If you can't see it does it still exist? Marine Debris in the Deep Sea

Meredith Ann Epp
Capstone Report April 28, 2014
Masters of Advanced Studies
Center for Marine Biodiversity and Conservation
Scripps Institution of Oceanography
University of California San Diego

Advisory Committee:
Kathryn Mengerink, *Scripps Institution of Oceanography, Environmental Law Institute* (Chair)
Lisa Levin, *Scripps Institution of Oceanography, Deep Ocean Stewardship Initiative*
Nicholas Mallos, *The Ocean Conservancy*

TABLE OF CONTENTS

ABSTRACT

The United Nations Environmental Programme (UNEP) estimates that 6.4 million tons of waste enter our oceans every year, with rubbish entering the oceans from both land- and ocean-based sources (Ramierez Llorda, 2013). Evidence of anthropogenic debris or "marine litter" has been found throughout the world in areas of the deep sea, classified here as >200 meters. (Ramierez Llorda, 2013, Bergmann, 2012; Keller et al., 2010; Miyake et. al., 2011; Ramirez-Llodra, et al., 2011; Schlining, et al. 2013, Pham, et al. 2013.) While some papers have been published on specific regions, debris data are typically a secondary priority on ships and when debris is observed during deep sea sampling this information goes unrecorded. In an effort to "crowdsource" data, or gather opportunistic data, on the type and location of debris in this area, I, in partnership with Arda Varilshua, have developed an iPhone application, Deep Sea Debris. This app allows users to photograph, describe and upload pictures to a network and map to visually display the types and distribution of debris. The Deep Sea Debris app can be used to share information to help create a better picture of human impacts in the deep sea.

EXECUTIVE SUMMARY

The United Nations Environment Programme (UNEP) defines marine litter (or debris as referred to in this document) as "any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment." Additionally the UNEP estimates that 6.4 million tons of litter enters our oceans every year, with rubbish entering the oceans from both land and ocean based sources (Ramirez-Llodra, 2013). While many research studies have been conducted on surface and coastal marine debris, far fewer studies have examined marine debris in the deep sea. The deep sea is defined as 200 meters and below the surface or beyond the shelf break and comprises over half the planet (Mengerink et. al., 2014). Studies have found plastics make up 60-80% of total marine litter, with other common types including glass, metal and fishing gear (Ramirez-Llodra, 2013). As the world population grows, so too does global plastics consumption. In 1950 the global production of plastics was 1.5 tons per year; today it is estimated to be over 250 tons per year with an annual production increase of 10% (Ramirez-Llodra, 2013). If current production trends continue, the total amount of global plastic production will reach 33 billion tonnes by 2050 (Rochman et. al., 2013).

The seafloor is home to some of the richest biodiversity on earth as well as valuable biological and mineral resources (Ramirez-Llodra, 2013). This knowledge should serve as an incentive to protect the deep seafloor. Studies have examined the distribution of marine debris in the deep, yet like any work conducted in the deep sea, research costs are incredibly high and more difficult to administer than coastal marine debris studies, which can rely on volunteers and non-profit organizations for support. Despite existing knowledge of the deep, much is still unknown. Further research is required about the biological effects of debris in deep sea habitats.

In an effort to help engage researchers and others operating in the deep ocean, this project develops a mobile phone application as well as online network to build a centralized, information database of marine debris in the deep sea. This paper provides an overview of biological and environmental impacts of marine debris, the unique characteristics of the deep sea, an outline of the network proposal, outreach plan and future recommendations. Additionally, this report will address the development of a mobile phone application and web portal designed to support the collection of deep sea marine debris data.

RESEARCH QUESTION

"Is there a way to get a better picture of anthropogenic debris in the deep sea?"

This project takes an interdisciplinary approach to solving the research question, by utilizing mobile phone technology to better facilitate scientific data collection. Establishing an easily accessible, free application researchers from around the world can store and share valuable data as well as visually compelling images. To better understand the specific requirements of the application this document will address the impacts of marine debris, the unique features of the deep sea and the development process for the application.

IMPACTS FROM MARINE DEBRIS

As discussed in this section, anthropogenic debris, especially plastic debris, can have many negative impacts once it enters the ocean including animal ingestion, entanglement, the transport of invasive species as well as habitat destruction.

