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Occurrences of the Macroinvertebrates in the Alimentary Canal of the Mangrove Oyster- *Crassostrea tulipa* (Family: Osteidea)

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ABSTRACT

The food contents of the mangrove oyster, *Crassostrea tulipa* (*C. tulipa*) from Tomaro mangrove swamp of the Lagos Lagoon were investigated monthly from January to December, 2022, using one hundred samples for each month. The stomachs were gutted and its contents examined under the microscope using frequency of occurrence and numerical methods for food items while the vacuity and fullness indices were calculated using standard formulae. The results revealed that the species feed on various food items of both plants and animal origins with dietary preference consisting of *Closterium ehrenbergi*, Detritus, *Melosira varians*, *Navicula elliptica*, *Oscillatoria tenuis*, *Nitzchia gracilis* and organic substrates. Of the 1200 stomachs examined, 346 were empty stomachs, 292 had quarter-full stomachs, 170 had half-full stomachs, 287 had three quarter-full stomachs and 107 had full stomachs, indicating that there were significant differences in different months ($P<0.05$). The study on the food items in the stomachs of *C. tulipa* indicated that they ingested a variety of benthic and pelagic food resources, mainly phytoplankton, suggesting therefore that *C. tulipa* is a phytoplankton feeder, mainly consumes aquatic insects, algae, diatoms, and organic decay material with modest feeding throughout the year while animal derivatives, aquatic plants and gastropods were eaten accidentally.

Keywords: Food items, fullness index, oysters, vacuity index

INTRODUCTION

According to Kurbah & Bhuyan, (2018), Feeding activity is one of the most essential activities of any organism in order to be able to carry out life processes (growth, movement, respiration, reproduction, excretion, etc.) which requires energy converted from the food eaten. Knowledge of feeding habits of fish species is important for understanding the ecological role and productive capacity of fish populations which is crucial to the development of conservation and ecosystem-based management, these plans are useful to fisheries scientists (Alimohammadi *et al*. 2022). However, it is impossible to assess fish's diet preferences without detailed complementary studies to estimate the range and abundance of potential food items available in their natural environment (Jorfipour *et al*. 2022).

The mangrove oyster, genus *Crassostrea* is a bivalve mollusk which possesses outer shells covering its entire body (Akinjogunla & Soyinka, 2022), They are nutritive species (Akinjogunla *et a*l., 2017) that are commercially obtainable in lagoons, lakes and estuarine waters in some western and southern parts of Nigeria. *Crassostrea* spp. are of immense economical and commercial importance as they serve as affordable source of protein for low-income earners (Akinjogunla *et al*., 2017) and a vital source of employment and livelihood for riverine communities, particularly in West Africa in developing and undeveloped countries across West Africa (Mahu *et al*., 2022).

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Regardless of its importance in Nigeria as a source of affordable protein and source of revenue, especially to the South-South population, who graciously include the oysters in their delicacies, very little is known about the ecology of this species.

Shellfish, such as *Crassostrea*, have been overlooked and neglected by the modern aquaculture and nothing is known about the feeding ecology of this bivalve in the wild. To develop the oyster aquaculture and to better manage the wild population, there is a need to provide scientific information on the trophic ecology of this species to evaluate energy sources for biological function such as reproduction, growth etc.

This research seeks to investigate on the feeding ecology of the mangrove oysters, *C. tulipa* collected from Tomaro mangrove swamp of the Lagos Lagoon, Nigeria in order to contribute to filling the gap in our knowledge of this economically important bivalve and its sustainable management. Therefore, this study is a contribution to understanding the feeding ecology of *Crassostrea tulipa* which include diet composition and the fullness or emptiness of the stomachs.

