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Zooplankton Morphology, Abundance, and their Relationship with Physicochemical Parameters in Coastal Waters of Fuerte, Caoayan, Ilocos Sur

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ABSTRACT

Zooplankton, which graze on the water column, play a crucial role in maintaining the balance of phytoplankton communities and reducing the frequency of blooms. Despite their substantial contributions to the marine ecosystem, their value to coastal communities was frequently overlooked because of their microscopic nature. The lack of data on marine zooplankton in the Ilocos Sur Region motivated this study conducted in Brgy. Fuerte, Caoayan, Ilocos Sur, to generate new insights into the zooplankton community. It aims to analyze zooplankton morphology, abundance, and physicochemical parameters. Sample collection was conducted during the evening (7 pm to 10 pm). Surface water samples were collected using a handheld fine mesh plankton net (50 μm) and preserved with formaldehyde and Lugol's solution. Thirteen groups of zooplankton populations were recorded in Brgy. Fuerte, Caoayan, Ilocos Sur. They were categorized into two kingdoms: Animalia and Chromista. Common zooplankton included Nauplius larvae, Calanus sp. (Calanoid), and Dioithona sp. (Cyclopoid). The overall density of zooplankton recorded was 192,050 cells/L, which comprises four stations. Regarding species density, the top five dominant species were Favella sp. (Tintinnids) with 163,689 cells/L, Nauplius larvae with 13,478 cells/L, Calanus sp. (Calanoid) with 9,300 cells/L, Sabellaria sp. (Middle trochophore larvae) with 1,283 cells/L, and Dioithona sp. (Cyclopoid) with 1,211 cells/. Future studies should investigate the complex relationships between physicochemical factors and zooplankton abundance and diversity while extending the sampling period to include additional zooplankton species. Understanding these relationships will enhance the comprehension of ecosystem dynamics and develop more effective coastal water management strategies.

Keywords: *Zooplankton, Stations, Density, Species diversity, Water parameters, Population, Ilocos Sur*

INTRODUCTION

Marine ecosystems support a wide variety of animals, from microscopic plankton to enormous whales, and encompass a variety of habitats like coral reefs, coastal regions, and open oceans (Ilac et al., 2024; Mendoza et al., 2023). Central to these ecosystems are zooplankton, which play an integral role in nutrient cycling and act as a foundational food source for many marine organisms, including fish and whales. They play a vital function in preserving the equilibrium and general health of the marine environment.

Spanning a wide size range—from microscopic protozoans to larger metazoans such as jellyfish—zooplankton are indispensable contributors to the food web and nutrient cycling, underscoring their ecological importance. They contribute to ecological processes such as carbon sequestration through the biological carbon pump, a mechanism that aids in transporting carbon to deeper ocean layers (Turner, 2004). Their role in regulating phytoplankton populations also helps maintain water quality and balance within aquatic ecosystems. Notably, they facilitate carbon sequestration through the biological carbon pump, as elucidated by Pinti et al. (2023), and enhance carbon export through fecal pellet deposition (Halfter et al., 2020). Furthermore, their ability to regulate phytoplankton populations contributes to preserving water quality and ecological balance (Okogwu, 2010; Turner, 2004).

The abundance, diversity, and biomass of zooplankton profoundly influence aquatic environments. As biomonitoring indicators, they serve as reliable indicators of ecosystem health (Davies et al., 2009; Florendo, 2003). Copepods, a subclass of zooplankton, exhibit filter-feeding capabilities and contribute to water quality maintenance. However, they are susceptible to ecological disturbances, such as pollution, which can disrupt metabolic processes (Lauritano et al., 2012). In the context of fisheries, zooplankton provide a nutrient-rich and cost-effective protein source for fish, thereby supporting global economies (El-Fattah et al., 2008; Kibria et al., 1997). For instance, (Mamaril, 2001), in Lake Taal in Batangas, renowned for its highly valued fish "*Sardinella tawilis*," zooplankton plays a crucial role as food items during early life and some adult stages.

Environmental factors like temperature, salinity, and human activity influence the distribution of zooplankton worldwide. With the help of tropical waters and nutrient-rich upwellings, zooplankton flourish in ecosystems like coral reefs and mangroves in the Philippines, known for its rich marine biodiversity (Villanoy et al., 2011). Nevertheless, seasonal variations and anthropogenic disturbances often lead to fluctuations in local populations (David et al., 2005). Advanced research techniques, including water quality monitoring system tools (Divina et al., 2023), in-situ sampling, and satellite remote sensing offer important insights into zooplankton dynamics (Basedow et al., 2019). Zooplankton form and distribution are influenced by biological succession stages, waterbody size, and trophic circumstances (Cloern, 2001). These studies improve resource management techniques and advance our understanding of their ecological significance (Hays et al., 2005; Villanoy et al., 2011). Environmental pressures endangering zooplankton populations globally include pollution, overfishing, and climate change. Their ability to survive and procreate is hampered by ocean acidification, warming temperatures, and microplastic pollution, which upsets marine food webs (Cole et al., 2013; Fabry et al., 2008). Global collaboration is required to monitor and lessen human impacts on ocean health and address these issues (Richardson, 2008). Pollution and climate change in the Philippines exacerbate the problems that marine ecosystems confront, causing zooplankton populations to drop and endangering the ecosystem's health (Botterell et al., 2023; Lasco, 2022; Shaira Elyza R. et al., 2024).

