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# Size Distribution, Length-Weight Relationship and Condition Index of *Tagelus adansonii* Bosc 1801 (Mollusca: Bivalvia, Solecurtidae) in the Joal-Fadiouth Lagoon (Senegal)

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**Abstract**

Size distribution, length-weight relationship and condition index are some of the many parameters that contribute to the study of the growth, environmental conditions and reproduction of an aquatic species. For *Tagelus adansonii*, only a few studies were carried out on these parameters. This species is a bivalve of the solecurtidae family only found on the East Atlantic Coast between Mauritania and Angola. The objective of this study was to examine the biometric relationships as well as size and condition index variations, within the perspective of resource management. In this study, the average size obtained (47.78mm) from the monthly sampling in Joal Fadiouth lagoon was smaller compared to sizes obtained in other countries for the same genus and species. The size frequency distribution is unimodal, the most abundant class is 45-50mm. The mean condition index is 18.41±16.47 using the formula by Beninger and Lucas (1984). The values of the condition indices varied throughout the duration of the study. In the period of cold-to-warm transition (June) the maximum values of the condition indices were observed, while in the period of warm-to-cold transition (November to December), the minimum values were registered. The allometry is positive (3.07) in Joal as in most studies on this genus.

**Keywords**: biometric relationships, condition indices, Bivalvia, East Atlantic Coast

## 1. Introduction

Growth in biology is defined as the increase in size and volume of a living organism. This growth results in variations of the quantity of organic tissue determined by environmental conditions. The size distribution, the length-weight relationship and the condition index of a species allow to study growth and reproduction. These parameters serve as useful knowledge for the management of a species. For a given population, the growth relationship between length and weight is established by expressing allometry (Ricker, 1971). The length-weight relationship is often used to monitor the relative growth of animal species in the natural environment. A huge works was done on the length-weight relationship. Most of these researches were focused on fish (Yahyaoui *et al.* 2004; Wambiji *et al.* 2008; Attou, 2010; Shawket *et al.* 2015; Touati and Benatmane, 2018). For molluscs, on the other hand, only a few studies were carried out (Gilles, 1992; Bertignac *et al.* 2001; Guilbert, 2007; Melouah *et al*. 2013).

Benthic molluscs are highly diverse and widely distributed in mangrove ecosystems. In West Africa, the malacological fauna include nearly 417 species of bivalves (Cosel and Gofas, 2019). A few studies were performed on several less-known bivalves with great *potentials in* terms of food, ecology and economy. Among these great diversity of bivalves, only two species are commonly exploited and studied in the mangrove ecosystems of Senegal. These are *Senilia senilis* and *Crassostrea tulipa* (Cormier-Salem, 1999; Dog, 2004; Diouf *et al.*

2009; Diatta, 2018). Among these bivalves, there is the genus *Tagelus* belonging to the family *Solecurtidae*, and accounting for nearly eleven species throughout the world. *Tagelus adansonii* is the only species of the *Tagelus* genus present in Africa. It is distributed on the East Atlantic Coast between Mauritania and Angola. In Africa, only a few studies were carried out on this species, particularly on its growth, biology, distribution, reproduction, ecology and socio-economic importance. *Tagelus adansonii* is very important delicacy in terms of taste. In other countries such as Chile, China, Spain and Brazil, there are other species of the same genus that are of economic importance and serve as a source of food (Farias, 2008). There were some studies performed on this genus in different place such as in Nigeria (Ansa and Allison, 2008), Guinea Bissau (Regalla de Barros *et al.*, 2013), and in the Gambia (Diouf *et al.*, 2016; Diouf *et al.*, 2017). In the current context of overexploitation and decline of fisheries resources, the study of an interesting species like *Tagelus adansonii* was pertinent. This study will contribute to a better analysis of:

- The type of *Tagelus adansonii* growth;

- The effects of seasonal variation on the size, the allometry and the condition index;

- The effect of the position and nature of the substrate on size distribution.

## 2. Material and Methods

### *2.1 Study Site*

The samplings were carried out in Joal-Fadiouth municipality located in the department of Mbour, between latitudes 14° 06' and 13° 13' North and longitudes 16° 47' and 16° 53' West on the small coast. It covers an area of 5035 hectares (law 66-20 of February 1, 1966 and decree number 72-82 of February 3, 1972). The lagoon of Joal Fadiouth has a hydrology characterized by a system of channels or inlets locally called bolongs. These bolongs or tributaries receive marine water through two openings, south of the Joal spit (figure 1).

