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Pervasive Microplastics and Zooplankton Abundance in Middle East Region of Java North Sea Indonesia: Spatio-Temporal of an Oceanic System

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Abstract: A significant threat to marine food webs is the ingestion of microplastics (MPs—plastic particles below 5 mm) by planktivorous organisms. Between February to August 2024, MPs samples from water coulomb and zooplankton were collected of Jepara and Rembang Region were related to Java North Sea Indonesia. This study was all related to the prey-predator linkage as a result of the size of microplastics affect plastic intake in oceanic islands' ecosystems collected from water samples. Microplastics collected from water sample then identified color, shape, size and abundance by microscope in this research. Microplastics type were analyzed used FTIR (*Fourier Transform Infrared Spectroscopy*) imaging. Zooplankton were identified and classified into their traits, size and abundance. The types of microplastics identified were fragments, fibers, films, and pellets. In water samples, black and fiber microplastics were increasingly common. Therefore, by analyzing the size and characteristics of zooplankton, comparing the abundance of microplastics and zooplankton in the marine environment, it is necessary to comprehend the probability of plastics invading the trophic web of the food chain.

Keywords: Marine, Prey-predator linkage

Introduction

The estimated annual emission of Indonesia microplastic pollution ranges from 0.48 to 1.29 million metric tons, which equates to a concentration of 30 to 960 particles per liter in Indonesian waters (Cordova et al., 2019). In 2021, Indonesia's solid waste volume reached 67.8 million metric tons, with a reported daily production of 31,200 tons of plastic waste (KLHK, 2022). Plastics have become an integral component of contemporary life, with a multitude of applications spanning various sectors, including clothing, electronics, furniture, and medical equipment. They are used extensively across the globe, are inexpensive to produce, and are available in a multitude of forms and qualities (Woods et al., 2019).

Microplastics represent a significant environmental concern, as they are among the most prevalent types of pollutants that can potentially harm living organisms and disrupt natural ecosystems. The provenance of microplastics can be attributed to anthropogenic activities that are deleterious to biota in both terrestrial and aquatic ecosystems. Microplastics have the potential to persist in the environment for extended periods, interacting with other hazardous pollutants, including heavy metals, polycyclic aromatic hydrocarbons, and polychlorinated biphenyls (Rochman et al., 2015).

As indicated by the findings of studies conducted by Hakim et al. (2023) and Ismanto et al. (2023), the majority of microplastic research analyses in Indonesia have been conducted on the south coast of Java Island. In contrast, research on the abundance and toxicity effects of microplastics in the north coast of Java Island remains scarce. The potential for climate change to cause sea level rise on the north coast of Java represents a significant limitation to microplastic research in this location. Furthermore, the topography of northern Java is more undulating than that of southern Java, with high precipitation levels and the presence of significant tidal waves at all times. It is evident that human activities in the northern coastal areas of Java are more prevalent and have the potential to generate a greater quantity of waste than those in the southern regions. The northern coastal area is characterised by a prevalence of industrial activities, tourism, mining and fish markets (Ismanto et al., 2023). This indicates that the characteristics of microplastics are likely to differ between the northern and southern regions of Java Island.

The plains of the upstream and downstream areas of the North Coast of Java are characterized by the presence of plastic clays, which exhibit a low bearing capacity. Consequently, these regions are susceptible to subsidence, which may result in tidal flooding. The rapid industrial growth that has occurred in the inland and coastal areas of the North Coast has resulted in the deforestation of the surrounding mangrove swamp. The results of a study conducted in Jakarta and Central Java (Cordova et al., 2023) demonstrated that mangrove habitats adjacent to the coast have been contaminated with pollutants, and there is a significant presence of microplastics, along with clear indications of anthropogenic impact in the region.

