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The influence of *Formica exsecta* ants on the abundance and diversity of other invertebrates in a private fragment of Tanzanias coastal forests

Nuru Said Mohamed*

Department of Biology, Faculty of Science, Muslim University of Morogoro, Morogoro, Tanzania

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Key words: *Formica exsecta*, Invertebrates abundance and Diversity, Tanzania's Coastal Forests

Abstract

This study was conducted in the fragment of Tanzania's Coastal Forests (TCFs), which is one of the world's ecoregions with varied endemic flora and fauna located on the coast of Indian Ocean. Its focus was on privately-owned TCFs, specifically a research and conservation centre of the late Prof. R.B.M Senzota since 1988. This fragment faces pressure from the surrounding population of more than seven million people of the Dar es salaam city, causing two visible habitat disturbances (disturbed and less disturbed) coupled with the outbreak of invasive species. The study assessed the influence of invasive *Formica exsecta* in varied disturbance levels and dry and wet seasons to invertebrate abundance and diversity. Pitfall trap, baited trap and dry leaf litter sifting were used in the invertebrate collection. The result show that this TCFs fragment to have higher invertebrate biodiversity with 484,481 individuals, 134 species, 87 families and 18 orders. Contrary to many findings, the disturbed habitat and dry season had higher abundance with lower diversity and species number compared to the less disturbed habitat and wet season with lower abundance but higher diversity and species number. Over dominance of aggressive *Formica exsecta* in the disturbed habitat and dry season by more than 90 present of all the individuals collected highly contributed to this variation as was also negative correlated to invertebrate abundances (r = -0.0012). The threat of the TCFs endangers enormous endemic wildlife; hence the need for the ultimate conservation efforts integrating both private and public-owned small and larger fragments before it was too late.

***Corresponding Author:** Nuru Said Mohamed ✉ nurumohamed@mum.ac.tz

Introduction

Tanzania's Coastal Forests (TCFs) refer to an ecological region globally recognised as biodiversity hotspots with varied endemic flora and fauna located along the Indian ocean coast in five regions of Tanzania Mainland (Tanga, Pwani [Coast], Dar es salaam, Lindi, and Mtwara) and Zanzibar Islands (Unguja and Pemba) (Burgess, 1992; Burgess, 2018). Out of the five TCFs regions on Tanzania Mainland, Dar es Salaam had the least protected forest reserve (Burgess, 2018) partly because of the over-crowding of the region with more than seven million people as reported by the World Population Review (WPR) (2023). Such population pressure exerted on the mosaic of forests require recourse to a variety of ecological and economical services for sustaining ecological cycles, controlling floods and soil erosion control, and support for carbon sequestration, medicinal plants, fuelwood and charcoal production, food sources and building materials (Senkoro, 2015; Wilson, 2011). Despite these significances, TCFs face rapid degradation largely due to uncontrolled fires, indiscriminate clearing of vegetation for settlement, agriculture, logging and charcoal making (Burgess, 1992; Mohamed, 2016). Consequently, there is an urgent to protect the numerous private-owned small fragments and a few large fragments owned by the government as national parks and forest reserves such as Saadani National Park, Pugu and Kazimzumbwi Forest Reserves, Kiwengwa-Pongwe, and Masingini catchment forest on Unguja, and Misitu Mkuu and Ras Kiuyu on Pemba. Most of the conservation efforts focus on government forest reserves, ignoring the small patches despite being home to relatively higher in biodiversity (Braschler *et al.,* 2020).

The former Dar es salaam Bioenvironmental Centre (DBC) is one of the private-owned small fragments of the TCFs highly affected by the continual wanton forest deforestation. Based on floral structures and density, Senkoro (2015) divided the DBC into two visible levels of habitat disturbance: The disturbed habitat and the less disturbed habitat. The present study used these two discernible levels of habitat disturbance to assess the effects of habitat disturbance on invertebrate abundance and diversity.

