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Original Article

Physicochemical Characteristics of *Anopheles* Larval Habitats and Their Influence on Adult Wing Morphometrics and Permethrin Susceptibility in Minna, Niger State, Nigeria

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ABSTRACT

The physicochemical quality of Anopheles larval habitats and its effects on adult traits remain poorly studied in Minna, Niger State, a high malaria burden city in North Central Nigeria. Two major breeding habitats (rice fields and rain pools across Bosso, Tunga and Maitumbi) were characterized and their influence on adult wing morphometrics, fluctuating asymmetry (FA), and susceptibility to permethrin (0.75%) were assessed. Rice fields exhibited significantly higher turbidity (52.67–68.30 NTU), total dissolved solids (168.29–204.28 mg/L), nitrate (22.62–28.48 mg/L), and biological oxygen demand (247.78–312.25 mg/L), but lower dissolved oxygen (2.15–2.63 vs. 5.22–5.79 mg/L; $p < 0.05$). Adults from rice fields consistently had longer wings, most notably at Bosso (3.24 ± 0.32 vs. 3.12 ± 0.18 mm; $p < 0.05$). Fluctuating asymmetry (FA) peaked at Bosso rice fields (0.18 ± 0.24 mm), indicating developmental stress in chemically extreme habitats. Permethrin bioassays confirmed resistance across all groups: no knockdown within 40 minutes and maximum 24-hour mortality of 37.50 ± 12.58%, far below the WHO 98% threshold. Rain pool mosquitoes from Maitumbi showed slightly higher mortality (37.50%) than rice field counterparts (27.50%), consistent with habitat-driven modulation of detoxification enzyme activity. These findings highlight rice fields as the most epidemiologically consequential breeding sites, underscoring the need for larval source management and rotation to non-pyrethroid insecticides in Niger State.

Keywords: *Anopheles*; breeding habitats; physicochemical parameters; wing morphometrics; fluctuating asymmetry; permethrin resistance

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INTRODUCTION

Malaria continues to be the most significant vector-borne disease across sub-Saharan Africa, and WHO Africa Region, which include Nigeria, continues to bear the heaviest burden, accounting for

94% of cases and 95% of deaths globally 2025 [1]. Transmission is sustained exclusively by infected female *Anopheles* mosquitoes, whose larval ecology, adult body size, and insecticide susceptibility are strongly influenced by the physicochemical quality of their breeding habitats [2,3]. Minna, the rapidly urbanising capital of Niger State, lies in Nigeria's North Central zone, where malaria prevalence consistently exceeds the national average. This elevated transmission is driven by diverse larval habitat typologies maintained by seasonal rainfall and agricultural land use [4].

The water chemistry of larval habitats particularly turbidity, nutrient loadings, dissolved oxygen, and biological oxygen demand: defines the nutritional and chemical milieu in which larvae develop. These parameters directly shape adult body size, developmental stability, and physiological fitness [5,6]. Wing length, a validated proxy for body size in *Anopheles* [7], predicts longevity, blood-meal size, fecundity, and ultimately vectorial capacity. Fluctuating asymmetry (FA), the random deviation from bilateral wing symmetry, serves as a sensitive indicator of developmental instability arising from sublethal environmental or nutritional stress [7]. Moreover, habitat nutritional quality modulates adult insecticide resistance by influencing the expression of detoxification enzymes such as P450 monooxygenases, glutathione S-transferases, and carboxylesterases [8].

In Minna, previous surveys documented five *Culex* species across five habitat types, with *Anopheles* larvae co-occurring in over 75% of rice fields and rain pools [4]. However, no study has examined how the physicochemical attributes of these habitats translate into differences in adult wing morphometrics or permethrin susceptibility—data essential for evidence-based vector control [9]. Although pyrethroid resistance has been confirmed in *Anopheles gambiae* populations in Niger State [9], the link between larval habitat ecology and resistance phenotype intensity remains unexplored in Minna. This study therefore characterised the physicochemical conditions of the two most productive *Anopheles* habitats in Minna and evaluated their influence on adult wing length, fluctuating asymmetry, and susceptibility to permethrin (0.75%).

