Comparing Macroplastic Distribution Using Drone Flights at Argilla Road & Pine Island

Merrimack Valley Planning Commission, Massachusetts Bays National Estuary Partnership, & Seaside Sustainability

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Introduction

The Great Marsh comprises 20,000-30,000 acres of saltwater marshes, mudflats, beaches, and other wetland systems in New England. The various bodies of water that make up the Great Marsh are subject to the ebb and flow of daily tides, and the debris they carry. Surveying the variable topography of this biome allowed us to make distinct correlations between characteristics of the Great Marsh (high and low marsh), its shorelines (beaches and granite headlands), and the volume and types of debris deposited within them.

In analyzing areas with a high accumulation of debris, our group, non-profit Seaside Sustainability, was able to quantify macroplastic deposition in the marsh based on *composition* (soft or hard plastic), *weight*, *type* (commercial marine, consumer, or industrial), and *number*. Volunteers and team members from Seaside Sustainability cleaned up multiple locations across the marsh. We created a grading system to examine the density of plastics, the environmental hazards, and the logistical difficulties in getting volunteer groups to come out to do more beach clean-ups in the future. To view this grading system, and learn more about our findings on types of macroplastic accumulation in the Great Marsh, click here or visit http://bit.ly/macroplasticsreport-seasidesustainability.

Our assessment of areas with little to no debris in comparison to their fouled counterparts allowed us to see accumulation patterns likely related to weather and environmental factors including: tidal currents; prevailing winds; and proximity to urban recreational areas, water treatment plants, and transfer stations. The notion of local homeowner informal stewardship - individual homeowners who monitor areas of the marsh clearly visible from their fields and yards- was of particular interest (see *Argilla Road, Ipswich* vs. *Coles Island, West Gloucester).*

Our rudimentary predictive models (topography and informal homeowner stewardship) have the potential to help various organizations decide on where they should focus their plastic clean-up efforts year after year. Local conservation commissions, public works departments, conservation landowners, and volunteer groups could benefit from these models.

The data collected might be useful for legislative initiatives. For example, local yacht clubs may ban the use of plastic cocktail stirrers and straws (see *Clark Beach, Ipswich*). Water treatment plants may be encouraged to refine their outflow filters to capture tampon applicators (see Pine Island, Newbury). Public relations initiatives may suggest that public areas of the Great Marsh are good candidates for local stewardship because the debris from the Marsh are within walking distance of several homes (see comparison of the *Argilla Road, Ipswich* and *Pine Island, Newbury* survey sites for illustrative examples).

Macroplastic Distribution Patterns

Areas mentioned throughout this report were surveyed between April and June, 2020. A DJI Mavic Pro, a drone programmed to fly autonomously via DJI GISPro software, was utilized to gather orthomosaics (orthos); the orthos were composed together from drone flights using open-source WedODM. Digital elevation models (DEMs) were also created from the drone flights using open-source WedODM.

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The salt marshes within the Great Marsh can be separated into tidal, high, and low marsh zones.

High marsh areas extend from above the mean high-water mark to the upland border of the marsh. High marsh areas (for example, Plum Island's federally-protected western edge from the guard shack to the saltwater panness, and as far south as the waterfowl impoundments above Sandy Point), flood less regularly than low marsh. These high marsh areas typically flood twice a month during the highest mean high tides, new or full moons, and during storms. Due to its tidal flows, areas of high marsh accumulate less debris, in comparison to areas of low marsh.

In contrast, low marsh is flooded twice daily by each high tide (Rockwell, 2016). By surveying areas of high marsh, we found low levels or, in some cases, a complete absence of debris accumulation (*Figure 1*). We attribute the negligible amount of debris in high marsh areas to the infrequency of debris-laden tides reaching the area. Areas of debris accumulation in high marsh are typically entangled within the vegetation bordering the edge of the marsh - in most instances, the phragmites that buffer the edge. The debris likely gets stuck on the fringes of the tidal marsh after the high tide events mentioned above, and when driven into the phragmites by prevailing northwesterly (winter) and southwesterly winds (summer).

The Great Marsh is a coastal biome. The usual water sources are ocean tides and tidal saltwater, as well as freshwater rivers and streams. These water sources generally flow from the north and the west. The freshwater and tidal rivers that play a significant role in the Great Marsh's composition are the Merrimack, Ipswich, Parker, Rowley, Mill, and Annisquam (Massachusetts Coastal Zone Management, 2011). The Great Marsh's low marsh areas contain tidal creeks, mudflats, and levees subject to the flow of these rivers; the urban and recreational areas they flow past; and the rivers' distributaries.

