**Participatory Marine Debris: Using participatory GIS to prioritize the remove of Marine Debris on sensitive shorelines**

Ryan Ulsberger

University of Washington Tacoma

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**Abstract:** Following the extensive damage caused 2011 Tohoku Japanese tsunami, a large amount of rubble, fishing vessels, nets, and other anthropogenic material was washed out to sea as the waters subsided. As this debris entered ocean currents, marine debris became a major concern for natural resources scientist along the west coast of the United States. Marine debris can carry invasive species, and can impede navigation in high traffic vessel zones within harbors and ports. As a result, the ability to map where different debris accumulates is necessary for preventing invasive species and for ensuring safe navigation in our nation’s waterways. The National Oceanic and Atmospheric Association (NOAA) partnered with the University of Georgia to create the Marine Debris Tracker app. This app is used by volunteers who comb shoreline, and take inventory of different debris which they may find during rudimentary walks on the beach and/or other recreation activities. This project will explore the ability to harvest the marine debris observations from the Marine Debris Tracker app and assess different types of debris, and prioritize the removal of said debris based on the proximity to sensitive resources and navigable waters. By using arcpy imported from the ArcGIS suite, I will be able to run a proximity and concentration analysis of debris types to minimize further damage to sensitive habitat and navigation. Furthermore, this project will explore the reliability of volunteered geographic information and the shared local behavior and knowledge as it relates to sensitive resources and invasive species.

Following the extensive damage caused 2011 Tohoku Japanese tsunami and 2012 Super storm Sandy, a large amount of rubble, fishing vessels, nets, and other anthropogenic material was washed out to sea as the waters subsided. As this debris entered ocean currents, marine debris became a major concern for natural resources scientist along the coasts of the United States. Though debris is widespread throughout the ocean, an estimated only an estimated 15% is expected to wash onto shorelines (Katsanevakis, 59). Of this debris, there is a noticeable concentration on bays and other protected shorelines due to weaker currents and wave action (Katsanevakis, 59). However, this habitat is also essential for endangered migratory species. Stelios Katsanevakis explains in the article “Marine Debris, A Growing Problem: Sources, Distribution, Composition, and Impacts” that marine debris can affect wildlife in several ways including entanglement, ingestion, and damage to Coral Reefs and Coral Facies (Katsanevakis). Furthermore, the marine debris can often harbor invasive species and transport them to sensitive ecosystem where there is a lack of natural predators (cite). Due to the pervasive distribution of debris, shoreline assessments of aggregation points are often difficult and costly to identify. As a result, natural resource scientists have begun to explore the ability to use public participatory GIS (PPGIS) to collect the location of debris as it comes ashore. In doing so, natural resource scientist can examine patterns in distribution of marine debris to clean up sensitive shoreline. The National Oceanic and Atmospheric Administration (NOAA) Marine Debris Program has been a leader in developing in exploring the opportunities to use citizen science for tracking marine debris (NOAA, 2011). In May of 2011, the office announced that they had partnered with the University of Georgia in developing a mobile application called the Marine Debris Tracker Application (<http://www.marinedebris.engr.uga.edu/>) for volunteers who comb shoreline, and take inventory of different debris which they may find during rudimentary walks on the beach and/or other recreation activities. In doing so, ORR and the University of Georgia are able to collect a large amount of data with help from the public without investing in scientific beach surveys for harmful debris.

This project uses volunteered data to assess the aggradation points of marine debris as it comes ashore. Furthermore, using the Environmental Sensitivity Index, developed by the Office of Response and Restoration (ORR), an index was made to quantify the affects that debris may have on species that may be present at the point of grounding. The process was automated to increase the usability of the Marine Debris Tracker Application and to stimulate an effort of beach cleanups and attempt to mitigate the effects that marine debris has on sensitive ecosystems

**Why PPGIS?**

“Comprehensive databases of spatial and temporal information for large geographic ranges are essential for rapid assessments, testing scientific hypotheses, and validating predictive models” (Delaney 2007). However, these large datasets are costly, time consuming for scientific personnel who are often already strapped for time. Citizen science, as a result, is becoming a popular method to increase the information about large geographic observational science for simple observational science. Initiatives such as the National Audubon Society’s Christmas Bird Counts, are valuable both for the scientists, who gain both time and personnel without significant funding, and also for the public, who benefit from the various learning experiences and community development (Delaney 2007).

