I. PROGRESS UPDATE – UNIVERSITY OF HAWAII AT MANOA

PROJECT TITLE:	**Synthesizing the State of Debris in Hawaii from 2015 Aerial Imagery and Spatial Analysis Data**
ORGANIZATION**:**	Hawaii Coral Reef Initiative; Social Science Research Institute
PRINCIPAL INVESTIGATOR:	Dr. Michael Hamnett hamnett@hawaii.edu, Kristine Davidson kgd@hawaii.edu, Brian Neilson Brian.J.Neilson@hawaii.gov
PROJECT PERIOD:	June 1, 2016 –December 15, 2016
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II. YEAR 3 PROGRESS SUMMARY

In 2015 and 2016 PICES and the Government of Japan Gift Fund for States administered by the Hawaii Department of Land and Natural Resources (DLNR) and the National Oceanic and Atmospheric Administration (NOAA) jointly funded *Mapping Patterns of Marine Debris in the Main Hawaiian Islands Using Aerial Imagery and Spatial Analysis*. The project was completed in three phases:

1. Aerial surveys of the eight main Hawaiian Islands (MHI) conducted in Fall 2015
2. Analysis of aerial imagery to identify and quantify coastal marine debris accumulations.
3. Interpreting and sharing the study's findings with resource managers and public partners.

Year 3 of the project focused on refining the data, recognizing the shortcomings of the aerial imagery analysis and supplementing the imagery with additional information. During the analysis, the project identified 52 suspected marine debris vessels. However the resolution of the imagery limited the analysts' ability to definitively conclude these vessels were, in fact, verifiable abandoned and derelict vessels (ADVs). Therefore, the project conducted *in situ* ground observations and found only 27 vessels from the imagery were ADVs.

It was a priority for the project to identify debris from the Tōhoku Earthquake and resulting tsunami of March 2011, and vessels were the only item large enough to recognize as potential Japanese tsunami marine debris (JTMD). The study compared the aerial imagery against historical satellite imagery in Google Earth (2016) to rule out all vessels present before 2012 and used observations from the in situ ground truthing to evaluate the vessels for shared characteristics with previously confirmed JTMD vessels. Of the 27 ADVs inspected, ten were submitted to the Japanese Consulate for confirmation as potential JTMD. In July, the project presented the findings to the DLNR's Division of Boating and Ocean Recreation (DOBOR), accompanied by a 60-page summary of the 27 ADVs identified and inspected to assist management and resource prioritization at the state agency.

To further refine the usefulness of the imagery analysis, the project acknowledged an unknown possible influence of cleanups occurring year-round throughout the state. It was important to account for the possibility of a cleanup event immediately preceding the date of imagery capture such that potentially hundreds of items may have been removed from the beach that would have otherwise been counted during the analysis. Year 3 synthesized the marine debris accumulation data with past community cleanup efforts. The project contacted over 50 organizations and received more than 2000 reports of marine debris removals in the months preceding the autumn 2015 aerial surveys. Under further examination, only sixteen cleanups were conducted within two weeks of the respective imagery capture dates on any beach. Only one cleanup preceded a flight by less than 24 hours and involved net removals that did not alter the accumulation rating for that beach. Similarly, of the 16 cleanups that occurred within two weeks of the flights, only four segments may have been adjusted to a higher rating. Beaches where cleanups occurred most frequently were also rated with some of the highest debris accumulations in the islands, even with the relatively frequent cleanups removing more than a ton of debris in a single event.

However, within one year prior to the flights, there were beach cleanups on 68 different segments throughout the MHI. Removals ranged from a few fishing nets to truckloads of miscellaneous debris. Without knowledge of the rate of debris deposition and retention for those coastlines, it is impossible to adequately measure the impact of marine debris removals on our accumulation study, but it is worth noting that well over 30,000 man-hours of beach removals contributed to more than 70 metric tons of debris being removed from the MHI in 2015, and may have had a significant effect on the overall debris count distribution between shorelines and between islands.

With more than 1000 miles of coastline analyzed, the project endeavored to effectively communicate the significance and usefulness of the method and the analysis via public presentations, scientific conferences, newsletters, television stations, and newspapers. All imagery is available online hosted by the State of Hawaii Office of Planning website and a summary of the project was arranged into an interactive Story Map from ArcGIS Online, currently available at http://arcg.is/29tjSqk. This map is a useful tool for sharing the project findings and for education and outreach purposes. The map shows current hotspots and past removal effort coverage. It can be used to plan future cleanups and was a catalyst for developing a statewide resource for cleanup groups under the newly formed Hawaii Environmental Cleanup Coalition. In this statewide collaboration, groups will contribute cleanup data to spatial mapping experts who will update a public map to share cleanup coverage and debris removal throughout the MHI.

