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RESEARCH PAPER

Potential of Gastropods as Bioassessment of Anthropogenic Litter Pollution in Urban Lake

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Abstract

This study on Anthropogenic Litter (AL) was conducted at 5 stations in Situ Gintung, South Tangerang, Indonesia, during the dry and rainy seasons between May to July 2015 and February to April 2016, respectively. The objectives were to determine the correlation between temporally and spatially distributed AL items with gastropods and bioassessment of lake from AL. Generally, the AL consisted of plastic products, rubber, cans, paper, and glass, where plastic bags were discovered more during the two seasons at insignificantly different quantities ($p>0.05$) and all stations at significantly different amounts ($p<0.05$). The total number and percentage AL cover with gastropods had a low linear regression value and increased by more than 80% during the rainy season. Meanwhile, the difference in the number of AL was insignificant by season but significant based on the station. Although AL had little effect on gastropods, the number of individual organisms decreased as the number and percentage of cover increased and vice versa. The results suggest that variation of presence of gastropods can be used as a bioassessment inorganic pollution of lake ecosystems.

Introduction

The global aquatic and terrestrial environments have been contaminated by synthetic and inorganic anthropogenic litter (AL) items. Micro- and macro-sized AL items have covered the environment (Barnes *et al.,* 2009), lakes (Baldwin, Corsi & Mason, 2016), rivers (Blettler *et al.,* 2017; Gasperi *et al.,* 2014), and the oceans (Jambeck *et al.,* 2015). AL has negatively impacted the environment due to its effects on the population (Besseling *et al.,* 2014), trophic interactions and groups of life (Gall & Thompson, 2015), economic costs (Driedger *et al.,* 2015; Newman *et al.,* 2015), alongside direct and indirect outcomes on human health (Thompson *et al.,* 2009a). Some sources of these items in the freshwater environment, such as plastic, glass, cans, and so on, are originate from human activities like shipping traffic, fisheries, agriculture, and recreation. Other sources come from industry, household waste, and population density (Arturo, 2021; Ballent *et al.,* 2016; Earn *et al.,* 2021; Egessa *et al.,* 2020; Lazcano *et al.,* 2020; Ngupula *et al.,* 2014; Vincent & Hoellein, 2017; Vincent *et al.,* 2017; Yin *et al.,* 2019).

Lake ecosystems are impacted by AL because they are used as a dumping ground for domestic and industrial waste (Chen *et al.,* 2016). The sources of AL in lakes are human and industrial activities (Driedger *et al.,* 2015), with the largest amount of plastic waste in urban

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areas (Baldwin *et al.,* 2016), due to the correlation with population density (Earn *et al.,* 2021; Hoellein *et al.,* 2015). AL pollution in lakes causes stunted reproduction and growth, disrupts hormones and biota tissues (Oehlmann *et al.,* 2009), inhibits water gas exchange (Ngupula & Kayanda, 2010), and gastropod, riparian, and fish (Akindele, Ehlers & Koop, 2019; Driedger *et al.,* 2015; Merga *et al.,* 2020). Furthermore, it results in sediment contamination (Ballent *et al.,* 2016; Blettler *et al.,* 2017; Corcoran *et al.,* 2015; Turner *et al.,* 2019), microorganism vectors (Hoellein *et al.,* 2014), inhibits growth (Vosshage, Neu & Gabel, 2018), and affects freshwater biota populations (Earn *et al.,* 2021). AL, such as plastic, also occurs in the sea and coasts, affecting water movement, coastal heat (Carson *et al.,* 2011), changes in organism behavior (Aloy, Vallejo & Juinio-Meñez, 2011; Thevenon, Carroll & Sousa, 2014), and leading to the accumulation of heavy metals in these synthetic materials (Pradit *et al.,* 2021).

Numerous studies have been conducted on AL in freshwater (Baldwin *et al.,* 2016; Biginagwa *et al.,* 2016; Corcoran *et al.,* 2015; Czarkowski *et al.,* 2016; Faure *et al.,* 2012; Fischer *et al.,* 2016; Free *et al.,* 2014; Hoellein *et al.,* 2014; Imhof *et al.,* 2013; Lazcano *et al.,* 2020; Ngupula *et al.,* 2014; Su *et al.,* 2016; Wang *et al.,* 2017; Zbyszewski & Corcoran, 2011; Zbyszewski, Corcoran & Hockin, 2014; Zhang *et al.,* 2016). However, there is little information on biological effect (Wagner *et al.,* 2014) and AL distribution in Asia (Wu, Zhang & Xiong, 2018) pertaining to the Indonesian lake ecosystem. Furthermore, bioassessment of AL in urban lakes has not been carried out using gastropods. Benthic biota, such as gstropods, that have limited movement will therefore be affected by the presence of the AL. The results of previous studies have shown that gastropods in the lake are used as bioassessments and bioindicators of water quality (Paylangco *et al.,* 2021; Mastrantuono & Mancinelli, 2005; Rijaluddin, Wijayanti & Joni, 2017; Theofilius *et al.,* 2021), heavy metal biomonitors (Krupnova *et al.,* 2018), bioindicators microplastics in sandy intertidal habitats (Kleinschmidt & Janosik, 2021) and rivers (Akindele *et al.,* 2019). Although gastropods are used with different approaches, the bioassessment of AL in urban lakes was not performed using gastropods (Cera & Scalici, 2021).

