

Examining the World War II Underwater Cultural Heritage of Maui and Lānaʻi through 3D Photogrammetric Modeling

¹Dominic Bush (East Carolina University, PhD Candidate)

²Jason Raupp (East Carolina University, Assistant Professor)

³Justin Dunnivant (University of California at Los Angeles, Assistant Professor)

ABSTRACT

In October 2022, archaeologists from East Carolina University and the University of California at Los Angeles investigated underwater cultural heritage associated with World War II around the islands of Maui and Lānaʻi in Hawaiʻi. Working in partnership with the National Geographic Society and the Ocean Exploration Trust, the team surveyed the remains of lost or abandoned aircraft, amphibious assault vehicles, ships, and moorings associated with WWII training and staging exercises. In keeping with Session Four's (Underwater Cultural Heritage of World War II in the Asia-Pacific Region) focus on "discoveries, opportunities and challenges", the maritime heritage research centered on assessing the physical state of these WWII wreck sites to evaluate preservation threats, while also contributing to the creation of educational resources and outreach tools. A total of eight WWII-era sites were surveyed using photogrammetric recording methods; these include the wrecks of two US Navy aircraft, five amphibious landing craft, a mooring station, and a semi-submerged gasoline tanker. Project members used the collected imagery to produce 3-dimensional photo models. The models proved not only to be effective visual aids for showcasing some of Hawaiʻi's rich submerged maritime heritage, but also provided archaeologists with detailed site maps made in a fraction of the time generally required. This paper examines the indelible impact left by the war on Maui and Lānaʻi through the investigation of tangible remains of the island's wartime cultural landscape.

KEY WORDS: World War II, Photogrammetry, Hawaii, LVT, Aircraft

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INTRODUCTION

In October 2022, the Ocean Exploration Trust (OET), with funding from the National Geographic Society, launched the third of its three "Shore to the Abyss" expeditions focused on the Hawaiian marine environment (OET 2022). Bringing together researchers, educators, and story-tellers with diverse backgrounds, this third expedition targeted the islands' World War II (WWII) maritime heritage, specifically around the southern coast of Maui and along Lānaʻi's Shipwreck Beach. Rather than emphasizing discovery, the research plan called for condition assessments of previously-recorded underwater cultural heritage (UCH) sites, many of which were subjected to prior archaeological investigation by the National Oceanic and Atmospheric Administration (NOAA) and the University of Hawaiʻi, Mānoa (UH).

The present study, however, diverges from previous efforts through its methodological focus on three-dimensional (3D) photogrammetric site recording. Instead of relying on standard recording techniques to generate two-dimensional site maps, the research team conducted video surveys of each site. The thousands of still images extracted from videos were used to construct 3D digital models, which

simultaneously serve as visual site assessments and powerful outreach tools. Photogrammetry is no longer a new concept in underwater archaeology and has been executed on a far more sophisticated level than presented here. That said, this study is intended to serve as an example of making this seemingly complex and expensive method of site documentation more accessible to management agencies and aspiring citizen scientists. In addition to providing site descriptions and analyses of notable changes, this paper highlights the maximization of time and budgetary resources in the creation of the ‘digital mosaic’ presented below.

METHODOLOGY

The initial Shore to the Abyss expedition plan called for the photogrammetric survey of three landing vehicles, tracked (LVT; two LVT(A)-4 and one LVT-4) and two aircraft (Grumman F6F-3 Hellcat and Curtiss SB2C-1C Helldiver) found in Mā‘alaea Bay (Figure 1). After consultation with the diver operator, however, it was decided that survey efforts would also include a WWII naval mooring and two previously unrecorded LVTs, also located within the bay. At each site, one-meter (m) scales were placed on the surrounding seafloor prior to the video survey to assist with later archaeological analysis. Using a GoPro Hero 9 Black action camera (\$299) situated within an underwater housing equipped with a fisheye-lens (Telesin Dome Port \$68), divers followed predetermined swim patterns over the site of interest. This involved first swimming overlapping east-west transects, followed by a series of intersecting north-south transects. The vertical site profile was filmed by swimming ascending circles around the object. The 4k videos were then imported into Adobe Photoshop for the extraction of still images (2 frames per second) and color correction. The color corrected images were processed using Agisoft Metashape Professional v1.8 (Professional Edition, Educational License, \$549) for the purpose of developing a 3D model.

