Marine Debris on San Juan Island Beaches: Argyle Spit and Eagle Cove

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Abstract

Marine debris (MD) (plastics, glass, rope, human waste, etc. that made its way into the ocean) is polluting the ocean and the shores across the world. This is a significant ecological concern due to its negative impacts on wildlife. This study focuses on marine debris on the shores of Argyle Spit and Eagle Cove, comparing the intertidal zonations, high, medium, and low, with the abundance of debris in those zones. Argyle Spit had a significant p-value when finding the most abundance of MD in the high-intertidal. Argyle Spit had a high amount of debris in the high-intertidal, but Eagle Cove did not have a significant enough p-value to say whether MD was most abundant in the high-intertidal. This is important because more MD in the high-intertidal zone can tell us how different species living in these intertidal zones at those two beaches may be more likely to interact with the MD. This can look like seabirds, sand fleas, or other high-intertidal organisms living in the same environment as MD and ingesting or absorbing the fragments and/or chemicals when exposed.

Introduction

Human-produced waste exceeds millions of tons every year (Salazar et al., 2022; Weideman, et al., 2020) worldwide, and a large proportion of this enters ocean waters as marine debris (MD), creating health risks issues for many marine organisms like loss of energy, abrasion, reaction time reduction, entanglement, choking, and death (Omeyer, et al., 2023). Harmful impacts of MD include risks to marine megafauna like seals, whales, and turtles that can be entangled in debris on their extremities or can ingest this debris (Omeyer, et al., 2023). In the intertidal zone, seabirds, and many invertebrates ingest or associate with MD and can absorb the chemicals created by the debris, causing them to have an increase in health issues (Weideman, et al., 2020).

Important intertidal species such as the anemone *Bunodactis reynaudi* sea anemones have been documented ingesting large amounts of plastic, and in a 4-year survey, approximately 491 pieces of litter were ingested in total by thousands of *Bunodactis reynaudi* in False Bay, South Africa, with the majority of it being flexible plastics (Weideman, et al., 2020). Understanding that flexible plastics were most abundant in interactions between *Bunodactis reynaudi* and MD can help support the knowledge of how organisms and MD interact in the intertidal. Another study in Korea focused on MD impacts on 21 marine intertidal species, mostly birds, and many of the sea birds were impacted with fish hooks and lines (Hong et al., 2013). The sea anemones, sea birds, and other marine invertebrate's interactions with MD are all examples of negative impacts on marine species in the intertidal zone from MD.

Sea surface currents and wave action move much of this MD across large portions of the ocean to areas at great distances from where the debris was originally deposited (Iskandar, et al., 2021; Murray, et al., 2018). Studying the conditions bringing MD to shore can be useful in the removal of debris to avoid further impacts on the intertidal and oceanic environments. Tracking the locations of MD can help environmental agencies focus their energy into mitigation efforts (Iskandar, et al., 2021). This information helps us understand how MD is ending up on shores across the world and if certain conditions may impact the abundance of MD. The goal of research studies like these is to avoid the interaction of marine organisms and MD due to negative health impacts.

The zonation of MD and where it may collect on the shores of San Juan Island, Washington (SJI) is interesting and can bring conclusions to other studies about how organisms interact with MD. This study focuses on the distribution of MD on the shores of Argyle Spit and Eagle Cove. It is expected that the density of MD is greater in the high-intertidal than the mid and low-intertidal at both locations. **Where in the intertidal zone is MD most abundant for Argyle Spit and Eagle Cove?** This present study will compare the high-intertidal, mid-intertidal, and low-intertidal and the density of MD in each intertidal zone. The hypothesis for this study is that the high-intertidal zone will have a greater abundance of MD when compared to the mid-intertidal and low-intertidal zones of Argyle Spit and Eagle Cove. Each location will be assessed separately.

Methods

Observational study preparations

Materials used were trash bags to collect trash after the study, 0.25 m^2 quadrat to study a given section, and a field notebook and pen for notes. A satellite image of Argyle Spit and Eagle Cove was screenshotted from Google Maps to plot the study area, then the beach was divided into equal sections of approximately 8 m^2. This was done on an iPad and 135 equal sections for Argyle Spit and 64 equal sections for Eagle Cove were hand-drawn using personal judgment. Twenty sections were randomly selected to survey for MD. This was done by numbering each drawn section from the satellite image and then using a random number generator to decide which sections would be surveyed. Figures 1 and 2 show satellite images of each location and how it was divided up in preparation for the survey. The top two rows are considered the high-intertidal zone, the middle two rows are the mid-intertidal zone and the bottom row is the low-intertidal zone. The lack of equipment to exactly section each area equally on the given beach and pinpoint the exact location on the beach that is highlighted in purple on the satellite image may cause the areas surveyed to be estimated based on the image and personal perspective when present on the beach to determine the exact placement of each section.

