c: morphotype C.

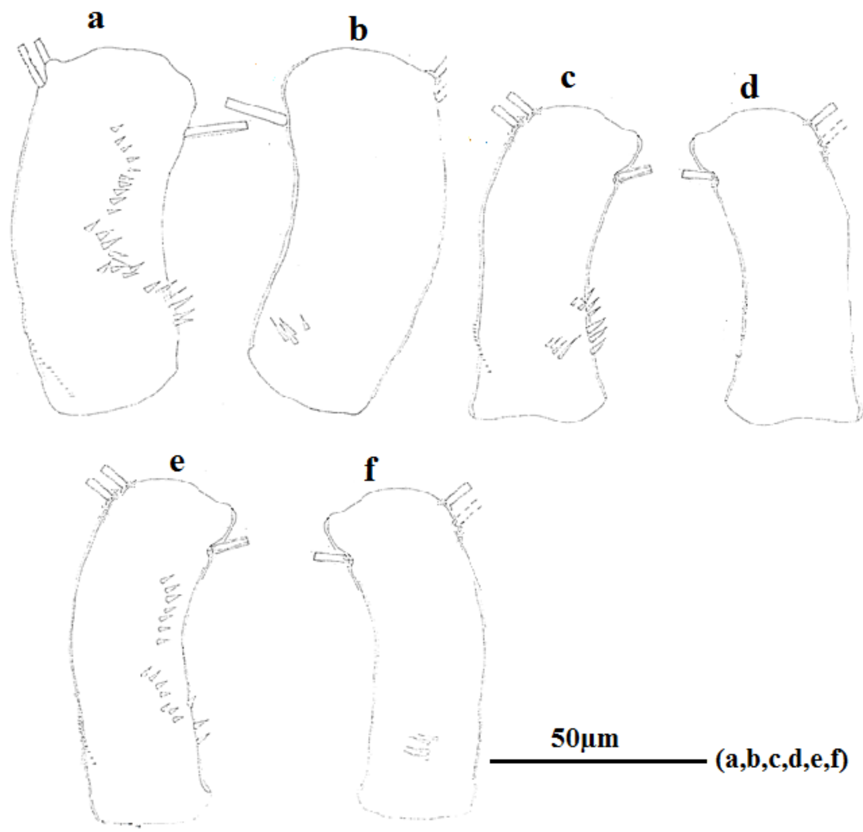

Figure 4. *C. abyssorum mauritaniae* Lindberg 1950. Surface ornamentation of antennal basis: Caudal surface (a) and frontal surface (b) of morphotype A, caudal surface (c) and frontal surface (d) of morphotype B; caudal surface (e) and frontal surface (f) of morphotype C.

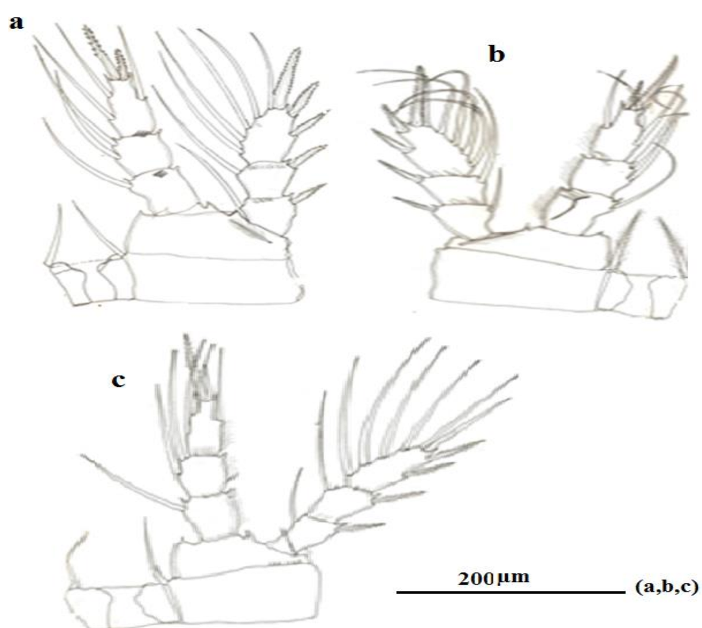

Figure 5. *C. abyssorum mauritaniae* Lindberg 1950. Fourth leg (P4): a, morphotype A; b: morphotype B; c: morphotype C.

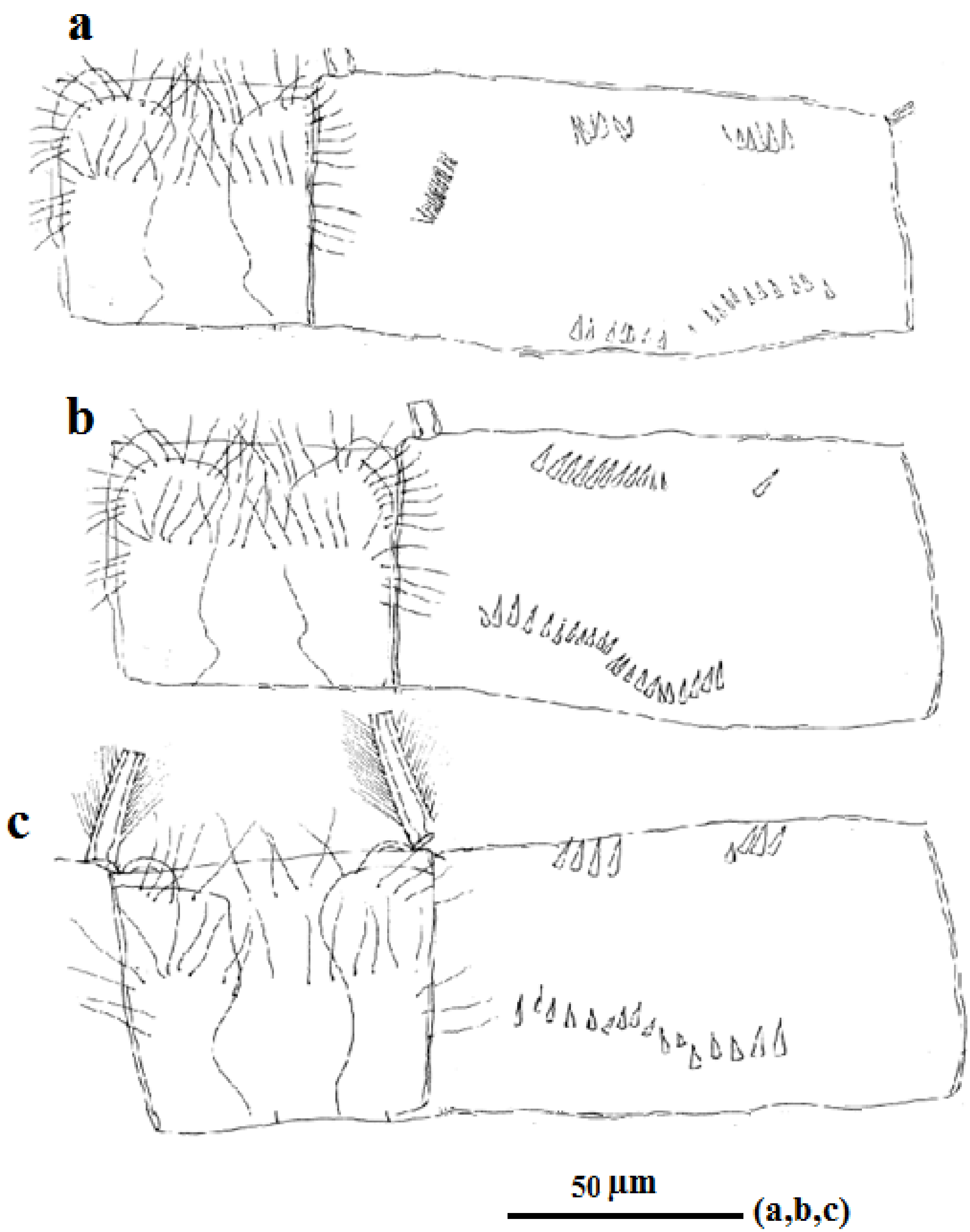

Figure 6. *C. abyssorum mauritaniae* Lindberg 1950. Caudal surface ornamentation of P4 coxa and connecting plate of the fourth legs (P4): a: morphotype A; b: morphotype B; c: morphotype C.

