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# Bio-ecological assessment of clams of the lower Sanaga Delta. Cameroon

**Dikoume Adolphe, Banjem Jacqueline, Ngassam Bruna, Tekou Guegang, Diyouke Eugene, Ajonina Gordon and Tomedi Minette**

**Abstract**
Bio-ecological assessment of clams of lower Sanaga Delta. Cameroon showed that clams of this area are in general burrowing bivalves with predominate shell oval shape (96.3%). with nuance of yellow coloration (62%). presenting lengths between 30 and 90 mm. The granulometry of clam fishing ground was predominantly fine sand (<0.25mm) with high temperatures (23–27 °C) and excessive salinity. Polluted slightly by chemical compounds such as nitrates. ammonium. Phosphates and chlorides. Some water characteristics (pH. sulphate. nitrate and fluoride) showed some influence on metric parameters of the clam (height (H). length (L) and Bulge (B)) with respective positive correlation with the fluoride ions (0.798; 0.802 and 0.662) while the same metric parameters (L. H and B) were negatively correlated with other compounds of water with respective r- values for L. H and B for pH (-0.764. -0.766 and 0.655); nitrate (-0.695. -0.691 and 0.625) and sulphate (-0.855. -0.855 and 0.769).

**Keywords:** Bioecology, manila clam, substrate, physico-chemical parameters, water, Sanaga, Cameroon

## 1. Introduction
Urbanization and demographic growth observed in general in the developing countries and Cameroon in particular have contributed to an increasing and urgent demand in proteins of animal origin [1]. According to MINEPIA [2], Cameroon's annual domestic fish demand was estimated at 240.000 tons with a value of more than 20 billion FCFA against current national fisheries production estimated at 168.000 tons (66.7% of projected demand) for all species. Of which 51.6% from which artisanal maritime fishing. 41.5% for continental fishing. 4.1% for industrial fishing and only 2.8% for aquaculture. As part of the strategy to close this demand gap (33.4%). there is need to explore the conservation and production of animal proteins existing in natural sources including bivalves [3].
The world production of bivalves is estimated at 14.6 million tons in 2010. Fishing provides 12% of these contributions; the rest comes from the aquaculture [4]. In terms of groups of species. These productions are dominated by clams/coques/arches and the oysters with respectively 38 and 31% of the global contributions. Among this group of the clams/coques/arches. The Japanese clam occupies an important place with two third the contributions (fishing and aquaculture).
Clam is a burrowing suspension animal of brackish water. Its area of distribution reveals strong environmental variations that it tolerates so much to the level of temperatures to that of salinity. It evolves in waters of 10 to 30 °C but optimal temperature of growth is between 20 and 24 °C [5, 6]. The salinity is favourable between 12‰ and 32‰ [7]. It is in the estran zone and also in subtidal zone. The sediment in which it lives is variable. It is present in muddy gravels coarse sands and thin sands. Clams buried themselves to some centimetres of depth and migrate very little. When they move some meters, they form characteristic trails to the surface of the sediment [8].
In Cameroon, bivalve molluscs are exploited along the Sanaga Delta for flesh and shell by a restricted local community fishing groups in the district of Mouanko with estimated production of over 800 000 tons per annum [9]. The authors expressed fears of declining production in the face of increasing demand of this palatable species. No bio-ecological studies have been carried out especially to contribute in addressing sustainable exploitation of this species.
The current study attempts to assess the immediate biotic and abiotic environment of of the clams through determination of some bio ecological parameters essential to the life of clams in the lower Sanaga in order to contribute to possible domestication of the species.

## 2. Materials and Methods
### 2.1 Site of study
The study site (3°38' N; 9°47'E) is located at the lower Sanaga River in the Malimba villages within Mouanko one of the nine (09) districts that make up the Department of the Sanaga Maritime of the Littoral region of Cameroon (Figure 1). The relief is generally flat with altitude generally varying between 1-50 m and rarely between 80-120 m [10]. Soils are argilo-sandy with weak water retention capacity. They are alluvium on the strands of the big rivers (Sanaga, Kwakwa) and are naturally fertile. Four groups of soils can be distinguished: acidic soils rich in iron; marine soils covered by the mangrove swamp; fluvial soils along the Sanaga River and its effluents and on the islets of sand in dry season; hydromorphic soils along the marshes [11]. The site has a vast hydrographic network to which is added the Atlantic Ocean that edges the coast. This varied hydrographical network is characterized by many courses of waters among which the Sanaga, the Dibamba, the Nyong, the Dipombé and some lakes notably the Tissongo and the Nsah lakes [12]. The climate of Mouanko is equatorial type extensively influenced by the Atlantic Ocean. it is characterized by a yearly average precipitation of between 2000 mm to 3000 mm mono-modally distributed peaking in August with 600mm, a yearly average temperature between 25 and 30 °C. Four seasons are marked locally: a big dry season of December to mid-March; a small dry season of mid-March to April; a small rainy season from May to June and a big rainy season from July to November [10]. The Douala-Edéa wildlife reserve sweeps a big part (80%) of the the district of Mouanko. The reserve has numerous fauna species with aquatic and terrestrial fauna being threatened extensively by poaching, overfishing and the destruction of the mangrove swamp ecosystem [10]. The population of Mouanko is estimated at 17.000 people [13]. The majority of the local populations essentially live on fishing. The fluvial fishing is essentially based on the Cichlidaes. The catfishes and the clams [13].