Information about AL in freshwater ecosystems is very important to provide solutions for reducing environmental waste (Thompson *et al.,* 2009ab) and discovering their source and fate in the waters (Wu, Zhang & Xiong, 2018). It is also necessary for decreasing and managing waste, preserving the freshwater environment, providing benefits to the government and society (Winton *et al.,* 2020), as well as pollution mitigation and policy information (Earn *et al.,* 2021). Therefore, the objectives of study were to determine the correlation between the temporal and spatial distribution of AL items with bioassessment of gastropods communities.

Materials and Methods

Study and Sampling Site

Situ Gintung is one of the lakes in the South Tangerang City area, Banten Province, Indonesia, surrounded by housing, plantations, and tourist places. As shown in Figure 1, the sampling for this study was conducted during the dry and rainy seasons between May to July 2015 and February to April 2016, respectively, in 5 stations with once a month sampling is done. The sampling method was based on the modified UNEP (2020), to facilitate interpretation of AL with

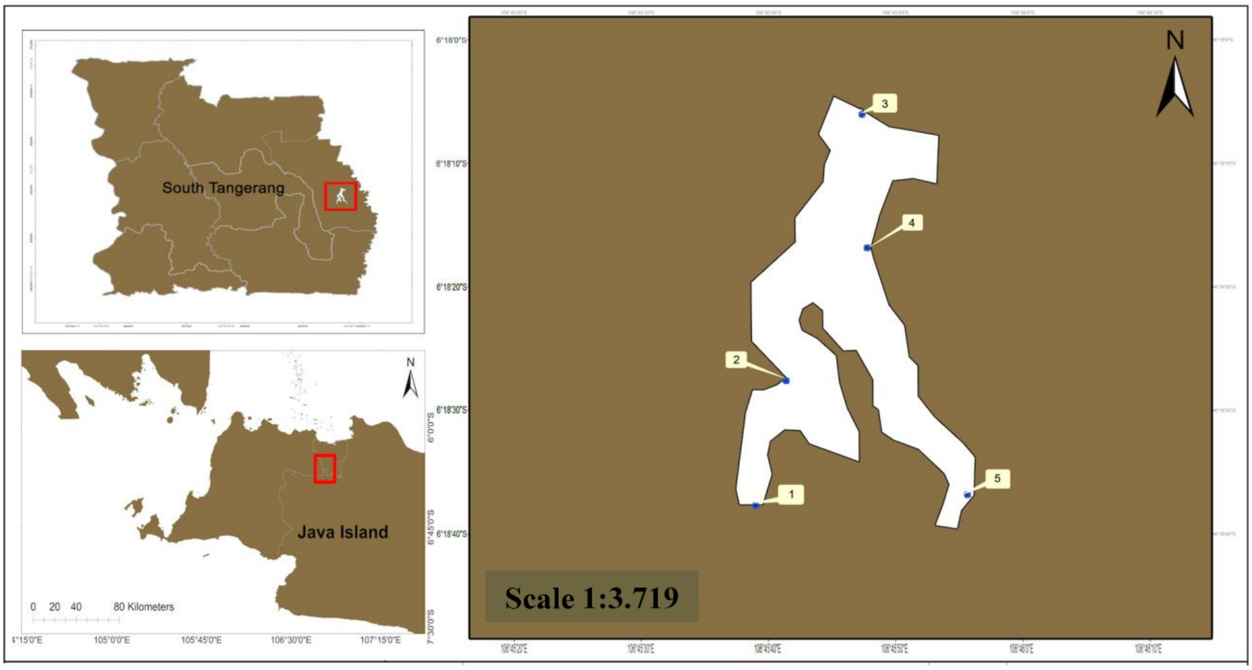

Figure 1. Map showing the research site of Situ Gintung lake.

gastropods results, sampling using transects was carried out at the same location based on categorization of stations or zoning and waste items. Stations 1 and 5 are inlets, 2 is close to residential areas, and 4 is near a farming region, while 3 is an outlet of lake. The sampling of AL and gastropods was conducted on the surface of the lake at 0 meters using a $1m^2$ to obtain 3 replicates of each station. Then, gastropods on the bottom of the waters or attached to the AL were collected by hand and then were counted individually by species, identified according to Thompson (2004), Marwoto et al., (2011), and (Quek et al., 2014).

