Exploring Along a Line of Micro Particles: Using Marine Debris Studies to Encourage Environmental Stewardship

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The accumulation of marine debris along beaches, in estuaries, and in the open ocean is a massive, but largely unknown issue. Along with the important issues of sea level rise and ocean acidification, marine debris accumulations have been recognized as a 21st Century global challenge (http://www.stapgef.org/impacts-of-marine-debris-on-biodiversity-current-status-and-potential-solutions/). Man-made debris can affect human health and safety, the economy, and biota of the marine environment. Much of this debris consists of plastic, which can persist in the marine environment for long periods of time. Marine debris can be found virtually anywhere one might look within the ocean and coastline; indeed, it is a wide-spread pollution problem.

Ironically, much of the loss of debris into rivers and ultimately the ocean is preventable, through adjustments in societal behaviors, ordinances, and the daily practices of all citizens. Articles about tsunami debris and oceanic “garbage patches” in the popular press and on social media sites have resulted in the increase in public awareness and interest, and local efforts have focused on mitigating some coastal sites. These efforts have involved volunteer beach cleanups, which concentrate upon plastic and other waste contaminants easily picked up and removed. But there is much more that needs to be done to increase general awareness about the issue, starting with education that examines the sources of debris, and mechanisms to reduce them.

The cleanup efforts to date are laudable, but they omit what may be an important—and even more poorly understood—component of the debris. There is growing recognition that much of the plastic debris breaks apart under physical stress and chemical degradation, that small (less than 5 mm) plastic particles are now ubiquitous in the coastal environment, and that these small particles can cause harm to marine organisms (http://marinedebris.noaa.gov/learn-basics/types-and-sources). Micro plastics are also common constituents of cosmetics and facial scrubs, and other commercial products, and large quantities are washed down the drain every day.

How, then, do we build citizen’s awareness of current global issues like marine debris, or micro plastics? Action-based, conservation programs are a useful tool to foster environmental awareness and stewardship among youth as we face important environmental challenges. We have developed an environmental education program, marine debris shoreline surveys (http://marex.uga.edu/marine-education-center-and-aquarium), as a useful tool to improve efforts to address marine debris. The marine debris surveys have become a valuable mechanism to educate and engage participants on important coastal issues as participants progress along a continuum of learning experiences that focuses on marine debris in coastal systems. Participants move from awareness to understanding the human activities that affect it, to taking positive actions (marine debris removal) on behalf of the environment. Participants are encouraged to think about how they interact with the environment on a daily basis, how inextricably connected human populations are to the land-water interface, and what changes in behavior (reduce, reuse, recycle, redesign, remove) they can make to prevent marine debris from entering the environment. Overall, the shoreline surveys provide a mechanism for educating citizens on the issues of marine debris, reducing and preventing the amount of marine debris in local habitats of importance through beach and salt marsh surveys, instilling the importance of stewardship, and collecting data for scientists that will provide a better understanding of marine debris accumulation in coastal and marine environments.

The following are testimonials from students that conducted marine debris surveys at a local salt marsh. When asked about first impressions of the marine debris survey experience, student responses included:

- "I never knew there would be so much litter in the salt marsh."
- "I was surprised at how much marine debris we collected in such a small area."
- "We found a lot of foamed plastic."

In the following activity, we have now begun to address the issue of micro plastics – the "unseen" pollutant discussed above. Not all teachers are able to take students "out into the field" to conduct marine debris shoreline surveys. In order to assist them, we have developed a classroom activity that is based on a field method developed by Dr. Richard Jahnke, in conjunction with the Port Townsend Marine Science Center. The classroom activity focuses on micro particles in coastal marine environments. This activity is designed to engage students in an investigation that explores the relative abundance and distribution of micro particles in marine environments through the use of a beach transect. Transecting is a useful, ecological tool designed to track changes spatially along a linear line. Students identify and count the number of micro particles in sand samples, graph their data and discuss results with their peers. They are able to quantify changes in abundance and types of micro particles along the transect and think about the impacts that micro particles may have on aquatic systems and the organisms living there. More importantly, the activity provides an opportunity for the students to share and exchange ideas on what changes in their daily behavior can prevent marine debris from entering the marine environment. Experiential learning has been shown to increase interest in science, technology, engineering and math (STEM) and we believe that this hands-on approach provides the ultimate tool for getting participants energized, excited, and engaged in what they are learning and how current environmental issues relate to their everyday lives.

The activity is detailed below. Interested educators are encouraged to think about how they might use this activity in their classroom. Other resources (introductory teaching/"powerpoint" presentation, sample data sheet) can be requested from the author. In addition, we hope that teachers who explore this activity will share their suggestions and modifications with us. The activity is focused to coincide with Georgia Performance Standards and Ocean Literacy Principles, but it should be straightforward to align the outcomes to the standards of other states.

