Spatial and Temporal Variations of Microplastics within Humboldt Bay

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Background

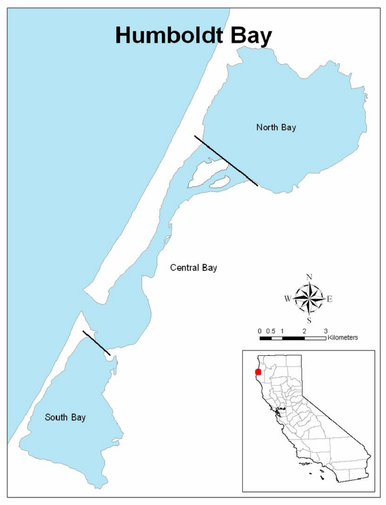


Figure 1: Map of Humboldt Bay, Eureka, CA, showing the three main areas within the bay: North Bay, Central Bay, and South Bay (Fish Communities in Eelgrass, Oyster Culture, and Mudflat Habitats of North Humboldt Bay, California Final Report).

In the last 70 years, the production and use of plastics has risen exponentially. From packaging to the primary material components of products, plastics have found a variety of convenient uses. Most types of plastic are very long lived in the environment, and almost 60% of plastics that have ever been produced are still prevalent in the environment (Dikareva & Simon, 2019). Plastic pollution has a variety of sources, including litter and industrial waste, and can enter the marine environment by various mechanisms (Dris et al., 2015) (Lambert & Wagner, 2018). Common plastic types (PVC, PET, PP, etc) have varying densities, durability, and sources; once in the marine environment, they are distributed heterogeneously, both in the local water column and in the world's oceans (Wagner et al., 2014) (Rios Mendoza & Balcer, 2019). This study deals with microplastics (MPs), which are plastic particles and fibers that are < 5mm in size.

Biofouling and chemical decomposition can increase the density of MPs in the water column (Van Cauwenberghe et al., 2015). These density modified MPs sink and become deposited in sediments or shorelines, where their concentrations can typically reach to 100 items kg^{-1} or in some cases as high as 400 items kg^{-1} (Wagner et al., 2014).

Not all the plastic in the marine environment originates in coastal areas. Plastic pollution from inland sources is carried to the ocean in storm runoff, sewage, and natural waterways. After extreme rainfall events, the concentration of marine MPs from terrestrial sources can increase sixfold (Lattin et al., 2004). Estuaries are particularly susceptible to plastic pollution (Zhang, 2017), and can be a sink for microplastics. In the low-energy environment of an enclosed estuary, many plastics eventually settle out of the water column and become embedded in sediments.

This study took place in Eureka, Ca. in Humboldt Bay, the second-largest estuary in California (Figure 1). The goal of this study was to quantify the amount of MPs in Humboldt Bay by observing its sediment and water column at specific locations during the tidal cycle. Additionally, we wanted to observe how tidal fluctuations impact the concentration and transport of MPs in the water column. We hypothesized that Humboldt Bay would be a net contributor of MPs to the Pacific Ocean. During ebb and flood tides, sediment and MPs would become suspended in Humboldt Bay, increasing the concentration of MPs in the water column exiting the bay. The expectation was that during slack tides, sediment and MPs will resettle, increasing the MP concentration in the sediment and decreasing MP concentration in the water column. It was anticipated that the surface sediment MP concentrations would be greater in the extremities of the bay, where there are less aggressive currents, compared to the sediment MP concentration in the tidally-driven mouth of the bay.

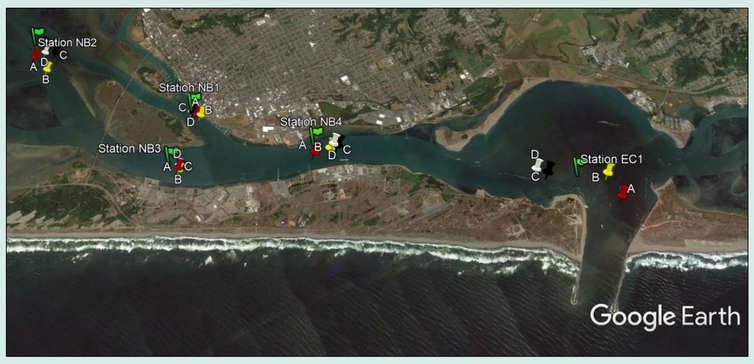


Figure 2: Station map of cruise stops on the Coral Sea and pontoon boat in Humboldt Bay. Green flags are indicators of station names. Pins A and B were station stops made on the Coral Sea, pins C and D were station stops made on the pontoon boat. Red (A) and White (D) colored pins were cruises during flood/slack tide and Black (C) and Yellow (B) colored pins were cruises during ebb/slack tide.

