VOLUME 1

Japanese Marine Debris Aerial Imagery Analysis and GIS Support

JANUARY 2016

Hawaii Coral Reef Initiative
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# CONTENTS

**SECTION 1: BACKGROUND** ................................................................................................................................. 2
  - Marine Debris and the Japanese Tsunami ................................................................................................. 2
  - How Marine Debris Arrives in Hawaii ................................................................................................. 2
  - Marine Debris Impact on the Environment ......................................................................................... 3
  - Previous Aerial Marine Debris Studies ................................................................................................. 3

**SECTION 2: PROJECT OVERVIEW** .................................................................................................................... 4
  - Project Need ............................................................................................................................................ 4
  - Project Objective ................................................................................................................................... 4
  - Deliverables/Outcomes ......................................................................................................................... 4

**SECTION 3: METHODS** ......................................................................................................................................... 5
  - Aerial Imagery Collection and Processing ..................................................................................... 5
  - Marine Debris Classifications and Categories ............................................................................. 5
  - GIS Analysis ........................................................................................................................................ 6
  - Marine Debris Identification ........................................................................................................... 7
  - Quality Control ................................................................................................................................... 8

**SECTION 3: RESULTS** ......................................................................................................................................... 10
  - Niihau .................................................................................................................................................. 11
  - Kauai ................................................................................................................................................... 15
  - Lanai .................................................................................................................................................. 18
  - Hawaii Island ....................................................................................................................................... 21

**NEXT STEPS** .................................................................................................................................................. 25

**ADDITIONAL DENSITY MAPS** ....................................................................................................................... 26

**APPENDIX** ...................................................................................................................................................... 34
  - Appendix A. Examples of types of marine debris .......................................................................... 34
  - Appendix B. Quality Control Protocols .......................................................................................... 45
  - Appendix C. Additional Maps .......................................................................................................... 48
SECTION 1: BACKGROUND

Marine Debris and the Japanese Tsunami

Marine debris is defined as “any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment or the Great Lakes.” The Great Tsunami of 2011 had catastrophic effects along the Japanese coast, which also created millions of tons of debris, some of which buoyant enough to float and travel thousands of miles driven by wind and current. Hawaii is one destination for this debris.

How Marine Debris Arrives in Hawaii

Several oceanographic processes, including gyres, eddies, and meanders, drive the movement and accumulation of marine debris. Hawaii is located in the center of the North Pacific Subtropical Convergence Zone and is largely powered by the Central Pacific Gyre. This gyre is powered by four major ocean currents that stretch across the north central Pacific Ocean from Japan to California. Because circulating bodies of water collect debris in its center, the coastlines of Hawaii receive significant numbers of debris each year.

On March 11, 2011, the Tohoku Earthquake and resulting tsunami devastated Japan, claiming human lives and damaging buildings, homes, vehicles, vessels, and coastal infrastructure. Much of these latter items ended up in the ocean and was subsequently swept away in coastal currents. The first confirmed item of Japanese tsunami-linked marine debris, a blue plastic fishing container, was recovered on September 18, 2012 off Makapuu, Oahu. Since 2012, a number of debris have been intercepted by the state of Hawaii, including 21 vessels and an assortment of buoys, fishing containers, signs, and other items.

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1 PIFSC. 2010. 2008 Main Hawaiian Islands Derelict Fishing Gear Survey. NOAA Fisheries Pacific Islands Fisheries Science Center, PIFSC Special Publication, SP-10-003.
6 Department of Land and Natural Resources. 2015. Division of Aquatic Resources Marine Debris Coordinator. Personal Communication.
**Marine Debris Impact**

In general terms, debris can impact marine ecosystems through wildlife entanglement or ingestion\(^7\), as well as physical damage to crucial habitat such as coral reef. It also presents a hazard to personal and boating safety.\(^4\) In addition, debris could transport species into a new location, thereby introducing a potentially invasive species. For example, a 188-ton dock that arrived on Oregon shores in 2012 carried over 100 different species.\(^3\)

**Previous Aerial Marine Debris Mapping of the Main Hawaiian Islands**

In 2006 and 2008, the NOAA Pacific Islands Fisheries Science Center (PIFSC) Coral Reef Ecosystem Division (CRED) conducted aerial surveys of marine debris in the Main Hawaiian Islands.\(^8\) The surveys were performed from Hughes 500 helicopters flying at 20-60 knots at altitudes of 31-92m. Observers recorded data while in-flight when derelict fishing gear was identified, noting its color, size class, and type of material.