MATERIALS AND METHODS

Study Area

The study was conducted in Minna (9°36′50″N, 6°33′25″E), capital of Niger State, Nigeria, which covers approximately 88 km^2. The climate is characterised by a wet season (May–October) and a dry season (November–April), with mean annual rainfall of 1,334 mm and mean temperature of 30.2°C [4]. Sampling was undertaken across three communities—Bosso, Tunga, and Maitumbi—representing urban and peri-urban ecological gradients.

Habitat Identification and Larval Sampling

A systematic survey identified nine *Anopheles* larval habitat types: stream edges, rain pools, potholes, tyre tracks, rice fields, wells, plastic containers, drainages, and septic runoffs. Larvae were collected between 07:00 and 09:00 h using the WHO standard dipping method with a 350 mL white plastic dipper (10 dips per site) [4]. Third- and fourth-instar larvae were morphologically identified using standard taxonomic keys [10] and transported in labelled containers containing habitat water to the laboratory.

Physicochemical Analysis of Breeding Habitats

Water samples were collected concurrently with larval sampling from rice fields and rain pools— the two most productive habitats—at each of the three locations. Samples for biological oxygen demand (BOD) were collected in airtight containers. All samples were transported to the Upper Niger River Basin Development Authority laboratory for analysis of water temperature, pH, dissolved oxygen (DO), electrical conductivity, turbidity, total dissolved solids (TDS), total hardness (TH), total alkalinity (TA), nitrate, phosphate, chemical oxygen demand (COD), and BOD, following WHO standard procedures [11].

Wing Length and Fluctuating Asymmetry

Adult *Anopheles* mosquitoes reared from larvae collected at each habitat-location combination were used for morphometric assessment. Right and left wings were carefully removed with fine forceps under a magnifying lens, and wing length was measured from the alular notch to the apical margin (excluding fringe scales) using a millimetre ruler [12]. Fluctuating asymmetry (FA) was calculated as the absolute difference between right- and left-wing lengths for each individual.

Permethrin Susceptibility Bioassay

Susceptibility to permethrin (0.75%) was assessed using the WHO tube bioassay protocol [13]. Adult mosquitoes were exposed to permethrin-impregnated papers for 60 minutes, with knockdown recorded at 0, 15, 30, 40, 45, and 60 minutes. Mortality was recorded 24 hours post-exposure. Populations were classified as resistant (24-hour mortality $< 90\%$) or possible resistant (90 - 97%), and susceptible when mortality ($> 98\%$) according to WHO (2022) criteria [13].

Data Analysis

Data were analysed using the R statistical computing environment. Kruskal–Wallis analysis with Dunn's post-hoc test was applied for multi-group comparisons of physicochemical parameters and habitat-wise morphometric data. Welch's t-test was used for location-wise pairwise comparisons between habitat types. Statistical significance was set at $p < 0.05$. Values are expressed as Mean $\pm$ SD.

RESULTS

Physicochemical Conditions of *Anopheles* Breeding Habitats

Physicochemical parameters of rice fields and rain pools across the three sampling stations are summarised in Tables 1 and 2. In rice fields, pH (8.10–8.32) and temperature (27.47–28.16°C) did not vary significantly across locations ($p > 0.05$). All other parameters showed significant differences ($p < 0.05$). Turbidity ranged from 52.67 $\pm$ 0.09 NTU at Tunga to 68.30 $\pm$ 0.14 NTU at Maitumbi; conductivity from 279.83 $\pm$ 0.25 to 340.70 $\pm$ 0.99 µS/cm; TDS from 168.29 $\pm$ 0.41 to 204.28 $\pm$ 0.39 mg/L; nitrate from 22.62 $\pm$ 0.02 to 28.48 $\pm$ 0.11 mg/L; BOD from 247.78 $\pm$ 0.31 to 312.25 $\pm$ 0.33 mg/L; and DO from 2.15 $\pm$ 0.07 to 2.63 $\pm$ 0.04 mg/L. Bosso rice fields recorded the highest values for conductivity, TDS, nitrate, and BOD respectively.

