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# Composition and distribution of aquatic molluscs in relation to water quality in rice and fish ponds in Daloa city (Centre-West, Côte d’Ivoire)

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**Abstract**
In this study, the aim was to highlight the influence of the physico-chemical quality of the water of rice ponds and fish ponds in the city of Daloa on the distribution of molluscs. This study was carried out from July to September 2020 and concerned 04 rice ponds and 04 fish ponds. The aquatic molluscs were collected using à turbid net (1 $m^2$ of sampled surface) and a Van Veen bucket (0.25 $m^2$ of sediment per sample). Physico-chemical analysis revealed that the waters of the fish pond were more alkaline and oxygenated. In contrast, the rice ponds were more mineralized. The inventory of molluscs showed the presence of 26 species divided into 10 families and 5 orders. The latter were more diversified and abundant in rice ponds (25 species and 4,606 individuals) than in fish ponds (17 species and 582 individuals). The influence of the water physico-chemical quality on the distribution of molluscs indicated that *Melanoides tuberculata* and *Aplexa marmorata* abounded in both excellent and good quality of water.

**Keywords:** Distribution, aquatic molluscs, water quality, rice and fish ponds, city of Daloa

## Introduction

The city of Daloa, located in the central-western part of Côte d'Ivoire, has a large number of lowlands. These lowlands are used for market gardening, rice cultivation and fish farming (Djéné, 2020) [1]. The food products (rice, cabbage, lettuce, etc.) and fish (*Oreochromis niloticus*, *Coptodon* sp., *Sarotherodon melanotheron*, etc.) produced in these wetlands contribute to the food self-sufficiency of the city's population. However, discharges from existing industrial and domestic activities in their watersheds contribute to considerable pressure on the rice and fish ponds in these areas. In addition, contaminants from agricultural inputs negatively influence the development of the biotope present (Djéné, 2020) [1]. These pressures result in the degradation of water quality and habitats in rice and fish ponds, which are essential for the survival of aquatic organisms, such as mollusks (Kiblut, 2002) [2]. The effects of these modifications are reflected in considerable changes in the species diversity and structure of mollusc populations (Bony *et al.*, 2013) [3]. Also, the proliferation of certain invasive mollusc species, intermediate hosts of certain diseases could constitute a public health risk for the populations of Daloa (Melhaoui, 2011) [4]. Thus, this study aims to show the influence of water quality of rice and fish ponds in the city of Daloa on the distribution of aquatic molluscs.

## Methods

### A. Study site

Daloa, the capital of the Haut-Sassandra region is located between 6°30'00" and 7°00'00" North latitude and between 6°00'00" and 6°30'00" West longitude (Djéné, 2020) [1]. It covers an area of 5305 hectares (RGPH, 2014) [5]. This city belongs to the Atenean climate characterized by two (02) seasons. One rainy which extends from March to October and the other dry going from November to February. The average monthly rainfall is between 6.21 and 183.34 millimeters, with an average temperature of about 28.53°C (N'Guessan *et al.*, 2014) [6].

### B. Sampling procedure

Eight (08) sampling stations were selected on four (04) fish ponds (EP1, EP2, EP3 and EP4) and four (04) rice ponds (ER1, ER2, ER3 and ER4) based on their accessibility and surrounding anthropogenic activities (Figure 1).

