STUDY ON MANGROVE LITTER ON KALUWAMODARA TRIBUTARY MANGROVE ECOSYSTEM

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Marine litter accumulates from both terrestrial environments via freshwater runoff during low tides and from marine environments through seawater runoff during high tides. This litter, floating into mangrove ecosystems, is subsequently retained within these ecosystems, which act as sinks for such debris. Marine litter is particularly detrimental to wildlife, coastal communities, and human activities, making it a significant issue for many coastal ecosystems globally. The objectives of this study are to assess pollution levels and to identify its sources. Marine litter was sampled using transect lines of 15 m in length, laid perpendicular to the shoreline and after that took a distance of 5 m on either side of the transect line and separated 15 m × 10 m plots. All litter was collected in garbage bags and categorized into plastic, glass, metal, paper, and other types. Plastics were further divided into High-Density Polyethylene (HDPE) and Polyethylene Terephthalate (PET), with their weights measured separately. The results indicated that site one had the highest litter density (0.5), while site six had the lowest density (0.0156). The highest CCI value (10) at site one indicates significant litter accumulation, while the lowest CCI value (0.3111) at site six reflects a "very clean" environment. Sites four (0.8888) and five (2.1778) are also considered "very clean" while sites two (4.0) and three (2.0) are classified as "clean". Plastic represents the highest litter volume at each site while, the mass of PET constitutes 92.85% of the total plastic mass, significantly surpassing the mass of HDPE, which accounts for 7.15%. Litter, transported by tidal actions, runoff, surges, and floods, accumulates among the mangrove roots, significantly impacting the ecosystem. This is attributable to the disposal of single-use items such as water bottles, soft drinks, and other beverages, as well as various types of plastic released through anthropogenic activities in the surrounding ecosystem. The mangrove root system is adapted to trap litter; therefore, implementing a well-managed waste disposal and waste minimization system is crucial for the conservation of this valuable ecosystem.

Keywords: Clean Coast Index, Anthropogenic Activity, Plastics, Kaluwamodara

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INTRODUCTION

Mangroves are woody plants uniquely located in the harsh inter-tidal zone between land and sea as well as the land-sea interface. This is a unique habitat as it is not only influenced by terrestrial environmental factors but also by oceanic conditions, especially the tides (Amarasinghe, 2018). The complexity of coastal areas dynamics arises from the interplay of tides, short waves, river input, wind, precipitation-evaporation balance, and surface heat balance, making it essential to understand the effects of these constantly changing natural forces on hydro-sedimentary dynamics and morphological development for effective and sustainable management of these systems (Wang *et al*., 1999). Marine litter or beach litter is the items from human activities that are discarded into coastal or marine environments, and increased production of consumer goods aligned with poor waste management policies can lead to litter accumulating in coastal regions and the oceans (Santos *et al*., 2020). Shore deposition has been identified as a major sink of marine plastic, and the pollution surveys have confirmed that even the shores of the remotest beaches accumulate significant plastic loads (Martin, et al., 2019). Roebroek et al. (2021) emphasized that their assessment estimated only the potential mobilization of plastics by floods, not the actual transport and emission into the ocean, noting that plastics mobilized by floods are unlikely to be transported over great distances but are deposited on floodplains and in riparian vegetation, where they can be retained and remobilized during subsequent flood events. In high tides, that litter floats from the sea to the mangrove ecosystem and mangroves act as sinks for marine litter (Martin et al., 2019). This marine litter is a global problem causing harm to marine wildlife, coastal communities and maritime activities as well as reducting marine litter pollution poses a complex challenge for humankind, requiring adjustments in human behaviours (Veiga et al., 2016). Plastic is the main pollution source, while the key role of mangroves as providers of important ecosystem services, including carbon sequestration, coastal protection and habitat for marine life, it requires efficient management of the threats affecting these ecosystems, including marine plastic pollution (Martin, *et al*., 2019). Plastic trapped by mangrove pneumatophores and prop roots may constitute a physical impediment affecting both the tree itself and the associated fauna, by preventing gas exchange and releasing harmful chemicals absorbed by or industrially added to plastic materials (Cole *et al*., 2011). In Sri Lanka mangroves are distributed along the coast around lagoons, bays and estuaries covering an area of 8000 - 7000 ha and extend of mangroves about 15670 ha (Ranawana, 2017). The Kaluwamodara River, a tributary of the Bentara River, discharges into the ocean at Moragalla Beach. It encompasses an estuarine mangrove ecosystem, characterized by a partially enclosed coastal embayment where freshwater and seawater converge and intermingle. Estuaries are highly dynamic environments with their physical, chemical and biological structure (Mateus *et al*., 2008). Due to the proximity of the Kaluwamodara River tributary to the estuary, saline water intrudes into the river, affecting its ecosystem. The tributary is home to a significant mangrove population, which thrives in brackish conditions. The area experiences distinct tidal variations, with high tides causing the roots of the mangrove plants to be submerged. These tidal changes play a crucial role in shaping the mangrove habitat and influencing the distribution of nutrients and species within this dynamic environment. There is not any previous study on pollution in this area and the organizations did not pay much attention to protecting this ecosystem from pollution. The main objective is to assess the pollution of diversity Kaluwamodara tributary ecosystem, and the specific objective is to determine the sources of pollution in this ecosystem.