The 2006 NOAA aerial survey identified 711 individual pieces of derelict fishing gear throughout the Main Hawaiian Islands (surveyed islands included Kauai, Oahu, Lanai, Maui, Molokai, and Hawaii Island). This project also completed a cleanup effort on Oahu, removing 225 piles of fishing gear weighing 16 tons. The funding also supported removal of fishing gear from a remote section of Lanai, measuring 17.4 metric tons.

This methodology was repeated in 2008, and identified 1086 points of derelict fishing gear. The increase from the 2006 study is thought to be reflective of refined flying methods. It was hypothesized that the larger debris piles were found at beaches without cleanup efforts because debris began to stick together, leading to massive piles of net and rope.

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SECTION 2: PROJECT OVERVIEW

Project Need
In order to help characterize the potential ecological consequence of tsunami debris, it is important to understand and quantify where the debris is accumulating and the type of debris. Given the vast extent and remoteness of coastlines in the Hawaiian Islands, large scale surveillance efforts are needed to identify these accumulations. Aerial imagery allows for rapid qualitative and quantitative assessments at this scale. This has been shown to be effective in Alaska and British Columbia. Image analysis techniques can provide large-scale understanding of debris distribution along the coastlines of the main Hawaiian Islands.

Once aerial photos are collected, further analysis is needed to identify, quantify, and categorize marine debris accumulations along Hawaiian coastlines. This information can then be used to plan further management actions and evaluate marine debris accumulation patterns in Hawaii.

Project Objective
Analyze aerial photos to document marine debris around the main Hawaiian Islands.

Deliverables/Outcomes
- GIS maps of segments of the main Hawaiian island coastline with locations of marine debris.
- Calculations of the amount of debris, type, and size of accumulations
- Shape file with supporting attribute table
- Summary report of the findings – hours spent, x number of debris, maps
SECTION 3: METHODS

The project was carried out in multiple 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 analyze this imagery using ArcGIS software to identify, quantify, and categorize marine debris accumulations along coastlines of the Main Hawaiian Islands. Phase three involved using the collected data to create maps and figures displaying marine debris composition, density, and distribution for each island, as well as statewide.

Aerial Imagery Collection and Processing

Resource Mapping Hawaii (RMH) was contracted by PICES and Hawaii Department of Land and Natural Resources (DLNR) to produce high resolution ortho-imagery of the coastlines of the main eight islands. Aerial surveys were conducted from a Cessna 206 between August and November 2015. Using an array of three DSLR cameras, multiple photos were captured every 0.7 seconds while flying at an average ground speed of 85 knots per hour. The cameras were mounted on a three-axis stabilizer gimbal to ensure that photos were taken within 4 degrees of crab, roll and pitch angles. The mapping system also includes differential GPS to collect latitude, longitude and altitude data. The surveys had a target altitude of 2000 feet above ground level to achieve a ground resolution of two centimeters per pixel and a swath width between 200-300 meters. Areas where flight restrictions apply, such as military bases and airports, were excluded from the imagery collection process. Using custom photogrammetry software, the aerial photos were mosaicked and ortho-rectified to an accuracy of five meters RMS, then divided into GeoTIFF raster tiles for use in ArcGIS.

Marine Debris Classifications and Categories

Marine debris type was classified into seven categories (Table 1) prior to GIS analysis. These categories were designed to characterize debris found on shorelines, as different debris types can pose different threats to the marine environment. For example, net and line pose a serious entanglement hazard, while small plastics and foam are more likely to be mistakenly ingested by wildlife. While there are limitations on the ability to determine debris types at this scale, categorization of identifiable debris is useful to determine trends in debris accumulation. If a piece of debris was made up of more than one type of material, the main material was listed and the additional materials were included as a comment.
Table 1. Seven categories of marine debris material observed in the aerial imagery. See Appendix A for image examples of each category.

