Department of Defense

Research Related to Effect of Ocean Disposal of Munitions in U.S. Coastal Waters

Report to Congress

November 2016

Office of the Under Secretary of Defense
for Acquisition, Technology, and Logistics

The estimated cost of this report or study for the Department of Defense is approximately $53,000 for the 2016 Fiscal Year. This includes $35,000 in expenses and $18,000 in DoD labor.
Generated on 2016Aug16 RefID: 5-F068FEE

INTRODUCTION

This report responds to House Report (H.R.)114-102 accompanying H.R. 1735, the National Defense Authorization Act for Fiscal Year (FY) 2016, to report research activities conducted related to the inventory of ocean-disposal sites the Department of Defense (DoD) identified in the FY 2009 Defense Environmental Programs Annual Report to Congress. DoD refers to these as munitions sea-disposal sites. This report presents the status of the DoD's activities related to munitions sea-disposal sites in U.S. coastal waters[1]. Specifically, the report discusses: (1) DoD's research to date regarding the effects of sea-disposed munitions on the ocean environment; (2) the feasibility of removing or otherwise remediating munitions sea-disposal sites; and (3) recommendations for additional research and remediation or cleanup of munitions sea-disposal sites.

DoD's research concludes that:

- sea-disposed munitions, which have become part of the ocean environment and also provide critical habitat to marine life, do not pose significant harm when left in place;
- removing or cleaning up munitions sea-disposal sites would have more serious effects on marine life and the ocean environment than would leaving them in place; and
- the potential health effects from sea-disposed munitions in U.S. coastal waters appear to be minimal.

At DoD's study sites, sea-disposed munitions did not appear to stress or have an adverse effect on marine life. Sea-disposed munitions were not destroying habitat or injuring mammals and other sea-life, instead they have provided habitat and become an integral part of the environment and ecosystem.

From an explosives safety perspective, DoD believes that it is best to leave sea-disposed munitions in place. DoD also found that the recovery of these munitions would likely result in a rapid release of munitions constituents that could cause more harm than would otherwise occur as the munitions continue to deteriorate over time.

For example, DoD found that a munition's deteriorated state and its encrustation by sea life make it virtually impossible to positively identify it as a munition or determine whether it is armed. Therefore, the uncertainty of this information would significantly increase the explosives safety risk posed to DoD personnel, the public, and the environment during recovery operations. As such, the risk to human health and the environment associated with the recovery of sea-disposed munitions is far greater than the risk of leaving the munitions in place and implementing an explosives safety education program, like DoD's 3Rs (Recognize, Retreat, Report) Explosives Safety Education Program.

DoD has programs in place to help ensure explosives safety and protect human health and the environment. DoD proactively uses the 3Rs Program to advise people of the actions to take

[1] DoD focused its research of munitions sea-disposal sites in U.S. coastal waters per Congressional direction in section 314 of the John Warner National Defense Authorization Act for FY 2007.

or avoid if they encounter or inadvertently recover a munition from the ocean. The 3Rs Program also includes explosives safety educational material targeted at the maritime industry and recreational ocean water users (e.g., divers, snorkelers) who may encounter munitions. DoD tailors its 3Rs Program to site-specific or location-specific conditions, targeted communities (e.g., maritime industry), or specific activities (e.g., recreational divers) to help ensure protectiveness. If a sea-disposed munition is determined to pose an unacceptable risk to the public or critical assets, DoD dispatches DoD explosives ordnance disposal personnel to prevent an accidental detonation.

DoD determined, based on its comprehensive research to date, that the potential health effects from sea-disposed munitions within U.S. coastal waters appear to be minimal. As such, DoD does not plan to clean up sea-disposal munitions sites in U.S. coastal waters. However, DoD will continue to support munitions and explosives emergencies that involve sea-disposed munitions that pose an unacceptable risk to the public or are inadvertently recovered during maritime activities.

DoD will continue targeted research to (1) determine the potential effects of different munitions constituents on marine life; and (2) assist in locating sea-disposed munitions in dynamic environments (e.g., surf zone) that can force munitions to the beach where they may pose an unacceptable risk to the public. Additionally, DoD intends to conduct follow-on monitoring at its study sites to determine whether a change in the munitions' condition has affected the ocean environment.

DoD believes its research and that of the international community provides sufficient information about the potential effects of sea-disposed munitions on the ocean environment. As such, DoD does not believe that research of additional munitions sea-disposal sites in U.S. coastal waters would provide significantly different findings.

I. STATUS OF DOD'S RESEARCH TO DATE

DoD researched the potential effects of sea-disposed munitions on the ocean environment and those that use it at two munitions sea-disposal sites in U.S. coastal waters in Hawaii. Both sites (Ordnance Reef and the Hawaii Undersea Military Munitions Assessment (HUMMA) Study Site) are off the Hawaiian Island of Oahu. The conditions at the two munitions sea-disposal sites where DoD conducted research, particularly the HUMMA Study Site, are similar to munitions sea-disposal sites in other U.S. coastal water bodies (e.g., Atlantic coast). Therefore, DoD is using this research to draw conclusions about other munitions sea-disposal sites in U.S. coastal waters. The findings from DoD's research at Ordnance Reef (see www.denix.osd.mil/orh/) and the HUMMA Study Site (see www.hummaproject.com) are widely published in peer-reviewed articles[2]. (Many of these articles are available from the Marine Technology Society at https://www.mtsociety.org/publications/.)