MATERIALS AND METHODS

Study Site

This study was conducted in the Tomaro mangrove swamp of the Lagos Lagoon, Nigeria, situated between 06°26′37″N and 03°23′40″E. The Lagos Lagoon covers a surface area of approximately 208 km² and is a brackish waterbody influenced by tidal flow from the Atlantic Ocean. Tomaro is bordered by residential and industrial zones, and the swamp serves as a transportation hub for watercraft, increasing its exposure to anthropogenic activities (Akinjogunla & Lawal-Are, 2020). The area is characterized by extensive Rhizophora mangroves, fluctuating salinity, and organic-rich sediments, creating a dynamic ecological niche suitable for filter-feeding organisms such as *Crassostrea tulipa*. Tomaro mangrove swamps serves as a passage for ships and boats as a mean of transportation between one place and another as it is surrounded by residential and industrial buildings (Akinjogunla & Soyinka, 2022).

Sample Collection and Preparation

A total of 1,200 adult specimens of *Crassostrea tulipa* were collected monthly from January to December 2022, using handpicking and dredging techniques during low tide. Samples were carefully detached from mangrove roots and submerged structures to avoid shell damage.

After collection, specimens were temporarily anesthetized using a 90% ethanol to minimize movement and were transported in insulated cool boxes (model: Coleman 28 QT Performance Cooler) to the laboratory within 2–4 hours. Upon arrival at the Laboratory, the oysters were individually rinsed with distilled water to remove debris. Specimens were then sacrificed by immersion in 1% clove oil solution (following ethical guidelines for molluscan euthanasia) and fixed in 10% neutral buffered formalin for 24 hours.

Morphometric and Biomass Measurement

The Shell length (cm) was measured using a digital Vernier caliper (model: Mitutoyo 500-196-30) with an accuracy of ±0.01 mm while the wet weight (total weight) was recorded using a digital analytical balance (model: OHAUS Pioneer PX4201) with an accurate precision of ±0.01 g). These parameters were recorded to analyze correlations between oyster size and stomach fullness.

Stomach Content Analysis

Gastrointestinal components were examined to evaluate the feeding parameters of stomach fullness and contents. Each oyster was

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dissected using a stainless-steel scalpel and forceps set under sterile conditions. The alimentary canal was carefully removed and dissected to expose the stomach contents. Stomach contents were examined under a compound light microscope (model: Olympus CX23) at 100× and 400× magnification. Identification of food items was conducted using standard taxonomic keys for phytoplankton and organic matter (Mahasri et al., 2020). Food particles were mounted in a drop of distilled water on a glass slide and covered with a cover slip. A minimum of 5 fields of view per slide were analyzed per specimen.

Feeding Indices Calculation

Vacuity Index (VI)

The gastrointestinal vacuity index was calculated using the equation:

$$VI = (ES/TS) \times 100,$$

Where:

ES = number of empty stomachs; TS = total number of stomachs examined.

The index (nutritional status of the habitat) is interpreted as follows:

- VI < 20%: Highly nutritious
- 20% ≤ VI < 40%: Relatively nutritious
- 40% ≤ VI < 60%: Nutritionally moderate
- 60% ≤ VI < 80%: Poor or low Nutrient
- VI ≥ 80%: Nutrient-deficient ecosystem

Fullness Index (FI)

The Fullness Index was analyzed across months to understand seasonal feeding activity. Stomachs were visually classified into five categories:

- Empty (0/4)
- Quarter-full (1/4)

Half-full (2/4)

Three-quarter full (3/4)

Full (4/4)

Quantitative Analysis of Food Items

These methods were adopted following Zhang *et al*. (2021**)** and validated by previous studies in estuarine mollusk.

Numerical method (%N):

Count of each food item was expressed as a percentage of the total number of food particles observed.

Frequency of occurrence (%F):

%F=
(Number of stomachs containing a food item\ Total number of stomachs with food) ×100

Data Analysis

Data were subjected to descriptive statistics and visualized using Microsoft Excel 2019. Results were presented in tables and figures showing monthly trends in feeding activity and dietary composition. One-way ANOVA was performed using IBM SPSS Statistics v26 to determine significant differences in vacuity and fullness indices across months, with significance set at $P < 0.05$.