<table>
<thead>
<tr>
<th>Type</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buoys and Floats</td>
<td>B</td>
<td>Any float used for mooring, as a buffer for boats, marking a channel, or fishing. Can be plastic, glass, rubber, foam or metal and can range in size.</td>
</tr>
<tr>
<td>Foam</td>
<td>F</td>
<td>Large blocks used as floats, insulation and packaging material. Foam will often vary in shape and size. Color typically ranges from white to yellow-orange.</td>
</tr>
<tr>
<td>Derelict Fishing Gear</td>
<td>N</td>
<td>Derelict fishing gear includes nets: any netting and line: single pieces of rope, fishing line, tangled rope, string, twine, and any other type of rope that is not woven into netting.</td>
</tr>
<tr>
<td>Plastic</td>
<td>P</td>
<td>All drums, jugs, tubs, buckets, bins, plastic chairs, plastic pallets, tables, gardening items, outdoor equipment like fins and masks, vehicle parts like bumpers and seats, as well as unidentifiable or broken pieces of plastic. Variable colors, shapes, and sizes with a majority of objects being white.</td>
</tr>
<tr>
<td>Tires</td>
<td>T</td>
<td>This category includes full tires and tire treads that have been repurposed as boat bumpers.</td>
</tr>
<tr>
<td>Other</td>
<td>O</td>
<td>Other includes the categories of processed wood, metal, cloth, and vessels: Wood is any wood-based product such as lumber, furniture, crates, pallets, wooden docks, and ply board. This category does not include fallen logs, tree branches, or any wood material that has not been altered by humans. Metal can include sheet metal, metal drums, tanks, machinery, appliances, and metal piping. Cloth includes sheets, sails and canvas, upholstered furniture, and carpet. Vessels are abandoned boats.</td>
</tr>
<tr>
<td>Inconclusive</td>
<td>I</td>
<td>If an item was clearly marine debris but it was not possible to determine the material category, the item was marked as ‘indeterminate.’</td>
</tr>
</tbody>
</table>

Debris was also categorized by size class (Table 2). Four size classes were delineated ranging from less than 0.5 square meters to over 2 square meters.

Table 2. Size classes used to classify items of marine debris.

<table>
<thead>
<tr>
<th>Size Class</th>
<th>Area Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very small</td>
<td>&lt; 0.5 m²</td>
</tr>
<tr>
<td>Small</td>
<td>0.5 – 1 m²</td>
</tr>
<tr>
<td>Medium</td>
<td>1 – 2.0 m²</td>
</tr>
<tr>
<td>Large</td>
<td>&gt; 2 m²</td>
</tr>
</tbody>
</table>

GIS Analysis

ArcGIS line shapefiles were created to divide the island’s coastline into one-mile-long segments, and tile outlines of polygon shapefiles were created for each of the imagery raster tiles, thus matching the aerial imagery files to the segment of coastline they depict (Figure 1). Analysis was conducted on a segment-
by-segment basis to ensure that each area of shoreline was fully analyzed without repetitive analysis of any areas.

Figure 1. Screenshot of the ArcGIS shapefiles depicting the Kauai coastline one-mile line segments and tile polygons, including example image tiles.

**Marine Debris Identification**

Point shapefiles were created by the analyst to mark each item of marine debris found (Figure 2). A unique, sequential identification number was attributed to each item, starting at 1 within each one-mile segment of shoreline. Descriptive data was then collected for each item, including location (latitude and longitude), type of debris, approximate size (area), any comments about the item, and the initials of the observer identifying the debris (Figure 3). Object size was estimated using the measurement tool within ArcGIS, and was categorized by size class.