Figure 2 shows areas that flank the mouth of some of these rivers. Flanking areas often show debris accumulation on both sides of the river, even in areas where northwest winds are not a factor. Equal levels of plastics accumulation can likely be linked to tidal eddies, the proximity or upriver presence of urban areas, or the equally influential power of nor'east winds during storms in the winter and early spring.

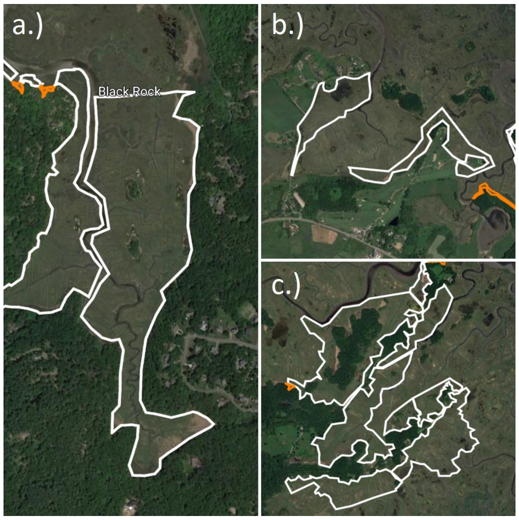

Figure 1. Examples of surveyed high marsh that accumulated negligible amounts of debris. Clean areas are denoted by white outlines; dirty areas warranting cleanup, orange.

Photo a.) *Coles Island, Gloucester*

Photo b.) *Lowe Island, Ipswich*

Photo c.) marsh area adjacent *Mass Audubon's Rough Meadows Wildlife Sanctuary, Rowley*

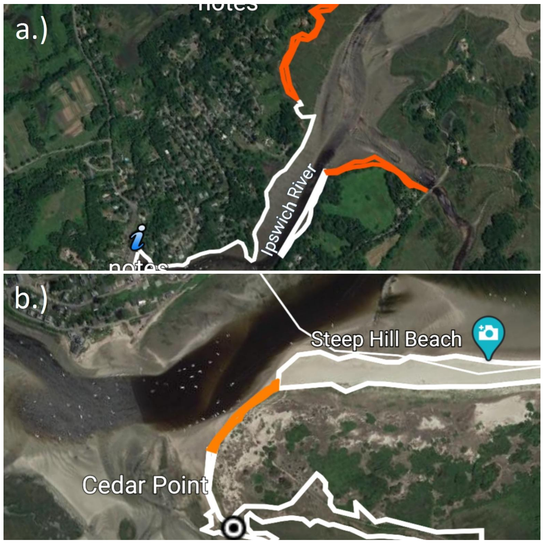

Figure 2. Examples of debris accumulation along the shores of the Ipswich River. Clean areas are denoted by white outlines; dirty areas warranting cleanup, orange.

Photo a.) Where the Ipswich River widens and enters the Great Marsh after flowing past the most densely settled areas of downtown Ipswich, including the early period houses neighborhoods near the state boat ramp.

Photo b.) The mouth of the Ipswich River where it empties into Ipswich Bay off Cedar Point at Crane Beach and Pavilion Beach at Little Neck.

There are other factors that contribute to significant debris accumulation in the Great Marsh. Coastal Massachusetts locations are subject to prevailing winds throughout the year. These winds generally follow a pattern of northwesterly in winter, southwesterly in summer, and easterly in May. During the winter and early spring, nor'easters storms and violent northeast winds occur (United States Department of Agriculture, 2003). With debris accumulation characterized by southeast or northeast orientation, the low marsh areas act as pockets that retain debris pushed in by west/northwest winds during the winter. Figure 3 shows the trapping of debris along the two islands' tidal marshes.

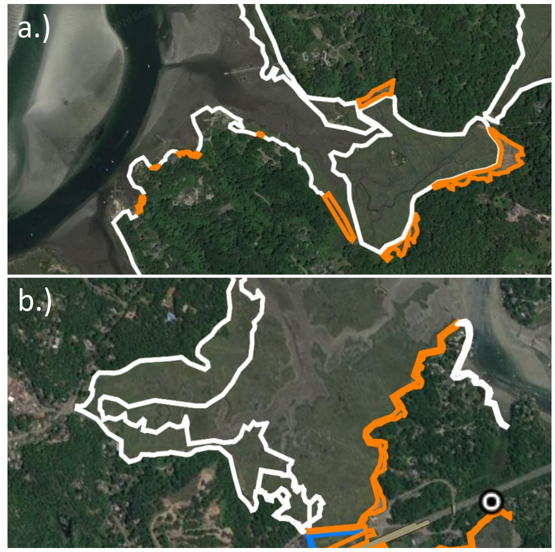

Figure 3. The trapping of debris along the two island's tidal marshes' northeast edges, we posit, is a result of the driving forces of powerful winter northwest/west winds. Clean areas denoted in white lie generally to the north and east, while dirty areas (orange outlines) warranting volunteer cleanup generally lie to the south and east at the endpoint of the fetch of winter's northwest/west winds. Blue areas denote areas cleaned by volunteers.