RESULTS

Food and Feeding Habits of *Crassostrea tulipa*

Vacuity Index (VI) of *Crassotrea tulipa* stomachs from Lagos Lagoon

The Vacuity Index of the 1200 stomachs of *C. tulipa* obtained in Tomaro and examined between January, to December, 2022 was 346 (28.8 %). The highest number of *C. tulipa* with empty stomachs was obtained in March, giving the highest Vacuity Index (VI = 38 %) and the lowest number of *C. tulipa* with empty stomachs was in June giving the lowest Vacuity Index (VI = 22 %), Table 1 shows that

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all the *C. tulipa* (n=1200) examined were relatively edacious (20 % ≤ VI < 40 %) within the study periods.

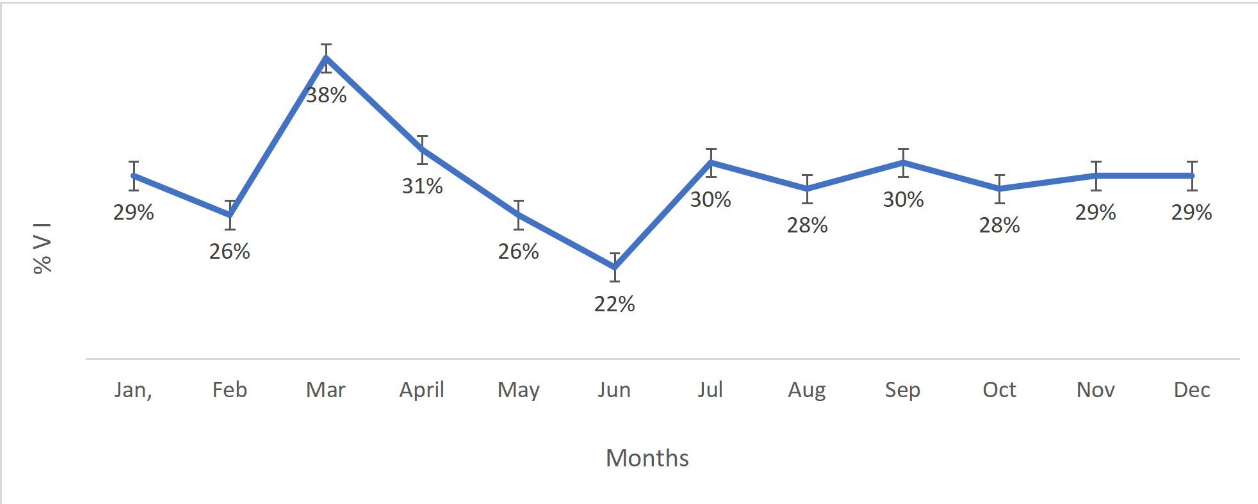

Figure 1: Monthly Vacuity Index (%) of *Crassostrea tulipa* from Tomaro Mangrove Swamp, Lagos Lagoon.

Fullness Index (FI) of *Crassostrea tulipa* stomachs from Lagos Lagoon

The stomach status of *C. tulipa* (n=1200) collected from Tomaro examined are illustrated in Figure 2. Of 1200 stomachs examined randomly from Oysters collected in Tomaro, only 105 /1200 (12 %) of the stomachs were full (4/4 Fed), 287/1200 (34 %) of the stomachs were almost full (3/4 Fed), 170/1200 (20 %) of the stomachs were half full (1/2 Fed), while 292 /1200 (34%) of the stomachs were almost empty (1/4 Fed). The numbers of full (4/4) fed and almost full (3/4 Fed) stomachs of the *C. tulipa* ranged from 4 (4%) to 15 (%) and 10 (10%) to 25 (25%), respectively.

