NORTH PACIFIC MARINE SCIENCE ORGANIZATION (PICES)
PROJECT ON *"EFFECTS OF MARINE DEBRIS CAUSED BY THE GREAT TSUNAMI OF 2011"*
Year 2 Final Report

1. PROJECT INFORMATION

Title:	Japanese Marine Debris Aerial Imagery Analysis and GIS Support
Award period	January 1, 2016 – April 30, 2016
Amount of funding	$14,995.00
Report submission date	April 29, 2016
Lead Author of Report*	Kristine Davidson

Principal Investigator(s), Co-Principal Investigators and Recipient Organization(s):

Michael P. Hamnett, Principal Investigator, Executive Director, RCUH (mhamnett@rcuh.com)
Kristine Davidson, Co-Principal Investigator, Program Director, HCRI-RP (KristineDavidson@hawaii.rr.com)

2. EXECUTIVE SUMMARY

Purpose and Objectives

After the Tohoku earthquake and resulting tsunami devastated Japan in 2011, marine debris from the event has found its way across the Pacific through oceanic currents and processes, and has been arriving on coastlines of the Hawaiian Islands since 2012. This debris introduces many potential hazards to the natural environment, including wildlife entanglement and ingestion as well as the possible establishment of invasive species that raft on debris items. In addition, debris can damage fragile reef infrastructure and coastal habitat, and can be a deterrent to the tourism that sustains much of Hawai‘i’s economy.

In order to characterize the potential ecological consequence of tsunami debris, it is important to characterize the debris itself. Understanding the type, size, and location of debris accumulating on Hawaiian coastlines is crucial in developing plans to streamline the removal process and mitigate any negative impacts this debris may have on the islands and their inhabitants. Given the vast extent and remoteness of coastlines in the Hawaiian Islands, large scale surveillance efforts are needed to identify and describe these accumulations. Capture and analysis of high-resolution aerial imagery allows for rapid qualitative and quantitative assessments at this scale, providing data that can be used to plan further management actions and evaluate marine debris accumulation patterns in Hawai‘i. During the previous project period, four of the eight Main Hawaiian Islands (Lāna‘i, Ni‘ihau, Kaua‘i, and Hawai‘i Island) were surveyed using these methods. The goal of this project period was to continue analysis of the remaining islands (Maui, Moloka‘i, Kaho‘olawe, and O‘ahu) and combine this data with results from the previous analysis to provide a comprehensive assessment of debris accumulations for all of the Main Hawaiian Islands. This baseline data will support future investigations into effective management and removal strategies that aim to minimize the negative impact of this debris on the environment.

Objectives of the overall project were to locate, categorize, and quantify debris accumulations that may be associated with the Japanese tsunami of 2011 on coastlines of all eight Main Hawaiian Islands through analysis of high-resolution aerial imagery paired with ArcGIS mapping software. Production of maps, figures, and reports detailing findings were included in this objective, in order to provide useful data to community groups, research organizations, and government agencies across the islands with the capacity to develop management plans and conduct removal operations.

Methods

A remote sensing firm, Resource Mapping Hawai'I (RMH), on a separate grant, collected aerial imagery of the coastlines of the Main Hawaiian Islands at 2-cm horizontal ground resolution, covering a swath of 200-300 meters that included shoreline and near-shore water. This imagery was then used to develop ortho-mosaic image datasets for analysis in ArcGIS. Prior to beginning analysis, coastlines were divided into segments, and debris categories were developed to classify debris by type and size. While there are limitations on the ability to determine debris types at this scale, categorization of identifiable debris is useful to determine possible ecological consequences; for example, nets and lines pose a serious entanglement hazard, while small plastics and foam are more likely to be mistakenly ingested by wildlife.

Imagery was analyzed by 1-mile coastline segment for systematic coverage of each island's coastline, and each piece of debris observed was identified in ArcGIS on a point shapefile and given a unique, sequential identification number, starting at 1 within each one-mile segment. For each data point, attributes such as debris type (material), size (object area), and observer information and comments were also recorded. Size was approximated using the measurement tool within ArcGIS, and was estimated in meters squared and sorted into size classes. Once analysis for a segment was completed, the segment was given a rating based on density and distribution of debris. Other attributes, including total item count, dates analyzed, and observer information were also recorded for each segment. Once all segments from an island were complete, 20% of the total number of segments were chosen at random for quality control, which involved re-analysis by a different observer in order to assess accuracy and precision of data collection. Data from quality control analysis was used to refine and standardize the data collection process. Original data was used to generate maps in ArcGIS to display debris density and distribution along Hawai'i's coastlines. Data analyses to determine composition and size distributions of debris were also conducted and used to create figures.

Results

A total of 6,909 pieces of marine debris were identified on the coastlines of Maui, Moloka'i, Kaho'olawe, and O'ahu. When combined with previous data for the remaining islands, a total of 20,658 marine debris items were identified across the Main Hawaiian Islands. Of the four islands surveyed during this project period, Moloka'i had the highest concentration of marine debris, while O'ahu had the lowest. When compared with results from the previous project period, Ni'ihau was determined to have the highest density of marine debris statewide, containing 38% of the total debris identified. Moloka'i was the next most dense overall, containing 14% of the total debris count, with O'ahu remaining the least dense, at 5% of the total debris count. On all islands, marine debris was primarily concentrated on north and east facing shores, with western facing shores containing the least amount of debris.

Composition of debris varied between islands, but the most common type of debris on all islands was plastic, making up 47% of the overall composition of debris identified and between 37% and 63% on any individual island. When comparing total counts statewide, he next most common debris types were buoys and floats and derelict fishing gear, at 22% and 11%, respectively. The remaining categories each made up 7% or less of the total debris composition, varying up to 14% on individual islands.

Marine debris size was found to be less variable than type composition, with regards to the defined size classes. 86% of the total debris found statewide fell into the smallest category of less than 0.5 m^2, with similar concentrations on individual islands (84% to 89%). The three remaining size classes each made up 7% or less

of the composition on any island, with 6% of all debris items being classified as small (0.1 – 1 m^2), and 8% of all items being divided equally between the medium (1 – 2 m^2) and large (> 2 m^2) size classes.

Achievements and Challenges

During the project period, aerial imagery analysis was completed for four of the Main Hawaiian Islands, identifying nearly 7,000 marine debris items potentially linked to the Japanese tsunami of 2011. This data was paired with previous data for the remaining islands, resulting in a comprehensive assessment of marine debris on coastlines of all eight Main Hawaiian Islands that identified over 20,000 data points of potential Japanese tsunami marine debris. Data analysis also provided a breakdown of composition and size of debris found, and maps generated in ArcGIS provided visual representation of debris density and distribution on the coastlines of Hawai‘i. Various additional analyses were also conducted in the remaining time, providing size sampling data and comparisons over time for the Kahuku area of O‘ahu using historical imagery datasets, though this data is not yet fully processed.

Challenges to this project included missing or fuzzy imagery, or difficulty determining item type or origin (*i.e.*, natural versus man-made). Issues with image quality can be attributed to the various conditions that affect the in-flight imagery collection process, such as variation in terrain and weather conditions. Gaps in imagery may also be a result of these factors, as well as flight restrictions over areas such as airports and military bases. Segments that could not be analyzed due to missing imagery are noted on maps and displayed as “No data” areas. Difficulty classifying debris items decreased over time, as analysts gained experience and became familiar with examples of debris encountered during the analysis process. Quality control procedures also helped to simplify the classification process through the development of standardized rules to enhance accuracy and precision of data collection between observers.

Timelines and Milestones

The aerial imagery collection process was conducted between August and November, 2015, and the image processing to create ArcGIS compatible files was conducted concurrently and continuously during this time. Aerial imagery analysis for the previous project period began in October 2015 and was concluded in December 2015. Aerial imagery analysis for this project period began in December 2015 and was concluded in February 2016. Data analysis and processing, final report writing, and additional tasks (size sampling, O‘ahu through time, *etc*.) were continued to present.