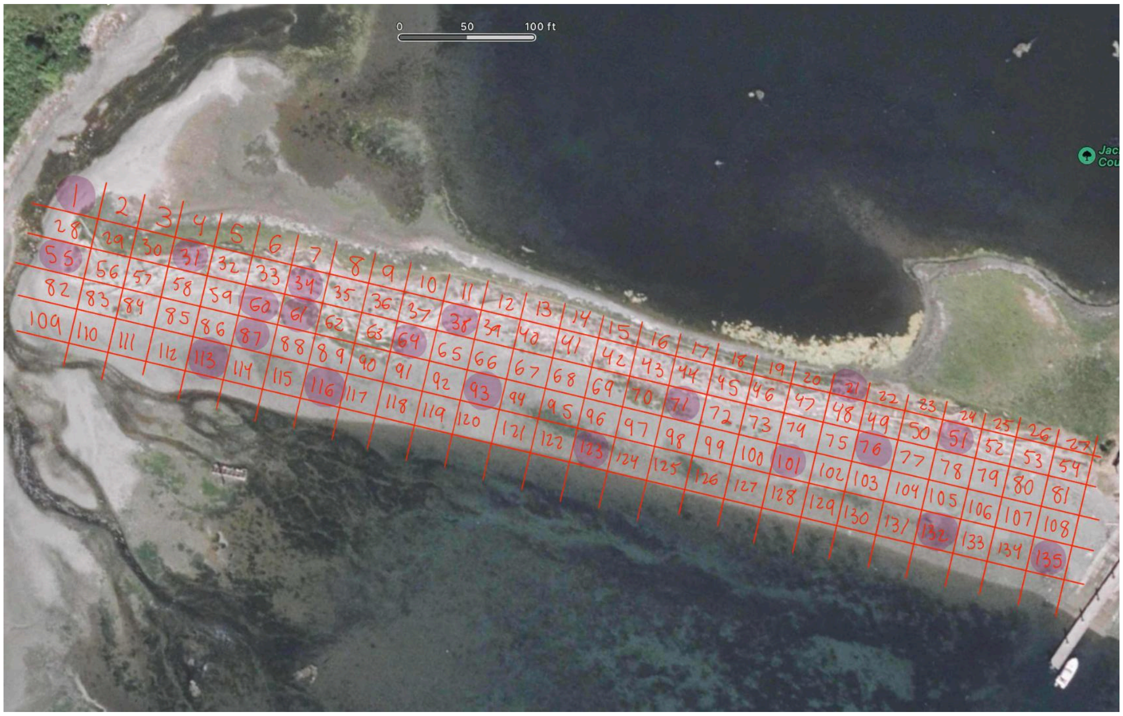

Fig. 1: Argyle Spit (48.52089° N, 123.01185° W) split into 135 approximately 8 m^2 sections *that were randomly selected using a number generator and surveyed in the field. Highlighted areas were partially surveyed with a 0.25 m*^{2} *quadrat.*