The square of each station was photographed and analyzed using Image J software to calculate the amount, litter materials, and percentage of waste cover. Subsequently, the AL items collected were inorganic and included plastic bags, bottles, straws, and household utensils, alongside food wrappers, rubber, clothing, glass, cans, children's toys, and others. The plastic items, children's toys, and beverage cans were categorized based on milliliters, liters, kilograms, and meters.

Data Analysis

The AL data items were tested for normality, while the total difference in the number of materials between stations by Kruskal-Wallis and by season was evaluated by Mann-Whitney U tests. Then, linear regression was used to analyze the relationship between the amount of litter and the percentage cover with gastropods. The plastics found were first reduced by the Principal Component Analysis (PCA) to determine the items with the most influence in the water. Subsequently, the results were analyzed by the Canonical Correspondence Analysis (CCA) to determine their relationship with the gastropods. SPSS version 25 was used for PCA, while PAST version 4.04 was employed for CCA (Hammer, Harper & Ryan, 2001).

Results and Discussions

Items and Distribution of AL

After the estimation, 17 AL items were found in Lake Situ Gintung consisting of plastic bags, bottles, bottle caps, beverage and beverage wrappers, soap wrappers, and straws, as well as rubber, cans, paper, and glass. As shown in Figure 2, the highest number was found during the rainy season, which included consumption containers, such as bags, bottles, alongside food and beverage wrappers. This was followed by toys, clothes, and plastic bags between <1 and >1 kg, while the item with the lowest number was toothpaste packets, discovered during the rain and dry seasons. Although the rainy had higher AL quantities compared to the dry season, as in Figure 3, the Mann-Whitney test results showed that the difference between both was insignificant (p>0.05).

The AL items found in Situ Gintung are similar to previous studies (Arturo, 2021; Blettler *et al.,* 2017; Hoellein *et al.,* 2015; Mayoma *et al.,* 2019; Vincent *et al.,* 2017; Winton *et al.,* 2020). Hoellein *et al.,* (2015) and Vincent *et al.,* (2017) found that most of the AL in lakes are smoking- and food-related items. Food wrappers, bags, bottles, and disposable styrofoam containers were the most dominant contaminants in the Paraná River floodplain and Setúbal Lake, Argentina (Blettler *et al.,* 2017). Mayoma *et al.,* (2019) found that the most

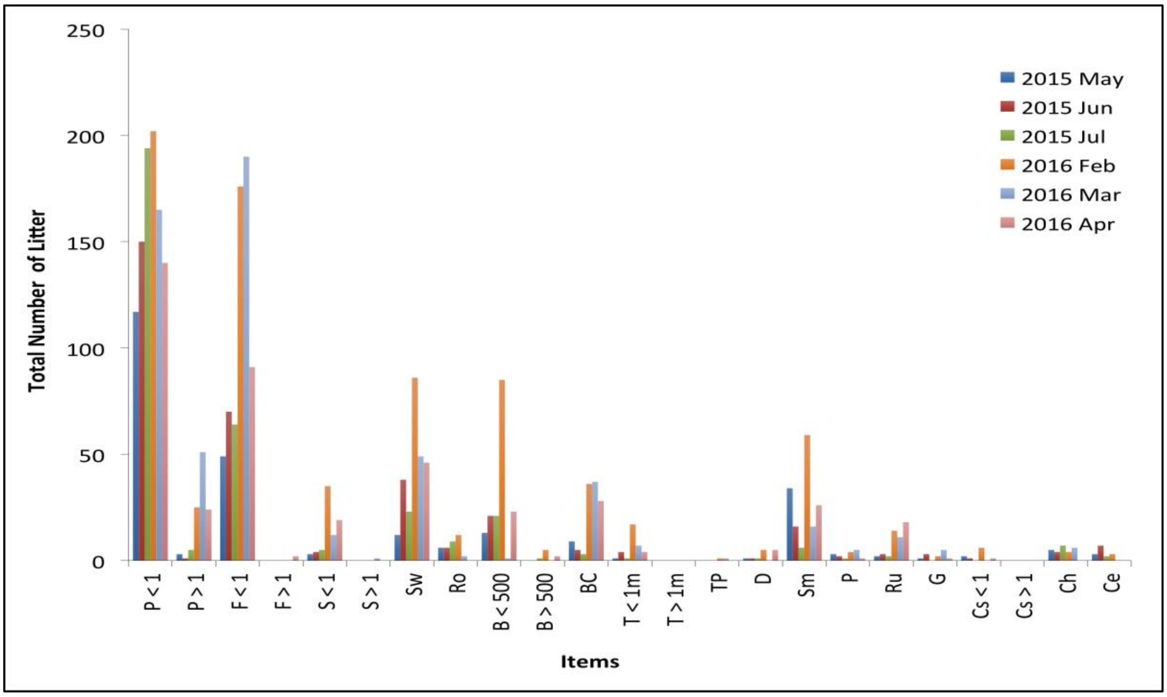

Figure 2. Total number of anthropogenic litter items. Note: P= Plastic bag (kg), F= Food and Drink plastic (kg), S= Soap plastic (kg), Sw= Straw, Ro= Rope, B= Bottle (ml), BC= Bottle cap, T= Toys (mtr), TP= Toothpaste, D= Diapers, Sm= Styrofoam, P= Paper Box Cigarrete, Ru= Rubber, G= Glass, Cs= Cans (ltr), Ch= Clothes, Ce= Cigarette gasoline.

