doi: 10.25923/8mnk-4e35

Ocean Exploration and Research

FY17 FFO Projects

I. Overview

1. Grant Number (if applicable): NA17OAR0110214
2. Amount of funding from OER: $89,969
3. Project Title: Peleliu's Forgotten WWII Battlefields
4. Area of Operation (include a map and/or coordinates):
   Peleliu, Republic of Palau, Caroline Islands. WWII invasion beaches: White 1, 2 and Orange 1, 2, 3 (Appendix 1)
5. Principle Investigator (name, address, contact information)

   Toni L. Carrell, Ph.D.
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6. Participating Institutions and key personnel
   Ships of Discovery: Toni L. Carrell, Ph.D.
   East Carolina University: Jennifer F. McKinnon, Ph.D.
   University of Hawai'i Hilo: John H.R. Burns, Ph.D.
   SEARCH, Inc.: Jeff Enright, M.A.
   RECON Offshore: Michael C. Krivor, M.A.
7. Award Period: From 09/01/2017 to 08/31/2020
8. Period Covered by this Report: From 09/01/2017 to 08/31/2020 Final Performance Report (ref: Semi-Annual Performance Report and Annual Report if applicable)

II. Summary

1. Abstract

   The science team revisited or located 100 sites that represent both WWII specific remains and modern debris (Appendix 3.1). The terrestrial survey inshore of the invasion beaches identified 60 artifact scatters, miscellaneous debris, pieces of equipment, or Japanese defensive positions. The team revisited 14 archaeological sites previously recorded by Denfeld (1980) and/or by Knecht, Price, and Lindsay (2012) and identified 11 previously unrecorded sites. Biological characterization of the reefs included high-resolution (mm-scale) 3D reconstructions from 424 reef plots. Five UCH sites were modeled providing baseline information on the condition and status of these WWII remains. The side-scan sonar imaged 18 acoustic contacts that were investigated; none resulted in identification of UCH. The magnetomer survey produced 20 anomalies. Of these, 12 were associated with project-located UCH, 7 remain unidentified, but are likely associated with single-point ferrous metal objects consistent with the historic Battle of Peleliu. A comprehensive KOCOA analysis of the invasion beaches and inshore area documented the effects of both defensive and offensive actions on the battlefield.

2. Purpose of Project:
   a. Describe issue that was addressed
      The purpose of this project was to locate the scattered material remains of Peleliu's submerged battlefield, to photogrammetrically record those remains, and to examine the reef substrate and its coral communities to determine if the scars from the UDT

mission to blow access ramps into the lagoon were still visible after 74 years. No systematic remote sensing survey of the invasion beaches and adjoining reef line to identify underwater cultural heritage sites (UCH) has ever been undertaken. Previous periods of shoreline development and reef clean-up have already altered the amount and type of WWII sites that are preserved, which directly impacts battlefield interpretation. The location and identification of all remaining UCH sites is critical to understanding the full battlefield on land and underwater.

b. Describe/list the project objectives
- High-resolution (mm-scale) 3D imagery of reef survey sites
- Identification of WWII underwater blast zones on reef shelf
- Shallow water survey of invasion beaches using traditional geophysical package
- Towed swimmer survey of the fringing reef where a boat cannot safely navigate
- Walking and wading survey of the lagoon from the reef to the shore
- Use of a drone to assist in lagoon site documentation
- Walking survey inshore of the invasion beaches to locate the remains of Japanese defensive positions to aid in interpreting the areas of offshore losses
- Staff development and training in remote sensing and 3D recording and processing
- Public outreach via news release in *Tia Belau* Newspaper Article: "Ships of Discovery in Palau for WWII Research" Vol. 27, No. 26, April 2, 2018, page 2, continued page 11 (Appendix 2).
- KOCOA analysis of the offshore reefs and nearshore invasion beaches.

3. Approach:

a. Describe the work that was performed

This project was a Phase I submerged cultural resources survey and inventory (as defined by the Secretary of the Interior Standards) that included:
- geophysical remote sensing using a side scan sonar and magnetometer
- swimmer/diver reconnaissance in the shallow areas of the reef not navigable by boat
- target diving on anomalies to identify submerged sites
- standard archaeological documentation for a Phase 1 survey (photographs, written documentation of significant features, and similar)
- walking survey of the invasion beaches from the shoreline to approximately 30 meters inland
- swimmer/diver examination reef to locate areas of pre-invasion destruction resulting from explosives used to permit amphibious landings
- marine biological characterization of:
  - coral reef structures and substrate encompassing the submerged sites and debris fields
  - coral reef structures in the known areas of pre-invasion blasting
  - control areas (not disturbed by human activity)

1) Methodology and Technology

a) Biological Characterization

High-resolution (mm-scale) 3D reconstructions were generated at survey sites by collecting overlapping images (70-80% overlap) from planar and oblique angles of reef plots. Images were collected from six 2x2-m plots at three isobaths (~40fsw, ~20fsw, ~10fsw) at each survey site (18 plots per site). The plots were located from the base of the blast zones to the top of the reef flat. Survey plots were also conducted along the same isobaths at locations that were not affected by blasting during the invasion battle.

Scale markers were placed across the study plots to ensure model precision and accurate spatial rectification. The resulting photographs were digitally reconstructed using SfM modeling software. SfM software generates 3D digital surface models in three primary stages: 1) photo alignment, 2) geometry building, and 3) texture building. This process creates 3D point clouds that result from the projection and intersection of pixel rays from the different positions and oriented images in 3D space (Clayput et al. 2016, James et al. 2017). These points are then triangulated and rendered with the original high-resolution imagery to create textured 3D mesh and georeferenced digital elevation models, which can be used to quantify metrics of 3D structural complexity (Burns et al. 2015a, Leon et al. 2015, James et al. 2017, see Photo 2). The 3D reconstructions were exported as DEMs and orthophotos to ArcGIS topographic software (ESRI Inc., USA) for quantification of coral health, community composition and metrics pertaining to structural complexity (Burns et al. 2015b).

The orthophoto provides a high-resolution photo-mosaic of the surveyed substrate and is layered with geometrically corrected DEM such that each cell contains accurate 3D information and can be used for measurement of topographic parameters. The orthophotos are digitized and annotated to create unique polygon shapefiles for all individual coral colonies within each surveyed plot. After the benthic features are annotated, the ArcGIS software is used to calculate multiple metrics pertaining to 3D characteristics and topographic structure. The data derived from this analysis is used to characterize differences in reef composition and structure at sites located in blast zones and those not affect by blast activities.

Several entire blast zones were modeled in entirety to create 3D maps of these unique areas and to quantify the geomorphology produced by these activities. Archaeological features were also surveyed in the same manner throughout the duration of the expedition.

b) Remote Sensing Survey

The survey, completed using a local fiberglass dive vessel, was well suited for the project environment using HYPACK, Inc. hydrographic navigation software for vessel guidance. Side Scan Sonar instrumentation for the survey included a Trimble SPS356 differentially corrected global positioning system (dGPS) receiver with GA830 global navigation satellite system antenna and an EdgeTech 4125 dual-frequency (600/1,600 kHz) CHIRP side-scan sonar. The Trimble dGPS utilizes MSK beacon or the Satellite Based Augmentation System to enhance the GPS positioning for improved, sub-meter-accurate real-time positioning. The 4125 side-scan sonar system utilizes CHIRP technology to provide higher-resolution imagery at ranges up to 50 percent greater than traditional continuous-wave systems operating at the same frequency. At 600 kHz, the 4125 is capable of obtaining resolution across track of 1.5 centimeters (0.6 inches); resolution improves to 0.6 centimeters at 1,600 kHz (0.2 inches). The magnetometer instrumentation used a Trimble DSM-232 dGPS and a Geometrics G-882 magnetometer.

The side-scan sonar towfish, deployed from the vessel gunwale, was maintained at a depth just below the vessel hull. This configuration did not provide 100-percent imagery overlap in the deep-water areas of the search. The system operated at a frequency of 1,600 kHz with acquisition range set at 35 meters (115 feet) (i.e., total swath width=70 meters [230 feet]). Vessel speed varied, but did not exceed 5 knots whenever possible, which maximized data collection. HYPACK navigation software, interfaced with the dGPS, maintained vessel positioning with sub-meter accuracy and logged real-time positional data at a rate of 5 hertz. The dGPS was interfaced with the side-scan sonar topside acquisition computer operating EdgeTech

Discover software, which embedded positional data into the raw imagery and allowed for geo-rectification of the side-scan sonar record during processing. The survey was conducted in the UTM coordinate system (Zone 53N) based on the WGS84 datum.

The magnetometer towfish, deployed from the vessel gunwale, was maintained at a depth just below the vessel hull. This configuration did not hamper 100-percent data collection in the deep-water areas of the search. Vessel speed varied, but did not exceed 5 knots, which maximized data collection. HYPACK navigation software, interfaced with the dGPS, maintained vessel positioning with sub-meter accuracy and logged real-time positional data at a rate of 5 hertz. The dGPS was interfaced with a Panasonic Toughbook survey laptop with Hypack Navigation Software for topside data acquisition. The survey was conducted in the UTM coordinate system (Zone 53N) based on the WGS84 datum.

c) Reef Towed Swimmer Survey
The towed swimmer survey consisted of two swimmers towed over four overlapping lines spaced approximately 20 meters apart. Water visibility was in excess of 60 ft., making visual inspection possible. Because the survey occurred during high tide, the towed swimmers were able to get very close to the reef. Survey tracks were recorded using a Garmin GPSMAP 64st GPS.

d) Lagoon and Terrestrial Inshore Walking Surveys
Lagoon: The walking survey inspected the lagoon from the mean low water line out to the fringing reef, approximately 300 meters (800 ft.). The survey area was roughly rectangular from the south end at the existing harbor to the northernmost end of White 1 beach, a distance of approximately 2.25 kilometers (1.4 miles). The 5-person team was spaced approximately 5-6 meters apart. The lagoon is less than 3 feet deep and the visibility was excellent, making visual identification possible. Survey tracks were recorded using a Garmin GPSMAP 64t GPS.
Terrestrial Inshore Survey: A 3-person survey team spaced 5-6 meters apart examined the shoreline from the mean low water line to approximately 30 meters (100 ft.) inland. The survey area was roughly rectangular from the south end at the existing harbor to the northernmost end of White 1 beach, a distance of approximately 2.25 km (1.4 miles). Survey tracks were recorded using a Garmin GPSMAP 64t GPS.

e) KOCOA analysis of the offshore reef, lagoon, and nearshore invasion beaches. KOCOA military terrain analysis originated with the U.S. armed forces as a means of analyzing battlespace geography prior to an engagement. KOCOA, also written as OCOKA or OAKOC, involves the systematic analysis of site terrain through different tactical lenses. Significant terrain features within the battlespace are classified as one or more of the following: Key Terrain, Observation, Cover/Concealment, Obstacles, and Avenues of Approach and Withdrawal. This classification assists with battle preparation and guides military strategy.

Today, the U.S. National Park Service (NPS) American Battlefield Protection Program (ABPP) utilizes KOCOA as one of several terrain analyses for interpreting and understanding historic battlefield sites (NPS 2016). While initially developed for terrestrial landscape analysis, KOCOA has successfully been applied to maritime and aerial engagements (Army 1994; Babits et al. 2011; Sabick and Dennis 2011; Frye and Resnick 2013; McKinnon and Carrell 2015). It was chosen for this research due to its flexibility and use on past ABPP projects.

b. Describe how the project was organized and managed
   - Toni L. Carrell, Ph.D. – PI, overall project management, field director
   - John H.R. Burns, Ph.D. – co-PI, biological characterization, photogrammetry
   - Jennifer F. McKinnon, Ph.D. – co-PI, data management, UCH survey
   - Jeff Enright, M.A. – remote sensing, side scan sonar
   - Michael C. Krivor, M.A. – remote sensing, magnetometer

c. Describe how data was organized, processed, and archived
   - Downloaded and copied to three (3) backup drives (field operations): Photos, field notes, GPS positions, and remote sensing data
   - Backup to cloud server (Ships of Discovery, East Carolina University, University of Hawaii Hilo)
   - Backup drives housed at Ships of Discovery, East Carolina University, University of Hawaii Hilo
   - Submitted to NOAA according to guidance issued under Public Access to Research Results (PARR) FFO Data Submission Guidance 2017

4. Findings:

a. Describe actual accomplishments and findings (Comprehensive Project Results Appendix 3)
   - High-resolution (mm-scale) 3D reconstructions were generated at survey sites by collecting overlapping images (70-80% overlap) from planar and oblique angles of reef plots. Images were collected from six 2x2-m plots at three isobaths (~40fsw, ~20fsw, ~10fsw) at each survey site (18 plots per site); 425 reef plots. The plots were located from the base of the blast zones to the top of the reef flat. Survey plots were also conducted along the same isobaths at locations that were not affected by blasting during pre-invasion preparation.
   - Three blast zones were modeled in entirety to create 3D maps and to quantify the geomorphology produced by these activities.
   - The science team revisited or located 100 sites that represent both modern debris and WWII specific remains (Appendix 3.1). The terrestrial survey inshore of the invasion beaches identified 60 artifact scatters, miscellaneous debris, pieces of equipment, or other defensive positions.
   - Twenty previously unrecorded cultural heritage sites were located offshore and an additional 20 in the inshore lagoon. Five UCH sites were documented by 3D photogrammetry.
   - The side-scan sonar imaged 18 acoustic contacts.
   - The magnetometer identified 20 anomalies.
   - Survey inshore of the invasion beaches revisited 14 sites previously recorded by Denfeld (1980) and/or by Knecht, Price, and Lindsay (2012) and identified 11 previously unrecorded sites.
   - KOCOA analysis of the reefs and nearshore invasion beaches.

b. Inventory of activities (number of submersible dives, CTD, net tows, etc.)
   - Biological Survey: 425 reef plots, 3 blast zones, and 5 underwater cultural heritage sites were documented.
   - Side Scan Survey: five parallel lines spaced 20 meters (66 ft.) apart covering approximately 12 line-miles.
   - Magnetometer Survey: 6 parallel lines spaced 20 meters (66 ft.) apart covering approximately 13.66 lines-miles.
   - Reef Towed Swimmer Survey: two-person teams towed on four overlapping survey lines spaced approximately 20 meters (66 ft.) apart covering approximately 9-1/2 line miles.
   - Lagoon Walking Survey: five-person team spaced 5-6 meters apart surveyed the lagoon from the mean low water line out to the fringing reef, approximately 300

meters (800 ft.), from the existing harbor in the south to the north end of White 1 beach, a distance of approximately 2.25 kilometers (1.4 miles).

- Terrestrial Inshore Survey: three-person team spaced 5-6 meters apart surveyed the shoreline from the mean low water line to approximately 30 meters (100 ft.) inland from the existing harbor in the south to the north end of White 1 beach, a distance of approximately 2.25 kilometers (1.4 miles).

c. Inventory of samples collected
No samples collected

d. Describe/list/append resulting publications, Web sites, presentations, etc.
All publications must refer to NOAA/OER funding

- News release in *Tia Belau* Newspaper Article: "Ships of Discovery in Palau for WWII Research" Vol. 27, No. 26, April 2, 2018, page 2, continued page 11. (refer to Appendix 2)
- Ships of Discovery Facebook
- NOAA OER Website

e. Location and status of data archive and/or sample storage, plan for public access, and final data inventory

- University of Hawaii Hilo
- East Carolina University
- Ships of Discovery
- NOAA OER program

f. Notation of major changes/adjustments to previously submitted documents (e.g. QLR, Semi-Annual Report, and/or Annual Report)
None

III. Evaluation:

1. Accomplishments – Explain special problems, differences between scheduled and accomplished work
   Equipment malfunction during the April 2018 fieldwork limited the ability of the team to collect magnetometer data. As a result, it was not until July 2019 that a return to Peleliu was possible to complete the magnetometer survey. The equipment problem and 2019 return required a grant extension to August 2020.
2. Expenditures:
   a. Describe original planned expenditures: $89,969
   b. Describe actual expenditures: $89,969
   c. Include a final budget table with a column of original planned expenditures and a column of actual grant expenditures

Table 1: Expenditures through 4/30/2020

	* Funds Available	Expenditures through 4/30/2020	
	For This Reporting Period	For This Reporting Period	Balance Remaining
Salaries & Wages	$7760.00	7,760.00	$0.00
Staff Benefits	$592.92	592.92	$0.00
Travel	$42,142.00	39,591.74	$2,550.26
Services	$35,157.00	38,420.63	($3,263.63)
Supplies	$3,317.08	3,603.71	($286.73)
Equipment	$0	$0	$0
Other	$1,000.00	$0	$1,000.00

	* Funds Available	Expenditures through 4/30/2020	
	For This Reporting Period	For This Reporting Period	Balance Remaining
Indirect Cost	$0	$0	$0
Total	$89,969.00	$89,969.00	$0

* Funds awarded this grant

d. Explain special problems, differences between planned and actual expenditures:
None

3. Next Steps:
   a. Planned or expected reports (professional papers, presentations, etc.):
   None planned at the time of this report.
   b. Brief description of need for additional work, if any (next project phase, new research questions, unaccomplished work, etc.)
   None required at this time.

Prepared By: Toni L. Carrell ____________________ April 17, 2020
Signature of Principal Investigator Date


Appendix 1
China
Palau
Indonesia
Papua New Guinea
Australia
New Zealand
PALAU
Melekeok
Peleliu Island
Palau Trench
Peleliu Island
N
0
600
Meters
Feet
0
2,000
Proposed Survey Area
Basemaps: ESRI World Imagery / ESRI Oceans

TIA BELAU

Ships of Discovery in Palau for WWII research

Ships of Exploration and Discovery Research, Inc. (Ships of Discovery) researcher are headed to Peleliu to undertake a Phase I remote sensing survey of the WWII invasion beaches. The project is funded through a 2017 NOAA Ocean Exploration Research grant with additional support from an NPS American Battlefield Protection Program (ABPP) grant.

This project will be the first comprehensive survey for underwater cultural heritage remains of the Peleliu invasion beaches, fringing reef, and lagoon. Integral to the project is an examination of the impacts of the pre-invasion blasting of the reef by Underwater Demolition Teams (UDTs). The reef study will be the first of its kind to document the WWII impacts and to quantify the interactive role of the corals and WWII materiel on both resources. Photogrammetric documentation of underwater cultural heritage sites and the reef will result in 3D interactive models for in-depth analysis and that will be publically viewable through SketchFab.

This project is a cooperative effort between Ships of Discovery, East Carolina University (ECU) Maritime Studies Program, University of Hawi'i Hilo, SEARCH Inc, the US Navy Joint Region Marianas, and the Palau Bureau of Cultural and Historical Preservation. Fieldwork will begin on April 2 and run through April 12.

Previous research in the Pacific by Ships of Discovery and ECU includes several projects in Saipan and Tinian under the National Park Service American Battlefield Protection Program (ABPP). Their work includes the creation of an underwater heritage maritime trail, consisting of twelve submerged and semi-submerged archaeological sites including four aircraft wrecks, two shipwrecks, three tanks, two landing craft and one Amtrak. Waterproof guides (in English and Japanese) including a site map and historical information, posters that included images of the wrecks and more in-depth information, and an

See SHIP on page 11

SHIP...

from Page 2

18-minute interpretive video created for the NPS are part of their Saipan work. The video is also available on Ships YouTube Channel: https://www.youtube.com/user/ShipsOfDiscovery

Special thanks and gratitude is deeply owed to the Office of the President and H.E. Tommy E. Remengesau, Jr., Minister Baklai Temengil-Chilton, Ministry of Community and Cultural Affairs and most especially to the Honorable Governor of Peleliu State, Mr. Temmy Shmull for their support to make this research possible that will contribute to the deep understanding and preservation of the Republic of Palau's WWII underwater heritage.

Appendix 2

Appendix 3: Comprehensive Project Results

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List of Acronyms and Abbreviations

dGPS	Differential Global Positioning System
DUKW	Amphibious Truck
fsw	Feet of Seawater
Km	Kilometers
KOCOA	Key terrain, Observation, Cover/concealment, Observation, Avenue of approach or withdrawal
LCM	Landing Craft, Mechanized
LCVP	Landing Craft, Personnel
LST	Landing Ship, Tank
LVT	Landing Vehicle, Tank
m	Meters
NARA	National Archives and Records Administration

NOAA	National Oceanic and Atmospheric Administration
ONI	Office of Naval Intelligence
PAD	Pontoon Assembly Detachment
SfM	Structure from Motion
UCH	Underwater Cultural Heritage
UDT	Underwater Demolition Team
UID	Unidentified
WWII	World War II

Introduction

The focus of this project is the World War II (WWII) battle that began on September 12, 1944, in the Palau Islands in the Caroline Island archipelago (Figure 1). Peleliu, located at the southern end of the island chain, was a strategic objective for both the Japanese and U.S. militaries (Figure 2). This project is the first effort to study the Peleliu WWII invasion beaches and the offshore battlespace.

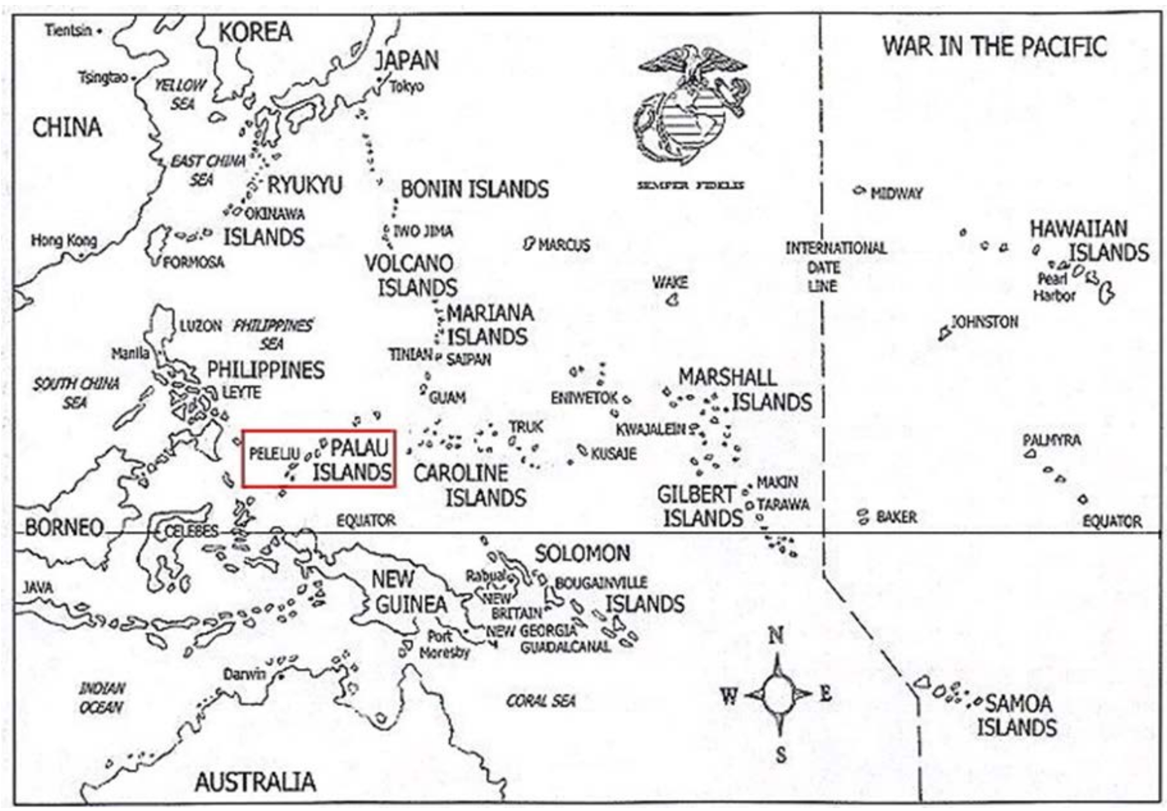


Figure 1. Location of Palau in the Western Caroline Islands. USMC map, n.d.

Archeological research on Peleliu has been remarkably limited given the importance and tremendous loss of life during the battle. D. Colt Denfeld's survey in 1981 was the first, funded through the National Park Service (NPS) as part of the on-going Micronesian Archeological Survey (Denfeld 1988). A long needed revisiting, reexamination, and expansion on Denfeld's 1981 survey was completed in 2010. Funded under an NPS American Battlefield Protection Program (ABPP) Grant, Rick Knecht, Neil Price, and Gavin Lindsay lead a team on an intensive nine-day survey of a portion of the Peleliu terrestrial battlefield (Knecht et.al. 2012). Both of these archeological investigations focused on the terrestrial battle.

The goal of this project was to locate the scattered material remains of Peleliu's submerged battlefield, to photogrammetrically record those remains, and to examine the reef substrate and its coral communities to determine if the scars from the U.S. military blasting of the reef to create access ramps into the lagoon were still visible after 74 years.

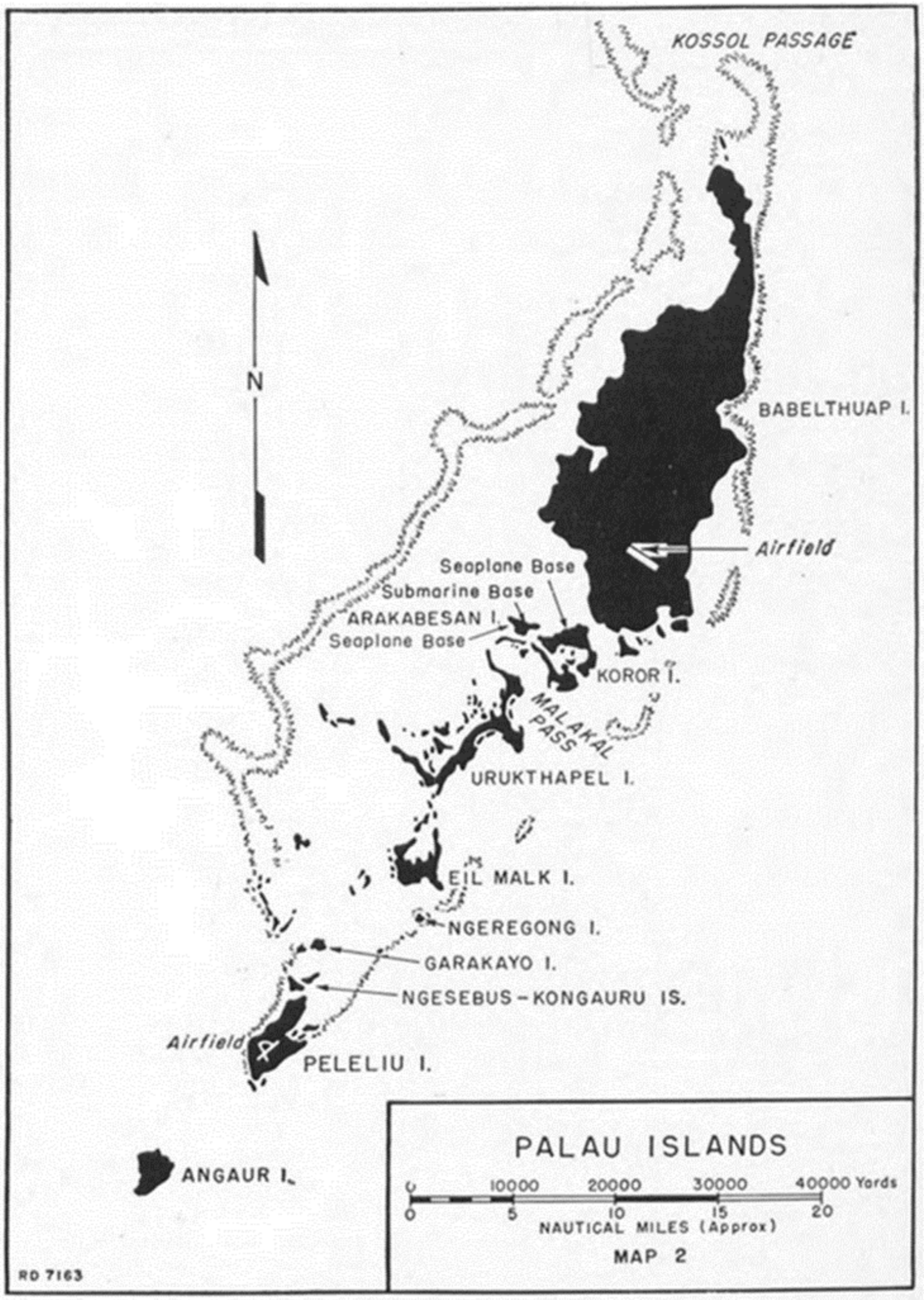


Figure 2. Location of Peleliu at the southern end of the island chain. Hough 1950:5, Map 2.

No systematic remote sensing survey of the invasion beaches, lagoon, and reef to identify underwater cultural heritage sites (UCH) has ever been undertaken at Peleliu. Previous periods of shoreline reef clean-up have already altered the amount and type of WWII sites that are preserved, which directly affects battlefield interpretation. The location and identification of all remaining UCH sites is critical to understanding the full battlefield on land and underwater.

No biological characterizations of coral reef structures have ever been undertaken to quantify and model the long-term effects of WWII blasting in the Pacific. The health and recovery of reefs is important for understanding the human impacts and because the date of impact is known, it allows a baseline to model recovery and for comparison to other similarly impacted reefs in the Pacific theater.

This project is a Phase I submerged cultural resources survey and inventory, as defined by the Secretary of the Interior Standards, which included:

- geophysical remote sensing using a side scan sonar and magnetometer
- swimmer/diver reconnaissance in the shallow areas of the reef
- target diving on anomalies to identify submerged sites
- standard archaeological documentation for a Phase 1 survey (photographs, written documentation of significant features, etc.)
- walking survey of the invasion beaches from the shoreline to approximately 30 meters inland to facilitate a KOCOA analysis
- swimmer/diver examination reef to locate areas of pre-invasion destruction resulting from explosives used to permit amphibious landings
- marine biological characterization of:
    - coral reef structures and substrate encompassing the submerged sites and debris fields
    - coral reef structures in the known areas of pre-invasion blasting
    - control areas (not disturbed by human activity)

The swimmer/diver reconnaissance and terrestrial shoreline survey identified a number of sites. The documentation of selected sites in this report is not intended to be exhaustive nor definitive. The information provided is an overview of the site with historical context, description, and preliminary analysis and serves as a baseline inventory.

Biological characterization of the reefs included high-resolution (mm-scale) 3D reconstructions from 424 reef plots by collecting overlapping images (70-80% overlap) from planar and oblique angles of reef plots. The plots were located from the base of the blast zones to the top of the reef flat at locations impacted by blasting during the invasion and locations where no blasting occurred.

A secondary component of this project was to produce a KOCOA analysis of the maritime battlefield. KOCOA is a widely used method in conflict archeology to model battlefield action and troop movements. In this context, it was used to understand the activities that influenced the invasion and the decisions and limitations imposed by the natural terrain and built environment. These features directly influence the loss of men and materiel in the first hours of the invasion.

A NOAA Ocean Exploration Grant funded this project under agreement NA17OAR0110214. The Department of the Interior (DOI), NPS, ABPP grant under agreement GA-2287-17-015, augmented these funds and permitted a longer site visit and in-depth KOCOA analysis. The results of the ABPP grant are reported in Carrell et.al. 2020.

The scope of the project is limited to the Peleliu invasion beaches designated as White 1, White 2, Orange 1, Orange 2, and Orange 3, to approximately 30 m (100 ft.) inland. Seaward, it includes the lagoon, the reef, and the immediate area just beyond the reef (Figure 3).

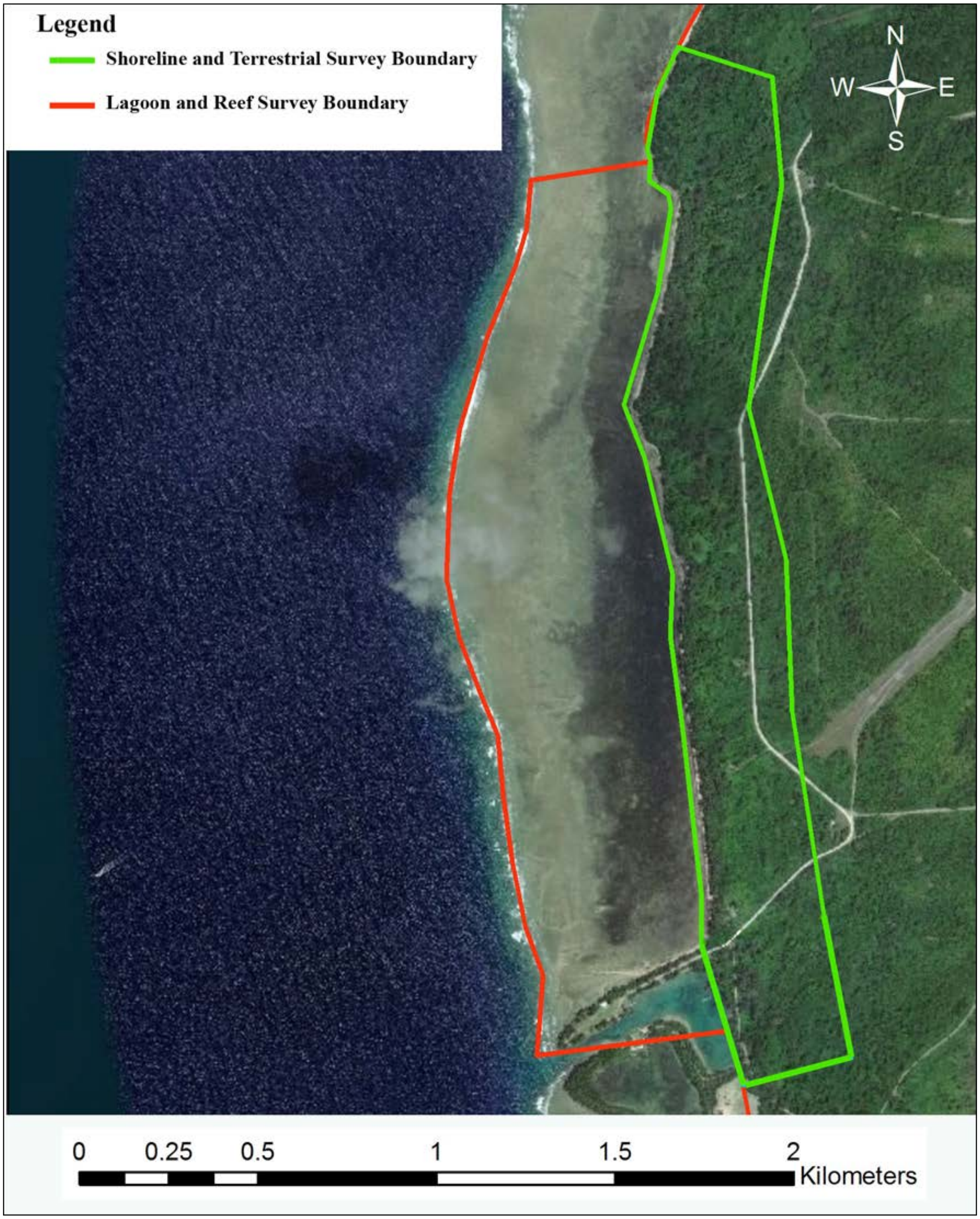


Figure 3. Project Area. Map by Roth/Ships of Discovery Science Team

The environmental characteristics of the invasion beaches necessitated that project area and investigation be broken into four zones: outside the reef, the reef top and margins, the shallow lagoon from the reef to the shore, and the area just inshore of the invasion beaches.

In each location, there were some challenges including large fluctuations in tidal range and longshore current, sometimes helping and other times hindering the search. The heavily overgrown shore made walking and locating Japanese defensive positions a challenge.

Description of Activities

Summary of Milestones Achieved

1. High-resolution (mm-scale) 3D reconstructions were generated at survey sites by collecting overlapping images (70-80% overlap) from planar and oblique angles of reef plots. Images were collected from six 2x2-m plots at three isobaths (~40fsw, ~20fsw, ~10fsw) at each survey site (18 plots per site) resulting in 425 reef plots. The plots were located from the base of the blast zones to the top of the reef flat. Survey plots were also conducted along the same isobaths at locations that were not affected by blasting during pre-invasion preparation.
2. Three blast zones were modeled in entirety to create 3D maps of these unique areas and to quantify the geomorphology produced by these activities.
3. The side-scan sonar imaged 18 acoustic contacts (Table 1). Extensive coral growth complicated contact selection, because of the difficultly in differentiating between natural coral reef and artificial coral reef development on manmade structures. The magnetometer identified 20 anomalies (Table 5).
4. Survey of the reef and lagoon identified 40 sites representing both the modern and WWII period. Twenty sites were identified on the reef and an additional 20 in the inshore lagoon (Table 7, Table 8). Five underwater cultural heritage (UCH) sites were documented by 3D photogrammetry and analyzed for coral species diversity.
5. Survey inshore of the invasion beaches identified 60 sites representing both modern debris and historic defensive positions, small artifact scatters, miscellaneous debris, equipment dumps, or pieces of equipment (Table 9). The team revisited 14 sites previously recorded by Denfeld (1980) and/or by Knecht, Price and Lindsay (2012) and identified 11 new defensive positions (Table 10 and Table 11). Figure 4 and Figure 5 illustrate the general locations of the archaeological sites located.
6. KOCOA analysis of the offshore reef, lagoon, and inshore defensive positions.

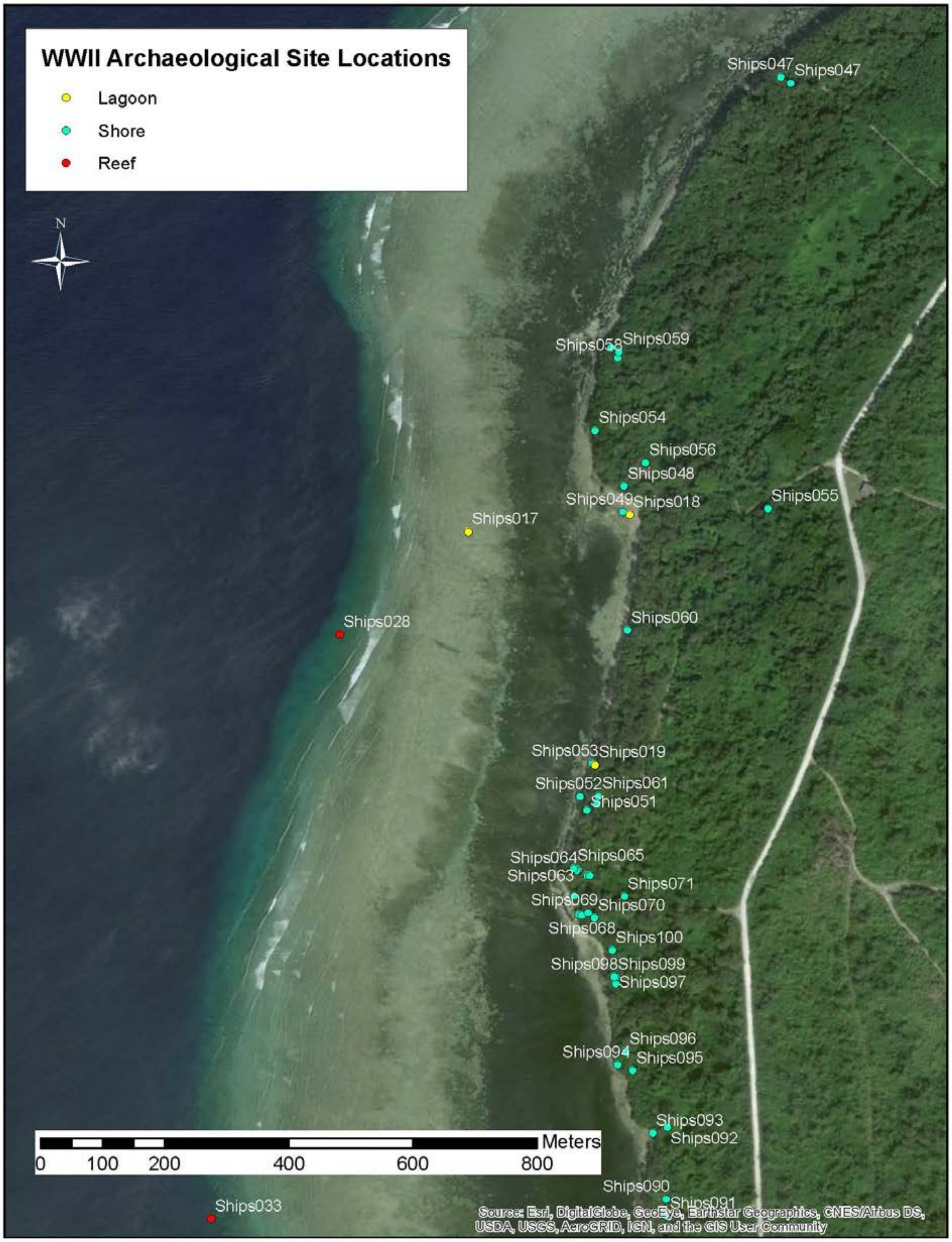


Figure 4. White Beach archaeological sites. Map by Roth/Ships of Discovery Science Team.

Figure 5. Orange Beach archaeological sites. Map by Roth/Ships of Discovery Science Team.

Results

Remote Sensing Survey

Marine remote-sensing survey of the Project Area occurred from April 2-14, 2018. Jeff Enright, from SEARCH Inc., participated in the survey from April 2-7, 2018. Equipment issues during the first week of fieldwork delayed the start of survey and prevented data collection while the team conducted troubleshooting of the equipment. A faulty magnetometer tow cable prohibited the collection of any magnetic data during this period, further hampering data collection. Only two lines of side-scan sonar imagery were acquired before a connection fault in the topside processing unit again delayed the side scan survey. The team identified a workaround on April 7 that allowed the side-scan survey to continue after Enright departed. Despite the problems, the remote sensing survey in April 2018, acquired side-scan sonar imagery over 5 parallel survey lines spaced 20 meters (66 ft.) apart (Figure 6). Two lines were collected the first week, while the remaining lines were collected during the second week. In total, the team acquired approximately 12 line-miles of imagery equating to approximately 8.5 gigabytes of data. Water depths in the survey area varied from less than 3.0 to approximately 35 meters (9.8 and 115 ft.).

On July 18, 2019, project PI Dr. Toni Carrell and Michael Krivor, Recon Offshore, returned to Peleliu to conduct a magnetometer survey of the offshore beaches. In total 13.66 line miles of data were collected, equating to approximately 135 megabytes of data. Water depths in the survey area varied from less than 3.0 to approximately 35 meters (9.8 to 115 ft.).

Side-Scan Sonar

The team reviewed each line of raw side-scan sonar imagery from the survey to locate acoustic contacts indicative of man-made features and potential submerged cultural resources protruding above the seafloor. Each contact was assigned a unique identifier, and descriptive information was collected and tabulated (e.g., length, width, dGPS position, etc.).

The team also generated a mosaic image of the project area comprising all raw sonar imagery. The ability to mosaic the imagery was made possible with embedded positional data from the dGPS utilizing Chesapeake Technology, Inc., SonarWiz 7 sonar processing software. High-frequency imagery files (600 kHz) were imported into the software using settings adjusted for the EdgeTech 4125 acquisition methods.

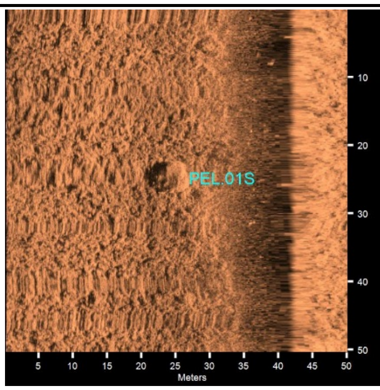
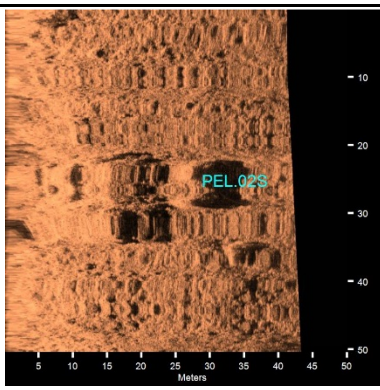
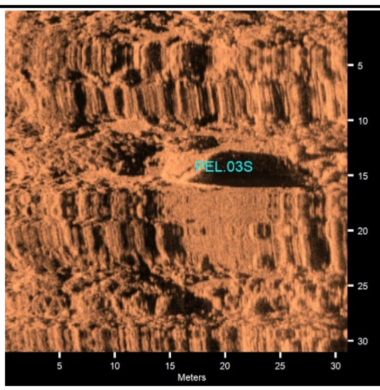
Following importation of the raw imagery, bottom tracking was performed to identify the first acoustic return, which determines the altitude of the towfish above the seafloor, creates a slant-range-corrected record, and removes the water column from the nadir region. Gain, color, and contrast settings were adjusted for each file in order to produce an optimal and even image across the entire mosaic. Returns from overlapping files were averaged. Thus, if a contact contrasts well on one trackline, but not on an adjacent line, averaged returns from both lines ensure significant contrast for contact detection. The mosaic was exported as a geo-rectified image (geotiff format) with a resolution of 0.15 meter/pixel (0.5 feet/pixel).