Indubitably, TCFs are known for their high diversity in invertebrate fauna (Mohamed, 2016) such as ground beetles, ants, and pollinator insects such as butterflies. Invertebrates are well known for their varied ecological roles despite attracting less attention in the world of science with the exception of insect pollinators. Invertebrates are ecologically known as ecosystem engineers, bio-indicators, and predators for a variety of pests (Cerdá & Dejean, 2011; Mora-Rubio & Parejo-Pulido, 2021; Kotze *et al.,* 2022). The ongoing environmental disturbances in TCFs have occasioned many effects on the ecosystems, including the invasion of non-native species such as *Formica exsecta* originally found in European alpine regions and Asia (Sundström & Vitikainen, 2022). *Formica exsecta,* as one of the social insect species, may have many negative effects on other invertebrates including high competition for the food resources and habitat available as found by (Lenoir, 2001) to be a key-stone predator on soil fauna, similar to its close relative *Formica (Coptoformica) pressilabris* (Hakala *et al.,* 2020). The present study, thus, assessed their influence on invertebrate diversity in the two forest disturbance levels of the TCFs fragment. Since studies have attested to how invertebrate biodiversity is highly affected by seasonal differences (Owens *et al.,* 2022), the present study also evaluated the contribution of the two distinct wet and dry seasons evidently in the Dar es Salaam city (Ndetto & Matzarakis, 2013; Weather Spark, 2023) in May and November, respectively, to invertebrate abundance and diversity for the two levels of habitat disturbance in the TCFs fragment under review.

Materials and methods

The study was conducted between November, 2014 and May, 2015 in the Tanzania's Coastal Forests (TCFs) generally and specifically a fragment formerly known as the Dar es salaam Bioenvironmental Centre (DBC). This area is located along the south-west coast of Indian Ocean, Kilimahewa, Kinondoni, Dar es Salaam, Tanzania (at 6º41'20.33" S 39º11'10.60" E, *Fig. 1*). The DBC was a seven-hectare TCFs fragment on an elevation of more than 90m asl, with a stable tropical climatic condition sustained by the Indian

Ocean breeze. This TCFs fragment served as a research and conservation centre under the ownership of the late Prof. R. B. M. Senzota since 1988 (Mohamed, 2023). The fragment had come under rising pressure from more than seven million human population of Dar es Salaam City due to several urbanisation activities such as waste disposals, burning and clearance of vegetation cover for settlement and many other uses to suffice its population.

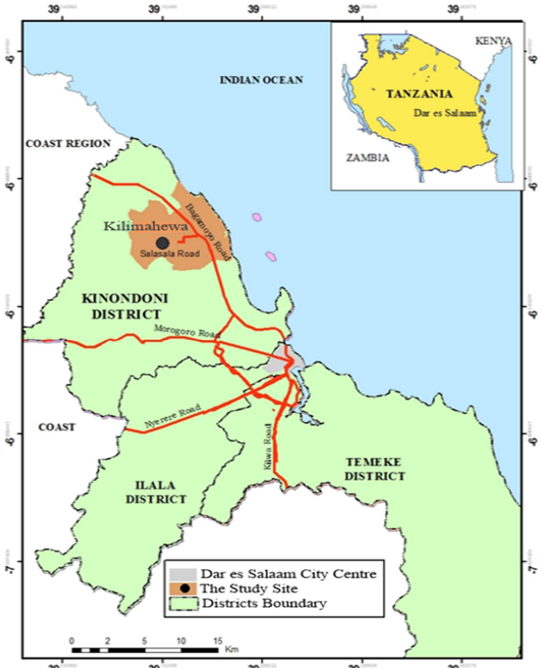

Fig. 1. Map of Dar es Salaam showing location of the study site (●), the Tanzania's Coastal Forests Fragment (modified from Mohamed, 2023).

The present study used pitfall traps, baited traps, and dry leaf litter sifting methods to collect invertebrates in the field. The study spent 18 days, each month from November 2014 up to May 2015 when nine days were available on collecting specimen for investigation. Pitfall traps and baited traps had seven successive days whereas dry leaf litter sifting method accounted for two days after every other day to minimise the disturbance effects around the study site. The specimens collected were conveyed to the laboratory for sorting out and identification purposes with invertebrate experts from the University of Dar es Salaam. Various field guides and other identification books were also used which includes McGavin (1992), McGavin (1993), Picker *et al.,* (2004), Scholtz & Holm (1996), and White (1983).

Pitfall trapping

Pitfall trapping has emerged to be the most efficient method for sampling invertebrates such as beetles, ants, millipedes and earthworms (Shayya & Lackner, 2020; Cajaiba *et al.*, 2017; Samways *et al.*, 2010). It has also known to be simple and less expensive and can sample species missed by other trapping methods (Niba & Yekwayo, 2016; Nyundo & Yarro, 2007). Thus, the present study decided to adopt pitfall trapping method in sampling invertebrates' fauna despite its complications during data interpretation. During specimen collection, 50 pitfall traps were buried fresh with the ground surface in two transects. Each transect comprised 25 pitfall traps (5 metres from one another) giving 100-metre long. Plastic container of one-litre volume with diameter of 8cm at the base, 12cm at the mouth and 14.8cm in height was used to create these pitfall traps. The buried pitfall traps were half-filled with soapy water and each trap was emptied in a nylon bag with 75 present ethanol three times a day early in the morning (from 9.00am), during afternoon (from 2.00pm) and in the evening (from 6.00pm). This setup was applicable in each of the dry and wet seasons and thus making a total of 100 pitfall traps in the whole study.