Ingestion

Studies have shown that all six species of sea turtle listed on the IUCN Red List ingest debris (Schuyler et al. 2012). Sea turtles ingest white colored marine debris as well as floating polyurethane bags, mistaking the floating plastic objects for food. Studies have found sea birds ingest debris, mistaking the plastic particles for prey, often only eating certain colors and shape (Derraik, 2002). One study off the coast of North Carolina found of 1,033 birds tested, 55% of the birds had recorded plastic particles in their guts (Moser and Lee, 1992). Health effects on birds from ingested plastic included reduced stomach size, resulting in decreased feeding as well as limits on the production of fat deposits, reducing fitness of the birds, thus impacting migration abilities (Derraik, 2002).

Larger marine animals have also felt the effects of plastics through ingestion, including 26 species of cetaceans ranging from endangered manatees to killer whales. The necropsy of one young male pygmy sperm whale revealed the stomach contents were completely full of plastic debris, including a garbage can liner, chip bag, and two pieces of plastic sheeting (Tarpley and Marwitz, 1993).

Entanglement

Entanglement in debris is a concern for larger marine species, especially for pinnipeds and cetaceans with fishing gear being the main source of entanglement.

Invasive Species

As defined by the Invasive Species Advisory Committee, an invasive species is "an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health" (ISAC, 2006.) Invasive species can have negative effects on ecosystems, particularly when these species overtake local organisms and alter ecosystems. As plastic particles enter the global currents system they create transport mechanisms for encrusting organisms such as bacteria, diatoms, algae, barnacles, hydroids and tunicates (Derraik, 2002). One example thought to have originated in the Caribbean is a species of bryozoan, which has been found in the Tasman Sea, travelling from Australia to New Zealand while encrusted on plastic pellets (Gregory, 1978). The same species has also been found on beaches on Florida, USA, leading investigators to believe they are increasing abundance by drifting on plastic.

MARINE DEBRIS IN THE DEEP SEA

For marine debris in the deep sea, below 200 meters in depth, means that any floating debris, such as buoyant plastics require some method of transport to make it to the deep sea. In the case of buoyant plastics, some researchers have noted that certain species of barnacles attach to floating pieces of plastics, and with this additional weight these plastics sink to the sea floor (Goldstein, 2013). For other types of debris such as glass or metal the weight of the item brings it to the bottom of the sea more quickly.

Most lightweight plastic debris is found within deep sea canyons, likely brought in through river runoff. Heavier and larger items such as oil drums, chairs and large pieces of industrial fabric are found away from the coast often under shipping channels. Plastics are more common at submarine canyons and closer to coastal areas especially near cities or communities with high populations (Ramirez-Llodra, 2013). It is thought that weather patterns as well as tourists seasons may play a part in the distribution of debris throughout coastal areas.

Biological Implications

Due to the relatively stable conditions in the deep sea the degradation of marine debris, especially plastics is presumed to be longer than in shallower coastal areas (Ramirez-Llodra, 2013). Low temperatures, limited sun irradiation and relatively consistent physical conditions allows for marine debris to settle in the deep sea and remain relatively intact. This long persistence can be problematic for deep sea species with certain types of debris such as nets that can continue "ghost fishing" and trapping animals.

Plastics can cause serious biological problems in the deep including suffocation and starvation to animals (Ramirez-Llodra, 2013). As plastics slowly break down in the sediment an anoxic environment is created causing harm to many benthic species. Also, bottom feeder species may ingest microplastics; however, the biological implications are unknown. Recent studies have indicated that plastics may act as carriers for toxic pollutants which can bio accumulate up the marine trophic levels, which could be a potential concern for deep-sea fisheries (Rochman, 2013).

Larger items of marine debris have been discovered in the deep such as toilets, oil drums, chairs, shoes, and even a container from a F15 airplane survival raft was pulled up in one Mediterranean trawl (Ramirez-Llodra, 2013). Sunken ships and oil rigs can create additional habitats for deep sea species. Members of the oil and gas industry as well as conservationists are still debating the biological ramifications of programs like "Rigs to Reefs" programs where old oil rigs are sunk and turned into artificial reef habitats (Macreadie, 2011). In the case of marine debris, some may argue additional habitat structures are beneficial, however it is difficult to determine for each situation.