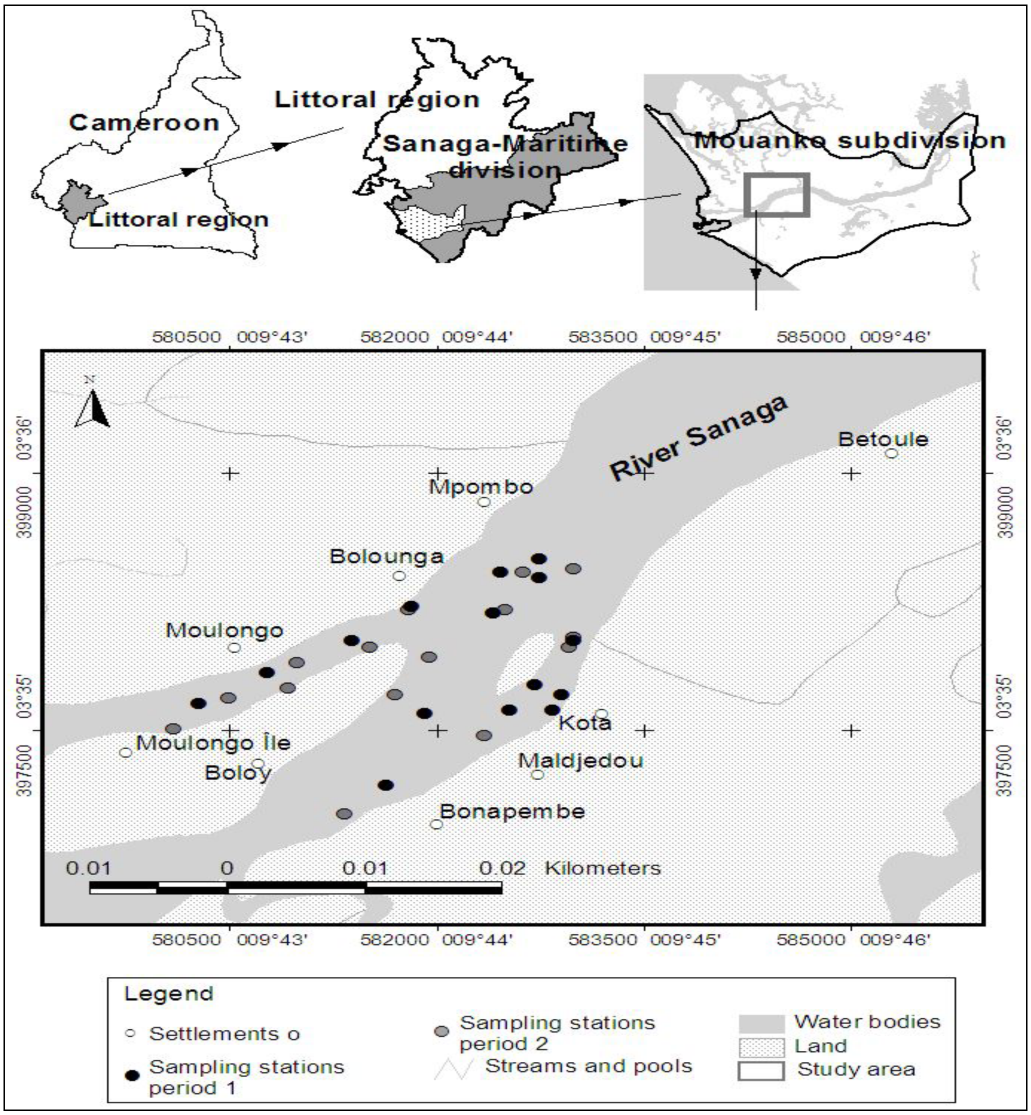



**Fig 1:** Map of the site of study showing the location of sampling stations

### 2.2 Data Collection
Data collection took place between the period from April 20 to October 20. 2015. Two data collection trips were carried out from June to July 2015 in the Malimba villages. Sampling was targeted at three big stations within which the clams were concentrated. accessible and often collected by the villagers (Bolounga-Moulongo, Mpombo-Maldjedou and Betouli-Maldjedou) within 2 km of river of an area of about 300 ha. In

every station, water substrate and clam samples were collected at constant three depth levels according to the method of fishing (surface. basket and deep fishing) by experienced clam collectors as follows:

- **Water samples:** a bucket of 10 litres was used to collect water then samples of up to one litre into polystyrene of 310 ml sampling bottles. A Multi-parameter (WATERPROOF mark) was used to record 5 parameters in-situ: temperature, pH, conductivity, salinity and TDS.
- **Substrate samples:** these were collected using plastic bags from the different depths by divers. The same parameters as for water samples were measured in-situ.
- **Clam samples:** these were collected in plastic bags and size measurements were taken on Length, Height, Width and bulge on every individual using a calliper.

### 2.3 Data analysis

**Laboratory analysis**

Water and substrate samples were analysed in the laboratory at the University of Yaounde.