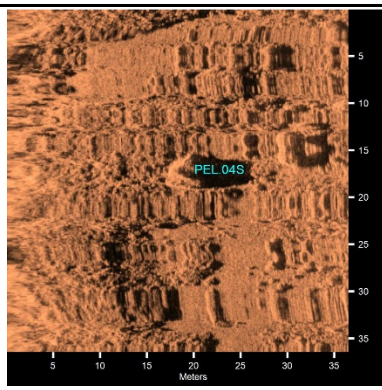
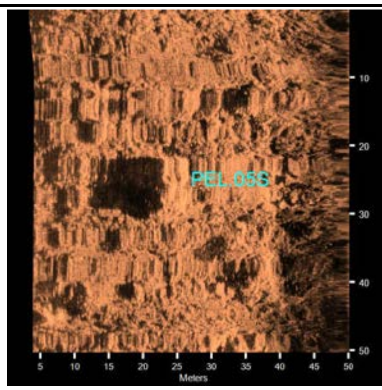
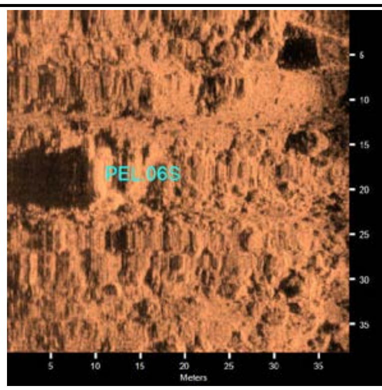
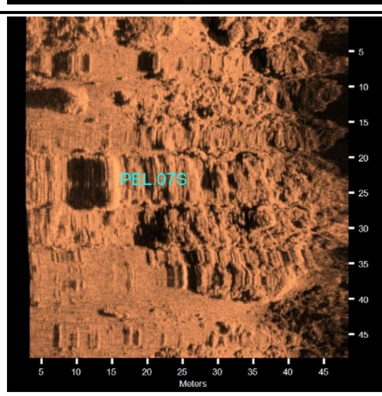
Figure 6. Side scan track plots and targets. Map by SEARCH, Inc.

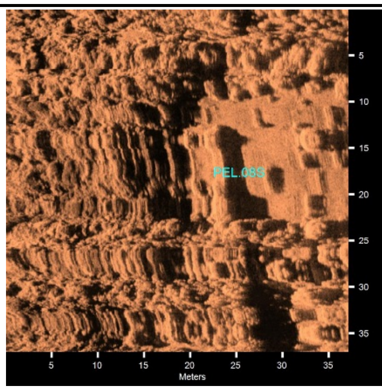
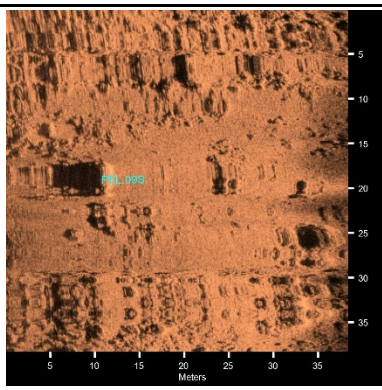
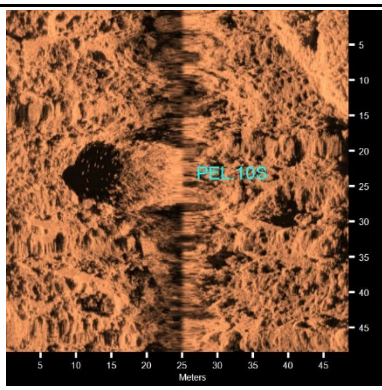
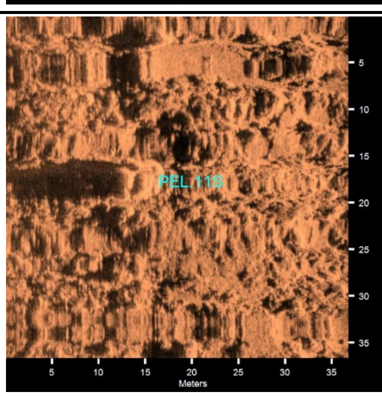
<u>Analysis</u>

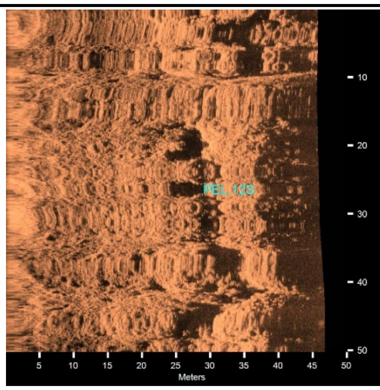
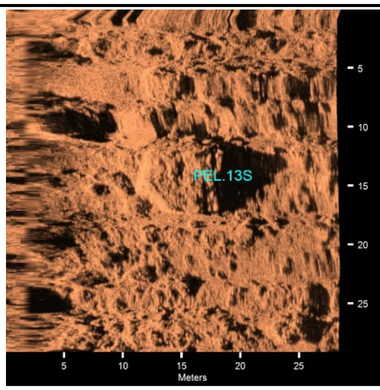
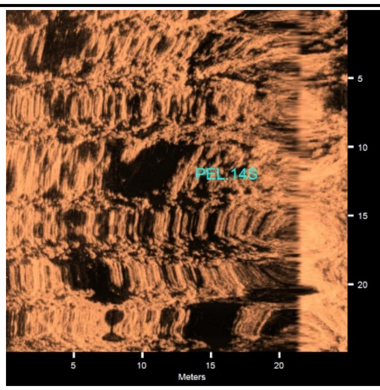
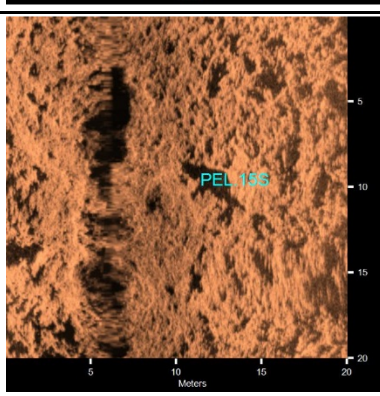
The side-scan sonar imaged 18 acoustic contacts that could represent manmade features. Extensive coral growth complicated contact selection because it was difficult to differentiate between natural coral reef and artificial coral reef. Figure 6 illustrates the locations of the 18 contacts, while Table 1 provides images and statistics. Each of the 18 targets were investigated by divers, but did not result in the identification of any UCH.

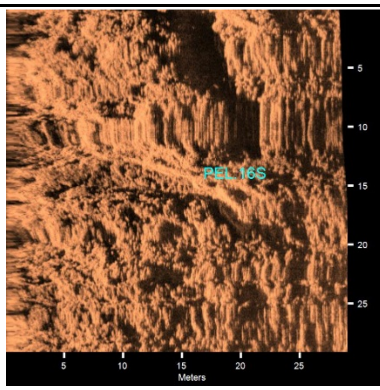
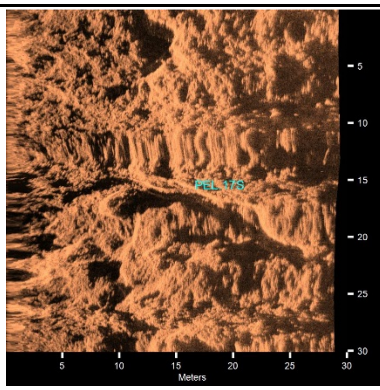
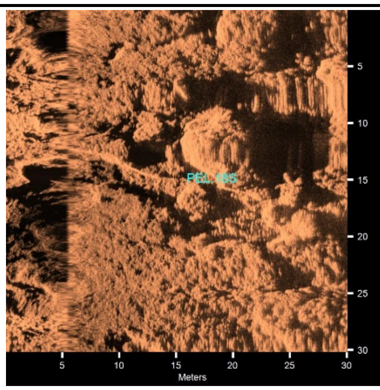
Table 1. Side scan targets. Analysis Enright/SEARCH.

Target Image	Target Info	User Entered Info
	**PEL.01S** • Sonar Time at Target: 4/7/2018 5:41:03 AM • Click Position [redacted] • Map Projection: UTM84-53N • Acoustic Source File: C:\SonarWiz-Projects\180033_Peleliu\RAW\Line2C.jsf • Ping Number: 20916 • Range to target: 16.89 Meters • Fish Height: 28.41 Meters • Heading: 10.300 Degrees • Line Name: Line2C	**Dimensions and attributes** • Target Width: 3.53 Meters • Target Height: 2.47 Meters • Target Length: 4.46 Meters • Target Shadow: 3.14 Meters
	**PEL.02S** • Sonar Time at Target: 4/7/2018 5:40:29 AM • Click Position [redacted] • Map Projection: UTM84-53N • Acoustic Source File: C:\SonarWiz-Projects\180033_Peleliu\RAW\Line2C.jsf • Ping Number: 20422 • Range to target: 26.85 Meters • Fish Height: 27.10 Meters • Heading: 351.200 Degrees • Line Name: Line2C	**Dimensions and attributes** • Target Width: 6.02 Meters • Target Height: 4.05 Meters • Target Length: 6.48 Meters • Target Shadow: 6.71 Meters
	**PEL.03S** • Sonar Time at Target: 4/7/2018 5:30:25 AM • Click Position [redacted] • Map Projection: UTM84-53N • Acoustic Source File: C:\SonarWiz-Projects\180033_Peleliu\RAW\Line2C.jsf • Ping Number: 11820 • Range to target: 24.21 Meters • Fish Height: 17.61 Meters • Heading: 355.290 Degrees • Line Name: Line2C	**Dimensions and attributes** • Target Width: 3.23 Meters • Target Height: 3.94 Meters • Target Length: 5.03 Meters • Target Shadow: 8.64 Meters

Target Image	Target Info	User Entered Info
	**PEL.04S** • Sonar Time at Target: 4/7/2018 5:29:44 AM • Click Position [redacted] • Map Projection: UTM84-53N • Acoustic Source File: C:\SonarWiz-Projects\180033_Peleliu\RAW\Line2C.jsf • Ping Number: 11229 • Range to target: 20.31 Meters • Fish Height: 20.09 Meters • Heading: 359.200 Degrees • Line Name: Line2C	**Dimensions and attributes** • Target Width: 4.24 Meters • Target Height: 3.45 Meters • Target Length: 4.07 Meters • Target Shadow: 5.93 Meters
	**PEL.05S** • Sonar Time at Target: 4/7/2018 5:38:30 AM • Click Position [redacted] • Map Projection: UTM84-53N • Acoustic Source File: C:\SonarWiz-Projects\180033_Peleliu\RAW\Line2C.jsf • Ping Number: 18733 • Range to target: 25.39 Meters • Fish Height: 18.10 Meters • Heading: 352.390 Degrees • Line Name: Line2C	**Dimensions and attributes** • Target Width: 4.31 Meters • Target Height: 4.30 Meters • Target Length: 8.49 Meters • Target Shadow: 9.71 Meters
	**PEL.06S** • Sonar Time at Target: 4/7/2018 5:38:05 AM • Click Position [redacted] • Map Projection: UTM84-53N • Acoustic Source File: C:\SonarWiz-Projects\180033_Peleliu\RAW\Line2C.jsf • Ping Number: 18372 • Range to target: 35.63 Meters • Fish Height: 18.26 Meters • Heading: 351.790 Degrees • Line Name: Line2C	**Dimensions and attributes** • Target Width: 3.30 Meters • Target Height: 2.99 Meters • Target Length: 7.81 Meters • Target Shadow: 7.83 Meters
	**PEL.07S** • Sonar Time at Target: 4/7/2018 4:51:05 AM • Click Position [redacted] • Map Projection: UTM84-53N • Acoustic Source File: C:\SonarWiz-Projects\180033_Peleliu\RAW\Line3B.jsf • Ping Number: 168215 • Range to target: 35.81 Meters • Fish Height: 16.06 Meters • Heading: 349.100 Degrees • Line Name: Line3B	**Dimensions and attributes** • Target Width: 2.77 Meters • Target Height: 1.96 Meters • Target Length: 7.72 Meters • Target Shadow: 5.47 Meters

Target Image	Target Info	User Entered Info
	**PEL.08S** • Sonar Time at Target: 4/7/2018 4:44:02 AM • Click Position [redacted] • Map Projection: UTM84-53N • Acoustic Source File: C:\SonarWiz-Projects\180033_Peleliu\RAW\Line3B.jsf • Ping Number: 162182 • Range to target: 27.11 Meters • Fish Height: 13.23 Meters • Heading: 355.890 Degrees • Line Name: Line3B	**Dimensions and attributes** • Target Width: 4.00 Meters • Target Height: 1.43 Meters • Target Length: 10.57 Meters • Target Shadow: 3.65 Meters
	**PEL.09S** • Sonar Time at Target: 4/7/2018 4:41:25 AM • Click Position [redacted] • Map Projection: UTM84-53N • Acoustic Source File: C:\SonarWiz-Projects\180033_Peleliu\RAW\Line3B.jsf • Ping Number: 159945 • Range to target: 35.07 Meters • Fish Height: 18.89 Meters • Heading: 352.790 Degrees • Line Name: Line3B	**Dimensions and attributes** • Target Width: 1.38 Meters • Target Height: 2.16 Meters • Target Length: 3.64 Meters • Target Shadow: 5.15 Meters
	**PEL.10S** • Sonar Time at Target: 4/7/2018 4:00:43 AM • Click Position [redacted] • Map Projection: UTM84-53N • Acoustic Source File: C:\SonarWiz-Projects\180033_Peleliu\RAW\Line4B.jsf • Ping Number: 140396 • Range to target: 0.00 Meters • Fish Height: 13.24 Meters • Heading: 354.700 Degrees • Line Name: Line4B	**Dimensions and attributes** • Target Width: 7.16 Meters • Target Height: 5.29 Meters • Target Length: 9.96 Meters • Target Shadow: 8.63 Meters
	**PEL.11S** • Sonar Time at Target: 4/7/2018 3:59:13 AM • Click Position [redacted] • Map Projection: UTM84-53N • Acoustic Source File: C:\SonarWiz-Projects\180033_Peleliu\RAW\Line4B.jsf • Ping Number: 139117 • Range to target: 29.19 Meters • Fish Height: 15.32 Meters • Heading: 347.100 Degrees • Line Name: Line4B	**Dimensions and attributes** • Target Width: 3.70 Meters • Target Height: 4.03 Meters • Target Length: 5.29 Meters • Target Shadow: 11.78 Meters

Target Image	Target Info	User Entered Info
	**PEL.12S** • Sonar Time at Target: 4/7/2018 3:48:34 AM • Click Position [redacted] • Map Projection: UTM84-53N • Acoustic Source File: C:\SonarWiz-Projects\180033_Peleliu\RAW\Line4B.jsf • Ping Number: 130012 • Range to target: 27.34 Meters • Fish Height: 19.99 Meters • Heading: 341.890 Degrees • Line Name: Line4B	**Dimensions and attributes** • Target Width: 7.47 Meters • Target Height: 2.38 Meters • Target Length: 16.02 Meters • Target Shadow: 4.58 Meters
	**PEL.13S** • Sonar Time at Target: 4/7/2018 3:29:16 AM • Click Position [redacted] • Map Projection: UTM84-53N • Acoustic Source File: C:\SonarWiz-Projects\180033_Peleliu\RAW\Line5B.jsf • Ping Number: 105093 • Range to target: 13.18 Meters • Fish Height: 14.17 Meters • Heading: 159.100 Degrees • Line Name: Line5B	**Dimensions and attributes** • Target Width: 6.00 Meters • Target Height: 3.25 Meters • Target Length: 7.19 Meters • Target Shadow: 5.75 Meters
	**PEL.14S** • Sonar Time at Target: 4/4/2018 3:05:54 AM • Click Position [redacted] • Map Projection: UTM84-53N • Acoustic Source File: C:\SonarWiz-Projects\180033_Peleliu\RAW\Line6.jsf • Ping Number: 29896 • Range to target: 8.44 Meters • Fish Height: 7.68 Meters • Heading: 1.290 Degrees • Line Name: Line6	**Dimensions and attributes** • Target Width: 0.92 Meters • Target Height: 2.08 Meters • Target Length: 4.46 Meters • Target Shadow: 4.24 Meters
	**PEL.15S** • Sonar Time at Target: 4/4/2018 3:02:41 AM • Click Position [redacted] • Map Projection: UTM84-53N • Acoustic Source File: C:\SonarWiz-Projects\180033_Peleliu\RAW\Line6.jsf • Ping Number: 25243 • Range to target: 4.39 Meters • Fish Height: 2.94 Meters • Heading: 326.890 Degrees • Line Name: Line6	**Dimensions and attributes** • Target Width: 1.36 Meters • Target Height: 1.00 Meters • Target Length: 2.21 Meters • Target Shadow: 2.74 Meters

Target Image	Target Info	User Entered Info
	**PEL.16S** • Sonar Time at Target: 4/4/2018 3:27:53 AM • Click Position [redacted] • Map Projection: UTM84-53N • Acoustic Source File: C:\SonarWiz-Projects\180033_Peleliu\RAW\Line6.001.jsf • Ping Number: 61661 • Range to target: 15.70 Meters • Fish Height: 8.42 Meters • Heading: 331.700 Degrees • Line Name: Line6.001	**Dimensions and attributes** • Target Width: 1.73 Meters • Target Height: 0.00 Meters • Target Length: 12.21 Meters • Target Shadow: 0.00 Meters
	**PEL.17S** • Sonar Time at Target: 4/7/2018 3:06:39 AM • Click Position [redacted] • Map Projection: UTM84-53N • Acoustic Source File: C:\SonarWiz-Projects\180033_Peleliu\RAW\Line6B.jsf • Ping Number: 72405 • Range to target: 15.70 Meters • Fish Height: 7.11 Meters • Heading: 14.600 Degrees • Line Name: Line6B	**Dimensions and attributes** • Target Width: 1.46 Meters • Target Height: 0.00 Meters • Target Length: 9.58 Meters • Target Shadow: 0.00 Meters
	**PEL.18S** • Sonar Time at Target: 4/7/2018 2:54:38 AM • Click Position [redacted] • Map Projection: UTM84-53N • Acoustic Source File: C:\SonarWiz-Projects\180033_Peleliu\RAW\Line6B.jsf • Ping Number: 55045 • Range to target: 9.55 Meters • Fish Height: 4.51 Meters • Heading: 346.890 Degrees • Line Name: Line6B	**Dimensions and attributes** • Target Width: 0.00 Meters • Target Height: 0.00 Meters • Target Length: 17.59 Meters • Target Shadow: 0.00 Meters

Magnetometer Survey

The magnetometer survey of the Peleliu Landing Beaches was undertaken on July 18, 2019. The following methods were used to document all magnetic anomalies within the project area.

Methodology and Equipment

All remote sensing survey data for the magnetometer survey was collected in the following geodetic parameters (Table 2).

Table 2. Geodetic Parameters Used During the Current Investigation

Predefined Grid	Ellipsoid	Zone	Distance Unit
UTM North	WGS84	Zone 53 (132E-138E)	Meter

An historic map (Palau Islands "Peleliu I. and Angaur I."; U.S.S. Hydrographer Survey Nov. 1944 – January 1945) was used as a background file for pre-planning the survey area, placement/orientation of survey area track lines, and navigation during the remote sensing survey (Figure 7).

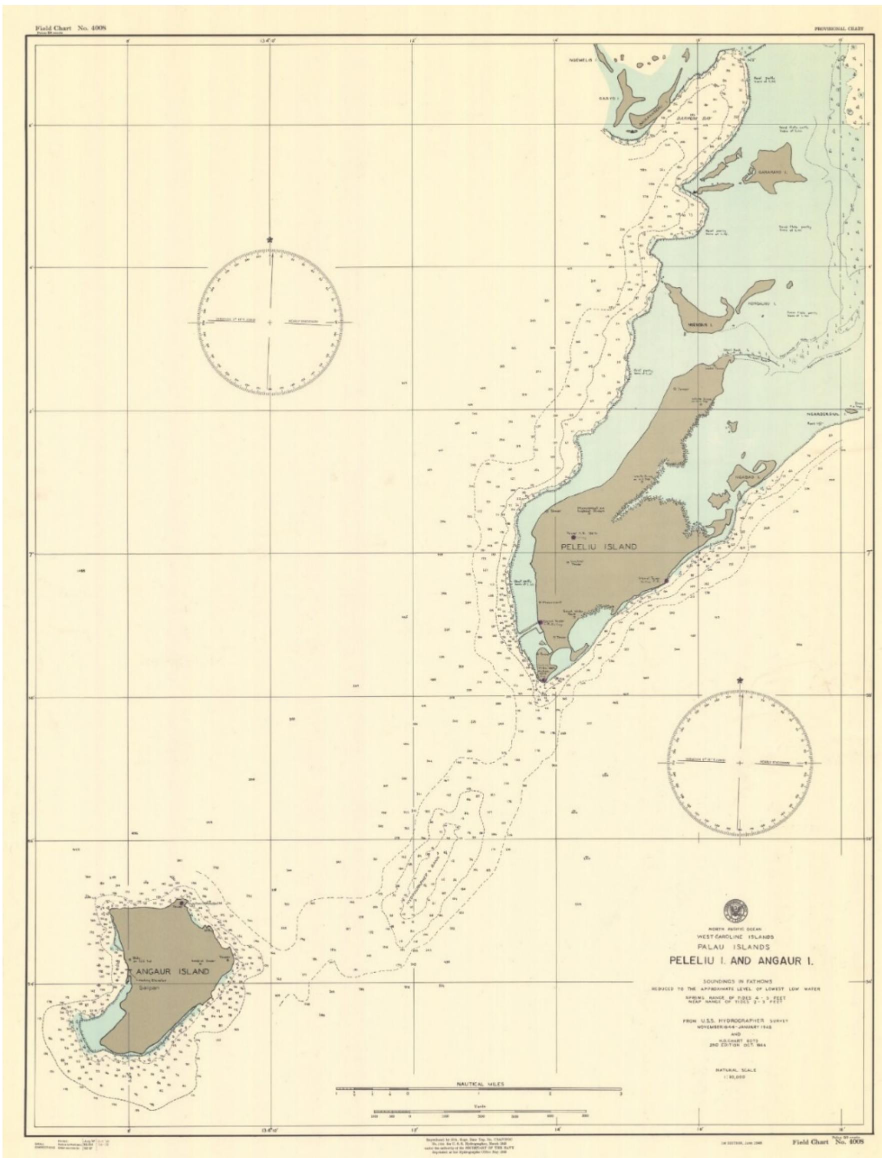


Figure 7. Historic map used for pre-planning and survey during the current investigation (Palau Islands "Peleliu I. and Angaur I."; from U.S.S. Hydrographer Survey November 1944 – January 1945).

One of the more important aspects of any remote sensing survey includes the accuracy of the remote sensing data and survey instrument layback. Layback includes the X, Y, and Z distance (in meters) from each of the remote sensing instruments tow point(s) relative to the “zero (center) point” on the survey vessel. The layback was physically measured, entered into the survey software prior to initiating activity, and corroborated at the end of the survey during data processing (Table 3). The magnetometer, towed 15 meters behind the survey vessel, used a towfish device driver (towfish.dll) in Hypack™. This uses cable out (15 meters) and a catenary factor to accurately determine the position of the towfish during the survey.

Table 3. Remote Sensing Instrument Layback (in meters) from the Center point of the Dukl Survey Vessel.

Instrument	X (Starboard)	Y (Aft)	Z (Vertical)
GPS	-1.00	-3.00	3.60
Magnetometer	-2.0	-5.50	1.00

Six (n=6) parallel track lines were plotted to accurately survey the western shoreline of Peleliu. Transect interval was 20 meters (66 ft.) and the survey vessel speed did not to exceed 5 knots. Parallel survey track lines were oriented based on the geography (primarily the extant reef line) running parallel to the shoreline of Peleliu.

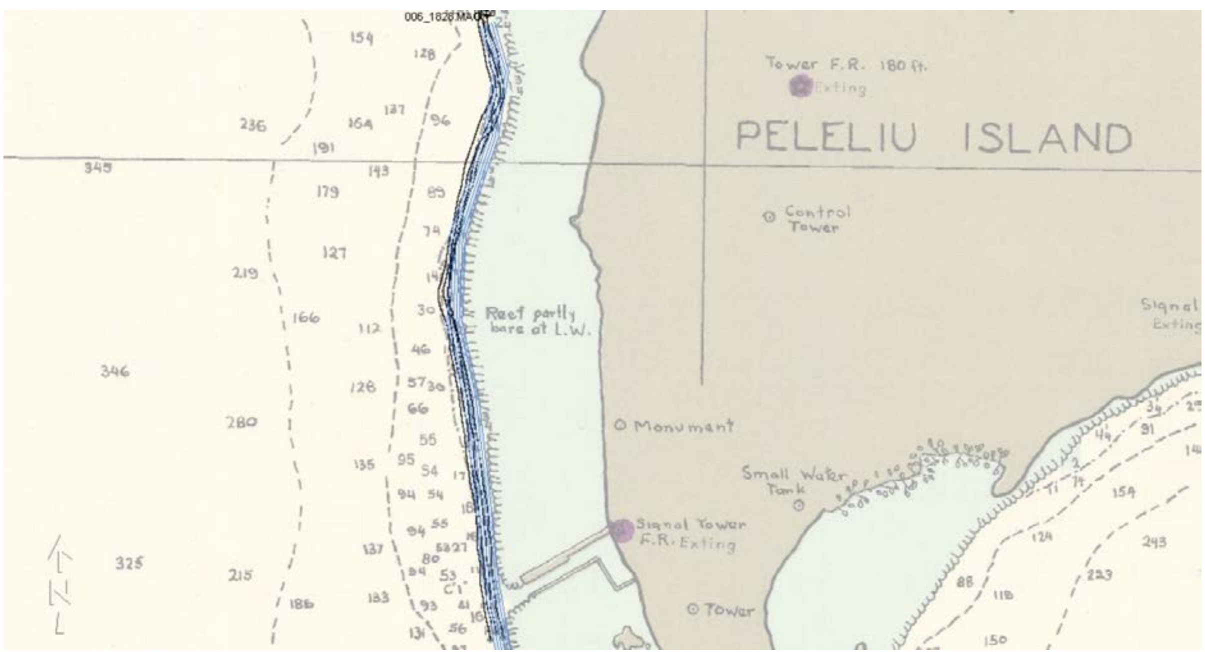


Figure 8. Six planned track lines (in blue), spaced at 20 meters, were plotted to conduct the magnetometer survey along the west coast of Peleliu (Palau Islands “Peleliu I. and Angaur I.”; from U.S.S. Hydrographer Survey November 1944 – January 1945).

Table 4 provides the total number of survey track lines, total linear feet, and total line miles of the survey area.

Table 4. Survey Area, Number of Survey Track Lines, Total Linear Feet, and Total Line Miles

Survey Area	Number of Survey Track Lines	Total Linear Feet	Total Line Miles
Mag Survey Areas	6	72,128	13.66

Nearshore conditions were ideal during the remote sensing survey (Figure 9). Winds, primarily out of the northeast, fluctuated from calm (Beaufort Wind Scale 0) in the morning to a light breeze (Beaufort Wind Scale 2) during the afternoon (https://www.weather.gov/mfl/beaufort).

Figure 9. Nearshore conditions were ideal for the magnetometer survey. View to southeast along exposed reef line and landing beaches, Peleliu. Carrell/Ships of Discovery Science Team.

The equipment used included Hypack® Navigation Software (integrated with a Trimble® DSM-232 dGPS (Figure 10) and Geometrics G-882 magnetometer (Figure 11). A Cat INV2000 generator was used to provide clean power to the instruments (Figure 12).

Figure 10. Panasonic Toughbook survey laptop outfitted with Hypack® Navigation Software and Trimble® DSM-232 dGPS (yellow box). Carrell/Ships of Discovery Science Team.

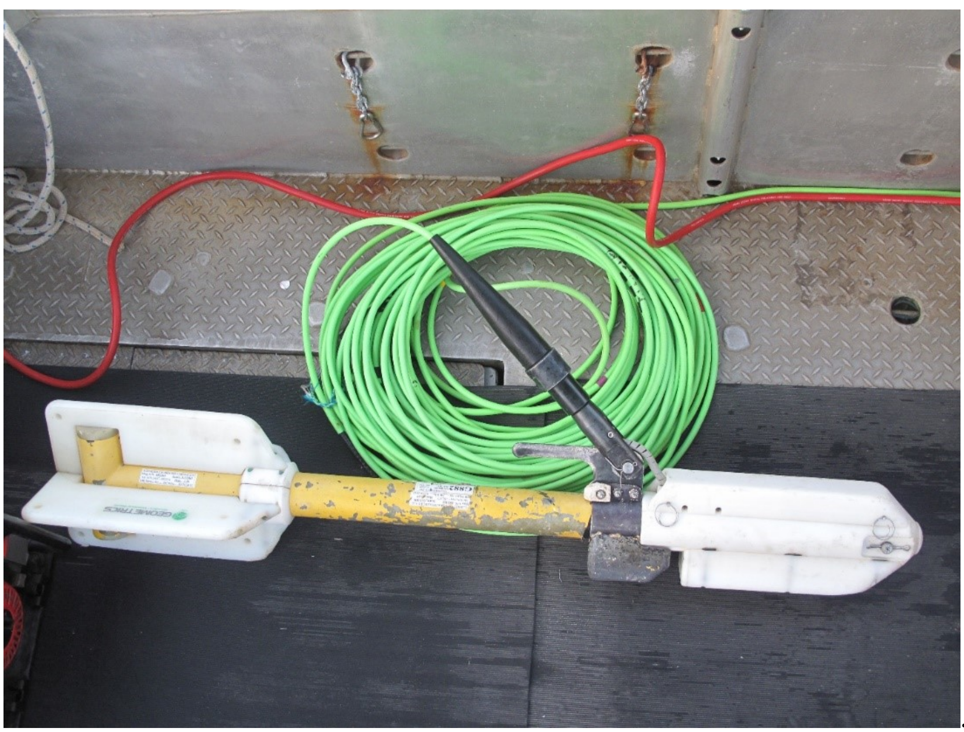


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Figure 11. Geometrics G-882 magnetometer. Carrell/Ships of Discovery Science Team.

Figure 12. A CAT INV2000 inverter generator provided power during the magnetometer survey. Carrell/Ships of Discovery Science Team.

The survey vessel, provided by Surangel and Sons of Palau, had ample room to conduct the magnetometer survey along the west coast of Peleliu (Figure 13). Named the Motor Vessel (M/V) *Dukl*, the crew mobilized the vessel in Malakal Harbor, Palau and then transited south to Peleliu for the magnetometer survey.

Data Security and Preservation

Vessel navigation and positioning data, along with field data files from the magnetometer were saved to a computer file and backed up on an external hard drive. All data collected during field operations (navigation, positioning, and ancillary data) were duplicated and stored on two hard drives, typically a primary laptop and an external hard drive. This storage occurs as soon as possible after collection but within the same day, depending on the field deployment. While on site, backup media are stored separately from the field computer.

Data Analysis

Following completion of the fieldwork, the analysis of the field data sets was accomplished to identify, characterize, and evaluate the magnetic anomalies for potential historical significance and correlate the findings with the previous remote sensing operations and diver investigations.

Figure 13. Prepping for the magnetometer survey aboard the M/V *Dukl* out of Koror, Palau. Carrell/Ships of Discovery Science Team.

Figure 14. The exposed reef and shallow water prevented two track lines from being completed. View east toward exposed reef line; Peleliu in the background. Carrell/Ships of Discovery Science Team.

Navigation Post Plot

All track lines were successfully surveyed during the current investigation (except for two track lines (1 and 2) that were too shallow to survey due to the exposed reef (Figure 14).

Magnetometer Data Analysis

After completion of the remote sensing survey the magnetometer data was processed, edited, and contoured in Hypack™. Processing the RAW magnetometer data involves a careful review of each track line including a profile view of the data, which identifies magnetic anomalies along a given track line (Figure 15). Errant data (commonly referred to as "spikes") are also visible and deleted from the RAW data. Spikes are typically one-second points that are easily discernable and removed when reviewing the data. Actual magnetic anomalies tend to be longer in duration and have either monopole, dipole, or multi-component characteristics. Magnetometer layback (15 meters) is automatically accounted for in Hypack™ during the processing of RAW data.

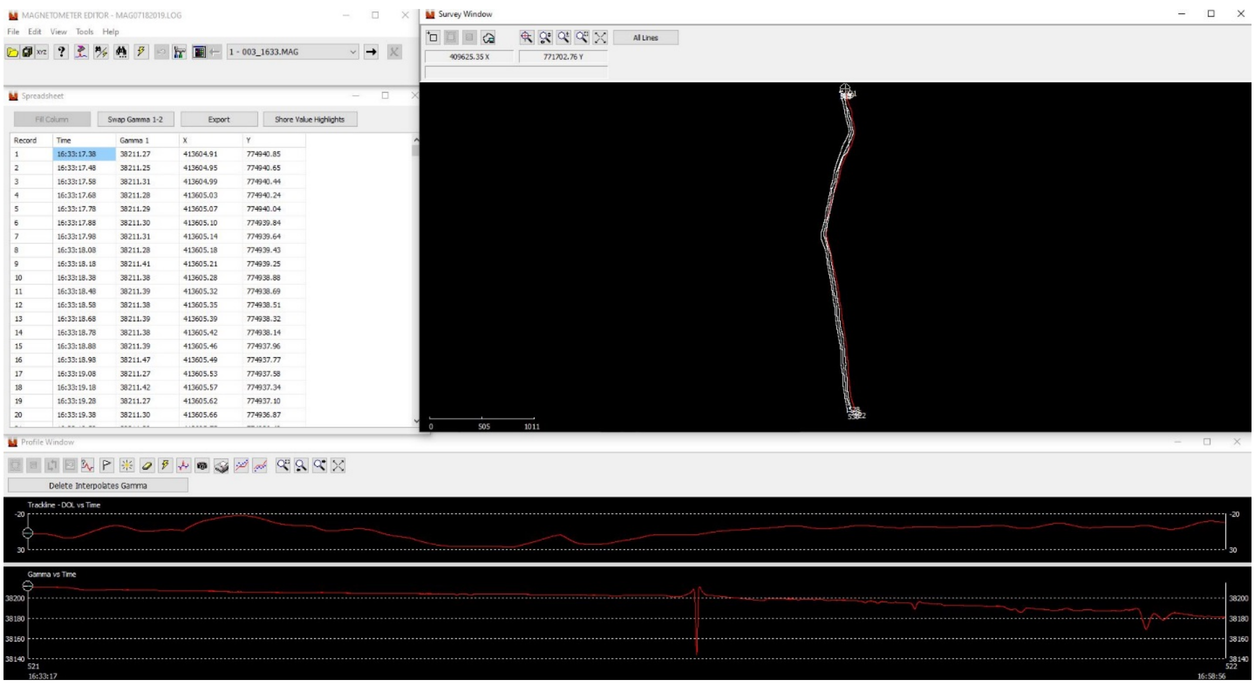


Figure 15. Typical single beam window showing data spreadsheet (time stamp, X/Y location, and gamma reading), survey window (showing survey vessel track line), and profile window (showing magnetic anomalies along a given track line). Krivor/RECON Offshore.

Once all individual track lines of data are edited, a .LOG file is assembled for each survey area that includes all corresponding track lines, associated magnetic data, and X/Y positioning. Individual magnetic targets are then pinpointed and evaluated for location (X/Y), type (monopole, dipole, multi-component), deviation, and duration. A target (.TGT file) is subsequently created for each target within the survey area.

After documentation, a magnetic contour map (TIN Model) is produced. This entails identifying the minimum and maximum gamma values within each area, allowing for the production of an accurate contour map. Using Hypack™ the operator chooses the contour interval for the prescribed area; for this project all magnetic data was contoured at 5-gamma intervals. Additional attributes can then be chosen such as contour colors, line width, TIN Max Side, Export type (.DXF, .XYZ, .KMZ), and contour type (2D, 3D).

Once a magnetic contour map is produced it can then be downloaded as a Background File in Hypack™, overlaid on a NOAA Raster Chart or aerial photograph, and correlated with other data such as .TGT files and/or side-scan sonar overlays.

Magnetometer Results

In July 2019, SHIPS completed the marine magnetometer survey of the Peleliu Landing Beaches. The results of the magnetometer survey identified twenty anomalies (N=20) within the survey area (Figures 13-16). Table 5 provides the Name, Location (Easting and Northing), Gamma Deviation, Duration (in meters), Type (M=Monopole, D=Dipole, MC= Multi-Component) and Description, of each magnetic anomaly.

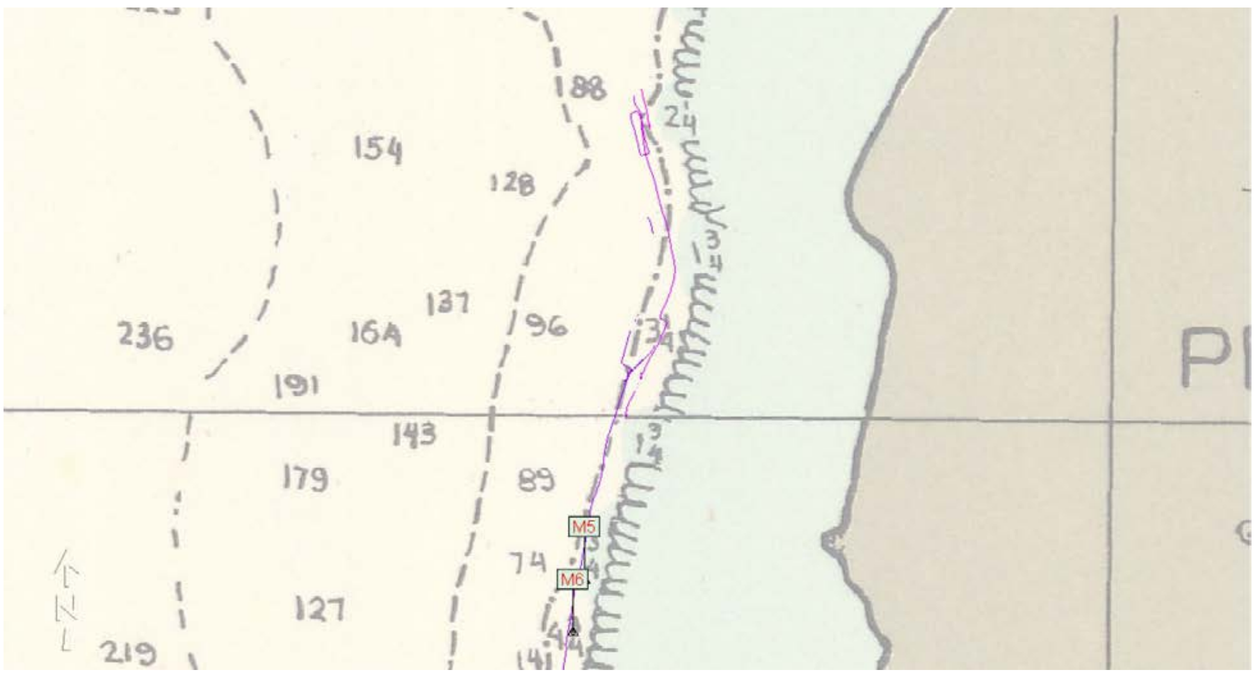


Figure 16. Magnetic Contour Map 1 of the Peleliu Landing Beach; contour interval equals 5 gammas (Palau Islands "Peleliu I. and Angaur I."; from U.S.S. Hydrographer Survey November 1944 – January 1945). Krivor/Recon Offshore.

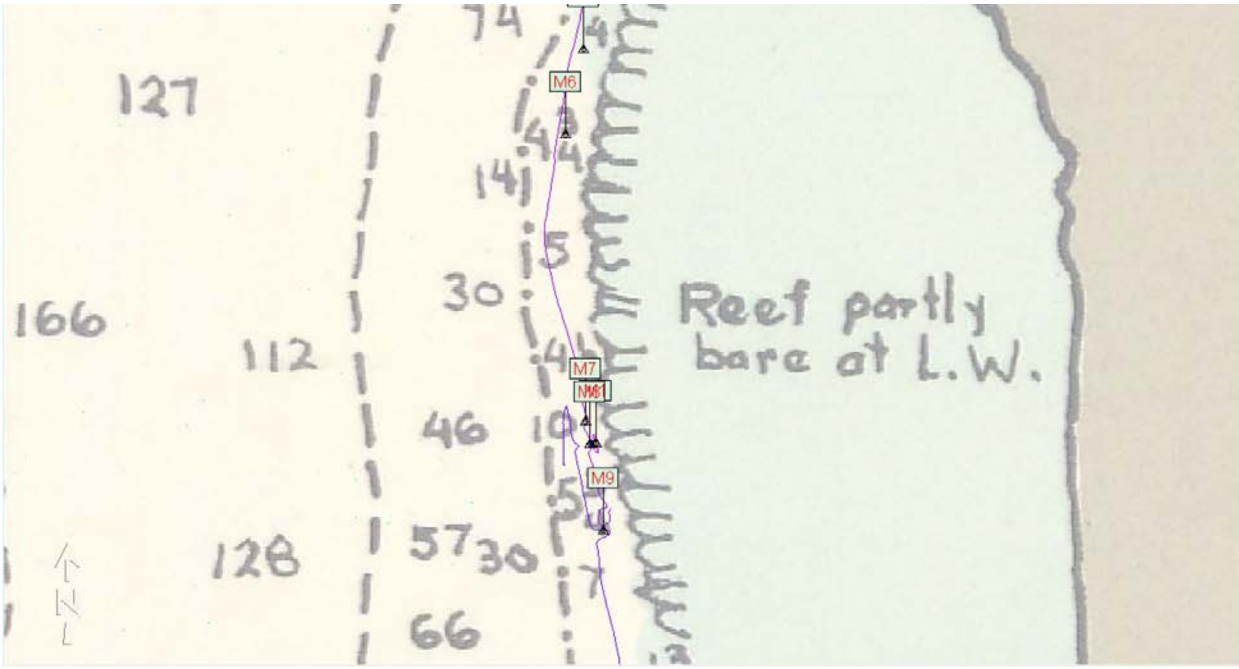


Figure 17. Magnetic Contour Map 2 of the Peleliu Landing Beach; contour interval equals 5 gammas (Palau Islands "Peleliu I. and Angaur I."; from U.S.S. Hydrographer Survey November 1944 – January 1945). Krivor/Recon Offshore.