In rain pools, pH (7.40–7.65) and temperature (26.50–26.91°C) likewise showed no significant variation ($p > 0.05$). Turbidity, conductivity, TDS, and total hardness differed significantly ($p < 0.05$), whereas total alkalinity, nutrients, COD, and DO did not vary across stations. BOD differed significantly ($p < 0.05$), ranging from 123.77 ± 0.33 mg/L at Tunga to 142.22 ± 0.30 mg/L at Bosso.

Table 1: Physicochemical Condition of Rice Field *Anopheline* mosquito breeding habitats in Minna

PARAMETERS	RICE FIELD		
	BOSSO	MAITUMBI	TUNGA
pH	8.1 – 8.2[a*]	8.3 – 8.32[a]	8.2 – 8.26[a]
Temperature (°C)	27.81±0.01[a]	28.16±0.06[a]	27.47±0.05[a]
Turbidity (NTU)	58.36±0.06[b]	68.30±0.14[c]	52.67±0.09[a]
Conductivity (µS/cm)	340.70±0.99[c]	279.83±0.25[a]	309.73±0.39[b]
Total Dissolved Solids (mg/L)	204.28±0.39[c]	168.29±0.41[a]	186.04±0.05[b]
Total Hardness (mg/L)	117.84±0.23[b]	102.33±0.45[a]	110.27±0.38[ab]
Total Alkalinity (mg $CaCO_3$/L)	157.99±0.01[b]	142.25±0.35[a]	150.08±0.11[b]
Nitrate (mg/L)	28.48±0.11[c]	22.62±0.02[a]	25.81±0.01[b]
Phosphate (mg/L)	1.18±0.01[b]	0.98±0.01[a]	1.04±0.01[ab]
Chemical Oxygen Demand (mg/L)	148.25±0.35[b]	116.06±0.08[a]	134.15±0.21[b]
Biological Oxygen Demand (mg/L)	312.25±0.33[b]	247.78±0.31[a]	280.65±0.92[a]
Dissolved Oxygen (mg/L)	2.15±0.07[a]	2.63±0.04[b]	2.42±0.02[ab]

Means with the same superscript letter within a row are not significantly different ($p > 0.05$); Kruskal-Wallis with Dunn's post-hoc; Mean±SD. TDS=Total Dissolved Solids, COD=Chemical Oxygen Demand, BOD=Biological Oxygen Demand, DO=Dissolved Oxygen.

Table 2: Physicochemical Condition of Rain Pool *Anopheline* mosquito breeding habitats in Minna

PARAMETERS	RAIN POOL		
	BOSSO	MAITUMBI	TUNGA
pH	7.62 – 7.65[a]	7.52 – 7.53[a]	7.40 – 7.41[a]
Temperature (°C)	26.91±0.01[a]	26.75±0.06[a]	26.50±0.01[a]
Turbidity (NTU)	42.79±0.02[b]	48.59±0.01[c]	38.37±0.24[a]
Conductivity (µS/cm)	107.99±0.01[b]	96.07±0.09[a]	92.17±0.24[a]
Total Dissolved Solids (mg/L)	64.79±0.01[b]	57.63±0.04[a]	55.24±0.06[a]

Total Hardness (mg/L)	72.25±0.35[c]	68.28±0.39[b]	65.89±0.16[a]
Total Alkalinity (mg $CaCO_3$/L)	112.60±0.85[a]	107.99±0.01[a]	105.90±0.14[a]
Nitrate (mg/L)	14.22±0.02[a]	12.81±0.01[a]	11.79±0.01[a]
Phosphate (mg/L)	0.54±0.01[a]	0.49±0.01[a]	0.43±0.01[a]
Chemical Oxygen Demand (mg/L)	56.11±0.15[a]	48.27±0.37[a]	42.16±0.23[a]
Biological Oxygen Demand (mg/L)	142.22±0.30[b]	127.83±0.25[a]	123.77±0.33[a]
Dissolved Oxygen (mg/L)	5.22±0.03[a]	5.61±0.01[a]	5.79±0.01[a]

Means with the same superscript letter within a row are not significantly different ($p > 0.05$); Kruskal-Wallis with Dunn's post-hoc; Mean±SD.

