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ORIGINAL PAPER

Land snail abundance and diversity in market gardening cultivation areas of Autonomous District of Abidjan, Côte d'Ivoire

Abondance et diversité des escargots terrestres des zones de cultures maraîchères du District Autonome d'Abidjan, Côte d'Ivoire

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Abstract The knowledge of land snail biodiversity is essential for making decisions relating to their conservation. This study aimed to contribute to the knowledge of their biodiversity by determining their abundance and diversity in different types of market gardening crops in the autonomous district of Abidjan. An inventory of snails was carried out on 72 plots of 10 m x 10 m each, delimited in four market gardening cultivation sites (Port-Bouët, Bingerville, Anyama and Abobo). A total of 3194 individuals belonging to four species (*Subulina striatella*, *Achatina fulica*, *Limicolaria flammea* and *Lignus interstinctus*) and two families (Achatinidae and Subulinidae) were collected. The number of species collected ranged from 3 to 4 (with an average of 3.96 ± 0.20) and the number of individuals varied from 45 to 242 (with an average of 133.08 ± 58.27) per crop type. Shannon index, Evenness and Berger Parker index varied significantly between types of crop (ANOVA 1; p = 0.027; 0.027 and 0.001 respectively). The snails had the same distribution and diversity in leafy vegetables (lettuce, cabbage and nightshade). The highest diversity and best distribution of snails were observed in the tomato crop (fruiting vegetable). The Berger Parker index showed a greater dominance of snails in leafy vegetables than in fruiting vegetables. Apart from *Subulina striatella*, which did not seem to have a preference for the crops visited, the other species preferred leafy vegetables to fruiting vegetables. Snail mortality rates were high at all the sites visited.

Key words: Diversity, Abundance, Land snails, Market gardening, Abidjan.

Résumé La connaissance de la biodiversité des escargots terrestres est indispensable à la prise de décisions relatives à leur conservation. Cette étude visait à contribuer à la connaissance de leur biodiversité à travers la détermination de leur abondance et diversité dans différents types de cultures maraîchères du district autonome d'Abidjan. Un inventaire des escargots a été fait sur 72 parcelles de 10 m x 10 m chacune, délimitées dans quatre sites de cultures maraîchères (Port-Bouët, Bingerville, Anyama et Abobo). Au total, 3194 individus appartenant à quatre espèces (*Subulina striatella, Achatina fulica, Limicolaria flammea* et *Lignus interstinctus*) et deux familles (Achatinidae et Subulinidae) ont été collectés. Le nombre d'espèces collectées variait de 3 à 4 (avec une moyenne de 3,96 ± 0,20) et le nombre d'individus variait de 45 à 242 (avec une moyenne de 133,08 ± 58,27) par type de culture. L'indice de Shannon, l'équitabilité et l'indice de Berger Parker variaient significativement entre les types de culture (ANOVA 1 ; respectivement p = 0,027 ; 0,027 et 0,001). Les escargots avaient une même distribution et diversité au niveau des légumes-feuilles (laitue, choux et morelle). La plus grande diversité et la meilleure distribution des escargots étaient observées dans la culture de tomate (légume-fruit). L'indice de Berger Parker présentait une plus grande dominance des escargots dans les légumes-feuilles comparativement aux légumes-fruits. Hormis *Subulina striatella* qui semblait ne pas avoir de préférence pour les cultures visitées, les autres espèces préféreraient les légumes-feuilles par rapport aux légumes-fruits. Le taux de mortalité des escargots sur l'ensemble des sites visités était élevé.

Mots clés : Abondance, Diversité, Escargots terrestres, Cultures maraîchères, Abidjan.

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Introduction

Land snails provide many ecosystem services. They constitute a source of calcium for avian reproduction (Graveland, 1996) and perform leaf litter decomposition (Atsor, 2014). In the trophic level, land snails are a source of food for various living organisms such as birds, salamanders, lizards, arthropods and small mammals (Graveland *et al.*, 1994, Barker, 2001). Among these snails, edible snails are very appreciated in many countries of the world because of their flavour and nutrient richness (Sodjinou *et al.*, 2002; Otchoumou *et al.*, 2010; Ghosh *et al.*, 2016). Unfortunately, land snails are subject to various forms of anthropogenic pressure, mainly the habitat destruction and the excessive hunting, which cause the reduction of their stock in natural habitats (Karamoko *et al.*, 2011).

