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Freshwater molluscs distribution in relation to human activities in the Nakanbé Catchment (Burkina Faso)

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Abstract

Biodiversity contributes enormously to the well-being of communities. However, human activities threaten this diversity, especially in aquatic ecosystems. This work was initiated to show the impact of these activities on the diversity and distribution of some key organisms such as freshwater molluscs. Its objective is to show the influence of anthropogenic activities on the distribution of freshwater molluscs in Burkina Faso. The study consisted first to make the malacological inventory in sites undergoing different types of anthropic pressures. Physicochemical conditions of these sites were measured at the same time. Then the relationship between the physicochemical factors and the species distribution was determined. In total, 11 species of molluscs were identified. They belong to two classes, 7 families and 10 genera. Most of the species has been found in agricultural areas related to nutrient availability in relation to fertilizer and the diversity of aquatic habitats. No species have been found in urban areas due to high level of pollution. The abundance of human and animal parasitic vectors in agricultural areas constitutes a risk to local communities. This study has shown that human activities influence the distribution of freshwater molluscs increasing their development in agricultural area but constitute a serious threat in urban areas.

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Introduction

Freshwater ecosystems provide many services to the communities 'well-being such as water for drinking, irrigation, food, and in stream benefits such as recreation and transportation. Unfortunately, climate change is imperilling both freshwater species and their use by humans by driving engineering responses that will further threaten the freshwater biota(Strayer and Dudgeon, 2010). To anticipate both ecological and human responses to climate change, it is necessary to understand the influence of environmental changes including climate change on freshwater organisms and especially on less studied animals such as freshwater molluscs.

Freshwater molluscs are essential to the maintenance of wetland ecosystems, firstly due to their action on water quality and nutrient balance by their filtration activity and algae-grazing and secondly as a food source for predators such as a number of fish species, birds, etc. (Tulp *et al.*, 2010; Szabó and Amesbury, 2011; Tacon and Metian, 2013). Molluscs are comparatively long living invertebrates (an average of 10 or more years) and can accumulate a variety of substances. Therefore molluscs are good indicators of pollution and can be used as "biological monitors" to indicate water quality in different water bodies (Li *etal.*, 2010; Tietze and de Francesco, 2010; Holt and Miller, 2011; Waykar and Deshmukh, 2012).

From a medical point of view, some mollusc species are important intermediate hosts for parasites and thus can be vectors of serious diseases (Brown,2002). A widespread disease is schistosomiasis also called snail fever and bilharzia which is caused by parasitic flatworms- schistosomes (Thétiot-Laurent *et al.*, 2013). In 2015, this disease affected about 252 million people worldwide including Burkina Faso and responsible for 4,400 to 200,000 deaths worldwide each year (Thétiot-Laurent *et al.*, 2013; Kassebaum *et al.* 2017; Wang *et al.*, 2017).

In Burkina Faso, preliminaries research on freshwater molluscs were focused only on the distribution of species that host parasitic flat worms causing schistosomiasis (Garba *et al.*, 1999; Poda *et al.*, 2001; Noël *etal.*, 2006; Zongo *et al.*, 2009; Savadogo *et al.*, 2015). Other studies addressed mollusc diversity in specific environment (Sanogo *etal.*, 2014; Ouedraogo *etal.*, 2015; Kaboré *etal.*, 2016). However, very few studies have examined the influence of environmental changes due to human activities on molluscs distribution in Burkina Faso. To address this issue, sites undergoing different types of anthropic pressures were selected to assess the distribution of freshwater molluscs within the Nakanbé Catchment.

Materials and methods

Study area

The study

Area is mainly locatedin the Nakanbécatchmenti n Burkina Faso between the centre of Ouagadougou, and the border of Ghanain the south. In this catchment, three sampling areas were chosen following a gradient of human impact, with an urban area located in Ouagadougou, an agricultural area in Koubri and a protected area in Nazinga (Fig. 1).

The sampling sites in urban area are constituted by the reservoir n°2 of Ouagadougou and two open waste and storm water canals. They are surrounded by residential and industrial and receive sewage input and waste disposal. The two canals transport slow moving waste water from the neighborhood (Koblinger and Trauner, 2013).

The agricultural area is characterized by high reservoir density (8.8 reservoirs/100 km^2), moderate population density, intensive small-scale agriculture and livestock husbandry (Koblinger and Trauner, 2013). Apart from rain fed agriculture, the reservoir banks serve as fields for vegetable production, mainly for the capital city (Ouedraogo, 2010). From local information and observation, the shoreline vegetable farms are treated with fertilizer and pesticides. Moreover, water abstraction, livestock watering and washing took place at all investigation sites (Koblinger and Trauner, 2013).

