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Biometric Relationships Study of *Tagelus adansonii* (Bosc 1801) in Three Different Environments (Deltaic, Estuarine and Lagoon) in Senegal

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Abstract: In Senegal, several studies have been carried out on molluscs of mangrove ecosystems, particularly on *Senilia senilis* and *Crassostrea tulipa*. However, there are other little known mollusc species that inhabit these ecosystems. It is the case of *Tagelus adansonii*, a bivalve of the family Solecurtidae present only in West Africa and whose biometric relationships are the subject of this study. The study of *Tagelus adansonii* biometry in Senegal was conducted from July to November 2019. *Tagelus adansonii* samples were collected together with physico-chemical parameters in four different areas: the Senegal river delta, the Joal-Fadiouth lagoon, the Saloum estuary, and the Casamance estuary. The results of the present study showed that the largest sizes (51.68±7.74 mm) and lowest densities (16±9.30 ind/m^2) were noted in the Senegal river delta. However, the smallest sizes (45.57±8.43 mm) and highest densities (48.26±34.21 ind/m^2) were recorded in the Joal-Fadiouth lagoon. In the Saloum and Casamance estuary the size and density values were relatively average. The allometric growth is minor for the individuals collected in the Casamance estuary (b=2.71) and in the Senegal river delta (b=2.95), while those sampled in the Joal-Fadiouth lagoon (b=3.02) and in the Saloum estuary (b=3.18) show a major allometric growth. Thus, the results of the present study constitute a basis of information on the biology of T. adansonii that can contribute to the sustainable management of this species.

Keywords: *Tagelus adansonii*, Senegal, Allometry, Sizes, Density

1. Introduction

Transition zones (estuaries, lagoons and deltas) are specific environments characterized by variations in salinity and the regular presence of water. They are particularly, the area of a great faunal diversity, especially in benthic macrofauna [5, 26]. In Senegal, the presence of mangroves is well known in the estuaries of Casamance, Saloum, in the Joal-Fadiouth lagoon and the Senegal river delta. Thus, many activities are linked to this wealth of fauna, particularly shellfish harvesting. Thus, several studies have been conducted on shellfish, and most of them focus on shellfish harvested in mangrove ecosystems. These are essentially 7 species [8] of which only two bivalves: *Senilia senilis* and *Crassostrea tulipa*. The other shellfish species populating these ecosystems are still little known. In West Africa and particularly in Senegal, *T. adansonii* is present in interface ecosystems (inverted delta-estuary, ria) and in lagoons all characterized by the presence of mangroves. It is a bivalve of the family Solecurtidae only present in West Africa. On other species of the same genus, several studies have been conducted on growth parameters in different coastal (delta, estuary, lagoon) or oceanic ecosystems [11]. This study deals with the biometric variations of a species in four coastal ecosystems along the East Atlantic coast of Senegal.

Figure 1. *Location of the different sites and sampling stations (Diouf, 2022, adapted from framacarte.org).*

2. Material and Methods

2.1. Study Area

The present study was conducted in four different areas: the Senegal river Delta, the Joal-Fadiouth lagoon, the Saloum estuary and the Casamance estuary. For each area and according to its own characteristics, stations were selected. Thus, samples were collected from a total of 20 stations, including 03 in the Senegal river delta, 04 in the Casamance estuary, 07 in the Saloum estuary, and 05 in the Joal-Fadiouth lagoon (Figure 1).

2.2. Sampling Protocol

Sampling was conducted from July to November 2019. The collection protocol adopted for the present study was inspired by those studies [17, 14, 6]. For each station, 09 quadrats of 0.5 x 0.5 m were randomly placed. In each quadrat all individuals present were extracted with a trowel and/or by hand. The entire surface of the quadrat was probed to a depth of 50 cm. In total, 1390 individuals were collected during this study, 107 of which were collected in the Senegal river delta, 534 in the Joal-Fadiouth lagoon, 448 in the Saloum estuary and 301 in the Casamance estuary. Individuals of *T. adansonii* from each quadrat were measured and weighed using a caliper and an electronic scale with a precision of 0.01 g, respectively. For each individual, the length (antero-posterior distance), height (dorso-ventral distance) and bulge (thickness) were measured and the weight of the animal with its shell, the weight of the fresh meat and the weight of the empty shell were weighed. The physico-chemical parameters of each station (nature of the substrate, salinity of the water and pH of the substrate) were also collected using a refractometer (ATC) and a soil pH meter.

