U.S. ARMY PUBLIC HEALTH COMMAND

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DRAFT
SOUTHERN US ARMY GARRISON - KWAJALEIN ATOLL
FISH STUDY
PROJECT NO. S.0012212
US ARMY GARRISON - KWAJALEIN ATOLL
REPUBLIC OF THE MARSHALL ISLANDS

CHPPM/PHC FORM 433-E (MCHB-CS-IP), SEP 10

DEPARTMENT OF THE ARMY
US ARMY INSTITUTE OF PUBLIC HEALTH
5158 BLACKHAWK ROAD
ABERDEEN PROVING GROUND MARYLAND 21010-5403

MCHB-IP-ESW

EXECUTIVE SUMMARY
DRAFT SOUTHERN US ARMY GARRISON - KWAJALEIN ATOLL FISH STUDY
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REPUBLIC OF THE MARSHALL ISLANDS
FEBRUARY 2014

1. PURPOSE. The purpose of this study was to determine if concentrations of metals, pesticides and polychlorinated biphenyls (PCBs) pose an unacceptable risk to humans who consume fish from islets in the southern portion of Kwajalein Atoll. The Southern U.S. Army Garrison - Kwajalein Atoll (USAG-KA) Fish Study was conducted as an expansion of the 2008 Kwajalein Harbor human health risk assessment and aimed to discern whether the previously observed contamination in fish tissue is specific to Kwajalein Harbor or is part of a wider contamination problem.

2. CONCLUSIONS.

- Contaminant concentrations or the proportion of detected concentrations are often higher in fish/water collected from Kwajalein Harbor when compared to samples from two other USAG-KA-utilized islets and two non-developed islets.

- Concentrations of PCBs and pesticides in fish tissue exceed available screening guidelines for the protection of human health.

- High concentrations of lead in fish pose risk to Marshallese children who consume fish from the southern atoll.

- Fish ingestion poses unacceptable cancer risk to Marshallese adults who draw fish from Kwajalein and Meck harbors. Risks are attributable to PCB Aroclor concentrations, particular Aroclor 1254. Unacceptable cancer risk for Marshallese adults at Illeginni is attributable to the pesticide, chlordane. Borderline unacceptable cancer risk was calculated for Marshallese adults using contaminant concentrations from Jerak fish samples. Noncancer hazard is unacceptable for Marshallese adults and children engaging in subsistence fishing at Kwajalein, Meck and Jerak.

- Of the three USAG-KA-utilized islets where fish consumption was considered for U.S. adults (Kwajalein, Meck and Illeginni), there is only borderline unacceptable noncancar hazard at Kwajalein.

- Contaminant concentrations in lagoon reef fish may adversely affect public health, the marine environment, and protected beneficial uses of surface waters (e.g., fishing).

3. RECOMMENDATIONS.

3.1. Fishing Prohibition.

Continue the existing fishing prohibition in Kwajalein Harbor until such a time that medical personnel have determined whether a consumption advisory should be developed and implemented. Current warning signs state: "Per USAKA Regulation 385-9 potential health risks exist from heavy metals in the fish, water, and sediments." The warning sign should be updated with the results of this risk assessment and explicitly state that consuming fish caught in these waters poses an increased risk of cancer and potentially other adverse health effects.

Modify wording on existing signs to emphasize the cancer risks associated with the consumption of fish due to high concentrations of PCBs in fish tissue. USAKA Regulation Number 385-9 Section 4.4 (Fishing) states that "Fishing is prohibited at certain areas around Kwajalein Island due to a build-up of heavy metals in the tissues of certain species." This regulation should be updated with the results of the risk assessment and explicitly state that consuming fish caught in Kwajalein Harbor poses an increased risk of cancer and adverse noncancer health effects.

Establish a similar fishing ban at Meck and Illeginni harbors to prevent the consumption of fish from these areas.

3.2. Eliminate Ongoing Sources of Contamination.

Eliminate the discharge of contaminants to Kwajalein Harbor. Continue to remediate known sources of PCBs on land. Determine possible on land sources of contamination stemming from Meck and Illeginni activities.