Few problems were encountered during this reporting period that hindered progress in the project's deliverables. There were limitations to the analysis' usefulness. Beach cleanups were difficult to account for without accumulation rates, and also due to the varied forms of documenting cleanups across the different organizations. Ultimately, some cleanups that were reported were discarded because of poor data integrity, lack of measurements, or inability to tease out what was marine debris and what was marine litter. This identified a statewide limitation that inspired cleanup organizations to sit down and strategize how to collect more useful data. With regards to ADVs, some were lost due to the time elapsed between aerial detection and ground truthing. Furthermore, removal of JTMD vessels is very costly and some of the ADVs detected in the study are beyond the capacity of the DLNR to remove. The state is working internally to overcome these challenges.

III. ABSTRACT

In 2015 and 2016, PICES jointly funded *Mapping Patterns of Marine Debris in the Main Hawaiian Islands Using Aerial Imagery and Spatial Analysis* with support provided by the State of Hawaii Department of Land and Natural Resources (DLNR) via the "Gift of Japan" fund to Pacific coast states administered through the National Oceanic and Atmospheric Administration (NOAA) from the Government of Japan. Aerial surveys of the eight main Hawaiian Islands (MHI) were conducted and the resulting imagery was analyzed to identify and quantify marine debris on Hawaiian coastlines.

The analysis concluded that about 12% of coastlines are areas of high marine debris accumulation, concentrated primarily on windward (north- and east-facing shores). The debris was evenly distributed throughout the MHI with the exception of Niihau, the northernmost and privately owned island, which had the highest concentration of debris (38% statewide). All other islands had less than 15% each, Oahu with the lowest at just 5% statewide.

In total, the project counted over 20,000 individual items of debris. Plastics were overwhelmingly the dominant debris type by category, accounting for 80% of total debris. Vessels, metal, cloth, tire, processed wood, foam, and unknown debris types made up the remaining 20% combined. This project provided a baseline of marine debris densities at a moment in time, and worked with federal, state, and local agencies to prioritize areas of highest need for debris removals and monitoring.

In addition, the analysis identified 52 vessels from the imagery that were difficult to definitively classify as abandoned and derelict vessels (ADVs). The project arranged for all 52 vessels to be further scrutinized through in situ evaluations and determined that only 27 vessels were in fact ADVs. Ten were identified as potential Japanese tsunami marine debris (JTMD), four of which were soon after officially confirmed as JTMD by the Japanese Consulate.

The final phase of refining the aerial survey analysis was the study of marine debris cleanup events that occurred prior to the flyover dates for each island. The project received removal data from over 20 federal, state, city & county, and private groups totaling more than 2000 cleanups. This effort represented at least 70 metric tons of debris removed and well over 30,000 man-hours. The time elapsed between flights and cleanup dates was used to evaluate any potential impact of debris removals on the apparent debris accumulations for a segment, and this spatial information was then made publicly available online.

Most importantly, the overall goal of the project was to prepare a public resource to share the study's findings. This data is available in the form of reports, a manuscript for a peer-reviewed publication, symposium and conference presentations, and an online ArcGIS Story Map at http://arcg.is/29tjSqk. The imagery is also available publicly through the Hawaii State Office of Planning.

IV. PROJECT DESCRIPTION

Research Purpose

In order to evaluate 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 necessary 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.

Objectives

The objective of this project was to document and describe marine debris on coastlines of the MHI through high-resolution aerial imagery paired with ArcGIS mapping software to locate, quantify, and categorize debris accumulations. Additionally, the project aimed to disburse and distribute its findings through peer-reviewed journal publication, presentations, conferences, and online resources.

Methods

The project was divided into a series of stages, (1) collect and process the high resolution aerial imagery of the MHI' coastlines to create ArcGIS image files, (2) analyze this imagery using ArcGIS software to identify, quantify, and categorize each distinct point of debris and use the collected data to generate maps and figures of debris composition, density, and distribution for each island as well as statewide, and (3) refine the results through in situ ground truthing of suspected ADVs and analysis of prior beach cleanups.

1. Aerial Imagery Collection and Processing

Resource Mapping Hawai‘i (RMH) was contracted by PICES and DLNR to conduct aerial surveys 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. 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 included differential GPS to collect latitude, longitude and altitude data. The surveys had a target altitude of 2,000 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 orthorectified to an accuracy of five meters RMS, then divided into GeoTIFF raster tiles for use in ArcGIS.

2. *Imagery Analysis for Debris Composition, Density, and Distribution*

Marine debris type was classified into seven categories (Table 1) prior to GIS analysis. 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. Debris was also categorized into size classes: very small (< 0.5 m^2), small (0.5 - 1.0 m^2), medium (1.0 - 2.0 m^2), or large (> 2.0 m^2). Size was measured as the approximate area of the object in meters squared, estimated using the measurement tool within ArcGIS.

Table 1: Seven categories of marine debris materials observed in the aerial imagery.