2.3. Biometric Relationships

2.3.1. Size Frequency Distribution

The size frequency distribution was determined using length with an interval of 5 mm. The following formula was used to calculate the frequencies:

$$Fi = ni \times N \times 100 \quad (1)$$

Where Fi is the frequency, ni is the number of specimens for a given length, and N is the total number of specimens.

2.3.2. Length -Weight Relationship

For many marine species, weight (W) is related to size (L) by a non-linear relationship [23]:

$$W=a\times L^b \quad (2)$$

In this relationship, W represents the weight of *T. adansonii*, L corresponds to the length, a is a constant and b is the allometric coefficient. The knowledge of this relationship has applications in fisheries biology and in the assessment of fish stocks [25, 16]. The coefficient b is often close to 3. It expresses the relative body shape of the species. If b = 3, the growth relationship is isometric; if b < 3, the relationship is allometric minorizing and if b is greater than 3, the relationship is allometric majorizing [18].

2.4. Density

Density is defined as the number of individuals per square meter. In this study, it is estimated using the number of individuals in each quadrat divided by its area.

2.5. Statistical Analysis

The statistical processing of the data and the graphs were performed with Microsoft Office Excel 2010 and R studio version 4.0.2.

3. Results

3.1. Physico-Chemical Parameters

The average values of the physico-chemical parameters are recorded in Table 1. The results indicate that the average pH value recorded is lowest in the Saloum estuary (6.4±0.51), followed by the Joal-Fadiouth lagoon (6.6±0.76) and the Senegal river delta (6.83±0.21). In these three ecosystems, an acidic pH was noted, while the Casamance estuary had a neutral pH (7). The largest average salinity values are recorded in the Casamance estuary (41.33±3.3‰), Saloum estuary (32.57±2.42‰) and Joal-Fadiouth lagoon (30.8±5.16‰), respectively. The lowest value of mean salinity was obtained in the Senegal river delta (21±0.74‰). The nature of the substrate at the sampling stations was sandy and muddy-sandy in Casamance, sandy in the Senegal river delta. In Joal-Fadiouth and in the Saloum the nature of the substrate is more diversified (sandy, sandy-muddy, muddy-sandy and sandy-gravel) (Table 1).

Table 1. *Physico-chemical parameter by stations and sites.*

Site/Station	pH mean	Salinity (‰) mean	Type of substrate
Casamance estuary	7	41.33±3.3	
Bouyouye	7	46	sandy
Haer			sandy
Niomoune	7	40	Sandy-maddy
Saloulou	7	38	Sandy-maddy
Joal-Fadiouth lagoon	6.6±0.76	30.8±5.16	
Finio	7	30	Sandy-gravel
Ngombel	7	33	Maddy-sandy
Mama Guedj	7	33	Sandy-maddy
Ndiassongué	7	30	Sandy
Ngoussé	5	28	Maddy
Senegal river delta	6.83±0.21	21±0.74	
Lakhlar	7.5	20	Sandy
Mboumbaye	6	21	sandy/ sandy-maddy
Nguiling Mbow	7	22	sandy
Saloum estuary	6.4±0.51	32.57±2.42	
Dassilamé Sérère	6	30	Sandy
Diattar	7	34	sandy-shell-maddy
Djirna	6.5	35	maddy-sandy
Falia	5.5	35	sandy
Missirah	6.5	30	maddy-sandy
Niodior	6.5	35	sandy
Rofangué	7	36	maddy
Total	6.64±0.64	32±6.6	