3.3. Further Investigation.

Initiate a second phase of the study to include collection of fish samples from Ebeye as the proximity of Ebeye to Kwajalein Islet could be contributing to the observed pesticide/PCB/metal accumulation in Kwajalein Harbor fish.

Conduct an epidemiological investigation to determine if consumption of fish from the contaminated areas is, in fact, resulting in negative health outcomes in the Marshallese population.

3.4. Risk Communication. A comprehensive education and outreach program should be conducted to explain the results of this study, the hazards of fish consumption and the necessity of maintaining the fishing prohibition.

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LIST OF ACRONYMS AND ABBREVIATIONS

ac	Acre
ANOVA	Analysis of Variance
BCF	Bioconcentration Factor
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Cr	Chromium
Cr(III)	Chromium, trivalent
Cr(VI)	Chromium, hexavalent
Cu	Copper
DEP	Document of Environmental Protection
FAO	Food and Agricultural Organization
FI	Fraction Ingested
FOD	Frequency of Detection
ha	Hectare
HI	Hazard Index
ILCR	Incremental Lifetime Cancer Risk
IR	Ingestion Rate
KRS	Kwajalein Range Services
LOQ	Limit of Quantitation
mg/kg	Milligram per kilogram
mg/L	Milligram per Liter
MRL	Method Reporting Limit
µg/dL	Microgram per Deciliter

µg/L	Microgram per Liter
ng/L	Nanogram per Liter
Ni	Nickel
PA/SI	Preliminary Assessment/Site Inspection
Pb	Lead
PCBs	Polychlorinated Biphenyls
PIFWO	Pacific Islands Fish and Wildlife Office
PIRO	Pacific Islands Regional Office
RBC	Risk-Based Concentration
RSL	Regional Screening Level
SPC	Stationary Point Count
TL	Total Length
UCL	Upper Confidence Limit
UES	USAKA Environmental Standards
USACHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
USAG-KA	U.S. Army Garrison – Kwajalein Atoll
USAKA	U.S. Army Kwajalein Atoll
USAPHC	U.S. Army Public Health Command
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
WHO	World Health Organization
Zn	Zinc

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1. REFERENCES.

See Appendix A for a list of references.

2. PURPOSE.

The purpose of this study was to determine if concentrations of metals, pesticides and polychlorinated biphenyls (PCBs) pose an unacceptable risk to humans who consume fish from islets in the southern portion of Kwajalein Atoll. The Southern U.S. Army Garrison - Kwajalein Atoll (USAG-KA) Fish Study was conducted as an expansion of the 2008 Kwajalein Harbor human health risk assessment and aimed to discern whether the previously observed contamination in fish tissue is specific to Kwajalein Harbor or is part of a wider contamination problem.

3. AUTHORITY.

Authorization to proceed with the Southern USAG-KA Fish Study was provided by Glen D. Shonkwiler, P.E., Restoration Program Manager, U.S. Army Space and Missile Defense Command/Army Forces Strategic Command, 2012.

4. OBJECTIVE.

In 2008, the Kwajalein Harbor Release Area Preliminary Assessment/Site Inspection (PA/SI) (USACHPPM, 2009) concluded that the consumption of fish from Kwajalein Harbor by Marshallese consumers posed an unacceptable level of risk. The risk derived from high concentrations of pesticides and PCBs in certain fish species caught in the harbor. However, the source of the pesticide/PCB contamination was not known and a follow on study was recommended to better understand risks throughout the southern portion of the atoll.

The overall objective of the Southern USAG-KA Fish Study was to provide sufficient information for USAG-KA to determine whether or not the consumption of fish from Kwajalein Atoll poses potentially unacceptable risks to human receptors. The field work resulted in the collection of two kinds of data, namely, analytical and ecological in nature. Pesticide, PCB and metal concentrations in fish and water samples collected from five study areas in the southern portion of Kwajalein Atoll were measured to determine if high concentrations of these contaminants in Kwajalein Harbor fish are due to localized industrial activities or the ubiquitous distribution of contaminants. Then, contaminant concentrations in tissue were compared to screening guidelines to discern if a contaminant needed to be assessed in the human health risk assessment. Biological community surveys of the study areas were conducted to census the diurnally active fish community of targeted species to characterize their natural abundance and habitat.