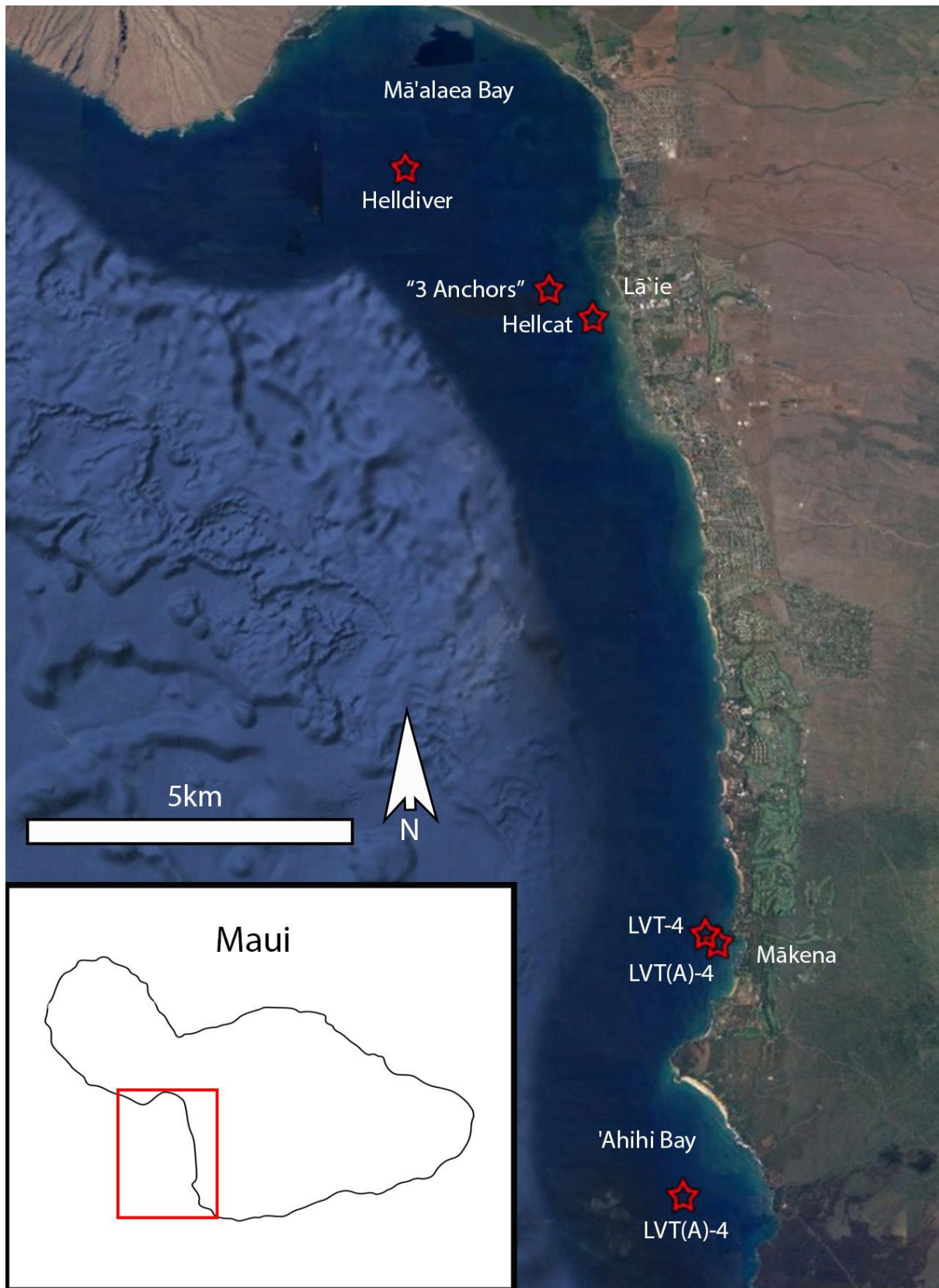


Figure 1. Map of Maui survey area with site locations

Proximity to the island of Lānaʻi permitted the research team to conduct an aerial videographic survey of USS YOGN-42, a decommissioned gasoline barge scuttled off Shipwreck Beach. For the exposed portion of YOGN-42, a 5-minute test survey was carried out using a DJI Mavic Air drone (starting at

\$799) with video capabilities flown from the deck of the research vessel. The same process was followed for extracting still images from the video, which were also imported into Metashape for processing. Hazardous surf conditions hampered attempts to video survey the submerged section of the wreck.

