The Legacy of urban sprawl on wildlife conservation: A case study of Nairobi National Park

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The Legacy of urban sprawl on wildlife conservation: A case study of Nairobi National Park

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Abstract: *Nairobi National Park (NNP) popularly known as "the wildlife capital" is the only national park located within a capital city in the world. The 117km^2 Park is surrounded by an ever-extending urban fabric that not only emphasizes its borders but is also influencing what is within the boundaries of this "natural" habitat. This study investigated the emissions of the City into the Park through analysis of the extent of seasonal pollutant load in water, soils, sediments and vegetation. Physico-chemical characteristics were determined in water using standard methods of analysis. Trace elements; Pb, Zn, Cr, Cd, and Hg were determined in water, soil, sediments and vegetation using X-ray Fluorescence (XRF). Coliforms were determined using 3M Petrifilm count plates, while macro invertebrates were identified using a biotic index card. Results reveal compromise of water quality in many water bodies of the NNP Park, while soil, sediments and vegetation were not adversely compromised.*

Keywords: Urbanization; Pollution; Habitat; Conservation; Protected area.

1. INTRODUCTION

Habitat loss and pollution are the major causes of threatened species decline; 34% of species are affected by habitat loss due to agriculture, 36% due to infrastructure development [1]. Land conversion to pave way for agriculture or urbanization can lead to altered runoff patterns, sedimentation, and pollution by; nutrients (phosphates and nitrates), trace elements, toxic chemicals. This can lead to mortality of biota through poisoning and habitat degradation and competition for nutrients from invasive species that thrive in degraded soils and waters (ibid).

Pollution from these broad range of sources is a major threat to ecosystems in Africa; it impacts 63% of threatened mollusks' species [2]. Water pollution threatens 25% of endangered aquatic species, drought impacts 8% while invasive alien species impacts 5%. Two percent (2%) of fish species across the African continent are threatened by pollution [1]. The resilience/vulnerability of ecosystems and sensitivity of species to negative change from human interferences such as pollution is subsequently affected [3]. Many species and ecosystems are increasingly vulnerable to the effects of pollution through compromised quality of ecosystem components (water, air, soil, and sediments), concentration of toxic chemicals in predators of food chains and disruption of predator-prey interactions [4].

Catchment ecological health state affects biodiversity through numerous complex direct and indirect pathways [5]. Sound management and conservation of natural resources is therefore of extreme urgency in every identified biosphere due to high rates of species loss associated with environmental degradation.

Streams, rivers and lakes can be characterized as landscape *'receivers.'* Upstream processes affect downstream assemblages in streams and rivers, making flowing-water habitats to double up as '*transmitters*' as well as 'receivers' [6]. Contaminants released upstream are conducted downstream hence spreading potential impacts to what could have been unadulterated reaches from anthropogenic interference [7;8;9].

Due to wide occurrence and persistence of toxic elements in various environmental matrices; soils, sediments and water monitoring is necessary to understand their effects on ecological health. Pollution is one of the major threats to protected areas in the world today [10;11;12;13]. Areas set aside as nature preserves need to be protected in the face of urban expansion, [14]. Identification and addressing of threats to conservation is necessary as a precaution measure for the preservation of undamaged areas and a response effort for the improvement of degraded spots. It's equally important to protect and conserve biodiversity not only as a resource for present use but also for its prospective; known and unknown use.

There are 209,429 protected areas in the world, which is approximately 14% of the terrestrial environment of the world [15]. Nationally, Kenya has 8% of its land mass as designated national parks and reserves. Two of which border major urban centres these are Lake Nakuru National Park and Nairobi National Park (NNP) the latter being 27 km from the city centre. Nairobi National Park (NNP) is home to numerous flora and fauna species including the endangered rhinoceros. This biodiversity hotspot is surrounded by a growing metropolis as shown in Figure 1. The wildlife park is thus faced by a pollution challenge from premises marking its horizons due to non-compliance to environmental conservation laws and city planning by-laws.

The Park is surrounded by numerous pollution point sources and is within reach of non-point sources of pollution: hotels, residential homes, industries, informal settlements, wastewater streams, urban run-off and agricultural run-off. However, in depth assessment on pollutant loads and effects in the ecosystem has been lacking.