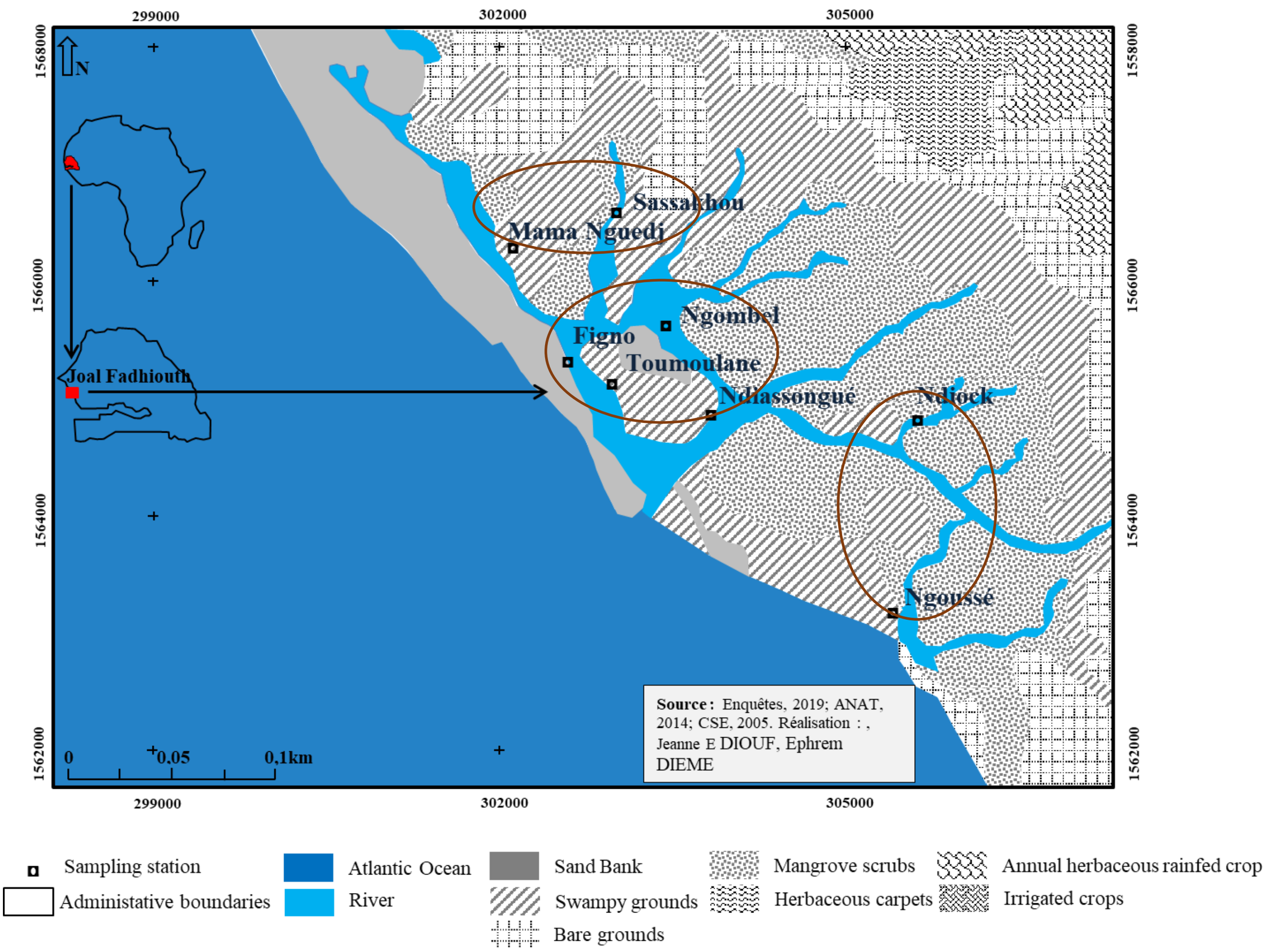


Figure 1. Location of sampling stations in Joal-Fadiouth, Senegal

Eight (08) stations were selected for this study: two (02) of which were in the northern part of the lagoon, four (04) in the center and two (02) in the southern part (Figure 1). The characteristics of the sampling stations are recorded in Table 1.

The complexes were made up of stations, each with a specific type of substrate. The northern complex consisting of the Sassakhou and Mama Guedj stations has predominantly sandy-muddy substrate type with some sandy areas. In the Central complex, the Figno and Toumoulane stations have a fairly hard substrate with the presence of grava and/or shells in some places. At the Ngombel station, the substrate was muddy-sandy, whereas at Ndiassongué the substrate was sandy. Finally, in the southern complex, two types of substrata were encountered: one was muddy and compacted in nature at Ngoussé; and the other was sandy-muddy at Ndiock (Table 1).