Material	Description
Plastic	Any items made from plastic as well as plastic fragments; usually identified by bright colors and/or sharp edges
Buoys and Floats	Any float used for mooring, as a buffer for boats, marking a channel, or fishing; can be plastic, glass, rubber, foam or metal
Derelict Fishing Gear (DFG)	Includes all woven netting and any type of line such as rope, fishing line, twine, etc.
Tires	Full tires and tire treads
Foam	Includes flotation, insulation, and packaging material
Other	Items consisting of processed wood, metal, or cloth, as well as vessels and vessel fragments that appear abandoned or derelict
Inconclusive	Items that were identified as marine debris, but could not be confidently classified into a material category

Line shapefiles divided each island's coastline into 1.6 km 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. Each segment was systematically surveyed and every point of debris recorded with its latitude, longitude, category, size, observer, and any relevant comments (Fig. 1).

Segments were further categorized by debris density; any segment with 100 debris items or more was considered a hotspot of debris accumulation. During the statewide analysis process, all segments were regrouped into 8-kilometer lengths to improve the visual usefulness of the statewide accumulation map at the required scale.

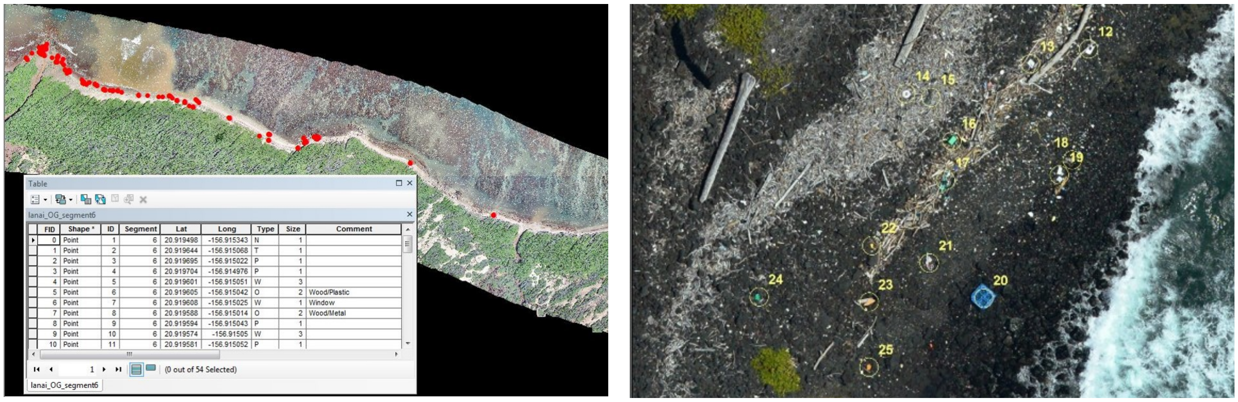

Figure 1: A swath of Kaua'i coastline in ArcGIS and the data table of the identified dots of debris (left), with a zoomed screenshot of identified marine debris with numbers on Kamilo Point, Hawaii Island (right)

3. Refining the Data: In Situ Ground Truthing ADVs and Beach Cleanup Analysis

The project recognized two shortcomings to the aerial imagery analysis: the resolution wasn't fine enough to determine whether vessels were in use or truly marine debris, and the analysis did not take into account the possibility that a beach cleanup group may have removed debris immediately prior to the aerial surveys, potentially altering the segment's classification as a marine debris hotspot. In the third phase of the project, we attempted to address these deficiencies.

All debris items detected and categorized as vessel were inspected to verify their status as marine debris. Each vessel's position relative to the high water mark, location, condition, and description were measured in situ. Additionally, the project used historical imagery from Google Earth to evaluate the likelihood of a vessel being JTMD; if a vessel was present in the imagery before 2012, it was not JTMD. Any suspected JTMD was evaluated for characteristics consistent with confirmed JTMD ADVs such as color, shape, size, and the presence of Japanese letters or registrations (Fig. 2)

Figure 2: JTMD vessels detected in the aerial imagery (top) and their corresponding in situ photo (bottom).

For beach cleanups, the project contacted over 50 community members, federal, state, and local organizations, and received over 2000 reports of marine debris removals. Those reports were catalogued by date, location, participants, duration, distance covered, and the debris removed was reported in various combinations of item counts, total weight removed, or man hours. The locations were nearly all reported by common name of the beach or area targeted, and the project approximated the coordinates. Events that only addressed litter or did not occur on coastlines were discarded.