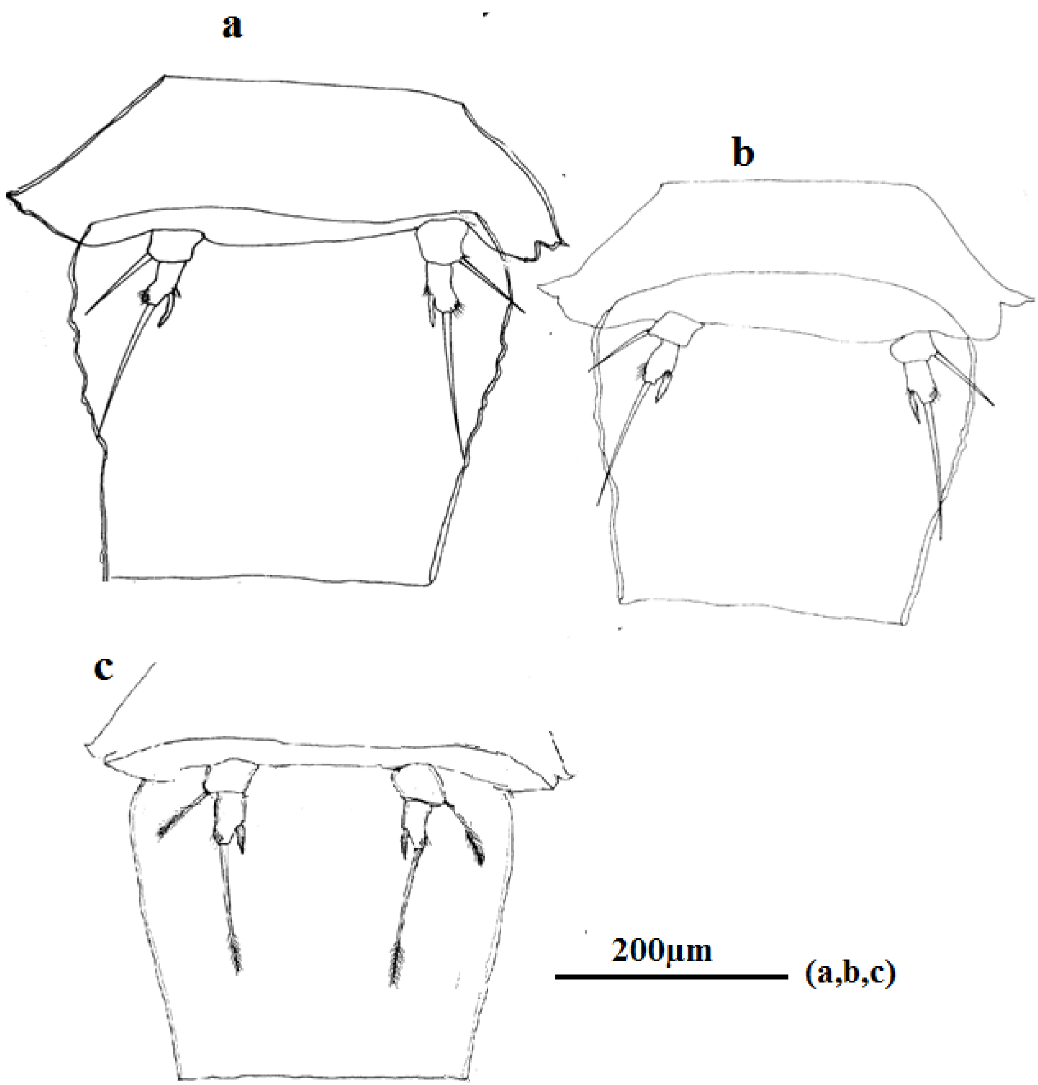

Figure 7. *C. abyssorum mauritaniae* Lindberg 1950. Fifth thoracic segment (Th5), fourth leg (P5) and genital segment: a: morphotype A; b: morphotype B; c: morphotype C.

mauritaniae is one of the relatively poorly known representatives of the Holarctic genus Cyclops. A study on the geographic variation of the morphological characters in this North African taxon might have been a very interesting.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Poor regeneration of Brown Oak (*Quercus semecarpifolia* Sm.) in high altitudes: A case study from Tungnath, Western Himalaya

Sunil Chandra Joshi[1*] and O. Roger Anderson[2]

[1]Government P. G. College Pithoragraph, India.
[2]Biology and Paleo Ecology, Lamont-Doherty Earth Observatory of Columbia University, Palisades, New York, U.S.A.

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This study was carried out in the timberline zone of Tungnath, Chopta region of the Chamoli District in India at eight altitudinal zones from 2,500 to 3,200 m, where the regeneration of Brown Oak was found to be very low. The data were obtained during the rainy season (August-September, 2016) by making counts of mature trees, saplings and seedlings in survey plots (50 × 50 m) at each of the eight altitudes. The results show a low regeneration of Brown Oak (*Quercus semecarpifolia* Sm.*)*. Three of the eight elevation zones (38%) were categorized as having fair regeneration, four (50 %) were categorized as poor, and one site had no regeneration. However, at some elevations, there were substantial numbers of seedlings (such as the highest density of 350,000 ha^{-1} was at an altitude of 2,800 m). This indicates that at this geographic region of Chamoli, where there is increasing annual temperatures and evidence of reduced precipitation, seedlings (though sometimes abundant) fail to survive and mature into saplings; thus, creating a threat to the survival of the Brown Oak in the near future unless remedial action is taken to ensure its conservation.

Key words: Biogeography, climate change, ecology of Tungnath forests, human livelihood, seedling survival, tree conservation.

INTRODUCTION

Across the Indian Himalayan region, over 35 species of Oak (*Quercus* spp.) are reported (Negi and Naithani, 1995). Among these, *Quercus semecarpifolia,* which represents the climax community, forms extensive forests in the high-altitude zones of Western Himalaya. *Quercus semecarpifolia* is a multipurpose tree used to provide fuelwood, fodder, agriculture implements and tannin. The species is also considered to be one of the oldest plants in the region (Shrestha, 2003), which has been over exploited for centuries in the Himalaya (Singh et al., 2011). Given the importance of this species, and other oak species in this region, additional attention has been given to documenting the regeneration capacity of the trees in high altitude forests of the Himalayan region. This

*Corresponding author. E-mail: sunil.svpg@gmail.com. Tel: 212 678-3385.