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Table 1. Characteristics of sampling stations in Joal-Fadiouth lagoon, Senegal

| Complex | Stations | Substrate | Position | Number |
|---|---|---|---|---|
| **North** | Sassakhou | Sandy /Sandy-muddy | Bolong | 2546 |
| | Mama Guedj | | Bolong | |
| **Center** | Ngombel | Muddy-sandy | Carrefour Bolong | 2704 |
| | Toumoulane | Shell sandy | Bolong | |
| | Figno | Shell sandy/rubble | Bolong | |
| | Ndiassongué | Sandy | Carrefour Bolong | |
| **South** | Ngoussé | Compact mud | Ocean side | 1610 |
| | Ndiock | Sandy- muddy/ sandy | Carrefour Bolong | |

*2.2 Sampling Protocol*

Samples were collected monthly from July 2018 to August 2019 in Joal Fadiouth Lagoon in Senegal. Following interviews with shellfish farmers and a visit to the mudflats, the sampling stations were selected.

The collection protocol used for this study was inspired by those of Hennache (2005), Farias (2008) and Bordeyne *et al.* (2009). On each station, 5 quadrats of 0.5 x 0.5 m were randomly placed. In each quadrat all the individuals present were extracted by hand with a trowel. The entire surface of the quadrat was probed to a depth of 50 cm.

At each quadrat, all the individuals collected were measured: length (anterior-posterior distance), height (dorso-ventral distance) and bulge (thickness) using a calliper (figure 2) and weighed (animal wet weight, flesh/meat weight, dry shell weight, dry flesh weight) with an electronic scale with a precision of 0.01(g).

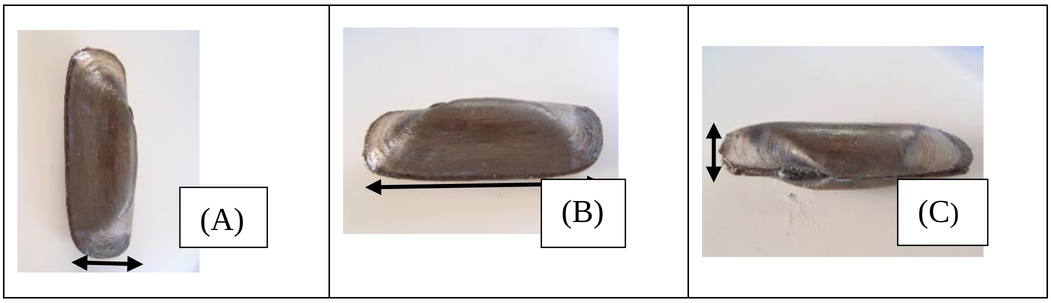


Figure 2. *Tagelus adansonii* sample measurement. (A) height, (B) length, (C) bulge

*2.3 Biological Parameters*

For all the biometric characteristics studied, a seasonal approach has been used. Indeed, several oceanographic studies carried out in Senegal (Berrit, 1962; Rebert, 1982) have shown that two currents with very different characteristics follow one another: a warm current from July to October (from the Gulf of Guinea) and a cold current from January to May (from the Canary Islands); these two currents are separated by periods of transition.

2.3.1 Size Structure

This is the size frequency distribution. For the establishment of size frequencies, specimens from each complex (north, center and south) were grouped into 5 mm intervals. The size frequency distribution was established using length measurements. The formula used for the calculation of the frequencies was based on Faye (2018) and is as follows:

**Fi = ni×100/N**

Where Fi is the frequency,

ni the number of specimens for a given class,

and N the total number of specimens.

2.3.2 Length-Weight Relationship

In many aquatic species, weight (W) is related to length (L) by a non-linear relationship of shape, **W=a*Lb**. This relationship has applications in fisheries biology and in aquatic stock assessment (Ruiz-Ramirez *et al.* 1997). The coefficient b is often close to 3 and express the relative shape of the body of the species. When it is equal to 3, growth is said to be isometric. When it is different from 3, growth is allometric. A coefficient b greater than 3 indicates better growth in weight than in length and vice versa (Ricker, 1980).