RESULTS

The four-person team completed 36 dives and logged roughly 28 hours of time underwater between the sites. Video surveys resulted in the collection of nearly 300 minutes of footage and over 34,000 extracted images. The project results and 3D models were shared directly from the research vessel during numerous virtual events for the public. Summaries of the project have since been presented as a documentary short via YouTube (<https://www.youtube.com/watch?v=iB0m-qu7bJU>) and as a segment for Hawaii News Now. After the expedition, models were uploaded to the interactive 3D modelling website Sketchfab, and textured versions can be viewed on YouTube. Results were shared with the State of Hawai'i's Historic Preservation Division and NOAA's Office of National Marine Sanctuaries (ONMS). Previously, most of the following sites were archaeologically recorded through collaborations between ONMS and UH's Maritime Option Program (MOP) (see NOAA Maritime Heritage Program 2017; ONMS 2011; Van Tilburg 2014). These earlier surveys and 2D site maps served as an invaluable baseline for assessing change at each of the known sites.

Landing Vehicles

An LVT-4 located off Makena Landing was the first site surveyed (Figure 2). It lies upright on the seafloor at a depth of 18 m, surrounded by a small debris field made up of structural elements and wiring. As was the case for all the LVTs surveyed, much of the vehicle is heavily encrusted in marine growth with pockets of coral concentrations, especially on engine parts. The driver's compartment (cab) has collapsed, exposing the front-mounted engine. The floor of the rear compartment is mostly worn away, apart from a segment on the port side that is noticeably more deteriorated than it was in 2011. A section of the cab plating has also shifted and broken apart. The most significant change in site condition is the complete collapse of the starboard pontoon. Snapped along the bottom front corner, the bulk of this pontoon now lies within the rear compartment.

