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A case study on quantification of plastic litter - A global menace and paving way for unleashing toxins into two mangrove ecosystems of Kerala

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Abstract

Plastic litter accumulation study was carried out from Kadalundy and Kolavipalam, Kerala on monthly basis in 2016-17. 72 quadrates surveyed and litter was sorted, weighed and expressed as number and weight of plastic debris per square meter (sq. m) with categorization into bottles, carry bags, plastic fragments and the miscellaneous group. The total amount of plastic litter in terms of number ($12.23 \pm 0.52 \text{ items.m}^{-2}$) and weight ($117.64 \pm 1.23 \text{ gm}^{-2}$) was higher in Kadalundy (highest abundance during July 2016 as $1.79 \text{ items} \pm 0.03 \text{ m}^{-2}$; $15.8 \pm 0.17 \text{ gm}^{-2}$). This considerable increase in plastic litter at Kadalundy is attributed to river runoff which may lead to the gradual destruction of mangrove seedlings and associated benthic biota due to smothering and release of toxins gradually from the plastic litters due to intense tidal and wave action as well as due to high temperature and intense sunlight leading to the degradation of entire ecosystems.

Keywords: Anthropogenic interventions, Destruction of the mangrove ecosystem, Kadalundy and Kolavipalam Mangroves, Plastic litters

Introduction

The mangroves are woody shrubs and trees which are taxonomically diverse with the ability to survive along the sheltered tropical coast in hyper saline environments under tidal influence^[1]. These are the important ecologically sensitive ecosystems with different functional roles since they help in protection and stabilization of coast belts slows the soil erosion rate and excessively enriches the coastal waters^[2]. The coastal communities may be viable and resilient because of the adjacent mangrove forests as they act as a buffering zone during hurricanes, tsunamis and extreme weather events. The mangroves are structurally very large and complex with numerous diversified terrestrial animals occupying the canopy and aquatic animals living on or around the trunk and prop roots, which make the mangroves one of the world's most productive ecosystems^[2].

With the increase in urbanization towards the coastal area and with the availability of these mangrove ecosystems to the urban areas, has to encounter a wide range of environmental degradation and of which one is marine debris^[2]. Marine debris is described as any persistent solid material, manufactured or processed, directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment which may include man-made products such as plastic, glass, metals, or rubber, as well as lost and derelict fishing gears, vessels, which ranges from micrometers (plastic pellets) to meters (shipwrecks)^[3, 4].

The dislodged debris gets transported to the marine ecosystem through wastewater, effluents, rivers and estuaries, and reaches and deposits in the ocean. The regular commercial fishing activities, recreational fishing activities, boating services and the industries setup along coastal belt provide a way for the entry of debris to the marine environment. The so transported debris throughout the world's ocean and water bodies get accumulated on beaches and also in the ecologically sensitive habitats viz mangroves and even the oceanic gyres etc. Marine debris leads to threatening the aquatic and human life, transports chemical pollutants, interferes with navigational activities, and degrades habitats due to its long persistence in nature. The main cause of marine debris in mangrove habitats may be either direct dumping (littering in mangrove habitats) or can be transported with wind and water^[5-12]. The collected debris in the mangrove ecosystem gets trapped. The mangroves act as a sink for filtering the debris, there by the larger debris get settled in between the complex root systems and the smaller debris

gets more and more penetrated deeper into the sediment [13] with the continuous tidal action.

The mangroves are often used for dumping waste, including plastics that are non-biodegradable; hence harm the ecosystem and the species living within the ecosystem. There are reports justifying that plastic accounts for about 83% of the observed marine litter items [14]. The so trapped plastic debris among mangrove trees and their complex aerial roots leads to cut off the usual tidal movements and causes detrimental effects to coastal habitats and their associated species [15]. It is reported that mangroves are very much affected by abandoned and derelict boats, which causes damages to trees and prop roots, especially when they are remobilized during storms [16].

It is reported that 4.8 to 12.7 million metric tons of plastic entered the ocean in 2010 from 192 coastal countries and may increase by an order of magnitude by 2025 if no strict regulations implied [17]. The accumulated debris in the seabed, beaches, estuaries, and other habitats affects the light penetration in underlying waters, leading to low oxygen levels, other physical changes and ultimately dreadful degradation of the sensitive habitats [18].