In marine ecosystems, the predator-prey relationship between fish and plankton represents a significant aspect of biotic interactions, potentially influencing the structure of the ecosystem. Plankton have a function as a fundamental component of the food web. Barton *et al*. (2013) was observed that planktivorous organisms exhibited selective behaviour, demonstrating a preference for larger prey and a tendency to select prey with specific shapes and colours. As a prevalent zooplanktivorous predator in marine ecosystems, fish have been observed to ingest plastic particles inadvertently, erroneously identifying them as food sources (Boerger et al., 2010). Ory *et al*. (2017) observed a higher prevalence of blue microplastics within the gastrointestinal tract of fish (*Decapterus muroadsi*), suggesting that these plastic particles were misidentified as prey for blue copepods. It is therefore essential to analyse the size and characteristics of plankton, and to compare the abundance of microplastics and plankton in the marine environment, in order to describe the probability of plastic entering the trophic web of the food chain.

Method

Study Area

Central Java has a wide area from Rembang regency in the east to Brebes regency in the west, Central Java's northern coastline region stretches. From east to west, it was measured approximately 427 kilometers. Jepara regency was located at 110°9'48.02“ to 110°58'37.40” east longitude and 5°43'20.67“ to 6°47'25.83” south latitude. It is the northernmost region of Central Java Province. Jepara Regency is located on the East Coast of Central Java, which is bordered to the west and north by the sea. Furthermore, Rembang Regency is located at the northeastern tip of Central Java Province and is traversed by the Java North Sea, was located at the coordinates 111° 00'-111° 30' East Longitude and 6° 30'-7° 6' South Latitude. The selection of research site was determined by the anthropogenic activities of the surrounding community, the level of pollution generated, and the consumption fishing activities by the local community.

Sample Collection

The sampling sites were recorded using the global positioning system. The Indonesian National Standard for Water Quality Sampling Methods was used as a reference for point sampling. The measurement of microplastic abundance in seawater is based on the observation of microplastic particles under a microscope and the subsequent grouping of data according to the research location and sampling time. Furthermore, the calculation of microplastic abundance is conducted by accumulating all microplastic particle data observed at each location and its replication, thereby determining the total number of microplastic particles present in each research site. Seawater and plankton samples were obtained using a plankton net (Kitahara) with a mesh size of 80 microns, a mesh mouth diameter of 0.31 m, and a length of 100 cm, connected to a 250 ml bottle. Samples were taken in 3 replicates at each station. The measurement of seawater samples was conducted using the NOAA (*National Oceanic and Atmospheric Administration*) WPO (*wet peroxide oxidation*) method. Seawater samples were filtered using a plankton net, with the filtered material transferred to a 50ml bottle. Furthermore, the sample was stored in a 140ml glass bottle and taken to the laboratory for microplastic analysis. The samples were transferred into Erlenmeyer and oven for 24 hours at a temperature range of 40-60°C. Subsequently, the sample was treated with 30% hydrogen peroxide and $FeSO_4$ in the amount of 20ml respectively. Thus it was heated using a hot plate stirrer for 30 minutes at a temperature range of 40-60°C. The sample was filtered using a vacuum pump and filter paper. The filter paper was examined under a photomicroscope and evaluated for its physical and chemical properties.

Sample Analysis

The ISCC-NBS color system is a nomenclature for color based on a set of fundamental and derived colors. The basic colors of microplastics, as defined by the ISCC-NBS (*Inter-Society Color Council National Bureau of Standards*), are as follows: red, brown, yellow, green, blue, purple, white, black, and transparent. The color of microplastics can be either the original color of the plastic prior to degradation or the derived color resulting from degradation (Wu et al., 2018). The presence of colored microplastics is more frequently reported than that of transparent colors (Zhao et al., 2015). The information on the color of microplastics can be applied to determine the propensity of biota to ingest microplastics that closely resemble their prey (Wu et al., 2018).