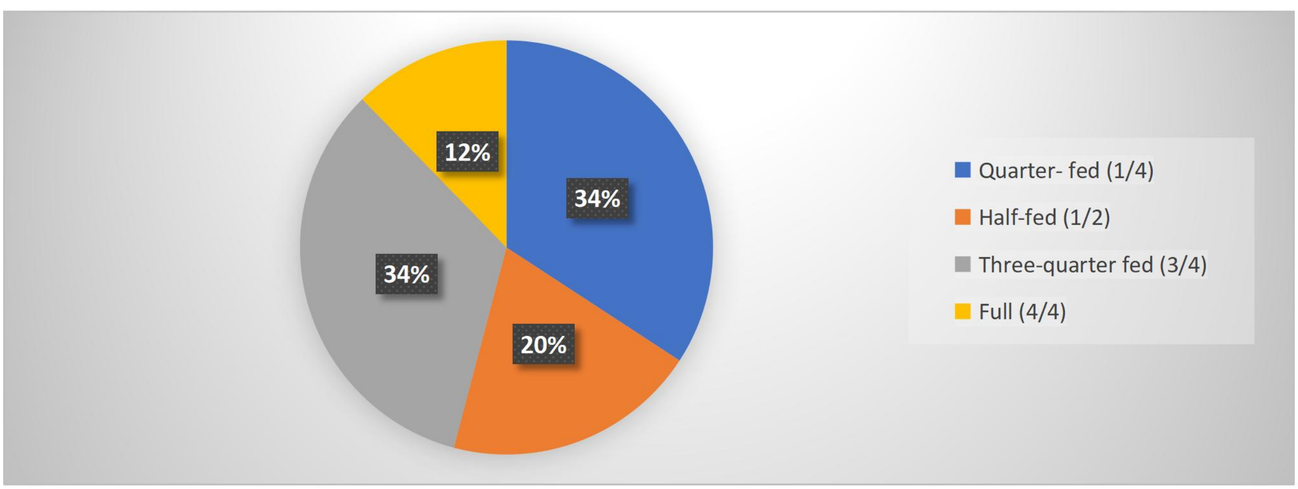

Figure 2: Fullness Index of *Crassostrea tulipa* stomachs collected from Tomaro Mangrove swamp of the Lagos Lagoon.

DOI: 10.56892/bima.v9i1B.1302

Food items in Stomachs of *Crassostrea tulipa* from Lagos Lagoon

Closterium ehrenbergii, Detritus, *Melosira varians, Navicula elliptica*, *Oscillatoria tenius* and *Nitsztchia gracilis* were the six food items observed and identified in the stomach of *C. tulipa* obtained in Tomaro. The food items found in the stomachs of *C. tulipa* in Tomaro by numerical analysis as illustrated in Figure 3 below was: *C. ehrenbergii* 2929 (17.6 %), Detritus 1620 (9.7 %), *M. varians* 4246 (25.5 %), *N. elliptica* 3760 (22.6 %), *O. tenius* 2107 (12.7 %) and *N. gracilis* 1994 (11.9 %).

