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Assessment of benthic molluscs diversity and distribution in urban reservoirs (Ouagadougou, Burkina Faso)

Idrissa OUEDRAOGO*, Adama OUEDA, Djidama SIRIMA, Ilassa OUEDRAOGO, Wendengoudi GUENDA and Gustave B. KABRE

Laboratoire de Biologie et Ecologie Animales, UFR-Sciences de la Vie et de la Terre,
Université de Ouagadougou 03 BP 7021 Ouagadougou 03, Burkina Faso.
**Corresponding author, E-mail: o.idrissa16@gmail.com; Tel.: 00226 70 99 05 74*

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ABSTRACT

The urban reservoirs n° 2 and n°3 of Ouagadougou, located in the middle of the city are subject to multiple anthropogenic pressures which threaten the diversity of benthic macroinvertebrates community group like molluscs. This study was initiated to assess the diversity and distribution of benthic molluscs in these reservoirs. Molluscs samples were collected monthly using an Eckman grab (12 x 20 cm^2) between September 2011 and February 2012 in 24 sampling points defined on each reservoir. In parallel, physicochemical variables and water colon depth were measured. After sampling, molluscs were transported to the laboratory for identification. A total of 328 specimens were collected of which 5 species were identified: three species of Gastropods (*Bellamya unicolor*, *Cleopatra bulimoïdes*, *Lanistes ovum*) and two species of Bivalves (*Coelatura aegyptiaca*, *Mutela rostrata*). *B. unicolor* was the most abundant species with 71% of the collected molluscs and preferentially occupied the edges of the reservoir. It was followed by *C. aegyptiaca* (27%) which was abundant in the central axis of the reservoir. Physicochemical variables influence the distribution of species. For all measured physicochemical factors, *B. unicolor* was more tolerant than *C. aegyptiaca* on the occupation of available habitat.

Keywords: Bivalves, Gastropods, available habitat, physicochemical variables, anthropogenic pressures.

INTRODUCTION

Burkina Faso, a sahelian country located in West Africa, does not enjoy much surface water and this lead to the implementation of a surface water control policy by building many dams throughout the country (Ouéda et al., 2007). The large majority of these reservoirs were created in the Nakanbé River catchment where the population density is high, particularly in and around the city of Ouagadougou. These reservoirs contribute to the local development by providing fisheries (Ouéda et al., 2008), drinking water, water for agriculture (Kpoda

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et al., 2015) and the preservation of biodiversity. But despite their importance, most of these reservoirs do not have sufficient attention and are gradually degrading due to the pressure imposed by human activities. As consequence, this water from some reservoirs (eg. Reservoir 2 and 3 of Ouagadougou) shows higher concentrations of sulphates, nitrates and also heavy metals (mercury, total selenium dissolved and total dissolved arsenic) (Ouédraogo and Aymot, 2013). Aquatic organisms are sensitive to such disturbances that can lead to species disappearance. Zheng et al. (2015) has showed that for Zn, Pb, Cr, Cd, Hg, and Cu, invertebrates exhibited higher sensitivity than vertebrates. Among these organisms, benthic molluscs are particularly vulnerable because of their limited ability to move and thus to escape pollution. Because of this vulnerability, it is important to assess the diversity of this group in these two reservoirs.

In Burkina Faso, most studies on molluscs have focused only on the distribution of the intermediate hosts of schistosomes (Poda et al., 2004). However, although some are parasites vectors, molluscs play important functions in aquatic ecosystems (El-Wakeil et al., 2013), especially in food chain (Odler et al., 2013), in bioindication (Payet and Obura, 2004; Younger and Reese, 2013) and bioaccumulation (Fang et al., 2001; Usero et al., 2005).

The objective of this study was to highlight the diversity of benthic molluscs in these reservoirs and analyse their distribution in relation to some physicochemical variables.

