Growth performance of the Snail *Archachatina ventricosa* in Urban Secondary Forest: The National Center of Floristics (NCF) of Abidjan, Côte d'Ivoire

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1 ABSTRACT

This study investigates the growth dynamics of *Archachatina ventricosa*, a terrestrial mollusk prevalent in West Africa, particularly in Côte d'Ivoire. Previous research indicates that environmental factors significantly influence its growth, making this study essential for understanding its biology within the unique climatic conditions of the NCF. Conducted from January 2017 to December 2018, the research utilized a capture-mark-recapture method to evaluate growth rates in juvenile snails with shell lengths under 4.5 cm. The study area, characterized by distinct rainy and dry seasons, facilitated a comprehensive assessment of the snails' growth in relation to environmental variations. The findings reveal an average recapture rate of 15.59%, with higher rates during dry seasons compared to rainy ones. Growth measurements indicated an increase in average shell length from 3.91 cm to 10.54 cm over two years, with significant growth occurring in the first year. The study also noted variations in growth rates, influenced by seasonal changes and food availability. The research highlights the importance of environmental factors on the growth of *Archachatina ventricosa*, suggesting that habitat management is crucial for their conservation. The results of this study are valuable because they constitute a scientific database allowing the breeding of this snail.

2 INTRODUCTION

Giant African snails continue to be a quality source of animal protein in many countries in sub-Saharan Africa. These giant snails belong to the family Achatinidae. Among these snails, the species *Achatina achatina*, which is the most consumed according to Kouassi et al. (2008), is becoming increasingly rare, forcing populations to turn to other species such as *Archachatina ventricosa*. In Côte d'Ivoire, these snails are particularly valued in gastronomy for their tender and flavorful flesh, rich in trace elements such as iron, magnesium, calcium, and phosphorus (Otchoumou *et al.,* 2010). In addition to collection pressure, these snails face several harmful anthropogenic actions such as deforestation and pollution, which contribute to the reduction of their natural stocks. Several works have been carried out in Côte d'Ivoire on some genera of the Achatinidae family in breeding. We can cite those devoted to their nutrition (Kouassi, 2002; Kouassi, 2008; Otchoumou *et al.,* 2004; Otchoumou *et al.,* 2005a; Karamoko, 2009), to their pace of activity (Hodasi, 1979; Otchoumou, 1990; Zongo, 1990), their reproduction (Hodasi, 1975; Otchoumou *et al.,* 2003; Otchoumou *et al.,* 2005b; Karamoko, 2009; Aman, 2013) and their growth (Kouassi *et al.,* 2010). However, the biology of Achatinidae in their natural living environment remains an unexplored area. It therefore becomes crucial to study some aspects of the biology of these species, such as growth in their natural habitats, in order to develop conservation strategies and promote their farming to meet the demand for snail meat. Terrestrial mollusks, in general, exhibit lifestyles and biological cycles that are closely linked to the climatic conditions of their habitat (Rousselet, 1982). In this context, the National Center for Floristics (NCF) of Felix Houphouet-Boigny University in Abidjan, created for the conservation of flora and housing an important malacofauna, proves to be an ideal setting for this study. The main objective of this research is to quantify the growth in length, width, height, and weight of *Archachatina ventricosa* individuals, as well as to analyze the environmental factors influencing these parameters.

3 MATERIALS AND METHODS

3.1 Study area: Located within the Félix Houphouet-Boigny University of Abidjan, the NCF is a center created for the in-situ conservation of floral biodiversity (Figure 1). It is located between 05°34'74.09 north latitude and -3°98'38.61 west longitude. It includes two entities. An arboretum which is the exploited area. The NCF arboretum houses a large collection of plants estimated at 750 species of Ivorian flora as well as those of the sub-region (CNF, 1998). Various arrangements have been made to accommodate all these species. These are in fact water basins intended to shelter aquatic species while arid lands are home to forest and savannah species. Paths have been created between the plots to allow visitors to discover them more easily. As for the second entity, it is a forest similar to the vegetation of the autonomous district of Abidjan. This vegetation is dominated by a dense and humid evergreen forest (Guillaumet and Adjanohoun, 1971). It is characterized by the presence of two species: Turraeanthus africanus (Meliaceae) and Heisteria parvifolia (Olacaceae) (Mangenot, 1955). The climate of the CNF is characterized by four seasons differentiated by their rainfall regime: the great rainy season which starts from March to July with a maximum of precipitation in June and the small rainy season which covers the months of September, October, November and December with a high of precipitation in October.