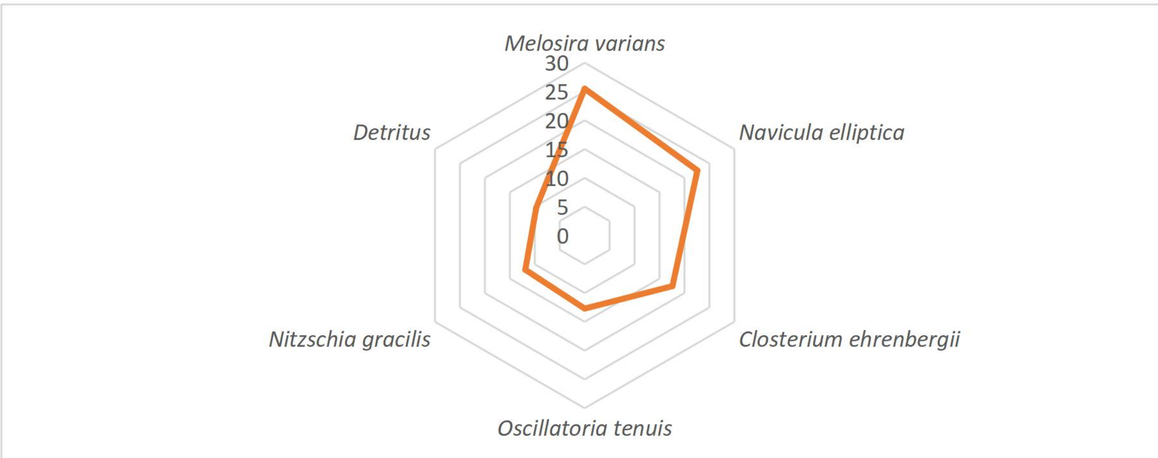

Figure 3: Food items in *Crassotrea tulipa* from Tomaro by Numerical method.

The food items by frequency of occurrence in the stomachs of *Crassotrea tulipa* from Tomaro are illustrated in Figure 4 below as *C. ehrenbergii* was 1141 (13.9 %), Detritus 1162 (14.2 %), *M. varians* 1169 (14.3 %), *N. elliptica* 1178 (14.4 %), *O. tenius* 1102 (13.5 %), *N. gracilis* 1201 (14.7 %) and organic substrate particles 1208 (14.8 %).

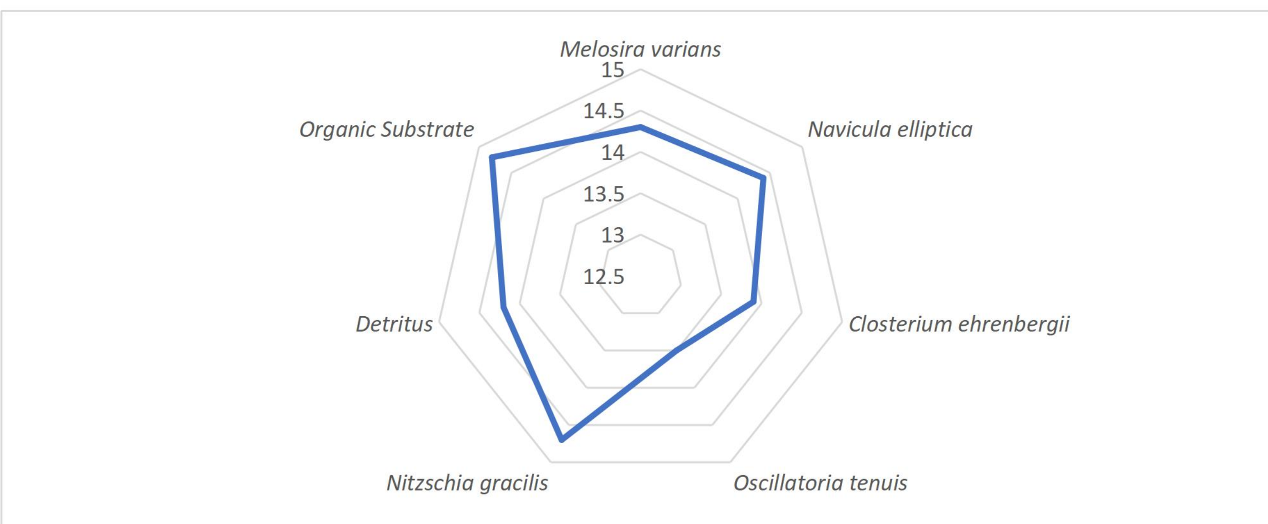

Figure 4: Food items in *Crassotrea tulipa* from Tomaro mangrove swamp of the Lagos Lagoon by occurrence method.