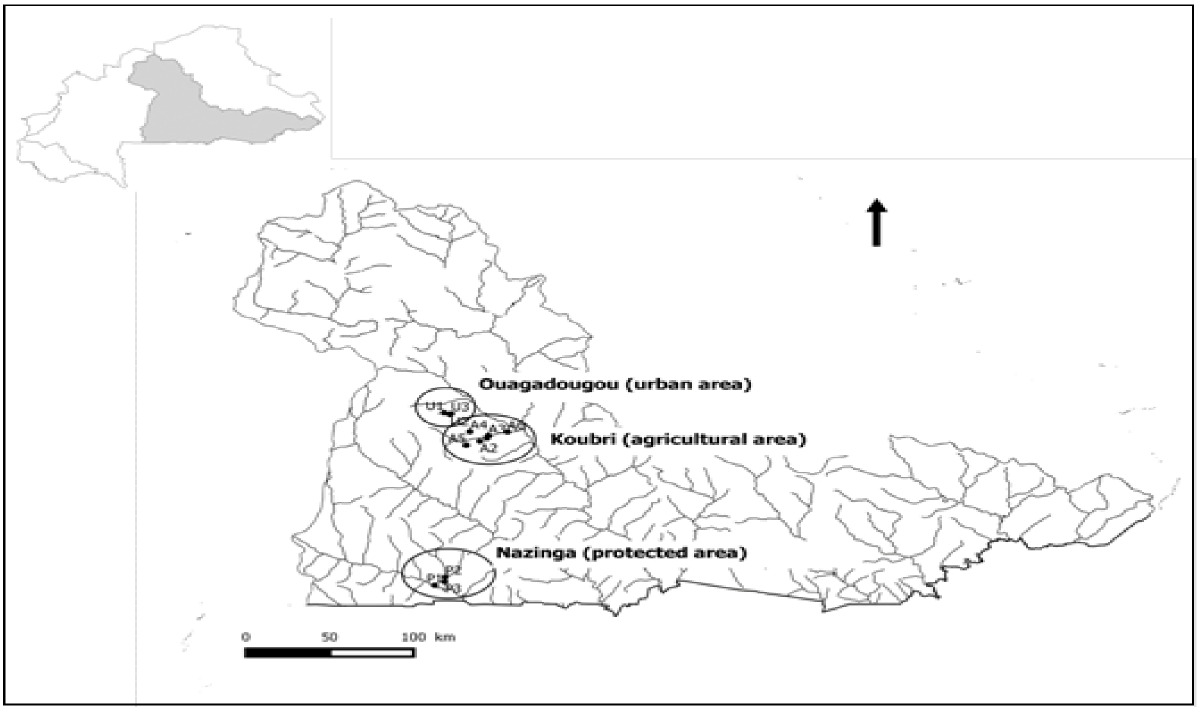

Fig. 1. Location of the sampling sites within the sampling areas.

In the protected game ranch of Nazinga, agricultural activity, livestock breeding and logging are forbidden and fishing is highly controlled. The reservoirs of Naguio (17 ha), Talanga (21 ha) and Kozougou (8 ha) were sampled. Sampling of the three areas took place between October and December 2012.

Physicochemical conditions of study sites

Before sampling of the molluscs four physicochemical variables were measured to describe water bodies physicochemical conditions at each site with a WTW340I multimeter: pH (pH units), temperature (°C), conductivity ($\mu S.cm^{-1}$), dissolved oxygen ($mg. L^{-1}$). These are important parameters for aquatic animals which are only adapted for a certain range. Fieldwork was conducted in the daytime.

Molluscs sampling

Molluscs were sampled using a standard handnet (25 × 25 mm frame, mesh 500 µm) to obtain quantitative samples. Twenty sample units were taken following multi-habitat sampling method (Kaboré *etal.*, 2016) at each site. Available micro-habitats sampled in each site are indicated in Table 2. All collected samples were sorted by size in the field, preserved in ethanol (90%) and transported to the laboratory.

In the laboratory, molluscs were sorted to species or genus level based on the literature and identification keys (Mandahl-Barth, 1965; Mandahl-Barth, 1978; Durand and Lévèque, 1980; Brown, 2002). Some specimens were discussed with taxonomic experts Alexander Reischütz, Horn (Austria), Dr Simon Schneider (NHM Vienna), Dr Bert Van Boxclaer (Evo, Eco Paléo of CNRS and Université de Lille, France) and Dr Christian Albrecth (Department of Animal Ecology & Systematics de Justus Liebig University, Giessen, Germany)to confirm identification.