3.2. Size Frequency Distribution

The size of the individuals collected, for all combined areas, varies between 10.83 mm and 70.93 mm with a mean size of 47.28±8.17 mm. Overall, the size frequency distribution of *T. adansonii* is unimodal with a modal size in the 45-50 mm size class (Figure 2). However, the bulk of the individuals collected are between the 30-35 mm and 60-65 mm size classes. The size frequencies by area also indicate an unimodal distribution (Figure 3). In the Senegal river delta and in the Saloum estuary the most frequent sizes are between 50 and 55 mm with respective mean sizes equal to 51.68±7.74 mm and 48.57±7.18 mm. In the Casamance estuary, the modal class of the size frequency distribution is 45-50 mm with a mean size of individuals equal to 46.77±8.37 mm. In the Joal-Fadiouth lagoon, the most frequent size is in the 40-45 mm size range with an average size equal to 45.57±8.43 mm. The results of the Kruskal-wallis test (Kruskal-Wallis chi-squared = 88.036, df = 3, p-value < 2.2e-16) show that there is at least one significant difference between the sampling areas. The Dunn test result shows that there are no significant differences in sizes between the sampled Tagelus in the Casamance and Saloum estuary. However, the individuals of *T. adansonii* collected in the stations of these two areas have significantly different sizes than those sampled in Joal-Fadiouth and the Senegal river delta. The test also indicates that the sizes of individuals collected at Joal-Fadiouth are significantly different from those from the Senegal river delta.