Results

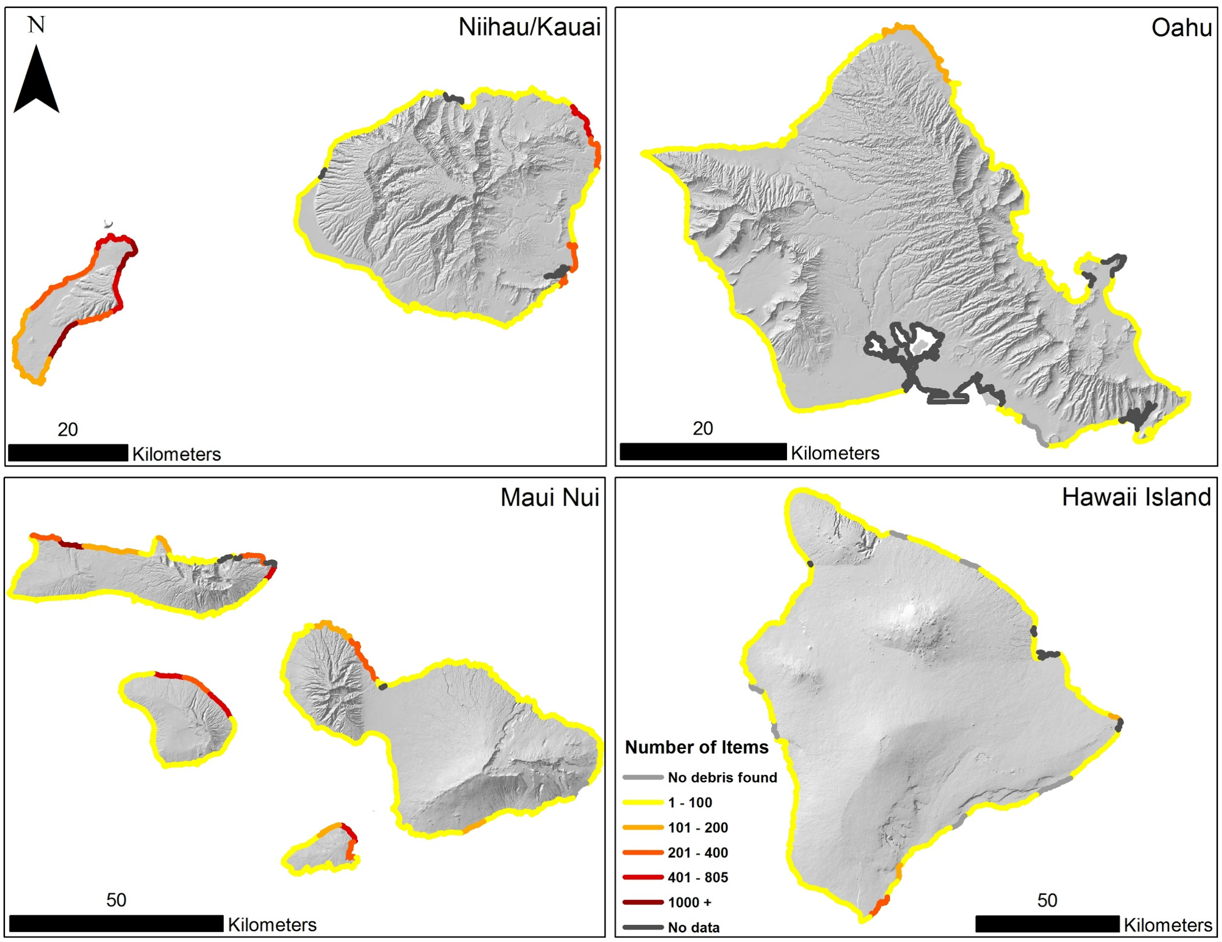

Figure 3: Density and distribution of debris on the MHI showing marine debris "hotspots," or segments with 100 or more items. Segments were divided into 8 km lengths to improve visual interpretability.

The project analyzed the data for each of the eight islands and created a 96-page report providing in-depth results by island in the DLNR publication, *Japanese Tsunami Marine Debris Aerial Imagery Analysis and GIS Support Final Report* (2016). That document is posted publicly on DLNR's Division of Aquatics website on the Reports page (http://dlnr.hawaii.gov/dar/reports/).

Marine debris was heavily concentrated on the island of Niihau. Niihau contained 38% of the total debris identified across all of the islands surveyed. All other islands contained 14% or less of the total debris identified, with Oahu being the least dense, containing only 5% of the total debris. Debris density was not reflective of coastline length or number of segments (Fig. 4). On all islands, marine debris was primarily concentrated on north and east-facing shores, with west-facing shores containing the least amount of debris (Fig. 3).