Dry leaf litter sifting method

On the other hand, the Dry leaf litter sifting method has been appreciated in the world of science as one of the best and most successful method for collecting invertebrate individuals such as ants and ground dwelling beetles (Shayya & Lackner, 2020; Wiezik *et al.,* 2015; Jacobs *et al.,* 2011; Samways *et al.,* 2010). In this regard, the present study opted for the dry leaf litter sifting method to collect invertebrate animals in both seasons and data on levels of habitat disturbance.

A total of five quadrats of 1m x 1m size each were randomly sampled in each of the disturbed and less disturbed habitats in a distance of not less than 15 metres, hence 10 quadrats in each of the dry and wet seasons. The sampling was made in the morning hours (from 9.00am to 11.00 am) during which the dry leaf litter and debris collected were emptied onto a piece of white cloth and invertebrate faunas were separately retrieved by hand, forceps, and aspirator into a nylon bag half filled with 75 present ethanol and taken in to the laboratory for identification.

Baited trapping

Invertebrate faunas continued being attracted to many baits such as sugar and honey (Mohamed, 2023), whose effectiveness in attracting numerous invertebrate individuals has already been determined (see, for example, Yousefi *et al.*, 2020; Crane & Baker, 2011; Müller & Schlein, 2011). Ten (10) mills of each of the two solutions comprised brown sugar from Kilombero Sugar Company and Tan HONEY harvested from Tabora region in Tanzania (the baits) were separately poured into a bottle of 500 mils with mouth diameter of 2.2cm and left open on the ground where invertebrates entered to follow the bait. The entered specimens were collected three times a day, early in the morning (from 9.00 am), during afternoon (from 2.00pm) and in the evening (from 6.00 pm) from which they were emptied into nylon bags half filled with 75 percent of ethanol and conveyed to the laboratory for identification.

The sugar baited solution was made with 1kg of sugar dissolved in 3 litres of water whereas the honey baited solution was used directly as derived from Tan HONEY sourced from Tabora region. Each of the sugar and honey baited solutions had four transects (two in each of the dry and wet seasons) with 100 metres long and 100 baited bottle traps (50 apiece for the two seasons) with a distance of 5 metres between traps. Out of the two transects for each of the dry and wet seasons, the disturbed and less disturbed habitat had one transect each. Also, out of the 50 baited bottle traps for each of the dry and wet seasons for both the disturbed and less disturbed habitats. This setup resulted in eight transects and 200 baited bottle traps for the study.

The abundance of the invertebrate individuals collected between the two disturbance levels (disturbed and less disturbed habitat) and the two seasons (dry and wet seasons) were both compared using Mann-Whitney U-test (Zar, 2010). Invertebrates species diversity of the present study for both in dry and wet seasons was computed using the Shannon Wiener diversity index, while its comparison was made using a special (t) test (Zar, 2010). The entire compositional analyses in this study was computed using the Paleontological Statistics software package (PAST) (Hammer *et al.*, 2001) whereas figs. were sketched out using Microsoft excel sheet.

Results and discussion

The study collected 484,481 invertebrate individuals from the study sites, out of which 474,118 (97.9%) and 10,363 (2.1%) *Formica exsecta* and other invertebrate individuals, respectively, collected in the two habitat disturbance levels (the disturbed and less disturbed habitat) and two seasons (dry and wet seasons). The disturbed habitat had 259,357 *Formica exsecta* and 2,216 other invertebrate individuals whereas the less disturbed habitat had 214,761 *Formica exsecta* and 8,147 other invertebrate individuals (*Table 1*). The abundance of *Formica exsecta* was significantly higher in the disturbed habitat than in the less disturbed habitat (*Fig. 2,* Mann Whitney U = 131, $p < 0.0004$, n1 = 25, n2 = 25). Other invertebrates were significantly higher in the less disturbed habitat level than in the disturbed habitat level (*Fig. 2,* Mann Whitney U = 54, $p < 0.0001$, n1 = 25, n2 = 25).