2.3.3 Condition Index

In shellfish farming, the condition index is a biometric index that is commonly used to account for the degree of shell filling of animals (Merzouki *et al.*, 2009). Several formulas are used to calculate this index. However, the study by (Bodoy et al., 1986) concluded that the use of dry weight in the calculation of the condition index would give more accurate and reliable values of the condition of individuals in *Crassostrea gigas*. Also taking into account the results of the studies by Merzouki *et al.* (2009) and Nadji (2016), we chose the formula used by Beninger and Lucas (1984), which is defined by the following expression:

**CI= Ps /Pcs × 100**

Where CI is the condition index,

Ps corresponds to the dry weight of the flesh in g,

Pcs is the dry weight of the shell in g.

*2.4 Statistical Analyses*

The statistical processing of the data and the graphs have been realized with Microsoft Office Excel 2010 and R studio version 4.0.2. The Pearson correlation was used to compared length and weigth, statistical significance was determined at $P<0.05$.

## 3. Results

A total of 6860 individuals were collected of which 2939 were from the northern zone; 2311 in the central part and 1610 in the south.

*3.1 Size Structure*

The size (length) of the individuals sampled from all the stations ranged between 10.16 and 73.59 mm with an average size of 47.78 mm and a modal class of 45-50 mm (table 2). Depending on the complexes, there was difference in the size frequency distribution of *Tagelus adansonii*. The minimum and maximum lengths of the individuals sampled in the southern complex were 14.59 and 59.85 mm respectively with an average length of 42.74 mm. In the central complex, the average length of *Tagelus adansonii* calculated is 46.33 mm. The maximum and minimum lengths of the individuals sampled are 73.59mm and 10.16mm respectively. Individuals in the northern complex have an average length of 52.51 mm. The maximum and minimum lengths are 69.49 and 16.22 mm respectively. In each of the complexes, the length frequency distribution is unimodal with equal modal classes of 40-45 mm, 45-50 mm and 50-55 mm in the southern, central and northern complexes respectively (Figure 3).

Table 2. Means, Minimum (min) and maximum (max) length of *Tagelus adansonii*, sampled in Joal-Fadiouth lagoon, Senegal

| Complex | Means, min and max (mm) | Modal class (mm) |
|---|---|---|
| **North** | 52.51 (16.22-69.49) | 50-55 |
| **Center** | 46.33 (10.16-73.59) | 45-50 |
| **South** | 42.74 (14.59-59.85) | 40-45 |

