

SECTION 6

DISCUSSION AND CONCLUSIONS

The objectives of this marine resources study, defined by the 2007 partial SA entered into by the Army and Malama Mākua, were as follows:

- To evaluate whether fish, shellfish, limu (marine algae), and other marine resources near Mākua Beach or muliwai (estuaries or stream mouths), which area residents rely on for subsistence are contaminated by substances associated with proposed military training at Mākua;
- To evaluate whether the potential that activities at MMR have contributed or will contribute to contamination in fish, shellfish, limu and other marine resources; and
- To evaluate whether the proposed training activities pose a human health risk to area residents who rely on marine resources for subsistence.

Tetra Tech sampled fish, shellfish, and limu in the muliwai or nearshore waters of Mākua and fish and shellfish at the background sites. All samples, except three shellfish samples, were analyzed for approximately 43 different constituents to assess whether marine resources at MMR are contaminated with compounds potentially associated with past military training at MMR. The exceedingly small populations of two shellfish species (Hawaiian prawns and rock crabs), and therefore small quantities of biomass collected, limited the analysis of these samples to a subset of the 43 constituents.

6.1 DIOXINS/FURANS

Only 18 of the 25 dioxin/furan or total congener groups from the standard EPA 8290 analyte list were detected in the fish, shellfish, and limu from either Mākua or background sites. Four or fewer dioxin/furan congeners were detected in greater than 25% of the fish, shellfish, or limu samples. All remaining congeners were detected in fewer than 15% of the samples of fish, shellfish, or limu. Seven dioxin/furan congeners were detected in the muliwai that were not detected in the nearshore environment. Three dioxin/furan congeners were detected at Mākua that were not detected at the background sites. Chemicals are differentially accumulated depending on the species and different species were collected in the muliwai and the nearshore environment. There were also differences between species

collected at Mākua and the background sites. Differences in dioxins/furans concentrations between Mākua and the background site and between the muliwai and nearshore waters may be a function of the different species collected in each of these locations. Finally, note that nearshore species may have larger ranges and may have accumulated contaminants from regions other than where they were collected.

Elevated levels of dioxins/furans were detected in soil, muliwai sediment, streambed sediments, surface water, and fish samples in the Mākua Valley; however, dioxins/furans are not constituents of past or proposed military munitions. Major sources of dioxins/furans are listed in Section 3.2.1 and include natural, civilian, and industrial sources. There are several potential sources of dioxins/furans on the Waianae Coast that could contribute to the concentrations at Mākua that exceed background.

6.2 VOCs AND SVOCs

Volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs) were detected in the fish, shellfish, or limu samples, but, when detected, these compounds were typically present at only trace concentrations. Two of the eight VOCs and three of seven SVOCs analyzed were detected in fish. Di-n-butylphthalate was detected in 100% of fish and limu samples both at Mākua and the background locations. Acetone was detected in 47% and 44% of the fish samples from Mākua and background sites, respectively. Acetone and di-n-butylphthalate are common lab contaminants and are not likely attributable to transport from MMR. All other VOCs and SVOCs were detected in fewer than 25% of the fish, shellfish, or limu samples. There are both natural and anthropogenic sources of most VOCs and SVOCs.

The SVOC that contributed to the risk to subsistence and recreational fishermen was bis(2-ethylhexyl)phthalate (DEHP). DEHP was also detected in groundwater during previous studies but is not a constituent of past or proposed military munitions. Natural, civilian, and industrial sources are provided in Section 3.2.3.

6.3 ORGANOCHLORINE PESTICIDES

Multiple organochlorine pesticides were detected in fish and limu samples, but aldrin was detected in only one shellfish sample. Several factors may contribute to these results. First, environmental conditions likely have changed between the fish and limu sampling in 2006 and shellfish in 2008. The 2006 sampling occurred in the summer following a severe rainy winter in which O'ahu was subjected to 40 consecutive days of heavy rains. A rain of this magnitude could have washed greater than normal quantities of contaminants into the muliwai. No additional severe rain events occurred between the 2006 and 2008 sampling events. In addition, Columbia Analytical Laboratory analyzed organochlorine pesticide in the fish and limu samples in 2006, while APPL, Inc., analyzed these compounds in the shellfish study in 2008 (this was unavoidable given the timeline for this study and the laboratories' schedules). Furthermore, pesticides, including organochlorine pesticides, have been used historically throughout the islands for agriculture and termite control and therefore are difficult to trace to a source, particularly during periods of high levels of transport from upland environments to the coastal wetlands and nearshore environments.