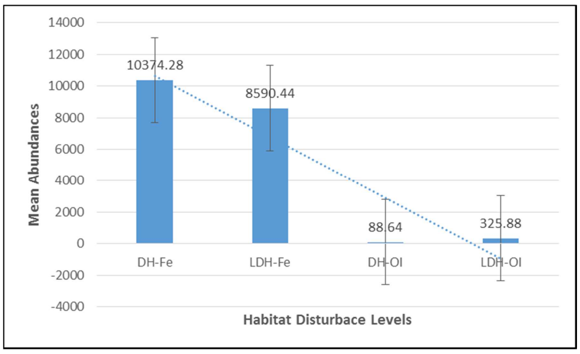

Fig. 2. The mean abundance of *Formica exsecta* and Other Invertebrates in the disturbed and less disturbed habitat levels in fragment of the Tanzania's Coastal Forests. DH = Disturbed Habitat, LDH = Less Disturbed Habitat, Fe = *Formica exsecta*, OI = Other Invertebrates.

The dry season had 338,539 *Formica exsecta* and 4,003 other invertebrate individuals whereas the wet season had 135,579 *Formica exsecta* and 6,360 other invertebrate individuals (Table 1). The abundance of *Formica exsecta* was significantly higher in the dry than in the wet season (Fig. 3, Mann Whitney U= 4, $p < 0.0001$, n1= 25, n2= 25). Other invertebrates were not significant in terms of the differentials between the dry season and the wet season (Fig. 3, Mann Whitney U= 219, p= 0.071, n1= 25, n2= 25).

The results indicate that *Formica exsecta* favoured high temperature of the dry season whereas the cool temperatures of wet season were more favourable to other invertebrate individuals (Richards & Windsor, 2007). It emerged that the wet environment ensured a well-developed canopy layer that found supporting terrestrial invertebrate such as ants, hence increasing its biomass, (Owens *et al.,* 2022) other invertebrates in the present study possibly embraced similar trend.

Formica exsecta and other aggressive *Formicidae* ants accounted for 99 percent of all the invertebrate individuals collected, which could also have lowered the diversity of other invertebrate in the dry season as was in the case of Mohamed (2023).

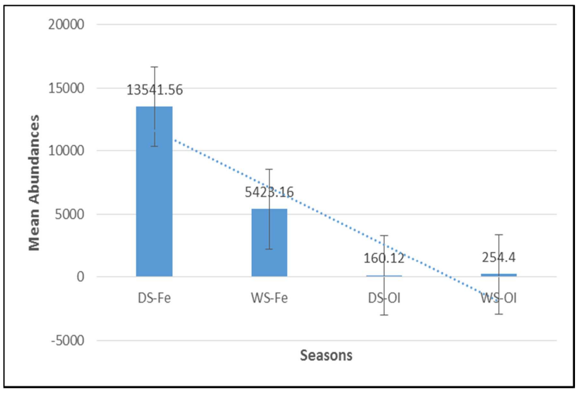

Fig. 3. The mean abundance of *Formica exsecta* and other invertebrates in the dry and wet seasons in fragment of the Tanzania's Coastal Forests. DS = Dry Season, WS= Wet Season, Fe= *Formica exsecta*, OI = Other Invertebrates.

The total abundance of *Formica exsecta* insignificantly and negatively correlated with the total abundance of other invertebrates ($r = -0.0012$, $p > 0.05$). This result could be attributable to its higher abundance by more than 99 percent of all the collected invertebrate individuals as Mohamed (2016) had established to be similar on aggressive *Solenopsis sp.* In the two disturbance levels, they negatively correlated in the disturbed habitat with dominance of 54.7 percent of all the collected *Formica exsecta* (r= -0.048) but positively correlated in the less disturbed habitat with dominance of 45.3% (r= 0.047). However, both results were insignificant (p> 0.05). This suggests that the higher the dominance of *Formica exsecta,* the more negative effects it would have on other invertebrates.

Also, the abundance of *Formica exsecta* were found to negatively correlate with the abundance of other invertebrates during the dry season (71.4% dominance of all the collected *Formica exsecta*). Between the two disturbance levels, it was higher in the disturbed habitat with 54.7 percent dominance (r= -0.206) than in less disturbed habitat with 45.3 percent dominance (r= -0.002). However, the differences were not significant ($p > 0.05$).