Furthermore, many of the concerns regarding citizen science can be mitigated with the incorporation of new technology. With the development of new wireless sensor networks, spatially distributed, autonomous or semi-autonomous sensors that monitor physical and/or environmental conditions, such as temperature, sound, vibration, pressure, motion, or pollutants are increasingly being used to for observational and quantitative science (Newman, 2012). Furthermore, mapping services enabled from mobile technology increase the rate and quality of data collection through locational services (Newman, 2012). PPGIS and citizen science is useful for marine debris because the observations of marine debris are easily obtainable without the oversight of trained personnel.

**The Marine Debris Tracker Application and Processing**

“Although the continued use of mobile and networked devices seems inevitable, managing the volumes of data they generate will require improved data management capabilities” (Newman, 2012). Currently the observations of Marine Debris Tracker Application are available from University of Georgia through its website <http://www.marinedebris.engr.uga.edu/data>. Any individual who wishes to use the data, can create a user account and download the data as a csv file. However, csvs are poorly managed for storing spatial datasets. As a result, this projects primary goal is to manipulate marine debris observations into a spatial dataset for analysis and visualization. Using a combination of python and the ERSI ArcGIS suite, a program was written to extract all attributes from the csv into a Feature Dataset within a Geodatabase. A geodatabase was chosen because of the ease updating and maintaining spatial information, and also because shapefiles are unable to store datetime fields with a time component. Furthermore, it was necessary to create a script that was easily run by any user. Two options were written into the script: first to create a database from the csv if the file does not exist within a file directory, or if the script has been ran already, new marine debris observations would be joined to existing database for easy file management. This tool was customized to run in the ArcGIS suite, with the only necessary actions from the user being to select the most recent csv that was downloaded from the University of Georgia *download date* website (<http://www.marinedebris.engr.uga.edu/data>).

As well, the script was also designed to be able to attribute shoreline sensitivity as an additional field for analysis. The shoreline data is a publically available dataset developed by the NOAA Office of Response and Restoration, categorizing the entire shoreline of the United States as a specific habitat. The data is available for download by State geographical extents from the ORR website, <http://response.restoration.noaa.gov/maps-and-spatial-data/download-esi-maps-and-gis-data.html>. However, to reduce the amount of processing by the user, this data was aggregated into a single shoreline feature. Though the Marine Debris Tracker Application has become increasingly popular as of late, and the spatial coverage of debris has increased dramatically including locations overseas and even for inland waterbodies such as the Great Lakes, ESI has only been developed for coastal waters of the United States. As a result only the location of points from shoreline within 50 ft. of shoreline characterized in the ESI index are used for this analysis.. A spatial join was then used to select the shoreline segment that was closest to any debris fell within 50 ft. of the national shoreline layers. The shoreline attribute was joined to each marine debris observation (see appendix 1).

Figure 1: Potential for Marine Debris to cause Damage to Shoreline and Animals

|  |  |
| --- | --- |
| **Score** | **Potential Damage to Shoreline/Animals** |
| 1-2 | Low |
| 3-4 | Medium |
| 5-6 | High |

At this point, we have an ArcGIS feature dataset with a shoreline characterization; the next step was to create an index was that ranks the impact any debris may have of the ecosystems and its inhabitants. Based on literature regarding the impacts of shoreline, the biggest risk that any debris may have was entanglement, followed closely by ability of debris being consumed (Sheavly, 2007). Furthermore, certain marine debris has the potential to carry invasive species or to also cause physical damage to shoreline features or sensitive species such as corals (Gregory, 2009). Deriving from this information, each item category of marine debris as reported by the Marine Debris Tracker application was assessed based on its impact on: 1) the possibility of consumption; 2) possibility for entanglement; 3) the possibility to cause extensive damage to shoreline and/or sensitive species (like corals); and 4) the possibility of carrying invasive species. Each items potential was based on the size of the generalization of the item as described by Viehman (2011) in her assessment in marshes in North Carolina. In this index, each possibility was assigned: 0 for now potential; 1 for low potential, and 2: for high potential (see appendix 2). However, fields with inaccurate/non descriptive terms were given a score of 0. Each category was summed to then identify which types of debris would likely cause the most damage to sensitive shoreline. The total values had a range from 1-6, with 6 having the highest potential for damage to ecosystem services, and 1 having the lowest potential. These scores were also categorized again into ranges of 2, having a low , medium and high potential of degrading ecosystem services (see figure 1). Values with a total score zero were eliminated from the classification since they did not have enough description to determine their potential damage to any shoreline or animals on shoreline.

