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Analysis of towed camera images to determine the effects of disposed mustard-filled bombs on the deep water benthic community off south Oahu

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ABSTRACT

Still images from a towed camera sled were used to evaluate the potential ecological effects of M47A2 mustard-filled (1,1′-thiobis[2-chloroethane]) bombs disposed of in over 500 m of water off the south coast of Oahu in 1944. The types of munitions and munitions debris in the images were identified by an ordnance and explosives safety specialist. To the extent feasible, non-munitions related debris were also identified. Biologists then examined the images and identified the types and numbers of animals: (1) on or near (< 1 m) the M47A2 bombs; (2) on other manmade debris, including other munitions; and (3) on the natural substrate that was predominantly sediment with little, if any, topographic relief. Multivariate statistical techniques were used to analyze these data to identify differences between the biota inhabiting the three substrates. The analysis indicated that the types and numbers of animals associated with the M47A2 bombs were not significantly different from those observed on other types of munitions and other manmade debris; however they were significantly different from the animals found only on the natural sediment. Based on these results, it appears that the mustard-filled bombs are providing hard substrate similar to other disposed objects, attracting “hard substrate species” that would not have otherwise colonized the area. Even though it is apparent that many of the mustard-filled bombs have breached and their contents exposed, the analysis did not find any evidence of animals avoiding the mustard-filled bombs.

1. Introduction

During World War II, 16,000 M47A2 100-lb (45-kg) mustard-filled bombs were reported disposed of about 5 nautical miles (9 km) south of the entrance to Pearl Harbor (Javits, 1944; Edwards et al., 2014, this volume). The bombs represent only a portion of the total number of military munitions, both conventional and chemical, sea disposed south of Oahu (Department of Defense (DoD), 2010). They furthermore represent an even smaller portion of the total amount of manmade objects of all kinds that has been disposed of in this area off the Hawaiian Islands. However, the M47A2 bombs are arguably the type of debris of most concern due their contents: mustard agent (1,1′-thiobis[2-chloroethane]). Information on the fate of mustard agent in seawater and its effect on benthic communities is sparse.

The behavior of munitions constituents[1] in the marine environment depend on their chemical and physical properties, as well as external factors (e.g., temperature, presence of oxygen). Chemical agents and their precursors are chemically very reactive and thus tend to be unstable (Lisichkin, 1996). Chemical agents are particularly unstable in an aqueous environment and tend to rapidly degrade into generally less toxic constituents due to physical (e.g., transport, immobilization, dilution), biological (e.g., biodegradation), or chemical (e.g., oxidation, reduction, hydrolysis, photolysis) processes (Lisichkin, 1996; Stock and Lohs, 1997). In virtually every case, the breakdown products of chemical agents

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[1] Munitions constituents—Generally, any materials originating from unexploded ordnance, discarded military munitions, or other military munitions, including explosive and non-explosive materials, and emission, degradation, or breakdown elements of such ordnance or munitions.

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and explosives in the marine environment are far less toxic than their original form. The time necessary to completely detoxify one-half of an arbitrary unit mass of a given chemical (i.e., its half-life) varies from a few minutes for phosgene to several hours for mustard (Stock and Lohs, 1997).

However the problem with mustard agent, unlike other types of chemical agents, is that it can form a polymer "skin" when it comes in contact with seawater that can shield active agent from degradation for many years (Bizzigotti et al., 2009). As a result, the long-term effects of this type of munition on the marine environment are presently unknown and need to be better understood. The potential marine ecosystem impacts (MEDEA, 1997) from sea disposals of any chemical munitions that should be considered include: (1) direct toxicity (lethal/sublethal) of the munitions constituents and their degradation products; (2) bioaccumulation and trophic transfer of munitions constituents or their degradation products up the food web; and (3) long-term contamination of sediments.

The munitions disposal sites off south Oahu offer a study area with a number of logistical advantages: (1) relatively close proximity to shore and the University of Hawaii's facilities; (2) in an area that has been subject to numerous studies; and (3) the presence of chemical and conventional munitions in relatively shallow waters (300–700 m). In 2007–2009, the US Army funded the Hawaii Undersea Military Munitions Assessment (HUMMA), a University of Hawaii project designed to evaluate the condition and potential impacts of both conventional and chemical munitions on the underwater environment and the impacts of the underwater environment on the munitions. Extensive side-scan sonar mapping followed by human occupied vehicle (HOV) and remote operated vehicle (ROV) surveys occurred in the purported disposal area for the M47A2 bombs but none were identified. This initial effort therefore turned its focus entirely on studying the numerous conventional munitions present in the study area (University of Hawaii, 2010).

