**Impact of Floating Cage, Suspension, and Bottom Culture Techniques on the Growth and Survival of the Mangrove Oyster *Crassostrea tulipa* in the Coastal Lagoon of Ouidah, Southern Benin**

**Aims:** Oyster farming remains an underdeveloped sector in West Africa, despite the importance of oysters in providing essential protein for local populations. The study aimed to compare the effectiveness of three farming techniques (floating cage, suspension, and bottom culture) in improving oyster growth.

**Study design:** The study was carried out by rearing 640 mangrove oyster *Crassostrea tulipa* spat using three culture techniques (Floating Cage, Suspension technique and Bottom Culture) in four stations. At each station, 180 specimens of oyster were reared in the three farming techniques: floating cage (60 oysters), suspension technique (60 oysters) and bottom culture (60 oysters).

**Place and Duration of Study:**The specimens used in the study were collectedin Djondji village in coastal lagoon of Ouidah (Benin) and cultured during 60 days from September to October 2022 in four stations (Djègbadji, Sèyigbé, Dégouè, and Azizakouè) distributed along the lagoon.

**Methodology:** For each technique, juvenile oysters (3.2 cm in length) were reared in locally adapted materials. Shell length, weight, and number of live and dead specimens were recorded at regular two-day intervals. Dead specimens are counted and removed from trials to assess mortality rates. Growth parameters (*K* and *L∞*) from the Von Bertalanffy equation, daily growth rate (GR), and survival rate were estimated for each trial.

**Results:** The *K* values ranged between 0.046–0.041 day⁻¹, 0.065–0.064 day⁻¹, 0.063–0.060 day⁻¹, and 0.041–0.033 day⁻¹ for floating cage and suspension techniques at Djègbadji, Sèyigbé, Dégouè, and Azizakouè, respectively higher than those obtained for traditional bottom culture (0.030, 0.017, 0.009, and 0.012 day⁻¹ at the same stations). Daily growth rates reached 3–2.667 cm/day with floating cages, 2.667–2.5 cm/day with suspension culture, and 0.667–0.5 cm/day with bottom culture. Survival rates were significantly higher (86.67–96.67%) with the new techniques compared to traditional farming (48–50%).

**Conclusion:** *Crassostrea tulipa* exhibited better survival and growth performance with the new techniques, particularly in floating cages, suggesting promising prospects for its aquaculture.

**ABSTRACT**

**Keywords:** Coastal lagoon, *Crassostrea tulipa*, oyster farming, suspension culture, floating cage culture, bottom culture.

1. **INTRODUCTION**

Oysters, marine bivalve molluscs, are ubiquitous in temperate and tropical coastal ecosystems, and their aquaculture has expanded over the decades due to their dietary, economic, and ecological importance (Dias et al., 2022). Among these species, mangrove oysters of the genus *Crassostrea*, particularly *Crassostrea gasar* and *Crassostrea tulipa*, play a crucial role in water filtration and coastal sediment stabilisation (Akélé et al., 2017). Studies by Chuku et al. (2021) highlight the socioeconomic significance of molluscs, especially crustaceans, in West Africa. Recent research confirms that *Crassostrea tulipa* is the only oyster species existing in West Africa (Dye et al., 2023). Earlier work by Boudry et al. (2022) elucidated the adaptive mechanisms of mangrove oysters in these regions, demonstrating their resilience to climate change and salinity fluctuations.

Beyond their role as a food source, oysters are ecologically vital. Dias et al. (2022) noted that *Crassostrea tulipa* harvested from mangroves contributes to food security and local livelihoods while supporting biodiversity by providing habitats for other marine species. As filter feeders, oysters help purify coastal waters. Economically, they sustain coastal communities through artisanal fishing and aquaculture (Akélé et al., 2017). Despite these benefits, mangrove oyster farming remains marginal in most African countries, except in Senegal, where it has achieved notable success. Mendy et al. (2023) found that *Crassostrea gasar* aquaculture could benefit from integrated mangrove ecosystem management, balancing conservation and profitability.

In Benin, the mangrove oyster *Crassostrea tulipa* is primarily harvested in the southern region, particularly in Lake Nokoué, where it thrives among *Rhizophora racemosa* mangroves (Akélé et al., 2022). Locally known as "Adakpin" (Fon) or "Atcha" (Aïzo), these oysters are part of inland fisheries and play a key role in local diets and mangrove ecosystem management, which protects coastlines from erosion and sustains biodiversity (Adjahoussou et al., 2020). However, small-scale exploitation persists, and oyster farming remains limited due to technical and ecological constraints.