The project was completed to satisfy requirements in Section 3-6.5.8 of the Environmental Standards and Procedures for USAKA Activities in the Republic of the Marshall Islands (UES) (USAKA, 2011) for a human health risk assessment.

5. GENERAL.

5.1. Site Location and Description.

Kwajalein Atoll is located 2,100 nautical miles southwest of Honolulu, Hawaii. USAG-KA has a land use agreement for 11 of the more than 100 islets comprising Kwajalein Atoll. The Southern USAG-KA Fish Study focused solely on islets in the southern portion of the atoll. The largest and most highly used USAG-KA islet is Kwajalein. Ebeye is the most populated islet on the atoll, but is not used by USAG-KA. The majority of Marshallese workers who commute to Kwajalein for work live on Ebeye. Meck and Illeginni are two other USAG-KA-utilized islets in this study while non-developed islets are represented by Ellep and Jerak. Figure 5.1.1 shows the southern portion of Kwajalein Atoll with the five study areas circled.

Kwajalein Harbor, on Kwajalein Islet, is located on the lagoon side of the islet and is enclosed by the fuel pier to the south and Echo Pier to the north (see Figure 5.1.2). The area encompasses approximately 23 acres and is subject to frequent boat traffic. The harbor is situated in shallow water and is protected from strong oceanic currents and large waves, although some tidal fluctuations occur. Lagoon currents are strongest when winds are out of the north and west.