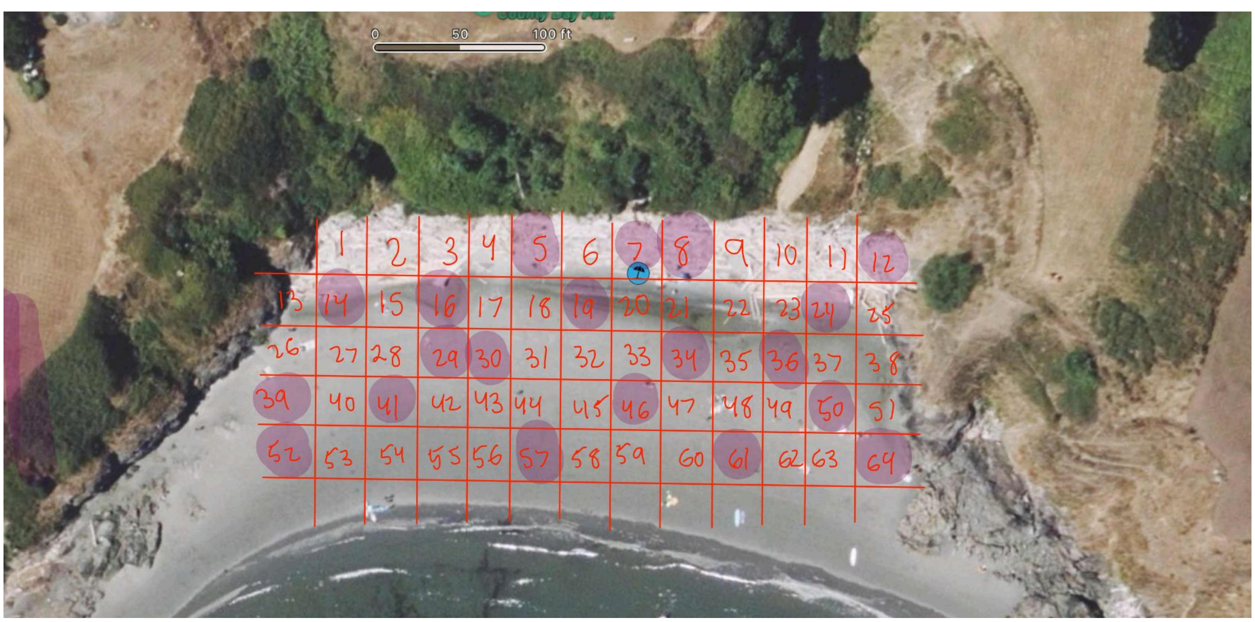

Fig. 2: Eagle Cove (48.46148° N, 123.03245° W) split into 64 approximately 8 m^2 sections that were randomly selected using a random number generator and surveyed in the field. Highlighted areas were partially surveyed with a 0.25 m^2 quadrat.

<u>*Data Collection*</u>

Twenty 0.25 m^2 sections were surveyed at each location. One 0.25 m^2 was surveyed in each selected 8 m^2 section (figures 1 and 2, purple dots highlight selected areas) using the quadrat. In a given selected section, a quadrat was set down, and MD was considered a part of the observational study if it was inside the physical quadrat or touching any area of the quadrat. In each quadrat, MD was collected and counted for each piece of MD that was seen and able to be collected using hands. Anything unable to be collected was not counted towards the total number of pieces of debris in this study and was left on the beach. In a cobblestone, gravel, or log-abundant area, surface-level rocks or logs were moved to assess if other debris may be in the quadrat. There was no digging in the substrate for debris. Collections were placed in a trash bag to clean the beach while doing this study. This was repeated for each section for both beaches. Some bias that may have occurred in this study was when personal judgment was being used while being present on the beach to estimate the placement of each number section based on the satellite images. Then, a spot in each section was chosen to place the quadrat.

<u>*Data analysis*</u>

After data collection, data was recorded and graphs were created on Google Sheets. Graphs were edited using the CollaNote app on iPad to add the title, x and y titles, and variable titles to make it well displayed. P-values were added to the graphs as well (figures 4 and 6) Data was recorded and analyzed for where the intertidal (zonation) section was studied and the number of pieces of

MD in each quadrant in that section. ANOVA was used for the stats test for each beach's data. This one was most suitable for the study because there were three independent variables, high-intertidal, mid-intertidal, and low-intertidal zones (the treatment variables), and one dependent variable, the number of MD. This matches the hypothesis; comparing the high-intertidal, mid-intertidal, and low-intertidal and the density of MD in each intertidal zone. An ANOVA was run using Social Science Statistics, one one-way ANOVA calculator, and Tukey HSD (https://www.socscistatistics.com/tests/anova/default2.aspx). The ANOVA helped find the p-value of the data and determine significance. The Tukey HSD provided comparisons between the high and mid, high and low, and mid and low-intertidal zone data and shared the p-value significance. Data was entered into "treatment" sections: treatment 1=high-intertidal, treatment 2= mid-intertidal, and treatment 3= low-intertidal. Then, each of the sections surveyed that are in a given intertidal zone had a number of MD in each of them, which was added to the treatment section data. Two ANOVAs were run, one for Argyle Spit and one for Eagle Cove. The Social Science Statistics website automatically used a Tukey HSD test with the ANOVA information to give p-values for significance between the different intertidal zones.