A large amount of human-raised litter reaches the coastal ecosystem and spreads throughout the sea, remain persistent for many years [5, 19] and leads to diverse harmful impacts on marine biota, such as entanglement [20] and introduction of alien species [21]. The marine litter also causes alteration, damage and complete degradation of benthic habitats [22] such as coral reefs and soft sediment abrasion from derelict fishing gear or smothering from macro and micro plastic on sandy sediments in the intertidal zones [22]. Reports emphasize that not only the coastal habitats [23, 24] but open-ocean habitats beyond the continental shelves are also affected by marine litter, especially in surface convergence zones located north and south of the equator [25-28].

The present marine ecosystems of the world are under serious threats by the anthropogenic interventions. One of these is the impact of never-ending marine debris on sensitive habitats. It has been observed that marine debris affect the coastal as well as the oceanic environment. There are more published studies concentrating on beach litter, but lacks research on the data for marine litter in adjoining mangrove ecosystems. The accumulated litter in the Eco sensitive habitats leads to damages caused by abrasion, shearing, or smothering, and can alter the physicochemical and biological composition of sediments. These affect the resilience and alter the marine ecosystems leading to an ultimate decline in fishery resources and biodiversity. The gradual leaching of the chemical from discarded plastics in mangrove beds can impair the organisms living there with toxicological effects and thus may enter into the food chain. With all these in mind, the present study is designed as a primary study to assess and quantify the accumulated plastic debris in two mangrove ecosystems which are highly dynamic, complex system and ecologically sensitive environment. This kind of studies combined with

concerted conservation measures is necessary to preserve and restore these fragile and unique environments [29].

Material and methods

Description of study sites

Kadalundy estuary ($11^{\circ} 32' N$; $075^{\circ} 35' E$) is a moderately large estuarine system with mangrove forest in patches around it. The Kadalundy mangrove area is mainly governed, strictly regulated and maintained by Kadalundy community reserve and forest department. It is the first community reserve of Kerala. The Kadalundy River flows all around the land area and flows to the Arabian Sea nearer to the community reserve and thus nutrient-rich estuarine mudflats are created. This attracts a lot of migratory birds for foraging. The study area extends between latitude $11^{\circ} 08' N$ and longitude $075^{\circ} 50' E$. As the area is having long-running river which carries all sorts of garbages and with the continuous inflow-outflow of freshwater and seawater, mangrove ecosystem became a habitat for the plastic litters to settle. Hence the present sampling station was selected in order to study the riverine influence of plastic debris settling and this was compared with the sampling points in Kolavipalam area extending between latitude $11^{\circ} 32.911' N$ and longitude $075^{\circ} 35.720' E$. It is one of the coastal areas in Calicut with less anthropogenic influence. It is emerging as one of the prominent places for eco-tourism and was ideal to compare with Kadalundy site. The co-ordinates of sampling points were recorded using GPS and were shown in Figure 1.

Sampling

Plastic litter sampling was carried out in the mangrove area on monthly basis from July 2016 to May 2017. In order to quantify the plastics litter accumulated in the mangrove areas, the 10×10 m quadrates (100 sq. m) were selected (Figure 2), sampled in triplicates on monthly intervals. Total of 72 quadrates (36 quadrates from each site) was surveyed. At each area, the quadrates were marked and the plastic debris within the quadrate was collected by hand and placed in a labelled bag in order to transport to the laboratory for further analyses.

Quantification of plastic litter

The plastic litters were washed thoroughly in order to remove all other dirt, sand etc. and were air dried. The dry weights of plastic items (individual ones) were estimated on a digital top pan balance. The plastic litters were sorted, counted, weighed and expressed as number and weight of plastic debris per square meter [30]. Then plastic items were categorized into plastic bottles, plastic carry bags, very small fragments of plastic termed as plastic fragments and other plastic items categorized as the miscellaneous group (other plastic and styrene items). The abundance of the number and weight category of plastic for each site was estimated which lead to total abundance calculation. The abundance of plastics litters was expressed as mean \pm SE.