3. PROGRESS SUMMARY

a. Describe original proposed research and planned outputs

This project proposed to continue research conducted during the previous project period, which characterized marine debris accumulations on the coastlines of Lāna‘i, Ni‘ihau, Kaua‘i, and Hawai‘i Island, by analyzing the coastlines of the remaining Main Hawaiian Islands (Maui, Moloka‘i, Kaho‘olawe, and O‘ahu) using the same methodology and approach, as described above. In addition, this research proposed to use data from both the previous and current analyses to provide a comparison of debris density and composition between all of the Main Hawaiian Islands, and provide an overview of marine debris accumulation statewide. The intended deliverables from this research were point shapefiles with supporting attribute tables that detail the location, type, and size of marine debris identified on Hawai‘i’s coastlines, as well as maps and figures that display debris density, distribution, and composition data. In addition, supporting segment shapefiles and attribute tables used in the analysis and map generation process were prepared. The anticipated ultimate outcome is the use of this data by community, research, and government organizations to plan effective management strategies for the removal of marine debris, and mitigation of any negative impacts of debris accumulations on coastal areas.

b. **Describe progress**

Aerial imagery analysis was carried out between December 2015 and February 2016 for the four islands included in this survey. Quality control for each island was conducted during this period as well, following completion of original analysis for each island. Once the quality control process was complete, data analysis proceeded to determine debris density and distribution, composition, and size on each island. Percentages of debris in each type and size category were calculated, as well as average segment density for each island. Results from the preceding study on Lānaʻi, Niʻihau, Kauaʻi, and Hawaiʻi Island were then compared to the current findings and incorporated into a statewide summary of marine debris accumulations, including maps and figures. From the total debris identified statewide, percentages of type, size, and quantity were calculated for each island and compared.

With remaining time, additional analyses were carried out. Size sampling of debris was studied on a 10% sample of all marine debris points identified on each of the eight Main Hawaiian Islands, including the islands from the previous project period. Analysis of historical aerial imagery of Oahu was also completed for the densest area (two segments on the northern coast, near Kahuku) for comparison to current study results. These data have not yet been processed to produce statistics or figures. Debris density data was reassigned into 5-mile segments of shoreline in addition to the 1-mile segment data for all eight islands, to provide better display options on larger scale maps such as statewide.

c. Describe results

Statewide Results

Debris density and distribution

Analysis identified a total of 6,909 pieces of marine debris on the coastlines of Maui, Molokaʻi, Kahoʻolawe, and Oʻahu. When combined with data from the previous project period, the total number of debris items detected on the Main Hawaiian Islands was 20,658. Marine debris was found to be most dense on northern and eastern facing shores for all islands, with western facing shores being the least dense. All islands had at least one segment containing 100 or more pieces of debris per mile, with the densest segment being found on Niʻihau (1,137 pieces of debris in a one-mile segment). Niʻihau was also found to have the highest debris density overall (Fig. 1), containing 38% of all debris items identified. Molokaʻi had the second highest density overall, with 14% of the total debris count, and was the most dense of the islands surveyed during this project period. Oʻahu had the lowest debris density, both overall and for the project period, contributing 5% to the total debris identified statewide. Average segment density was highest for Niʻihau (151 items per mile), and lowest for Hawaiʻi Island (6 items per mile), and segment density was not reflective of total coastline length (number of segments) (Fig. 2).

Debris Composition

Composition of debris varied between islands (Fig. 3), but plastic was the most common type of debris identified, both on individual islands and statewide, making up 47% of the total debris identified (Fig. 4), and between 37% and 63% of the composition on individual islands. Buoys and floats and derelict fishing gear were the next largest categories when comparing total debris counts, at 22% and 11%, respectively. Between islands, however, the amount of debris in these categories varied from 8% to 35% (average of 19%) for buoys and floats, and 5% to 21% (average 11%) for derelict fishing gear. Both tires and foam each made up less than 10% of the composition on any island, and 5% and 3% across all islands, respectively. "Other" category items (items identified as processed wood, metal, cloth, or vessels) contributed 6% to the overall debris count, and inconclusive items contributed 7%, with varying degrees of density across islands.

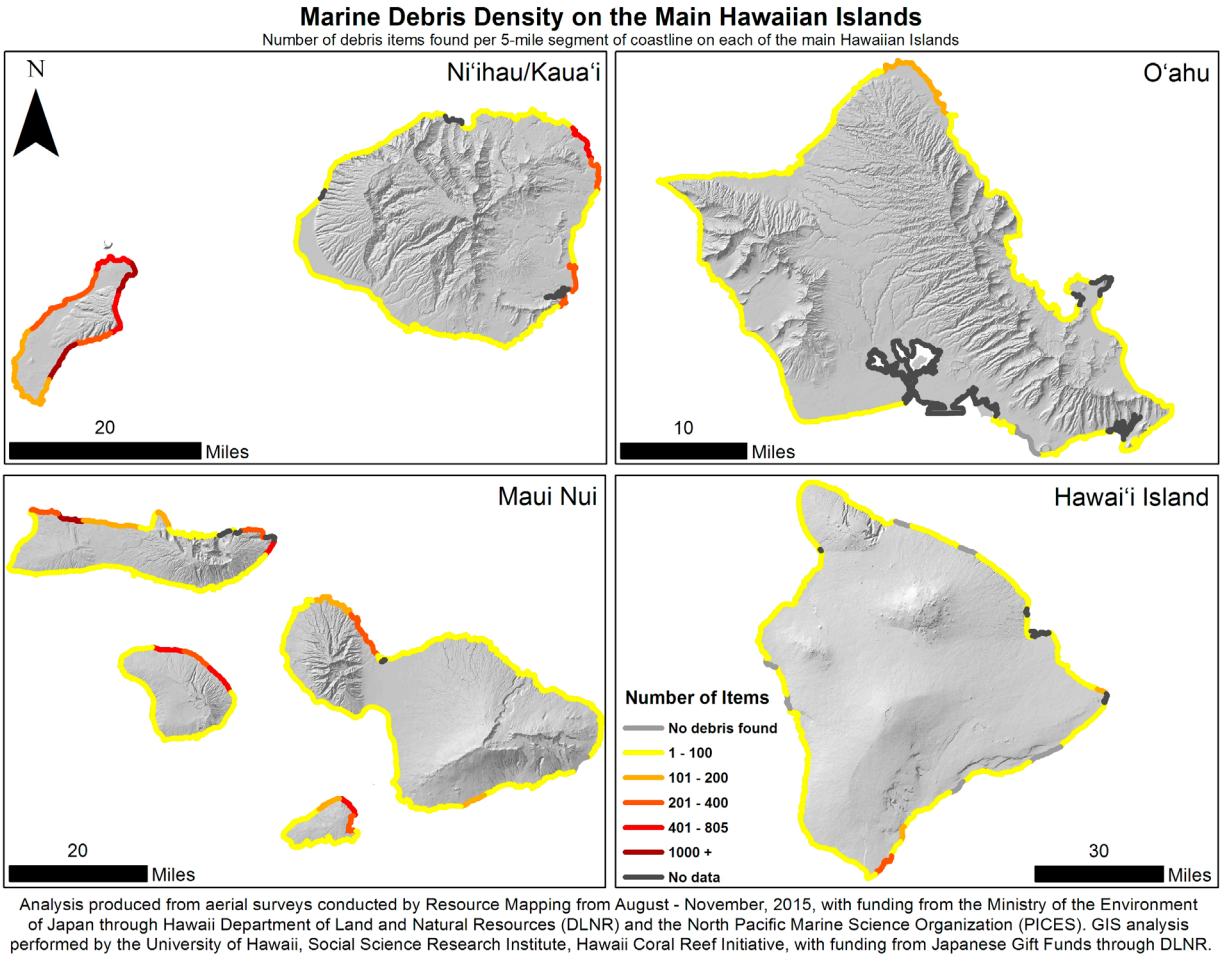


Fig. 1 Marine debris density across the Main Hawaiian Islands. For this figure, segment data was re-assigned to 5-mile segments of coastline for better display at large scales.