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Instructional Objectives:

1.) Students will learn about marine debris and understand its types and sources and the impacts to aquatic systems and the organisms living there.
2.) Students will conduct a transect to estimate distribution and abundance of micro particles.
3.) Students will collect, analyze and showcase data.

Georgia Performance Standards:
SCSh2, SCSh3, SCSh4, SCSh5, SEC5, SEV4, SEV5, SO4, SO6, SZ5

Ocean Literacy Principles:
1) The Earth has one big ocean with many features: A,C
5) The ocean supports a great diversity of life and ecosystems: A
6) The ocean and humans are inextricably interconnected: D,G

Background Information:

Along with the important issues of sea level rise and ocean acidification, the accumulation of marine debris along beaches, and in estuaries and the open ocean, is recognized as a 21st century global challenge (http://www.stapgef.org/impacts-of-marine-debris-on-biodiversity-current-status-and-potential-solutions/). Man-made debris can affect human health and safety, the economy, and biota of the marine environment. Much of this debris consists of plastic, which can persist in the marine environment for long periods of time. Articles about oceanic 'garbage patches' have galvanized public interest in mitigating these anthropogenic impacts. Some of these mitigation efforts have involved volunteer beach cleanup efforts, which concentrate upon plastic and other waste contaminants easily picked up and removed. Marine debris clean up efforts result in thousands of kilograms of plastics removed per year. However, there is growing recognition that plastic debris breaks apart under physical and chemical degradation, that small (< 5 mm) plastic particles are ubiquitous in the coastal environment, and that these small particles can cause harm to marine organisms.

Micro plastics are defined as small particles that are 5 mm or less in size. There are primary and secondary sources of plastic micro particles. Primary sources of micro particles include industrial abrasives, micro beads in personal care products like exfoliants, cosmetics, and pre-production plastic beads or pellets or "nurdles". Secondary plastic micro particles are the results of degradation of plastic debris in the marine environment. The rate of plastic degradation in the marine environment depends upon a number of factors, such as chemical composition, size, molecular weight, additives, environmental conditions, temperature, wave action, exposure to sunlight, and location. There are several good, general references for further information, for example, (http://marinedebris.noaa.gov/).

Micro plastics in the marine environment are a detriment to organisms. Degrading plastics can leach toxic chemicals such as polychlorinated biphenyls (PCBs) and bisphenol A (BPA), thus serving as potential sources for chemical pollution in the marine environment. Micro plastics are often mistaken for food by marine life, are ingested and may impact organisms at higher trophic levels. The National Oceanic and Atmospheric Administration has also reported that plastic marine debris may concentrate other pollutants on the plastic surface and further harm marine organisms when ingested (http://marinedebris.noaa.gov/).

This activity is designed to engage students in an investigation that explores the relative abundance and distribution of micro particles in marine environments through the use of a transect. Transecting is a useful ecological tool designed to track changes spatially along a linear line. Students are able to quantify changes in abundance and types of micro particles, compare the sites along the transect and think about the impacts that micro particles may have on aquatic systems and the organisms living there. The program can be designed to take place in coastal environments like sandy beaches; however, this program activity is performed on a much smaller scale for the classroom; using pre-collected micro particles.

Setting the stage for micro particles investigations:

Prior to students conducting the micro particle activity, introduce the topic of marine debris. One possible mechanism is to use the Marine Debris and Micro Particles Powerpoint presentation available from the author; or you may develop your own introduction. Have students brainstorm a definition of marine debris. This may lead to a discussion of the types of marine debris encountered in coastal and oceanic systems (glass, metal rubber, plastic). Discuss land-based and ocean sources of marine debris. Where does marine debris come from? Responses for ocean-based sources may include fishing vessels, offshore oil and gas platforms, cargo ships, cruise ships and other vessels, sewage sludge, and sea-based aquaculture activities. Responses for land-based sources may include debris generated on land, littering, dumping, and poor waste management practices, storm water, extreme natural events like hurricanes, tsunamis, and floods, illegal dumping, and inadequately covered waste container vehicles.

Discuss the topic of micro particles, definition of micro plastics, their sources and their impacts on the marine environment.

Introduce transecting and the important role that it plays in scientific investigation. Describe how the students will be conducting a transect to collect micro particles along the length of the upper and intertidal section of the beach that extends from the wrack line (line of debris left by high tide) to the swash zone.