| | | |
|---|---|---|
| **Total** | 47.78 (10.16-73.59) | 45-50 |

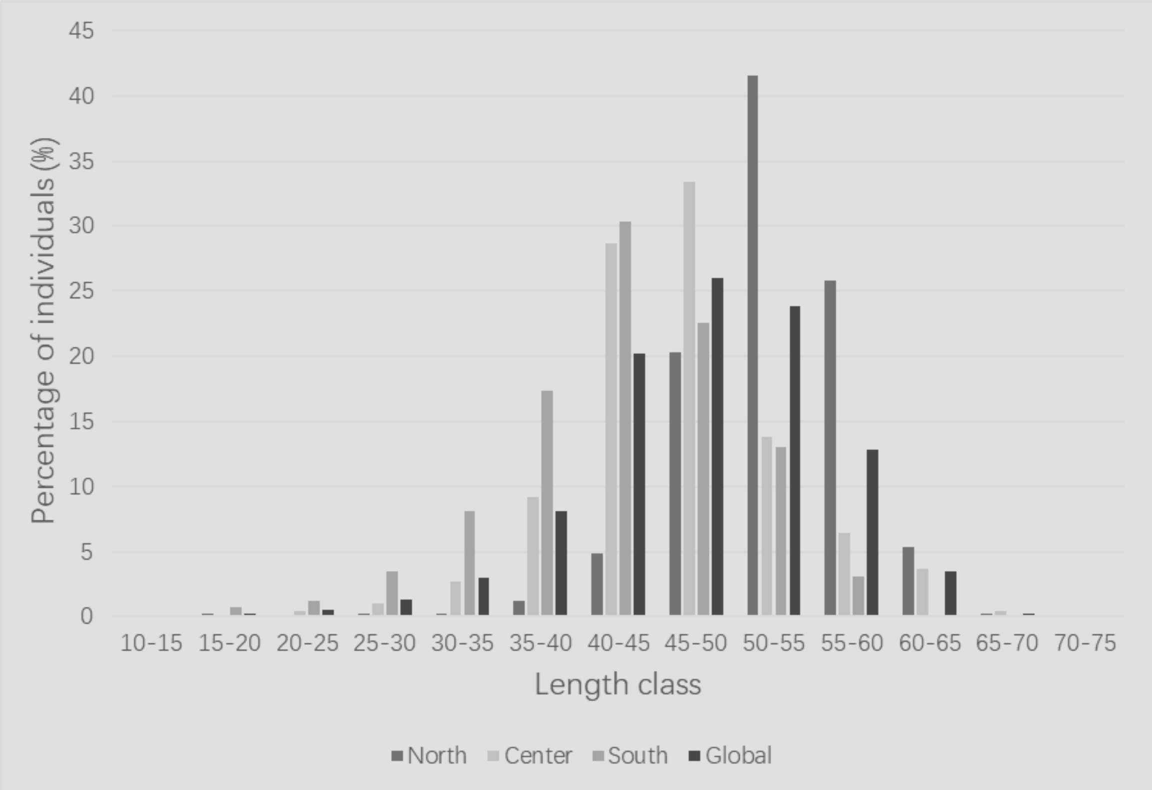


Figure 3. Distribution of *Tagelus adansonii* length class by complex, sampled in Joal-Fadiouth lagoon, Senegal

*3.2 Length- Weight Relationship*

Overall, the length-weight relationship of *Tagelus adansonii* shows a major allometry (b = 3.07) with a strong positive Pearson correlation (r = 0.91, P<2.2$^{e}$-16) between weight and length. As a function of the complexes, *Tagelus adansonii* shows a major allometric growth with an allometry coefficient of 3.13; 3.11 and 3.12 in the southern, central and northern complexes respectively (Figure 4). In each complex, the variables: weight and length also remain highly correlated.

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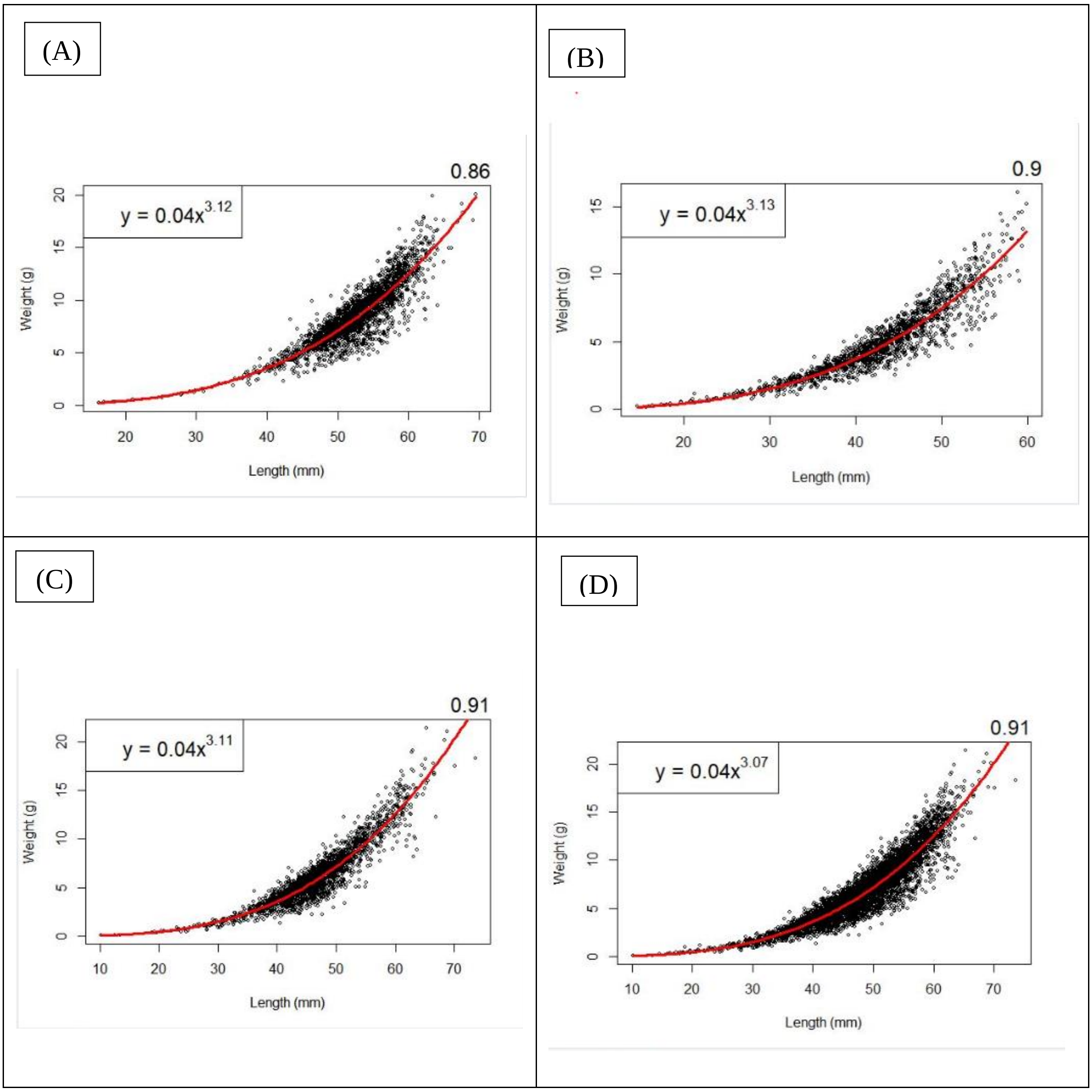