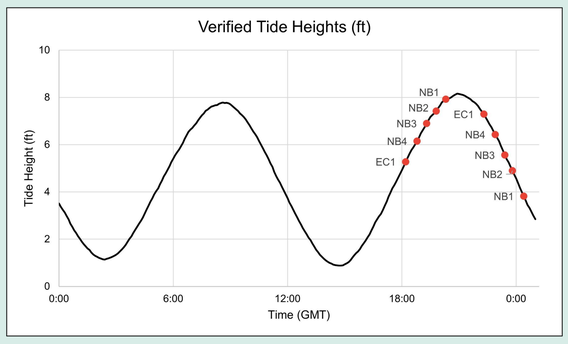


Figure 3: Verified tide heights (ft) at North Spit, Eureka, CA for the R/V Coral Sea cruise on September 19, 2020.

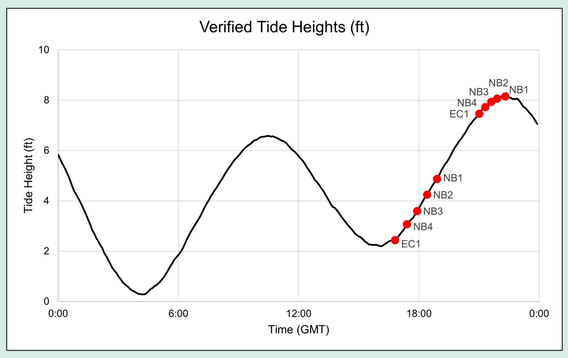


Figure 4: Verified tide heights (ft) at North Spit, Eureka, CA for the pontoon cruise on September 21, 2020.

Methods

Cruise Procedures

Water Collection Process (R/V Coral Sea):

Niskin Bottles

- Load niskins onto rosette (Figure 6)
- Collect sample
- While sample is being collected set up miniature filtration station in sink, this included:
  - set mason jar
  - foil lined cone in mason jar (to reduce sample loss)
  - sieves (-2 and 5.25 phi) set on top of cone
- Niskin water poured through sieve/cone/jar set up
- Sieves were rinsed with hose water and deposited into sink
- Mason jars topped with foil, capped, and set in wooden crate for lab processing

Phytoplankton Net

- Attach net to davit winch (Figure 5)
- Deploy net to ~1m above bottom depth and retrieve
- Rinse net thoroughly with freshwater hose into cod end
- Pour cod end into jar
- Rinse cod end from the outside with freshwater hose
- Top jar with foil, cap, and set in wooden crate for lab processing

Sediment Collection Process (Pontoon Boat):

- Clean jars with alconox and rinsed with DDI water
- Attach shipek grab to davit winch on pontoon boat
- Shipek grab dropped twice at one station for a bulk sample (Figure 7)
- Sampled scooped into 2, 1L jars and capped with aluminum foil lined lids (Figure 8)
- Jars stored in wooden crate for future processing

Figure 5: Leah Newton alongside recently deployed phytonet.

Figure 6: Bennett Hosselkus preparing the rosette for deployment.

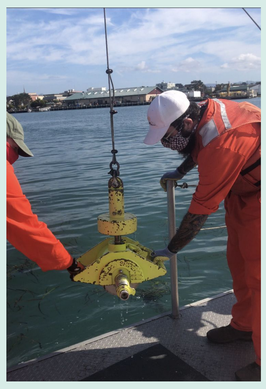


Figure 7: deployment of shipek grab by Michael Jacobs and Connor McNeil.

Figure 8: sediment samples.

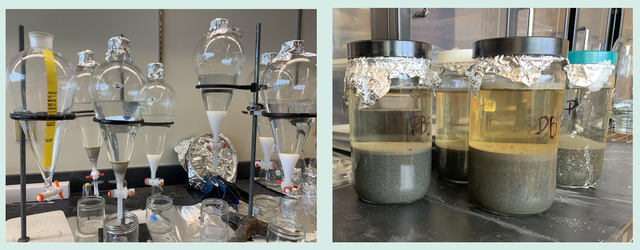
Laboratory Procedures

Density Separation Process:

- Add 100 mL of 30% H2O2 to all water samples to remove organisms
- Let settle for 48 hours
- Weigh full sample jar without lid
- Pour sample jar into separatory funnel (Figure 9)
- Weigh empty sample jar, simplify full weight and empty weight for sample volume
- Sample volume used to calculate NaCl mass needed to saturate sample to a density of 1.3g/m3(ratio of salt to water ~360g/L)
- Salt added to funnel with sample water, shaken vigorously and allowed to set for 48 hours

Filtration Process:

- Water and compacted salt released from spigot at base of separatory funnel down to ~200 mL and discarded
- Remaining 200mL poured into filtration setup to be filtered onto 45mm GFF/C filter by vacuum pump
- Post filtration, filters placed in aluminum boats and allowed to dry in sealed, off, oven (Figure 11)



Figures 9, 10: the density separation process.