Snails record the largest number of species extinction recently (Lydeard *et al.*, 2004) with several threatened species (Oke and Chokor 2010). Meanwhile, basic information of their diversity remains poorly known in many tropical regions of the world (Sen *et al.*, 2012; Idohou *et al.*, 2013). Particularly in Côte d'Ivoire, in spite of the numerous works carried out on land snails (Otchoumou *et al.*, 2005; Kouassi *et al.*, 2008; Memel, 2009; Karamoko *et al.*, 2011; Sika, 2015; Amani *et al.*, 2016), only very few refer to their diversity (Memel, 2009; Amani *et al.*, 2016). Nevertheless, the better knowledge of the snail's diversity is essential for decisions related to their conservation. Moreover, the extensive knowledge on their biology, and their ecology appear as a necessity for a sustainable management of this resource.

In the current context of sustainable cities, the knowledge of urban biodiversity is important because it enables to assess the environmental, ecological and aesthetic quality of the city (Jai and Pruneau, 2015). For the specific case of land snails, the study of their diversity in the autonomous district of Abidjan is useful because of the environmental disturbances of which this area is facing. Indeed, urbanisation reduces green spaces. In addition, the high density of human populations exerts a pressure of degradation on the residual green spaces, on which the survival of land snail populations remains highly dependent. Concerning market gardening cultivation areas, they constitute an exceptional biotope for assessing the diversity of land snails because vegetables are their favourite food. Consequently, they could attract a large number of species and individuals. Unfortunately, because of the significant damage that snails cause to crops, they are perceived as redoubtable pests and therefore are killed by market gardeners (Bosso *et al.*, 2020), hence the urgent need to assess their diversity. Moreover, this study could serve as a basis for future studies on the assessment of the snail populations dynamic in market gardening crops in this area, in relation to the expansion of these crops, in order to make predictions about the evolution of snails in these environments.

The main objective of this study was to contribute to the knowledge of the land snail biodiversity in Côte d'Ivoire in order to serve as a decision-making tool for their conservation measures. Specifically, this study aimed to: (1) determine the abundance and diversity of land snails in different types of market gardening crops in the autonomous district of Abidjan; (2) establish the relationship between snail abundance and the different types of crops in order to assess their level of preference for the vegetables grown; (3) assess the mortality rate of snails in these vegetable crops. Three hypotheses underpinned this study: (1) land snail abundance and diversity would be low in market gardening because of intensity of anthropogenic activities combined to the opening of the environment; (2) land snail abundance would closely linked to types of crops related to their preference of food; (3) land snail mortality rate would be very high in market gardening environment due to the pesticides used by farmers against crop pests.

Material and Methods

Study area

The study was carried out in four localities (Port-Bouët, Anyama, Bingerville and Abobo) of the autonomous district of Abidjan located in the south of Côte d'Ivoire between latitudes 5 °10 and 5 °38 North and longitudes 3 °45 and 4 °21 West. This district includes 10 communes (Abobo, Adjamé, Plateau, Cocody, Port-Bouët, Koumassi, Treichville, Marcory, Yopougon, and Attécoubé) and 3 sub-prefectures (Songon, Bingerville and Anyama). The autonomous district of Abidjan is limited to the South, by the Atlantic Ocean, to the South-West, by the sub-prefecture of Dabou, to the South-East, by the sub-prefecture of Grand Bassam; in the North, by the sub-prefectures of Grand Lahou and Agboville; in the East, by the sub-prefecture of Alépé (Figure 1). The climate of the district is the equatorial type with two dry seasons (December-April and August-September) and two rainy seasons (May-July and October-November). The average monthly temperature was between 24.8 and 26.2 °C. The annual pluviometry was 1334.8 mm.