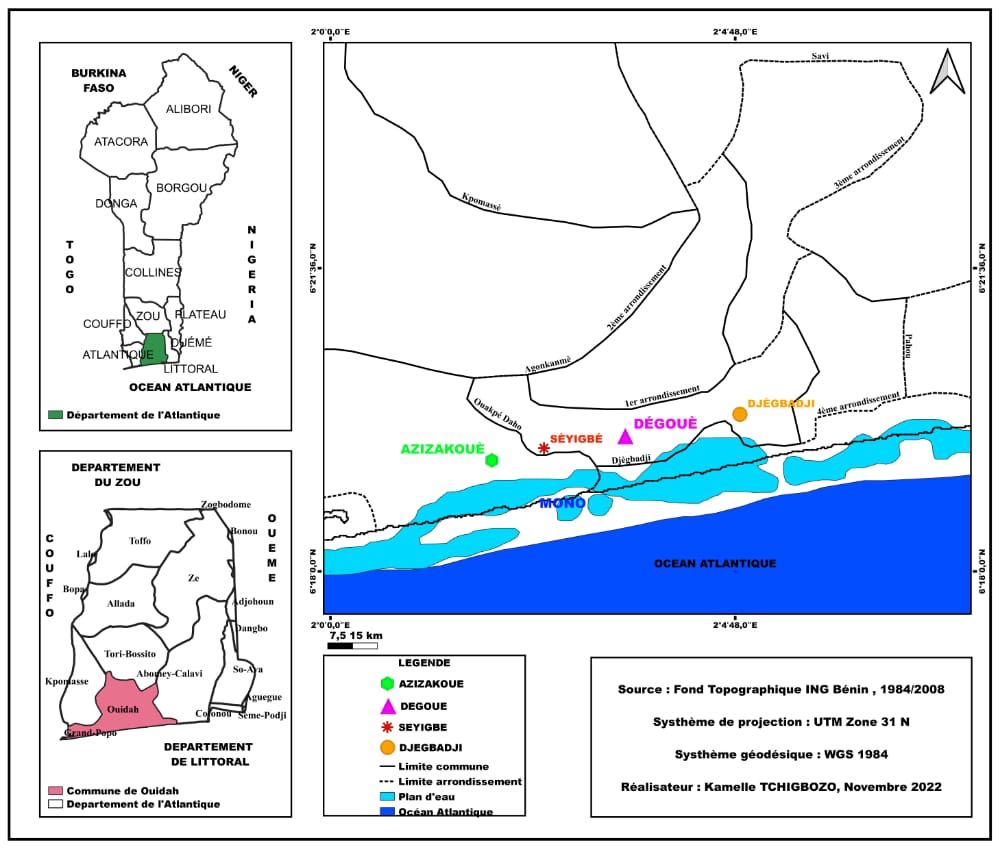
The potential for sustainable *Crassostrea tulipa* aquaculture in the Ouidah coastal lagoon (southern Benin) offers an opportunity to enhance mangrove conservation while supporting local food supplies. Recent studies (Lemaître et al., 2021) suggest that combining suspension, bottom, and cage culture techniques could improve productivity while minimising environmental impacts on these fragile ecosystems.

This study explores innovative aquaculture techniques for *Crassostrea tulipa*, aiming to optimise production while preserving mangroves and enhancing ecosystem resilience in the Ouidah coastal lagoon amid current ecological and climatic challenges.

1. **MATERIALS AND METHODS**

The coastal lagoon comprises two sections: the Grand-Popo Lagoon and the Ouidah Lagoon. The Ouidah Lagoon, located in southern Benin, covers 4,000 hectares and is fed by upstream freshwater and downstream marine inflows. It supports diverse fish, shrimp, turtle, oyster, and mangrove species. During high-water periods, the lagoon connects to low-lying areas, many of which have been dredged for sand extraction, forming artificial lakes. Local livelihoods depend on fishing, agriculture, salt production, and sand mining (Lalèyè, 2019).

Four village (Djègbadji, Dégouè, Sèyigbé, and Azizakouè) were selected as experimental sites (Fig 1) based on traditional oyster farming practices, local community engagement, accessibility, and phytoplankton abundance.