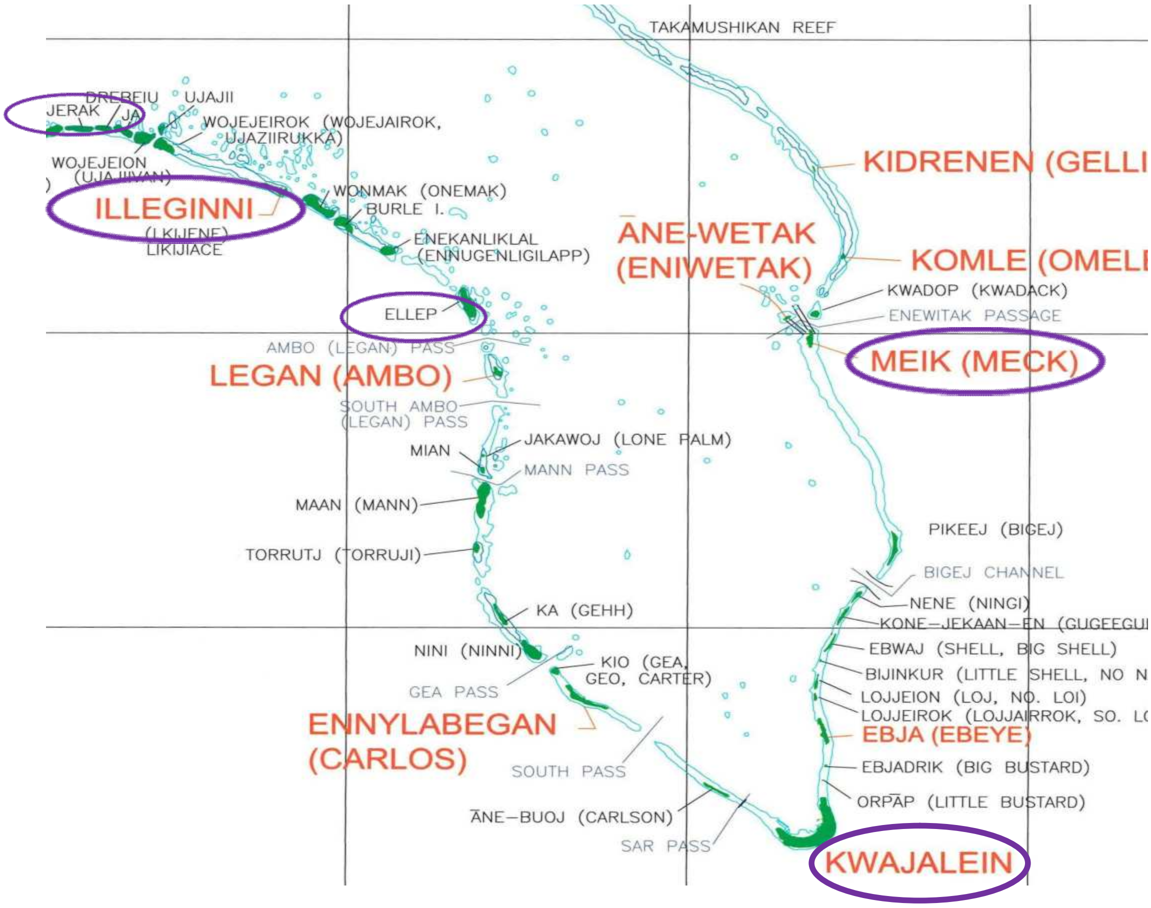

Figure 5.1.1. Location of the Five Study Areas in the Southern Atoll.

Figure 5.1.2. Location of Kwajalein Harbor on Kwajalein Islet.

5.2. Location of Sample Collection.

All fish and water samples were collected on the lagoon side of each islet. Fish that were collected by hook and line were caught from harbor docks on Kwajalein, Meck and Illeginni. Fish that were caught by spear were collected in shallow water (less than 30 feet deep) in coral reef areas near shore of all five study areas. Water samples were collected in the harbor areas of the USAG-KA-leased islets and near shore for the non-developed islets.

5.3. Environmental Setting.

Kwajalein is the world's largest coral atoll surrounding the world's largest lagoon. Previous studies have indicated that the excellent marine water quality of the atoll is impaired only in the immediate areas of industrial activities, most of which occur in the vicinities of the harbor and landfill on Kwajalein Islet (USASMDC, 1993). Islets not used by USAG-KA may be contributing to the total contaminant load, but the extent to which this is a factor is not currently understood.

5.4. Background.

During the last several decades, human activities and industrial processes on Kwajalein Islet have contributed contaminants to Kwajalein Harbor. The predominant source of this historical pollution is thought to be sandblast material derived from vehicle and boat maintenance operations. Pesticides have been applied to building foundations to treat for termites and other pests. PCB-containing liquids were used in electrical equipment and are a component of many anti-fouling agents. PCBs were manufactured and sold under many names, but mixtures known as Aroclors are the most commonly known trade names. There are many types of Aroclors and each has a distinguishing suffix number that indicates the degree of chlorination. The first two digits of the Aroclor designation refer to the number of carbon atoms in the phenyl rings and the second two numbers indicate the percentage of chlorine by mass in the mixture. For example, the name Aroclor 1260 means that the mixture contains approximately 60% chlorine by weight (USEPA, 2013).

Best management practices have been implemented to reduce the total contaminant load and ongoing land investigations have identified and removed localized contaminant sources. Most recently, Kwajalein areas known to be contaminated with PCBs including a former vault building were remediated (WHPacific, 2013a). This source was located in one of the stormwater drainage basins that lead to the harbor, so it was likely an ongoing source of Kwajalein Harbor Aroclor contamination. Other identified sources of PCBs undergoing remediation include harbor storm drains and former PCB vault building Facility Number 713 (WHPacific, 2013b).

Although no commercial fishing takes place in the harbor area, fishing by Marshallese and American individuals alike was banned due to the potential for adverse conditions in the harbor. In 2004, a sign was posted in the vicinity of the harbor that contained a warning in both English and native languages: “No fishing in the Harbor per USAG-KA regulation 385-9. Potential health risks exist from heavy metals in the fish, water, and sediments.” Despite the posted warning signs, fishing occurs periodically and Kwajalein residents and visitors continue to fish in waters near the harbor.

A detailed summary of previous Kwajalein Harbor investigations is included in the project work plan (Appendix B). Only studies that are relevant to the discussion herein are included below.

5.4.1. Kwajalein Harbor Release Area PA/SI (USACHPPM, 2009).

The 2008 PA/SI study took place in two concurrent phases. Phase I was conducted to characterize the nature and extent of contamination by sampling sediment from the harbor area, analyzing the samples for the contaminants of potential concern (COPC), namely metals, butyltins, PAHs, pesticides and PCBs, and comparing these concentrations to reference levels and sediment screening guidelines for human and ecological health. In Phase II of the project, fish were collected from the harbor and analyzed for the COPCs as part of the site-specific human health risk assessment. COPC concentrations in water, sediment and fish tissue were compared to screening guidelines and used to assess risk.