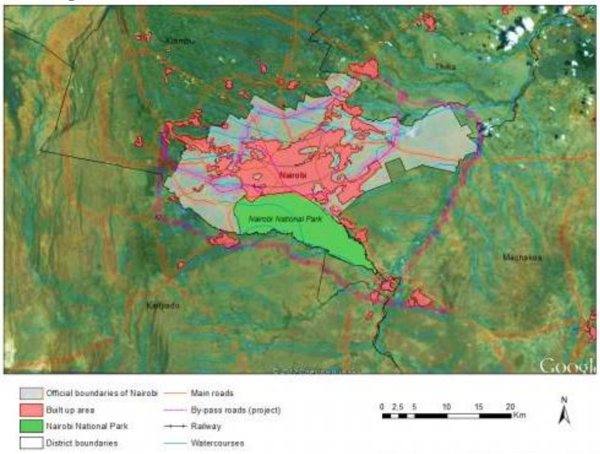


Figure 1. Nairobi National Park and the built environment surrounding it. Source: Heyman, 2013 [26].

Nairobi city has been expanding overtime as shown in Figure 2 and 3 necessitating electric fences to be put up in the west, north, and east boundaries to separate NNP from the intensifying urban growth and settlements.

Figure 2.1976, Nairobi seen to be away from the NNP Park. Source: UNEP, 2009[27].

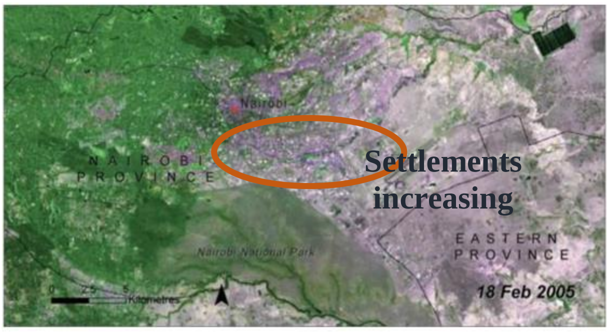


Figure 3. 2005, Nairobi urbanization extends towards the NNP Park, Source: UNEP, 2009

The Park management together with like-minded stakeholders have made various efforts to contain pollution into this wildlife park. This includes a secondary "border" named the Nairobi Green-line which comprises of a 50 m wide forest of native trees, along 30 km planted along the border of the NNP Park with an aim to cushion what lies within from degradation without as shown in Figure 3.

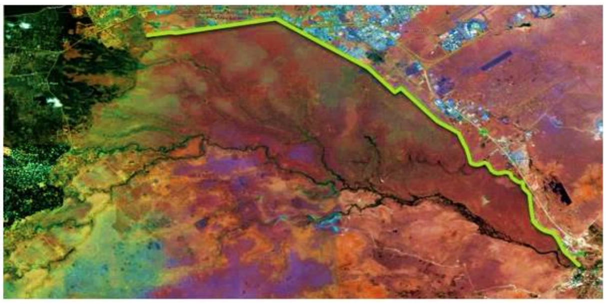


Figure 3. Fencing of Nairobi National Park against anthropogenic activities in the area Source: Heyman, (2013).

However, these efforts have not prevented continued effluent discharge into the park from neighbouring domestic and industrial premises. Considering the ever-increasing developments around the NNP and the very important role the Park plays in conserving endangered species like the rhinocerous, evaluation of the concentration of potentially harmful elements in Nairobi National Park is vital so as to estimate the potential risks to biodiversity through pollution.

Pollution assessment on the environmental matrices can yield results indicative of ecological health. Thus, information on existing water, soil, sediment quality and pollutant load in vegetation is vital for natural resource management. This information can be obtained from long term ecosystem monitoring that yields data vital for research-based management which is critical for successful natural resource management and conservation [16].

Ecological degradation is more evident in urbanite green spaces and streams than in remote protected areas and rivulets [17; 18; 19]. This is due to a greater combination of stressors from sewer flows, urban run-off and effluent from commercial and residential premises [20]. Sources of highly persistent bio-accumulative and toxic compounds in aquatic systems include sewerage treatment works, landfill leachate, industrial effluents and urban run-off. Heavy metals for example cannot be removed in wastewater treatment plants [21].

The study measured ecological health status through physical, chemical, and biological assessment of water and organisms shown in Table 1 in the Park in the wet season and dry season. The chemical analysis results were compared with aquatic invertebrate species identified in the sampled sites.

Aquatic invertebrates are a very good biological indicator of physical and chemical water quality due to their sensitivity to chemical or physical water quality changes. A healthy ecosystem is able to maintain a balanced and integrated community of organisms and a functional organization analogous to natural habitats within the same geographical region. Studies have established macro invertebrates to be accurate and advantageous compared with other organisms on evaluating ecological health as macro invertebrates they are widely distributed, easy and economical to sample and they are very sensitive to organic pollutants [22;23].

The measurement of ecological health status combines physical, chemical, and biological assessment of elements and organisms. A healthy ecosystem is able to maintain a balanced and integrated community of organisms and a functional organization analogous to natural habitats within the same geographical region [33;34].