The Ilocos Sur Region lacks published data on marine zooplankton studies, making this potentially the area's first documented account of zooplankton communities. The coastal waters of Brgy. Fuerte, Caoayan, Ilocos Sur, are an ideal site for zooplankton research due to their rich fishing grounds and distinctive features, including an oyster farm, estuarine regions, Fuerte Beach (a residential area), and Choco Surf (a tourist destination). These diverse environments and varying levels of human and natural disturbances provide a valuable opportunity to examine their effects on zooplankton populations.

Objectives of the Study

This study examined the morphological characteristics, abundance, diversity, and the relationship between physicochemical parameters across four selected stations in Brgy. Fuerte, Caoayan, Ilocos Sur.

METHODOLOGY

Research Design

This study used a mixed design (qualitative-descriptive) to determine zooplankton species composition, abundance, and diversity at four stations in Barangay Fuerte, Caoayan, Ilocos Sur.

Study Site

The study was conducted in Barangay Fuerte, Caoayan, Ilocos Sur. Fuerte is a barangay in the municipality of Caoayan, located in the province of Ilocos Sur.

The 2020 Census (PhilAtlas, 2024) reported a population of 2,675, representing 13.67% of Caoayan’s total population. Four coastal stations were selected: ST1-Choco Surf (tourist area), ST2-Fuerte Beach (residential area), ST3-Estuary, and ST4-Oyster Farm. Each station has unique characteristics, including anthropogenic disturbances that impact the zooplankton community. The coastal waters of Fuerte Caoayan are also fishing grounds for marine shore fish and shellfish.

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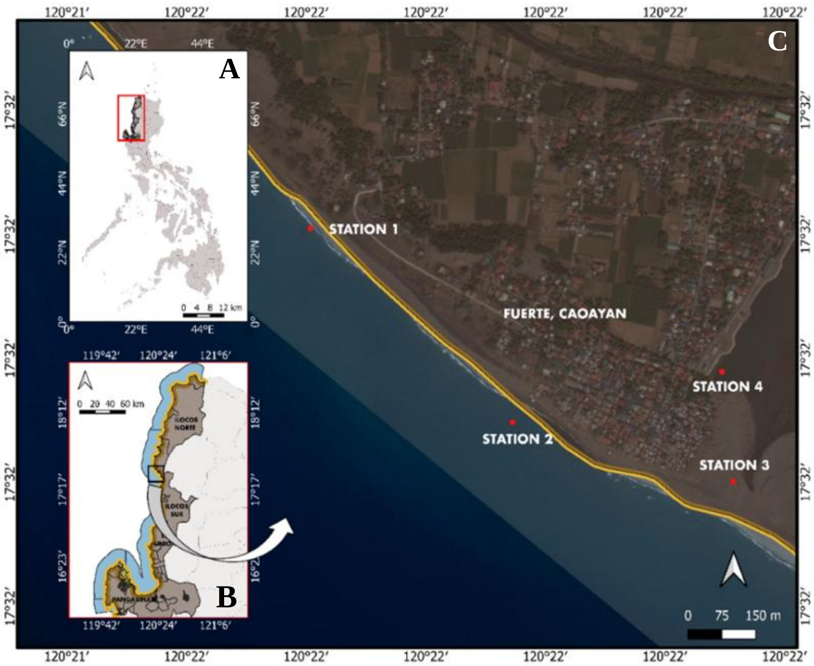

Figure 1
Map showing the study site. A) Map of the Philippines showing Region 1. B) Map of Region 1 showing Brgy. Fuerte, Caoayan. C) Map of Brgy. Fuerte, Caoayan showing the four sampling stations (red circles).

Data Gathering Procedure

Sample Collection. Sampling was conducted from 7:00 PM to 10:00 PM to account for the nocturnal behavior of zooplankton, which undergoes vertical migration at night. From February to March 2024, which serves as cool-dry to warm-dry months, samples were collected three times over a month, with a 10-day interval between each collection. Surface samples were collected using a handheld fine mesh plankton net (50 μm) and a 10L bucket. Water was filtered through the net, washed, and transferred into 100ml empty canisters. Samples were labeled with the date and time of sampling. Three canisters were collected from each station, representing three replicates.