MATERIALS AND METHODS

Study area

Our study sites, reservoirs n°2 and n°3 of Ouagadougou, are located in the central part of the town between longitudes 01°30'03.79’’W and 01°33'17.48’’W and latitudes 12°23’03,79’’N and 12°23’36,04’’N. The reservoir n°2’s surface is 226 ha with a capacity of 2.33 million m^3. The dyke’s depth is around 288.3 m. The reservoir n°3’s surface is around 88 ha with a capacity of 3 733 334 m^3. The depth of the dykes is about 288.67 m. Reservoir n° 2 is situated upstream the reservoir n° 3, and water can flow from reservoir n°2 to the reservoir n°3 throughout 60 rectangular opening (1.20 x 0.5 m) situated under the dyke of the reservoir n° 2 (Gueye, 2004). Created in 1963, these reservoirs are actually impacted by diverse activities, including vegetable gardening (that use prohibited chemicals fertilizers and pesticides); fisheries activities; car washing and regular water withdrawals. Another remarkable impact is the discharge of wastewater and solid wastes directly into the reservoirs from the neighbouring houses.

By means of Garmin GPS 76, 6 transects, each with 4 sampling points, were defined on each reservoir. Then, twenty four sampling points were visited each month during the dry season (from September 2011 to February 2012) in each reservoir.

Environmental variables

The stations were characterized by using 4 physicochemical variables and depth. Physicochemical variables measured are: temperature, conductivity, pH and transparency. Apart from the transparency which has been measured with a Secchi disk, the other physicochemical variables were measured with a multiparameter HANNA. The depth of the water column was measured with a ballasted tri -decameter.

Molluscs sampling

Molluscs was sampled aboard a canoe with an Eckman grab (sampling surface = 0.024 m^2). In each reservoir, one sample unit was taken from each of the 24 sampling point. After the grab raised, its content was spilled on a sieve (mesh size 0.8 mm) and washed to remove the mud. Living specimens and empty shell found were sorted and preserved in alcohol (70° final concentration). In the laboratory, molluscs specimens were determined using Mandahl-Barth (1978) and Leveque (1980) identifications keys.

Data analysis

All the analyses were performed with the R.3.1.1 software (R Development Core Team, 2014) in RStudio (Version 0.98.1049) interface. Statistical tests were performed using the stats package. The Shapiro-Wilk test was first performed to check the normality of physicochemical variables distributions. As all variables are not normaly distributed, we used the Mann Whitney-Wilcoxon test to check variability of physicochemical variables according to reservoirs and also to test the difference between available habitat and those used by species. This test was considered significant for $p < 0.05$.

Rarefaction curve (Magurran, 2004) was used to estimate molluscs species richness in the two reservoirs. It is accompanied by Chao index which gives an estimation of the maximum richness expected in the area. Rarefaction curve was graphed based on the matrix of species using the vegan and BiodiversityR packages (Kindt and Coe, 2005).

To analyse spatial distribution, only the most abundant and species found alive in the reservoir n° 3 were considered. First, a map of the reservoirs shape and sampling points was created with the adehabitat (Calenge, 2006) and lattice (Sarkar, 2008) packages using geographical coordinates recorded with a GPS (Figure 1). Abundance of species at each sampling point were then projected.

RESULTS

Physicochemical characteristics of reservoirs

Figure 2 (A-D) shows the variation of physicochemical variables in the two reservoirs. The median values of transparency, temperature and depth are highest in the reservoir n°3 than reservoir n°2. The average values of pH and conductivity are highest in the reservoir n°2 than reservoir n°3. The Mann Whitney-Wilcoxon test confirmed that these differences in the two reservoirs were all statistically significant ($p < 0.05$).

Species diversity

Table 1 shows the taxonomic composition of Molluscs community in the two reservoirs. Five species belonging to five families and two classes (Gastropoda and Bivalves) were identified. Thus, each family is represented by a single species. The class of Gastropoda is composed by *Bellamya unicolor* Olivier, 1804; *Cleopatra bulimoïdes* (Olivier, 1804), and *Lanistes ovum* Peters, 1854. Bivalves are composed by *Coelatura aegyptiaca* (Cailliaud, 1827) and *Mutela rostrata* (Rank, 1835). The living specimens found belong to *Bellamya unicolor* and *Coelatura aegyptiaca*. *Cleopatra bulimoïdes* and *Mutela rostrata* were mentioned on the basis of empty shells. *Lanistes ovum* was observed in a sample from the reservoir n°2 and collected outside the method used for this study.

Rarefaction curve gives no horizontal tangent (Figure 3). This means that the probability to find new species exists if other samplings are conducted. Indeed, the Chao test foresees a total of 8 species in these reservoirs. So we can hypothesize that three more species are susceptible to be found in these reservoirs.