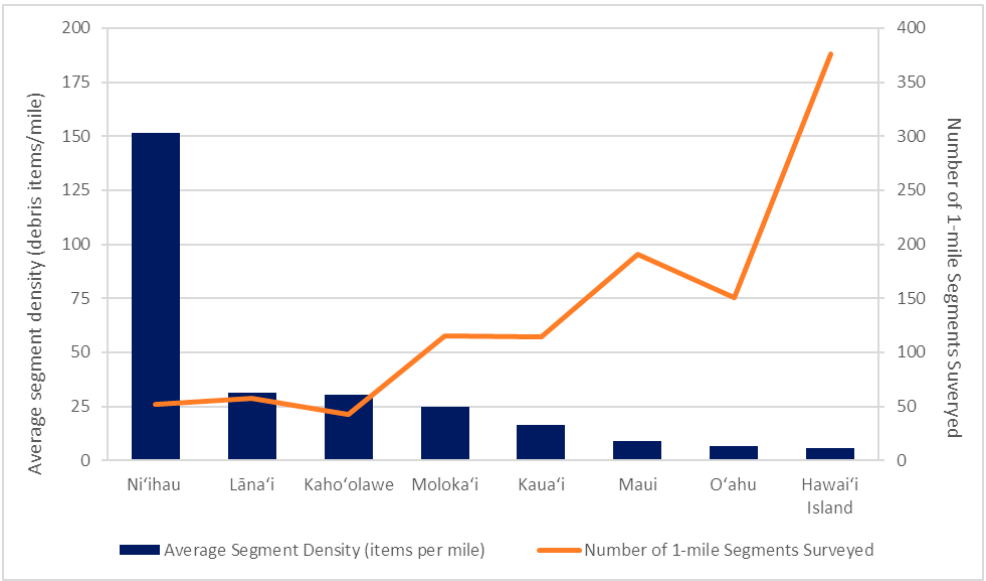


Fig. 2 Average number of debris items found per 1-mile segment of coastline for the Main Hawaiian Islands, in relation to total number of 1-mile segments analyzed (excludes "no data" areas).

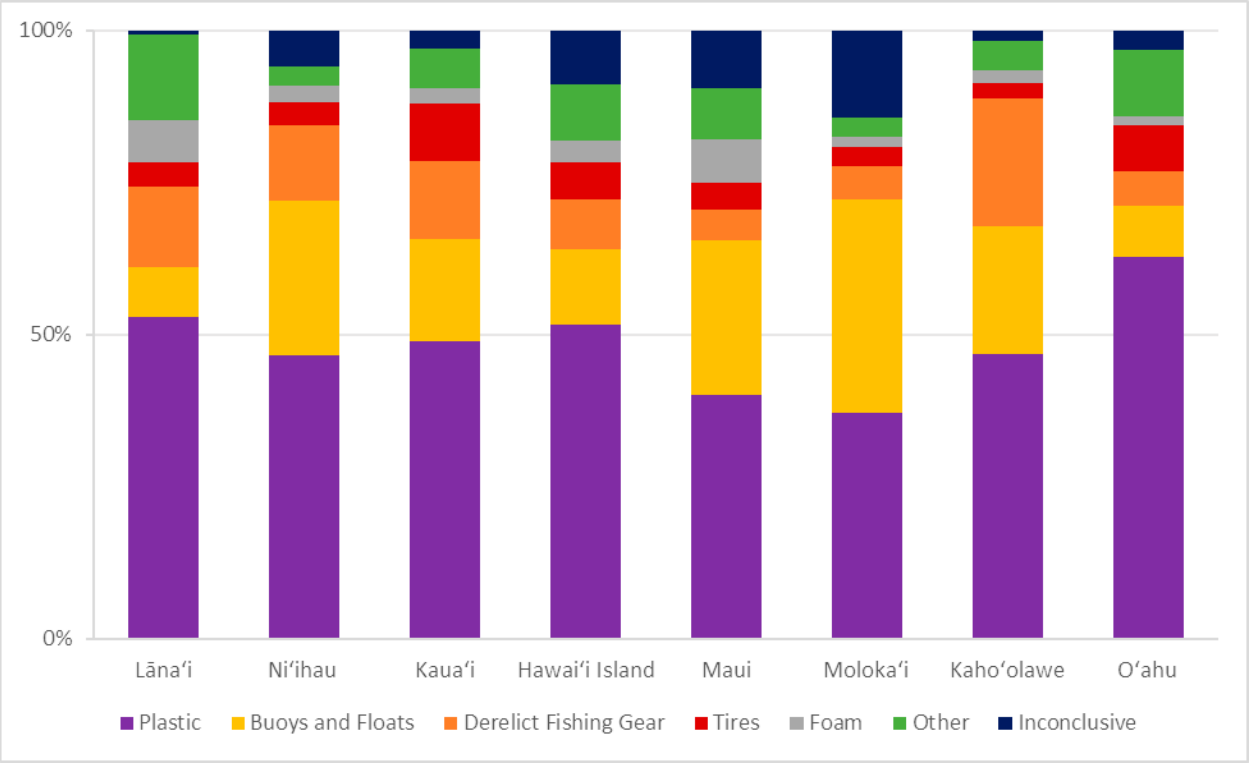


Fig. 3 Composition of marine debris compared between the Main Hawaiian Islands. Derelict Fishing Gear: nets and lines; Other: processed wood, metal, cloth, and vessels.

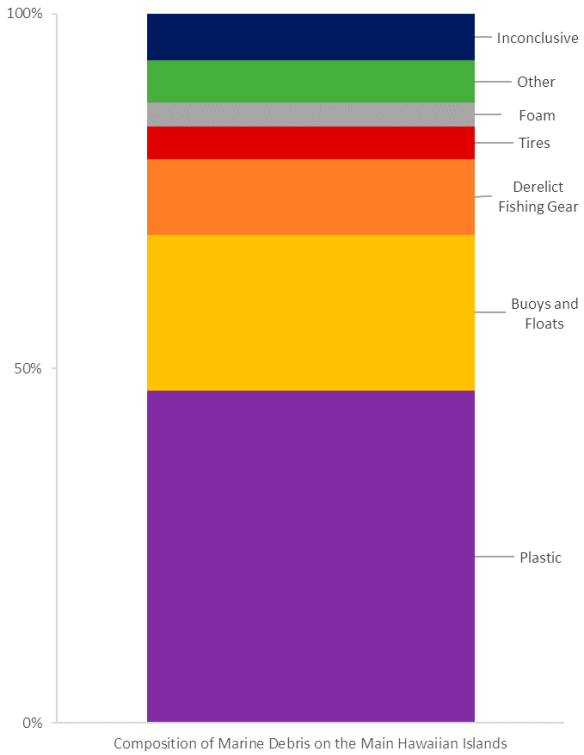


Fig. 4 Composition of the total marine debris found on all of the Main Hawaiian Islands. Derelict Fishing Gear: nets and line; Other: processed wood, metal, cloth, and vessels.

Debris Size Distribution

Size distribution of marine debris identified on the Main Hawaiian Islands was less variable than type composition (Fig. 5). The smallest category (< 0.5 m^2) made up 86% of the total debris found on all islands (Fig. 6), and contributed from 84% to 89% on individual islands. The remaining categories each made up less than 10% on any island, with the total contribution statewide from the small category (0.5 – 1 m^2) being 6% and the total contribution from the remaining size classes (1 – 2 m^2 and > 2 m^2) being 4% each.

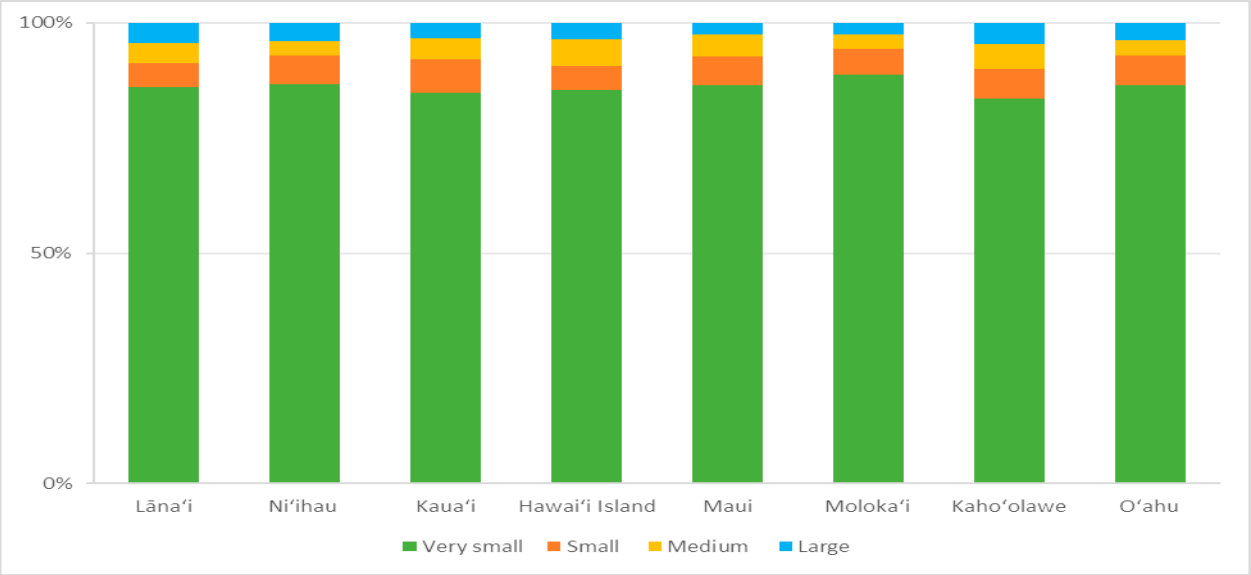


Fig. 5 Size distribution of marine debris compared between the Main Hawaiian Islands. Very Small: < 0.5 m^2, Small: 0.5 – 1 m^2, Medium: 1 – 2 m^2, Large: >2 m^2.