METHODOLOGY

The location is Kaluwamodara tributary (6^{0} 26' 30.50" N, 79^{0} 59' 31.20" E) belongs to the Western Province and is located between Kalutara and Aluthgama. The area has tropical conditions as well an average annual temperature is 26.3 ºC and annual rainfall is 2931 mm. The sampling sites were selected to encompass mangrove-rich areas on both sides of the river, utilizing a Global Navigation Satellite System (Sholarin and Awange, 2015) following a preliminary study. Figure 01 illustrates the locations of the selected sites. Six sites were selected for sampling, with three transect lines established at each site, positioned perpendicular to the shoreline. Each transect line measured 15 m in length, and the distance between adjacent transect lines was minimally 15 m. In each transect, plots measuring (15 m × 10 m) were established at 5 m intervals, determined by the diversity of mangrove vegetation and accessibility. Litter was collected separately at each site into garbage bags. The collected litter was then counted and categorized into groups such as plastic, glass, metal, paper, and other types. The mass of each category was measured, with plastic being further classified into PET (Polyethylene Terephthalate) and HDPE (High-Density Polyethylene). In data analysis, calculated the Clean Coast Index (CCI) (Santos, *et al.*, 2020) and density of litter for sites (Gjyli *et al.*, 2020). The CCI classifies the degree of cleanliness as very clean (0–2), clean (2–5), moderate (5–10), dirty (10‒20) and extremely dirty (> 20) (Santos, *et al.*, 2020). As well as also analysed the mass of litter to get an idea about the highest polluted site.