Invertebrate species richness and diversity serve as Indices of Biological Integrity (IBIs). IBI scores have been shown to be negatively correlated with % urbanization and anthropogenic interference of a watershed. Many invertebrates and water insects require adequate oxygen, constant flows, clear cool waters and steady supply of food to complete their life cycles [35].

Therefore, the presence, diversity or population (species richness) of these invertebrates is an indicator of the water quality as shown in Table 1. Surveying their presence sheds light on water quality problems. [24].

This paper discusses the pollution extent in Nairobi National Park and the impact on its ecological health.

Table 1: macro- invertebrates found in various degrees of water quality. Source: (Hadley, 2019) [32].

Highly Sensitive to Pollution *(Found in healthy aquatic system)*	Somewhat Tolerant of Pollution *(Found in moderately healthy/slightly disturbed aquatic system)*	Pollution Tolerant (Found in poor health/ very disturbed aquatic system)
• Adult riffle beetles • Gilled snails • Mayflies (nymphs) • Caddisflies (larvae) • Stoneflies (nymphs) • Water Pennies • Hellgrammites (dobsonfly larvae) • Alderflies	• Clams, • Mussels, • Crayfish, • Sowbugs, • Alderflies (larvae) • Dragonflies and Damselflies (nymphs) • Whirligig Beetles (larvae) • Riffle Beetles (larvae) • Fishflies (larvae) • Scuds	• Leeches and aquatic worms • Black Flies (larvae) • Midge Flies (larvae) • Lunged Snails • Boatman • Backswimmers

2. MATERIALS AND METHODS

2.1 Site identification

Following a reconnaissance, sites were selected to represent the anticipated spatial variation of water, sediment, vegetation, and soil pollution at NNP. The sampling sites were broadly distributed through the park and selected such that spatial variation in pollution was covered. This choice of sampling sites was made 'informally', that is without performing the actual GIS calculations of the different variables in different buffers around measurement points. Figure 4 represents the sampling points for water quality assessment and aquatic invertebrate evaluation.

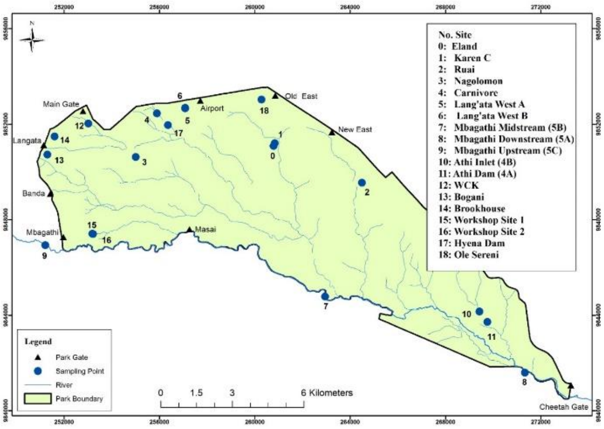


Figure 4. Water and Wastewater sampling points

Homogeneity was factored in as the samples from a site were collected and mixed together so as to provide a representative average sample, over the cross-section.

2.2 Determination of macro-invertebrates in water

A Surber sampler was used to collect benthic organisms in shallow waters and flowing waters. This being a wildlife area with hippopotamus and Nile crocodiles in some waters kick sampling was not used. The collected specimens were separated from sediment and stored in 70% ethanol solution for identification in the laboratory under magnification alongside a provided biotic index card.

The water samples collected from the Park were subjected to macro-invertebrate analysis under a light microscope. The Macro-invertebrate community were counted in every 10ml of the 300 ml sample placed in a petri dish and examined under the microscope. A tally of every species spotted was done [25]. A biotic index card was used to identify and interpret key information about key macro-invertebrates.