Species abundance

The relative abundance of benthic molluscs, considering living specimens and empty shell in reservoirs n°2 and n°3 of Ouagadougou is presented in Figure 4. *B. unicolor* is the most abundant with 71% of collected specimens. It is followed by *Coelatura aegyptiaca* (27%) and *Cleopatra bulimoïdes* with (2%). *M. rostrata* represents less than 1% of specimens. Figure 5 compares the abundance of empty shells to living molluscs for each species. For all species, empty shells are more abundant than living specimens.

Species distribution

As *C. aegyptiaca* and *B. unicolor* were the two species found alive in this study, they were used for micro-spatial distribution and habitat preferendum analysis. The spatial distribution analyses have shown that *C. aegyptiaca* occurs mainly in the middle of the reservoir while *B. unicolor* prefers area near to the bank (Figure 6 (A & B)).

Figure 7 (A-D) shows for each physicochemical variable, the preferendum for *B. unicolor* and *C. aegyptiaca*. The available pH varied between 7.3 and 9.61. *B. unicolor* occupies the same range but *C. aegyptiaca* occupied a narrow niche and is not found for pH lower than 8.25 and higher than 9. The water temperature ranged between 21.8 °C and 38.5 °C. With temperature, the two species shows the same behavior like with the pH. *B. unicolor*, more tolerant to temperature variation, is just absent for temperature higher than 36.7 °C but *C. aegyptiaca* is sensitive to high temperatures, occupied one more time a narrow niche and disappears beyond 25.2 °C. The conductivity values varied between 221 and 361 µS/cm. The two species show opposite patterns according to conductivity. *C. aegyptiaca* prefers high conductivity (preferendum between 311 and 318 µS/cm) and *B. unicolor* is seen to avoid higher conductivity (appearing between 223 and 318 µS/cm). In this study, available water depth varied from 50 to 450 cm. However, no living specimen was collected below 1 m depth and no one beyond 3 m *C. aegyptiaca* was found in areas where the water column depth varied between 1 and 1.6 m and *B. unicolor* was found where the water column depth varies between 1 and 3 m. For the water transparency, it varied from 3 to 56 cm. *C. aegyptiaca* and *B.* unicolor avoid both extreme values. However, *C. aegyptiaca* is more demanding than *B. unicolor* because its distribution range is lower (21 to 28 cm) while those of *B. unicolor* is between 14 and 47 cm. The Mann Whitney-Wilcoxon test showed that there was no significant difference between the available habitat and the preferendum of *B. unicolor*. For *C. aegyptiaca* a significant difference was observed for temperature (p = 0.0066).

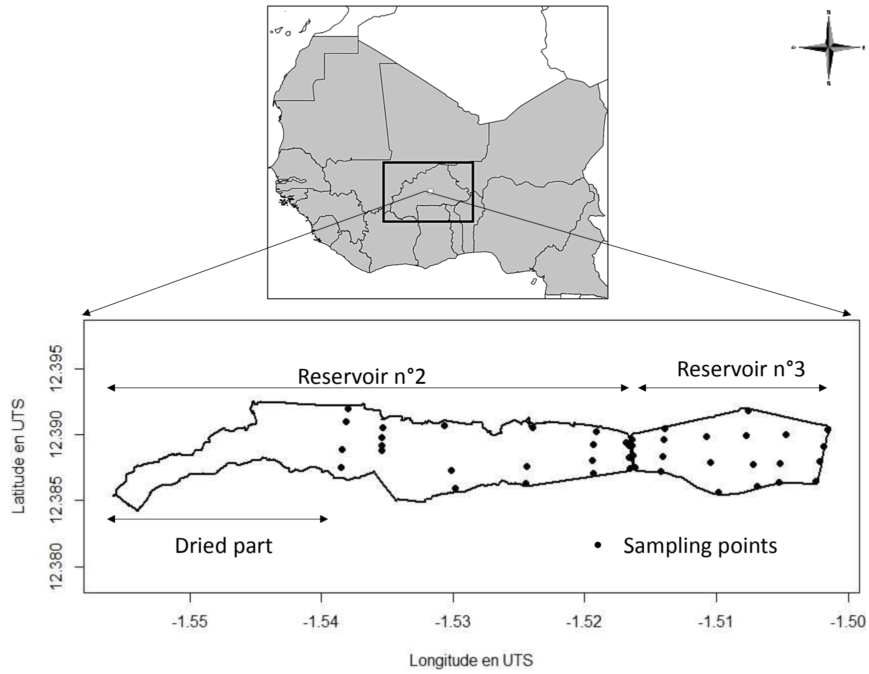

Figure 1: Presentation of study area and sampling design.