Data analysis

For the three study areas, mollusc community structure was described through species richness (number of species found), abundance, occurrence frequency (FO), Shannon–Wiener and Pielou's evenness diversity indices (Magurran, 2013). Occurrence frequency specifies the percentage of samples in which each species of mollusc occurred. It was calculated according to Dajoz (2000).

The Kolmogorov–Smirnov test was first applied to check the normality of the distribution before comparing the measured parameters and abundances of the found mollusk species.

The Kruskal-Wallis test and Mann–Whitney test were then performed to verify significant differences of environmental parameters and molluscs' abundance between sampling areas. R (R Development Core Team, 2005) software was used for these statistical analyses, and the level of significance considered wasfor $p<0.05$. Relationship between environmental variables and taxonomic richness and abundance of mollusks were determined by canonical redundancy analysis (RDA).

The RDA is a constrained linear ordination method, which combines multiple regressions with principal component analysis (PCA). To perform this analysis wodata matrix were prepared: the environmental matrix with physicochemical variables and micro-habitats categories and the biotic matrix containing the species abundance.

In the environmental matrix the categorial variable (micro-habitat) was transformed.

The species data was transformed using Hellinger's transformation Which offers a better compromise between linearity and resolution than the chi-square metric and the chi-square distance (Legendre and Gallagher 2001).

Results

Environmental condition of sampling area

Among the physicochemical parameters only the pH did not vary significantly among the three sampling areas (Fig. 2). Water conductivity was very high in urban area. The Kruskal-Wallis test showed that this parameter is significantly different between the three areas. Water temperature showed its highest values in agricultural areas.

Table 1. Available micro-habitats per investigate dsite. These sites are grouped following the main land use type : Urban area, Agricultural area and Protected area.

Area name and type	Site name	Available micro-habitats	Latitude	Longitude
Urban area (Ouagadougou)	Reservoir n°2 of Ouagadougou	Sediment, Reeds	12.2042	-1.3041
	University canal	Concrete	12.1804	-1.3415
	ODE canel	Concrete	12.2212	-1.2972
Agricultural area	Noungou	Sediment, Reeds	12.2503	-1.3961
(Koubri)	Peodgo	Sediment, Reeds	12.1518	-1.4156
	Ancien reservoir	Sediment, Reeds	12.2488	-1.1938
	Mogtedo	Sediment, Reeds	12.3902	-1.5341
	Wedbila	Sediment, Reeds	12.3777	-1.5012
	Peele	Sediment	12.3837	-1.4964
Protected area (Nazinga)	Naguio	Sediment, waterslad	11.1283	-1.5832
	Talanga	Sediment, waterslad	11.18879	-1.5281
	Kozougou	Sediment, waterslad	11.15430	-1.5310

The dissolved oxygen was very low in urban areas compared to agricultural and protected areas.

Composition and distribution of molluscan fauna

Species richness: In total, the malacological survey identified eleven species of molluscs belonging to two classes and seven families (Table 2): Ampullaridae (*Lanistes varicus)*; Viviparidae (*Bellamya unicolor*); Lymnaeidae (*Lymnaea natalensis*); Thiaridae (*Cleopatra bulimoides*) Planorbidae (*Biomphalaria pfeifferi, Bulinus forskalii, Bulinus truncatus*); Unionidae (*Coelatura aegyptiaca*); Iridinidae (*Chambardia wahlbergi, Mutela rostrata, Aspatharia chaiziana*). No mollusc species was found in two sites (the University and ODE canals) in the urban area.

Species frequency: Among the eleven species, only *B. truncatus* (FO = 72.72%), *B. pfeifferi* (FO = 72.72%) and *B. unicolor* (FO = 54.54%) were very frequent (

Fig.). *L. varicus* (FO = 54,45%), *L. natalensis* (FO = 36.36%), *B. forskalii* (FO =36.36%), *C. bulimoides* (FO = 27.27%) and *C. aegyptiaca* (FO = 27.27%) were constant and *C. wahlbergi, A. chaiziana* and *M. rostrata* were very rare (FO <25%). The Fig. 4 indicates the relative abundance of the freshwater mollusc species collected within all investigated areas. The most abundant species is *B. truncatus* (48%). It is followed by *B. pfeifferi* (23%), *B. unicolor* (9%), *B. forskalii* (8%) and *C. bulimoides* (6%). The other species represent 5%. Following the sampling area, species richness varied between three and six in the agricultural area (Koubri), between one and 3 in the protected area (Nazinga) and between 3 and four in the Urban area (Ouagadougou).

Table 2. Freshwatermolluscspeciesencountered in the investigated area in NakambéCatchmentorganised by family and class.