2.3 Physico-chemical analysis of water samples

a) **Nutrients**-Ultraviolet (UV/VIS) Spectroscopy was used in the determination of nitrates and orthophosphates in water. Colorimetric Method of Vanadomolybdophosphoric Acid was adopted as a pilot test in determination of orthophosphate concentration in water.
b) **Chloride and fluoride concentration**-Ion selective electrodes were used to determine the chloride and fluoride concentration of chlorides and fluorides. A Microprocessor pH/Ion Meter pMX 3000 WTW equipped with a reference electrode WTW R 500 and the F 500 lanthanum fluoride electrode and a YSI instrument with a chloride probe Cl 500 silver sulfide/silver chloride electrode was used to determine chloride concentration.
c) **Dissolved Oxygen (DO) and (Biological Oxygen Demand)**-Winkler's method was used in the determination of DO and BOD as it is established to be highly accurate [28].
d) **Chemical Oxygen Demand (COD)**-was determined in the sampled waters through refluxing method.
e) **Total Suspended Solids (TSS)** -was determined in the sampled waters through filtering 50 ml aliquots of each water sample through a pre-weighed, oven dried Whatmann glass fiber filter paper No.42.
f) **pH, temperature, salinity, DO, conductivity**-A YSI water quality meter with respective parameter probes was calibrated and used to determine pH temperature, salinity, DO, conductivity onsite.
g) **Determination of coliforms in water**-3M™ Petrifilm™ *E. coli*, total coliform ready to use count plates were used.
h) **Heavy metals-**10 ml of sample was pipetted in triplicates. For removal of any suspended particulate matter the samples were filtered in ester cellulose membranes of 0.45 µm pore size. The Samples were then pre-concentrated through precipitation with Ammonium Pyrrolydine Dithiocarbamate (APDC). Three pre-concentrated membranes of each sample were prepared and irradiated three times by Xray fluorescence (XRF) technique. Analysis time was 180 seconds per sample. [29]. Rigaku NEX CG Energy dispersive X-ray fluorescence (EDXRF) machine with Rigaku RPF-SQX Fundamental Parameters (FP) software for elements from sodium (11Na) to Uranium (92U) was used.

3. RESULTS & DISCUSSION

3.1 Heavy metals in water (µg/L)

There were apparent elevated levels of cadmium (Cd) in sampled points in the Park except Nagolomon dam, R. Mbagathi downstream (exit point from the Park), Wildlife Clubs of Kenya (WCK) area and the Workshop area.

Lead (Pb) levels were high in WCK area. Higher than the stipulated National Environment Management Authority (NEMA) standards of 0.01 mg/L. Zinc (Zn) in all areas it was detected was within the recommended levels by NEMA standards of 0.5 mg/l for effluent discharged to the environment within the limits of NEMA standards for water suitable for irrigation and drinking water sources of 2.0 mg/l and 1.5 mg/l respectively [30].

On average the heavy metal content was higher in the sediment than in water. This can be attributed to direct enrichment from weathering, erosion and anthropogenic contamination profile. Near absence of the Pb in the water but presence in sediments could be due to its inability to remain in solution.

3.2 Physical parameters results

Temperature

Most water points in the Park with a canopy showed least temperature variations. However, watering points with no tree cover like Eland, Ruai, Athi dam, Karen C (With average temperature readings of 28.02 ±0.704°C, 28.07 ±0.457°C, 26 ±0.694°C and 30.57 ±0.513°C respectively as shown in Figure 5, were noted to have higher temperatures more so in the dry season despite their conductivity being lower hence heat changes/anomalies cannot be attributed to reactivity and perhaps pollution.

Observed significant seasonal variation in temperature can be attributed to ambient temperature changes coupled with a higher concentration of compounds in the water during dry season unlike in the wet season where dilution lowers concentration. A high concentration of compounds can mean increased reactivity and associated temperature influence.

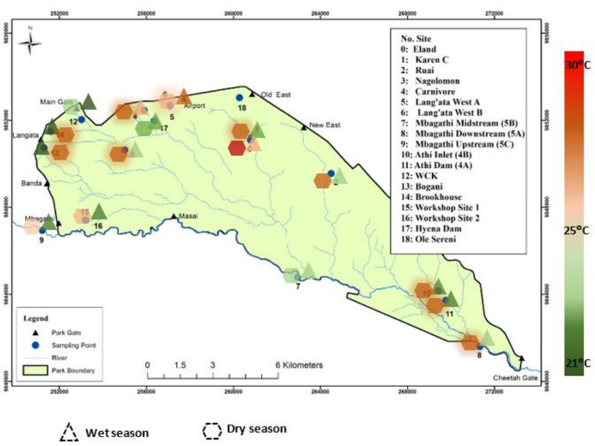


Figure 5. Temperature variation in sampled waters.

pH

For majority of the sampling points, water pH levels were normal range 6.5-8.5 (As per the NEMA water quality Standards, 2006) [30]. during both seasons. Few anomalies and non-conformities were observed in Hyena dam during the wet season with a pH reading of 9.54, and Brookhouse inflow which was strongly alkaline in the dry season with average pH reading of 9.43 as presented in Figure 6. These areas with extreme pH ranges are associated with sewage effluent. Some water pans within the Park namely Eland and Ruai had a higher pH reading during the wet season of 8.61 and 8.84 respectively. This could be due to the geological location and not direct anthropogenic interference.

