Vertical distribution of microplastics in sediment at One Mile Harbour, Minjerribah, Queensland

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Note: In respect to the Traditional Custodians of the island, the Quandamooka people, this paper uses the terms Minjerribah to refer to North Stradbroke Island and Quandamooka to refer to Moreton Bay.

Abstract:

Microplastics are becoming increasingly prevalent within coastal ecosystems. The biodiversity of Quandamooka is impacted heavily by human activities in Queensland, specifically in terms of plastic pollution. This study aims to determine whether the amount of microplastics has changed over the past 50 years by examining their distribution through a sediment core. 50 centimeter sediment cores were collected using yabby pumps on the strandline at One Mile Harbour, Quandamooka. The cores were divided into five centimeter segments, each representing five years. These sediment segments were then were then mixed with a saline solution in order to suspend the microplastics. The microplastics were analyzed using a microscope and quantified within each sediment sample with microplastics found within each sample. However, the sediment samples taken closer to the surface, and therefore representing more recent history, contained more microplastics than the deeper sediment samples. A p-value of 0.0015 shows a strong correlation between microplastic abundance and sediment age. These findings emphasize the rise in microplastics resulting from increased plastic production over the past 50 years.

Keywords: sediment cores, microplastics, microplastic distribution, sediment dating

Introduction:

Marine debris is a major threat to biodiversity in the ocean, with 92% of this debris consisting of plastics (Jambeck *et al* 2015). Plastic pollution threatens marine life by ingestion, entanglement, and altering coral reef systems (Gall & Thompson 2015). This plastic debris then gradually breaks down into microplastic particles. While there is no universally accepted classification for microplastics, most categorize them as particles ranging from 1 μm–5 mm (Worm *et al* 2017).

Quanamooka is located in southeast Queensland and is partially enclosed by four islands, including Minjerribah to the south (Laycock 1978). One Mile Harbour, located on Minjerribah, is the site of this study. Quandamooka is one of Australia's largest estuaries in which a great amount of sediment is deposited from the rivers, such as the Brisbane River, and the Pacific Ocean (McPhee 2017). Where sediment is deposited, microplastics are commonly deposited as well, especially considering the ongoing turbidity Quandamooka undergoes (Morelli and Gasparon 2014).

There are seven types of plastic found in Quandamooka: polystyrene (PS), polycarbonate (PC), poly-(methyl methacrylate) (PMMA), polypropylene (PP), polyethylene terephthalate (PET), polyethylene (PE) and polyvinyl chloride (Grinham *et al* 2024). Microplastics contain harmful chemicals such as polybrominated diphenyl ether, phthalates, and bisphenol A which are endocrine disruptors and have been linked to genotoxic damage in mussels and mobility restrictions in invertebrates (Agbekpornu & Kevudo 2023). The fragmentation of macroplastics into microplastics increases the plastic's ability to concentrate harmful pollutants and transfer them to the organisms that ingest these microplastics. Similarly, ingestion of microplastics can cause malnutrition in organisms as plastics in the stomach may cause organisms to feel full and therefore reduce food consumption (Agbekpornu & Kevudo 2023). Plastic consumption can also block stomach secretion, decrease hormone balance, decrease fertility, prolong the ovulatory cycle, and act as a channel for other waterborne contaminants such as heavy metals (Agbekpornu & Kevudo 2023).

While it is clear that these microplastics are present in marine systems and beaches throughout Australia, it is still unclear when certain microplastics were deposited onto Minjerribah from Quandamooka. However, looking at the depth at which certain microplastics are located can give insight into when these plastics were deposited into the sediment as the deeper the sediment is, the older it is. Therefore, microplastics in deeper sediments were deposited earlier than those in shallower sediments (A. Grinham, pers. comm).

As microplastics are harmful to biodiversity, knowing their distribution patterns can be helpful in determining the correlation between increased plastic fragmentation and marine ecosystem health. This study aims to determine whether the amount of microplastics on the beach has changed over the past 50 years by looking at the distribution of microplastics through a sediment core. We hypothesized that microplastic concentrations would decrease with depth, reflecting the increased deposition of microplastics in recent years due to increased plastic pollution.

Methods and Experimental Design:

Sample Collection

Sediment cores were collected from the strand line in One Mile Harbor, Quandamooka at 27°29'39"S 153°24'04"E. Sediment cores are helpful as they preserve the pollution histories of aquatic systems (Lintern and Beng 2017). A yabby pump was used for sampling to maintain integrity of the core for depth fractionation. On day one of sampling, four replicate cores each measuring 50 cm in length were taken above the strandline. This was repeated over three additional sampling days, resulting in 16 total cores being sampled at the same site.