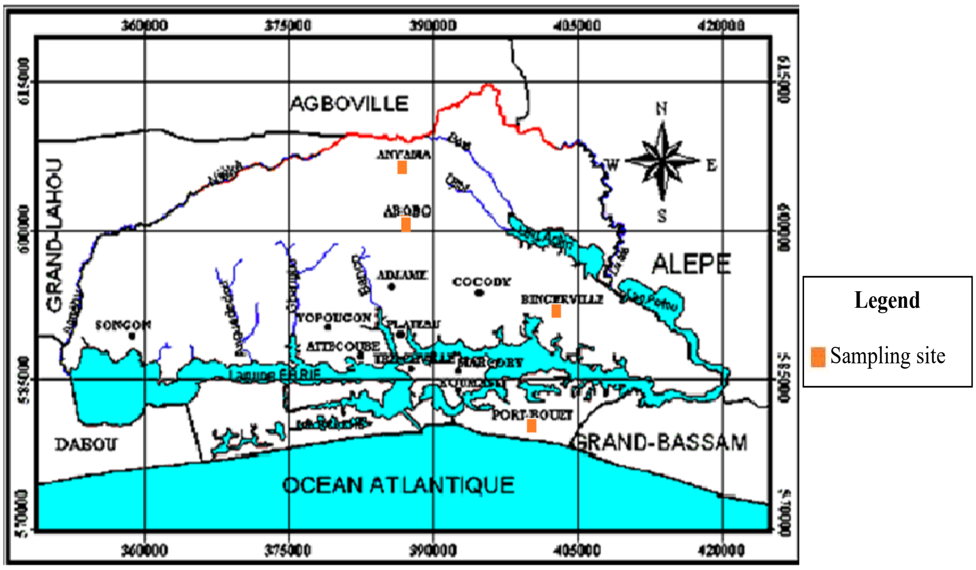

Figure 1. Location of the sampling sites in the autonomous district of Abidjan, Côte d'Ivoire

Delimitation of study plots

A total of 72 plots of 10 m x 10 m each were delimited on the 4 sites using stakes and strings. Indeed, 18 plots were delimited per site (9 plots delimited in leafy vegetable crops and 9 plots in fruiting vegetable crops). The delimitation of plots in leafy vegetables was done taking account to three types of crops (nightshade, cabbage and lettuce), the most widely grown in the area. The types of crops chosen as fruit vegetables (also widely grown) were: tomato, aubergine and cucumber. In each crop type area, three plots were delimited.

On the whole, all the areas visited were completely open (almost no trees). The plots were regularly cleaned and plant waste were collected by horticulturists leading to lack of litter. However, some weeds can be founded in these areas (generally on the edges of the plots).

Snail sampling and identification

The snails were collected once a week for three months using the technique of direct search. At each collection campaign, land snails were actively searched for 30 minutes on each plot by two persons. Snails were collected at night and early morning because they are more active at these periods (Coppolino, 2008). Living specimens and empty shells were collected, packed into perforated plastic bags and labeled for identification in the laboratory.

The specimens collected were identified in the laboratory based on morphological criteria and using standard keys: Daget (2003), Rowson (2009), Oke (2013) and Claudio (2015).

Data analysis

Land snail diversity was evaluated with specie richness (RS), Shannon index (H) and Evenness of Shannon (E).

RS = total number of species collected.

H = - Σ pi log2 pi, with i = 1 to S.

pi: probability to meet a taxon i on a plot; S: total number of taxa founded on the plot.

E = H / H_{max}, with H_{max} = log2 S (where S is the total number of taxa).

The high values of these diversity indexes mean great diversity.

Species abundance was evaluated by counting the total number of individuals on each plot.