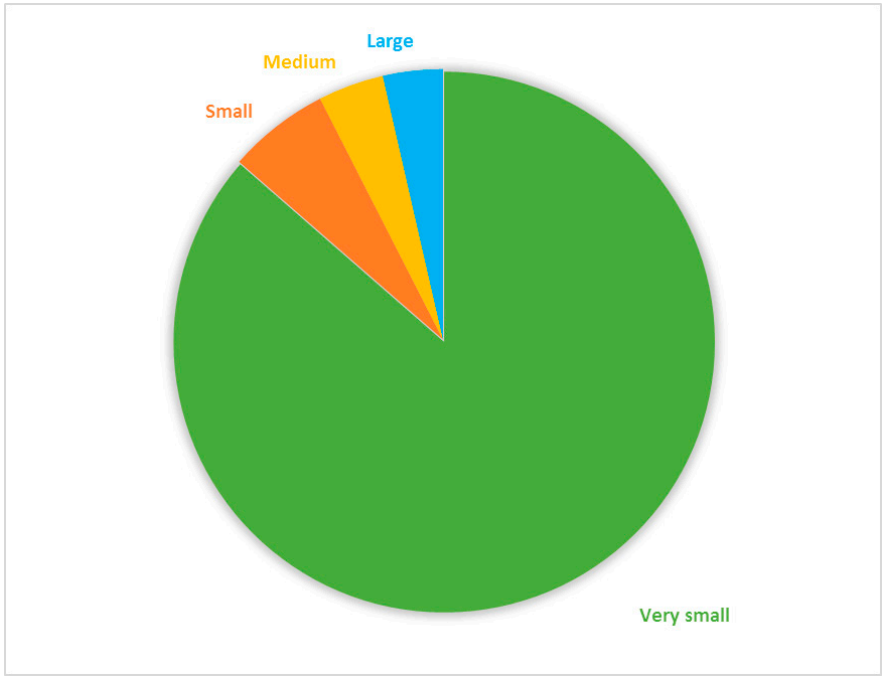


Fig. 6 Debris size distribution across all of the Main Hawaiian Islands. Very Small: < 0.5 m^2, Small: 0.5 – 1 m^2, Medium: 1 – 2 m^2, Large: >2 m^2.

Individual Island Results

NOTE: Only the islands surveyed during this project period (Maui, Moloka'i, Kaho'olawe, and O'ahu) are included here. Results for the other islands are included in previous reports.

Density and Distribution of Debris – Maui

Maui had the greatest debris density on the northern coast, particularly to the west where the coastline slopes south toward Kahului Bay (Fig. 7). The segment with the highest density was also located in this area, with a total of 116 debris items within one mile. Only one other segment, located along the southern coast, contained a density greater than 100 pieces of debris per mile. All but two segments on the southern and western coasts of the island contained 20 or fewer pieces of debris per mile.

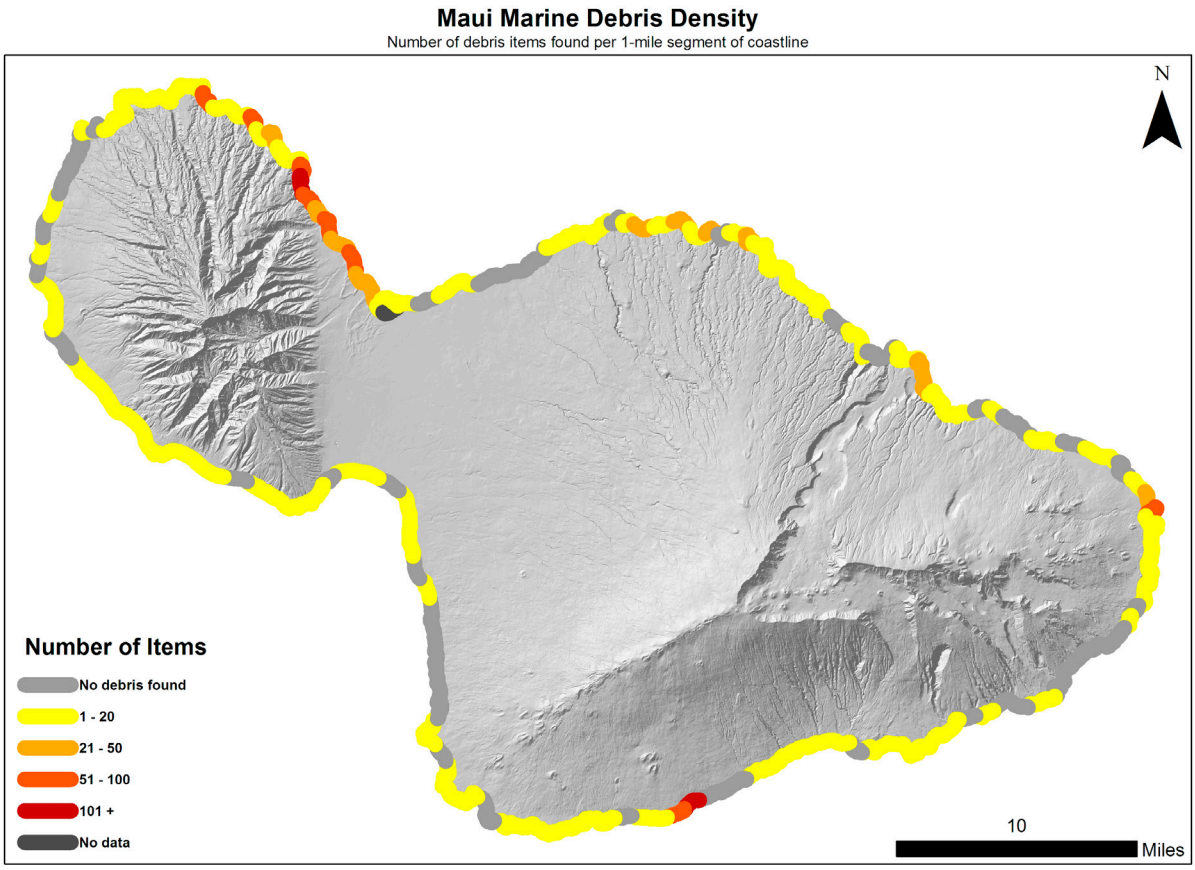


Fig. 7 Relative density of marine debris identified around the island of Maui.

Debris Composition – Maui

A total of 1,749 marine debris items were found around the Maui coastline. The most common type of debris was plastic (40%) followed by buoys and floats (25%), and inconclusive items (10%) (Fig. 8). The remaining categories each made up 8% or less of the debris composition.

Debris Size Distribution – Maui

Most (87%) of the marine debris around Maui fell into the smallest size classification of less than 0.5 m^2 (Fig. 9). The remaining size classes each contributed 6% or less to the total debris count.