Photo a: Coles Island, Gloucester (Annisquam and Ipswich Rivers)
Photo b: Rust Island, Gloucester (Annisquam River)

Clean areas are marked in white; dirty areas warranting cleanup, orange.

Comparative Analysis

While many of the areas we surveyed displayed clear connections between the presence and absence of debris accumulation, their topography (high vs. low marsh), and exposure to the fetch of prevailing winter winds, other connections are not anywhere near as clear. Research conducted *en vivo* in areas subject to numerous simultaneous forces present data set outliers. A small series of drumlin islands off Argilla Road in Ipswich was anticipated to have a large amount of debris due to its location relative to westerly winds, a tidal creek, and proximity to both private residential and commercial shellfishing properties.

A two-hour foot survey revealed an area unexpectedly free of debris along both an island used as an access point by commercial shellfishermen and a marsh shoreline that borders numerous residential properties, marsh boardwalks, and at least three private boat docks. This unusually clean area was a contrast to Pine Island in Newbury. Pine Island is subject to the same sorts of tidal forces and winds. The island has geographic features nearly identical to the Argilla Road area. However, Pine Island's accumulation of plastics (and deadfall and blowdown driftwood) was thick, extensive, and profuse.

The comparison of both sites can be seen in *Figure 4.* All photos are oriented with cardinal directions as follows: True North aligned to top edge of the bortho or DEM, South aligned to bottom edge, West aligned to left edge, East aligned to right edge. The similarities in topography yet differences in debris distribution warrant additional analysis to search for supporting information.

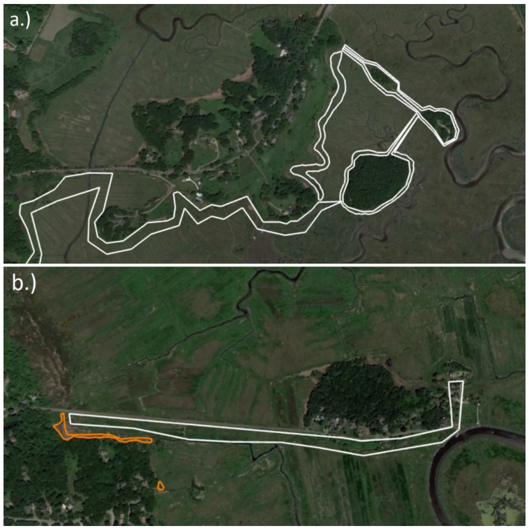

Figure 4. Comparison of the commercially-used drumlin islands and adjacent private lands at Argilla Road, Ipswich (Photo A.) and Pine Island, Newbury (Photo b.) Clean areas are denoted by white polygons; dirty areas warranting volunteer clean up, orange.

We used DJI GSPro to program autonomous Mavic Pro drone flights over the Argilla Road and Pine Island areas. Both survey sites include high marsh corners positioned to trap debris pushed in by prevailing winds and high tide storm surge. Likewise, both areas lie close to tidal rivers (the Essex and Rowley/Parker) subject to regular tidal influence. Finally, both areas contain small tidal creeks that terminate at land's edge and have in their immediate vicinity roadways with the potential to act as an additional source for macroplastic deposition (*Figures 5 & 6)*.

The orthomosaic and surface model maps generated from the flights indicated the topographic similarities between the two locations and provided additional information on changes in elevation relative to debris distribution. The debris at Pine Island collected in areas that were flat, indicated by blue and green on the surface map in *Figure 8*. The similar areas at Argilla Road, we posited before making a field visit, had the same potential to collect debris *(Figure 7).*

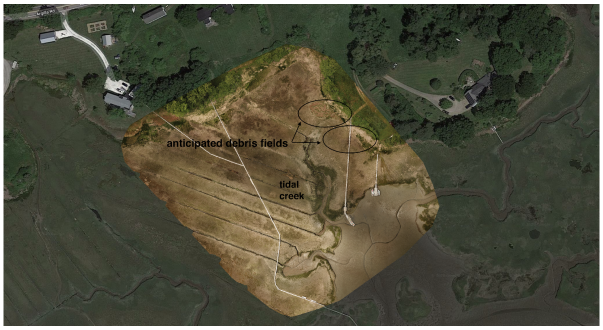

Figure 5. Orthomosaic of Argilla Road (Ipswich) selected for its similarities to Pine Island (Newbury), seen below in **Figure 6.**