During wet season (with 28.6% dominance of all the collected *Formica exsecta*), the abundance of *Formica exsecta* significantly positive correlated with the abundance of other invertebrates (r= 0.436, p= 0.03) in the disturbed habitat but slightly negatively correlated in the less disturbed habitat (r= -0.205) though not statistically significant ($p > 0.05$).

Furthermore, the present studies found that Formica exsecta were more active during the dry seasons with 71.4 percent followed by the disturbed habitat (54.7%). The less disturbed habitat accounted for 45.3 percent. Finally, the least active occurred during wet season (28.6%) for of all the *Formica exsecta* individuals collected. Essentially, all the collection efforts required the movement of the targeted organisms or else they could not have been captured. Implicitly, more collections imply being more active in the respective season or habitat disturbance level and vice-versa.

Table 1. The abundance of *Formica exsecta* and other Invertebrates in the two habitat disturbance levels and the two seasons in fragment of the Tanzania's Coastal Forests. DH = Disturbed Habitat, LDH = Less Disturbed Habitat, DS = Dry Season, WS = Wet Season.

Trap ID	*Formica exsecta*							Other Invertebrates							Grand Total
	DH			LDH			Total	DH			LDH			Total	
	DS	WS	TOTAL	DS	WS	Total		DS	WS	TOTAL	DS	WS	Total		
1	3478	5790	9268	3683	2793	6476	15744	65	86	151	45	58	103	254	15998
2	5341	3125	8466	3982	2878	6860	15326	131	94	225	70	127	197	422	15748
3	7285	3588	10873	4118	2948	7066	17939	85	73	158	286	98	384	542	18481
4	6188	3027	9215	5286	2639	7925	17140	75	104	179	160	115	275	454	17594
5	7209	3973	11182	7560	2453	10013	21195	83	82	165	282	314	596	761	21956
6	6124	2120	8244	5377	1239	6616	14860	10	85	95	457	862	1319	1414	16274
7	5953	2203	8156	4068	1780	5848	14004	13	16	29	74	32	106	135	14139
8	7457	3443	10900	4766	2566	7332	18232	20	54	74	165	28	193	267	18499
9	8608	4113	12721	6247	3289	9536	22257	56	37	93	51	34	85	178	22435
10	7764	3183	10947	5052	2291	7343	18290	38	44	82	31	56	87	169	18459
11	8541	1697	10238	4616	2360	6976	17214	27	41	68	111	56	167	235	17449
12	7750	1872	9622	5985	2298	8283	17905	13	31	44	74	96	170	214	18119
13	7928	2546	10474	4314	1040	5354	15828	24	25	49	37	371	408	457	16285
14	6697	2409	9106	6839	1277	8116	17222	17	17	34	66	183	249	283	17505
15	6589	2899	9488	6888	1468	8356	17844	40	21	61	95	425	520	581	18425
16	7582	2095	9677	6372	2049	8421	18098	29	21	50	38	431	469	519	18617
17	6135	2927	9062	6060	2989	9049	18111	69	36	105	34	67	101	206	18317
18	6632	2632	9264	6225	1605	7830	17094	16	31	47	59	31	90	137	17231
19	7867	2064	9931	5498	3005	8503	18434	11	35	46	89	211	300	346	18780
20	9061	4165	13226	5412	1530	6942	20168	24	30	54	52	485	537	591	20759
21	8319	2055	10374	6603	2699	9302	19676	18	25	43	272	202	474	517	20193
22	10664	2150	12814	8984	2239	11223	24037	52	23	75	50	131	181	256	24293
23	10096	2000	12096	9754	3681	13435	25531	22	41	63	111	129	240	303	25834
24	8121	3516	11637	10213	5466	15679	27316	36	36	72	146	437	583	655	27971
25	8872	3504	12376	8376	3901	12277	24653	114	40	154	60	253	313	467	25120
Total	186261	73096	259357	152278	62483	214761	474118	1088	1128	2216	2915	5232	8147	10363	484481

Species Diversity

A total of 134 species were collected out of which 12 were identified at the species level and 122 as morpho species. *Formica exsecta* dominated by accounting for 97.9 percent of all the 484,481 invertebrate individuals collected. The rest having less than 1.2 percent each. A total of 87 families and 18 orders were collected, out of which the family *Formicidae* and order *Hymenoptera* each led by more than 99% of all the collected individuals (*Table 2*) relating to study conducted by Popescu *et al.* (2021) who also found greater representation of the *Formicidae* individuals.