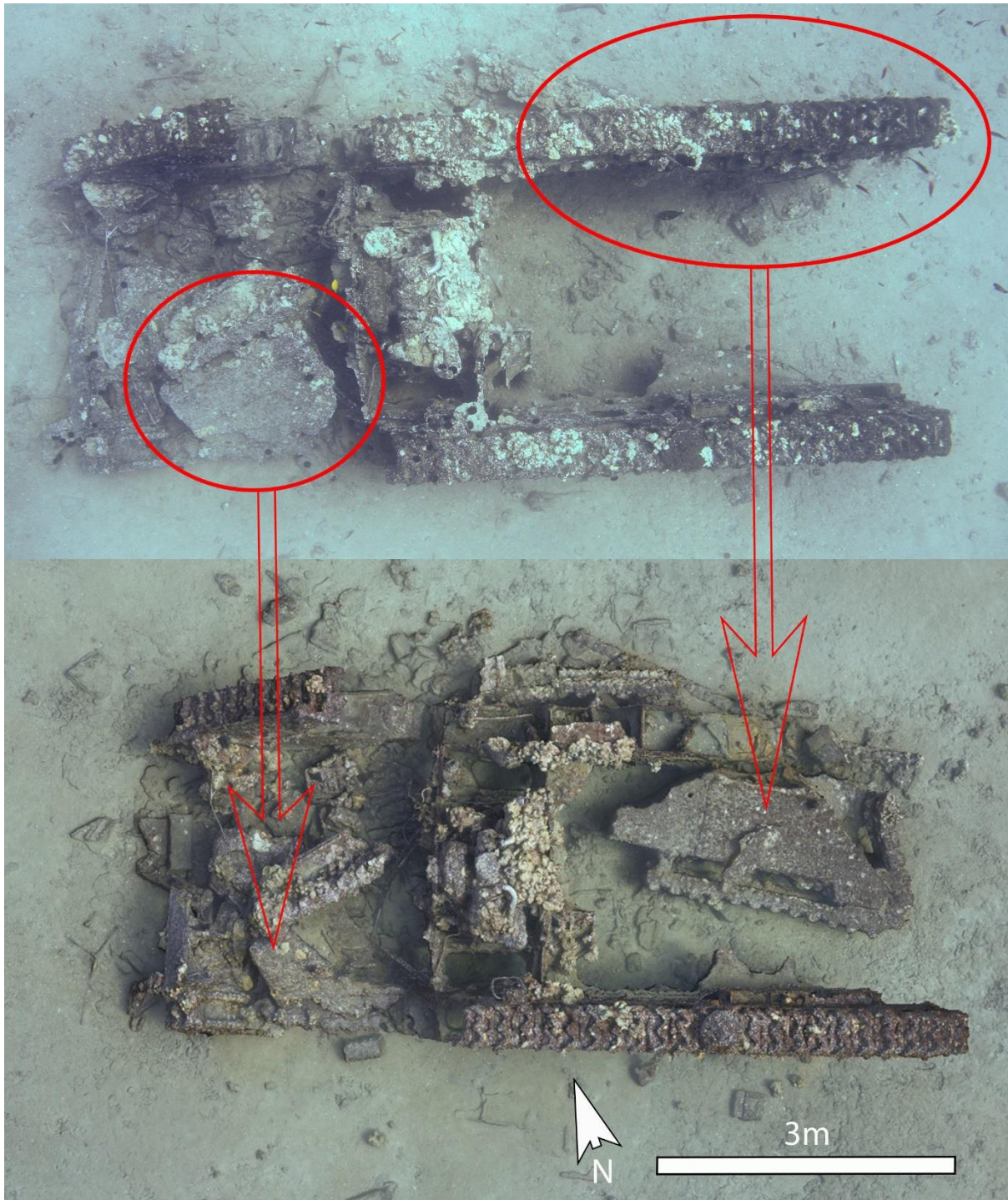


Figure 2. A 2011 photograph of the site (above) juxtaposed over 3D model of Makena LVT-4 (below); damage to pontoon and cab plating indicated in red (Top image courtesy of NOAA ONMS/UH MOP; bottom image courtesy of ECU/UCLA).

According to a local informant (P. Fiene pers. comm. 2022), the pontoon collapsed after the magnitude 6.9 earthquake, which impacted Hawai‘i in 2018. This tectonic event and over a decade of storm events have affected the site by increasing debris strewn around it.

The second site, an LVT(A)-4, is also located near Makena Landing. Unlike the previous site, the debris field is more expansive and diverse in its composition. Batteries, driving sprockets, hoses, and sections of track and grouser are amongst the scattered remains. The driver’s cab cowling can be

clearly identified 4 m forward of the wreck. The only portions of the vehicle that remain upright and marginally intact are the diagnostic 75-milimeter (mm) howitzer barrel, turret, rear-mounted engine, and a rear starboard section of the hull. Beyond the shifting of smaller debris pieces, no appreciable changes were observed. The highly disarticulated nature of this site is attributed to the postwar detonation of the vehicle's unexploded ordinance (ONMS 2011).

In 'Ahihi Bay, lies a second LVT(A)-4 at a depth of 24 m. Though not as fragmented as the LVT(A)-4 at Makena Landing, this site is also characterized by significant deterioration and scattered debris. The rear deck plating has disappeared, exposing both the engine and two fuel tanks. Both driving sockets are resting on the seafloor, forward of the collapsed driver's compartment. Hull support for the turret has weakened, causing it to collapse onto the wreck and slump towards the more deteriorated starboard side. In 2011, the portside hull and track are noted as "almost complete" (ONMS 2011). This is no longer the case, as the portside track has disintegrated and can now be found in segments both in and around the wreck. Given the less diffused debris field, this LVT(A)-4 likely represents natural deterioration brought on by corrosion and swell energy. It is possible the destruction of the portside track is a result of the same earthquake activity that collapsed the Makena Landing LVT(A)-4 pontoon.

Project team members were alerted by a local consultant of the remains of an unrecorded site located within Mā'alaea Bay. As this site is not currently included in the state database, information related to its position is withheld until it can be properly assessed for management purposes. The site consists of two, abutting LVTs (Figure 3). Based on the rear engine configuration, dimensions, and presence of a small glass window (55 centimeter (cm) -x-40 cm), both vehicles are tentatively identified as being LVT-2 types (Mesko 1993; US War Department 1944). The first LVT-2 has its bow pointing west and sits upright. Its starboard pontoon has collapsed and lies on the seafloor, with some pieces of track still attached. The port pontoon remains intact and standing, though most of the track has broken off and is scattered around the wreck. The bottom third of this pontoon appears dug into the sediment. The coral encrusted rear-mounted engine is clearly visible and is connected to the front transmission via a propeller shaft. The midpoint of the shaft is connected to a power takeoff that leads to a buried bilge pump. The hull floor cannot be discerned as it is covered by sediment overlaid with debris. Near the engine, identifiable components, including both oil coolers, the portside battery, and fire extinguishers are evident. Toward the bow, in the vicinity of the transmission, appears to be the vehicle's radio, side window, and possibly one of its guns. Forward of this area are the driving sockets, which have collapsed and remain partially buried.