Rank abundance curves or Whittaker plots were constructed to show the frequency distribution of the species collected (Cameron and Pokryszko, 2005). These curves were used to explain two aspects of diversity (species abundance and species evenness) and can be interpreted as follows : in the horizontal direction, the width of the curves reflects the abundance of species, the higher abundance of species is the larger the range of the curves on the abscissa. The smoothness of the curves reflects the evenness of species, the smoother the curves, the more uniform the distribution of species. These curves are charted using a database in which species are ranked according to their abundance (relative abundances). The most abundant species is given rank 1, the second most abundant species is 2 and so on.

Berger Parker index (D) was used to appreciate the dominance of snail species in the community. D = ni_{max} / N, with ni_{max} = the most abundant species and N = total abundance.

After checking the homogeneity of variances with the Levene test and the normality of distribution with the Shapiro-Wilk test, ANOVA 1 was used to compare the averages of Shannon index, Evenness of Shannon, Specie richness and Berger Parker index through the software STATISTICA 7.1 at the limit of 5%. When a significant difference was found, the post ANOVA (LSD) test was performed to determine the significantly different averages according to the variables considered.

The relationship between land snail abundance and the types of crops was analysed by the Pearson correlation using the software STATISTICA7.1 at the limit of 5%. A positive and significant correlation means that snails are attracted by the type of vegetable considered. In contrast, a negative and significant correlation means that snails are repelled by the type of vegetable considered. A null correlation means that there is no link between the type of vegetable in question and the snails.

Pearson correlation was also used to show the relationship between the number of individuals and the number of species. This analysis was based on abundance data for each snail species in all the types of crops visited.

The number of empty shells among the snails collected was used to estimate the mortality rate (Mr) using the following expression:

Mr (%) = (n/N) x 100, with n = number of empty shells and N = total number of shells (empty shells + living specimens).

Results

Table 1 shows the abundance of land snail species on each site according to type of crop. A total of 3194 individuals belonging to two families (Achatinidae and Subulinidae) and four species which are (*Achatina fulica* (Bowdich, 1822), *Limicolaria flammea* (Müller, 1774), *Lignus interstinctus* (Gould, 1843) and *Subulina striatella* (Rang, 1831). They were collected from 72 plots delimited in the six types of crops. Considering the types of crops, the total number of individuals collected in each type of crop whatever the site ranged from 45 to 242 with an average of 133.08 ± 58.27 and the number of species ranged from 3 to 4 (average 3.96 ± 0.20). Considering the species, the total number of individuals recorded in the four sites combined varied from 529 to 1207 (average 798.50 ± 162.69).

Table 1. Abundance of land snail species on each site according to the types of crops

Sites	Types of crops	Species				Total number of individuals	Total number of species
		Achatina fulica (Ach)	*Limicolaria flammea* (Ach)	*Lignus interstinctus* (Ach)	*Subulina striatella* (Sub)		
Port-Bouët	Lettuce	85	93	33	19	230	4
	Cabbage	57	81	14	5	157	4
	Nightshade	23	29	29	0	81	3
	Tomato	33	58	28	13	132	4
	Cucumber	45	67	31	28	171	4
	Aubergine	12	28	10	13	63	4
Anyama	Lettuce	71	56	25	13	165	4
	Cabbage	22	45	19	25	111	4
	Nightshade	10	26	8	5	49	4
	Tomato	37	30	23	25	115	4
	Cucumber	41	44	18	47	150	4
	Aubergine	28	27	7	21	83	4
Bingerville	Lettuce	65	48	12	18	143	4
	Cabbage	39	31	9	15	94	4
	Nightshade	18	18	2	7	45	4
	Tomato	38	46	13	37	134	4
	Cucumber	21	69	36	49	175	4
	Aubergine	18	17	10	30	75	4
Abobo	Lettuce	77	97	45	23	242	4
	Cabbage	53	81	39	19	192	4
	Nightshade	36	55	18	11	120	4
	Tomato	41	56	47	40	184	4
	Cucumber	29	85	52	61	227	4
	Aubergine	15	20	16	5	56	4
Total		**914**	**1207**	**544**	**529**	**3194**	**4**