The disturbed habitat had a higher number of individuals (n= 261,573) than the less disturbed habitat (n= 222,908). On the other hand, the disturbed habitat had a lower diversity and number of species (H= 0.078, Taxa S= 110) than the less disturbed habitat (H= 0.224, Taxa S= 119) the difference was significant (t= -55.03, df = 3.8655E05, p =0). The higher number of taxa and diversity in the less disturbed habitat level corresponded with the results of Niba & Yekwayo (2016) who had found higher taxa in natural forests and grasslands with less distortion coupled with higher diversity, which could have been contributed by the lower abundance of aggressive *Formica exsecta* relative to the disturbed habitat, which raised its higher abundance by more than 99% of all the individuals collected in the disturbed habitat.

Table 2. Taxonomic profile, abundance and diversity of Invertebrate taxa sampled in the two habitat disturbance levels and the two seasons in fragment of the Tanzania's Coastal Forests. DH= Disturbed Habitat, LDH= Less Disturbed Habitat, DS= Dry Season, WS= Wet Season.

Taxonomy			Data				
			Habitat Disturbance Levels		Seasons		TOTAL
Order	Family	Morpho Species & Species Names	DH	LDH	DS	WS	
Araneae	Agelenidae	*Agelenopsis* sp.	69	67	49	87	136
	Lycosidae	*Lycosid* sp.	10	9	6	13	19
	Salticidae	*Salticid* sp.	35	30	24	41	65
	Thomicidae	*Thomicid* sp.	15	12	4	23	27
	Sparassidae	*Sparassid* sp.	1	4	1	4	5
	Corinnidae	*Corinnid* sp.	169	130	123	176	299
	Mimetidae	*Mimetid* sp.	2	3	1	4	5
	Pholcidae	*Pholcus* sp.	3	4	5	2	7
Blattodea	Blattidae	*Periplaneta americana*	105	185	151	139	290
		Periplaneta sp.	13	45	43	15	58
		Blattid sp.	8	21	23	6	29
		Blatta sp.	85	146	76	155	231
	Blaberidae	*Blaberid* sp.1	17	13	20	10	30
		Blaberid sp.2	10	23	31	2	33
		Blaberus sp.	8	16	22	2	24
	Blattellidae	*Blattellid* sp.	15	19	20	14	34
		Blattella sp.	13	28	19	22	41
Coleoptera	Trogidae	*Omorgus* sp.	1	1	2	0	2
	Passalidae	*Passalid* sp.	0	6	1	5	6
	Tenebrionidae	*Tenebrionid* sp.1	7	9	3	13	16
		Tenebrionid sp.2	5	5	3	7	10
		Tenebrio molitor	2	2	1	3	4
		Cossyphus sp.	2	1	1	2	3
	Coccinellidae	*Coccinellid* sp.	17	14	2	29	31
	Carabidae	*Carabid* sp.1	14	18	11	21	32
		Carabid sp.2	3	7	3	7	10
		Carabid sp.3	1	4	1	4	5
		Carabid sp.4	1	2	1	2	3
		Crepidogaster sp.	23	27	22	28	50
	Histeridae	*Histerid* sp.	1	0	1	0	1
	Chrysomelidae	*Chrysomelid* sp.1	19	4	1	22	23
		Chrysomelid sp.2	11	3	0	14	14
		Dicladispa sp.	2	2	1	3	4
	Scarabaeidae	*Scarabaeid* sp.1	5	5	8	2	10
		Scarabaeid sp.2	1	4	5	0	5
		Garreta azureus	4	2	0	6	6
		Garreta sp.	3	2	0	5	5
		Hypopholis sommeri.	1	2	0	3	3
		Serica brunnea	0	1	0	1	1
	Phalacridae	*Phalacrid* sp.	0	1	1	0	1
	Elateridae	*Elaterid* sp.	0	1	1	0	1
	Nitidulidae	*Nitidulid* sp.	45	27	0	72	72
	Curculionidae	*Curculionid* sp.	8	7	0	15	15
	Drilidae	*Drilid* sp.	1	0	0	1	1
	Staphylinidae	*Staphylinid* sp.	1	2	0	3	3
	Cerambycidae	*Cerambycid* sp.	1	0	0	1	1
Dermaptera	Forficulidae	*Forficulid* sp.	4	3	6	1	7
	Labiduridae	*Labidurid* sp.	4	4	0	8	8
Diptera	Muscidae	*Muscid* sp.1	10	1	6	5	11
		Muscid sp.2	5	6	0	11	11
	Calliphoridae	*Lucilia sericata*	2	5	1	6	7
	Phoridae	*Phorid* sp.	7	0	2	5	7
	Sciaridae	*Sciarid* sp.	3	0	2	1	3
	Drosophillidae	*Drosophila* sp.	67	182	20	229	249
	Platystomatidae	*Amphicnephes* sp.	6	7	0	13	13
	Pyrgotidae	*Pyrgotid* sp.	0	1	0	1	1
	Stratiomyiidae	*Stratiomyiid* sp.	1	0	0	1	1