Results

When running the one-way ANOVA test for Argyle Spit, the p-value is 0.0021, showing its significance. Figure 3 shows the data results from the stats test. Figure 4 shows the number of pieces of MD in each intertidal zone for Argyle Spit. One-way ANOVA had a p-value of 0.002074 and the Tukey HSD showed T1=high-intertidal, T2= mid-intertidal, and T3= low-intertidal. The comparison of abundance of MD between high and mid-intertidal (p=0.00339), and high and low-intertidal (p=0.0028) is significant, but between mid and low-intertidal (p=0.99549) is not significant.

Result Details

Source	*SS*	*df*	*MS*	
Between-treatments	1373.5278	2	686.7639	F = 9.08261
Within-treatments	1285.4222	17	75.6131	
Total	2658.95	19		

The F-ratio value is 9.08261. The p-value is .002074. The result is significant at $p < .05$.

Post Hoc Tukey HSD (beta)

The Tukey's HSD (honestly significant difference) procedure facilitates pairwise comparisons within your ANOVA data. The F statistic (above) tells you whether there is an overall difference between your sample means. Tukey's HSD test allows you to determine between which of the various pairs of means - if any of them - there is a signficant difference.

A couple of things to note. First, a blue value for Q (below) indicates a significant result. Second, it's worth bearing in mind that there is some disagreement about whether Tukey's HSD is appropriate if the F-ratio score has not reached significance.

Pairwise Comparisons		$HSD_{.05}$ = 12.5898 $HSD_{.01}$ = 16.4549	$Q_{.05}$ = 3.6280 $Q_{.01}$ = 4.7418
T_1:T_2	M_1 = 19.40 M_2 = 0.44	18.96	Q = 5.46 (p = .00339)
T_1:T_3	M_1 = 19.40 M_3 = 0.00	19.40	Q = 5.59 (p = .00280)
T_2:T_3	M_2 = 0.44 M_3 = 0.00	0.44	Q = 0.13 (p = .99549)

Fig. 3: Argyle Spit (48.52089° N, 123.01185° W) data after running one-way ANOVA and Tukey HSD. T1=high-intertidal, T2= mid-intertidal, and T3= low-intertidal.

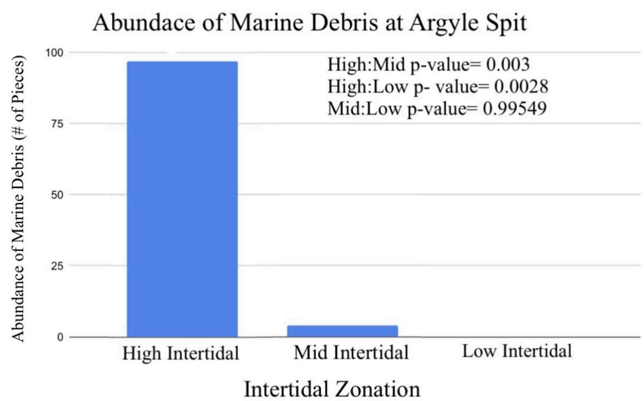

Fig. 4: Abundance of MD in each intertidal zone at Argyle Spit. The high-intertidal zone is significantly more abundant.

For Eagle Cove, data ran through the same ANOVA process and Figure 5 shows the p-value was 0.054226 and is not significant. Eagle Cove's One-way ANOVA had a p-value of 0.054226. The comparison between high and mid-intertidal (p=0.10773), high and low-intertidal (p=0.10646), and mid and low-intertidal (p=0.99998) are not significant. Figure 6 shows the number of pieces of MD in each intertidal zone and the p values for relationships between intertidal zones.

Result Details				
Source	***SS***	***df***	***MS***	
Between-treatments	1351.4381	2	675.719	F = 3.44189
Within-treatments	3533.8	18	196.3222	
Total	4885.2381	20		

The F-ratio value is 3.44189. The p-value is .054226. The result is *not* significant at $p < .05$.

Post Hoc Tukey HSD (beta)

The Tukey's HSD (honestly significant difference) procedure facilitates pairwise comparisons within your ANOVA data. The F statistic (above) tells you whether there is an overall difference between your sample means. Tukey's HSD test allows you to determine between which of the various pairs of means - if any of them - there is a signficant difference.

A couple of things to note. First, a blue value for Q (below) indicates a significant result. Second, it's worth bearing in mind that there is some disagreement about whether Tukey's HSD is appropriate if the F-ratio score has not reached significance.