Wing Length and Fluctuating Asymmetry

Wing length and FA data are presented in Tables 3 and 4. Mosquitoes reared from rice fields consistently exhibited larger wing lengths than those from rain pools at the same location. At Bosso, the difference was significant ($p < 0.05$): right wing length was 3.24 ± 0.32 mm in rice field adults compared to 3.12 ± 0.18 mm in rain pool adults. At Tunga, rice field mosquitoes (3.10 ± 0.10 mm) were likewise significantly larger than rain pool counterparts (3.00 ± 0.12 mm; $p < 0.05$). In contrast, no significant difference was observed at Maitumbi (3.08 ± 0.16 vs. 3.06 ± 0.09 mm; $p > 0.05$), the station with the least pronounced physicochemical contrast between habitats.

Fluctuating asymmetry was generally low across all groups (0.02–0.04 mm), except at Bosso rice fields, where FA was markedly elevated (0.18 ± 0.24 mm; $p < 0.05$) compared to all other habitat-location combinations. Rain pool FA values did not differ significantly among stations ($p > 0.05$), ranging narrowly between 0.02 ± 0.04 and 0.04 ± 0.05 mm.

Table 3: Location-wise variation in wing length and fluctuating asymmetry of *Anopheles* mosquitoes in Minna

LOCATION	BREEDING SITE	Right Wing (mm)	Left Wing (mm)	Fluctuating Asymmetry
Tunga	Rice field	3.10±0.10[b*]	3.06±0.09[b]	0.04±0.05[a]
	Rain pool	3.00±0.12[a]	2.98±0.11[a]	0.02±0.04[a]
Bosso	Rice field	3.24±0.32[b]	3.34±0.43[b]	0.18±0.24[b]
	Rain pool	3.12±0.18[a]	3.10±0.16[a]	0.02±0.04[a]
Maitumbi	Rice field	3.08±0.16[a]	3.08±0.12[a]	0.04±0.05[a]
	Rain pool	3.06±0.09[a]	3.02±0.11[a]	0.04±0.05[a]

Superscript letters within a location denote significance between breeding sites; Welch's t-test; FA=Fluctuating Asymmetry; Mean±SD.

Permethrin Susceptibility

Permethrin (0.75%) bioassay results are presented in Table 4. No knockdown was observed at 0, 15, 30, or 40 minutes across any habitat-location combination. At 60 minutes, knockdown ranged from 0.00%

in Tunga and Maitumbi rice fields to 20.00 ± 14.14% in Tunga rain pools. At 24 hours post-exposure, mortality varied between 22.50 ± 17.08% (Tunga rice fields) and 37.50 ± 12.58% (Maitumbi rain pools). None of the populations approached the WHO susceptibility threshold of 98%, confirming resistance in all groups.

Table 4: Susceptibility (%) to permethrin (0.75%) of *Anopheles* mosquitoes from rice fields and rain pools in Minna

LOCATION	BREEDING SITE	Time of Exposure						
		0 min	15 min	30 min	40 min	45 min	60 min	24 hours
Tunga	Rice field	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	22.50±17.08
	Rain pool	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	5.00±5.77	20.00±14.14	30.00±8.16
Bosso	Rice field	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	7.50±9.57	30.00±8.16
	Rain pool	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	2.50±5.00	15.00±19.15	25.00±12.91
Maitumbi	Rice field	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	27.50±12.58
	Rain pool	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	10.00±14.14	37.50±12.58

All values are % knockdown or mortality; Mean±SD; WHO susceptibility threshold ≥98%.

DISCUSSION

The physicochemical analysis revealed that rice fields in Minna are markedly more nutrient-rich, turbid, and organically loaded than rain pools—a pattern consistent with agricultural inputs (fertilisers, crop residues) that typify irrigated rice paddies in sub-Saharan Africa [5,14]. The exceptionally high BOD values in rice fields (247.78–312.25 mg/L) reflect abundant decomposable organic matter that fuels phytoplankton and microbial communities, the primary larval food sources [3]. Although dissolved oxygen was lower in rice fields (2.15–2.63 mg/L) compared to rain pools (5.22–5.79 mg/L), *Anopheles* larvae are atmospheric airbreathers and therefore not constrained by aquatic DO [4]. The higher DO in rain pools simply reflects their lower organic load rather than a developmental advantage.