Taxonomy			Data				
			Habitat Disturbance Levels		Seasons		TOTAL
Order	Family	Morpho Species & Species Names	DH	LDH	DS	WS	
	Sarcophagidae	*Sarcophagid* sp.	0	2	0	2	2
	Culicidae	*Aedes* sp.	0	1	0	1	1
Embiidina	Oligotomidae	*Oligotomid* sp.	0	8	7	1	8
Geophilomorpha	Geophildae	*Geophilus* sp.	10	13	11	12	23
Haplotaxida	Lumbricidae	*Lumbricid* sp.	7	6	0	13	13
Hemiptera	Reduviidae	*Reduviid* sp.1	5	5	3	7	10
		Reduviid sp.2	5	3	1	7	8
		Reduviid sp.3	0	2	1	1	2
		Reduviid sp.4	1	2	0	3	3
	Pseudococcidae	*Pseudococcid* sp.	65	37	41	61	102
	Coreidae	*Coreid* sp.	2	10	1	11	12
	Fulgoridae	*Fulgorid sp.*	2	1	3	0	3
	Lygaeidae	*Lygaeid* sp.1	4	8	4	8	12
		Lygaeid sp.2	1	4	1	4	5
	Pyrrhocoridae	*Dysdercus* sp.1	8	10	1	17	18
		Dysdercus sp.2	2	2	0	4	4
	Miridae	*Mirid* sp.	0	2	2	0	2
	Tingidae	*Tingid* sp.	1	0	0	1	1
	Cixiidae	*Cixiid* sp.	0	1	0	1	1
	Scutelleridae	*Scutellerid* sp.	2	0	0	2	2
	Pentatomidae	*Pentatomid* sp.	0	1	0	1	1
	Alydidae	*Alydid* sp.	0	1	0	1	1
	Cydnidae	*Pangaeus* sp.	3	4	0	7	7
	Aradidae	*Aradid* sp.	0	1	0	1	1
Hymenoptera	Formicidae	*Formica exsecta*	259357	214761	338539	135579	474118
		Polyrhachis gagates	31	61	85	7	92
		Pachycondyla sp.	23	35	41	17	58
		Messor capensis	155	450	503	102	605
		Lepisiota sp.1	22	33	7	48	55
		Tetraponera sp.	50	115	132	33	165
		Lepisiota sp.2	36	7	10	33	43
		Formicid sp.1	131	600	723	8	731
		Formicid sp.2	447	5166	1341	4272	5613
		Formicid sp.3	0	2	1	1	2
	Eumenidae	*Eumenid* sp.	3	3	2	4	6
	Mutillidae	*Ronisia* sp.	1	1	2	0	2
		Mutillid sp.	1	2	2	1	3
	Sphecidae	*Chlorion maxillosum*	1	1	2	0	2
		Sphecid sp.	0	1	0	1	1
	Pompilidae	*Pompilid* sp.	1	4	1	4	5
	Masaridae	*Masarid* sp.	0	2	1	1	2
	Ichneumonidae	*Ichneumon* sp.	1	0	0	1	1
	Halictidae	*Halictid* sp.	1	0	0	1	1
	Pteromalidae	*Pteromalid* sp.	1	0	0	1	1
	Evaniidae	*Evaniid* sp.	1	1	0	2	2
	Braconidae	*Braconid* sp.	0	2	0	2	2
	Tiphiidae	*Tiphiid* sp.	0	2	0	2	2
Isoptera	Termitidae	*Macrotermes* sp.	18	50	58	10	68
Julida	Julidae	*Cylindroiulus* sp.	39	36	54	21	75
		Julid sp.	23	30	34	19	53
Lepidoptera	Psychidae	*Psychid* sp.1	10	4	4	10	14
		Psychid sp.2	3	2	0	5	5
	Hepialidae	*Hepialid* sp.	2	2	2	2	4
	Nymphalidae	*Nymphalid* sp.1	0	2	1	1	2
		Nymphalid sp.2	7	8	2	13	15
	Tineidae	*Tineid* sp.	2	0	0	2	2
	Noctuidae	*Noctuid* sp.1	2	1	0	3	3
		Noctuid sp.2	0	1	0	1	1
	Sphingidae	*Sphingid* sp.	0	1	0	1	1
	Tortricidae	*Tortricid* sp.	0	2	0	2	2
	Satyridae	*Satyrid* sp.	1	0	0	1	1
Mantodea	Thespidae	*Thespid* sp.	2	0	2	0	2