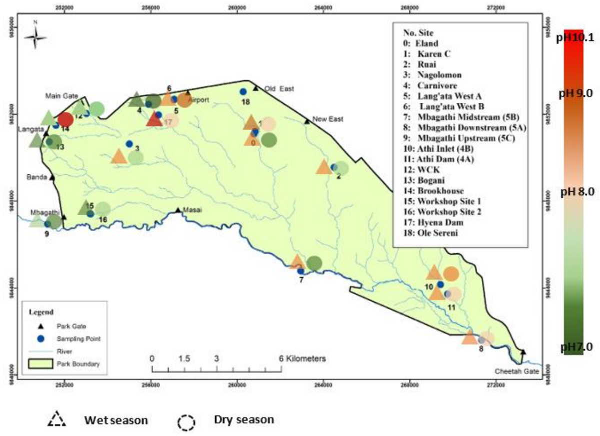


Figure 6. Water pH variation in sampled sites

3.3 Chemical parameters results

Water Salinity

Hyena dam had highest salinity levels of all the water pans in the park at 0.35±0.05 in the dry season which can be attributed to compromised water inflow from carnivore area.

Nutrients: Nitrates and Phosphates

Hyena dam also had a high concentration of nutrients which explains the high level of eutrophication in the dam with 256.7067 ±24.843 mg/l of nitrate concentration. Carnivore sampling point, Hyena dam, Brookhouse sewage inflow, Nagolomon dam, Hyena dam, R. Mbagathi upstream (Park entry point from Ongata Rongai estate) and Athi dam had elevated levels of nitrates outside the NEMA water quality limit of 10 mg/L for sources of drinking water for humans and 20 mg/L in Standards for Effluent Discharge into Public Sewers.

There are no local standards on quality of drinking water for domestic and wild animals. The EPA standards for orthophosphates for A3 waters is 0.7 mg/l. All the sampled sites had levels within this range. The phosphate standards in the NEMA water quality Standards is 30 mg/L in Standards for Effluent Discharge into Public Sewers. The sampled sites had phosphate readings within these limits.

Hydrocotyle ranunculoides overgrowth is very manifest from carnivore inflow point and rampant in Hyena dam. This species was only observed in Hyena dam and Carnivore. *Cyperus sp* in the dam are thicker, longer than in other dams due to nutrient enrichment.

Fluorides and Chlorides

Brookhouse sewage inflow had highest fluoride levels in both seasons at 9.37 ±0.0457mg/L in the wet season and 10.3333 ±0.173 mg/L in the dry season. Carnivore and Lang'ata West Sewage inflows exhibited similar anomalies with Carnivore recording 7.5667 ±0.065 mg/L in the dry season and 4.18 ±0.0196 mg/L in the wet season. Lang'ata West had higher Fluoride concentration in the wet season 7.4133 ±0.0236 mg/L and in the dry season it was slightly lower at 6.4333 ±0.017 mg/L. Hyena dam had the highest fluoride content of the water pans in the NNP Park having a reading of 6.0233 ±0.0173 mg/L in the wet season and 4.7867 ±0.03 mg/L in the dry season. All sites except Karen C dam, Ruai dam in the dry season, R. Mbagathi upstream/Park entry point in the dry season had a concentration higher than the recommended levels of 1.5 mg/l.

Chloride levels were highest in Hyena dam during the dry season at 342.5 ±0.792 mg/L. In the wet season the inlet to Athi inlet recorded higher chloride levels at 363.91 ±1.811mg/L. The sewage effluent inlet through Lang'ata west had the highest chloride concentration at 370.91 ±1.162 mg/L. This is above the NEMA water standard limit of 250 mg/l.

Chemical Oxygen Demand (COD)

COD levels were high in sewerage points: Carnivore 278.4, Brookhouse 195.2 and abnormally high during the dry season in Hyena dam as shown in Figure 7. COD readings were within NEMA limits in both seasons at Eland dam. Eland in the dry season with 679.7 ±1.757 and 478.3333 ±1.473 and in the wet season, Karen C 613.5333 ±0.949 in the dry season and Ruai Dam had the highest ORP at 812.3667 ±0.131, indicating a low concentration of organic matter. The areas also had higher dissolved oxygen (DO) levels of 4.7 ±0.41, 5.4 ±0.13 and 6.1 ±0.36 respectively as well as lower biological oxygen demand (BOD) levels of 8, 22 and 24 respectively. Carnivore inflow (-117.2333 ±0.457) registered a negative value of oxygen reduction potential (ORP) indicative of its very poor quality with high organic matter.