**Studied parameters**

- **Physico-chemical characteristics of water:** These were read directly from the multi parameters (WATERPROOF mark). Temperature readings were taken by dipping the instrument in the bucket of water withdrawing after 5 to 10 minutes to take readings expressed in Celsius degree (°C). pH) expressed in Conventional Units (U.C). Electric Conductivity in micro Siemens by centimetre (µS/cm). Salinity in parts per thousand (‰) and TDS (Total Dissolved Solids) in parts per million (ppm). Alkalinity by titration of pipetted HCl up to a stable 0.05 ml with measurement with the help of a pH-meter of mark WTW 330.
- **The major ions. By ionic chromatography:** It rests on a principle of difference of size and load of the ions of a sample. Indeed, this technique includes 2 stages. The separation: a volume of 25 to 100 ml of the sample is injected at the head of column and the migration of the species makes itself according to their affinity (capacity of the ion to be kept more or less) for the resin.
- **Nature of the substrate:** The texture of the substrate was determined through microscopic analysis of soil. A shift with conventional mesh sizes (round pebbles, very coarse sand, coarse sand, medium sand and fine sand) were used to separate this textural components following the principle described [14].

**Morphometrical Variables *in situ***

These data made references to the physical (qualitative) descriptors of coloration of the clams. and to the morphometrical descriptors according to the following allometric relationships:

- Shape of the valve lateral view [15] : *H/L*
- Oval *(L/H <1.5);* Elliptical *(L/H = 1.5-2.0)* and Elongate or subtrapezoidale *(L/H≥ 2.0).*
- Shape of the clam ventral view
- Indication of convexity [16] : *Cn = B/H* So Cn> 0.5 then convex Bivalve
- Indication of compactness [16] : *Cm = B/L* So Cm> 0.5 then compact Bivalve

Where in all cases L = length (mm); H=height (mm); B = bulge (mm)

NB: a clam is convex when it tends to grow more in height in relation to the length or compact when it tends to grow more in length in relation to the height.

**Statistical analyses**

The collected data was subjected to descriptive statistical analysis using tables, graphics, etc with Excel 2007 software. Inference statistical analysis using a two-way ANOVA by SPSS version 17 according to the model: Yijk = µ+ zi + tj + eijk (i=1. 2.3.; j=1.2). Where Yijk is the response variable. u is general mean. z. the three zones and t the two time collection times. Statistically significance was assessed at $p$ <0.05.

## 3. Results

### 3.1 Physical and chemical variables of water (see of annex 1)

Key physico-chemical characteristics of the water for the two sampling periods are presented at Annex 1. There generally indicate some variation between the two periods especially the chemical properties.

### 3.2 Substrate granulometry

The particle distribution of the substrate is presented in Figure 2. This shows that clam were more abundant in the fine sand (<0.25mm) category.

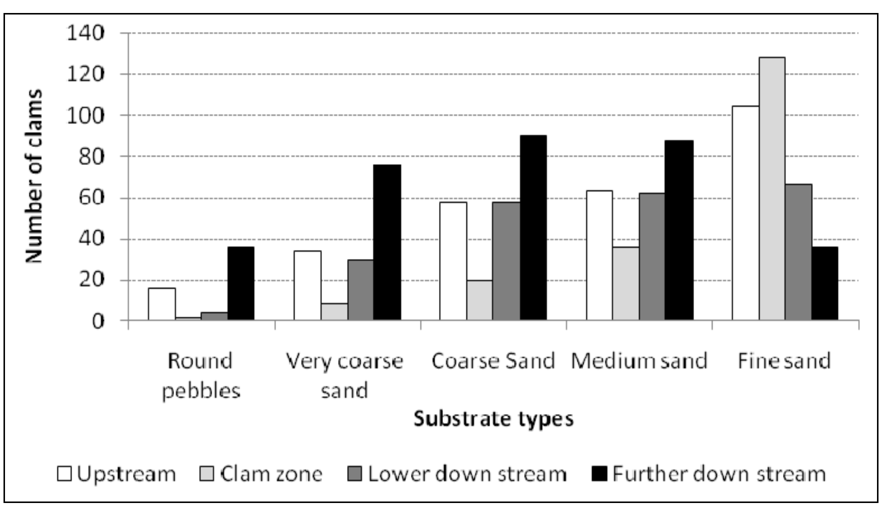



**Fig 2:** Particle size class distribution of substrate according within sampling stations

### 3.3 Morphometry of the clams

**Physical or qualitative descriptors**

Here the retained variables made reference to the diversity of external coloration of the shell of the colonies of clams recovered in the lower Sanaga.

- *Coloration*. Collected clams showed five nuances of colour: Yellow. Brown. Black. Pink and Orange in the zone of Malimba with some variation in distribution of clams with various colour shades between the zones: zones 1 and 2 the distribution of the clams was as: the nuances of yellow colour (62%). nuances of brown colour (29. 5%) then 4.5% of clam with nuances of rose 2% with black nuances and 2% with orange nuances. Gold in the zone 3. the distribution of the clams showed: the nuances of more abundant brown colours (48%). of the rose nuances (27%). then of the yellow nuances (23%) and of the crotchet nuances (2%). The clams with nuances of orange have been observed solely in the zones 1 and 2 with a weak proportion.

- **Morphometrics Index**
  - Shape. Using the morphometry descriptors showed that the harvested Clams presented various shapes among which: oval (96.3%) and convex (87.2%) were more numerous than the clams with elliptic (3.7%) and compact (2.8%) shapes.
  - Size. The size class distribution of the clams the collected clams presented some sizes between 30 to over 90 mm subdivided in 14 classes. Figure 3 showed that in the zones 1 and 2, the biggest quantity of clams belongs respectively to the class of size between 50 to 55 mm (10.8%) and 55 to 60 mm (9.8%). On the other hand in the zone 3, the class of size 65 to 70 mm (6.1%) was the most numerous, with maximum size (115 mm).

