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Distribution, diversity and abundance of some insects around a telecommunication mast in Ilorin, Kwara State, Nigeria

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Abstract

Background: The preponderant use of wireless telecommunication in the twenty-first century has enabled ease and efficient communication and a pervasive occurrence of electromagnetic fields (EMFs) that has significantly impacted the ecosystem. This study looks at the effect of radiations from wireless telecommunication EMF on the distribution, diversity and abundance of some insects in Nigeria. The study was undertaken in Ilorin, Kwara State, which is located in the Guinea Savannah belt of Nigeria. The chosen choice of study area was one with a telecommunication mast devoid of residential and human interference within a 10 km radius. Five sampling stations were selected around the mast and a control station. EMR intensity levels and pollinating insect number were monitored daily for 22 weeks using an acoustimeter and malaise traps. Collected insects were identified morphologically using appropriate keys.

Results: The mean electromagnetic radiation (EMR) intensity was significantly ($P < 0.05$) highest (1.58 ± 1.52 V/m) at sampling station B, and there was an increase in EMR intensity as the radius reduced around the mast. A total of 1878 insects were recovered from the study with the dominant species in terms of abundance of insects collected from the study being *Musca domestica* (0.39) followed by *Apis mellifera* (0.31) and *Locusta migratoria* (0.30), while the least dominant species *Tetramorium caespitum* (0.23).

Conclusions: Indeed, EMR intensity has an effect on the distribution, diversity and abundance of insects and there is a need to reduce the number of masts in use in the environment by encouraging telecommunication service providers to jointly use the same mast in an area for broadcast.

Keywords: EMF, EMR intensity, Insects, Nigeria

Background

The intensity of electromagnetic radiation (EMR) and preponderance of electromagnetic fields (EMFs) have been on a steady increase in the environment (Galeev 2000; Levitt and Lai 2010). The advent and popularity of wireless telecommunication system that functions solely within EMFs have been a major reason behind this trend. This is more so because high rising masts are

frequently used for the establishment of EMFs in environments for wireless telecommunication (Urbiniello et al. 2014). The Nigerian environment has witnessed unprecedented input of EMR and EMFs' coverage in the last three decades, and these are still on the increase. The situation in Nigeria is further compounded by numerous competing telecommunication outfits, each of which saddles itself with the responsibility of providing its own EMF using its own mast to cover the Nigerian space and market. Further encouraging EMR pollution in Nigeria is the improved ownership coverage and use of mobile phones by the citizenry.

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Electromagnetic fields and irradiations therein have been variously documented as abiotic factors that influence insect communities and could impact on their roles in the provision of some ecosystem services they render. Studies have shown the negative effects of EMFs on the reproductive success, development and navigation of flying insects, e.g. butterflies, honeybees, etc., and other pollinators (Favre 2011; Guerra et al. 2014; Lazaro et al. 2016).

Honeybees' sensitivity to EMFs generated from mobile phones informs intrinsic behavioural alterations and frequent loss of colonies (Lazaro et al. 2016). EMFs also affect monarch butterfly orientation, and it is perceived as a cause of their population decline (Brower et al. 2012; Guerra et al. 2014). Lazaro et al. (2016) also reported that EMR impacted negatively on the abundance and diversity of all pollinators which included wild bees, hoverflies, bee flies, beetles and wasps, except butterflies within the environment they evaluated.

Going by these reports and observations, EMFs and EMRs are highly potent abiotic factors that can weaken an ecosystem by disabling coordinated action and service delivery of flying insects (Lazaro et al. 2016). Unfortunately, a general overview of the impacts of EMFs and EMRs on the general distribution, diversity and abundance of insects in Nigeria is yet to be documented despite the valid need for same. Here, the possible effects of EMFs and EMR levels from a

telecommunication mast on insects' abundance, diversity and distribution are studied and reported.

