Applications of GIS and Remote Sensing involving Marine Debris

Plastics are a significant component of our anthropogenic impact on the environment, especially in our global oceans. Plastic marine debris leads to a variety of negative environmental issues. These include animal mortality through ingestion and entanglement, infrastructure damage and clogged pipes, leeching of harmful microplastics and chemicals due to photodegradation, and human health threats (Sheavly and Register 2007). Since the 1960s the global production of plastic has dramatically increased. In 1960, 0.5 million tons of plastic per year was produced compared to the 280 million tons/yr in 2012. Almost 10% of this annual production of plastics ends up in the ocean (Avio et al. 2015). In 2010, 275 million metric tons of plastic waste was generated by 192 counties. Of that, 4.8 to 12.7 million metric tons entered the ocean (Jembeck et al. 2015).

Marine debris is defined as any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment (Gall and Thompson 2015). Marine debris is one of the major threats to biodiversity, affecting 17% of species on the IUCN Red List listed as threatened or above (Gall and Thompson 2015). The U.S Marine Mammal Commission reported that 136 marine species have been involved in entanglement incidents. Entanglement in nets, fishing lines, ropes, and ingestion of plastics are the more noticeable damaging effects of marine debris.

Derelict fishing gear is either intentionally discarded or lost due to storms or fishing activity in the ocean (Martens and Huntington 2012). This gear accumulates in nursery zones, shallow coral reefs, and benthic habitats (Boland and Donohue 2003; Dameron et al. 2007; Martens and Huntington 2012). Once accumulated in these areas, they have shown to have severe negative effects on the environment and animals. Derelict nets can cause engagement in fish, birds, sea turtles, and marine mammals (Veenstra and Churnside 2010), while derelict lobster traps continue to catch fish and crustaceans (Martens and Huntington 2012). This not only depletes marine organisms, but also has negative economic impacts on fisherman due to loss of gear and profit from the animals that have been caught but not sold on the market. There is a great need to remove this gear from the ocean before more harm is done. A substantial amount of studies set out to find a more efficient way of locating this gear to effectively remove it from the environment (Boland and Donohue 2003; Dameron et al. 2007; Martens and Huntington 2012; Veenstra and Churnside 2010).

In order to obtain a more effective way to locate and remove plastic debris and derelict fishing gear in the open ocean, GIS methods and remote sensing have been used. GIS methods include overlay procedures, grid cell math, interpolation (inverse distance weighting (IDW)) and map algebra. Boland and Donohue used overlay procedures in order to compare initial transects of derelict fishing gear in Northwestern Hawaii to the transects done a year later in order to define the area resurveyed. In a different study, the overlay procedure was also used to find areas over overlap, however they then created a geographic grid with 30x30 meter cells in order to calculate the debris density per grid (Dameron et al. 2007). Spatial analysis tools have been used to determine where hot spots of debris are located. Creating hot spots will aid in the removal of debris from the environment. Hot spots were created by collecting spatially-explicit points of debris and importing them into ArcGIS 9.3. Bathymetric raster was then created by using data points and interpolating them using IDW. A polygon benthic habitat map was then rasterized to use it for map algebra, which was done by combining the benthic habitat and bathymetric rasters into a single layer, to incorporate habitat type and depth that correlated with the amount of debris removed. This study showed that using GIS analysis to generate hot spot maps is helpful tool to locate and remove derelict fishing gear (Martens and Huntington 2012).
Although GIS is a helpful tool for creating study area maps and hot spot maps, a larger method is needed to assess the world’s oceans. Currently, most data pertaining to marine debris is based off survey collection. Not much is known about the locations and types of debris that is spanning our world’s oceans. It is known however, that debris accumulates along water parcel boundaries or eddy lines (Dameron et al. 2007; Mace 2012). This knowledge aids in where to start looking for debris in the ocean, but still leaves a large surface area to cover. Remote sensing is a useful tool in order to cover an expansive amount of area at one time in the open ocean (Veenstra and Churnside 2010).