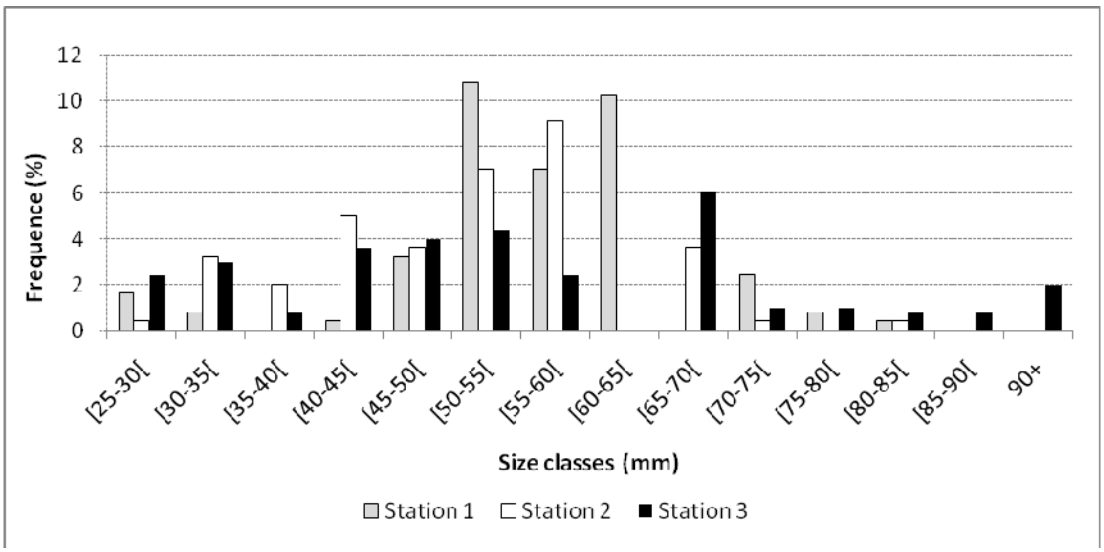



**Fig 3:** Size class distribution of clam by zone

### 3.4 Correlation between some physical and chemical parameters of water, the nature of the substratum and the clams

**Correlation between some physicochemical parameters of water and the clam**

Table 1 presents the correlation matrix of parameters studied.

This showed that some of the water characteristics (pH. sulphate. nitrate and fluoride) showed some influence on metric parameters of the clam (height (H). length (L) and Bulge (B)) with respective positive correlation with the fluoride ions (0.798; 0.802 and 0.662) while the same metric parameters (L. H and B) were negatively correlated with other compounds of water with respective r- values for L. H and B for pH (-0.764. -0.766 and 0.655); nitrate (-0.695. -0.691 and 0.625) and sulphate (-0.855. -0.855 and 0.769).

Table 1: Correlation between the morphometrical parameters of the clams and the physical and chemical parameters of water (see to the annex 2)

Correlation between the nature of the substrate and the metric parameters of the clam

Table 2 shows absence of correlation between the metric parameters of clams and most substrate granulometry except a manifestation of positive association (r = 0.550) between the weight of the clam and the rich sand zone that was observed.

**Table 2:** Matrix of the correlations between the nature of the substrate and the metric parameters of the clams

| Metric parameters of the Clam | Granulometrical Parameters | | | | |
|---|---|---|---|---|---|
| | **Round pebble (>2 mm)** | **Very coarse sand (1-2mm)** | **Coarse Sand (0.5-1mm)** | **Medium Sand (0.25-0.5mm)** | **Fine sand (<0.25mm)** |
| Compacity Index. (B/L) | -0.116 | -0.208 | -0.214 | -0.001 | 0.131 |
| Elongation Index. (H/L) | -0.013 | -0.013 | 0.091 | -0.130 | 0.257 |
| Convexity Index. (B/H) | -0.105 | -0.197 | -0.244 | 0.074 | -0.006 |
| Weight (g) | 0.043 | -0.033 | -0.141 | $0.550^{**}$ | -0.040 |
| Length (mm) | 0.026 | 0.092 | 0.211 | 0.133 | 0.222 |
| Height (mm) | 0.041 | 0.107 | 0.235 | 0.118 | 0.220 |
| Bulge (mm) | -0.030 | 0.002 | 0.088 | 0.134 | 0.157 |

## 4. Discussion

### 4.1 Clam morphometry

Coloration of the clams presented five nuances of coloration (yellow. brown. pink and orange black) listed in the lower Sanaga which could be explained by the fact that the clams possess a malleability that allows it to take some coloration according to the environment or where they are found [17-19]. This corroborates the findings of Gallois (1973) in Thau pond (France), for the species *Ruditapes philippinarum* with a coloration of the variable individuals as a function of the surroundings in which they were recovered [20].

The predominant shapes found were oval and convex which could be explained by the fact that most of clams possess some features similar to those of *R. philippinarum* (yellow clam). Gallois (1973) obtained results with oval shapes for the species *Ruditapes philippinarum* and but different from the shapes round and globular described for *R. philippinarum* by Caill-milly (2012) in Arcachon Bay (France) [21].