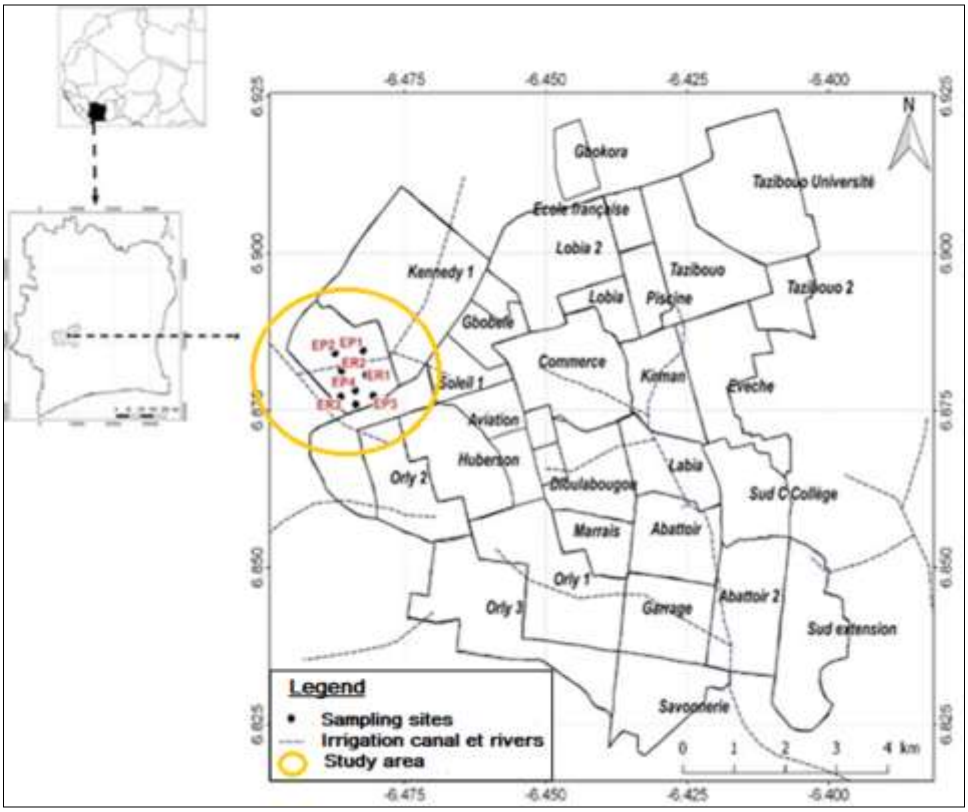



**Fig 1:** Location of sampling stations on a map of the city of Daloa

The collection of aquatic macroinvertebrates on the rice and fish ponds of the city of Daloa was conducted between July and September 2020. Sampling of pelagic macroinvertebrates was carried out using a 400 µm mesh net (2 m x 0.5 m, i.e., an area of 1 m²), and benthic macroinvertebrates using a Van Veen bucket (0.05 m x 3, i.e., an area of 0.15 m²) (Oertli *et al.*, 2005) [7]. Samples were stored in one-liter plastic jars containing 70% alcohol.

In the laboratory, mollusks were sorted from the total macroinvertebrates collected in a glass petri dish under a binocular loupe at 40 x magnification. The different molluscs specimens were counted and identified to the lowest possible specific level using identification keys and books suggested by (Mary, 2000 ; Brown, 2005) [8, 9]. The measurement of the physico-chemical parameters of the waters (conductivity, dissolved oxygen and pH) were carried out in situ between 06:00 and 08:00 in the morning.

**Data analysis**

The physico-chemical quality of the water in the fish and rice ponds of Daloa was determined from the European water standards defined by the Water Framework Directive (WFD, 2011) [10] (Table I). A Principal Component Analysis (PCA) was used to highlight the water quality classes in the Daloa fish and rice ponds compared to the WFD standards.

The composition and distribution of aquatic mollusks in the rice and fish ponds was highlighted by the frequency of occurrence "F" which determines the constancy of a species in a given habitat (Dajoz, 2000) [11]. F= Fi×100 / Ft. Where Fi is the number of surveys where species "i" appears and Ft is the total number of samples from the biocenotic unit considered.

The value of the frequency F was used to determine three (3) categories of species: F > 50% = Constant species; 25% ≤ F ≤ 50% = Accessory species and F < 25% = Accidental species (Dajoz, 2000) [11].

Only constant species from the different sampling sites that were considered in the relationship to physicochemical water quality.

The relative abundances of the main mollusc species were used to determine their distribution in relation to the ecological quality of the fish and rice ponds in Daloa. These species were those that represent at least 5% of the total number of molluscs collected at least one of the 08 sampling stations (Wasson *et al.*, 2002) [12].