Sediment Processing:

- Cleaned baking pans with alconox and rinsed with DDI water
- Placed wet sediment into pan
- Dried the sediment at 105 C for 48 hours.
- Took dry weight of sediments
- Rotapped between -2 and 5.25 phi dried sediments for 10 minutes
- Took post rotap dry weight of sediments
- Weighed out 500g of sediment per sample and placed in a 1L mason jar with 180g of sodium chloride and 500mL of DDI water
- Vigorously shook sample
- Allowed to set for a minimum of 48 hours (Image 6)
- Decanted/piped the supernatant into a separate 1L mason jar
- Put on the foil and cap until filtration procedure

Filter Count Procedure:

- Filters pressed and sealed between plastic graph paper
- Filters labeled with filter number
- Images of filters taken under microscope using imaging tool
- Each image consisted of 1 5x5mm square of the filter
- Images uploaded to google drive, 62 image files total
- 6 total people counting, 3 counters per filter
- Count sheets created on google sheets and separated into color and size columns
- Color columns: Green (G), White/Clear (W), Red/Orange (R), Yellow (Y) and Gray(G)/Black(B)/Blue(Bl)
- Size columns: < 0.5mm, 0.5 - 1mm, 1 - 3mm, 3 - 5mm

Figure 11: the filtration process.

Results

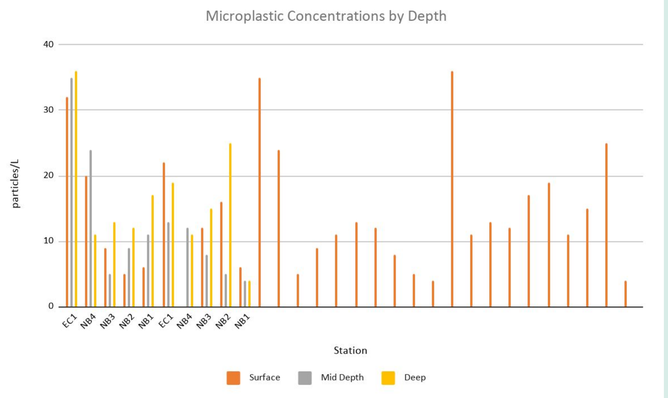


Figure 12: From the microplastic concentration by depth graph, the concentration of microplastics in the surface of the water column were noticeably the greatest at EC1 and NB2. These stations corresponded to the tidal change from flood to ebb and from ebb to flood, respectively. Because the concentrations of microplastics in the surface of the water column were the greatest when the currents were the strongest in Humboldt Bay, this supports our initial hypothesis that the energy associated with the currents did not allow the microplastic particles to settle in the sediment along with some of the MPs already in sediments were resuspended into the water column.

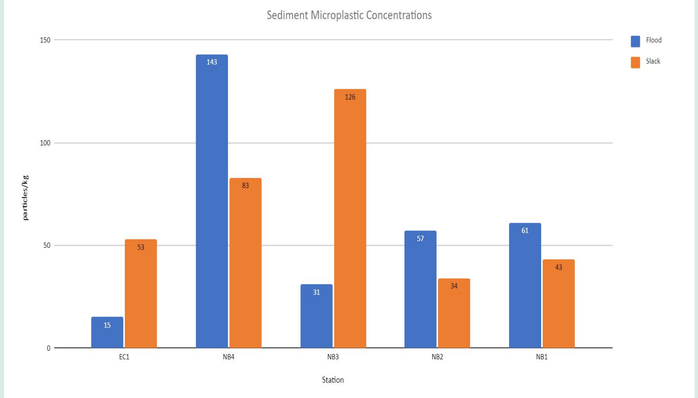
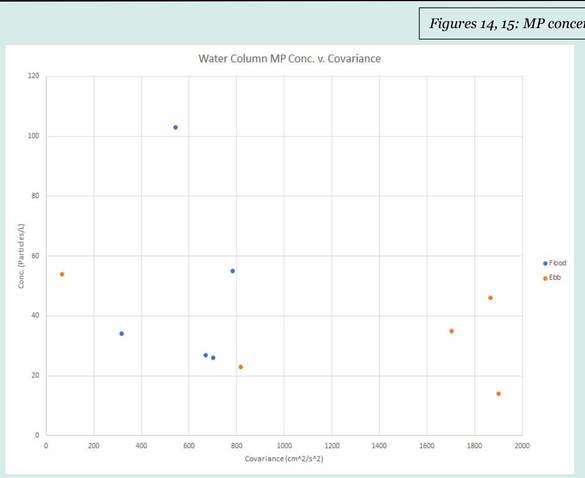
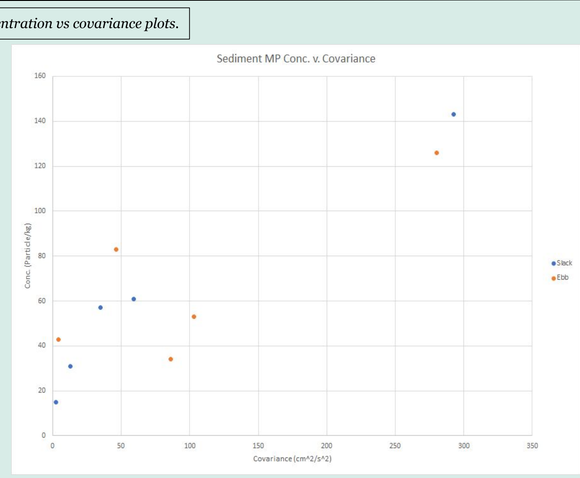