The shell in general, is the most visible feature of the body of mollusc. It also exposes a big degree of variation as for the morphology, even among the individuals of the same species [22]. The morphology of the shell of the bivalve is bound to a set of endogenous factors (genetic and physiological) and exogenous factors (biotic and abiotic interactions). The interactions between endogenous and exogenous factors are translated by the malleability of the phenotype of the shells in aquatic environment. Besides, the variation in the phenotypes of the shell hinders their correct identification. Most descriptions of current shells of soft water are based on the subtle differences in the length and the coloration, but only a small percentage of these have valid identifications which can be greatly explained by advancement in genetics [23].

The collected clams were of variable sizes between 30 and over 90 mm due to lack of fishing regulations in the area unlike in some countries where venericulture is recognized [9]. Elsewhere Gallois (1973) collected clams with length ranging between 35 and 40mm reaching 80 mm for aged individuals in Thau pond (Orlean, France) [20]. But the maximal sizes of the clams of the lower Sanaga are superior (115 mm versus 104 mm) to those of the survey of Caill-milly (2012) in Arcachon Bay (France) [21].

### 4.2 Variable physical and chemical properties of water

The growth of the clam through its shell is a factor influenced by the temperature of the sea water [19]. During the study, the weak variations of water temperature observed (23.6 °C-24.1 °C) was probably influenced by the closeness of the periods of withdrawals. Indeed, it could justified by the absence of meaningful difference observed between the sampling periods ($p>0.05$). However the temperature in the site was not unfavourable to the presence of the clams, knowing that the temperature represents an important parameter in the calculation of the energy balance of a mollusc [24]. These results corroborate those found by Gallois (1973) that stipulated that the clams are the species that live and develop better in the midium where the temperature varies between 6 °C and 27 °C.

The total dissolved particles dissolved is an indicator of the high pollution (values of TDS: 26.9 ±0.826mg/L) transparency values (17.6 ±1.206) measured which were influenced by periods of withdrawals. Since during the second sampling period, water was disturbed due to a small rain in the morning of the withdrawal that increased particle suspensions. But the closeness between the stations is translated by the absence of meaningful differences ($p>0.05$) between the two collections of data. Concerning the chemical water parameters, the average values of water pH showed weak basicity during the first sampling period (7.44± 0.17) and weak acidity (6.4±0.15) during the second sampling period. However no meaningful difference between the stations was observed due to local run-off [25].

The salinity varied weakly (26.5-27.7%) between the two sampling periods. These values could be explained by the fact that the sampling took place in fresh water zone. These results are in the norm defined according to Dang (2009) in its work of clams with optimal salinity levels of 15 to 50% for healthy growth of living organisms that live in the zones without salt water or on excessive salt water [8].

The electric conductivity during our study oscillated between 29 µS/cm and 40.3 µS/cm showing these zones are poor in ions. With regard to the present average major ions, sodium as a cation was less dominant and present in very weak proportions (0 to 0.20 mg/l), for an average value of 0.092 mg/l, since sampling took place in fresh water. Fluoride varied between 0.07mg/l and 0.35 mg/l but these values could not influence average fauna and flora values according to Foussard et Etcheber (2011), because of their extensively below the acceptable values (1.5 to 2.0 mg/L) [26].

The oscillating variations contents in ammonium nitrogen, nitrates, phosphates and chloride ($NO_3^-$. $NH_4^+$. $PO_4^{3-}$. $Cl^-$) contents indicated average pollution. This would be due to the industrial and domestic wastes in addition to the washing of the cultivated soils containing the phosphate manures by some pesticides upstream where some plantations exist. Ammonium can come from the wastes of organic nitrogen or nitrate transformation. However these ionic compounds remained in the range tolerated by the clams [27]. Since according to clam breeding guide produced by IFREMER (2006), the average values of favourable mineral salts are: 3 to 8mg/L for nitrates, 0.2mg/L for nitrites and 1 to 6mg/L for the phosphates. The values of the alkalinity (467.3-744) showed the strong power of waters and it would explain the weak variability of the pH. Otherwise significant difference doesn't exist ($p>0.05$) between the stations with regard to these parameters with the exception of the nitrate ($p<0.05$).

### 4.3 Correlation between the physico-chemical characteristics of water and the clam

The physico-chemical parameters of water associated to clam metric parameters revealed that only ion fluoride was positively correlated to the clam metric parameters. While a negative correlation was observed with pH, nitrate and sulphate (an increase of these compounds was associated with a decrease of the metric parameters of the clam (Length, Height and Bulge) and vice versa showing their influence on primary production and that eutrophication could negatively affect growth of clams. Some authors claimed that bivalves through their most visible feature (shell) may present some adaptation to exogenous factors (the biotic and abiotic interactions) thanks to shell malleability [23]. So the result of the interactions between endogenous and exogenous factors will be translated by shell malleability as expressed by the observed phenotype. Be sides, the variation in shell phenotypes is also bound to malleability [23].