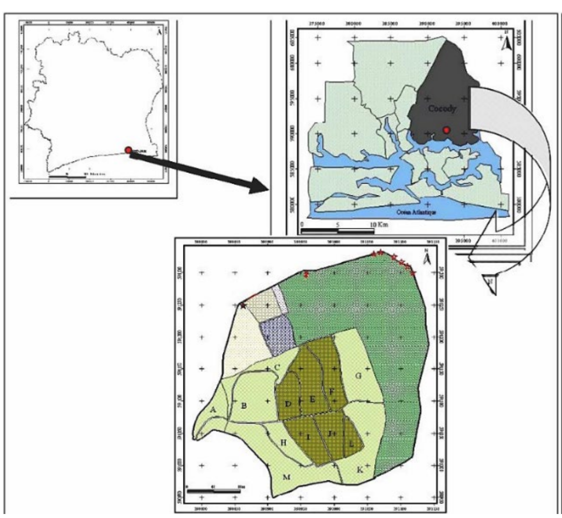

Fig 1: Location of the National Center of Floristic (NCF) within the Félix HOUPHOUET-BOIGNY University (Kpangui, 2009)

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The study was conducted from January 2017 to December 2018, relying on stratified sampling. The NCF forest comprises two main parts: a section used for botanical research called the arboretum, covering 4.25 hectares and subdivided into 11 plots by artificial boundaries. The unexploited area is a secondary forest known as fallow land, covering 6 hectares. For sampling purposes, it was divided into four parts: fallow 1 (J1), fallow 2 (J2), fallow 3 (J3), and fallow 4 (J4). Within each plot, two quadrants totaling 5% of the area of the plot were randomly delimited monthly. Each month, two new quadrants were defined in different locations within each plot. Thus, a total of 30 quadrants were delimited and sampled each month. This rotation of quadrants allowed for sampling the entire area of the NCF to collect the maximum number of specimens. The collection of mollusks was done by sight. The Jolly-Seber's capture-mark-recapture method (Jolly-Seber, 1965) was used, involving repeated sampling of a population (multiple recapture sessions). This method is applicable to less mobile animal populations (limited mobility in a given perimeter and/or time) during the implementation period of the procedure and where individuals can be marked without jeopardizing their survival (Abele *et al.,* 2015). The study was conducted in two phases. The first phase, which took place in January 2017, involved capturing and marking 619 juveniles (shell length less than 4.5 cm) of *Archachatina ventricosa* from the NCF. This phase focused on young snails to better assess their growth. It occurred during the dry season (January 2017) to allow the paint used to dry and to evaluate growth during the rainy season, which is the period of growth for snails (Kouassi, 2008). During this capture phase, the specimens found were marked with red oil paint using a method derived from (Fontenelle and Miranda, 2012) for identification. This type of marking consists of writing codes by making horizontal and/or vertical lines at different locations on the snail's shell. Each of these lines corresponds to a number so that by adding up all the numbers corresponding to all the marked lines, we find the number of the snail in question. The second phase consisted of a series of monthly recaptures from February 2017 to December 2018, totaling 23 months (one recapture session per month). The so-called direct or visual prospecting method was used to search for snails. It consists of an intense search for all places likely to harbor snails on each plot by researchers for a given time (Amani, 2018) This method is widely used in numerous studies on terrestrial mollusks (Oke, 2013; Wronski *et al.,* 2014; N'dri, 2015; Amani, 2016). When a marked specimen is recaptured, the plot where it was recaptured is noted, along with its mass, shell length L (the greatest distance separating the anterior edge from the posterior edge of the shell), external height H (measured across), and maximum width I of the shell. These data are compared to data from the same snail during previous captures. Additionally, the empty shells of marked specimens were collected, identified, and counted. These were eliminated from the sampling areas. The data collected allowed for the evaluation of the following parameters.

Fig 2: An *Archachatina venticosa* juvenile marked

3.2 Monthly Recapture Rate: This is the ratio of the number of individuals recaptured during each recapture session to the total number of marked individuals. Its formula is as follows:

$$Tr = \frac{r \times 100}{M}$$

3.3 Monthly Mortality : This is the ratio of the number of marked individuals collected monthly that died to the total number of marked individuals. Its formula is as follows:

$$Tm = \frac{m \times 100}{M}$$

3.4 Average Shell Length: This is the ratio of the total lengths of shells to the total number of snails:

$$Lm = \frac{\sum Lc}{Ne}$$

Furthermore, the Bertalanffy model (Bertalanffy, 1938) was chosen to express the linear growth of *Archachatina ventricosa*. This model is best suited to express individual growth in length, particularly concerning juveniles. The mathematical development of this method leads to the following absolute linear growth equation:

$$\mathbf{Lt = L_\infty\ [1 - e^{-K(t-to)}]}$$

Lt : total length at age t (cm);
L_∞ : asymptotic length or theoretical maximum length (cm);
K : growth rate or instantaneous growth coefficient (K > 0);
to : theoretical age (in years) that individuals would have at size zero (Lt = 0).
The mathematical expression of Bertalanffy shows three adjustment parameters L∞, to and K which are determined in this case using Past 3.0 software.

