

Interdisciplinary and Community Inclusive Approaches to Submerged WWII Heritage Research in the Pacific

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ABSTRACT

There are many opportunities, challenges, and competing interests related to the development of research on and preservation of submerged WWII heritage in the Pacific. This paper outlines an interdisciplinary, community inclusive project which brings together historians, archaeologists, biologists, conservation scientists, photogrammetry specialists, GIS specialists, veterans and Micronesians to focus on the archaeological and biological research of WWII underwater cultural heritage (UCH) in the Mariana Islands, specifically Saipan. It is a continuation of research that has been underway since 2008 on WWII sites related to the battle for Saipan and includes a third set of data collection spanning 15 years. At the time of writing, the project is currently underway, and results will be reported at the conference. As such, this paper is an overview of the work being conducted with adjustments made as the field project progresses.

KEY WORDS: WWII, Lidar, Photogrammetry, eDNA

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INTRODUCTION

Saipan is one of 15 islands in the Mariana Islands chain situated in the western Pacific Ocean. It is the capital of the U.S. Commonwealth of the Northern Mariana Islands. The battle for Saipan in the Mariana Islands, code-named Operation TEARAWAY, was the largest U.S. amphibious invasion in the Pacific Theatre by June/July 1944. The operation involved thousands of troops from all branches of the military and an imposing number of vessels, vehicles, and weapons. In the lead up to D-Day, 15 June 1944, U.S. fleet commanders conducted staging operations approximately 1,000 yards off the western coast of Saipan. These operations included battleships, cruisers, destroyers, carriers, support craft, amphibious vehicles, and the very first offshore seadrome (a floating airdrome serving as an intermediate or emergency landing place for airplanes) in the Pacific theatre. The battle for Saipan marked the end of the drive through the Western Pacific and allowed the U.S. to access mainland Japan directly through a controlled airspace. After nearly a month of conflict, almost the entire Japanese garrison of over 29,000 soldiers were killed. Of the roughly 67,000 U.S. troops that landed, nearly 3,500 lost their lives with nearly 10,000 wounded. Hundreds of Japanese civilians were killed in crossfire or by suicide, and nearly 933 non-combatant Pacific Islanders of Chamorro and Carolinian heritage were killed (Cabrera 2015).

The battle for Saipan is considered of such significance that large portions of the island including the World War II (WWII) landing beaches were listed on the U.S. National Register of Historic Places and designated a U.S. National Historical Landmark (NHL) in 1985. The NHL, designated based on

the history of the area and the integrity of the landing beaches, encompasses 1,366 acres of land and water (Thompson 1984). Dozens of publications, official histories, biographies, memoirs, documentaries, films, and reports focus on the conflict on land, but there has been less focus on the offshore naval, amphibious, and aerial operations and the losses incurred. To date, no Pacific War offshore staging area or seadrome has been investigated archaeologically. Furthermore, no comprehensive, systematic geophysical or remote sensing survey for associated submerged heritage in the offshore staging areas and seadrome of the Saipan battlefield has been conducted. The staging and aerial invasions were critical areas of activities during the battle. The location and investigation of these areas is essential to holistically identifying, analysing, managing, and preserving the full battlefield.

As such, a project was conceived to utilize emerging technologies to explore, locate, and characterize the UCH of the offshore deepwater battlefield including the first Pacific war seadrome, invasion staging area, and potential environmental hazards from post-war dumping. Shoreline development and reef clean-up have already altered the amount and type of WWII sites preserved in the shallow lagoon areas of Saipan. Additionally, a long-term research investigation and monitoring program has been focussed on the lagoon sites (McKinnon et al. 2011, 2014, 2018). The deeper areas offshore, however, remain relatively untouched by development and disturbance and no research has been conducted in this area (Figure 1).



Figure 1. Project area indicating targets to be tested and sites to be investigated (Map by Aleck Tan).

