Hydrobiologia (2022) 849:4857–4869
https://doi.org/10.1007/s10750-022-05034-0

PRIMARY RESEARCH PAPER

Effects of urban-agricultural land-use on Afrotropical macroinvertebrate functional feeding groups in selected rivers in the Niger Delta Region, Nigeria

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Received: 3 December 2021 / Revised: 9 August 2022 / Accepted: 19 September 2022 / Published online: 6 October 2022

Abstract Anthropogenic pollution from urban and agricultural activities continually affects freshwater ecosystems in Africa, adversely affecting water quality and biodiversity. In this study, we explored the responses of macroinvertebrate functional feeding groups (FFGs) to an urban-agricultural disturbance in the Niger Delta Region, aiming to examine their utility for long-term monitoring of urban-agricultural disturbance in the region. We sampled 17 sites in 11 rivers between 2008 and 2012. We classified the sites into urban, agricultural, and reference (control) sites based on the watershed land-uses and reach-scale anthropogenic disturbance. Permutational multivariate analysis of variance showed that physical and chemical variables differed significantly between the site groups ($P < 0.05$) across the land-use types in the study area. Multivariate analysis of similarity (ANOSIM) indicated that urban land-use had more effect on FFGs than agricultural activities, differing significantly from the forested sites ($P < 0.05$). Macroinvertebrate FFGs such as collectors-filter, collector-gatherers, and scrapers/grazers were identified as sensitive FFGs of urban-agricultural pollution. These FFGs showed strong negative associations with physical and chemical indicators increasing urban-agricultural pollution (e.g. conductivity, nutrients, and turbidity) and favoured by DO at the reference sites. Conversely, shredders and predators were tolerant, indicating significant positive associations with increasing urban-agricultural pollution. They were

Handling editor: Sally A. Entrekin

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10750-022-05034-0.

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associated with variables such as temperature, BOD and nitrates. Overall, this study revealed that urban and agricultural pollution differentially affected macroinvertebrate functional feeding groups, and indicator FFGs were identified. This provided further insights on urban-agricultural land-use effects on Afrotropical riverine systems and using FFGs as reliable indicators of ecosystem integrity.

Keywords Pollution · Long-term monitoring · RLQ · Fourth-corner test and Afrotropical rivers

Introduction

Global biodiversity is changing at an alarming rate in response to human land-uses (Foley et al., 2005; da Conceição et al., 2020). In particular, urban-agricultural activities in the surrounding landscape of freshwater ecosystems have been implicated as the leading anthropic activities altering abiotic and biotic characteristics of freshwater ecosystems (Uriarte et al., 2011; Dalu et al., 2020). Agricultural activities, for example, affect aquatic ecosystems through habitat degradation, water abstraction for irrigation, and the removal of natural forests (Horak et al., 2020; Akamagwuna et al., 2021, 2022). Similarly, the rapid development of society, economy, and industrialisation in urban cities affect aquatic ecosystem integrity through the so-called "urban river syndrome" (Li et al., 2021; Oyedotun & Ally, 2021; Yadav et al., 2021). Urban-agricultural land-use causes the input of inorganic sediment, nutrients, and other pollutants such as metals and pesticides to water bodies and alters hydrological regimes, consequently reducing the water quality of freshwater ecosystems, biodiversity extinction, and ecosystem functioning (Davis et al., 2018; Ali & Chidambaram, 2020). For example, urban activities can cause temperature and acidity regimes and significantly modify basal resources supporting food webs and functional feeding groups (FFGs) structure in streams (Dalu et al., 2020; Sitati et al., 2021). These effects on water resources and ecosystem functioning are expected to worsen in Africa with the rapid population growth, projected to double by 2050 (Dao, 2013; World Bank Group, 2020).

Although significant efforts have been put in most developed countries to develop appropriate biomonitoring strategies to assess the impacts of urban-agricultural pollution (Chen et al., 2019; Wang et al., 2019; Tampo et al., 2020), a significant knowledge gap remains in the tropical region. For example, developing biomonitoring tools in the area primarily rely on macroinvertebrate structural assemblages without recourse to their functional ecology. To make things worse, taxonomic keys from the temperate region still form the basis for identification as well as their response to environmental pressures (Mangadze et al., 2019a; Lubanga et al., 2021). These challenges have limited our understanding of aquatic community response to environmental stress and identifying reliable indicators of anthropogenic pressure required to develop effective mitigation strategies for protecting and managing aquatic ecosystems in the region. A few authors have explored a functional trait-based approach in the last decade to monitor water quality deterioration in the region (e.g. Akamagwuna et al., 2019; 2022; Odume, 2020; Edegbene et al., 2021a, b; Edegbene et al., 2022; Matomela et al., 2021). These efforts have been constrained by sparse taxonomic expertise and the availability of trait information (Akamagwuna et al., 2021; Edegbene et al., 2021b; Edegbene et al., 2022). Furthermore, using multiple traits presents enormous challenges as multiple trait interactions have been demonstrated to influence responses of a given trait to anthropogenic stressors (seeVerberk et al., 2013; Pilière et al., 2016; Odume, 2020). Globally, macroinvertebrate FFGs have gained traction in assessing the ecological integrity of freshwater ecosystems, providing excellent insights into pollution studies (Varadinova & Kerakova, 2018). However, we lack explicit understanding regarding macroinvertebrate FFGs responses to urban-agricultural disturbance in tropical climates in the African continent, with the few studies on this subject producing ambiguous outcomes (Akamagwuna & Odume, 2020; Sitati et al., 2021).