The positive association between rice field nutritional richness and adult wing length—most pronounced at Bosso, where TDS and BOD were highest—confirms that larval habitat quality is a primary determinant of adult body size in *Anopheles* from North Central Nigeria, consistent with Kura et al. [7] and Takken et al. [5]. The absence of significant wing length differences at Maitumbi, where physicochemical contrasts between habitats were minimal, provides strong internal evidence for a nutritional mechanism rather than a generic habitat effect. Larger rice field adults are predicted to carry greater teneral reserves, take larger blood meals, survive longer, and produce more eggs—all traits that amplify malaria transmission risk [5].

The elevated FA observed at Bosso rice fields (0.18 ± 0.24 mm), despite producing the largest adults, illustrates a developmental stress paradox. While organic richness promotes somatic growth, high turbidity, conductivity, nitrate, and COD impose sublethal stress that disrupts symmetric morphological development [7]. This aligns with the stress-gradient hypothesis, which predicts co-occurrence of large trait size and elevated FA under conditions of nutritional abundance combined with chemical perturbation [7]. Elevated FA may partially offset the fitness advantage of large body size by reducing flight efficiency and host-seeking ability.

Permethrin bioassays documented confirmed, population-wide pyrethroid resistance in Minna's *Anopheles* populations, independent of larval habitat type. Zero knockdown at ≤40 minutes and maximum 24-hour mortality of only 37.50% corroborate Awolola et al. [9], who reported universal *kdr-w* allele presence and elevated P450 monooxygenase activity in Niger State *An. gambiae*. The marginally higher mortality in rain pool mosquitoes suggests that larvae from nutritionally enriched rice fields develop higher constitutive detoxification enzyme expression [8], as dietary precursors for P450 synthesis are more abundant in organically rich environments [8]. This nutritional–resistance linkage indicates that habitat characterisation data are directly relevant to predicting spatial variation in resistance intensity.

The complete absence of knockdown at ≤40 minutes confirms that the rapid sodium channel paralysis mechanism underpinning pyrethroid efficacy in susceptible populations is entirely non-functional in Minna. This renders current LLIN and IRS programmes reliant on pyrethroids potentially ineffective [9,15], underscoring the urgent need for larval source management targeting rice fields and rotation to non-pyrethroid insecticide classes.

CONCLUSION

This study shows that larval habitat physicochemistry in Minna strongly influences *Anopheles* mosquito fitness and resistance. Rice fields, enriched with nutrients and organic matter, produced larger adults with greater vectorial capacity but also imposed developmental stress, reflected in elevated fluctuating asymmetry. Rain pools yielded smaller adults with lower FA, yet both habitats produced populations with confirmed pyrethroid resistance, evidenced by zero knockdown at ≤40 minutes and maximum 24-hour mortality far below WHO thresholds. These findings highlight rice fields as the most epidemiologically significant habitats, underscoring the urgent need for targeted larval source management and rotation to non-pyrethroid insecticides.

Declarations

Authors' Contribution

Conceptualisation: IKO, UAC and CSO **Study Design**: IKO, UAC and CSO **Study Execution**: CSO and YM **Data Collection**: CSO and YM **Data Analysis**: UAC, IKO and CSO **Data Interpretation**: UAC, IKO and CSO **Manuscript Editing**: UAC, IKO and CSO **Manuscript Preparation**: CSO **Manuscript Approval**: UAC and IKO

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REFERENCES

1. World Health Organization (WHO). (2025). *Malaria Fact Sheet*. WHO, Geneva. Retrieved on 10th March, 2025 from https://www.who.int/news-room/fact-sheets/detail/malaria

2. Huzortey, A. A., Kudom, A. A., Mensah, B. A., Addo-Minta, E., Ameyaw, E. K. and Anderson, B. (2024). Larval habitat diversity, physicochemical characteristics and their effect on the larval density of malaria vectors in the city of Accra, Ghana. *Malaria Journal*, 23, 312. https://doi.org/10.1186/s12936-025-05540-1

3. Olayemi, I.K., Abdullahi-Sani, H., Ukubuiwe, A.C., Adeniyi, K.A. and Jibrin, A.I. (2014). Influence of ecological setting on occurrence of artificial container-breeding vector mosquito species (Diptera: Culicidae) and oviposition attraction to mineral salts in larval habitats in Minna, North Central Nigeria. *International Journal of Innovative Science Research*, 9(1): 94–99.