Sediment Preparation

After sample collection, the 50 cm cores were then separated into 5 cm segments, yielding 10 segments per core. Each centimeter of sediment in the One Mile Harbor represents one year (A. Grinham, pers. comm.). Deeper core segments correspond to progressively older periods of sediment deposition. Therefore, the top segment of five centimeters includes sediment from the present up until five years ago. Core segments taken from the same site on the same day were then assembled into uniform 100 gram samples, organized by their five cm segments.

After sample preparation, these samples were combined with 300 ml of 80 g/L saline solution to a mixing container. Once properly mixed, the sediment with the saline solution was left to settle to allow the microplastics to separate from the sediments and float to the surface (Sampling for microplastics in beach sand).

24 hours was allotted to allow the solution to settle (Takagi *et al* 2010). Once 24 hours had elapsed, the microplastics floating in the top layer were ready to be transferred to test tubes for further observation. A pipette was used to decant the top layer of water from the sample into a test tube. This process was repeated for each 100 gram sample of sediment.

Microplastic Identification

After extracting the sediment, the next steps included identifying the microplastics present and determining their depth within the core (Suara *et al* 2020). During sediment analysis, a 0.25 mL subsample from each sediment sample was placed on a petri dish, and suspended microplastics were counted under a microscope (He *et al* 2020). Microplastics have a similar appearance to sediment particles, so knowing their properties is vital for identification (Sampling for microplastics in beach sand). Plastics are generally milky white or colored rather than clear (Sampling for microplastics in beach sand). There are five main shapes they can take on: fragments that are jagged edged, pellets that are round and hard, fibers that are uniform strands, films that are thin and two-dimensional, and foams that are styrofoam bubbles (Razeghi *et al.* 2021).

Data Analysis

After identification, the results were graphed which displayed the distribution of plastics versus the depth at which they were collected.

Results:

Microplastics were identified in all sediment samples taken. The concentration of microplastics between each five centimeter segment varied. There were two outliers that can be seen in Figure 1. In the 25-30 cm segment, there is an outlier of 283 microplastics and in the 30-25 cm segment there is an outlier of 374 microplastics. These outliers were omitted from our study as they are significantly higher than the rest of the data. After omitting these values, the data ranged from a minimum of six microplastics at 45-50 cm to a maximum of 85 microplastics at 0-5 cm, as seen in Figure 2. The segment with the highest abundance of microplastics was found at 0-5 cm with a mean of 51.25 microplastics and a standard error of 12.04 microplastics. The segment with the lowest microplastic abundance was found at 45-50 cm with a mean of 13.0 microplastics and a standard error of 2.415. The coefficient of determination of the graphed data's trendline was 0.355 which represents a moderately strong fit to the data. The p-value of this data set was found to be 0.0015 which is statistically significant at a 0.05 significance level.

Discussion:

The results demonstrate a clear trend of decreasing microplastic concentrations with increasing sediment depth. This pattern is consistent with previous studies that suggest that microplastics are found primarily in the upper layers of intertidal sediments (Darabi 2021). Our findings align with the increase in plastic production in recent years as the highest amounts of microplastic were found in the top layers of sediment. The deposited plastic in sediment seems to be growing exponentially, as seen in Figure 2.

There was some variability in microplastic abundance across sampling days. This was particularly clear in the upper sediment segments of 0-35 centimeters. This was likely due to human activities that may have redistributed microplastics from the surface such as digging. It may have also been impacted by bioturbation which is especially prevalent on One Mile Harbour due to the presence of soldier crabs who excavate the top layer of sediment looking for food (Katrak & Bird 2003). As sediment depth increased, there was more consistent microplastic counts between sample days which is likely due to the lack of disturbance by these biological and mechanical factors.

Even so, there is clearly an inverse relationship between depth and microplastic abundance. There is a statistically significant correlation between abundance of microplastics and age of sediment. It is clear that as production of plastics increases, so will the deposition of these plastics in sediment. This observation at One Mile Harbour is a good indicator of what is likely happening on beaches throughout the world. The adverse effects of microplastics on ecosystems is known and with this data of increased microplastic deposition, these effects may become even more prevalent.

There is a need for more research on this topic in order to fully understand the impacts of increased plastics in sediment. Knowing that the abundance of microplastics in sediment is increasing over time, it would be interesting to look into how the effects of plastics on communities surrounding these waters. One Mile Harbour is located on Minjerribah, a place of cultural and biological richness. Future studies should focus on how these microplastics are impacting the local aboriginal community through health impacts and effects on fisheries. It would also be interesting to take a deeper sediment core to look at whether there are microplastics in the sediment that pre-dates the production of plastic. This would allow researchers to gain a better understanding of how microplastics are distributed in the sediment. Gaining more information about microplastic behavior within the environment can allow society to decide how to manage their impact.