Class	Family	Species
Gastropoda	Viviparidae	*Bellamya unicolor* (Olivier, 1804)
	Planorbidae	*Biomphalaria pfeifferi* (Krauss, 1848)
		Bulinus forskalii (Ehrenberg, 1831)
		Bulinus truncatus (Audouin, 1827)
	Thiaridae	*Cleopatra bulimoïdes* (Olivier, 1804)
	Ampullaridae	*Lanistes ovum*Peters, 1845
		Lanistes varicus (Müller, 1774)
	Lymnaeidae	*Lymnaea (Radix) natalensis* Krauss, 1848
Bivalvia	Iridinidae	*Aspatharia chaiziana* (Rang 1835)
		Mutela rostrata (Rang 1835)
		Chambardia wahlbergi (Krauss, 1848)
	Unionidae	*Coelatura aegyptiaca* (Cailliaud 1827)

Relationships between environmental variables and molluscs species

The bivalves (*C. wahlbergi, C. aegyptiaca M. rostrata*and *A. chaiziana*) were found only in sediments (

Fig.a). The most abundant species among bivalve is *C. aegyptiaca*. Also, the prosobranchs were abundant in sediment. Despite the fact that micro-habitats consisting of reeds and watersalad are poorly represented comparatively to sediment, they harbour the highest abundance of pulmonates (

Fig.c). *B. truncates* is the most abundant in reeds while *B. pfeifferi* is the most abundant in watersalad.

The results of redundancy analysis (RDA) are showed in the

Fig.. It revealed that the relationships between fresh water gastropod species and their habitat conditions follow mainly the first two axes (RDA1 = 43,59 with p=0,007; %; RDA2 = 26.27 % with p=0.034)whichaccountedfor69.86 % of the total variance. Following the first axis (RDA1) in positive coordinates, *L. natalensis*, *B. pfeifferi*, and *B. truncatus* are positively and significantly influenced by water temperature, reeds, and dissolved oxygen. In negative coordinates, only bivalves and *B.* unicolor are correlated to sediments. Following the second axis (RDA2), only *C. bulimoides* is negatively correlated to water conductivity, concrete, watersalad and pH.

Discussion

Environmental condition of sampling area

The significant differences observed for physicochemical parameters such as temperature, conductivity and dissolved oxygen between the three sampling areas reflect the nature and the degree of anthropogenic impacts. Indeed, the highest values of conductivity recorded in the canals are due to the waste water they receive from households and industries. Similar values were reported by Kpoda *et al.* (2015) which ranged from 111 to 27890 µS/cm for wastewater used in the city of Ouagadougou for gardening. According to Le Bonté *et al.* (2008) these high values are caused by anions and cations abundant in in wastewater.