Figure 2. Screenshot of identified marine debris on the Niihau coast displaying the identification number, line segment, and image tile file name.
Figure 3. Descriptive data including latitude, longitude, material type, and size were added to each item of marine debris in a table.

Following completed analysis of each one-mile segment of shoreline, the segment was given a rating based on density and distribution of debris. Density ratings used were as follows: 0 = no visible debris; 1 = 1-5 pieces of debris; 2 = 6-15 pieces of debris; 3 = 16-30 pieces of debris; 4 = 30+ pieces of debris in pockets or aggregations; 5 = 30+ pieces of debris evenly distributed. Total item count, dates completed, comments, and observer were recorded for each segment in addition to the density rating.

Quality Control

Quality control was performed after analysis was completed, to assess the accuracy and precision of the data collection, identify potential errors, improve standardization of data collection between observers throughout the course of the project, and enhance confidence in the data. The result of the quality control process was the creation of standardized rules (Table 3), which were subsequently used to guide the marine debris identification process. See Appendix B for more information on quality control.
Table 3. Standardized rules for marine debris identification that were used to ensure quality control.

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the minimum qualifying size for marine debris?</td>
<td>If you can make out clear features of the target debris, then count it. If the object is &lt; 0.2m² and ambiguous, disregard the item as inconclusive</td>
</tr>
<tr>
<td>How far inland should I count debris?</td>
<td>On most sand beaches, there is a line of small items washed up by the tide. If there is debris seaward of the high tide line, count it. If it is clear that the waves have washed the debris past the high tide line (you can see water marks and a line of debris past the high tide line), then count it. If the debris is landward of the high tide line, disregard the item as inconclusive.</td>
</tr>
<tr>
<td>What counts as “evenly distributed”?</td>
<td>When classifying the segments according to the debris rating, “evenly distributed” means, “are there clear areas of debris and no debris?”. If so, the segment is not evenly distributed. However, if there are not clear gaps between debris and beach, then that means the segment is evenly distributed. Also, if there is equal spacing between debris, then that segment is evenly distributed.</td>
</tr>
<tr>
<td>What counts as “debris” vs “natural material”?</td>
<td>Any object that is a ‘natural’ color (white, beige, brown) has the potential to be a natural feature (coconut, driftwood, rock). Marine debris should be identified based on its shape (jagged edges, spherical, large objects), color (bright or ‘unnatural’ colors), and size (can range, but very large objects are likely to be debris).</td>
</tr>
<tr>
<td>What do I do if there is a concentrated spot of debris?</td>
<td>If there is a clump or pile of debris, label each individual item as best you can. Marking each item is important for the final debris density statistics.</td>
</tr>
<tr>
<td>What do I do if I can’t tell if an item is processed wood or driftwood?</td>
<td>If it has rounded edges, it is most likely driftwood. If it has square edges, it is probably processed.</td>
</tr>
</tbody>
</table>
SECTION 3: RESULTS
Figure 4. Relative density of marine debris identified around the island of Niihau.
Density and Distribution of Debris

Niihau had the greatest debris densities on its eastern facing shores, particularly on the northeastern corner and a portion of the coast further to the south (Figure 4). All segments on the western coast of the island had 175 or fewer items per one mile. The highest density of debris found was 1,137 items within a one-mile segment, which occurred along the southeastern coast. Three additional segments had a density greater than 600 items per one mile of coast.

Type of Debris

Imagery analysis identified a total of 7,871 pieces of marine debris around the coastline of Niihau (Table 4). The most common type of the debris was plastic (3,665 items, 46%) followed by buoys and floats (2,000 items, 25%), and derelict fishing gear (975 items, 12%) (Figure 5).

Table 4. Count of number of items of each type of marine debris found around Niihau. Derelict Fishing Gear: nets and line; Other: processed wood, metal, cloth, and vessels.