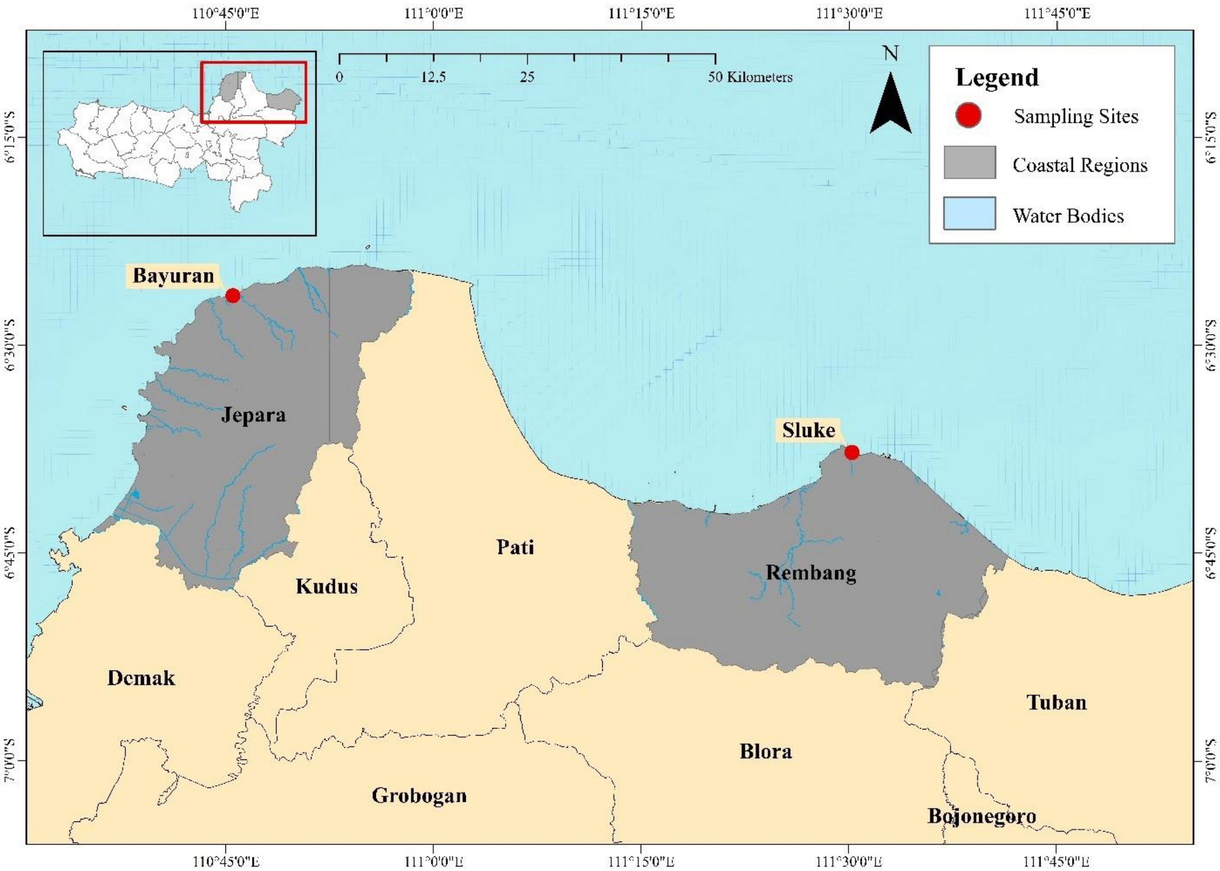

Figure 1. Location of sampling sites along the coast. Note the red dots represent points of water and plankton sampel collections.

Microplastics is defined as particles measuring less than 5 mm in size (Coppock et al., 2017). Pelleted microplastics have a reference diameter of 1 to 5 mm, with a typical diameter of 3.5 mm (Mato et al., 2001). In the case of microplastic fragments, the size range is from 1 µm to 2 mm. The chemical characterization of microplastics can be accomplished through the implementation of a *Fourier Transform Infrared Spectroscopy*, which is designed to determine the specific type of microplastic polymer based on the wavelength that is reflected by the polymer.

The sample fraction method (2.5 ml per 150 ml sample) was applied to calculate the number of zooplankton individuals present in each sample bottle. Subsequently, the samples were transferred to a *Bogorov counting tray* and observed under a microscope with a magnification range of 4-40x. In order to identify the plankton taxonomic groups present in the samples, the reference provided by Nontji (2000) was used as a guide.