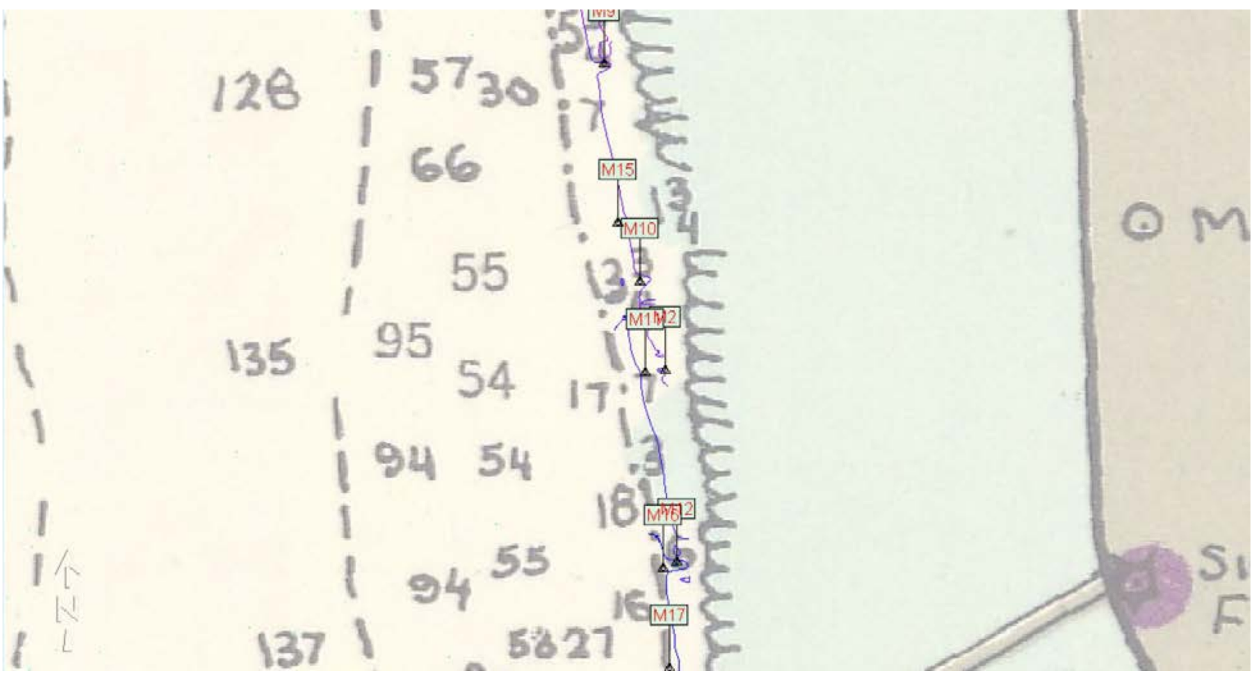


Figure 18. Magnetic Contour Map 3 of the Peleliu Landing Beach; contour interval equals 5 gammas (Palau Islands "Peleliu I. and Angaur I."; from U.S.S. Hydrographer Survey November 1944 – January 1945). Krivor/Recon Offshore.

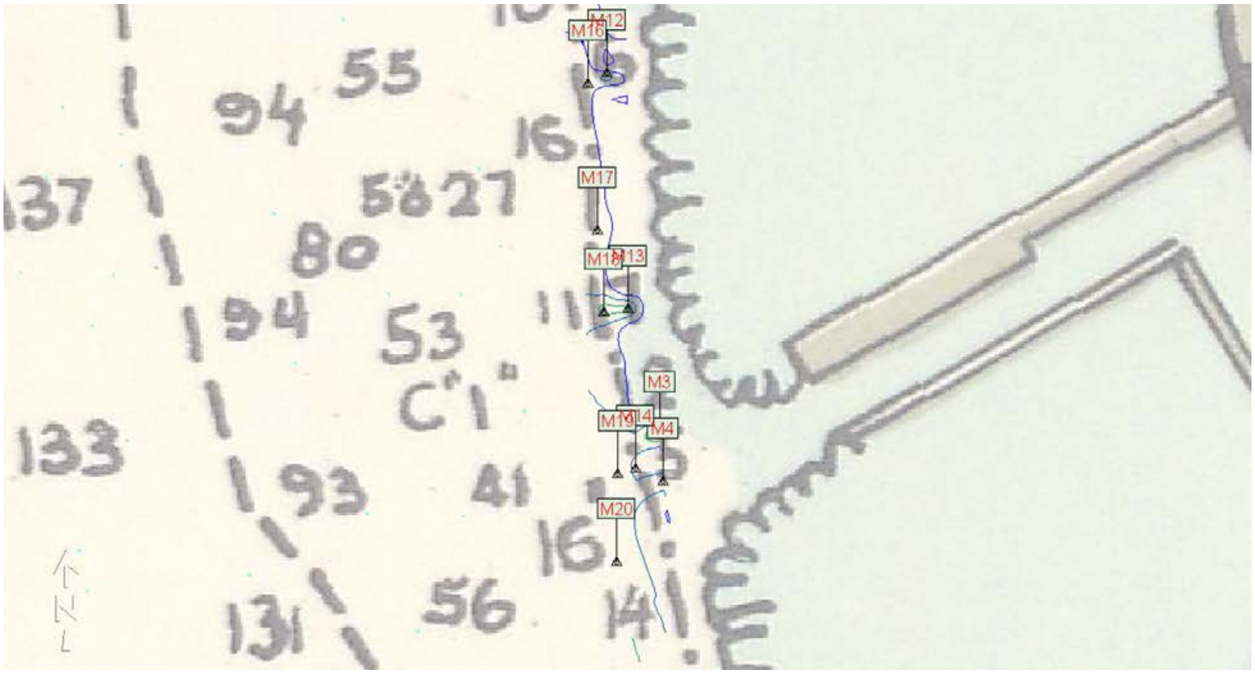


Figure 19. Magnetic Contour Map 4 of the Peleliu Landing Beach; contour interval equals 5 gammas (Palau Islands “Peleliu I. and Angaur I.”; from U.S.S. Hydrographer Survey November 1944 – January 1945). Krivor/Recon Offshore.

Table 5. Magnetic Anomalies, Location, Gamma Deviation, Duration, Type, and Description Documented Within the Peleliu Landing Beaches Survey Area. Krivor/Recon Offshore.

Peleliu	Easting	Northing	Gamma Deviation	Duration (in meters)	Type	Description
M1	[redacted]	[redacted]	-56	56	M	Associated with M8
M2	[redacted]	[redacted]	-7	27	M	Associated with M11
M3	[redacted]	[redacted]	-20	66	M	Associated with M4, M14, M19. Near entrance to ferry dock.
M4	[redacted]	[redacted]	-5	39	M	Associated with M3, M14, M19. Near entrance to ferry dock.
M5	[redacted]	[redacted]	-2	18	M	Isolated
M6	[redacted]	[redacted]	+.5/-.3	21	D	Isolated
M7	[redacted]	[redacted]	-2	18	M	Isolated
M8	[redacted]	[redacted]	-5	36	M	Associated with M1
M9	[redacted]	[redacted]	+3/-7	63	D	Isolated
M10	[redacted]	[redacted]	-3	38	M	Isolated
M11	[redacted]	[redacted]	-3	33	M	Associated with M2
M12	[redacted]	[redacted]	+1/-11	45	D	Associated with M16
M13	[redacted]	[redacted]	-15	47	M	Associated with M18
M14	[redacted]	[redacted]	+1/-8	99	MC	Associated with M3, M4, M19. Near entrance to ferry dock.
M15	[redacted]	[redacted]	-1	25	M	Isolated

Peleliu	Easting	Northing	Gamma Deviation	Duration (in meters)	Type	Description
M16	[redacted]	[redacted]	-3	50	M	Associated with M12
M17	[redacted]	[redacted]	-2	52	M	Isolated
M18	[redacted]	[redacted]	-10	52	M	Associated with M13
M19	[redacted]	[redacted]	+1/-3	111	MC	Associated with M3, M4, M14. Near entrance to ferry dock.
M20	[redacted]	[redacted]	+2	48	M	Isolated

(Type M=Monopole, D=Dipole, MC=Multi-Component).

Analysis of the magnetic anomalies indicated the majority are low gamma (>10 gammas), short duration, monopole anomalies indicative of small, single-point ferrous metal objects. These types of anomalies are consistent with the historic use of the area as multiple Landing Beaches associated with the Battle of Peleliu. A number of larger magnetic anomalies (<10 gammas) were also recorded that have associated magnetic anomalies meaning they were recorded over more than one track line. These anomalies are likely larger ferrous metal objects.

<u>Correlation of Clustered Magnetic Anomalies</u>

All clustered magnetic anomalies consisting of more than one magnetic anomaly located on adjacent track lines were correlated with findings from the previous side-scan sonar survey and diver investigations and are presented below. Target locations from the previous investigations were imported into Hypack™ and compared to the magnetometer target locations.

Targets M1 and M8

Targets M1 and M8 comprise one ferrous metal target located near the reef line and is one of the larger anomalies documented during the magnetometer survey (Figure 20).

Figure 20.Magnetic contour map of Targets M1 and M8]; Contour interval equals 5 gammas (Palau Islands “Peleliu I. and Angaur I.”; from U.S.S. Hydrographer Survey November 1944 – January 1945). Krivor/Recon Offshore.

Plotting targets from the side-scan sonar survey and diver investigations indicate two targets are in the general location of Targets M1 and M8 (Figure 21). Review of the previous investigation indicate both Targets P.05 and P.11 are “Survey points identified during Sonar Anomaly. No cultural material located.” Therefore, side-scan sonar targets were plotted in the area, but nothing was confirmed during diver investigations. Targets M1 and M8 remain unidentified.

Figure 21. Magnetic contour map of Targets M1 and M8 with previously documented targets (P.05 and P.11) plotted; Contour interval equals 5 gammas (Palau Islands “Peleliu I. and Angaur I.”; from U.S.S. Hydrographer Survey November 1944 – January 1945). Krivor/Recon Offshore.

Targets M2 and M11

Targets M2 and M11 represent another single ferrous metal anomaly documented on more than one survey track line. Plotting the location of previously recorded anomalies indicates Targets M2 and M11 are associated with Targets Ships025 and Ships035 (Figure 22).

Figure 22. Magnetic contour map of Targets M2 and M11 with previously documented targets (Ships025 and Ships035) plotted; Contour interval equals 5 gammas (Palau Islands "Peleliu I. and Angaur I."; from U.S.S. Hydrographer Survey November 1944 – January 1945). Krivor/Recon Offshore.

Review of the previously documented targets indicate Ships025 and Ships035 was identified as a "Large stud link anchor chain which runs from the reef crest to edge." In addition, an unidentified (UID) site was documented in the area. Results of the magnetometer survey would indicate Targets M2 and M11 represent the same stud-link anchor chain that continues to extend offshore from the reef line.

Targets M3, M4, M14, and M19
Magnetic Targets M3, M4, M14, and M19 represent a large cluster of magnetic anomalies located near the mouth of the manmade jetty located at the southern end of the project area and Landing Beaches (Figure 23).

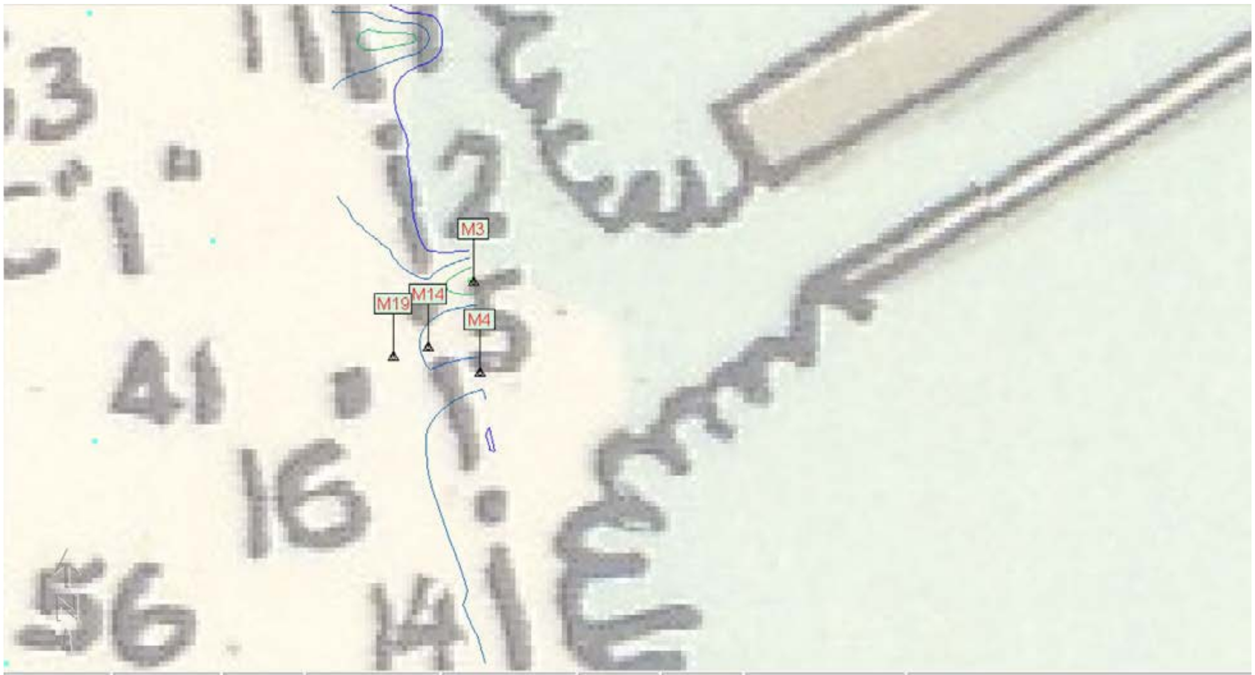


Figure 23. Magnetic Targets M3, M4, M14, and M19 are located near the entrance to the manmade jetty near the south end of the project area; Contour interval equals 5 gammas (Palau Islands "Peleliu I. and Angaur I."; from U.S.S. Hydrographer Survey November 1944 – January 1945). Krivor/Recon Offshore.

Plotting the target locations from the previous investigations indicate the cluster of magnetic anomalies are associated with Targets Ships023 identified as a "Pontoon Barge and Pontoon Barge Fragments" (Figure 24).

Figure 24. Magnetic Targets M3, M4, M14, and M19 and Targets Ships023 represent the remains of a Pontoon Barge and Pontoon Fragments; Contour interval equals 5 gammas (Palau Islands "Peleliu I. and Angaur I."; from U.S.S. Hydrographer Survey November 1944 – January 1945)**. Krivor/Recon Offshore.**

Targets M12 and M16

Targets M12 and M16 represent a single magnetic anomaly documented on two adjacent track lines (Figure 25).

Figure 25. Magnetic Targets M12 and M16; Contour interval equals 5 gammas (Palau Islands "Peleliu I. and Angaur I."; from U.S.S. Hydrographer Survey November 1944 – January 1945). Krivor/Recon Offshore.

Plotting the location of previously documented targets near Targets M12 and M16 indicate the anomalies are likely associated with Targets Ships030 identified as a “Pipe at Orange 3 and Dock” as well as a “Stockless Navy Anchor, associated with a continuation of debris scatter” (Figure 26). Target Ships024, located inshore of the magnetic anomalies, were documented as an “Aircraft Propeller Blade”.

Figure 26. Magnetic Targets M12 and M16 and previously documented targets located nearby; Contour interval equals 5 gammas (Palau Islands “Peleliu I. and Angaur I.”; from U.S.S. Hydrographer Survey November 1944 – January 1945). Krivor/Recon Offshore.

Targets M13 and M18
Targets M13 and M18 represent one magnetic target located immediately north of the manmade jetty located near the southern end of the Landing Beaches (Figure 27).

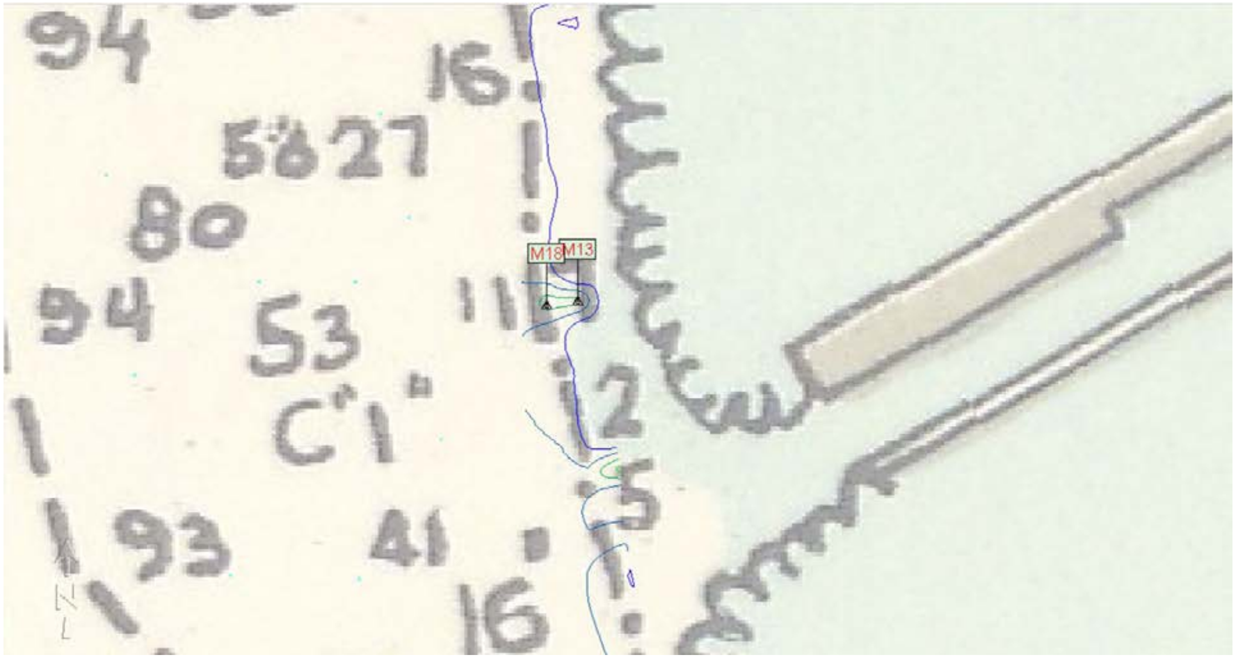


Figure 27. Magnetic Targets M13 and M18; Contour interval equals 5 gammas (Palau Islands "Peleliu I. and Angaur I."; from U.S.S. Hydrographer Survey November 1944 – January 1945). Krivor/Recon Offshore.

Review of the previously documented targets indicates that Magnetic Targets M13 and M18 are associated with Targets Ships038 (Figure 28) identified as an "LVT identified in previous survey by Bent Prop". This is also associated with the LVT dumpsite.

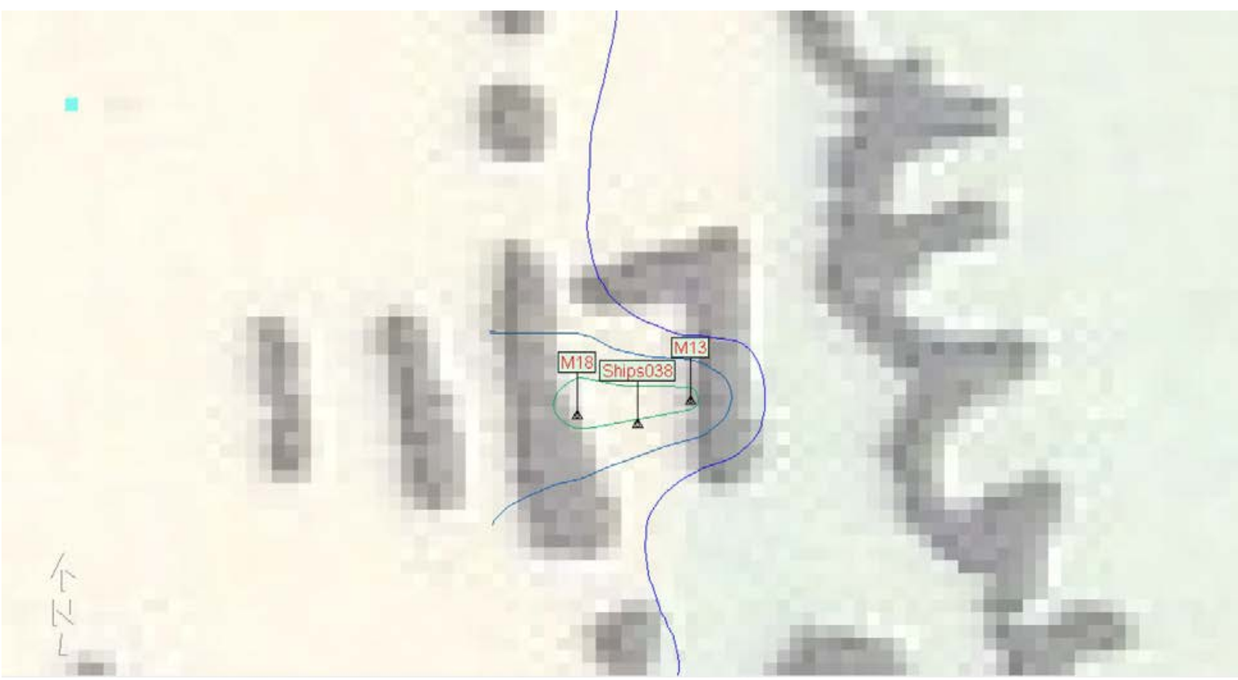


Figure 28. Magnetic Targets M13 and M18 are associated with Target Ships038 identified as an LVT; Contour interval equals 5 gammas (Palau Islands "Peleliu I. and Angaur I."; from U.S.S. Hydrographer Survey November 1944 – January 1945). Krivor/Recon Offshore.

Correlation of Isolated Magnetic Anomalies

All isolated magnetic anomalies consisting of a single magnetic anomaly were also correlated with findings from the previous side-scan sonar survey and diver investigations. Target locations from the previous investigations were imported into Hypack™ and compared to the magnetometer target locations.

Target M10

Target M10 is a single, isolated 3-gamma magnetic anomaly documented on one track line (**Figure 29**).

Figure 29. Magnetic Target M10; Contour interval equals 5 gammas (Palau Islands "Peleliu I. and Angaur I."; from U.S.S. Hydrographer Survey Nov. 1944 – January 1945). Krivor/Recon Offshore.

Review of the previously documented targets indicate Target M10 is associated with Targets P.03 (large cable), Ships034 (steel cable), and Ships020 (Unexploded Ordnance) (Figure 30).

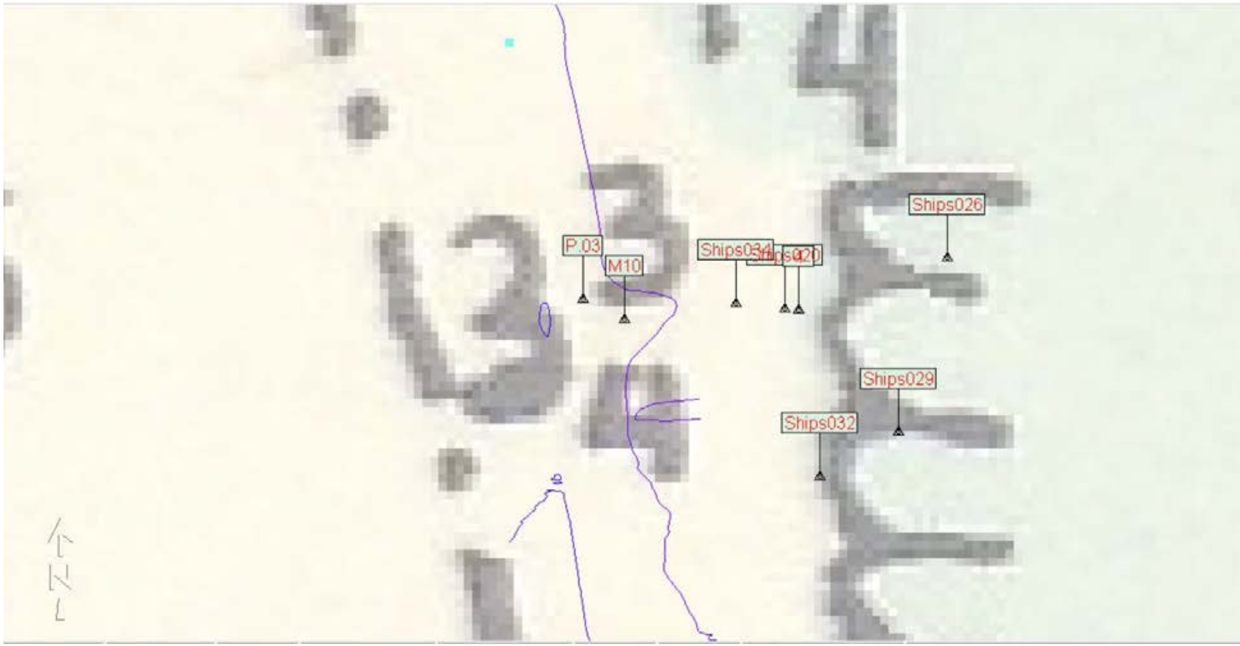


Figure 30. Magnetic Target M10 and previously documented anomalies in the area; Contour interval equals 5 gammas (Palau Islands "Peleliu I. and Angaur I."; from U.S.S. Hydrographer Survey November 1944 – January 1945). Krivor/Recon Offshore.

All remaining isolated magnetic anomalies (M5-M9, M15, M17, and M20) do not have any correlating targets and remain unidentified.

Table 6 provides the results of the magnetometer survey including description of anomalies that were successfully correlated with targets documented during the previous side-scan sonar survey and diver investigations.

Table 6. Clustered and Isolated Magnetic Anomalies Description and Potential Significance. Krivor/Recon Offshore.

Clustered Anomalies	Easting	Northing	Gamma Deviation	Duration (in meters)	Type	Description	Potentially Significant
M1/M8	[redacted]	[redacted]	-56	56	M	Unidentified	Unknown
	[redacted]	[redacted]	-5	36	M		
M2/M11	[redacted]	[redacted]	-7	27	M	Stud Link Anchor Chain	Yes
	[redacted]	[redacted]	-3	33	M		
M3/M4/M14/M19	[redacted]	[redacted]	-20	66	M	Pontoon Barge and Pontoon Barge Fragments	Yes
	[redacted]	[redacted]	-5	39	M		
	[redacted]	[redacted]	+1/-8	99	MC		
	[redacted]	[redacted]	+1/-3	111	MC		
M12/M16	[redacted]	[redacted]	+1/-11	45	D	Pipe and Stockless Navy Anchor	Yes
	[redacted]	[redacted]	-3	50	M		
M13/M18	[redacted]	[redacted]	-15	47	M		Yes

Clustered Anomalies	Easting	Northing	Gamma Deviation	Duration (in meters)	Type	Description	Potentially Significant
	[redacted]	[redacted]	-10	52	M	LVT previously identified by Bent Prop	
Isolated Anomalies	**Easting**	**Northing**	**Gamma Deviation**	**Duration**	**Type**	**Description**	**Potentially Significant**
M5	[redacted]	[redacted]	-2	18	M	Unidentified	Unknown
M6	[redacted]	[redacted]	+.5/-.3	21	D	Unidentified	Unknown
M7	[redacted]	[redacted]	-2	18	M	Unidentified	Unknown
M9	[redacted]	[redacted]	+3/-7	63	D	Unidentified	Unknown
M10	[redacted]	[redacted]	-3	38	M	Steel Cable	No
M15	[redacted]	[redacted]	-1	25	M	Unidentified	Unknown
M17	[redacted]	[redacted]	-2	52	M	Unidentified	Unknown
M20	[redacted]	[redacted]	+2	48	M	Unidentified	Unknown

Summary

Of the 20 anomalies identified, 12 were associated with UCH and 1 is modern, and all were located during the field investigation, representing clearly discernable remains. The seven unidentified isolated anomalies are off the Orange Beaches, which saw some of the heaviest defensive fire during the invasion. The defensive fire was so intense that the units tasked with landing on Orange 3 were forced to divert north and land closer to Orange 2. The nature of these low gamma anomalies suggests small single-point ferrous metal objects. These types of anomalies are consistent with the historic use of the area as multiple landing beaches associated with the Battle of Peleliu.

Identification of Underwater Cultural Heritage Sites

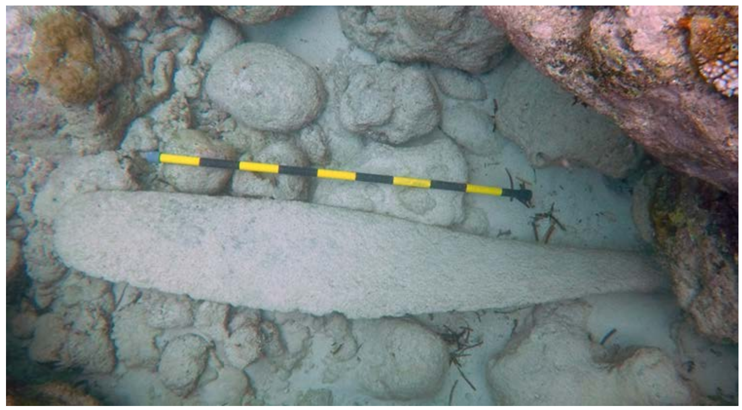
Because the reef is shallow with limited boat and remote sensing equipment access, the search for UCH included a towed swimmer survey of the reef margins and seaward reef flat. A walking survey of the shallow lagoon from the mean low water line to the reef completed the inspection.

Reef Towed Swimmer Survey

The towed swimmer survey on April 8 consisted of four of overlapping lines spaced approximately 20 meters (66 ft.) apart covering approximately 9-1/2 line miles. Water visibility was in excess of 60 ft., making visual inspection possible. Because the survey occurred during high tide, the two-person teams were able to get very close to the reef resulting in the location of 12 sites. A Garmin GPSMAP 64st was use to record survey tracks and site locations.

Both historic and modern debris sites were recorded during this survey (Table 7). Selected sites discussed below represent remains only associated with the WWII invasion of Peleliu.

Table 7. Summary of Reef Sites

Site Number	Denfeld Site ID	Price/Knecht Site ID	Description and Designation Historic/Modern
Ships020	N/A	N/A	UXO, HIST
Ships021	N/A	N/A	Navy Stockless Anchor, HIST
Ships022	N/A	N/A	Anchor, MOD
Ships023	N/A	N/A	Pontoon Barge Fragments, HIST
Ships024	N/A	N/A	American Aircraft Propeller Blade, HIST  This blade may be associated with aircraft remains found in the lagoon, discussed elsewhere in this report.
Ships025	N/A	N/A	Stud Link Anchor Chain, HIST
Ships026	N/A	N/A	Metal Scatter w/3” cable, MOD
Ships027	N/A	N/A	Tractor with blade, HIST
Ships028	N/A	N/A	Navy Stockless Anchor, HIST
Ships029	N/A	N/A	Danforth Anchor, MOD
Ships030	N/A	N/A	Debris Scatter (poss. Pontoons) and Stockless Navy Anchor, HIST
Ships031	N/A	N/A	Concrete Mooring Block, MOD
Ships032	N/A	N/A	LVT, disarticulated HIST
Ships033	N/A	N/A	Iron Rod/Beam, MOD
Ships034	N/A	N/A	Steel Cable, MOD
Ships035	N/A	N/A	Stud Link Anchor Chain, HIST
Ships036	N/A	N/A	LCM, HIST
Ships037	N/A	N/A	Anchor, MOD
Ships038	N/A	N/A	LVT, HIST
Ships039	N/A	N/A	LVT, HIST
Ships040	N/A	N/A	LVT, HIST

Tractor with Blade

The reasonably intact remains of a tractor with blade (Ships027) sits in about 10 ft. of water off Orange 2 Beach.

Historic Context

During WWII, tractors were used by the U.S. military for combat construction in Europe, Asia, and the Pacific theaters. The tractors had unsurpassed capability to move and tow in the muddy jungles of the Pacific islands, which made them especially valued by Seabee, Marine Corps, and Army units. When equipped with a bulldozer blade, they could level ground for roads and airfields, clear debris, construct fortifications, and more.

Tractors were produced in a great variety, from small, air transportable units that flew with airborne engineers to those used to move the heaviest field artillery under adverse conditions. According to TM 9-2800 (U.S. War Department 1943) War Department tractors were standardized under three general classifications, with several commercially available models in each group. While other tractors were used by the military during WWII, the most common were the following standardized units:

- Tractor, Light
  - Caterpillar Tractor Co. Model D4 (G-151)
  - International Harvester Model TD9 (G-99)
- Tractor, Medium, M1
  - Allis-Chalmers Co. Model HD7W (G-125)
  - Caterpillar Tractor Co. Model D6 (G-69)
  - Cleveland Tractor Co.
  - International Harvester Co. Model TD14 (G-132)
- Tractor, Heavy, M1
  - Allis-Chalmers Co. Model HD10W (G-98)
  - Caterpillar Tractor Co. Model D7 (G-126)
  - International Harvester Co. Model TD18 (G-101)

During the war, the D4 was one of the tractors collectively known as “Tractor, Light.” The Caterpillar D4 models, Ordnance G-151 (US War Department 1943), was used to move light artillery, for general duty as a tractor, or as a bulldozer when equipped with a suitable blade attachment (D-4 Caterpillar https://olive-drab.com/idphoto/id_photos_d4cat.php).

The evolution of the D4 included these models:

- D4 4G series 1937-1938, Orchard model
- D4 7J series 1939-1942
- D4 2T series 1943-1945
- D4 5T series 1945-1947
- D4 6U series 1947-1959, 44 inch gauge
- D4 7U series 1947-1959, 60 inch gauge

The diesel powered Caterpillar D4 (Figure 31) evolved from the Cat R4 gasoline tractor. In 1936, the Cat R4 was joined by the diesel RD4 (4G series) and in 1937 the RD4, with some minor modifications, was renamed the D4 (4G series). The early D4 models (4G, 7J, 2T, 5T) were powered by the Cat D4400 engine with 35 drawbar horsepower. A small gasoline pony motor was used to start the diesel. The 6U and 7U were upgraded to the Cat D315 4 cylinder diesel with 43 drawbar horsepower. Tractor serial numbers were composed of the series (e.g. 4G, 6J) followed by a four or five digit serial number (D-4 Caterpillar https://olive-drab.com/idphoto/id_photos_d4cat.php).

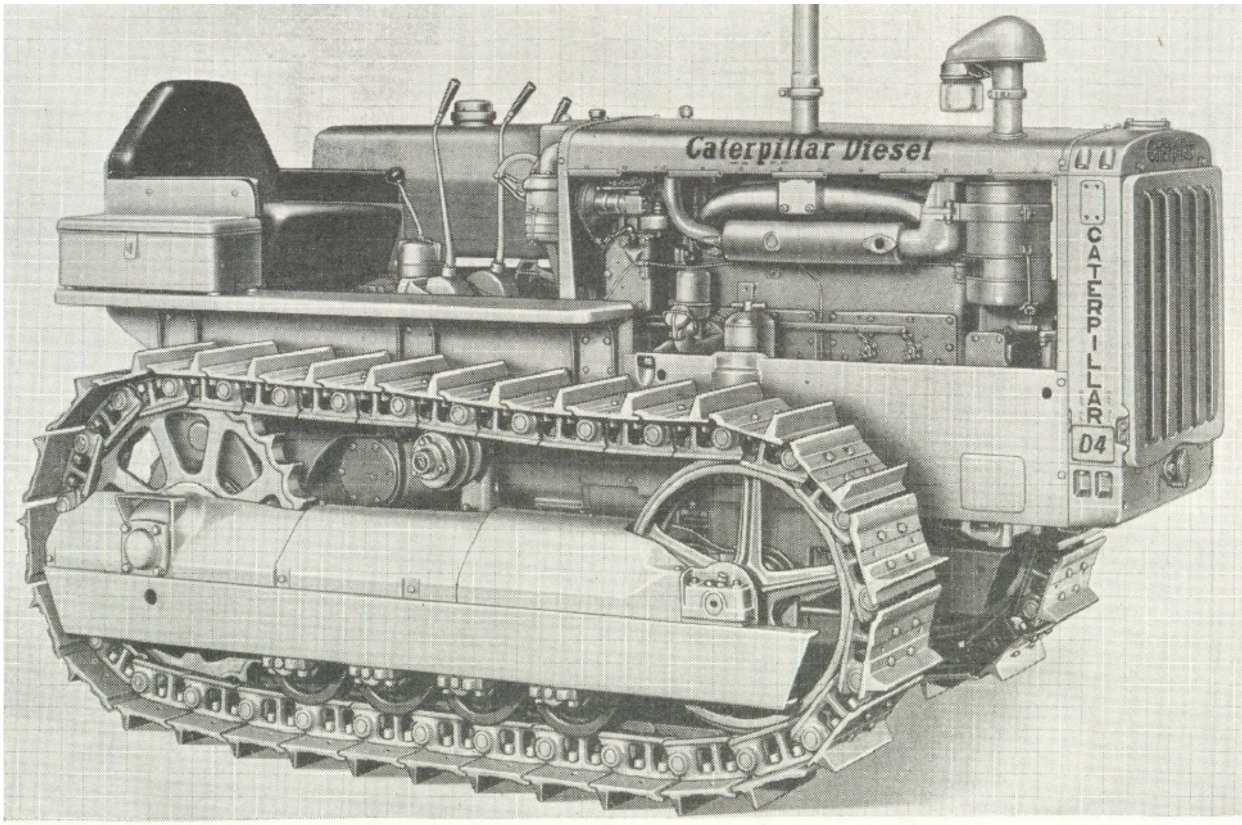


FIGURE 9.—Caterpillar D4 Tractor, Crawler, Diesel.

Figure 31. Caterpillar D4 Tractor, Type 2T. U.S. Army, War Department, Figure 2, 1943.

Analysis

Immediately following the Peleliu invasion, the Seabees used tractors to clear the beaches of debris, disabled LVTs, and upended DUKWs before setting to work on rebuilding the airfield (Figure 32). This tractor appears to be a Caterpillar D-4 Type 2T fitted with a bulldozer blade. Based on the tractor's location in a small bomb crater, it may have foundered while working to clear debris in the lagoon and, unable to drive itself out, was abandoned in place (Figure 33.)

Figure 32. Tractors on the Peleliu shoreline after the successful capture of the southern beaches. Norm Hatch Collection, National Museum of the Pacific War, image Peleliu 031, 1944.

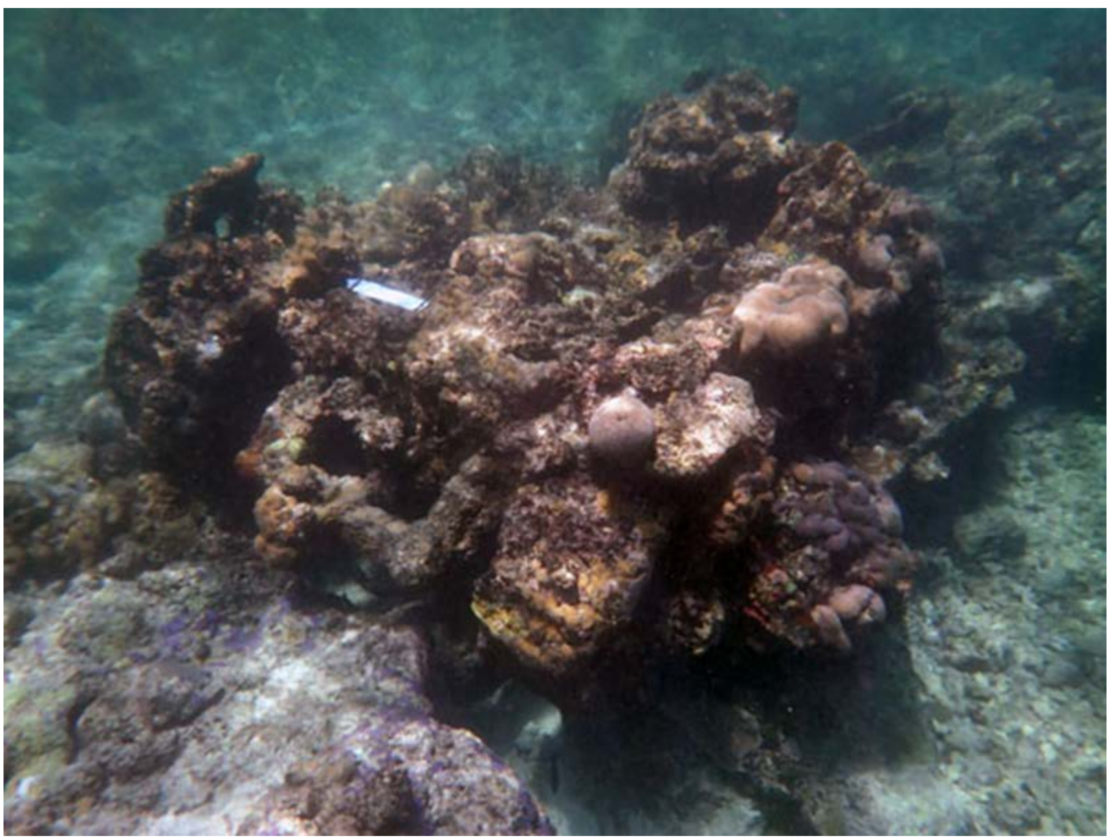


Figure 33. Nearly intact tractor with blade off Orange beach (Ships027). View is from the right rear. McKinnon/Ships of Discovery Science Team.

Navy Stockless Anchors

Three navy stockless anchors were found at the edge of the Peleliu reef shelf. One was positioned south of the harbor entrance and designated Ships021, another off Orange beach designated Ships030, and a third off White Beach designated Ships028.

Historic Context

Navy stockless anchors, or “patent anchors” as they were known during WWII, began to replace Admiralty, or “old fashioned” anchors in the United States Navy around 1875 (Figure 34 and Figure 35). Admiralty anchors had fixed flukes and stocks. The stocks were set at 90 degrees from the direction of the flukes. During the war, Admiralty anchors were only used on some older destroyers. Admiralty anchors were stowed on horizontal platforms near the bow. Deploying and recovering them presented some challenges because as they had to be brought completely over the side of a vessel during either process (U.S. Naval Institute, 1940:442-445).

Stockless anchors had no stock and flukes that could swing from 40 to 45 degrees. The lack of a stock allowed the anchor to be brought up into a hawse pipe rather than completely onboard a vessel – so deployment and recovery of these anchors was less complicated than that of Admiralty anchors (U.S. Naval Institute, 1940:445).

Figure 34. Admiralty anchor. The Mariners’ Museum and Park.

Figure 35. Stockless anchor. The Mariners' Museum and Park.

Analysis

Crane barges were positioned at the reef's edge during the invasion. Two barges were situated off Orange Beach 3, and a third was located off the right flank of Orange Beach. Initially, these barges were moored to buoys. However, the buoys proved to be too light, and the barges were set with anchors. On September 16, 1944 one crane lost its anchor during the process of anchoring, and thereafter had to moor alongside craft to unload (Wright 1944:7-8). Crane barges at Peleliu were equipped with two 200lbs navy stockless anchors (Bureau of Yards and Docks 1942:49, 51).

Ships030 was found off Orange Beach 3 (Figure 36) and Ships021 (Figure 37) was found in the vicinity of the "right flank of Orange Beach" in 40 ft. of water. No other related artifacts were located in the area. The potential exists that either Ships030, or Ships021, is the anchor lost from the crane barge. Ships028 (Figure 38) was located off White Beach in approximately 6 ft. of water. It is not associated with any other debris or site.

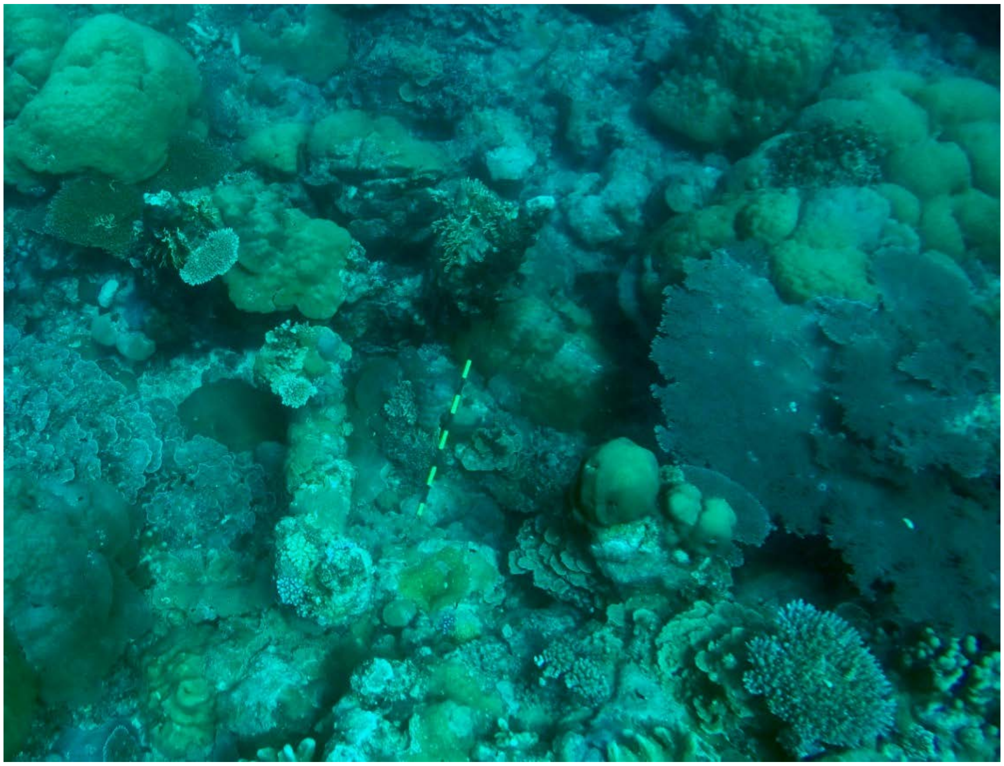


Figure 36. Navy stockless anchor (Ships030). The shank is 2.50m long, and the flukes are 1.15m. The anchor was found in a scatter of unidentifiable debris. Raupp/Ships of Discovery Science Team.