Methods

Study area

This research work was carried out in Ilorin South Local Government Area of Kwara State (Latitude: 8° 44' to 8°46' N and Longitude: 4°55' to 4°57' E) (Fig. 1) in the Guinea savannah belt of Nigeria. The area is marked by two climatic seasons: the dry and wet seasons with an intervening cold and dry Harmattan from December to January and an annual rainfall range between 1000 mm and 1500 mm. The choice location which was frantically sought after and selected was one that has a telecommunication mast at the centre of a grassland vegetation devoid of residential house and human interference within a 10 km radius (Lazaro et al. 2016).

Study design

The telecommunication mast within the study area is a mobile telephony base station (GSM-1800), a typical mast type in use in Nigeria, with a height of 300 m, located at below 350 m above sea level, emitting non-ionizing radiation, and using a frequency band of between 900 and 1,800 MHz (Opara et al. 2014). Using the same gadget, instantaneous radiation levels at various radii ranges from the base of the mast were monitored at various times of the day and times of the year for comparison. Radii ranges that recorded radiation levels that were not significantly different ($P > 0.05$) were taken to

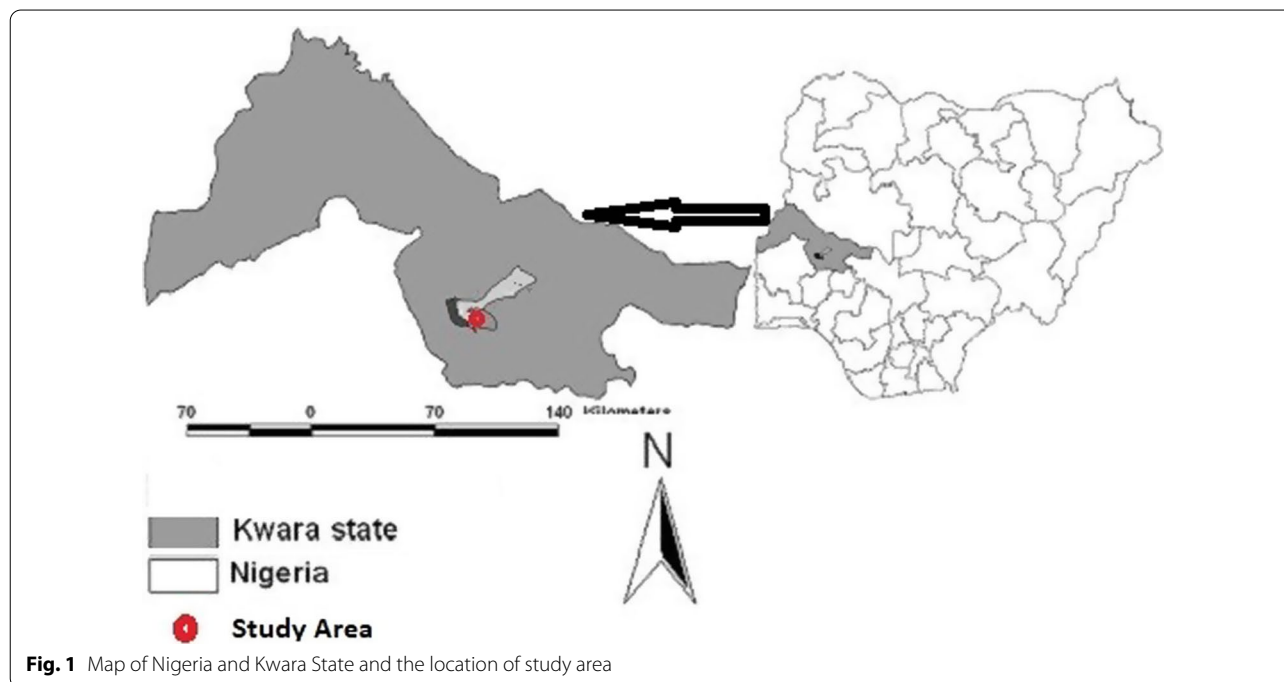


Fig. 1 Map of Nigeria and Kwara State and the location of study area

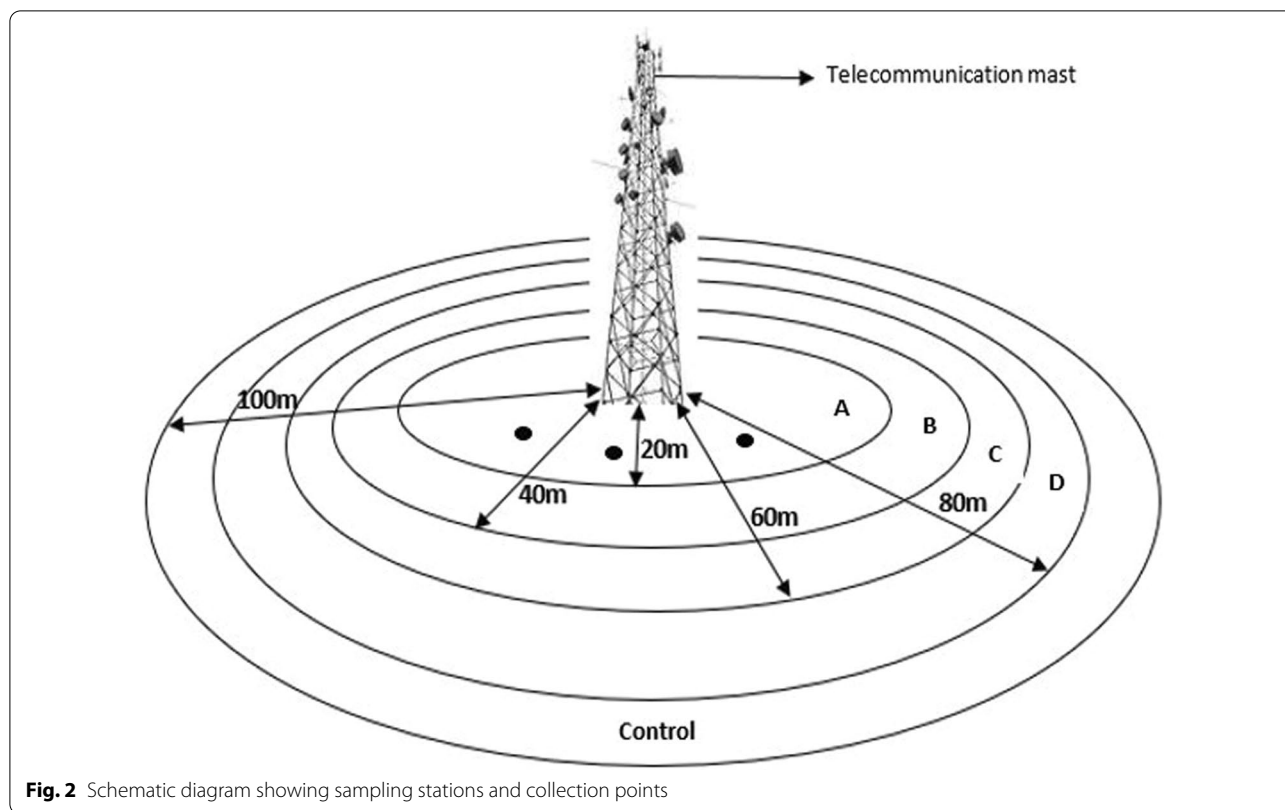
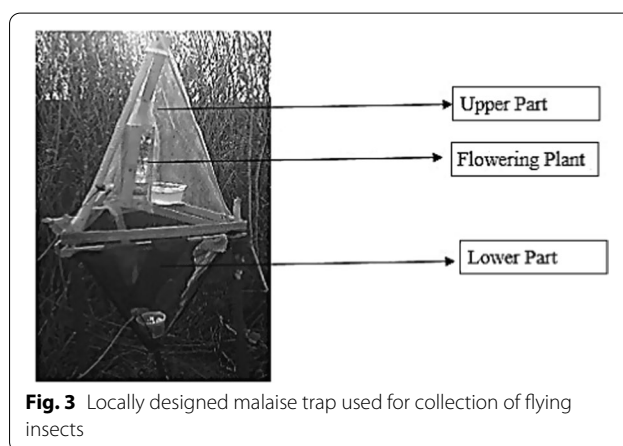