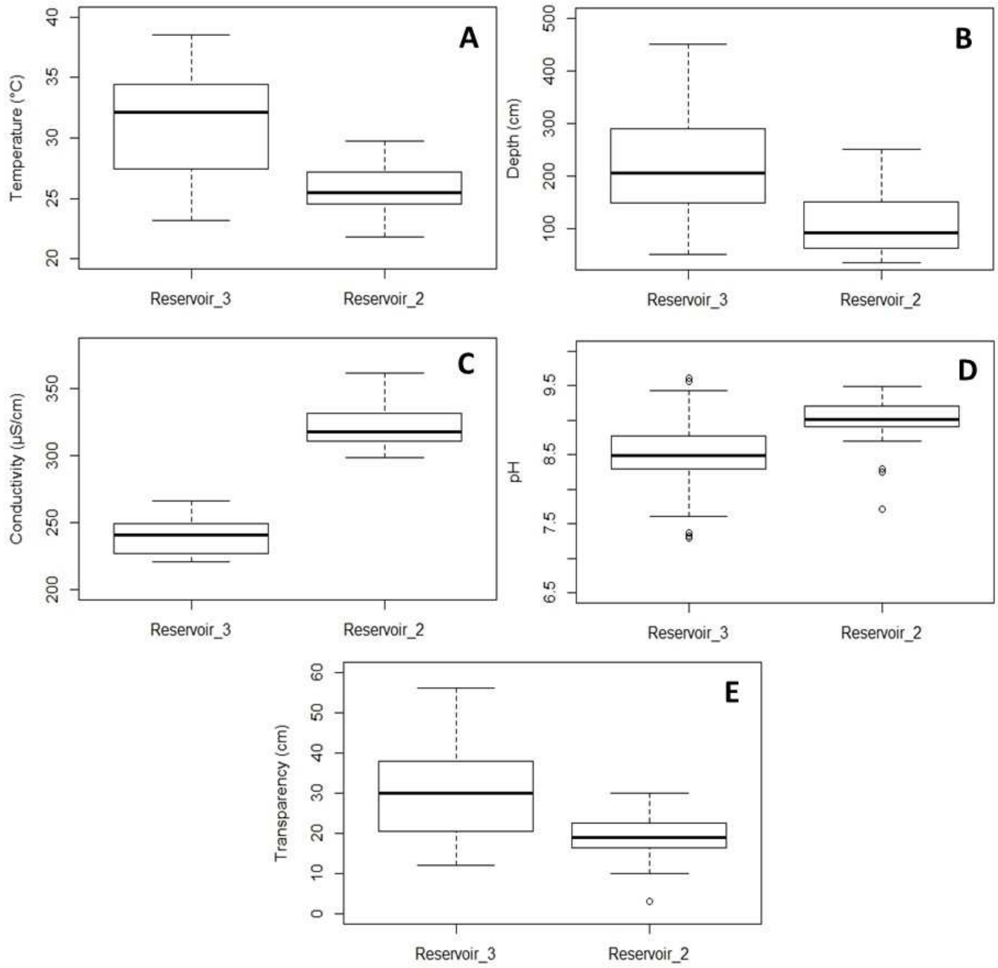

Figure 2: Boxplot showing physicochemical variables distribution in the two reservoirs. A= temperature (°C); B= Depth (cm); C= Conductivity (µS/cm); D= pH; E= Transparency (cm).