The following year, the state of Hawaii funded towed camera surveys and subsequently HOV surveys along a planned undersea electrical cable route that found and documented 101 M47A2 bombs (Taylor, 2010). The munitions were a considerable distance from their reported disposal location and although highly deteriorated, double green bands visible on several of the bombs confirmed the contents were mustard agent. The bombs showed evidence of pressure crushing indicative of the thin casings characteristic of chemical bombs. Many of the bombs were also breeched, which could have happened as they descended to the seafloor, when they contacted the seafloor, or after they had been on the seafloor for some time.

With a confirmed location of M47A2 bombs now available, a second HUMMA effort aimed at evaluating the extent of the chemical munitions and their potential effect on the environment was initiated in 2011. The study began with a side-scan sonar survey out from the known location to identify the boundaries of the site as well as additional munition disposal sites. These surveys located several fields of thousands of reflective targets on the seafloor near the known M47A2 bombs. In 2012, HOV dives were carried out to sample the bombs and their surrounding sediment for the presence of mustard agent and/or its degradates. The HOV sampling results are described in another paper in this issue. Following the daytime HOV dives, a towed camera system leased from the Woods Hole Oceanographic Institution (WHOI, see Fornari, 2003, http://www.whoi.edu/page.do?pid=17619) was deployed at night to conduct a more extensive visual reconnaissance of the M47A2 bomb field and the nearby potential munition fields identified by side-scan sonar. The camera surveys were used to ground-truth the side-scan targets as well as document the fishes and invertebrates in the known M47A2 disposal field allowing a determination of what if any effect the mustard bombs are having on the benthic community. Over 32,000 digital still images were collected during these camera surveys. In this paper, we present the results from a biological analysis of a subset of these images taken in and around the M47A2 disposal field.

2. Materials and methods

The M47A2 disposal site is approximately 9 nautical miles (16.7 km) southeast of the entrance to Pearl Harbor or approximately 6 nautical miles (11 km) due south of the entrance to Honolulu Harbor. The depth of the site ranges between 524 and 576 m and the seafloor in the general area of the site has been characterized as a "flat silty plain with no significant topographic features" (University of Hawaii, 1996). The natural substrate is predominantly sediment, pebbles, and shell hash with very low bed forms (Fletcher et al., 2008). From the previous cable route survey, manmade debris, both military and non-military, provides the only source of hard substrate greater than a few inches (centimeters) in diameter. In general, considerable amounts of dredged materials are present on the seafloor south of Honolulu, however, very little is present in the study site, which is several miles east of both previously designated and currently designated dredge disposal areas.

This setting, one of a natural sediment substrate disturbed by a variety of manmade debris including munitions, suggests two obvious and testable research hypotheses regarding the possible effects of the munitions (including the M47A2 bombs) on the local benthic community:

Research (alternate) Hypothesis 1 (H_1): There is a statistically significant difference in benthic communities dwelling on munitions (including M47A2 bombs) and other manmade debris with the null hypothesis (H_0) being that there is no difference.

Research (alternate) Hypothesis 2 (H_2): There is a statistically significant difference in benthic communities dwelling on manmade debris and the natural sediment, again with the null hypothesis (H_0) that there is no difference.

The first hypothesis addresses whether animals that settle on manmade debris are differentiating between munitions and other debris. The second addresses whether animals living on manmade debris, including munitions, are different than those living on the surrounding natural sediment. One would intuitively expect this to be the case given that most benthic animals have distinct preferences for either soft or hard substrates. However, this hypothesis was still important to test because the results, taken together with those from testing the first hypothesis, would clarify the effects of disposed munitions on the benthic community in the study area and would confirm the utility of using nonparametric, multivariate statistical techniques. Both hypotheses were tested by acquiring and statistically analyzing visual census data.

2.1. Visual census methods

The WHOI towed camera system used for this survey was operated by WHOI staff. This instrument, named the "TowCam" is a deep-water digital camera system towed and connected to a ship via a standard 0.322-in. (8.18-mm) coaxial cable. Still images from its 16-megapixel Nikon D7000 DSLR camera were 4928×3264 pixel and were acquired on 10-s intervals. Low-resolution versions of these images were transmitted up the cable as they were acquired so the observers could see the seafloor in real time and make operational decisions on the fly. Illumination for the camera system was provided by a Benthos 383® strobe electronics unit and two Benthos 386® flash heads with each head providing 300 W/s of illumination. Minimum recharge time for the strobe system is 7 s. The TowCam has a large "tail" that provides stability and the coaxial cable provided the winch operator with access to real-time depth and altitude information that allowed the system to be steadily towed at an altitude of 4–8 m