Composition and diversity of xylophagous and predatory beetles in Vachellia xanthophloea (Benth.) P.J.H.Hurter (Fabales: Fabaceae) at Kenyatta University and Mitaboni, Kenya

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Original Article

Composition and diversity of xylophagous and predatory beetles in *Vachellia xanthophloea* (Benth.) P.J.H.Hurter (Fabales: Fabaceae) at Kenyatta University and Mitaboni, Kenya

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A B S T R A C T

Xylophagous beetles cause damage to *Vachellia xanthophloea* (Benth.) P.J.H.Hurter by burrowing and tunneling damaged or deadwood resulting in extensive frass-filled galleries. A study was conducted from 2016 to 2018 to evaluate the composition and diversity of the xylophagous beetles. Fresh infested pieces of *V. xanthophloea* were collected from Mitaboni and Kenyatta University (KU), Kenya, and kept in KU laboratories for adult emergence. We recorded 7,959 and 7,804 beetles in KU and Mitaboni, respectively. The families included Bostrichidae, Bothrideridae, Buprestidae, Ciidae, Cerambycidae, Cleridae, Curculionidae, Dermestidae, Histeridae, Laemophloeidae, Lyctidae, Ptinidae, Silvanidae, Staphylinidae, Tenebrionidae, Trogossitidae, and Zopheridae. Ptinidae was present in Mitaboni only, while Ciidae and Zopheridae were unique in KU. Bostrichidae was the most abundant family accounting for 28.82% and 57.27% beetles followed by Curculionidae at 15.00% and 20.46% in KU and Mitaboni, respectively. *Xylion adustus* (Fahraeus) (Bostrichidae) accounted for 24.73% in KU, while *Sinoxylon ruficorne* Fahraeus (Bostrichidae) accounted for 24.83% in Mitaboni. Species richness (*S*), Shannon diversity index (*H*), and evenness (*J*) were higher at Mitaboni ($S=54$; $H=2.45$; and $J=0.614$) than KU ($S=51$; $H=2.33$; and $J=0.596$). Further studies should be conducted to document and enrich knowledge on diversity and distribution of the species associated with decaying *V. xanthophloea.*

Introduction

Terrestrial insects form an integral component of more than half of the known biodiversity on earth (Speight et al 1999). They are a core biota in terms of ecosystem's structure and function (Crawley 1983) and are used as indicators of environmental degradation as well as indicators of the ecological well-being of an ecosystem. Order Coleoptera plays a pivotal ecological role in the forest ecosystem accounting for 40% of insect species worldwide (Hong et al 2017). Beetles have a high diversity, representing about 30% of all insects (Lawrence and Britton 1991; Kahuthia-Gathu et al 2018b). They play important roles, such as herbivore, predator, and fungivore, as food sources for other organisms (Janzen 1987), decomposition and nutrient cycling in forest ecosystems (Siitonen 2001; Grove 2002), and act as indicators of environmental change (Forsythe 1987).

Bostrichidae are adept at locating and infesting freshly cut wood (Orwa et al 2009; Kahuthia-Gathu et al 2018a). They are of considerable economic importance to forestry and the wood-using industries in tropical countries (Liu et al 2008; Beaver et al 2011). Within the family, there are 89 genera with approximately 570 species (Lawrence 2010), of which over 40 species are associated with *Vachellia* species. Many forest managers also recognize bark beetles (Curculionidae: Scolytinae) as another very economically important group of forest insects (Ciesla 1993).

Both predators and parasitoids are known to attack bostrichids and scolytines. The predators are mostly in the beetle families Cleridae, Histeridae, Melyridae, and Trogossitidae (Bahillo de la Puebla et al 2007; Kolibáč 2013; Lawrence and Slipinski 2013; Kahuthia-Gathu et al 2018b), while parasitoids are wasps in the families Pteromalidae and Braconidae (Yu et al 2012; Ghahari et al 2015; May 2015; Noyes 2015). However, they are not known to have a significant effect on beetle populations in natural conditions (Edde 2012; May 2015).