Functional feeding groups define macroinvertebrates' behavioural and physiological mechanisms for food acquisition and habitat use in different environmental conditions (Cummins & Klug, 1979; Wallace & Merritt, 1980). The varied ecological and food requirements of macroinvertebrate FFGs make them respond differentially to environmental stressors, making them valuable indicators of aquatic ecosystem health and ecosystem functioning (Vannote et al., 1980; Wallace & Merritt, 1980). For example, studies have found a shift in FFGs structure with the elimination of some FFGs such as filter-feeders in response to urban-agricultural disturbance (Mangadze et al., 2019a). Miserendino & Masi (2010) revealed substantial differences in the biomass of shredders and collector-gatherers in Patagonian streams affected by various land-uses (agriculture and urbanisation). Similarly, Fu et al. (2016) observed that shredder and predator abundances significantly declined in urban streams of Dongjiang River in China. Akamagwuna & Odume (2020) observed differential responses of Afrotropical Ephemeroptera, Plecoptera, and Plecoptera FFGs to fine sediment from agricultural landscapes in the Tsitsa River, South Africa. However, our knowledge of FFGs responses to urban-agricultural pollution is limited to South America (Couceiro et al., 2011; Van Echelpoel et al., 2018) and Asia (Fu et al., 2016).

Anthropogenic pressures such as urban and agricultural land-use practices unique to different regions affect aquatic communities in various ways (Edegbene et al., 2020a; Akamagwuna, 2021). Hence, using classification keys from the temperate region for awarding FFGs to macroinvertebrates in a bid to use them for long-term biomonitoring can sometimes lead to ambiguous outcomes and results (Masese et al., 2014; Mangadze et al., 2019b; Sitati et al., 2021). These challenges have limited our ability to develop an appropriate FFG biomonitoring tool unique to the tropics for long-term monitoring of anthropogenic pressures. Developing a regional FFG bioassessment tool can allow us monitor ecological conditions in the region, avoiding the need to use whole macroinvertebrate taxa when resources and taxonomic expertise are scarce. Therefore, understanding macroinvertebrate FFGs' relationships with ecological and environmental descriptors (e.g. urban-agricultural land-use) are urgently needed to develop reliable FFG classification unique to the tropics.

In this study, we explored the response patterns of macroinvertebrate FFGs to urban-agricultural land-use induced water quality changes in the Niger Delta Region. We examined the utility of macroinvertebrate FFGs as reliable indicators of urban-agricultural disturbance in the area. The Niger Delta Region is influenced by different land-use practices, most notably agricultural and urban land-uses, which have been demonstrated to significantly affect the river systems' ecological integrity (Matemilola et al., 2018). However, an explicit understanding of how these activities affect the structure and function of the river systems is limited, hindering efforts to develop a reliable management strategy for water quality monitoring in the area. More importantly, the continued degradation of the river ecosystems occasioned by human activities in the region has been noted to significantly hamper the sustainable delivery of critical ecosystems services to humans and animals in the areas, drawing us far from achieving the global goals of wellbeing and livelihood for the communities around the rivers. Our hypothesis was that due to environmental filtering, macroinvertebrate FFGs such as predators, shredders and filter-feeders that are more susceptible to reduced litter input, clogging effects, and visual impairment will decrease with changes in water quality resulting from urban-agricultural-induced disturbances such as habitat fragmentation and deforestation, increased sedimentation and turbidity. Second, we hypothesised that agricultural and urban-induced disturbance would differentially influence FFGs, with urban disturbance having more harmful effects on FFGs due to intensive pressure from urban activities.

Materials and methods

Study area and samplings sites

This study was undertaken in 11 rivers in the Niger Delta Region, with a watershed area of 35,340 km^2. The rivers (Anwai, Ogba, Orogodo, Ossiomo, Umaluku, Edor, Eriora, Ethiope, Obosh, Owan, and Umu) are situated in the Delta and Edo administrative boundaries of the Niger Delta Region of Nigeria (Fig. 1). The rivers are tributaries to the Niger River, emptying into the Atlantic Ocean at the Gulf of Guinea (Fig. 1). These rivers flow through urban and agricultural land, where water is abstracted for irrigation (Edegbene et al., 2020a). Urban land-use in the area mainly includes urban development and industrialisation related to oil exploration (Ukhurebor et al., 2021; Umar et al., 2021). Urban expansion in the region is accelerating with increasing rural–urban migration (Edegbene et al., 2021b). Agriculture consists mainly of subsistence (crop cultivation and fisheries) and commercial (maize, yam, rice, cassava, sugarcane, and pineapples production; Ekanem & Nwachukwu, 2015).