3.5 Average Live Weight: This is the ratio of the sum of individual live weights to the total number of snails.

$$Pvm = \frac{\sum Pv}{Ne}$$

4 RESULTS

4.1 Monthly Recapture Rates : Overall, the average recapture rate is low (15.59%). The recapture rate, which is 25.19% during the first year, is about three times higher than that of the second year (7.51% for the second year). The recapture rate is higher during the dry seasons while relatively low during the rainy seasons. It ranges from 100% to 58.11% during the main dry season of the first year. This rate drops from 15.25% to 7.53% during the small rainy season of the second year. In the main dry season of the second year, it fluctuates between 13.51% and 12.36%, while during the small rainy season of that year, it decreases to between 9.07% and 5.02%, peaking in June at 3.67%. Overall, the average recapture rate remains low (15.59%). In the first year, the recapture rate of 25.19% is about three times higher than that of the second year (7.51% for the second year) (Figure 3).

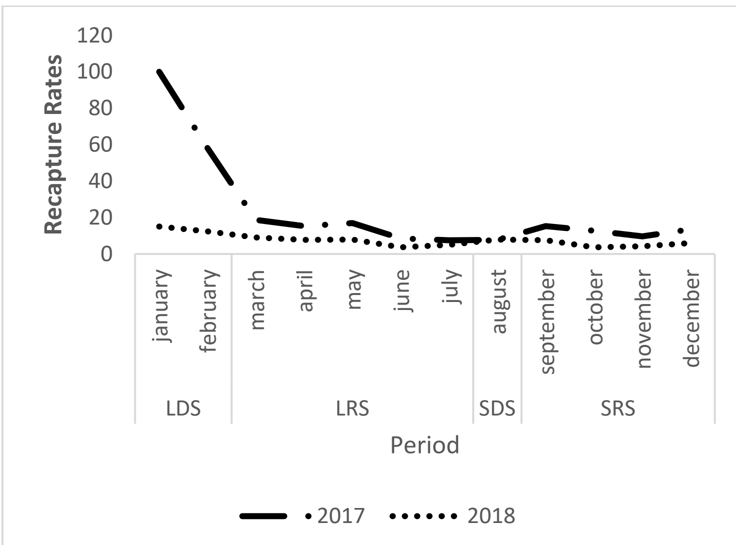

Fig 3: Evolution of the recapture rate of *Archachatina ventricosa* at the National Center for Floristics

4.2 Monthly Mortality Rates: The mortality rate fluctuates between 0% and 2.51%, with much higher rates during the rainy seasons. However, a high mortality rate is observed during the first three months at the start of recaptures **(Figure 4).**

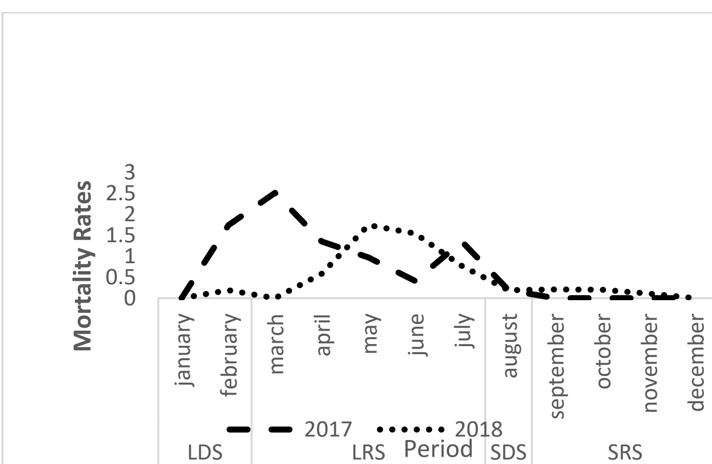

Fig 4: Mortality's evolution of *Archachatina ventricosa* at the National Center for Floristics