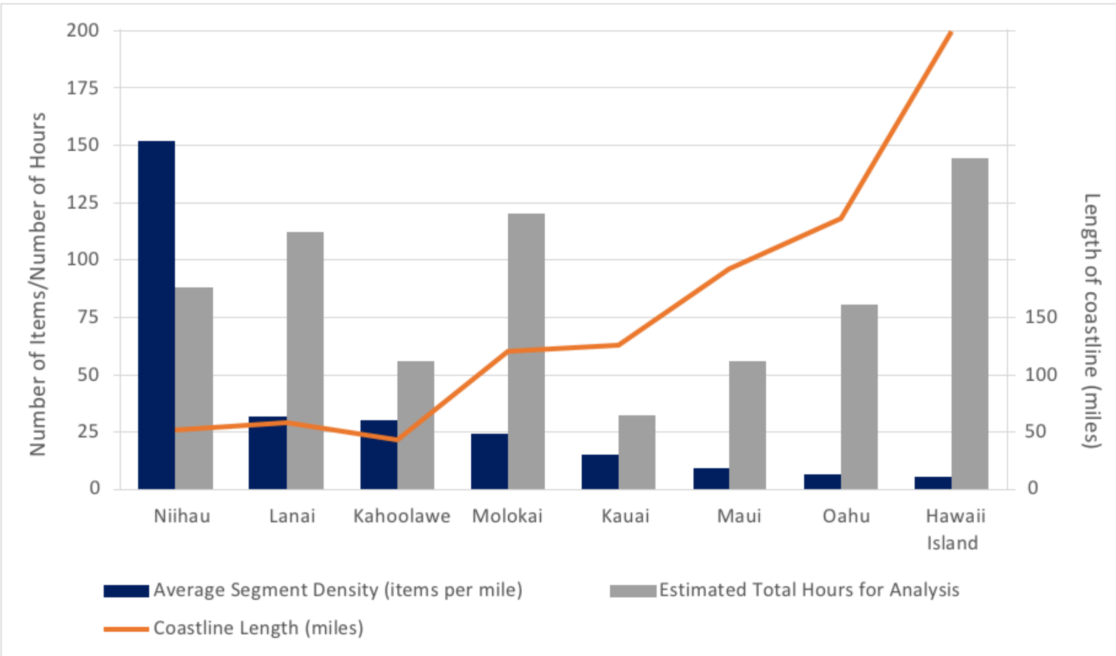

Figure 4: Average number of debris items found per 1-mile segment of coastline for the MHI, in relation to total coastline length in miles.

The imagery analysis identified a total of 20,658 pieces of marine debris. Composition of debris varied between islands, but the most common type of debris on all islands was plastic (not including buoys, floats, net and line), which made up 47% of the overall composition of debris identified and at least 37% on any individual island. 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. As the vast majority of buoys, floats, and derelict fishing gear are plastic, the total average plastic composition of debris on any one island was around 80%. Tires and foam each made up less than 10% of the debris 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.

The size class distribution of identified debris was far more unanimous across all islands. The "very small" category (< 0.5 m^2) made up 86% of the total debris found on all islands, and contributed 84% to 89% on any one island. The remaining categories each made up less than 10% on any island, with the total contribution statewide from the small category (0.5 m^2 – 1 m^2)

being 6% and the total contribution from the remaining size classes (1 m^2 – 2 m^2 and > 2 m^2) being 4% each. Items much smaller than 0.5 m^2 were increasingly difficult to distinguish in the aerial imagery.

Larger items such as vessels proved easier to identify and measure, but still posed challenges to the analysis. Of the original 52 vessels detected in the aerial imagery analysis, only 27 were determined to be ADVs. Of those 27, the project was unable to locate six based on the coordinates observed in the aerial imagery. These vessels were presumed lost and in five cases, broken pieces of wood, an engine, a Japanese fuel pump, fragments of registration numbers, and other evidence was observed seeming to indicate that the vessels were washed out and broken up after being captured in the imagery. All six of the lost vessels shared characteristics with other JTMD ADVs and the Japanese Consulate later confirmed three as JTMD. In total, four suspected JTMD ADVs were submitted to the Consulate, NOAA, and DLNR-DOBOR for confirmation.

Once the imagery analysis concluded, beach cleanup data was compiled to evaluate the potential influence of removals on shoreline density ratings. 2,134 individual cleanup events were reported to the project by 21 separate organizations at the federal, state, local, and private level. Only 376 of those occurred within 365 days of a flyover date for the corresponding island, and occurred on 68 out of the 1,223 segments, or approximately 5% of the full coastline of the MHI. Within two weeks of flights, there were only sixteen cleanups that occurred on ten different segments. Four of those cleanups may have caused the analysis to underestimate the appropriate rating for their corresponding segment, but these amounts of debris removed do not alter the overall distribution of debris between islands by more than 1%. Only one cleanup occurred on the same day as a flyover on Kauai and involved a few derelict fishing gear removals, but would not have altered the segment rating had it occurred after the imagery was taken (Fig. 5).