Figure 3. 3D model of previously unrecorded LVT-2 wrecks in Mā'alaea Bay. Identifiable components are labeled (courtesy ECU/UCLA).

The other LVT-2, with its bow pointing east, is situated upside down. Listing towards its port side, the bow (driving socket and front hull plating) is propped up by the adjacent vehicle on its starboard side. The starboard pontoon has collapsed inwards, following the direction of the list. The track and grousers on both pontoons are in relatively good condition. Much of the floor hull plating, extending from the engine compartment, up to the driving sprockets has deteriorated. This has exposed the bottom of the engine compartment, though the top half of the engine itself remains buried. From the engine, various pipes and tubing, some of which are related to the bilge pump at the hull's floor, run along the vehicle's centerline and terminate just aft of the driving sockets.

The debris fields for the Mā'alaea Bay LVT-2 wrecks are rather limited, suggesting that this site has been protected from natural and cultural transformations. Furthermore, the presence of removable gauges, knobs, and other salvageable parts is a clear indicator of the site's lack of recreational visitation. The coincidence of two LVTs in such close alignment may represent an intentional dumping effort as opposed to an accidental loss.

Aircraft

The first aircraft survey of the Shore to the Abyss project centered on the partial remains of a Grumman F6F-3 Hellcat situated in 11 m of water near Mā'alaea Bay's southeastern shore. The site is

divided into two main components, with the first consisting of the plane's midsection. Here, portions of both wings are still attached to the fuselage. This part of the aircraft is upside down, making visible the retracted landing gears. Some of the wing's aluminum skin, especially on the portside, have deteriorated away, exposing frames. As the aircraft is upside down, it is not possible to discern if the cockpit is buried, or if it sheared off in the wrecking event.

Around 23 m away, the radial engine (cowling missing), propellor, and nose ring are intact and standing upright. Just below the propellor hub, sediment covers two of the propellor blades and the bottom third of the engine. The third propellor blade is broken in half and extends vertically into the water column. Like most ferrous components in this environment, the engine is heavily encrusted in coral. During the photogrammetric survey, divers recognized what appears to be either the distal end of one of the wings or a portion of the tail stabilizer buried 5 m away. The only two observable changes to the site, when compared to the results of the 2011 survey, are a missing piece of the portside wing flap and increased sediment cover of the starboard wing. While the landing gear configuration, engine, and exhaust flaps all led to the identification of the site as an F6F-3 Hellcat (ONMS 2011), the specific identity of the plane is unknown.

In the middle of Mā'alaea Bay lies an almost fully-intact Curtiss SB2C-1C Helldiver (Figure 4). The aircraft's structural completeness made its identification fairly easy (ONMS 2011). Its engine has slightly broken off from the airframe and the cowling rests on the seafloor to the starboard side. The vertical tail stabilizer is also detached and partially buried aft of the wreck. Since 2011, the Helldiver has remained in relatively good condition. The most notable changes include the collapse of the port wing aileron, and the dislodgment of an aluminum panel on the starboard side of the nose, exposing the engine bearing struts. Minor damage has occurred to the plane's tail, where part of the elevator's portside framing is now missing. After its discovery in 2010 by a local dive operator, the Helldiver's Bureau Number (184000) was identified on the detached vertical stabilizer. The ONMS (2011) website provides a description of the crash incident, which along with the subsequent rescue of the pilot and radioman, explain the missing rescue raft and the open position of both canopies. The aircraft's story is now memorialized on an interpretive plaque that was recently placed at the site.