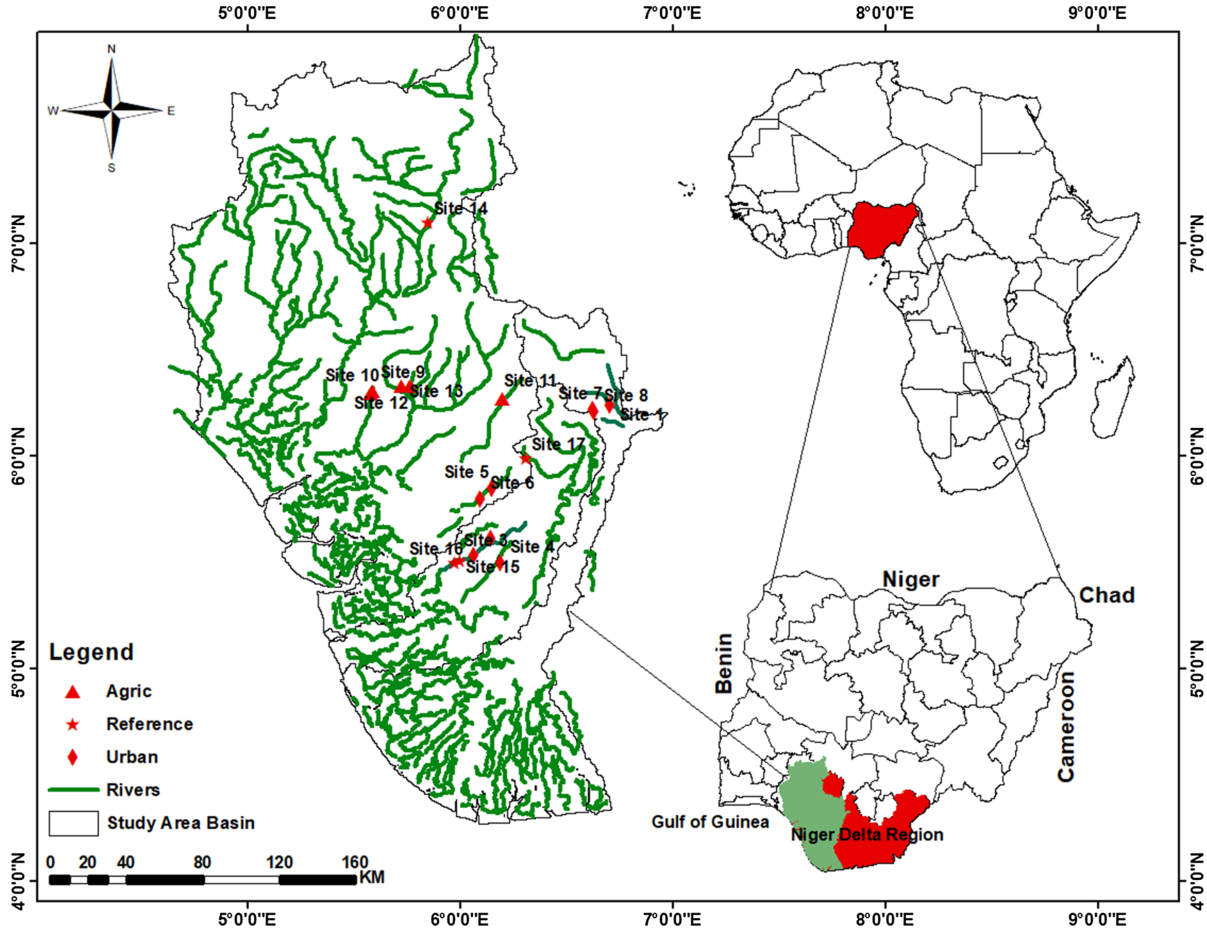

Fig. 1 Study area map showing the location of sampling points within the Niger Delta Region of Nigeria. Site 1 = Orogodo River, Site 2 = Umaluku River 1, Site 3 = Umaluku River 2, Site 4 = Anwai River, Site 5 = Edor River 1, Site 6 = Edor River 2, Site 7 = Ethiope River 1, Site 8 = Ethiope River 2, Site 9 = Ogba River 1, Site 10 = Ogba River 2, Site 11 = Eriora River, Site 12 = Ossiomo River 1, Site 13 = Ossiomo River 2, Site 14 = Obosh River 1, Site 15 = Obosh River 2, Site 16 = Umu River, Site 17 = Owan River

Average annual rainfall in the Nigeria Delta Region ranges from 1250 mm in the evergreen forests of the central region to over 2900 mm in the moist tropical forests (Igweze et al., 2014). The area is characterised by two distinct seasons (wet and dry; Edegbene et al., 2021b; Edegbene et al., 2022). The wet season starts from April to September, and the dry season is between October and March (Edegbene et al., 2021b). The annual temperature is about 28 °C (Tonkin et al., 2016). The underlying geology is shales, clay, loam, and sandy soil (Onyena et al., 2021).