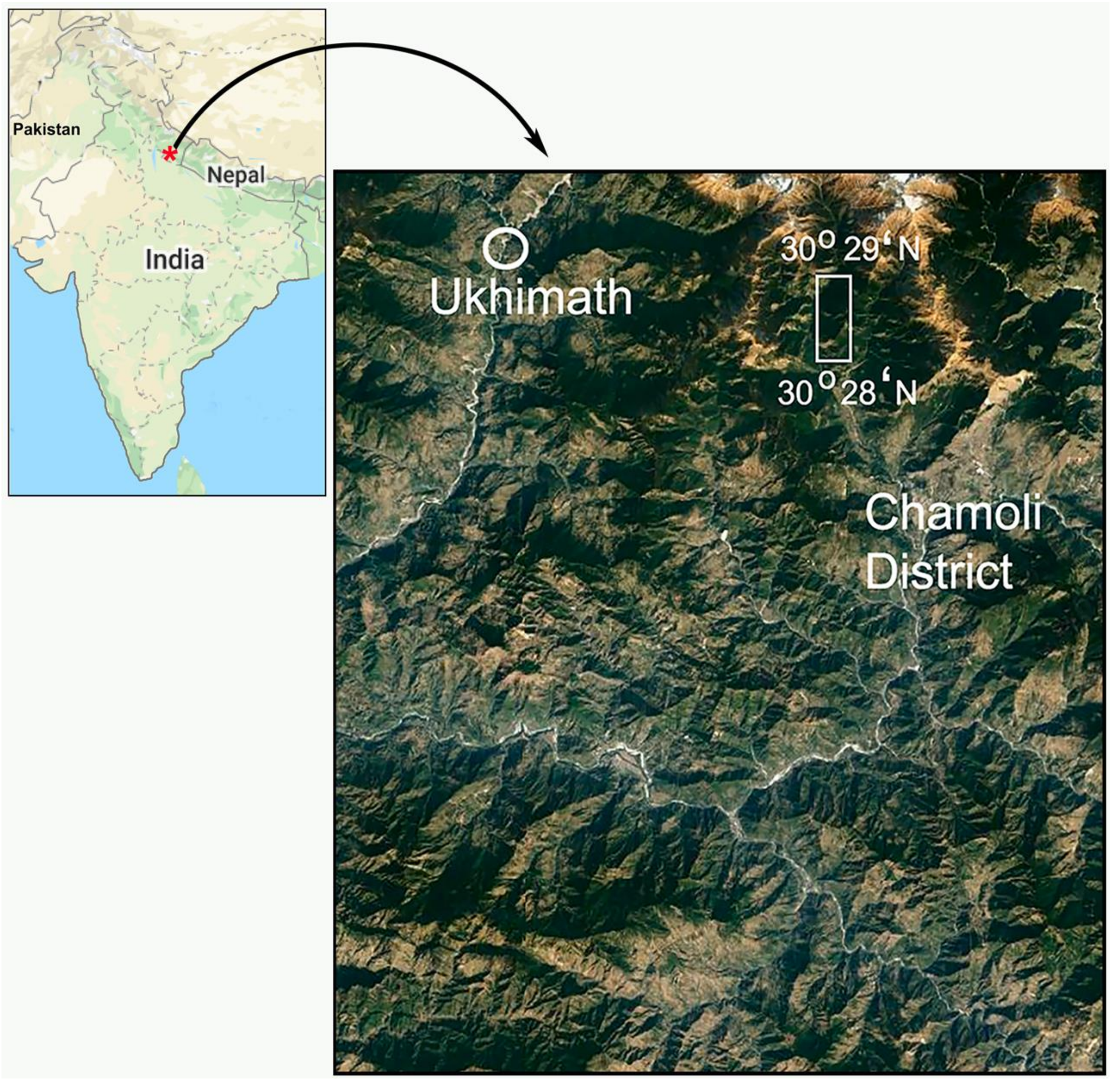

Figure 1. Study site (White rectangle) southeast of Ukhimath in the Chamoli District, State of Uttarakhand, India near the southern border of the Northwestern Himalayas (red asterisk) (Adapted from Google Earth).

includes Nepal (Shrestha, 2003; Vetaas, 2000), Western Himalaya (Bisht et al., 2011, 2013; Kumar et al., 2014; Rai et al., 2013; Singh and Rawat, 2012; Sing et al., 2011) and Northwestern Himalaya (Pant and Samant, 2012).

More recently, particular attention has been given to documenting the relative abundance and likely regeneration of *Q. semecarpifolia* in relation to other tree species in locations such as ridge forests of Western Himalaya (Malik and Bhatt, 2016; Sharma et al., 2016; Tiwari et al., 2018, Tewari et al., 2019). Nearly 70% of such studies have reported very poor regeneration in natural stands. Moreover, *Q. Semecarpifolia* has been reported to be vulnerable to climate change (Bisht et al., 2013), and there is increasing evidence that Western Himalaya is undergoing climate change with increasing annual temperatures in the State of Uttarakhand, and declining precipitation, especially in Chamoli (Yadav et al., 2014). Therefore, the purpose of this research was to document the status of *Q. Semecarpifolia* along an altitudinal range in the Western Himalaya district of Chamoli, and interpret its status in relation to current climate trends in the district.

MATERIALS AND METHODS

Study location

This study was carried out in the timberline zone of Tungnath, Chopta region of the Chamoli District in India (30°27'46.38'' – 30°28'58.30'' N; 79°13'07.80'' – 79°12'53.62'' E) as shown in Figure 1. The Chopta region is 29 km from Ukhimath, 162 km from Rishkesh, and approximately 450 km from the capital (Dehli). Sampling was done at eight altitude zones from 2,500 to 3,200 m, where the regeneration of Brown Oak was found to be very low.

Table 1. Results of the Brown Oak survey reported for each elevation zone.

Zone S/N	Elevation zone (m)	Latitude (N)	Longitude (E)	Trees (ind. ha^{-1})	Saplings (ind. ha^{-1})	Seedlings (ind. ha^{-1})	Regeneration pattern
1	2,500	30°27'46.38"	79°13'07.80"	123	0	13,833	Poor
2	2,600	30°27'58.67"	79°13'00.97"	120	13	7500	Fair
3	2,700	30°28'00.39"	79°33'10.44"	143	0	128,333	Poor
4	2,800	30°28'14.35"	79°33'12.38"	293	20	350,000	Fair
5	2,900	30°28'46.92"	79°12'35.82"	403	0	133,333	Poor
6	3,000	30°28'45.90"	79°12'46.59"	276	0	173,333	Poor
7	3,100	30°28'54.28"	79°12'53.63"	443	10	50,000	Fair
8	3,200	30°28'58.30"	79°12'53.62"	10	0	0	None

No. = number, N = North, E = East, ind. = individuals.

The data were obtained during the rainy season (August-September, 2016).

Sampling design and methods

For tree vegetation sampling at each of the eight elevation zones, three 50 × 50 m plots were identified that were representative of the forest vegetation at each zone. Within each plot, ten square sub-plots (10 × 10 m) were randomly placed for a total of 30 sub-plots. The size and number of sub-plots were determined according to Misra (1968), and Ellenberg and Mueller-Dombois (1974). Tree circumference at breast height (cbh) at 1.37 m height from the ground was measured in each sub-plot. Individuals > 31.5 cm cbh were considered trees, 31.5-10.5 cm cbh as saplings, and individuals <10.5 cm cbh (less than 1 m height) were considered as seedlings. To assess the current regeneration status, the method given in Kumar et al. (2014) was used, and their four categories of regeneration were applied to categorize the stands of *Q. Semecarpifolia* as follows: (i) *Good regeneration* - Seedling > Sapling > Adults, (ii) *Fair regeneration* - Seedling > Sapling ≤ Adults, (iii) *Poor regeneration* -Seedling and Adult trees only (Saplings absent), and (iv) *None* (no regeneration).

Additional data on changes in temperature and precipitation (www.carbonbrief.org; Yadav et al., 2014) have been included and used to interpret the results of this study, as reported in the Results and Discussion section. Data were entered in Excel files, tables were created to list numerical data, and column graphs were made to display densities of trees and seedlings at each sampling elevation. Chi-square analysis (http://quantpsy.org) was used to analyze tree density data within each altitudinal zone and to compare seedling densities with mature tree densities across the eight altitudinal zones. Correlation coefficients were calculated using an online calculator (socscistatistics.com).

RESULTS AND DISCUSSION

With respect to regeneration (Table 1), three of the elevation zones (38%) were categorized as having fair regeneration (altitude zones 2, 4 and 7) with negligible densities of saplings in the range of 10 to 20 individuals ha^{-1}. Four altitude zones (50%) were categorized as poor, with absence of saplings (altitude zones 1, 3, 5, and 6). One zone (altitude zone 8) had no evidence of regeneration and was categorized as none. This indicates that in some cases, the seedlings apparently fail to survive and mature into saplings. However, at some elevations there were substantial numbers of seedlings (the highest density of 350,000 ha^{-1} at altitude zone 4), although the density of samplings at this altitude zone was relatively low (20 individuals ha^{-1}).

The densities of mature trees and of seedlings are plotted as column graphs in Figure 2 to more clearly display the pattern of the densities, comparatively, in relation to elevation. In general, mature-tree densities (Figure 2A) are less at elevations of 2,500 to 2,700 m, but are substantially denser at elevations of 2,800 to 3,100 m. However, they are markedly less at 3,200 m. In contrast, seedlings (Figure 2B) are most dense in the range of 2,700 to 3,000 m, with a peak density in zone 4 (2,800 m); but even here, the number of saplings is not large (20 individuals ha^{-1}) as reported in Table 1.

By comparison, the mature tree density peaked at 3,100 m elevation (Figure 2A), while the seedling density at 3,100 m was among the lowest densities recorded at this site (Figure 2B). Overall, both mature trees and seedlings were least abundant in zone 8 (3,200 m). Most of the sampling zones occurred in locations that were either an approximate plateau or with a gently sloping terrain. However, zone 4 (2800 m) was a rather steep south-east facing slope extending for over 300 m from the base up to a small ridge at the top that marked the beginning of the next rather gentle sloping plateau where zones 5 through 8 were located. The presence of a peak in seedling densities (350,000 ha^{-1}) in zone 4 is likely due to the inaccessibility of this terrain to cattle and other grazing animals. Overgrazing and trampling on seedlings and young saplings by animals has been widely recognized as one of the threats to regeneration of *Q. semecarpifolia* more broadly in Western Himalaya (Shrestha, 2003).