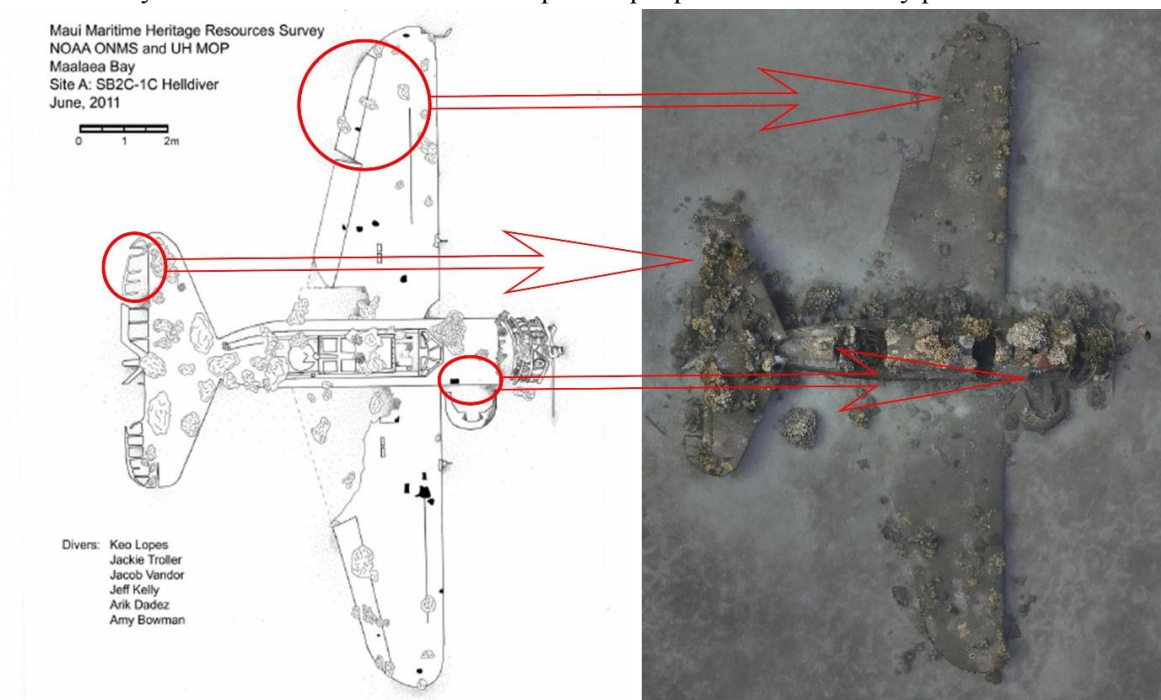


Figure 4. 3D model of Helldiver site (right) compared with 2D site plan (left) (courtesy NOAA ONMS/UH MOP)

The aluminum planes appear to have undergone less deterioration than the steel LVT sites, which is likely owed to the anti-corrosive properties of aluminum and the LVTs' lack of cathodic protection due to their increased fragmentation (i.e. less components electronically connected) (e.g. Richards and Carpenter 2017).

Naval Mooring

Known locally as “Three Anchors”, a naval mooring is found 1 kilometer (km) off Lā‘ie Beach, near the Mā‘alaia Bay Hellcat site (Figure 5). This location has become a recreational diving destination, due to an abundance of marine life attracted to it. The site consists of two large admiralty anchors and one US Navy (USN) stockless anchor that are all chained to a central cement block. The block is chained to an octagonal, hollow concrete mooring buoy, which is thought to have supported a naval degaussing station (Settle-Chesser n.d.). The station itself was located 2 km to the northeast, currently the site of the ONMS Visitor Center in Kihei (ONMS 2009). This site was not surveyed in 2011 or 2013, though it has been recorded by others and is featured prominently on dive operator websites.