The project is an interdisciplinary collaboration between historians, archaeologists, biologists, conservation scientists, photogrammetry specialists, and GIS specialists that focuses on the archaeological and biological aspects of WWII UCH. It contributes to the study of the naval, amphibious, and aerial staging in the offshore battlefield through the location, identification, and characterization of sites, as well as their function as artificial reefs and contributors to the local Blue Economy. Blue Economy is a term introduced by the United Nations and used by many world organizations to describe the ocean in economic terms with a particular focus on sustainable use.

LIDAR, MACHINE LEARNING, AND Artificial Intelligence (AI)

Funded by a NOAA Ocean Exploration Grant, the project leverages biophysical data products from a bathymetric and benthic mapping effort (FY20-22) that has been coordinated across multiple NOAA offices and has direct spatial and temporal overlap with the development of high-resolution benthic

habitat maps for Saipan through Pacific Islands Fisheries Science Center and National Centers for Coastal Ocean Science. This survey covers the land and nearshore waters (depths < 50 meters). Bathymetric data meet, and in some cases, exceed USGS Lidar base specifications for quality level two data, which supports the gridding of a one-meter resolution three-dimensional bathymetric model. Additionally, post-processing of the Lidar point clouds has included classes 43 (Submerged objects) and 44 (International Hydrographic Organization S-57 Objects). For this project the bathymetric data was reprocessed in ArcGIS Pro utilizing a machine learning approach by training a deep learning model to identify and predict UCH site locations based on known sites in Saipan. The output, however, did not successfully identify potential UCH sites as the model appeared to select natural features. Unknown wreckage may be partially buried under sand or may contain coral growth, making it difficult for the model to detect remains. Potential ways to improve the model include increasing the training sample size or utilizing a different machine learning model outside of ArcGIS Pro.

In another visual analysis method, the bathymetry imagery was processed using the Relief Visualization Toolbox in order to obtain a visualization for archaeological topography, highlighting archaeological characteristics (Kokalj and Somrak 2019; Zakšek et al. 2011). By visual analysis of the archaeological topography for potential non-natural features, target anomalies were identified. Target anomalies were ranked based on discovery potential, and testing was conducted via veteran and archaeological divers on SCUBA and closed-circuit rebreather and through remote operated vehicles (ROV) investigations. While most targets appeared natural, cultural remains were still identified during target testing.

When successful, the exploration and identification of WWII UCH sites using emerging technologies such as machine learning, AI, and Lidar can help develop a concept of operations (ConOps) for future cultural heritage surveys with the potential to decrease costs through reduction of in-field survey and increase accuracy in discovery and identification. The scientific impact of discovery of underwater cultural resources from new and re-processed bathymetric mapping has significant relevance for future location and management of such heritage in other areas where similar surveys have been conducted. Additionally, both sets of biophysical data and heritage data can contribute a better understanding of the scientific value of UCH more broadly.

ROV AND PHOTOGRAMMETRY

Once sites were confirmed to be cultural, further survey and characterization proceeded using 3D structure-from-motion photogrammetric diver survey consisting of underwater still and video cameras to capture 100+% coverage of sites and surroundings. Ground control points and scale markers were used to ensure accurate spatial reconstruction of the sites at the millimetre (mm)-scale. Wrecks located deeper than 40 m were recorded utilizing a Chasing Gladius ROV. Data is being processed with Agisoft Metashape modelling software to create a 3D reconstruction of each site. The resulting 3D models will be rendered with the original imagery to create the final digital surface model that provides high-resolution textured 3D models of the study sites.

High-resolution ROV photogrammetric surveys are used in the exploration of sites and provide ground validation data that can be georeferenced for benthic environment and habitat models, archaeological site models that provide the first record of a site, as well as site formation data and public outreach materials. Few studies have been conducted utilizing high-resolution ROV photogrammetric surveys on underwater cultural heritage sites for understanding benthic environment and habitat models. The Mega Lab at University of Hawaii, Hilo has conducted some SCUBA photogrammetric survey of underwater cultural heritage in the Pacific, but the use of a ROV provides additional scientific methodologies that can be used in deep-water environments on underwater cultural heritage.