4. Ukubuiwe, A.C., Abioye, J.O.K., Olayemi, I.K., Arimoro, F.O., Abolarinwa, S.O., Ukubuiwe, C.C., Mustapha, M.O., Sule, B.U., Aina, A.O. and Bala, E. (2024). Occurrence and distribution of Culex mosquito larvae in relation to breeding habitat characteristics in four communities in Minna, North Central, Nigeria. *International Journal of Tropical Insect Science*. https://doi.org/10.1007/s42690-024-01399-y

5. Takken, W., Smallegange, R.C., Vigneau, A.J., Johnston, V., Brown, M., Mordue-Luntz, A.J. and Billingsley, P.F. (2013). Larval nutrition differentially affects adult fitness and Plasmodium development in the malaria vectors *Anopheles gambiae* and *Anopheles stephensi* (Diptera: Culicidae). Parasites and Vectors, 6, 345. https://doi.org/10.1186/1756-3305-6-345

6. Olayemi, I.K., Omalu, I.C.J., Famotele, O.I., Shegna, S.P. and Idris, B. (2010). Distribution of mosquito larvae in relation to physico-chemical characteristics of breeding habitats in Minna, North Central Nigeria. *Review of Infection*, 1(1): 49–53.

7. Kura, S.I., Salim, H., Hassan, A.A., Yakudima, I.I., Abdulazeez, A.K., Kontagora, I.K., Abuh, A.H., Babale, S.K., Bawa, S., Kabir, B.M., Passi, A.D., Kayode, O.I. and Solomon, D. (2025). The influence of teneral reserves mobilization on wing development for vectorial fitness in Anopheles gambiae and *Culex quinquefasciatus* mosquitoes. *American Journal of Entomology*, 9(2): 87–99. https://doi.org/10.11648/j.aje.20250902.14

8. Machani, M.G., Ochomo, E., Wanjala, C., Omukunda, E., Munga, S., Githeko, A.K., Yan, G. and Afrane, Y.A. (2021). Insecticide resistance exerts significant fitness costs in immature stages of *Anopheles gambiae* in western Kenya. *Malaria Journal*, 20, 258. https://doi.org/10.1186/s12936-021-03798-9

9. Awolola, T. S., Adeogun, A., Olakiigbe, A. K., Oyeniyi, T., Olukosi, Y. A. and Okoh, H. (2018). Pyrethroids resistance intensity and resistance mechanisms in *Anopheles gambiae* from malaria vector surveillance sites in Nigeria. *PLOS ONE*, 13(12), e0205230. https://doi.org/10.1371/journal.pone.0205230

10. Gillies, M.T. and De Meillon, B. (1968). The *Anophelinae of Africa South of the Sahara*. The South African Institute for Medical Research, Johannesburg. 385pp.

11. World Health Organization (WHO). (2013). Guidelines for Drinking-Water Quality, 4th Edition. Geneva: WHO Press.

12. Greenberg, J.A., DiMenna, M.A., Hanelt, B. and Hofkin, B.V. (2012). Analysis of post-blood meal flight distances in mosquitoes utilising zoo animal blood meals. *Journal of Vector Ecology*, 37(1): 83–89.

13. World Health Organization (WHO). (2022). Report on Malaria in Nigeria 2022. WHO Regional Office for Africa, Brazzaville.

14. Munga, S., Minakawa, N., Zhou, G., Githeko, A.K. and Yan, G. (2007). Survivorship of immature stages of *Anopheles gambiae s.l.* (Diptera: Culicidae) in natural habitats in western Kenya highlands. *Journal of Medical Entomology*, 44(5): 758–764. https://doi.org/10.1093/jme/44.5.758

15. Yusuf, S., Tiri, G.D. and Ismail, H. (2024). Insecticidal and knockdown resistance status of *Anopheles gambiae s.l.* (Diptera: Culicidae) to pyrethroid and organophosphate insecticides in Osun State, Nigeria. *PLOS ONE*, 19(4), e0347416. https://doi.org/10.1371/journal.pone.0347416