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In Kenya, little information is available on the composition and diversity of xylophagous beetles infesting damaged portions of *Vachellia xanthophloea* (Benth.) P.J.H.Hurter (Fabales: Fabaceae) and their associated natural enemies. The main objective of this study was to identify and document the composition, abundance, species diversity, species richness, and species evenness of the xylophagous beetle fauna infesting *V. xanthophloea* and their associated predators in two agro-ecological regions with different land-use types. *V. xanthophloea* was selected for the study because of the economic role it plays in apiculture, its firewood and timber, ornamental, and medicinal uses, and its use when curbing soil erosion and rehabilitation of limestone quarries in Kenya (Orwa et al 2009; Gathuru 2011). Our research also aimed at evaluating whether different habitat types affected the composition, abundance, and diversity of beetles and associated predatory beetles.

Species diversity, which is sometimes called species heterogeneity, is an expression of community structure. It is one of the basic concepts of ecology that has been used to characterize communities and ecosystems and measured by species richness (the number of species present in a particular community) and species evenness (the relative abundance of the different species).

Material and methods

Study sites

The study began during May 2016 at Mitaboni, Machakos County, located at 1° 21′34′ S and 37° 16′46′ E, and Kenyatta University (KU), Nairobi County, at 1°1107′S 36°5540′E. Mitaboni lies at 1,500 m above the sea level, experiences bimodal rainfall between 650 and 800 mm per year, with average temperatures of 22–28°C. KU lies at 1,680 m above the sea level, experiences bimodal rainfall between 1,000 and 1,400 mm per year, with average temperatures between 18 and 26°C. The distance between the two regions is approximately 160 kilometers apart. KU is mainly residential with many buildings, *V. xanthophloea*, Eucalyptus, and minimal farming unlike Mitaboni, where most of the land is agricultural with *V. xanthophloea* being grown for shade and hedge, while the other area is under crop cultivation.

Sampling and identification of xylophagous and predatory beetles

The study was conducted during May 2016 through December 2017. Dead and infested branches of *V. xanthophloea* were examined and collected from three sites (A, B, and C) in each region, which were 500 meters apart, and materials from each site were kept separately for comparative purposes and to minimize bias. The samples were collected before the beetles had emerged. The samples were transversely cut into pieces measuring 30cm and a diameter of 10–15cm. Six pieces of wood were placed in well-ventilated 20-liter plastic containers as described by Sittichaya and Beaver (2009), Kangkamanee (2011), and Kahuthia-Gathu et al (2018a) and taken to KU Biotechnology laboratories and kept at an ambient room temperatures of 23±2°C, 60±10% relative humidity, and 12 L: 12 D photoperiod. The emerging and positively phototropic adult beetles were collected as described by Kahuthia-Gathu et al (2018a) and their numbers recorded. The insects were preserved in 70% ethanol.

The xylophagous beetles were identified to genus or species using Arnett and Thomas (2001), Arnett et al (2002), Beaver et al (2011), Sakalian and Georgi (2013), Bellamy (2013), and Liu et al (2016). Some specimens were confirmed by Morris Mutua from the National Museums of Kenya, Bostrichidae by Prof. Liu Lan-Yu of National Pingtung University, Taiwan, Buprestidae by Prof. Xiao-Yi Wang of Research Institute of Forest Ecology, Environment and Protection, Chinese Academy of Forest, China. The identified voucher specimens were kept in the KU laboratory, while others were deposited into the National Museums of Kenya.

Diversity indices

In this study, different species diversity indices were used for comparative estimation of the insect diversity. Shannon diversity index (H′) (Shannon and Weaver 1949; Brower and Zar 1984), richness (R) (Margalef 1958), and evenness (E) (Pielou 1966) were calculated to evaluate species diversity of the wood-boring and predatory beetles recovered from *V. xanthophloea.*