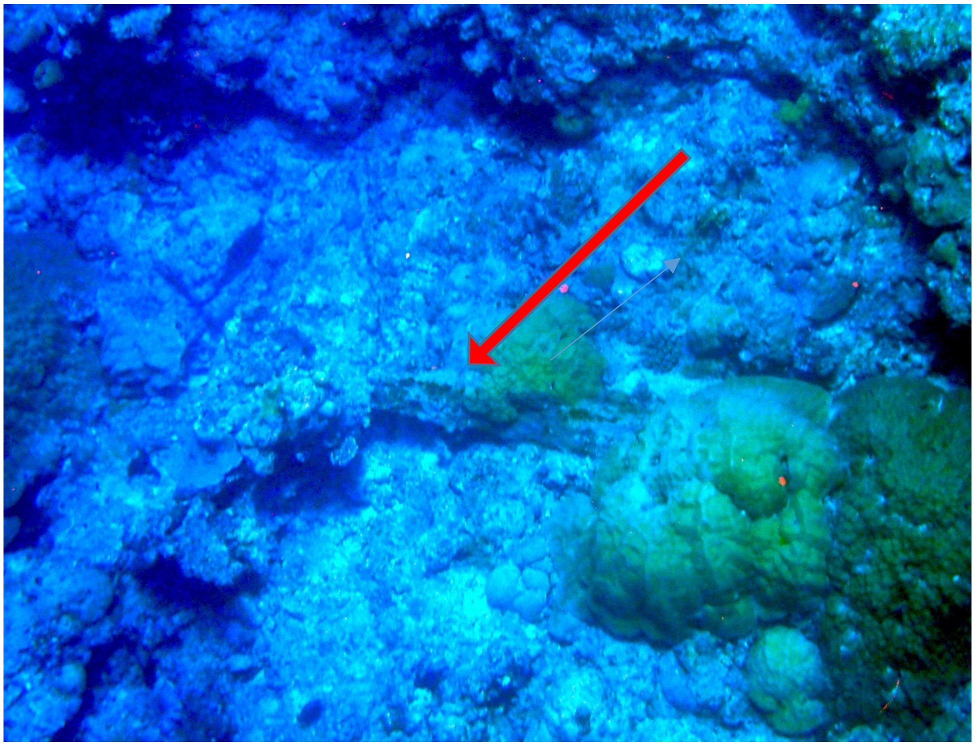


Figure 37. Navy stockless (Ships021) anchor in approximately 40 ft. of water. Carrell/Ships of Discovery Science Team.

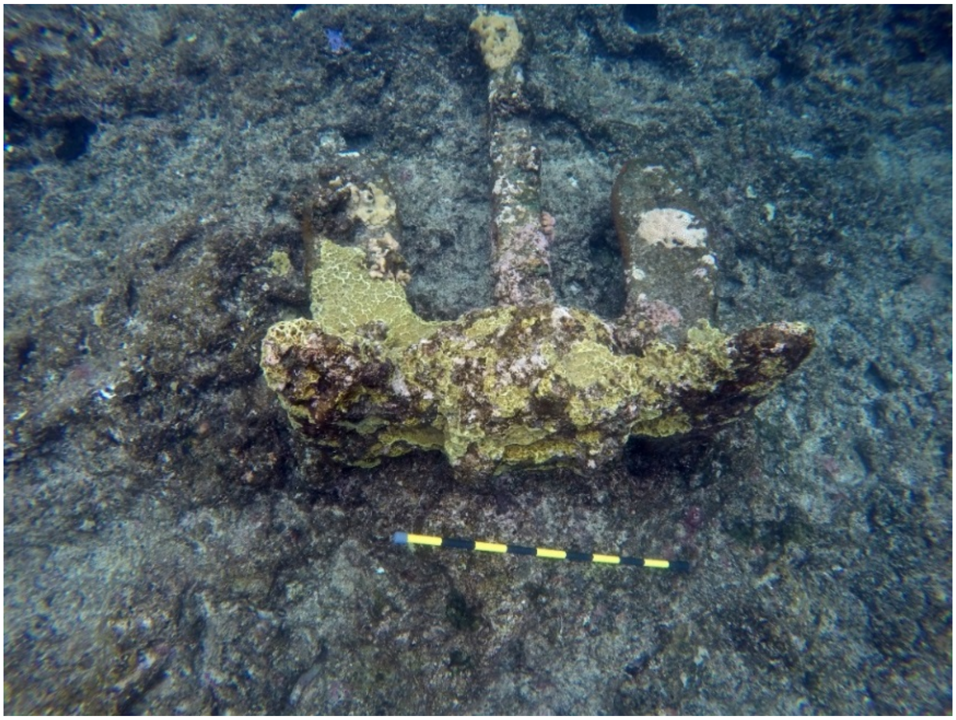


Figure 38. Navy Anchor (Ships028) located off White Beach. The shank is 1.14m long, and the flukes are 1.35m wide. Raupp/Ships of Discovery Science Team.

Pontoons

Pontoon debris (Ships023), consisting of three sections, were found outside the entrance to the harbor. Two are resting parallel to each other and appear joined while the third section is nearby.

Historic Context
Pontoons were welded buoyant steel boxes designed by the U.S. Navy's Bureau of Yards and Docks. In February 1941, the Pittsburgh-Des Moines Steel Company received a contract to produce pontoons for the Navy. Disassembled pontoons were shipped to the Pacific to designated U.S. Navy Pontoon Assembly Detachments (PADs). There were five PADs situated in various locations including Guam, New Caledonia, and New Guinea. Each PAD could assemble around 1,800 pontoons per month (Naval History and Heritage Command 2019).

Pontoons were 5 x 7 x 5 ft. and weighed approximately 2,000 lbs. each. They had an interior support structure consisting of six-inch steel plates welded together to form a "T" shape, which was welded girth-wise inside the pontoons. Pontoons could be connected to each other to create a variety of structures. To facilitate this connection, the right-angled corners of the pontoons were removed, and punched steel angles were welded in their place. Each pontoon was rated to support 2,240 lbs. (Department of the Navy, Bureau of Yards and Docks 1947a:157-158, Friedman 2002:197).

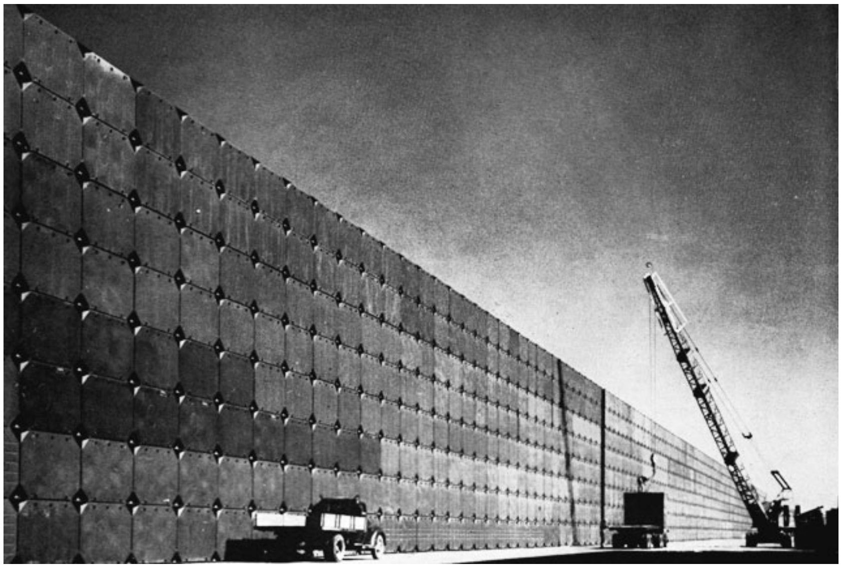


Figure 39. Stockpile of pontoons at Port Hueneme. Note the absence of right angles at the corners of each pontoon. Department of the Navy, Bureau of Yards and Docks 1947a:158.

In addition to the standard 5 x 7 x 5 ft. pontoon, a curved bow pontoon was also made. These could be attached to standard pontoons to create mobile barges, or Rhino ferries, powered by Murray-Tregurtha outboard engines. Rhino ferries were typically 6 x 18 ft., 4 x 12 ft., or 3 x 7 ft. individual pontoons. Other sizes of barges were also built (Department of the Navy, Bureau of Yards and Docks 1947a:159, Friedman 2002:199).

Pontoons were used for a wide variety of purposes. The Bureau of Yards and Docks published the *Pontoon Gear Manual* in 1944 listing 31 standard configurations. These included causeways, dry-docks, finger piers, and crane barges. Pontoons were also used to store gasoline (Department of the Navy, Bureau of Yards and Docks 1947a:157-158).

The draft of a loaded LST (Landing Ship, Tank) ranged from more than three feet forward to over nine feet aft (Department of the Navy, Bureau of Yards and Docks 1947a:114). This draft was too deep for LSTs to be beached and unloaded in many areas. So, pontoon causeways were often used to help facilitate offloading. LSTs transported causeway sections slung on shelves and secured by rope on the ship's sides. They were released as the vessel moved shoreward letting momentum carry the sections toward the shore where one end was beached (Figure 40).

Figure 40. Pontoon causeway section being released from the side of an LST. Department of the Navy, Bureau of Yards and Docks 1947b:78.

On Peleliu, pontoons were used for three primary purposes: as causeways, barges, and in the construction of the harbor. Causeways were constructed on Orange Beach 3 and on Purple Beach (Figure 41). The causeway at Orange Beach 3 was started on D-day September 15, 1944 and completed six days later (Figure 42). Seabees and engineers built it under Japanese fire using bulldozers to clear coral heads from the reef before the causeway could be installed. (Doane 1945:414-415, Hough 1950:22). Six LSTs brought pontoon causeway sections to Peleliu consisting of 2 x 30 pontoons, and were approximately 175 ft. long and 14 ft. wide (Figure 43) (Doane 1945:414, Hough 1950:23).

Figure 41. Pontoon causeways and LSTs at Purple Beach, Peleliu. NARA RG-127

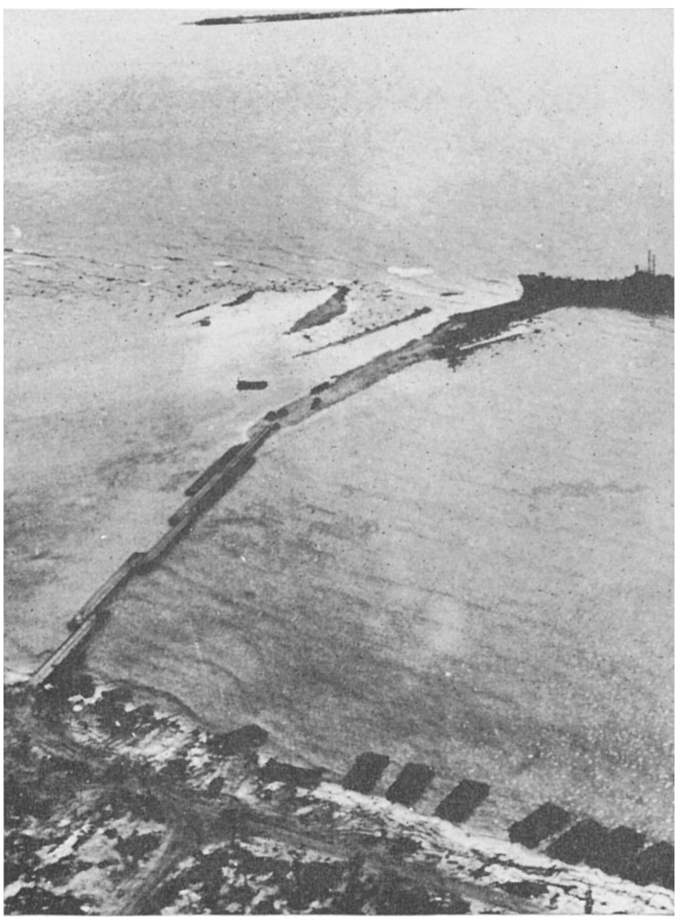


Figure 42. Causeway on Peleliu at Orange Beach 3. Hough 1950:22.

Figure 43. Soldiers land on Peleliu using pontoon causeway. Hough 1950:110.

A storm destroyed the Peleliu causeways about two weeks after they were constructed scattering pontoons over the beaches for several miles (Doane 1945:415). The causeways were quickly rebuilt and were back in operation within 24 hours. Pontoons composing the causeway at Orange 3 were filled with coral rubble to prevent them being washed away again (Doan 1945:415-417).

Landing craft other than DUKWs and LVTs generally could not cross the shallow fringing reef at Peleliu, so moving cargo from ship to shore was challenging. An innovative solution using motorized barges and cranes was tried for the first time at Peleliu. Barges were outfitted with cranes in landing operations such as Guadalcanal. However, these stationary barges were vulnerable to enemy fire. Cranes mounted on barges, however, could move out of range of Japanese fire when necessary. To address this issue, nine motorized barges, each seven pontoons long and three wide, were transported to Peleliu intact and slung on the sides of LSTs. When cut loose, they moved under their own power to specially designated ships and each received a crane. From there the barges went to stations on the reef (Figure 44). Landing craft loaded with cargo approached from one side, and the crane picked up the cargo and transferred it to an LVT or DUKW moored on the other side. In this way, cargo was efficiently transferred from ship to beach. These crane-mounted barges were a successful innovation (Hough 1950:23).

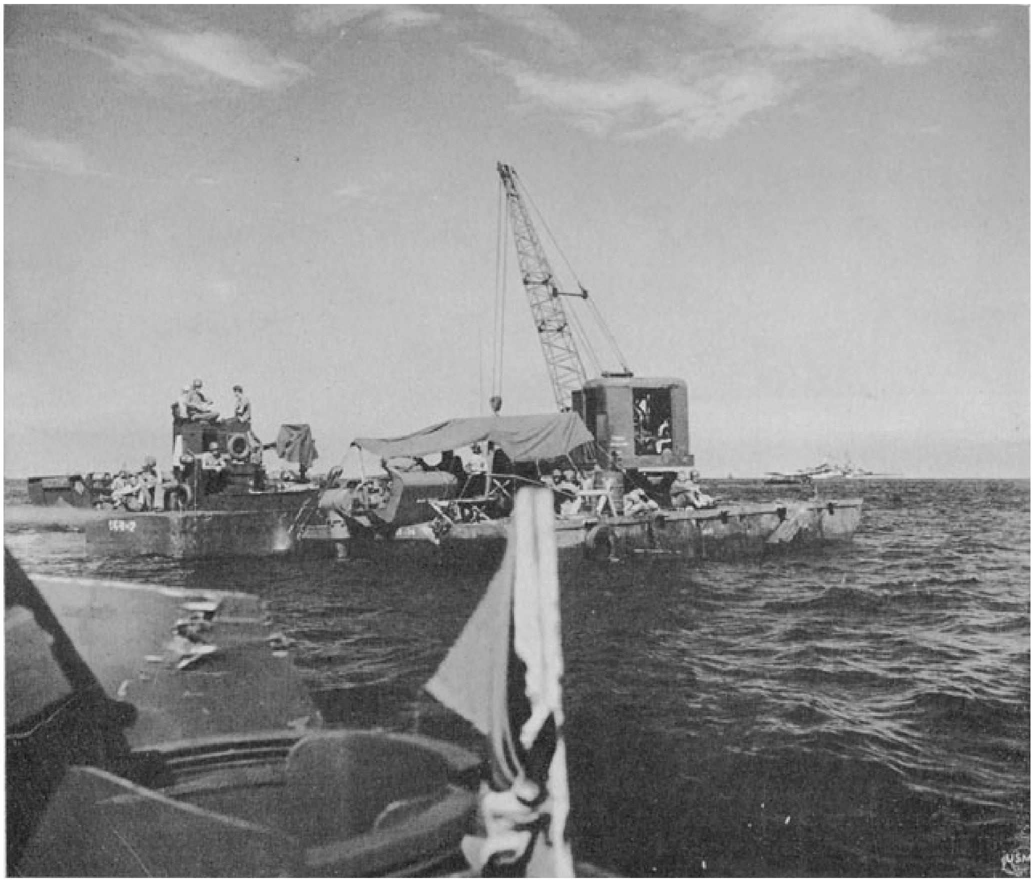


Figure 44. Pontoon barge with crane at Peleliu. Hough 1950:24; Department of Defense Photo, USMC 95354.

Additionally, small pontoon rafts were used as intermediate aid stations for wounded being transported by DUKW or LVT between Peleliu and ships offshore. They were marked with a Red Cross insignia, consisted of six pontoons, and were operated by one doctor and two corpsmen (Bronemann 1982:44).

Construction of a channel and harbor began on October 20, 1944 (Figure 45). The channel was located just south of the causeway at Orange 3. The causeway became the northern bulkhead of the channel, and was eventually covered with coral rubble. Cranes for dredging the channel were mounted on barges and on the beach. Dredging continued 24 hours per day for three months. Coral-filled pontoons were laid alongside the channel to form a dock on which cranes could be mounted. Pontoons were also used to line the harbor to create bulkheads and piers for a boat basin. This was the final stage of harbor construction, and because they were no longer needed to support operations, pontoons were taken from the barges and causeways used in the invasion (Doane 1945:415-417). These pontoons are still in evidence today at the harbor (Figure 46).

Figure 45. Harbor at Peleliu. Department of the Navy, Bureau of Yards and Docks 1947b:331.

Figure 46. Remains of a pontoon used in the construction of the harbor. Roth/Ships of Discovery Science Team.

Analysis

The three sections of pontoon barge remains are located outside the harbor in approximately 40 ft. of water (Figure 47). Two conjoined sections and a separate section are clearly distinguishable. It is possible that the pontoon debris found outside the entrance to the harbor are sections of the causeway destroyed by a storm shortly after they were installed. Subsequently, pontoons composing the causeway at Orange 3 were filled with coral rubble to prevent them being washed away again (Doan 1945:415-417).

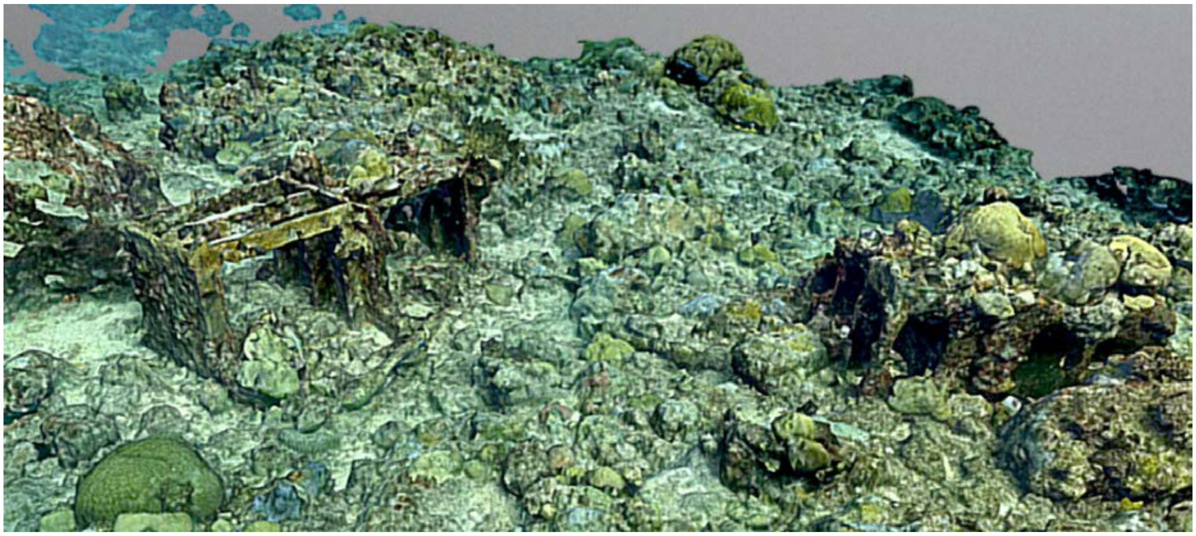


Figure 47. 3D model of the three sections of pontoon found outside the harbor in approximately 40 ft. of water. Model rendering by Pascoe/UHH/Ships of Discovery Science Team.

<u>LVT Wreck</u>

The disarticulated remains of a landing vehicle, tracked (LVT) in 30 ft. of water off the White beach are scattered across a 30-meter area (Ships032).

Historic Context

LVTs used in the invasion of Peleliu were the troop carrying LVT-2 and 4 (Figure 49) and the cannon mounting LVT (A)-1 and (A)-4 and the. Troop transport LVTs could carry 24 troops plus a crew of 2-3 during the initial waves of the invasion.

Analysis

The site consists of a radial engine, miscellaneous framing (Figure 48), and multiple roller assembly pieces (Figure 50). The remains of this LVT were few and widely scattered across the sea floor. Most of the pieces remaining of this LVT are unidentifiable pieces of metal and tubing. Divers searched the area but were unable to locate any further remains of this vehicle. However, the radial engine is recognizable and still inside its engine mount. Three rollers that were used to guide the vehicle's tracks are also scattered about around the site. The only other identifiable piece is a ring hook that is located towards the beach from the engine. Ring hooks like this were found on the bow of most LVTs. The scatter and lack of material remains at this site are what one would expect to find in the event of a catastrophic loss. It is impossible to determine the model of this LVT, but it is probably a LVT 2 or 4 based on the fact that there is not a turret nearby. This LVT was most likely destroyed on its way to the beach.

Figure 48. LVT-2/LVT-4 could carry up to 24 troops with a crew of 2-3. Photo Milityfactory.com.

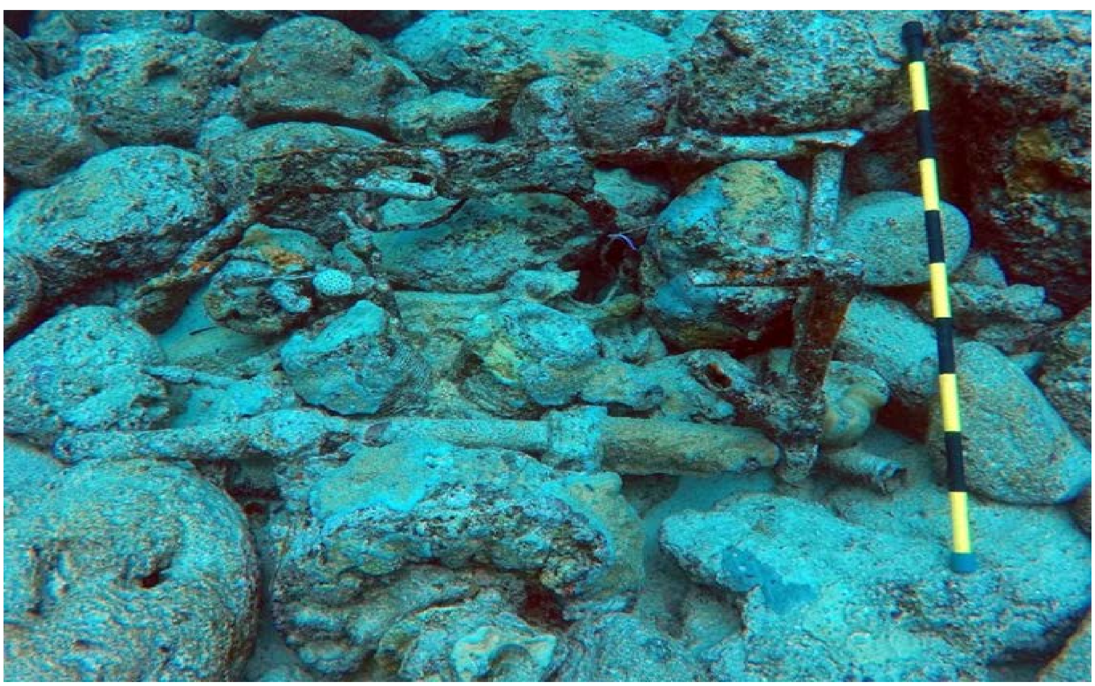


Figure 49. Portion of the disarticulated remains of an LVT (Ships032). Raupp/Ships of Discovery Science Team.

Figure 50. Roller assembly from disarticulated remains of an LVT (Ships032). Raupp/Ships of Discovery Science Team.

<u>LVT Dump Site</u>

Prior to the project, the Ships team reached out to Bent Prop to inquire about reports of at least one LVT sunk off Orange Beach 3 at Camp Beck. Based on information from Bent Prop, the site was just outside of the harbor mouth in approximately 70-80 ft. of water (Dan O'Brien, personal communication February 5, 2018). After relocating the site, the first objective was to determine if these vehicles were catastrophic losses or post war wreckage that was dumped.

Analysis

The first vehicle lies in 61 ft. of water with the bow pointing roughly north at 353 degrees (Ships038). LVT #1 is almost completely encrusted with hard corals. The most obvious feature of the site is a large open top 75mm howitzer turret. The only WWII LVT that used a 75mm howitzer was the LVT(A)-4 (Figure 51). Early versions of the turret have a 50-caliber machine gun "ring mount" located in the rear of the turret. This turret does not contain a ring mount and therefore clearly indicates that this is a late model LVT(A)-4 (Figure 52).

Figure 51. Cannon-mounting LVT(A)-1. Photo http://www.tanks-encyclopedia.com/ww2/US/photos/photo_us_lvt-2_1-cdts-TheWorldWarsnet.jpg

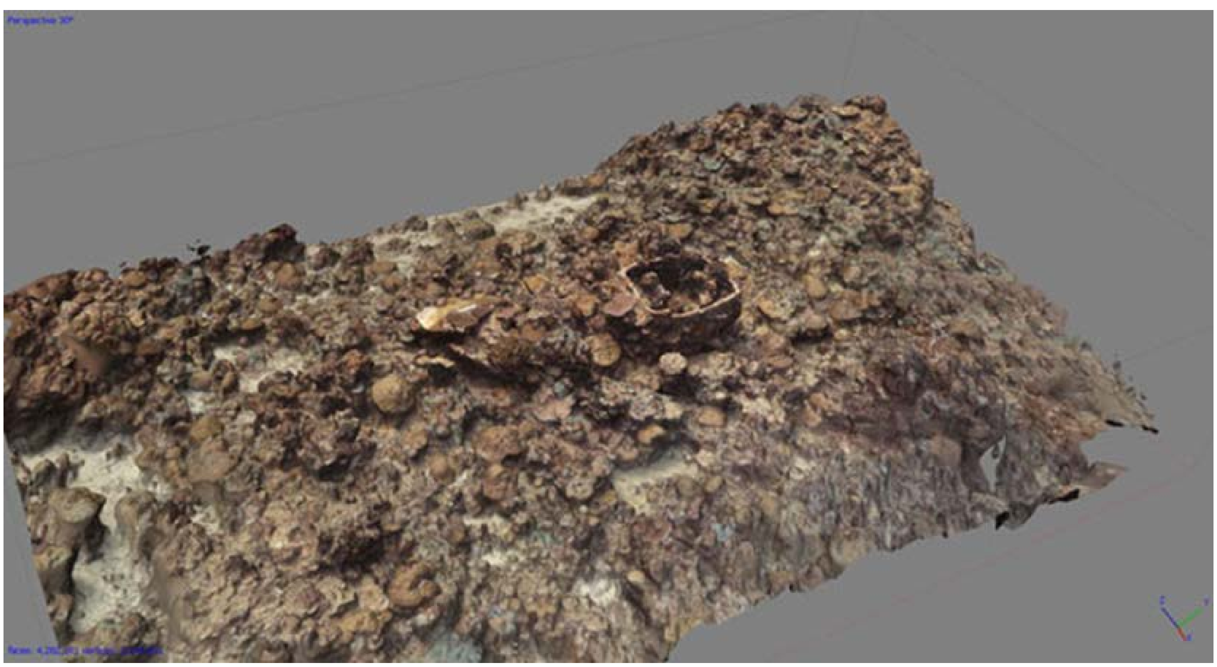


Figure 52. 3D image of an LVT (A)-4 dumped offshore of Camp Beck. 3D Model by Burns and Pascoe/UHH/Ships of Discovery Science Team.

LVT #2 (Ships039) is located down slope from LVT #1 and just before the reef drops steeply off into the abyss. In 96 ft. of water, this vehicle is essentially completely covered with hard corals and is nearly unrecognizable (Figure 53). The only portion of this vehicle that is not covered in coral is the underside of the bow. What remains of the superstructure has collapsed under the tons of coral now anchored to the vessel making the type unidentifiable.

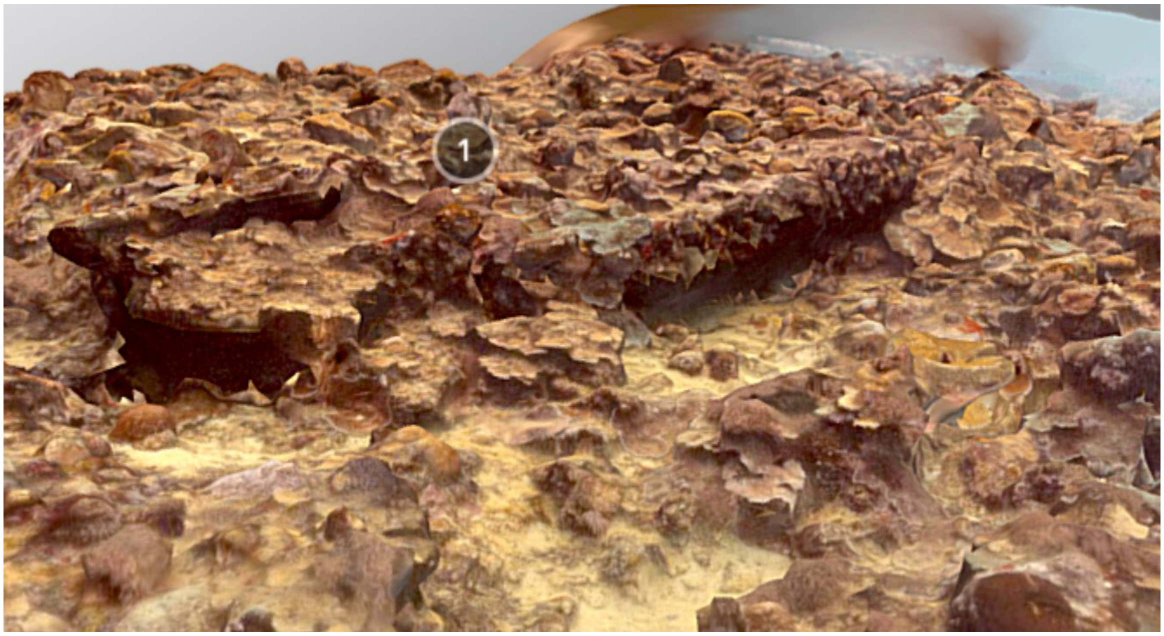


Figure 53. LVT #2 has collapsed under the weight of the coral (Ships039). 3D model by Burns/UHH/Ships of Discovery Science Team.

A series of straight lines in the coral slightly east of LVT #1 and north of LVT #2 were noted while attempting to identify LVT #2. Upon closer inspection, the outline of a third vehicle, LVT #3 (Ships040) began to appear in 75-80 ft. of water (Figure 54). This LVT is also almost completely covered in coral and collapsing under the weight. It is apparent that this LVT is an armored (A) version, meaning that it had a large caliber weapon turret mounted to the top of it. The turret is not present. However, the presence of two lifting hooks on each side of the wrecking identify this as a LVT(A)-4.

The LVT(A)-4's predecessor was the LVT (A)-1. This LVT had a 37mm cannon mounted to the top. The (A)-1 and the (A)-4 used the same vehicle base. The LVT (A)-4's 75mm turret is significantly larger and heavier. Therefore the super structure of the LVT(A)-1 needed to be extended in order to accommodate the 75mm howitzer turret. A pair of lifting hooks was attached to either side of the rear portion of this elongated superstructure in order to facilitate assembly. Due to coral growth and the lack of turret, it was not possible to determine if this LVT(A)-4 is an early or late model.

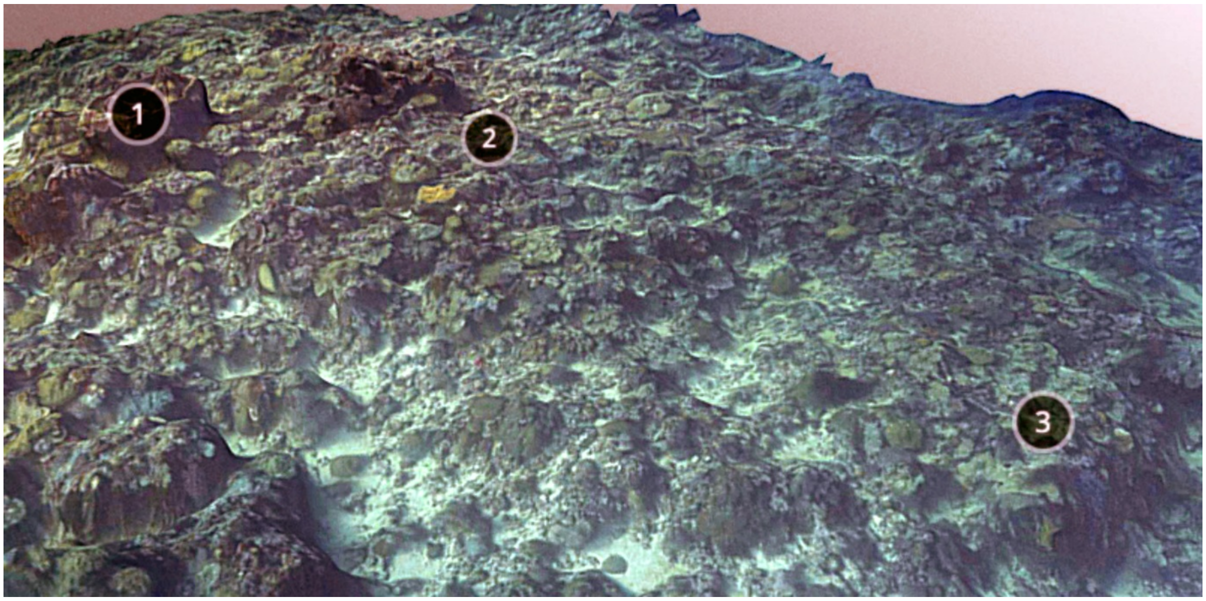


Figure 54. LVT #3 (Ships040) (annotated #3) is nearly indistinguishable from the corals in which it is embedded. 3D model by Burns/UHH/Ships of Discovery Science Team.

Based on the preliminary inspections of the three sites, is no indication any of these vehicles possess the mechanical or electrical equipment required to operate. During WWII, troops regularly salvaged every piece of usable material from the wreckage of battle. The purpose was twofold. One, these parts could be used to repair other vehicles. Two, the opposition would salvage and use anything available to them against the invasion forces. The coral encrusted breach of LVT #1 is the only item that seems to not have been salvaged.

The fact that three LVTs lay in such close proximity and completely salvaged of usable parts supports a conclusion that this is the location of a post war dumpsite. The location of the site between the harbor and just before the reef edge further supports this conclusion. After the initial invasion, it was imperative for troops to remove wreckage and debris from the battlefield in order to facilitate supply deliveries and the evacuation of casualties. It is likely that these vehicles were deemed beyond repair, salvaged of usable equipment, and disposed of at sea. It is also very probable that beyond LVT #2 off the reef edge, there are likely to be more military vehicles. That the sites are heavily coral encrusted and extremely well camouflaged attest to the health of the reefs in general and are in stark contrast to the UDT blast zones.

Lagoon Survey

The walking survey, undertaken on April 10 and 11, 2018, consisted of a 5-person team spaced approximately 5-6 meters apart. The lagoon is less than 3 ft. deep and the visibility is excellent, making visual identification possible. An unusual storm in October 2017 eroded areas of the landing beaches, exposing some remains previously buried but now visible for documentation. The survey area was roughly rectangular from the south end at the existing harbor at Orange Beach 3 to the northernmost end of White 1 beach, a distance of approximately 2.25 km (1.4

miles) and from the mean low water line out to the fringing reef, approximately 300 meters (800 ft.). Survey tracks and site locations were recorded using a Garmin GPSMAP 64st GPS.

Sites identified included: disarticulated Sherman tank tracks, DUKW wheels and axels, LCM-3 (Landing Craft, Mechanized model 3), possible bulldozer blade, possible LVT roller and tread, unidentified engine components, the remains of a U.S. aircraft, and miscellaneous unidentifiable pipe and cable. Some of the sites recorded are definitely associated with WWII activities (HIST) or are presumably modern (MOD). Table 8 is a summary of recorded sites. Selected sites discussed below represent remains only associated with the WWII invasion of Peleliu.

Table 8. Summary of Lagoon Sites

Site Number	Denfeld Site ID	Price/Knecht Site ID	Description and Designation Historic/Modern
Ships001	N/A	N/A	Remnants of a pipe, approx. 20cm diameter, MOD
Ships002	N/A	N/A	Remnants of a pipe, approx. 20cm diameter, MOD
Ships003	N/A	N/A	Remnants of a pipe, approx. 20cm diameter, MOD
Ships004	N/A	N/A	Remnants of a pipe, approx. 20cm diameter, MOD
Ships005	N/A	N/A	Remnants of a pipe, approx. 20cm diameter, MOD
Ships006	N/A	N/A	Remnants of a pipe, approx. 20cm diameter, MOD
Ships007	N/A	N/A	Unidentified metal scatter that may be part of a steel casing. MOD.
Ships008	N/A	N/A	Remnants of a pipe, approx. 20cm diameter, MOD
Ships009	N/A	N/A	Metal Plate, MOD
Ships010	N/A	N/A	LVT Roller, HIST
Ships011	N/A	N/A	American Aircraft Landing Gear Strut, HIST
Ships012	N/A	N/A	American Aircraft Plane wing with landing gear, HIST
Ships012	N/A	N/A	American Aircraft Plane section (curved), HIST
Ships012	N/A	N/A	American Aircraft Plane fragment (shot up), HIST
Ships013	N/A	N/A	American Aircraft Radial Engine (1.25 x 1.2m), HIST
Ships014	N/A	N/A	Wheel, DUKW, HIST
Ships015	N/A	N/A	Wheel, DUKW, HIST
Ships016	N/A	N/A	LVT Tread, HIST
Ships017	N/A	N/A	Two strands of cable, MOD

Site Number	Denfeld Site ID	Price/Knecht Site ID	Description and Designation Historic/Modern
Ships018	N/A	N/A	Sherman tank tread possibly Model M4A2, HIST 
Ships019	N/A	N/A	Bulldozer bucket, HIST 
Ships042	N/A	N/A	Two Axles with vehicle debris, DUKW, HST
Ships052	Site 1, Fea. 5	N/A	DUKW, Axel and wheel assemblies, HIST

DUKW (Amphibious Truck)

Axle and wheel assemblies from amphibious vehicles known as the DUKW (pronounced duck) were exposed on the beach off White Beach 2 (Ships052), Orange Beach 3 (Ships042), and Orange Beach 1 (Ships015). The presence of these assemblies from different vehicles in widely spaced locations attested to their extensive use during the battle of Peleliu.

Historic Context
The DUKW was a six-wheeled amphibious modification of the Army's 2 ½-ton truck that was designed to deliver equipment and troops to shore during amphibious landings (Figure 55). The developmental path of these vehicles differed from that of most other types of landing craft and landing vehicles used in WWII. Some landing craft, such as the LCM-2, were developed by the Navy Bureau of Ships (Friedman 2002:98). Other craft were developed by private contractors. Andrew Higgins designed the LCVP (landing craft, personnel). This vessel became the standard WWII small landing craft which "literally made large scale U.S. amphibious operations possible." Donald Roebling designed the LVT, which was used extensively by Marines in the Pacific Theater (Friedman 2002:207, 99-100).

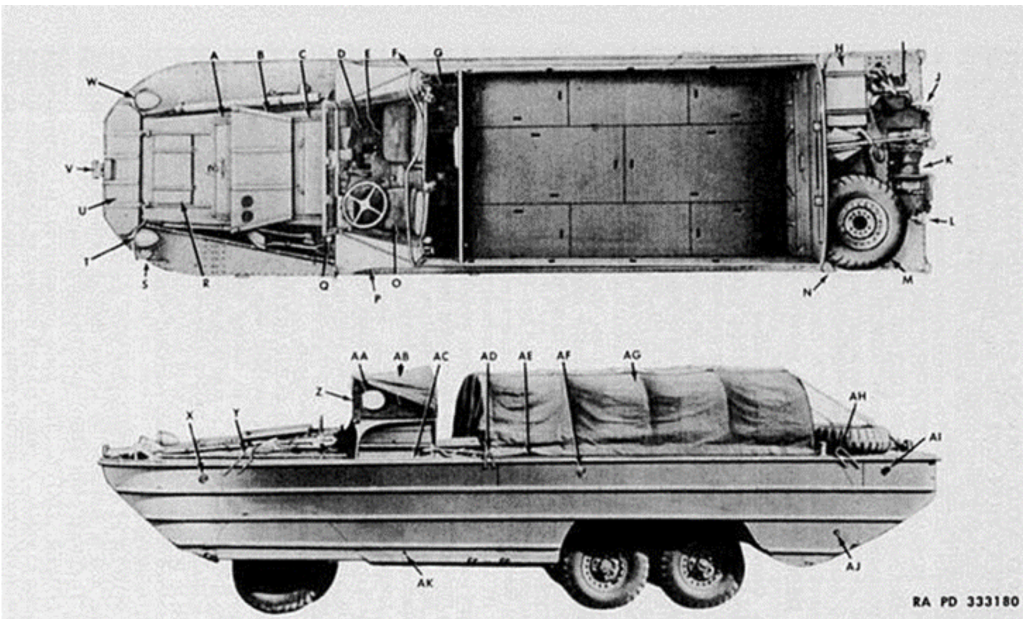


Figure 1—Truck, 2 1/2-Ton, 6x6, Amphibian (GMC Model DUKW-353)—Prior to Chassis Serial No. 2006

Figure 55. Drawing of DUKW from US Army Service Manual. Note the dual rear wheels. (ww2db.com).

The DUKW was developed by the National Defense Research Committee (NDRC). This governmental agency was formed to connect the U.S. military with "rapidly advancing science," and was not part of the War Department (Doyle 2013:5). Rather, the committee was placed under the purview of the Office of Scientific Research and Development. The NDRC was composed of a number of prominent scientists and engineers including Karl Taylor Compton, President of MIT, James Bryant Constant, President of Harvard University, and Frank Baldwin Jewett, President of the National Academy of Sciences and President of Bell Telephone Laboratories. Rear Admiral Harold G. Bowen, Director of the Naval Research Laboratory, also served on the committee. The goals of the NDRC were lofty – they would essentially coordinate the input of the scientific community of the U.S. into matters of defense. As such, the committee was composed of several divisions, which addressed a variety of defense related issues including armor and ordinance, bombs, fuels, gases, chemical problems, and patents and inventions. Division C, Communication and Transportation, assisted the Army's Quartermaster Corps in designing amphibious vehicles (Doyle 2013:6-7).

The needs for an amphibious truck were manifold. Trucks were integral in amphibious warfare for moving material from established beachheads to points inland. Amphibious exercises conducted in 1941 revealed however, that landing craft were unable to bring sufficient numbers of trucks to shore. An amphibious truck could help remedy this problem (Friedman 2002:100-101). Additionally, the Army was interested in amphibious trucks that could work in tandem to carry tanks ashore, and to serve as pontoon units in bridges and ferries. Finally, such a truck would be capable of moving large amounts of equipment and men ashore in areas where dock facilities were lacking (Doyle 2013:14-20).