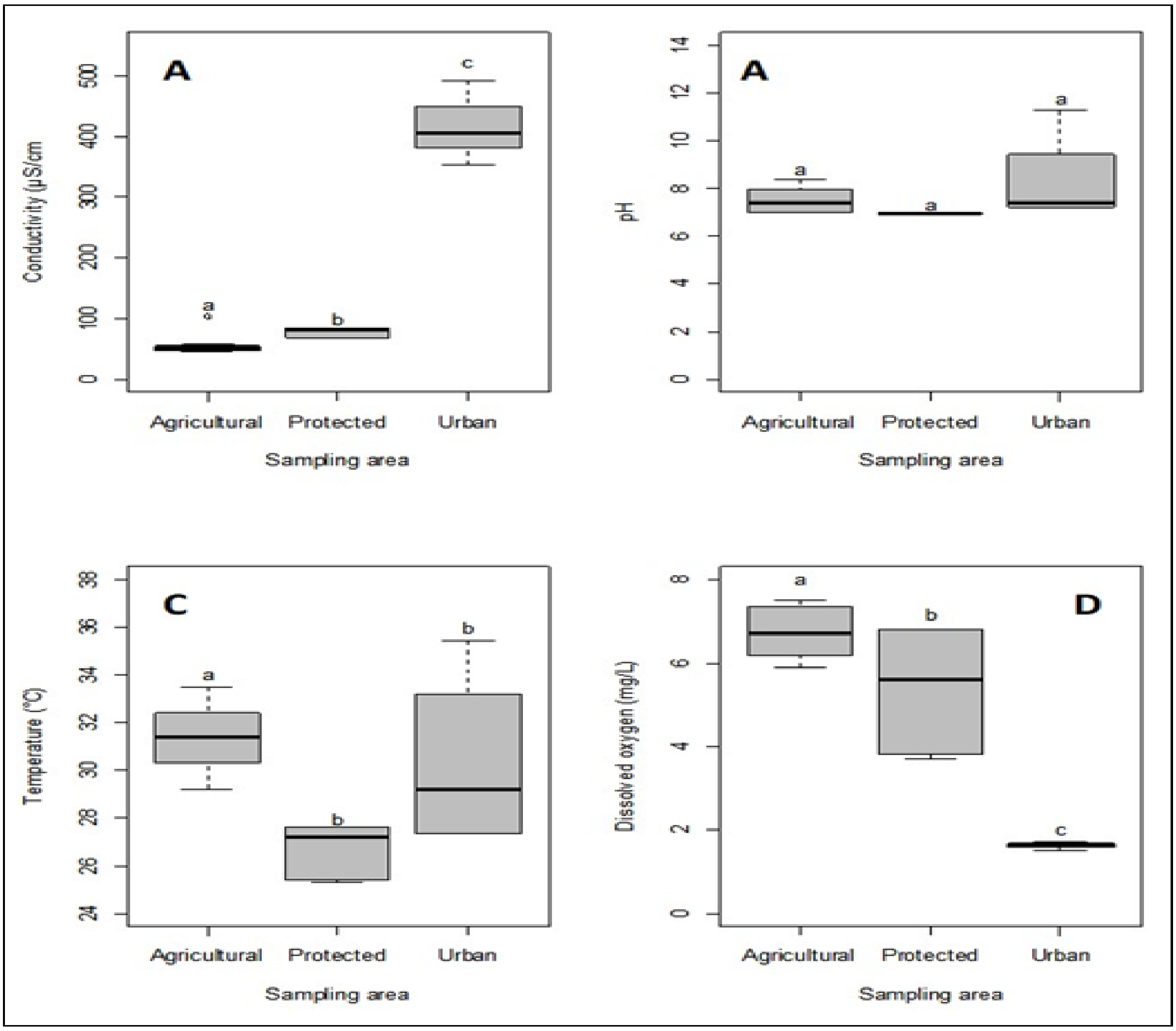

Fig. 2. Physicochemical conditions of the three sampling areas: A) Conductivity, B) pH, C) Temperature, D) Dissolved oxygen. The same letter for two or more boxplot indicates that they are not statistically different whereas different letter indicate that they are statistically different.

The low concentration of dissolved oxygen in canals and urban areas is also due to the influx of sewage loaded with organic matter, as evidenced by the high values of conductivities. As shown by Jonnalagadda and Mhere (2001), the high values of conductivity in a river increase the biological oxygen demand and the chemical oxygen demand; caused by, greater oxygen consumption in the processes of degradation of organic matter by decomposer micro-organisms.

Berman (2000) and Allan (2004) indicated the human activities affecting water temperature include the discharge of heated industrial effluents, agriculture and forest harvesting (due to effects on shading), urban development that alters the characteristics and path of storm water runoff, and climate change. But in the case of this study, the effect of agriculture seems to be more important because of the highest values recorded in this area.

This may be explained by the deforestation in agricultural area which has diminished the shading around the reservoirs. In the urban area the University canal is surrounded by trees and buildings which can reduce the effect of solar radiation. The ODE canal is also surrounded by houses and have small wide which contribute to reduce the penetration of solar radiation.