4.3 Shell Growth

4.3.1 Growth in Length*:* Shell growth is continuous (Figure 5). However, it does not occur at the same rate throughout the two years. The average shell length increases from 3.91 ± 0.41 cm at the beginning of the first year to 10.54 ± 0.06 cm at the end of the second year; representing a total growth of 6.64 cm and an average daily gain of 0.09 ± 0.03 mm over the two years. Growth is more pronounced during the first year than during the second year, increasing from 3.91 ± 0.41 cm to 8.87 ± 0.18 cm; representing an annual gain of 4.97 mm corresponding to an average daily gain of 0.13 ± 0.05 mm/day for the first year and from 8.87 ± 0.18 cm at the beginning of the first year to 10.54 ± 0.06 cm at the end of the second year; representing an annual gain of 1.67 cm with an average daily gain of 0.04 ± 0.03 mm/day for the second year. Figure 6 shows the average daily growth in length over the two years. The average gains in the first year are higher than those in the second year. The lowest average gain is observed during the long dry season of the second year (0.013 ± 0.0024 mm/day), while the highest average gain (0.23 ± 0.017 mm/day) is recorded during the long rainy season of the first year. The resulting growth curve from the individual growth of the snail *Archachatina ventricosa* based on recorded data allowed us to determine the following parameters: Lmax = 105.4 mm; L_∞ = 119.1 mm (theoretical maximum length that a specimen of *Archachatina ventricosa* can reach at the NCF) ; K = 0.8 (growth constant) et T_0 = -0.025. By substituting these values into the linear growth equation according to the Bertalanffy model, we obtain:

$$Lt = 119.1[1-e^{-0.8(t-(-0.025)}]$$

Thus, the average maximum length obtained in our work, which is 10.54 ± 0.06 cm, corresponds to an age of 37 months, or 3 years and 1 month.

4.3.2 Growth in Width : The evolution of shell width is presented in Figure 5. Shell growth is continuous and regular. The average shell width increases from 2.57 ± 0.26 cm at the beginning of the first year to 6.45 ± 0.06 cm at the end of the second year. This represents a total growth of 3.88 cm, corresponding to an average daily gain of 0.05 ± 0.03 mm over the two years. Growth is less pronounced during the first year compared to the second year. It increases from 2.57 ± 0.26 cm to 3.83 ± 0.21 cm, representing an annual gain of 1.26 cm corresponding to an average daily gain of 0.03 ± 0.002 mm/day for the first year, and from 3.83 ± 0.21 cm at the beginning of the first year to 6.45 ± 0.06 cm at the end of the second year; representing an average gain of 2.62 cm and an average daily gain of 0.071 ± 0.005 mm/day for the second year. Figure 5 presents the average daily gains in width over the two years. The average daily gains in width are higher during the rainy seasons of the second year, respectively 0.12 ± 0.06 mm/day for the small rainy season 2 and 0.07 ± 0.009 mm/day for the main rainy season 2. The lowest average gain was recorded during the main dry season 1 with 0.006 ± 0.001 mm/day.

4.3.3 Growth in Height : The evolution of shell height is presented in Figure 5. This shell growth is continuous and relatively regular. The average shell height increases from 2.11 ± 0.23 cm at the beginning of the first year to 5.26 ± 0.09 cm at the end of the second year; representing a total growth of 3.15 cm corresponding to an average daily gain of 0.043 ± 0.002 mm/day over the two years. Growth is more pronounced during the first year than during the second year. It increases from 2.11 ± 0.23 cm to 4.45 ± 0.06 cm; representing an average gain of 2.34 cm and an average daily gain of 0.064 ± 0.03 mm/day for the first year and from 4.45 ± 0.06 cm at the beginning of the first year to 5.26 ± 0.09 cm at the end of the second year, representing an average gain of 0.81 cm and an average daily gain of 0.022 ± 0.001 mm/day for the second year. The diagram in Figure 5 presents the average daily gains in height over the two years. The average daily gains in height are higher during the first year with maximums in the main rainy season 1 and the small rainy season 1, respectively 0.11 ± 0.03 mm/day and 0.8 ± 0.002 mm/day. The lowest average gains were recorded during the second year with a minimum during the main dry season 2 of 0.01 ± 0.005 mm/day.