We collected both physical and chemical variables and macroinvertebrate samples once a month from 17 sites (Sites 1–17) in the 11 rivers using objective criteria and best professional judgement to select the least impacted sites as control (reference) sites (Hughes et al., 1986; Stoddard et al., 2006; Whittier et al., 2007). Samples were collected between 2008 and 2012. We collected physical and chemical variables from the 17 sites from 2008 to 2012. For each year, sampling was done monthly covering three months in the dry season and three months in the wet season. We collected physical and chemical variables and macroinvertebrate samples once every month, covering three months both dry and wet seasons from 2008 to 2012 from 17 sites (Sites 1–17) in the 11 rivers. In 2008, sampling was done between March and August (6 months). In 2009, sampling was done between February and July (6 months). For 2010, sampling was done from June to December (7 months), while in 2011 we sampled between January and May (5 months). Finally, in 2012, we sampled from March to September (7 months). Overall sampling was carried out for 31 months in the entire study period. The sites were carefully selected to represent an increasing gradient of urban-agricultural disturbance and further confirmed by the water physical and chemical variables collected from the sites (Fig. 2). Control (reference) sites (Sites 14, 15, 16 and 17) were identified as those with no industrial and agricultural activities with > 80% forest land in their catchments (see Sitati et al., 2021). The four sites identified as reference sites, include Obosh River 1, Obosh River 2, Owan River and Umu River. The remaining 13 sites that did not meet reference criteria were classified as either urban (Sites 1–8) or agricultural (Sites 9–13) disturbed sites. Urban sites (Sites 1–8) were classified as those covered by > 70% human settlements and forest < 30% while agricultural sites had > 70% agricultural lands. We determined the main land-uses and cover in the rivers of each site through manual interpretation of high-resolution images from Google Earth (Google, 2019), and combined with knowledge of the field observation data and experience of the catchments.

Physical and chemical variables sampling

We collected physical and chemical variables from the 17 sites once every month, covering both dry and wet seasons from 2008 to 2012. Dissolved oxygen (DO) was taken using YSI 55 DO meter, whereas conductivity (EC), pH, and temperature were taken using the portable multi-meter analyser HANNA HI 9913001/1. We measured water depth (meters) using a calibrated rod and followed Gordon et al. (1994) approach to measure water flow velocity. Five-day biochemical oxygen demand (BOD_5), nutrient variables, including nitrate and phosphate were measured by collecting separate water on each sampling occasion in a sterile bottle of 500 ml and analysed in the laboratory within 24 h of collection using a standard method by American Public Health Association (APHA, 1995).

Macroinvertebrate sampling

Concurrently with physical and chemical sampling, we collected macroinvertebrates covering both dry and wet seasons from 2008 to 2012 following the South African Scoring System version 5 protocol (SASS5; Dickens and Graham, 2002). These samples were collected quantitatively by kick-sampling method using a 1.5 m long using kick-net (dimension 30 × 30 cm, 500 μm). Four replicates were collected from all biotopes recognised by Dickens and Graham (2002); we spent 4 minutes sampling each

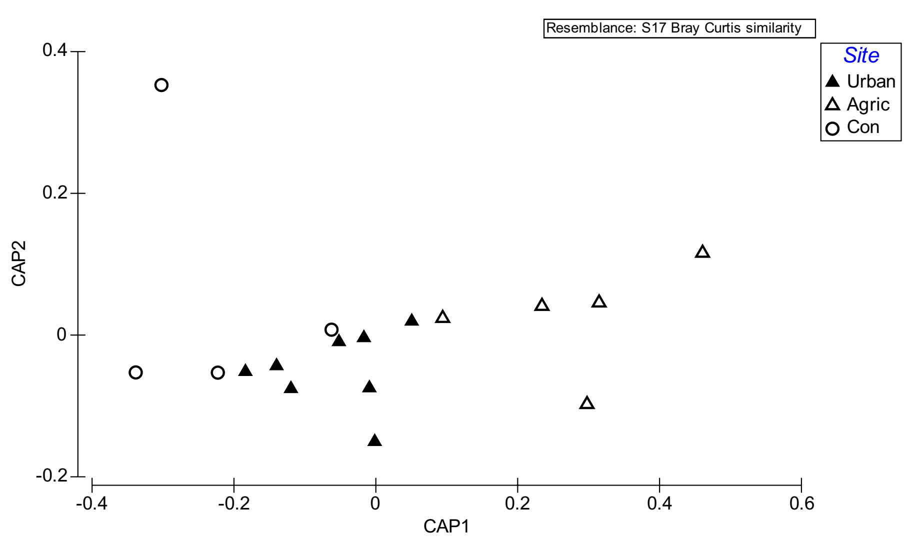

Fig. 2 Canonical analysis of principal coordinates (CAP) shows sites' grouping based on physical and chemical variables analysed during the study period. Urban = Urban land-use sites, Agric = Agriculture land-use sites, Con = Control (reference) sites

biotope. Biotopes are the microhabitats inhabited by macroinvertebrates, including stone, vegetation, and sediments. Stone biotope is defined as pebbles and cobbles (2–25 cm), and boulders (> 25 cm) situated in riffles (stones in currents) and pools (stones out of current). Vegetation biotopes comprised marginal vegetation growing on the river edge and fringing into the river, and aquatic vegetation submerged in the main river channel. Sediment biotope was gravels (small stones usually less than 2 cm in diameter), sand and mud that are less than 2 mm and 0.06 mm, respectively. We stored the collected samples in 70% ethanol; transported them to the laboratory for taxonomic sorting, identification, and abundance counting. Macroinvertebrates samples were identified to families using taxonomic keys by Day and de Moor (2002), De Moor et al. (2003) and Merrit et al. (2008). Based on studies, each macroinvertebrate taxon was placed into one of six FFG classes, including filter-feeders, collector-feeders, scrapers, gatherers, predators, and shredders (Merritt & Cummins, 1996; Cummins et al., 2005; Merritt et al., 2008).