[2] Examples of published DoD research on munitions sea-disposal sites:

Carton, Geoffrey, J. C. King, and R. Josh Bowers. "Munitions-related Technology Demonstrations at Ordnance Reef (HI-06), Hawaii." Marine Technology Society Journal 46.1 (2012): 63-82.

DoD's research is also well respected and used within the International Dialogue on Underwater Munitions community, a group of international policy, science, and technology experts who collaboratively discuss the risks, options, and procedures for addressing sea-disposed munitions. International consensus supports a preferred long-term approach to limit encounters by documenting munitions sea-disposal locations on nautical charts, restricting access and activities at these locations, and providing safety education to maritime and coastal communities. These actions have proven effective for reducing inadvertent encounters and for reducing the potential effects of such encounters.

Characteristics of Ordnance Reef and the HUMMA Study Site include:

- *Ordnance Reef* is located from the shoreline to approximately 1.5 nautical miles off Oahu's Waianae coast and contains conventional sea-disposed munitions at depths from 30 to over 300 feet. Because a number of sea-disposed munitions at Ordnance Reef are at depths less than 120 feet, this is considered a shallow-water site. The nearby shore property is used for residential and recreational purposes, with the waters used for maritime recreational activities and reportedly for subsistence fishing.
- *HUMMA Study Site* is located approximately five miles south of Pearl Harbor in waters in excess of 900 feet deep. Based on vague historical records, the Army believed this site potentially contained sea-disposed chemical warfare material (chemical munitions or bulk containers of chemical agent). As a result, the researchers designed their research effort to investigate both conventional and chemical munitions.

Appendix A summarizes the research studies and study conclusions for Ordnance Reef and the HUMMA Study Site. The table includes the web site link to the full report for further information.

Summary of the Effects of Sea-Disposed Munitions on the Ocean Environment

Ecological Effects

DoD takes a holistic approach when assessing the potential effects of munitions sea-disposal sites on the ocean environment and the people who use the ocean environment. These assessments look at how munitions, human activities, and natural phenomena impact marine life. For example, the waters off the Waianae coast where Ordnance Reef is located are subject to typical community activities (e.g., releases at the Waianae sewage outfall from sewage treatment, storms, runoff from highways) and natural activities (e.g., storms). These activities release contamination (e.g., lead, arsenic) to the ocean environment that may be the same as or similar to the release of munitions constituents from sea-disposed munitions. As such, when studying the

---

Silva, Jeff AK, and Taylor Chock. "Munitions Integrity and Corrosion Features Observed During the HUMMA Deep-Sea Munitions Disposal Site Investigations." *Deep Sea Research Part II: Topical Studies in Oceanography* (2015).

Edwards, Margo H., et al. "The Hawaii Undersea Military Munitions Assessment." *Deep Sea Research Part II: Topical Studies in Oceanography* 128 (2016): 4-13.

potential effects of sea-disposed munitions on human health and the ocean environment, the study team must identify and consider the cumulative effects of community, naturally-occurring, and munitions activities on the ocean environment.

At Ordnance Reef, researchers observed that area marine life is vibrant and concluded that there were no significant adverse effects from munitions on the reef community. Sea-disposed munitions have become habitat for marine life, with most of the munitions encrusted by corals. DoD's research has determined that these munitions, which have been present on the reef for over 60 years, do not pose a significant effect on human health or the environment. Based on its research, which included a demonstration of removal and disposal technologies, DoD believes action to recover sea-disposed munitions must be balanced against the potential harm to the reef community and increased explosives safety risk to workers and the surrounding communities. The researchers made similar observations at the HUMMA Study Site, which provide habitat for marine life at deeper depths.

Human Health Effects

A majority of munitions sea-disposal sites in U.S. coastal waters are in deep ocean water (e.g., depth over 900 feet), with munitions dispersed over a wide area. Key factors to determine whether munitions constituents pose a human health hazard are the quantity and dispersal of munitions within a munitions sea-disposal site, the depth of the disposal area, the effects of currents (e.g., direction, speed) and tidal flushing, and the quantity of munitions constituents released in a given period of time.

Based on laboratory and field research, DoD concluded that sea-disposed munitions in U.S. coastal waters pose no adverse effects on human health and the environment. Munitions constituents released to the marine environment: (1) may be released in such small quantities and not concentrated enough to be toxic; (2) degrade quickly; (3) do not bioaccumulate; and (4) do not appear to present a risk of exposure or toxicity to either human health or the environment. Moreover, sampling at both Ordnance Reef and the HUMMA Study Site did not detect munitions constituents in seawater and only detected low concentrations in the sediment. The detected concentrations rapidly decreased with increasing distance from the munitions.