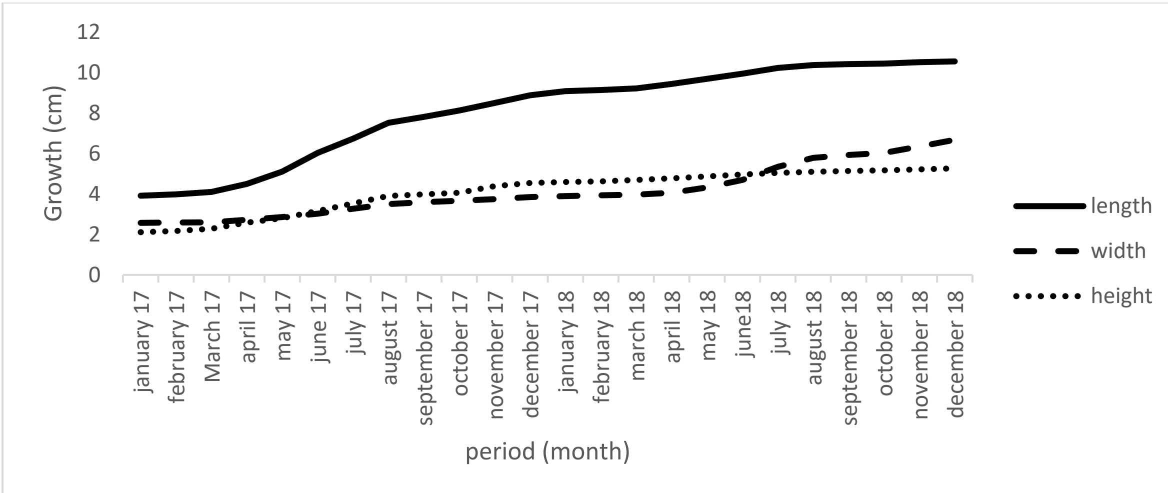

Fig 5 : Growth in Length, Width and Height of the snail *Archachatina ventricosa* in the NCF

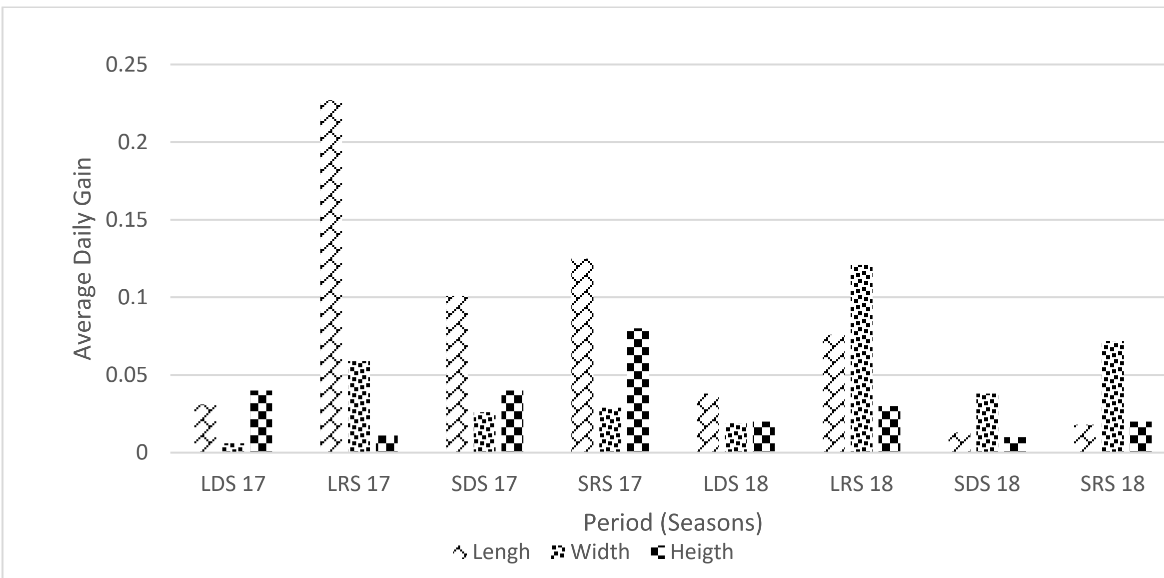

Fig 6 : Average daily gain in Length, Width and Height of the snail *Archachatina ventricosa* in the NCF

4.3.4 Weight Growth: The evolution of mass over time is presented in Figure 7. The graph indicates discontinuous growth with weight losses observed between January and February 2017 and from December 2017 to March 2018. The average mass increases from 14.70 ± 3.61 g to 183.1 ± 1.45 g; representing a total gain of 168.4 g. This corresponds to an average daily gain of 0.23 ± 0.07 g/day. During the first year, the mass increases from 14.70 ± 3.61 g to 84.34 ± 0.94 g, representing an annual gain of 69.64 g and an annual average daily gain of 0.19 ± 0.01 g/day. In the second year, the mass increases from 84.34 ± 0.94 g to 183.1 ± 1.45 g; representing an annual gain of 98.76 g corresponding to an average daily gain of 0.27 ± 0.08 g/day. Figure 48 shows the average daily gains in mass during the two years of sampling. Generally, the average daily gains in mass peak during the rainy seasons with 0.38 ± 0.21 g/day and 0.54 ± 0.17 g/day respectively for the small rainy season 1 and the small rainy season 2. The lowest average daily gains were recorded during the main dry seasons 1 and 2 with -0.006 ± 0.02 g/day and 0.0002 ± 0.00001 g/day respectively (Figure 8).