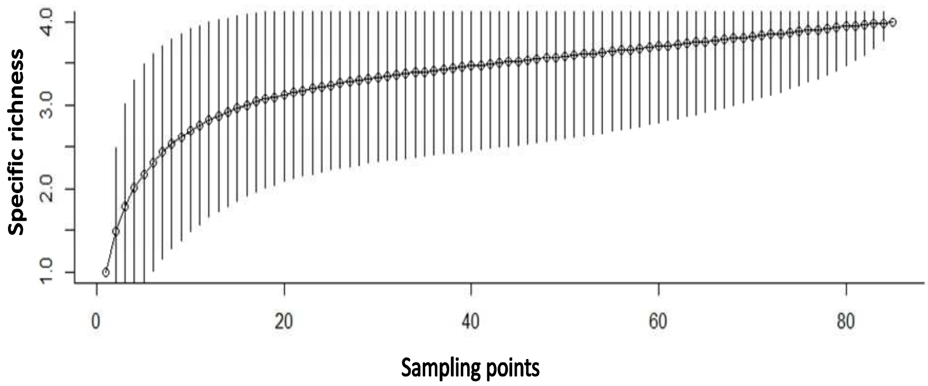

Figure 3: Rarefaction curve in relation to sampling points in the studied reservoirs.

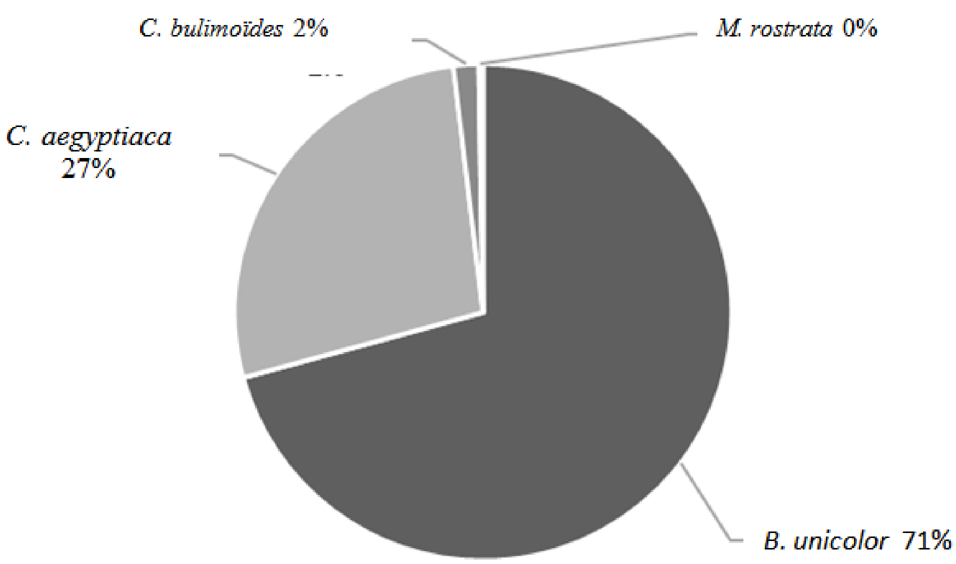

Figure 4: Species proportion in the reservoirs (n°2 and n°3) of Ouagadougou.

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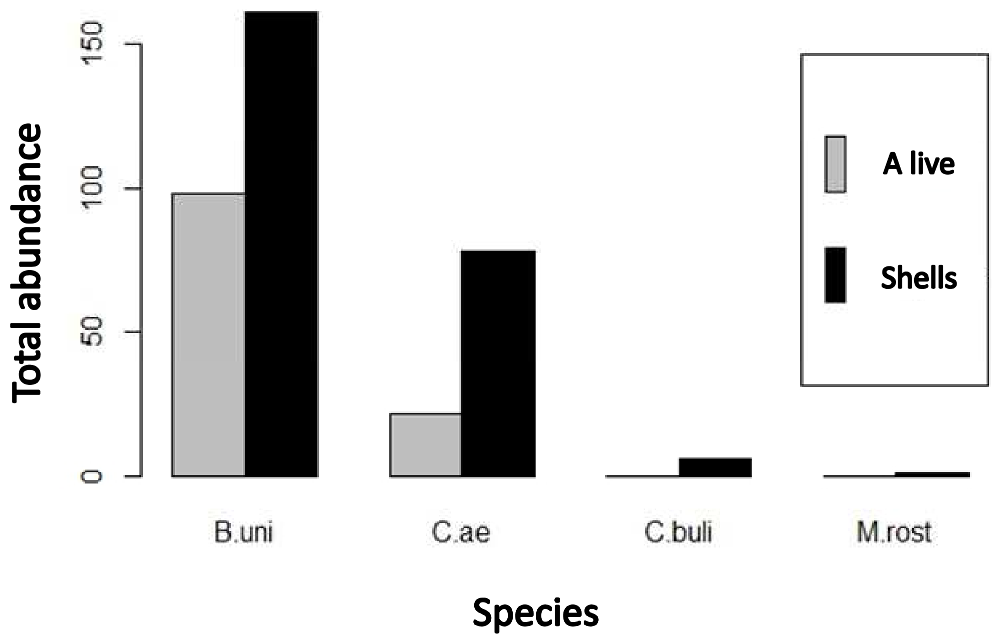