Pairwise Comparisons		$HSD_{.05}$ = 19.5863 $HSD_{.01}$ = 25.5236	$Q_{.05}$ = 3.6093 $Q_{.01}$ = 4.7034
T_1:T_2	M_1 = 16.75 M_2 = 0.25	16.50	Q = 3.04 (*p* = .10773)
T_1:T_3	M_1 = 16.75 M_3 = 0.20	16.55	Q = 3.05 (*p* = .10646)
T_2:T_3	M_2 = 0.25 M_3 = 0.20	0.05	Q = 0.01 (*p* = .99998)

Fig. 5: Eagle Cove (48.46148° N, 123.03245° W) data after running one-way ANOVA and Tukey HSD. T1=high-intertidal, T2= mid-intertidal, and T3= low-intertidal

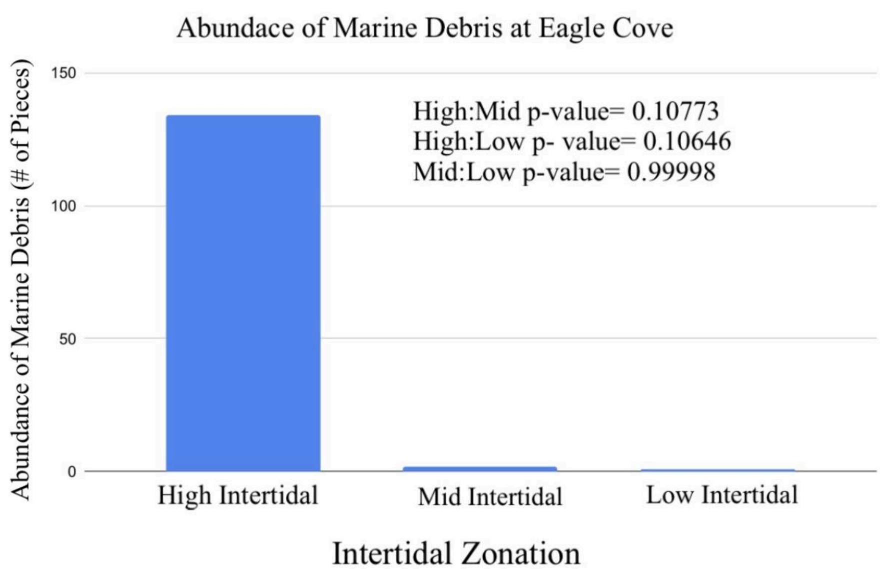

Fig.6: Abundance of MD in each intertidal zone at Eagle Cove. The high-intertidal is more abundant in the number of pieces overall, but not statistically significant.

The hypothesis is that the high-intertidal zone will have a greater abundance of MD when compared to the mid-intertidal and low-intertidal zones of Argyle Spit and Eagle Cove. This was correct for Argyle Spit and can be said in confidence due to the significant p-value. Eagle Cove did not have a significant p-value for the most abundance of MD in the high intertidal so the hypothesis cannot be accepted for that location. These results were partially expected based on personal experience while being on a beach. I expected both beaches to have a high significance.

Discussion

After observing the two locations on SJI for MD, there is significant evidence for MD abundance being higher in the high-intertidal than other intertidal zones from Argyle Spit, but not from Eagle Cove. One potential explanation for this result could be because there were 64 sections in Eagle Cove, but 135 sections at Argyle Spit; that is nearly double the amount of space studied. This was not intentional, but rather based on the size of the natural space on that beach. This could have skewed results since 31 percent of Eagle Cove was surveyed, while Argyle Spit was only 15 percent. Another aspect that may have not provided accurate results is that MD was accounted for when it was able to be hand-picked from the quadrat, not accounting for many of the smaller debris, like microplastics. Another portion of this problem with accuracy is that only 60 to 100 percent of plastics are detected based on the observer and biological material that is on the beach which may make it hard to find certain colored MD (Lavers et al., 2016). Many other studies do not account for microplastics or other smaller debris. This comes from studies mentioned by McWilliams et al. (2018) that used camera imaging to survey areas of beaches, but the cameras do not have the resolution to pick up on MD that small. This information is useful and can contribute to the conversation of improving methods of observational studies on MD.