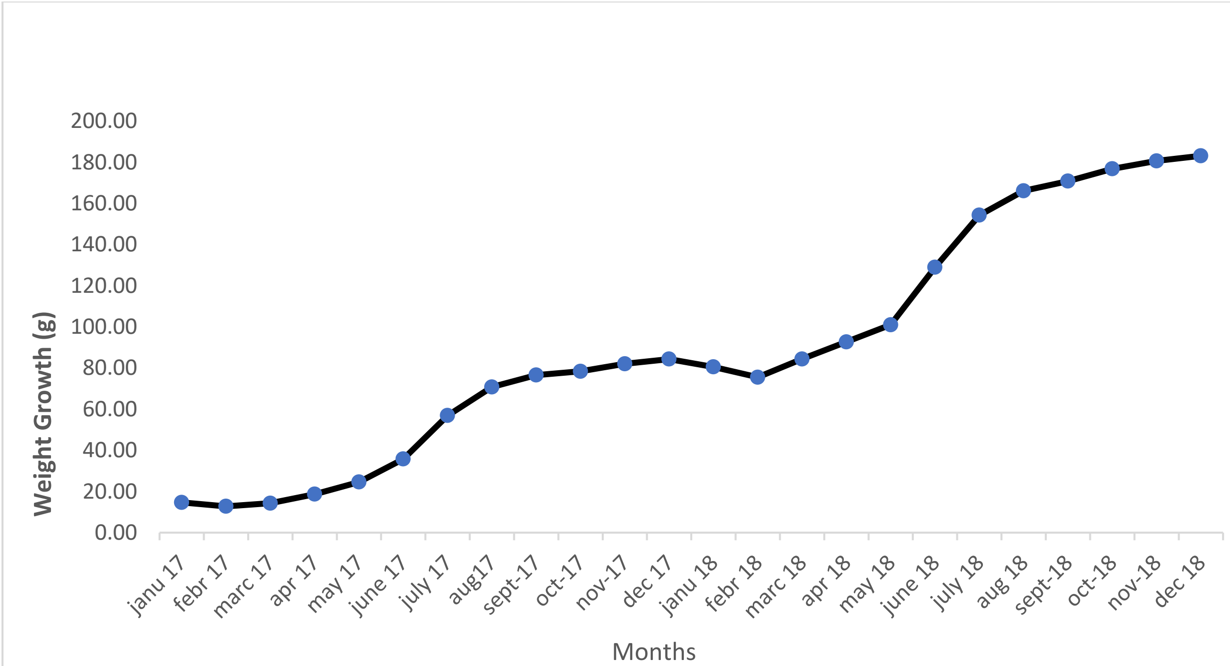

Fig 7 : *Archachatina ventricosa's* mass evolution in the NCF

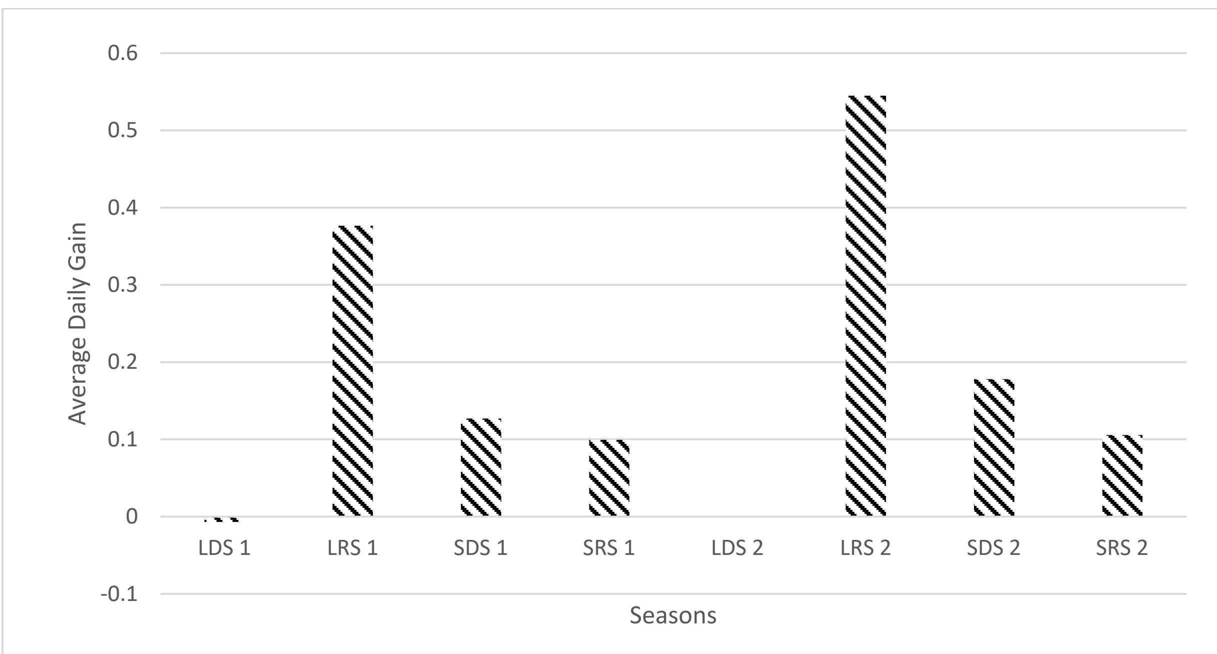

Fig 8 : Average daily gain in weight of the snail *Archachatina ventricosa* in the NCF

