Analysis of Benthic Fauna in the Seagrass Bed Ecosystem of the Pearl River Estuary

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Abstract: To investigate the benthic fauna of the seagrass-bed ecosystem in the Pearl River Estuary, six ecological surveys on benthic fauna were carried out in the seagrass beds of Tangjiawan from August 2021 to September 2022. The Shannon-Wiener diversity index (H'), Pielou evenness index (J)and dominance index (Y) were used to analyse benthic community characteristics. The results showed that a total of 31 macrobenthos species belonging to 7 taxonomic groups were identified, among which Mollusca had the highest species richness with 14 species. A total of 29 meiofauna species from 15 major taxa were detected. The composition of dominant species varied greatly among the six sampling batches. Batch T2110 exhibited the highest diversity and evenness, while batch T2204 had the maximum diversity index. These findings can provide basic data for seagrass bed ecosystem research in China.

Keywords: Seagrass Bed; Benthic Fauna; Pearl River Estuary; Biodiversity

1. Introduction

Seagrasses are monocotyledonous plants growing in shallow coastal waters from tropical to temperate zones [1-2]. Seagrass meadows, constructed with seagrass as the key species, represent one of the most productive ecosystems on Earth with the highest value of ecosystem service functions [3-5]. Seagrass beds deliver ecological services including wildlife habitat provision, water purification, carbon sequestration and climate regulation. Characterized by large carbon sink capacity, high carbon sequestration efficiency and long carbon storage cycles, they are internationally recognized as one of the "blue carbon" ecosystems. Nevertheless, global seagrass resources have suffered sharp degradation driven by anthropogenic disturbances and climate change [6-7].

With intensified human exploitation of coastal seas, marine eco-environmental problems have become increasingly prominent. Activities including industrial wastewater discharge, domestic waste dumping and overfishing have exerted severe ecological impacts on marine environments. Driven by intensive industrialization of coastal cities, massive pollutants are discharged into the sea, triggering a cascade of environmental issues such as eutrophication, biodiversity loss and habitat degradation. Accordingly, research on the biodiversity of seagrass beds contributes to formulating rational conservation and utilization strategies and ensures the sustainable exploitation of resources. As vital components of ecosystems, benthos play critical roles in marine food webs and biogeochemical cycling at the sediment-water interface. By participating in the biogeochemical cycles of carbon, nitrogen, sulfur and other elements, as well as modulating pollutant migration-transformation and sediment stability, benthos sustain ecosystem structure and function. They are regarded as the most important indicators for assessing the integrity of estuarine-bay ecosystems. Benthos mainly comprise Annelida, Mollusca, Arthropoda, Platyhelminthes, Echinodermata and other taxa, forming complex animal assemblages. Macrobenthos are defined as benthic organisms that cannot pass through a 0.5 mm mesh sieve[8-9]. Meiofauna refer to benthic organisms passing through a 0.5mm sieve but retained by a 0.042 mm mesh sieve. Previous studies have demonstrated that benthos serve as valuable biological indicators for environmental pollution, anthropogenic disturbance and climate change[10-12]. In China, benthos investigation and analysis have been incorporated into routine protocols for assessing river ecosystem health.

Due to high-level industrialization of cities along the Pearl River, large quantities of pollutants are discharged into coastal waters, resulting in eutrophication, biodiversity decline, habitat loss and other environmental problems. Therefore, investigating benthic biodiversity in bay seagrass beds helps develop sound conservation and utilization strategies for sustainable resource use, and provides scientific support for ecosystem conservation and management decision-making in the new era.

2. Investigation Content and Methods

2.1 Seagrass Bed Area

According to previous literature records [13], seagrass beds in Zhuhai were historically documented in three locations: Sanzao, Hengqin and Tangjia. Field reconnaissance failed to detect seagrass beds in Hengqin and Sanzao, leaving only the Tangjiawan site confirmed to host seagrasses (Fig 1). The dominant seagrass species here is Halophila beccarii. The seagrass bed is distributed on both sides of the drainage outlet under Jishan Bridge; seagrass density is low near the outlet, rises on the two flanks, and gradually declines outward. Three survey stations were established along the depth gradient from shallow to deep waters.