**Table I:** Surface water quality classes according to the values of physicochemical parameters defined by WFD (2011) [10].

| Parameters | Values | Quality class |
|---|---|---|
| Conductivity | 100 – 750 µS/cm | Excellent |
| | 750-1300 µS/cm | Good |
| | 1300-2700 µS/cm | Average |
| | 2700-3000 µS/cm | Poor |
| | 3000 -7000 µS/cm | Very poor |
| Dissolved oxygen | >7 mg/L | Excellent |
| | 7-5 mg/L | Good |
| | 5-3 mg/L | Average |
| | 3-1 mg/L | Poor |

| | | |
|---|---|---|
| | <1 mg/L | Very poor |
| pH | pH < 7 | Acidic |
| | pH = 7 | Good |
| | pH > 7 | Basic |

**Results**

**Analysis of the physico-chemistry of water**

The maximum and minimum values of the physico-chemical parameters of the rice and fish ponds in Daloa were recorded in Table II. The pH values range from 7.1 (ER3) to 9.4 (EP4). Dissolved oxygen values range from 0.2 mg/L (ER4) to 9.8 mg/L (EP1). In contrast, conductivity values ranging from 110 µS/cm (ER4) to 565 µS/cm (EP4) were obtained in the rice ponds. The results showed that the waters of the fish and rice ponds in Daloa were basic with pH values above 7. Conductivity values were all below 700 µS/cm.The values of pH, conductivity and dissolved oxygen do not differed significantly in the rice and fish ponds (Kruskal-Wallis test, p-value > 0.05).

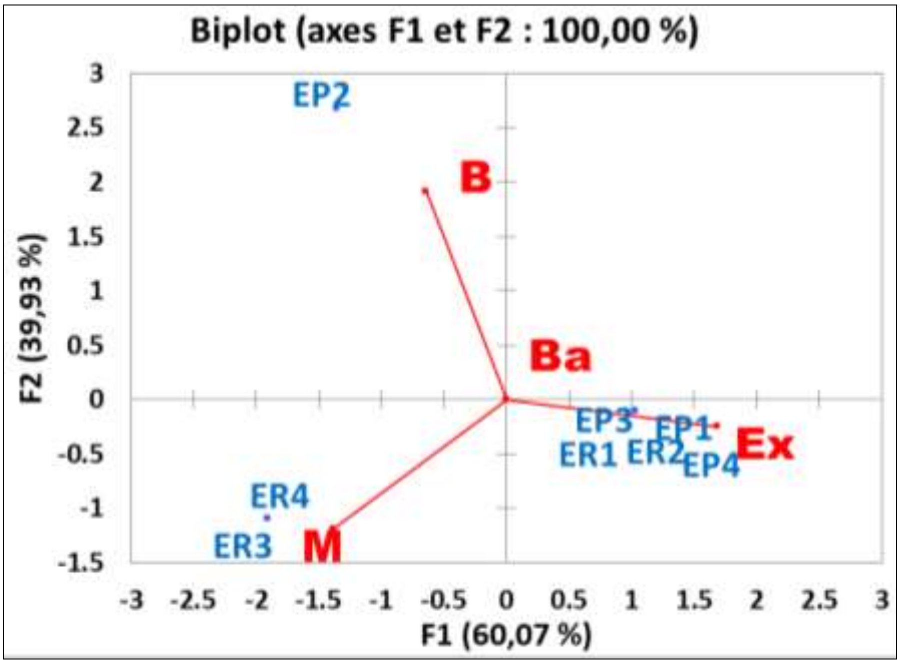
**Table II :** Maximum and minimum values of physico-chemical variables of rice and fish ponds in Daloa