5 DISCUSSION

The recapture rates recorded during this study are generally low. This weakness is mainly due to the recapture method used. Indeed, visual searching is not very effective for locating individuals in the natural environment. Furthermore, Memel (2009) using the same method, found very few taxa in the large forest of Banco National Park. Moreover, the recapture rate is relatively high during dry seasons and low during rainy seasons. This could be explained by the fact that during dry seasons, *Archachatina ventricosa* is preferentially found in the leaf litter, which increases the probability of locating them. In contrast, when conditions change (during the rainy season), they occupy other habitats such as tree trunks and branches, which decreases the chances of finding them since they are very active during this season. Similar observations were made by N'Dri (2015) in the UNA forest. This author noted that *Archachatina ventricosa* is more arboreal than *Archachatina marginata*, *Achatina fulica*, and *Limicolaria flammea*. Regarding mortality, it is higher during rainy seasons and lower during dry seasons. This could be attributed to the fact that during rainy seasons, *Archachatina ventricosa*, in particular, and mollusks in general, are very exposed to vehicles and human activities such as cleaning and research activities, due to their high activity (feeding, moving, mating). Many individuals are crushed by vehicles and humans, while others are cut by machetes. Additionally, the high mortality rate observed in the first months of our study could be due to the handling of the animals. Indeed, animals newly subjected to handling may succumb. These results confirm those of Kouassi (2015), who reported that the frequency of handling has negative consequences on *Archachatina marginata*. The average length increases rapidly when conditions are favorable during the first year and slows down during the second year. The average daily gain obtained in our study, which is 0.09 ± 0.03 mm/day, is relatively low compared to that reported by Kouassi et al. (2010). These authors noted that in *Archachatina ventricosa*, the average daily gain in shell length can reach 0.29 mm/day in farming conditions where the animal is fed a mineral-enriched vegetable diet. The low average daily gain in our study may be due to the fact that in the NCF, *Archachatina ventricosa* primarily feeds on plants, which alone may not support good growth performance. Indeed, Kouassi et al. (2008) demonstrated that diets enriched with mineral elements, particularly calcium, promote better performance compared to exclusively vegetarian diets. However, the shell growth obtained in our study is greater than that reported by Kouassi et al. (2007) on the same species when exclusively fed a plant-based diet. These authors reported a shell growth of 0.08 ± 0.04 mm/day. Additionally, this growth is higher than that noted by N'Dri (2015) in the site and forest of the University Nangui ABROGOUA for *Achatina fulica*. This author reported an average shell growth of 0.043 ± 0.04 mm/day. Furthermore, Adou et al. (2011) reported lower shell growth rates than ours in *Achatina achatina* when exclusively fed a plant-based diet. Several factors could explain this difference. First, the NCF is located in the city of Abidjan, where rainfall and humidity are high year-round. Additionally, the water retention found in the NCF arboretum provides a permanent source of moisture for mollusks in general and for *Archachatina ventricosa*. These conditions favor good growth of *Archachatina ventricosa* in the NCF. These results align with those of Takeda and Ozaki (1986) and Zongo (1994) who stated that a temperature between 25 and 26 °C and humidity above 70% are suitable for terrestrial mollusks. Furthermore, this superior growth may be due to the biological potential of the species itself. Studies have shown that among the Achatinidae, the genus *Archachatin*a performs better in terms of biological and zootechnical parameters than the genus *Achatina* (Kouassi *et al.,* 2010). Moreover, the growth constant k obtained in our study (0.8) is higher than that reported by Silva and Omena (2014) for *Achatina fulica* in a natural environment (0.75). This indicates that growth in *Archachatina ventricosa* is faster under natural conditions than that in *Achatina fulica*. These authors showed that it takes 3 years and 11 months (47 months) for *Achatina