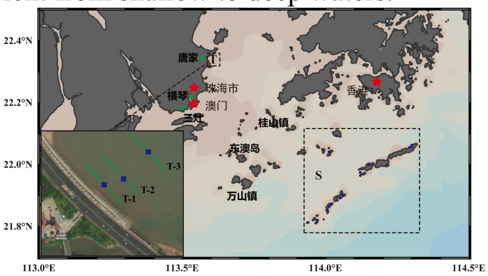

Figure 1. Figure Example

2.2. Station Layout

In accordance with relevant guidelines and specifications, survey transects were laid perpendicular to the coastline for intertidal seagrass beds. Along each transect, 3 environmental monitoring stations were set from shallow to deep water. A 50 m-long, 1–3 m-wide sampling belt parallel to the coastline was deployed adjacent to each environmental station. Random quadrats of 0.5 m × 0.5 m were marked with PVC pipes or other markers within each belt for biological sampling. The number of quadrats was adjusted based on seagrass species diversity in each belt, ensuring no fewer than 2 quadrats per seagrass species.

For seagrass beds covering less than 20 hectares, only one transect with three sampling belts was required. The area south of the flood drainage channel hosted sparse seagrass, and sampling belts near the outlet lacked representativeness, so belts were placed in the northern zone with high seagrass coverage. Naming rules for samples are listed in Table 1.

Table 1. Naming Rules for Seagrass Bed Sampling Batches and Stations

No	Batch	Date	Sample Point
1	T2107	2021.07.25	T1, T2,T3
2	T2110	2021.10.7	T1, T2,T3
3	T2201	2022.01.5	T1, T2,T3
4	T2204	2022.04.19	T1, T2,T3
5	T2207	2022.07.13	T1, T2,T3
6	T2209	2022.09.9	T1, T2,T3

2.3 Biological Community Assessment Metrics

Two indices reflecting community characteristics were used to analyze the community structure of phytoplankton, zooplankton, intertidal organisms and macrobenthos:Shannon-Wiener diversity index (H'), and Pielou evenness index (J). Calculation formulas are listed below:

① Shannon-Wiener diversity index：

$$H' = -\sum_{i=1}^{s} P_i \log_2 P_i \quad (1)$$

② Pielou evenness index：

$$J = H' / H_{\max} \quad (2)$$

③ Dominance index (Y)：

$$Y = \frac{n_i}{N} \cdot f_i \quad (3)$$

Pi＝n_i/N; n_i: Individual quantity of species i (ind./m³); N: Total biological quantity at a station (ind./m³); S: Total number of species detected;Hmax＝$\log_2$S, the theoretical maximum diversity index;f_i is the occurrence frequency of a certain species (%).

3. Status of Biological Diversity

The surveyed seagrass bed lies in the intertidal zone of Tangjiawan, Zhuhai, hosting dominant biota including mollusks, fish and crustaceans. All surveys were conducted during low tide via intertidal field observation without trawling, so only benthic organisms captured by field sighting and sampling are reported herein.

3.1 Macrobenthos

3.1.1 Species composition and spatiotemporal variation

A total of 48 macro-benthic species across 7 taxonomic groups were identified from seagrass bed surveys (Figure 2). Mollusca dominated with 23 species, followed by Annelida with 14 species; Echiura and Cnidaria were the least diverse, with only one species each. Species richness varied drastically between Batch T2208 and T2209: T2209 contained the highest number of species (16), while T2110 contained the fewest (5). Overall species richness trended upward from T2108 to T2204. Echiurans were exclusively detected in T2204; Platyhelminthes mainly occurred in T2108 and T2110; Cnidarians were only found in T2201.

In T2204, species richness decreased gradually from nearshore to offshore stations. No macro-benthic organisms were collected at Station T-2 in T2108, while T-1 and T-3 exhibited comparable species counts. T2110 shared similar species assemblages at T-1 and T-2, both solely composed of mollusks, whereas Platyhelminthes and Annelida were recovered at T-3. Species composition diverged sharply across stations in T2201: only mollusks existed at T-1, while T-2 supported Cnidaria, Annelida, Arthropoda, Nemertea and Mollusca, delivering far higher diversity.