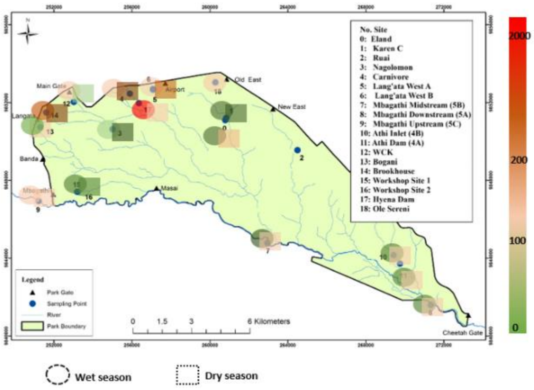


Figure 7. Chemical oxygen demand variation in sampled waters

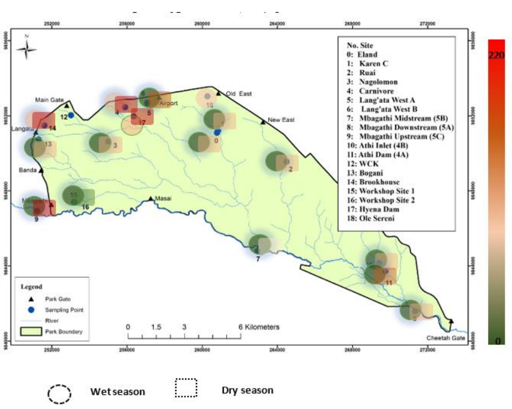


Figure 8. Biological oxygen variation in sampled waters

3.4 Biological parameters results

Biological Oxygen Demand (BOD)

BOD levels varied as shown in Figure 8 Carnivore, Lang'ata West, Brookhouse sewage in flows, Hyena dam Mbagathi Park entry point exhibited high BOD levels and lower dissolved oxygen amounts as presented in Figure 8. This indicates level of organic contamination in these sites. The seasonal variation as shown in Figure 8 in the various sampling points indicates that areas far from human interference like Ruai dam, the near midpoint of River Mbagathi as it flows through the Park have a higher dissolved oxygen. Water pans neighbouring residential estates like Hyena dam had very low DO and high BOD.

Only the Workshop/Kingfisher area in both seasons had BOD within the NEMA water Quality standards of 30 mg/l. In the dry season Eland dam, Karen C dam, Ruai dam, Mbagathi midstream, Athi dam and Athi dam inlet had BOD levels within the stipulated limits. However, in the wet season due to run off the BOD levels were elevated and outside the 30 mg/l limit.

Dissolved oxygen (DO)

Dissolved oxygen levels were low in Carnivore sampling point (0.9 ±0.226 mg/l in the wet season and 0.4667 ±0.346 in the dry season), Lang'ata West (2.2667 ±0.285 mg/l in the wet season and 0.8333 ±0.131 mg/l) in the dry season), Brookhouse (0.9333 ±0.173 mg/l in the wet season and 0.6333 ±0.682 mg/l in the dry season) and Hyena dam (1.8333 ±0.0653 mg/l in the wet season and 1.3333 ±0.653 mg/l in the dry season). Only 3 sites had DO of 5 mg/l and above; Eland dam in the wet season, Karen C dam in the wet season, Ruai dam in the wet season, R. Mbagathi mid-stream in the dry season and R. Mbagathi Park's entry point in the wet season.

Total coliform and E-coli

A total coliform and *E-coli* count was done in this study. However, the identification and taxonomy of respective species of coliforms present and the *E-coli* strains available is beyond the scope of this study which was to quantify physical parameters including total coliforms and *E-Coli*.

The total coliform count was generally higher in the wet season than in the dry season. Carnivore had the highest total coliform count in the wet season at 138±2.85 average number of coliform counts in 1 ml followed by Brookhouse with 124±5.19 coliforms/1ml. The inflow sewage volume is greater from the carnivore area compared to the other areas (even greater during the rainy season) as shown in Figure 9.