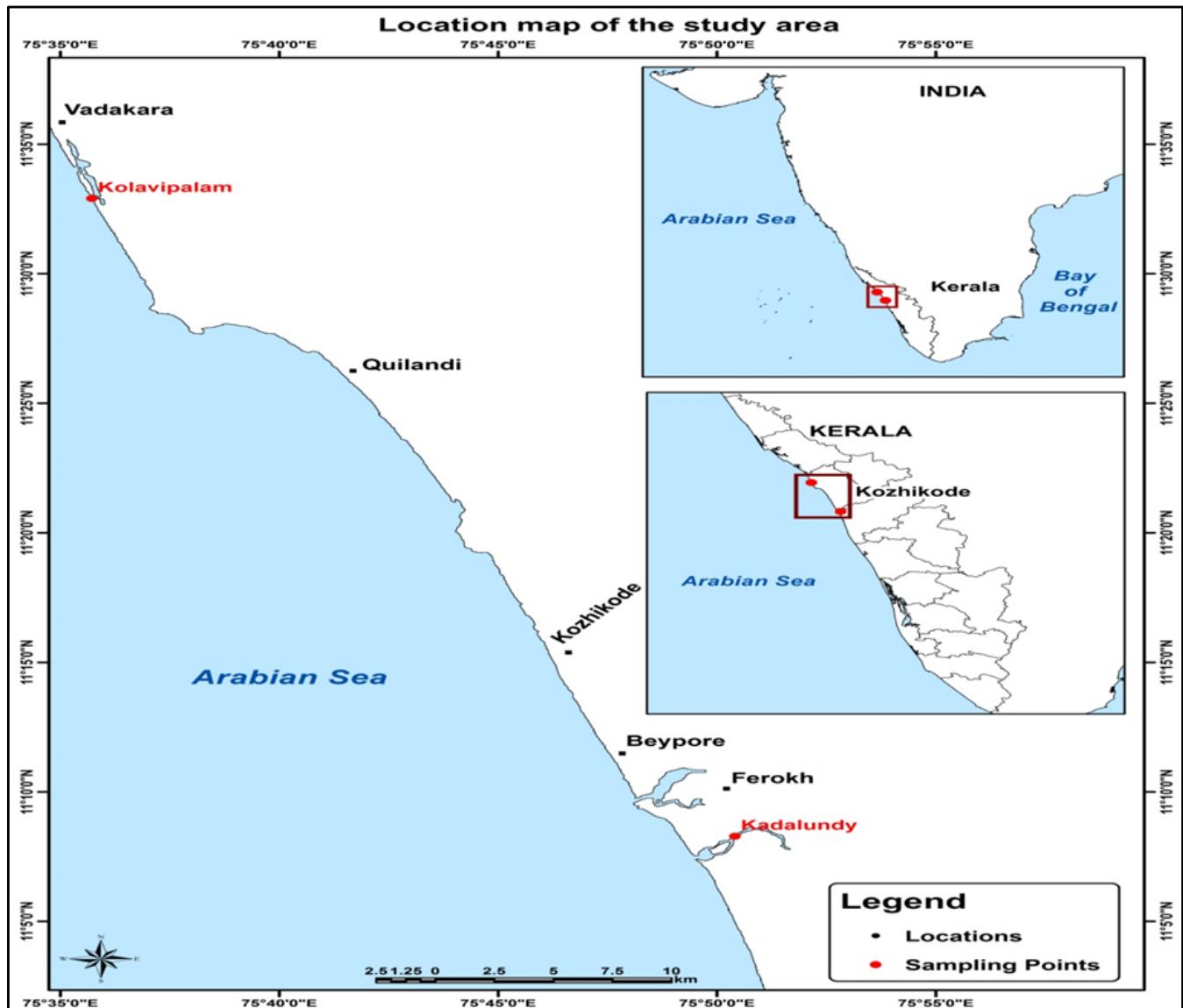


Fig 1: Location map of the sampling stations



Fig 2: 10 x10 meter quadrat marked in mangrove area

Results

From the sampling stations of Kadalundy and Kolavipalam area, a total of 72 quadrates (36 quadrates from each site) were surveyed for the estimation of the plastic litter abundance in the mangrove forests which was observed as settled in between the roots and dumped at the mangrove sites (Figure 3). From the study, it was observed that 139.81 ± 1.73 g per sq. m plastics in terms of total weight (Figure 4 a) and 13.57 ± 0.77 plastic items per sq. m in terms of the number of plastic litter items (Figure 4b) was estimated from both the sampling sites.

From Kolavipalam, the total sampled number of plastic items and weight of plastic litters was estimated at 1.34 ± 0.25 items per sq. m (Figure 5a) and 22.17 ± 0.49 g per sq. m (Figure 5b). The lowest abundance of plastic litter in Kolavipalam in terms of items was noted in December 2016 (0.07 ± 0.008 items per sq.m) and in terms of weight is in March 2017 (0.33 ± 0.02 g per sq. m). During the month of July 2016, highest abundance of plastic litters in terms of items (0.2 ± 0.02 items per sq. m) and in terms of weight in the month of July 2016 (5.65 ± 0.18 g per sq.m) were observed.