<table>
<thead>
<tr>
<th>Material</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic</td>
<td>3665</td>
</tr>
<tr>
<td>Buoys and Floats</td>
<td>2000</td>
</tr>
<tr>
<td>Derelict Fishing Gear</td>
<td>975</td>
</tr>
<tr>
<td>Inconclusive</td>
<td>472</td>
</tr>
<tr>
<td>Tires</td>
<td>306</td>
</tr>
<tr>
<td>Other</td>
<td>239</td>
</tr>
<tr>
<td>Foam</td>
<td>214</td>
</tr>
<tr>
<td>Total</td>
<td>7871</td>
</tr>
</tbody>
</table>
Figure 5. Composition of marine debris identified around Niihau. *Derelict Fishing Gear*: nets and line; *Other*: processed wood, metal, cloth, and vessels.
Size of Debris

The majority (87%) of marine debris around Niihau fell into the smallest size classification of very small, or less than 0.5m$^2$ (Table 5). The next most common was 0.5 - 1m$^2$ (6%). The remaining size classes 1 - 2m$^2$, and over 2m$^2$ each contained 3% and 4% of the debris, respectively (Figure 6).

Table 5. Count of classified marine debris items by size around Niihau.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Size Class (m$^2$)</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very small</td>
<td>&lt; 0.5</td>
<td>6825</td>
</tr>
<tr>
<td>Small</td>
<td>0.5 - 1</td>
<td>490</td>
</tr>
<tr>
<td>Medium</td>
<td>1 - 2</td>
<td>249</td>
</tr>
<tr>
<td>Large</td>
<td>&gt; 2</td>
<td>307</td>
</tr>
</tbody>
</table>

Figure 6. Percentage of the size of marine debris identified around Niihau. Very Small: < 0.5m$^2$, Small: 0.5 – 1m$^2$, Medium: 1 – 2m$^2$, Large: >2m$^2$. 
Kauai

Figure 7. Relative density of marine debris identified around the island of Kauai.

Density and Distribution of Debris

On Kauai, marine debris was most concentrated on eastern shores, particularly at the northern and southern extents (Figure 7). The highest density of debris was found in a segment on the northeast corner, which contained 276 pieces of debris per one mile of shoreline. Almost all segments on the north, west, and southern shores contained 25 or fewer pieces of debris per mile, with the exception of one segment along the south shore, which had a total of 35 pieces of debris.

Type of Debris

Imagery analysis identified a total of 1,849 pieces of marine debris around the coastline of Kauai (Table 6). The most common type of the debris was plastic (905 items, 49%) followed by buoys and floats (310 items, 27%), and derelict fishing gear (239 items, 13%) (Figure 8).
Table 6. Count of number of items of each type of marine debris found around Kauai.

<table>
<thead>
<tr>
<th>Material</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic</td>
<td>905</td>
</tr>
<tr>
<td>Buoys and Floats</td>
<td>310</td>
</tr>
<tr>
<td>Derelict Fishing Gear</td>
<td>239</td>
</tr>
<tr>
<td>Tires</td>
<td>172</td>
</tr>
<tr>
<td>Other</td>
<td>122</td>
</tr>
<tr>
<td>Inconclusive</td>
<td>55</td>
</tr>
<tr>
<td>Foam</td>
<td>46</td>
</tr>
<tr>
<td>Total</td>
<td>1849</td>
</tr>
</tbody>
</table>

Figure 8. Composition of marine debris identified around Kauai. Derelict Fishing Gear: nets and line; Other: processed wood, metal, cloth, and vessels.
Size of Debris

The majority (84%) of marine debris around Kauai fell into the smallest size classification of very small, or less than 0.5m$^2$ (Table 7). The next most common was 0.5 - 1m$^2$ (7%). The remaining size classes 1 - 2m$^2$, and over 2m$^2$ each contained 4% and 3% of the debris, respectively (Figure 9).