Marine debris is always in motion, due to weather conditions and currents, therefore from the time of the sensor to the removal of debris needs to be within a couple hours. This limits the types of sensors that can be used. For example, MODIS instruments would be most ideal since they provide two-daily views of most of the earth. RADAR systems such as the along-track Interferometric Satellite Radar (InSAR) is optimal for surface currents and can be useful to find convergence zones where marine debris may be found (Mace 2012). Currently, not many passive sensors can be used to detect marine debris. RBG video is only usable during the day and has a large false detection rate from surface characteristics, clouds and breaking waves. Infrared cameras capture images of heat radiated, however the ocean is not transparent at the wavelengths detected and therefore it only works for surface debris. Hyperspectral sensors are usually only used for terrestrial purposes and may be used for shallow waters, but it is not as useful in open ocean. Multispectral sensors, like SeaWiFS, is often used in monitoring phytoplankton and thus can be used for marine debris. However, little information exists on the spectral content of marine debris, which is needed for effective use of this sensor. Active sensors such as LIDAR and RADAR can also be used, but LIDAR hasn’t been explored enough with debris and RADAR is problematic due to a low radar return from the debris (Veenstra and Churnside 2010).

Remote sensing is a tool that can be used to detect marine debris in the future. Most authors suggest a suite of sensors in order to detect debris, however this is costly and not yet explored (Veenstra and Churnside 2010; Mace 2012). There is considerable room for growth and improvement to be able to effectively use remote sensing to locate marine debris in the open ocean. GIS is a helpful tool to map survey data of debris but this is small scale meaning there is work to be done in regards to large scale area mapping and remote sensing.

Annotated Bibliography


This study focused on how marine debris is effecting the endangered monk seal, Monachus Schauinslandi in Northwestern Hawaii. Marine debris is accumulating in reefs that are home to seal pup nurseries, causing injury and death due to entanglement. Therefore, this study set out to find high entanglement risk zones (HERZ) in order to determine where large amounts of debris occur to remove it from the marine environment in a more efficient manner. Data was collected by divers being dragged behind boats along transect lines in 1999. The debris found was removed and then the transects were resurveyed in 2000-2001. The transects were logged using GPS (Garmin 12, Garmin International) and downloaded into GIS software (ARCVIEW, ESRI Inc.) daily. The two transects were then overlaid to define the area resurveyed. The HERZ zones, areas with a high amount of debris, were then identified to be areas with shallow bathymetry.

Derelict fishing gear, lost or abandoned fishing gear, is accumulating in shallow coral reefs in the Northwestern Hawaiian Islands (NWHI). This study conducted two surveys in 2006, Manta tow surveys and non-linear swim surveys, to gather accumulation rate data. The survey areas were mapped using a GIS overlay procedure to identify areas of overlap. The geographic grid contained 30x30 m cells which were used to calculate debris densities per area, normalized to account for survey coverage. Accumulation was dependent on bathymetry and benthic habitat, which was obtained from 4-m resolution IKONOS satellite imagery and LIDAR depths, and energy regime, determined from dominate coral species found in different wave stress environments. Based on the grid cells, mean accumulation density in lagoonal areas of shallow reefs is 2.5 times greater than backreef areas.


This article was a general overview of the different techniques that can be used to detect marine debris in the ocean environment. Marine debris in the open ocean is hard to quantify because it is partially submerged, making it difficult to see. Debris usually accumulates around water parcel boundaries or eddy lines, creating a specific area to search for debris. Direct measures, searching for debris in a vessel, can be used. Indirect measures can also be used by using a model of behavior of debris. First, observations over large areas should be looked at to determine regional concerns. Next higher resolution should be used and finally, if densities are known, the amount of material can be calculated. Remote sensing can be used to detect this plastic debris, since plastics are likely to have significant features in the 0.4-2.8 μm range. However, reflected infrared energy only penetrates the water a few millimeters, placing the range from 0.4-0.7 μm, which is smaller than the range for plastics. From time to detection to removal also needs to be within a few hours due to the unpredictable movements of the ocean, which limits sensors and platforms to MODIS (twice daily). The sensors must be multi-spectral and RADAR is additionally needed. Therefore, this paper suggests a multistage modeling approach, using a model, satellite radar, and multispectral data to focus on eddies and convergent zones to efficiently find marine debris in the open ocean.