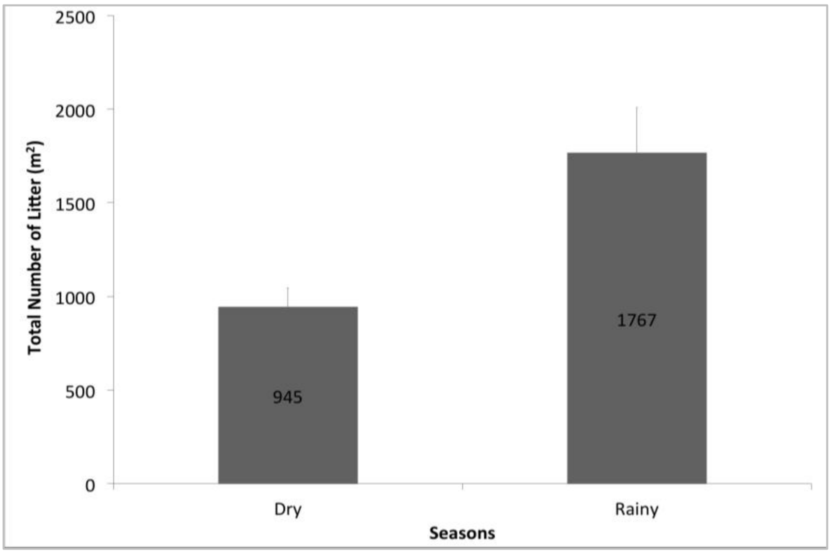

Figure 3. Total number of AL items in the two seasons.

common in Lake Malawi were carrier bags, personal hygiene products, bottles, fishing gear, tires, and straws, with 80% coming from plastic. The 50 macro AL items were discovered in the Laurentian Great Lakes System, with the majority being fragments and straws (Arturo, 2021). The garbage from several European countries also indicated that the 10 most common AL items found in freshwater are food wrappers, bottles and lids, bags, cigarette butts, sanitary items, smoking-related packaging, cotton bud sticks, takeaway containers, cups, and straws, as well as stirrers, and cutlery (Winton *et al.,* 2020).

Although the total number of AL found in Situ Gintung by season indicated an insignificant difference ($p>0.05$), the results varied, as shown in Figure 3. The total number of AL items was more found in rainy than in the dry season, with a total of 1767 and 945, respectively. Previous studies demonstrate that the differences in the number of AL in freshwater are influenced by population density, impervious surface cover, location, alongside tourism and recreation (Hoellein *et al.,* 2015), holidays (Vincent *et al.,* 2017), and seasons (Arturo, 2021; Hoellein *et al.,* 2015; Vincent *et al.,* 2017; Vincent & Hoellein, 2017). The urban areas around Situ Gintung are thought to have affected the number of AL. According to Vincent *et al.,* (2017), the difference in AL quantities is influenced by urban, suburban, and rural locations.

The highest total was at station 5, with 265 and 1013 items during the dry and rainy seasons, respectively, while the lowest quantities were 117 and 73 items at station 2, alongside 73 and 74 in stations 3 and 4, respectively, during the rainy season. Figure 4 shows that the most common AL in all stations was plastic bag products, while Figure 5 indicates that the highest cover percentage was 122% in February 2016, and the lowest was 48.2% in July 2015. The Kruskal-Wallis test result showed a difference in the amount of AL between the stations (Table 1; $p<0.05$).

Generally, location and habitat affect the amount and items of AL in the aquatic environment. The numbers found in Situ Gintung were higher at the inlet location (stations 1 and 5; Figure 4), leading to the hypothesis that the inlet is the location for AL accumulation originating from small rivers and sewers whose source is waste discharged from households or other human activities. According to MEF (2020), 8% of the waste flow into Indonesian waters comes from households. Also, the differences in the water column, such as rivers and lakes, as well as habitats, affect the amount of waste expelled (Czarkowski *et al.,* 2016; Vincent & Hoellein, 2017). Inflow areas that enter into the water column have a higher amount of plastic than water bodies without such systems due to the influence of human activities, especially those close to rural and urban areas (Su *et al.,* 2016).

The AL cover percentage in Situ Gintung shows an increasing trend from the dry to the rainy season at an average of above 80%. As shown in Figure 2, the cover of water columns is due to the high number of litter, which increases during the rainy season. The highest number of AL found can affect the water column cover and shows the total area affected by these contaminants. According to previous studies, plastic bags have a higher than other items (Blettler *et al.,* 2017). Plastic waste affects the correlation between gastropods and food sources. According to Aloy *et al*., (2011), the cover of plastic waste affects the availability of food for the diverse organisms and also for the gastropods, as it reduces the nutrients and eventually depletes the abundance of these organisms.