DOI: 10.56892/bima.v9i1B.1302

The predominant food item observed in the stomach of *C. tulipa* was *Melosira varians* and the food item with least numerical occurrence was Detritus (Figure 5)**.** The highest number of food items (1298) was observed during the dry season (March 2022), while the lowest number of food items (570) was observed in wet season. Of the 1298 food items observed in March 2022, the *Melosira varians* constituted 308 (23.7%), followed by *N. elliptica* with 281 (21.6%), *C. ehrenbergii* 244 (18.8%), *O. tenius* 190 (14.6%), Detritus, 169 (13.0%) and *Nitztchia gracilis* 106 (8.17%). Of the 570 food items observed in wet season, the *Melosira varians* constituted 108 (18.9%), *N. elliptica* 98 (17.2%), *C. ehrenbergii* 81 (14.2%), *O. tenius* 62 (10.9%), Detritus, 43 (7.5%) and *Nitztchia gracilis* 178 (31.2%).

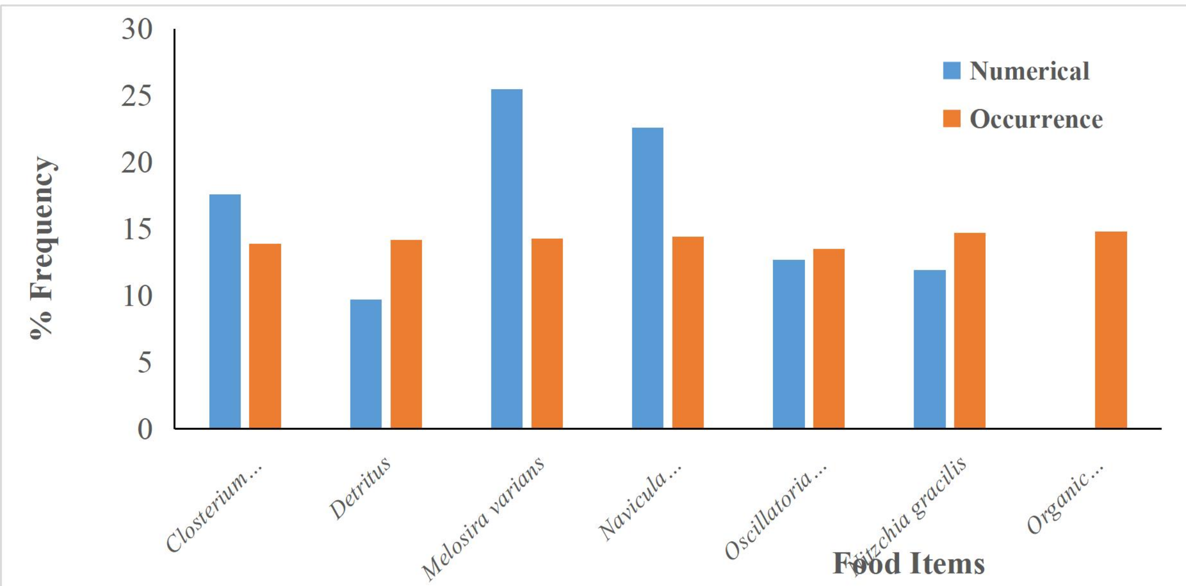

Figure 5: Food items in *Crassostrea tulipa* stomachs from Tomaro of Lagos Lagoon.

DISCUSSION

This study on the feeding ecology and stomach content analysis of *Crassostrea tulipa* in the Tomaro mangrove swamp of Lagos Lagoon provides valuable insights into the dietary habits and ecological role of this species.

The results indicated that *C. tulipa* primarily feeds on phytoplankton, diatoms, and organic detritus, which is consistent with findings on the feeding habits of other bivalve mollusks. Bivalves, including oysters, have been widely documented as suspension feeders, primarily consuming microalgae and organic matter from their environment (Bordeyne *et al*., 2019). In this study, *C. tulipa* was documented to have ingested the following food items using numerical and frequency of occurrence analysis respectively - *Melosira varians* (25.5%, 14.3%); *Navicula elliptica* (22.6%, 14.4%); *Closterium ehrenbergii* (17.6%, 13.9%); *Oscillatoria tenuis* (12.7%, 13.5%); *Nitzschia gracilis* (11.9%, 14.7%), Detritus (9.7%, 14.2%) and Organic substrate particles (14.8%) by frequency of occurrence method only.