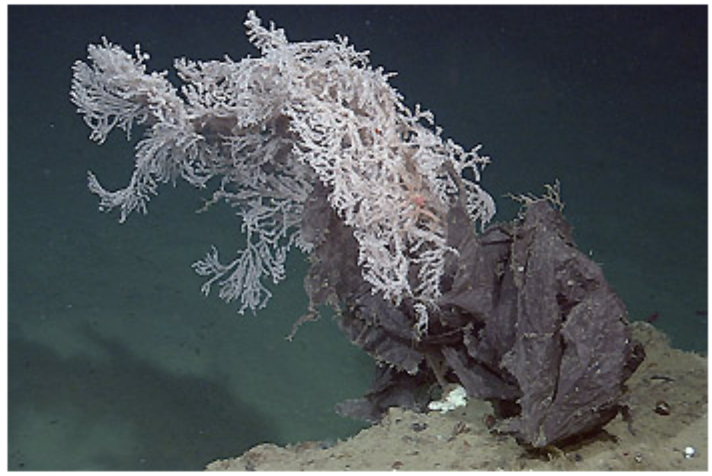
Removal

The removal of debris in the deep sea may not always be advisable or even feasible. Just as in the case of large oil rigs, removal costs and disruption to the environment may be greater than allowing items to remain in place. In some cases debris will already be acting as part of a new ecosystem and removal will only disrupt the settled species. What should be considered especially with ROV studies is to investigate how marine species are interacting with the debris and what implications these interactions might have.

Additional topics for further research regarding deep sea debris includes the provision of habitat, debris as a food source for microbes, or debris as a stepping stone for connectivity of certain species.

Monitoring Methods

Trawling



Deep-sea currents wrapped this plastic bag around a deep-sea gorgonian coral 2,115 meters (almost 7,000 feet) below the ocean surface in Astoria Canyon, off the Coast of Oregon. Image: ©2006 MBARI

Trawling is a traditional method for deep sea research on ground-fish populations, which often has the incidental effect of collecting marine debris. By deploying nets along the seafloor researchers can collect samples and obtain an understanding of the demersal and benthic species. However, trawling can have substantial negative impacts, such as habitat destruction and possibilities of by-catch even on short research cruises (Jones, 1992). Trawls may be difficult to use for research in areas with complex topography, where the risk of damage or loss of the trawl is a possibility. A benefit of the use of a trawl when researching marine debris is that the debris is actually removed from the seafloor, which is seen as a positive in most cases as mentioned above. It also allows for researchers to examine debris particles for signs of colonizing species and to collect samples for research projects (Spengler, 2008).

Remote Operated Vehicle (ROV)

A young rockfish hides out in a discarded shoe, 472 meters (1,548 feet) deep in San Gabriel Canyon, off Southern California. Image: ©2010 MBARI

Another research approach is the use of a remotely operated vechicle (ROV), which is less destructive to deep sea habitats and allows for *in situ* observations of abundance. However, ROVs are expensive to purchase and operate and can be easily damaged. Kyra Schlining, the head researcher from a team out of MBARI recently published a paper documenting marine debris in the deep sea by analyzing over 22 years of ROV video footage. Some images from the study included a young rockfish inside a discarded shoe, an anemone on a car tire, and plastic bags wrapped around deep-sea corals (Schlining, 2013).

APPLICATION DEVELOPMENT

Crowdsourcing mobile phone applications such as Creek Watch by IBM ask users to upload photos of creeks and streams to help monitor watershed flow and pollution. App users are already in the location and contribute to a greater dataset. This mindset of opportunistic data gathering and sampling was the starting point for the development of the Deep Sea Debris app.

In an effort to fill these gaps and create a broader awareness of deep-sea debris, the goal of this project was to create a visual database where information about human impacts in the deepest parts of the ocean, at least 200 meters or deeper, can be easily viewed, mapped, and evaluated. Ninety percent of American adults have a cell phone (Pew, 2014) and a majority of photos taken are now via mobile devices, with some of the highest number of photos coming from iPhones 4, 4S and 5 (USA Today, 2013). The convenience of mobile phones and the ever expanding uses of these devices allows for an opportunity for new technology to increase scientific knowledge. This holds especially true for oceanographic science in the deepest, largest, most remote and complex ecosystem in on our planet.

Desired Capabilities:

The idea for a deep sea debris app came from a student cruise for the Scripps Institution of Oceanography (SIO) 296: Deep Sea Policy course where the class conducted short trawls at 900m bottom depth. After deploying an otter trawl, the load on the winch was stressed and the retrieving the net indicated that the net was caught on something or potentially buried in the mud. The net was recovered intact, full of mud, fauna and debris. One of the items of debris collected included a long, grey cylinder. While there was some concern that the cylinder was an unexploded ordinance, fortunately, the cylinder turned out to be a large flare. This experience sparked a conversation and ideas between the crew of the vessel, students and professors.

From this experience the following questions were identified:

1. How much human debris is at the bottom of the sea?
2. How is the debris distributed?
3. How does debris interact with the deep-sea environments?
4. What should be done with debris once it is recovered?
5. What does this mean for industry in the deep sea?
6. Should new pollution laws be enacted to protect the deep sea?