Members of Division C coordinated with the Yellow Truck and Coach Manufacturing Company of General Motors, the design firm of Sparkman and Stephens, and the Drexel Institute, on plans for a 2 ½ ton amphibious truck in April 1942 and was given the model designation DUKW. "D" indicated the year of vehicle introduction, 1942. "U" meant "Utility," "K" stood for front wheel drive, and "W" indicated 6–wheel dual-driving axels. The initial pilot version of the DUKW was built in Pontiac, Michigan, and tested in June 1942 (Doyle 2013:20).

Mass production of the DUKW began at the Yellow Truck and Coach's plant in Pontiac, Michigan in late September 1942. Orders for the DUKW became so large that, to accommodate them, a Chevrolet plant in St. Louis, Missouri also began producing the vehicle in October 1943 (Doyle 2013:51,131). By the end of WWII, General Motors had produced 21,147 DUKWs (Doyle 2013:304).

The basis for the DUKW was the CCKW 6x6 truck. This standard Army truck was produced in great numbers, and so facilitated the production of DUKWs as well (Doyle 2013:14, 35). To create the DUKW, the truck chassis was fitted with a watertight hull, rudder, propeller, and bilge pumps (Younts 1950:35). The length of the DUKW was 31ft with a beam of 8 ft. Total weight was 13,000 lbs (ONI 226 1944:20). DUKWs were powered by a 91-hp GMC Model 270 six-cylinder gasoline engine that could move the vehicle in water at 5.5 knots and on land at 50 mph (ONI 226 1944:104). The carrying capacity of the DUKW was 5,000 lbs. or 25 troops and their equipment. The standard crew was two men, a driver and an assistant driver or gunner; however, the driver could operate the vehicle alone (Headquarters United States Army Forces, Pacific Ocean Areas 1944:3).

DUKWs were designed to accomplish a variety of missions in different environments. Beginning in June, 1943, DUKWs were equipped with a central tire inflation system (CTIS) that could be used to automatically deflate or inflate tires as needed (Doyle 2013:118). Deflation of tires was necessary in order for DUKWs to move efficiently through sand, and tires had to be properly inflated to cross coral reefs and move on firm surfaces (Headquarters United States Army Forces, Pacific Ocean Areas 1944:42, Doyle 2013:118). Prior to the development of the CTIS, this process was quite laborious and time-consuming, and drivers had to exit the vehicle. The CTIS allowed the adjustment of tire pressure while the vehicle was in motion (Younts 1950:35, Doyle 2013:118).

The principle function of the DUKW was bringing cargo from ships to dumps and transfer points, particularly on undeveloped beaches inaccessible to standard trucks, and to areas where docks were damaged or destroyed. DUKWs could operate in environments that landing craft could not. They were capable of crossing fringing reefs and offshore bars that might prevent the use of landing craft, and could also operate in rough surf that would stop landing craft (Younts 1950:5). An A-frame boom with a 5,000 lbs. capacity could be mounted on the rear of a DUKW (Figure 56). This A-frame allowed a DUKW to unload other vehicles when cranes were not available (Doyle 2013:101).

Figure 56. DUKW using aft-mounted A-frame boom to load jeep onto a CCKW 6 x 6 truck. Headquarters United States Army Forces, Pacific Ocean Areas 1944:2.

DUKWs were particularly adept at transporting the 105mm Howitzer, and this was another primary function of the vehicle. The DUKW could get these howitzers into action sometimes days before other means of conveyance were available (Younts 1950:35). Unarmored DUKWs were not really designed for use during the assault phase of amphibious landings, the lack of armor providing no protection from enemy fire (Headquarters United States Army Forces, Pacific Ocean Areas 1944:2). However, they were used in this capacity in some actions. They could be outfitted with a variety of armament, and could provide fire support when called upon to do so. DUKWs had ring mounts for .50 caliber machine guns, and could carry a pallet of quad .50 caliber machine guns that could be fired during transit. Additionally, 105mm Howitzers were carried by DUKWs, and these could be rigged so that they could fire while being transported. They could also carry Mark 7 and Type 7, Model 1 rocket launchers (Headquarters United States Army Forces, Pacific Ocean Areas 1944:5, 7-8, Younts 1950:35).

Evacuating wounded from battlefields to hospital ships was another of the primary functions of DUKWs (Doyle 2013:135). DUKWs were outstanding in this capacity for a variety of reasons. Wounded could be loaded onto the vehicle on land rather than at the water's edge, which was preferable, particularly if surf conditions were rough. Additionally, DUKWs had a very low center of gravity, and so were stable relative to other craft used for this purpose. This helped insure the safety and comfort of the wounded. Finally, DUKWs could drive up the ramp of an LST so that patients would not need to be unloaded to be taken aboard (Younts 1950:61).

Up to 12 casualties on stretchers were carried by a DUKW in a two-tiered configuration (Headquarters United States Army Forces, Pacific Ocean Areas 1944:5). Six stretchers could rest in the cargo hold on a lower level, and six more stretchers could be arranged above those resting on specially designed combings with guardrails that prevented this top tier from becoming dislodged and falling (Doyle 2013:132-137). DUKWs could carry up to 40 walking wounded as well (Headquarters United States Army Forces, Pacific Ocean Areas 1944:5).

The DUKW did have certain limitations. The size of the cargo area was somewhat limited, so that they could not carry larger artillery such as 155mm Howitzers. The largest vehicle that could be transported by a DUKW was a ¾-ton truck. There was no ramp or gate for loading or offloading, so all cargo had to be moved over the side of the vehicle, presenting challenges when handling cargo. Additionally, the slow cruising speed while transiting water meant that the DUKW was not generally deployed far from shore. Finally, DUKWs had trouble gaining traction in mud and could not negotiate large rocks. Therefore, they avoided swamps, marshes, rivers with muddy banks, and areas with tree stumps, boulders, and wreckage (Headquarters United States Army Forces, Pacific Ocean Areas 1944:2-3, Younts 1950:62)

DUKWs were used in every theater of battle in WWII. In July, 1943, 400 participated in the invasion of Sicily in their first operational use of the war (Younts 1950:60, Doyle 2013:153). At Normandy, they brought ashore roughly 40 percent of all cargo between the invasion on June 6, 1944, and September 1, 1944. Some 2,000 DUKWs were used in this action (Younts 1950:60-61). In the Pacific, DUKWs were used in New Guinea, Kwajalein, and the Mariana Islands. During the battle of Saipan in June, 1944, they landed behind waves of LVTs, and brought ashore men, ammunition, and medical supplies and were used extensively to evacuate wounded to hospital ships. Later, Marines used DUKWs in the assaults on Tinian, Guam, Peleliu, the Philippines, Iwo Jima, and Okinawa.

The assault on Peleliu began on September 15, 1944, and DUKWs encountered one of the most difficult landings of the war (Doyle 2013 203-213). Despite being unarmored, DUKWs very much played a role in the assault phase of the battle.

The 454th and 456th Amphibian Truck Companies (Marine Div 1 1944:1) operated DUKWs at Peleliu. These were U.S. Army units attached to the 1st Marine Division. Each truck company consisted of 6 officers and approximately 170 men (Headquarters, III Amphibious Corps 1944:1). These two companies were each to have operated 50 DUKWs at Peleliu (Rottman 2005:54). According to one primary source however, there were only a 95 DUKWs present during the assault (Brittain 1944:9).

DUKWs were deployed to the Peleliu beaches in the fourth and fifth waves of the attack (Leroy B. Bronemann Collection). Vehicles in these assault waves faced intense mortar and artillery fire, particularly on White Beach 1 and Orange Beach 3, where Japanese defenders were positioned on the flanks of the invasion force (Figure 57) (Marine Division 1 1944:37). To provide some indication of the volume of this fire, high explosive shells struck all but one of the 18 Sherman medium tanks landing in the fourth wave.(Hough 1950:37). One source stated that 25 of the 454th Amphibian Truck Company's 50 DUKWs were destroyed that morning (Bronemann 1982:47-48). Another report stated that on September 16, only 45 of the original 95 DUKWs were still operating, while 33 were under repair, and 17 had been knocked out (Brittain 1944:9).

Passages from Eugene Sledge, a 1st Division Marine who landed on Orange Beach, and Leroy Bronemann, a soldier with the 454th Amphibian Truck Company, provide insights into what conditions were like on the invasion beaches on September 15 and detail some of the human costs associated with the invasion. Sledge landed on Orange Beach 2, and Bronemann landed on one of the White Beaches (he did not specify which) (Sledge 1981:62, Bronemann 1982:40).

> "*I glanced back across the beach and saw a DUKW (rubber-tired amphibious truck) roll up on the sand at a point near where we had just landed. The instant the DUKW stopped, it was engulfed in thick, dirty black smoke as a shell scored a direct hit on it. Bits of debris flew into the air. I watched with that odd, detached fascination peculiar to men under fire, as a flat metal panel about two feet square spun high into the air then splashed into shallow water like a big pancake. I didn't see any men get out of the DUKW."* Eugene Sledge (Sledge 1981:59)

> *"Some of our DUKWs were on the 4th wave and I was on the 5th wave. On the 4th wave, hell almighty! We go in on a high tide and the DUKWs are up there to move the Marines in to shore, and the Marines that went in on Higgins boats were layin' in the water on high tide! And we couldn't…those ducks were up to the edge of the men, they couldn't go over the men, so everybody piled out and there was more men in the water. Everybody with their head out of the water. And along come our 5th wave and we couldn't advance 'cause here the other DUKWs are being knocked out and burning. Out of 50 DUKWs, 25 of 'em are knocked out the first morning. 25. Half of them! Half of them! Well, hell almighty, I was with, our group, was in communications and they had a little van like on a trailer, and they had all their equipment in their like in a box, like a shoe box, and we had to throw that into the water and push it up onto the beach, and I got into position between two rocks, so that I couldn't get shot at except from the ocean side, they couldn't hit me from either side, and I was poking around there wondering what the hell this is all about, and somebody says "Get DUKW 427 out of here," and I said that's my DUKW, so I got the hell off of between these two rocks, went down there, and here there were wounded men crawling over to the DUKW to be evacuated, and one guy says "Don't touch me, don't touch me." I said "What's the matter?" and he says "I've been shot through the chest," and he said "And I'm doped up on morphine." He says "don't let me lie down, I can't breathe." You could see the blood bubbling out of his chest, and so I said "Buddy, I'll hold you," and I put my gun up on top of the hood of the DUKW, and hoisted him up, and I held him in my arms like this, across my legs, and I held him."*

We got at least 8 men that were badly wounded. And we took off, my buddy and I, with our DUKW, and we got out to the platform where we were supposed to take any wounded. And here was a doctor, and his crew, the medics, and they were so stunned, and amazed - they didn't know what to do. And I says for cripes sakes men, these are men that need your help. And we started lifting over. And what happened, we'll never know, because… anyway, you never know what happens to your buddies. As I said 25 of our 50 ducks were knocked out that very day. And what happened to those men I'll never know. And, in the meantime, the casualties in our team were the same as the first marine division. Four of our boys were killed that very morning." Leroy Bronemann (Oral History Interview, Veterans History Project).

Figure 57. DUWK smoldering on beach Peleliu after taking a direct hit. Norm Hatch Collection, National Pacific War Museum, image Peleliu 039, 1944.

DUKWs were tasked with bringing men, communications equipment, artillery, ammunition, flamethrower fuel, water, and rations ashore on D-day (Wright 1944:7, Bronemann 1982:40-46). Later in the battle, DUKWs continued to move equipment ashore from ships and from transfer points at the reef (Wright 1944:7). They also moved reinforcements, ammunition, rations, communications gear, and even war dogs from beach areas to the front lines. DUKWs acted as prime movers for artillery as well (Bronemann 1982:52).

Despite experiencing heavy casualties and the loss, permanent or temporary, of more than half of the available DUKWs on D-day, the men of the 454th and 456th Amphibian Truck Companies performed their jobs with great bravery during the battle for Peleliu. As part of the First Marine Division, Reinforced, both units earned Presidential Unit Citations (Navy). The Citation reads as follows (Department of the Army, 1948:3):

> *For extraordinary heroism in action against enemy Japanese forces at Peleliu and Ngesebus from September 15 to 29, 1944. Landing over a treacherous coral reef against hostile mortar and artillery fire, the First Marine Division, Reinforced, seized a narrow, heavily mined beachhead and advanced foot by foot in the face of relentless enfilade fire through rain-forests and mangrove swamps toward the air strip, the key to the enemy defenses of the southern Palaus. Opposed all the way by thoroughly disciplined, veteran Japanese troops heavily entrenched in caves and in reinforced concrete pillboxes which honeycombed the high ground throughout the island, the officers and men of the Division fought with undiminished spirit and courage despite heavy losses, exhausting heat and difficult terrain, seizing and holding a highly strategic air and land base for future operations in the Western Pacific. By their individual acts of heroism, their aggressiveness and their fortitude, the men of the First Marine Division, Reinforced, upheld the highest traditions of the United States Naval Service.*

Analysis

Three axle and wheel assemblies (Ships052) are exposed on the shore at White Beach 2 (Figure 58). The distribution of these axles indicates that they probably originated from a single amphibious vehicle. Denfeld previously recorded this as Site 1, Feature 5 (Denfeld 1988:54). A previously unrecorded DUKW wheel was found in shallow water off Orange Beach 1 (Ships015) (Figure 59). No other remains were located in association with Ships015, suggesting it was dumped rather than from of a combat loss.

Figure 58. Wheel rims and axles from a DUKW exposed during low tide off White Beach 2 (Ships052). Carrell/Ships of Discovery Science Team.

Figure 59. DUKW wheel in shallow water off Orange Beach 1 (Ships015). Arnold/Ships of Discovery Science Team.

LCM (Landing Craft, Mechanized)

The deteriorated remains of a landing craft (Ships036) were identified in the lagoon adjacent to Camp Beck/Orange Beach 3. The wreck was noted along with several other metallic objects of varying size while scanning the lagoon at low tide. Based on physical measurements and observations of the remains, the wreck appears to be that of a U.S. Navy Landing Craft Mechanized, Mark III (LCM (3).

Historic Context
Equipped with bow ramps, the LCM (3) type was primarily employed for landing bulldozers, medium tanks, guns, and trucks in ship-to-shore traffic (Vagts 1963:634) (Figure 60). Until 1940, amphibious warfare vessels were not part of the U.S. Naval fleet; instead ship's launches and lifeboats were employed as landing craft, though they were entirely unsuited for the task (Rottman 2004:31). With the entry of the U.S. into WWII, it soon became clear that purpose-built landing craft were needed for amphibious invasions.

Figure 60. The LCM in Peleliu is likely similar to the pictured LCM(3) offloading a bulldozer on the Aleutian Islands in April 1945. Greenfield, 1952, pg. 181.

Though numerous designs were considered, an adaptation of the Higgins Corporation's "Eureka Boat" was adopted by the U.S. Navy Bureau of Ships in 1942 (
Figure ***61***) and designated the LCM (Neushul 1998:153). Used during battle and the ensuing aftermath, the LCM (3) was essential to securing WWII battlefields and establishing necessary infrastructure thereafter.

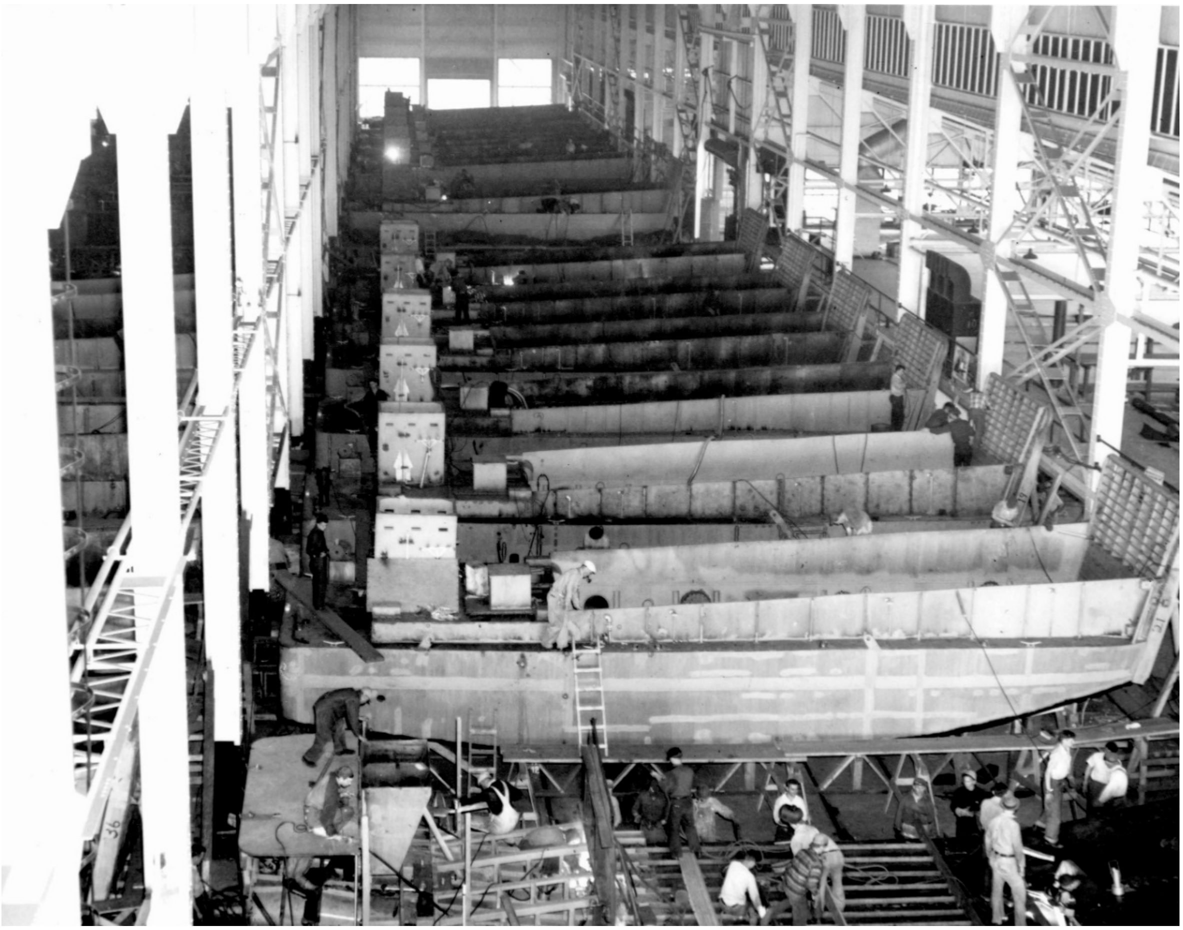


Figure 61. LCM-3 production line at the Boston Naval Shipyard 1942. NARA 7326808

The LCM (3) was a variation of Higgins' original design that incorporated increased size and cargo capacity (Figure 62). Measuring 50 ft. (15.15 meters (m)) long with a beam of 14 ft. (4.25 m), the LCM (3) weighed approximately 25 tons and incorporated a cargo space of 32 ft. (9.7 m) by 9.5 ft. (2.87 m) (U.S. Navy 1945: 13).

Often referred to as a tank lighter due to its ability to ferry tanks and other vehicles, the vessel could carry up to 60,000 pounds of cargo or 120 troops ashore on each run (U.S. Navy 1945:13). Twin Gray Marine Diesel engines capable of producing 225 hp. provided an average operating speed of 10 miles per hour (16.1 km per hour). To allow the vessel to be driven well up on the beach, the LCM (3) incorporated a very shallow draft forward, and but a few feet aft. Two wing tanks, divided into watertight compartments extend the length of the LCM (3), could keep the boat afloat even when the cargo space was flooded (U.S. Navy 1945:13-14).

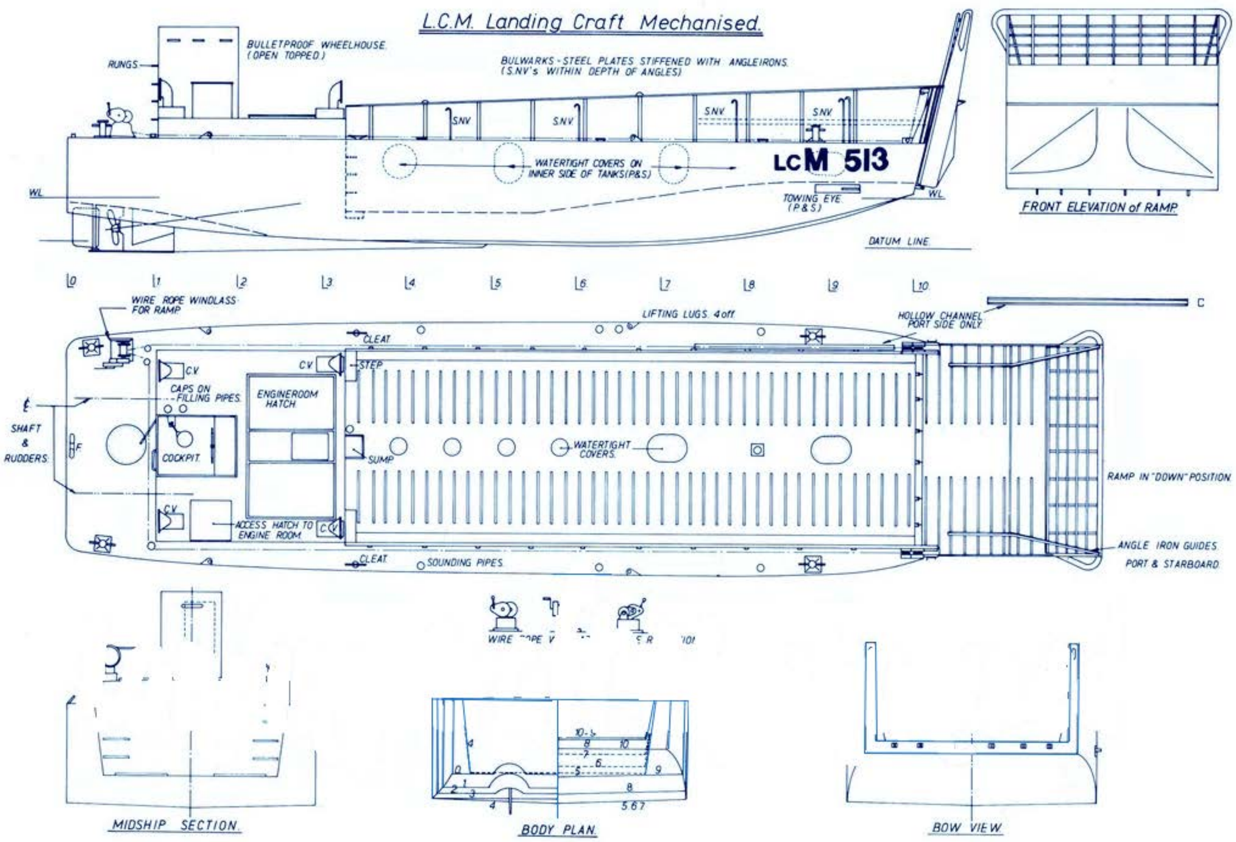


Figure 62. LCM-3 ship model plans, modified. Vintage Model Plans Full Sized Printed Plans Landing Craft Mechanized; adapted by East Carolina University Program in Maritime Studies; https://www.vintagemodelplans.com/products/full-size-printed-plan-landing-craft-mechanized-scale-1-16-l37-b-10-suitable-for-radio-control.

The LCM (3) was extensively used for support operations at Peleliu both during the battle and in the afterwards. Preliminary planning for the battle assumed that various types of landing craft, including the LCM (3), would be able to beach themselves on the shore for loading and unloading activities. In reality, the reef proved to be an obstacle that made beaching operations dependent on the tide. Instead, the LCMs transported cargo from ships positioned offshore to floating pontoon causeways that were established off the landing beaches. The LCM (3) carried cargos of fuel drums, barbed wire, and ammunition, as well as bulldozers, vehicles, and trailers.

Analysis

Though heavily deteriorated, much of the lower portion of the landing craft hull is visible (Figure 63). While the exposed wreckage measures 12.95 m (42.7 ft.) in length and 4.1 m (13.5 ft.) in beam, it is clear that a portion of the bow is missing. Visible remains of the vessel's structure include: two wing tanks and their compartment partitions; two of the six manhole covers used to access them; cargo space plating including two circular hatch covers; many of the 1 m (3.3 ft.) long raised battens that created traction for vehicle wheels; remains of the engine room's aft bulkhead; and sections of rounded deck plate from lower portion of the starboard side, which created a tunnel for the propeller.

Other discernable features that correspond with construction diagrams for the LCM (3) include raised deck plating used to create a "non-skid" surface; mooring bitts in the corners of stern; and pulley sheaves situated near the bow, which were components of the ramp raising and lowering mechanism.

Portions of iron wreckage thought to be associated with the LCM (3) are also located adjacent to the wreck site (Figure 63). Approximately 10 m (33 ft.) to the south are the remains of a bow ramp, which corresponds in size and design to one used on an LCM (3). Though heavily deteriorated, at the time of inspection the ramp measured approximately 3.63 m (12 ft.) long and 3.2 m (10.5 ft.) wide, and 32 cm (12.6 inches) thick. Located east of the wreck, and situated on the riprap structure used to support the Camp Beck doc, is a pile of iron debris consisting of "non-skid" deck plating, possible hull plating, and structural members. This material may be portions of superstructure that have been displaced over time.

Figure 63. Aerial view of LCM in the shallow lagoon at Orange Beach 3. The nearly 13m by 4 m remains are barely awash at high tide and completely exposed at low tide. Raupp/Ships of Discovery Science Team.

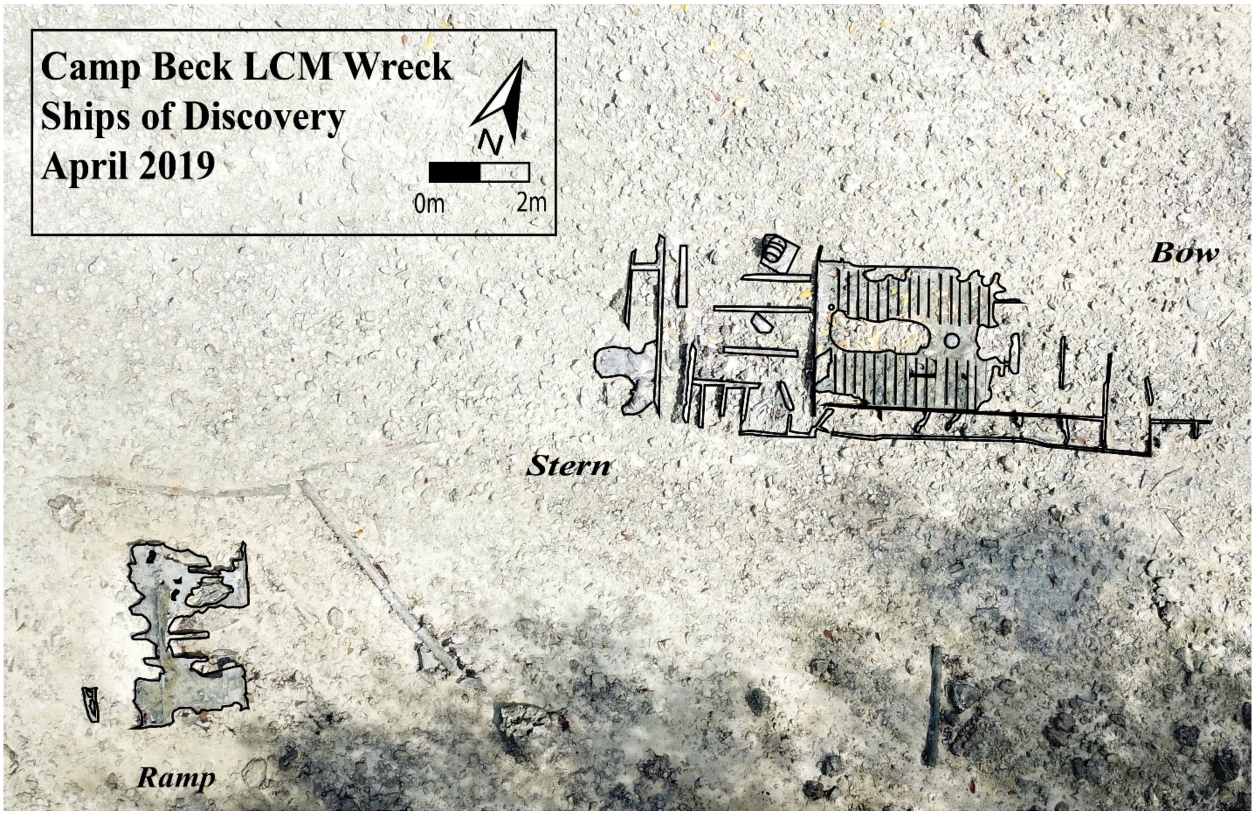


Figure 64. Camp Beck LCM site. Map by Raupp/Ships of Discovery Science Team.

US Aircraft

The scattered remains of a U.S. aircraft was located off Orange 3 Beach. The four pieces of aluminum and iron aircraft wreckage are located within a 200-m area in 1-2ft. (.25-5m) of water. The aircraft identified as a U.S. aircraft because of several English language and numeric part numbers. The largest single element of the site scatter consists of a portion of a wing with landing strut in approximately 2 ft. of water (Ships012). Present elsewhere in the lagoon is a separate piece of landing gear (Ships011), a radial engine (Ships013) and an unidentified curved piece of aluminum aircraft. Just offshore of the reef a single propeller blade (Ships024) was also located that may be associated with this site (Table 7).

Historic Context
The F4U Corsair were designed and manufactured by Chance Vought, but as more were needed and additional production developed, Goodyear built more designated by FG and Brewster built more designated by F3A. Developed as a carrier-based aircraft, Corsairs entered service in WWII late in 1944 and early 1945. They were powered by the Pratt & Whitney Double Wasp twin-row, 18-cylinder radial engine and to extract as much power as possible they were fitted with the large Hamilton Standard Hydromatic three-blade propeller (13ft and 4 inches [4.06m]).

Built for carriers, Corsairs were designed with a folded inverted gull wing, which shortened the required length of the struts. They were also fitted with six .50 caliber guns, three in each wing due to reports coming back from Europe that planes fitted with four were insufficient. This greatly increased the Corsair's ability to shoot down enemy aircraft.

Analysis

Aircraft Wing: A large section of disarticulated aluminum aircraft wing and strut was located during the lagoon survey. The port wing is inverted with three .50 caliber gun ports, the ailerons are missing, and one piece of landing gear is still attached. Bullet holes are present on the surfaces of the wreckage (Figure 65).

Based on the short length of the strut and configuration, the curvature of the wing and port configurations configuration, as well as the three .50 caliber wing ports, this structure matches a Corsair plane design (Figure 66, Figure 67, Figure 68, and Figure 69).

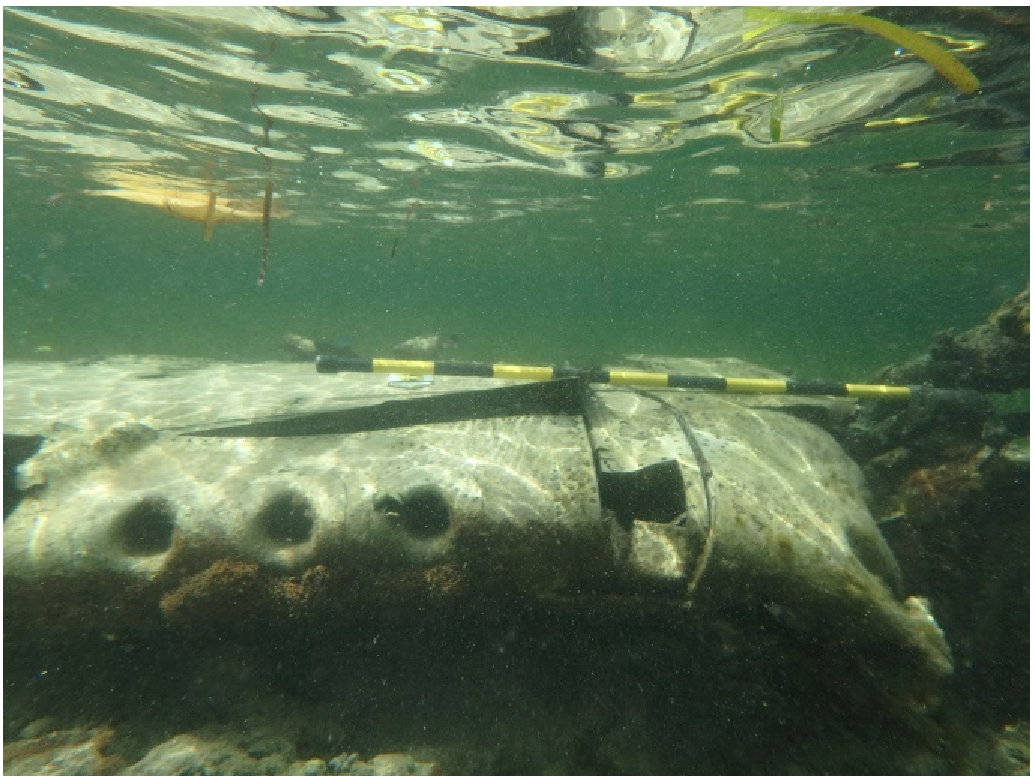


Figure 65. Inverted wing section with three .50 caliber gun ports and square light port to the right outlined in red circle. Note the bend to the right of light port. Keusenkothen/Ships of Discovery Science Team.

Figure 66. F4U Corsair inverted gull wing showing gun port and square light port outlined in red circle. Photograph by Julian Hertzog, Wikipedia Creative Commons.

Figure 67. Inverted wing. Note rectangular and circular ports patterns. McKinnon/Ships of Discovery Science Team.

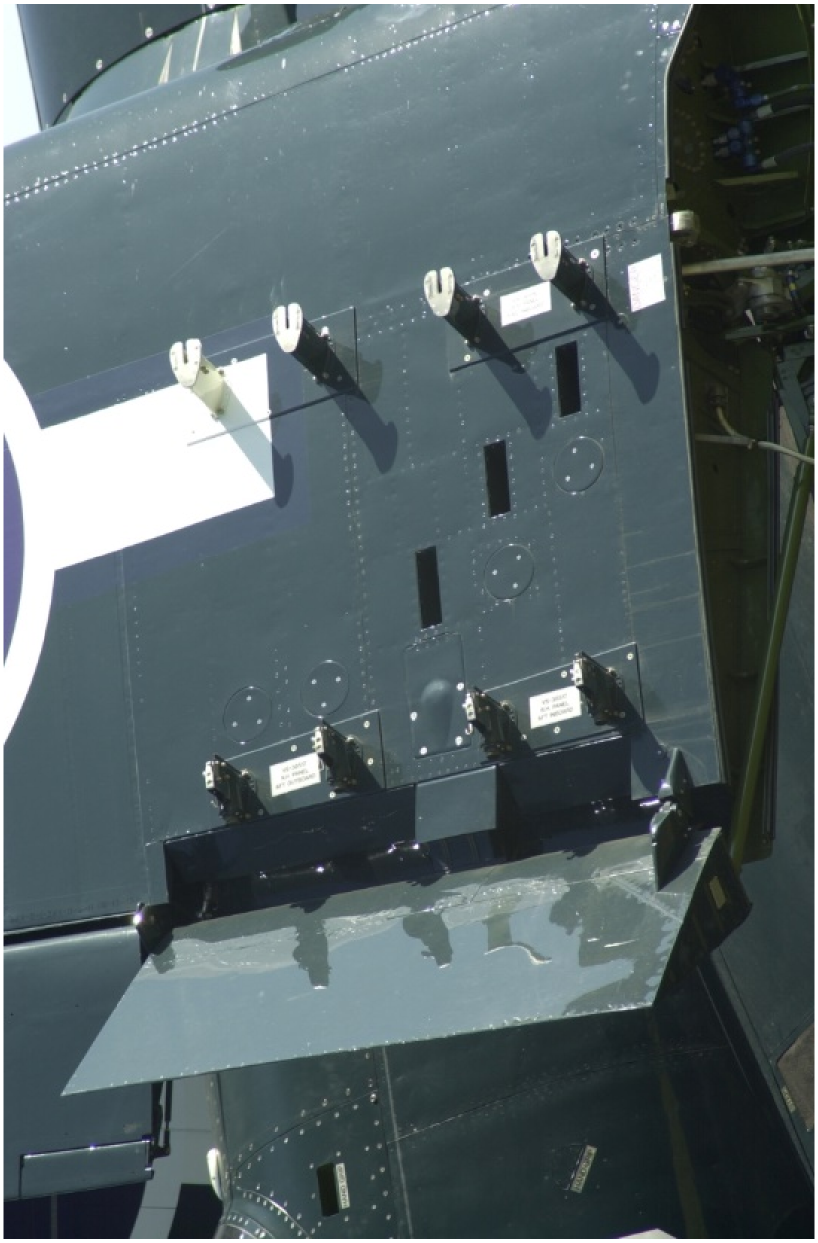


Figure 68. F4U Corsair underside of starboard wing. Note rectangular and circular ports patterns similar to the wreckage. Photo by Kevin Reynolds http://warbirdlegends.com/Allied_Fighters.html).

Figure 69. Aerial view of the aircraft wing at low tide in the lagoon. The landing strut is visible at the bottom of the photo. Raupp/Ships of Discovery Science Team.

Strut: A second strut (Ships011) was found approximately 143 m southwest of the wing structure (Figure 70). The strut matches the strut still attached to the wing structure and as such is considered to be part of the same plane.


Figure 70. Detached strut located in shallow water. Arnold/Ships of Discovery Science Team.

Engine and possible engine parts: Approximately 156 m northwest of the wing is a radial engine (Ships013) (Figure 71) and a possible section of engine cowling. The engine appears to match a Pratt & Whitney Double Wasp twin-row, 18-cylinder radial engine, which was the type used on Corsairs. This piece is considered to be part of the same wreckage (Figure 72). The possible engine cowling is buried and encrusted with marine growth, which makes its identification difficult (Figure 73). It is lying about 10 m from the engine

Figure 71. Radial engine exposed on the reef. Arnold/Ships of Discovery Science Team.

Figure 72. Radial engine. Keusenkothen/Ships of Discovery Science Team.

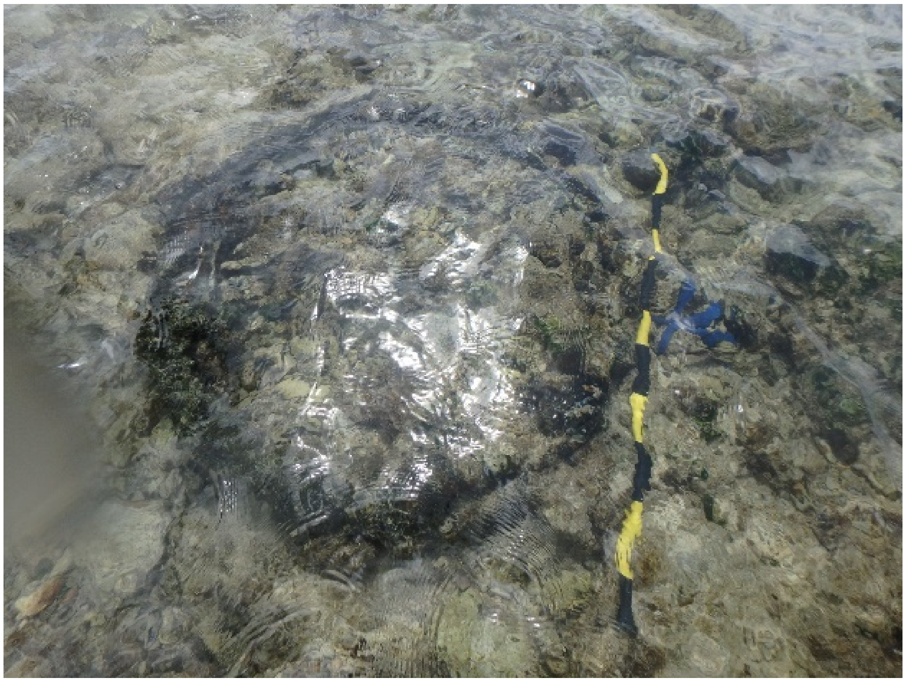


Figure 73. Possible engine cowling. Keusenkothen/Ships of Discovery Science Team.

<ins>Fuselage: </ins>Approximately 45 m northeast of the aircraft wing, lies a section of internal fuselage (Ships012). It appears to be a portion of the main beam assembly center section that supports the inverted gull wing shape (Figure 74, Figure 75, Figure 76, Figure 77).

Figure 74. Curved piece of aluminum fuselage. McKinnon/Ships of Discovery Science Team.

Figure 75. Disarticulated portion of the main beam assembly center section of the inverted gull wing shape. Keusenkothen/Ships of Discovery Science Team.

Figure 76. Disarticulated portion of the main beam assembly center section of the inverted gull wing shape. Keusenkothen/Ships of Discovery Science Team.

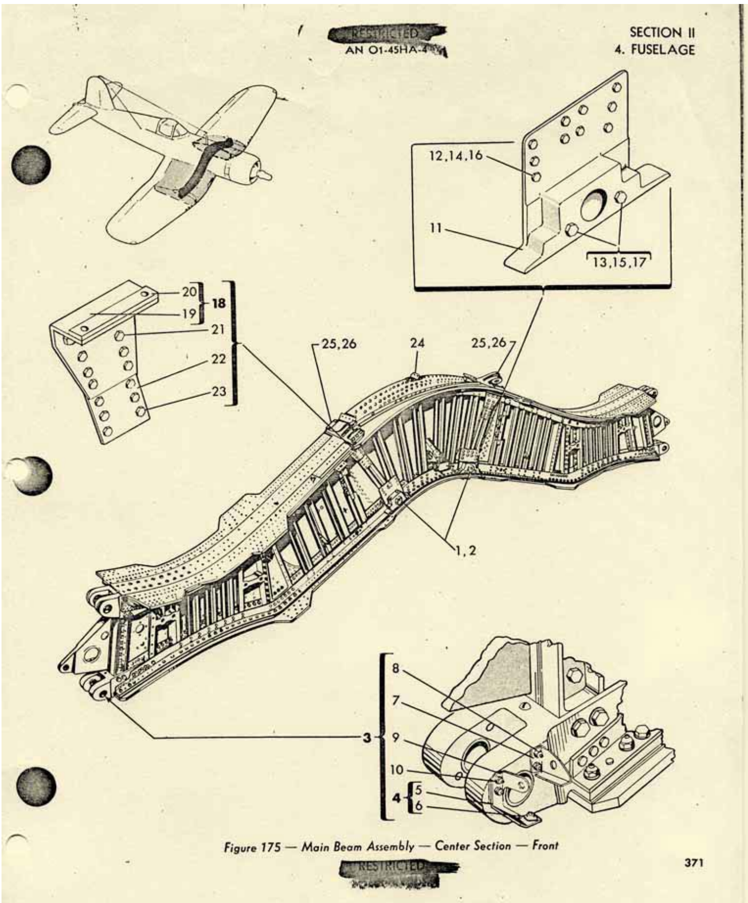


Figure 77. Main Beam Assembly http://www.scharch.org/Ed_Scharch/usn-aircraft/07-f4u-corsair.html.

The wreckage likely belongs to a single aircraft tentatively identified as a U.S. Marine F4U or FG Corsair based on the number wing guns, shape of wing and internal fuselage structure, and shape and length of strut. Forty-seven Corsair are known to have been lost in 1944-45 in Peleliu in combat or other operations. The versions of Corsairs lost include the F4U-1D, F4U-4, FG-1, and FG-1A. If all the identified parts are related, the site would represent a catastrophic loss.

Terrestrial Inshore Survey

The inshore survey was conducted between April 3-6, 2018, during which a three-person survey team, spaced 5-6 meters apart, examined the shoreline from the mean low water line to approximately 30 meters (100 ft.) inland. The survey area was roughly rectangular from the south end at the existing harbor to the northernmost end of White 1 beach, a distance of approximately 2.25 km (1.4 miles). Survey tracks and site locations were recorded using a Garmin GPSMAP 64st.

The purpose of the inshore survey was to locate Japanese defensive positions that were strategically located to direct enfilading fire from the shore out to the reef line (Figure 78).