Ach : Achatinidae and Sub : Subulinidae are families of land snails

The Achatinidae family was represented by 3 species, *Achatina fulica* (Bowdich, 1822), *Limicolaria flammea* (Müller, 1774) and *Lignus interstinctus* (Gould, 1843) while the Subulinidae family was represented by *Subulina striatella* (Rang, 1831). The total number of individuals and species were dominated by the Achatinidae family represented by 2665 individuals (83.43% of the total number) and 3 species (75% of the total number) (Figure 2). The 4 land snail species were recorded in all sites and each type of crop. Table 2 shows the land snail diversity in different types of crops. The specie richness was not significantly different (ANOVA 1; $p > 0.05$) between types of crops. However, the Shannon diversity index (ANOVA 1; $p = 0.027$); the Evenness (ANOVA 1; $p = 0.027$) and the Berger Parker index ($p = 0.001$) varied significantly across all types of crops.

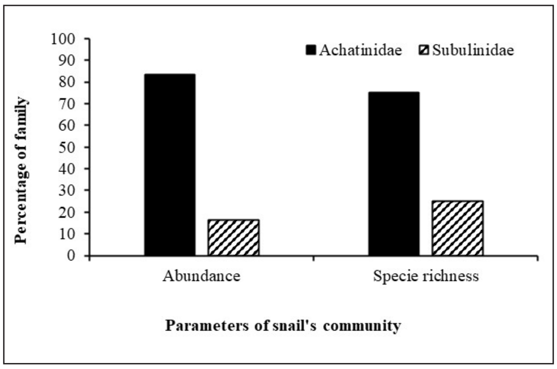

Figure 2. Percentage of land snail family according to abundance and specie richness

Table 2. Metrics of land snail diversity in different types of crops

	Specie richness	Shannon index	Evenness	Berger Parker index
Lettuce	4	1.22 ± 0.01^{a}	0.88 ± 0.01^{a}	0.42 ± 0.01^{a}
Cabbage	4	1.22 ± 0.06^{a}	0.88 ± 0.05^{a}	0.61 ± 0.04^{b}
Nightshade	4	1.17 ± 0.03^{a}	0.84 ± 0.02^{a}	0.44 ± 0.04^{a}
Tomato	4	1.33 ± 0.03^{b}	0.96 ± 0.02^{b}	0.35 ± 0.03^{a}
Cucumber	4	1.29 ± 0.03^{ab}	0.93 ± 0.02^{ab}	0.37 ± 0.02^{a}
Aubergine	4	1.30 ± 0.01^{ab}	0.94 ± 0.01^{ab}	0.38 ± 0.02^{a}
p-value	-	0.027	0.027	0.001

Land snail species diversity and the distribution of their abundance were statistically identical in leafy vegetables (lettuce, cabbage and nightshade) crop (Table 2). The most important diversity of snail species and distribution of their abundance were observed in fruit vegetables especially in the tomato crop. The Berger Parker index was significantly higher in leafy vegetables, especially in the cabbage crop. The relationship between numerical abundance and specie richness was illustrated in figure 3. This relationship was positive (r = 0.954) and significant (p = 0.043).

The figure 4 shows the rank abundance distribution of land snails collected in all types of crops. The lettuce recorded the highest abundances of species but presented the lowest regularity of these abundances. However, the aubergine recorded the lowest abundances but showed the most regular pattern of these abundances.

The analysis of the relationship between land snail abundance and the types of crops was recorded in the table 3. The abundance of *Achatina fulica* was significantly and positively correlated with the lettuce (r = 0.988; p = 0.013). Regarding *Limicolaria flammea,* its abundance was significantly and positively correlated with the lettuce (r = 0.979; p = 0.021), the cabbage (r = 0.976; p = 0.024) and the nightshade (r = 0.956; p = 0.044) but significantly and negatively correlated with the aubergine (r = - 0.962; p = 0.038). The abundance of *Lignus interstinctus* was significantly and positively correlated with the cabbage (r = 0.983; p = 0.017) and the nightshade (r = 0.996; p = 0.003) but significantly and negatively correlated with aubergine (r = - 0.889; p = 0.111). The abundance of *Subulina striatella* was not significantly correlated with the types of crops.