Table 1 Sampling stations radii ranges around the telecommunication mast and their respective EMR characteristics

Sample station	Radius range description around mast	Electromagnetic radiation range
A	< 20 m	1.35 ± 1.28 ^{bc}
B	< 40 m	1.58 ± 1.52 ^c
C	< 60 m	1.03 ± 0.98 ^b
D	< 80 m	1.04 ± 0.94 ^b
Control	> 80 m	0.51 ± 0.44 ^a

Values along column with different superscript are significantly different ($p > 0.05$)

represent a sampling station. Five sampling stations were identified on this premise as shown in Fig. 2 and Table 1. Within each sampling station, three collection points of 2 m² were selected carefully around the mast to avoid contiguity across sampling stations as replicate collection points per station. The selected sampling stations were tagged as Control Station (> 80 m from the mast), Station A (< 80 m from the mast), Station B (< 60 m from the mast), Station C (< 40 m from the mast) and Station D (< 20 m from the mast) (Fig. 2).



Electromagnetic radiation intensity monitoring

The electromagnetic radiation intensities (Volt/meter) were taken monitored and noted between 08:00 h and 10:00 h, 12:00 h and 14:00 h and 16:00 h and 18:00 h each sampling day, and per collection point using an RF acoustimeter (Model AM-10), a broadband meter that measures the totality of the radiation frequencies in the range 200 MHz to over 8000 MHz.

Insect collection and identification

Insects' sampling was done once a week at all the collection points and sampling stations for 22 weeks using locally designed malaise traps. The traps were modified with an upper part made of white net with a potted flowering plant in between the cone and a lower part with black net with a colour striped cloth (red blue and yellow) alongside (Chittka and Thomson 2001) (Fig. 3). Soapy water was used as killing agent in the pan traps.

Traps were set in each sample point and allowed to stand for 24 h after which all insect collections were retrieved. Each collection was harvested from the traps, sorted and preserved wet in 70% ethanol inside vials labelled according to sample point, station and collection date. All samples collected were taken to the Entomology Laboratory of the Department of Zoology, University of Ilorin, for identification and enumeration. Morphological identification of collected insects was done using dissecting microscope (Olympus) and identification keys (Buck et al. (2008) for Lepidopterans, Zenner et al. (2005) for Hymenopterans, Stejskal et al. (2014) for Coleopterans Veer et al. (2013) for Orthopterans and Whitworth (2010) for Dipterans).

Data collation and analysis

Three diversity indexes were used to determine the differences between selected sample stations, including Simpson's diversity index (S), Shannon–Weiner diversity index (H) and Evenness index (E). Average density and recovery rate of insects collected were evaluated. Also, the distribution per station per insect type was calculated. Chi-square was used to evaluate the significant difference between the EMR intensity values at the various sampling stations and to compare insects' species abundance from each sampling station using GraphPad Prism 8. The diversity indices of all collected insect's species in the sampling stations were evaluated using PAST.