**Fig. 1. Experimental sites in the Ouidah Lagoon**

**2.1. Collection of juveniles and experimental setup**

The oysters were collected in Djondji, a village near Sèkanmin and close to Gbato, by women harvesters from Djondji. They were then transported at 7:00 AM from Djondji to the various experimental sites. The experiment began on September 1st and ended on October 30th. In total, 640 spat specimens were purchased in Djondji. The spat size ranged between 3 and 3.5 cm, with 180 specimens allocated to each of the four selected sites. The distribution of oysters was 60 specimens each for cage, suspension and bottom culture. At each station, three culture techniques were tested: floating cage culture, suspension culture, and bottom culture. The oyster stocking density in cages was the first step in the cage culture technique.

* 1. **Stocking in cages**

For the stocking process, the spats were sorted, separated from each other, and counted. They were then placed in the cagesdesigned to be closable while remaining open for measurements.

* 1. **Floating cage culture**

For this technique, fine-mesh galvanised wire grids were purchased to make the cages. The cages used measured 85 cm × 40 cm. The wooden frame for these cages was constructed using *Zanthoxylum zanthoxyloides* (Fagara), locally called "*Hêtin*". These wooden frames were arranged in a shelved configuration measuring 1m × 1m, on which the cages were placed side by side at 70 cm above ground and 30 cm below the water surface. The cages were secured with plastic ropes. For suspension culture, the attachment of oysters is the crucial step. (Fig. 2a)

* 1. **Oyster attachment**

To attach oysters to the ropes, they are arranged in pairs between the ropes at regular intervals of approximately 10 cm. The right valve is placed against the rope, and the inner hinges of the two oysters must touch to ensure secure attachment. A mixture of cement and water, with a consistency similar to strong cement, is applied between the rope and oysters. Drying is carried out for 24 hours.

* 1. **Suspension culture**

For this technique, white ropes were used to attach oysters in pairs using strong cement. The ropes were cut with scissors to a length of 1m each. The oysters are arranged in pairs, spaced 10 cm apart on the rope. Then, three wooden stakes of *Zanthoxylum zanthoxyloides* were placed in the water, forming an open rectangle on which the oyster-bearing ropes were attached. The oysters are then submerged between the surface and up to one meter (1m) depth.

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| (a) | (b) |
| **Fig. 2.** Farming techniques: (a) Floating cage system; (b) Setting up the suspension rearing system | |

* 1. **Bottom culture or traditional culture**

For this technique, the oysters were placed at the bottom of the water after being sorted and separated from each other. This is the control technique, practised daily by women oyster farmers.

* 1. **Monitoring methods and data collection**

The experiment lasted sixty (60) days, or two (02) months, between September 1 and October 30. Shell length, weight, and the number of live and dead specimens were recorded at regular intervals of two days, early in the morning between 6 and 7 AM. Data were collected on the sites in rotation. Dead specimens were counted and removed from the trials to assess mortality rates. Monitoring of physicochemical parameters (conductivity, salinity, pH, temperature, TDS) was conducted throughout the experiment to understand environmental conditions (every ten (10) days). The physicochemical parameters were measured by collecting water samples from the lagoon at each station. Then, the probes of the measuring equipment were immersed in the collected water to obtain the values for each parameter.

* 1. **Data processing and statistical analyses**

The linear growth rate was estimated for oysters cultured in the different stations. Among the various equations used in the literature to describe mollusc growth curves, the Von Bertalanffy growth function provides the best growth fit for bivalve (Lévêque, 1971). The growth equation is as follows (Von Bertalanffy, 1938):

Lt = L∞(1 - e^(-K(t - t0)))

Where:

* Lt = size of the animal at time t;
* L∞ = maximum size at infinity, the maximum size the oyster can approach;
* K = growth constant, indicating the speed at which the size approaches L∞;
* t = age (expressed in days, months, years, etc.);
* t0 = hypothetical time at which the animal would have had a size of 0.

The infinite length or size L∞, determined by the intersection of the regression line with the y-axis (L in cm), corresponds to a zero-growth rate. It is an estimate of the theoretical maximum average size based on observational data (Knight, 1968). The growth parameters (K and L∞) of Von Bertalanffy were estimated using the Ford-Walford method (Walford, 1946). Thus, the length (Lt+1) at age t+1 (in months) is constructed as a function of the length (Lt) at age t. The equation of the best-fit regression line is of the form: Y = α + βx, where β is the slope and α is the y-intercept. L∞ is given by the formula: L∞ = [α / (1 - β)].