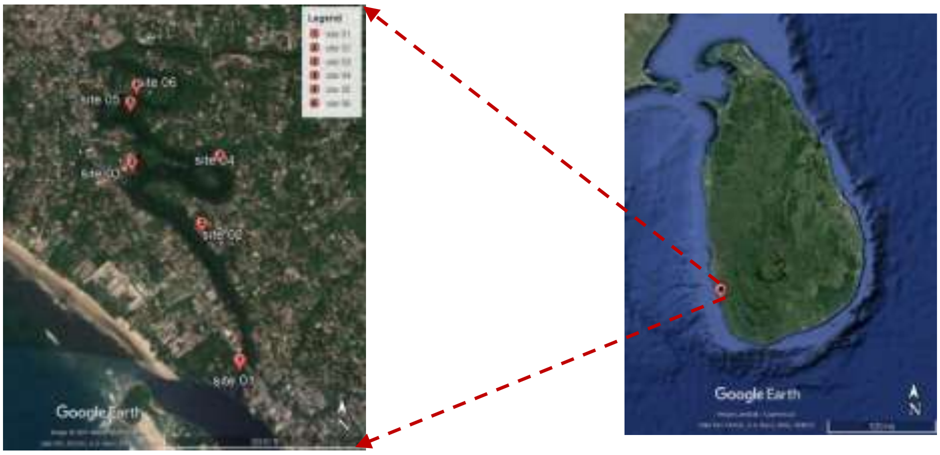

Figure 01.Map of the selected sites

Source: Google earth pro version 7.3 2021

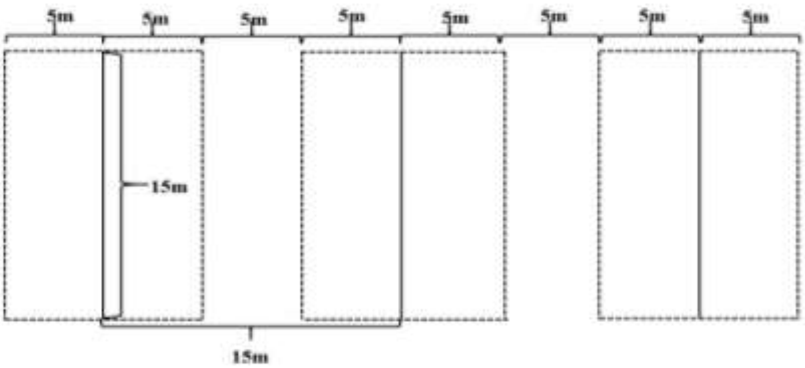

Figure 02. Transect lines for a site

RESULTS AND DISCUSSION

According to Table 01, the density of litter was highest at site one (0.5) and lowest at site six (0.015556). This variation is attributed to the amount of litter per square meter, which was greatest at site one and least at site six. In terms of the Clean Coast Index (CCI), site one had the highest CCI value of 10, indicating a highly polluted ecosystem. Conversely, site six had the lowest CCI value of 0.3111, reflecting a very clean environment. Sites four (0.8888) and five (2.1778) also exhibited very clean environments, while sites two (4.0) and three (2.0) were characterized as clean.

Table 02 details the mass of each type of litter, categorized by site. Analysis of the data reveals that the mass of litter at site one was markedly higher than that at other sites, while site six displayed very low levels of litter. In terms of composition, glass was the second most prevalent material, following plastic, across all sites. Additionally, some sites were devoid of specific types of litter, such as paper, and site six was notably lacking in glass.

Figure 03 illustrates the total mass of litter, indicating that the ecosystem was predominantly polluted with plastic (18.14), while paper pollution was minimal (0.592). Glass litter also constituted a significant portion, amounting to approximately 10.166. Plastic was the most prevalent type of litter at every site, with site one having the highest mass of plastic and site six the lowest. In terms of glass litter, the majority consisted of beer, wine, and arrack bottles, which were collected from sites one, two, three, four, and five, but were notably absent from site six. Metal litter, primarily beer cans, was present at all sites. Paper litter was uniformly low across all sites.

Table 03 presents the mass of PET and HDPE separately. The percentage of PET is notably higher, primarily due to the predominance of water bottles and soft drink bottles. In contrast, HDPE consists mainly of poison bottles and various household waste items. According to figure 04, the mass of PET constitutes 92.85%, significantly surpassing the mass of HDPE, which is 7.15%. This indicates that PET predominates among the plastics, with a substantial majority being PET and a smaller proportion consisting of HDPE.