For the HUMMA Study Site, where the depth of sea-disposed munitions range from 900 feet to over 1,800 feet, the maximum chemical agent (e.g., mustard) detection was in low parts per million. Chemical analysis revealed the detections were primarily limited to the vicinity of the munitions (e.g., within two meters). Analysis showed chemical agents and degradation products in sediments, but not biological samples. Analysis also showed explosives in biological samples (i.e., shrimp), but not sediments. Under current and potential future uses of the HUMMA Study Site, the health risks are within the U.S. Environmental Protection Agency (EPA) acceptable levels.

For Ordnance Reef, there is little evidence that munitions constituents from sea-disposed munitions pose a human health hazard to surrounding communities. Some communities reportedly use the area for subsistence. The Ordnance Reef Human Health Risk Assessment survey concluded that risks and hazards are acceptable if consumption is limited to quantities

consumed by an average resident. The conclusion from this risk assessment is consistent with the EPA and the U.S. Food and Drug Administration general consumption advisories for fish and shellfish.

II. FEASIBILITY OF REMOVAL OR REMEDIATION OF MUNITIONS AT SEA-DISPOSAL SITES

DoD has determined that known munitions sea-disposal sites in U.S. coastal waters do not pose an unacceptable risk to ecological, environmental, or human health or to maritime safety. DoD has not disposed of munitions in oceans since 1970.[3] Removing or cleaning up these 45-year old munitions sites may pose several significant challenges.

Recovery of Sea-Disposed Munitions

Based on current research, the risk associated with recovering sea-disposed munitions appears to be far greater than the risk of leaving the munitions in place. Recovering sea-disposed munitions may cause them to either break apart and release their contents or detonate. Either scenario can have an adverse effect on human health and the environment.

An accidental detonation during recovery can destroy habitat, including protected or sensitive corals, injure mammals and other sea-life, or result in injury to workers or the public. Consistent with the DoD Explosives Safety Board's (DDESB's) recommendation, the Army implemented a comprehensive, targeted 3Rs explosives safety education program for the communities near Ordnance Reef. This program educated the public on munitions and, when followed, helps protect the local community from the explosives safety risks associated with the sea-disposed munitions present on the reef.

Destruction of Successfully Recovered Sea-Disposed Munitions

The demonstration of recovery technology concluded that once a sea-disposed munition is recovered from the ocean floor, its explosive risk increases until the munition is destroyed and the explosive or chemical agent hazard is removed. During the recovery process DoD must take actions to protect its workers, the public, recovery assets, and the environment in the event of an accidental detonation. For example, at the HUMMA Study Site, DoD found that recovery was directly affected by the type of sea-disposed munitions present (e.g., thick-skinned projectiles, thin-skinned bombs) and deteriorated state. The research showed that thinned-skinned chemical munitions are deteriorated to a point that recovery would likely result in a rapid release of more constituents than would slowly occur over time as the munitions continue to deteriorate. The rapid release could lead to greater concentrations of constituents and potential effects on human health and the environment. Many compounds (e.g., chemical agents) are degraded or continue to release at a slow rate. The low concentrations detected and the concentrations expected with the slow release over time do not have a significant effect on human health and the environment.

[3] In 1969, the National Academy of Sciences released a report recommending that munitions be safety neutralized or destroyed as opposed to burying them intact on land or at sea. In 1972, Congress enacted the Ocean Dumping Act to prohibit the disposal of waste into the ocean waters of the United States, including prohibition of the offshore disposal of chemical warfare agents.

Upon recovery of a sea-disposed munition from the ocean floor, DoD must take some action to remove the explosive or chemical agent hazard. Due to the munitions deteriorated state, this increases the explosive risks to DoD personnel and the public until the munition can be transported to a location to be destroyed. Therefore, as indicated previously, safety considerations for DoD personnel and the public during recovery actions of sea-disposed munitions must be balanced against environmental effects.

Prior to its research at Ordnance Reef, several options were considered for addressing recovered sea-disposed munitions, including transporting recovered munitions to the beach or a safe location for destruction, floating munitions to a controlled area for destruction, or destroying recovered munitions at sea. Because of the greater explosive risk posed by these options, it was decided to destroy the munitions at sea and implement protective measures to reduce the explosives risk to DoD personnel and the public. Protective measures included:

- Establishing DDESB-approved explosives safety quantity distances from publicly accessible areas (e.g., beaches, residences, marinas);
- Establishing and enforcing exclusion zones for commercial vessels and recreational boats;
- Establishing a shielded control room on the barge to mount the energetics hazard destruction system;
- Imposing personnel restrictions during recovery and destruction operations at sea; and
- Using protective shielding within the energetics hazard destruction system, both for remote cutting operations and destruction of munitions.