Zooplankton Samples Preservation. Collected samples were preserved with 5% formaldehyde for 1 minute. Lugol's solution was added to stain cells using a medicine dropper and then mixed gently. Phytoplankton samples were undistributed in the dark at room temperature for 48 hours to settle. After sedimentation, the water bottle was carefully sucked

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out, and the final volume was adjusted to 50 mL. The remaining 50mL water sample was used for cell count and zooplankton identification. After the experiment, the water samples were disposed of properly in the designated waste containers. Used bottles, containers, and other materials were also discarded properly.

Taxonomic Identification. The volume of collected samples from each station was standardized to 50mL. Gently shake the canister and mix the upper and lower layers. Five mL aliquots were examined under a microscope using a 1ml Sedgewick-R after the counting chamber. Zooplankton identification at the genus level and phylum categorization was based on morphology, structures, and shape, aided by manuals and field guides of Slotwinski et al. (2014); Yamani et al. (2011a) & (2011b). Photographs were taken at 4x and 10x magnification.

Zooplankton Density. Aliquots were placed in the Sedgewick-Rafter cell under the microscope for accurate phytoplankton counting. To prevent overfilling, coverslips were used to mitigate evaporation-induced air space formation. The counting process involved moving the cell vertically along the first column of squares, tallying organisms in each square. The total plankton count in a 50 ml water sample was determined using the formula established by (Santhanam et al., 1989).

$$N=(n \times v)/V$$

Where in: N = the total number of plankton cells per liter of water-filtered; n = average number of plankton cells in 1 ml. of plankton samples; v = volume of plankton concentration (ml); V = volume of water filtered (l)

Species Diversity. Zooplankton species diversity was determined using the Shannon-Weiner Index, which is presented below;

$$H' = -\sum_{n-1}^{n} (pi * lnpi)$$

Where pi = proportion of total sample represented by species; n = represents the total number of species (or different categories) in the community or sample.

Furthermore, the results of the diversity index were interpreted using the guidelines of Fernando et al. (1998), as cited by (Coracero et al., 2020).

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Table 1
Categories of Species Diversity Index

Relative Values	*H'* Values	Evenness Index
Very High	3.5 and above	0.75 – 1.00
High	3.0 – 3.49	0.5 - 0.74
Moderate	2.5 – 2.99	0.25 - 0.49
Low	2.0 – 2.49	0.15 - 0.24
Very Low	1.9 and below	0.05 - 0.14

Dana Analysis

Mean was used to determine the average value of water parameters and the abundance of zooplankton species.

RESULTS AND DISCUSSIONS

1. Morphological Characteristics of Zooplankton

Thirteen species of zooplankton populations were recorded in Brgy. Fuerte, Caoayan, Ilocos Sur. They were categorized into two kingdoms: Animalia and Chromista. The populations were divided into five phyla with corresponding classes: Arthropoda (three classes: Malacostraca, Copepoda, Branchiopoda), Annelida (one class: Polychaeta), Cnidaria (two classes: Scyphozoa, Cubozoa), Ciliophora (one class: Oligotrichea), and Foraminifera (one class: Globothalamea); see below the taxonomic classification system.

Kingdom: Animalia
- **Phylum:** Arthropoda (Gravenhorst, 1843)
  - **Subphylum:** Crustacea (Brünnich, 1772)
    - Nauplius larvae (**Figure 2**)
    - **Class:** Malacostraca (Latreille, 1802)
      - **Order:** Amphipoda (Latreille, 1816)
        - **Family:** Gammaridae (Latreille, 1802)
          - **Genus:** *Gammarus* (Fabricius, 1775)
            - *Gammarus* sp. (**Figure 3**)
      - **Order:** Cumacea (Krøyer, 1846)
        - **Family:** Leuconidae (Sars, 1878)
          - **Genus:** *Nannastacus* (Bate, 1865)
            - *Nannastacus* sp. (**Figure 4**)
    - **Class:** Copepoda (Edwards, 1840)

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Order: Calanoida (Sars, 1903)
Family: Calanidae (Dana, 1849)
Genus: *Calanus* (Leach, 1816)
Calanus sp. (**Figure 5**)
Order: Cyclopoida (Burmeister, 1834)
Family: Oithonidae (Dana, 1853-1855)
Genus: *Dioithona* (Kiefer, 1935)
Dioithona sp. (**Figure 6**)
Order: Harpacticoida (Sars, 1903)
Family: Ectinosomatidae (Sars, 1903)
Genus: *Microsetella* (Brady & Robertson, 1873)
Microsetella sp. (**Figure 7**)
Class: Branchiopoda (Latreille, 1817)
Order: Onychopoda (Sars, 1865)
Family: Podonidae (Mordukhai-Boltovskoi, 1968)
Genus: *Evadne* (Lovén, 1836)
Evadne sp. (**Figure 8**)
Phylum: Annelida (Lamarck, 1802)
Class: Polychaeta (Grube, 1850)
Order: Canalipalpata
Family: Sabellariidae (Johnston, 1865)
Genus: *Sabellaria* (Lamarck, 1818)
Sabellaria sp. (Early trochophore) (**Figure 9**)
Sabellaria sp. (Mid trochophore) (**Figure 10**)
Phylum: Cnidaria (Hatschek, 1888)
Class: Scyphozoa (Goette, 1887)
Ephyra (Scyphozoa) (**Figure 11**)
Class: Cubozoa (Werner, 1973)
Medusa (Cubuzoa) (**Figure 12**)
Kingdom: Chromista
Phylum: Ciliophora (WoRMS, 2024)
Class: Oligotrichea (Bütschli, 1887)
Order: Choreotrichida (Small & Lynn, 1985)
Family: Ptychocylididae (Kofoid & Campbell, 1929)
Genus: *Favella* (Jörgensen, 1924)
Favella sp. (**Figure 13**)
Phylum: Foraminifera (d'Orbigny, 1826)
Class: Globothalamea (Pawlowski et al., 2013)