The findings on the predominant food items—*Melosira varians*, *Navicula elliptica*, and *Oscillatoria tenuis*—reinforced previous studies that highlighted diatoms as major food sources for filter-feeding mollusks (Zhang *et al*., 2021). Atindana *et al*. (2023) who conducted research in the Densu estuary,

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Ghana, revealed that the diet of *C. tulipa* was dominated by golden algae (*Ochrophyta*), red algae (*Rhodophyta*), green algae (*Chlorophyta*), and diatoms (*Bacillariophyta*), which aligns with this present study.

However, some recent studies have reported broader dietary plasticity under varying environmental conditions and contrasting results observed in other bivalve feeding studies in estuarine systems. For instance, Effe *et al*. (2020) observed in the Volta estuary (Ghana) that *C. tulipa* exhibited seasonal shifts in feeding preferences, ingesting higher proportions of detritus and zooplankton during periods of low phytoplankton productivity, which was not a major pattern in our study. This difference may be due to local hydrological variation or differing levels of anthropogenic input between estuaries. For instance, Zhang *et al*. (2021) reported that estuarine bivalves in the Yangtze River Estuary displayed a broader diet diversity, including large quantities of cyanobacteria and flagellates, indicating dietary plasticity depending on the local phytoplankton community structure. This suggests that while *C. tulipa* may be a selective suspension feeder in Lagos Lagoon, its feeding behavior may shift in response to changing food availability or environmental stressors elsewhere. The dominance of *Melosira varians* and *Navicula elliptica* in this study suggests that these diatoms are abundant in the water column and serve as primary food sources while this diversity in diet underscores the oyster's adaptability to available food sources in its environment.

The recorded vacuity index values in this study (ranging between 22% and 38%) suggest seasonal variations in food availability, with the highest vacuity index observed in March and the lowest in June. Similar seasonal fluctuations in oyster feeding behavior have been noted in other studies, where dry-season months often exhibit higher vacuity indices due to reduced food availability and metabolic adjustments in oysters (Bordeyne *et al*., 2019). The presence of empty stomachs in certain months could be attributed to environmental factors, including fluctuations in temperature, salinity, and selective particle availability (Zhang, *et al*., 2021). Furthermore, while our study found a relatively modest proportion of full stomachs (only 12% full-fed), similar studies on *Crassostrea gigas* in estuarine systems reported higher fullness indices under comparable salinity and temperature conditions (Wang *et al*., 2020), suggesting that either *C. tulipa* has lower feeding rates or that food availability was temporally constrained in Tomaro.

In contrast, Nunes *et al*. (2021**)** documented that high particulate organic matter and phytoplankton densities during the wet season in Brazilian mangrove creeks enhanced feeding efficiency in *C. gasar*, which contrasts with our observation of lower food item counts in the wet season. Moreover, the current study reports only 12% full stomachs over the sampling period. Wang *et al*. (2020) found that tidal exposure and temperature significantly influenced feeding rhythms and fullness in estuarine oysters, with peak feeding occurring during submersion under stable salinity. This could explain the relatively low fullness index observed in the present study, particularly if environmental fluctuations at Tomaro swamp disrupt regular feeding cycles.

Another notable point is the dominance of diatoms in *C. tulipa*'s diet, which contrasts with findings by Adeniji *et al*. (2020) in the Cross River Estuary, where bivalve mollusks showed a higher reliance on detrital organic matter than live phytoplankton, likely due to seasonal eutrophication and sediment resuspension.

Environmental variables such as salinity and turbidity are key drivers of feeding in oysters. The seasonal fluctuations in vacuity and fullness indices observed in this research are consistent with findings from other regions. Variations in environmental factors such as salinity and temperature significantly influence the feeding activity of *C. tulipa*. For instance, a study by Sühnel *et al*. (2023) demonstrated that salinity variations affect the reproductive cycle of *C. tulipa* under hatchery conditions, which may indirectly impact feeding behaviors, corroborating our inference that seasonal vacuity index variation could reflect environmental stress or reduced filter-feeding efficiency. Understanding these environmental influences is crucial for effective management and conservation strategies. Nonetheless, Shumway *et al*. (2020) caution that natural populations may compensate for environmental variability through behavioral adaptations such as selective filtration or increased particle retention—factors not directly measured in our study.