At Ordnance Reef, the researchers learned that they could not easily recover sea-disposed munitions because the munitions had become cemented to the sea floor by coral encrustation.[4]

III. RECOMMENDATIONS FOR ADDITIONAL RESEARCH

DoD recognizes that each sea-disposal munitions site in U.S. coastal waters may differ slightly given currents, tides, and water column profile (i.e., temperature and salinity). However, based on our research, these variances would not provide significantly different findings. Sites located in stagnant waters, like the Baltic Sea where there is minimal water movement are likely to provide vastly different findings from those in U.S. coastal waters. It should be noted that none of the munitions sea-disposal sites in DoD's inventory are located in stagnant water. DoD can extrapolate information from the conclusions of its studies about the effects from the sea-disposed munitions in Hawaii and apply this information to munitions sea-disposal sites in other U.S. coastal waters. Additional research on munitions sea-disposal sites in other U.S. coastal waters are unlikely to provide different conclusions on how the coastal waters impact munitions than those drawn from existing research presented in this report.

[4] The recoveries conducted or attempted during this demonstration resulted in minimal damage to coral and habitat that the sea-disposed munitions had created. However, it should be understood that the munitions the researchers selected for recovery were in areas surveyed by National Oceanic and Atmospheric Administration (NOAA) where NOAA had indicated damage would be minimized.

However, DoD believes that additional research, in targeted laboratories, is needed to determine the potential effects munitions constituents may have on marine life, including coral. Some additional research is needed to assist in locating sea-disposed munitions, particularly those in the surf zone or similar dynamic environments that can force munitions to the beach where they may pose an unacceptable risk to the public. Additionally, follow-on monitoring may be necessary at Ordnance Reef and HUMMA Study Site within the next 10-15 years given the types of munitions present and the potential effect on the coral reef. DoD intends, subject to the availability of funds, to demonstrate technology to remove the fill (e.g., explosives) from sea-disposed munitions in place without removing them from the water. Based on DoD's research to date and its current inventory, Table 1 presents a description and timelines, if known, for DoD's recommended future research initiatives.

Table 1: DoD Recommendations for Future Research Initiatives at Munitions Sea-Disposal Sites

Site / Timeframe	Description
Site: HUMMA Study Timeline: 2018 - 2020	Re-visit the HUMMA Study Site within the next 10-15 years to conduct another round of sampling near sea-disposed chemical munitions present at the site. Research to-date showed that the slightest disturbance (e.g., a touch during sampling) can cause sea-disposed chemical munitions, which are thinned skinned, to disintegrate. The Army believes additional sampling at the HUMMA Study Site would be beneficial to better understand the potential effect of chemical munitions on the ocean and the rate of deterioration.
Site: Ordnance Reef Timeline: 2020 - 2030	Monitoring the conventional munitions present at Ordnance Reef within the next 10-15 years to determine whether a change in the munitions' condition (e.g., deterioration) has affected the reef. DoD will consider the type of munitions present, the time span of the studies already complete, and the level of information known and data collected on the munitions to determine the scope of and necessity for monitoring.
Site: TBD Timeline: Upon availability of funding (approximately $5M)	Prove that a technological approach to recover a munition's fill (e.g., explosive munitions constituents, chemical agent) without removing the munition from the ocean environment is feasible, and demonstrate the technology's ability to both render a munition safe by removing the fuze, recovering the fill and leaving the munitions body in place. The advantage of this approach include: ▪ Eliminating the risk to response workers and the public during recovery and avoiding potentially significant and costly environmental damage. ▪ Replacing current procedures that require munitions to be recovered and destroyed on the surface or destroyed in place by detonation. Both of which may destroy critical habitat and increase the risk to workers or the public. ▪ Leaving munitions casings, which provide habitat for marine life, in place unless such munitions are determined to pose an unacceptable risk to human safety.
Site: NA Timeline: 2013 - on-going	▪ Study the uptake and toxicity of munitions constituents to aquatic organisms and publish these studies in peer-reviewed publications. These type studies are in controlled environments (i.e., aquariums in laboratories).

CONCLUSION

DoD's research at Ordnance Reef and the HUMMA Study Site show that sea-disposed munitions do not pose a significant threat to human health and the environment. Attempting to recover and remove these munitions from the water would have more serious consequences, such

as a rapid release of munitions constituents and harm to existing habitat and coral. DoD believes it is best to leave the sea-disposed munitions in place unless there is an explosives emergency or serious threat to human health or the environment. If an emergency situation arises, DoD has programs in place to address it. DoD will continue its research in support of sea-disposed munitions to ensure projection of human health and the environment.

Appendix A

DoD Research To-Date on the Effects of Sea-Disposed Munitions

Ordnance Reef (Pacific, HI-06), Waianae, Oahu, Hawaii (www.denix.osd.mil/orh/)

Research	Purpose/Scope	Findings/Conclusions
National Oceanic and Atmospheric Administration (NOAA) Screening-Level Survey (May 2006) https://www.denix.osd.mil/orh/research.cfm	▪ Determined the sea-disposal munitions site's boundaries, and the general quantity, type, and location of sea-disposed munitions present. ▪ Collected 96 sediment and 49 fish tissue samples. ▪ Analyzed samples for metals, and fish tissues and 47 of the sediment samples for explosives.	▪ Potential releases of munitions constituents (metals, explosive or chemical fills) from sea-disposed munitions do not pose an unacceptable risk to human health or the environment. ▪ DoD's explosives safety community believe that munitions should be left in place, unless they are determined to pose an unacceptable risk to human health and the environment. ▪ DoD's health and environmental risk assessors concluded that munitions present are not expected to pose a human health risk. Found no overt signs of stress or ecological effect. ▪ The Agency for Toxic Substances and Disease Registry (ATSDR) concluded the inorganic chemicals detected in fish did not pose human health hazards, but identified data gaps. ▪ The Army, in coordination with state agencies, affected communities, and ATSDR identified data gaps, designed additional investigations, and subsequently conducted studies that are addressed in the research discussed below to close these gaps. ▪ The Army also implemented comprehensive explosive-safety awareness efforts based on the Army's 3Rs Explosive Safety Education Program.