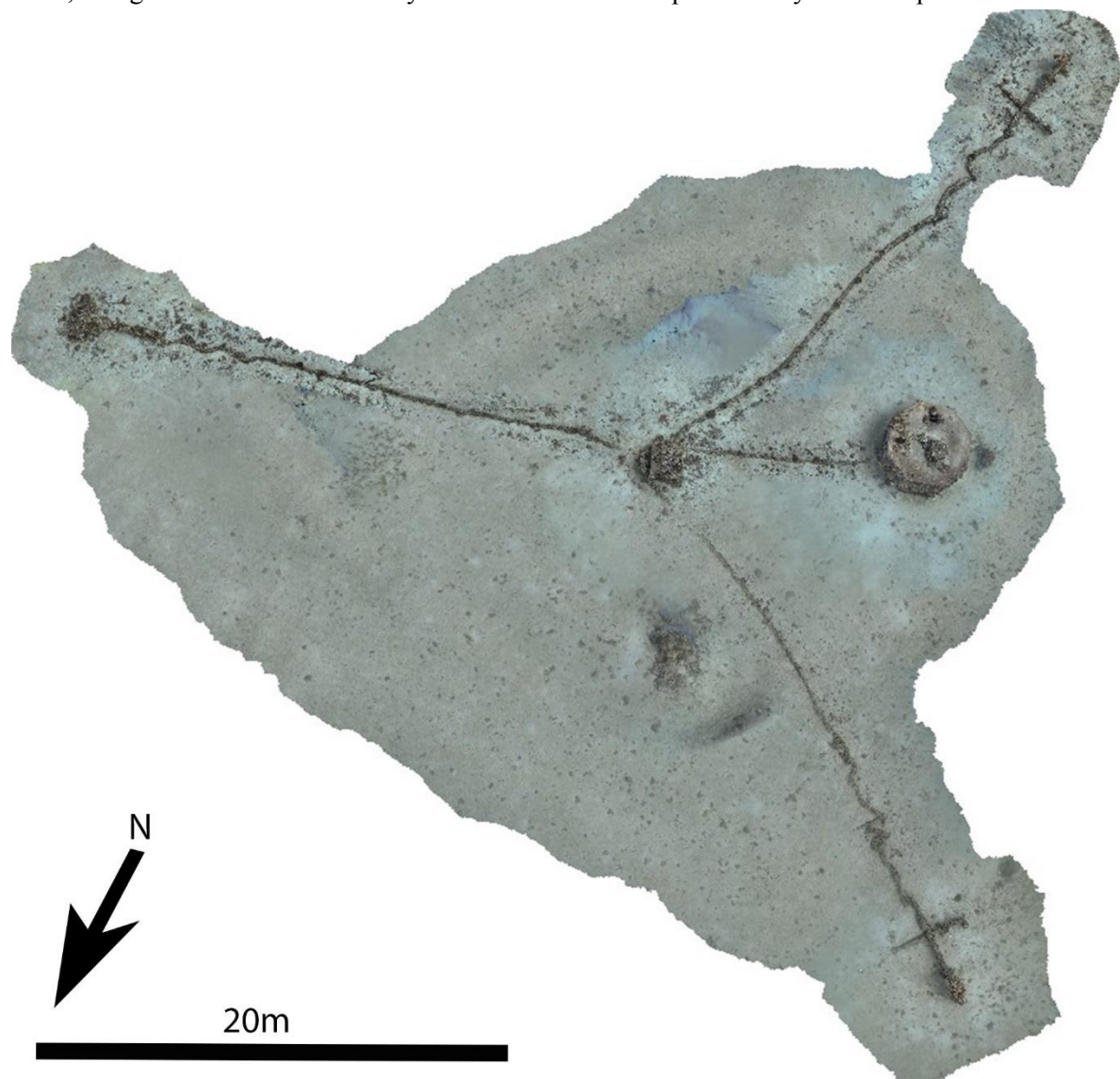


Figure 5. 3D model of “3 Anchors”, a WWII era USN mooring (courtesy ECU/UCLA)

Shipwreck Beach

Shipwreck Beach takes its name from the presence of YOGN-42 (Van Tilburg 2003), which lies stranded on the reef, 350 m from the shoreline. Launched in March 1943, this ferrocement (reinforced concrete) vessel served in the Pacific Theatre until the war's end (NavSource 2015). Stricken from the USN Register in 1949, the ship was intentionally scuttled at Lānaʻi in 1950 (Van Tilburg 2003). YOGN-42 lies parallel to the coast, with its bow pointed east, causing the ship's portside to absorb the waves. Most of its hull is above the waterline, making the 114 m vessel easily visible from the beach. While the ship's ferrocement composition has helped maintain hull integrity, it is not free of deterioration as evidenced by the chunks of concrete and rebar that litter the surrounding seafloor. Corrosion of the ferrous structural elements, combined with over 70 years of exposure to the prevailing winds, rain, and swell energy, has slowly chipped away at the WWII vestige.

Due to its size and fragility, traditional archaeological surveys are extremely difficult. To circumvent this problem, the research team worked with an aerial drone pilot to capture 4K video of the barge. The team obtained approximately 5-minutes of footage, which included several passes over the ship's deck and around the sides of the hull. The resulting photogrammetric model was then compared with publicly-available photos of the ship (Figure 6).



Figure 6. Earlier photo of YOGN-42 (above) compared with 3D model of YOGN-42 (below) (Top image courtesy of R. and K. Brooke n.d.; bottom image courtesy of ECU/UCLA).