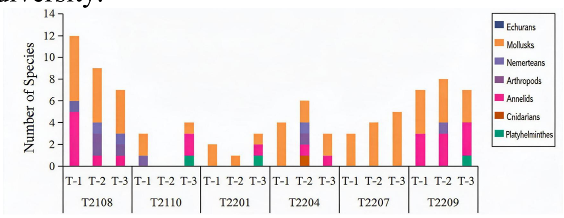

Figure 2. Spatial Variation of Macrobenthic Species Composition

3.1.2 Variation in abundance and biomass

Macro-benthic abundance statistics (Fig3) indicated that T2204 recorded the highest average density across three stations at 4,893 ind./m², followed by T2207 at 4,063 ind./m². T2108 had the lowest average density of 293 ind./m². Annual average density differed substantially by station: T-1 reached the highest at 2,800 ind./m², T-2 followed at 2,543 ind./m², and T-3 had the minimum at 1,440 ind./m².

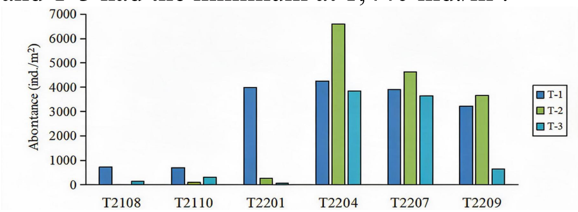

Figure 3. Temporal Variation in Abundance of Macro-Benthic Fauna

Biomass measurements of macro-benthic fauna (Fig4) showed T2201 achieved the maximum biomass of 1,078.24 g/m², while T2110 had the minimum at 88.73 g/m². Annual average biomass stood at 1310.00 g/m² for T-1, 309.00 g/m² for T-2 and 88.00 g/m² for T-3, presenting a clear nearshore-to-offshore declining gradient.

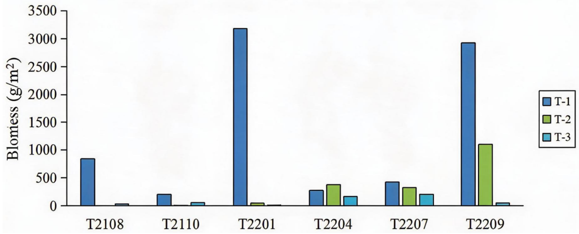

Figure 4. Temporal Variation in Biomass of Macro-Benthic Fauna

3.1.3 Diversity levels

Shannon-Wiener diversity index calculations (Figure 5) revealed minor discrepancies across six survey batches. T2108 attained the highest diversity index of 1.31, while T2201 reached the minimum at 1.00. Diversity index increased progressively from nearshore to offshore: annual average H′ was 0.66 at nearshore T-1, 0.96 at mid-shore T-2 and 1.31 at offshore T-3.

Temporal trends varied by station: diversity at T-1 declined from T2204 to T2201; T-2 showed negligible differences between T2201 and T2204; T-3's diversity rose from T2204 to T2108 then dropped from T2108 to T2201.

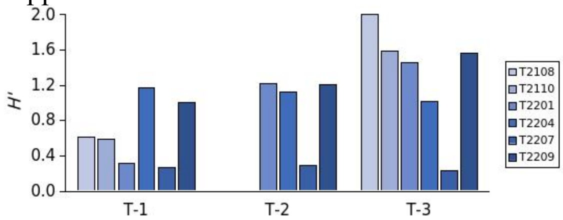

Figure 5. Spatial Distribution of Macrobenthic Diversity Index

Pielou evenness index results (Fig 6) showed a rise-then-fall pattern from T2108 to T2201. T2110 recorded the maximum evenness of 0.80, and T2207 the minimum of 0.14. Evenness values remained consistent across stations in T2204; T-3 exhibited elevated evenness in both T2108 and T2110, and evenness increased from nearshore to offshore in T2201. Annual average evenness followed an offshore-rising gradient: T-1 averaged 0.33, T-2 averaged 0.34 (nearly identical to T-1), and T-3 peaked at 0.66. The evenness value of T2207 was drastically lower than all other batches.