Aldrin, alpha-BHC, and heptachlor epoxide were detected in several environmental media in the Mākua Valley, including groundwater, streambed sediments, fish, and shellfish. However, organochlorine pesticides are not a constituent of military munitions. Major sources of these compounds are provided in Section 3.2.4.

6.4 EXPLOSIVES

Nitroglycerin and RDX, potentially originating from both military and civilian uses such as fireworks or rodenticides, were detected in fewer than 8% of the samples. Perchlorate, which is found in both military ordnance and fireworks, was detected in 42%, 9%, and 50% of the fish, shellfish, and limu samples, regardless of origin. Detection of perchlorate in fish was similar between Mākua (47%) and background sites (33%). Perchlorate was more commonly sampled in the shellfish samples at the Mākua sites (one detection) than at the background site where there was no detection. Perchlorate was sampled in 53% of the muliwai samples and only 27% of the nearshore samples, suggesting that the muliwai served the typical wetland function of filtering contaminants.

The only explosive-related chemical detected in the muliwai sediment samples was RDX, while 1,3-dinitrobenzene was the only explosive-related chemical detected in the streambed sediment samples and perchlorate and 2,4-dinitrotoluene were the only explosive-related chemicals detected in the surface water samples. Nitroglycerin (2 samples), and perchlorate (6 samples) were detected in muliwai fish samples, while 2,4-dinitrotoluene and RDX were not. The nitroglycerin results were considered invalid, because QA/QC issues precluded quantification of this analyte (see Appendix C).

Perchlorate was the only explosive compound that contributed to noncarcinogenic hazards. While perchlorate is a constituent of military munitions, it is also a constituent of fireworks and over 80 other manufactured products used by civilians and industry. Natural and anthropogenic sources of perchlorate are provided in Section 3.2.5.

6.5 METALS

Samples from the muliwai locations tended to have higher concentrations of metals than the nearshore samples, although the nearshore samples typically had higher concentrations of arsenic. The scientific literature suggests that organic nontoxic forms of arsenic dominate that found in marine organisms. Differences in metals concentrations between habitats (muliwai versus nearshore) may result from differences in sample species composition between the two habitats rather than differences in environmental concentration of metals. All metals except antimony, beryllium, mercury, silver, and thallium were detected in 100% of the samples, including both Mākua and background sites. Of these metals only thallium was in a greater percentage of samples at background sites than at Mākua. In addition to the species listed above, chromium and selenium were detected in less than 100% of the limu samples. No metals were detected in greater than 75% of the shellfish samples, and less than 50% of the metals analyzed were detected in greater than 50% of the shellfish samples. Again, the differences in detection between the fish and limu and the shellfish samples may have resulted from changes in environmental conditions between 2006 and 2008 or analytical laboratories. There are natural and anthropogenic sources of metals other than military munitions. These sources are provided in Section 3.2.6.

The analytical data for the fish samples do not appear to follow any obvious geographic pattern. The results from the Mākua samples were similar to the results from the background location samples. Samples from the muliwai locations tended to have higher concentrations of metals than the nearshore samples, although the nearshore samples typically had higher concentrations of arsenic. Based on these results, there is no definitive link between the training activities at MMR and the presence of contaminants detected in the marine resources.

6.6 HUMAN HEALTH RISK ASSESSMENT

6.6.1 Risks and Uncertainties Associated with Consuming Fish in the Muliwai

The human health risk assessment indicated that the carcinogenic incremental risks (i.e., over background) from fish consumption at the muliwai is approximately 3.5×10^{-5} for subsistence fishermen. This risk estimate exceeds the 1×10^{-5} risk level (one person in 100,000 people may develop cancer) used in assessing fish consumption (USEPA 2000a), although it is within the USEPA (1990) target risk range of 10^{-6} to 10^{-4} . The incremental risks over background are largely due to assumed exposures to dioxins/furans. The incremental risks (i.e., over background) from fish consumption from the nearshore waters at Mākua is approximately 3×10^{-5} for subsistence fishermen. The incremental risks over background are largely due to assumed exposures to alpha-BHC, heptachlor epoxide, and bis(2-ethylhexyl)phthalate (DEHP). The first two compounds are organochlorine pesticides with primarily agricultural and urban sources. The third, DEHP is in polyvinyl chloride (PVC) plastic products like toys, vinyl upholstery, shower curtains, adhesives, and coatings. It is used in some food packaging, and medical product containers (including those for blood) and equipment. It is also used in some inks, pesticides, and cosmetics and in vacuum pump oil. The noncarcinogenic hazards exceeded 1 at both Mākua and the background sites, but the hazard was greater at the background site.