**What Happened?**

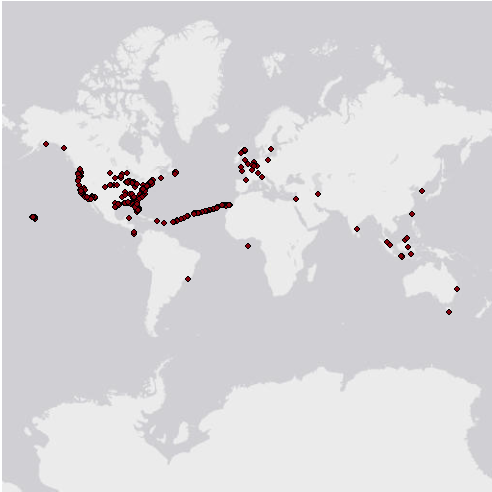
After writing and running the scripts on the data from the Marine Debris Tracker App, there were mixed results. Primarily, the main function of the script for exporting the csv into a useable geodatabase file work very well. However, for the first time creating the database, the script may take upwards of two hours if a full report of the data is exported into the feature dataset. Figure 2 shows the feature dataset viewed in ArcMap, exported on December 4, 2014; this map shows all 39,655 records from the Marine Debris Tracking Application. With the success, it seemed that any other analysis would be straight forward. Prior to running the analysis, as I mentioned before, I prepped the ESI national shoreline layer by merging all the State Shoreline Indexes into a single layer; however, upon the merge, the feature had over 400,000 individual segments of shoreline. Writing a script to select that marine debris within a 50 ft. distance of any shoreline resulted in maxing out of the memory on my personal computer for analysis. Furthermore, trying to modify my plan to reduce my footprint to either the Eastern Seaboard, and further to the state of Georgia resulted in the same error. As an additional measure, I tried exporting only a small handful of records by selecting Marine Debris by classification type; however, this resulted in a file, but the ESI index that I wrote would not have been as useful in that scenario.

Figure 2: Marine Debris recorded as of December 04, 2014

Unfortunately, I ran out of time for more analysis and other attempts to work around these issues. For future analysis, I may have to generalize my shoreline so that it is not as accurate as the National Shoreline or perhaps I only run analysis’ on State extents. It would be interesting to create a dictionary to export the records from the main Marine Debris geospatial database into each state.

Another possible and better use of the Environmental Sensitivity Shoreline data would be to track the migratory species that are in the areas where marine debris is located. In particular, the ESI shoreline is used to link a migratory species database in which it is determined what times of the month migratory species may be in that shoreline segment. This would be an additional way that could prioritize removal of debris, and may stimulate more removal efforts for state partners and the volunteers using the app for citizen science.

Furthermore, there were several other observations that are notable, the first being the formats in which data are written in the csv. Not having been on the development team for the Marine Debris Tracker Application, the csv had several unique characters which were difficult to work with while writing to exports the csv to a geospatial database. In the future, I would limit the characters from the Mobile Device User end so that only ascii characters could be entered in. As well, another noticeable trait in regards to the mobile app is the lack of description fields of marine debris. My hypothesis is that this is likely due to user fatigue, an observation that Greg Newman explored in his article “The future of citizen science: emerging technologies and shifting paradigms” (2012). Greg writes, “Participants are motivated by contributing to authentic scientific research, by the social interactions such participation affords” (Newman 2012, 301). Without seeing the use of the Marine Debris observations being used for scientific data, users entering observations on the beach lack the motivation to describe the feature accurately and in a detailed manner. Another solution to this problem would be to incorporate photos into the mobile app, so the user can refer back to the photo if need be to update descriptions of debris. Furthermore, from a data analyst perspective, photos would be a useful tool to qa/qc uncommon observations or descriptions.