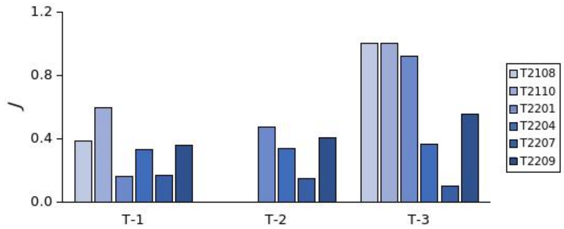

Figure 6. Spatial Distribution of Macrobenthic Evenness Index

3.1.4 Dominance index

Dominant species were determined when the dominance index (Y) of macrobenthos was ≥0.02. One dominant species, Glauconome chinensis, was identified in batch T2108, with a dominance value of 0.25. Five dominant species were detected in batch T2110, including Musculus senhousei, Glauconome chinensis, Batillaria sp., Paraspio sp. and Marphysa depressa. Among them, Glauconome chinensis was the absolute dominant species with a dominance value of 0.18, followed by Batillaria sp. (Y=0.12). Three dominant species were found in batch T2201: Glauconome chinensis, Laternula marilina and Musculus senhousei. Glauconome chinensis acted as the absolute dominant species with a dominance value of 3.68. Seven dominant species were recorded in batch T2204, namely Sanguinilemma sanguinea, Pectinaria plumosa, Glauconome chinensis, Potamocorbula laevis, Tapes durus, Pitar japonica and Musculus senhousei. Potamocorbula laevis showed the highest dominance value of 10.47 and was the absolute dominant species of this batch. Only one dominant species, Potamocorbula laevis (Y=0.96), was obtained in batch T2207. Two dominant species occurred in batch T2209, Potamocorbula laevis and Glauconome chinensis, with dominance values of 0.41 and 0.53, respectively. Glauconome chinensis was recognized as a dominant species across multiple survey batches, and served as the absolute dominant species in batches T2108, T2110, T2201 and T2209.

3.2 Meiobenthic Fauna

3.2.1 Species composition and spatiotemporal variation

Surveys identified 29 meiobenthic species across 15 major taxonomic groups (Fig 7). Polychaeta, Copepoda and Nematoda were the most speciose groups, each with 4 recorded species. Species richness displayed an increase-then-decline temporal pattern from T2201 to T2204. T2108 and T2110 supported the highest species count (9 species each), while T2204 and T2201 contained fewer taxa (6 and 5 species respectively).

In T2204, species richness diverged across stations, with T-2 hosting the most species and T-3 the fewest. T2108 had uniform species counts across stations; T2110 recorded the maximum species number (7) at T-3, where Isopoda were uniquely detected in T2201. T2207 contained minimal species diversity, with only Nematoda recovered. Four meiobenthic taxa were collected in T2209: Nematoda, Copepoda, Polychaeta and Halacarida.

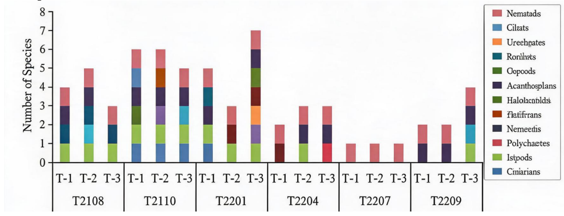

Figure 7. Spatial Distribution of Meiobenthic Species Composition

3.2.2 Variation in abundance and biomass

The overall average meiobenthic abundance in the seagrass bed reached 3.45 ind./cm³ (Figure 8). T2110 had the highest batch average density of 7.19 ind./cm³, with T-2 hitting the station peak at 8.39 ind./cm³. T2108 ranked second at an average of 6.66 ind./cm³, where T-3 recorded the highest density of 7.55 ind./cm³. T2201 had the lowest average density of 0.93 ind./cm³, with insignificant inter-station differences.