Table 01. Density of Litter and Clean Coast Index

Number of site	**Number of items**	**Density of litter (m^{-2})**	**Clean Coast Index (CCI)**
1	225	0.5	10
2	90	0.2	4
3	45	0.1	2
4	20	0.04444	0.8888
5	49	0.108889	2.177778
6	7	0.015556	0.31111

Table 02. Mass of Litter according to the sites (kg)

Source	Site 01	Site 02	Site 03	Site 04	Site 05	Site 06
Plastic	8.7	3.391	2.41	0.678	2.621	0.34
Glass	6.135	2.903	0.425	0.203	0.5	0
Metal	0.254	0.112	0.125	0.069	0.083	0.018
Paper	0.343	0	0.025	0	0.224	0
Other	0.302	0.882	0	0.807	0	0.054

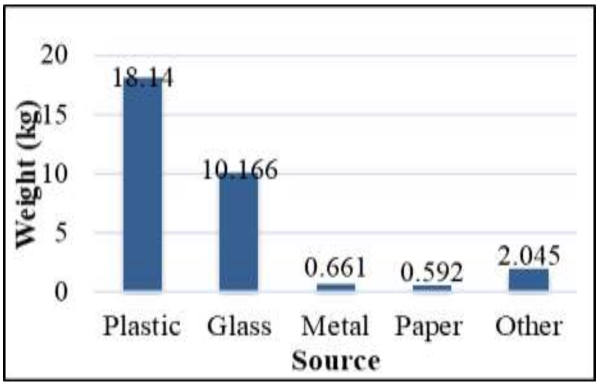

Figure 03. Total Mass of litter

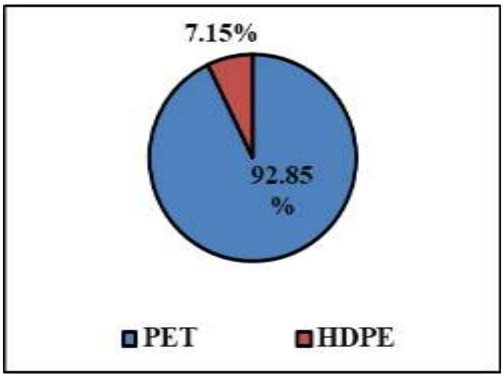

Figure 04. Percentage of HDPE and PET

Table 03. PET and HDPE percentage

Plastic source	Site 01	Site 02	Site 03	Site 04	Site 05	Site 06	Total Mass (kg)	Percentage (%)
PET	7.347	2.554	1.725	0.231	1.921	0.114	13.892	92.855
HDPE	0.662	0	0.304	0.103	0	0	1.069	7.145

CONCLUSIONS/RECOMMENDATIONS

The study offers valuable insights into the types and mass of litter within the Kaluwamodara Mangrove Ecosystem. *Rhizophora apiculata*, the predominant plant species in this ecosystem, acts as a significant trap for plastic debris due to its complex root system. This accumulation is largely attributed to the increasing use of plastics, such as water and soft drink bottles, and their improper disposal. Furthermore, it can be concluded that the situation has been exacerbated by urbanisation and tourism in the Aluthgama area.

Paper litter is found in lower quantities because it tends to break into smaller pieces upon absorbing water. Consequently, these fragments either drift away with the current or sink, thus not remaining

within the mangrove roots.
Floating plastic is first transported to site one due to its proximity to high tide areas, whereas site six, being farther from the sea, exhibits very low levels of floating litter. Additionally, sites one and two, being close to urban areas, experience higher quantities of metal and glass litter, which correlates with increased tourism activities.
Based on the Clean Coast Index (CCI) values, site one is identified as having a highly polluted ecosystem, while site six is characterized by a very clean environment. Similarly, sites four and five are noted for their very clean environments, whereas sites two and three are classified as having clean environments.

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ACKNOWLEDGMENTS

I would like to express my heartfelt gratitude to my supervisor Ms. A.P. Abeygunawardana, Lecturer at the Department of Animal Science, Faculty of Animal Science and Export Agriculture for providing me the opportunity to perform my research successfully and who have been an excellent extraordinary helpful supervisor and I greatly thank Mr. N.P.P. Liyanage, Senior Lecturer of the Department of Animal Science, Faculty of Animal Science and Export Agriculture, and Mr. E.P.D.N. Thilakarathne, Lecturer of the Department of Animal Science, Faculty of Animal Science and Export Agriculture,for providing excellent advices and support as supervisors to fulfil my research in successful manner.