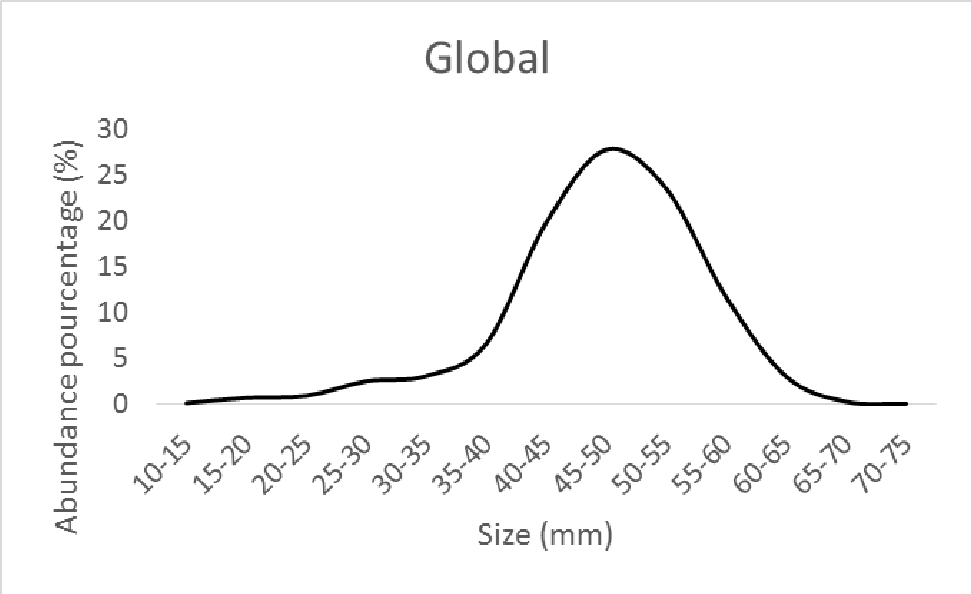

Figure 2. *Size frequency distribution of T. adansonii for all areas combined.*

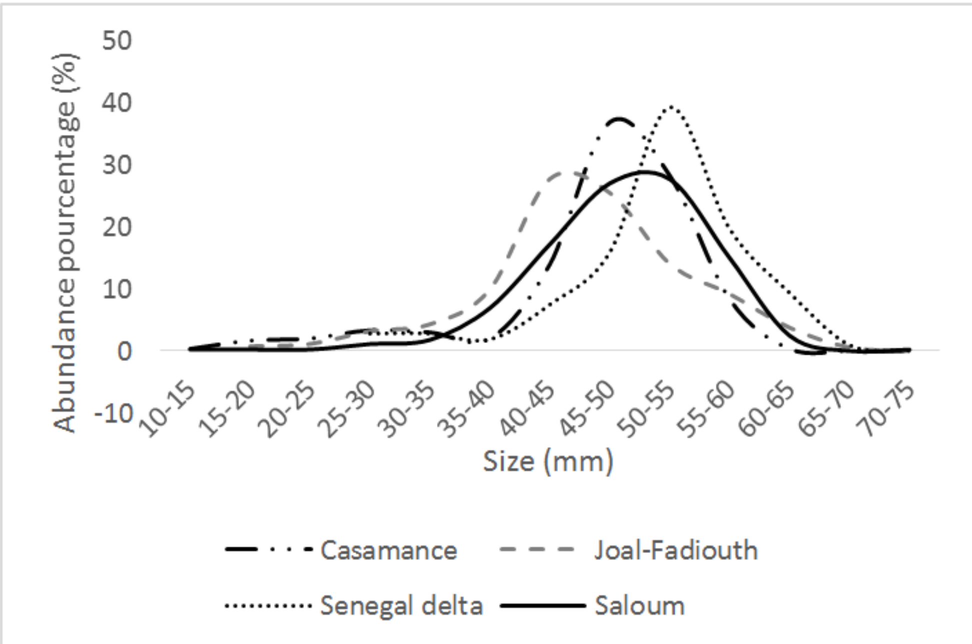

Figure 3. *Size frequency distribution of T. adansonii by area.*

3.3. Size-Weight Relationship

Without distinguishing sites and sampling stations, the results on the size-weight relationship of *T. adansonii* presents globally a major allometry (b=3.09) (Figure 4e). However, depending on the sampling sites, the allometry increases or decreases. Thus, individuals sampled in the Senegal river delta (b=2.95) and in the Casamance estuary (b=2.71) show a minorizing allometric growth (Figure 4a and 4c) while in the Joal-Fadiouth lagoon (b=3.02) and in the Saloum estuary (b=3.18), the growth of *T. adansonii* is majorizing allometric (Figure 4b and 4d). Regardless of the study site considered, the establishment of the size-weight relationship shows that these two variables are strongly correlated. The overall allometry coefficient in Senegal is 0.89 with a Kendal correlation coefficient (tau=0.78, p-value < 2.2e-16). The correlation coefficient in the Casamance estuary is 0.85 with a Kendall correlation coefficient of (tau=0.63; p-value < 2.2e-16). At Joal-Fadiouth the Kendall correlation coefficient is (tau=0.82; p-value < 2.2e-16), the correlation coefficient of complete observations at Joal-Fadiouth is 0.92. The correlation coefficient of complete observations in the Saloum estuary is 0.89. The Kendall correlation coefficient is (tau=0.75; p-value < 2.2e-16). In the Senegal Delta the Kendall correlation coefficient is (tau=0.76; p-value < 2.2e-16). The correlation coefficient for complete observations is 0.89.