In the case of Kadalundy samples, the abundance of number items and weight of plastic litters was 12.23 ± 0.52 items per sq. m (Figure 6a) and 117.64 ± 1.23 g per sq. m (Figure 6b). Lowest abundance for Kadalundy both in terms of number items and weight was 0.8 ± 0.08 items per sq. m (April 2017) and 7.2 ± 0.12 g per sq. m (January 2017). In July 2016, the

highest abundance of litters noted in terms of items (1.79 ± 0.03 per sq.m) and weight (15.8 ± 0.17 g per sq.m \pm) were observed at Kadalundy.

It was observed that in Kadalundy samples the major contributor was plastic carry bags, then the plastic bottles, miscellaneous items and the least contributor was plastic fragments. The abundance in terms of items per sq. m is categorized as plastic carry bags (49%), plastic bottles (38%), miscellaneous items (7%) and plastic fragments (6%) whereas in terms of weight per sq. m, the grouping of plastic litter reveals 54% of plastic carry bags, 32% of plastic bottles, 9% of miscellaneous items and 5% of plastic fragments (Figure 7a & 7b).

The major plastic litter contributor in Kolavipalam site was plastic bottles, then plastic carry bags, miscellaneous items and the least contributor was plastic fragments. The abundance of plastic litter by number per sq. m is categorized as plastic bottles (46%), plastic carry bags (24%), miscellaneous items (16%) and plastic fragments (14%) whereas the abundance of plastic litter by weight per sq. m, the plastic bottles contributed 64%, 26% of plastic carry bags and 5% each of miscellaneous items and plastic fragments (Figure 7c & 7d). From the study, it was observed that there were more plastic carry bags in the mangrove ecosystem of Kadalundy area whereas in Kolavipalam plastic bottles contributed more.