Contamination Control

To guarantee the integrity of the results, a series of measures were implemented to maintain a hygienic and uncontaminated working environment, both in the field and laboratory. Prior to the commencement of any experimental procedures, all apparatus, glassware, and work areas were meticulously sanitized using distilled water. It is preferred to use non-plastic research tools and materials. The solutions were filtered using GF/C Whatman 1,2 µm glass microfiber filters. Prior to use, the filter papers and petri dishes were examined under a photomicroscope for magnification. Additionally, procedural blanks (three in total) were conducted concurrently with the sample processing to ensure the absence of cross-contamination. The use of cotton lab coats and nitrile gloves was also implemented to further prevent contamination.

Data Analysis

The zooplankton composition was determined by classification into the following 7 taxonomic groups: Copepoda, Keratella, Chatognatha, Asplanchna, Crustaceans larvae, Siphonophora and Gelatinous zooplankton (others). For the purposes of the present analysis, only groups with an overall abundance proportion exceeding 1% were considered. Subsequently, the length of the longest body dimension for the zooplankton specimens was determined using a photomicroscope. The data has been organised in tables and graphs.

The MP samples were collected and classified according to their type and color. MPs are available in a variety of forms, including pellets, film, fiber or filament, and fragments. Meanwhile, MP types are identified according to Calcutt et al. (2018) by color (translucent, black, blue, red, green, etc.). The MPs were identified using FTIR transmission measurements based on the materials found through library search. The sample's FTIR reading is represented by peaks with different absorption ratings. A quality index of more than 0.7 (70%) is permitted, and the absorption score shows the comparability of particular plastic elements (Comnea-Stancu et al., 2017). The lowest possible score in this examination, as determined by comparison with the reference from the FTIR library for the first characterization study, was set at 60%. Before filtering MPs, a blank study utilizing filter paper was also carried out to ascertain the constituent materials and structure of the original filter paper. The procedure is used to remove bias from FTIR and SEM analysis.

Results and Discussion

Microplastics and Zooplankton Characteristics

A total of 162 particles in all samples were found and examined. All of the samples contained microplastics, with 36.8% of the particles made up of fibers (Fig. 2A). Nevertheless, various forms of plastic particles, such as fragments were present in 13.7%, films in 22.2% and pellets were present in 27.4% of the samples (Fig.2A). The most appearance color of microplastics were in black color (Fig.2B). The majority of the fibers were black, whereas the pellets and fragments were primarily (transculent and black) in color (Fig. 2B). According to Fig. 2B, the most favored color overall was black (56.8%), which was followed by translucent (33.1%), brown (3.4%), blue and orange (2.5%) respectively. There are three class sizes were categorized in each sample type. Their classes were classified based on their size found in microplastics. Furthermore, small size (1000–5000 µm) of pellets and medium size (100-1000 µm) of fibers, accounting for 24.57% of all particles, were frequently discovered. Thus, films were commonly found in the medium size classes (100–1000 μm), followed by fragments were mostly represented in the medium size classes (100–1000 μm) (Fig. 2D).

In the zooplankton analysis, a total 105 zooplankton found in water sample. There are Asplanchna and Crustaceans Larvae were the most common appearance (representing 33.63% and 22.12% of the total sample respectively), followed by Gelatinous Zooplankton (18.58%) and Copepoda (17.69%), they represented over 85% of the total zooplankton community (Fig. 5). Asplanchna was the most favoured taxa in terms of size classes, in medium size classes (100–1000 μm). Furthermore both Chatognatha and Siphonophora were recorded only 3.39% of total samples.Other groups were recorded in low abundances (< 1 % of the total) was Keratella that only 0.84% in total samples.