The dietary composition of *C. tulipa* suggests its role in nutrient cycling, as it actively consumes detritus and organic particles, which are important in maintaining estuarine ecosystem health. The presence of detritus in the stomachs also indicates that *C. tulipa* from Tomaro mangrove swamp of Lagos Lagoon is an opportunistic feeder, similar to other oyster species that ingest available organic matter along with their preferred phytoplankton diet (Atindana *et al*. (2023).

The availability of food resources for *C. tulipa* is closely linked to spatfall dynamics and prevailing estuarine conditions. Research by Osei *et al*. (2023) in the Gulf of Guinea highlighted that spatfall varied significantly across different water bodies and seasons, with higher spatfall observed during the dry season. These findings suggest that seasonal environmental conditions play a pivotal role in the life cycle and feeding ecology of *C. tulipa.*

Osei *et al*. (2023) reported that overexploitation and habitat degradation threaten *C. tulipa* populations, necessitating habitat restoration and pollution control measures. Additionally, Climate variability poses significant challenges to the survival and feeding ecology of *C. tulipa*. Mahu *et al*. (2022) assessed the vulnerability of *C. tulipa* to climate change in West African oyster fisheries, noted that fluctuations in salinity and temperature, along with other stressors like pollution and habitat degradation, adversely affect oyster populations. These environmental changes can lead to alterations in food availability and quality, impacting the feeding habits and overall health of *C. tulipa*

This study corroborates findings from previous research on *Crassostrea* species. For example, studies on *Crassostrea virginica* in estuarine environments found a similar preference for diatoms and detritus, with feeding rates varying according to environmental conditions (Shumway *et al.,* 2020).

Interestingly, results of occasional ingestion of non-preferred items such as filamentous algae and detritus supports the view of *C. tulipa* as an opportunistic feeder, especially when preferred food sources are scarce. Zhang *et al*. (2021) found that estuarine bivalves like *Crassostrea hongkongensis* adapted their diet based on particle size availability, suggesting a more nuanced particle selection mechanism than previously assumed.

These contrasts underline the importance of considering spatial and temporal variability in diet studies. Our study focused on a single site over one year; broader spatial comparisons could uncover whether observed patterns are localized or part of a regional trend. Furthermore, integrating chlorophyll-a data or suspended particulate matter analysis could

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help clarify the link between environmental productivity and feeding activity.

Finally, the current findings in this study emphasize the ecological importance of *C. tulipa* in nutrient cycling within the Lagos Lagoon. Oysters enhance water quality through filtration and organic matter assimilation. This role is also reinforced by Shumway *et al*. (2020), who reviewed ecosystem services provided by suspension-feeding bivalves, including nitrogen removal and water clarity improvements—services essential for the resilience of urban estuarine systems like Lagos Lagoon

CONCLUSION

This research contributes to the growing body of knowledge on the feeding ecology of *C. tulipa*, emphasizing its dietary diversity, feeding ecology and the influence of environmental factors on its feeding behavior, reinforcing its ecological role as a suspension feeder in Lagos Lagoon. The species primarily consumes diatoms and organic detritus, with seasonal fluctuations affecting feeding intensity. Understanding these patterns is essential for sustainable fisheries management and conservation efforts. Future research should explore the long-term impacts of climate change on oyster populations, assess potential mitigation strategies and investigate the influence of water quality and anthropogenic impacts on oyster feeding behavior to enhance conservation and aquaculture management strategies. Integrating the results from this study with other literature accentuates the importance of monitoring environmental conditions and implementing adaptive management strategies to ensure the sustainability of *C. tulipa* populations in the face of climate change and anthropogenic pressures.

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