Data analysis

Based on Euclidean distance, the canonical analysis of principal coordinates (CAP; Anderson et al., 2008) was used to assess the effects of sites on physical and chemical variables. This analysis confirmed the site classification into urban, and agricultural sites based on land-use cover. We tested the differences in physical and chemical variables between the site categories (urban, and agricultural site categories) using the permutational multivariate analysis of variance (PERMANOVA; Anderson et al., 2008). We tested the assumption of analysis of variance using Levene's and Kolmogorov's tests before PERMANOVA. Univariate indices indicated changes in each FFG community composition between urban and agricultural site groups; therefore, the multivariate analyses of similarity (ANOSIM) were performed to check if this translated into shifts in the whole FFG community. Canonical correspondence analysis (CCA) was used to examine the correlations between macroinvertebrate FFGs and physical and chemical variables across the three sites groups (reference (control), agriculture and urban). The detrended canonical analysis was used to examine the gradient of FFGs community data before CCA. Monte-Carlo permutation test was further used to confirm the level of significance of the FFGs between the land-uses. Except for PERMANOVA that was conducted in Primer version 6, we performed all analyses in R (R Core Team, 2020).

Results

Water quality

The mean, standard deviation, and range values of the physical and chemical variables analysed for the land-use during the study are presented in Supporting information, Table S1. The canonical analysis of principal coordinates (CAP) revealed that the physical and chemical variables differed among urban, agricultural land-uses and the reference (control) sites

Table 1 Canonical analysis of principal coordinates (CAP) statistics

Original group	Urban	Agricultural	Control	Total	%Correct	Total correct	Delta (*P*)
Urban	7	0	1	8	88	13/17 (76.471%)	0.79 (0.005)
Agric	1	4	0	5	80		
Con	2	0	2	4	50		

Table 2 PERMANOVA results showing the statistical differences between urban, agricultural, and control (reference) sites in the Niger Delta Region

Source	df	SS	MS	Pseudo-*F*	*P*(perm)	perms
Site	2	1408.7	704.3	2.21	0.044	998
Res	14	4459.6	318.5			
Total	16	5868.3				

(Fig. 2). The analysis revealed that 88% of the sites were correctly classified into their parent groups, supporting the prior site classification into land-use types (Table 1). The agriculturally impacted sites were clearly separated from other sites, whereas the urban sites clustered closely with the control (reference) sites (Fig. 2). PERMANOVA showed that the differences in physical and chemical variables between land-use types were highly significant ($F=2.2$; $P=0.04$; Table 2).

Macroinvertebrate functional structure in the Niger Delta ecoregion

A total of 55 macroinvertebrate families, represented by 11 orders, were identified across the sampling site categories during the study period (see Edegbene et al., 2020b). Generally, relative abundances of FFGs decreased from the Reference (Control) sites to Urban sites, with predators as the most predominant in the study area compared to other feeding groups, representing 34%, 58%, and 53% of FFGs recorded in the Urban, Agricultural, and Reference (Control), respectively (Fig. 3). Shredders (<3%) were the least occurring FFGs in the Niger Delta Region; this was followed by scrapers that occurred less than 17% at all sites (Fig. 3). ANOSIM indicated that functional organisation of macroinvertebrates varied significantly between the land-uses (Global R-statistic = 0.25, $P=0.021$; Table 3), and pairwise ANOSIM revealed a significant difference between Urban and Reference (Control) sites only (R-statistics = 0.49; $P=0.016$). These findings suggest a stronger effect of urban disturbance on the functional structure of macroinvertebrates than agricultural disturbance.

Macroinvertebrate FFG responses to urban-agricultural pollution

The CCA results indicated distinct spatial distribution patterns of macroinvertebrate functional composition associated with physical and chemical variables (Fig. 4). The first two axes of the CCA model with eigenvalues of 0.04 and 0.03, respectively,