The growth rate K is calculated as the natural logarithm of the inverse of the slope, according to the formula (Gulland, 1969): K = ln (1 / β).

Additionally, the mean growth rate (GR) or growth increment was estimated using the formula:  
GR = (Xt+1 - Xt) / D

Where:

* Xt+1 = mean shell length (cm) at the end of the current month,
* Xt = shell length in the previous month,
* D = number of days between two consecutive observations (Paterson et al., 2003).

The survival rate was calculated using the formula:

SR (%) = (Nf / Ni) × 100,

Where:

* Ni = initial number of individuals,
* Nf = number of individuals at the end of the experiment.

Growth parameters between culture techniques were compared by experimental site using a Kruskal-Wallis test. When these tests revealed significant differences, post-hoc (LSD) comparisons were performed. For each experimental site, survival rates were compared using the χ² test. Differences were considered significant at the 5% threshold for all analyses. Statistical tests were performed using Statistica software.

A Kruskal-Wallis test was conducted for physicochemical parameters (pH, temperature, conductivity, salinity, TDS), and variation diagrams of these parameters by station were plotted in Excel for interpretation.

1. **Results**

**3.1. Variation of physicochemical parameters by site**

**3.1.1. Variation of temperature and TDS across different sites**

The results obtained in this study showed that the average water temperature values in the different stations were 28.18°C at Sèyigbé, 28.27°C at Djègbadji, 28.95°C at Azizakouè, and 29.16°C at Dégouè (Fig. 3a). The trend of the curves for each site was almost identical from day 0 (J0) to day 60 (J60). A sharp increase in temperature was observed from day 20 (J20), peaking on day 30 (J30), corresponding to the end of the low-water period. A drop in temperature was then noted from day 30 (J30) to day 40 (J40), followed by an increase from day 40 (J40) to day 50 (J50), marking the beginning of the flood period (Fig.3a).

The ANOVA test showed no significant differences between stations for mean TDS values. Overall, the highest values were recorded at Djègbadji (8501 mg/L) and Azizakouè (8148 mg/L) at the end of October (J30) (Fig.3b).

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| **(a)** | **(b)** |
| **Fig.3. Temperature and TDS variation across experimental sites** | |

**3.1.2. Variation of pH at the different stations**

The pH of analysed waters ranged from 7.2 to 7.93, showing near uniformity across selected stations in the Ouidah Lagoon (Fig 4). The highest pH values were recorded at Dégouè.

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| **Fig.4: pH variation across experimental sites** |

**3.1.3. Variation in Conductivity and Salinity Across Different Stations**

Recorded conductivity values across sites ranged from 14.06 µS/m to 19.42 µS/m (Fig. 7), reflecting the saline conditions of Ouidah Lagoon waters. Salinity curves showed consistent patterns across stations, with minimum values of 0.77% (7700 mg/L) at Dégouè and maximum values of 0.99% (9900 mg/L) at Djègbadji (Fig.5).

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| **(a)** | **(b)** |
| **Fig.5*.* Conductivity and salinity variation across experimental sites** | |
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**Table 1.** Kruskal-Wallis test of physicochemical parameters

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| --- | --- | --- | --- | --- | --- |
| **Zone** | **Temperature** | **TDS** | **pH** | **Conductivity** | **Salinity** |
| **Azizakouè** | 29.51 ± 1.56 | 4642.86± 2342.26 | 7.5 ± 0.25 | 16.64 ± 2.45 | 0.92 ± 0.07 |
| **Dégouè** | 28.77 ± 1.73 | 5171.43± 2332.89 | 7.62 ± 0.3 | 16.44 ± 2.49 | 0.89 ± 0.08 |
| **Djègbadji** | 29.03 ± 1.36 | 5614.29 ± 2210.9 | 7.36 ± 0.2 | 17.01 ± 2.47 | 0.93 ± 0.07 |
| **Sèyigbé** | 28.94 ± 1.94 | 5371.43± 2064.55 | 7.47 ± 0.27 | 16.51 ± 2.32 | 0.92 ± 0.08 |
| **F-value** | 0.2577 | 0.2381 | 1.207 | 0.0763 | 0.3063 |
| **P-value** | 0.8551 | 0.8689 | 0.3285 | 0.9722 | 0.8205 |