Table 7. Count of classified marine debris items by size around Kauai.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Size Class (m$^2$)</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very small</td>
<td>&lt; 0.5</td>
<td>1569</td>
</tr>
<tr>
<td>Small</td>
<td>0.5 - 1</td>
<td>135</td>
</tr>
<tr>
<td>Medium</td>
<td>1 - 2</td>
<td>84</td>
</tr>
<tr>
<td>Large</td>
<td>&gt; 2</td>
<td>61</td>
</tr>
</tbody>
</table>

Figure 9. Percentage of the size of marine debris identified around Kauai. Very Small: < 0.5m$^2$, Small: 0.5 – 1m$^2$, Medium: 1 – 2m$^2$, Large: >2m$^2$. 
Lanai

Figure 10. Relative density of marine debris identified around the island of Lanai.

Distribution of Debris

Marine debris was heavily concentrated on the northeast coast of the island (Figure 10). The highest density of debris was found in segment 13, which contained 386 items. Most of the segments on the south and west shores had fewer than 50 pieces of marine debris, with the exception of segment 36, which contained 56 items.

Type of Debris

Imagery analysis identified a total of 1,829 pieces of marine debris around the coastline of Lanai (Table 8). The most common type of the debris was plastic (969 items, 53%) followed by items in the “other” category (includes processed wood, metal, cloth, and vessels) (258 items, 14%), and derelict fishing gear (241 items, 13%) (Figure 11).
Table 8. Count of number of items of each type of marine debris found around Lanai.

<table>
<thead>
<tr>
<th>Material</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic</td>
<td>969</td>
</tr>
<tr>
<td>Other</td>
<td>258</td>
</tr>
<tr>
<td>Derelict Fishing Gear</td>
<td>241</td>
</tr>
<tr>
<td>Buoys and Floats</td>
<td>150</td>
</tr>
<tr>
<td>Foam</td>
<td>130</td>
</tr>
<tr>
<td>Tires</td>
<td>71</td>
</tr>
<tr>
<td>Inconclusive</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>1829</td>
</tr>
</tbody>
</table>

Figure 11. Composition of marine debris around Lanai. Derelict Fishing Gear: nets and line; Other: processed wood, metal, cloth, and vessels.
Size of Debris

The majority (86%) of marine debris around Lanai fell into the smallest size classification of less than 0.5m² (Figure 12). The remaining size classes 0.5 - 1m², 1 - 2m², and over 2m² each contained around 5% of the debris (Table 9).

Table 9. Count of number of items of each size class found around Lanai

<table>
<thead>
<tr>
<th>Classification</th>
<th>Size Class (m²)</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very small</td>
<td>&lt; 0.5</td>
<td>1574</td>
</tr>
<tr>
<td>Small</td>
<td>0.5 - 1</td>
<td>97</td>
</tr>
<tr>
<td>Medium</td>
<td>1 - 2</td>
<td>79</td>
</tr>
<tr>
<td>Large</td>
<td>&gt; 2</td>
<td>79</td>
</tr>
</tbody>
</table>

Figure 12. Percentage of types of debris around Lanai. Very Small: < 0.5m², Small: 0.5 – 1m², Medium: 1 – 2m², Large: >2m².
Hawaii Island

Figure 13. Relative density of marine debris identified around the island of Hawaii.
Distribution of Debris

Hawaii Island had the greatest debris densities near the Kamilo Beach area, which is located on the southeastern tip of the island (Figure 13). Highest density of debris items identified was 129 pieces of debris per one-mile segment. All western facing shores had 25 or fewer pieces of debris per one-mile segment of coast. Small portions of the eastern coast, particularly to the north, had relatively higher densities, but no density higher than 75 items per mile was found anywhere except for the Kamilo Beach area on the southeastern tip.

Type of Debris

Imagery analysis identified a total of 2,200 pieces of marine debris around the coastline of Hawaii Island (Table 10). The most common type of the debris was plastic (1138 items, 52%) followed by buoys and floats (271 items, 12%), and other (206 items, 9%) (Figure 14).

Table 10. Count of number of items of each type of marine debris found around Hawaii Island. Derelict Fishing Gear: nets and line; Other: processed wood, metal, cloth, and vessels.