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Figure Legends:

Figure 1. The plastic abundance in sediment cores at the strand line in One Mile Harbor, Quandamooka. Linear trendline is shown. R squared value is 0.007. This data set contains outliers 287 at 25-30 cm and 374 at 30-35 cm.

Figure 2. The plastic abundance in sediment cores at the strand line in One Mile Harbor, Quandamooka. Exponential trendline is shown. R squared value is 0.355. This data set omits outliers 287 at 25-30 cm and 374 at 30-35 cm.

Figures:

Figure 1:

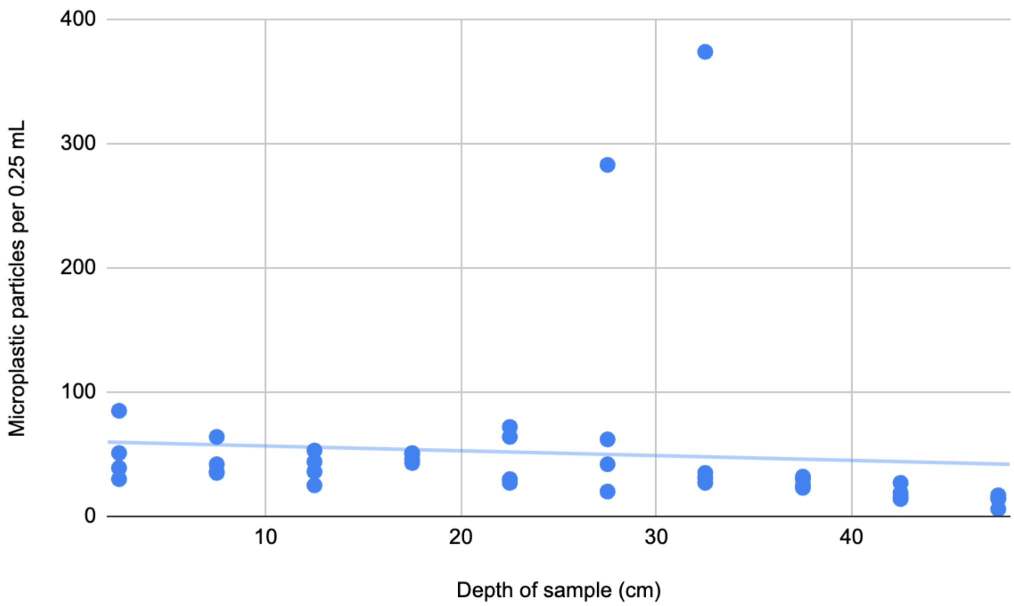
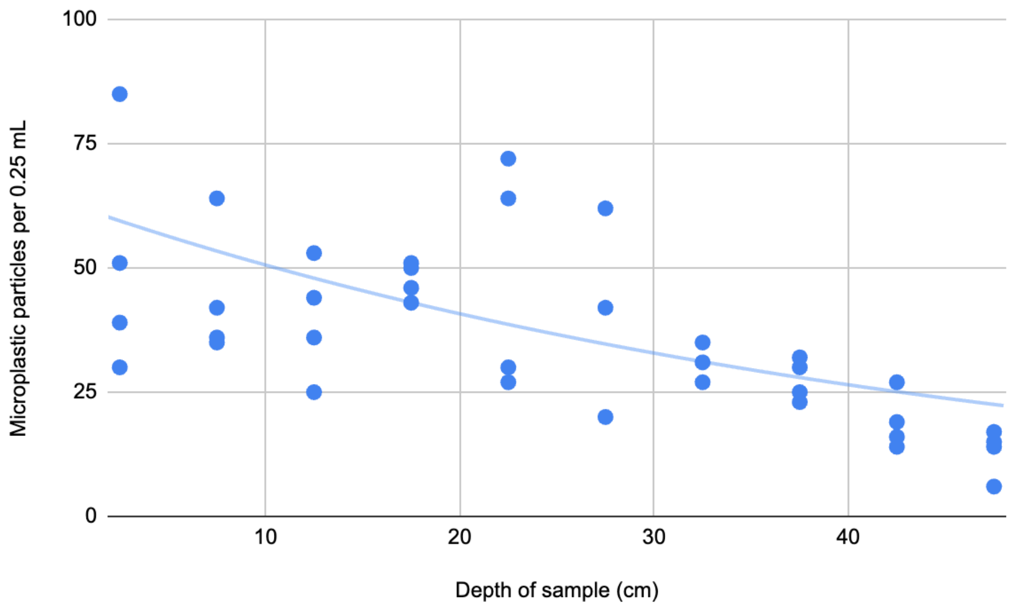


Figure 2:


100
75
50
25
0
10
20
30
40
Microplastic particles per 0.25 mL
Depth of sample (cm)