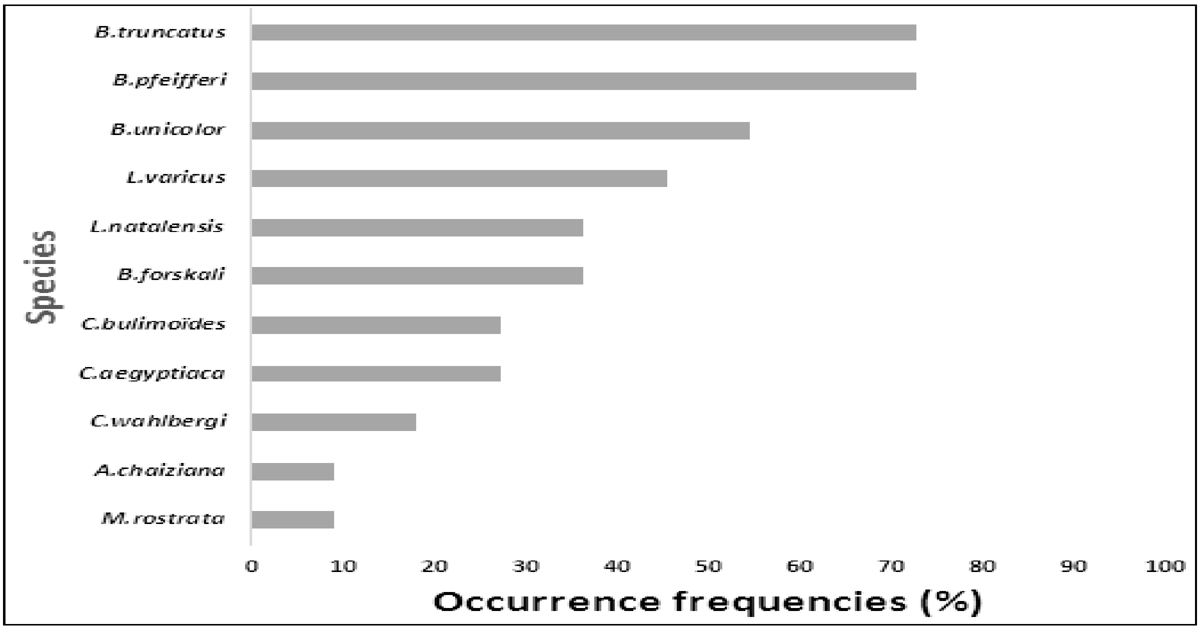

Fig. 3. Frequency of occurrence of molluscspecies.

Composition and distribution of molluscan fauna

During the malacological assessment, no species was found in canal of urban site of Ouagadougou. The absence of molluscs in these sites is likely due to its very bad health status (Kaboré *et al.*, 2016) because they receive domestic and industrial effluents which are not favorable to the development of aquatic life. They are characterized by high conductivity and very low dissolved oxygen. These conditions are not conducive to the development of fresh water molluscs. Similar observations were made by(Tchakonté *et al.*, 2014) who reported the absence of freshwater snails in a site downstream the outlet of a mixture of industrial effluents in Douala (Cameroon). Moreover, Pérez-Quintero (2011) did not find any mollusc species in severely impacted sites during his study in two Mediterranean acid mine drainage-impacted basins of the southern Iberian Peninsula. Concerning the nature of the substrate which is concrete Abdel-Malek (1958) indicated that it has been suggested to line the irrigation ditches and drains with concrete to control bilharziasis vectors, meaning that this type of habitats is not suitable for freshwater rmolluscs.

Contrary to urban and protected areas, the diversity of molluscs is more important in agricultural areas. This observation is in line with the study of Kaboré *etal.*, (2016) which found that the mean overall taxonomic richness of macroinvertebrates per site was higher in agricultural areas than in protected and urban areas. This observation was particularly outstanding for molluscs that they found to be are abundant in agricultural areas. So, this study confirms that the use of manure and fertilizer to improve productions enhances algal and macrophytes production as found by Kaboré *et al.*, (2016). The majority of gastropods are scrapers (Moog, 1995) and it is known that algae constitute an important food source for this group (Strong *et al.*, 2008).

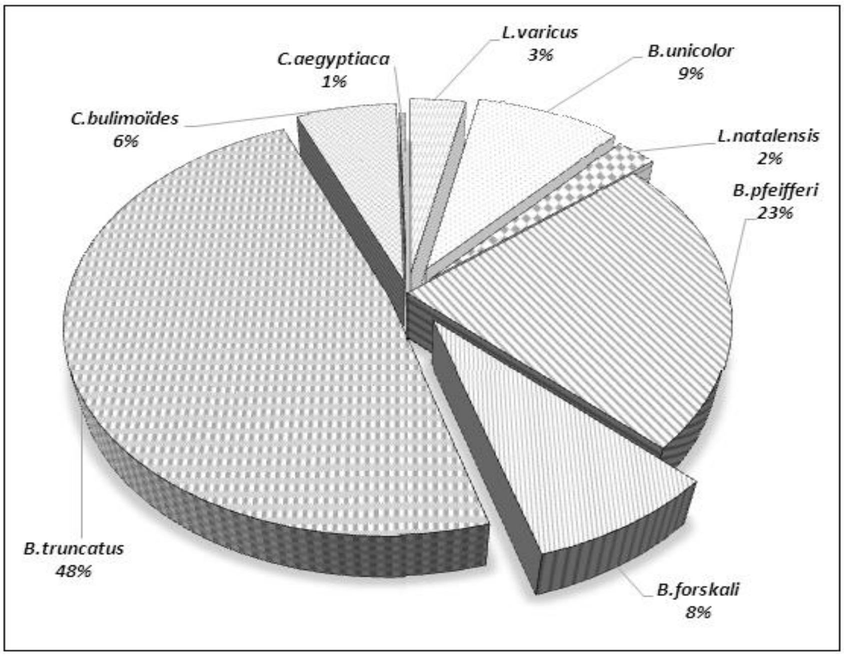

Fig. 4. Relative abundance of freshwater mollusc species collected within all investigated areas.

Lacoursière *et al.,* (1975) and Maltchik *et al.*, (2010) showed that aquatic vegetation that proliferate in agricultural area constitute appropriate habitats for molluscs such as gastropods.