Immediately, it was apparent that the ship's decks were becoming increasingly compromised. Deck plating on the starboard quarter of the main deck has disappeared, exposing underlying deck beams. A similar observation was made for the starboard side of the forecastle deck. More concerning is the near-total collapse of the ship's quarterdeck. Deck plating in this area, beside the footprint of the former pilothouse, is almost non-existent. A large mechanical piece (perhaps a towing winch) once supported by the quarterdeck, has fallen through to the underlying hold and much of the deck's concrete sides have broken off, exposing rooms and bulkheads. A large section of the forecastle deck on the portside has also weathered away, exposing support stanchions. This area is likely to further undergo collapse, as the ship's windlass and anchor chain sit precariously on the crumbling deck.

Changes such as these are important to monitor for safety reasons, as snorkelers and divers are drawn to both the wreck and the marine biota it supports.

DISCUSSION AND CONCLUSION

The archaeological sites of the 2022 Shore to the Abyss expedition survey represent a snapshot of the islands' WWII underwater heritage. The global conflict had a profound impact on Maui, in particular, where almost 200,000 servicemembers were hosted during the war's duration (Maui Historical Society 1992). Training accidents were an inherent risk, and today the sunken remains of landing vehicles and aircraft wrecks attest to those hazards. Other physical manifestations of the US war effort, including moorings and intentionally scuttled vessels, speak to strategic and logistical considerations. Aside from the newly-documented LVT-2 wrecks, each of the sites possess both historical and socioeconomic significance given their status as dive and snorkel sites. Local and off-island stakeholders routinely visit these sites out of reverence, enthusiasm, and recreational motivations related to wreck diving and marine ecology.

The Shore to the Abyss project results demonstrate the significant changes these sites experience within a relatively limited period of time (10-12 years). Environmental forces, such as corrosion, tectonic activity, and wave energy, are the most likely culprits, though the effects of improper site visitation (e.g. anchoring onsite) should not be discounted. To combat the former, rigorous scientific methods should be applied, including corrosion studies. Understanding the various corrosive pathways, as well as the way in which steel and aluminum react differently, will be key in formulating mitigation strategies. Climate change and its influence on corrosion poses another fruitful topic for further exploration. For direct human-induced threats, education remains an important resource. The hope is by presenting the physical layout and historical significance of these sites, they are seen as recognizable archaeological resources worthy of reverence and protection. Onsite interpretive plaques, such as the one installed at the Helldiver site, and the dissemination of dive guides generated from archaeological investigations are two immediate ways of spreading awareness to the diving community. Eventually, it may be desirable to establish a heritage dive trail, as done elsewhere in the Pacific (McKinnon 2013; Philippou and Staniforth 2003). At a broader level, projects that seek to bring the general public's attention to Maui and Lānaʻi's WWII heritage may help foster a new appreciation for a site category that remains 'out-of-sight-out-of-mind' for many.

The photogrammetric surveys presented here were completed using small teams and inexpensive technology. The results helped identify significant alterations to several of the sites and aided in the interpretation of two unrecorded LVT-2 wrecks. Rather than spending days or weeks documenting a single wreck, 3D models for each site were produced within 24 hours. Additionally, the 3D models can provide detailed plan views and cross-sections of the sites with a greater degree of accuracy than traditional 2D methods. This form of rapid site evaluation is in no way intended to replace traditional archaeological recording methods, nor is this methodology a novel application of photogrammetry. Instead, this project represents a case study demonstrating the utility of periodic assessments that do not require significant resources in the form of time and money. The scalable 3D models are easily viewed from different combinations of distances and angles. Details not readily apparent to divers or easily captured in 2D photographs can now be identified when examining the 3D site representations.

These photogrammetric surveys can be repeated (with higher quality photography equipment when possible) at scheduled intervals, to create a visual log of how a site is changing. Recognizing physical site alterations or areas of structural weakness could help site managers devise in situ preservation

strategies. Furthermore, the visually stimulating digital 3D models produced have proven to be an effective and engaging way of presenting archeological sites to the public, especially amongst the youth. Online, these models can be compared with earlier iterations and site photos to illustrate the fact these are fragile, 'living' sites susceptible to further loss and destruction. By doing so, the preservation threats that site managers fret about are made real to current and future site stakeholders.

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