The majority of the metal, butyltin and PAH compounds in sediment exceeded the reference concentrations, and metals were often present in concentrations that exceeded screening guidelines in localized areas of the harbor with known historical and ongoing sources of contamination. However, only aldrin, dieldrin (both pesticides) and PCBs were detected in fish tissue at concentrations that warranted a risk assessment for human consumption. Pesticides and PCBs were not detected in the harbor sediment and water, but were routinely detected in annual stormwater monitoring samples; therefore, it was concluded that ongoing sources of pesticides and PCBs are likely contributing to the accumulation of these compounds by harbor fish.

The human health risk assessment indicated that Marshallese fish consumers would have a health concern if they consumed rabbitfish and bluefin trevally from the harbor on a daily basis for a 30-year exposure duration. The recommendation was made that the harbor fishing ban should be maintained.

5.4.2. Point-Source Discharge Monitoring (USACHPPM 1999-2009, USAPHC 2010-2012a).

Stormwater monitoring data at four point-source discharges in the harbor (KISW01, KISW01A, KISW03 and KISW04) have been collected on an annual basis since 1999 in fulfillment of Document of Environmental Protection (DEP) requirements. UES water quality criteria (WQC) for surface waters were exceeded for the analyzed contaminants at numerous points. Table 5.4.2.1 summarizes criteria exceedances reported from 1999-2012.

Table 5.4.2.1. Exceedances of Water Quality Criteria in Kwajalein Harbor Discharges KISW01, KISW01A, KISW03 and/or KISW04, 1999-2012.

COPC	Water Quality Criteria		KISW01 (µg/L)	KISW01A (µg/L)	KISW03 (µg/L)	KISW04 (µg/L)
	Chronic (µg/L)	Acute (µg/L)				
Chromium	50*	1100*	0.88-160	0.105-27	1.87-170	8.07-170
Copper	3.1	4.8	2.5-120	0.963-790	7.12-210	20.2-250
Lead	8.1	210	0.73-54.9	0.451-130	0.99-150	15.6-170
Nickel	8.2	74	0.51-76.4	ND-660	1.1-48.5	3.58-49
Selenium	71	290	ND-200	ND-13	ND-13	0.169-3.76
Zinc	81	90	10.3-199	1.84-660	8.84-750	47.9-630
Tributyltin	0.01	0.37	ND-0.0177	ND-0.02223	ND-0.01128	ND-0.00653
Aroclor 1260	0.03		ND-1	ND-0.61	ND-0.18	ND-0.25
Aroclor 1248	0.03		ND-0.27	ND	ND	ND
Chlordane	0.004	0.09	ND-0.63	ND-0.072	ND-2.2	ND-0.76
4,4'-DDT	0.001	0.13	ND-0.067	ND-0.0062	ND-0.17	ND-0.087
Endosulfan I	0.0087	0.034	ND-0.0034	ND-0.011	ND-0.0047	ND
Endosulfan II	0.0087	0.034	ND-0.0081	ND-0.09	ND-0.035	ND-0.06
Heptachlor	0.0036	0.053	ND-0.0059	ND-0.020	ND-0.019	ND-0.0042
Heptachlor epoxide	0.0036	0.053	ND-0.011	ND	ND-0.0039	ND
Dieldrin	0.0019	0.71	ND	ND	ND-0.061	ND-0.0081

*WQC for Cr VI (most toxic form)
ND = Not Detected
[light blue] Analyte dectected
[green] Maximum concentration exceeded chronic WQC
[red] Maximum concentration exceeded acute WQC

5.4.3. Fish Sampling Pilot Study (USAPHC, 2012).

In conjunction with the Kwajalein Landfill Baseline Risk Assessment (November 2012), fish samples were collected to determine a path forward for future fish studies. Fish were collected from Kwajalein Harbor and the landfill reef flat to investigate whether certain parts of the fish preferentially accumulated contaminants. Based on the knowledge that Marshallese citizens consume various fish organs, whole fish samples were dissected and livers, eyeballs and muscle fillets were analyzed separately for contaminant uptake. In order to obtain sufficient sample mass for analysis, fish samples were composited from many individual specimens representing different species and trophic levels. The fish parts were analyzed for metals, pesticides and PCBs and the data were treated statistically to determine significance using either traditional analysis of variance (ANOVA) or Kruskal-Wallis ANOVA.