Gastropods and AL

The gastropods found in the study area comprised 11 species, namely *Pomacea canaliculata* (PC), *Lymnaea rubiginosa* (LR), *Gyraulus convexiusculus* (GC), *Indoplanorbis exustus* (IE), *Physastra stagnalis* (PS),

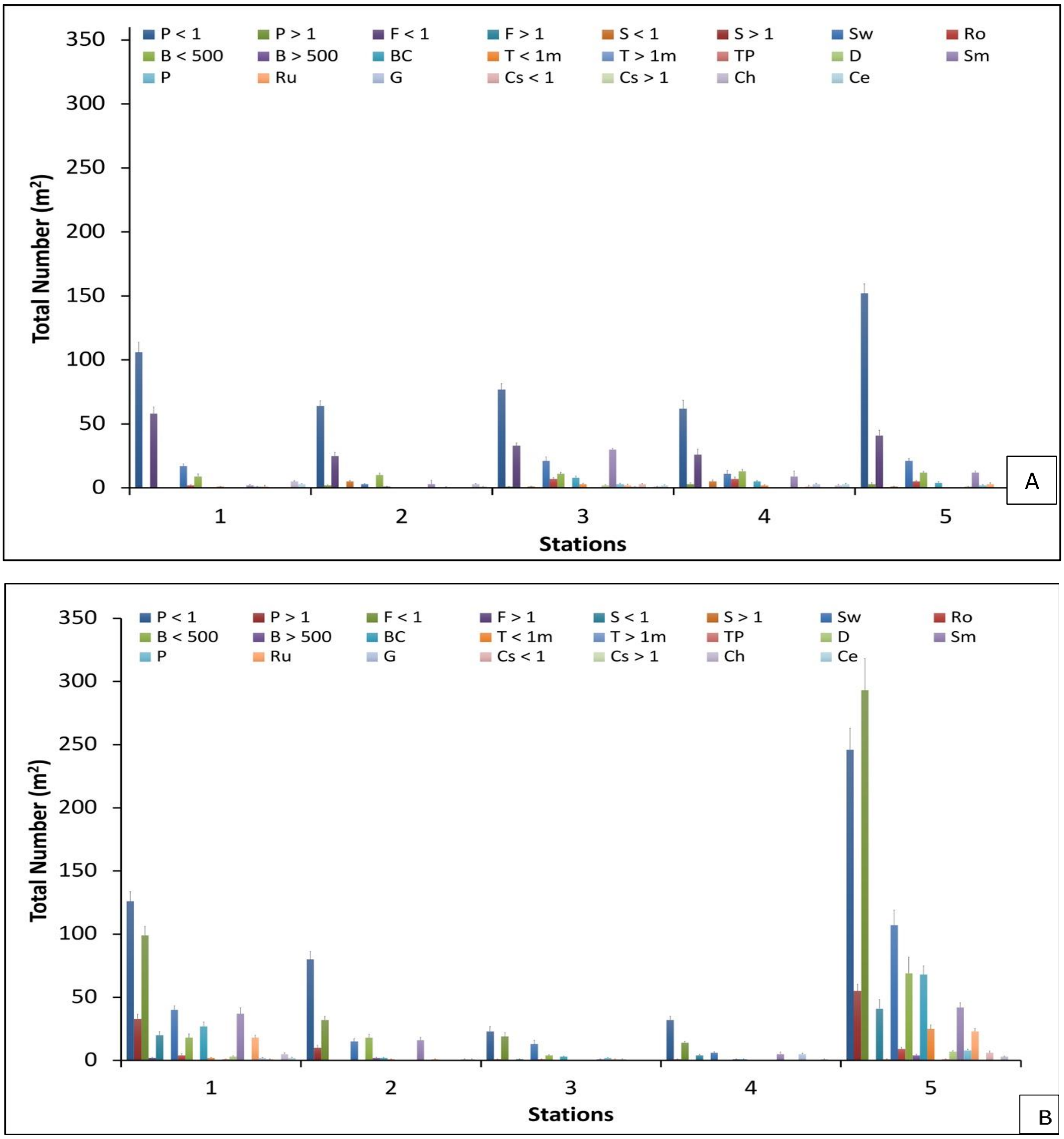

Figure 4. Items of AL found at the station based on dry (A) and rain (B) seasons.

Melanoides plicaria (MP), *Melanoides tuberculata* (MT), *Tarebia granifera* (TG), *Thiara scabra* (TS), *Filopaludina javanica* (FJ), and *Filopaludina sumatrensis* (FS). According to Figure 6, the highest number was *P. canaliculata,* while the lowest was *T. scabra* in both seasons. As shown in Figures 7A and 7B, respectively, the number of individual gastropods showed a low correlation value with the AL amount (r=0.36) and cover percentage (r=0.33). The correlation coefficients R^2 were 13% and 10.7% for the amount and cover percentage, showing that other factors affect the presence of individual gastropods in Situ Gintung.