From the 3194 snails collected in the four sites, 1832 (57.36%) were unliving individuals. Through these sites, the distribution of snail mortality rates was presented as follow: 52.5%, 74.5%, 37.5% and 63% respectively at Port-Bouët, Anyama, Bingerville and Abobo (Figure 5).

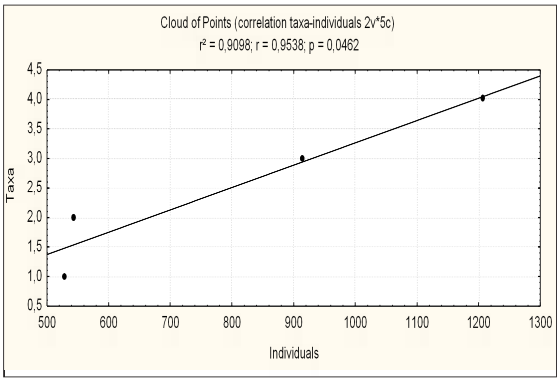

Figure 3. Relationship between total number of land snails and the number of species recorded in the different types of market gardening's fields

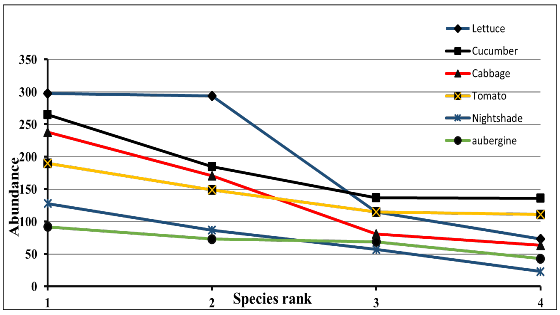

Figure 4. Rank abundance distribution of land snail community in the different types of market gardening crop

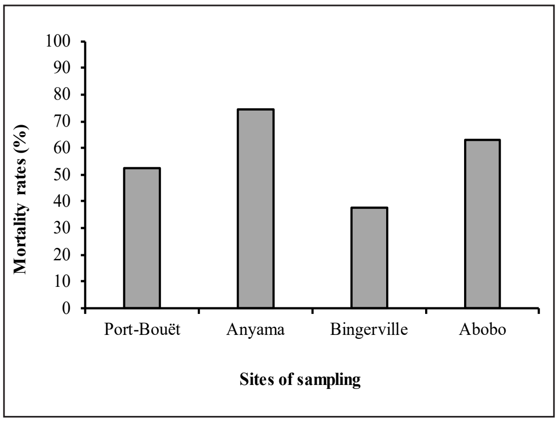

Figure 5. Land snail's mortality rates in simpling sites

Table 3. Relationship between land snail abundance and the types of crops

	Achatina fulica		*Limicolaria flammea*		*Lignus interstinctus*		*Subulina striatella*	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Lettuce	0.988	0.013 *	0.979	0.021*	0.916	0.083	- 0.384	0.636
Cabbage	0.927	0.073	0.976	0.024*	0.983	0.017*	- 0.146	0.854
Nightshade	0.858	0.142	0.956	0.044*	0.996	0.003**	0.017	0.982
Tomato	0.564	0.435	0.769	0.230	0.878	0.121	0.401	0.590
Cucumber	0.552	0.448	0.761	0.239	0.859	0.140	0.410	0.589
Aubergine	- 0.869	0.130	- 0.962	0.038*	- 0.889	0.111	0.127	0.873