Goals of the network:

Figure 1:

Table 1 displays the initial goals and capabilities identified as necessary to create a useful and successful app.

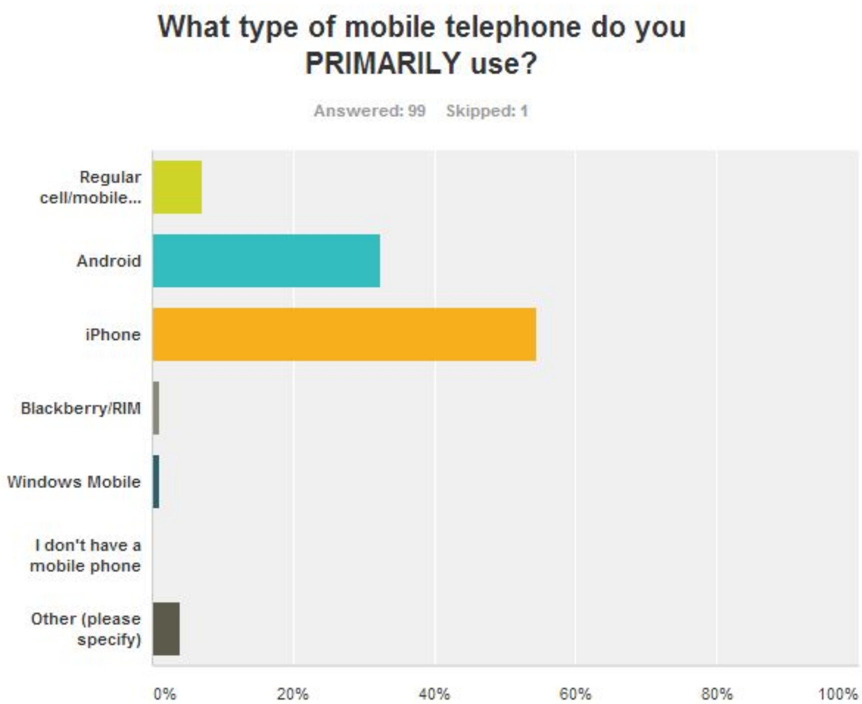
Figure 1
- Establish an easy to use platform for inputting data
○ Type of debris ○ Location of debris ○ Date, time, depth ○ Geomorphic habitat ○ Up loadable picture ○ Any relation to species (encrusted, larvae, entanglement)
- Make data open access
- Educate communities on value of deep sea

Market research

To effectively interact with the target user groups of the app, I conducted a survey via the Scripps Students listserv asking graduate students about cell phone use. Results showed that iPhones are the most common type of phone with 54% of participants using these. Android phones were the second most common with 32% of the group. Due to time and budget constraints, the initial stage of this project only developed an iPhone application; however, an Android compatible device is recommended for the future (Figure 2).

Figure 2:

Survey results from email survey of Scripps Institution of Oceanography students.



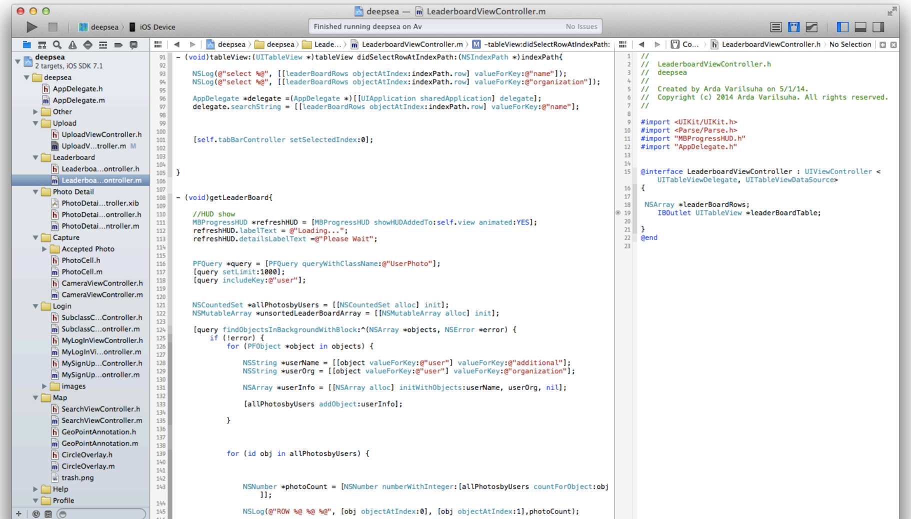
Planning and Execution:

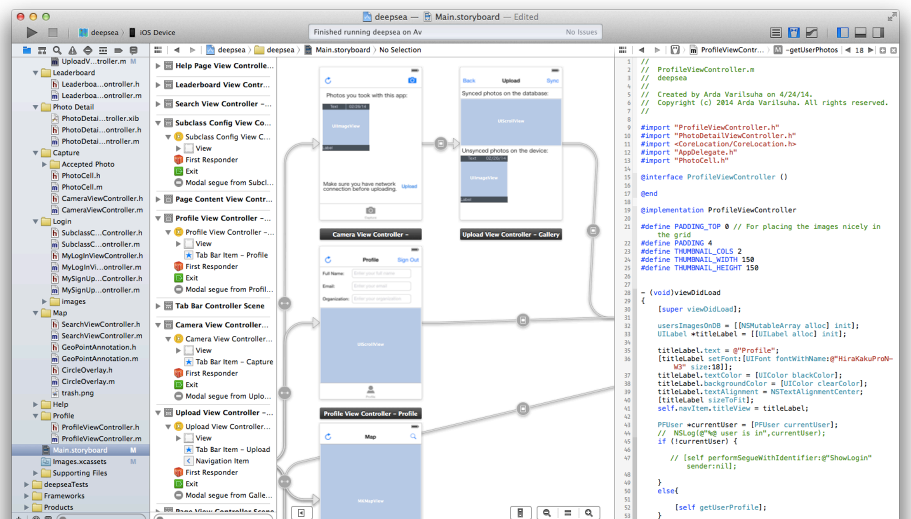
After researching various options for coding and developing, a graduate student at the Rady School of Management at the University of California San Diego was suggested as a potential partner. MBA student Arda Varilshua agreed to help develop the front and backend functionality of the app.

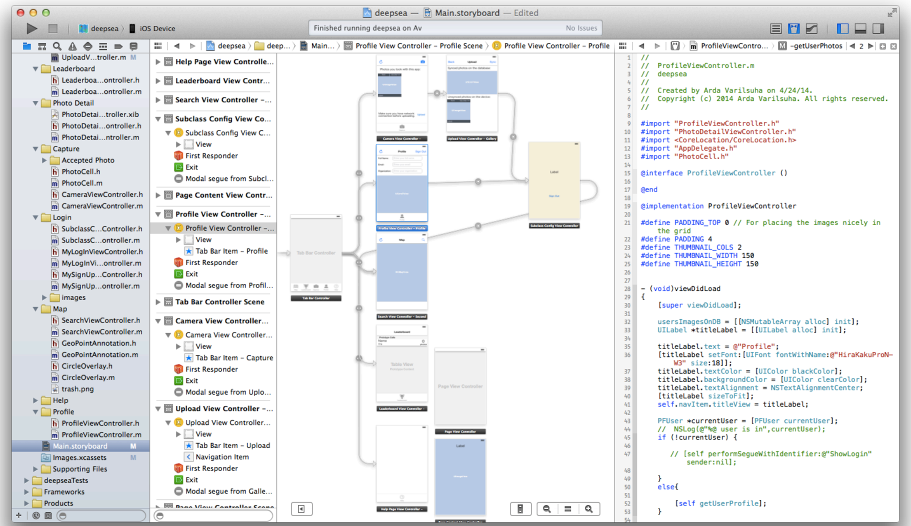
I developed a contract, outlining a timeline, terms of ownership, software rights, expectations for both parties as well as identifying a support period after the app launches. Meeting weekly we were able to incorporate the desired capabilities as well as features suggested by the Capstone Committee and other marine debris researchers.

Front End Development:

Using the Mac Developer software, XCode, Arda wrote and developed the code for the application based on content input and functionality needs from me. Arda and I developed a flow chart of how we wanted the app to operate and how each page would influence the user experience. Below is screen shot of the flow chart we used as well as the code used for different pages.

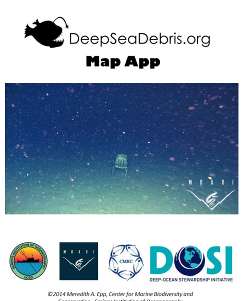




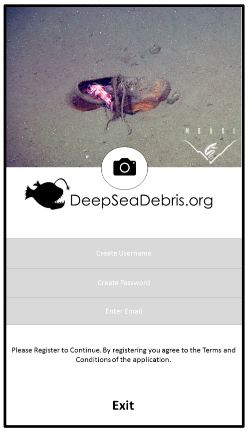


Pages and Functions:

Welcome:

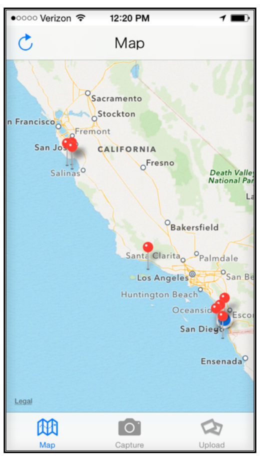


The Welcome page displays an image of a solitary chair resting on the ocean floor discovered by MBARI researchers while analyzing 22 years of ROV footage for a marine debris study (Schiling, 2013). This page also displays the logos of supporting organizations including the Center for Marine Biodiversity and Conservation, Scripps Institution of Oceanography, The Deep Ocean Stewardship Initiative (DOSI) and the Monterey Bay Aquarium Research Institute (MBARI).



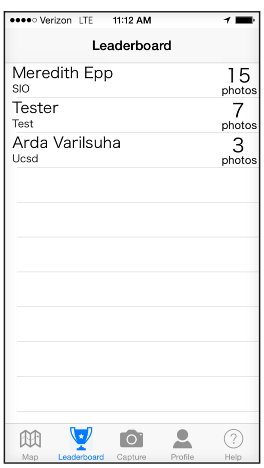
Sign In:

The Sign In page requests that users create a username, password and organization. The emails from the sign in list could be used for outreach purposes if there are new updates to the application.



Map:

The Map page is the default page for users once they are logged in. The map automatically zooms to the location of the user and displays red pins wherever debris has been located and entered into the system. When the pins are selected they display a thumbnail of the image and type of debris associated. The thumbnail image can then be opened to reveal the full photo and comment section about the type of debris. The map can be zoomed in or out with the same pinching motion as on other image features of an iPhone.



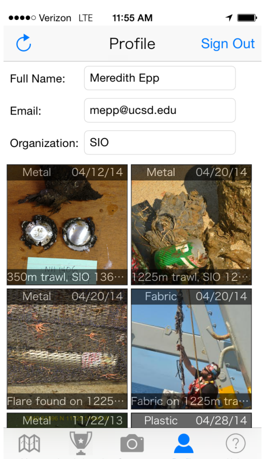
Leaderboard:

The Leaderboard page creates a “gamified” characteristic of the application to add in a more fun and competitive aspect of the experience. This can help users interact with other deep sea researchers and see what types of debris have been found on through other organizations.

Capture:

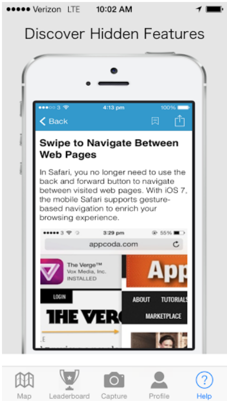
By selecting the Capture feature, users are prompted to take a photo of their debris. The application uses the traditional iPhone camera feature to take a photo and allows the user to submit a comment about the debris. The app also requests that the user enter the type of debris from a selection category of either soft plastic, hard plastic, glass, metal, fabric, wood, high environmental risk, rubber or other. Users can take as many photos of the debris as they like and GPS coordinates are saved with the Geolocation services currently associated with the camera capabilities in iPhones.

To upload photos users are prompted to "upload once a connection is established." The app then searches for unsynced photos taken with the app to be uploaded to the user's profile as well as to the database. There are also edit, save and share functions for each entry. The share function works if a user has Facebook or Twitter applications on their phone and then the photo can be distributed through social media.



Profile:

The Profile page displays the user's name, email and organization, all of which can be edited here. This page also displays all of the synced photos that have been taken by the user. Whenever a user clicks on one of their own photos they can click on "options" and have the choice to edit, share or delete their photos.

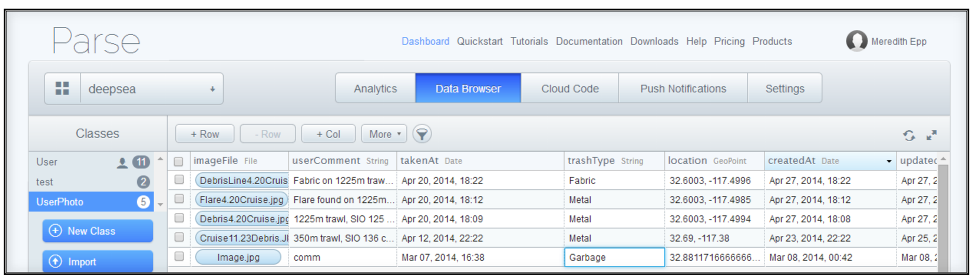


Help:

The help page tells users why debris in the deep sea is a problem and what the Deep Sea Debris app aims to accomplish. This section also advises users on what to do with debris once it has been discovered and addresses frequent questions and answers.