The densities of mature trees in elevation zones 1 to 8 (Figure 2A) were statistically different from one another based on one-way chi-square analysis (X^2 = 710.3, df = 7, p < 0.001). Likewise, the densities of seedlings in the eight elevation zones (Figure 2B) were statistically

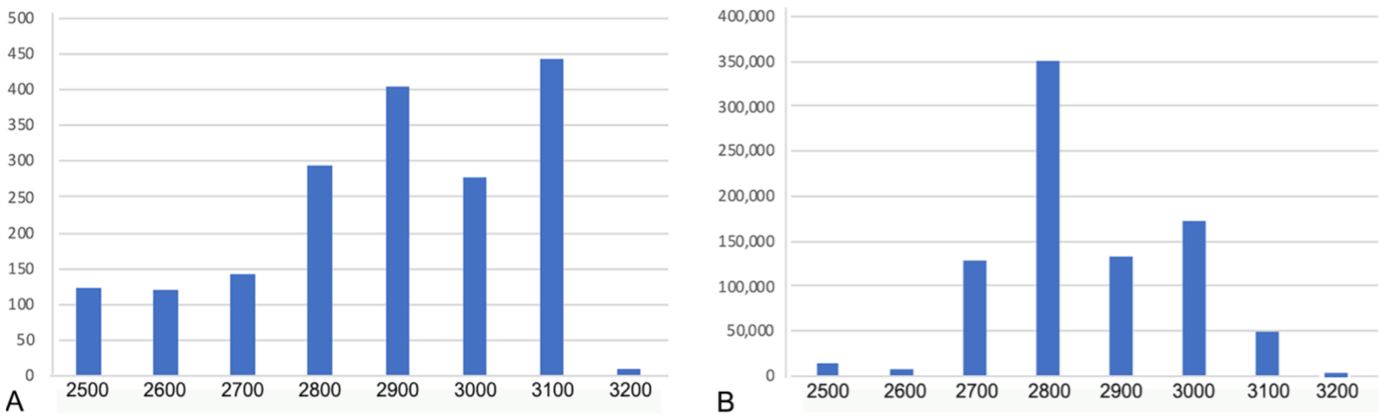

Figure 2. Column graphs comparing densities (number ha^{-1}, ordinate) of mature trees (A) and seedlings (B) across the eight altitude zones 2,500 to 3,200 m (abscissa).

different (X^2 = 914.4, df =7, p < 0.001). Furthermore, a two-way chi-square analysis of the densities of the mature trees compared to the densities of the seedlings across the eight elevation zones was statistically significant (X^2 = 3,523, df = 7, p < 0.001), suggesting a lack of correlation between densities of mature, seed-producing trees and densities of seedlings at the eight elevation zones. A correlation analysis of the densities of mature trees and the densities of seedlings at the eight altitude zones was used to further examine the pattern of relationships. There was no statistically significant correlation between densities of mature trees and the densities of seedlings (r = 0.42, p = 0.30, df = 7). Given the very low densities of saplings across all altitudinal zones, no further statistical analyses were made with this data. Overall, these data indicate that the densities of seedlings are not significantly related to the densities of mature, acorn-bearing trees in these eight elevation zones in the Chamoli District; and this suggests that other factors such as animal predation, environmental stress and climatic forcing functions may account for some of the poor regeneration in the region.

Currently, there is increasing evidence of climate change in the Western Himalayas. For example, there has been a 1.1°C warming as of 2020, in the State of Uttarakhand where the District of Chamoli is located (https://www.carbonbrief.org); and based on an analysis of 41 years of data, there has been a statistically significant decrease in the annual precipitation in the District of Chamoli, particularly during the post-monsoon and winter seasons (Yadav et al., 2014). *Q. Semecarpifolia* is a viviparous oak; the acorns begin germination before or during their deposition on the ground (Tewari et al., 2019). This makes them particularly sensitive to possible stress during the post-monsoon and subsequent winter seasons, when the seedlings are becoming established. Tewari et al. (2019), who studied acorn maturation and regeneration in *Q. Semecarpifolia* in the Western Indian Himalayan region, reported that acorn maturation and regeneration are particularly dependent on moisture. They noted the presence of a large number of fallen seeds with dried emerged radicals, varying in length between 2 and 6 cm, and stated this was a clear indicator that intermittent patterns of rainfall, followed by long stretches of rainless periods, resulted in drying of radicals and ultimate mortality of seeds. Furthermore, the seedlings of *Q. Semecarpifolia* are light-demanding, and any change in canopy tree species with possible increased shade could result in further decreased regeneration of this species (Singh and Singh, 1987).

The study is consistent with most of the previous reports, suggesting failure of Brown Oak regeneration in the Himalaya region (Tewari et al., 2019), but it provides additional information on the status of seedlings and likely regeneration potential of Brown Oak across a much broader altitudinal range (2,500 to 3,200 m) up to the timberline; particularly in the District of Chamoli, where there is evidence of declining patterns of precipitation. An earlier study by Saran et al. (2010) concluded that there can be a reduction of 40% or as much as 76% in the stands of *Q. semecarpifolia* in present habitats; if there is a 1 or 2°C global temperature rise, respectively, as predicted (IPCC, 2014). Evidence also indicates a relatively higher rate of temperature rise in some regions of the Himalayas (1.5°C) in recent decades compared to the global average (Shrestha et al., 2012), suggesting that the pressure on survival of *Q. semecarpifolia* may be even more severe than predicted by some conservative estimates. Increasing temperatures, particularly during night, places additional respiratory demands on seedlings and saplings; thus, contributing to potential declines in their carbohydrate reserves, especially if increased temperatures are coupled with decreasing precipitation that may result in water stress and lower stomatal conductance producing less photosynthetic gains during the day. This scenario of seedlings' failure to establish calls for more dedicated attention to conservation of the species, including more diligence in reducing anthropogenic sources of stress such as predation by domesticated animals, and excessive harvesting of the trees for lumber and other practical uses, especially at higher elevations. *Q. semecarpifolia* is an important component of high-altitude forest ecosystems, and changes in its dominance could have wide-ranging implications for regional ecology and human livelihoods.

Conclusions

Regeneration of Brown oak (*Q. semecarpifolia*) across eight altitudinal zones (2,500 - 3,200 m) in the Chamoli District of the state of Uttarakhand shows evidence of serious decline, ranging from no regeneration at the highest altitude (3,200 m) to *poor* or *fair* at the seven other lower altitudes. In addition to possible anthropogenic effects (cutting the forests and damage due to invading domestic animals), a changing climate (including increased temperatures and declining precipitation, particularly in the Chamoli District) may adversely affect regeneration of Brown Oak more broadly in Uttarakhand. Given the changing stress due to climate change, more earnest attention should be given to conservation of the Brown Oak, especially at higher altitudes, with particular attention to reducing anthropogenic sources of damage such as limiting grazing by domesticated animals and regulating cutting of trees for lumber and other practical uses.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

An appraisal of ecotourism's impact on biodiversity conservation: The case of Campo Ma'an National Park, Cameroon

Gadinga W. Forje[1]* Tchamba N. Martin[1] and Eno-Nku Manasseh[2]

[1]Department of Forestry, University of Dschang, P. O. Box 222, Cameroon.
[2]WWF Kudu Zombo Programme, P. O. Box 6776 Yaounde, Cameroon.

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Ecotourism is often perceived as a strategy for sustainable biodiversity conservation for protected areas. In Cameroon, there is dearth of information on the impacts of ecotourism on biodiversity conservation of protected areas. The main thrust of this study is to examine local population's perceptions of the impact of ecotourism on biodiversity conservation in and around the Campo Ma'an National Park (CMNP). Data were collected from both primary and secondary sources. Primary data were gotten from household survey (N=124), focus group discussions (N=8) and key informant interviews (N=16). From the findings, 44.4% of the local population perceived ecotourism activities contributing to biodiversity conservation of CMNP against 55.6% with contrary views. Spearman rank correlation coefficients and Chi-square test statistics indicated that, variables plausibly influencing local population's perception of ecotourism impact on biodiversity conservation in and around CMNP were age ($p<0.10$), gender ($p<0.50$), main occupation ($p<0.10$), secondary occupation ($p<0.10$), time spent in the community ($p<0.50$), and number of children ($p<0.50$). From the logistic regression model, the main variables affecting the local population's perception were age, gender and time spent in the community. This study recommends the development of ecotourism friendly policies that can accelerate Public Private Partnership for a participatory and sustainable ecotourism approach for biodiversity conservation and livelihood enhancement in and around the CMNP. It also recommends the development of a gender sensitive ecotourism that will fair opportunities for rural women to benefit from ecotourism activities.

Key words: Ecotourism, biodiversity conservation, perception, adjacent population, national parks, Campo Ma'an National Park, South Cameroon.