Results

EMR intensities at sampling stations

The mean EMR intensity at the control station (0.51 ± 0.44 V/m) was significantly lower ($P < 0.05$) than readings recorded from all of the other four sampling stations. Although the minimum values recorded in the ranges of intensities per station were not discreetly different, the maximum intensities were different and these seem to decrease with the radii from the mast. This was corroborated by readily observable and statistically viable mean EMR intensity increase with radius reduction, i.e. towards the mast, but there was no significant difference ($P > 0.05$) between the intensities in sampling stations D (1.04 ± 0.94 V/m) and C (1.03 ± 0.99 V/m). The mean

Table 2 Range and mean EMR intensity values at different sampling stations

Station	Radius range (m)	EMR intensity range (V/m)		Mean EMR intensity \pm S.E. (V/m)
		Minimum	Maximum	
Control	80–100	0.07	0.95	0.51 ± 0.44^a
D	60–80	0.10	1.98	1.04 ± 0.94^b
C	40–60	0.04	2.01	1.03 ± 0.99^b
B	20–40	0.06	3.10	1.58 ± 1.52^c
A	<20	0.07	2.63	1.35 ± 1.28^d

Values along column with different superscripts are significantly different ($P > 0.05$), $n = 22$

EMR intensity was highest (1.58 ± 1.52 V/m) at sampling station B and significantly different ($P < 0.05$) from all other sampling stations. However, at sampling station A, mean EMR intensity dropped slightly (1.35 ± 1.28 V/m) but was significantly higher ($P < 0.05$) than mean values recorded in sampling stations D and C (Table 2).

Insects' abundance and distribution

The Guinea Savannah belt location sampled for insects around a telecommunication mast presented quite an array some of which were eluded by the malaise trapping method adopted for the study. Majority were, however, trapped, identified and enumerated per sampling point and station. The total numbers of individual insects and types of species recovered all through the sampling period were quite impressive and varied. Some of these were, however, not conclusively identified and hence were not reckoned with. A total of 1878 known individuals were recovered from all the sampling points in the course of the study.

Insects that featured most readily amidst recoveries in the traps within the location include *Locusta migratoria* Linn. (Orthoptera: Acrididae), *Apis mellifera* Linn. (Hymenoptera: Apidae), *Tetramorium caespitum* Linn. (Hymenoptera: Formicidae), *Vespula maculata* Linn. (Hymenoptera: Vespidae), *Bicyclus anynana* But. (Lepidoptera: Nymphalidae), *Musca domestica* Linn. (Diptera: Muscidae) and *Lasioderma serricorne* Fab. (Coleoptera: Ptinidae). Each of these insects featured in a completely randomized pattern although reflecting periods of relative abundance within the sampling era. The total numbers of each species recovered by traps on site of the 22 weeks of sampling were 293, 490, 435, 188, 109, 141 and 222, respectively. The average density of recovery per trap (N') and total numbers of traps that had the insects were 24.2, 40.83, 36.25, 15.67, 9.08, 11.75 and 18.50 individuals/trap, respectively, while the average recovery rate

Table 3 Average density and recovery rate of identified insects from sampling area

Species	Orders	Family	N	N'	N''
<i>Locusta migratoria</i>	Orthoptera	Acrididae	293	24.42	1.11
<i>Apis mellifera</i>	Hymenoptera	Apidae	490	40.83	1.86
<i>Tetramorium caespitum</i>	Hymenoptera	Formicidae	435	36.25	1.65
<i>Vespula maculata</i>	Hymenoptera	Vespidae	188	15.67	0.71
<i>Bicyclus anynana</i>	Lepidoptera	Nymphalidae	109	9.08	0.41
<i>Musca domestica</i>	Diptera	Muscidae	141	11.75	0.53
<i>Lasioderma serricorne</i>	Coleoptera	Ptinidae	222	18.50	0.84
Total			1878		

N = Number of individuals, N' = number of individuals per trap, N'' = number of individuals per trap per week

per week (N'') for each one of them was 1.11, 1.86, 1.65, 0.71, 0.41, 0.53 and 0.84 individuals per trap per week, respectively (Table 3).