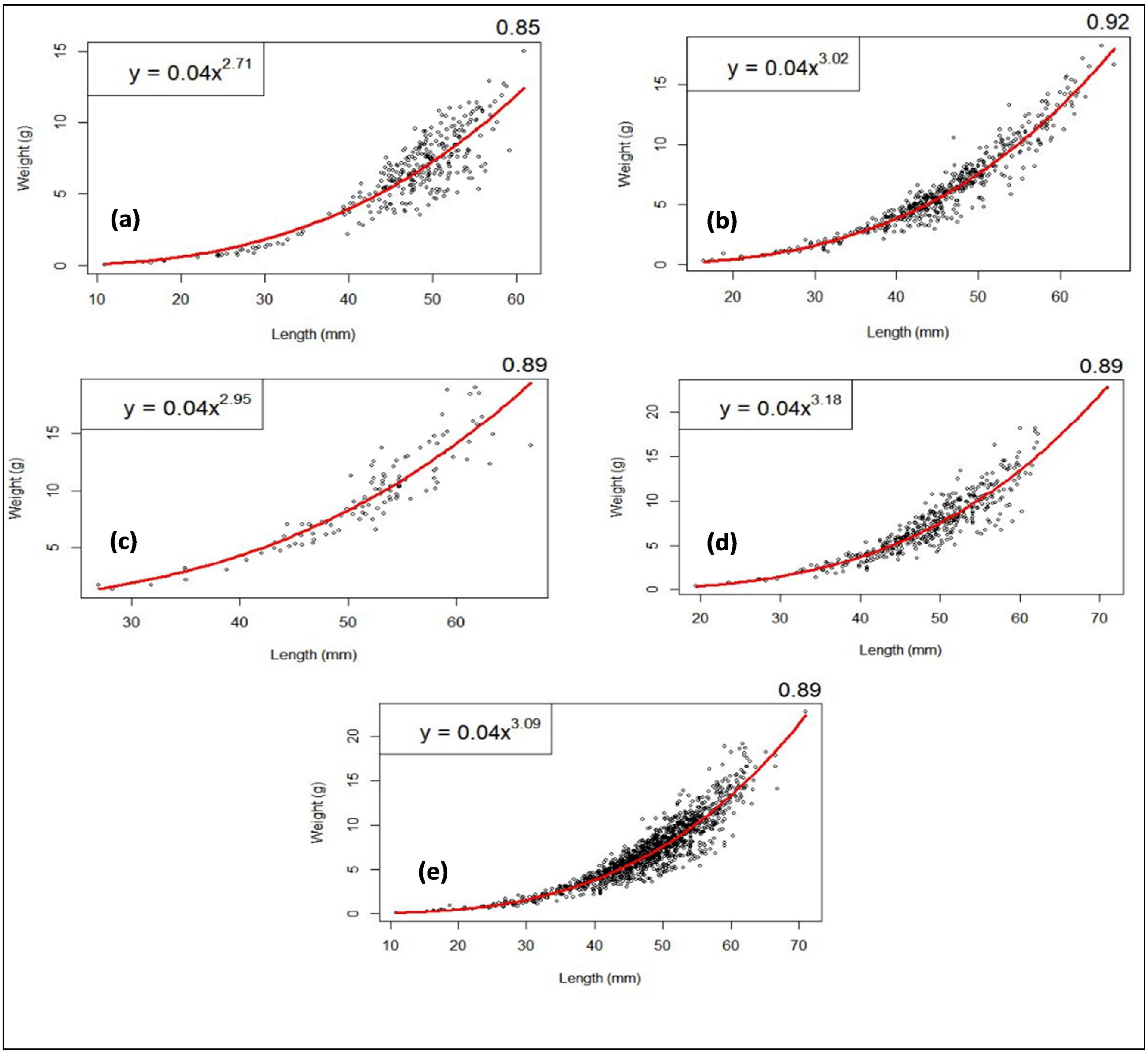

Figure 4. *Lenght weight per site and global: (a= Casamance) (b=Joal-Fadiouth) (c=Senegal delta) (d=Saloum) (e=Global).*

3.4. Density

On all the sampled stations, the overall average density per square meter is estimated at 32.51±12.02 ind/m^2. The density varied according to the sites. It was highest in Joal-Fadiouth (47.47±34.21 ind/m^2) followed by Casamance (33.44±18.22 ind/m^2), Saloum (28.44±13.7 ind/m^2) and at the end of the Senegal River delta (15.85±9.30 ind/m^2) (Figure 5b). However, variations in density are observed between stations at different sampling sites (Figure 5a). The results of the Kruskal Wallis test (chi-squared = 15.021, df = 3, p-value = 0.001799) show that there is at least one significant difference in mean density per site. The result of Dunn's test indicates that the density of individuals sampled in the Senegal river delta is significantly different from that of individuals collected in Joal-Fadiouth lagoon and in the Saloum estuary.