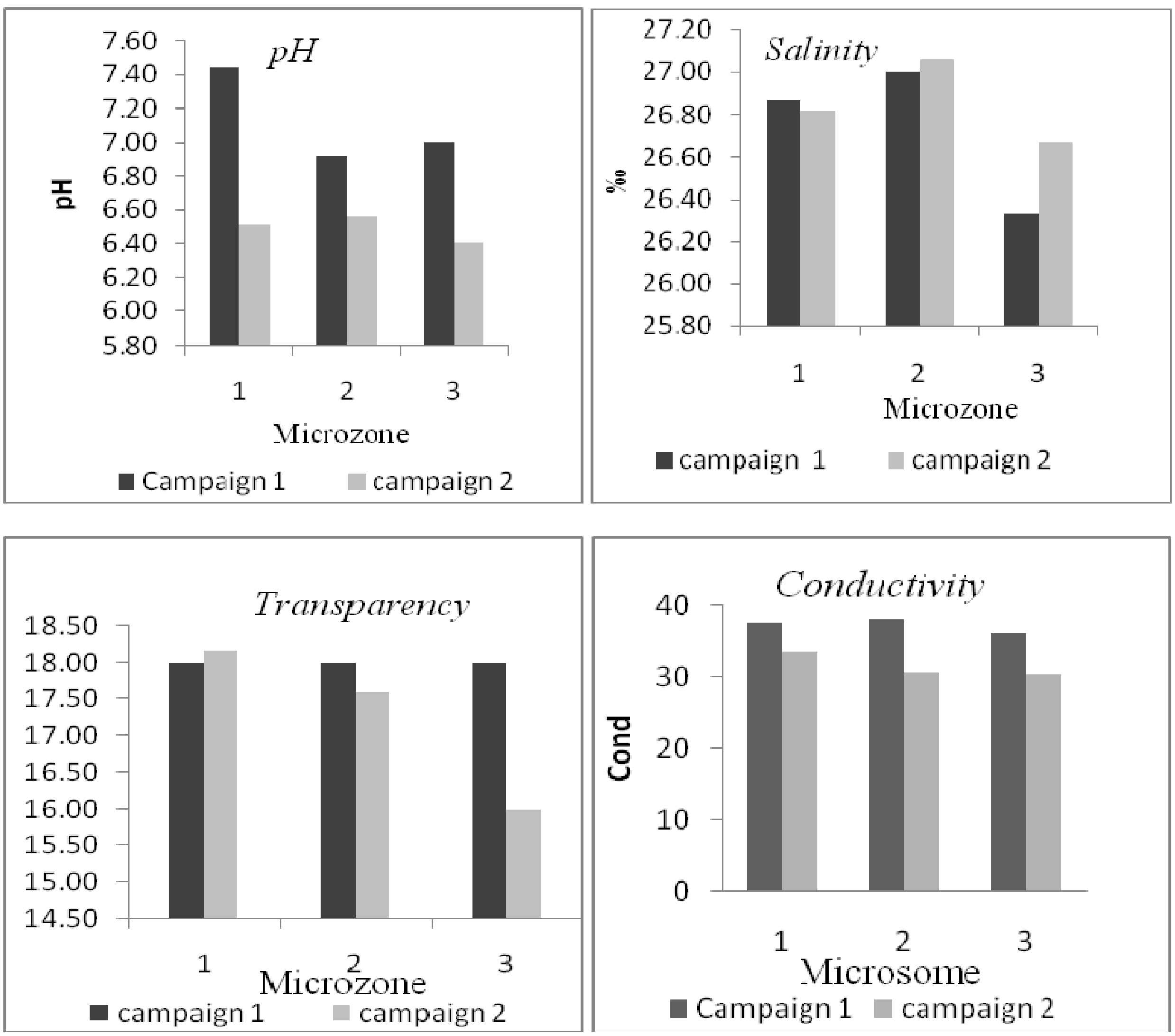
### 4.4 Substrate granulometry

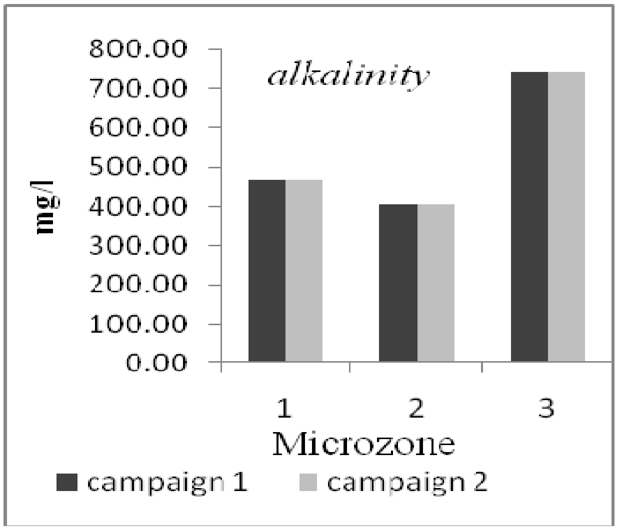
Five granulometrical classes were observed constituting the nature of the substrate along the lower Sanaga. The dominant class was in the lower than 0.25mm (fine sand) category. It could be explained by the situation of study area in an on-shore zone with inward washing of the substrate giving it a finer granulometry. The zone is intertidal and corresponds in the middle of life of the bivalves [23]. The clam prefers to grow in the highest part of the intertidal zone. in a substrate of sand-gravel nature [23]. It also lives a little in deep sediment [28]. Toupoint (2005) noted also that the growth of the clams was better in muddy environment that in sandy surroundings (coarse sand) [29].