The molluscan fauna was dominated by pulmonates gastropods which present high abundance and occurrence frequency. This abundance is high in the reeds micro-habitats of the sampled agricultural and urban areas. This observation is not surprising because pulmonates are generally adapted to harsher conditions due to the fact that they are able to assimilate atmospheric air via a vascularized mantle cavity (Tchakonté *et al.,* 2014).Some pulomates in the Planorbidae family have readapted further to aquatic conditions by using a conical extension of epithelium as a gill, and also have a respiratory pigment, hemoglobin, which increases the efficiency of oxygen transport (McMahon, 1983). As the species of the genus *Bulinus* and *Biomphalaria*, are respectively intermediate hosts of *Schistosoma haematobium* and *S. mansoni* which are known as the two predominant species parasitizing humans, this abundance in urban and agricultural areas also constitutes a high transmission risk for schistosomiasis (Moser *et al.*, 2014; Colley *et al.*, 2014, Dabo *et al.*, 2015).

Relationships between environmental variables and molluscs species

According to the RDA analyses, freshwater molluscs have shown different levels of sensitivity to environmental variables measured.

The habitat selection depends on the biology and the adaptability of each species. Species tend to avoid high conductivity and concrete habitats and are more positively correlated to high dissolved oxygen, temperature and aquatic habitats like reeds and sediments. Our results are in line with those De Kock (1985)who showed that the highest daily temperature fluctuation is important for the net reproduction rate and mean mass of *L. natalensis* specimens. According to Abdel-Malek (1958) temperature is also extremely important for planorbids snails to maintain their number. Moreover, Abdel-Malek (1958) has reported that low concentration of oxygen, even if not immediately fatal to the snail, reduces its movements and thus impairs feeding and reproduction.

In conclusion, physicochemical variable measured on the different sampling areas showed that human activities threaten the aquatic environment.