These models also contribute to historical and archaeological research and understanding of the battle and resulting UCH resources (Figure 2). Models can be studied and reviewed in detail without having

the limitations of diving at depths. They are analysed for cultural and natural features, modifications, battle scars, identifying marks, and any other details that may aid in the interpretation of the sites. These models can then be used to create traditional line drawing site plans. Models can also be used as longitudinal data for preservation initiatives using deviation analysis which can provide physical decay trajectories. Finally, photogrammetric recording is a permanent record that allows for the raw data of UCH to be stored for future use by archaeologists and biologists.

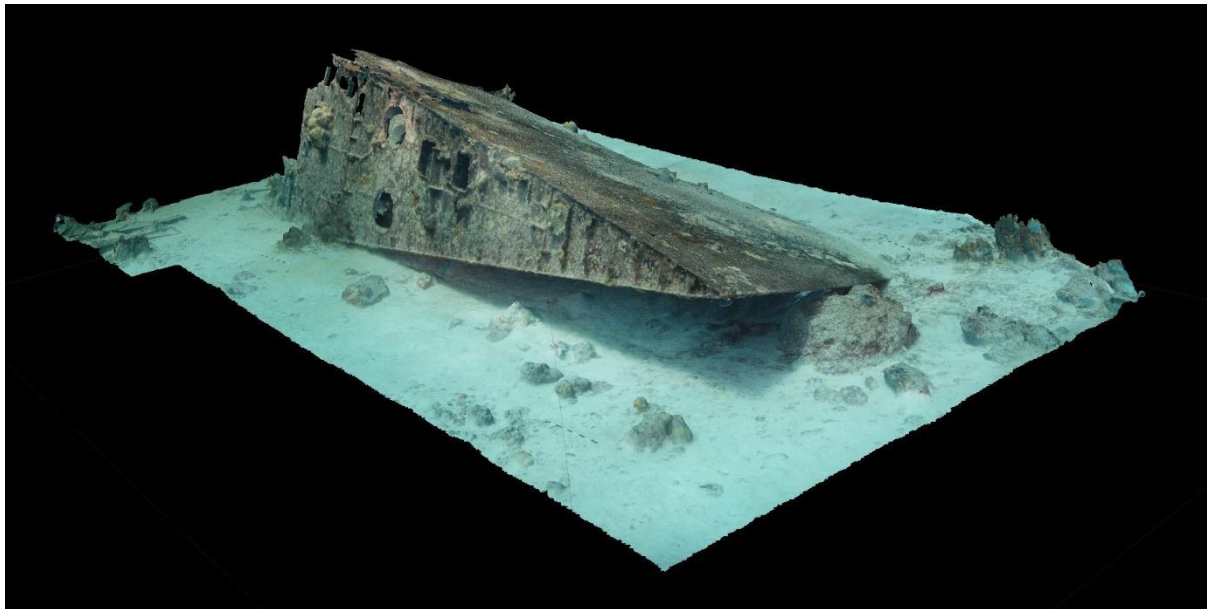


Figure 2. 3D model of Japanese auxiliary submarine chaser in Saipan Lagoon (Model by Kota Yamafune).

BLUE ECONOMY AND EDNA

The project focusses on wrecks as habitat and Blue Economy in local and regional commercial and recreational fisheries and ecotourism industries. Sunken WWII shipwrecks, tanks, amphibious vehicles, and aircraft represent significant cultural remains in the Pacific for the US and Japan. They also have substantial socioeconomic value for local small Pacific Island communities. WWII UCH provides Blue Economy opportunities in diving and marine tourism and fisheries, significantly bolstering island economies.

The use of eDNA sample collection and analyses allows for assessing biodiversity in an aquatic environment on UCH (Figure 3). The organisms associated with these wreck environments such as microorganisms, fish, and corals leave DNA traces (i.e., eDNA) through their attachment to wrecks, release in the nearby water column from skin cell shedding, release of waste products, and the persistence of this DNA in the nearby sediment over time. As each organism has a unique DNA signature, the same sample can be used to detect thousands of different organisms ultimately providing a snapshot of which organisms live in the current environment and where (Rees et al. 2014). Studies have shown that increased biodiversity led to a more productive environment (Lehman and Tilman 2000; Liang et al. 2016), which is important for monitoring the success of artificial reefs for supporting fisheries and other economic resources. Researchers can compare the biodiversity indices between locations to better understand which areas may be more productive as there is a direct correlation between biodiversity and ecosystem health. In addition to assessing overall biodiversity the project also focusses on specific taxa of importance to the wreck environment and Blue Economy of the region. This data combined can be leveraged with the other physical, biological, and biogeochemical data collected to begin answering questions about how we can better manage these environments long-term.