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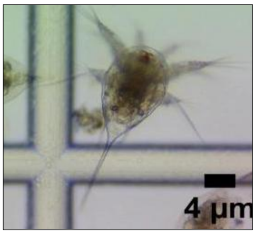
Order: Rotaliida (Lankester, 1885)
Family: Discorbidae (Ehrenberg, 1838)
Genus: *Discorbis* (Lamarck, 1804)
Discorbis sp. (**Figure 14**)

Figure 2

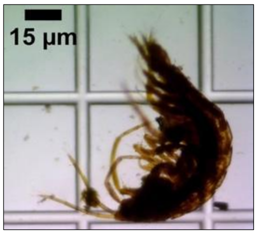
Nauplius larvae



The nauplius larvae were found at all stations, with a mean length of 26.22 µm ± 3.61 µm. They have three pairs of appendages: the first antennae, the second antennae, and the mandibles. The body is unsegmented, and they have a single eye in the center of the head. (Martin & Davis, 2001).

Figure 3

Gammarus sp.



The amphipod genus *Gammarus* was found only in Oyster Farm, averaging 82.29 µm ± 5.46 µm in length. They can infiltrate and colonize environments due to their extensive trophic repertoire, foraging adaptability, migration, and tendency to wander. *Gammarus* also have a high reproductive capacity, producing many broods, offspring, and a relatively long lifespan of 1-2 years (Gerhardt et al., 2011).

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Figure 4

Nannastacus sp.

The genus *Nannastacus*, found only in Residential, has an average length of 38.86 μm ± 1.20 μm. It has elongated bodies segmented into distinct parts, including a carapace fused to the first thoracic segment, forming a protective hood. Cumaceans usually lie submerged in the sediment, needing to stay in contact with the water to pump oxygenated water over their gills (Schram & Koenemann, 2022b).

Figure 5

Calanus sp.

The calanoid genus *Calanus* was found at all stations, with a mean length of 88.04 μm ± 14.22 μm. They have elongated bodies and segmented appendages for swimming and feeding (Blaxter et al., 1998).

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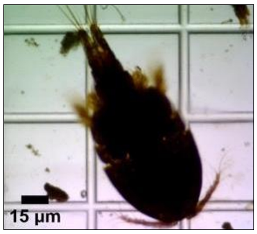
Figure 6

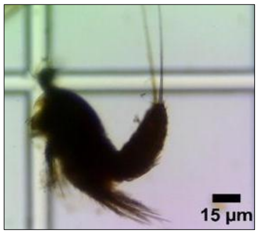
Dioithona sp.



Cyclopoid genus *Dioithona* was found at all stations Choco Surf, Residential, Estuary, and Oyster Farm, averaging 103.11 µm ± 26.28 µm. They have streamlined bodies, single eyes, antennae, and swimming legs for rapid movement, often as freshwater and marine predators (Schram & Koenemann, 2022a).

Figure 7

Microsetella sp.



Microsetella, a harpacticoid genus, was found at three stations: Fuerte Beach, Estuary, and Oyster Farm with a mean length of 63.56 µm ± 15.46 µm. It has an elongated worm-like body equipped with caudal setae that help slow down its sinking velocity (Uye et al., 2002).

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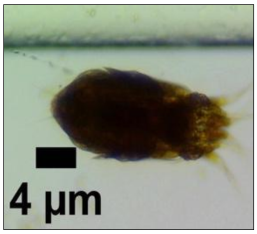
Figure 8

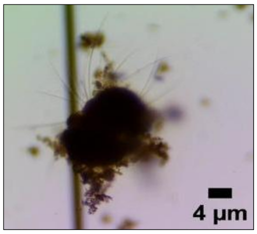
Evadne sp.



The cladoceran genus *Evadne* was found only in Estuary, averaging 17.80 ⌠m ± 0.06 ⌠m in length. Evadne are oval-shaped with large compound eyes, several swimming appendages, and a long tailspin (Aquascope, 2000).