Data analysis

The biodiversity software, PRIMER (ver 6.1.11) (Primer-E Ltd., Plymouth, United Kingdom), was used to determine diversity indices, richness, and evenness. The collected beetles were counted to obtain the number of individuals (N) and species (S), while the abundance was calculated as percentage of the total number of beetles recovered. The Shannon diversity index (H'), species richness (d), and evenness (J) (Magurran 2004) were calculated to evaluate species diversity of the xylophagous and predatory beetles. The indices were computed as described by Magurran (2010), species richness $\boldsymbol{d=(S\text{-}1)/Log(N)}$ (as a measure of the number of species present, making some allowance for the number of individuals). Pielou's evenness $\boldsymbol{J=H/ln(S)}$ (as a measure of equitability) is a measure of how evenly the individuals are distributed among the different species. Shannon–Wiener index $H' = -\Sigma\ p_i \ln(p_i)$ incorporates both species richness and equitability components. n_i = the number of individuals of species i in the sample, $\Sigma n_i = N$. p_i = the proportion of individuals of species i in the sample, $P_i = n_i/N$. S = the number of species in the sample, N = the total number of individuals in the sample (Shannon and Weaver's (1949). It also shows a value of maximum diversity, dominance, and evenness as well as a diversity index. A t test was used to analyze the diversity difference between the two regions and research sites, $t=H_1\text{-}H_2/(\text{var } H_1+\text{var } H_2)1/2$ (Magurran 1988).

Results

Species and abundance of xylophagous and predatory beetles from KU

In total, 7,959 individual beetles belonging to 52 species in 16 families were recovered from KU. The families collected were Buprestidae, Bostrichidae, Bothrideridae, Cerambycidae, Ciidae, Cleridae, Curculionidae, Dermestidae, Histeridae, Laemophloeidae, Lyctidae, Silvanindae, Staphylinidae, Tenebrionidae, Trogossitidae, and Zopheridae (Table 1). The families Ciidae and Trogossitidae were only collected from samples taken at KU. Samples from site A yielded 1,933 individuals from 35 species, site B yielded 2,686 beetles from 46 species, and site C had the highest number of beetles, 3,340 individuals from 24 species. Across all three sites, Bostrichidae was the most dominant family with 2,293 individuals from nine species accounting for 28.82% of the total abundance, followed by Scolytinae with 1,187 individuals accounting for 14.90%. *Xylion adustus* Fahraeus (Bostrichidae) was the most dominant species (24.73%), followed by *Glostatus* sp. (Curculionidae) (10.64%), *Smodicum* sp. (Cerambycidae) (5.28%), and *Triboderus* sp. (Bothrideridae) (5.19%) (Table 1).

Predators in the orders Coleoptera were recorded from the KU samples. *Hister* sp., (Coleoptera: Histeridae) was the most dominant with 2,231 individuals (28.03%), and *Cylidrus fasciatus* Laporte (Coleoptera: Cleridae) was the second (287 individuals, 3.61%)

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Table 1. Species and abundance of xylophagous and predatory beetles in damaged and dying *Vachellia xanthophloea* wood at Kenyatta University.