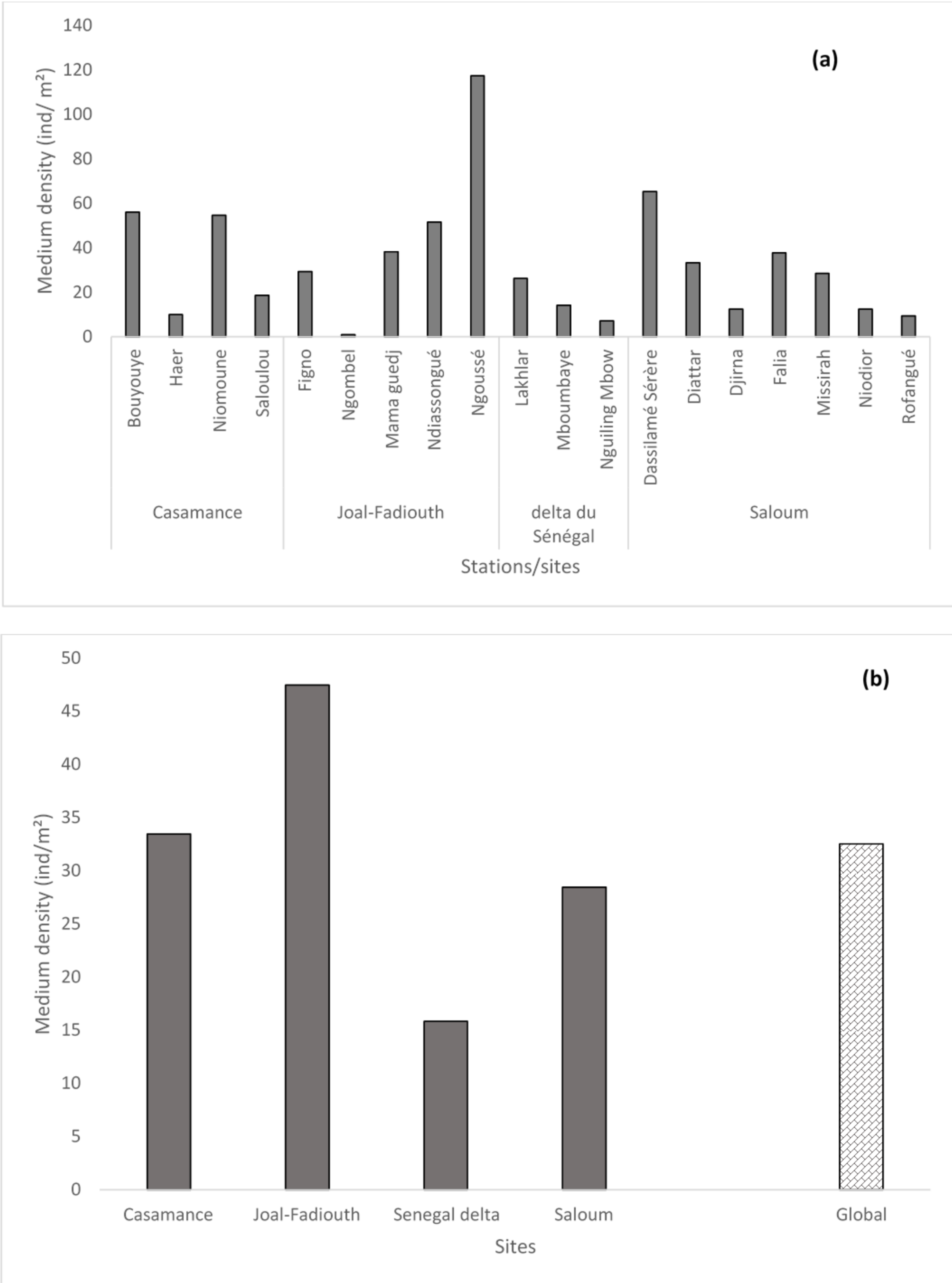

Figure 5. *Medium density (ind/m^2) per stations (a) and sites (b).*

4. Discussion

Biometric aspects of the genus *Tagelus* have been the subject of several studies in the American and African continents [1-3, 9, 10]. These studies focus on the size-weight relationship, density, width/length relationship, and condition index [11]. This work focuses on three species of the genus: *T. plebeius* and *divisus* in South America and *T. adansonii* (synonym *T. angulatus*) in West Africa.

This comparative biometric study across the country found variations in size class distribution; size-weight relationship and density of the species.