fulica* to reach a length of 10.76 cm in the wild, while *Archachatina ventricosa* would reach this same length in 3 years and 5 months (41 months). Finally, the rapid growth of *Archachatina ventricosa* in the NCF could be explained by the high availability and variety of edible plants in the NCF. The NCF, in general, and the arboretum, in particular, with over 750 plant species, offer a diverse range of nutritious plants, some of which are highly favored by *Archachatina ventricosa*. This species particularly enjoys wild plants (Otchoumou *et al.,* 2003) and cultivated plants such as lettuce (*Lactuca sativa*, Asteraceae), papaya (*Carica papaya*, Caricaceae), cabbage (*Brassica oleracea*, Brassicaceae), spinach (*Basella alba*, Chenopodiaceae), taro (*Xanthosoma maffafa*, Araceae), and sweet potato (*Ipomoea batatas*, Convolvulaceae) (Otchoumou *et al.,* 1990). Regarding the growth in width, it is regular with a slight increase during the second year compared to the first year, resulting in a higher average daily gain during the second year. The height, on the other hand, grows more during the first year than in the second year. Thus, by the end of the first year, *Archachatina ventricosa* has a tapered and elongated shape, becoming globular in the second year with a more pronounced growth in width. This change in growth may be explained by the fact that once it reaches 7 cm, *Archachatina ventricosa* has likely reached sexual maturity and is preparing to lay eggs. At this stage, *Archachatina ventricosa* may use its energy to grow in width to create more space in the shell for the eggs. Similar observations were made for *Archachatina marginata* and *Limicolaria flammea* by Egonmwan (1988)**,** who showed that during the laying period, the snail uses its internal reserves to meet its physiological needs. Additionally, Adou et al. (2011) showed that *Achatina achatina* utilizes energy according to its needs, either for growth or reproduction. Thus, during certain periods, a slowdown in shell length is observed due to reproductive needs. Furthermore, Karamoko et al. (2011) observed a slowdown in shell lengths during the weeks preceding laying, regardless of breeding densities. Our results establish three levels of growth in *Archachatina ventricosa*: a first level characterized by rapid growth in shell length; a second level marked by a slowdown in length in favor of width; and finally, a last level characterized by low growth in length. Stievenart (1990) made similar observations in *Achatina fulica* and *Archachatina marginata suturalis*. The growth in weight is discontinuous because during dry seasons, *Archachatina ventricosa*, like most Achatinidae, stops feeding and enters a resting period called estivation (Stievenart, 1990). As a result, it can experience significant weight loss. Furthermore, average daily gains are higher during rainy seasons, as snails find their nutrient sources in abundance during these times. Indeed, being herbivores, they take advantage of these seasons to feed and accumulate the energy necessary for their metabolism, which allows them to survive during dry seasons. These results align with those of several authors, including Otchoumou et al. (1990), Zongo (1994) and Otchoumou et al. (2004).

6 CONCLUSION

The study on the growth of the snail *Archachatina ventricosa* within the National Center for Floristics (NCF) revealed significant results regarding its recapture, mortality, and growth rates. The data collected over two years show continuous but variable growth, with average daily gains being higher during the first year compared to the second. This can be attributed to favorable environmental conditions and the availability of food resources, particularly during the rainy seasons. Although recapture rates were generally low, they indicate better visibility of the snails during dry periods when they are more active in the litter. Conversely, mortality increased during the rainy seasons, probably due to greater exposure to environmental hazards. The Bertalanffy growth model allowed for the quantification of the growth dynamics of *Archachatina ventricosa*, establishing key parameters that highlight its growth potential in natural environments. The results suggest that habitat management and the protection of snails in their natural environment are essential to ensure their survival and development.

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