Working with information recorded by Denfeld (1980), and Price and Knecht (2012) the science team re-examined previously recorded sites and documented several previously unrecorded sites. Fields of fire were recorded at each defensive position that had clear access to the shore to support an invasion beach specific KOCOA analysis.

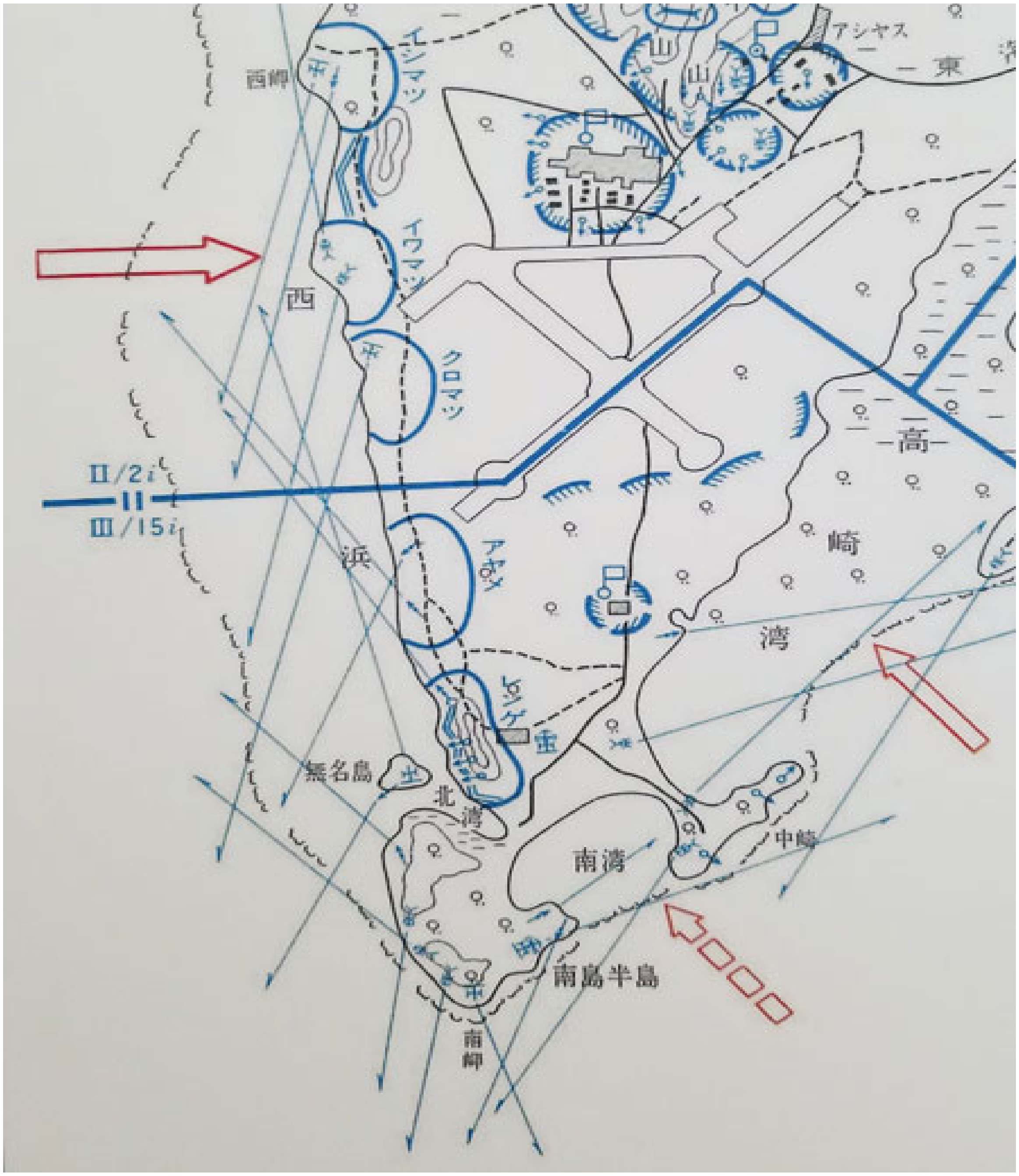


Figure 78. Section of an August 1945 Japanese defensive plan. The red arrows are the Japanese presumed US avenues of approach for the invasion. The blue arrows represent the fields of fire of the gun emplacements across the invasion beaches and reef. The blue half-circles on the beaches represent general defensive positions. Peleliu State Museum.

Modern and historic sites were recorded; these included: abandoned machinery, equipment dumps, pontoon dock sections, secondary defensive positions inshore from the main landing beaches, collapsed defensive caves, concrete “box-like” structures on the shore with unidentified purpose, secondary low defensive positions with poured concrete, defensive trenches, and concrete foundations for buildings associated with either the Japanese or U.S. bases were recorded. Table 9 summarizes the terrestrial sites inshore of the invasion beaches.

Table 9. Summary of Terrestrial Sites Located Inshore of the Invasion Beaches

Site Number	Denfeld Site ID	Price/Knecht Site ID	Description and Designation (MOD = Modern)
Ships041	N/A	N/A	Tug Boat, MOD
Ships043	N/A	N/A	Tractor Engine
Ships044	N/A	N/A	Debris Scatter (Dumping Area)
N/A	N/A	AB219	Aircraft Dump, 100 m long
Ships045	N/A	N/A	Pontoon from Seabee Dock
N/A	N/A	AB230	C-46 Aircraft Engine Cowling
Ships046	N/A	N/A	Pontoon from Seabee Dock
N/A	N/A	AB218	LARC Amphibious Vehicle
N/A	Site 7	AB221	Japanese Defensive cave
N/A	Site 7	AB220	Japanese Defensive cave
Ships047	N/A	N/A	Japanese Fuel Barrel Embankment Defensive platform
Ships048	Site 1 Feature 10	N/A	Japanese Defensive Structure
N/A	N/A	AB58	American Navy Officer Area, Tower Foundation
Ships049	N/A	N/A	Tracked Vehicle Treads, prob. Sherman Tank
Ships050	Site 1 Feature 7	AB279	Japanese Fuel Drum Embankment Defensive platform
Ships051	Site 1 Feature 6	AB280	LVT
Ships052	Site 1 Feature 5	N/A	3 Axles with Tires, DUKW
Ships053	N/A	N/A	Tracked Vehicle, prob. Tractor/Bulldozer
Ships054	Site 1 Feature 11	AB50	Japanese Defensive Structure on "the Point"
Ships055	N/A	AB60	Japanese Defensive Structure on the road to White Beaches
Ships056	Site 1 Feature 20	AB55	Japanese Coral Ridges and Rifle Pits
N/A	N/A	AB148	Aircraft Dump w/Merlin Engines and Japanese Tanks
N/A	N/A	AB268	A6M "Zero" Aircraft
Ships057	Site 1 Feature 12	N/A	Japanese Gun and Defensive Structure
Ships058	Site 1 Feature 12	N/A	Japanese Reinforced Defensive Cave
Ships059	Site 1 Feature 12	N/A	Japanese Gun Housing
Ships060	N/A	N/A	Sprocket from an Amphibious Vehicle
Ships061	N/A	N/A	Japanese Fuel Drum Embankment with pipe fixture

Site Number	Denfeld Site ID	Price/Knecht Site ID	Description and Designation (MOD = Modern)
Ships062	Site 1 Feature 1	AB52.1	Japanese Defensive Cave, Structure, and Gun
Ships063	N/A	AB54	Japanese Defensive Cave
Ships064	Site 1 Feature 2	N/A	Japanese Observation Platform
Ships065	N/A	AB53	Japanese Defensive Cave, collapsed
Ships066	Site 1 Feature 3	N/A	Japanese Gun Cave, Collapsed Concrete Slab and Boulders
Ships067	N/A	N/A	Engine, poss. from Amphibious Vehicle
Ships068	N/A	N/A	Japanese Gun
Ships069	N/A	N/A	Pipe Fixture on Concrete Mount
Ships070	Site 3 Feature 1	N/A	Japanese Defensive Structure
Ships071	N/A	N/A	Octagonal Platform w/trapezoidal monument
Ships072	N/A	N/A	Memorial Pedestal, MOD
Ships073	N/A	N/A	Concrete Slabs, collapsed box-like structures
Ships074	N/A	N/A	Iron Debris, approx. 4 sq. m MOD
Ships075	N/A	N/A	Tractor, disarticulated, degraded
Ships076	N/A	N/A	Japanese Tug, MOD 

Site Number	Denfeld Site ID	Price/Knecht Site ID	Description and Designation (MOD = Modern)
Ships077	N/A	N/A	Iron Buoy, MOD 
Ships078	N/A	N/A	Vehicle Debris, multiple types
Ships079	N/A	N/A	Vehicle Debris, multiple types
Ships080	N/A	N/A	Disarticulated Concrete Structure
Ships081	N/A	N/A	Iron Debris, poss. dock or pontoon
Ships082	N/A	N/A	Engine, poss. amphibious vehicle
Ships083	N/A	N/A	Japanese Low Defensive Position, poured concrete
Ships084	N/A	N/A	Tower Foundations, set of 4, MOD
Ships085	N/A	N/A	Japanese Defensive Trenches and American Dump
Ships086	N/A	N/A	Japanese Defensive Position With Mount
Ships087	N/A	N/A	Tank Base, possible fuel or water tank
Ships088	N/A	N/A	Single Aluminum Fragment, MOD
Ships089	N/A	N/A	Cement Marker, MOD
Ships090	N/A	N/A	Concrete Foundations, prob. assoc. w/Base construction.
Ships091	N/A	N/A	Iron frame, MOD
Ships092	N/A	N/A	Concrete Foundations
Ships093	N/A	N/A	Metal Scrap and Debris, MOD
Ships094	N/A	N/A	Engine, tracked vehicle
Ships095	N/A	N/A	Japanese Defensive Structure
Ships096	N/A	N/A	Concrete Foundations
Ships097	N/A	N/A	Concrete Foundations
Ships098	N/A	N/A	Concrete Slab with Boilers
Ships099	N/A	N/A	Concrete Foundations
Ships100	N/A	N/A	Concrete Foundations

Previously Recorded Japanese Defensive Positions

In 1980, Denfeld documented nine defensive positions along the shoreline. In 2010, Knecht, Price, and Lindsay revisited the majority of the Denfeld shoreline sites and documented an additional three, adding considerable details on each in their 2012 report. Table 10 summarizes the 14 previously recorded sites.

Table 10. Summary of Previously Recorded Japanese Defensive Positions

Site Number	Denfeld Site ID	Price/Knecht Site ID	Description
Ships048	Site 1 Feature 10	N/A	Japanese defensive site
Ships050	Site 1 Feature 7	AB279	Japanese defensive, Fuel drum embankment
Ships054	Site 1 Feature 11	AB50	Japanese defensive structure on “the Point”
Ships055	N/A	AB60	Japanese defensive structure
Ships056	Site 1 Feature 20	AB550	Japanese defensive structure coral ridges and rifle pits
Ships057	Site 1 Feature 12	N/A	Japanese Gun and Defensive Structure
Ships058	Site 1 Feature 12	N/A	Japanese Reinforced Defensive Cave
Ships059	Site 1 Feature 12	N/A	Japanese Gun Housing
Ships062	Site 1 Feature 1	AB52.1	Japanese Defensive Cave, Structure, and Gun
Ships063	N/A	AB54	Japanese Defensive Cave
Ships064	Site 1 Feature 2	N/A	Japanese Observation Platform
Ships065	N/A	AB53	Japanese Defensive Cave, Collapsed
Ships066	Site 1 Feature 3	N/A	Japanese Defensive, Concrete Slab and Boulders
Ships070	Site 3 Feature 1	N/A	Japanese Defensive Structure

Previously Unrecorded Japanese Defensive Positions

Eleven previously unrecorded Japanese defensive positions, summarized in Table 11, were located during the shoreline survey.

Table 11. Previously Unrecorded Japanese Defensive Positions

Site Number	Denfeld Site ID	Price/Knecht Site ID	Description
Ships047	N/A	N/A	Fuel Drum Embankment.  Fuel drums were used to create the corner of a built up Japanese defensive position. The rim of a second fuel drum sitting upright is visible at the top edge of the fuel drum in the foreground .Roth/Ships of Discovery Science Team.
Ships061	N/A	N/A	Japanese Fuel Drum Embankment with pipe fixture

Site Number	Denfeld Site ID	Price/Knecht Site ID	Description
Ships068	N/A	N/A	Gun. A recently exposed Japanese gun eroding out of a defensive position (associated with Ships069). Roth/Ships of Discovery Science Team. 
Ships069	N/A	N/A	Fixture on Concrete Mount; associated with Ships068. Roth/Ships of Discovery Science Team 
Ships071	N/A	N/A	Octagonal Platform, with mount

Site Number	Denfeld Site ID	Price/Knecht Site ID	Description
Ships073	N/A	N/A	Concrete Box-like structures, collapsed. Roth/Ships of Discovery Science Team. 
Ships083	N/A	N/A	Low Defensive Position constructed of rebar and concrete. Roth/Ships of Discovery Science Team. 

Site Number	Denfeld Site ID	Price/Knecht Site ID	Description
Ships085	N/A	N/A	Japanese Defensive Trenches associated with a dumpsite. Roth/Ships of Discovery Science Team. 
Ships086	N/A	N/A	Defensive Position With Gun Mount. Roth/Ships of Discovery Science Team. 

Site Number	Denfeld Site ID	Price/Knecht Site ID	Description
Ships092	N/A	N/A	Concrete Building Foundation. Roth/Ships of Discovery Science Team. 
Ships095	N/A	N/A	Japanese Defensive Position (collapsed) built into rock. Roth/Ships of Discovery Science Team. 

Biological Characterization and UDT Blast Impacts on Reef Structures

Introduction

The reef characterization was conducted over 8 days, April 3-8 and 10-11, 2018. The purpose was to document areas of the reef that were blasted by UDTs in preparation for the invasion and to compare the condition and species of the reef with those areas that were unaffected. Several entire blast zones were modeled in entirety to create 3D maps of these unique areas and to quantify the geomorphology produced by these activities.

The results of the 3D surveys is available for public view at the Multi-scale Environmental Graphical Analyses (MEGA) Lab University of Hawaiʻi at Hilo on Sketchfab at: https://sketchfab.com/BurnsLab/collections/peleliu-project.

Archaeological features were also surveyed to provide information on the presence of coral species and to document the impact of corals on the preservation of these sites.

Methodology

High-resolution (mm-scale) 3D reconstructions were generated at survey sites by collecting overlapping images (70-80% overlap) from planar and oblique angles of reef plots. Images were collected from six 2x2-m plots at three isobaths (~40fsw, ~20fsw, ~10fsw) at each survey site (18 plots per site). The plots were located from the base of the blast zones to the top of the reef flat. Survey plots were also conducted along the same isobaths at locations that were not affected by bombing during the invasion battle.

Scale markers were placed across the study plots to ensure model precision and accurate spatial rectification. The resulting photographs were digitally reconstructed using SfM modeling software. SfM software generates 3D digital surface models in three primary stages: 1) photo alignment, 2) geometry building, and 3) texture building. This process creates 3D point clouds that result from the projection and intersection of pixel rays from the different positions and oriented images in 3D space (Clayput et al. 2016, James et al. 2017). These points are then triangulated and rendered with the original high-resolution imagery to create textured 3D mesh and georeferenced digital elevation models, which can be used to quantify metrics of 3D structural complexity (Burns et al. 2015a, Leon et al. 2015, James et al. 2017). The 3D reconstructions were exported as DEMs and orthophotos to ArcGIS topographic software (ESRI Inc., USA) for quantification of coral health, community composition and metrics pertaining to structural complexity (Burns et al. 2015b).

The orthophoto provided a high-resolution photo-mosaic of the surveyed substrate layered with geometrically corrected DEM such that each cell contains accurate 3D information and can be used for measurement of topographic parameters. The orthophotos were digitized and annotated to create unique polygon shapefiles for all individual coral colonies within each surveyed plot.

After the benthic features were annotated, the ArcGIS software was used to calculate multiple metrics pertaining to 3D characteristics and topographic structure. The data derived from this analysis was used to characterize differences in reef composition and structure at sites located in blast zones and those not affect by blast activities.

The original UDT maps, georectified over current aerials images of the invasion beaches, facilitated preselection of several sites within and outside of the blast zones (Figure 79). At each location six 2x2 m plots at ~40 feet seawater (fsw), ~20fsw, and ~10fsw were documented, producing 18 plots per survey site. In total, data was collected on 425 reef plots, 3 complete blast zones, and 5 underwater cultural heritage sites.

Figure 79. A section of the southern invasion beach with the historic UDT blast zones map overlaying a modern aerial. Two of the blast zones are at the top. Immediately after the invasion, the Seabees extensively modified a shallow coral flat and created a small harbor. Map by Roth/Ships of Discovery Science Team.

This is the first time that historic UDT blast zones have been examined and characterized. The data collected will enable a statistical comparison of coral reef communities inside and outside these blast zones to determine the potential impacts on coral reef habitats at these sites.

Results

Benthic Characterization

Orange Beach benthos was comprised of coral, turf algae and crustose coralline algae, whereas White Barbed[1] Beach was comprised of turf algae and crustose coralline algae (Figure 80). Similar percentages for invertebrates, macroalgae, and rock and rubble found at Orange and White Barbed Beach. There was no significant difference in genus richness between regions. On average Orange Beach had six genera per plot, whereas White Barbed Beach showed five genera per plot.

White Barbed Beach showed the highest genus richness in shallow sites compared to White Barbed Beach at mid depths. Orange Beach exhibited highest genus richness (12 genera per plot) in deeper zones (36-50 ft.). A two-sample t-test comparing the mean genus richness between Orange and White Beach Barbed found no significant difference (t= 0.77288, df= 47.204, p =0.44). *Porites* and *Montipora* were the most prevalent coral genera at Orange Beach (Figure 81). *Diplostrea* were most prevalent at White Barbed Beach (Figure 81).

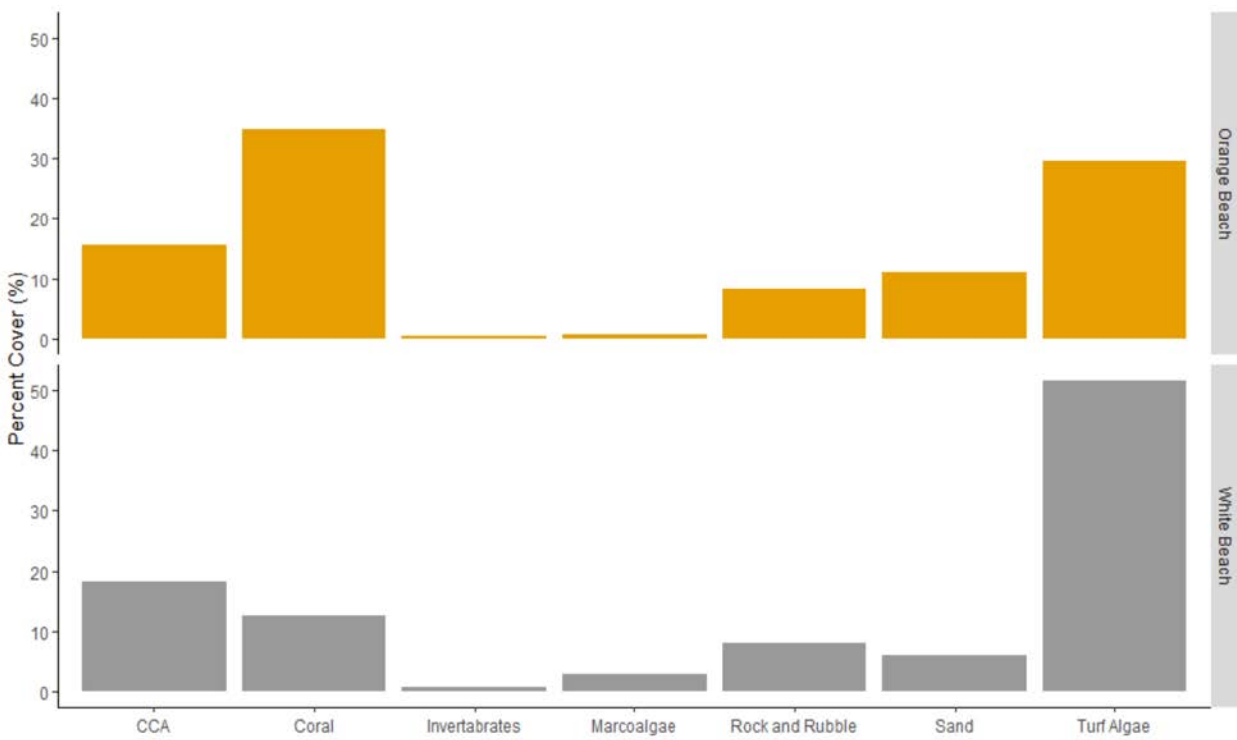


Figure 80. Percent cover of benthic types found among regions. Pascoe and Burns/UHH/Ships of Discovery Science Team.

[1] To differentiate between the blast zones and those areas of the reef that were not, the science team adopted the short hand term 'barbed' for the blast zones. This stemmed from the presence of barbed wire placed on the reef as a defensive measure.

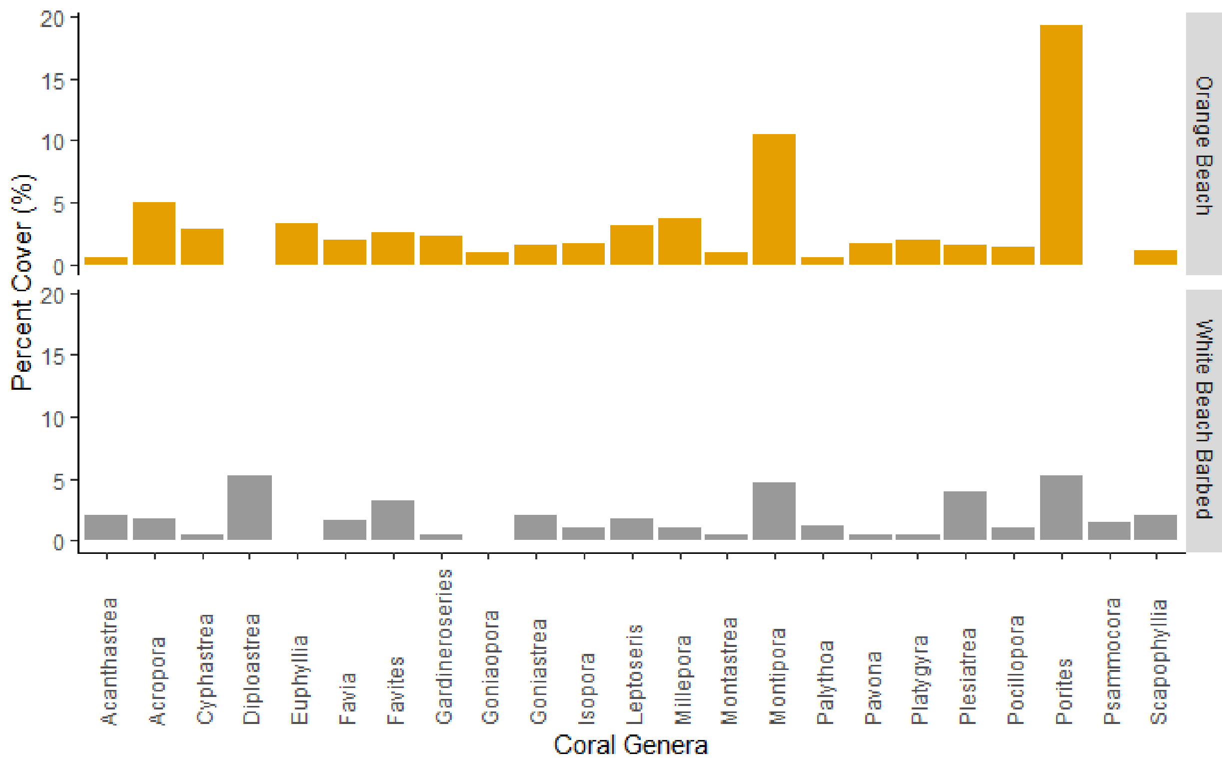


Figure 81. Percent cover of coral genera found in each region. Pascoe and Burns/UHH/Ships of Discovery Science Team.

<u>Percent Coral Cover</u>

Sites within Orange Beach had greater mean values of coral cover (mean=34.9 % ± 26.0) than sites at White Barbed Beach (mean=12.46 ± 14.90) (Figure 82). Results of a two-sample t-test found a significant difference in coral cover between Orange and White Barbed Beach (t=0.4832, df=73.204, $p \leq 0.01$). There were many sites located within Orange Beach that had coral cover mean values greater than 50%. White Barbed beach sites showed mean coral cover values less than 25%, apart from White Barbed Beach 2 site, which had 45% coral cover. Overall, Orange Beach showed the greatest percent coral cover. Depth categories were created at both regions and cross-compared. White Barbed Beach encompassed two depth ranges Shallow (0-15 ft.) and mid (16-35 ft.) (Figure 83). Mid depths showed highest coral cover at White Barbed Beach (mean=16.16 ± 9.712). The mid depth range showed a contrastingly lower coral cover for White Barbed Beach. A deep depth range was not recorded during survey due to the steep decline in slope going down to a depth greater than 100 fsw.

Orange Beach showed the highest coral cover percentage for deeper depths (36-50 ft.). There was significantly less percent coral cover in shallow regions at Orange Beach. A positive significant linear relationship was found between coral cover and depth. As depth increased coral cover also increased. This trend was found between both Orange and White Barbed Beach (Figure 84).

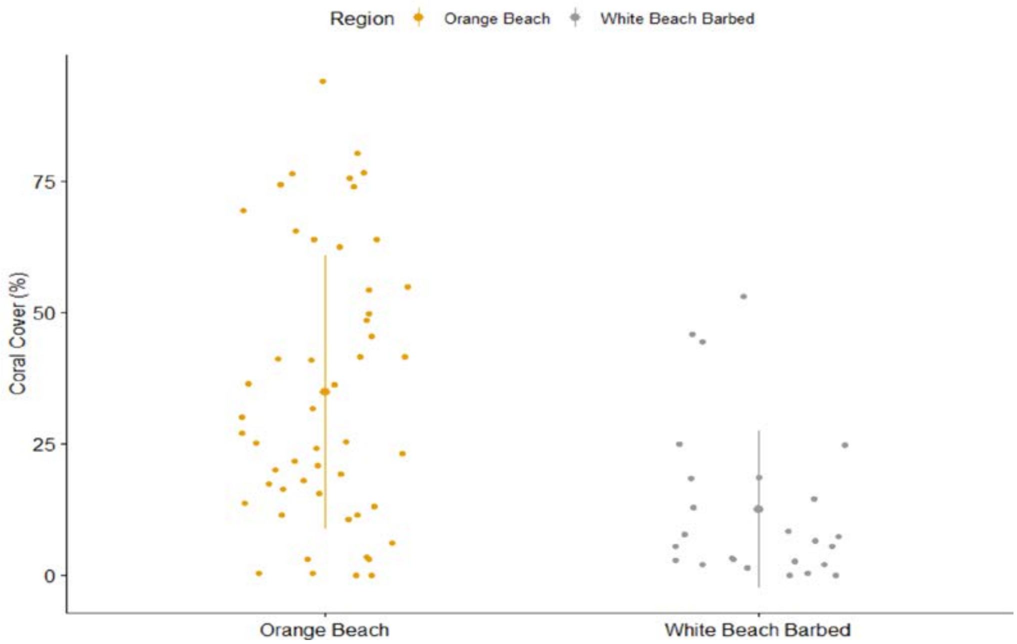


Figure 82. Coral cover percent among regions. Scatter plot points represent the averages for each plot surveyed at each region. Along with the average with standard deviation for each region. Pascoe and Burns/UHH/Ships of Discovery Science Team.

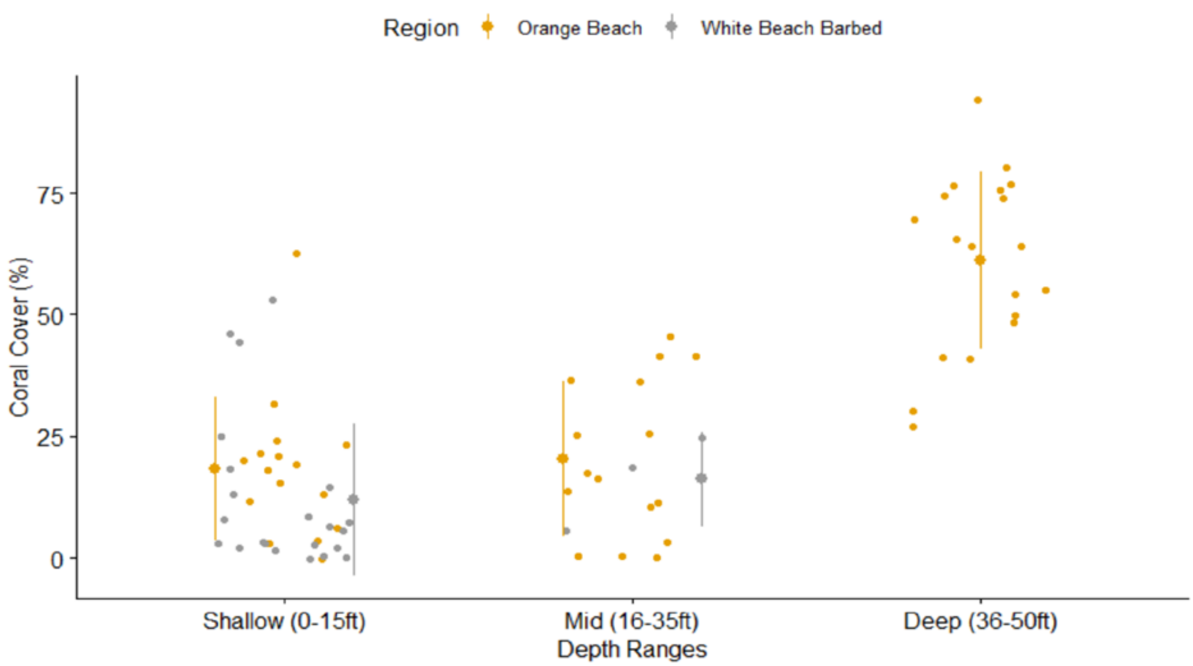


Figure 83. Average coral cover found for each plot among depth ranges and region. Region average and standard deviation represented with large point and error bars. Pascoe and Burns/UHH/Ships of Discovery Science Team.

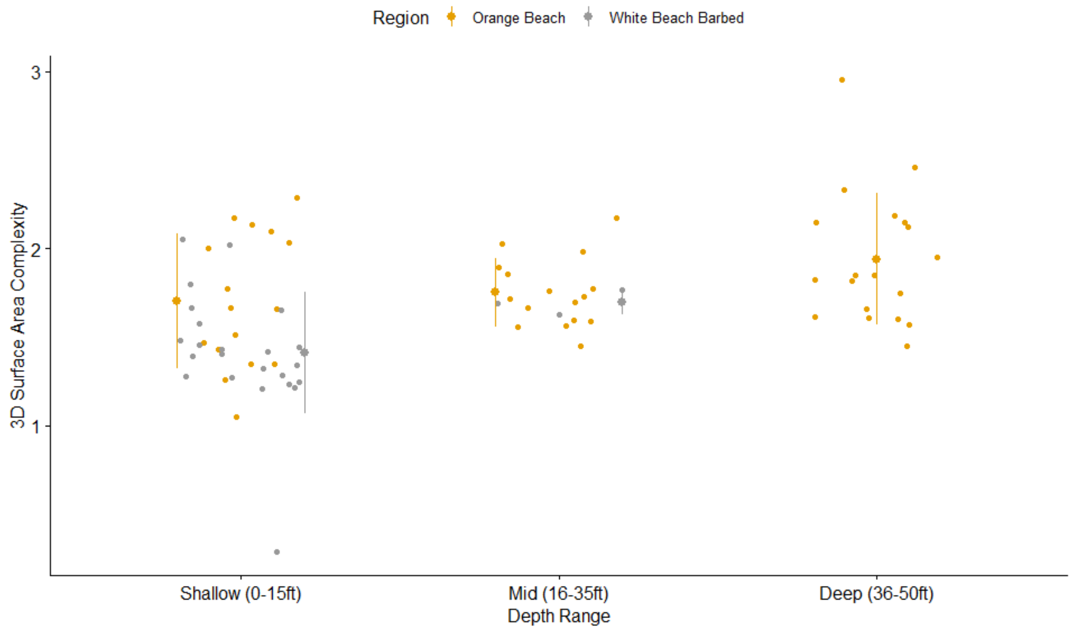


Figure 84. Average 3D surface area complexity found for each plot among depth ranges and region. Region average and standard deviation represented with large point and error bars. Pascoe and Burns/UHH/Ships of Discovery Science Team.

<u>3D Surface Area Complexity</u>

3D surface area complexity is 3-dimensional complexity divided by the 2-dimensional complexity. This metric shows how structurally complex the benthic terrain is. Orange Beach had the highest average 3D surface area complexity (mean=1.806 ± 0.431) (Figure 85). Compared to White Barbed Beach, which exhibited a lower 3D surface area complexity (mean= 1.444 ± 0.334). A two-sample t-test found a significant difference between means at each site (t= 4.4647, d.f.= 51.334, p p ≤ 0.01).

Multiple Tukey tests analyzed the 3D surface area complexity between different depth zones. Orange Beach, shallow had (mean=1.702 ± 0.379) 3D surface area complexity, mid depths (mean=1.751 ± 0.194), and deep (mean=1.941 ± 0.373). The mean 3D surface area complexity at White Barbed Beach in shallow zones was (mean=1.464 ± 0.341), and mid depths (mean=1.696 ± 0.070).

Significant relationship was found between 3D surface area complexity, diversity, and region. A positive linear relationship was found between 3D surface area complexity and diversity. As 3D surface area complexity increased coral diversity also increased. This trend was found between both Orange and White Barbed Beach (Figure 86).

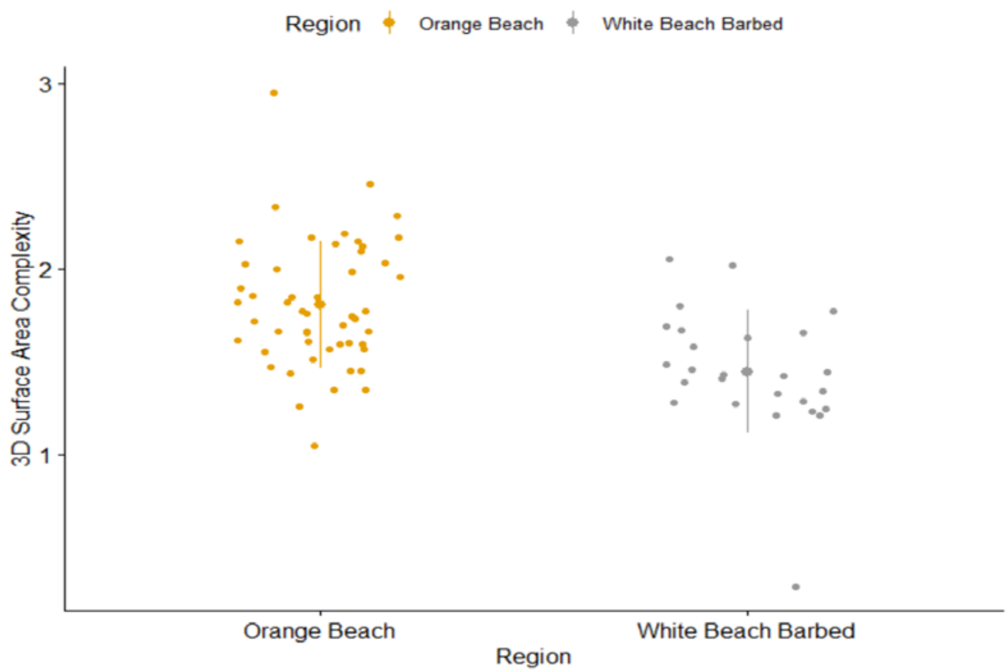


Figure 85. 3D surface area complexity among regions with plotted averages per each plot. Mean values and standard deviation is represented with the large point and variance. Pascoe and Burns/UHH/Ships of Discovery Science Team.

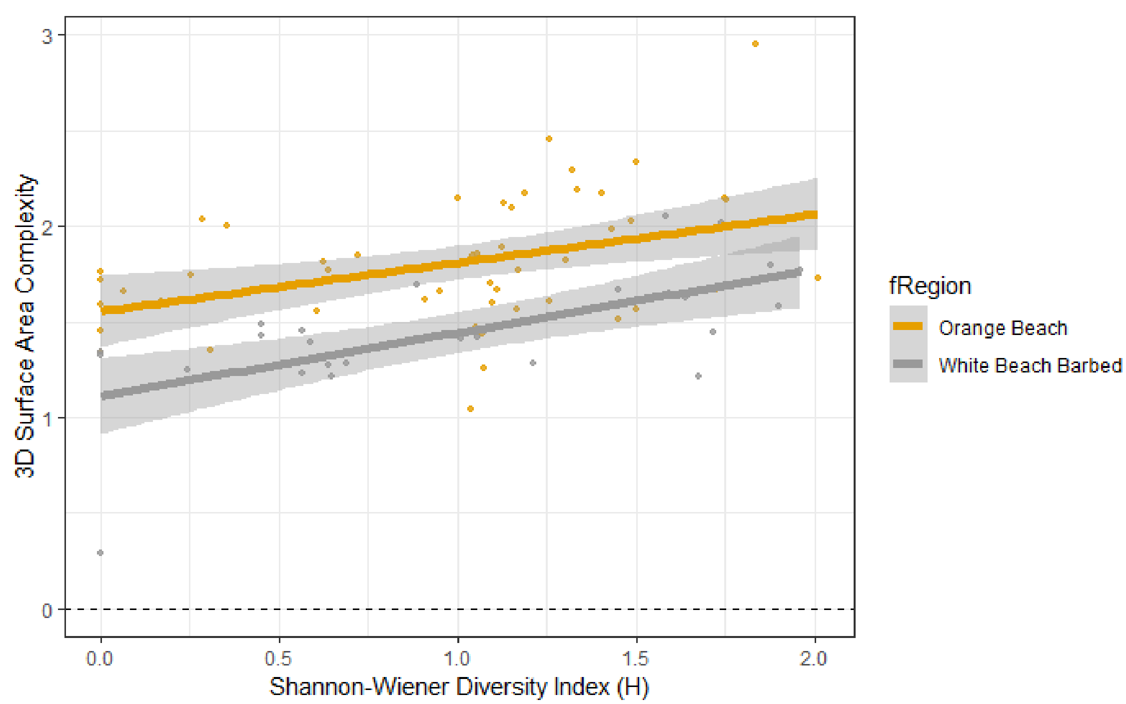


Figure 86. Diversity of coral showed a positive relationship with 3D surface area complexity. Between regions White and Orange there was also a significant difference in 3D surface area complexity. Pascoe and Burns/UHH/Ships of Discovery Science Team.

Discussion

Negative impacts on coral reef habitat and composition due to ecological disasters have been widely documented from hurricane disturbances to blast fishing on coral reefs and found little to no recovery over time (McManus 1997; Mescher & Sturgess 2018). Contrastingly, this study found significant recovery at Orange Beach, most likely because the time frame of recovery was more substantial (74 years at the time of sampling). Given the average growth rate of common species, *Porites* and *Montastraea*, are one to ten centimeters a year (Mescher & Sturgess 2018), it is reasonable that regrowth was seen after 74 years. The coral composition at Orange Beach, however, was characterized by having significantly higher percent coral cover and 3D habitat complexity, when compared to non-blasted reef segments (Figure 82 and Figure 85).

Natural and anthropogenic ecological disturbances influence biodiversity and species richness across all ecosystems, including coral reefs (Biswas & Mallik 2010). The intermediate disturbance hypothesis shows that ecological disturbances play a fundamental role in shaping biodiversity and species richness in an ecosystem (Biswas & Mallik 2010). Percent coral cover, diversity of species, and three-dimensional (3D) habitat complexity are good indicators of a reefs overall ecosystem health. Results were supported by the intermediate disturbance hypothesis on coral reefs after bombing. Overall Orange beach showed a higher percent coral cover, surface area complexity and diversity then compared to White Barbed Beach (Figure 82, Figure 85, and Figure 87). This suggests that the ecological disturbance that occurred on Orange Beach altered the reef by stimulating 3D habitat complexity, thereby providing an opportunistic environment for dominant coral species to grow rapidly.

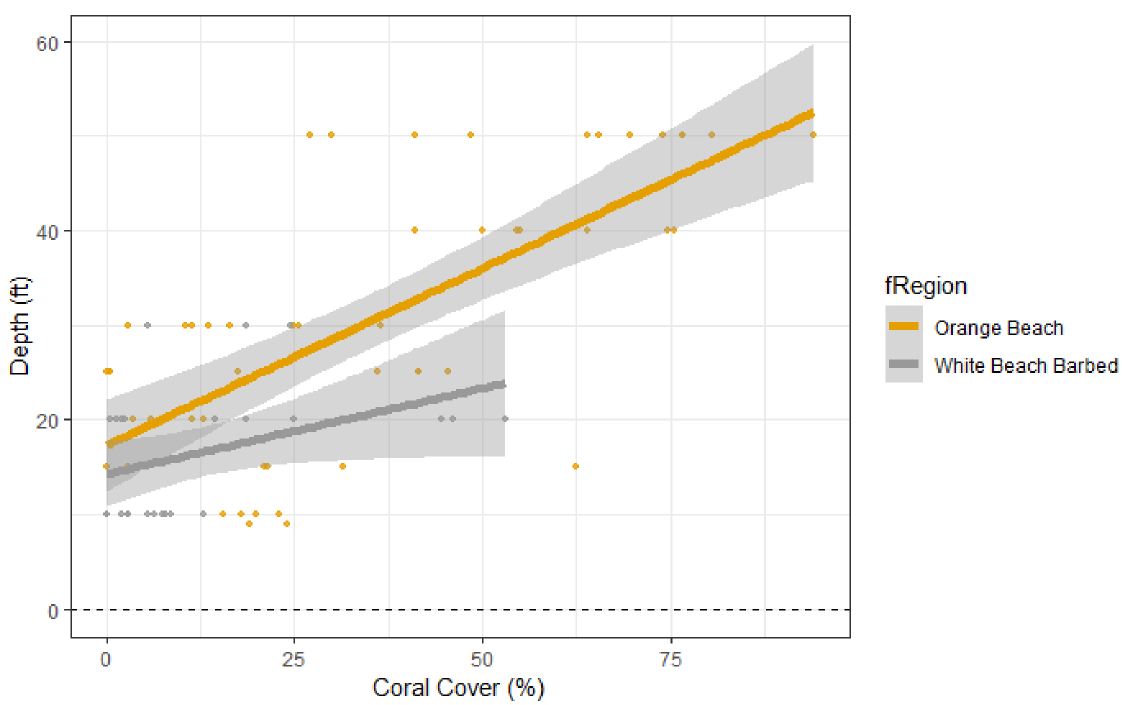


Figure 87. Coral cover showed a positive relationship with depth. As depth increased coral cover also increased. Pascoe and Burns/UHH/Ships of Discovery Science Team.

White and Orange Beaches had similarities and differences between coral genus richness (Figure 81). Both Porites, and Montipora dominated at Orange and White Beaches. Montipora is important for reef building because colonies initially form massive boulders and flat plates that provide reef framework, protecting against hurricanes and tropical storms by dampening the intensity of wave action (Hummann 1993). Porites is a foundation species in the South Pacific Ocean and carries complex morphological variations. Species of Porites have among the highest dispersal potentials (Fadlallah 1983; Harrison 2011), and largest geographic ranges, and the genus is one of very few to occur worldwide in the tropics (Veron & Stafford-Smith 2000).

Given the morphology and importance of these corals, it is reasonable that they exist predominantly at Orange Beach.

While Orange Beach included a greater variety of hard corals, White Beach was composed primarily of sand, turf, rock, and soft corals (Diploastrea). Diploastrea was likely found in the deeper regions of White Beach due to its large mounding dome shape that favors strong currents found in the White Beach region. Higher percent coral cover and 3D habitat complexity in deeper waters at Orange and White Barbed Beaches, compared to shallow reef zones (Figure 84). This is not surprising because fewer disturbances are seen on deeper portions of the reef across the Indo-Pacific.