Teacher Preparation

Materials:

Sand box sand
10 hand sifters
1, 30 foot clothes line
2 laminated signs (wrack line and swash zone)
Laminated quadrat numbers (1-10)
10, Plastic gallon Ziploc bags (one for each quadrat)
2 sizes of plastic beads. Pick a variety of beads of different colors (blue, yellow, orange, black, white and red) in two different sizes to represent macro (larger) and micro particles. Note that the smaller beads need to be larger than the sifter mesh.
20 Paper plates to use as sorting trays (10 labeled macro and 10 micro)
50 small Dixie cups
String or cable ties (10) to attach quadrat numbers to clothes line
Identification sheet for macro and micro particles
Data sheet
10, 2 gallon buckets
10, 25 ml glass graduated cylinders
Marine Debris ppt presentation, and Excel spreadsheet.
http://marex.uga.edu/education_resources/

Teacher Set up Procedure:

1. Place laminated labels at opposite ends of a 30 foot clothes line to designate the wrack line (0 feet) and the swash zone (30 feet). Attach the laminated quadrat numbers to the clothes line with string or cable ties from the wrack line (0 feet) to the swash zone (30 feet). Place the clothes line on the floor to designate the transect along the beach.

2. Label 10 Ziploc bags "Quadrat", with numbers 1-10. Place play sand and beads to represent macro and micro particles for each quadrat (1-10) in the 10 Ziploc bags. The bags will represent the sample "collected" at a particular quadrat along the transect.

3. Place the 10 Ziploc bags along the transect extending from the wrack line to the swash zone.

Activity:

1. Divide students into groups of three. Each group of three students will select a quadrat number (1-10) as their sample. Provide each group of students with:

- the Ziploc bag that corresponds with their quadrat number that they selected
- hand sifter
- 2 gallon bucket
- 25 ml glass graduated cylinder
- 2 paper plates (1 labeled macro, >5mm and 1 labeled micro < 5mm)
- 5 small Dixie cups
- macro/micro particle identification sheet
- data sheet
- paper towel

Have students conduct the following:

2. Place the hand sifter over the 2 gallon bucket. Pour the sand with the beads from the Ziploc bag into the sifter. The sand goes through the sifter and the beads will remain in the sifter. Extract the macro and micro particles from the sifter and place on one paper plate.

3. Separate the sample of macro particles (larger beads) from the micro particles (smaller beads). Place the macro particles on the plate labeled macro and the micro particles on the plate labeled micro.

4. For each size class (macro and micro), separate the particles (beads) by color. Use the small Dixie cups for separating the micro particle beads (one cup for each color). Identify the type of particle using the macro/micro particle identification sheet.

5. Count each type of macro and micro particle and record the number on the data sheet.

6. To determine the weight of each type of **micro** particle in grams, fill the 25 ml graduated cylinder with 10 mls of water. Place the beads of one type of micro particle in the 25 ml graduated cylinder and record the change in volume (mls) on the data sheet. Once the volume has been recorded, place the sifter over the empty 2 gallon bucket. Pour the beads and water from the graduated cylinder into the sifter. Place beads on a paper towel to dry and repeat procedure for each type of micro particle (bead).

7. Once the volume (mls) of each type of micro particle has been determined and recorded, complete the calculations on the data sheet to estimate the weight (grams) of each type of micro particle. Density of each plastic type (g/cm^3) x Volume (mls) = Weight (g)

8. Enter data on the macro/micro particle excel data spreadsheet, create graphs for your quadrat and compare findings with other students.

9. You can reuse the beads over again, however, make sure to **dry beads thoroughly** before placing them in the Ziploc bags.

Data sheet:

Quadrat Number =	**Films**	**Fragments**	**Foams**	**Filaments**	**Cigarettes**	**Glass**
Number of macro particles (>5mm)						
Number of micro particles (<5 mm)						
Density of micro particles (g/cm^3)						
Change in volume of micro particles in graduated cylinder (mls)						
Weight (g) of micro particles Density (g/cm^3) x Volume (ml) = Weight (g)						

Wrap Up Discussion:

Using the graphs that the students created, discuss what types of items they encountered. Where were most of the items found along the transect? What was the most common item? What was the least common item? Why items might you expect to find on a beach with higher human impact and development than a less developed beach? Each teacher should give some thought to these questions before building the contents of the quadrat bags. For example, you may want to:

1. Distribute the micro particles along the transect based on density (place more beads that represent foamed plastics in the quadrat closest to the wrack line and hard plastics towards the swash zone).

2. Choose plastics that are more indicative of a developed barrier island (foams, glass, fragments and cigarette butts).

Extension Activity:

Have students research the location of a developed barrier island and an undeveloped barrier island using Google Earth. Have students think about how human activities and urbanization may impact the land on a developed beach. What are some examples of human impacts on a developed beach versus an undeveloped beach?

Have students look at surrounding watershed and landscape. Are there rivers? Tidal creeks? Are the beaches influenced by long-shore currents and tides? What is the closest populated area? Is there human development? What would be potential land-based sources of marine debris?

Based on density of the micro particle and where it might be in a column of ocean water, what types of organism are more likely to come into contact with that particle?