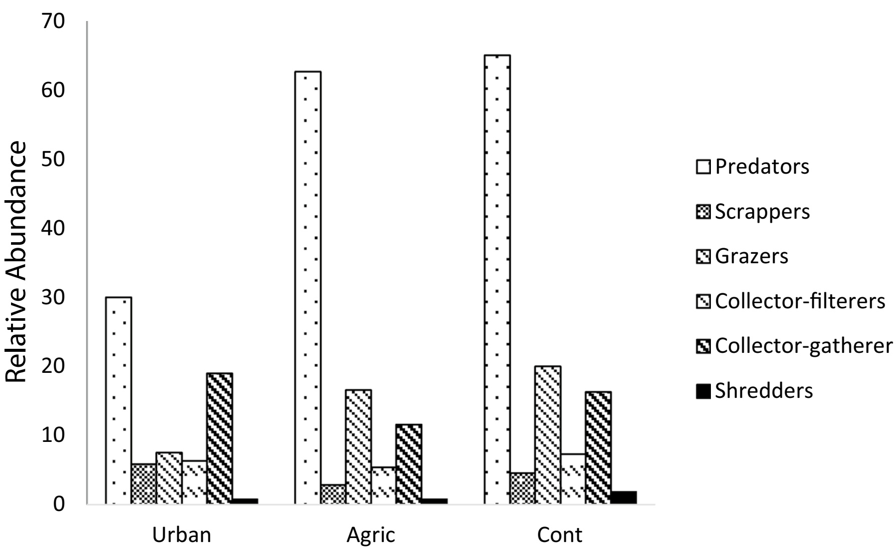

Fig. 3 Relative abundance of macroinvertebrate functional feeding groups collected in the Niger Delta Region during the study period. Urban = Urban land-use sites, Agric = Agriculture land-use sites, Cont = Control (reference) sites

Table 3 Pairwise ANOSIM statistics showing the differences between land-uses in the Niger Delta Regions

Pairwise Tests, Global R = 0.25; P = 0.021					
Groups	*R* statistic	*P*-value	Possible permutations	Actual permutations	Number ≥ Observed
Urban, Agricultural	0.217	0.065	1287	999	64
Urban, Reference	0.485	0.016	495	495	8
Agric, Reference	−0.019	0.563	126	126	71

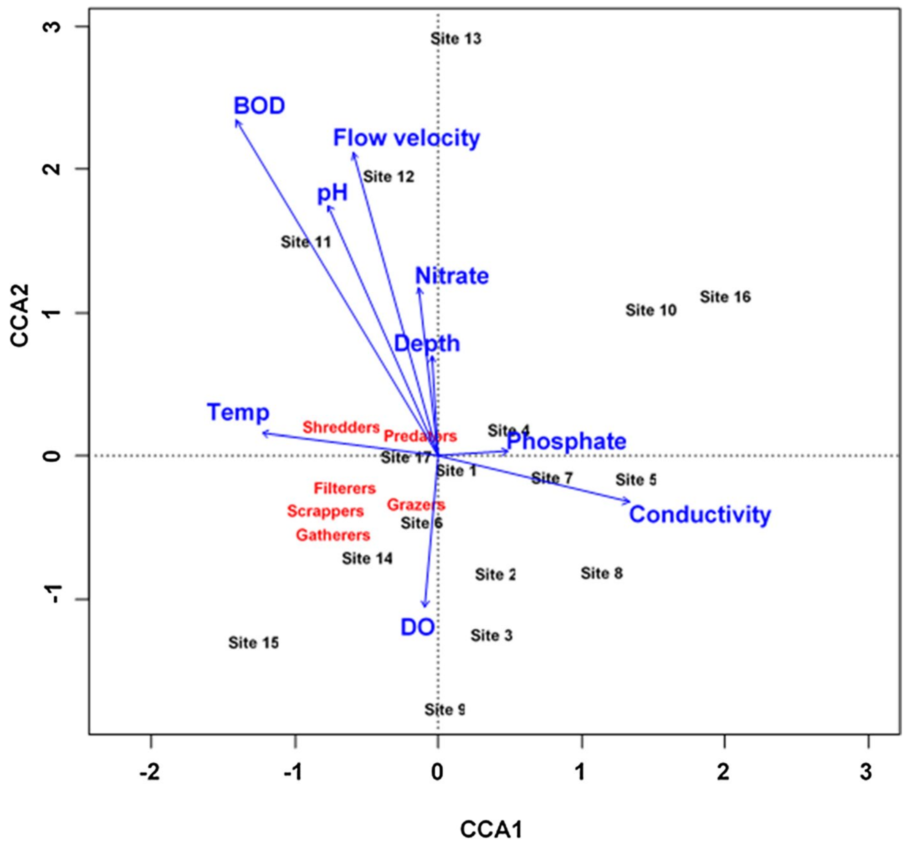

Fig. 4 Canonical correspondence analysis (CCA) of the relationships between physical and chemical variables and macroinvertebrate functional feeding groups (FFGs) in the Niger Delta Region. *Temp* temperature, *DO* dissolved oxygen, *BOD* biochemical oxygen demand. Site 1 = Orogodo River, Site 2 = Umaluku River 1, Site 3 = Umaluku River 2, Site 4 = Anwai River, Site 5 = Edor River 1, Site 6 = Edor River 2, Site 7 = Ethiope River 1, Site 8 = Ethiope River 2, Site 9 = Ogba River 1, Site 10 = Ogba River 2, Site 11 = Eriora River, Site 12 = Ossiomo River 1, Site 13 = Ossiomo River 2, Site 14 = Obosh River 1, Site 15 = Obosh River 2, Site 16 = Umu River, Site 17 = Owan River