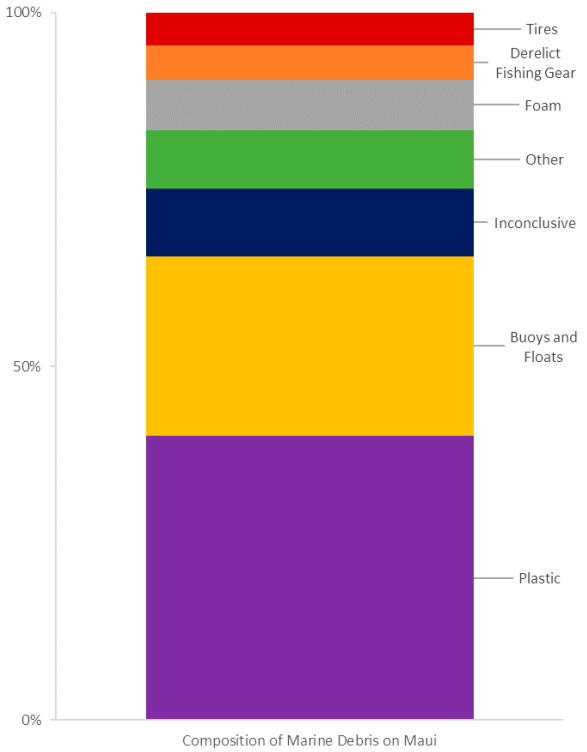


Fig. 8 Composition of marine debris identified around Maui. Derelict Fishing Gear: nets and line; Other: processed wood, metal, cloth, and vessels.

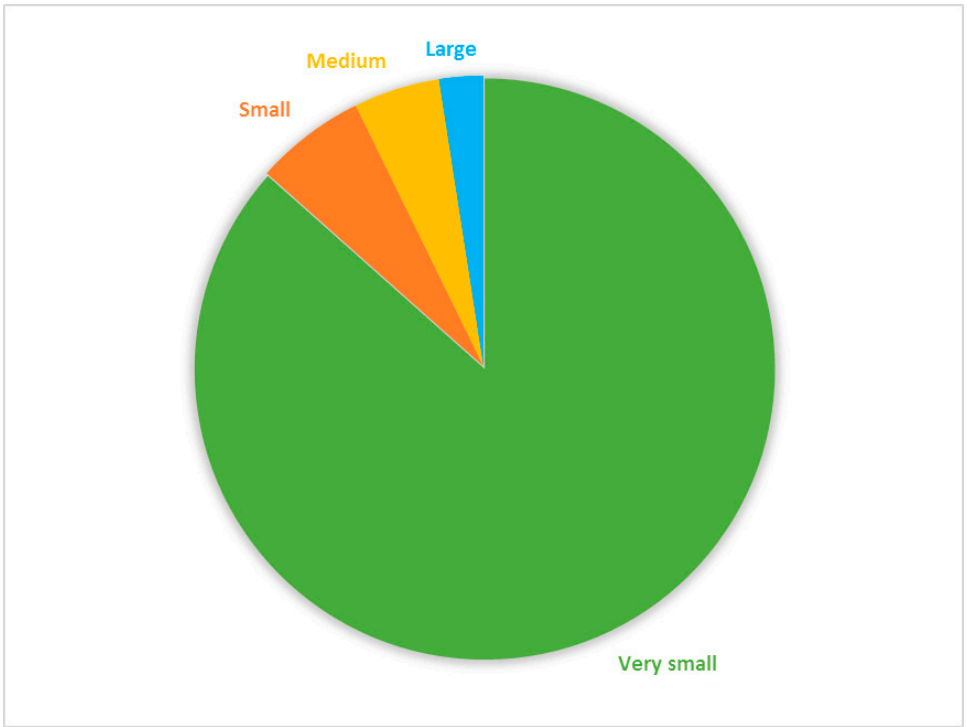


Fig. 9 Debris size distribution on Maui. Very Small: < 0.5 m^2, Small: 0.5 – 1 m^2, Medium: 1 – 2 m^2, Large: >2 m^2.

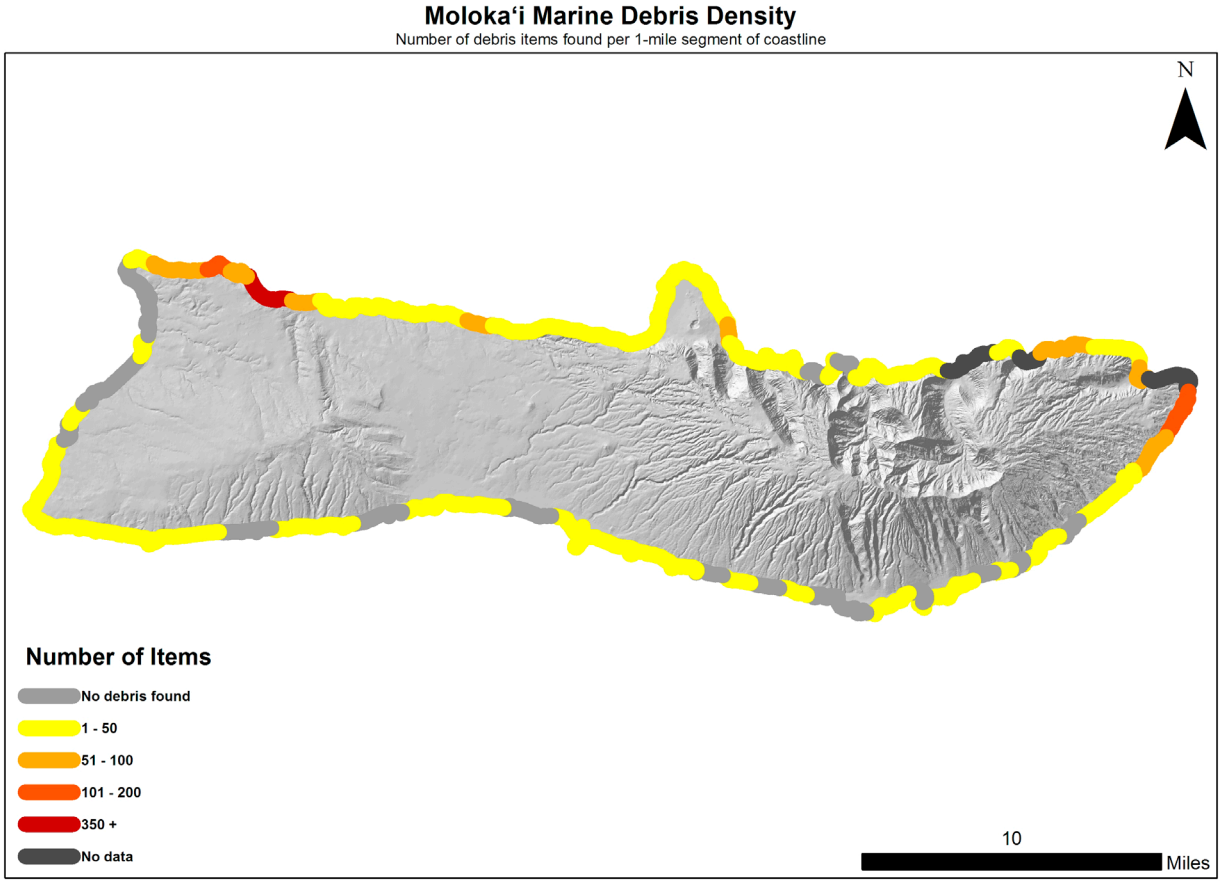


Fig. 10 Relative density of marine debris identified around the island of Moloka‘i.

Density and Distribution of Debris – Moloka‘i

On Moloka‘i, marine debris was concentrated on northwestern shores, and a small area on the north-eastern corner (Fig. 10). Highest debris density found was 612 items within a one-mile segment, with the next highest being 360 items per mile. These segments were adjacent to each other, and both were located on the northwest coast of the island. All remaining segments had fewer than 200 items per mile, with all segments on south and west facing shores having 50 or fewer items per mile.

Debris Composition – Moloka‘i

Imagery analysis identified a total of 2,878 pieces of marine debris around the coastline of Moloka‘i. The most common types of debris were plastic and buoys and floats, which had similar densities of 37% and 35%, respectively (Fig. 11). Inconclusive items made up 14% of the debris composition, with all remaining categories contributing 5% or less.

Debris Size Distribution – Moloka‘i

89% of the marine debris on Moloka‘i fell into the smallest size classification of less than 0.5 m^2 (Fig. 12). The next size class, 0.5 – 1 m^2, contained 6% of the debris, with the remaining size classes each having approximately 3% of the debris.