The statistical analysis of physicochemical parameters measured across the four zones (Azizakouè, Dégouè, Djègbadji, and Sèyigbé) revealed p-values for temperature (p=0.8551), TDS (p=0.8689), pH (p=0.3285), conductivity (p=0.9722), and salinity (p=0.8205) all substantially exceeding the 0.05 significance threshold (Table 1). This indicates no statistically significant differences between zones for any of these parameters. In other words, the observed variations in mean values were minimal and likely attributable to random variation.

* 1. **Survival Rate**

The survival rate of oysters ranged from 66.67% to 96.67% with the new culture techniques (Tables 2, 3, 4, 5). In contrast, survival rates in traditional culture ranged from 42% to 50% (Tables 2, 3, 4, 5). A clear difference was observed between the survival rate values (p > 0.05).

* 1. **Growth Parameters of Oysters Cultured at Djègbadji**

After a one-week adaptation phase, oysters in floating cages show accelerated growth from 3.4 cm (D5) to 5 cm (D60), an increase of 1.6 cm. Suspension-cultured oysters grew from 3.3 cm (D5) to 4.8 cm (D60), an increase of 1.5 cm. In contrast, bottom-cultured oysters showed linear growth from 3.2 cm (D5) to 3.6 cm (D60), an increase of 0.4 cm. Thus, shell growth in floating cages was slightly greater than in suspension culture and double that of bottom-cultured individuals (Fig 6).

The Von Bertalanffy growth parameters for traditional culture (K = 0.005 day⁻¹, L∞ = 1.028 cm) were lower than those for suspension culture (K = 0.041 day⁻¹, L∞ = 7.185 cm), which in turn were lower than floating cage culture (K = 0.046 day⁻¹, L∞ = 7.525 cm). The growth rate (GR) of oysters in floating cages (3 cm/day) was 1.12 times higher than in suspension culture (2.667 cm/day) and 4.49 times higher than in bottom culture (0.667 cm/day) (Table 2).

Fig7 presents the Von Bertalanffy growth curves of oysters over time, showing an exponential pattern. Oysters reached commercial size (6.7 cm) earlier (day 60) with traditional methods compared to suspension and floating cage techniques.

**Table 2.** Growth parameters of the von Bertalanffy curve, growth rate and survival rate of oysters cultured at Djègbadji and Azizakoue

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| **Stations** | **Djègbadji** | | | **Azizakoue** | | |
| **Farming techniques** | Bottom culture | Floating cage | Suspension technique | Bottom culture | Floating cage | Suspension technique |
| **K (Day-1)** | 0.005 | 0.046 | 0.041 | 0.012 | 0.081 | 0.073 |
| **L∞ (cm)** | 1.028 | 7.525 | 7.185 | 4.604 | 6.03 | 5.728 |
| **Growth rate (cm/day)** | 0.667 | 3 | 2.667 | 0.5 | 2.667 | 2.5 |
| **Growth rate(cm/month)** | 20 | 90 | 80 | 15 | 80 | 75 |
| **Survival rate (%)** | 50 | 96.67 | 76.67 | 48 | 93.33 | 80 |
| **pvalues**> 0.05 | | | | | | |

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| **Fig.6. Mean shell length growth of oysters in floating cages, suspension culture, and bottom culture at Djègbadji** | **Fig.7. Von Bertalanffy growth curve of juvenile *C. tulipa* at Djègbadji** |

**3.2.1. Growth Parameters of Oysters Cultured at Azizakouè**

The average size of oysters in floating cages increased from 3.3 cm (D5) to 4.8 cm (D60), a growth of 1.5 cm. Suspension-cultured oysters grew from 3.3 cm (D5) to 4.7 cm (D60), an increase of 1.4 cm. In contrast, bottom-cultured oysters showed linear growth from 3.2 cm (D5) to 3.5 cm (D60), gaining only 0.3 cm. Thus, floating cage oysters exhibited slightly greater growth than suspension-cultured oysters and double that of bottom-cultured specimens (Fig8).