Family	Species	Site A	Site B	Site C	Total	% Abundance	% Family
Bostrichidae	*Dinoderus gabonicus* Lesne	3	1	-	4	0.05	28.82
	Lyctus brunneus Stephens	1	2	1	4	0.05	
	Metahylesinus oblongus Eggers	-	26	-	26	0.33	
	Sinoxylon doliolum Lesne	86	41	29	156	1.96	
	Xylion adustus Fahraeus	555	651	762	1,968	24.73	
	Xyloperthella picea Olivier	2	1	-	3	0.04	
	Xyloperthodes nitidipennis Murray	63	15	33	111	1.39	
	Xylopscocus castanoptera Fairmaire	3	3	-	6	0.08	
	Xylopsocus sp.	9	4	2	15	0.19	
Bothrideridae	*Triboderus* sp.	124	135	154	413	5.19	5.19
Buprestidae	*Agrilus* sp. 1	72	85	27	184	2.31	2.74
	Agrilus sp. 2	7	5	10	22	0.28	
	Chalcogenia sp.	1	-	-	1	0.01	
	Meliboeus sp.	8	1	1	10	0.13	
	Sphenoptera (*Tropeopeltis*) sp.	-	1	-	1	0.01	
Cerambycidae	Cerambycidae sp. 1	-	1	-	1	0.01	5.64
	Coptops aedificator Fabricius	3	5	-	8	0.10	
	Crossotus plumicornis Fabricius	-	8	-	8	0.10	
	Dichostates lignarius lignarius (Guerin-Meneville)	5	-	2	7	0.09	
	Precemes longipes Oliver	-	1	-	1	0.01	
	Smodicum sp.	108	66	246	420	5.28	
	Xystrocera ansorgei Gaham	-	4	-	4	0.05	
Ciidae	Ciidae sp. 1	8	2	1	11	0.14	0.14
Cleridae	*Cylidrus fasciatus* Laporte	113	60	114	287	3.61	3.67
	Eucymatodera senegalensis Laporte	3	1	-	4	0.05	
	Tarsostenus univittatus Rossi	-	1	-	1	0.01	
Curculionidae	Curculionidae sp. 1	-	1	4	5	0.06	15.00
	Curculionidae sp. 2	-	2	-	2	0.03	
	Glostatus sp.	149	260	438	847	10.64	
	Metahylesinus oblongus Eggers	91	157	85	333	4.18	
	Metahylesinus sp.	-	1	-	1	0.01	
	Scolytinae sp. 1	-	2	-	2	0.03	
	Scolytinae sp. 2	1	-	-	1	0.01	
	Scolytinae sp. 3	-	3	-	3	0.04	
Dermestidae	Dermestidae sp. 1	-	1	-	1	0.01	0.10
Histeridae	*Teretrius* sp.	98	44	36	178	2.24	28.03
	Hister sp.	184	658	1,211	2,053	25.79	
	Placonotus zimmermanni LeConte	39	25	97	161	2.02	
Laemophloeidae	Laemophloeidae sp. 1	-	-	2	2	0.03	2.11
	Laemophloeidae sp. 2	-	2	3	5	0.06	
Lyctidae	Lyctidae sp. 1	-	3	-	3	0.04	0.39
	Lyctidae sp. 2	5	-	-	5	0.06	
	Minthea sp.	17	6	-	23	0.29	
Silvanidae	Silvanidae sp. 1	-	4	-	4	0.05	0.39
	Silvanidae sp. 2	7	16	4	27	0.34	
Staphylinidae	Staphylinidae sp. 1	68	351	31	450	5.65	5.65
Tenebrionidae	*Corticeus fasciatus* Fabricius	69	24	38	131	1.65	2.16
	Lyphia tetraphylla Fairmaire	7	-	-	7	0.09	
	Tenebrionidae sp. 1	10	4	-	14	0.18	
	Tenebrionidae sp. 2	10	1	8	19	0.24	
Trogossitidae	*Grynocharis oblonga* Linnaeus	2	-	1	3	0.04	0.04
Zopheridae	*Sosylus* sp.	2	1	-	3	0.04	0.04
	Total	1,933	2,686	3,340	7,959	100	100
	No. of species	35	46	24	52		

(Table 1). Both larvae and adults of the predatory beetles (Histeridae and Cleridae) were found preying on various stages of the wood-boing beetles, while others were found scavenging on dead insects.

Species and abundance of xylophagous and predatory beetles from Mitaboni

In total 7,804 specimens within 55 species and 17 families emerged from the material collected in Mitaboni. The xylophagous and predatory beetles were from the families Bostrichidae, Bothrideridae, Buprestidae, Cerambycidae, Cleridae, Curculionidae, Dermestidae, Elateridae, Histeridae, Laemophloeidae, Lyctidae, Ptinidae, Silvanindae, Staphylinidae, Tenebrionidae, and Zopheridae (Table 2). Beetles from the family Ptinidae were only collected from samples from Mitaboni and represented 3.22% of the total abundance. Bostrichidae was the most dominant family with 4,466 specimens (57.27%), followed by Scolytinae (1,594 individuals, 20.43%). The family Bostrichidae was the most diverse, with 11 species (Table 2). *Sinoxylon ruficorne* was the most dominant species with 1,937 individuals (24.82%), followed by *Glostatus* sp. (Curculionidae) (1,581 individuals, 20.26%) and *Xylopsoccus* sp. (Bostrichidae) (1,189 individuals, 15.24%).