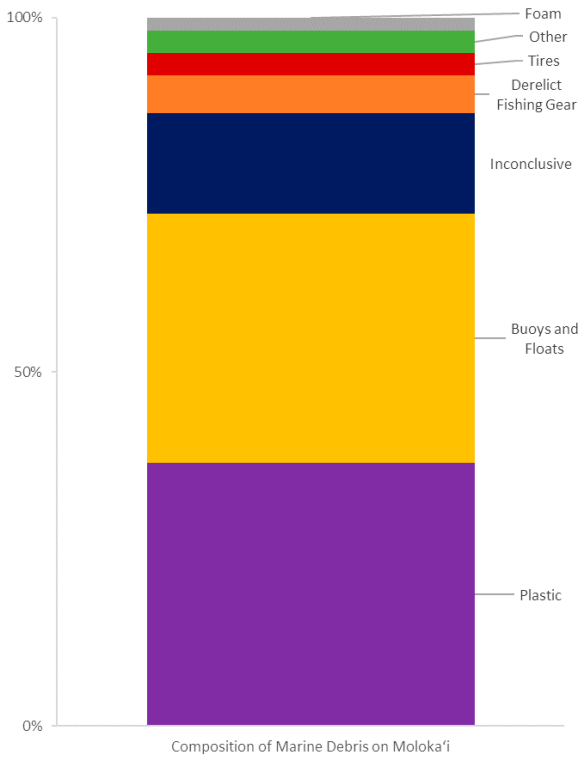


Fig. 11 Composition of marine debris identified around Moloka'i. Derelict Fishing Gear: nets and line; Other: processed wood, metal, cloth, and vessels.

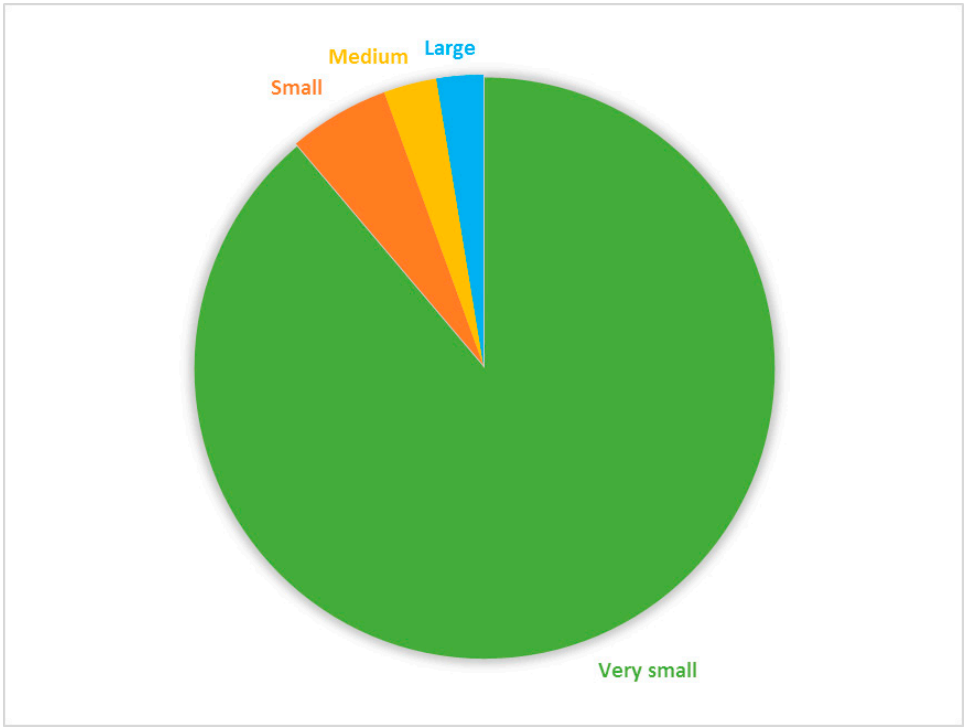


Fig. 12 Debris size distribution on Moloka'i. Very Small: < 0.5 m^2, Small: 0.5 – 1 m^2, Medium: 1 – 2 m^2, Large: >2 m^2.

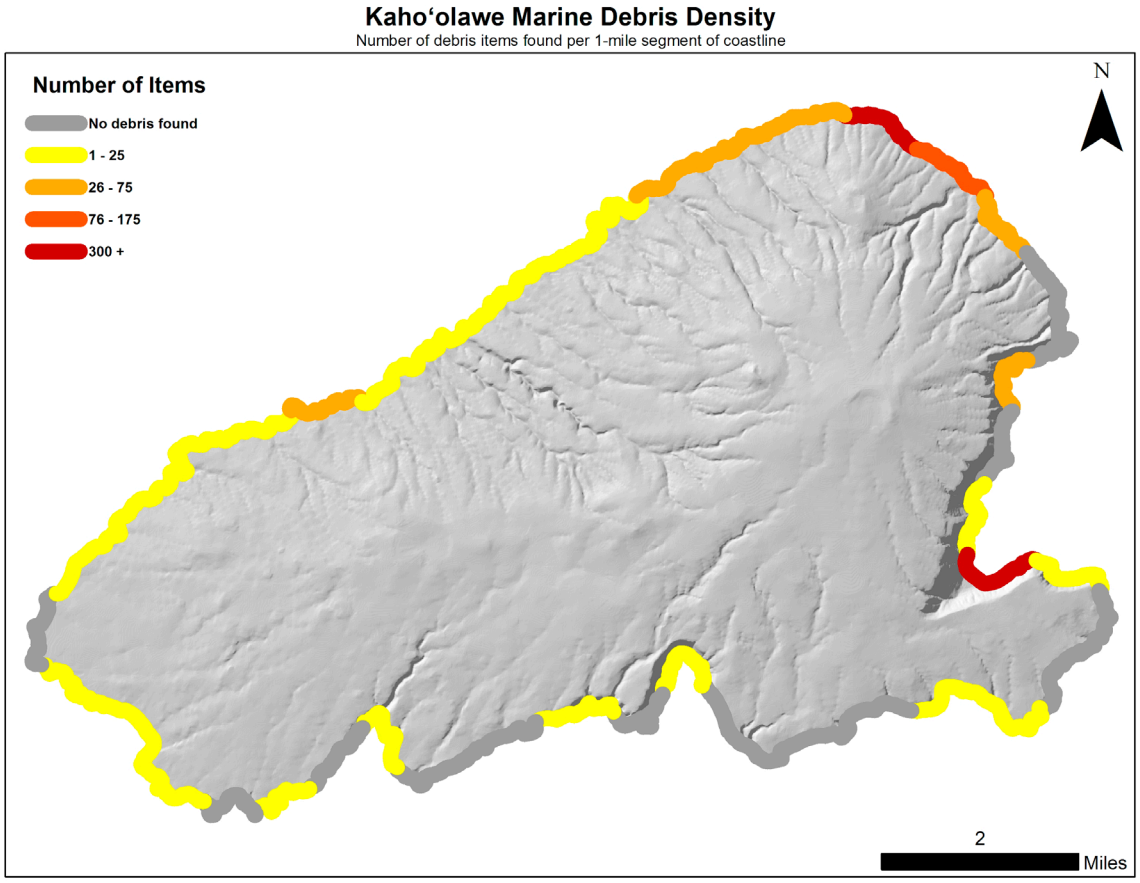


Fig. 13 Relative density of marine debris identified around the island of Kaho‘olawe.

Density and Distribution of Debris – Kaho‘olawe

Marine debris on Kaho‘olawe was concentrated in two locations along the coast, both on the northern tip of the island and in the Keoneuli area along the eastern coast, where the shoreline curves inward (Fig. 13). The Keoneuli area contained the highest debris density, with 342 debris items found in a one-mile segment. The segment at the northern-most point of the island contained 304 items per mile. All southern facing shores contained 25 or fewer items per mile.

Debris Composition – Kaho‘olawe

A total of 1,298 pieces of marine debris were identified around the Kaho‘olawe coastline. The most common type of debris was plastic (47%), followed by buoys and floats and derelict fishing gear, which each made up 21% of the debris composition (Fig. 14). All other categories made up 5% or less of the total debris count.

Debris Size Distribution – Kaho‘olawe

The majority (84%) of marine debris around Kaho‘olawe fell into the smallest size classification of less than 0.5 m^2 (Fig. 15). The next size class of 0.5 – 1 m^2 contained 7% of the debris, while the remaining size classes each contained around 5% of the debris.