Most of *L. migratoria* and *B. anynana* collected were from the control station with 1.65 and 0.76 individual/station/week, respectively, while most of *T. caespitum*, *V. maculata*, *M. domestica* and *L. serricorne* were collected from station A with 2.00, 1.03, 1.20 and 1.29 individual/station/week, respectively. Most of *A. mellifera*

were collected from station C with 3.35 individual/station/week, and this is the highest in all of the collections made from all the stations in relation to species. In all the individual species collected, there was no significant difference ($P > 0.05$) between the collections made at the control station and stations A, B and C, while there was a significance difference ($P < 0.05$) between collections made at the control station and station D (Table 4).

Insects diversity indices across stations

The most dominant species in terms of abundance of insects collected from the study area was *Musca domestica* (0.39) followed by *A. mellifera* (0.31) and *L. migratoria* (0.30), while the least dominant species was *T. caespitum* (0.23). Meanwhile, the richest and most evenly distributed species was *T. caespitum* with a Simpson index of 0.77, Shannon index of 1.53 and Evenness index of 0.92 followed by *L. serricorne* ($S = 0.73$, $H = 1.41$ and $E = 0.82$, respectively), *B. anynana* ($S = 0.71$, $H = 1.41$ and $E = 0.82$, respectively) and *V. maculata* ($S = 0.72$, $H = 1.38$ and $E = 0.80$, respectively). The least rich and evenly distributed species is *M. domestica* with a Simpson index of 0.61, Shannon index of 1.16 and Evenness index of 0.64 (Table 5).

Table 4 Distribution of identified insects across sampling stations

Species	Sampling stations N (n)				
	Control	A	B	C	D
<i>Locusta migratoria</i>	109 (1.65) ^a	104 (1.58) ^a	49 (0.74) ^a	16 (0.24) ^a	15 (0.23) ^b
<i>Apis mellifera</i>	128 (1.94) ^a	75 (1.14) ^a	47 (0.71) ^a	221 (3.35) ^a	19 (0.29) ^b
<i>Tetramorium caespitum</i>	116 (1.76) ^a	132 (2.00) ^a	87 (1.32) ^a	63 (0.95) ^a	37 (0.56) ^b
<i>Vespula maculata</i>	54 (0.82) ^a	68 (1.03) ^a	46 (0.70) ^a	10 (0.15) ^a	10 (0.15) ^b
<i>Bicyclus anynana</i>	50 (0.76) ^a	17 (0.26) ^a	20 (0.30) ^a	14 (0.21) ^a	8 (0.12) ^b
<i>Musca domestica</i>	30 (0.45) ^a	79 (1.20) ^a	23 (0.35) ^a	7 (0.11) ^a	2 (0.03) ^b
<i>Lasioderma serricorne</i>	59 (0.89) ^a	85 (1.29) ^a	45 (0.68) ^a	25 (0.38) ^a	8 (0.12) ^b

N = Number of individuals, n = number of individuals per station per week, values along row with different superscripts are significantly different ($P > 0.05$)

Table 5 Diversity indices for identified insects around a telecommunication mast

Species	N	Dominance	Simpson (S)	Shannon (H)	Evenness (E)
<i>Locusta migratoria</i>	293	0.30	0.70	1.35	0.77
<i>Apis mellifera</i>	490	0.31	0.69	1.35	0.77
<i>Tetramorium caespitum</i>	435	0.23	0.77	1.53	0.92
<i>Vespula maculata</i>	188	0.28	0.72	1.38	0.80
<i>Bicyclus anynana</i>	109	0.29	0.71	1.41	0.82
<i>Musca domestica</i>	141	0.39	0.61	1.16	0.64
<i>Lasioderma serricorne</i>	222	0.27	0.73	1.41	0.82