Predatory beetles in the families Histeridae and Cleridae were recovered in Mitaboni (Table 2). *Hister* sp. was the most dominant predator with 396 individuals accounting for 5.07% of the total abundance. We observed both predator larvae and adults eating the xylophagous beetles. However, predation rates could not be determined as both predators feed within the galleries.

Table 2. Species and abundance of xylophagous and predatory beetles from *Vachellia xanthophloea* in Mitaboni.

Family	Species	Site A	Site B	Site C	Total (n)	Species Abundance (%)	Abundance per Family (%)
Bostrichidae	*Heterobostrychus brunnes* Murray	1	-	-	1	0.01	57.21
	Lyctus brunneus Stephens	21	3	3	27	0.35	
	Metahylesinus oblongus Shedl	172	57	29	258	3.31	
	Sinoxylon doliolum Lesne	136	75	218	429	5.50	
	Sinoxylon ruficorne Fåhraeus	474	744	719	1,937	24.82	
	Xylion adustus Fahraeus	17	95	72	184	2.36	
	Xylopsocus castanoptera Fairmaire	116	455	618	1,189	15.24	
	Xyloperthodes nitidipennis Murray	262	82	58	402	5.15	
	Xylopsocus sp. 1.	6	-	-	6	0.08	
	Xylopsocus sp. 2.	2	1	-	3	0.04	
	Trypopholoeus sp.	13	12	2	27	0.35	
Bothrideridae	Bothrideridae sp. 1.	22	21	18	61	0.78	1.53
	Bothrideridae sp. 2	-	1	1	2	0.03	
	Triboderus sp. 1.	8	11	2	21	0.27	
	Triboderus sp. 2.	20	11	4	35	0.45	
Buprestidae	*Chalcogenia* sp.	2	3	2	7	0.09	0.19
	Chrysobothris dorsata Fabricius	-	3	1	4	0.05	
	Chrysobothris sp.	-	3	1	4	0.05	
Cerambycidae	Cerambycidae sp. 1	8	-	-	8	0.10	0.47
	Coptops aedificator Fabricius	-	8	-	8	0.10	
	Derolus incultus Gerstaecker	2	2	1	5	0.06	
	Eucymatodera senegalensis Laporte	6	2	4	12	0.15	
	Smodicum sp.	2	2	-	4	0.05	
	Tetropium castaneum Linnaeus	-	1	-	1	0.01	
Cleridae	*Eucymatodera* sp.	3	2	-	5	0.06	4.75
	Tarsostenus univittatus	6	4	-	10	0.13	
	Tillus sp.	6	1	-	7	0.09	
	Cylidrus fasciatus Spinola	62	70	56	188	2.41	
	Cylidrus megacephalus Spinola	54	56	51	161	2.06	
Curculionidae	Curculionidae sp. 1	1	1	-	2	0.03	20.46
	Glostatus sp.	637	543	401	1,581	20.26	
	Scolytinae sp. 1	5	1	1	7	0.09	
	Scolytinae sp. 2	5	1	-	6	0.08	
Dermestidae	Dermestidae sp. 1	1	16	16	33	0.42	0.42
Histeridae	*Teretrius* sp.	18	49	71	138	1.77	6.84
	Hister sp.	12	143	241	396	5.07	
Laemophloeidae	*Placonotus* zimmermanni LeConte	-	3	1	4	0.05	0.48
	Laemophloeidae sp. 1	1	-	-	1	0.01	
	Laemophloeidae sp. 2	0	2	-	2	0.03	
	Cathartosilvanus sp.	10	5	9	24	0.31	
	Cryptolestes sp.	1	-	1	2	0.03	
	Minthea sp.	4	-	-	4	0.05	
Lyctidae	*Heterobostrychus brunneus* Murray	68	-	1	69	0.88	2.50
	Lyctus brunneus Stephens	86	26	18	130	1.67	
	Lyctidae sp. 1	1	1	2	4	0.05	
Ptinidae	Ptinidae sp. 1	162	20	69	251	3.22	3.22
Silvanidae	Silvanidae sp. 1	-	2	-	2	0.03	0.03
Staphylinidae	Staphylinidae sp. 1	6	4	6	16	0.21	0.30
	Staphylinidae sp. 2	5	2	-	7	0.09	
Tenebrionidae	*Corticeus fasciatus* Fabricius	-	6	3	9	0.12	1.39
	Corticeus sp.	-	3	-	3	0.04	
	Lyphia tetraphylla fairmaire	40	23	30	93	1.19	
	Tenebrionidae sp. 1	-	3	-	3	0.04	
Zopheridae	Zopheridae sp. 1	5	-	3	8	0.10	0.10
	Total	2,491	2,580	2,733	7,804	100	
	No of species	44	47	35	55		