For every contaminant showing significant differences in accumulation, the mean concentration in the liver samples was higher than the other fish parts. Likewise, the mean concentrations in the fillet samples were lower than those concentrations reported in the other fish parts. Key data are presented in Table 5.4.3.1.

Table 5.4.3.1. Summary Concentrations in Fish Parts and Statistical Comparisons.

Analyte	Mean Concentrations (µg/kg)				p-value	Statistically Significant Comparisons
	Eyes (E)	Livers (L)	Whole Fish (W)	Fillets (F)		
PESTICIDES						
2,4'-DDD	2.7	9.4	2.0	1.4	0.02	L > E, W, F
4, 4'-DDT	57.2	762.3	109.9	30.4	0.03	L > F
Oxychlordane	1.6	10.4	0.8	0.8	0.01	L > E, W, F
Endosulfan I	1.3	9.5	1.0	0.7	0.02	L > E, W, F
Endrin	2.0	23.2	4.0	1.1	0.00	L> E, W, F
Heptachlor epoxide	2.7	26.7	3.0	1.3	0.01	L > E, W, F
Hexachlorobenzene	1.4	8.1	1.5	0.5	0.00	L > E, F W,E > F
Technical Chlordane	24.2	145.8	26.5	18.1	0.00	L > E, W, F
PCBs						
Aroclor 1242	53.6	246.2	24.6	9.8	0.01	L > E, W, F
Aroclor 1254	330.6	4223.3	718.5	135.4	0.22	
Aroclor 1260	321.3	3353.3	406.6	137.9	0.00	L > E, W, F
Aroclor 1262	53.6	216.0	24.6	9.8	0.01	L > E, W, F
METALS						
Chromium	211.8	89.7	198.5	30.7	0.00	E, L, W > F
Copper	700.0	47,805.0	1,993.3	251.7	0.00	L > E, W, F W > F
Nickel	36.7	80.0	49.2	23.3	0.10	
Lead	159.33	552.83	437.83	14.17	0.00	E, L, W > F
Zinc	68,350.0	142,266.7	28,573.3	4,598.3	0.00	L > E, W, F E > W, F W > F

Although reported PCB concentrations in muscle fillet were lower than the highest mean fillet concentration measured in the previous study (247µg/kg in Kwajalein Harbor

Release Area PA/SI), it should be noted that the mean concentration of all Aroclor compounds in the pilot study fillet tissue still exceeded the screening guideline of 1.6 µg/kg. Therefore, based on the pilot study and the PA/SI results, no commonly consumed fish parts are contaminant-free or should be eaten regularly.

Since it would not be reasonable to collect fish and only analyze liver concentrations given the amount of fish that would need to be collected and the fact that Marshallese citizens do eat other fish parts, the pilot study indicated that whole fish samples should be analyzed in subsequent studies. It was concluded that this would be the most appropriate approach when determining risks from fish consumption at Kwajalein.

5.5. Regulatory Requirements.

The Southern USAG-KA Fish Study was conducted in accordance with UES Section 3-6.5.8 Restoration requirements (USAKA, 2011). Data were collected in this investigation to support one of the following three outcomes specified in UES Section 3-6.5.8(m):

(1) Where the data falls below the prescribed screening levels, or the prevalent risks are deemed to fall within acceptable limits, and resource damage restoration is deemed inappropriate, further remedial actions are not warranted. A NFA/RC determination, along with the associated assessment rationale, shall be submitted to the Appropriate Agencies for their review. Additional data clarification shall be provided to a reviewing agency upon request.

(2) Where it is determined that remedial action is necessary to mitigate the threats/risks posed to human health, safety, and/or the environment, a feasibility study shall be initiated in accordance with Section 3-6.5.8(n).

(3) Where it is determined that a time critical environmental condition exists, a removal action will be initiated under the procedures described in Section 3-6.5.8(h). This approach shall allow a more timely, expedient accomplishment of requisite mitigation.