Temporally, meiobenthic abundance followed an increase-then-decline trajectory from T2201 to T2204, consistent with seasonal temperature fluctuation, and this pattern was uniform across all stations. Spatially, abundance rose then fell from nearshore to offshore with mild inter-station gaps: T-2 had the highest annual average density (3.62 ind./cm³), followed by T-3 (3.39 ind./cm³), and T-1 the lowest (3.35 ind./cm³).

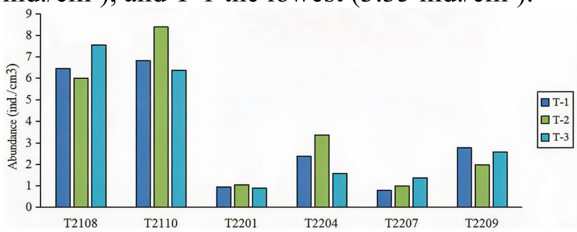

Figure 8. Temporal Variation in Abundance of Meiobenthic Fauna

Average annual meiobenthic biomass in the seagrass bed was 6.46 μg/cm³ (Figure 9). T2108 delivered the maximum biomass of 14.48 μg/cm³, T2110 ranked second at 11.62μg/cm³, and T2207 reached the minimum of 0.42μg/cm³. Biomass also followed an increase-then-decline trend from T2201 to T2204.

T-1 in T2108 yielded the highest single-sample biomass of 20.70 μg/cm³. Biomass declined slightly from nearshore to offshore in T2110. T-2 dominated biomass in T2201 (1.99 μg/cm³) and T2204 (8.27μg/cm³), with comparable biomass at T-1 and T-3 in T2204. All stations in

T2207 exhibited extremely low biomass with a batch average of 0.42μg/cm³. T2209 averaged 3.7μg/cm³ across stations, with the peak value of 7.48 μg/cm³detected at offshore T-3.

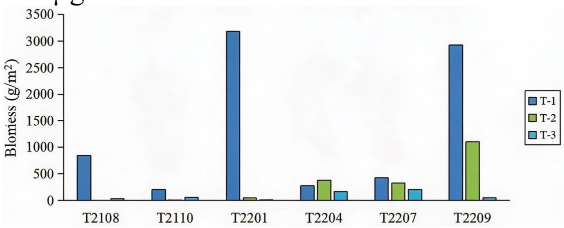

Figure 9. Temporal Variation in Biomass of Meiobenthic Fauna

3.2.3 Diversity levels

Shannon-Wiener diversity index of meiobenthic fauna declined continuously from T2204 to T2201 (Figure 10). T2204 had the highest batch average H' of 1.89, followed by T2108 at 1.48, and T2201 the lowest at 0.69. Inter-station diversity varied moderately in T2204, with T-2 reaching the station maximum of 2.31. Diversity decreased from nearshore to offshore in T2108; T-3 had the highest $H'$of 0.57 in T2110; nearshore T-1 recorded the minimum diversity of 0.31 in T2201. T2209 averaged H' of 1.05 across stations, with diversity rising offshore and a peak value of 1.58 at T-3. Spatially, diversity index marginally increased from nearshore to offshore: annual average H′ stood at 1.24 for T-1, 1.25 for T-2 and 1.29 for T-3.

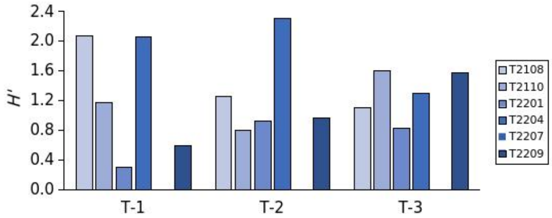

Figure 10. Variation in Shannon-Wiener Diversity Index of Meiobenthic Fauna

Pielou evenness index for meiobenthic fauna (Fig 11) peaked in T2204 with a batch average of 0.87 and bottomed out in T2201 at 0.47. Evenness values were highly consistent across stations in T2204 with a range of only 0.07. T-1 attained the maximum evenness of 0.80 in T2108; inter-station evenness varied little in T2110, peaking at T-3 (0.57). In T2201, T-2 had the highest evenness (0.58) and T-1 the lowest (0.31). T2209 averaged evenness of 0.78, with a maximum of 0.97 at T-2.