Figure 9

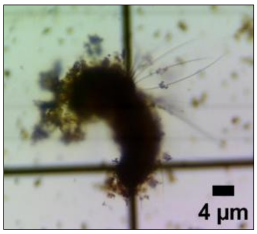
Sabellaria sp. (Early trochophore)



The tubeworm genus *Sabellaria* (early trochophore) larvae were found in Estuary and Oyster Farm, averaging 15.62 µm ± 0.59 µm. The turf, which beats slowly from one side of the episphere, is wrinkled in the apical and hypospherical regions of the vitelline membrane (Smith & Chia, 2011).

Figure 10

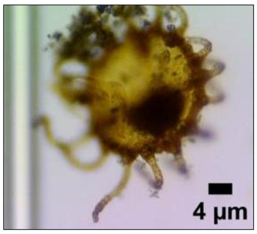
Sabellaria sp. (Mid trochophore)



Mid trochophore larvae found in Choco Surf, Fuerte Beach, and Oyster Farm average 24.32 ⌠m ± 2.09 ⌠m in length. It is distinguished by a pygidium, a provisional setae, and the hyposphere's division into two segments. The apical turf comprises three bundles of short, laterally beating cilia (Smith & Chia, 2011).

Figure 11

Ephyra (Scyphozoa)



Ephyra (scyphozoa), a jellyfish genus, was found at three stations: Fuerte Beach, Estuary, and Oyster Farm. The mean length of *Ephyrae* was 20.40 ⌠m ± 0.70 ⌠m. They have bell-shaped bodies with trailing tentacles, arising from the medusa stage. *Ephyrae* lack the polyp stage, possessing simple radial symmetry and a gelatinous mesoglea between two epithelial layers (Gershwin, 2016).

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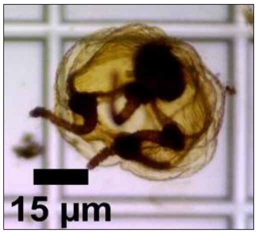
Figure 12

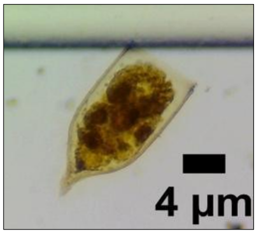
Medusa (Cubuzoa)



The Medusa (cubozoan), found only in the Estuary, has a mean length of 43.61 ⌠m ± 0.26 ⌠m. Box jellyfish, as they're known, have a distinctive cuboidal bell with four tentacles at each corner and a centrally located cluster of appendages called rhopalia containing eyes and sensory structures. This distinguishes them from other jellyfish and reflects their advanced predatory capabilities in the ocean (Gershwin, 2016).

Figure 13

Favella sp.



The *Favella* genus, found in Estuary and Oyster Farms, has a mean length of 16.19 ⌠m ± 0.93 ⌠m. It's a hyaline, particle-free lorica that differs in shape from tintinnids. The Favela form is predominantly cylindrical with a bowl-shaped body and an aboral constriction (Kim et al., 2010).

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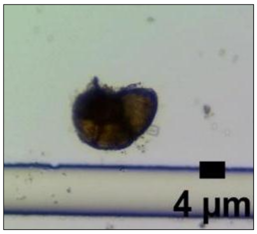
Figure 14

Discorbis sp.



Discorbis, a foraminifera genus, was found only on Oyster Farms. It has a mean length of 10.10 ⌠m ± 0.09 ⌠m. Discorbis are known for their spiral-shaped, chambered shells, commonly found in marine sedimentary environments (Loeblich & Tappan, 1988).

All organisms in Kingdom Animalia that are planktonic during their lives are part of zooplankton communities. Some settle as meroplankton during adulthood. In Kingdom Chromista, organisms such as holoplankton are planktonic for life. They lack chloroplasts or are heterotrophic.

2. Abundance and Diversity of Zooplankton

Table 2 shows the overall zooplankton density in Brgy. Fuerte, Caoayan, Ilocos Sur, comprising four stations. The highest density was in Estuary (159,517 cells/L), followed by Oyster Farm (24,583 cells/L) and Choco Surf (3,311 cells/L). *Favella* sp. (Tintinnids) dominated with 163,689 cells/L, followed by Nauplius larvae (13,478 cells/L), *Calanus* sp. (Calanoid) (9,300 cells/L), *Sabellaria* sp. (Middle trochophore larvae) (1,283 cells/L), and *Dioithona* sp. (Cyclopoid) (1,211 cells/L).

Favella sp. dominated the abundance, with 147,544 cells/L in the Estuary and 16,144 cells/L in the Oyster Farm. Temperature and the summer period contributed to its high abundance at both stations. Similar findings were observed in a study by Durmus et al. (2023), where Tintinnids were prevalent throughout spring and summer, with temperature as the primary factor influencing their composition.