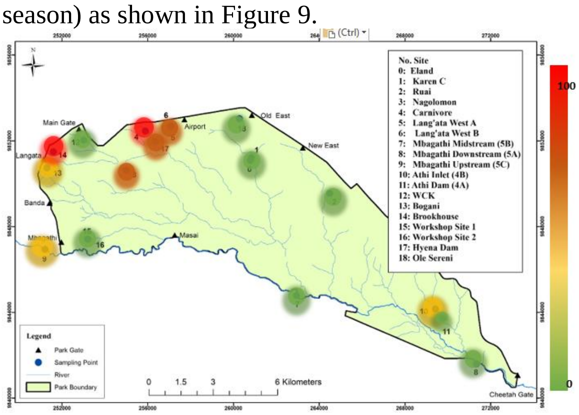


Figure 9. E-coli variation in sampled waters

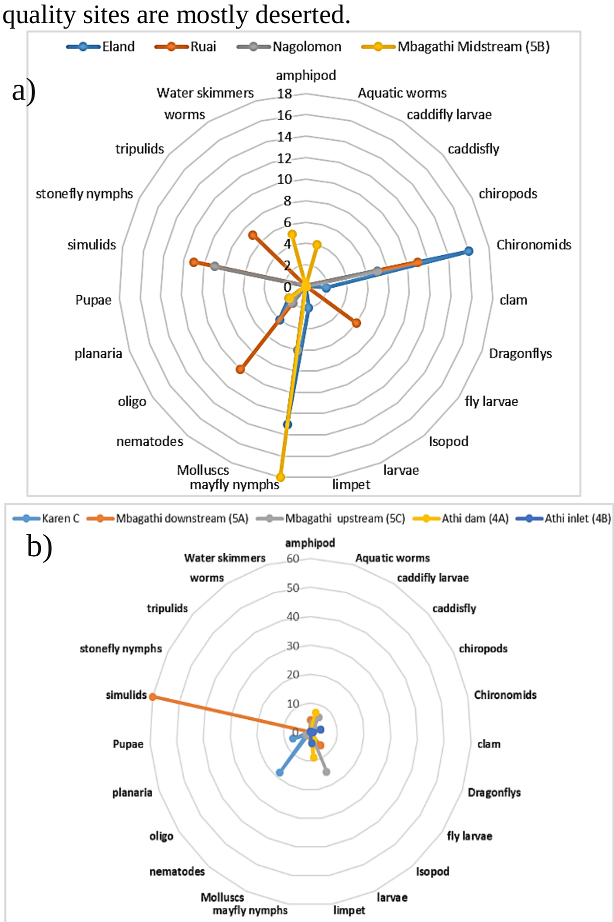
Lang'ata West at 64±3.4 coliforms/ml was third highest, Mbagathi Park entry point with 34±3.4 coliforms/1ml, and Hyena dam with 12±2.26 coliforms/1ml were among those with high coliform count thus indicating possible contamination with harmful pathogens and viruses. The *E-coli* count was correspondingly high in the wet season than the dry during season. This is attributed to enrichment by run-off from storm water and bursting sewer lines with an exception to Ruai dam that had coliforms in the dry season and zero coliform count in the wet season. Ruai dam (2 on the map) does not have any inflows from outside the Park. It recharges water from underground.

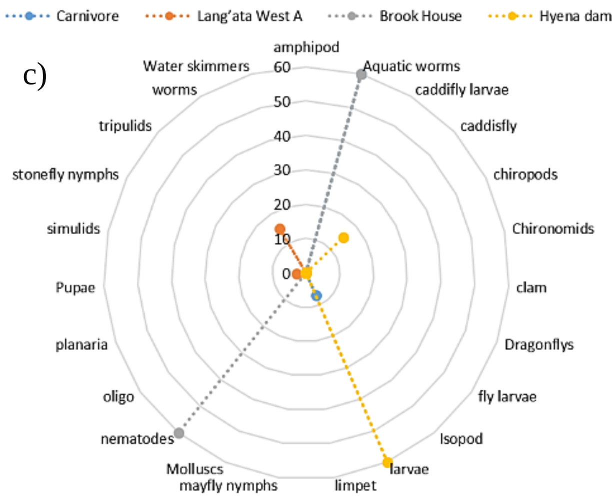
Carnivore area, Brookhouse and Lang'ata West are the areas closely neighbouring human settlement areas. The Carnivore sewage inflow empties directly into hyena dam therefore corrupting its quality immensely. Of all the water pans in the Park, Hyena dam had the highest coliform count in the wet season with 34±2.26 total coliform/1ml count and E-coli count average was 8±2.78 in 1 ml of sample water. This is not in harmony with the NEMA water quality standards that require E-Coli to be nil.

Ecosystem health as per Macro-invertebrate presence

The summary of macro invertebrates viewed in the water samples, their numbers and indication of the health of the aquatic system is shown in Figure 10.

Water points located deep within the park were good water quality sites while those located at the Park boundary had the worst water quality. Unfortunately, these very poor water quality sites are the ones preferred by wildlife for drinking water. High numbers of wildlife frequent poor water quality sites while good water quality sites are mostly deserted.





(a) Macroinvertebrate count in good water quality sites

(b) Macroinvertebrate count in moderately disturbed water quality sites

(c) Macroinvertebrate count in very poor water quality sites

Figure 10. Macroinvertebrates distribution in the Park

4. DISCUSSION

Only four out of the thirteen sampled sites (31%) were found to have good water quality as shown in Figure 11. Nine of the remaining sites (69%) had compromised water quality with four of them being extremely poor water quality.