Results on the size frequency distribution collected indicate that size classes vary globally between 10 and 75 mm with a mean size of 47.28±8.17mm. These results are similar to those studies [10] in Guinea Bissau who found a mean size of 48, 65±9.53mm. However, these same authors found for the same species a mean size (58.49±5.43mm) thus relatively larger in The Gambia. For *T. bombei* and *T. plebeius* the average size varies from 40.3±6.21 to 73.8mm on the western Atlantic coast of Brazil, Peru and Argentina [20, 13, 7]. Thus on both sides of the Atlantic Ocean, the same size ranges were observed for the genus *Tagelus*. Variations in mean size, from one collecting point to another in the same locality the collection sites, were noted [1, 10, 11]. Also for the present study, the highest average sizes were recorded in the Senegal river delta and in the Saloum estuary. The Joal-Fadiouth lagoon has the lowest average size. The results of these studies [9, 10] show that estuarine environments seem to be more favorable for the development of *T. adansonii*. The difference in size between the individuals sampled in our study does not seem yet to follow this trend especially since our study was also done on a deltaic environment. Several biotic factors (virus, bacteria, protozoa) as abiotic (salinity, temperature, heavy metals) affect the growth of bivalves and thus their sizes. Predation, substrate grain size, nutrient supply among other factors also affect the growth of benthic bivalves [4]. Thus, concerning the abiotic factors monitored during this study (salinity, pH and nature of the substrate), the Table 2 shows us that where salinity is lower (Senegal Delta) the average size is larger and where salinity is higher (Casamance estuary) the average size is among the lowest. Dunn's test showed that only the Saloum estuary and Casamance sites had sizes that were not significantly different. These two sites are geographically close and also have the highest salinities recorded in this study. Thus the effect of salinity on size distribution seems to be proven. The pH between 6 and 7.5 and the sandy substratum seem to be favorable to the development of bivalves.

Table 2. *Variation of abiotic factors in relation to size averages of T. adansonii according to sites.*

Site	pH mean	Salinity (‰) mean	Type of substrate	Mean sizes
Casamance	7	41.33±3.3	Sandy and sandy maddy	46.77
Joal-Fadiouth	6.6±0.76	30.8±5.16	mixte	45.57
Senegal delta	6.83±0.21	21±0.74	Majority sandy	51.68
Saloum	6.4±0.51	32.57±2.42	mixte	48.57

The study of the size-weight relationship indicates that the individuals collected in the Saloum estuary and in the Joal-Fadiouth lagoon show a major allometric growth with allometric coefficients equal to 3.19 and 3.02, respectively. On the other hand, in the Senegal river delta and in the Casamance estuary, the growth of *T. adansonii* is allometrically minor with allometric coefficients equal to 2.02 and 2.21, respectively. These observed differences could be due to the nature of the substrates. Indeed, in the Senegal delta and in the Casamance estuary the substrate of the sampling stations is sandy and sandy-muddy. In the Saloum delta and in the Joal-Fadiouth lagoon the types of substrates encountered are more diverse [11]. Other factors such as pH variation could also be at the origin of this difference in allometric growth. Indeed, the results of the present study on the correlation between pH and allometric coefficient indicate a decrease of the allometric coefficient when the pH increases (Table 3).

Table 3. *Variation of the allometry coefficient of T. adansonii as a function of pH.*

Site	pH	Allometric coefficients
Casamance	7	2.02
Senegal delta	6.83	2.21
Joal-Fadiouth	6.6	3.02
Saloum	6.4	3.19

For the same species, growth in weight is faster than growth in size in the Bijagos Islands of Guinea Bissau [10] with inter- and intra-site variation (Table 4). Allometry is negative in The Gambia [9]. The same is true on the western Atlantic coast with another species of the same genus *T. plebeius* that has a majoring allometry in Argentina [20] and minoring in Brazil [1]. Similarly in Portugal for another species of the same family (*Pharus legumen*) the size weight relationship is isometric. The study [11] showed variations in allometry within the same ecosystem. These variabilities are due to the nature of the substrate with approximately equal salinities and pH. Thus, it can be said that in *T. adansonii*, the relationship between size and weight growth is influenced by salinity, the nature of the substrate and the season. Indeed, the West African coast under the influence of the Canary Current System (CCS) is subject to variable water regimes during the year with particularities between the northern coast and the southern part of the country. The same is true for nutritional intake [22, 12, 24].