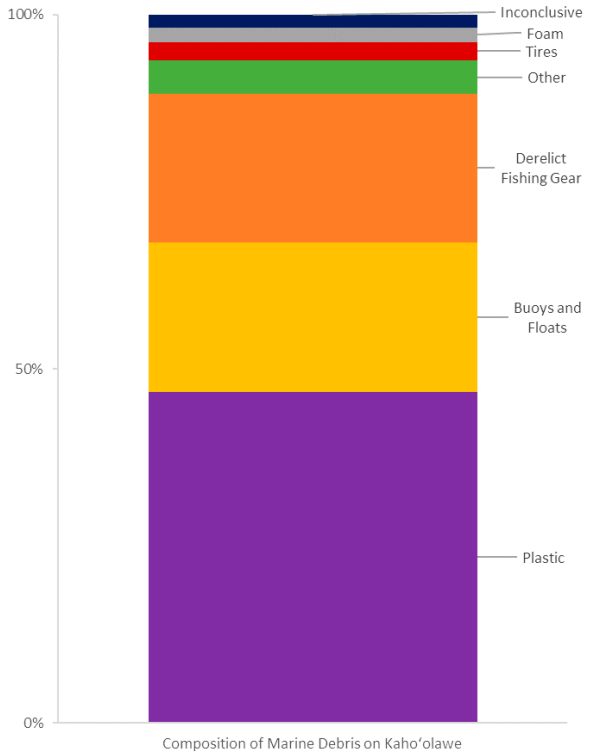


Fig. 14 Composition of marine debris around Kaho'olawe. Derelict Fishing Gear: nets and line; Other: processed wood, metal, cloth, and vessels.

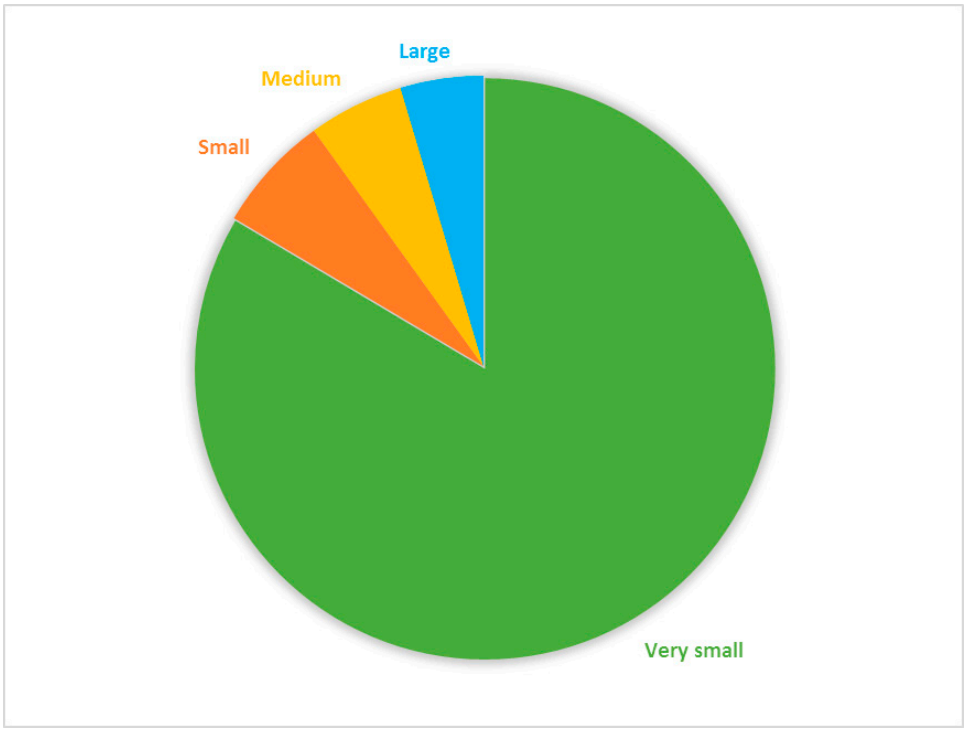
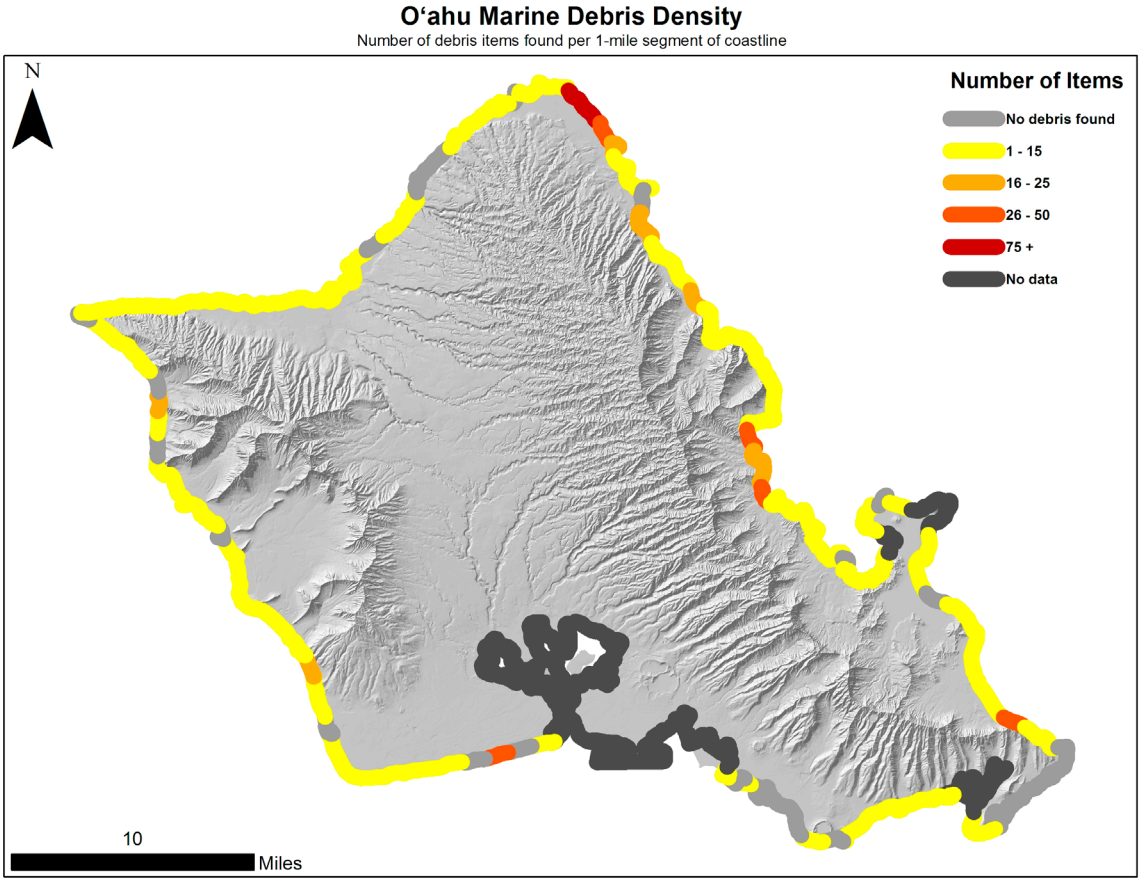


Fig. 15 Debris size distribution on Kaho'olawe. Very Small: < 0.5 m^2, Small: 0.5 – 1 m^2, Medium: 1 – 2 m^2, Large: >2 m^2.



Analysis produced from aerial surveys conducted by Resource Mapping from August - November, 2015, with funding from the Ministry of the Environment of Japan through Hawaii Department of Land and Natural Resources (DLNR) and the North Pacific Marine Science Organization (PICES). GIS analysis performed by the University of Hawaii, Social Science Research Institute, Hawaii Coral Reef Initiative, with funding from Japanese Gift Funds through DLNR.

Fig. 16 Relative density of marine debris identified around the island of O‘ahu.

Density and Distribution of Debris – O‘ahu

O‘ahu marine debris was concentrated on the northern tip of the island, on the eastern facing shore between the northern-most point and the Kahuku area (Fig. 16). Only two segments contained 75 or greater debris items per mile, with the densest segment containing 108 debris items in one mile. All remaining segments contained 50 or fewer debris items per mile, with the majority of segments having a density of 15 or fewer items per mile.