Research	Purpose/Scope	Findings/Conclusions
Remote Sensing Survey and Sampling at a Discarded Military Munitions Disposal Site (March 2007) https://www.denix.osd.mil/orh/upload/Ordnance-Reef-NOAA-Study-Report-2007.pdf	▪ NOAA independently collected data to define the extent of this sea-disposal munitions site and determine the presence or absence of munitions constituents through biological, sediment, and water sampling. ▪ NOAA surveyed an 81.7 linear mile area using side scan sound navigation and ranging survey; collected 96 sediment samples and 49 fish tissue samples; and collected water samples. ▪ Research confined to within optimum survey limits (approximately 300 ft) of the vessel and equipment. Munitions area depth extended from 24 ft to the maximum depth of the study area (300 ft). The seafloor beyond the reef begins at approximately 100 meters depth and continues to a depth of 5,000 meters.	▪ Overall trace metal in sediments from the study area is very low, suggesting that little contamination at Ordnance Reef is from munitions. ▪ The study detected high metal concentrations at the Waianae Ocean (Sewage) Outfall area. The higher detections of metal were attributed to operations of the on-shore Waianae Wastewater Treatment Plant and natural land drainage from adjacent road surfaces and volcanic rock minerals. There were no explosives or related compounds detected in the fish.
U.S. Army Technical Center for Explosives Safety (USATCES) Risk Assessment of Ordnance Reef, Waianae, Hawaii Remote Sensing Survey and Sampling at a Discarded Military Munitions Sea Disposal Site (April 2007)	▪ USATCES evaluated the risk factors for a number of different situations, considering both naturally occurring phenomena and human activities. ▪ USATCES used the Army Risk Management Worksheet and Hazard matrix and applied the Munitions Response Site Prioritization Protocol.	▪ USATCES considers it far more dangerous to move or remove military munitions from Ordnance Reef than to leave them in place. ▪ USATCES recommended: (1) a public education program about the hazards associated with munitions; (2) restricting some activities at Ordnance Reef; (3) leaving the munitions in place, and (4) the Army or another entity periodically reassessing the area after disturbances from natural phenomena and at scheduled intervals. The State of Hawaii has, for some time, restricted bottom-fishing within this and adjacent areas, which include protected fisheries. ▪ The DDESB agreed with USATCES findings and recommended DoD consider periodic monitoring of the site to determine if additional actions are necessary.

Research	Purpose/Scope	Findings/Conclusions
Assessment of Disposal Technologies (July 2009)	▪ Native Hawaiian Veterans, LLC, (NHV) evaluated technologies capable of disposing of sea-disposed munitions. ▪ NHV used open source information and data collected from companies with munitions disposal technology.	▪ Due to the variety of sea-disposed munitions present at Ordnance Reef there is no single best technology for recovering and destroying the munitions. ▪ NHV recommended combined technologies that are both complimentary and capable of operating on the ocean surface (e.g., on a barge).
Report of Findings Ordnance Reef Technology Demonstrations for the Remotely Operated Underwater Munitions Recovery System (ROUMRS) and Energetics Hazard Demilitarization System (EHDS) (October 2012) http://www.denix.osd.mil/orh/upload/Ordnance-Reef-Tech-Demo-Report-Text-2012.pdf	▪ This demonstration involved the limited recovery of the underwater military munitions and the destruction of munitions recovered using commercially available technologies adapted for the destruction of underwater military munitions. ▪ ROUMRS used a standard underwater remotely operated vehicle fitted with components to remotely locate and recover sea-disposed munitions. ▪ EHDS was an assembly of proven land-based munitions destruction technologies placed on a barge to provide for the safe destruction of recovered sea-disposed munitions at sea.	▪ This demonstration validated ROUMRS' capabilities to locate, identify, and recover underwater military munitions. It also validated EHDS' capabilities to destroy recovered munitions at sea while minimizing effects on human health and the environment. ▪ ROUMRS and EHDS provide additional tools that DoD can use to address sea-disposed and other military munitions in the marine environment when DoD determines that such munitions pose an unacceptable risk to human health and the environment. ▪ Under many circumstances, ROUMRS offers distinct operational advantages over using divers to recover and destroy underwater military munitions. ROURMS involved fewer personnel and allows for extended bottom time. Additionally, using ROUMRS improves the overall safety of recovery operations and decreases costs. ▪ The research included detailed planning for demonstration of the recovery system to attempt to avoid damage to coral and critical habitat. ▪ The system attempted to recover 218 surveyed munitions, but only recovered 80 items because most of the items were cemented to the ocean floor by marine growth. ▪ The EDHS provides an efficient, safe, and environmentally sound means of treating recovered munitions both at sea and on