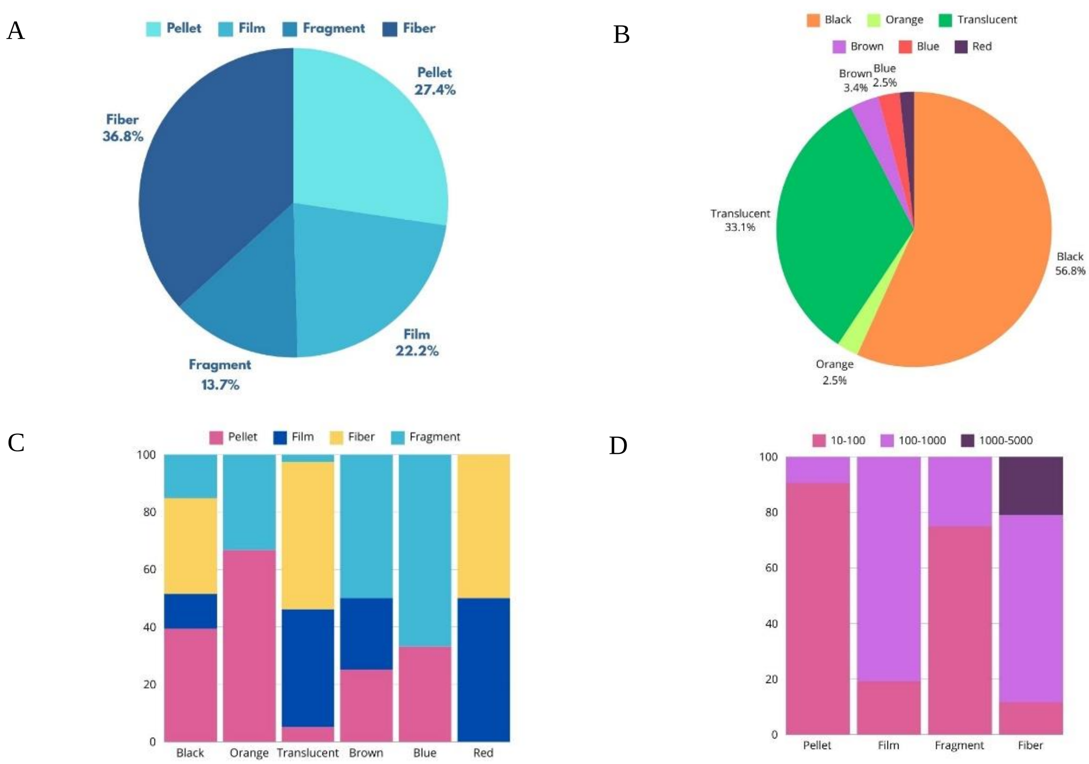

Figure 2. Characteristics of Microplastics found in the water samples: proportion of microplastic type categories (A), proportion of microplastic colors type (B), proportion of microplastics color composition(C) and proportion of size categories for types of microplastic (D).

The abundance of zooplankton and microplastics found was 0.33 individuals/m3 and 0.84 items/m, respectively. The seasonal factors may occur and depend for their abundant. In this research, sampling was conducted in the dry season. Jepara and Rembang were located in tropical region. The temperature showed 30^{o}C and low precipitation. Furthermore, the abundance of microplastics was not correlated with average precipitation, whereas a positive correlation was identified between precipitation and zooplankton abundance (Sambolino et al, 2022).

The prevalence of microplastics and zooplankton in seawater samples suggests a correlation between marine pollutants and the dietary habits of marine life. Such a conclusion may be drawn based on the size, colour, and groupings that are likely to be selected by natural processes. This phenomenon should be considered in relation to the potential impact of plastic pollution in open-ocean ecosystems. The coincidence in the variation of microplastics (MPs) and zooplankton traits increases the likelihood of MPs ingestion by planktivorous organisms. Moreover, it has been predicted that moderate to high levels of water turbulence will increase the ingestion rates of prey due to an increased frequency of particle contacts, thereby further increasing the possibility of ingestion (Botterell et al., 2019; Saiz et al., 2003).