5.6. Study Design. Appendix B contains a detailed description of the study design; therefore, only key points are summarized in this section.

5.6.1. Sample Size. The sample size was determined based on a desire to detect a 20% difference in the mean analyte concentrations at the 95% confidence level with a power of 80%, given an assumed variability of 35% in biological samples. Six samples of water were collected from each of five islets and 120 fish samples were collected from each of the three primary areas of interest, namely, Kwajalein, Meck/Illeginni and Ellep/Jerak. Following the field work, it was determined that sufficient samples were collected from the study areas to allow each of the five islets to be evaluated separately.

5.6.2. Analytes. Contaminants of potential concern were selected based on previously detected concentrations of Kwajalein harbor fish contamination. Pesticides and PCB concentrations in fish have historically exceeded screening guidelines so it was imperative that these analytes be included. Although concentrations of metals in Kwajalein Harbor fish have not exceeded screening guidelines in the past, these contaminants were included in the study to ensure this is still the case and to gather data from the other islets not included in previous investigations.

5.6.3. Target Fish Species.

Interviews were conducted in April 2007 with Marshallese workers at the marina to determine the top 20 consumed fish/invertebrates caught in the harbor. In January 2008, a fish consumption survey was distributed to 50 Marshallese workers showing pictures and common names of each of these species. Recipients were asked to circle the fish they consumed the most from the harbor and to indicate how the fish was prepared and the frequency of consumption. The primary criteria for selection of a target species included:

- Was the fish commonly consumed?
- Was the fish commonly caught in the harbor?
- Did the chosen fish represent various trophic levels and feeding preferences?
- Did the fish maintain a fairly limited territory?

The survey did not show a clear pattern regarding the quantity of fish consumed from Kwajalein Harbor, but was effective in identifying the target species for this study. In 2011, the survey was modified and re-distributed to Marshallese workers disembarking from the commuter ferry. The Republic of the Marshall Islands Environmental Protection Authority (RMIEPA) distributed the survey to more than 100 workers and submitted the completed forms to USAPHC. As was the case with the previous survey attempt, no conclusive data were provided on the quantity of fish consumed from Kwajalein Harbor. It is thought that the fear of reprisal prevented survey recipients from responding to the questions.

In addition to consumption preference, target fish species were selected based on their classification into a trophic level and limited migratory range. The study was designed to include carnivorous and herbivorous species since some contaminants (organics such as pesticides and PCBs) are known to bioaccumulate and biomagnify up the food chain, while other contaminants (inorganics such as metals) are not readily transferred to higher order predators. Species were sought that have the tendency to stay in near shore coral reef communities with the thought that if contamination is found in a territorial species, the source of the contamination will likely derive from the study area. Appendix B of this report (project work plan) contains more specific information on the target species.

5.6.4. Screening Guidelines.

In accordance with UES protocol, tissue concentration data were to be compared to U.S. Environmental Protection Agency (USEPA) Regional Screening Levels (RSLs) for Fish Ingestion (previously known as Risk-Based Concentrations (RBCs) in fish for the protection of human health) (USEPA, 2011).

Prior to the initiation of field work, it was determined that the following findings would result in a “no further action” decision:

- Tissue COPC concentrations do not exceed USEPA RSLs for fish ingestion. Contaminants with concentrations that do not exceed RSLs will not be evaluated as contaminants of concern (COCs) in the human health risk assessment.

- Final human health risk characterization does not show potential adverse effect to human receptors from consumption of fish, dermal contact with tissue/water or incidental ingestion of water. The Kwajalein Harbor fishing ban can be removed.

5.7. Deviations from Study Work Plan.

Every effort was made to complete the field work and data analysis as outlined in the approved project work plan (Appendix B of this document). However, deviations from the plan were necessary at times due to circumstances dictated by field conditions or analytical method.

- In May 2013, the USEPA published an updated list of RSLs for fish ingestion to include screening guidelines for previously unlisted risks. Of the contaminants analyzed in this study, a carcinogenic screening guideline was added for chromium. However, as that value was for the hexavalent chromium species, it was not used. A 2011 Ecological Effects Investigation of Kwajalein Harbor showed that all of the chromium in water and sediment samples was present in the trivalent form (USAPHC, 2012b). Therefore, the screening guideline for Cr(III) was used to compare the tissue data.