Figure 13: Sediment microplastic concentrations in particles/kg, from both legs of the pontoon boat cruise in Humboldt Bay. Blue represents sampling taken during flood tide, and orange represents sampling done during slack tide. Concentrations were highest at NB4 flood sample, and NB3 slack sample with 143 and 128 particles/kg. Lowest concentration was seen at EC1 flood, at 15 particles/kg. These results don't support that changes in tidal currents affect MP concentration in the sediments.

Figures 14, 15: MP concentration vs covariance plots.





The energy associated with the tidal cycle was expected to affect the microplastic concentrations in the sediments and the water column. Above are plots of the covariance, which is directly proportional to the kinetic energy, against the microplastic concentrations in the sediment and water samples from each station. The expectation was that when the covariance would be large, the microplastic concentration in the sediments would be very low, as the microplastics would be resuspended in the water column. The microplastic concentration in the water column should be large when the covariance is large. Due to this pattern not appearing in the data, the hypothesis can neither be confirmed or refuted.

Discussion

Sediment microplastic concentrations were predicted to be at a maximum during the lowest current speed within Humboldt Bay (during slack tide), as the relatively lower kinetic energy without the tides would potentially allow the microplastics to settle in the sediment. In contrast, when the kinetic energy in the water column is the highest, microplastics are expected to be more concentrated in the water column. Our results show at stations EC1 and NB2, which correspond during the flood or the ebb tide, the highest microplastic concentrations. Due to this, our hypothesis that microplastic concentration in the water column was highest during max flood. This supports the idea that the current speed at max flood was fast enough to not allow microplastics to settle in the sediments, rather they would stay suspended in the water column.

The sediment samples did not meet the hypothesis, as the samples do not represent the changes in concentration that were expected to be seen with the variation in tide. Other than NB3, all stations saw higher concentrations of MPs during the second leg of the pontoon boat cruise. Instead of plastics settling during slack tides, they had mostly higher concentrations during the flood tide. This could be because the tide was bringing in MPs from the ocean and depositing them into the bay or it could be due to the heterogeneous nature of MP distribution . The changes seen at each site are due to natural variations in the concentration of MPs, and the Shipek grab sampler not being deployed at the exact same location at each site. It is also important to note the tide was weaker than we would ideally have wanted to test our hypothesis. The tide on this day was also weaker than during our water sampling day.

We hypothesized that sediment MP concentrations in the extremities of the bay would have larger concentration. NB2 was the farthest station from the mouth of the bay, yet it saw the second lowest total concentration of the 5 stations, this could be due to the fact that it was in the center of the bay and farther from the terrigenous sources. EC1, which was hypothesized to have the highest sediment concentration due to how much tidal influence is there, saw the lowest MP concentration of any station. This area is heavily dredged and the fact that thousands of pounds of sediments are removed from the area at least once a year gives MPs little chance to accumulate here. Due to conditions on the water while sampling, the pontoon could not maneuver to the ideal coordinates for sampling, which also could have an affect on why the concentration was lower than expected.

The concentrations we found were much lower than the 100 particle/kg average mentioned by Wagner et al. (2014), with only 2 samples showing slightly higher concentrations at 143 particles/kg NB4 flood, and 126 particles/kg NB3 slack. The average sediment MP concentration was 64.6 particles/kg making Humboldt Bay sediment relatively plastic free. But it is important to note that procedures for MP extraction are not standardized yet.

Figure 16:Transmissivity vs MP concentration. It is expected to see that the more turbidity, the more microplastics suspended into the water column.

Acknowledgements

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