Table 4 Canonical correspondence analysis (CCA) statistics result for the relationships between analysed physical and chemical variables and macroinvertebrate functional feeding groups (FFGs) in the Niger Delta region during the study period

CCA statistics, $F = 2.9$; $P = 0.014$		
Axis	CCA1	CCA2
Explained variance (%)	43	31
Cumulative variance (%)	43	74
Eigenvalues	0.04	0.03

explained 74% of the total relationships between physical and chemical variables and macroinvertebrate FFGs (Table 4). The Monte-Carlo test showed that this explained relationship was statistically significant (Table 4), indicating a good ordination model. The CCA plot showed that collector-filters, collector-gatherers, and scrappers were positively associated with the reference (control) sites (Sites 14, 15 and 17), favoured by increasing DO, and negatively associated with nutrients (e.g. nutrients, phosphate and nitrates; Fig. 4). On the other hand, FFGs such as shredders, grazers, and predators indicated strong negative associations with conductivity at the urban sites. Nevertheless, these FFGs (shredders, grazers and predators) were positively associated with the agriculturally impacted sites, and temperature, depth, BOD and nitrates, flow velocity (Fig. 4). These findings further suggest urban-induced stress affected FFGs in this study than agricultural disturbance.

Discussion

In this study, we explored the response patterns of macroinvertebrate FFGs to an urban and agricultural disturbance in 17 Sites from 11 rivers in the Niger Delta region, Nigeria. The study revealed that macroinvertebrates FFGs exhibited varying responses to physical and chemical indicators of urban- agricultural disturbance in the area, with urban disturbance having more substantial impacts on macroinvertebrates' FFGs. These results are congruent with studies that have reported significant effects of urban and agricultural disturbance on the structure and functioning of river ecosystems in the tropical region (Akamagwuna et al., 2019; Odume, 2020; Sitati et al., 2021) and elsewhere (Fierro et al., 2019; Kumari & Maiti, 2020). For example, Edegbene et al. (2020a, b) observed a significant influence of urban activities on macroinvertebrate assemblages in Nigeria's Niger Delta Region. Similarly, a recent study by Onyena et al. (2021) to examine the water quality and the assemblages of macroinvertebrates in the Chanomi Creek, Niger Delta, observed differential distribution of macroinvertebrates, with reduced abundance of sensitive filter-feeding taxa from organic pollution in the area.

Macroinvertebrate FFGs structure decreased in control (reference) sites compared to the urban and agricultural sites in the Niger Delta Region, with urban sites having stronger effects on FFGs compared to agricultural sites. The stronger effects of urban disturbance on macroinvertebrate FFGs than agricultural activities suggest that urban practices (e.g. dredging, industrial and waste-water discharges, and flow alteration) may have severe consequences on the functioning of the river systems. Urban rivers are prone to run-off and leakages from sewage facilities and waste disposal from agro-industrial activities (Aura et al., 2010), leading to anoxic and acidic conditions in-stream habitat through increased nutrient and other harmful contaminants. The more substantial effects of urban activities than agricultural activities may be attributed to the combined pollution from riparian habitat degradation and point source pollution from waste-water treatment plants and other industrial activities in urban cities (Kuzmanovic et al., 2017). The adverse effects of urban activities in Afrotropical rivers and their aquatic communities, including FFGs, have been observed in previous studies (Masese et al., 2014). Sitati et al. (2021) recently examined shifts in taxon richness, abundance and biomass of macroinvertebrate functional feeding groups (FFGs) in Kenyan rivers affected by urban and agricultural land-uses. Moreover, they found urban land-use to significantly influence macroinvertebrate FFGs. Macroinvertebrate FFGs are known to be highly sensitive to habitat degradation (i.e. reduced canopy), sedimentation (i.e. organic particles), and water quality (Fu et al., 2016; Gebrehiwot et al., 2017; Fierro et al., 2019; Mangadze et al., 2019b), suggesting why they decreased significantly in the urban sites compared to the agricultural and reference sites (forested sites).

The differential response of macroinvertebrate FFGs to an urban-agricultural disturbance on macroinvertebrate FFGs was evident in the CCA ordination results, with macroinvertebrates displaying FFGs-specific responses to physical and chemical indicators of urban-agricultural pollution (Fig. 4). We identified collector-filters and collector-gatherers as sensitive indicators of urban-agricultural pollution, indicating strong negative associations with increasing urban-agricultural pollution at urban impacted sites (Site 10 and 16; Fig. 4). Collector and filter-feeders dominate areas impacted by high human disturbance level, which reflect the relatively elevated accumulation of fine particulate organic matter in bed sediment and water column of such habitats (Miserendino & Masi, 2010). However, at elevated levels of fine organic sediments in perturbed areas, macroinvertebrate FFGs such as filter-feeders and collector-gatherers are negatively impacted by clogging and abrasion of sensitive parts (Jones et al., 2012; Akamagwuna et al., 2019). Fine sediment accumulation in the impacted sites was likely beyond the acceptable background level (Bilotta & Brazier, 2008; Jones et al., 2012), thereby affecting collectors in the impacted sites in the Niger Delta Region. Furthermore, this finding may be partly because filterers in our study are primarily caddisflies (e.g. Hydropsychidae) that require the stable coarse substrate net and case attachment (Statzner & Béche, 2011).