There are several sources of uncertainty in the risk estimates that tend to indicate that the risk estimates are high. One source of uncertainty is the assumption of fish consumption rates. A second source of uncertainty in this risk estimate is the assumption that a subsistence fisherman could rely only on the muliwai for fish. The 95th percentile fish consumption rate for Hawaiians from a 2003 study of 100.3 grams per day (g/day) was used in the human health risk assessment to provide a health-protective estimate of risk from consuming fish caught in the muliwai and nearshore areas of MMR. Furthermore, the muliwai are generally the size of a small pond, having a maximum water surface area of less than one acre. It is unlikely that the two muliwai evaluated here could hold enough fish to support even one subsistence fisherman, let alone a population of subsistence fishermen. The assumption of a subsistence fisherman relying exclusively on the muliwai is unrealistic, so the risk estimate likely overestimates exposures to chemicals in the fish.

6.6.2 Risks and Uncertainties Associated with Consuming Shellfish in Mākua Nearshore Waters

The incremental risk (i.e., over background) to subsistence and recreational fisherman from shellfish consumption at the muliwai is below the 1×10^{-5} risk level (one person in 100,000 people may develop cancer) used in assessing fish consumption (USEPA 2000a). The

noncarcinogenic hazard index (HI) from muliwai shellfish subsistence and recreational consumption exceeds background. The incremental hazard exceeds the threshold HI of 1, primarily due to assumed exposures to manganese and cobalt. There is no incremental cancer risk (i.e., over background) for shellfish harvested at Mākua Beach because the risk estimated for background is higher than that estimated for shellfish harvested at Mākua Beach. The noncarcinogenic HI from shellfish consumption exceeds background, and the incremental risk exceeds the threshold HI of 1. This is primarily due to assumed exposures to cadmium and perchlorate, with the latter found only in helmet urchins and not Kona crab collected at Mākua Beach.

For shellfish, the risk and hazard estimates were based on the likely fish consumption rate for Hawai'i (i.e., 100.6 g/day). This rate is higher than the shellfish consumption rate estimated for the US population in general, particularly the rate reported for prepared crab and shrimp (mean of approximately 2 g/day) (USEPA 2002c). Further, risk and hazard estimates were calculated using the maximum concentrations of COPCs in shellfish, given the limited data with which to estimate mean concentrations. In combination, these assumptions likely resulted in overestimation of risks and hazards due to shellfish consumption.

6.6.3 Risks and Uncertainties Associated with Consuming Limu in Mākua Nearshore Waters

The human health risk assessment indicated that the combined cumulative risk for current and future subsistence fishermen potentially exposed to the chemicals of potential concern in limu harvested from the shallow nearshore waters at Mākua Beach is approximately 8×10^{-3} . This risk estimate exceeds the risk level used in assessing fish consumption of 1×10^{-5} (USEPA 2000a) and the USEPA (1990) target risk range of 10^{-6} to 10^{-4} . This risk estimate is almost entirely due to assumed exposures to arsenic in limu, which was present at concentrations up to 109 mg/kg in the limu samples. The arsenic in limu was assumed to be entirely inorganic, which can be toxic. In many limu species, arsenic can be present entirely in nontoxic organic forms, although it is present in some species in inorganic forms at up to 50 percent or more. A review of the scientific literature did not indicate if the limu collected in this study typically contained arsenic in organic or inorganic form. It is likely that at least some of the arsenic in the limu harvested from the shallow nearshore waters at Mākua Beach is present in nontoxic organic forms, indicating that the risks here may be overestimated. Limu samples were not collected from the background location (Sandy Beach), so it is not possible to determine whether the arsenic levels detected in limu at Mākua Beach are elevated over background.