Comparison of diversity across collection sites

We calculated the diversity indices of the beetles recovered from KU (7,959) and Mitaboni (7,804) (Table 3). Species diversity differed significantly between KU and Mitaboni (t = 7.15; df = 13643; $P < 0.001$). Higher species diversity and species evenness of the total xylophagous beetle abundance was found in Mitaboni ($H = 2.45$, $J = 0.614$) than at KU ($H = 2.33$, $J = 0.596$). Within KU, site A had the highest species diversity of 2.56, followed by site B (2.25) and C (1.96). Maximum and minimum species evenness of 0.75 and 0.62 was recorded in site A and site C, respectively. Significant differences on the total number of xylophagous beetles were recorded between site A and site B (t=9.312; df=4341; P=0.002) and site B and C (t=11.733; df=4105; P=0.0008), and site A and C

Table 3. Diversity indices and richness estimators for xylophagous beetle species recorded from Kenyatta University and Mitaboni.

Region	Site	S	N	*d*	*J'*	*H'*
Kenyatta University	A	35	1,933	4.93	0.73	2.60
	B	46	2,686	5.70	0.59	2.28
	C	26	3,340	3.08	0.60	1.96
	Total	51	7,959	5.57	0.59	2.33
Mitaboni	A	41	2,488	5.12	0.68	2.50
	B	39	2,568	4.84	0.61	2.25
	C	32	2,729	3.92	0.64	2.21
	Total	54	7,804	5.91	0.61	2.45

S = species richness; N = number of individuals; d = Margalef's index; J' = Pielou's evenness index; H' = Shannon–Wiener index.

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(t=22.85; df=2727; P=0.0046) in KU (Table 3). The average species diversity of xylophagous beetles in Mitaboni was 2.45. There was significant difference in the number of beetles recorded from the three sites in Mitaboni, site A and site B (t=7.1069; df=5051; P=0.0026), site B and C (t=1.3272; df=5110; P=0.00065), and site A and C (t=8.93; df=5079; P=0.0025). Species diversity and species evenness varied between sites with site A (H= 2.502, J=0.678), site B (H=2.252, J=0.610), and site C (H=2.207, J=0.637).

Discussion

Many beetle species were recovered from both KU and Mitaboni. The composition of the beetles differed significantly between the regions and the sites. At least 19 families of xylophagous and predatory beetles were recorded from both KU and Mitaboni, predominantly from the families Ptinidae, Bostrichidae, Cerambycidae, Buprestidae, and Scolytinae. Kuria et al (2010) recorded rich beetle communities from *Acacia drepanolobium* (Harms ex Sjöstedt) P.J.H.Hurter in Kenya comprising 13 beetle families, predominantly Bostrichidae, Curculionidae, Anthicidae, Cleridae, Buprestidae, and Cerambycidae. The xylophagous beetles in the family Bostrichidae were the most abundant and diverse group of insects recorded from *V. xanthophloea* in both KU and Mitaboni. This concurs with the studies by Speight et al (2008) and Sittichaya et al (2009) who found Bostrichidae was the most abundant and diverse group of insects in the study system. Similar observations were made by Orwa et al (2009) and Kahuthia-Gathu et al (2018a) where the family Bostrichidae was the most abundant and notorious in infesting freshly cut wood, followed by Scolytinae. Lawrence (2010) also reported Bostrichidae as serious pests of trees, forest products, agricultural crops, and stored vegetable products. The family has an important function in the ecosystem where they are saproxylic, pollinators, food of other organisms, and act as bioindicators. The saproxylic insects play an important role in nutrient cycling in forests by feeding on dead trees or wood, while saprophagous insects feed on decaying organic material. Similar observations were made by Kahuthia et al (2018b) who recorded 3,411 individual *X. adustus* accounting for 55.33% of the total insect abundance in Thika, Kenya.