Figure 5: Total abundance of living specimens and empty shells. B.uni: *Bellamya unicolor*, C.aeg: *Coelatura aegyptiaca*, Cl.bul: *Cleopatra bulimoïdes*, M.rost: *Mutela rostrata*.

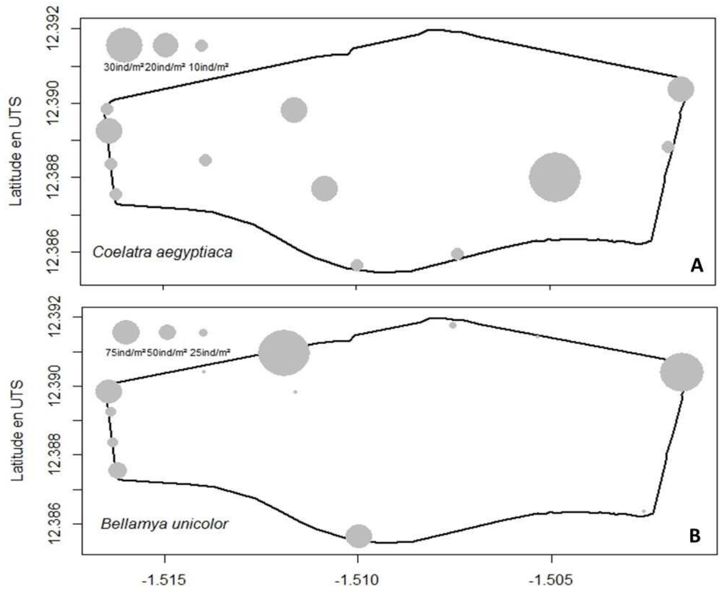

Figure 6: Spatial distribution of *C. aegyptiaca* and *B. unicolor* in the reservoir n°3 of Ouagadougou. A= Spatial distribution of *C. aegyptiaca*; B= Spatial distribution of *B. unicolor*.