The primary source of uncertainty in the limu consumption risk estimate is the assumption that all arsenic in the limu was inorganic and toxic. However, there are many species of algae in which nearly all arsenic is present in nontoxic organic forms. The limu were identified to species and a review of the scientific literature did not identify the type of arsenic (organic or inorganic) that is expected to be present in the limu samples. Therefore, depending on the species actually consumed by fishermen, the risks may be much lower than estimated here.

6.7 ECOLOGICAL RISK ASSESSMENT

A screening level ecological risk assessment was conducted to evaluate the potential for adverse effects on ecological receptors that may be exposed to chemicals in muliwai and nearshore waters. Data from the fish, shellfish, and limu sampling conducted as part of this study and data from muliwai sediment sampling conducted in 2003 were used in this assessment. Two sets of receptors were evaluated: (1) benthic invertebrates exposed to chemicals of potential ecological concern in sediments and (2) fish exposed to chemicals from multiple pathways, represented by measured concentrations in fish tissues. The results from the screening level ecological risk assessment indicated that there were no hazards to fish in the north muliwai, the south muliwai and the nearshore Mākua area, and that there was a potential hazard to benthic invertebrates from 2,3,7,8-tetrachlorodibenzo-*p*-dioxin in sediments in the south muliwai. The primary sources of dioxins are backyard burning of household refuse, medical waste incinerators, municipal waste combustion, coal-fire utility boilers, cement kilns, and diesel heavy duty trucks.

Hazards to shellfish in the north and south muliwai did not exceed those at the Nanakuli background muliwai. Hazards at the nearshore habitat at Mākua were equivocal in that the hazard index for Kona crabs was greater than that at the Sandy Beach background site, but the hazard index for helmet urchins was less than background. The hazard index for Kona crabs was predominantly due to cadmium, copper, and zinc in tissues. The potential hazard to crabs from copper is uncertain because tissue concentrations in crabs could be compared only to those in sea urchins, which are expected to have lower body burdens of copper than crabs due to their physiology.

Several lines of evidence were considered in evaluating the potential for risks to organisms in the Mākua muliwai and nearshore waters: the number of chemicals with calculated HQs above 1, the magnitudes of HQs above 1, likely sources of chemicals, confidence in toxicity values, cumulative risks represented by HIs, and comparisons of site HIs to HIs from background sites. Based on the weight of evidence, limited hazards were identified:

- North muliwai—No hazards to benthic invertebrates, shellfish, or fish;
- South muliwai—Potential hazard to benthic invertebrates from dioxans/furans in sediments; no hazards to shellfish or fish; and
- Nearshore waters—Potential hazards to Kona crabs from cadmium, copper, and zinc but no hazards to sea urchins; no hazards to fish.

6.8 CONCLUSIONS

In accordance with the 2007 partial SA entered into by the Army and Malama Mākua, the Army "...shall complete one or more studies to whether fish, limu, shellfish, and other marine resources near Mākua Beach and in the muliwai on which area residents rely for subsistence are contaminated by substances associated with the proposed training activities at MMR... evaluate the potential that activities at MMR have contributed or will contribute to any such contamination and whether the proposed training activities at MMR pose a human health risk to area residents that rely on marine resources for subsistence." This study was an

investigation of the resources at Mākua and background sites and provides the information necessary to answer these questions posed in the SA.

1) Determine whether fish, shellfish, limu, and other marine resources near Mākua Beach or muliwai, which area residents rely on for subsistence, are contaminated by substances associated with the proposed training at Mākua.

This study has identified a number of substances in fish, shellfish, and limu that are also known to be by-products of the type of military training being proposed at MMR. These substances are RDX, perchlorate, arsenic, chromium, cobalt, nitroglycerin, and manganese. While other substances may be products or by-products of military training and civilian and industrial activities, these are the substances for which a potential health risk may exist. Though these and other substances may be by-products of military training at MMR, they are also linked to natural and anthropogenic sources, such as fireworks, rodenticides, gasoline, and volcanic rock. In fact, a comparison of the site data with the available background data shows little if any difference between substances found in the Mākua area and the background sites. Compounds identified for analysis by the SA are not unique to military training and are found at both Mākua and background sites; therefore, proposed military activities are anticipated to have little influence on contaminant levels within marine resources in the Mākua nearshore or muliwai areas.