Fig 3: Plastic litter being settled and dumped at mangrove area

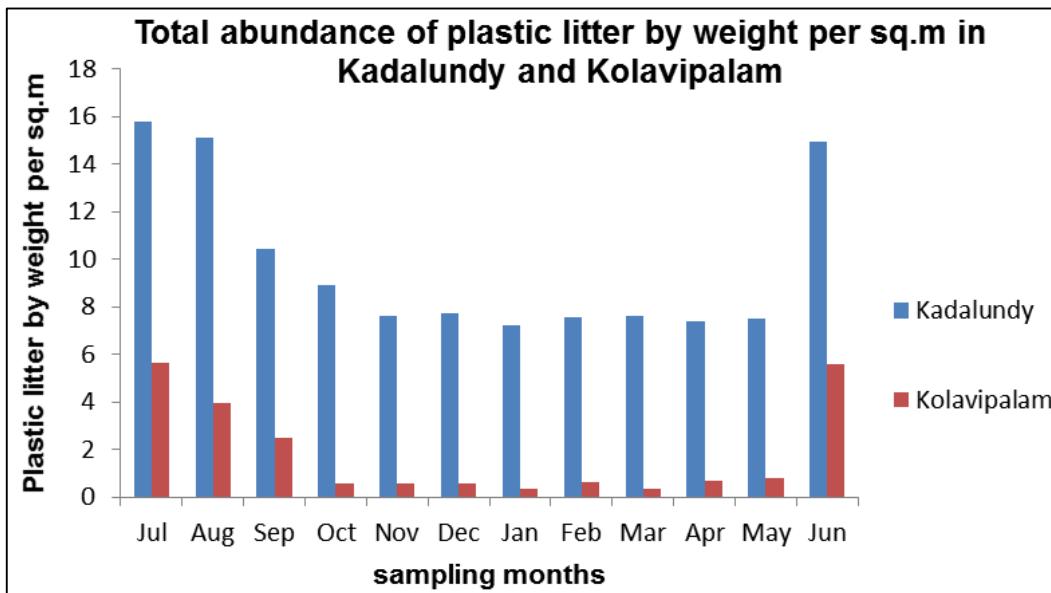


Fig 4 a

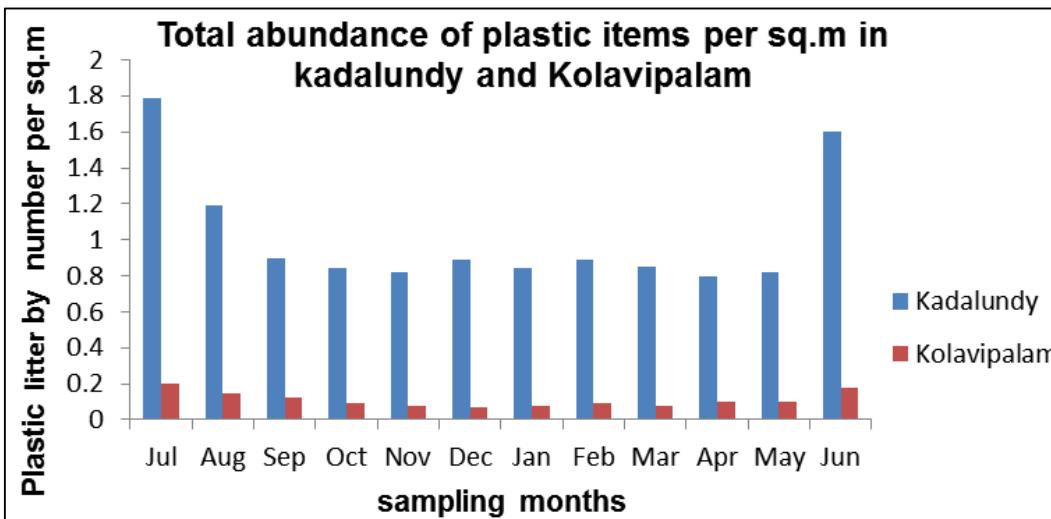


Fig 4 b

Fig 4: Total abundance of plastic per sq. m in Kadalundy and Kolavipalam a. based on weight b. based on the number of items