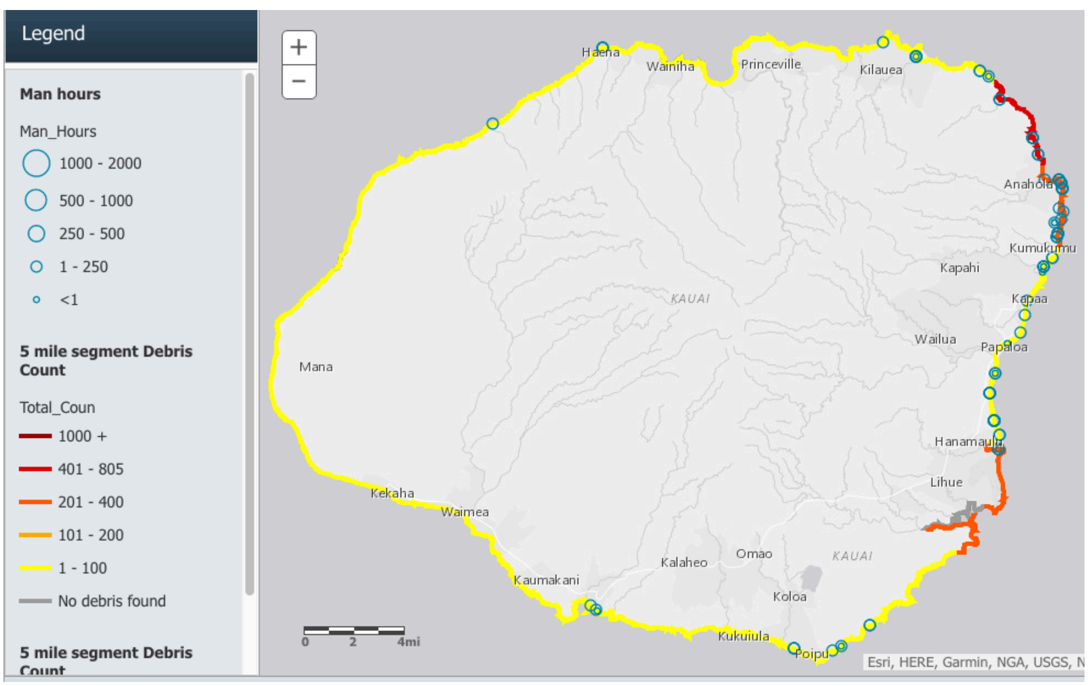

Figure 5: Sample screenshot of Kauai showings how man-hours were mapped over segment ratings.

Discussion

Imagery Capture Methodology

Marine debris is detected by a variety of technologies beyond aerial surveys with different results. NOAA (2015) compared the more common methods for detecting JTMD and prioritized high-resolution and wide-range coverage due to the diversity of debris types and spread of debris fields at sea. In this evaluation, the NOAA report concluded that satellite sensors are at the boundary of their ability to detect small debris and that the currently available unmanned aerial system (UAS) platforms were still inadequate and experimental. UAS can offer higher resolution but do not have the required range to replace aerial surveys. While both of these technologies are further developed and improved, the most effective method available for both land-based and at-sea detection of marine debris is the aerial platform.

Previous attempts to locate and characterize debris in the MHI through aerial surveys were done at oblique angles and relied on in-flight observations rather than post-flight analysis (PIFSC, 2010). Similarly, an Alaska survey collected and analyzed geotagged photos but without mosaicking. This process of locating debris is more tedious and less reliable. Overall, the combination of 2 cm resolution and orthorectified mosaicked imagery allowed our analysts to pan seamlessly through the coastlines of each island. When the team encountered items that were difficult to identify, it was easy to revisit the imagery with other analysts or even provide latitude and longitude coordinates for in situ ground truthing. The imagery is useful beyond marine debris and can be used for a variety of other purposes including wildlife observations, sediment runoff, historic and cultural landmarks, and shoreline erosion.

The Analysis

The distribution of debris within the MHI strongly indicated the prevalence of debris on the windward side, as 76% ± 7.1% of debris was found on these North- and East-facing shores. This is likely due to a combination of oceanic drivers, particularly a northwesterly current running alongside the east of the island chain and the prevailing trade winds from the northeast that drive debris from the Pacific Garbage Patch (Blickley et al., 2016; PIFSC 2010). These factors may also explain why Niihau, the northernmost main Hawaiian island, had 38% of all debris in the state and all other islands had less than 14% each. It is important to evaluate the relative abundance of debris within the eight MHI to assist regulatory agencies like the DLNR and community cleanup organizations with prioritizing debris removal efforts, resources, and monitoring to improve the overall understanding of marine debris' impact in the state.

The study was limited in its ability to detect items much smaller than a detergent bottle on the shoreline. Though the imagery was high-resolution, categorizing debris became increasingly difficult with smaller items. Despite the difficulty of detecting small items, very small (< 0.5 m^2) items were the majority of all debris found. Items in this smallest size class are predominantly plastic (Gregory & Ryan 1997; Martin and Sobral 2011; Moret-Ferguson et al 2010) and given the study's inability to detect the smallest items on the beach, the proportion of plastics in the debris makeup is likely severely underestimated. The dominance of plastic on the beach is consistent with a review by Gregory & Ryan (1997) that found plastics accounted for 60% - 80% of all debris in a number of studies. The global use of plastics has increased over the past 45 years and its proliferation continues to exacerbate the problem of marine debris, and more recently, microplastics in our environment (Barboza 2015; Derraik 2002; Gall & Thompson 2015; Vegter et al 2014). While the current survey was unable to address the question of microplastics, the prolific abundance of plastic within the overall debris makeup suggests a more insidious problem that modern sensor technologies cannot adequately measure.

Refining the Results

Following the analysis, the in situ ground truth observations for vessels demonstrated the shortcomings of the imagery to identify whether a vessel was an ADV or in use. However, the method proved very effective in detecting and locating vessels. Since the first JTMD vessel was reported in the MHI in 2012, there have been four to ten JTMD ADVs reported each year (DLNR, personal communication). In 2015, ten vessels were reported to DLNR. The aerial surveys increased detection by nearly twofold, identifying eight unreported potential JTMD vessels. These ADVs were nearly all in isolated and relatively inaccessible coastlines where marine debris goes unreported, further demonstrating the advantage of the aerial surveys. Additionally, six of those eight vessels were lost within six months of initially being detected on shore. Detecting and removing ADVs is extremely time sensitive to reduce the threat of a vessel returning to sea and inflicting further harm on the marine environment.