Although marine resources other than fish, shellfish, and limu were not tested, the sampling was representative of other marine resources within the Mākua area. It is reasonable to suggest that other marine resources occupying similar trophic levels and ecological niches contain similar substances and concentrations as those detected in fish, limu, and shellfish collected as part of this study. Regardless, on authorization to implement the proposed training at MMR, the Army will conduct a long-term water quality monitoring program to assess current and future water quality. A monitoring program will provide the Army with another tool to evaluate potential pathways for substances to migrate beyond the boundaries of MMR.

2) Evaluate the potential that activities at MMR have contributed or will contribute to contamination in fish, shellfish, limu and other marine resources.

Per the requirements of the 2001 SA, the Army investigated soil, surface water, groundwater, and air for potential contamination associated with proposed training activities at MMR. These studies also evaluated whether there was a potential for contaminants to be transported off of MMR. Based on the data from these studies, there is no obvious pattern or pathway for migration of substances from MMR to the muliwai and nearshore areas. However, several substances detected in the marine resources were also detected in environmental media on MMR (air, soil, and water). This suggests there is a potential but as of yet unsubstantiated pathway for substances to migrate from MMR to marine resources.

Thus, there is some potential for past and future release of substances from activities at MMR. However, the low levels of most substances detected during these investigations support the position that if 60 years of live-fire training has not resulted in significant

detectable levels of most substances in the area, then future live-fire activities at MMR would be expected to be likewise insignificant. For those substances detected at higher levels, their occurrence in the area cannot uniquely be attributed to military activities because there are and have been many natural and anthropogenic sources that contribute substances to the Mākua area.

Based on the results of the past investigations, the Army was required to conduct a marine study to determine if contaminants were also found in the marine resources consumed by residents. This study found that a number of substances identified for analysis were detected in these marine resources. Although this and other reports have not provided any definitive evidence that links military training to resource contamination, these reports also do not definitively exclude the possibility that such substances in the fish, shellfish, and limu are a result of activities conducted at MMR. However, it needs to be reemphasized that there are numerous other natural and anthropogenic sources that contribute substances to the Mākua and background areas.

3) Whether the proposed training activities pose a human health risk to area residents who rely on marine resources for subsistence.

This third question posed by the SA calls for a definitive answer concerning whether future training at MMR will result in the release of substances that will, with certainty, contaminate marine resources consumed by local residents for subsistence. This question cannot be answered with certainty because it relies on predictions of the effects of future activities and assumptions based on the assessment of effects from past activities at MMR. Therefore, from a scientific standpoint, we must predict whether or not future training at MMR is likely to cause a human health risk from consumption of marine resources.

It is not likely that future training at MMR will result in the release of substances sufficient to contaminate marine resources around Mākua and to cause a risk to area residents who consume marine resources for subsistence. As stated throughout this section and the overall document, the substances identified for analysis that were found in biota within the Mākua area could be associated with many past and present natural and anthropogenic causes that are not unique to past training at MMR. In addition, based on the general similarity of carcinogenic and noncarcinogenic health risks between the Mākua area and the background sites, it is apparent that the Army's past activities at MMR are not independently responsible for any human health risks from the substances detected in marine resources. Considering the level of substances found within the Mākua area, the numerous sources with which these substances are associated, and the ability of these substances from multiple sources to be transported by rain flow and ocean currents, it is not likely that future activities at MMR alone would contribute substances to the marine environment at a level sufficient to cause a human health risk. Even though it is not likely that future activities at MMR alone would cause this risk to human health, they could add to existing contamination in marine resources.

However, on authorization to resume live-fire training at MMR, the Army would evaluate the potential impacts from the proposed training by conducting a long-term monitoring program

to detect if there is a potential for substances to migrate off the installation and into the Mākua nearshore and muliwai areas. If a substance were identified during monitoring, the Army would conduct further analysis to verify the detection. If the identified substance were detected above the USEPA acceptable risk level, then the Army would take appropriate action to correct the situation and prevent or minimize the potential for the substance to be released into the muliwai or nearshore areas of Mākua. In accordance with the requirements of the 2001 SA, before finalizing a long-term program to monitor detected contaminants, the Army would provide a 60-day public comment period on the scope of and protocol for such monitoring.

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