Nauplius larvae, commonly found in all stations, had the highest density in the Estuary (7,866 cells/L), followed by Oyster Farm (2,833 cells/L), and Choco Surf (633 cells/L). This larval stage is characteristic of most crustaceans. (Naung, 2018) noted copepod and barnacle nauplii in shallow coastal estuaries. *Calanus* sp. had the highest density in Oyster Farms (3,533 cells/L), followed by the Estuary (2,422 cells/L), and Fuerte Beach (1,211 cells/L). *Calanus*, a vital ecosystem component and planktivorous fish food mentioned by (Ramírez & Sabatini, 2000), is also temperature-dependent, especially in summer.

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Table 2
Zooplankton Species Abundance in the Four Stations of Fuerte, Caoayan, Ilocos Sur

Zooplankton Population	Coastal Waters				Overall Density
	Choco Surf	Fuerte Beach	Estuary	Oyster Farm	
	x̄ Density (cells/L)				Density (cells/L)
I. Kingdom Animalia					
1. Nauplius larvae	633	2,144	7,866	2,833	13,478
2. *Gammarus* sp.				333	333
3. *Nannastacus* sp.		100			100
4. *Calanus* sp.	2,133	1,211	2,422	3,533	9,300
5. *Dioithona* sp.	244	300	466	200	1,211
6. *Microsetella* sp.		183	133	233	550
7. *Evadne* sp.			133		133
8. *Sabellaria* sp. (Early trochophore larvae)			350	656	1,006
9. *Sabellaria* sp. (Mid trochophore larvae)	300	267		717	1,283
10. Ephyra (scyphozoa)		100	167	133	400
11. Medusa (cubozoan)			100		100
12. *Favella* sp.			147,544	16,144	163,689
13. *Discorbis* sp.			333	133	467
Grand Total	3,311	4,306	159,517	24,583	192,050
Shannon's index (*H'*)	0.98	1.28	0.32	1.03	0.63
Shannon evenness (E_{Sh})	0.77	0.80	0.18	0.56	0.25
***H'* Condition Index**	Very Low	Very Low	Very Low	Very Low	Very Low

Sabellaria sp. (middle trochophore) larvae were the second most abundant species at all three stations, except the Estuary. Oyster Farm had the highest density (717 cells/L), followed by Choco Surf (300 cells/L), and Fuerte Beach (267 cells/L). These larvae are just before settlement. The Estuary's narrow inlet and restricted water flow during low tide made it unsuitable for settlement. The other stations provided favorable conditions due to their wide areas and suitable substrates. Larvae exhibit selective settling in areas with appropriate sediment conditions (Tait & Dipper, 1998). *Dioithona* sp. was found at all stations, with the highest density at the Estuary (466 cells/L), followed by Fuerte Beach (300 cells/L), and the lowest at Oyster Farm (200 cells/L). This zooplankton group belongs to the Orders Cyclopoida

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and Calanoida, indicating suitable marine water conditions for survival (Canencia, 2017).

The Estuary station has the highest overall zooplankton density, with a mean density of 159,517 cells/L. The Oyster Farm station has the second highest density, at 192,050 cells/L. The Fuerte Beach station has the third highest density, at 4,306 cells/L. The Choco Surf station has the lowest density, at 3,311 cells/L. The high density in the Estuary is due to the nutrient-rich environment, which fosters optimal plankton growth. Estuaries receive nutrients from land and ocean sources, promoting plankton proliferation (Cloern, 2001). Mixing fresh and saltwater creates a dynamic ecosystem supporting diverse plankton populations. The elevated plankton levels in the Estuary align with Cloern's understanding of estuarine ecology.

In contrast, the other stations are near residential zones and tourist areas that could affect zooplankton populations. Human activities and pollution inputs, such as garbage, can cause a decline in marine zooplankton abundance (Thushari & Senevirathna, 2020). With their high human activity, Choco Surf and Fuerte Beach experienced lower zooplankton populations due to these factors.

Pollution in the Bilbao estuary enhanced zooplankton abundance in the outer euhaline zone but limited it in the inner zone, as observed by (Uriarte & Villate, 2004). (Mwagona et al., 2018) further demonstrated that water pollution, particularly from total nitrogen and nitrate, significantly influenced zooplankton biodiversity, though the study did not test this. (Echeveste et al., 2011) highlighted the toxic effect of complex organic pollutants on phytoplankton, a crucial food source for zooplankton. These studies collectively underscore the detrimental impact of human activities and pollution on marine zooplankton abundance.

The overall species diversity of Zooplankton populations is very low, with $H' < 1.99$ (Table 1 & 2). Evenness (E_{Sh}) is slightly even at Fuerte Beach ($E_{Sh} = 0.80$) and Choco Surf ($E_{Sh} = 0.77$), but not at Oyster Farm ($E_{Sh} = 0.25$), and Estuary ($E_{Sh} = 0.56$) (Table 1 & 3). Shannon's theorem states that evenness (E_{Sh}) ranges from 0 to 1, with 1 representing high evenness.