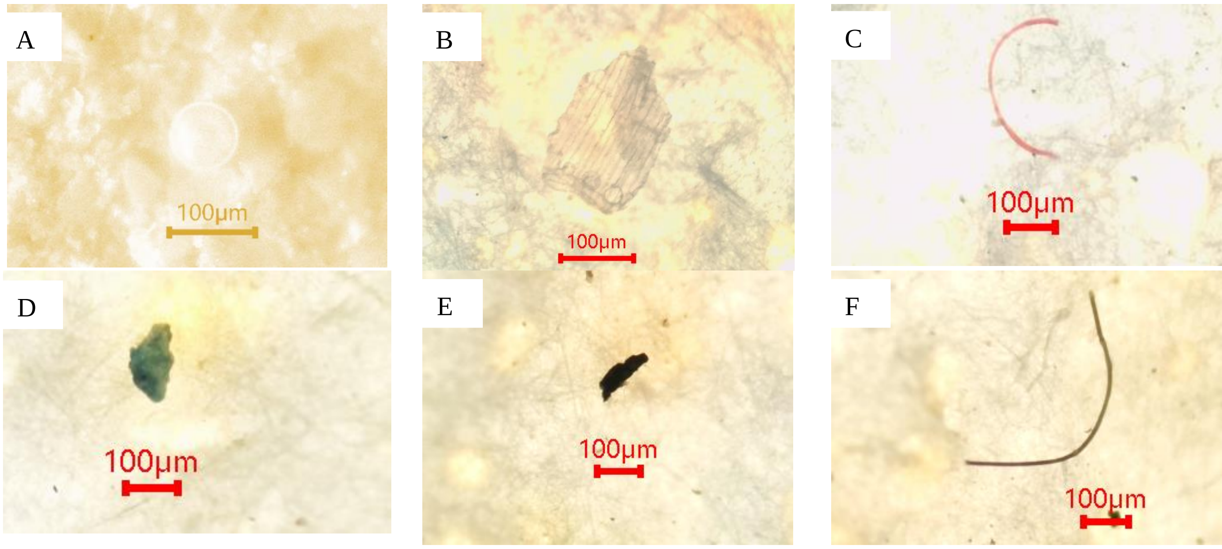

Figure 3. Microplastic identification using a photomicroscope: (a) transparant pellet, (b) transparant film, (c) red filament (d) blue film, (e) black fragment, and (f) black filament. *) (a), (b) with 10x magnification (c), (d), (e), (f) with 4x magnification.

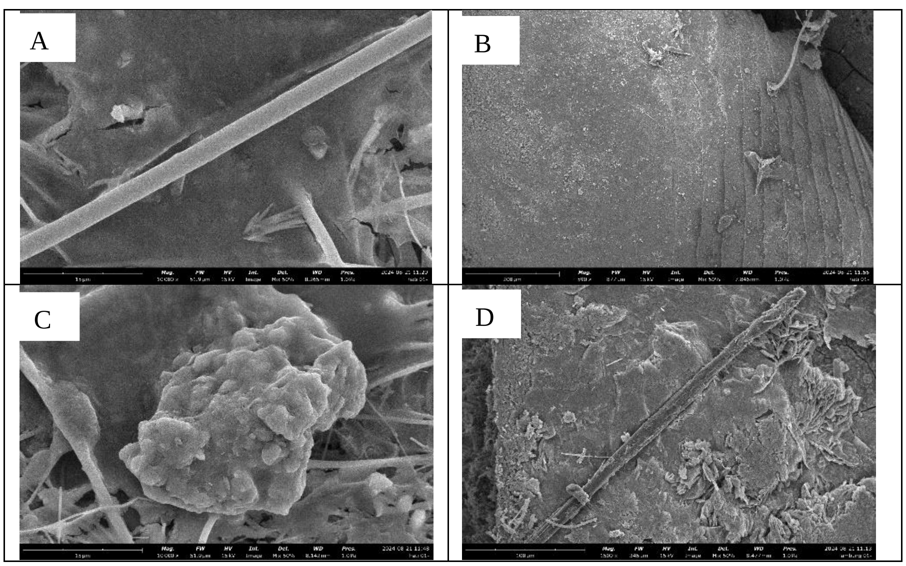

Figure 4. Results for MP surface analysis with SEM microscope: (a) filament magnification = 10.000×; (b) film magnification = 590×; (c) irregular fragment magnification = 10.000×; (d) filament magnification = 2000×.