Figure 3. Mariana Islands Nature Alliance rangers extracting eDNA samples on the project (Photo by Mike Thomin).

Samples for eDNA were collected through biofilm surface sampling of the wrecks, filtration of nearby water, and sediment collection across the entire site. For each wreck environment, 10 biofilm surface samples were collected spaced evenly across the wreck for even coverage. Water column (surface and benthic) and sediment samples were collected. Samples will be processed to evaluate relative abundance and calculate diversity indices of the entire biological communities to assess overall biodiversity and health of the wreck ecosystem. The indices directly correlate to and can be used to visualize community differences and identify taxonomic members responsible for differences across the environments. These data will be compared within niche environments (i.e., across one wreck), as well as between areas, to identify areas that have high diversity vs. low diversity, as well as to compare the community structures (i.e., who's there) in order to identify the organisms responsible for this diversity. Ultimately, this can be used to assess the ecosystem health of each sample area and develop recommendations for monitoring and preservation of these areas.

The eDNA data will be leveraged to take a targeted organismal approach of those taxa that may play a particularly important role in the wreck environment and its connection to Blue Economy. Researchers will identify and quantify corrosion-causing microorganisms including known sulfate-reducing bacteria (e.g. Deltaproteobacteria) and iron-oxidizing bacteria (e.g. Zetaproteobacteria), as well as waterborne pathogens such as *Vibrio* and *Prevotella* spp. which may have negative effects on fisheries, ecosystem health, and ultimately the productivity of these artificial reefs. Lastly, researchers will look for evidence of terrestrial or human-associated species that may represent contaminant species that have been brought in through boating, tourism, or other human activities. The relative abundances of any specific targeted taxonomic group such as those mentioned above can be identified. Researchers will also use the whole community extracted DNA to conduct quantitative polymerase chain reaction (PCR), which amplifies and quantifies taxa of interest as well as functional genes from the whole community extracted DNA involved in sulfate reduction (e.g. *dsrAB*) and iron oxidation (e.g. *cyc2*). The research will help capture taxonomic groups that may be rare but still play an important functional role, or taxa that are not currently associated with known sulfate reduction or iron oxidation functions. The data will also be analysed for contaminants (both biological and chemical) to identify the human impacts on wreck sites and the impacts of these wrecks on the nearby natural environments looking for taxonomic groups, such as freshwater or human-associated taxa, not typically found in the nearby environment and may have been carried in through human-based processes. Combined with archaeological integrity results, this approach allows for assessing the

ecosystem health and current status of the wreck areas and for developing recommendations for improved monitoring and preservation methods.

Difficult issues related to WWII UCH involve human remains and repatriation; unexploded ordnance; pollution through oil, metals, and ammunition; lack of legal protection; unintentional damage through anchoring and fishing; and looting and souveniring. eDNA sampling and analysis of biocorrosion-causing microbes, human health hazard and invasive species, and overall microbial and eukaryotic biodiversity indices using universal microbial and eukaryotic primers contributes more broadly to the difficult issues that plague WWII UCH.

IN SITU CORROSION SURVEYS

In situ corrosion surveys provide the decay mechanisms and rates of deterioration for in situ management and preservation with an eye towards sustainability. In situ corrosion surveys are critical to small island Pacific nations with limited funding and resources to conduct recovery and conservation of cultural heritage; management happens in situ, rather than the recovery and conservation that larger nations may undertake. As such, understanding the condition of the resources is an important step in this management process. Corrosion surveys explore sites for identification of decay mechanisms and corrosion rates that help managers make informed decisions about their management and preservation. Understanding corrosion status and rates contributes to broader scientific questions about climate change, as ferrous and non-ferrous metals are excellent materials for testing the impacts of acid acidification, temperature changes, and differences in oxygen levels that can be related to deterioration rates of all UCH.