Habitat complexity is notable for its fundamental role in providing diverse, physical structures for living corals (Magel & Burns 2019). Complex, or greater habitat structure supports a higher diversity of marine organisms, and promotes resiliency to ecological disturbances (Graham et al. 2015). These results provide support for the intermediate disturbance hypothesis on coral reefs after blasting. The same coral genera (Porties and Montipora) prevailed in both blasted and non-blasted regions. Orange Beach, however, had a significantly higher percent coral cover of Porties and Montipora than that of White Beach (Figure 81). Perhaps the ecological disturbance that occurred on Orange Beach caused higher 3D habitat complexity seen in the region, thereby providing an opportunistic environment for dominant coral species to grow rapidly. These findings provoke further research on the dynamics between 3D habitat complexity, coral cover, and species richness in the event of growing ecological disturbances.

Summary

Orange Beach exhibits the highest levels of coral cover and 3D habitat complexity. Orange beach is mostly coral dominated whereas White Barbed Beach was dominated by turf algae. The differences in benthic habitat slope and water current likely drive these observed differences in benthic cover. White Beach has a steep slope and receives more wave energy, which likely impedes the ability of corals to colonize and grow as large and robust as seen at Orange Beach. Coral cover increases with depth at both Orange and White Barbed Beach. Coral diversity is a strong driver of 3D habitat complexity. This trend was found at both Orange and White barbed beach. These findings indicate that the substantial growth and diversity of corals at Orange beach cause a structurally complex habitat with high levels of coral cover. Although the reefs at Peleliu experienced dramatic changes during the battle of WWII, this study found significant recovery of corals at Orange Beach, which is most likely because the time frame of recovery was substantial (74 years).

Biological Characterization of Underwater Cultural Heritage Sites

The biological characterization of the underwater cultural heritage sites occurred during the period of April 3-8 and 10-11, 2018. This documentation was undertaken to provide baseline information on species recovery and potential impacts to the sites.

Results

<u>Tractor with Blade</u>

The tractor wreck, in eight feet of water, is mostly comprised of turf, sand, crustose coralline algae and corals (Figure 88). The SfM model had a coverage area of 78.8 m^2. Turf algae was 69.5% of the benthic characterization, while there was 10.5% crustose coralline algae present. The coral genera that were found at the site was Favia, Isopora, Montipora, and Porites. In total coral represented 19% of the benthic substrate.

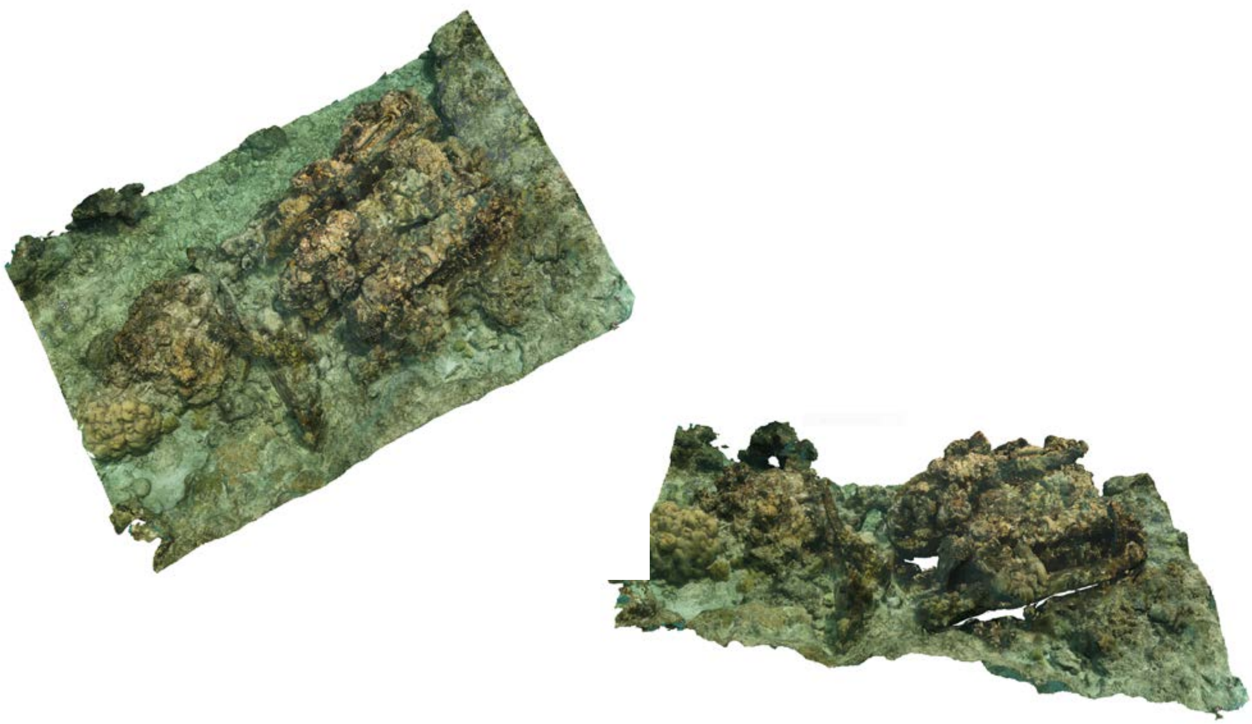


Figure 88. SfM model of tractor wreck found in eight feet of water on the reef flats at Orange beach. Pascoe and Burns/UHH/Ships of Discovery Science Team.

LVT Dump Site Wreck #1

This site is a portion of an LVT dumpsite in 90 fsw with a coverage area of $191m^2$ (Figure 89). This LVT wreck had a large percentage of coral, representing 65%. Coral genera found at this site was Porites, Montipora, Acropora and Isopora. Soft corals cladiella, lobohypyton and sinularia were also found at this site and made up 10% of the benthos. Crustose coralline algae comprised of 16.5% of the benthos. Also present at this cultural site was sand at 2% of the benthos.

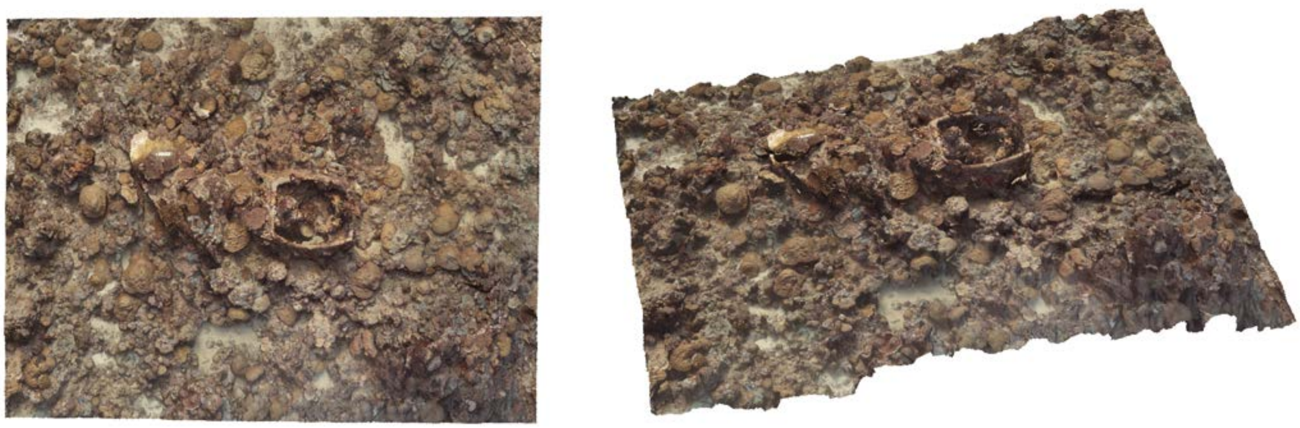


Figure 89. Sfm model of one of the LVT wrecks located in the LVT dumpsite at Peleliu, Island. Pascoe and Burns/UHH/Ships of Discovery Science Team.

LVT Dump Site Full Model

This cultural site consisted of three potential LVT wrecks (Figure 90). This SfM model has a coverage area of 443 m2. There was a large benthic percentage of coral at 45.5%; the coral genera found at this site was Porites, Montipora, and Acropora. There was also a fair amount of of Sinularia soft coral cover at 13%. Crustose coralline algae covered 13% of the benthic substrate whereas turf algae covered 22%. Sand covered about 6.5% of this dumpsite. This site was at a depth of 90-110 ft. on a slight slope in the reef.

Figure 90. Large SfM model of an LVT Dump Site located off Orange Beach, Peleliu. Potentially there are three LVT located within this model. Pascoe and Burns/UHH/Ships of Discovery Science Team.

LVT Wreck

This site is off Orange Beach in a depth of 25 ft., with a coverage area 41.5 m^2 (Figure 91). A SfM model was created for the remains of the LVT engine and roller assembly parts. The benthic substrate was mostly made up from Turf algae on hard substrate at 92%. There was only one coral genius found at this site which as Montipora, and covered 3.5% of the reef. Crustose coralline algae comprised 3.5% of the benthic substrate and there was 1% sand.

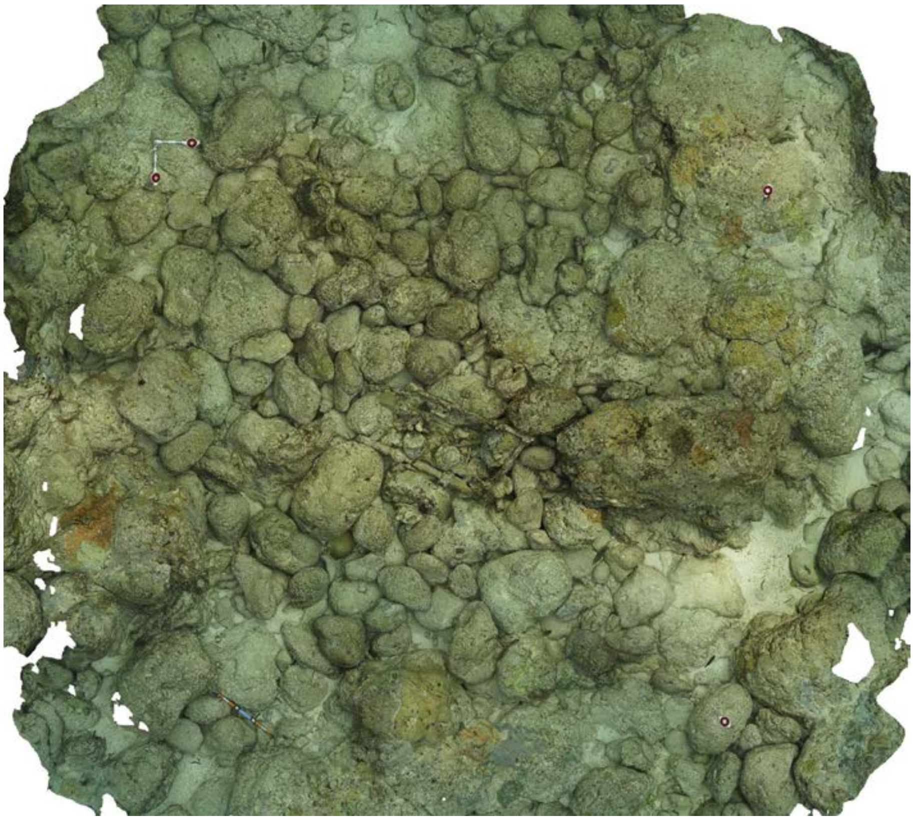


Figure 91. SfM model of remains of an LVT engine and roller assembly. Pascoe and Burns/UHH/Ships of Discovery Science Team.

Pontoon Barge

Remains of a pontoon barge was found at roughly 40 ft. (Figure 92). The SfM model had a coverage area 313m^2. The benthic substrate was mostly made up of 66% turf algae on hard substrate and 20% coral. The coral genera found at this site was Pocillopora and Porites. Crustose coralline algae covered 7.5% and 6.5% was sand.

Figure 92. SfM model of remains a pontoon barges. Pascoe and Burns/UHH/Ships of Discovery Science Team.

Summary

Five underwater cultural heritage sites were reconstructed in 3D using structure-from-motion (SfM) photogrammetry. Cultural Heritage sites consisted of a tractor, LVT dump site, remains of an LVT, and pontoon barges. All sites were found within Orange Beach in depths of 5 to 110 ft. The benthic communities on the cultural heritage artifacts consisted primarily of turf algae, coral and crustose coralline algae. After a substantial amount of recovery time, coral genera Porites, Favia, Isopora, Montipora, Acropora, and Pocillopora have been able to settle and thrive on these wreck substrates

KOCOA Analysis

Introduction

KOCOA analysis was mandated as part of the overall project requirements. It is an extremely useful tool in understanding the loss, potential presence, and potential absence of archeological remains associated with a battlefield and their broader historical context.

KOCOA military terrain analysis originated with the U.S. armed forces as a means of analyzing battlespace geography prior to an engagement (Army 1994:1-1). KOCOA, also written as OCOKA or OAKOC, involves the systematic analysis of site terrain through different tactical lenses. Significant terrain features within the battlespace are classified as one or more of the following: **K**ey Terrain, **O**bservation, **C**over/Concealment, **O**bstacles, and **A**venues of Approach and Withdrawal (Table 12). This classification assists with battle preparation and guides military strategy.

Today, the U.S. National Park Service (NPS) American Battlefield Protection Program (ABPP) utilizes KOCOA as one of several terrain analyses for interpreting and understanding historic battlefield sites (NPS 2016). While initially developed for terrestrial landscape analysis, KOCOA has successfully been applied to maritime and aerial engagements (Army 1994; Babits et al. 2011; Sabick and Dennis 2011; Frye and Resnick 2013; McKinnon and Carrell 2015). It was selected for this research due to its flexibility and use on past ABPP projects.

Table 12. Overview of KOCOA Attributes (after NPS 2016:5 and Babits et al. 2011)

KOCOA Attribute	Definition	Examples
Key Terrain and Decisive Terrain	Features that dominate their surroundings by a quality that enhances attack or defeat. Decisive terrain includes areas that must be controlled to succeed in the mission.	Navigable routes, choke points, significant infrastructure, landing areas, high ground.
Observation and Fields of Fire	Features that provide ability to see friendly and enemy forces. Fields of fire are areas that weapons can cover/fire upon.	High ground, entrenched positions, radar operations, coastal defenses.
Cover and Concealment	Features that provide protection from enemy fire, observation, and surveillance.	Vessels, buildings, ravines, ditches, overgrowth.
Obstacles	Natural or man-made features which prevent, impede, or divert movement.	Reefs, entrenchments, earthworks, defenses, swamps, mines.
Avenues of Approach and Withdrawal	Unobstructed routes that lead to/away from objectives and key terrain.	Roads, navigable channels, valleys, paths.

Prior to fieldwork, researchers compiled a list of significant terrain features, identified in primary and secondary sources, which influenced the amphibious invasion (Table 13). During the 2018 project, these features were visited and documented, if possible. While various sites were investigated during the project, the only terrain features discussed here are those involved with the initial amphibious landings. These are located between the offshore drying reef and the area approximately 300 m inshore of the landing beaches.

The following paragraphs present an historical narrative of the amphibious invasion supplemented by eyewitness accounts. KOCOA terrain features within the study area are emphasized with bold text and are summarized in Table 13. The chapter ends with a brief discussion on battlefield integrity and post-battle landscape modification.

Table 13. Terrain Features and KOCOA Attributes Associated with Peleliu Amphibious Invasion

Feature	Attribute	Description
Beachhead	Key Terrain	Located 300-700m inshore of the landing beaches, the beachhead was the first goal of the amphibious invasion (O-1). The beachhead stretched along the western coast and included the southern half of the airfield, the landing beaches, and the island's southern tip.
Drying Reef	Observation	During the pre-invasion bombardment, both UDT teams used the reef (and cover provided by the water) as an observation point for investigating Japanese shoreline defenses.
	Avenue of Approach/Withdrawal	The offshore area of the beaches, a stretch of 600 yards, remained exposed at low tide. Crossing this stretch of reef was the only avenue of approach to the beaches.
	Obstacle	The reef's shallow depth acted as a bottleneck for resources moving inshore. At low tide, only wheeled and tracked vehicles could cross, while at high tide, some smaller amphibious craft such as LCVPs could also cross in certain areas, although only for very limited periods of time.
Lagoon Defenses, White Beach	Obstacle	Prior to the invasion, Japanese troops placed barbed wire, range markers, and posts in the shallows of the reef to slow an amphibious invasion.
Lagoon Defenses, Orange Beach	Obstacle	UDT-6 encountered mines, bombs, and wooden posts strewn along the Orange drying reef. These obstacles were found on the beachfront periodically throughout the invasion. Many coral heads were also present on the drying reef.
	Avenue of Approach/Withdrawal	The mines and bombs severely impeded movement ashore as they slowed and/or re-routed amphibious vehicles. Coral heads worked to funnel invasion forces into narrow avenues of approach.
The Point	Key Terrain	Forming the northern end of the first terrain objective (O-1), The Point was high priority for marines coming ashore. Control of The Point was key to forming and maintaining a beachhead.

Feature	Attribute	Description
	Observation	The Point was used by the Japanese for observation over the White Beaches. Under American control, it became a means of watching the landing progress.
Pillboxes on The Point	Cover/Concealment	Pre-invasion bombardment caused little damage to these structures. Construction materials were chosen carefully to provide concealment for the occupants.
	Obstacle	Sturdy construction and strong defenses made pillboxes on The Point a deadly obstacle. Marines were forced to clear the pillboxes by hand to gain cover from Japanese fire.
Tank Traps	Obstacle	On White 1, Japanese defenders were successfully able to pin down marines caught in the tank traps.
	Cover/Concealment	The White 2 and Orange 3 tank traps were used as American cover from Japanese artillery on the Orange/White promontory and southern peninsula, respectively.
Amphibious Vehicles	Obstacle	As mortar fire increased, so did the number of damaged LVTs and DUKWs. The heaviest losses on White 1 and Orange 3 became obstacles for other vehicles trying to land.
White 2 Ridgeline	Cover/Concealment	The Japanese used island stratigraphy as a means of cover. High ground such as the White 2 ridgeline became ideal locations for artillery and small arms positions.
Orange/White Promontory	Key Terrain	The marines who landed on White 2 were charged with taking the Orange/White Promontory. Those who landed closest to the promontory succeeded and moved the forward line towards the airport.
	Obstacle	The artillery facing the White beaches significantly slowed the movement of those in the tank traps. Fortunately, marines who landed on White 2 surpassed the area and moved towards the airfield.
Orange Beach	Obstacle	Lack of cover (in addition to wide Japanese fields of fire) made crossing the Orange beaches a deadly endeavor.
Orange Brush	Cover/Concealment	Bordering the Orange beaches was a thin strip of brush which became the sole source of cover for marines on the beach.
Artillery on the Southern Peninsula	Obstacle	Japanese artillery on the southern peninsula destroyed marines on Orange 3 and delayed movement towards the beach which caused further confusion on shore.

Pre-invasion Planning

By June 1944, U.S. armed forces had made significant headway in their island-hopping campaign across the Pacific. Having captured or destabilized the Solomon, Eastern Caroline, and Marshall Islands, the American military was gaining momentum while looking ahead to the recapture of the Philippines and Guam. Termed Operation FORAGER, the combined Mariana and Palau Islands campaign aimed to destroy the Japanese “Absolute National Defense Sphere” (Moran and Rottman 2002:9). The capture of the Marianas would provide U.S. forces with access to airfields within range of the Japanese homeland, while control of Palau would limit Japanese reinforcement of the Philippines (Halsey and Bryan 1947:195). The Peleliu campaign, further differentiated as Operation STALEMATE II, was planned to secure air operations by capturing airfields on Peleliu and Angaur Islands (Halsey and Bryan 1947:195).

During the summer of 1944, U.S. forces collected aerial intelligence on Palau’s southern airfields while periodically strafing visible ground installations on Peleliu. This effort to destabilize Japanese resources was the continuation of air strikes conducted in late March 1944 under the codename Operation DESECRATE I. While U.S. fighter and bomber aircraft targeted the entire island chain, the Peleliu airfield bore the brunt of the southern bombings (Montgomery 1944:6, 10). At the onset of STALEMATE II, U.S. intelligence confirmed that the airfield was rebuilt, which once again made it a target. One crucial element of the reconstruction was missed, however; the continued focus on Peleliu’s airfield indicated to the Japanese that it was a resource worth protecting (Gayle 1996:8).

Between March and July 1944, Japanese troops stationed on Peleliu were joined by reinforcements from the Second Infantry Regiment, an elite group of soldiers who had prior experience in the Manchuria invasion. By early summer, the total number of Imperial Japanese Forces on the island was 10,900 (Gayle 1996:8). The arrival of these forces also brought a change in tactics; previous defensive combat emphasized beachfront attacks using obstacles (booby traps, mines, etc.) and banzai charges intended to destabilize the enemy (Gayle 1996:5). American forces that encountered these attacks early in the war found them far easier to counteract than conducting conventional assaults against fortified positions. By 1944, however, Japanese generals incorporated a more conservative stance on defense positions into their battle plans, which emphasized prolonged fighting (Gayle 1996:5). An already extensive cave and phosphorus mineshaft network existed on Peleliu throughout the northern ridgeline. With the arrival of the Second Infantry, Imperial Japanese Army and Navy personnel enlarged and enhanced these caves and shafts with artillery, supply caches, and living quarters to facilitate extended engagement (Phelan 1945:3). Finally, Japanese leaders anticipated American avenues of approach and reinforced the beaches and roads with obstacles, observation posts, and artillery (Gayle 1996:10).

The U.S. invasion of the Marianas in June 1944, proved critical for the Palau campaign because Japanese documents detailing the troop increase on Peleliu were uncovered during the battle for Saipan (Moran and Rottman 2002:17). As a result, D-Day was moved from September 7 to September 15, 1944, which provided a better timeframe for landing beach reconnaissance (Fort 1944:215; Moran and Rottman 2002:17). Aerial imagery, supplemented by current and tidal data collected via submarine scouting, suggested troops should land near the airfield on the island’s western beaches, code named White and Orange (Fort 1944:215).

Pre-invasion Beach Reconnaissance

Establishing the **White and Orange beachfront**, stretching 2,200 yards in length, was the first objective (O-1) of the amphibious invasion (Figure 93). Chosen for their favorable inshore terrain and distance from areas of higher ground, the beaches were well defended, necessitating careful planning. The 600 yard stretch of **drying reef** off the beaches, which remained partially exposed at low tide, was of further concern because it was too shallow for LSTs and LCVPs to successfully maneuver (Rupertus 1944:5). As preparations continued, it became evident that more information on beach hydrography and potential obstacles was needed. Three days before the invasion, twelve swimmers from Underwater Demolition Teams (UDT) 6 and 7 deployed to investigate the submerged reef scape and landing beach terrain (Rupertus 1944:17).

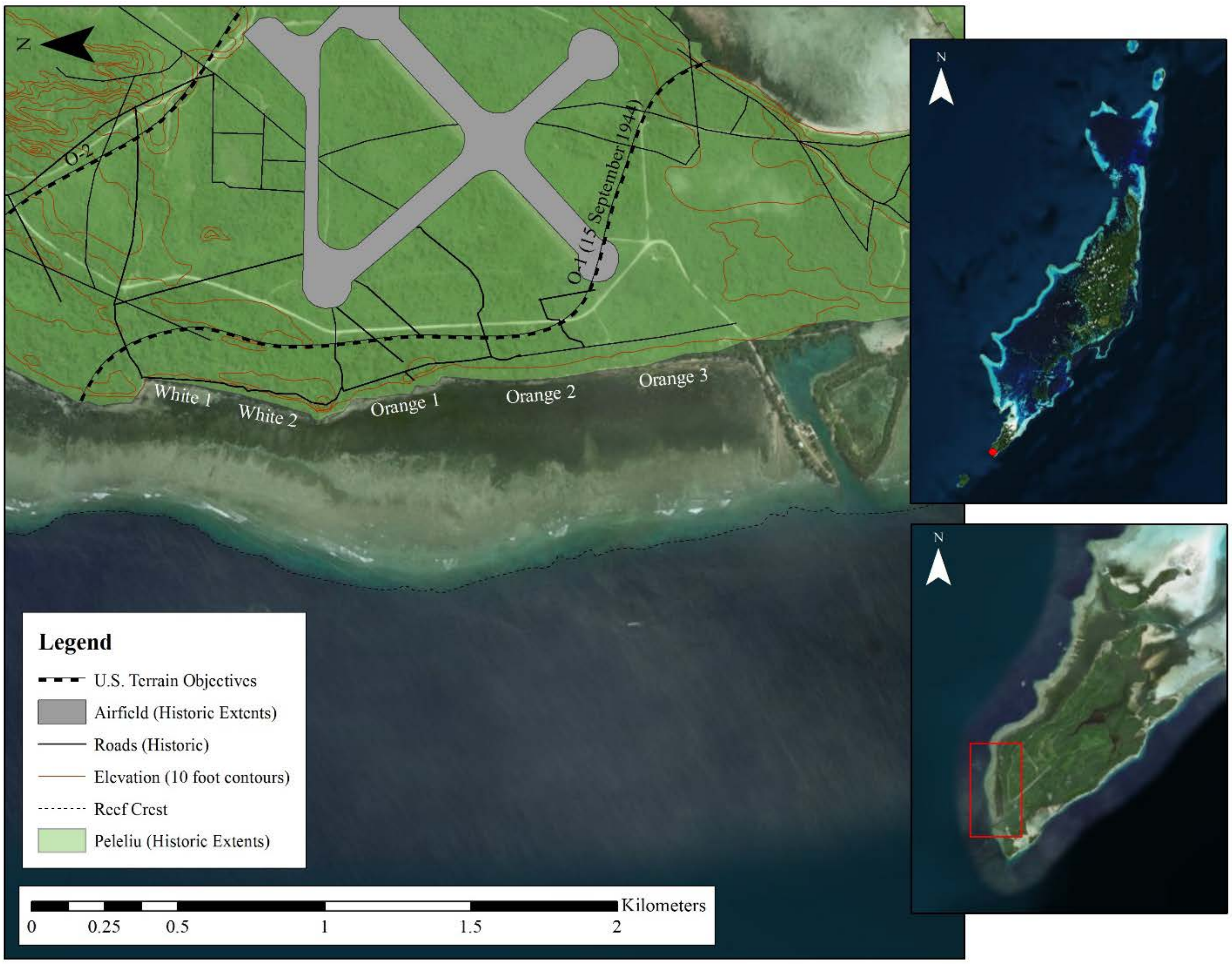


Figure 93. U.S. Invasion Objectives at Peleliu. Top inset: Location of Landing Beaches in Palauan Archipelago. Bottom inset: Location of Landing Beaches on Peleliu Island. Image by Roth/Ships of Discovery Science Team.

The first reports from UDT 7 investigating the White beaches were promising. The reef depth was favorable to amphibious vehicle crossings, and few hazardous obstacles were encountered (Figure **94**). **Posts and barbed wire** had been driven into the seabed off the White beaches to slow amphibious craft; however, the swimmers determined they posed no threat to vehicles

(Burke 1944:3). Several **pillboxes** were visible along the beach; however, the swimmers reported they "had been demolished by naval gunfire" during previous strafing runs (Burke 1944:1). **Range markers**, too, were discovered on the shallow reef. Because these were built to increase efficiency of shore-based Japanese guns, UDT 7 returned the evening of September 14 to blast the reef and remove the markers (Burke 1944:3).

UDT 6 encountered significantly more obstacles than their counterparts did farther north. The Orange beachfront was lined with **wooden posts,** and **submerged mines, bombs, and boulders** were discovered on the drying reef. Following the initial swim survey, UDT 6 transformed into a forward observation post; the swimmers relayed the positions of shore defenses to the officers on the destroyers positioned offshore, who, in turn, targeted and shelled Japanese coastal fortifications (Hutson 1944:2; Rupertus 1944:2). Despite the cover fire provided by the destroyers, members of UDT 6 spent September 12 to 14 clearing the beachfront under continuous Japanese sniper and machine gun fire (Hutson 1944:2).

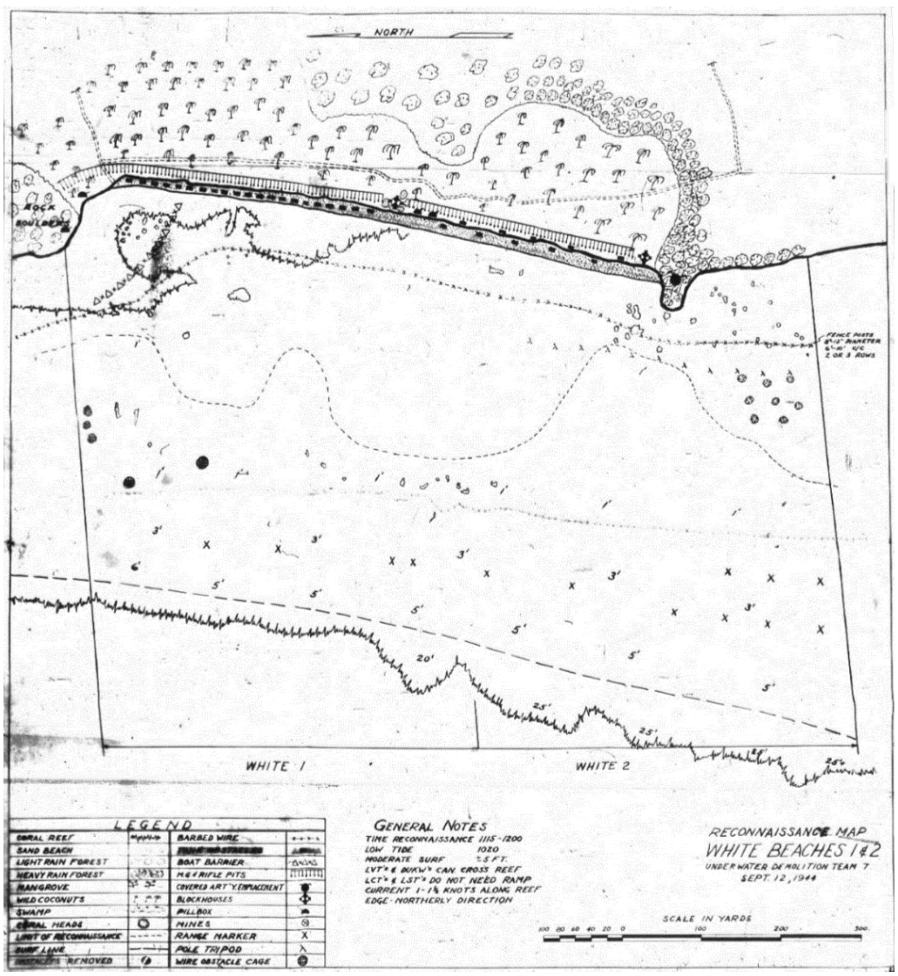


Figure 94. Reconnaissance Map of the White Beaches created by UDT 7. Burke 1944. NARA RG-38.

D-Day Landing and Initial Assault

As September 15, 1944 dawned gray and overcast, fire support ships set to work delivering one final salvo before the assault (Figure 95) (Fort 1944:2). During the night, transport vessels carrying the 1st Marine Division had arrived off the coast; those on board woke to the deafening sound of U.S. rockets and aircraft strafing runs (Davis 1988:3). Private Leroy Bronemann, a soldier aboard one of the LSTs, recalls an eerie silence shrouded the island: "it seemed incredible that anyone could be alive after the Navy's blistering assault" (Bronemann 1982:38).

Stationed 16,000 yards from shore, naval transports began loading their cargo into smaller Higgins boats at 0600 hours (Lea 1988:35). Receiving a signal shortly after 0700, the boats approached the transport lines of waiting LSTs and amphibious vehicles. Each craft bore a pennant marking the assault wave and group. Located 4,000 yards off the reef, the seemingly random mass of vessels slowly organized as the 1st Marine Division piled into amtracs and DUKWs (Hunt 1946:39; Lea 1988:35).

The assault tactics for each wave of amphibious craft were, in the words of Bronemann, "a simple formation maneuver" (1982:40). The 1st, 5th, and 7th Marine Regiments, all of the 1st Marine Division, would make a target landfall on their respective beaches with each new wave of the assault. The 1st Marine Regiment was to land on White 1 and 2, the 5th on Orange 1 and 2, and the 7th on Orange 3 (Sledge 2007:62).

As the first wave departed the transport lines, the din of the rockets and guns was eclipsed by the grind and rumble of the amphibious engines (Hunt 1946:40). While the preliminary bombardment had provided some cover for transport operations, it could do nothing to protect the LVTs as they approached the reef flat. Fearful of hitting friendly forces, the barrage moved 500-1,000 yards inland beyond the beachfront (Fort 1944:23). Upon final approach, the amphibious vehicles were met with a deadly mix of mortar and artillery fire (Baker 1944:3; Bronemann 1982: 41; Sledge 2007:59). Eugene Sledge (2007:59) recalls:

> *Shells crashed all around. Fragments tore and whirred, slapping on the sand and splashing into the water a few yards behind us. The Japanese were recovered from the shock of our pre-landing bombardment. Their machine gun and rifle fire got thicker, snapping viciously overhead in increasing volume.*

As the first wave of armored LVTs touched the sand at 0832H, scheduled for high tide, those on board threw themselves down onto the beach. The battle had begun.

Figure 95. Smoke from the naval and aerial bombardment rises from Peleliu the morning of 15 September 1944. Photograph taken from USS Clemson. Image from Bureau of Aeronautics Materials, 247290.

<u>White Beaches</u>

As soon as they crossed the reef, marines began moving towards their key terrain targets. For the 1st Marine Regiment, this meant securing **the two massive coral promontories** that flanked the White beaches. At the northern end of White 1 stood '**The Point**', a jagged coral outcropping,30 ft. in height, honeycombed with infantry positions (Hunt 1946:58). The entire rock face was reinforced by heavy artillery in pillbox; one 20mm cannon and one 47mm anti-tank gun stood atop the cliff in pillboxes while another gun, a Model 94 75-mm, was located at the perpendicular drop to the beach (Figure 96) (Hunt 1946:58).

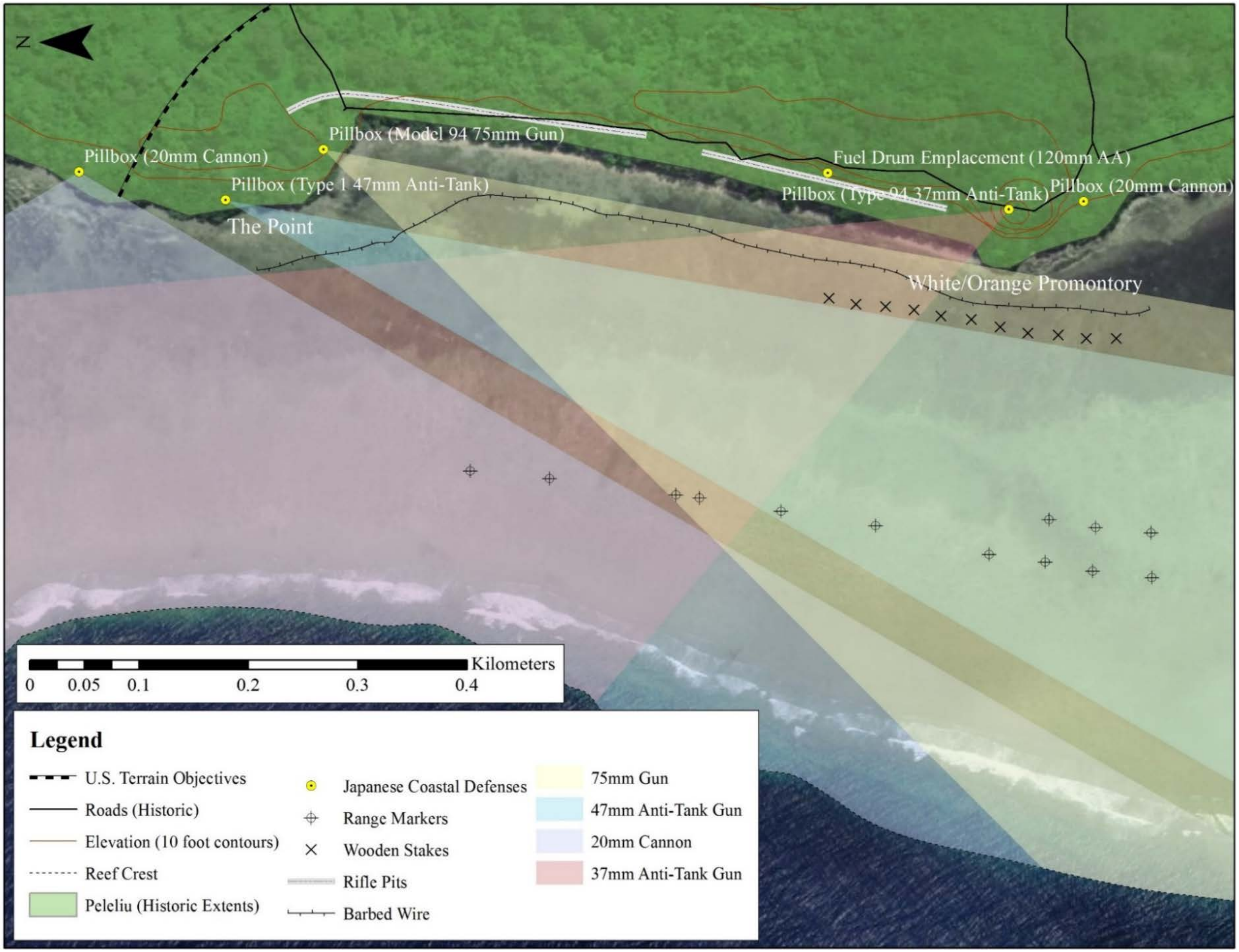


Figure 96. Japanese military beach obstacles and fields of fire from coastal defenses on the White beaches. Although range markers were removed by UDT 7, they remain in this image to aid reader with artillery visualization. Artillery caliber sizes and associated ranges were calculated from 2018 site investigation and previous investigation of coastal defenses (Denfeld 1988; Price et al. 2012; Price and Knecht 2015). Map by Roth/Ships of Discovery Science Team.

Leading the charge against The Point was Company K, part of the 3rd Marine Battalion, 1st Regiment. Immediately met with an onslaught of artillery and small arms fire, Captain George Hunt later wrote that The Point "surpassed by far anything we had conceived of when we studied the aerial photographs" (1946:58). The intelligence provided by the UDTs and aircraft grossly underrepresented the island's terrain and Japanese military fortifications. For example, the **rubble topped pillboxes,** which UDT 7 believed destroyed, were concealment points, "unscarred by the terrific bombardment" (Hunt 1946:68).

To gain control of The Point, marines from Hunt's Company climbed the rocky embrasures and cleared the structures by hand (Hunt 1946:63-64). Despite the short duration of the fighting, it was under U.S. military control by mid-morning, both the Japanese defenders and the First Marine Regiment paid a steep price in casualties (Hunt 1946:69). As those on The Point awaited reinforcements, a picture of the White beach defenses (Figure 97) began forming:

> *Extending from the Point inland and then running parallel to the beach was a* ***coral ridge about twenty-five feet high****. From this as well as from the Point the Japanese raked the beach and the flat area of the coconut grove with murderous machine-gun, rifle, and mortar fire. On our left, by the use of two platoons, that momentum carried us over the Point. On the right, the momentum died when the second platoon was caught in the tank trap, which was covered by that ridge about fifty yards in front of them* (Hunt 1946:81).

While the **tank traps** were observed by UDT 7, Hunt's comments indicate they were heavily underestimated by those on White 1. The trenches measured anywhere from 5 to 15 yards across, were close to 10 ft. deep, and ran parallel to each of the beaches for several hundred yards (Hunt 1946:75). One of the men caught in the trap later told Hunt (1946:82):

> *Just after we landed on the beach, the fellas began getting' shot by machine guns from that ridge. Then after a lot of runnin' with bullets and shrapnel flyin' all over, I found myself in this deep tank trap, and already could see that everybody was split up and separated.… Any time anybody tried to climb out and keep attackin', they was shot.*

In a curious twist of fate, it was the arrival of amphibious tanks during the later invasion waves that provided enough cover for the marines in the White 1 trap to retreat (Hunt 1946:86).

Other obstacles, too, slowed reinforcement of The Point. Having arrived on the front as part of the 5th assault wave, Bronemann (1982:41) recalls:

> ***Burning DUKWs and burning amtracs*** *told us that all the mortar shells weren't missing. Marines were lying behind a small coral shelf, making it impossible to drive our DUKWs on land. Whistling bullets bore down on us as we hit the water like rats leaving a burning ship. By now the front line extended twenty feet from the beach into the water!*

Of the 50 DUKWs in Bronemann's transportation division, half were knocked out from mortar and artillery fire (Figure 97) (Bronemann 1982:47). While the abandoned vessels became chokepoints for transport across the reef, men and provisions eventually made it onto the White beachfront.

Figure 97. Burning amphibious vehicles off White beaches 1 and 2 on September 15, 1944. The White/Orange coral promontory is visible with smoke rising behind in center of image. Note range markers and posts off the beach. Bureau of Aeronautics Materials, 46697.

At the southern end of the White beaches, marines were making significant inroads towards the day's objective. On White 2, members of the 2nd Battalion, 1st Marine Regiment, used the tank traps to their advantage. Rifleman Russell Davis (1988:21) would later write that the trench was "the best cover on the beach." The tank trap bottom was out of range of the deadly artillery fire coming from **the bunker on the White/Orange promontory**.

Ordered to link up with the 5th Marine Regiment, Davis used the cover provided by the trenches as he traversed the beachfront (Davis 1988:23). By the time he arrived at the bunker, "the assault men had it in its last stages. Riflemen worked all around it and some of them were in close to the wall, stuffing hand grenades through the fire ports" (Figure 98) (Davis 1988:24). Shortly after, the White/Orange promontory was taken and the 1st Marine Regiment met with the 5th on the western edge of the airfield, thus completing O-1.

Figure 98. The White/Orange promontory, seen on the right, caused little delay in troop movement on White 2. By the time Davis reached the area, the majority of men were already nearing the airfield. Frederick R. Findtner Collection, USMC Archives, 2-10.

Orange Beaches

Over 1,500 yards across, and close to double the length of the White beaches, both the 5th and 7th Marine Regiments assaulted the Orange beachfront (Sledge 2007:65). The initial plan for landing was straightforward; once on the beach, the 1st Battalion, 5th Marine Regiment, was to swing north to join the 1st Marine Regiment and push east towards the airfield. The 3rd Battalion, 5th Marine Regiment,would land on Orange 2 and work towards the airfield, only a mere 300 yards inshore. Finally, the 7th Marine Regiment, landing on Orange 3, would move southeast and secure the southern peninsula (Sledge 2007:62). Simple in design, execution of the landing proved far more challenging than anticipated.

Unknown to the landing parties, Japanese swimmers had returned to Orange 3 the evening of September 14 to plant **submerged mines and bombs** on the reef (Figure 99 and Figure 100). **Boulders and coral heads**, too, remained exposed in the surf. As amphibious vehicles carrying the 7th Regiment churned towards shore, individual craft moved into the waiting minefield. By a sheer stroke of luck, the Japanese military had failed to prime the devices (Baker 1944:6).