The Von Bertalanffy growth parameters for traditional culture (K=0.012 day⁻¹, L∞=4.604 cm) were lower than those for suspension culture (K=0.073 day⁻¹, L∞=5.728 cm), which in turn were lower than floating cage culture (K=0.081 day⁻¹, L∞=6.03 cm). The growth rate (GR) of floating cage oysters (2.667 cm/day) was 1.06 times higher than suspension culture (2.5 cm/day) and 5.34 times higher than bottom culture (0.5 cm/day) (Table 3).

Fig 9 shows the over-time Von Bertalanffy growth curves, displaying exponential patterns. Oysters reached commercial size (6.7 cm) earlier (day 60) with traditional methods compared to suspension and floating cage techniques.

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| **Fig.8. Mean shell length growth of oysters in floating cages, suspension culture, and bottom culture at Azizakouè** | **Fig.9. Von Bertalanffy's growth curve of juvenile *C. tulipa*inAzizakouè** |

**3.2.2. Growth Parameters of Oysters Cultured at Sèyigbé**

The average size of specimens from floating cage culture increased from 3.4 cm (D5) to 4.9 cm (D60), representing a growth of 1.5 cm. Suspension-cultured oysters grew from 3.3 cm (D5) to 4.8 cm (D60), also showing a 1.5 cm increase. In contrast, bottom-cultured oysters exhibited linear growth from 3.2 cm (D5) to 3.6 cm (D60), with only 0.4 cm of growth. Therefore, size growth was equivalent between floating cage and suspension techniques, and double that of bottom culture (Fig 10).

The Von Bertalanffy growth parameters for traditional culture (K = 0.017 day⁻¹, L∞ = 5.255 cm) were lower than those for suspension culture (K = 0.064 day⁻¹, L∞ = 6.154 cm), which in turn were lower than floating cage culture (K = 0.065 day⁻¹, L∞ = 6.268 cm). The growth rate of floating cage oysters was 1.06 times higher than suspension culture and 4.32 times higher than bottom culture (Table 4).

Fig 11shows the over-time Von Bertalanffy growth curves, displaying exponential patterns. Oysters reached commercial size (6.7 cm) earlier (day 60) with traditional methods compared to suspension and floating cage techniques.

**Table 4.** Growth parameters of the von Bertalanffy curve, growth rate and survival rate of oysters cultured at Sèyigbé and Dégouè

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| **Stations** | | **Sèyigbé** | | | **Dégouè** | | | |
| **Farming techniques** | | Bottom culture | Floating cage | Suspension technique | Bottom culture | Floating cage | Suspension technique | |
| **K (Day-1)** | | 0.017 | 0.065 | 0.064 | 0.009 | 0.063 | 0.06 | |
| **L∞ (cm)** | | 5.255 | 6.268 | 6.154 | 4.979 | 6.05 | 5.815 | |
| **Growth rate (cm/day)** | | 0.667 | 2.833 | 2.667 | 0.5 | 2.5 | 2.333 | |
| **Growth rate(cm/month)** | | 20 | 85 | 80 | 15 | 75 | 70 | |
| **Survival rate (%)** | | 40 | 91.67 | 70 | 42 | 86.67 | 66.67 | |
| **pvalues**> 0.05 | | | | | | |

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| **Fig. 10. Mean shell length growth of oysters in floating cages, suspension culture, and bottom culture at Sèyigbé** | **Fig. 11. Von Bertalanffy growth curve of juvenile *C. tulipa* at Sèyigbé** |

**3.2.3. Growth Parameters of Oysters Cultured at Dégouè**

The average size of specimens in floating cage culture increased from 3.4 cm (D5) to 4.7 cm (D60), representing a growth of 1.3 cm. Suspension-cultured oysters grew from 3.3 cm (D5) to 4.6 cm (D60), also showing a 1.3 cm increase. In contrast, bottom-cultured oysters exhibited linear growth from 3.2 cm (D5) to 3.5 cm (D60), with only 0.3 cm of growth. We observe that size growth in floating cage oysters was similar to suspension culture and double that of bottom-cultured specimens (Fig 12).

The Von Bertalanffy growth parameters for traditional culture (K = 0.009 day⁻¹ and L∞ = 4.979 cm) were lower than those for suspension culture (K= 0.060 day⁻¹ and L∞ = 5.815 cm), which in turn were lower than floating cage culture (K= 0.063 day⁻¹ and L∞ = 6.050 cm). The growth rate of floating cage oysters was 1.07 times higher than suspension culture and 5 times higher than bottom culture (Table 5).