Furthermore, the CCA results revealed that almost all the gastropods were inversely or negatively related to the AL found in Situ Gintung except for *L. rubiginosa* (LR), which had a positive correlation and was included in the AL component. As shown in Figure 8, *M. tuberculata* (MT) and *P. canaliculata* (PC) were in the middle of the components and are thought to be influenced by environmental factors.

Hence, the number of individual gastropods decreased as the AL number and percentage cover increased. Figure 6 shows an increase in the number of these individual organisms with the decrease in AL during the period of February-March, indicating that the presence of these contaminants affects the presence of gastropods. Generally, plastic waste is a substrate for the emergence of biofilm layers (Shen *et al.,* 2021), thereby supporting the growth of bacteria and algae, which serve as benthic biota feed (Gong, Xie & Wang, 2000). Vosshage *et al.,* (2018) reported the presence of the grazing activity of *Radix balthica* biofilm on plastic

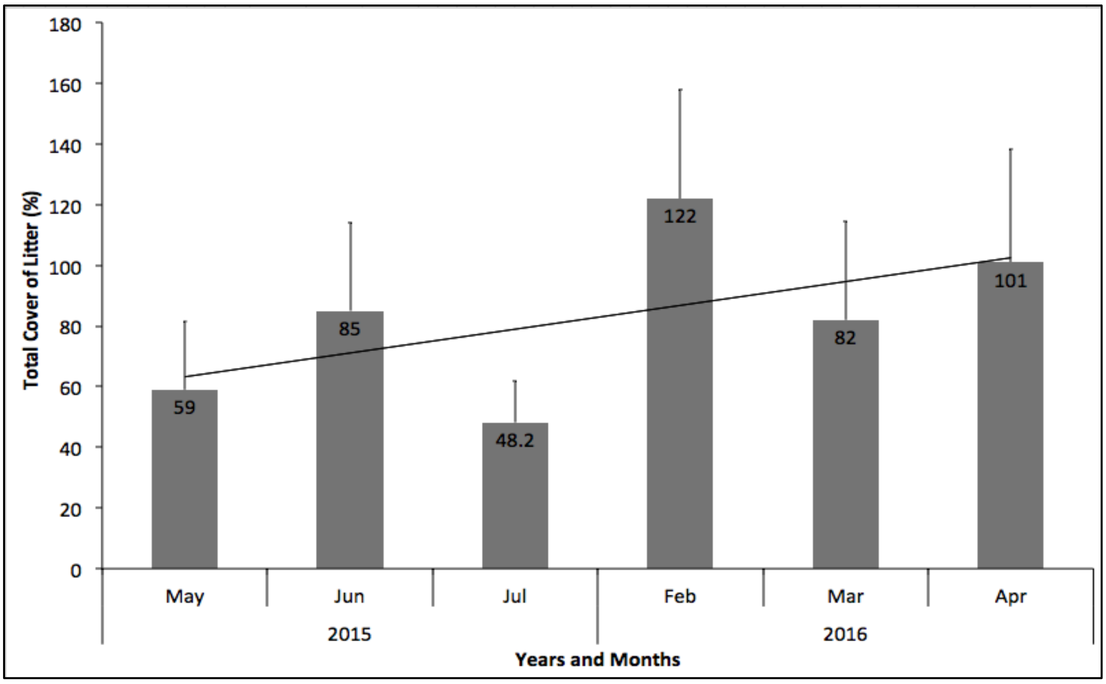

Figure 5. Percentage of total AL cover.

Table 1. The Kruskal-Wallis test result amount of AL between the stations

Test Statistics[a,b]