Debris Composition – O‘ahu

Imagery analysis identified a total of 984 pieces of marine debris around the O‘ahu coastline. The most common debris type was plastic (63%) followed by debris in the category “other” (11%), which is a compilation of debris identified as either processed wood, metal, cloth, or vessels (Fig. 17). All remaining debris categories each made up less than 10% of the total debris count.

Debris Size Distribution – O‘ahu

The smallest size category of less than 0.5 m^2 contained the majority (86%) of marine debris on O‘ahu (Fig. 18). The small size class (0.5 – 1 m^2) contained 7% of the debris, and the remaining size classes contained 3% and 4% of the debris, respectively.

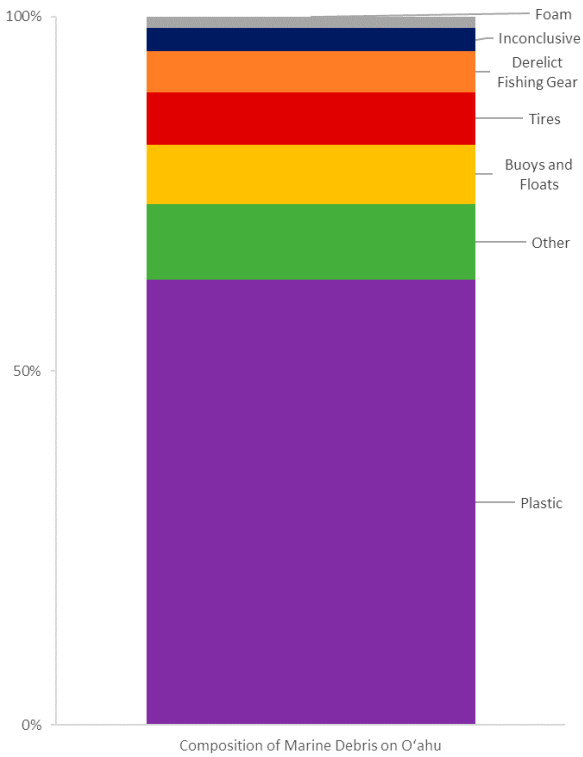


Fig. 17 Composition of marine debris around O'ahu. Derelict Fishing Gear: nets and line; Other: processed wood, metal, cloth, and vessels.

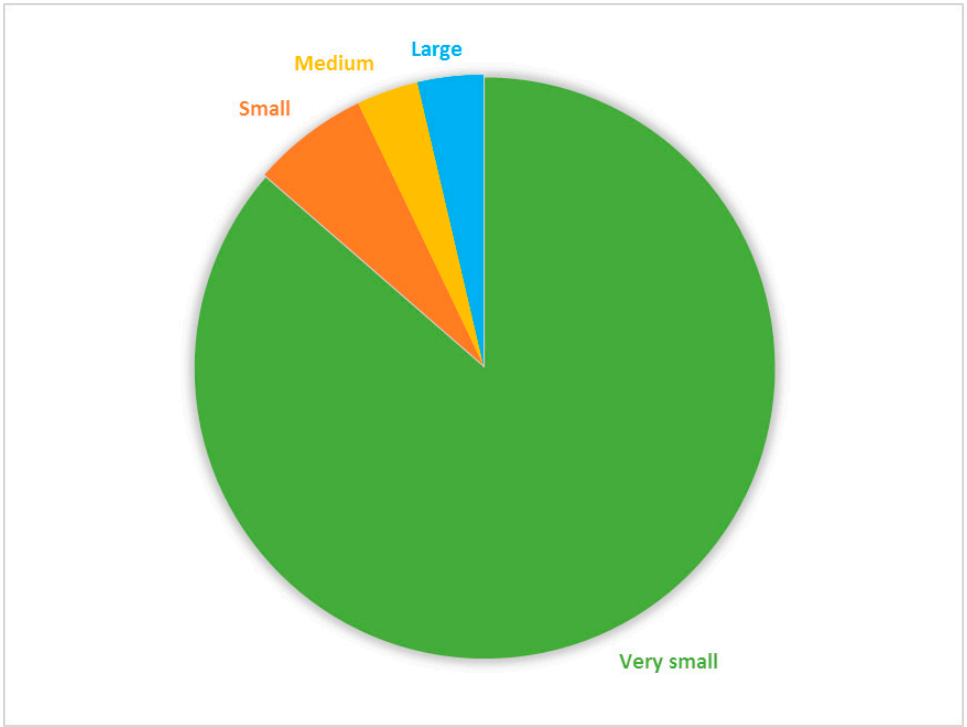


Fig. 18 Debris size distribution on O'ahu. Very Small: < 0.5 m^2, Small: 0.5 – 1 m^2, Medium: 1 – 2 m^2, Large: >2 m^2.

d. Describe any concerns you may have about your project's progress

No significant problems were encountered during the reporting period, and all outlined objectives were accomplished.

e. Completed and planned publications

There are currently no published or in review publications for this project. A baseline report detailing project background, methods, and results for all islands surveyed during this and previous periods is currently being prepared, but it is not planned for submission to a publisher or journal at this time.

f. Poster and oral presentations at scientific conferences or seminars

Hawai'i Coral Reef Initiative submitted an abstract to attend the 13th International Coral Reef Symposium to be held June 19–24, 2016, in Honolulu, Hawai'i, USA (http://coralreefs.org/conferences-and-workshops/13th-international-coral-reef-symposium-hawaii/). Please see abstract below:

"Hawai'i's coral reef ecosystems are valuable natural resources that support a unique and diverse host of marine life, providing sustenance to Hawaii and its inhabitants. The Great Tsunami of 2011 had dire effects on the Japanese coast, creating millions of tons of debris, some of which buoyant enough to float and travel great distances driven by wind and current. Items such as vessels and large docks already have made their way to shores along the Hawaiian Islands damaging, many of Hawaii's fragile reefs. In order to characterize the ecological consequence of tsunami debris, it is important to understand and quantify where the debris is accumulating and the type of debris. Given the remoteness of coastlines in the Hawaiian Islands, large scale surveillance efforts are needed to identify these accumulations. Previous aerial marine studies were conducted in 2006 and 2008 and to continue survey efforts we are analyzing aerial photos to document debris around the Main Hawaiian islands. The project was carried out in three phases, beginning with the collection of high-resolution aerial imagery for the Main Hawaiian Islands and processing to create ArcGIS image files. The second phase was to identify, quantify, and categorize marine debris accumulations along Hawaiian coastlines. Lastly, a final report will be created to showcase our findings. We hope our project will increase awareness to the damages human impacts can impose on Hawai'i's marine ecosystem."

g. Education and outreach

- Presented a summary at the workshop on Mission Concepts for Marine Debris Sensing. 30 participants from NOAA, NASA, UH, DLNR, and a host of other national partners (January 2016).
- Collaborated with the Division of Aquatic Resources' marine debris coordinator to ground truth marine debris identified from aerial imagery analysis on the island of Lanai. The report was given to the DLNR, Division of Boating and Ocean Recreation for their use in possible vessel removal efforts (January 2016).
- Presented the project to the Division of Aquatic Resources (March 2016)
- Shared maps with Megan Lamson at Hawaii Wildlife Fund to solicit feedback.
- Shared monk seal and turtle observations with Brenda Becker at NOAA Fisheries.
- Shared a summary of this project to be included in NOAA's April Marine Debris Action Plan Quarterly.
- Provided a recommendation report to the Department of Land and Natural Resources (DLNR) to help them determine where to conduct marine debris removal efforts (April 2016).
- Collaboration with Pacific Whale Foundation on their digital poster session on marine debris for the IUCN World Conservation Congress.
- Working with the State of Hawaii's, Office of Planning, Hawaii Statewide GIS Program to house the high resolution ortho-imagery of the coastlines of the main eight islands captured and produced by Resource Mapping Hawai'i (RMH) with funding from PICES and Hawai'i Department of Land and Natural Resources (DLNR). Anticipated June 2016.

4. PROGRESS STATUS

Accomplishment of the objectives was achieved within the proposed timeframe, with additional time being used effectively to further our understanding of the data and its implications. This project also provided a solid baseline for future studies, and serves as an example of how aerial imagery can be used to conduct large-scale research assessments. These methods provide numerous possibilities for use on this and other projects in the future.