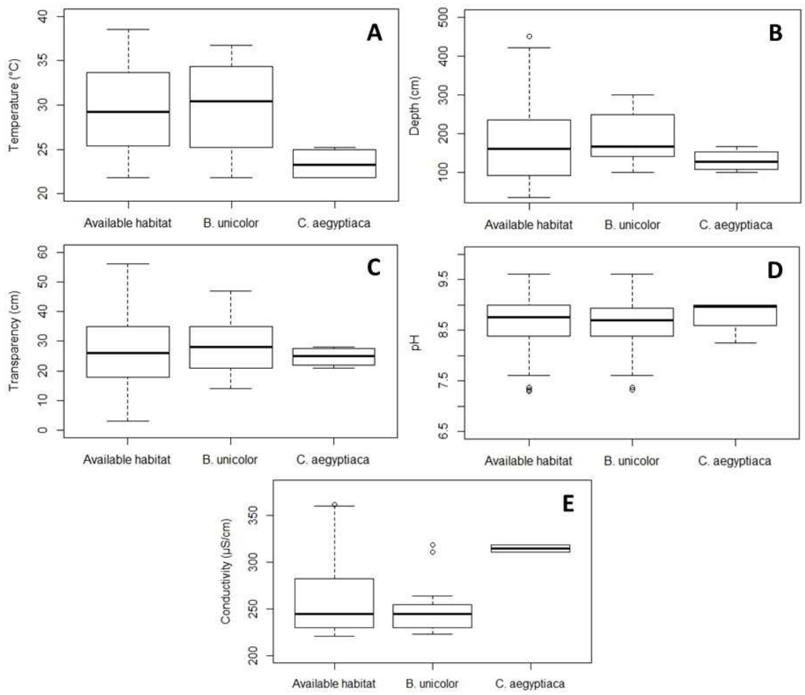

Figure 7: Habitats used by *C. aegyptiaca* and *B. unicolor in* the reservoir n°3 of Ouagadougou. A= Habit use by *B. unicolor and C. aegyptiaca* following water temperature; B= Habit use by *B. unicolor and C. aegyptiaca* following water column depth; C= Habit use by *B. unicolor and C. aegyptiaca* following water Transparency; D= Habit use by *B. unicolor and C. aegyptiaca* following water pH; E= Habit use by *B. unicolor and C. aegyptiaca* following water conductivity.

Table 1: Taxonomic composition of molluscs in reservoirs n°2 and n°3 of Ouagadougou.

Class	Family	Species
Gasteropoda	Viviparidae	*Bellamya unicolor* Olivier, 1804
	Thiaridae	*Cleopatra bulimoïdes* (Olivier, 1804)
	Ampullaridae	*Lanistes ovum* Peters, 1854
Bivalvia	Iridinidae	*Mutela rostrata* (Rang, 1835)
	Unionidae	*Coelatura aegyptiaca* (Cailliaud, 1827)

DISCUSSION

Although interconnected, reservoirs n°2 and n°3 of Ouagadougou present differences in their physicochemical characteristics. These differences are probably related to difference in exposition to human activities. There are two things that limit direct access and human activities in the reservoir n°3: first, the banks are completely concrete and second the reservoir n°3 is deeper than reservoir n°2 (mean: 2.205 m vs. 1.096 m). In contrast to reservoir n°3, the reservoir n°2 receives wastewater from toilets of neighbouring houses and a part of its bed is used for vegetable gardening where chemical fertilizers and pesticides are usually used (Kpoda et al., 2015). All these practices can explain the high turbidity in the reservoir n°2. Wastewaters are characterized by very high concentrations of dissolved elements which increase the electrical conductivity (Abba et al., 2008). The intensive use of chemical fertilizers can make water alkaline resulting to high values of pH as seen in the reservoir n°2. The lower depth and the connection to the river basin make the reservoir n°2 more exposed to human activities and pollution. These impacts and pollution in turn lead to lower transparency and high conductivity of reservoir n°2.

Despite the disturbance affecting the two reservoirs, five species of molluscs were founded. These species, as mentioned by Seddon et al. (2011) for African freshwater molluscs fall into two main groups, the Bivalves and the Gastropods. While all the five species are new record for Burkina Faso, they were already reported in previous studies on African freshwater molluscs or macroinvertebrates (Sarr et al., 2011; Seddon et al., 2011). *Cleopatra bulimoïdes* and *Mutela rostrata* were reported in the sediment of the Agnéby River in Côte d'Ivoire (Diomandé et al., 2009). *Bellamya unicolor* is widespread in West Africa through the Sahel (Ghamizi et al., 2010). It was recorded in Egypt by Odler et al. (2013). *Coelatura aegyptiaca* is also widespread in West Africa (Van Damme and Ghamizi, 2010) and was recorded by Odler et al. (2013) in the mud-brick tomb in Abusir (Egypt). *Lanistes ovum* was recently recorded in south-western Nigeria in Aiba stream by Akindele et al. (2014).

Significant relationship exists between benthic macroinvertebrates and physicochemical variables (Pham et al., 2015). With regard to available habitat (according to physicochemical variables) *B. unicolor* and *C. aegyptiaca* have different preferendums. In general, *B. unicolor* is more tolerant than *C. aegyptiaca. For all the studied physicochemical variables, C. aegyptiaca* shows narrow niche than *B. unicolor*.

A large majority of molluscs species and a large number of specimens develop in alkaline conditions (Martins-Siva and Barros, 2001). The pH values recorded in this study are slightly alkaline (7.55 to 9.5) and similar to those reported by Akindele et al., (2014) in the Aiba stream in Nigeria (6.55-7.55) where they found *C. aegyptiaca and B. unicolor*. In this study, we can go to more details on the preferred pH range for *C. aegyptiaca* (8.25 and 9).