	AmountAL
Chi-Square	40.069
df	4
Asymp. Sig.	.000

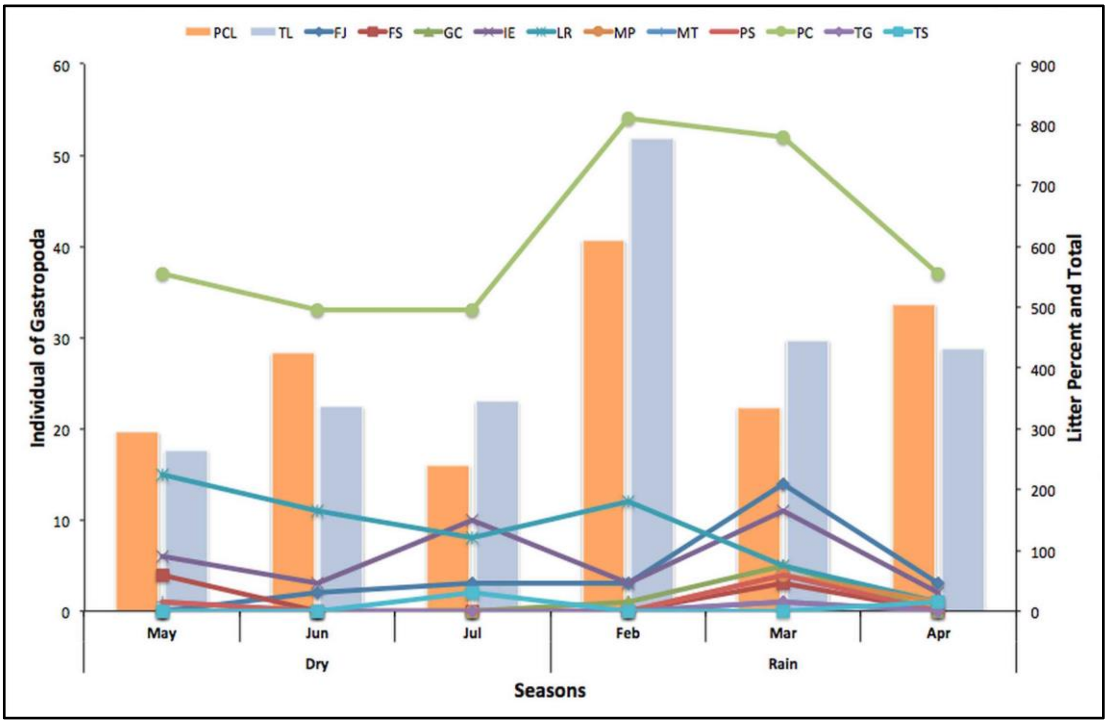

Figure 6. Number of individual gastropods with AL in the two seasons. Note: PCL=Percent Cover of Litter; TL= Total of Litter.

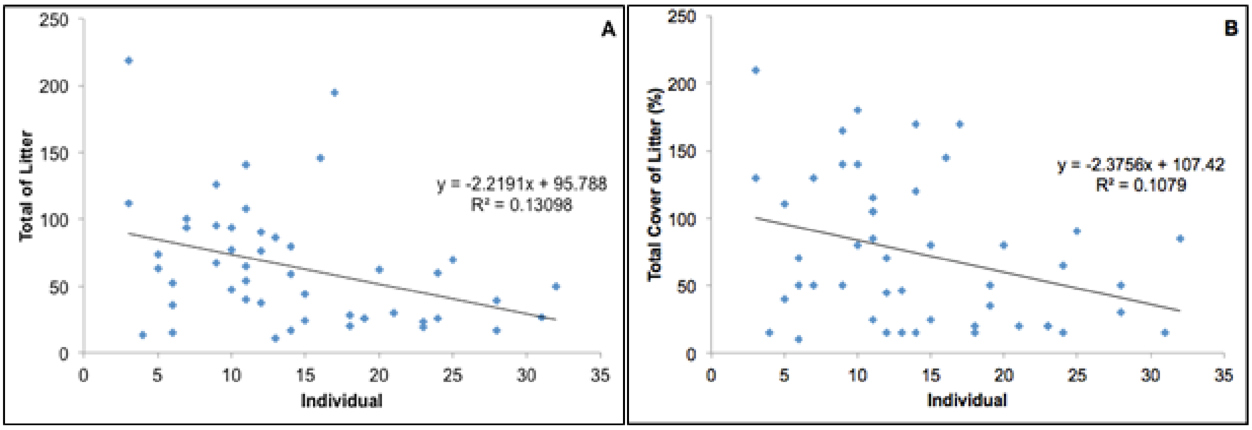

Figure 7. Linear regression of total number (A) and litter cover (B) with individual gastropods.