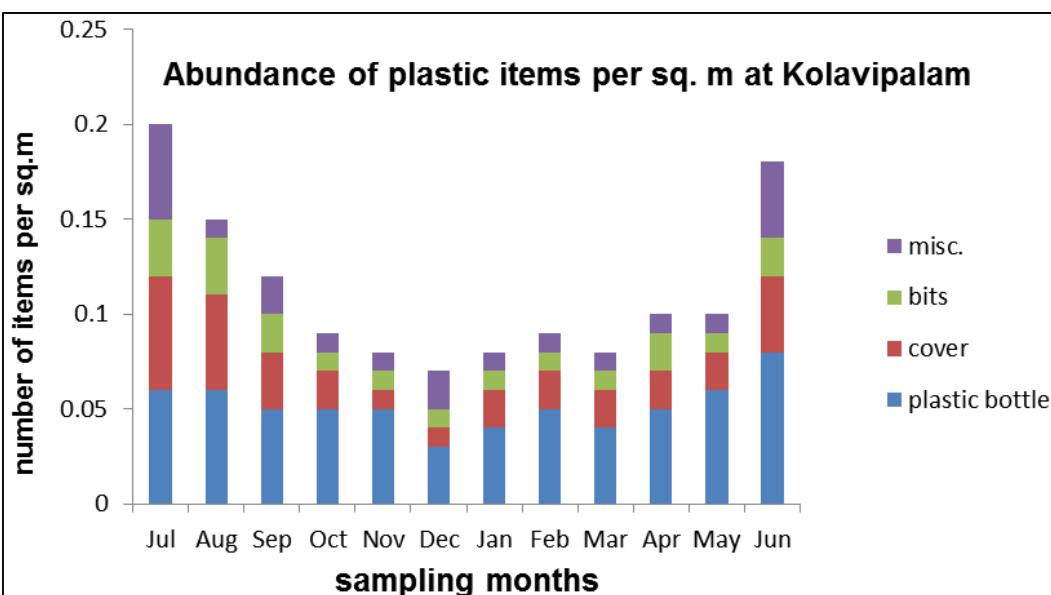


Fig 5a

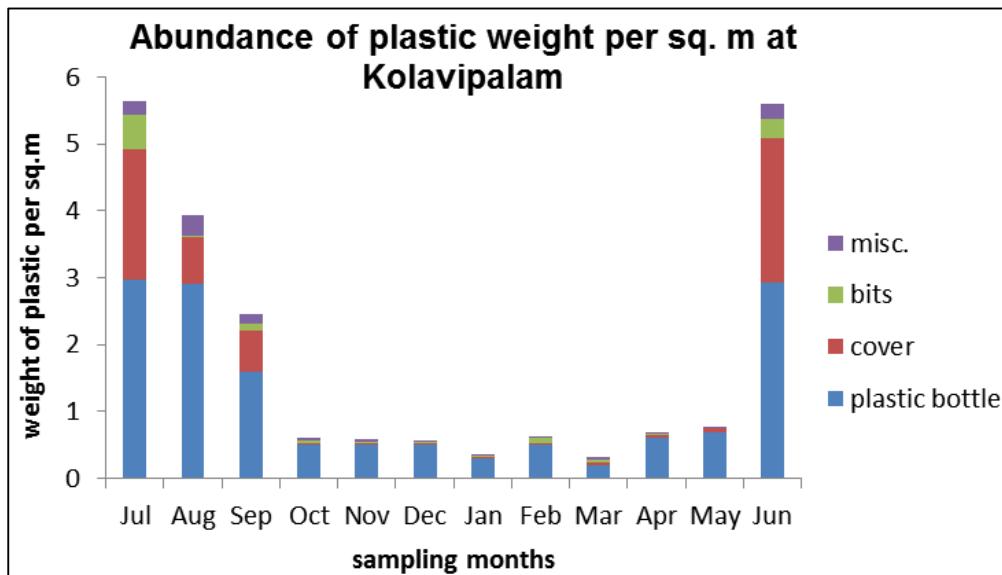


Fig 5b

Fig 5: Abundance of plastic per sq. m at Kolavipalam a) Based on number of items b) based on weight

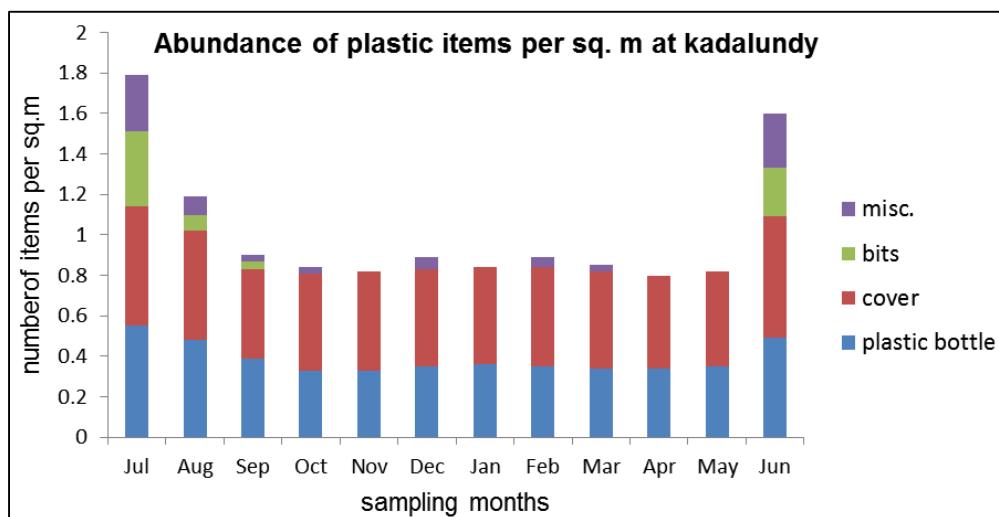


Fig 6a

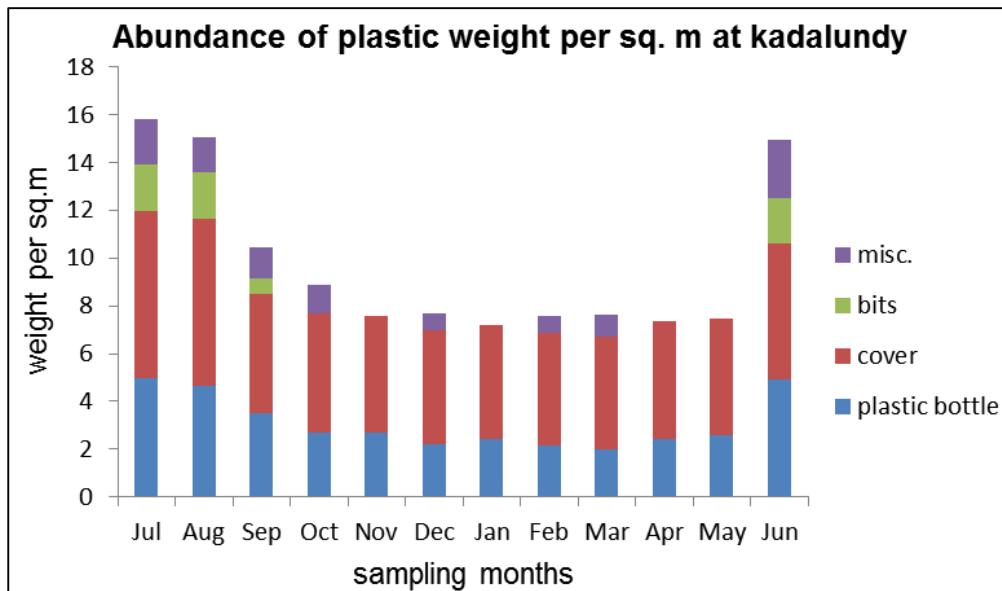


Fig 6b

Fig 6: Abundance of plastics per sq. m at Kadalundy a) based on number of items b) based on weight