Any living specimen of molluscs was found beyond 36.7 °C. *C. aegyptiaca* and *B. unicolor* were previously found in Lake Victoria where the temperature ranged between 24 to 25 °C (Mwambungu, 2004) in Aiba stream in Nigeria where it ranged from 21.9 to 30.08 °C Akindele et al., (2014). It is therefore apparent that 36.7 °C recorded in this study is the bearable limit for these species even if high temperatures are reported to favour their growth in the Ramsagar reservoir (maximum temperature =31.87 °C) (Garg et al., 2009). A future increase of the temperature in these reservoirs due to global warming of the planet could lead to their disappearance (Yasuhara and Donavaro, 2014). This could happen early for *C. aegyptiaca* because Bivalves seem to prefer low temperatures (Saddozai et al., 2013; Sharma et al., 2013).

Compared to Lake Chad where these species were found, conductivity varied between 50 and 550 µS/cm with a maximum density at 400 µS/cm for *B. unicolor*. It was also present in Lake Victoria where the average conductivity was 123 µS/cm (Mwambungu, 2004). The absence of *Cleopatra bulimoïdes* does not seem to be related to the conductivity because it was found in the river Agnéby where conductivity ranged between 119.7 and 151.95 µS/cm (Diomandé et al., 2009).

No specimen was found in depth below 1 m. The reservoir n°3 has concrete bank with high slope, then the bottom is found in depth higher than 1 m. In reservoir n°2 there is too much activities in the bank, creating too much disturbance that doesn't allow establishment of molluscs community. The average depth of the reservoir n°3 of Ouagadougou is similar to the average depth of Lake Chad which varies around 4 to 3 m (Leveque et al., 1979). This species was found in depths of about 18 m in Golf Winam near Kisumu (Brown, 1994), but in our study, no specimen was found beyond 3 m. This means that the depth only cannot explain the distribution of this species; it can also be related to the nature of bottom sediments. In this Golf, *B. unicolor* was abundant in bottom sediment which was mostly fine organic detritus derived from the papyrus swamps (Brown, 1994).

B. unicolor and *C. aegyptiaca* were found in waters like Lake Victoria where transparency were 1.6 m (Mwambungu, 2004). Here, we found these species in very turbid water (transparency lower than 60 cm). This higher turbidity is not favourable to the development of Gastropods (Brown, 1994). Bivalves by their filtration activities enhance the water clarity by reducing the number of suspended particles (McIvor, 2004).

B. unicolor occurs preferentially near the bank of the reservoir where immerged plants and debris (twigs, sticks, and leaves) are abundant and represented good habitat for them (Leveque, 1979). This habitat preference is the reason why *B. unicolor* is not found in beyond 3 m. *C. aegyptiaca* is better represented in the central axis of the reservoir. Bivalves seem more related to areas where water velocity is higher (Leveque, 1980) due to their feeding mode by filtering water to retain particles in suspension.

Important quantities of empty shells were found in our samples. Empty shells of *C. bulimoïdes* and *M. rostrata* are indicator of the presence of those species in the reservoir n°3. The absence of living specimens of these species can be interpreted in two ways: one, these species had disappeared because pollution of the reservoir has reached an unfavorable level to their development, and two, living specimens exist but they are so rare. Molluscs with live specimens have high abundance of empty shells in the two reservoirs. This can be explained by the fact that once molluscs are dead, their shells remain in the sediments take long time to be decomposed. A study of the degradation rate of the shells based on physicochemical conditions of the environment could give light to this phenomenon.

Conclusion

This study showed that five species of benthic molluscs occur in reservoirs n°2 and n°3 of Ouagadougou. Living specimens only belong to two species: *C. aegyptiaca* and *B. unicolor* are also the most abundant. As far as the occupation of available habitat defined with physicochemical variables is concerned, *B. unicolor* is more tolerant than *C. aegyptiaca* that always shows narrow niche for the measured variables. *B. unicolor* occurs preferentially near the bank of the reservoir where immerged plants and debris are abundant and represented good habitat for them. *C. aegyptiaca* is better represented in the central axis of the reservoir.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

IO participated in the conception, study design, field work, sampling systematic, data analyses and manuscript writing. AO also contributed to the conception, study design, data analyses and manuscript editing. DS and IO conducted the field work, sampling and samples procession. WG and GBK designed the study and supervised the work. All authors read and approved the manuscript.

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