Figure 4. Length- weight relationship of *Tagelus adansonii* sampled in Joal-Fadiouth lagoon, Senegal. (A) North complex, (B) South complex, (C) Center complex, (D) Global

The average allometry at Joal is positive (3.07). The overall average is 47.78±7.59 mm for length and 6.71±3.15g for weight.

In all the complexes, the Pearson correlation coefficients remain very high during all the seasons (between 0.86 and 0.94 with the same $P<2.2^{e}$-16). The monitoring of the allometry by period and by complex showed a major allometry for all the complexes during the hot-cold transition period and the cold period. The allometry was minor in the warm period only for the southern complex; and in the cold to warm transition for the northern complex. The northern complex always has the highest average size and weight regardless of the period. Of all the complexes, the southern complex presented the smallest average size and weight.

The results of the periodic variation of the allometry rate are recorded in (Table 3). In the northern complex, the allometric growth was higher during the transition between the warm and cold periods. From the cold period onwards, the allometric growth gradually decreased before experiencing a slight increase in the warm period.

In the central complex, the periodic variations in growth indicate a gradual increase in the allometric rate from the warm period to the cold period where it reaches its maximum and then begins to decrease at the cold warm transition (table3).

The allometry rate per period in the southern part of the lagoon showed a lower allometric growth in the warm period. Then a progressive increase of the allometry rate was noticed from the warm-cold transition and reached its maximum value in the cold period (table 3).

Table 3: Variation of the parameters of the size-weight relationship of *T. adansonii* according to periods and complexes (N= number of individuals collected, a=constant of the relation, r=Pearson *correlation coefficient*)

| Period : | Complex | N | a | b | r | Mean Condition Index | Mean size (mm) | Mean weight (g) |
|---|---|---|---|---|---|---|---|---|
| Warm Atlantic currents July-October | North | 912 | 0.04 | 3.16 | 0.86 | 19.88±38.91 | 52.18±5.76 | 8.34±2.96 |
| | Center | 1105 | 0.04 | 3.01 | 0.91 | 19.38±12.69 | 47.21±7.07 | 6.42±3.12 |
| | South | 653 | 0.04 | 2.99 | 0.91 | 19.12±7.43 | 43.62±7.47 | 5.4±2.64 |
| Warm-cold transition November-December | North | 446 | 0.04 | 3.3 | 0.87 | 15.72±3.33 | 52.9±5.23 | 8.57±2.91 |
| | Center | 404 | 0.04 | 3.09 | 0.91 | 16.85±8.63 | 45.33±7.31 | 5.45±2.84 |
| | South | 153 | 0.04 | 3.16 | 0.93 | 16.61±3.56 | 42.13±7.89 | 4.96±2.91 |
| Cold Atlantic currents January-May | North | 1034 | 0.04 | 3.03 | 0.86 | 15.79±7.78 | 52.59±5.09 | 8.59±2.54 |
| | Center | 978 | 0.04 | 3.24 | 0.92 | 18.55±7.47 | 45.98±6.75 | 5.88±2.88 |
| | South | 675 | 0.04 | 3.25 | 0.89 | 19.1±7.2 | 42.12±7.02 | 4.66±2.4 |
| Cold-warm Transition June | North | 154 | 0.04 | 2.97 | 0.91 | 20.49±5.5 | 52.84±5.14 | 8.92±2.56 |
| | Center | 103 | 0.04 | 3.07 | 0.94 | 22.35±6.29 | 47.13±6.37 | 6.65±3.08 |
| | South | 129 | 0.04 | 3.14 | 0.89 | 20.53±5.77 | 42.27±7.46 | 4.99±2.48 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Total season | North | 2546 | 0.04 | 3.12 | 0.86 | 17.56±24.17 | 52.51±5.37 | 8.52±2.77 |
| | Center | 2704 | 0.04 | 3.11 | 0.91 | 18.89±10.18 | 46.33±6.95 | 6.02±2.96 |
| | South | 1610 | 0.04 | 3.13 | 0.9 | 18.98±6.95 | 42.73±7.39 | 5.01±2.58 |
| GENERAL TOTAL | Joal-Fadiouth | 6860 | 0.04 | 3.07 | 0.91 | 18.41±16.47 | 47.78±7.59 | 6.71±3.15 |