Research	Purpose/Scope	Findings/Conclusions
		land. EHDS reduces reliance on open detonation.
Ocean Circulation and Predictive Modeling Study of Two Sea-Disposed Military Munitions Sites in Hawaii-Ordnance Reef and Oahu Area 1 (November 2012) http://www.denix.osd.mil/orh/upload/Ordnance-Reef-NOAA-Current-Study-2012.pdf	▪ Study evaluated the potential human health hazards to shoreline communities posed by a potential catastrophic (based on a highly unlikely worst-case scenario) release of munitions constituents from sea-disposed munitions located on the sea bottom. ▪ DoD identified the site closest to shore as Ordnance Reef. This site, which is within 1.5 nautical miles of Oahu's Waianae coast contains conventional munitions at depths between 30 and 300 ft. The site's eastern boundary is within 0.5 km (0.25 nautical miles) of the Oahu coast. ▪ DoD identified the second site, Oahu Area 1. This site, which is roughly 10 nautical miles from shore, contains chemical munitions at depths from about 5,300 to 8,500 ft.	▪ NOAA considered munitions constituents as being most likely present at each site. NOAA used predictive modeling of a "worst-case" release scenario of hydrogen cyanide at Oahu Area 1 and ammonium picrate at Ordnance Reef. DoD, which provided NOAA the worst-case scenario, believes the "worst-case" scenario was highly unlikely, but agreed to their use for modeling purposes. ▪ NOAA determined that (1) hydrogen cyanide from chemical munitions posed the greatest potential human health hazard at Oahu Area 1; and (2) ammonium picrate present in some conventional munitions at Ordnance Reef, posed the greatest potential human health hazard there. ▪ For Oahu Area 1, the study's overall conclusion is that in the event of a catastrophic release of hydrogen cyanide, there would be no shoreline or shallow water exposure. Dissolved hydrogen cyanide concentrations would reach hazardous levels too far below the surface and too far offshore to pose a risk to human health. Chemicals released from the deep water disposal site are likely to dissipate to concentrations below 1 part per billion within a period of 8 hours to 40 days of the release (depending on the amount released and on the actual mixing rates). During this period after the release, the chemicals are not likely to reach detectable quantities except in the bottom several hundred meters of the water column. ▪ For Ordnance Reef, the study's overall conclusion is that in the event of a catastrophic release of dissolved ammonium picrate concentrations in nearshore waters, the maximum

Research	Purpose/Scope	Findings/Conclusions
		concentrations of dissolved ammonium picrate or its dissolution products would not exceed the modeling endpoint of 1 part per billion, which is lower than drinking water standards. Exposure times to the predicted peak concentrations above 0.1 part per billion would be less than 3 hours.
Final Environmental Study (July 2014) https://www.denix.osd.mil/orh/upload/Ordnance-Reef-Environmental-Study-Report-Text-2014.pdf	▪ The Army and the University of Hawaii designed this environmental study to determine whether sea-disposed munitions at Ordnance Reef might have an effect on human health or the ocean environment. This study, along with the Follow-up Investigation, was intended to close gaps identified by the initial 2006 screening level study, including answering questions about the safety of the fish for consumption. ▪ The primary focus of sample site selection was to target the collection of biota that the community identified as food items, and sediment samples in close proximity to specific types of munitions. ▪ Sample sites were selected to reflect anticipated worst-case conditions (i.e., sites likely to have the highest concentrations of contaminants present) at Ordnance Reef.	▪ The concentrations of metals of potential concern in the organisms collected from different areas are similar and generally low; therefore, there is no evidence that sea-disposed munitions have contributed to the observed concentrations of trace metals in the food items sampled (e.g., fish, sea weed and crustaceans). ▪ The risk associated with consumption of seafood from the sea-disposed munitions area is similar to those of other areas within Ordnance Reef except for "high-end" seafood consumer, with the assumption that the "high-end" seafood consumer eats seafood collected exclusively from the sea-disposed munitions area. This scenario is not considered plausible because it assumes a level of harvest from the area that is not likely to be sustainable because there are not enough fish. For the average Waianae community consumer, whose seafood consumption habits are greater than most Hawaii residents and far greater than considered typical of U.S. citizen's consumption, there is no significant risk associated with consuming seafood from the sea-disposed munitions area or other areas of Ordnance Reef. ▪ The results of the Ordnance Reef environmental risk assessment indicate no risk from energetic compounds in sediments.