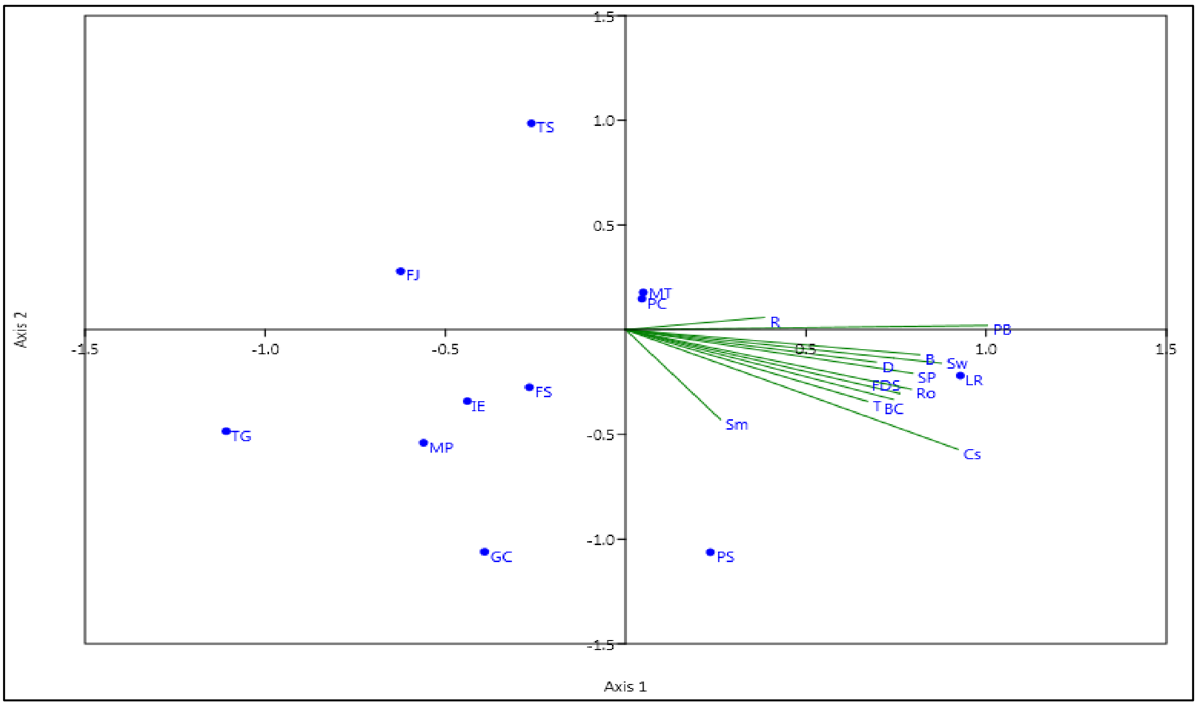

Figure 8. Canonical Correspondence Analysis (CCA) AL with gastropods.

substrates. It shows that plastic waste is indirectly thought to be able to support the life of several types of gastropods. In addition, the existence of gastropods in waters is usually influenced by the temperature and turbidity (Assuyuti *et al.,* 2017), substrates, turbidity, pH, and dissolved organic matter (Saru, 2014).

Floating AL will cover and block the incoming light and then affect the biology, chemistry, and physics in the water column. According to Moslemi *et al.,* (2012), the production of algae and organic matter increases in locations where sunlight can reach water bodies. However, the amount of AL, such as plastic, affects gas exchange (Ngupula & Kayanda, 2010) in freshwater, impacts the movement of water and heat in coastal areas (Carson *et al.,* 2011), changes organism behavior (Aloy *et al.,* 2011; Thevenon *et al.,* 2014), and promotes the accumulation of heavy metals in plastics (Pradit *et al.,* 2021). The inhibited gas exchange results in a reduced availability of dissolved oxygen for benthic organisms, though certain species can live in AL-contaminated waters. This is proven by *P. canaliculata,* as shown in Figure 6, which was found in water bodies contaminated with AL during both seasons. Species of *P. canaliculata* has a siphon that allows it to take oxygen directly from the air (Pyron & Brown, 2015).

Macro-AL is naturally degraded by the physical chemistry of water into micro-contaminants (Zbyszewski & Corcoran, 2011). This is suspected to cause the aquatic biota of Situ Gintung to be contaminated by micro-AL through consumption or ingestion. According to Bellasi *et al.,* (2020), micro-AL will be ingested by benthic biota, accumulate, and eventually affect food webs. Furthermore, AL, like microplastics, has an impact on the growth inhibition of gastropods (Vosshage *et al.,* 2018) and freshwater biota (Earn *et al.,* 2021). In addition to being found in AL contaminated waters, gastropods are found in waters contaminated with organic pollutants. The gastropods species found in Situ Gintung are pollutant tolerant taxa. Among the pollutant tolerant taxa are from the Ampullariidae, Lymnaeidae, Thiaridae and Viviparidae families (Mandaville, 2002; Paylangco *et al.,* 2020). The results of previous studies showed that species from this family (Ampullariidae, Lymnaeidae, Thiaridae and Viviparidae) were used as indicators of organic pollution in lakes (Rijaluddin *et al.,* 2017).

Conclusion

Situ Gintung waters have been polluted by AL consisting of plastic, rubber, cans, paper, and glass products derived from daily human activities. The cover percentage of AL increases during the rainy season by over 80%. Meanwhile, the difference in AL numbers was insignificant by season but significant based on station. Although AL had little effect on gastropods, the number of individual organisms decreased as the quantity and cover percentage of contaminants increased and vice versa. Furthermore, these results indicate that gastropods can be used to assess the quality of lake waters contaminated with anthropogenic litter pollution inorganic pollutants.

Ethical Statement

Not applicable

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Author Contribution

First Author: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Visualization and Writing-original draf, Writing-review and editing, Supervision; Second Author: Funding Acquisition, Data Curation, Investigation, Methodology, Visualization and Writing-original draft; Third Author: Funding Acquisition, Data Curation, Investigation, Methodology, Editing; Fourth Author: Formal Analysis; Five Author: Funding Acquisition, Project Administration, Resources, Writing-review and editing.

Conflict of Interest

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy have been completely observed by the authors

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