**Recollection**

In retrospect, using citizen science for observations for marine debris provides both some benefits, but also has some severe limitations if not addressed appropriately. First, without the oversight of a natural resource scientist, citizen scientist can collect a large amount of data which is useful since it is both costly, and often ineffective to send shoreline survey teams to survey marine debris. However, in doing so, the quality of data may also regress as the input of data as it is observed is at the discretion of the user. More stringent data standards can be incorporated within the planning stages of mobile app design; but it is often catch every problem which may occur while an app is operational in the field. Newman also suggest that combing some interactive component to mobile technology and citizen science can also keep an user attention; for example, a leader board for user which have logged the most marine debris (Newman 2012).

Furthermore, the errors specifying that the computer had run out of memory need some more investigating. Regardless of how many files that are in a file, python should be able to perform the calculation. As well, it would be useful to be able to remove all user need to input data into the python script. To do this, I would explore web scraping, where I would access the data servers from the University of Georgia remotely, and call that data into the export script without downloading anything. However at this time I had not learned JavaScript, and it was outside of the feasibility of this project.

Regardless, the lessons learned from interacting with data gathered from citizen science programs have been invaluable. With constraints on academic and other corporate budgets, citizen science will continue to be a useful tool for scientist to collect data.

Appendix 2: Potential for Marine Debris to cause Damage to Shoreline and Animals

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Categorization | Possibility for being consumed | Possibility to carry invasive species | Possibility to damage coral reefs and other sensitive shoreline (physically) | Possibility for entanglement | Total |
| Lumber/Building Materials | 0 | 2 | 1 | 0 | 3 |
| Cigarettes | 2 | 0 | 0 | 0 | 2 |
| Plastic Bottle or Container Caps | 2 | 0 | 0 | 0 | 2 |
| Aerosol cans | 0 | 0 | 0 | 0 | 0 |
| Straws | 2 | 0 | 0 | 0 | 2 |
| Cigarette lighters/tobacco packaging | 2 | 0 | 0 | 0 | 2 |
| Plastic or Foam Fragments | 2 | 1 | 0 | 0 | 3 |
| Cigarette or tobacco packaging | 2 | 0 | 0 | 0 | 2 |
| Metal Bottle Caps | 2 | 0 | 0 | 0 | 2 |
| Plastic Food Wrappers | 2 | 0 | 0 | 0 | 2 |
| Food wrappers (paper) | 2 | 0 | 0 | 0 | 2 |
| Clothing and Shoes | 1 | 0 | 0 | 1 | 2 |
| Aluminum or tin cans | 1 | 0 | 0 | 0 | 1 |
| Other | 0 | 0 | 0 | 0 | 0 |
| Toys (plastic) | 1 | 1 | 1 | 0 | 3 |