<table>
<thead>
<tr>
<th>Material</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic</td>
<td>1138</td>
</tr>
<tr>
<td>Buoys and Floats</td>
<td>271</td>
</tr>
<tr>
<td>Other</td>
<td>206</td>
</tr>
<tr>
<td>Inconclusive</td>
<td>194</td>
</tr>
<tr>
<td>Derelict Fishing Gear</td>
<td>180</td>
</tr>
<tr>
<td>Tires</td>
<td>134</td>
</tr>
<tr>
<td>Foam</td>
<td>77</td>
</tr>
<tr>
<td>Total</td>
<td>2200</td>
</tr>
</tbody>
</table>
Figure 14. Composition of marine debris around Hawaii Island. Derelict Fishing Gear: nets and line; Other: processed wood, metal, cloth, and vessels.

Size of Debris

The majority (85%) of marine debris around Lanai fell into the smallest size classification of less than 0.5m² (Figure 15). The remaining size classes 0.5 - 1m², 1 - 2m², and over 2m² each contained around 5% of the debris (Table 11).
Table 11. Count of number of items of each size class found around Hawaii Island.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Size Class (m²)</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very small</td>
<td>&lt; 0.5</td>
<td>1880</td>
</tr>
<tr>
<td>Small</td>
<td>0.5 - 1</td>
<td>115</td>
</tr>
<tr>
<td>Medium</td>
<td>1 - 2</td>
<td>127</td>
</tr>
<tr>
<td>Large</td>
<td>&gt; 2</td>
<td>78</td>
</tr>
</tbody>
</table>

Figure 15. Percentage of types of debris around Hawaii Island. Very Small: < 0.5m², Small: 0.5 – 1m², Medium: 1 – 2m², Large: >2m².
NEXT STEPS

The next report for this project will include information on amount of debris, type, and size of accumulations for the remaining islands: Maui, Molokai, Oahu, and Kahoolawe. An inter-island summary will also be including describing trends in marine debris accumulation across the Main Hawaiian Islands. The report will also include GIS maps, figures, and tables.
ADDITIONAL DENSITY MAPS

Niihau

Niihau Marine Debris Density
Density rating for each 1-mi segment

Segment Rating
- 0 = no visible debris
- 1 = 1-5 pieces of debris
- 2 = 6-15 pieces of debris
- 3 = 16-30 pieces of debris
- 4 = 30+ pieces of debris (aggregations)
- 5 = 30+ pieces of debris (even distribution)

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.
Kauai Marine Debris Density
Density rating for each 1-mile segment

Segment Rating
- 0 = no debris found
- 1 = 1-5 pieces of debris
- 2 = 6-15 pieces of debris
- 3 = 16-30 pieces of debris
- 4 = 30+ pieces of debris (aggregations)
- 5 = 30+ pieces of debris (even distribution)

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 Grant Funds through DLNR.
Kauai Debris Density by Item Type

Number of items per segment for three main debris types

- Plastic
- DFG (net & line)
- Buoys
- Total Count

Number of items:
- No debris found
- 1-24
- 25-74
- 75-124
- 125+

Actual Item Locations

10 Miles
Lanai Marine Debris Density

Density rating for each 1-mile segment

Segment Ratings
- 0 = no visible debris
- 1 = 1-5 pieces of debris
- 2 = 6-15 pieces of debris
- 3 = 16-30 pieces of debris
- 4 = 30+ pieces of debris (aggregations)
- 5 = 30+ pieces of debris (even distribution)

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Lanai Debris Density by Item Type
Number of items per segment for three main debris types

Plastic

DFG (net & line)

Buoys

Total Count

Number of Items
- No debris found
- 1 - 25
- 26 - 75
- 76 - 150
- 200 +

Actual item locations

2 Miles
Hawaii Island

Big Island Marine Debris Density

Density rating for each 1-mile segment

Segment Rating

0 = no visible debris
1 = 1-5 pieces of debris
2 = 6-15 pieces of debris
3 = 16-30 pieces of debris
4 = 30+ pieces of debris (aggregations)
5 = 30+ pieces of debris (even distribution)

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APPENDIX

Appendix A. Examples of types of marine debris

Buoys and Floats:
Cloth:
Foam:
Metal:
Plastic:
Tire:
Wood:
Vessel:
Indeterminate:
Appendix B. Quality Control Protocols

1. QC was performed 1 mile coastline segments. 20% of the line segments for each island will be selected at random using a random number generator.
2. Marine debris observers were not made aware of which line segments are designated as QC segments until after that segment has been completely processed.
3. Marine debris was identified in the QC segments in the exact same way as the original analysis.
4. Once a QC line segment is fully processed it was compared against the original and discrepancies between the datasets were quantified.