This article analyzed 5 years of lobster trap removal data in Biscayne National Park, Florida. Lobster traps left in the ocean are known as derelict fishing gear. If traps are not recovered they can remain fully functional, catching fish and crustaceans for extensive amounts of time. This study created a hot spot map of high densities of lobster traps, in order to effectively remove gear to prevent ghost fishing. Scuba divers were used to search for debris and a benthic habitat map along with bathymetric data from NOAA Office of Coast Survey was used as other sources of data. The debris collection points were spatially-explicit points that were imputed into ESRI, ArcGIS 9.3. The bathymetric raster was created by interpolating 3667 data points using inverse distance weighing. The benthic habitat map was a polygon shapefile rasterized to be used for map algebra. Map algebra was used to classify the rasters into a single later to correlated habitat type, depth and debris removed. A hot spot layer map was created from the GIS analysis, showing the high probability zones for lobster traps in order to remove them more efficiently.

In order to detect marine debris in the Northeast Indiana Ocean, Ryan used a size and distance-based technique to assess the distribution, abundance and composition of floating debris. There is minimal data on floating plastic debris at sea due to the hard accessibility of the open ocean. Most data collected are from sea surveys, but this technique is costly, only covers small areas, and creates patchy data. Aerial surveys sample large areas in a timely manner, however they do not provide information on types of litter. Finally, remote sensing can be useful, but most studies are in their infancy and are unlikely to get information on litter composition. Due to these factors, Ryan counted the amount of debris by naked eye on a research cruise in the Straits of Malacca and Bay of Bengal. He found a larger density in the Strait, correlating this with its closer proximity to land based sources of marine debris.


This article provides an overview of the types of airborne sensors that can be used to detect marine debris at sea, specifically derelict fishing gear. Passive remote sensors, using energy reflected or emitted from objects, is most commonly used. RGB (red, green, blue) video is only usable during the day and there is a tradeoff between spatial coverage and resolution. It is a low cost, but there is a large false detection rate from lighting and surface characteristics. Digital camera has high resolution but is problematic with the dynamic ocean. Infrared cameras capture the heat radiated where the atmosphere is transparent, but the ocean is not transparent at the possible wavelength’s and only works for surface debris. Hyperspectral has a resolution of 10nm or less, but is normally only used in shallow waters. Multispectral can be used to detect debris, however there is little information on the spectral content of marine debris. Active sensors, LIDAR and RADAR can also be used. Debris does not produce a large enough RADAR return, therefore LIDAR should be used, however it is not been used widely with marine debris. The authors recommend many sensors, with a filtered multispectral camera and LIDAR being the best combination to sense marine debris in the ocean.


This study combined plastic surface data from the western North Atlantic Ocean and Caribbean Sea from 1986-2008. The authors analyzed 22 years of ship survey data from plankton net tows obtained from Sea Education Association (SEA). The largest amount of plastic debris was in the subtropical latitudes and associated with convergence zones from surface currents. 62% of all the net tows contained plastic debris, which most likely originated from the sub-tropical western North Atlantic where the currents can retain it. A map was made of the collection points to show the density of plastics sampled. An average plastic concentration was computed by creating bins and smoothing them with a Gaussian filter. A black contour of the 10 year mean surface circulation was also calculated from drifters, satellite altimetry, hydrographic profiles, and reanalysis winds. It is estimated from this map that the total amount of plastic in the domain was 1100 metric tons.

OTHER SOURCES USED:

Avio, Carlo Giacomo, Stefania Gorbi, Massimo Milan, et al. 2015. Pollutants
Bioavailability and Toxicological Risk from Microplastics to Marine Mussels. Environmental Pollution 198: 211–222.