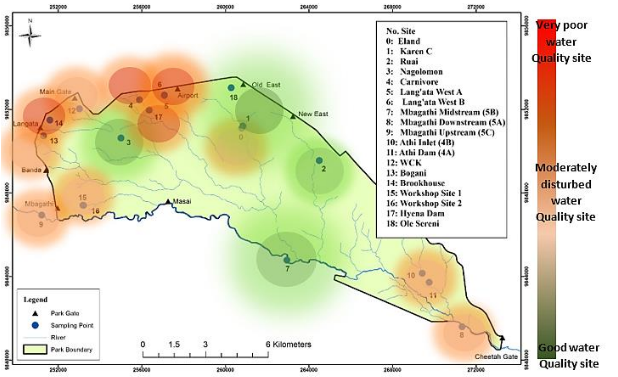


Figure 11. Water quality status in NNP

Unregulated and lowly enforced water quality compliance of nonpoint sources of pollution are affecting the ecological integrity of Nairobi National Park. The overall standard of water quality in the Park is not consistent with its designated use of species conservation. Ideally, all water quality parameters should be below levels likely to undesirably disturb receiving environment biota. However, the water quality of water pans like Hyena dam that receive sewage inflows directly are clearly compromised. Same with River Mbagathi's Park entry point (upstream). However, there are some water pans within the Park that naturally have elevated levels of compounds like cadmium, zinc, iron and lead despite them being located far from human interference. Nonetheless, it's evident that the water quality needs to be improved and protected.

Further, it was observed that wild animals seemed to prefer Hyena Dam waters to that of less polluted water pans in the Park. In the reconnaissance, and following sampling site visits it was observed that many animals flock to this polluted water point for a drink compared to nearby water bodies like Nagolomon dam. While they seem to have an affinity for nutrient rich waters this will impact their health and procreation ability in the long run. Pollution can affect the survival rate and quality of biodiversity. An investigation on the effect of pollution in the Park to wildlife and its possible contribution to the wildlife population should be conducted.

The extent of pollution is manageable but needs to be continually monitored and measures to counter pollution put in place. The Kenya Wildlife Act 2013 needs to recognize pollution as a threat to bio-diversity and stipulate harsh measures to counter it. Its regulation should also feature standards/criteria for Water quality for wildlife, permissible trace elements concentration in water, air, vegetation and soils in wildlife habitat.
Use of cut offs walls should be employed some meters below the ground forming an invisible and below the ground barrier to pollutants. It will enable protection of the park ecosystem from pollutants originating from outside the park as illustrated in Figure 12.

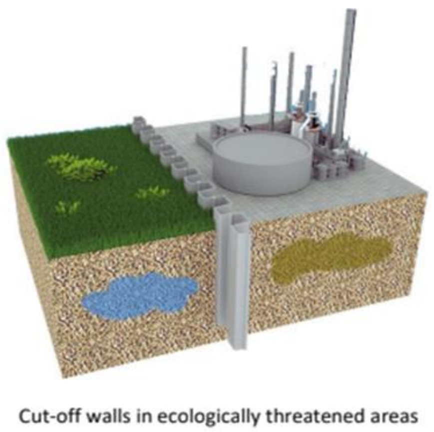


Figure 12. Application of Cut off walls for ecological protection, Source: Mirosław, G. (2018)

5. CONCLUSION

- The macro invertebrates detected, their numbers and diversity indicated the 31% of the sampled sites to be of good water quality. Water pans far from direct human interference and with underground recharge were rich with good water quality macro-invertebrates.
- Levels of physic-chemical characteristics of water (pH, temperature, Conductivity, orthophosphate, nitrate, ORP, Salinity, TDS, TSS, DO, fluoride, chloride) in Nairobi National Park indicate pollution in water bodies near human settlements and industries especially in the wet season. Nitrate and chlorides were also very elevated on average, however, phosphates were on average within range. Dissolved oxygen was of good concentration in water pans within the Park with underground recharge than those with inflows from outside the Park.
- In interior located water pans where particularly marabou storks inhabit. Continued deterioration as result of business as usual will lead to contamination of those located in the interior due to transmission of vectors by migration of species.
- For some selected pollutants, there is a strong positive relationship between the pollutant load in the ecosystem and seasonal variation further indicating that pollutant concentration in the ecosystem varies with seasonality.
- The results and analysis confirm Hypothesis 1 that there's a higher pollutant load in the periphery of the Park.
- Zonation plans in areas near biodiversity protected areas should be strictly adhered to in a similar manner zonation adheres to aviation rules. Otherwise uncontrolled urbanization will gradually reduce wildlife parks to empty ecological islands or ecological islands ridden with invasive species with little to no indigenous species. Conservation efforts should not just focus on rangers with guns but mitigate pollution and uncontrolled development.

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