Table 4. *Parameters of length-weight relationship of T. adansonii compared with other results.*

Pays	Species	Parameters		Authors
		a	B	
Senegal	*T. adansonii*	0.04	3.09	Present study
Senegal	*T. adansonii*	0.04	3.07	[11]
Gambia	*T. angulatus*	0.0005	2.503	[9]
Guinea-Bissau	*T. angulatus*	4.10^{-5}	3.76	[10]
Nigeria	*T. adansonii*	0.075	3.395	[3]
Brésil	*T. plebleius*	0.008 0.005	2.599 2.281	[1]

Compared to this study [11], the average density of *T. adansonii* in Senegal (32.51±12.02 ind/ m^2) for the present study is higher. However, for the same study [11], densities in the different collection sites vary from 36.78±3.62 ind./m^2 in Nago to

10.06±10.39 ind./m^2 in Formosa. Work done on *T. divisus* in Biscayne Bay, Florida [15] showed higher densities (49.6 and 35.2 ind/m^2) and lower densities (equal to or less than 13.8 ind/m^2) in northern and southern Biscayne Bay respectively. Thus, for this study, density values vary from one locality to another and between collection sites. The highest densities are observed in Casamance (33.66 ±18.22 ind/m^2) and Joal (47.47±34.21 ind/m^2) while the lowest is recorded in the Senegal river delta (15,85±9.30ind/m^2). The lagoon environments seem to be more favorable to the development of high densities of *T. adansonii*. The Senegal River delta, which records the lowest salinity values, seems to be less favorable to high densities. Between Casamance and Saloum, density variations could be due to several abiotic factors, including salinity and the nature of the substrate. Indeed, the Casamance estuary is actually a ria whereas the Saloum delta is a reverse estuary.

In relation to the substrate, the sandy-muddy type remains the most favorable for the development of the species. The spatial distribution is heterogeneous [11, 19] with preferences related to the nature of the substrate. On the mudflats, it has been observed that the populations of *T. adansonii* are more concentrated around the edges of the small channels that ensure the circulation of water during tidal movements, whose substrate is of the sandy-muddy type. The animal by the means of its foot digs galleries. According to the tides, it carries out (vertical) movements towards the surface of the sediment. Thus it would seem that for this kind the nature of the substrate, plays a role in the stability resistance and the depth of these galleries. According to the tides, it carries out (vertical) movements towards the surface of the sediment. Thus it would appear that for this genus, the nature of the substrate plays a role in the resistance and depth of these galleries. Thus, according to the study [21], each species of filter-feeding mollusc has a preferred type of substrate, for which the biomass is more important. Comparing the average densities and average sizes per site for the present study, it was noted that in general, sites where large individuals were collected had low densities (Senegal River Delta). On the other hand, the opposite was noted in sites with high densities with small individuals (Joal-Fadiouth). This could be due to several factors including food. This same observation was made on *Senilia senilis* in the Saloum estuary [8] which is a benthic bivalve with low displacement.

5. Conclusion

The results of this study show that it is in the north (Senegal river delta where salinity is lower and the substrate sandy) that the largest individuals with lower densities and a minor allometric growth were found. On the other hand, smaller individuals with higher densities and greater allometric growth were found in the Joal-Fadiouth lagoon. The Saloum estuary and Casamance sites have similar mean size and density values. These last two sites have mean sizes that are not significantly different, however the allometry is minor in Casamance and major in the Saloum estuary. The mean salinity of the Casamance estuary is very high, whereas in the Saloum estuary it is lower. Thus it is in the Saloum estuary that we have a more interesting average size, density and allometry of T. adansonii than in the other sites. As our study is a one-off, the results obtained can only give an incomplete picture of what is happening globally in these different environments.

In Senegal, *T. adansonii* is present but is not exploited, unlike in Guinea Bissau where, in addition to being consumed, it is used for cultural purposes. The exploitation of mollusks is more oriented towards other bivalves such as oysters (*Crassostrea tulipa*) and clams (*Senilia senilis*), which are the object of an intense economic activity that has led to a proven decrease of their stocks. Faced with the scarcity of the latter, *T. adansonii* could be an interesting alternative. Thus, the results of the present study can contribute to a better knowledge and sustainable management of this resource. The optimal conditions of growth of *T. adansonii* could be better known if sclerochronological analyses are associated with this type of study.

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