INTRODUCTION

Ecotourism has often been perceived as a strategy for sustainable biodiversity conservation in and around protected areas (Andrade and Rhode, 2012; Tchamba et al., 2015; Moshi, 2016; Imanishimwe et al., 2018; Sama

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

and Molua, 2019). Across sub-Saharan Africa, different studies have been undertaken resulting in different findings. Kruger (2003) has highlighted two important factors affecting the level of conservation within protected areas by ecotourism: the type of flagship species and the involvement of the local communities and noted the inevitable participation of local communities in the success of ecotourism projects for conservation goals.

Ecotourism functions as an alternative source of livelihood to those which are environmentally degrading (poaching, illegal timber exploitation, unsustainable farming, etc.), thus contributing to both biodiversity conservation and sustainable community development (Das and Chatterjee, 2015). This is seen through environmental education within protected areas through tourism; alternative livelihood opportunities to the unemployed; benefit-sharing of ecotourism-based conservation revenue to local communities (Sander, 2012; Sunita, 2013; Cheung, 2015).

For ecotourism to contribute to biodiversity conservation, the local population must be engaged, involved and empowered in the ecotourism chain for imperative success in Africa’s conservation model (Cheung, 2015). Imanishimwe et al. (2018) investigated the contribution of ecotourism to the conservation of Nyungwe National Park in Rwanda, by examining the integration of local communities in the conservation of the park and ecotourism's contribution to revenue sharing for community development and conservation. The outcome of the study reveals that the number of tourists increased remarkably, suggesting more revenue to be shared. Unfortunately, benefits earned by the local population is not up to their expectations as huge proportion of the benefits is earned by lodge owners in contrast to the promises they were made to belief they will have from ecotourism activities.

Although revenue sharing is an imperative to ecotourism enhancing biodiversity conservation, inadequate revenue sharing from ecotourism to communities have negatively affected biodiversity conservation efforts to reduce threats in and around parks (Kimbu, 2010), with cases of poaching, tree felling and mining, cited among many other illegal activities which are jeopardizing conservation efforts despite ecotourism increase in and around Parks (Kimbu, 2010; Imanishimwe et al., 2018).

Ecotourism shall contribute more to conservation if it is expanded above the traditional ‘Big five' species (lions, elephants, buffaloes, leopards and rhinoceros). Such an expansion will increase the viewing preferences and interests of different visitors and can call for attention and stimulate funding to species which are less iconic so as to achieve greater overall biodiversity conservation (Cheung, 2015).

Spenceley (2006), questioned if ecotourism benefits conservation and the local people? The development of large ecotourism groups such as Wilderness Safaris and Conservation Corporation Africa has demonstrated their commitment to conservation efforts and poverty alleviation within the local communities around protected areas in South Africa. In terms of the contribution of ecotourism to conservation efforts, ecotourism, through ecotourism groups have been involved in joint ventures with local communities. This has been through sensitization, employment opportunities, training, scholarship for students in higher learning institutions and benefit-sharing resulting in the reduction of pressure on the conserved biodiversity. The efforts of the ecotourism groups in different communities in South Africa have helped in the conservation of endangered species like Black and White Rhino and Cheetah. Also, the partnership between ecotourism groups and the local communities in South Africa has also contributed directly to conservation through the transformation of degraded farmland within ecotourism communities into world-class wild life destination. For example, 12699 ha of the degraded farm plots in the Munyawana conservancy in the KwaZulu-Natal area was taken over in 1991, resulting in its rehabilitation and restocking with over 1500 animals amongst which were white rhino.

Tieguhong (2008) pointed out that the high expectations of ecotourism to cater for the needs of the local people and the conservation of biodiversity are achievable in the Congo Basin. He further explains that ecotourism accounts for 20% of the total international tourism. The number of protected areas with potentials for ecotourism is also increasing in the Congo Basin, therefore so too could be the revenue from ecotourism. The result of the study also shows that, if all other sources of park revenue like lodging, donations, restaurants and shops are ignored with focus only on maximum entrance fees, the Lobeke National Park will be able to cover its recurrent costs in 31 years and to self-fund the entire park budget in 36 years with an annual growth rate of 10% in the tourism sector. As for the Dzanga-Ndoki National Park, 11 years would be required to cover recurrent costs and 17 years to cover the funding of the entire Park.

As seen from the foregoing, most studies have laid emphasis on the role played by ecotourism in biodiversity conservation around protected areas in general. The specificity of this study lies in the fact that it sought to assess the impact of ecotourism on biodiversity conservation in and around the Campo Ma'an National Park, where a western lowland gorilla habituation project, the first in Cameroon is near completion. The study examined the factors affecting the local population's perception of ecotourism's impact on biodiversity conservation in and around the CMNP, South region of Cameroon. Biodiversity conservation in this study focuses on the efforts made in the sustainable management of protected wildlife species found in and around the park, amongst which are gorillas, chimpanzees, forest elephants, giant pangolin and

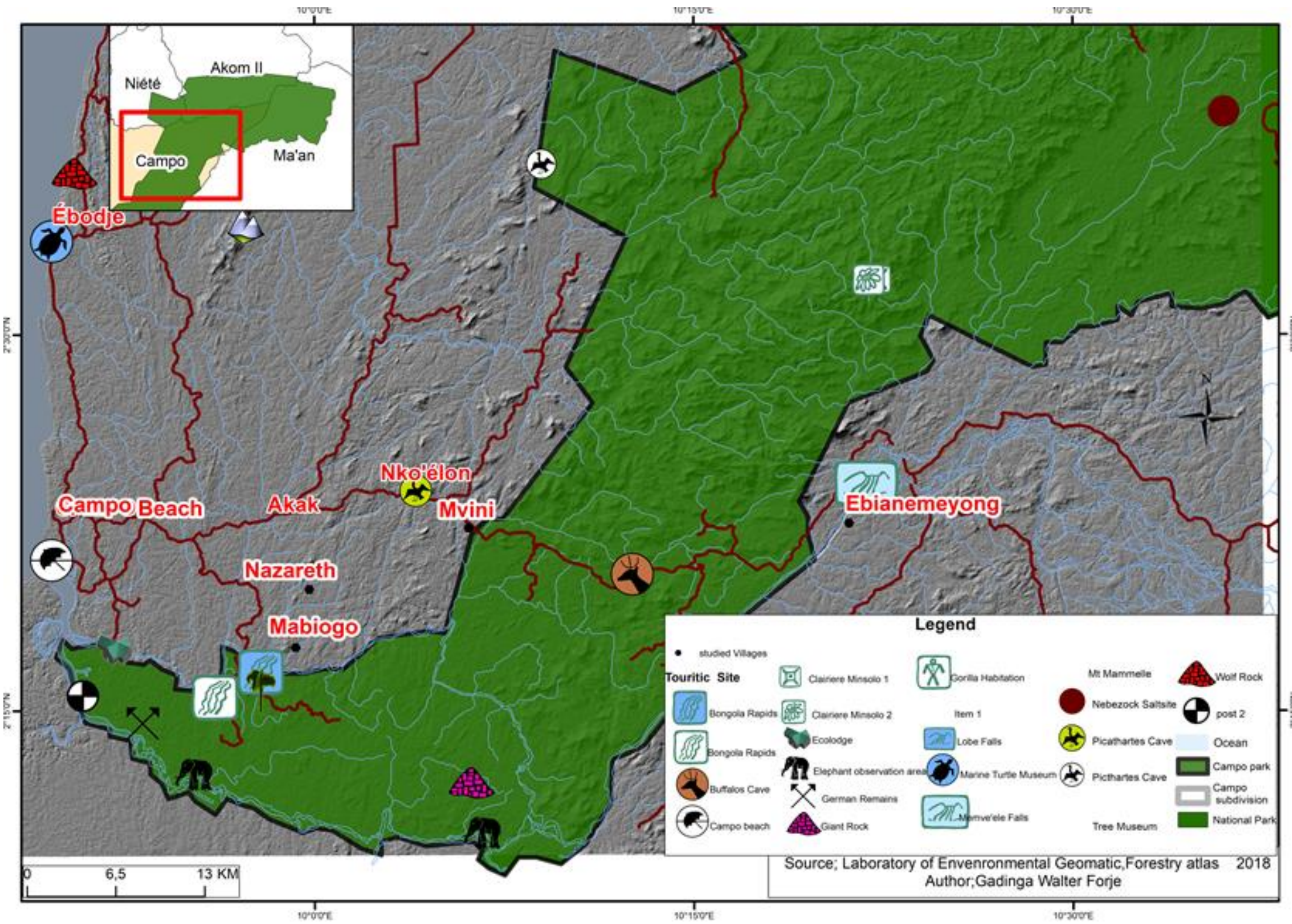

Figure 1. Map of the study area.

marine turtles. The objectives were to:

(1) Assess the local perception of ecotourism on biodiversity conservation in CMNP, and
(2) Examine the factors affecting the perceived ecotourism impacts on biodiversity conservation in the CMNP.