### *3.3 Condition Index*

The condition indeces varied between 22.35 and 15.72 depending on the complex and the season (table 3). The condition index values are approximately the same in all the complexes during the warm period (between 19.12 and 19.88). The cold-warm transition period was the period when condition indices were highest in all complexes (between 20.49 and 22.35). The north, south and central complexes had the lowest condition index during the warm-cold transition period (between 15.72 and 16.85). The average condition index per complex decreased from south to north (table 3). The difference between the highest and lowest condition index values for the complexes recorded higher value for the center (5.5) followed by the north (4.77) and then the south (3.82).

## 4. Discussion

The result of the length frequency of *Tagelus adansonii* in this study showed that the most common sizes at Joal were between 45-50mm (the modal class). In Brazil, the study by AbrahãoI *et al.* (2010) on *Tagelus plebeius* at two different sites showed higher values for modal classes which were between 50.1 and 52.6mm at one site and 55.1 and 57.6mm at the other site. The average sizes (48.76mm ± 7.22 and 52.02mm ± 9.8) in the two sites studied by AbrahãoI *et al*. (2010) are higher than the average size (47.78±7.59mm) obtained in the present study. Compared to other studies on the same genus (Ansa and Allison, 2008; Diouf *et al.* 2016; Diouf *et al.* 2017; Lomovasky *et al.* 2018), the value of the average is lower at Joal (Table 4). These differences could be due to limiting environmental factors present in the Joal lagoon, such as the nature of the substrate. According to Baron and Clavier (1992), the granulometry of the substrate influences the distribution of benthic species. In endobenthic suspension species, the accumulation of fine particles in suspension can create clogging in the gills. In this study the nature of the substrates could have influenced the growth of the species because a clear difference in the size distribution was noticed at different complexes. From North to South, the individuals at the complexes became more and more smaller in sizes. The types of substrates encountered during the study can be classified into three categories according to texture and grain size: soft substrates (muddy to vaso-sandy); intermediate substrates (sandy to sandy-muddy) and hard substrates (gravel and shell sand). Thus the northern complex (intermediate substrate) had the highest frequencies for maximum and average sizes. The central complex (intermediate, soft and hard substrates) had the medium frequencies for maximum and average sizes. The southern complex (soft substrates) had the smallest frequencies for maximum and average sizes. From the results, it can be assumed that sandy-muddy substrates offer better growth for *Tagelus adansonii*.

The values of the correlation coefficients obtained during this study were very high. There was a strong correlation between weight and length. This strong correlation noted in this study could be due to the fact that the sizes encountered were small. The full growth potential in size may not have been achieved in the lagoon (table 4). Nevertheless, the effort made during our sampling compared to other studies could also explain the sizes obtained at Joal. The total length-weight relationship at Joal had a major allometry. However, there were variations in the value of the allometry within the same complex according to the seasons. This means that overall in Joal, *Tagelus adansonii* grows more in weight than in the length, especially during cold periods in the central and southern complexes and warm-cold transition in the northern complex. The allometry was minor in the southern complex during the warm period and in the northern complex during the warm-cold transition period. Apart from the above-mentioned minor allometries the rest of the allometries by period and by complex were major. The overall results obtained in Joal are similar to those of Ansa and Allison (2008) in Nigeria; Diouf *et al*. (2017) in Guinea Bissau and Lomovasky *et al.* (2018). In contrast, the study by Abrahaol *et al.* (2010) on *Tagelus plebeius* in Brazil and that of Diouf *et al.* (2016) on *Tagelus adansonii* showed minor allometries. Environmental factors (salinity in marine environments, hardness in freshwater environments, temperature. etc.) have a major influence on growth (Rodriguez, 2017; Addino *et al.* 2019). Indeed benthic bivalves are molluscs subject to physico-chemical variations in the environment. For the same species the allometry changes from one place to another due to external factors.