3. Significant Difference Between and Among the Abundance and Species of Zooplankton in the Different Sampling Stations

Table 3 shows the ANOVA results for zooplankton abundance across different stations. The stations revealed no substantial variation in the abundance of the species across different stations because the upper and lower limits of all species overlapped in the 95% confidence interval. Variations across species demonstrated significant differences based on Tukey's Honestly Significant Difference. In the group of *Favella* sp.-Calanoid (p = 0.000143), *Favella* sp.-Cyclopoid (p = 0.0000349), *Favella* sp.-Early trochopore larvae (p = 0.00141), *Favella* sp.-Ephyra scyphozoa (p = 0.0135), Harpacticoid-*Favella* sp. (p = 0.00131), Mid trochophore larvae-*Favella* sp. (p = 0.00399), and Nauplius larvae-*Favella* sp. (p = 0.

0.0000915).

Table 3

One-way Analysis of Variance (One-Way ANOVA) on the significant difference in zooplankton abundance

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
Species	12	1.056e+11	8.802e+09	3.129	0.000494	***
Station	3	1.454e+10	4.848e+09	1.723	0.164175	
Residuals	167	4.698e+11	2.813e+09			

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

The high abundance of *Favella* sp. was due to their exhibits of behavioral selective particle feeding mechanisms, which are common to the group of tintinnid ciliate, according to (Stoecker et al., 1995). It also exhibits intricate behavioral responses to phytoplankton, such as adjustments in swimming speed and turning rate when interacting with its exudates (Buskey & Stoecker, 1989). On the other hand, harpacticoid copepods, along with their nauplii, are essential components of marine ecosystems. They possess varied life cycles, progressing through six nauplius and six copepodid stages, and are well-suited to various habitats, spanning from marine to freshwater environments (Dahms & Qian, 2004). Lastly, the abundance of this mid-trochophore larva is due to its dominant larval stages in different phyla, which constitute the major branch of Bilateria. (Dahms & Qian, 2004).

Coastal Water Parameters

Table 4 shows the mean values of water parameters at the four stations in Fuerte, Caoayan, and Ilocos Sur compared with the standard values of seawater and estuarine water.

Coastal water salinity varies widely, with Choco Surf recording the highest average of 32.77‰ (± 0.03), followed by Fuerte Beach at 32.40‰ (± 0.60). The Estuary has a lower average of 29.67‰ (± 0.58), while the Oyster Farm has the lowest at 28.63‰ (± 0.58). All stations met the optimum marine biota salinity range of 0.5 ‰-40 ‰ (Jain, 2011; van Velzen, 2022). Choco Surf and Fuerte Beach are euhaline (32.77±0.03 ‰), while Oyster Farm and Estuary are polyhaline (18 ‰-30 ‰) based on Mitsch and Gosselink (1986) as cited by Ohrel and Register (2006). Mixing freshwater from the Mestizo River slightly decreased salinity in these stations. Salinity, a chemical stressor of dissolved salts, indicates species tolerance or range limitations and affects community organization (Smyth & Elliott, 2016).

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Table 4
Mean Physicochemical Parameters in the four stations

Water Parameters	Coastal Waters				Optimum Requirements	
	Choco Surf	Fuerte Beach	Estuary	Oyster Farm		
	x̄ values				Marine	Estuarine
a. Salinity (‰)	32.77±0.03	32.40±0.60	29.67±0.58	28.63±0.58	30-40 (Jain, 2011)	0.5-30 (van Velzen, 2022)
b. Temperature (°C)	27.27±0.13	27.30±0.15	28.10±0.40	28.23±0.28	25.00-31.00 (DAO, 2016)	0-30 (Kennish, 1990)
c. pH	7.90±0.03	7.93±0.03	8.14±0.08	7.94±0.06	6.50-8.50 (DAO, 2016)	7.0-7.5 (USEPA, 2006)
d. Turbidity (NTU)	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	30 (FEI, 2014))	1-100 (Gallegos et al. 1990)
e. Dissolved oxygen (mg/L)	8.90±1.35	8.93±1.33	4.97±0.26	5.50±1.04	> 5.00 (DAO, 2016)	5.5-11.8 (Priya et al., 2022)
f. Total Dissolved Solids (ppm)	266.33±0.67	267.33±1.20	241.00±5.03	234.30±5.33	>10,000 (Adjovu et al., (2023)	500-30,000 (Horsburgh & Wilson, 2007)
g. Electrical conductivity (mS/cm)	53.43±0.07	53.73±0.26	48.63±0.88	47.40±1.02	30.00-60.00 (Zheng et al., 2018)	35.10-49.34 (Cameron & Pritchard, 1963)

Table 4 shows that all stations maintain optimal temperatures between 25-31°C (DENR Administrative Order 2016-08, 2016). Oyster Farm and Estuary recorded slightly higher temperatures (28.23±0.28 and 28.10±0.40°C, respectively) than Fuerte Beach (27.30±0.15°C) and Choco Surf (27.27±0.13°C). The colder sea surface temperature and winds during nighttime sampling may have affected water cooling.