| | | Fish Pond Stations | | | | Rice Pond Stations | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Parameters** | | **EP1** | **EP2** | **EP3** | **EP4** | **ER1** | **ER2** | **ER3** | **ER4** |
| pH | *Maxi* | 8,7 | 8,94 | 8,6 | 9,4 | 7,9 | 8,7 | 7,8 | 7,7 |
| | *Mini* | 7,5 | 8,6 | 7,7 | 7,8 | 7,7 | 7,3 | 7,1 | 7,3 |
| Conductivity (µS/cm) | *Maxi* | 175 | 550 | 170 | 565 | 525 | 500 | 400 | 375 |
| | *Mini* | 125 | 400 | 145 | 140 | 390 | 350 | 147 | 110 |
| Dissolved oxygen (mg/L) | *Maxi* | 9,8 | 7 | 12,1 | 9,5 | 13,1 | 13,5 | 3,0 | 2,9 |
| | *Mini* | 7,5 | 5 | 7,2 | 8,1 | 7,2 | 6,2 | 2,4 | 0,2 |

Max = Maximum value, Mini = Minimum value

**Physico-chemical quality of water**

A Principal Component Analysis was used to identify the water quality classes in the fish and rice ponds in Daloa. The results of this analysis reveal that the first two factorial axes explain 100% (F1 = 60.07%; F2 = 39.493%) of the total variability of the parameters. Projections on the axes of the graph show that on the F1 axis, the waters in the fish ponds (stations EP1, EP3 and EP4) and in the rice ponds (stations ER1 and ER2) were excellent quality for dissolved oxygen values greater than 7 mg/L and conductivity values less than 700 µS/cm. Also on this axis F1, the water at the rice ponds ER3 and ER4 was of poor quality, with values ranging from 1 to 3 mg/L. On the F2 axis, the water at the fish farm station EP2 is of good quality, with a dissolved oxygen value of between 5 and 7 mg/L.




Ex = excellent quality; Ba = basic water; B = good quality; M = poor quality, EP1, EP2, EP3 and EP4 = fish ponds and ER1, ER2, ER3 and ER4 = rice ponds

**Fig 2:** Fish and rice ponds of Daloa water quality according Physico-chemical parameters.

**Analysis of the mollusc population**

Table III presents population of the fish and rice ponds of Daloa. The inventory the specific composition and occurrences of the aquatic mollusc showed the presence of 26 species belonging to 10 families and 5 orders. The rice ponds with 25 species were more diversified than the fish ponds (17 species). The order Basommatophores (13 species) was the most diverse. However, Stylommatophores and Sorbeoconcha with 1 species each were the least species rich. *Aplexa marmorata* and *Melanoides tuberculata* were collected in all stations. Moreover, these species were constantly met in the rice ponds. In addition, *Aplexa marmorata* was incidental to the fish ponds.