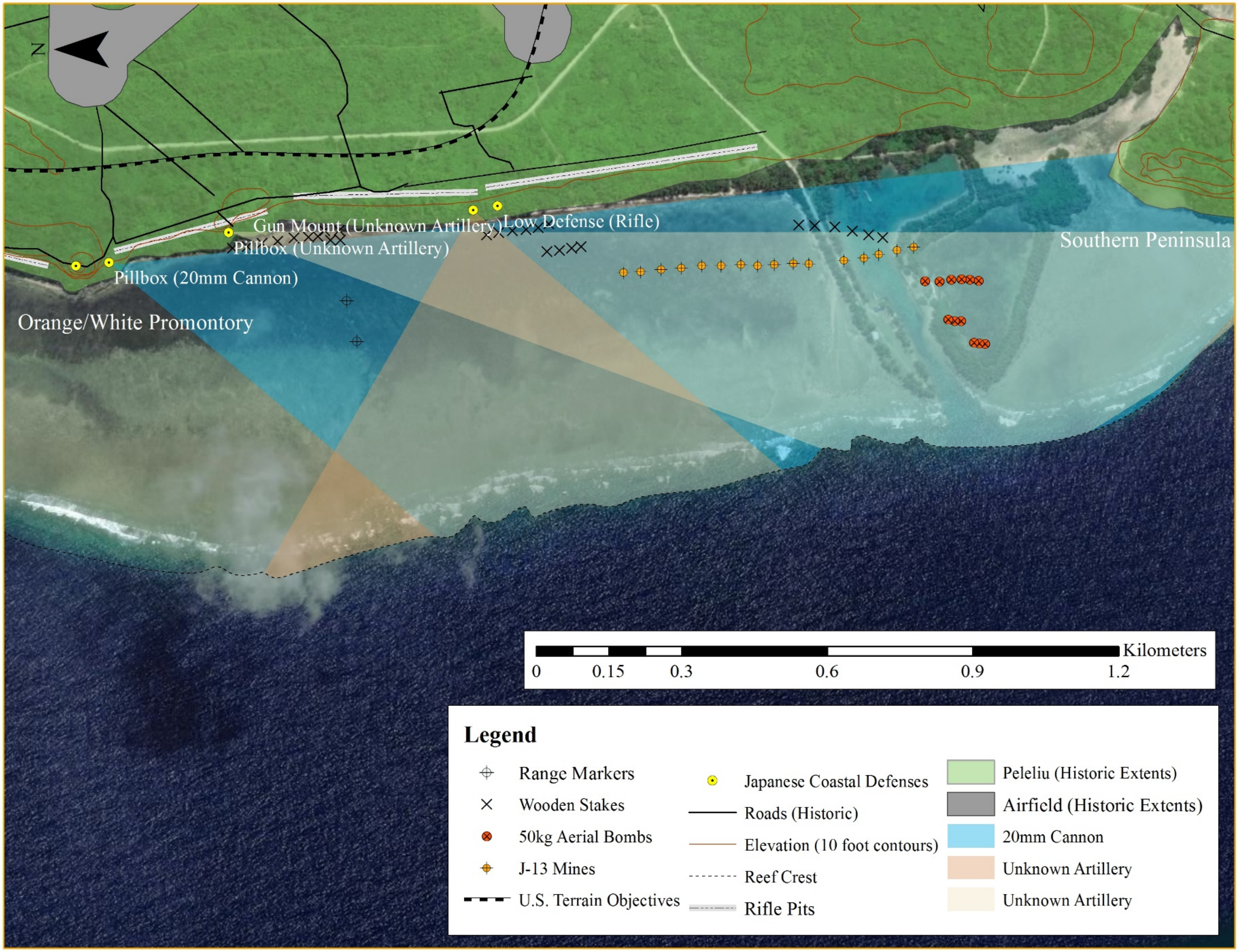


Figure 99. Japanese beach obstacles and fields of fire from coastal defenses on the Orange beaches. Artillery caliber sizes and associated ranges were calculated from 2018 site investigation and previous investigation of coastal defenses (Denfeld 1988; Price et al. 2012; Price and Knecht 2015). Map by Roth/Ships of Discovery Science Team.

Figure 100. Andy Anderson, UDT 7, with a Japanese J-13 mine at Peleliu, 1944. National Navy UDT Seal Museum, 2002.00334.12.

Still, discovery of the trap slowed the vehicles long enough for Japanese **75mm guns on the southern peninsula** to begin firing[2] (Fort 1944:2; Lea 1988:40). *LIFE* magazine correspondent Tom Lea (1988:35) later remarked that after watching a forward LVT stopped dead by a Japanese shell, there was no way for their transport to land on the far right of Orange 3. While Lea (1988) does not discuss their eventual landing location, it is likely many vehicles carrying the 7th landed at Orange 2 (Moran and Rottman 2002:52). When they reached the beach, the 7th Marines encountered **more land mines and crude booby traps** that again slowed movement as the men were forced to move carefully (Lea 1988: 42-43).

[2] Due to heavy post-war landscape modification of Orange 3, these firing positions were not relocated during the 2018 survey. Japanese defensive maps from May and August 1944 indicate there were several artillery pieces located on the southern end of Orange 3 and on the southern peninsula.

On Orange beaches 1 and 2, the first waves of amphibious craft landed just as American naval gunfire shifted inshore. Nevertheless, within the first ten minutes on the beachfront, eleven LVTs were dead in the water (Fort 1944:23). The open expanses of sand and lack of cover made any visible structure a target of Japanese fire (Lea 1988; Sledge 2007:59). An eyewitness to the destruction, mortar man Eugene Sledge (2007:59) writes:

> *I reached the edge of the beach and flattened on the deck. The world was a nightmare of flashes, violent explosions, and snapping bullets. Most of what I saw blurred. My mind was benumbed by the shock of it. I glanced across the beach and saw a DUKW roll up on the sand at a point near where we had just landed. The instant the DUKW stopped, it was engulfed in thick, dirty black smoke as a shell scored a direct hit on it. … I didn't see any men get out…*

Despite the fiery onslaught directed towards the amphibious vehicles, rifleman Jim McEnery states "the First Marines were on our left, and the Seventh Marines were on our right, and it looked like both of them were catching hell. But those of us in the center of the beachhead with the Fifth Marines weren't as bad off" (McEnery and Sloan 2012:208). While the **dead DUKWs and LVTs** again became an obstacle for landing, the wider expanse of beach at Orange 1 and 2 prevented severe congestion and allowed many of the vehicles to make it to shore.

Once on the sand, the largest obstacle to movement across the Orange beaches **was the lack of cover**; nowhere along the beachhead was there any structure "over knee high" (Sledge 2007:61). McEnery (2012:211-212) remembers the difficulties in moving towards the airfield:

> *Once K/3/5 got past the beach, the ground was solid coral that was next to impossible to even dent with a trenching tool, and the only natural cover between the beach and the field was some scrubby brush and a few low outcroppings of coral. Some of the men were able to find enough rocks to pile up and crawl behind, but many others were basically out in the open with nothing to protect them.*

Echoing the same sentiment, Johnston (1998:74) states:

> *As I stood there on that beach, it didn't seem to me that our attack had worked out quite as planned. Nowhere could I see that anyone had gotten across the beach and through that little strip of brush that was between the beach and the airfield. Mortars and artillery rounds landed up and down the length of the beach. Automatic small arms fire came at us from the **high ground on our flank**. We advanced through the fire across the beach as rapidly as possible. When we reached the cover of the **brush strip** we stopped. Everywhere people were trying to figure out where everybody was (both our elements and theirs) and what the hell was going on.*

While many of the marines took cover in the brush that formed a shallow defilade, Sledge (2007:61) recalls only a temporary feeling of relief, as "the Japanese probably would pour mortar fire into it to prevent it being used for shelter." The sentiment which grasped the 5th Marine

Regiment was to continue moving, pushing forward towards the other regiments. The 1st Battalion, 5th Regiment soon encountered the 1st Regiment and was able to hold O-1 on the outskirts of the airfield (Moran and Rottman 2002:49). The 3rd Battalion, 5th Regiment moved south to link up with the 7th Regiment.

On Orange 3, the 7th Marine Regiment was finally able to gain some ground. U.S. dive-bombers had targeted the southern peninsula, which silenced the Japanese 75mm guns (Lea 1988:41). As the marines moved forward, they stumbled into the Japanese **tank traps**, and finding they provided decent cover, the 3rd Marine Division 7th Regiment used the deep ditches for the command post (Lea 1988:42).

While the 7th Regiment began clearing the area, a critical flaw in the front was discovered. In an effort to join the 5th and 7th Regiments, twice the 3rd Battalion of the 5th Marine Regiment outpaced their counterparts, resulting in gaps along the far-right flank. K Company of the 3rd Battalion, 5th Marine Division, made it across to the scarlet beaches on the island's eastern shore before realizing their mistake (Sledge 2007:65). Fortunately, the 7th Marines were able to close the gap by the end of the day, creating an awkward but complete frontline.

By 1800 on the evening of September 15, the 1st Marine Division had secured a beachhead measuring over 3,000 yards in length and stretching close to 500 yards in depth, with K Company, 3rd Battalion, 5th Marine Regiment stationed almost 1,500 yards inshore (Rupertus 1944:37). This area encompassed the majority of the first day's objectives and was hard won; total U.S. military casualties alone amounted to 1,298 killed, wounded, or missing in action (Rupertus 1944:37). Tom Lea (1988:48) notes that as marines dug into the hard coral, "the Jap mortars were far from silent, and direct hits on this kind of concentration really played hell. Yet regardless of fire, the marines were pouring everything they could get on the beach before nightfall and the expected counterattack." The beachfront would survive three separate *banzai* charges from Japanese soldiers before dawn.

Aftermath of the Landing and Beach Modifications

As the battle moved further inshore on D+1 (September 16, 1944), the beachfront became an active interface between maritime and terrestrial parties. UDTs returned to the reef to remove mines and bombs that were discovered in "unprecedented numbers" (Fort 1944:218). To more efficiently move resources and personnel ashore, a pontoon causeway joining the shore and deeper water was constructed at Orange 3 (Rupertus 1944:136). With the introduction of crawler cranes mounted on barges, supplies from LSTs were directly deposited on LVTs and transferred to waiting trucks on shore (Gayle 1996:16).

For the marines on the frontlines, stiff Japanese resistance was encountered until the end of the battle. The discovery of an extensive network of caves on D+1 set the stage for the remainder of fighting which stretched through November 1944. On October 20, the remaining 1st Marine Division was withdrawn to the landing beaches, replaced by the Army 81st Infantry Division (Mueller 1945:9). Final combat deaths from the Peleliu campaign are estimated at 10,000 Japanese and 3,000 Okinawan and Korean conscript laborers (Price and Knecht 2012:11). Of the

16,459 First Marine Division personnel involved with action on the ground, 7% (1,124) were killed in combat and 31% (5,141) were injured (Rupertus 1944:55).

Under U.S. military control after the battle, air facilities on Peleliu and Angaur were used as a staging point for invasion of the Philippines (Hough 1950:179). The U.S. Navy commissioned the Peleliu Naval Base in 1945 and remained in operation through 1947. During this period, Japanese soldiers continued to emerge from entrenched positions; a group of 19 surrendered in February 1945, while 34 emerged from a cave in 1947, the last formal surrender of WWII (Price and Knecht 2012:12).

Summary of KOCOA Features and Battlefield Boundaries

The Peleliu landing beach invasion required coordinated efforts between U.S. Naval, Army, and Marine forces. Key terrain for the initial assault included the **beaches**, the primary terrain objective (O-1) for September 15, and **coral promontories** expected to hold Japanese defenders (Figure 101). While pre-invasion observation provided detailed information on reef hydrology, it failed to account for the Japanese island defenses including the extensive fields of fire covering the **reef tract** (Figure 101). The U.S. amphibious vehicles that traversed the **shallow lagoon** soon encountered artillery and mortar fire, becoming themselves obstacles for later waves of the invasion (Figure 101). Despite the efficacy of Japanese defenses, including **mines, tank traps,** and concealed **gun emplacements,** several obstacles became a means of cover for marines on the beaches (Figure 101). Nevertheless, the effort to secure the beachhead was extensive and both Japanese and American personnel endured heavy losses by the end of D-Day.

<u>Post-Battle Landscape Modification and Integrity</u>

Today, the landing beaches on Peleliu remain much as they were when U.S. forces left the island in 1947. Japanese pillboxes stand empty on prominent rocky outcroppings along the shoreline while earthen defenses are, in some cases, still present (see Ships086). The Japanese tank traps and rifle pits, which feature prominently in historic accounts, can also be encountered in the landscape (e.g. Ships056 and 085). Perhaps most significant to understanding post-battle activity is that some of these pits became middens for WWII materials. While visiting the Orange beaches in 2018, researchers encountered a wide array of material culture including rolls of barbed wire, U.S. military canteens, and both Japanese and American vehicles buried at Ships085. The location of these materials on site suggests they were bulldozed into the traps as the airfield and surrounding areas was cleared for American use (Figure 101). While these actions did not occur during the initial invasion, they represent historic U.S. military area use and immediate post-battle occupation.

Figure 101. KOCOA terrain features on the Peleliu Landing Beaches. Map by Roth/Ships of Discovery Science Team.

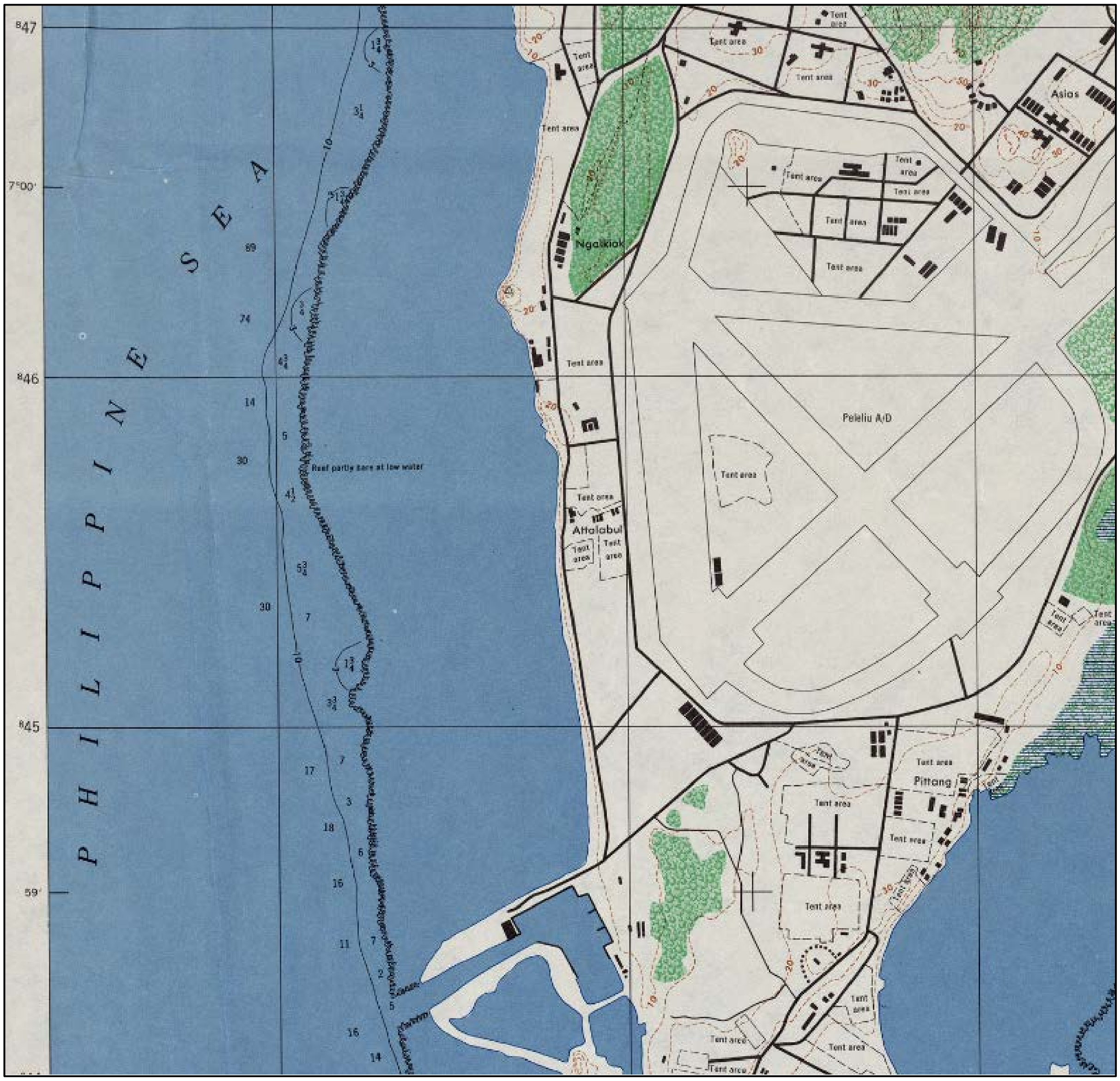


Figure 102. Detail from 1946 map of Peleliu titled “Ngarmoked NW-D, Palau Islands.” Note southern harbor and tent areas on the White and Orange beaches. U.S. Army Map Service, 1946.

The heaviest area of landscape modification occurred at the southern end of Orange 3. Following establishment of the Peleliu Naval Base, the U.S. Navy Seabees filled the reef to create an artificial harbor for small craft **(**Figure 102). Nev**e**rtheless, WWII cultural materials are still visible in the construction of the marina; part of the fill for land reclamation includes the pontoon barges from the 1944 Orange beach LST ramp. Moreover, post-battle cleanup is exhibited nearby; the extensive remains of an U.S. aircraft graveyard are present on the southern side of the marina. The aircraft, likely deposited at the harbor after the war for shipment, never managed to leave the island. Post-war, aluminum and iron scrap drives were common throughout the Pacific. Similar scrap middens from salvaged WWII sites have been encountered throughout the Marianas, Marshall, and Caroline Islands (Spennemann 1998).

Battlefield, Core, and PotNR Boundaries

In 1944, the entirety of Peleliu was a battlefield and the entire island was nominated to the National Register of Historic Places in 1984 (National Park Service 1984) and was considered for national landmark status in 1991 and again in 2003 (National Park Service 2003).

Should the National Register boundary ever be considered for modification, the entirety of the Orange and White landing beaches, including the lagoon and reef crest, should be included as part of the larger battlefield boundary due to the significance of the reef to pre-battle planning and the initials assault. The project study area, if it were to stand on its own, can be characterized as representing the core battlefield boundary (i.e. areas of heaviest fighting), which are the landing beaches (including 20 ft. into the lagoon) and the immediate areas 300 yards inshore. A potential national register boundary includes the core area except for Orange 3, because it was extensively modified post-battle. (Figure 103).

Figure 103. Suggested Battlefield, Core, and Potential National Register Boundary following 2018 fieldwork. Map by Roth/Ships of Discovery Science Team.

Conclusion

The science team revisited or located 100 sites that represent both WWII specific remains and modern debris (Appendix 3.1). The terrestrial survey inshore of the invasion beaches identified 60 artifact scatters, miscellaneous debris, pieces of equipment, or defensive positions (Table 9). The team revisited 14 archaeological sites previously recorded by Denfeld (1980) and/or by Knecht, Price, and Lindsay (2012) and identified 11 previously unrecorded sites.

Twenty previously unrecorded sites were located offshore in the reef (Table 7) and an additional 20 were located in the inshore lagoon (Table 8). The UCH offshore include historic anchors, pontoon barges, aircraft propeller, LVTs, a Caterpillar tractor, and anchor chain. UCH sites in the lagoon include aircraft remains with radial engine, DUKW remains, LCM remains, and Sherman tank treads.

Biological characterization of the reefs included high-resolution (mm-scale) 3D reconstructions at survey sites by collecting overlapping images from planar and oblique angles of reef plots. Images were collected from six 2x2-m plots at three isobaths (~40fsw, ~20fsw, ~10fsw) at each survey site (18 plots per site), resulting in 425 reef plots. The plots were located from the base of the blast zones to the top of the reef flat. Survey plots were also conducted along the same isobaths at locations that were not affected by blasting during pre-invasion preparation. Three blast zones were modeled in entirety to create 3D maps and to quantify the geomorphology produced by these activities.

Orange Beach exhibits the highest levels of coral cover and 3D habitat complexity. Orange beach is mostly coral dominated whereas White Barbed Beach was dominated by turf algae. The differences in benthic habitat slope and water current likely drive these observed differences in benthic cover. White Beach has a steep slope and receives more wave energy, which likely impedes the ability of corals to colonize and grow as large and robust as seen at Orange Beach. Coral cover increases with depth at both Orange Barbed and White Barbed Beaches. Coral diversity is a strong driver of 3D habitat complexity. This trend was found at both the Orange and White beaches. These findings indicate that the substantial growth and diversity of corals at Orange Beach cause a structurally complex habitat with high levels of coral cover. Although the reefs at Peleliu experienced dramatic changes during the battle of WWII, this study found significant recovery of corals at Orange Beach, which is most likely because the time frame of recovery was substantial (74 years).

Five UCH sites were documented by 3D photogrammetry. All sites were found within Orange Beach in depths of 5 to 110 ft. The benthic communities on the cultural heritage artifacts consisted primarily of turf algae, coral and crustose coralline algae. After a substantial amount of recovery time, coral genera Porites, Favia, Isopora, Montipora, Acropora, and Pocillopora have been able to settle and thrive on these wreck substrates

The side-scan sonar imaged 18 acoustic contacts that were diver investigated; none resulted in the identification of UCH. The magnetometer results produced 20 anomalies. Of these, 12 were associated with UCH, 1 is modern, and all were located during the field investigation and represent clearly distinguishable remains. The seven unidentified isolated anomalies are off the

Orange Beaches, which saw some of the heaviest defensive fire during the invasion. The defensive fire was so intense that the units tasked with landing on Orange 3 were forced to divert north and land closer to Orange 2. The nature of these low gamma anomalies suggests small single-point ferrous metal objects. These types of anomalies are consistent with the historic use of the area as multiple landing beaches associated with the Battle of Peleliu.

The application of KOCOA analysis to the offshore reef and nearshore invasion beaches provides additional details of the influence of Japanese defensive positions and preparation on the invasion. While the larger battlefield has been studied in this manner (Knecht et al 2012), detailed study of the invasion beaches was not undertaken at that time. This study is the first application of KOCOA to the invasion beaches in Palau.

The results of this project, when combined with the previous research of Denfeld (1988), Price, Knecht, Lindsay (2012), and others, provides a more complete picture of the battle for Peleliu. The information on surviving UCH and information on newly identified sites will contribute to the Peleliu site inventory and provide baseline information for management of their important WWII resources. Most importantly, understanding and preserving these sites will serve to recognize and honor all who lost their lives.

Summary of Metadata Collected

Remote Sensing: 8.5 GB of data (SSS) 135 MB of data (Magnetometer)
Photographs (general): 19.8 GB
3D photos, unrectified: 713.2 GB
GIS: 35.6 MB
3D reconstructions: 8

Summary of Metadata Collected
Several categories of data were collected and will be curated in the OER Digital Atlas. These include:

Remote Sensing data from magnetometer and side scan sonar survey. Approximately 8.5 GB of side scan sonar data and approximately 135 MB of magnetometer data were collected. Files types include geotiff, RAW, LOG, and TGT

Photography and videography data in the form of still photos and videos for a total of 19.8 GB. File types include .jpeg and .mov.

Photogrammetry models through photography. A total of 713.2 GB of unrectified raw photos in the form of .RAW and .jpeg. Additionally, the final photogrammetric models include 350.5 GB in the form of DEMs and orthophotos as .tiffs.

A GIS database. A total of approximately 35.6 MB of data. File types include shp, shx, dbf, prj, xml, sbn and sbx (ArcGIS).

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Appendix 3.1 Summary Table of Sites Revisited or Documented

Site Number	Denfeld Site ID	Price/Knecht Site ID	Description (MOD = Modern)	General Location
Ships001	N/A	N/A	Pipe MOD	Orange Drying Reef
Ships002	N/A	N/A	Pipe MOD	Orange Drying Reef
Ships003	N/A	N/A	End of Pipe MOD	Orange Drying Reef
Ships004	N/A	N/A	End of Pipe MOD	Orange Drying Reef
Ships005	N/A	N/A	End of Pipe MOD	Orange Drying Reef
Ships006	N/A	N/A	Pipe MOD	Orange Drying Reef
Ships007	N/A	N/A	Steel Casing MOD	Orange Drying Reef
Ships008	N/A	N/A	Pipe MOD	Orange Drying Reef
Ships009	N/A	N/A	Metal Plate MOD	Orange Drying Reef
Ships010	N/A	N/A	LVT Roller	Orange Drying Reef
Ships011	N/A	N/A	Aircraft Landing Gear Strut	Orange Drying Reef
Ships012	N/A	N/A	Aircraft Wing, Landing Gear, Fuselage, and fragments	Orange Drying Reef
Ships013	N/A	N/A	Aircraft Radial Engine	Orange Drying Reef
Ships014	N/A	N/A	Wheel, DUKW	Orange Drying Reef
Ships015	N/A	N/A	Wheel, DUKW	Orange Beaches
Ships016	N/A	N/A	LVT Tread	Orange Beaches
Ships017	N/A	N/A	Heavy Duty Cable MOD	White Drying Reef
Ships018	N/A	N/A	Tank Tread, Sherman	White Drying Reef
Ships019	N/A	N/A	Bulldozer Bucket	White Beaches
Ships020	N/A	N/A	UXO	Offshore Orange Beaches
Ships021	N/A	N/A	Navy Stockless Anchor	Offshore Orange Beaches
Ships022	N/A	N/A	Anchor MOD	Offshore Orange Beaches
Ships023	N/A	N/A	Pontoon Barge Fragments	Offshore Orange Beaches
Ships024	N/A	N/A	American Aircraft Propeller Blade	Offshore Orange Beaches

Site Number	Denfeld Site ID	Price/Knecht Site ID	Description (MOD = Modern)	General Location
Ships025	N/A	N/A	Stud Link Anchor Chain	Offshore Orange Beaches
Ships026	N/A	N/A	Metal Scatter w/cable MOD	Offshore Orange Beaches
Ships027	N/A	N/A	Tractor w/blade	Offshore Orange Beaches
Ships028	N/A	N/A	Navy Stockless Anchor	Offshore White Beaches
Ships029	N/A	N/A	Danforth Anchor MOD	Offshore Orange Beaches
Ships030	N/A	N/A	Debris Scatter (poss. Pontoon) and Navy Stockless Anchor	Offshore Orange Beaches
Ships031	N/A	N/A	Concrete Mooring Block MOD	Offshore Orange Beaches
Ships032	N/A	N/A	LVT, Disarticulated	Offshore Orange Beaches
Ships033	N/A	N/A	Iron Rod/Beam MOD	Offshore Orange Beaches
Ships034	N/A	N/A	Steel Cable MOD	Offshore Orange Beaches
Ships035	N/A	N/A	Stud Link Anchor Chain	Offshore Orange Beaches
Ships036	N/A	N/A	LCM	Orange Beach Drying Reef
Ships037	N/A	N/A	Anchor MOD	Offshore Orange Beaches
Ships038	N/A	N/A	LVT (Dumpsite)	Offshore Orange Beaches
Ships039	N/A	N/A	LVT (Dumpsite)	Offshore Orange Beaches
Ships040	N/A	N/A	LVT (Dumpsite)	Offshore Orange Beaches
Ships041	N/A	N/A	Tug Boat MOD	Orange Beaches
Ships042	N/A	N/A	Two Axles w/vehicle debris, DUKW	Orange Beaches
Ships043	N/A	N/A	Tractor Engine	Orange Beaches
Ships044	N/A	N/A	Debris Scatter (Dumping Area)	Orange Beaches
N/A	Site 3 Feature 6	AB219	Aircraft Dump, 100m long	Orange Beaches
Ships045	N/A	N/A	Pontoon from Seabee Dock	Orange Beaches
N/A	N/A	AB230	C-46 Aircraft Engine Cowling	Orange Beaches
Ships046	N/A	N/A	Pontoon from Seabee Dock	Orange Beaches
N/A	N/A	AB218	LARC Amphibious Vehicle	Orange Beaches
N/A	Site 7	AB221	Japanese Defensive cave	Orange Beaches
N/A	Site 7	AB220	Japanese Defensive cave	Orange Beaches
Ships047	N/A	N/A	Japanese Defensive Position, Fuel Barrel Embankment	North of White Beaches

Site Number	Denfeld Site ID	Price/Knecht Site ID	Description (MOD = Modern)	General Location
Ships048	Site 1 Feature 10	N/A	Japanese Defensive Structure	White Beaches
N/A	N/A	AB58	American Navy Officer Area, Tower Foundation	White Beaches
Ships049	N/A	N/A	Tracked Vehicle Treads, prob. Sherman tank	White Beaches
Ships050	Site 1 Feature 7	AB279	Japanese Defensive Position, Fuel Drum Embankment	White Beaches
Ships051	Site 1 Feature 6	AB280	LVT, partially buried	White Beaches
Ships052	Site 1 Feature 5	N/A	3 Axles with Tires, DUKW	White Beaches
Ships053	N/A	N/A	Tractor with blade, beached	White Beaches
Ships054	Site 1 Feature 11	AB50	Japanese Defensive Structure on "the Point"	White Beaches
Ships055	N/A	AB60	Japanese Defensive Structure on the road to White Beaches	White Beaches
Ships056	Site 1 Feature 20	AB55	Japanese Defensive Position, Coral Ridges and Rifle Pits	White Beaches
N/A	N/A	AB148	Aircraft Dump w/Merlin Engines and Japanese Tanks	Orange Beaches
N/A	N/A	AB268	A6M "Zero" Aircraft	Inshore Orange Beaches
Ships057	Site 1 Feature 12	N/A	Japanese Gun and Defensive Structure	White Beaches
Ships058	Site 1 Feature 12	N/A	Japanese Reinforced Defensive Cave	White Beaches
Ships059	Site 1 Feature 12	N/A	Japanese Defensive position, Gun Housing	White Beaches
Ships060	N/A	N/A	Amphibious Vehicle Sprocket	White Beaches
Ships061	N/A	N/A	Japanese Defensive Position, Fuel Drum Embankment	White Beaches
Ships062	Site 1 Feature 1	AB52.1	Japanese Defensive Cave, Structure, and Gun	White Beaches
Ships062	Site 1 Feature 1	AB52	Japanese Defensive Structure and Gun	White Beaches
Ships063	N/A	AB54	Japanese Defensive Cave	White Beaches
Ships064	Site 1 Feature 2	N/A	Japanese Defensive Position, Observation Platform	White Beaches
Ships065	N/A	AB53	Japanese Defensive Cave, Collapsed	White Beaches
Ships066	Site 1 Feature 3	N/A	Concrete Slab and Boulders	Orange Beaches
Ships067	N/A	N/A	Engine Block from amphibious vehicle	Orange Beaches
Ships068	N/A	N/A	Japanese Gun, assoc. with Ships069	Orange Beaches

Site Number	Denfeld Site ID	Price/Knecht Site ID	Description (MOD = Modern)	General Location
Ships069	N/A	N/A	Pipe Fixture on Concrete Mount assoc. w/Ships068	Orange Beaches
Ships070	Site 3 Feature 1	N/A	Japanese Defensive Structure	Orange Beaches
Ships071	N/A	N/A	Octagonal Platform, w/trapezoidal monument	Orange Beaches
Ships072	N/A	N/A	Memorial Pedestal MOD	Orange Beaches
Ships073	N/A	N/A	Concrete Box-like structure, collapsed	Orange Beaches
Ships074	N/A	N/A	Iron debris MOD, approx. 4 sq. m	Orange Beaches
Ships075	N/A	N/A	Tractor, disarticulated, degraded	Orange Beaches
Ships076	N/A	N/A	Tug, poss. Japanese MOD	Orange Beaches
Ships077	N/A	N/A	Iron Buoy MOD	Orange Beaches
Ships078	N/A	N/A	Vehicle Debris	Orange Beaches
Ships079	N/A	N/A	Vehicle Debris	Orange Beaches
Ships080	N/A	N/A	Disarticulated Concrete Structure	Orange Beaches
Ships081	N/A	N/A	Iron Debris, poss. dock or pontoon	Orange Beaches
Ships082	N/A	N/A	Engine Block	Orange Beaches
Ships083	N/A	N/A	Japanese Low Defensive Position, Poured Concrete	Orange Beaches
Ships084	N/A	N/A	Tower Foundations, set of 4	Orange Beaches
Ships085	N/A	N/A	Japanese Defensive Trenches and American Dump	Orange Beaches
Ships086	N/A	N/A	Japanese Defensive Position with Gun Mount	Orange Beaches
Ships087	N/A	N/A	Tank Base, iron	Orange Beaches
Ships088	N/A	N/A	Single Aluminum Frag prob. MOD	Orange Beaches
Ships089	N/A	N/A	Cement Marker, poss. memorial MOD	Orange Beaches
Ships090	N/A	N/A	Concrete Foundation	Orange Beaches
Ships091	N/A	N/A	Iron frame, highly degraded MOD	Orange Beaches
Ships092	N/A	N/A	Concrete Foundation	Orange Beaches
Ships093	N/A	N/A	Metal Scrap and Debris scatter, approx. 15m long	Orange Beaches
Ships094	N/A	N/A	Engine Block w/debris scatter	Orange Beaches
Ships095	N/A	N/A	Japanese defensive structure	Orange Beaches
Ships096	N/A	N/A	Concrete Foundation w/trapezoidal monument, set of 5	Orange Beaches
Ships097	N/A	N/A	Concrete Foundation	Orange Beaches
Ships098	N/A	N/A	Concrete Slab with Boilers	Orange Beaches
Ships099	N/A	N/A	Concrete Foundation	Orange Beaches
Ships100	N/A	N/A	Concrete Foundation	Orange Beaches

Appendix 3.2 Metadata

Magnetometer

a) Observation Category: Geophysical
b) Data type: ship navigation, magnetic variance readings
c) Units/Resolution: UTM WGS84 datum, Zone 53 (132E-138E); meters
d) Instrument/gear identification or description, including model, if applicable: Geometrics G-882 magnetometer; Trimble DSM-232 differential Global Positioning System (dGPS) with global navigation satellite system antenna; Hypack® Inc. hydrographic navigation software
e) Sampling and analyzing method: The laybacks were physically measured and input into survey software prior to the remote sensing survey and corroborated at the end of the survey during data processing. A towfish device driver (towfish.dll) was applied in Hypack™, which uses cable out and a catenary factor to accurately determine the position of the towfish during the survey. The magnetometer was towed 15 meters behind the survey vessel.

    Six (n=6) parallel track lines were plotted to survey the western shoreline of Peleliu. Transect interval was 20 m (66 ft.) and the survey vessel speed did not to exceed 5 knots. Parallel survey track lines were oriented based on the geography (primarily the extant reef line running parallel to the shoreline of Peleliu.

    Vessel navigation and positioning data, along with field data files from the magnetometer were saved to a computer file and backed up on an external hard drive. All data collected during field operations (navigation, positioning, and ancillary data) were duplicated and stored on two hard drives (typically, a primary laptop and an external hard drive). This storage occurs as soon as possible after collection but within the same day, depending on the field deployment. While on site, backup media are stored separately from the field computer.

    Following completion of the fieldwork, the analysis of the field data sets was accomplished to identify, characterize, and evaluate the magnetic anomalies for potential historical significance and correlate the findings with the previous remote sensing operations and diver investigations.
f) Data Quality Method - A brief description of quality assurance checks, acceptable value ranges, quality indication flags related to this parameter/variable: After completion of the remote sensing survey the magnetometer data was processed, edited, and contoured in Hypack™. Processing the RAW magnetometer data involved a careful review of each track line including a profile view of the data, which identifies magnetic anomalies along a given track line errant data (commonly referred to as "spikes"). These were deleted from the RAW data. Spikes are typically one-second spikes that are easily discernable (and removed) when reviewing the data. Magnetometer layback (15 meters) is automatically accounted for in Hypack™ during the processing of RAW data.

    Once all individual track lines of data were edited a .LOG file was assembled for each survey area that included all corresponding track lines, associated magnetic data, and X/Y positioning. Individual magnetic targets were pinpointed and evaluated for location (X/Y), type (monopole, dipole, multi-component), deviation, and duration. A target (.TGT file) was subsequently created for each target within the survey area.

After documentation, a magnetic contour map (TIN Model) was produced. This entailed identifying the minimum and maximum gamma values within each area (allowing for the production of an accurate contour map). The contour interval for this project was 5-gamma intervals. After the magnetic contour map was produced, it was downloaded as a Background File in Hypack™, overlaid on a NOAA Raster Chart (or aerial photograph), and correlated with other data such as .TGT files and/or side-scan sonar overlays.

Side scan sonar

a) Observation Category: geophysical
b) Data type: ship navigation and sonar imagery
c) Units/Resolution: UTM WGS84 datum; meters; resolution track of 0.6 centimeters at 1,600 kHz (0.2 inches); geotiff resolution of 0.15 meter/pixel (0.5 feet/pixel)
d) Instrument/gear identification or description, including model, if applicable: EdgeTech 4125 dual-frequency (600/1,600 kHz) CHIRP side-scan sonar; Trimble SPS356 differentially corrected global positioning system (dGPS) receiver with GA830 global navigation satellite system antenna; HYPACK, Inc. hydrographic navigation software
e) Sampling and analyzing method: The side-scan sonar towfish was towed from the vessel gunwale and maintained at a depth just below the vessel hull, which did not provide 100-percent imagery overlap in deeper water. The system operated at a frequency of 1,600 kHz with acquisition range set at 35 meters (115 ft.) (i.e., total swath width=70 meters [230 ft.]). Vessel speed varied, but did not exceed 5 knots whenever possible, which maximized data collection. HYPACK navigation software, interfaced with the dGPS, maintained vessel positioning with sub-meter accuracy and logged real-time positional data at a rate of 5 hertz. The dGPS was interfaced with the side-scan sonar topside acquisition computer operating EdgeTech Discover software, which embedded positional data into the raw imagery and allowed for geo-rectification of the side-scan sonar record during processing. The survey was conducted in the UTM coordinate system (Zone 53N) based on the WGS84 datum.

   The Team reviewed each line of raw side-scan sonar imagery from the survey to locate acoustic contacts indicative of man-made features and potential submerged cultural resources protruding above the seafloor. Each contact was assigned a unique identifier, and descriptive information was collected and tabulated (e.g., length, width, dGPS position, etc.). The Team also generated a mosaic image of the Project Area comprising all raw sonar imagery. The ability to mosaic the imagery was made possible with embedded positional data from the dGPS utilizing Chesapeake Technology, Inc., SonarWiz 7 sonar processing software. High-frequency imagery files (600 kHz) were imported into the software utilizing settings adjusted for the EdgeTech 4125 acquisition methods. Following importation of the raw imagery, bottom tracking was performed to identify the first acoustic return, which determines the altitude of the towfish above the seafloor, creates a slant-range-corrected record, and removes the water column from the nadir region. Gain, color, and contrast settings were adjusted for each file in order to produce an optimal and even image across the entire mosaic. Returns from overlapping files were averaged. Thus, if a contact contrasts well on one trackline, but not on an adjacent line, averaged returns from both lines ensure significant contrast for contact detection. The mosaic was exported as a geo-rectified images (geotiff format) with a resolution of 0.15 meter/pixel (0.5 feet/pixel).

f) Data Quality Method: The Team reviewed each line of raw side-scan sonar imagery from the survey to locate acoustic contacts indicative of man-made features and potential submerged cultural resources protruding above the seafloor. Each contact was assigned a unique identifier, and descriptive information was collected and tabulated (e.g., length, width, dGPS position, etc.). The Team also generated a mosaic image of the Project Area comprising all raw sonar imagery. The ability to mosaic the imagery was made possible with embedded positional data from the dGPS utilizing Chesapeake Technology, Inc., SonarWiz 7 sonar processing software. High-frequency imagery files (600 kHz) were imported into the software utilizing settings adjusted for the EdgeTech 4125 acquisition methods. Following importation of the raw imagery, bottom tracking was performed to identify the first acoustic return, which determines the altitude of the towfish above the seafloor, creates a slant-range-corrected record, and removes the water column from the nadir region. Gain, color, and contrast settings were adjusted for each file in order to produce an optimal and even image across the entire mosaic. Returns from overlapping files were averaged. Thus, if a contact contrasts well on one trackline, but not on an adjacent line, averaged returns from both lines ensure significant contrast for contact detection. The mosaic was exported as a geo-rectified images (geotiff format) with a resolution of 0.15 meter/pixel (0.5 feet/pixel).

Photogrammetry

a) Observation Category: navigational, biological, geophysical
b) Data type: photographs, orthophotos, DEMs, shapefiles
c) Units/Resolution (mg/l, degrees Celsius, psu, meters, etc.): metric, mm resolution
d) Instrument/gear identification or description, including model, if applicable: single lens reflex (SLR) Sony Alpha 7 II with Ikelite Water Housing; SLR Canon 5D Mk III camera with Ikelite Water Housing; a SLR Canon EOS Rebel SL2 with Ikelite water housing; Agisoft PhotoScan modeling software
e) Sampling and analyzing method – A brief description of how the parameter/variable was measured or calculated. Include a citation to a published methodology or process, if applicable: High-resolution (mm-scale) 3D reconstructions were generated at survey sites by collecting overlapping images (70-80% overlap) from planar and oblique angles of reef plots. Images were collected from six 2x2-m plots at three isobaths (~40fsw, ~20fsw, ~10fsw) at each survey site (18 plots per site). The plots were located from the base of the blast zones to the top of the reef flat. Survey plots were also conducted along the same isobaths at locations that were not affected by blasting during the invasion battle.

   The resulting photographs were digitally reconstructed using SfM modeling software. SfM software generates 3D digital surface models in three primary stages: 1) photo alignment, 2) geometry building, and 3) texture building. This process creates 3D point clouds that result from the projection and intersection of pixel rays from the different positions and oriented images in 3D space (Clayput et al. 2016, James et al. 2017). These points are triangulated and rendered with the original high-resolution imagery to create textured 3D mesh and georeferenced digital elevation models, which can be used to quantify metrics of 3D structural complexity (Burns et al. 2015a, Leon et al. 2015, James et al. 2017, see Photo 2). The 3D reconstructions are exported as DEMs and orthophotos to ArcGIS topographic software (ESRI Inc., USA) for quantification of coral health, community composition and metrics pertaining to structural complexity (Burns et al. 2015b).

The orthophoto provides a high-resolution photo-mosaic of the surveyed substrate and is layered with geometrically corrected DEM such that each cell contains accurate 3D information and can be used for measurement of topographic parameters. The orthophotos are digitized and annotated to create unique polygon shapefiles for all individual coral colonies within each surveyed plot. Once the benthic features are annotated, the ArcGIS software is used to calculate multiple metrics pertaining to 3D characteristics and topographic structure. The data derived from this analysis will be used to characterize differences in reef composition and structure at sites located in blast zones and those not affect by blast activities.

Several entire blast zones were modeled in entirety to create 3D maps of these unique areas and to quantify the geomorphology produced by these activities. Archaeological features were also surveyed in the same manner throughout the duration of the expedition.

f) Data Quality Method – A brief description of quality assurance checks, acceptable value ranges, quality indication flags related to this parameter/variable: Scale markers were placed across the study plots to ensure model precision and accurate spatial rectification.

Sources

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Leon JX, Roelfsema C, Saunders MI, Phinn S (2015) Measuring coral reef terrain roughness using 'Structure-from-Motion' close-range photogrammetry. *Geomorphology*, 242: 21–28

Photographs and Video

a) Observation Category: archaeological
b) Data type: photography, aerial photography and videography exported as .jpeg and .mov
c) Units/Resolution: 300dpi or higher; utilizing 1meter scale

d) Instrument/gear identification or description, including model, if applicable: Olympus Tough TG-5; DJI Mavic Pro Platinum drone; Olympus PEN Lite E-PL5 camera with Olympus PT-EP10 underwater housing; GoPro Hero 4; Nikon D700 Digital Camera
e) Sampling and analyzing method: when possible two still photographs were taken of each site/object/feature which include at a minimum a scale and sometimes a north arrow; video was collected of sites until the battery ran out or the card was filled.
f) Data Quality Method: scales were used for accuracy; cameras were set to factory settings thus no settings were adjusted; drone utilized pre-set system settings and was not adjusted

GPS/GIS

a) Observation Category: navigational, archaeological
b) Data type: GPS coordinates
c) Units/Resolution: UTM, WGS84 datum
d) Instrument/gear identification or description, including model, if applicable: a Garmin 64st handheld; a Trimble SPS356 differentially corrected global positioning system (dGPS) receiver with GA830 global navigation satellite system antenna; and a GlobalSat Gstar IV4 GPS; Geometrics G-882 magnetometer; Trimble DSM-232 differential Global Positioning System (dGPS) with global navigation satellite system antenna; Hypack® Inc. hydrographic navigation software; ESRI ArcMap
e) Sampling and analyzing method – A brief description of how the parameter/variable was measured or calculated. Include a citation to a published methodology or process, if applicable: GPS coordinates were collected and transferred to an Excel spreadsheet and integrated into the final GIS package utilizing ESRI ArcMap.
f) Data Quality Method – A brief description of quality assurance checks, acceptable value ranges, quality indication flags related to this parameter/variable: All GPS coordinates were double-checked by hand once they were transferred from the GPS.