* $p < 0.05$; ** $p < 0.01$

Discussion

The total number of species supported by the given habitat is one of the most fundamental ecological characteristics in any systems (Oke and Omoregie, 2012). This study which consisted of a qualitative and quantitative inventory of land snails in market gardening crop areas, revealed four species and 3194 individuals. The number of species collected in this study was lower than that obtained by Amani *et al*. (2016) who collected 27 species in the Yapo classified forest in southern Côte d'Ivoire. This number was lower than the 60 species collected by Oke and Chokor (2009) in different land use patterns in Nigeria. The number of species collected in this study was also lower than the 22 species collected by Oke *et al.* (2008) in oil palm agro-forests in Nigeria and the eight species collected by Memel (2009) in Banco National Park in Côte d'Ivoire. The low species richness recorded in this study could be explained by various reasons: firstly, all sampling sites were open habitats when most snail species require closed habitats for their establishment; although some of the Achatinidae family have been found to be very abundant in open habitats (Memel, 2009). The second reason could be linked to the weak amount of litter in the different crop areas visited. Litter is an important microhabitat for land snails (Jordan and Black, 2012). The plots on which snails were collected were almost poor in litter because of recurrent cleaning and collection of plant debris by horticulturists. The cleaning of plots constitutes a source of microhabitat destruction of these organisms, which are very vulnerable to habitat disturbance (Oke and Chokor, 2002). Finally, the use of many agrochemical products against crop pests, especially molluscicides, could be a basis of this low specie richness observed in this study.

The high number of individuals collected (3194) in this environment could be due to the presence of vegetables, preferential food for snails. In addition, the synanthropic nature of some species favors their proliferation despite the anthropogenic disturbance (Herbert, 2010). This is probably the case of *Achatina fulica*, *Limicolaria flammea* and *Lignus interstinctus,* species with high abundance in the environment disturbed by human activities (Raut and Barker, 2002).

The relationship between numerical abundance and specie richness was positive and significant. Such positive and significant relationship between snail species richness and numerical abundance suggests the possibility of positive interspecific interactions among species, wherein the high numbers of individuals contribute to determine the important numbers of species.

Shannon diversity index and Evenness showed the same distribution and diversity of snails in leafy vegetables and revealed the highest diversity and the best distribution in the fruit vegetables specifically in the crop of tomato; as for the Berger Parker index, it showed a better dominance of snail species in leafy vegetables compared to fruiting vegetables. These results could be due to a diet preference of snails. Indeed, land snails are on the whole phytophagous organisms, feeding on a variety of plant species. However, they have preferences for plant species (Karamoko *et al.*, 2008). Although this food preference depends on snail species, it is generally directed towards almost all vegetables (Maheshini *et al*., 2019). In market gardening production areas where several types of crops are grown, the high abundance of a snail species in a given type of crop could be linked to its preference for that crop. According to

Dar *et al.* (2017), *Achatina fulica* can feed on more than 500 types of crops. But, here this species seemed to be more attracted by lettuce probably because of its leaves, which are much soft and rich in water, characteristics of plant more desired by snails according to Otchoumou *et al.* (2004) and Adeola *et al.* (2010). *Limicolaria flammea* seemed to be more attracted to leafy vegetables, notably lettuce, cabbage and nightshade, while aubergine appeared to be repugnant to this species. Like *Achatina fulica* and *Limicolaria flammea*, *Lignus interstinctus* was attracted to leafy vegetables, mainly cabbage and nightshade. However, *Subulina striatella* was not influenced by these types of crops. This result could be due to the fact that this species is a micro-snail which lives the litter and the topsoil, and is a detritivorous.

Overall, the snail mortality rate recorded in the four sites was high. This result could be a consequence of the pest control organized by farmers against these organisms. Indeed, snails are seen as fearsome pests in market gardening production areas (Bosso *et al.*, 2020). Therefore, there are killed directly by farmers when they see them in their fields. Also, farmers use molluscicides against them (Bosso *et al.*, 2020). The variation in snail mortality rates between sites could be linked to the difference of pests control intensity.

Conclusion

In this study, we investigated on land snail abundance and diversity in four vegetable cultivation areas in the district of Abidjan. Results showed that land snails' diversity was low in the market gardening area, but the number of individuals was relatively high. Overall, snails tended to prefer leafy vegetables to fruit vegetables. The mortality rates of snails were high in this environment. Because of the high number of individuals and the high mortality rates of land snails, this area can be recommended for land snail collection for breeding and studies on their functions.

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