**Table III :** Specific compositions and occurrences of aquatic molluscs of fish and rice pond of the city of Daloa.

| | | | | **Fish Pond Stations** | | | | **Rice Pond Stations** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Orders** | Famillies | Species | Acr | EP1 | EP2 | EP3 | EP4 | ER1 | ER2 | ER3 | ER4 |
| **Basommatophores** | Ampullariidae | *Lanistes ciliatus* | Lan | - | - | - | * | - | * | ** | ** |
| | | *Lanistes ovum* | Lao | - | - | * | - | ** | * | - | *** |
| | | *Pila ovata* | Pio | - | * | - | * | * | *** | *** | * |
| | Lymnaeidae | *Lymnaea truneatula* | Lym | - | - | * | - | * | * | *** | *** |
| | Physidae | *Aplexa marmorata* | Apl | ** | * | ** | ** | *** | *** | *** | *** |
| | | *Aplexa waterloti* | Apw | - | - | - | - | - | - | * | * |
| | Planorbidae | *Afrogyrus* sp. | Afr | - | - | *** | ** | * | - | - | - |
| | | *Biomphalaria glabrata* | Bio | - | - | - | - | - | - | - | * |
| | | *Bulinus beccarii* | Bub | - | - | - | - | *** | - | *** | * |
| | | *Bulinus forskali* | Buf | - | - | * | - | ** | * | *** | * |
| | | *Bulinus nyassanus* | Bun | - | - | - | - | - | - | * | ** |
| | | *Bulinus tropicus* | But | - | | *** | - | * | * | ** | ** |
| | | *Gyraulus corinna* | Gyr | - | - | * | - | - | - | - | - |
| **Littorinimorpha** | Pomatiopsidae | *Tomichia differens* | Tod | * | - | *** | - | *** | ** | * | ** |
| | | *Tomichia rogersi* | Tor | - | * | - | - | * | - | *** | *** |
| | | *Tomichia ventricosa* | Tov | - | - | - | - | ** | * | ** | *** |
| | | *Tomichia zwellendamensis* | Toz | - | - | * | - | * | ** | - | ** |
| | Tateidae | *Hemistomia* sp. | Hes | - | - | - | - | * | - | - | - |
| **Mésogastéropodes** | Bithyniidae | *Bithynia tentaculata* | Bit | - | - | - | - | - | * | * | * |
| | | *Gabbiella africana* | Gab | - | - | - | - | * | * | * | ** |
| | | *Liminitesta sulcata* | Lis | - | - | ** | - | * | * | * | * |
| | Hydrobiidae | *Cleopatra bulimoides* | Cle | * | - | * | - | ** | *** | *** | * |
| | | *Lobogenes michaelis* | Lob | - | - | * | * | ** | - | - | - |
| | | *Lobogenes pusilla* | Lop | - | - | - | - | * | - | * | - |
| **Sorbeoconcha** | Thiaridae | *Melanoides tuberculata* | Met | ** | * | *** | *** | *** | *** | *** | ** |
| **Stylommatophores** | Succineidae | *Oxyloma patentissima* | Oxp | - | - | - | ** | * | - | * | * |
| **Total = 5** | 10 | 26 | | 4 | 4 | 13 | 7 | 20 | 15 | 19 | 21 |
| **Number of species per pond type** | | | | 17 | | | | 25 | | | |

Acr= Acronyms; *** = Constant species; ** = Incidental species; * = Incidental species; - Absent species.

**Distribution of molluscs according to water quality**

Table IV presents the relative abundances of the main mollusc species according to the water quality classes of the fish and rice ponds in Daloa. In fish and rice ponds of excellent quality, *Melanoides tuberculata* was more abundant, this species represents 80% at station EP3. However, *Cleopatra bulimoides* (station EP4), *Tomichia differens* (station ER2), *Bilinus tropicus* (stations EP4 and ER2) and *Bilinus forskali* (station ER1), were less abundant with 1% each. In fish pond 2 (station EP2) of good quality, *Melanoides tuberculata* (91.67%) is predominant. In contrast, *Aplexa marmorata* (2.33%) was less abundant. For rice ponds 3 and 4 (ER3 and ER4) of poor ecological quality, *Aplexa marmorata* (32%) was in high numbers. In contrast, *Afrogyrus rodrignezensis* (ER3 station) and *Bilinus forskali* (ER4 station) were poorly represented with 1% each.

**Table IV :** Relative abundances (in %) of the main mollusc species according to water quality classes in the fish and rice ponds of Daloa between July and September 2020.

| | **Qualities according to the stations** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | EP1 | EP3 | EP4 | ER1 | ER2 | EP2 | ER3 | ER4 |
| **Species** | Ex | Ex | Ex | Ex | Ex | B | M | M |
| *Pila ovata* | - | - | 3 | 2 | 6,84 | 6 | 17 | 2,12 |
| *Lymnaea truneatula* | - | - | - | - | 1,16 | - | 14,12 | 31,45 |
| *Aplexa marmorata* | 10,6 | 1,18 | 34 | 10 | 10,68 | 2,33 | 10 | 32 |
| *Afrogyrus rodrignezensis* | - | 4 | 7 | - | - | - | - | 1 |
| *Bilinus forskali* | - | 1,9 | - | 1 | - | - | 1 | 7 |
| *Bilinus tropicus* | - | 6 | 1 | - | 1 | - | 6,38 | 5 |
| *Tomichia differens* | 4,7 | 5,89 | - | 6 | 1 | - | 5 | 8,43 |
| *Cleopatra bulimoides* | 10,6 | 1,03 | 1 | 11 | 26,9 | - | 30 | 5 |
| *Melanoides tuberculata* | 74,1 | 80 | 54 | 70 | 52,42 | 91,67 | 16,5 | 8 |