Concerning the grazers/scrapers, it was surprising that they proved sensitive to urban-agricultural pollution as increased nutrients and organic pollution stimulate algal and macrophyte growth, primary food sources for the grazers/scrapers (Odume, 2020). Scrapers consist of taxa exhibiting diverse feeding modes, and inhabit the trophic roles of herbivores, detritivores and generalist feeders (Mangadze et al., 2019a). The different environmental conditions in streams can cause macroinvertebrates to change their feeding mode (Rawer-Jost et al., 2000; Kelly et al., 2002). Moreover, taxa that are taxonomically linked can have different diets in different geographical regions (Tomanova et al., 2006). As such, researchers have alluded to the fact that some functional categorisation of macroinvertebrates is not well established (Tomanova et al., 2006). Thus, grouping taxa into a single trophic category based on FFG assignment may not be relevant (Hawkins & MacMahon, 1989). This may have affected the results of scrapers observed in the Niger Delta Region. This result emphasises a clear urgent need to improve and standardise FFG grouping and to develop FFG classifications unique to the tropical region. Nevertheless, grazers and scarpers' negative response to urban-agricultural pollution has been observed in studies in the tropics (Odume, 2020) and elsewhere (Van Echelpoel et al., 2018). The studies attributed the sensitivity of grazers and scrapers to increased unstable habitat in impacted sites.

On the other hand, shredders, predators and grazers significantly increased in control (reference) sites compared to the urban and agriculturally impacted sites. Shredder abundance is known to dominate in forested sites compared to sites in the other land-uses (e.g. urban and agriculture), as they are sensitive to reduced quality and quantity of detritus through deforestation and clearance of indigenous riparian vegetation, water pollution and habitat disturbance caused by farming activities and urbanisation in the region (Sitati et al., 2021). However, macroinvertebrate shredders such as Potamonautidae are known to have wide habitat distribution and a high degree of tolerance, especially to pollutants and habitat modification (Cumberlidge et al., 2008; Cumberlidge et al., 2009). Furthermore, shredders were the least dominant FFG recorded, and predatory taxa such Tipulidae were among the few shredders observed in the Niger Delta Region. The majority of the predatory shredders use specialise respiratory organs like the trachea and spiracles for intake of atmospheric oxygen, conferring them resilience to depleted DO, and hence their significant association with the urban-agricultural impacted sites and nutrients in the Niger Delta. In a study to investigate the influence of land-use practices on physical and chemical characteristics and macroinvertebrate FFGs in the Dongjiang River, southeast China, Fu et al. (2016) found predator abundance significantly increased in disturbed sites. Similarly, Odume (2020) observed increased proportions of predatory taxa in polluted urban sites in the Swartkops River, South Africa, and Compin and Céréghino (2007) detected significant increases in the proportions of predators in an agricultural landscape in the Adour-Garonne stream system in France. The combination of results from these studies, taken together with our results from the Niger Delta Region, supports the conclusion that the abundance of predatory taxa can indicate deteriorating water quality.

Conclusions

In the present study, we examined the functional composition responses of macroinvertebrates to an urban-agricultural disturbance in the Niger Delta region to identify FFG indicators of urban-agricultural disturbance. We observed differential effects of urban-agricultural pollution on macroinvertebrate FFGs, and these influences were stronger for urban disturbance compared to agricultural disturbance. Macroinvertebrate FFGs such as collector-filters and collector-gatherers were sensitive to urban-agricultural disturbance, showing strong positive associations to the reference sites and DO. Conversely, shredders, predators, and grazers/scrapers were tolerant FFGs of urban-agricultural disturbance. These FFGs were positively associated with physical and chemical indicators of urban-agricultural pollution such as EC, nutrients and BOD_5. This finding indicated that urban-agricultural development in the Niger Delta has deteriorating effects on the biodiversity and functioning of natural ecosystems in this region. Overall, our study provides further insights and evidence of the potential use of macroinvertebrate FFGs as indicators of water quality impacted by urban-agricultural pollution.

Acknowledgements This project was supported by National Research Foundation of South Africa (NRF) and The World Academy of Sciences (TWAS) with grant number: 110894. Special thanks to Edegbene Ovie Tega Treasure (Mrs.) for her technical and office assistance.

Author contributions AOE and FCA: Project conceptualisation; AOE: Funding acquisition; AOE and FCA: Data analysis; AOE FCA, FOA, ECA and EAK: Methodology; AOE and FCA: Writing—original draft; AOE, FCA, FOA, ECA and EAK: Writing -review and editing; AOE: Manuscript finalization; AOE: Project supervision.

Funding This work was supported by the National Research Foundation of South Africa (NRF) and The World Academy of Science (TWAS) [grant number 110894].

Data availability Dataset used in this study will be made available upon request by the corresponding without hesitation.

Declarations

Conflict of interest We declare that there are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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