MATERIALS AND METHODS

Description of study area

The investigation was undertaken in communities adjacent to the Campo Ma'an National Park (CMNP), found within the Campo sub-division, south region of Cameroon. The CMNP lies between latitude 2°15'N to 2°30'N and longitude 10°00'E to 10°15'E (Figure 1). Rainfall generally increases as one goes from the interior towards the coast, implying the coast receives more rainfall than the hinterlands. Located close to the coast, the community of Campo receives an average annual rainfall of 2800 mm and while Nyabissan found further inland receives an average annual rainfall of 1670 mm annually (PNCM, 2014; Tchouto, 2006). The mean annual temperature is about 25°C. Some variations however occur between the western and eastern sections of the CMNP in terms of temperature.

Hydromorphic and ferralitic soils are the most dominant types of soils. Hydromorphic soils are found within the valleys and lowlands; while ferralitic soils develop on acidic parent rocks, and are generally yellowish or reddish in colour. The dense Guineo-Congolese evergreen forest is the main vegetation type (Letouzey, 1985) found around the CMNP and its environs. The CMNP and its environs make up part of the Atlantic basin drainage system. Two main watersheds are found in the environs of the CMNP: The Ntem and the Lobé watersheds, characterized by rivers which flow in a NE-SW direction (Mbenoun, 2017).

Sampling

The study made use of purposive sampling to select suitable communities and sections of the park. The selection of these communities or sections of the park were based on endowments with ecotourism potentials or existing ecotourism facilities. Households with persons indigenous to the community, and persons living in the community for the past 1 year and more were targeted if they practiced activities around the park like: harvesting of Non-Timber Forest Products (NTFPs), farming, tourism and trade, fishing, and hunting. This was due to the fact that such activities are related to biodiversity management in and around the park. Snowball sampling was used to select the participants for focus group discussions and key informant interviews.

Data collection

Data for the study were collected from primary and secondary sources. With regards to secondary data, data were collected from books and book chapters, scientific articles, dissertations, theses, projects and technical reports and from other internet sources. Emphasis was laid on the relationship between ecotourism and conservation in protected areas in general and national parks in particular.

The administering of questionnaires, key informant interviews, focus group discussions and observations were used to collect primary data. The questionnaires, interviews and questions for focus group discussions were developed by the authors in collaboration with the Wildlife Fund for Nature (WWF) after a reconnaissance survey of the area. The questionnaires for the local population were made up of 27 questions focusing on the socio-economic characteristics, their involvement in ecotourism activities and the perceived impact of ecotourism to conservation in the area. The interview guides and questions for focus group discussion were made up of 15 and 17 questions, aimed at investigating the level of involvement of the local population to ecotourism and the perceived impact of ecotourism to conservation for cross validation of local perception and data triangulation. Both open and close-ended questions were used. The services of a local translator were solicited in each community, to help translate the questions into the dialect.

In order to obtain information on the perceived contributions of ecotourism to biodiversity conservation in and around the CMNP, household surveys were carried out using semi-structured questionnaires. These semi-structured questionnaires were administered to the different actors in the ecotourism sector. A total of 124 questionnaires were administered. The questions were structured to collect information on the role played by ecotourism (positive or negative) on biodiversity conservation in and around the CMNP.

Key informant interviews and focus group discussions were used to collect information on the capacity of ecotourism to enhance biodiversity conservation in and around the CMNP. Information collected through key informant interviews, focus group discussions and direct field observations was mainly used to ascertain the truthfulness of responses obtained during household surveys.

Data analysis

Data collected were coded and inserted into the Statistical Package for Social Sciences (SPSS 19.1) for descriptive and inferential statistical analysis. The main descriptive statistics computed were charts and percentage indices. The main inferential statistics computed were Chi-square test statistic, Spearman rank correlation and the binomial logistic regression.

To determine the non-cause-effect relationship existing between independent variables and the impact of ecotourism on biodiversity conservation in and around the CMNP, the Chi-square test statistic (Equation 1) and Spearman correlation (Equation 2) were used. The Chi-square test statistic and the Spearman correlation are expressed as follows:

Chi-square test statistic $(\chi^2)=(a\times d-b\times c)^2\times N/(a+c)\times(b+d)\times(a+b)\times(c+d)$ (1)

Where a is frequency of males who think ecotourism contributes to biodiversity conservation; b is frequency of males who think ecotourism does not contribute to biodiversity conservation; c is frequency of females who think ecotourism contributes to biodiversity conservation; d is frequency of females who think ecotourism does not contribute to biodiversity conservation; N is the total frequency of all observations.

$$\text{Spearman rho} = 1 - \frac{6\Sigma(\mathrm{di})^2}{\mathrm{n}(\mathrm{n}^2-1)} \quad (2)$$

where n is the numbers of pairs of values of variables X and Y; di is the difference obtained from subtracting the rank of Yi from the rank of Xi; $\Sigma(\mathrm{di})^2$ is the sum of the squared values of di.

To evaluate the cause-effect relationship existing between independent variables and the impact of ecotourism on biodiversity conservation around the CMNP, the binomial logistic regression (BNL) (Equation 3) was used. The binomial logistic regression model is expressed as follows:

$$\mathrm{BNL} = \ln\left(\frac{\hat{\mathrm{Y}}}{1-\hat{\mathrm{Y}}}\right) = \propto\ +\beta X \quad (3)$$

where $\hat{Y}$ is the predicted probability of the event (ecotourism contributes to biodiversity conservation); $1-\hat{\mathrm{Y}}$ is the predicted probability of the other decision (ecotourism does not contribute to biodiversity conservation); X are the independent variables (gender, age, occupation, level of education, marital status, etc).

SPSS version 19.1 was used for descriptive and inferential statistical analysis.

RESULTS

Descriptive statistics for independent variables

The main descriptive statistics computed for the independent variables of the study were mean, standard deviation, variance, minimum and maximum (Table 1).

Since most of the variables were qualitative, they were coded using numbers ranging from 0, 1, 2, 3, 4, etc. Based on these, the aforementioned descriptive statistics were computed. Table 1 shows the descriptive statistics for independent variables like community, age, gender, main occupation, secondary occupation, level of education, ethnic group, time spent in the community, marital status and number of children.

Local population's perception of the impact of ecotourism around the CMNP on biodiversity conservation

An analysis of local population's perception of the impact of ecotourism around the CMNP on biodiversity conservation showed that the population had divergent views (Figure 2).

Findings revealed that most of the respondents (55.6%) perceived ecotourism as not contributing to biodiversity conservation; meanwhile 44.4% of the respondents' perceived ecotourism as contributing to biodiversity conservation. This goes to show that the respondents

Table 1. Descriptive statistics for independent variables of the study.

Independent variable	Mean	Std. Dev.	Variance	Min.	Max.	N
Community	4.50	2.83	8.01	1	9	124
Age	2.13	0.75	0.57	1	3	124
Gender	0.66	0.48	0.23	0	1	124
Main occupation	4.07	2.79	7.78	1	11	124
Secondary occupation	2.84	2.87	8.25	0	10	124
Level of education	1.46	1.28	1.65	0	4	124
Ethnic group	2.84	1.70	2.88	1	6	124
Time spent in the community	2.39	0.79	0.63	1	3	124
Marital status	0.73	0.51	0.26	0	2	124
Number of children	3.77	2.53	6.40	0	12	124