Percentage composition of plastic items per sq.m at Kadalundy

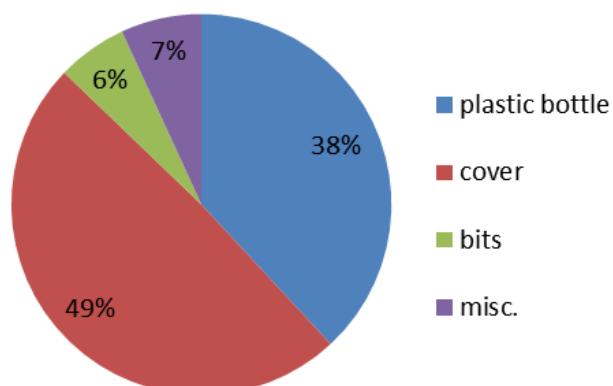


Fig 7a

Percentage composition of plastic weight per sq.m at Kadalundy

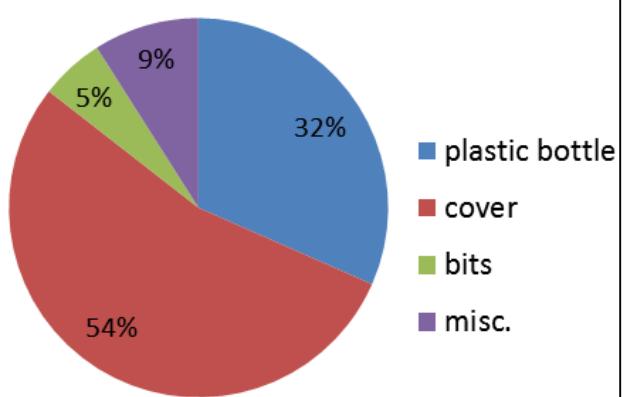


Fig 7b

Percentage composition of plastic items per sq.m at Kolavipalam

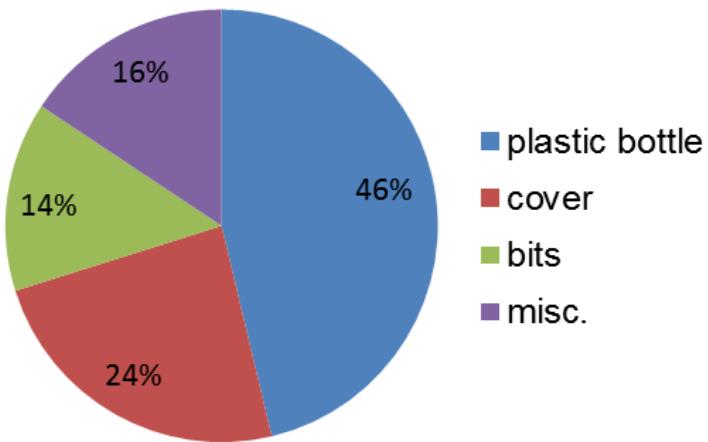


Fig 7c

Percentage composition of plastic weight per sq.m at Kolavipalam

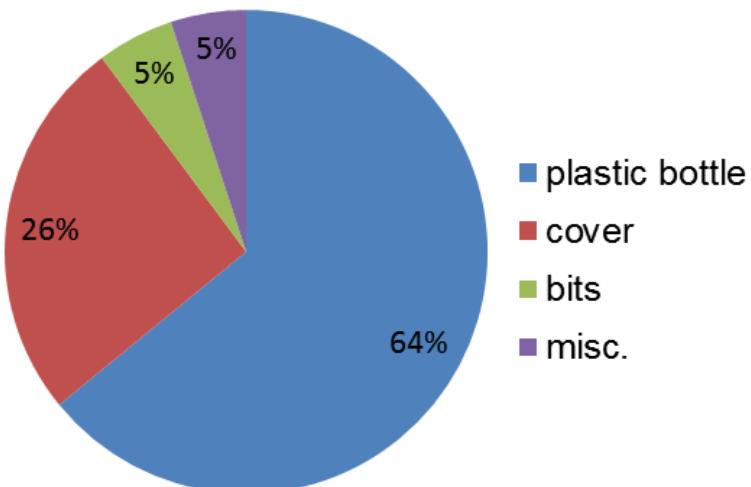


Fig 7d

Fig 7: Percentage composition of plastic a) Kadalundy (item per sq.m) b. Kadalundy (weight per sq.m) c. Kolavipalam (item per sq.m) d. Kolavipalam (weight per sq.m)

Discussion

The sources for plastic debris in the ocean are mainly due to the discharge of wastewater and runoff water by rivers, including outfalls of wastewater treatment plants, and the dislodging of discarded plastic products from landfills [31].