| Plastic Bottle | 1 | 0 | 0 | 0 | 1 |
| Foam or Plastic Cups | 1 | 0 | 0 | 0 | 1 |
| Plastic Utensils | 1 | 0 | 0 | 0 | 1 |
| Fishing lures and lines | 2 | 0 | 1 | 2 | 5 |
| Paper and Cardboard | 1 | 0 | 0 | 0 | 1 |
| Glass Bottle | 0 | 0 | 0 | 0 | 0 |
| Plastic Bags | 1 | 0 | 0 | 0 | 1 |
| Styrofoam packaging | 2 | 0 | 0 | 0 | 2 |
| Balloons and/or string | 2 | 0 | 0 | 2 | 4 |
| Personal care products | 2 | 0 | 0 | 0 | 2 |
| Other Plastic Jugs or Containers | 0 | 2 | 0 | 0 | 2 |
| Tires | 0 | 2 | 1 | 0 | 3 |
| Plastic rope / Small Net Pieces | 1 | 1 | 1 | 2 | 5 |
| Paper Bags | 0 | 0 | 0 | 0 | 0 |
| Fabric pieces | 2 | 0 | 1 | 0 | 3 |
| Gloves (non-rubber) | 1 | 0 | 0 | 0 | 1 |
| Flip-flops | 1 | 0 | 0 | 0 | 1 |
| Rope or Net Pieces (non-nylon) | 2 | 0 | 1 | 2 | 5 |
| Six-pack rings | 2 | 0 | 0 | 2 | 4 |
| Buoys and floats | 0 | 2 | 1 | 1 | 4 |
| Fireworks | 2 | 0 | 0 | 0 | 2 |
| Chemicals and chemical containers | 1 | 0 | 0 | 0 | 1 |
| Paper Cups | 1 | 0 | 0 | 0 | 1 |
| Towels or rags | 1 | 0 | 0 | 1 | 2 |
| Rubber Gloves | 1 | 0 | 0 | 0 | 1 |
| Glass Jars | 0 | 0 | 0 | 0 | 0 |
| Non-food related plastic packaging | 2 | 0 | 0 | 0 | 2 |
| Batteries (acidic and alkaline) | 1 | 0 | 2 | 0 | 3 |
| Crab/Lobster/Fish trap parts | 0 | 2 | 2 | 2 | 6 |
| Pallets | 0 | 2 | 2 | 0 | 4 |
| Fishing nets | 0 | 2 | 2 | 2 | 6 |
| Test Item | 0 | 0 | 0 | 0 | 0 |
| Crab Trap in Need of Removal | 0 | 2 | 2 | 2 | 6 |
| Mammals | 0 | 0 | 0 | 0 | 0 |
| Sea Birds | 0 | 0 | 0 | 0 | 0 |
| Time | 0 | 0 | 0 | 0 | 0 |
| Visibility | 0 | 0 | 0 | 0 | 0 |
| Fish | 0 | 0 | 0 | 0 | 0 |
| Turtle | 0 | 0 | 0 | 0 | 0 |
| Marine Debris | 1 | 0 | 0 | 0 | 1 |
| Sargassum Clump | 0 | 0 | 0 | 0 | 0 |
| Sargassum Fragment | 0 | 0 | 0 | 0 | 0 |
| Sargassum Windrow | 0 | 0 | 0 | 0 | 0 |
| Your Inititals | 0 | 0 | 0 | 0 | 0 |
| Wind Direction | 0 | 0 | 0 | 0 | 0 |
| Ship Heading | 0 | 0 | 0 | 0 | 0 |
| Ship Speed | 0 | 0 | 0 | 0 | 0 |
| Wind Speed | 0 | 0 | 0 | 0 | 0 |
| Unknown number of Microplastic Pieces | 2 | 0 | 0 | 0 | 2 |
| Less than 100 Microplastic Pieces | 2 | 0 | 0 | 0 | 2 |
| 200,000 or more Microplastic Pieces | 2 | 0 | 0 | 0 | 2 |
| Start Microplastic Sampling | 0 | 0 | 0 | 0 | 0 |
| Microplastic Sampling Track | 0 | 0 | 0 | 0 | 0 |
| End of Micoplastic Sampling | 0 | 0 | 0 | 0 | 0 |
| Beverage Bottles (Plastic) | 1 | 0 | 0 | 0 | 1 |
| Beverage Bottles (Glass) | 1 | 0 | 0 | 0 | 1 |
| Cups & Plastes (Paper) | 1 | 0 | 0 | 0 | 1 |
| Food Wrappers | 2 | 0 | 0 | 0 | 2 |
| Grocery Bags (Plastic) | 1 | 0 | 0 | 1 | 2 |
| Other Plastic Bags | 1 | 0 | 0 | 1 | 2 |
| Bottle Caps (plastic) | 2 | 0 | 0 | 0 | 2 |
| Cigarrette Butts | 2 | 0 | 0 | 0 | 2 |
| Take Out/Away Containers (Plastic) | 2 | 0 | 0 | 1 | 3 |
| Beverage Cans | 1 | 0 | 0 | 0 | 1 |
| Straws/Stirrers | 2 | 0 | 0 | 0 | 2 |
| Plastic Pieces | 2 | 0 | 0 | 0 | 2 |
| Rope | 1 | 1 | 1 | 2 | 5 |