A total of microplastics was identified type of polymers with Fourier Transform Infrared Spectroscopy (FTIR) shimadzu Irtracer 100. A total of seven types of polymer were identified: LDPE, Latex, Polystirena, Nylon Polyamides, Polypropilena and PET. The properties of Nylon Polyamides polymer are notable for their strength, durability, flexibility, elasticity, and lack of residual monomers. Nylon polymers are utilised in the production of clothing and rope products, as well as in the manufacture of toothbrush bristles. Furthermore Polypropilena is more robust than HDPE, with superior tensile durability and resistance to cracking. The properties of propylene permit the use of this type of polymer in the production of drinking bottles and food containers.

The application of Polystirena polymers is widely found in household appliances, insulators, and food wrapping materials. The properties of LDPE that make it particularly suitable for a number of applications are its weather resistance, strength, chemical resistance, crack resistance, and recyclability. LDPE can be identified as a constituent of a number of commonly used consumer items, including shopping and newspaper bags, packaging for frozen food items, milk carton laminates, plastic wrap and laundry plastic. Latex is a polymer formed through the copolymerisation of several monomers, such as vinyl acetate monomer (VAM) and methacrylic monomer (MMA). The characteristics of latex polymers include resistance to oxidative degradation, ease of production, elasticity, and water resistance. Plastic bottles typically comprise PET polymers, which are used in a variety of packaging applications. These include cooking oil, mineral water, and chili sauce bottles, as well as cosmetic and drug packaging.

Microplastics profiling are necessary to describe the type of polymer. It's prior to conduct in each type of microplastics (fragment, fiber, film and pellet) that would be support the antropogenic activity by surrounding. To support the visualization of microplastics, projections were taken with visual SEM. This aims to determine the morphological structure of microplastics at the size of the nano structure (Fig.4).

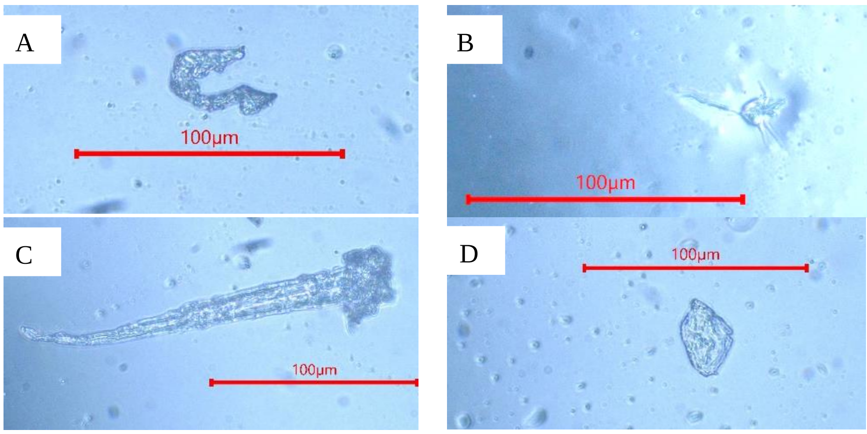

Figure 5. Zooplankton mapping based on their traits and morphology: (a) Copepoda; (b) Keratella; (c) Chaetognatha; (d) Asplancna *) with magnification = 40× respectively.

Conclusion

In the present study, we highlighted the importance of the influence of the occurrence of microplastics and zooplankton in a environment such as a deep ocean system. The most appearance color of microplastics were in fiber type and black color. Because of microplastics was found in black color, the degradation of plastics was occurred in oceanic system. Both microplastic and zooplankton size uptake occurred in the range of 100-1000µm. This provides of the prey-predatory relationship within the food chain, which is correlated with the uptake of microplastics in nature, both in their intact and degraded forms. Microplastics, acting as pollutants, are ingested by planktivorous organisms, which perceive them as food. Barton *et al*. (2013) was observed that planktivorous organisms exhibited selective behaviour, demonstrating a preference for larger prey and a tendency to select prey with specific shapes and colours.

Recommendations

In order to compare the quantity of zooplankton and microplastics in tropical oceans during the wet and dry seasons, this article suggests using seasonal fluctuations to measure these quantities.

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of this article published in EPHELS Journal belongs to the author.

* The authors declare that none of the work reported in this study could have been influenced by any known competing financial interests or personal relationships.

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