Spatial evenness differences were minor: T-1 averaged the highest evenness of 0.63, and T-3 the lowest at 0.60. Temporal trends differed by station: evenness at T-1 declined steadily over sampling periods; T-2's evenness dropped then rebounded from T2201 to T2204; T-3 followed a nearly identical trajectory to T-2.

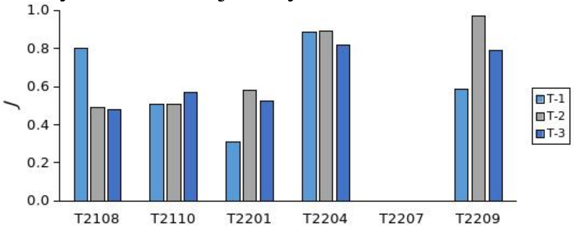

Figure 11. Spatial Distribution of Meiobenthic Evenness Index

3.2.4 Dominance index

Dominant meiofauna species were determined based on the dominance index (Y) ≥ 0.02. A total of five dominant taxa were identified in batch T2108, including Cnidaria, Polychaeta, Halacaroidea, Copepoda and Nematoda, among which Nematoda exhibited the highest dominance value of 0.69. Five dominant taxa were detected in batch T2110, namely Cnidaria, Polychaeta, Rotifera, Copepoda and Nematoda. Nematoda served as the absolute dominant taxon with the highest dominance of 0.78. Four dominant taxa were recorded in batch T2201 (Rotifera, Copepoda, Nematoda and Polychaeta), and Nematoda dominated the community with a dominance value of 0.86. Six dominant taxa (including one undetermined species) were found in batch T2204, ranked by dominance index as follows: Nematoda (0.89) > Acanthocephala (0.82) > Polychaeta (0.34) > unidentified species (0.09) > Halacaroidea (0.02). Only Nematoda was detected in batch T2207. Two dominant taxa, Copepoda and Nematoda, were identified in batch T2209, with dominance values of 0.27 and 0.68, respectively, and Nematoda was the absolute dominant taxon. Overall, Nematoda occurred as the dominant taxon across all sampling batches and was the core dominant meiofauna group in the study area.

4. Conclusions

Surveys confirmed that the Tangjiawan seagrass bed sustains a single seagrass species, Halophila beccarii. The bed reached its maximum coverage in July 2021 and shrank to the minimum area in July 2022, representing a dramatic loss compared with the 2009 baseline area. Key characteristics of benthic biotic communities are summarized as follows:

A total of 31 macro-benthic species across 7 taxonomic groups were identified, with Mollusca as the dominant group containing 14 species. T2204 had the highest average macro-benthic density of 4,893 ind./m² across stations, followed by T2201 at 1,437 ind./m^2. T2201 achieved the maximum macro-benthic biomass of 1,078.24 g/m^2, while T2110 recorded the minimum at 88.73 g/m^2. Macro-benthic diversity index peaked at 1.31 in T2108 and troughed at 1.00 in T2201. Pielou evenness reached its maximum of 0.80 in T2110 and minimum of 0.34 in T2204.

Twenty-nine meiobenthic species across 15 major groups were recovered, with Polychaeta and Copepoda as the most diverse groups (5 species each). The overall average meiobenthic density was 3.45 ind./cm^3, with T2110 recording the highest density. The average annual meiobenthic biomass was 6.46μg/cm^3; T2108 attained the peak biomass of 14.48μg/cm^3, followed by T2110 at 11.62μg/cm^3. Meiobenthic diversity index declined continuously from T2204 to T2201: T2204 had the highest batch average H′of 1.89, T2108 averaged 1.48, and T2201 the lowest at 0.69. Pielou evenness also decreased steadily from T2204 to T2201, with T2204 averaging 0.87 and T2201 averaging 0.47.

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