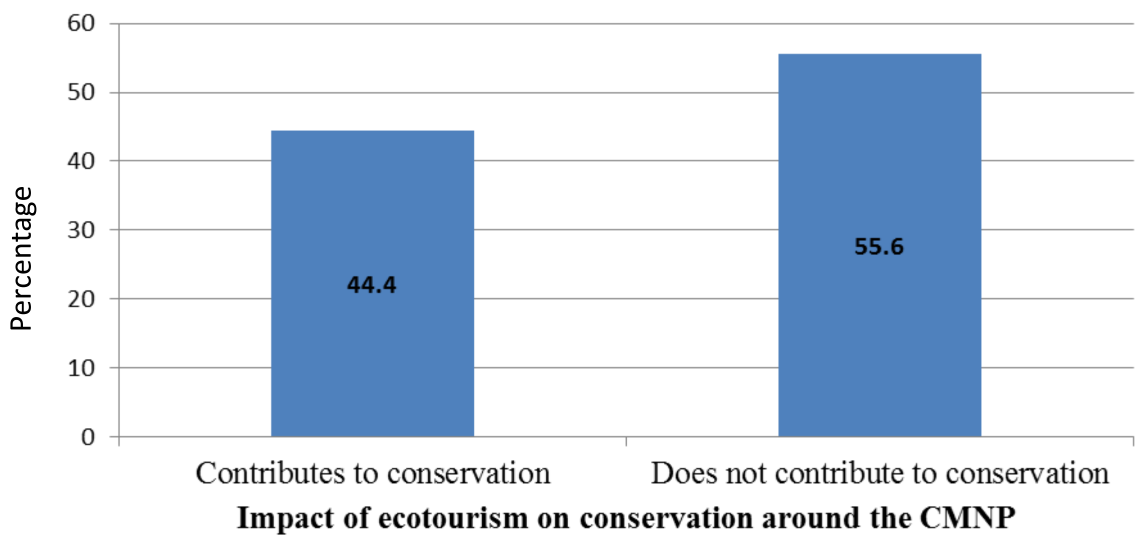

Figure 2. Perceived impact of ecotourism on biodiversity conservation around the CMNP.

had divergent views as far the role played by ecotourism in biodiversity conservation in and around the CMNP is concerned. However, it is clearly noticed that most respondents perceived ecotourism as contributing little to biodiversity conservation in and around the CMNP.

Non-cause-effect and cause-effect relationship between the impact of ecotourism on biodiversity conservation around the CMNP and independent variables

Non-cause-effect relationship between the impact of ecotourism on biodiversity conservation around the CMNP and independent variables

Chi-square test statistic demonstrated the existence of a non-cause-effect relationship between independent variables and the role played by ecotourism in biodiversity conservation in and around the CMNP (Table 2).

The Chi-square test statistics indicated that independent variables like age (χ^2 = 3.95; p<0.10); gender (χ^2 = 4.62; p<0.05); main occupation (χ^2 = 8.50; p<0.10); secondary occupation (χ^2 = 13.68; p<0.10); time spent in the community (χ^2 = 11.45; p<0.05); and number of children (χ^2 = 9.42; p<0.05) had a statistically non-cause-effect relationship with the perceived impact of ecotourism on biodiversity conservation. Meanwhile independent variables like community (χ^2 = 9.24; p>0.10); level of education (χ^2 = 3.98; p>0.10); ethnic group (χ^2 = 9.22; p>0.10); and marital status (χ^2 = 0.49; p>0.10) had a statistically insignificant cause-effect relationship with the perceived impact of ecotourism on biodiversity conservation. This implies that independent variables like age, gender, main occupation, secondary occupation, time spent in the community and number of children

Table 2. Chi-square test statistic showing non-cause-effect relationship between the impact of ecotourism on biodiversity conservation around the CMNP and independent variables.

Independent variable	Description	Contributes to conservation (freq.)	Does not contribute to conservation (freq.)	Chi-square (χ^2)	p-level
Community	Ebianemeyong	11	12	9.24^{ns}	0.323
	Ebodje	10	10		
	Mabiogo	3	11		
	Nazareth	4	7		
	Mvini	3	2		
	Nkoelon	8	7		
	Campo Beach	4	6		
	Akak	2	8		
	Campo	10	6		
Age	≤ 30 years	17	11	3.95*	0.089
	31 - 45 years	21	31		
	> 46 years	17	27		
Gender	Female	13	29	4.62**	0.034
	Male	42	40		
Main occupation	Hunting	3	6	8.50*	0.084
	Fishing	11	11		
	Farming	20	34		
	Petty trade	5	6		
	Building	1	3		
	Driving	1	0		
	Gorilla tracking	2	1		
	Working with NGO	7	2		
	Eco-guard	3	4		
	Others	2	2		
Secondary occupation	None	14	21	13.68*	0.091
	Hunting	10	2		
	Fishing	5	6		
	Farming	13	20		
	Petty trade	3	12		
	Dress making	0	1		
	Gorilla tracking	3	1		
	Working with NGO	5	4		
	Others	2	2		
Level of education	No formal education	12	18	3.98^{ns}	0.409
	Primary	21	27		
	Secondary	7	13		
	High school	5	6		
	Tertiary	10	5		
Ethnic group	Iyassa	13	16	9.22^{ns}	0.101
	Mvae	18	25		
	Bagyeli	8	5		
	Mabi	4	10		

Table 2. Contd.

	Beti	1	7		
	Others	11	6		
Time spent in the community	≤ 5 years	10	14		
	6 -10 years	10	18	11.45**	0.045
	> 10 years	35	37		
Marital status	Not married	18	19		
	Married	35	48	0.49^{ns}	0.783
	Divorced	2	2		
Number of children	0	9	6		
	1	3	6		
	2	12	8		
	3	5	11		
	4	6	10		
	5	6	10	9.42**	0.049
	6	5	8		
	7	6	4		
	8	1	4		
	9	1	2		
	12	1	0		

**, *Significant at 5 and 10% probability levels respectively; ns = not significant.

Table 3. Spearman correlation showing direct and indirect non-cause-effect relationship between the impact of ecotourism on biodiversity conservation around the CMNP and independent variables.

Independent variable	Spearman rho coefficient	p-level
Community	0.018	0.840
Age	-0.153*	0.089
Gender	0.200**	0.032
Main occupation	0.300**	0.012
Secondary occupation	-0.037	0.682
Level of education	0.100	0.290
Ethnic group	0.027	0.769
Time spent in the community	0.287**	0.017
Marital status	-0.047	0.602
Number of children	-0.286*	0.018

**, *Significant at 5 and 10% probability levels respectively; ns = not significant.

plays a plausible significant role in influencing the community perception on the impact of ecotourism on biodiversity conservation in and around the CMNP.

Findings equally showed the existence of a direct and indirect non-cause-effect relationship between independent variables and the perceived impact of ecotourism on biodiversity conservation in and around the CMNP (Table 3).

Coefficients of the Spearman rank correlation showed that independent variables like gender (rho = 0.200; p<0.05); main occupation (rho = 0.300; p<0.05); and time spent in the community (rho = 0.287; p<0.05) all had a statistically significant direct non-cause-effect relationship with perceived impact of ecotourism on biodiversity conservation in and around the CMNP. Independent variables like age (rho = -0.153; p<0.05) and number of

Table 4. Logistic regression showing cause-effect relationship between independent variables and impact of ecotourism on the local population around CMNP.

Independent variable	B	p-level	df	Exp (B)
Constant	-1.089*	0.098	1	0.337
Community	-0.063	0.461	1	0.939
Age	-0.683**	0.037	1	0.505
Gender	0.917**	0.045	1	2.501
Main occupation	0.148	0.185	1	1.160
Secondary occupation	0.021	0.776	1	1.021
Level of education	0.156	0.453	1	1.169
Ethnic group	-0.121	0.483	1	0.886
Time spent in the community	0.473*	0.095	1	1.604
Marital status	0.106	0.817	1	1.111
Number of children	0.055	0.610	1	1.057
Number of observations	124			
-2 Log Likelihood	155.762			
Nagelkerke R^2	0.148			

**, *Significant at 5 and 10% probability levels respectively.

children (rho = -0.286; p<0.05) had a statistically significant indirect non-cause-effect relationship with perceived impact of ecotourism on biodiversity conservation in and around the CMNP. On their part, independent variables like community (rho = 0.018; p>0.10), secondary occupation (rho = -0.037; p>0.10), level of education (rho = 0.100; p>0.10), ethnic group (rho = 0.027; p>0.10), and marital status (rho = -0.047; p>0.10) had a statistically insignificant cause-effect relationship with perceived impacts of ecotourism on biodiversity conservation in and around the CMNP. The aforementioned findings indicate that independent variables like gender, main occupation, and time spent in the community play a plausible significant role in enhancing biodiversity conservation in and around the CMNP; meanwhile independent variables like age and number of children play a plausibly significant negative role in the perception on the impact of ecotourism on biodiversity conservation in and around the CMNP.

Cause-effect relationship between the impact of ecotourism on biodiversity conservation around the CMNP and independent variables

A direct and indirect cause-effect relationship existed between independent variables and the perceived impact of ecotourism on biodiversity conservation in and around the CMNP (Table 4).