Ex = Excellent, G = Good, P = Poor, - = No molluscs

**Discussion**

The objective of this study was to show the influence of water quality on the distribution of aquatic molluscs in rice and fish ponds in the city of Daloa. The analysis of the physico-chemistry indicates that the highest average values of pH and dissolved oxygen were recorded in the fish pond. The high alkalinity of the waters of the fish ponds would be linked on the one hand to the ferralitic soil of Daloa made

up of limestone rocks, which by altering under the action of water release calcium and carbonate ions (Djéné, 2015) [13]. On the other hand, this situation would be explained by the process of decomposition of organic matter (food and fish excreta) accumulated in these ponds (González *et al.*, 2004) [14]. This phenomenon leads to a high content of certain chemical elements (nitrites, iron..) in the water of fish ponds, which is responsible for their high alkalinity. In addition, the high oxygenation of water in fish ponds could be due to a strong photosynthetic activity related to the penetration of solar radiation in the water column (Komoé *et al*. 2009) [15]. On the other hand, the high conductivity observed in rice ponds would be due to the use of phytosanitary products and agricultural fertilizers which favors the concentration of nutrients (phosphorus, nitrate, nitrite...) responsible for the mineralization of the water (Edia, 2008) [16]. In addition, contamination of rice pond water by household waste, sewage and human excreta from households located around the lowlands contributes to the high mineralization of these waters (Yapo *et al.*, 2010) [17].
The population analysis showed that molluscs were more diversified and abundant in rice pond. This would be due to the trophic chain in the fish ponds. Indeed, fish in these ponds *Oreochromis niloticus, Coptodon sp., Hemichromis bimaculatus, Sarotherodon melanotheron* and *Clarias anguillaris* feed on invertebrates such as mollusks (Morin *et al.*, 2010) [18]. However, the high diversity and abundance of molluscs at rice ponds was thought to be related to farming. Rosa *et al.* (2010) [19] showed that the use of agricultural fertilizers increases the growth and diversity of molluscs.
The result relating to the distribution of the main mollusc species according to the physico-chemical quality of the water in the fish and rice ponds of Daloa indicated the strong proliferation of *Melanoides tuberculata* in water of excellent and good quality. This result corroborates that of Bony (2008) [20], who during his work in Côte d'Ivoire on the Mé, Agnéby and Banco basins showed that *Melanoides tuberculata* can proliferate in polluted waters as well as in waters of good quality. For this author, this situation would be linked to the fact that this species was not a great ecological requirement. Moreover, the strong proliferation of *Melanoides tuberculata* and *Aplexa marmorata* in the fish and rice ponds of Daloa was due to their rapid growth. Indeed, *Aplexa marmorata* reproduces by self-fertilization and *Melanoides tuberculata* by parthenogenesis (a mode of reproduction where the ovule develops without fertilization) (Pointier *et al.*, 1989) [21].

## Conclusion

The present study made it possible to relate the physico-chemical quality of the water in the rice and fish ponds of the city of Daloa to the distribution of molluscs. Water analysis revealed that pH and dissolved oxygen values were higher in the fish ponds. The highest conductivity values were found in the rice pond.
The inventory of molluscs in the rice and fish farming systems of Daloa indicated 26 species divided into 10 families and 5 orders. The rice ponds were more diverse than fish ponds. The distribution of molluscs species in relation to the water physico-chemical quality defined according to the WFD quality standard indicated that *Melanoides tuberculata* proliferated in waters of excellent and good quality. However, *Aplexa marmorata* was more abundant in waters of poor ecological quality.
In view of the domestic discharges (household waste, wastewater) in these wetlands, the bio-monitoring of these environnements was necessary.

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