It was observed that most of the abundant species recorded during the study were in the family Bostrichidae. The species included *X. adustus*, *S. ruficorne*, *S. doliolum*, *Xylopsocus castanoptera*, *Xyloperthodes nitidipennis*, and *Metahylesinus oblongus.* Other species recovered were *Glostatus* sp. (Scolytinae), *Smodicum* sp. (Cerambycidae), and *Triboderus* sp. (Bothrideridae). Kahuthia-Gathu et al (2018a; 2018b) reported *X. adustus* as the most diverse and abundant species accounting for 55% of the total beetle abundance. The species have also been reported in Tanzania, Malawi, Southern Africa, and South Africa. However, there are no reports regarding their abundance for comparative. Past studies have shown that size of wood leads to differences in beetle abundance (Banno and Yamagami 1991), and the species compositions of their assemblage (Foit 2010). Stokland et al (2012) also observed that deadwood provides a favorable habitat to various arthropods.

The diversity indices (species diversity and species evenness) between the KU and Mitaboni were relatively high. This concurs with the previous studies conducted by Kahuthia et al (2018a) who recorded species diversity (1.36) and species evenness (0.648) from wood-boring beetles, predators, and parasitoids of *Acacia xanthophloea* in Thika. Presence of exit holes, galleries, and tunnels made by the primary colonizers subsequently had a positive effect on the species richness and abundances of secondary colonizers and their predators (Buse et al 2008; Calderon-Cortes et al 2011). These could have been attributed to both abiotic and biotic factors. Higher diversity indices in Mitaboni than KU could be attributed to land use and climatic conditions, where the former is more agricultural, while the latter is more residential with minimal agriculture. Fragmentation, loss, and decline of habitats, invasion of exotic species, lack of natural resources, and climate changes could have affected the biological diversity as suggested by Werner and Raffa (2000). Tree species, age, girth, and the status of the tree (bark present or absent, fallen trees) could have also played a role in the composition and diversity of the beetles. Kra et al (2009) observed that beetle diversity and distribution varied due to influence of land use change. Forest conversion causes biodiversity loss and a threat to ecosystem function and sustainable land use (Hoekstra et al 2005; Cardillo 2006). Baral et al (2014) observed that human influence on the natural environment consistently deteriorates the ecological functions and biological diversity. Studies have shown that arthropod richness and abundance are positively affected by increasing habitat structure (Leal et al 2016).

Predatory beetles and parasitoids were recorded as part of the natural enemies, and most of the predators were from the families Histeridae and Cleridae. The results concur with those of Kahuthia-Gathu et al (2018b) who recorded a large number of predatory beetles in the family Cleridae and Histeridae in Thika. Numerous predators, especially Cleridae and Histeridae, have been reported attacking the wood-boring beetles in many regions (Bahillo de la Puebla et al 2007; Kolibác 2013; Lawrence and Slipinski 2013). Factors such as resource availability for the larvae and adults, behavioral traits, and interaction with other species (Pinheiro and Ortiz 1992) may explain the increase in diversity and richness of the predatory beetles during the study. The predators play a major role in maintaining balanced ecosystems and reduction of the wood-boring beetles through predation (Kahuthia-Gathu et al 2018b)

The rate of predation was not determined due to the nature of the study, which involved the collection of the emerged adult beetles from the bucket. It was observed that most of the beetles burrowed and fed within the galleries. Presence of the predators is an indication that they can be used as a part of biological control because they depend on availability of deadwood and are sensitive to forest conditions as observed by Yanega (1996). Because of social, economic, and environmental concerns on pesticide use, the clerid and histerid beetles may be of use in the management of the xylophagous beetles.

Further studies should be conducted in other regions to document and enrich the knowledge about numbers and distribution of these species in Kenya as observed by Salikan and Georgi (2013). Although the number of species recorded during the study was high, heterogeneity was not high due to differences in species abundance. With more information and data, the predatory beetles recovered could be used as part of integrated pest management strategies.

Conflict of interest

The authors declare that there is no conflict of interest.

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