Based on the coefficients of the logistic regression model, it was found that independent variables like gender (β = 0.917; p<0.05) and time spent in the community (β = 0.473; p<0.10) had a statistically significant direct cause-effect relationship with perceived impacts of ecotourism on biodiversity conservation in and around the CMNP. The independent variable, age (β = -0.683; p<0.05) had a statistically significant indirect cause-effect relationship with perceived impacts of ecotourism on biodiversity conservation in and around the CMNP. Meanwhile independent variables like community (β = -0.063; p>0.10), main occupation (β = -0.148; p>0.10), secondary occupation (β = 0.021; p>0.10), level of education (β = -0.156; p>0.10), ethnic group (β = -0.121; p>0.10), marital status (β = 0.106; p>0.10), and number of children (β = 0.055; p>0.10) had a statistically insignificant cause-effect relationship with perceived impacts of ecotourism on biodiversity conservation in and around the CMNP. Thus, it is clearly noticed that gender and time spent in the community positively affects the perceived impacts of ecotourism on biodiversity conservation of communities while age negatively affects the perceived impacts of ecotourism on biodiversity conservation.

The binary logistic regression's classification table showed the predicted and observed statistics for the perceived impacts of ecotourism on biodiversity conservation in and around the CMNP (Table 5).

Based on the overall percentage of the perceived impacts correctly classified, it was noticed that up to 66.1% of the perceived impacts of ecotourism on biodiversity conservation was correctly classified. This proves that the predictions of the model are good enough to be used in the study.

DISCUSSION

Local population's perception of the impact of ecotourism on biodiversity conservation around the CMNP

From the perspective of the local population living around

Table 5. Classification table for the logistic regression model.

Observed	Predicted		
	Contributes to conservation	Does not contribute to conservation	Percentage correct
Contributes to conservation	51	18	73.9
Does not contribute to conservation	24	31	56.4
Overall percentage	-	-	66.1

the CMNP, marginally above average think ecotourism activities do not contribute to the conservation of biodiversity in and around the Park. This finding is unprecedented because most studies have found that ecotourism activities around protected areas contribute to biodiversity conservation (Imanishimwe et al., 2018; Das and Chatterjee, 2015; Sunita, 2013; Lambi et al., 2012; Conrad-J et al., 2013; Ajonina et al., 2014; Kruger, 2003) For example, in the Andhra Pradesh region of India, ecotourism contributed to biodiversity conservation in the adjacent forest reserve, by providing alternative livelihood activities to some community members who were involved in illegally timber exploitation (Sunita, 2013). Also, in South Africa, ecotourism groups such as Wilderness Safaris and Conservation Corporation Africa have demonstrated strong commitment to conservation efforts by providing alternatives to poverty alleviation in local communities around protected areas (Spenceley, 2006).

The perceived limited contribution of ecotourism to biodiversity conservation can be linked to inadequate development and non-community-based ecotourism projects. This is visible through poor accessibility, dilapidation of eco-lodges, an almost absence of tourism circuits, those managing ecotourism are not trained in tourism management, the presence of a draft ecotourism plan still to be adopted and implemented and the incapacity of the local population to manage community base ecotourism initiatives, as observed in the field and confirmed by key informants.

The majority of the respondents highlighted environmental education and sensitization as important perceived benefits of ecotourism to biodiversity conservation in the area. However, the degree to which ecotourism contributes to conservation in and around protected areas, is so much linked to the level at which the local population are actively involved in ecotourism activities that can provide better livelihood alternatives (Das and Chatterjee, 2015; Sunita, 2013). Unfortunately, ecotourism is perceived not to have provided a veritable livelihood option to degrading livelihood activities in and around the CMNP like poaching, illegal logging and fishing, thus the perceive limited contribution of ecotourism to biodiversity conservation (Forje et al., 2020). In areas where there is a clear and more equitable benefit sharing of revenue from ecotourism activities, the contribution of ecotourism to biodiversity conservation and community development is more significant (Imanishimwe et al., 2018). In the CMNP, revenue generated from key ecotourism activities (park entrance fee, camera and car usage fees) are collected by the park authorities and transferred directly into the state treasury, with the other stakeholders like the local communities and the NGOs working in the area exempted from the benefit sharing process. This thus limits revenue that could be used for local development as well as to enhance biodiversity conservation.

Factors affecting the perceived impact of ecotourism on biodiversity conservation around the CMNP

From the different inferential statistical tests and more importantly the logistic regression model, three independent variables (age, gender and time spent in the community) were statistically significant in terms of the factors affecting the perceived impacts of ecotourism on biodiversity conservation in and around the CMNP. Gender and time spent in the community had a direct causal relationship with the perceived impact of the ecotourism on biodiversity conservation in and around the CMNP. This implies that for the variable gender, males were more of the standpoint that ecotourism contributes to biodiversity conservation. These results are different from those of Tran and Walter (2014), where there is a near equality in the involvement of men and women in ecotourism activities resulting in both sexes engaging almost the same in biodiversity conservation in Northern Vietnam. In the CMNP, there is the dominance of men in the ecotourism sector, with very few women involved (Forje et al., 2020). This is most likely responsible for many female perceiving that ecotourism does not contribute to biodiversity conservation. In the Western Highlands of Cameroon, Kimengsi (2019), noticed that, the quasi totality of the female population involved in ecotourism, did not only foresaw ecotourism contributing to biodiversity conservation, but help in fostering biodiversity conservation by participating mainly in environmental education ecotourism activities. This implies that, if there is parity in ecotourism activities, with the introduction of gender sensitive and more inclusive activities, along site environmental education, the perception of the female population of CMNP on the contribution of ecotourism to both biodiversity and livelihood enhancement will probably change.

In terms of age as a factor influencing the perception of the local population on biodiversity conservation in the CMNP, there was a direct relationship between age and the perceived impact of ecotourism on biodiversity in the area. That is, as the age of the respondent increased, the more they are in concord that ecotourism contributes to biodiversity conservation in the areas. This result is in consonant with the findings of Peake et al. (2009) who noticed that those who are older are more susceptible to ecotourism conservation messages and implicitly may foster biodiversity conservation if the message is understood. It is also in line the findings of Kimengsi (2019), where the likelihood to participate in ecotourism conservation education increased with increasing age. This may be explained by the fact that, the elderly population around the CMNP, have more knowledge on the changing biodiversity status in the area than the younger ones, and are more willing to conserve the area.

From literature, research has not been carried out; establishing how time spent in the community affects the perceived impact of ecotourism on biodiversity conservation. In the CMNP, the variable time spent in the community had an inverse relationship with ecotourism contribution to biodiversity conservation. Members of the local population who had spent more time in the community were more for the opinion that ecotourism does not contribute to biodiversity conservation than their counterparts who had spent less time in the community. Those who have spent more time in the community explained that ecotourism had witnessed some downward trends over the years, with tourism structure dilapidating and the number of tourist reducing. This has thus resulted in limited benefits, pushing some community members into other activities which may be destructive to the environment so as to make earns meet. However, many of those who have stayed for long in the community acknowledged that if ecotourism is improved upon, it will obviously contribute more not just to biodiversity conservation, but will act as a sustained livelihood choice for their communities.

The management implication of the perceived impact of ecotourism on biodiversity conservation in the CMNP

The high perception of ecotourism contributing little to biodiversity conservation in and around the CMNP by the local communities is an indication that ecotourism which has been trumpeted by the second management plan of the CMNP, is still to deliver the desired results. There is thus the need, to develop and implement policies which can promote a better development of the ecotourism sector in and around the CMNP. For this to be done, the government of Cameroon through the inter-ministerial departments charged with the development of ecotourism in the CMNP, should work in collaboration with the communities, conservation and livelihood NGOs and ecotourism enterprises to develop public-private partnership for ecotourism in the environs of the CMNP. Such a public-private partnership should be able to develop gender sensitive and ecotourism products and packages that can provide a more equal opportunity for both men and women. There is a need for a memorandum of understanding between the park management, the local community as well as conservation NGO, stating clearly the quota of income each stakeholder will benefit from ecotourism activities. Such a benefit-sharing mechanism should be fair and transparent to all.

Conclusion

From the findings of the study, the perceived impact of ecotourism on biodiversity conservation in and around the CMNP was varied, slightly above average of the local population perceived that ecotourism does not contribute to biodiversity conservation in and around the CMNP. Different variables affected the perceived impact of ecotourism on biodiversity in and around the CMNP. The factors plausibly affecting the perceived impact of ecotourism on biodiversity conservation were age, gender, main occupation, secondary occupation, and number of children while the factors having a direct causal relationship with the perceived impact of ecotourism on biodiversity conservation were age, gender and time spent in the community. Based on these findings, it is recommended that policy makers and the government accelerate the process of Public-Private Partnership in order to implement participatory and sustainable ecotourism approaches in and around the CMNP for biodiversity conservation enhancement.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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