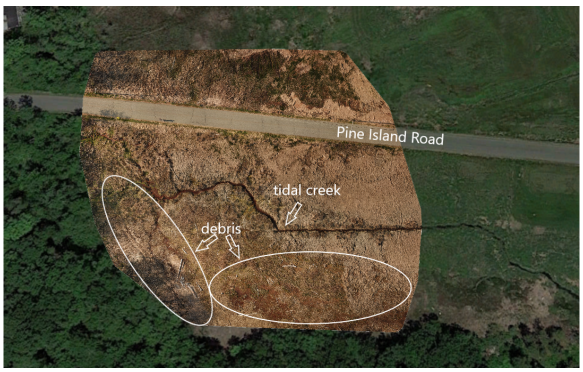

Figure 6. Orthomosaic of Pine Island (Newbury).

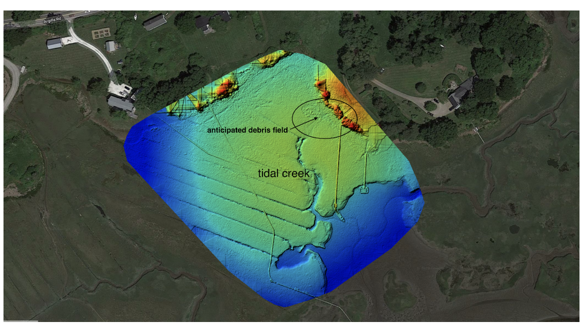

Figure 7. Surface model of Argilla Road (Ipswich) revealing potential for collection of macroplastic debris in flat areas of the marsh indicated in light green.

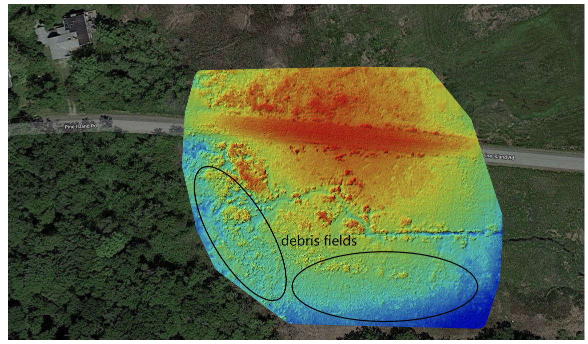

Figure 8. Surface model of Pine Island (Newbury) reveals a collection of macroplastic debris accumulation in flat areas of the marsh indicated in light green/dark blue.

With the similarities between both locations yielding such different results, the challenge was to find an explanation. Analyzing each area gave rise to the following suggested hypothesis. Homeowners on Argilla Road have installed a labyrinth of docks and walkways within the marsh, making for easy and repeated access to the area and a daily awareness of debris. This suggests homeowners are inclined to clean up areas of the marsh they view as a real or subjective extension of their property. The marsh area at Pine Island Road, on the other hand, doesn't give clear visual access to residential property, which decreases the likelihood that homeowners will take the initiative to clean the area. Moreover, the marsh plants, which obscure the marsh from the road, also make the debris invisible - a phenomenon we pinpoint in the debris field adjacent to private property at Samoset Creek, Gloucester, on the Annisquam River.

Conclusion:

A DJI Mavic Pro, a drone programmed to fly autonomously via DJI GISPro software, was used to take photographs of different areas of the Great Marsh including Coles Island, Rust Island, areas of the Ipswich River, drumlin islands and land near Agrilla Road, and Pine Island. These photographs were utilized to create orthomosaics and surface models that depict the amount of current debris and potential macroplastic debris accumulation that can develop within the Great Marsh. High marsh areas were found to have low debris accumulation when compared to low marsh areas. During winter and spring, stronger wind events occur that cause high debris accumulation. Debris was found to be heavily surfaced in areas that were flat as well. On the other hand, areas of the marsh that were near residential areas had low debris accumulation; it suggests that homeowners may frequently clean-up debris near them. The drone technology utilized in this study can be used for further research on topography, debris accumulation, and pollution studies. For example, the DJI Mavic Pro can survey the evolution of disappearing beach fronts that are threatened by rising sea levels. Likewise, aerial images captured by the drone can effectively show the magnitude of pollution plumes on land and oceans due to its vantage point.

This technology provides aerial perspectives that can inform scientists and policy makers about how pollution is affecting the environment over time; these findings can help them identify key areas that require clean-ups and opportunities for improving environmental laws and policies.

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