Conservation surveys primarily include the collection of data related to the environment (chemical and physical) that allows for a better understanding of the degradative forces affecting sites and artifacts and specific cultural information including data on material composition of objects, as well as modern cultural impacts to sites (MacLeod and Richards 2011, 2014). This data is vital to understanding the longevity of sites with relation to the material composition of metals and organics, how they react to and survive within the environment, and their overall structural integrity. Further, they record the modern cultural impacts on a site and produce a scientific, systematic record that can be used for managing sites. Conservation surveys will obtain a clearer understanding of the nature of the degradation forces operating on selected sites, determine the extent of degradation of materials on-site, and determine the overall stability of a site.

This data adds to an existing set of baseline data for future measuring and monitoring of the sites whereby they can be assessed quantitatively (in contrast to qualitative visual surveys) for passive or active corrosion. As a result, this information can help to prioritize sites with regards to future loss and retention of historical information and to develop an appropriate monitoring and management program.

COMMUNITY COLLABORATION, ENGAGEMENT AND CITIZEN SCIENCE

Collaboration and engagement with the community is central to the project. It incorporates Micronesian researchers with local knowledge of the waters who contribute ideas to the development of the project, are involved in collecting data, and promote sustainable management programs after the project has ended. The project provides materials for an immersive learning activity for local schoolchildren who cannot otherwise access submerged shipwrecks. The activity involves the storytelling of science, technologies, and careers in science of discovery and utilizes 3D animations. 3D models also provide opportunities for sharing important ocean discoveries with a wider audience via webpages such as Sketchfab and on the existing WWII Maritime Heritage Trail website so that it is accessible after the project ends.

Finally, partnerships and meetings with the local Historic Preservation Office, Division of Fish and Wildlife, Department of Coastal Resource Management, on island non-profit organizations, and Micronesian researchers provide opportunities for co-production of knowledge and hands-on training. Commonwealth of the Northern Mariana Islands agencies and researchers have been involved in all phases of project development and data collection to ensure that outputs are geared towards local management needs. Furthermore, engaging local heritage and natural resource practitioners and managers in developing techniques for identifying and recording UCH sites helps increase interdisciplinary management programs on island.

This project takes a public archaeology and citizen science approach to community engagement. A citizen science veteran rehabilitative program and event was developed and involves Special Operation Forces and local veterans who are injured or have illnesses and are reintegrating into civilian society (Figure 4). The combination of citizen science and rehabilitative therapy in underwater archaeology is a recent development and suggests that there are psychological and physiological benefits of participation in outdoor activities, scuba diving, and connection with peer support groups for veterans. Participation in science projects allows veterans to use many of their professional skills and experiences, which also advanced overall goals of the research. This project utilizes veteran citizen scientists in all aspects of planning, data collection, and processing. Surveys of participants and the efficacy of the citizen science experience will be administered by archaeological trainers.



Figure 4. Veterans preparing for dive inspection on a Japanese Daihatsu landing craft (Photo by Mike Thomin).

CONCLUSION

While the project is still underway at the time of writing, this paper has outlined the overall plan for an interdisciplinary, community inclusive, exploratory research agenda utilizing emerging technologies. The project leverages existing biophysical data products from bathymetric Lidar to conduct machine learning and AI to identify submerged sites in deeper waters up to 50 m below the surface. Archaeological and biological surveys of the sites include a focus on the wrecks as habitats and part of the Blue Economy in local and regional commercial and recreational fisheries and ecotourism industries. Samples of eDNA and corrosion data as well as 3D models using ROV will contribute to questions about the health of these sites, potential contamination, and their long-term preservation. Collaboration with veterans for an adaptive rehabilitative event trains off- and on-island veterans in citizen science archaeology and biology skills. Finally, engagement with local agencies,

non-profits, and schools provide opportunities for knowledge creation and exchange. Results from the project will be presented in further detail at the conference.

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