If this study were reproduced or continued, some changes may be appropriate to create a more equal comparison between the two locations. Either determining a percentage of area to cover/study for Argyle Spit and Eagle Cove or finding a different location to study that is similar in size to another. One or both of these options may be more appropriate and change the data to be more accurate and have different results. These results could show the significance for Eagle Cove in the future. Another change could be the size of the quadrat used and how each section of the beach can be surveyed. One option could be to do a $1m^2$ sized area in a given section, rather than a $0.25m^2$ area. Lastly, another change would be to be more accurate when sectioning the satellite imaging. The sectioning of the image was estimated to be the same size, but no formal measurements were made. Some possible ways to be more accurate with this is to have some sort of computer program that can do this for you, or do some measuring in the field and divide accordingly using more mathematical strategies.

This observational study can contribute to the conversation in understanding if the placement of MD on the shore can help us understand what species may be more impacted by the MD. Species are being negatively impacted by MD on shores, and this can create bigger environmental issues for that beach. Another aspect of why MD is an issue is the seafood industry. People are consuming many crustaceans and bivalves across the world and when they are ingesting microplastics, they can give health risks to people who are consuming them (Thushari, et al., 2017). These impacts are making their way up the food web and affect all animals.

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Bibliography

Hong, S., Lee, J., Jang, YC., Kim, YJ., Kim, HJ., Han, D., Hong, SH., Kang, D., Shim, WJ., 2013, *Impacts of Marine Debris on Wild Animals in the Coastal Area of Korea,* volume 66, p 117-124, DOI: 10.1016/j.marpolbul.2012.10.022

Iskandar MR., Surinati, D., Cordova, M., Siong, K., 2021, *Pathways of Floating Marine Debris in Jakarta Bay, Indonesia*, volume 169, DOI: 10.1016/j.marpolbul.2021.112511

Lavers, JL., Oppel, S., Bond, AL., 2016, *Factors Influencing the Detection of Beach Plastic Debris,* volume 119, p 245-251, DOI: 10.1016/j.marenvres.2016.06.009

McWilliams, M., Liboiron, M., Wiersma, Y., 2018, *Rocky Shoreline Protocols Miss Microplastics in Marine Debris Surveys (Fogo Island, Newfoundland and Labrador)*, volume 129, DOI: 10.1016/j.marpolbul.2017.10.018

Murray, CC., Maximenko, N., Lippiatt, S., 2018, *The Influx of Marine Debris From the Great Japan Tsunami of 2011 to the North American Shorelines*, volume 132, p 26-32, DOI: 10.1016/j.marpolbul.2018.01.004

Omeyer, LCM., Duncan, EM., Abreo, NAS., Acebes, JMV., AngSinco-Jimenez, LA., Anuar, ST., Araujo, G., Carrasco, LR., Chua, MAH., Cordova, MR., Dewanti, LP., Espiritu, EQ., Garay, JB., Germanov, ES., Getliff, J., Horcajo- Berna, E., Ibrahim, YS., Jaafar, Z., Janairo, JIB., Gyi, TK., Kerberos, D., Lim, CL., Lyons, Y., Mustika, PLK, Neo, ML, No, SZH., Pasaribu, B., Pariatamby, A., Peter, C., Porter, L., Purba, NP., Cruz, ETS., Shams, S., Thompson, KF., Torres, DS., Westerlaken, R., Wongtawan, T., Godley, BJ., 202, *Interaction Between Marine Megafauna and Plastic Pollution in Southeast Asia*, volume: 874, DOI: 10.1016/j.scitotenv.2023.162502

Salazar, JA., Gonzalez, R., Navarrete, AL., Calle, P., Alava, JJ., Dominguez, GA., 2022, *A Temporal assessment of Anthropogenic Marine Debris on Sandy Beaches from Ecuador's Southern Coast,* volume 9, DOI: 10.3389/fmars.2022.977650

Thushari, GGN., Senevirathna JDM., Yakupitiyage, A., Chavanich, S., 2017, *Effects of Microplastics on Sessile Invertebrates in the Eastern Coast of Thailand: An Approach to Coastal Zone Conservation,* volume 124, p 349-355, DOI: 10.1016/j.marpolbul.2017.06.010

Walker TR., Grant, J., Archambault, MC., 2006, *Accumulation of Marine Debris on an Intertidal Beach in an Urban Park (Halifax Harbour, Nova Scotia)*, volume 41, p 256-262, DOI: 10.2166/wqrj.2006.029

Wiedeman, EA., Munro, C., Perold, V., Omardien, A., Ryan, PG., 2020, *Ingestion of Plastic Litter by the Sandy Anemone Bunodactis reynaudi*, volume 267, DOI: 10.1016/j.envpol.2020.115543

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