Research	Purpose/Scope	Findings/Conclusions
Follow-up Investigation Final Assessment Report (September 2014) https://www.denix.osd.mil/orh/upload/Ordnance-Reef-FUI-Report-2014.pdf	▪ National Defense Center for Energy and the Environment (NDCEE) funded an assessment of potential changes in conditions (e.g., a change in the presence of munitions constituents and concentrations) at Ordnance Reef following the Army's ROUMRS technology demonstration. ▪ The primary focus was assessing effects on biota and sediment from munitions recovery at Ordnance Reef during the ROUMRS technology demonstration. ▪ The study team collected 88 sediment samples from the four areas, including an area with sea-disposed munitions and a control area with no munitions, and 108 biota samples consisting of limu (seaweed), crab, octopus, and fish.	▪ In the analysis of both pre- and post-ROUMRS sediment data, four elements (copper, lead, zinc, and magnesium) were clearly associated with munitions and energetics. ▪ The study team surmised that brass shell casings were the source of much of the copper, zinc, lead, and magnesium Arsenic was more closely associated with the terrestrial elements (e.g., aluminum, chromium, iron) because the source may be terrestrial runoff. ▪ Copper, zinc, and lead were generally higher in the sea-disposed munitions area whereas concentrations of arsenic were higher in the control area compared with other areas. ▪ Overall, there were no significant differences identified between pre- and post-ROUMRS sediment and biota data. However, there were differences. It is difficult to say that these differences resulted from the ROUMRS technology demonstration. Data suggest that there were other, unknown factors that may have contributed the differences.
Recovery, Corrosion Analysis, and Characteristics of Military Munitions from Ordnance Reef (March 2015) https://www.denix.osd.mil/orh/upload/Ordnance-Reef-Corrosion-Study-2015.pdf	▪ The Army collected data to develop an initial understanding of corrosion mechanisms and to enhance its capability to predict the failure of munitions casings. ▪ The Army collected the metal from a variety of munitions that had been treated in the energetics hazard destruction system. ▪ Overall study objective was to evaluate corroded underwater military munitions and develop a scientific basis for informing predictive modeling of specific corrosion environment.	▪ Identified sea-disposed munitions casings as high-carbon, and the rotating band 99.7% pure copper. ▪ Corrosion rate of steel coupled to copper under the immersed condition was much higher than those buried a few inches under the sand due to lack of dissolved oxygen in buried condition. ▪ Penetration rate of steel in the immersed condition due to galvanic corrosion does not represent the total corrosion rate. ▪ More testing is needed to obtain reliable long-term galvanic, local, and normal corrosion rates.

Hawaii Undersea Military Munitions Assessment (HUMMA) Study Site, South of Pearl Harbor (Pacific, HI-05), Oahu, HI

Research	Purpose/Scope	Findings/Conclusions
Final Investigation Report – HUMMA Study Area South of Pearl Harbor, Oahu, HI (June 2010) http://www.hummaproject.com/wp-content/uploads/2014/01/HUMMA_Final_Report_June2010.pdf	▪ Assess and characterize a historic deep-water (depths of over 900 ft.) munitions sea-disposal site to determine the potential effect of the ocean environment on sea-disposed munitions and of sea-disposed munitions on the ocean environment and those that use it. ▪ Evaluate whether significant ecological differences existed between sites with sea-disposed munitions and similar sites without sea-disposed munitions. ▪ Develop and demonstrate cost-efficient and effective methodologies for surveying and sampling other historic munitions sea-disposal sites.	▪ Narrow, linear trails of reflective targets are readily recognized by near-bottom towed side-scan sound navigation and ranging survey, and suggest that most sea-disposed munitions in the HUMMA Study Area were disposed of by ships that were underway as munitions were cast overboard. ▪ Sea-disposed munitions integrity in the HUMMA Study Area spans a broad spectrum, with even the best-preserved munitions casings deteriorating at a yet-to-be-determined rate. Skirts and pedestals at the base of munitions may be the result of rusting, possibly in combination with munitions constituent leakage. ▪ The analytical methods used to detect munitions constituents during sampling were effective. Except for one unconfirmed mustard detection, neither chemical agents nor energetics were detected in any of the samples. ▪ Most constituents of potential concern were not detected in any area. Research only detected metals during the HUMMA field program, but contact with contaminated sediment was ruled out as a potential exposure route. Sediment samples from the sea-disposed munitions area displayed relatively little influence on the environment. ▪ Collection of push core samples for the ecological region at the lowest level of the HUMMA Study Area was successful for gauging infauna abundance and diversity, although larger sample sizes would provide a more robust data set. The observations and data collected do not indicate adverse effect on