From the study in a total of 72 quadrates, it was observed that accumulated plastics were more in terms of weight than in numbers from all the sampling sites. It was surveyed in mangrove stands in Brazil and found the major litter type in terms of density were plastics (62.81 per cent) and, by weight, wood (55.53 per cent). The debris accumulation leads to direct mortality of animal species, habitat suppression and local economy losses by tourist avoidance [32].

The Kolavipalam mangrove area is very near to sea and the mangroves are somewhat in isolation from the direct anthropogenic impact and this was depicted in results with lesser accumulation of plastics (1.34 ± 0.25 items per sq. m and 22.17 ± 0.49 g per sq. m) compared to Kadalundy. Highest abundance of plastic litters in terms of items were noted (0.2 ± 0.02 items per sq. m) and in terms of weight (5.65 ± 0.18 g per sq. m) in the month of July 2016. This accumulation of plastic litter in July may be due southwest monsoon flooding.

In Kadalundy sampling sites, total abundance of items and weight of plastic litter was 12.23 ± 0.52 items per sq. m and 117.64 ± 1.23 g per sq. m. This was very high when compared to Kolavipalam. The Kadalundy is having a long running river which carries and deposits tonnes of garbage into the mangrove swamps. Kerala experiences torrential rain during June - July months, which may lead to heavy dislodging of all sorts of garbage generated by anthropogenic interventions into the mangrove-estuarine channel and thus get trapped in between the complex root systems of mangroves, which otherwise would have reached the sea. The river adjoining helps in bringing down of all sorts of garbages into mangrove estuarine channel and thus gets deposited in between the complex root systems. This is observed in the present study for Kadalundy site. So these kind of heavy accumulation plastics in such a fragile and eco-sensitive mangrove ecosystems may lead to the gradual destruction of mangrove seedlings and associated benthic biota due to smothering and release of toxins which may eventually lead to the degradation of mangrove ecosystems.

In future, the heavy accumulation of plastics in these sensitive mangrove ecosystems may lead to the gradual destruction of mangrove seedlings by smothering of roots and finally leading to complete destruction of mangroves and hence deterioration of entire water resources. Similar study was done by [33] and reported that an island off the coast of Papua New Guinea showed unusually high loads of litter in its mangrove forests, with one 50 m section containing a combined weight of 889 kg of marine debris (90 per cent plastic). Being sparsely populated, the island had close proximity to highly-populated regions and may have been transported by wind, wave and tidal action. The observation of this plastic debris was seen as a setback in rehabilitating depleted mangrove forests, as it leads to smothering of seedlings and also deteriorated the water quality in the surrounding bay [33].

In fact, the abundance of plastics in the marine environment primarily varies spatially as a function of the distance to coastal populated areas and popular tourist destinations, as well as with the occurrence of heavy rain and flood, but also with the speed and direction of the surface current which

control the transport pathway and accumulation of plastic debris (with the oceanographic conditions) [34]. Mangrove forests act as both a trap and as an filter for debris, with larger debris like plastic bags, rope, and wooden flotsam trapped up front, and smaller debris penetrating deeper into the forest [13]. It was clear from our study that more plastic carry bags in the mangrove ecosystem of Kadalundy area and its lesser occurrence in Kolavipalam mangroves is due to the result of river discharge (Kadalundy River). However, in Kolavipalam, though the litter present were very less, the topmost litter component being plastic bottles do indicate more human interventions.

It is reported that the ecological role of mangrove forests in the estuarine ecosystem is very much affected by plastic litters due to its long persistence in nature, high resistance to extreme tidal action and the seasonal riverine drainage. It is justified in a controlled study with the introduction of tagged plastic debris in a Brazilian mangrove forest [35]. We strongly opine that mangrove conservation is dependent on solving the plastic pollution issue, with source control a priority target and litter disposal the sole responsibility of the litter generator policy.

Conclusion

The salt-tolerant mangroves are very sensitive and fragile ecosystems with complex root system which help them in surviving in water-logged mud but also captures (filter) dislodged and free-floating plastics from land area through their pneumatophore and prop roots. Mangrove forests across the world have varying levels of pollution, but the situation is worsening everywhere. Ultimately, it is the responsibility of each individual to think globally and act locally in order to cut short the environmental hazards. Strict enforcement of legislation and environmental awareness activities can be imparted through education. Combined efforts of people in all sectors can lead to pave a way against plastic pollution.

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