Appendix 1: Shoreline Sensitivity Index

|  |  |  |  |
| --- | --- | --- | --- |
| **ESI Rank** | **Estuarine** | **Lacustrine** | **Riverine** |
| 1A | Exposed rocky shores | Exposed rocky shores | Exposed rocky banks |
| 1B | Exposed, solid man-made structures | Exposed, solid man-made structures | Exposed, solid man-made structures |
| 1C | Exposed rocky cliffs with boulder talus base | Exposed rocky cliffs with boulder talus base | Exposed rocky cliffs with boulder talus base |
| 2A | Exposed wave-cut platforms in bedrock, mud, or clay | Shelving bedrock shores | Rocky shoals, bedrock ledges |
| 2B | Exposed scarps and steep slopes in clay | http://response.restoration.noaa.gov/sites/default/files/spacer.gif | http://response.restoration.noaa.gov/sites/default/files/spacer.gif |
| 3A | Fine to medium-grained sand beaches | http://response.restoration.noaa.gov/sites/default/files/spacer.gif | http://response.restoration.noaa.gov/sites/default/files/spacer.gif |
| 3B | Scarps and steep slopes in sand | Eroding scarps in unconsolidated sediment | Exposed, eroding banks in unconsolidated sediments |
| 3C | Tundra cliffs | http://response.restoration.noaa.gov/sites/default/files/spacer.gif | http://response.restoration.noaa.gov/sites/default/files/spacer.gif |
| 4 | Coarse-grained sand beaches | Sand beaches | Sandy bars and gently sloping banks |
| 5 | Mixed sand and gravel beaches | Mixed sand and gravel beaches | Mixed sand and gravel bars and gently sloping banks |
| 6A | Gravel beaches | Gravel beaches | Gravel bars and gently sloping banks |
|  |
| Gravel beaches (granules and pebbles)\* |
| 6B | Riprap | Riprap | Riprap |
|  |
| Gravel beaches (cobbles and boulders)\* |
| 6C\* | Riprap | http://response.restoration.noaa.gov/sites/default/files/spacer.gif | http://response.restoration.noaa.gov/sites/default/files/spacer.gif |
| 7 | Exposed tidal flats | Exposed tidal flats | http://response.restoration.noaa.gov/sites/default/files/spacer.gif |
| 8A | Sheltered scarps in bedrock, mud, or clay | Sheltered scarps in bedrock, mud, or clay | http://response.restoration.noaa.gov/sites/default/files/spacer.gif   |  | | --- | |  | | |
|  |
| Sheltered rocky shores (impermeable)\* |
| 8B | Sheltered, solid man-made structures | Sheltered, solid man-made structures | Sheltered, solid man-made structures |
|  |
| Sheltered rocky shores (permeable)\* |
| 8C | Sheltered riprap | Sheltered riprap | Sheltered riprap |
| 8D | Sheltered rocky rubble shores | http://response.restoration.noaa.gov/sites/default/files/spacer.gif | http://response.restoration.noaa.gov/sites/default/files/spacer.gif |
| 8E | Peat shorelines | http://response.restoration.noaa.gov/sites/default/files/spacer.gif | http://response.restoration.noaa.gov/sites/default/files/spacer.gif |
| 8F | http://response.restoration.noaa.gov/sites/default/files/spacer.gif | http://response.restoration.noaa.gov/sites/default/files/spacer.gif | Vegetated, steeply-sloping bluffs |
| 9A | Sheltered tidal flats | Sheltered sand/mud flats | http://response.restoration.noaa.gov/sites/default/files/spacer.gif |
| 9B | Vegetated low banks | Vegetated low banks | Vegetated low banks |
| 9 | Hypersaline tidal flats | http://response.restoration.noaa.gov/sites/default/files/spacer.gif | http://response.restoration.noaa.gov/sites/default/files/spacer.gif |
| 10A | Salt- and brackish-water marshes | http://response.restoration.noaa.gov/sites/default/files/spacer.gif | http://response.restoration.noaa.gov/sites/default/files/spacer.gif |
| 10B | Freshwater marshes | Freshwater marshes | Freshwater marshes |
| 10C | Swamps | Swamps | Swamps |
| 10D | Scrub-shrub wetlands; Mangroves\*\* | Scrub-shrub wetlands | Scrub-shrub wetlands |
| 10E | Inundated low-lying tundra | http://response.restoration.noaa.gov/sites/default/files/spacer.gif |  |

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