The results of the beach cleanup analysis demonstrate that the removals from 2015 had little to no discernable effect on the statewide hotspot assessment. Beaches where debris cleanups occurred regularly were still hotspots of marine debris accumulation. However, these hotspots were rated using a measure of relativity – segments with more than 100 debris items. Niihau had a segment with over 1000 pieces of debris. Statewide cleanups may have an impact on the unequal distribution of debris between the eight MHI, particularly between Niihau (38%) and Oahu (5%), but further research on the rate of deposition and the oceanic processes affecting the individual islands is needed.

Challenges

Initially, capturing the imagery proved to be a challenge for the project's partner Resource Mapping Hawaii. All flights had to be scheduled in as small a time frame as possible to reduce the influence of temporal variations on debris accumulations. There were restricted airspaces that had to be omitted from the process, and several areas of coastline presented a hazardous challenge as the Cessna aircraft attempted to maintain the necessary altitude without flying too closely to some of Hawaii's more dramatic coastlines. About 10% of the coastlines of the MHI were left out of the analysis due to these challenges.

During the analysis, the team made an unexpected improvement in processing speed. The first few weeks started out slowly as the analysts familiarized themselves with the protocols and the software, but after a month their efficiency increased dramatically. The imagery mosaicking process eventually became the bottleneck of progress. The analysts revisited the segments they initially processed to perform quality control and also to reevaluate some of the unidentified debris, having become more familiar with the different types of marine debris in the imagery.

There were limitations in the project with the chosen method of a snapshot accumulation study. Seasonal variation and change over time couldn't be measured with a single set of flyovers, but it did provide a baseline for future accumulation studies. The project also did not plan for the possibility of a cleanup organization clearing all the debris from a segment the day before the flyovers. With the support of ADRIFT Year 3, the project was able to verify there were no cleanups immediately prior to the surveys. In future aerial survey studies, local cleanup groups should be notified and asked to refrain from cleaning the coastline until after the flights are completed. Starting in 2017, Hawaii's cleanup organizations will enter into a new data-sharing endeavor to increase transparency and coordination to cleanup efforts throughout the MHI.

Achievements

The project was successful in creating a baseline of marine debris in the MHI and was the first comprehensive debris evaluation in the state. Employing a unique methodology, the study provided strong evidence of the accumulation patterns and densities throughout the islands and also identified suspect JTMD items of major concern throughout the Pacific. This first endeavor to collate cleanup data from all organizations throughout the state also initiated a statewide data-sharing movement towards applying the spatial mapping and meta-data analysis techniques from this project to all cleanups in the MHI since 2004. This PICES ADRIFT project inspired a cooperative shift in the marine debris network of Hawaii to better document and share cleanups under the Hawaii Marine Debris Action Plan (NOAA Marine Debris Program 2016) and the newly formed Hawaii Environmental Cleanup Coalition of 2017, and both its spatial mapping method and aerial survey method are priorities for the state to continue using in the future.

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V. OUTPUTS

Starting in December 2015, the project began its public circuit at *The International Symposium on Marine Debris* in Hilo and continued at the *Workshop on Mission Concepts for Marine Debris Sensing* in Honolulu in January 2016. Upon completion of the PICES/DLNR publication, *Japanese Tsunami Marine Debris Aerial Imagery Analysis and GIS Support Final Report* (http://dlnr.hawaii.gov/dar/reports/), the DLNR team was interviewed at a press conference and featured across national and international news networks such as KHON2, HI Public Radio, Honolulu Magazine, FOX News, the Washington Post, and CNN.

In June 2016, the project presented a poster at the *International Coral Reef Symposium* in Honolulu, HI and engaged participants at the conference during nightly poster sessions. The project also participated in the *2016 Hawaii Marine Debris Action Plan Workshop* with NOAA and shared methodologies and accomplishments from this project in the state document. The team staffed a booth at the *International Union for Conservation of Nature's World Conservation Congress* in September and demonstrated the high-resolution imagery and study findings to participants and the public. The project also participated in the *PICES Annual Meeting* and presented the project's poster during the ADRIFT S8: The Effect of Marine Debris

Caused by the Great Tsunami of 2011 session, and was honored with the Best Poster Presentation Award by the MEQ Committee.

The project team has a manuscript for submission to the Marine Pollution Bulletin's special issue on "The Effect of Marine Debris Caused by the Great Tsunami of 2011," and will also have the project featured in the upcoming PICES Newsletter. Most importantly, the project's Story Map is online at http://arcg.is/29tjSqk (Fig. 6).