Table 4. Synthesis of the results of the length-weight relationship for the genus Tagelus

| **Species** | **Country** | **a** | **b** | **n** | **$R^2$** | **Lenght mean (mm)** | **Authors** |
|---|---|---|---|---|---|---|---|
| ***T.adansonii*** | Nigeria | 0.075 | 3.395 | / | 0.997 | / | Ansa and Allison (2008) |
| ***T.angulatus*** | Gambia | 0.000 5 | 2.503 | 176 | 0.88 | 58.49±5.43 | Diouf *et al.* (2016) |
| ***T.angulatus*** | Guinea Bissau | $4^e$-05 | 3.076 | 1596 | 0.877 | 48.65±9.53 | Diouf *et al.* (2017) |
| ***T.plebleius*** | Brazil | 0.008 | 2.599 | 831 | 0.86 | 48.77±7.22 | Abrahàol *et al.* (2010) |
| | | 0.005 | 2.281 | 541 | 0.71 | 52.02±9.8 | |
| ***T.plebleius*** | Argentina | $8.29^e7$ | 3.76 | 2491 | 0.89 | 52.19 | Lomovasky *et al.* (2018) |
| ***T.adansonii*** | Senegal | 0.04 | 3.07 | 6860 | 0.91 | 47.78±7.59 | The present study |

The condition index (CI) is used to characterize the physiological state of an individual. The seasonal changes of the condition index values between the different complexes showed differences between the warm cold transition period (June) and the warm cold transition period (November-December). The variation in water temperatures (Table 3) and the upwelling phenomenon characterize the western Atlantic coastal waters. In this area, the upwelling season lasts from December to May. Taleb (2005). During the upwelling period, water rich in nutrients (phytoplankton) favor the accumulation of reserves for reproduction. This could be confirmed by the increasing CI values obtained between the cold period (January-May) and the warm cold transition (June). The drop in CI during the warm period could correspond to the reproduction period (gamete release). In West Africa, the peak breeding period of other bivalves such as *Senilia senilis* generally coincides with the rainy season (June-July-August) (Diouf *et al.*, 2009) or September-October for the oyster *Crassostrea gasar* (Diadhiou, 1995). If this is the case for *Tagelus adansonii*, this would explain the decrease in CI during the warm period (July-October) and the obtaining of the lowest values during the warm-cold transition period (November-December). This fall in CI is also noticed on *Ruditapes decussatus* between May and September in Algeria (Nadji, 2016). In coastal bivalves, the condition index is essentially linked to sexual maturation with increasing values of the condition indexes (CI) being interpreted as the beginning of gonadal development and decreasing values as a release of genital products (Paulet *et al.*, 1992).

Table 5. Comparison between average length, average weight and condition index (CI)

| Complex | Mean size (mm) | Mean weight (g) | Mean CI |
|---|---|---|---|
| **North** | 52.51±5.37 | 8.52±2.77 | 17.56±24.17 |
| **Center** | 46.33±6.95 | 6.02±2.96 | 18.89±10.18 |
| **South** | 42.73±7.39 | 5.01±2.58 | 18.98±6.95 |
| **Total** | 47.78±7.59 | 6.71±3.15 | 18.41±16.47 |

Comparing CI values of the central, northern and southern complexes, the highest value was recorded in the south. However, in the same complex, the average weight and length of the individuals are the smallest. Individuals in the southern complex accumulated more reserves. The difference in the extreme CI values from one complex to another suggests that reproduction is more favorable in the central complex. The northern complex may be the most favorable site for growth. Environmental conditions could play a role in the variation of CI. Indeed Nadja (2016) found different CI values from north to south in a lagoon complex in Algeria. Generally, the environmental factors influence reproduction and growth of organisms. Therefore, the environmental conditions would be more optimal in the central and northern complexes.

## 5. Conclusion

This is the first study to determine some biological parameters of *T. adansonii* in Senegal. The study shows that *T. adansonii* has a unimodal class for total length frequency distribution. The established length-weight relationship indicates a positive allometry in each of the complexes. However, the allometric growth studied in each complex as a function of the seasons reveals a minor allometry in the southern and northern complexes in the warm season and in the cold to warm transition season. The result of the condition index shows a variation in different complexes with a slightly higher average value in the southern complex. This pioneering study on *T. adansonii* in Senegal has highlighted basic elements of the biology of this species. This study is therefore in line with the perspectives of environmental study, exploitation, nutrition and sustainable management, with a view of diversifying the sources of proteins of aquatic origin on the West coast of Africa.

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