Research	Purpose/Scope	Findings/Conclusions
		ecological health in the HUMMA Study Area. The risk to human health from the consumption of fish and shrimp collected near the HUMMA Study Area were within the EPA's acceptable risk levels.
HUMMA 2011 Sound Navigation and Ranging Survey – Final Project Letter (May 2012) http://www.hummaproject.com/wp-content/uploads/2015/03/1727-12-HUMMA.pdf	▪ Determine the area where DoD disposed of sea-disposed munitions, characterize the sound navigation and ranging survey signature of munitions trains demonstrating improved effectiveness for surveying disposal areas, and develop software for automatically detecting sea-disposed munitions. ▪ Design to characterize the spatial extent and distribution of sea-disposed munitions within the shallower portions of the HUMMA Study Area, the region where the water depth did not exceed 700 meters.	▪ This survey's strategy proved effective for detecting sea-disposed munitions. The survey covered approximately four times as much area over approximately the same time period as the 2007 Survey. ▪ Differences in the sound navigation and ranging survey eco intensity between metal targets (e.g., sea-disposed munitions, sandy or muddy sediments) can be used effectively to automatically detect sea-disposed munitions resting on the seafloor. ▪ Report recommends work (1) continue on developing the software to evaluate intensity-based detection in regions where the seafloor is more reflective, and (2) future field programs include visual reconnaissance of candidate trains where chemical-filled bombs may be located. These recommendations were implemented as part of follow-on studies.
2015 DRAFT Investigation Report – HUMMA Study Area South of Pearl Harbor, Oahu, HI (July 2015)	▪ Objectives include evaluating the risk from chemical agents in sea-disposed munitions to human health; measuring ecological differences between the disposal area and nearby, but otherwise, similar areas; and evaluating the most efficient platforms for surveying, characterizing, and assessing munitions sea-disposal sites.	▪ A 120 kilohertz (kHz) sound navigation and ranging survey system did not distinguish munitions having thin steel casings between munitions with thick casings. The available data did not allow the study team to quantify the minimum thickness necessary for detection. ▪ Mapping the extent of munitions trails depends on the seafloor substrate. ▪ Conventional munitions follow curvilinear trails, most of which radiate away from Pearl Harbor. Occasionally there are east-west trails, which were likely the result of the prevailing sea state at the time of disposal. ▪ M47A2 munitions are found

Research	Purpose/Scope	Findings/Conclusions
		throughout the HUMMA Study Area. An area of concentrated M47A2 munitions (approximately 500 munitions over 5 kilometer area) trends roughly northwest-southeast through the HUMMA Study Area, but more than 15,000 M47A2 munitions remain uncharted. ▪ Observed munitions exhibit various degrees of corrosion; some sea-disposed munitions are almost completely disintegrated while others of the same type look as if they have been recently sea-disposed. Sea-disposed munitions corrosion in the HUMMA Study Area remains poorly understood. ▪ There was no systematic difference in metal and energetic constituents of potential concern between study and control sites. Chemical agents were detected at trace amounts near each of the M47A2 munitions. ▪ Edible shrimp tissue showed no detectable levels of chemical agent and its degradation products for the 2012 or the 2014 HUMMA Sampling Surveys, indicating bioaccumulation is not occurring. Energetics and metal constituents of potential concern in shrimp were not significantly different at sea-disposed munitions and control sites. ▪ There is no statistically distinguishable difference between organism distributions in dense and sparse munitions fields.

GLOSSARY - DEFINITIONS

These terms and their definitions are for the purposes of this report:

bioaccumulate	Accumulation of substances (e.g., chemicals) in an organism. Bioaccumulation occurs when an organism absorbs a possibly toxic substance at a rate faster than the rate at which the substance is lost by catabolism and excretion.
chemical agent	A chemical compound (to include experimental compounds) that, through its chemical properties produces lethal or other damaging effects on human beings, is intended for use in military operations to kill, seriously injure, or incapacitate persons through its physiological effects. Excluded are research, development, testing, and evaluation (RDTE) solutions; riot control agents; chemical defoliants and herbicides; smoke and other obscuration materials; flame and incendiary materials; and industrial chemicals. (This definition is based on the definition of "chemical agent and munition" in title 50 U.S.C., 1521(j)(1).) (32 CFR 179.3)
chemical agent degradation	The breakdown of chemical agent.
DoD	The Department of Defense
DDESB	Department of Defense Explosive Safety Board
deep water	Anything greater than 300 ft. that is not easily accessible for commercial fishing or other recreational activity.
encapsulation	Enclosed by a protective coating or membrane.
encrustation	A crust-like deposit or growth over a substratum, which is an underlying layer or substance beneath the surface. (http://www.coris.noaa.gov/assets/coris_glossary.pdf)
energetics	A class of material with a high amount of stored chemical energy for release.
EPA	U.S. Environmental Protection Agency
HUMMA	Hawaii Undersea Military Munitions Assessment
in-situ	In its original, natural, or existing place or position.
munitions constituents	Any material originating from unexploded ordnance, discarded military munitions, or other military munitions, including explosive and nonexplosive materials, and emission, degradation, or breakdown elements of such ordnance or munitions. (title 10 U.S.C., § 2710(e)(3))

munitions trains	A pattern of munitions resulting from disposal over–the–side of a vessel underway.
NOAA	National Oceanic and Atmospheric Administration
pedestals	A formation or base, most likely composed of coral, and possibly rust and munitions constituents, affixing a sea-disposed munition to the ocean floor.
sea-disposed munitions	Historical disposal of excess, obsolete, and unserviceable military munitions or foreign munitions in U.S. coastal waters.
skirts	See pedestal.
subsistence	The food products used (with exception of water) to make a meal for consumption by diners to maintain life and meet mission objectives. (DoD Instruction 1338.10, "Department of Defense Food Service Program (DFSP)," September 12, 2012)
water column	The water mass between the surface and the sea bottom. (http://www.coris.noaa.gov/assets/coris_glossary.pdf)