Taxonomy			Data				
			Habitat Disturbance Levels		Seasons		TOTAL
Order	Family	Morpho Species & Species Names	DH	LDH	DS	WS	
Mesogastropoda	Pomatiasidae	*Tropidophora* sp.	2	2	1	3	4
Orthoptera	Acrididae	*Acridid* sp.	20	13	13	20	33
		Acrotylus sp.	7	5	5	7	12
		Cannula grasilis	4	1	1	4	5
	Gryllidae	*Cophogryllus* sp.1	111	138	111	138	249
		Cophogryllus sp.2	44	78	54	68	122
		Brachytrupes sp.	0	1	1	0	1
		Gryllidae sp.	1	1	2	0	2
	Anostostomatidae	*Anostostomatid* sp.	3	1	3	1	4
	Tettigoniidae	*Tettigoniid* sp.	1	0	0	1	1
Solifugae	Solpugidae	*Solpugid* sp.	2	1	0	3	3
Stylommatophora	Subulinidae	*Pseudoglessula* sp.	3	7	0	10	10
	Streptaxidae	*Gullella* sp.	1	4	1	4	5
		Gonaxis sp.	1	2	0	3	3
	Urocyclidae	*Urocyclid* sp.	17	19	1	35	36
Total Number of Individuals (N)			261573	222908	342542	141939	484481
Total Number of Taxa (S)			110	119	89	122	134
Shannon Wiener Diversity Index (H’)			0.0779	0.2241	0.0931	0.2656	0.152

Contrary to many findings (see, for example, Zeng *et al.*, 2023; Owens *et al.*, 2022), the dry season had a higher number of individuals (n = 342,542) than the wet season (n = 141,939), possibly, due to the over-dominance of aggressive *Formica exsecta*. Indeed, the *Formica exsecta* collected accounted for more than 98 percent of all the individuals in the dry season, which naturally lowered the diversity and number of species (H = 0.093, Taxa S = 89) in comparison to the wet season (H = 0.266, Taxa S = 122). The difference was significant (t = -53.081, df = 1.9746E05, p = 0) primarily because several invertebrates are incapable of enduring the hostility of the *Formicidae* ants (Mohamed, 2023), hence resulting into their displacement. The higher invertebrate biodiversity in the wet season correlate with both Zeng *et al.* (2023) and Owens *et al.* (2022) who similarly found high levels of diversity and biomass of terrestrial invertebrates such as termites and ants. Also, the wet season supports the sprouting of a variety of trees and rotten woods (Schowalter *et al.*, 2021) fostering eco-system productivity, which created amenable environments for many invertebrate individuals and, hence, the higher taxa numbers and diversity also registered in this study.

Conclusion

Despite the difficulties inherent in estimating invertebrate biodiversity, still are worldwide known as a major component in terrestrial ecosystems (Dopheide *et al.*, 2019). Therefore, the present study provides a unique foundation for estimating invertebrate biodiversity in the Tanzania’s Coastal Forests (TCFs) and the onset of invasive *Formica exsecta* with their respective ecological effects. In fact, this study has demonstrated that TCFs have a higher number of invertebrate species and diversity, hence raising the possibility of higher litter decomposition. This conclusion is consistent with Zeng *et al.* (2023) who had reported higher invertebrate diversity together with other factors such as warm, humidity and acidity being highly associated with forest litter decompositions, hence directly ensuring TCFs sustainability and continuity. The ongoing deterioration of TCFs may have many ecological effects including the invasion of non-native flora and fauna such as *Maesopsis eminii* and *Formica exsecta,* respectively, as they are both enticed by low canopy cover (Mwendwa *et al.*, 2019; UK-Wood Ant (UK-WA), n.d.). Such threats to the TCFs can endangers enormous endemic wildlife. Implicitly, there is a need for conservation efforts that can integrate both private and public-owned small and large-scale fragments before it was too late.

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