To quantify how consistently observers identify debris, percent accuracy was used:

\[
\text{Original analysis } \% \text{ accuracy} = \frac{\text{total debris identified} - \text{debris only identified in QC}}{\text{total debris identified}} \times 100
\]

\[
\text{QC analysis } \% \text{ accuracy} = \frac{\text{total debris identified} - \text{debris only identified in OG}}{\text{total debris identified}} \times 100
\]

\[
\text{Total } \% \text{ accuracy} = \frac{\text{total debris identified} - \text{debris only identified in QC and OG}}{\text{total debris identified}} \times 100
\]

QC Results Summary:

Accuracy increased in later analyses and the large gap in consistency between the original analysis and QC analysis also decreased. This suggests that observers were becoming more discerning in identifying debris over time. The original and QC analysis had a statically similar percent accuracy (ANOVA, F = 0.14, p = 0.72), there was little variation between the two separate analyses in the number of debris items identified. However, there was a statistically significant difference in the total debris items identified between the two analyses (ANOVA, F = 4.53, p = 0.02). Therefore, observers should be aware of commonly overlooked items and natural items that are commonly identified as debris.
The QC process in the formation of the following marine debris identification rules:

1. If you can make out clear features of the target debris, then count it. If the object is <0.2m² and ambiguous, disregard the item as inconclusive.

2. On most sand beaches, there is a line of small items washed up by the tide. If there is debris seaward of the high tide line, count it. If it is clear that the waves have washed the debris past the high tide line (you can see water marks and a line of debris past the high tide line), then count it. If the debris is landward of the high tide line, disregard the item as inconclusive.
3. When classifying the segments according to the debris rating, “evenly distributed” means, “are there clear areas of debris and no debris?”. If so, the segment is not evenly distributed. However, if there are not clear gaps between debris and beach, then that means the segment is evenly distributed. Also, if there is equal spacing between debris, then that segment is evenly distributed.

4. Any object that is a ‘natural’ color (white, beige, brown) has the potential to be a natural feature (coconut, driftwood, rock). Marine debris should be identified based on its shape (jagged edges, spherical, large objects), color (bright or ‘unnatural’ colors), and size (can range, but very large objects are likely to be debris).

5. If there is a clump or pile of debris, label each individual item as best you can. Marking each item is important for the final debris density statistics.

6. If it has rounded edges, it is most likely driftwood. If it has square edges, it is probably processed.
Appendix C. Additional Maps

Niihau Marine Debris Density in Relation to Reef Habitat

Number of Items
- No debris found
- 1 - 175
- 176 - 350
- 351 - 550
- 500 +
- Coral Reef and Hardbottom

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Kauai Derelict Fishing Gear
Comparing the 2008 NOAA study to current findings

DFG Locations
- 2015 Study
- 2008 Study

<table>
<thead>
<tr>
<th>Year</th>
<th>Total # of Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>373</td>
</tr>
<tr>
<td>2015</td>
<td>239</td>
</tr>
</tbody>
</table>

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.
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Comparison of 2015 Project results and the PICES Japanese Tsunami Marine Debris report database
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Big Island Derelict Fishing Gear
Comparing the 2008 NOAA study to current findings

DFG Locations

- 2015 Study
- 2008 Study

<table>
<thead>
<tr>
<th>Year</th>
<th>Total # of Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>324</td>
</tr>
<tr>
<td>2015</td>
<td>180</td>
</tr>
</tbody>
</table>

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.
Big Island Debris Density in Relation to Reef Habitat

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