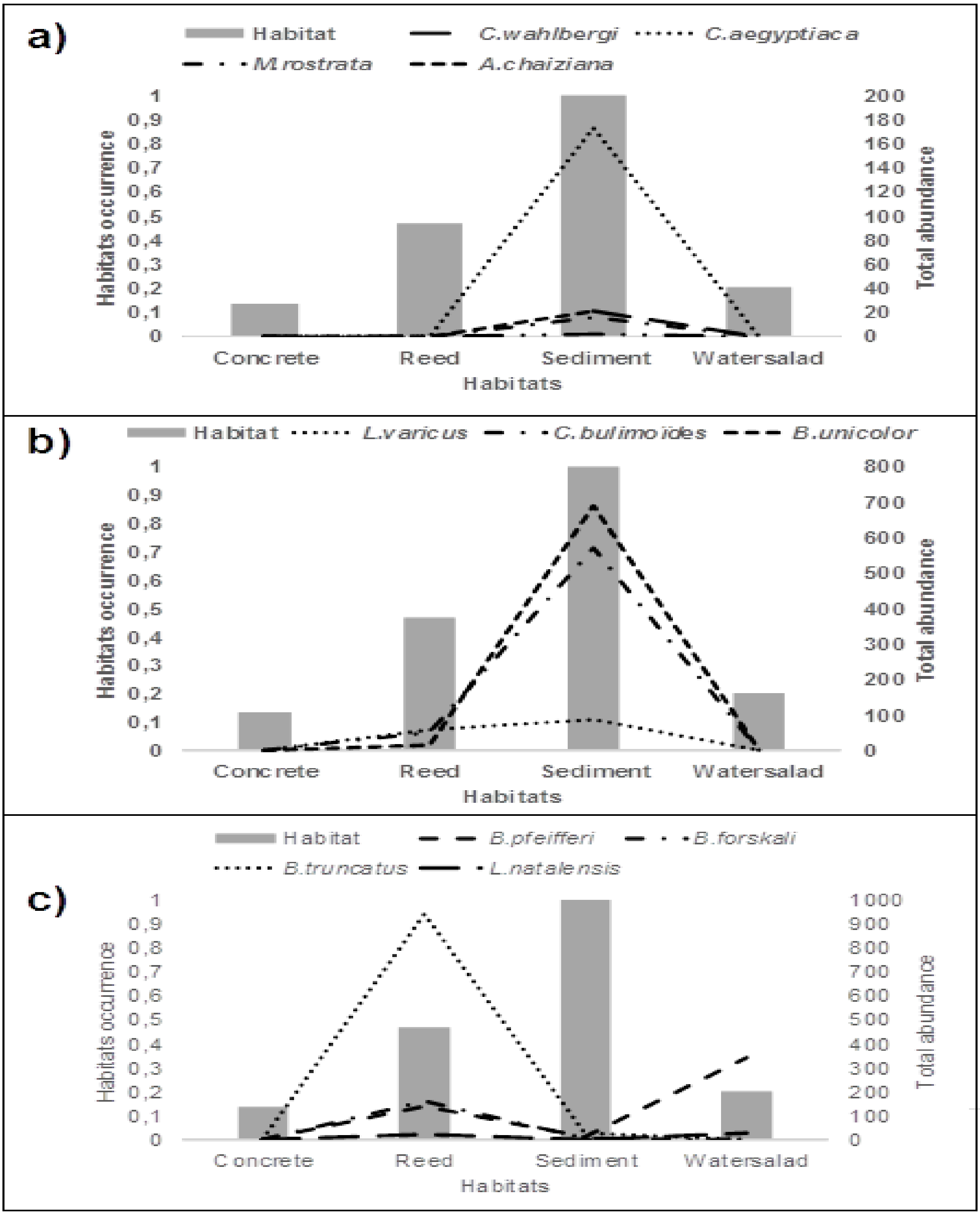

Fig. 5. Molluscs abundance following micro-habitats. a) Bivalves were only found in sediment, b) prosobranchs are also most abundant in sediment, c) pulmonates are the reed micro-habitats and *B. pfeifferiis* the most abundant in watersalad.

The consequences of these changes influence the distribution of molluscs species. At very high levels of pollution in urban areas no mollusc species were found.

The abundance of intermediate hosts of parasitosis in agricultural areas must also be surveyed for the control of the epidemiology of diseases such as schistosomiasis, which still causes casualties.

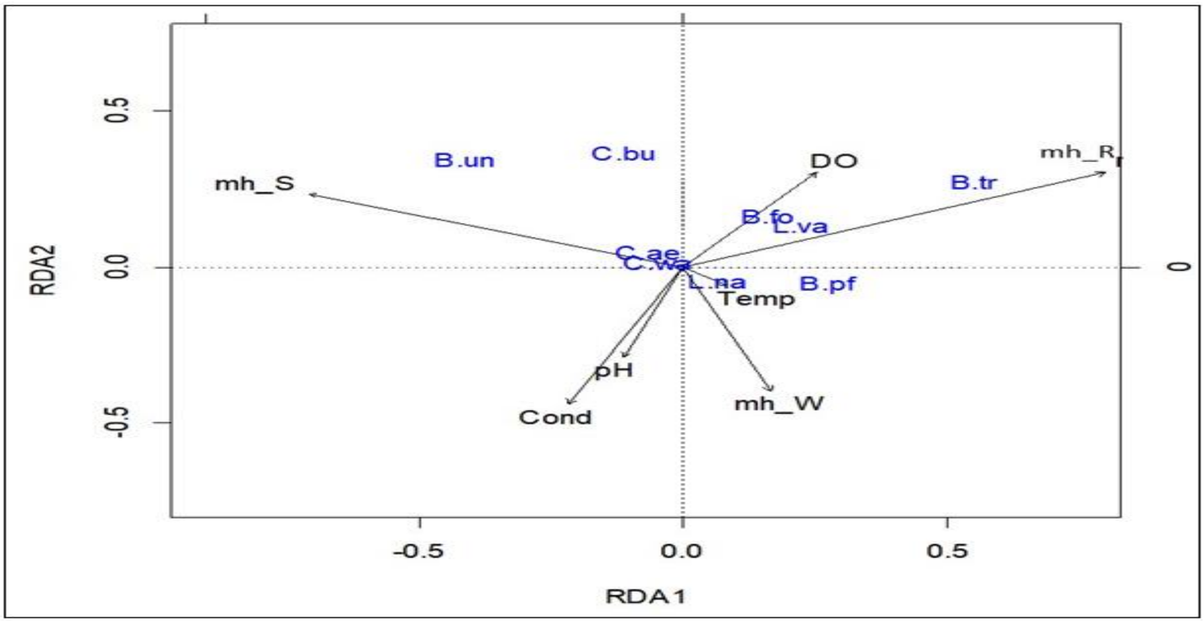

Fig. 6. Redundancy analysis biplot showing gathering of freshwater molluscs in response to environmental variables. Cond: conductivity, Temp: temperature, Oxy.dis: dissolved oxygen, B.un: B. unicolor, C.bu: C. bulimoides, C.ae: C. aegyptiaca, C.wa: C. wahlbergi, Lna: L. natalensis, B.pf: B. pfeifferi, B.fo: B. forskalii, B.tr: B. truncatus, L.va: L. varicus, mh: micro-habitat, S: Sediment, W: watersalad, R: reeds.

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