**4.5 Correlation of substrate granulometry and clam metric variables**

The correlation between the granulometry of the substrate and the metric variables of the clams of the lower Sanaga revealed very little association between these different parameters. This may be due to the varied nature of this substratum that remained adequate to life and to the growth of the clams. However, a weak association was observed between the presence of the clams and the average granulometry that varies between 0.25 and 0.5mm (sand). Furthermore. the clam adjusts and develops itself buried in various types of substrata in intertidal zone [23, 28, 29]. These results corroborate those of Maitre - Allain (1992) who observed that clams live on many types of substrata : mud, sands and gravels, as well as those to mixed granulometry [30]. According to Caill-milly (2012), the clam also lives in varied sediments (muddy, sablo-muddy, sandy) [21]. She also observed them in zones associating gravels and silt. Being buried, the clams inhale in priority phyto-benthic elements and all rubbishes deposited on the neighbouring substrate [21]. According to the works of Kalyagina, the spatial distribution of the adults is of aggregative type (Kalyagina. 1994) [31].

**Annex 1:** Some physico-chemical characteristics of water during the sampling periods

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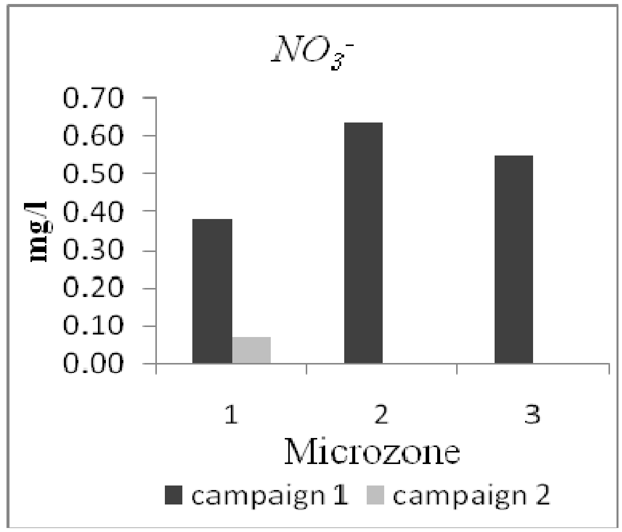
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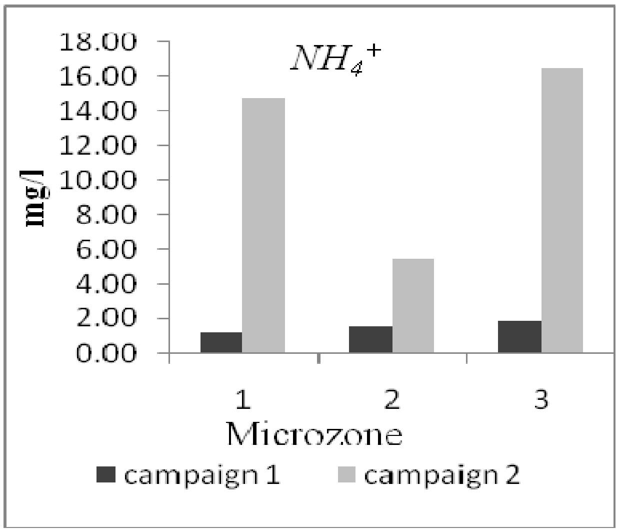
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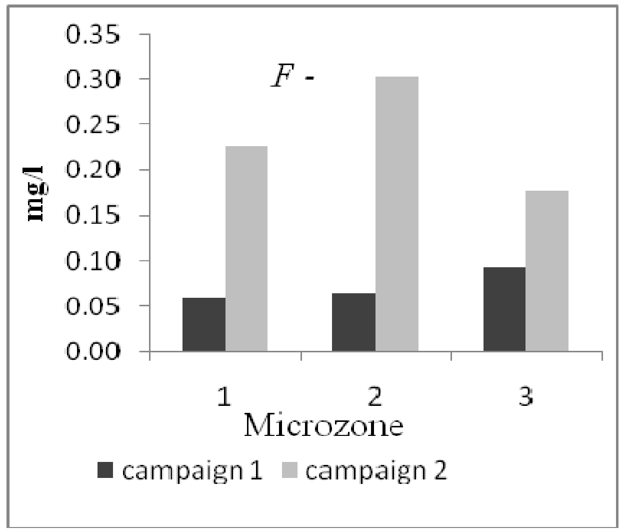
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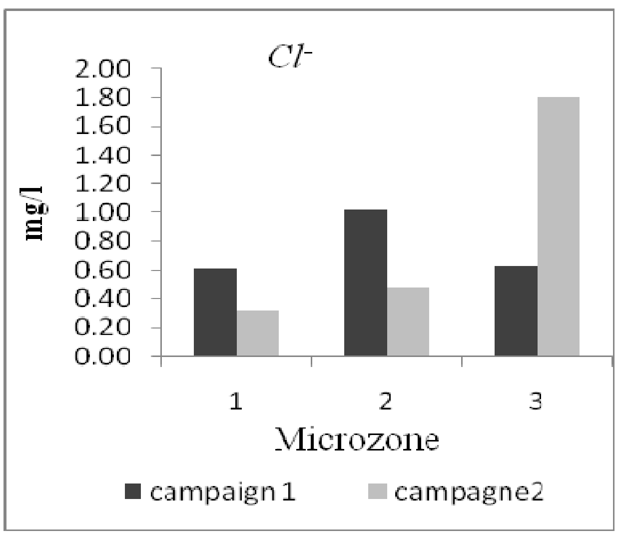
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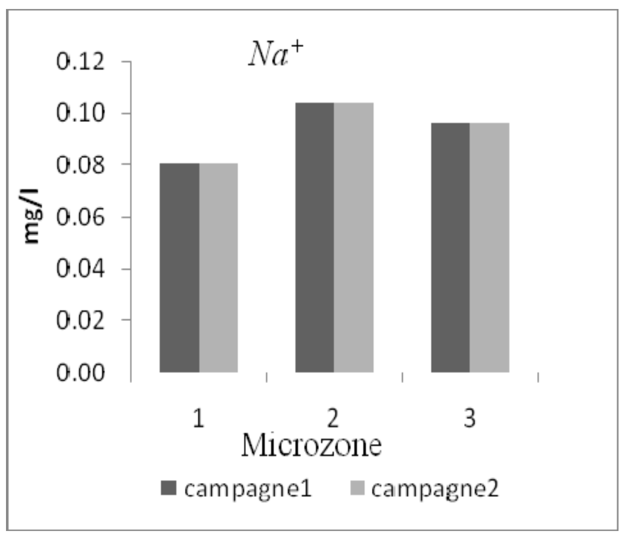
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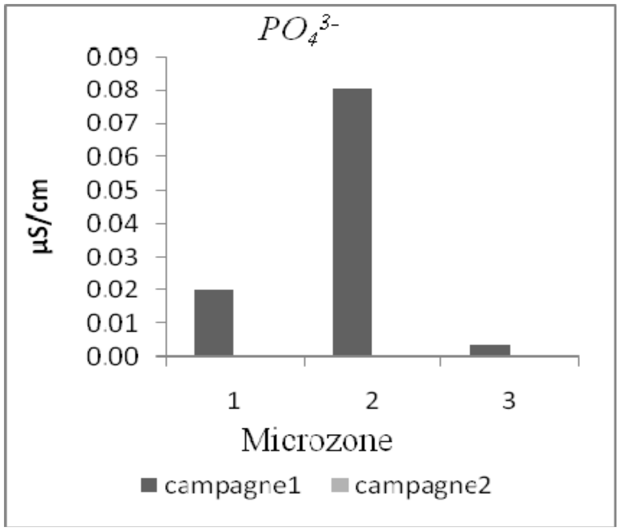