Coastal waters exhibit varying pH levels, with the highest average pH (8.14±0.08) in the Estuary, which is slightly alkaline. Fuerte Beach and Choco Surf have similar pH levels (7.93±0.03 and 7.90±0.03, respectively). The Oyster Farm area has the lowest average pH (7.94±0.06), slightly acidic. All stations' pH levels are optimal (6.50-8.50) for marine and estuarine water. The estuary's slightly higher pH (8.14±0.08) is due to the mixing of freshwater and saltwater at the mouth, as suggested by the (United States Environmental Protection Agency, 2006). This could include the estuarine mouth, which connects to the ocean.

Across all stations, turbidity was lower than the optimum requirements in Marine and Estuarine (Table 4). Sandy substrates at Choco Surf and Fuerte Beach settle sediment-granulated particles quickly, even under strong wave action. In the Estuary and Oyster Farm, sandy-muddy substrates with less water movement and agitation exhibit low sedimentation. Lower turbidity reduces pollutant concentration, promoting a healthy ecosystem (Fondriest Environmental Inc., 2014).

Coastal waters vary in dissolved oxygen levels. Choco Surf and Fuerte Beach have the highest average concentrations (8.90±1.35 mg/L and 8.93±1.33 mg/L, respectively), while the Estuary and Oyster Farm areas have lower concentrations (4.97±0.26 mg/L and 5.50±1.04 mg/L, respectively). These levels meet the optimum requirement except in the Estuary. Choco Surf and Fuerte Beach exceed the requirement of > 5 mg/L, while the Estuary falls below it. This oxygen deficiency could be due to rapid oxygen consumption, especially at night, caused by respiration and organic matter degradation (Horak et al., 2016).

Coastal waters exhibit significant TDS variation, with Fuerte Beach having the highest average concentration (267.33±1.20 ppm) and Choco Surf (266.33±0.67 ppm) closely behind. The Estuary (241.00±5.03 ppm) shows a decrease, while the Oyster Farm area (234.30±5.33 ppm) has the lowest. All stations below the optimum TDS requirements (500 to > 10,000 ppm) (Adjovu et al., 2023; Horsburgh & Wilson, 2007). Lower TDS indicates minimal nutrient influx, resulting in fewer ions and organic ions. Weber-Scannell and Duffy (2007) suggest alterations in ionic composition can eliminate certain species while promoting others, but it doesn't quantify TDS and can't determine if species composition has been compromised. The area's good condition is attributed to fewer ions and no signs of eutrophication.

Coastal waters exhibit variations in electrical conductivity. Fuerte Beach and Choco Surf have the highest average conductivity (53.73±0.26 mS/cm and 53.43±0.07 mS/cm, respectively). In contrast, the Estuary and Oyster Farm areas have lower values (48.63±0.88 mS/cm and 47.40±1.02 mS/cm, respectively). Based on (Chanson et al., 2005; Zheng et al., 2018), all values fall within the optimum range of 30.00-60.00 or 35.10-49.34 mS/cm. According to (Aluwong et al., 2024), increased electrical conductivity indicates elevated dissolved solids, which can harm aquatic organisms, human well-being, and industrial operations. However, the EC levels in this study were not alarming as they met the optimum requirement, suggesting low inorganic and organic ions. Despite the low dissolved solids, the EC remained within the optimum range due to the concentration of dissolved salts.

CONCLUSIONS

The findings of the study revealed that Brgy. Fuerte, Caoayan, Ilocos Sur exhibited a high species richness with a distinct group of morphological characteristics of a planktonic microbiota. Choco Surf Point exhibited the highest salinity, temperature, dissolved solids, and electrical conductivity, while Fuerte Beach recorded the highest pH and dissolved oxygen levels among the studied stations. The highest recorded physicochemical values of the two stations are attributed to frequent water movement, such as wave action. However, Brgy.

Fuerte, Caoayan, Ilocos Sur, and the four sampling stations are in very low conditions for species diversity, with no evenness in a population due to the significant dominance of the species *Favella* sp.

RECOMMENDATIONS

Implementing a comprehensive monitoring program to evaluate nutrient water quality in Brgy. Fuerte, Caoayan, and Ilocos Sur is imperative to ensure consistent adherence to minimum standards and identify potential alterations or trends over time. The findings of this study will be disseminated to the community for ongoing public awareness. Investigate the diel vertical migration pattern of zooplankton to elucidate the movement of zooplankton to deeper depths as they ascend from the surface.

ETHICAL STATEMENT

The study underwent Harmonized Gender and Development Guidelines (HGDG) and the College of Arts and Sciences Research Ethics Committee (CAS RERC certification no. 2024-015). The researcher asked permission from the local government unit (LGU) of Fuerte, Caoayan, Ilocos Sur, to collect water samples in study sites through a requested letter. Also, the study was at low risk to the researcher's health since it had minimal fixative use for water samples. After being used, the water samples were properly disposed of following the laboratory protocol.

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