Back End Data Storage and Website:

Parse.com is the storage and analytics tool used for batch uploads of data, exporting data and for managing analytics of app users. From this site the data can also be pulled onto a webpage created for the project called deepseadebris.org.



I created Deepseadebris.org using Wordpress software and is hosted through Bluehost. The purpose of the website is to act as a resource and outreach tool for those interested in learning more about deep sea and marine debris. The website is divided into five different main pages, a home page which serves as a welcome, the page with the interactive debris map, a science page which gives background information on the biology of the deep sea and impacts of marine debris, a resources page listing publications and suggestions for further information. Additionally, there is also an “about” page with general information on SIO and partner organizations.

The page has been SEO optimized with the search terms deep sea debris and as the site continues to grow and add more content, more links to other high ranking sites will help increase the site’s prioritization.

OUTREACH

The Deep Sea Debris app is designed to be used at sea. Therefore the main target user group will be the deep sea research community. A list of target users and the general audience for which this app is designed include the following:

- Graduate students focused on deep sea research
- Deep-sea specialists: contacts made from Deep-sea Biology Society, INDEEP, DOSI
- Maritime academies
- Marine scientists
- Resident technicians aboard research vessels
- ROV specialists

Possible Vessels:

- UNOLS vessels
- International research vessels
- NOAA vessels
- Foundation vessels
- Educational vessels-e.g. Semester at Sea
- Fishermen and fishing organizations

Means of Communication:

- Email outreach campaign
- Posters on research vessels
- Social media and advertising in science technology publications

POTENTIAL CHALLENGES

The main challenges facing the success of this project is the potential lack of participation, a misuse and abuse of the app, a lack of funding and long-term technical maintenance.

With successful outreach and communication of the project goals and purpose the application should achieve use on deep-sea research cruises. A potential misuse of the app could be if users started recording debris in coastal areas that are less than 200 meters deep, or if they recorded false data. As with any technical application and website proper maintenance is required to maintain the latest updates and functionality. Maintenance of the website and application may also require additional funding.

FUTURE RECOMMENDATIONS

To be an efficient method of data collection and to advance scientific and public knowledge about debris in the deep sea, certain measures should be taken, including the following:

Operational:

1. Expand application to Android devices.
2. Obtain funding to provide additional server support.
3. Develop an agreement for all research vessels to report debris discovered below 200 meters.
4. Create a one year report of app progress and evaluate data recovered.
5. Present data to policy makers and incorporate debris data when discussing human impacts in the deep sea.
6. Create a public outreach plan to incorporate deep sea science into classrooms and with grassroots organizations. Build further on the crowdsourcing aspect through ROV footage.

Outcomes:

Data gathered via this application could assist in addressing the interactions of marine debris and the different areas of research such as topographic features, physical oceanography processes, climate change, weather patterns, animal interactions and the carbon cycle. Below are further outcomes which could be a result of data gathered from this app.

1. Advise additional scientific research on how debris behaves differently in the deep sea versus surface debris. Study the degradation process at cold temperatures and high pressures – develop materials that degrade faster under deep-sea conditions, or properties that reduce animal entrapment etc.
2. Work with scientists to determine origins of debris and to rank countries in terms of biggest emitters of marine debris and most destructive.
3. Develop an international marine debris policy agreement to reduce debris by certain percentage and to use funds to incentivize new biodegradable packaging technologies.
4. Establish detailed projections on quantity and location of debris for the next 5, 10, 50 and 100 years with different reduction measurements in place.

The data gathered from this network can be used by governments to track and monitor where high concentrations of debris are gathered and can also be used if highly dangerous debris is discovered. Knowing where hazardous debris is located will help ships to avoid trawling in these areas thus saving money from potential damages to gear. By establishing a baseline of what types of man-made items are already sitting in the deepest parts of the sea we can better regulate and enforce upcoming human activities in the largest ecosystem on earth.

ACKNOWLEDGEMENTS

This paper and project could not have been conceived without the expert advice of the Capstone Advisory Committee, Dr. Kathryn Mengerink, of SIO and the Environmental Law Institute; Professor Lisa Levin, SIO and Nicholas Mallos, of the Ocean Conservancy. Each of the members brought incredibly valuable knowledge and insight from their respective disciplines of ocean policy, deep sea biology and marine debris regulation. Additionally, I would like to thank my PhD student mentor, Jennifer Brandon, for her support, laughter and expert insight into the world of anthropogenic debris in the sciences. Images, data and insight from the deep-sea science community were also incredibly helpful especially the use of images from Kyra Schlining and the Video Annotation and Reference System (VARS) team at the Monterey Bay Aquarium Research Institute (MBARI).