**Annex 2:** Correlation matrix of clam morphometrical and water physico-chemical characteristics

| Morphometrical Parameters | Physical and Chemical parameters | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Temp | pH | TDS | Transp | Salinity | F- | alc | Cl- | $NO^{3-}$ | $PO_4^{3-}$ | $SO_4^{2-}$ | Na+ | K+ | $HCO^{3-}$ |
| Compacity Index (R/L) | 0.167 | -0.270 | -0.396$^{*}$ | 0.212 | -0.423$^{*}$ | 0.167 | -0.075 | -0.004 | -0.279 | -0.224 | -0.373 | -0.158 | -0.033 | -0.305 |
| Elongation Index (H/L) | 0.460$^{*}$ | -0.344 | 0.218 | -0.117 | 0.149 | 0.235 | -0.208 | 0.075 | -0.104 | -0.144 | -0.252 | -0.249 | 0.102 | -0.300 |
| Convexity Index (R/H) | -0.043 | -0.111 | -0.512$^{**}$ | 0.281 | -0.502$^{**}$ | 0.059 | 0.022 | -0.042 | -0.223 | -0.152 | -0.251 | -0.043 | -0.082 | -0.168 |
| Weight (g) | 0.144 | 0.207 | -0.535$^{**}$ | 0.310 | -0.377$^{*}$ | -0.232 | 0.080 | 0.106 | 0.342 | 0.025 | 0.405$^{*}$ | -0.105 | 0.097 | 0.187 |
| Length (mm) | 0.174 | -0.764$^{**}$ | -0.009 | -0.140 | 0.009 | 0.798$^{**}$ | 0.025 | 0.054 | -0.695$^{**}$ | -0.347 | -0.855$^{**}$ | -0.072 | -0. 031 | -0.280 |
| Heigth (mm) | 0.190 | -0.766$^{**}$ | 0.019 | -0.161 | 0.026 | 0.802$^{**}$ | 0.019 | 0.066 | -0.691$^{**}$ | -0.348 | -0.855$^{**}$ | -0.096 | -0.030 | -0.288 |
| Buldiness (mm) | 0.145 | -0.655$^{**}$ | -0.196 | -0.003 | -0.185 | 0.662$^{**}$ | 0.012 | 0.033 | -0.625$^{**}$ | -0.314 | -0.769$^{**}$ | -0.094 | -0.058 | -0.311 |

## 5. Conclusion
The clams of the lower Sanaga are in general burrowing bivalves with predominating oval shell shapes. with nuances of yellow and brown coloration. They are met preferentially in substrate constituted of sand with hot temperatures and excessive salinity. polluted slightly by chemical compounds such as nitrate. ammonium. phosphate and chloride. There has been influence of some abiotic factors of water notably pH. sulphate. nitrate and fluoride on the metric parameters of clams especially height. length and bulge. This study strengthens the hypothesis that physical chemistry of water influences the growth and dynamics of clam populations.


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