Discussion

A steady exponential increase in the use of wireless telecommunication technologies today is leading to a significant change in EMR exposure, and different organisms react to EMR intensities in different ways which man can leverage upon to determine the quality of his environment (Levitt and Lai 2010). This is a first-time report on the abundance, diversity and distribution of some insects around a telecommunication mast in Nigeria. In this study, apart from the control station that has EMR intensity of less than 1 V/m, all other sampling stations had above 1 V/m. Unfortunately, Cammaerts and Johansson (2014), reported profound visual and olfactory memory effects of electromagnetic intensities ≥ 1 V/m on ants which caused them to lose their abilities to follow visual cues. Insects dwelling around telecommunication masts and within 100 m may be beset with some challenges in the ecosystem. Also, in this study, it was discovered that EMR intensities increased with radius reduction. This was consistent with Opara et al. (2014) but did not conform with earlier reports of Vijver et al. (2013) and Lazaro et al. (2016).

Three out of the seven species of insects recovered and identified in the study were Hymenopterans with *Apis mellifera* being the most recovered in terms of number of individuals, average density and recovery rate. Similarly, Lazaro et al. (2016) reported the preponderance of Hymenopterans in electromagnetic-rich zones. Most of *Locusta migratoria* and *Bicyclus anyana* collected were from the control station, while most of *Tetramorium caespitum*, *Vesicula maculata*, *Musca domestica* and *Lasioderma serricornis* were collected from station A. Diverse studies have reported that EMR intensities affect orientation abilities, foraging and homing abilities of pollinating insects in various ways, which are essential for their success and survival (Chittka and Thomson 2001; Sahib 2011; Cammaerts and Johansson 2014). This fact is displayed by preference of insects collected to varying sampling stations with EMR intensity being one of the major distinguishing factors evaluated. Most of the *A. mellifera* (honeybee) collected in the study were recovered from sampling station C. It has been reported that honeybees in nature rely on perception of electric fields among others to adapt and survive in the environment (Clarke et al. 2013) and are sensitive to generated electric fields from telecommunication masts (Favre 2011). However, there has been reported honeybee's colony losses as a result of EMR exposure (Favre 2011) which might be one of the contributing factors to their decline (Potts et al. 2010) which has serious economic and ecological implications because of their role in the ecosystem (Sahib 2011).

Information on the impact of telecommunication mast on insect community structures altering species diversity (richness and evenness) and threatening the maintenance of ecosystem service is lacking (Lazaro et al. 2016). This study was able to evaluate the species diversity of some insects on EMR fields generated from telecommunication mast, and it was observed that the most dominant insect species was *M. domestica* followed by *A. mellifera*. Meanwhile, the richest and most evenly distributed species was *T. caespitum* which was the least dominant. Evidently, EMR intensity levels in the ecosystem significantly affect the behaviour and community structure of insects (Cammaerts and Johansson 2014). With the increase in EMR intensity levels in our environment, this may have an impact on the distribution, diversity and abundance of insects who play a major role in the ecosystem, hence creating gaps which might impact food security.

Conclusions

This study has been able to establish that the abundance, distribution and diversity of insects are affected by EMR fields and intensity, showing that most insects favoured areas with lower EMR intensities, hence the more need to regulate the amount of EMR intensity in the environment by encouraging telecommunication service providers to jointly use the same mast for broadcast in order to reduce the number of masts in Nigeria.

Abbreviations

EMF: Electromagnetic field; EMR: Electromagnetic radiation.

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Authors' contributions

OJA designed the research protocol and methodology and did the statistical analysis and developed the manuscript. ATA conceptualize this research concept and designed the research protocol and methodology. GDA carried out the field work. IAO carried out the field work. OAO designed the research protocol and methodology. AOO provided technical input. All the authors read and approved the final manuscript.

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Availability of data and materials

The data sets generated during and/or analysed during the current study are not publicly available (general agreement among the authors) but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Ethical clearance was obtained from the Faculty of Life Science ethical committee before the onset of the research with the University Ethical Review Committee Approval Number of UERC/ASN/2016/435.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interest.

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