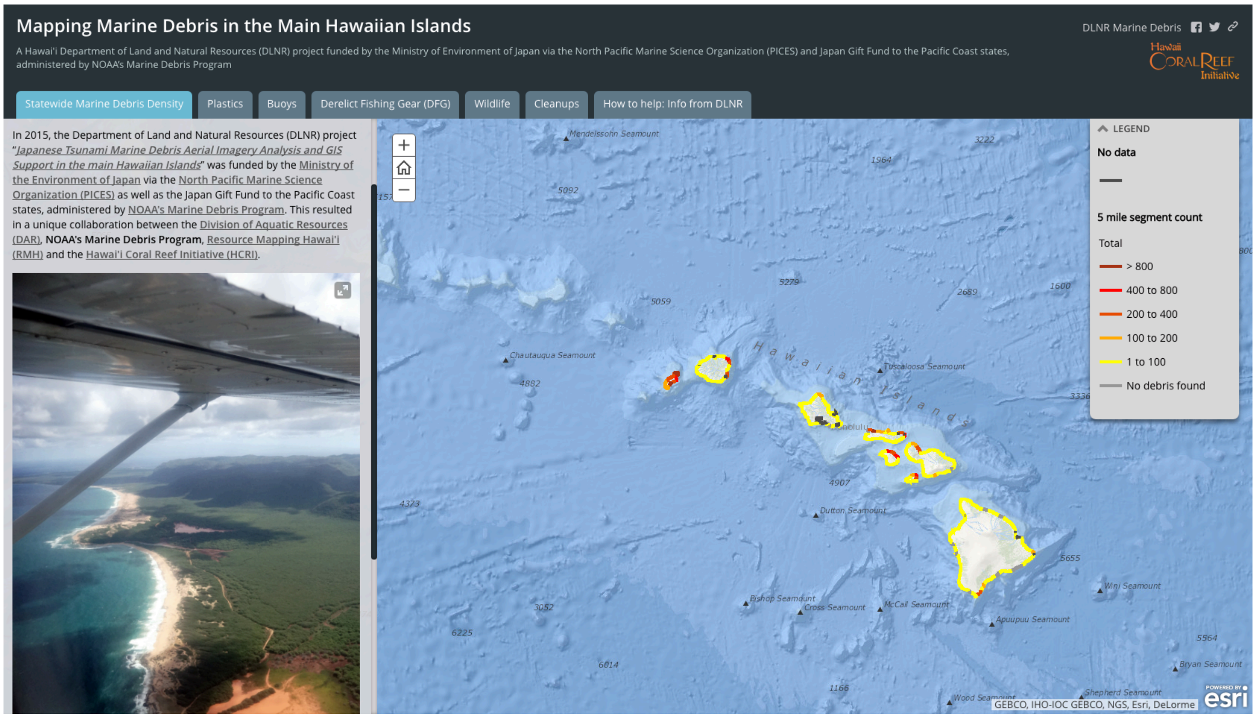

Figure 6: Screenshot of the ArcGIS Story Map http://arcg.is/29tjSqk

All imagery is hosted on the State of Hawaii Office of Planning directory at http://geodata.hawaii.gov/arcgis/rest/services/SoH_Imagery/Coastal_2015/ImageServer and can be viewed online or downloaded for public use. Request for proper accreditation as well as watermarks are present on all public materials, as directed by PICES and DLNR.

These resources were used to provide educational outreach regarding marine debris accumulations in the state and the capacity of spatial mapping tools to measure marine debris. Approximately 150 peers in the fields of marine debris, remote sensing, and ocean recreation and boating attended an oral presentation on the project, and the results were shared with NOAA's Marine Debris Office, DLNR's Division of Boating and Ocean Recreation, Division of Aquatic Resources, Land Division, Chair's Office, the Aha Moku Advisory Committee, Hawaii Wildlife Fund, Sustainable Coastlines Hawaii, Surfrider Foundation chapters in the MHI, 808 Cleanups, Kokua Foundation, B.E.A.C.H., Niihau, the Pulama Lanai Natural Resources Management office, and with the greater public via various news outlets.

VI. RESEARCH STATUS AND FUTURE STEPS

The ultimate goal of this project is to mitigate possible negative effects that marine debris may have on coastal areas. The next steps toward achievement of this goal would be to use the data provided from this project to organize and plan cleanup efforts, and develop a community-accessible database to distribute debris data and track removal efforts throughout the islands. These endeavors are underway in the statewide collaboration, The Hawaii Environmental Cleanup Coalition. Additional possibilities for future directions include analysis of changes over time with repeated imagery datasets, and investigating patterns in debris movement and accumulation in relation to oceanographic features such as currents and wind, or coastal features such as coral reef or wildlife habitat. The image collection and analysis techniques used here could also be applied to other areas of research and conservation as a method for collecting data on a large scale. For example, similar approaches could be used in projects that seek to characterize distribution of other natural resources, such as native or invasive species, or to survey coral bleaching on nearshore reefs. There are numerous other possibilities for using aerial imagery data to identify and analyze features important to the understanding of biological, ecological, and geographical processes.