Fig 13 presents the Von Bertalanffy growth curves of oysters over time, showing an exponential pattern. Oysters reached commercial size (6.7 cm) earlier (day 60) with traditional methods compared to suspension and floating cage techniques.

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| **Fig. 12. Mean shell length growth of oysters in floating cages, suspension technique and bottom culture at Dégouè** | **Fig. 13. Von Bertalanffy growth curve of juveniles of *C. tulipa* reared at Dégouè** |

1. **Discussion**

**4.1. Physico-chemical parameters**

During this study, physico-chemical parameters were measured at the four (04) sites (Djègbadji, Dégouè, Azizakouè, Sèyigbé). The oyster *C.tulipa* grows and survives in a wide range of salinities (6% to 60%) (Akélé et al, 2022), the salinity values recorded in the current study varied from 0.77% to 0.99%, these somewhat low values are explained by the flood period which corresponds to the period when the study was carried out. Thus, salinity was a limiting factor for oyster survival and growth in this study. In addition, the conductivity of water indicates its ability to conduct current, which depends on the water's mineral salt content (Dimon et al, 2014). The highest conductivity values were recorded at Djègbadji station, which is explained by its proximity to the Atlantic Ocean. Conductivity is a parameter closely linked to the amount of salt in the water.

During the 60 days of rearing, water temperature varied between 25.3°C and 31.63°C. Thermal variation is an indicator that determines the distribution of ecological niches in the aquatic environment (Attingli et al., 2016). As stated by Attingli et al. (2016), the dips and peaks observed correspond respectively to the start of floods and the end of ebbs. The high values observed for temperature measurement would probably be due to the influence of meteorological and hydrodynamic factors that the waters undergo. This explanation refers to the study conducted by Chouti et al. (2017) on the physicochemical characterisation and those on the toxicity of the Coastal Lagoon, from Togbin to Grand-Popo (South-West Benin) where they point out that according to (Boko et al, 2012) who studied the issue of climate change in Benin the temperature rose by 0.9°C after 2010. The pH at the various sites varied between 7.2 and 7.93. It falls within the interval [6.5; 9.5] corresponding to the guideline set by the World Health Organisation (WHO) for surface waters (Chouti et al, 2017). This leads to the conclusion that the values obtained are tolerable.

For these two parameters (pH and temperature), no extreme or lethal values were recorded. Statistical analyses showed that the physico-chemical conditions of the water were broadly similar between the four sites studied, suggesting an environmental homogeneity favourable to reliable comparisons in experiments or ecological monitoring, particularly in the context of oyster farming. The TDS graphs have the same appearance as those for temperature, suggesting that temperature affects TDS. Technically, TDS is based on weight (mg/l), so temperature does not affect it. However, we often use conductivity as an analogue for TDS. The high values obtained for TDS are 8501 mg/L and 8148 mg/L for Djègbadji and Azizakouè, respectively. Water intended for human consumption has a TDS less than or equal to one thousand ppm (≤ 1000 ppm). (Dach, 2008). The values obtained for the physico-chemical parameters show that they are favourable for monitoring oysters in these environments.

* 1. **Survival rates**

The survival rate was calculated by station for each of the three rearing techniques. Overall, the lowest survival rates were recorded on the four sites by the bottomculture technique (50%, 40%, 42% and 48%) respectively for (Djègbadji, Sèyigbé, Dégouè and Azizakouè) and the highest rates by the floating cage culture technique (96.67%, 91.67%, 86.67% and 93.33%) respectively for (Djègbadji, Sèyigbé, Dégouè and Azizakouè). Thus, the survival rates recorded in this study appear to be better with the new techniques than with traditional breeding, as noted by (Akélé et al, 2022). The high mortalities recorded in traditional farming can be attributed to the direct contact of the oysters with the bottom (Akélé et al, 2022). The suspension culture approach is preferable to bottom culture, according to Osei et al. (2018). A similar finding was made by Obodai (1997) in studying the effectiveness of suspension and bottom culture methods in Benya lagoon using coconut cultch. The author attributes the poor growth performance of oysters cultivated by bottom methods to low sediment bulk density. Indeed, the bottoms of the study stations are sandy-clayey, and the study period (September-October) corresponds to the study area's flooding period. The arrival of rainwater would have changed the lagoon water into organic particles and sand grains (Akélé et al, 2022).