REFERENCES

Bergmann, Melanie, and Michael Klages. "Increase of litter at the Arctic deep-sea observatory HAUSGARTEN." Marine pollution bulletin 64.12 (2012): 2734-2741.

Davison, P. & Asch, R. Plastic ingestion by mesopelagic fishes in the North Pacific Subtropical Gyre. Mar. Ecol. Prog. Ser. 432, 173–180 (2011). http://www.int-res.com/articles/meps2011/432/m432p173.pdf

Derraik, José G.B . The pollution of the marine environment by plastic debris: a review, Marine Pollution Bulletin, Volume 44, Issue 9, September 2002, Pages 842-852, ISSN 0025-326X, http://dx.doi.org/10.1016/S0025-326X(02)00220-5.

Goldstein, Miriam C., and Deborah S. Goodwin. "Gooseneck barnacles (Lepas spp.) ingest microplastic debris in the North Pacific Subtropical Gyre." PeerJ 1 (2013): e184.

Invasive Species Definition Clarification and Guidance White Paper Submitted by the Definitions Subcommittee of the Invasive Species Advisory Committee (ISAC) Approved by ISAC April 27, 2006 http://www.invasivespeciesinfo.gov/docs/council/isacdef.pdf

Jones, J. B. "Environmental impact of trawling on the seabed: a review." New Zealand Journal of Marine and Freshwater Research 26.1 (1992): 59-67.

Keller, Aimee A., Erica L. Fruh, Melanie M. Johnson, Victor Simon, Catherine McGourty, Distribution and abundance of anthropogenic marine debris along the shelf and slope of the US West Coast, Marine Pollution Bulletin, Volume 60, Issue 5, May 2010, Pages 692-700, ISSN 0025-326X, http://dx.doi.org/10.1016/j.marpolbul.2009.12.006.

Macreadie, Peter I., Ashley M. Fowler, and David J. Booth. "Rigs-to-reefs: will the deep sea benefit from artificial habitat?." Frontiers in Ecology and the Environment 9.8 (2011): 455-461.

Miyake, Hiroshi, Haruka Shibata, and Yasuo Furushima. "Deep-sea litter study using deep-sea observation tools." Interdisciplinary Studies on Environmental Chemistry-Marine Environmental Modeling and Analysis Terrapub (2011): 261-269.

M.R. Gregory. Plastic "scrubbers" in hand cleansers: a further (and minor) source for marine pollution identified. Marine Pollution Bulletin, 32 (1996), pp. 867–871

MOSER, M.L. & LEE, D.S. 1992. A fourteen-year survey of plastic ingestion by western North Atlantic seabirds. Colonial Waterbirds 15: 83–94.

Pew, 2014 http://www.pewinternet.org/fact-sheets/mobile-technology-fact-sheet/

Pham, C. K., et al. "Abundance of litter on Condor seamount (Azores, Portugal, Northeast Atlantic)." Deep Sea Research Part II: Topical Studies in Oceanography 98 (2013): 204-208.

Ramirez-Llodra, Eva, et al. "Effects of natural and anthropogenic processes in the distribution of marine litter in the deep Mediterranean Sea." Progress in Oceanography 118 (2013): 273-287.

Ramirez-Llodra, Eva, et al. "Man and the last great wilderness: human impact on the deep sea." PLoS One 6.8 (2011): e22588.

Rochman, Chelsea M., et al. "Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress." Scientific reports 3 (2013).

Schlining, Kyra, et al. "Debris in the deep: Using a 22-year video annotation database to survey marine litter in Monterey Canyon, central California, USA." Deep Sea Research Part I: Oceanographic Research Papers (2013).

Schuyler et al. 2012, To eat or not to eat? Debris selectivity by marine turtles. *PLOS ONE* 7(7): 1-9

Spengler, Angela, and Monica F. Costa. "Methods applied in studies of benthic marine debris." Marine Pollution Bulletin 56.2 (2008): 226-230.

Tarpley and Marwitz, 1993 R.J. Tarpley, S. Marwitz. Plastic debris ingestion by cetaceans along the Texas coast: two case reports. Aquatic Mammals, 19 (1993), pp. 93–98

Van Cauwenberghe, Lisbeth, et al. "Assessment of marine debris on the Belgian Continental Shelf." Marine Pollution Bulletin (2013).