* 1. **Growth parameters**

After analysis of the values collected during the 60 days of rearing, the best values for the Von Bertalanffy growth parameters (K and L∞) were recorded with the new techniques compared with the traditional technique whatever the station, as noted by (Akélé et al, 2022) and (Osei et al, 2018). Suspension cultivation (rack and raft) proved the most promising (Akélé et al, 2022). K values are 0.046 and 0.041 day-1 for the new techniques at Djègbadji (floating cage and suspension), 0.065 and 0.064 day-1 for the Sèyigbé station (floating cage and suspension), 0.063 and 0.060 day-1 for the Dégouè station (floating cage and suspension), 0.073 and 0.081 day-1 for the Azizakouè station (floating cage and suspension). For traditional rearing, the growth rate K was 0.030, 0.017, 0.009 and 0.012 day-1 at Djègbadji, Sèyigbé, Dégouè and Azizakouè, respectively. L∞ values evolved in the same direction as those of K velocity. The best values were obtained with the new techniques compared with traditional breeding. The best growth performances were recorded at the Dègbadji station, whatever the rearing technique (Table 3). The better growth recorded at Djègbadji can be attributed to the fact that this station is a little closer to the sea and records the highest values for salinity and the highest values for TDS.

The growth rates recorded in the present study showed the same trend as the Von Bertalanffy growth parameters. Oysters reared in floating cages (GR=3 cm/day or 90 cm/month) at Djègbadji, (GR=2.833 cm/day or 85 cm/month) at Sèyigbé and (GR=2.5 cm/day and 75 cm/month) at Dégouè, (GR=2.667 cm/day and 80 cm/month) at Azizakouè gave higher growth rates than those recorded in suspended rearing (GR=2, 667 cm/day or 80 cm/month) at Djègbadji, (GR=2.667 cm/day or 80 cm/month) at Sèyigbé and (GR=2.333 cm/day and 70 cm/month) at Dégouè, (GR=2, 5 cm/day and 75 cm/month) in Azizakouè gave growth rates almost twice as high as those recorded on traditional farms (20, 15, 15, 20 cm/month respectively in Djègbadji, Sèyigbé, Dégouè and Azizakouè). Floating cage and suspension farming accelerate the growth of *Crassostrea* oysters. The better growth performance of oysters with the new techniques could be explained by trophic reasons (Adité et al, 2012; Abgrall et al, 2010). The mangrove oyster *Crassostrea tulipa* feeds mainly on phytoplankton (around 73% phytoplankton) dominated by diatoms (Adité et al, 2013). A high abundance of phytoplankton at the surface and in the water column (compared to the bottom, where photosynthesis is low) would explain this large difference in growth between new farming techniques and traditional farming. Cage culture gave higher growth rates than suspension culture, all stations taken together, so cage culture is more favourable for the good growth of *Crassostrea tulipa* oysters than suspension culture. Also, in economic terms, it should be noted that floating cage farming is more profitable than suspension farming, as caged oysters are more easily marketed. Oysters living in floating cages would have more phytoplankton and oxygen than oysters living in suspension and bottom. Because of the salt content of the water, we have also noticed that galvanised cages have a limited lifespan of no more than a month and a half.

Von Bertalanffy's growth curves confirm that the floating cage technique is the most effective for oyster growth, and the Djègbadji station is the most favourable for this growth. According to Akélé et al (2017), the marketable size of *Crassostrea tulipa* is 6.7cm, and the technique that achieves this size fastest is the floating cage technique. The glueing of oysters for suspension with cement may explain the slow growth in this technique, and the oysters in this technique are not all in the same column, which explains the mortality of specimens close to the bottom.

1. **CONCLUSION**

This work was carried out to contribute to introducing new farming techniques for the *Crassostrea tulipa* oyster in the coastal lagoon of Benin. A comparison of the growth and survival of the mangrove oyster *Crassostrea tulipa* showed that the caged technique was better than the suspended and flat techniques in the Ouidah coastal lagoon in southern Benin. As the oysters are not in direct contact with the ground, the mortality rate for this technique was reduced compared to that recorded for suspended and flat farming. As oyster farming is an income-generating activity in Benin, the improvement and development of these techniques is essential to help local populations.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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