- Due to a high degree of non-detected analytical data, some of the planned statistical tests could not be completed. The alternate methods are detailed in Appendix C.

- No gill nets were used in the collection of fish. Hook-and-line fishing from docks and spearfishing on scuba were effective means of collecting samples.

- Due to insufficient numbers of detritivorous fish samples collected from each islet, these fish were categorized with the herbivorous trophic level. Likewise, carnivores and piscivores were grouped into one trophic level.

- After the collection of fish samples, it was determined that there was an adequate number of fish from each islet to consider each of the five sampling locations as separate study areas. In the work plan, the two non-developed islets of Ellep and Jerak were to be combined and were Meck and Illeginni, two USAG-KA-utilized islets, were to be considered as one data set.

- The NOAA Marine Fisheries Service Pacific Islands Regional Office (NMFS-PIRO) field team member did not participate in the study. Instead, a third diver from U.S. Army Public Health Command joined the sampling team.

- The Stationary Point Count (SPC) method was not used due to bottom time limitations and because the fish community survey required two divers, taking away from time needed to spear targeted reef fish species.

- Water contaminant concentrations were not used in the risk assessment as it was determined that fishermen were not getting in the water to collect fish from the study areas. Instead, concentrations were compared to water quality criteria.

6. PROCEDURES.

6.1. Field Team.

From 12-26 March 2013. a team from USAPHC Army Institute of Public Health (AIPH), conducted the field work in collaboration with the U.S. Fish and Wildlife Pacific Islands Fish and Wildlife Office (USFWS-PIFWO). The members of the USAPHC field team were Dr. Lisa Ruth (aquatic biologist), Ms. Jennifer Cearfoss (environmental engineer) and Ms. Ellyce Bushong (environmental engineer). Ms. Nadiera Sukhraj (fisheries biologist) represented the USFWS-PIFWO in the field. Two free-diving spearfishermen, Ms. Darla White and Dr. Zoltan Szabo, were hired by WHPacific to assist the field team.

6.2. Procedures for Sampling Surface Water.

Surface water samples were collected from all five islets by submerging sample bottles two feet under water and capping the bottle at depth. In this way, the “grab” sampling technique was utilized to collect the water samples. Due to the number of sample bottles that needed to be filled at each location, a two person team was deployed in the water. Once filled, sample bottles were placed in mesh bags suspended from a flotation device made of a bucket and boogie boards as shown in Figure 6.2.1. Bottles were then lifted onto the boat and transferred to coolers of ice.

Figure 6.2.1. Flotation Device Used for Sampling.

6.3. Procedures for Collection of Fish Samples.

Fish samples were collected either by hook-and-line fishing or by spearfishing on scuba depending on the study location and target species. For the three USAG-KA-utilized islets with harbor areas, the boat was docked and the field team attempted hook-and-line fishing using squid as bait. Scuba divers and free-diving spearfishermen used Hawaiian slings to collect the majority of fish specimens. A snorkeler followed the divers and transported the flotation device (shown in Figure 6.2.1) from which a mesh dive bag was suspended. Once a target fish was speared, the diver placed the fish in the bag and the surface tender lifted the fish out of the water and placed it in the attached bucket. This reduced the amount of blood in the water and, therefore, kept most sharks from entering the sampling area. At the end of each dive, fish were transferred to coolers of ice and were taken back to the warehouse for identification and storage.

6.4. Fish Specimen Preparation.

At the end of each day, the length/width/height of the fish samples were measured and the sample masses were recorded. For smaller fish species such as lemonpeel angelfish (*Centropyge flavissima)* or farmer fish (*Stegastes migricans*) samples, composites were made by combining fish from more than one individual until the required 35 grams of tissue were obtained for analysis. The fish was identified to the species level by the project aquatic biologists. Following the necessary measurements, the fish specimens were wrapped in aluminum foil and placed in a plastic bag onto which the date and sampling location were marked. The fish were placed in a -20°C freezer each night.

At the conclusion of the field work, whole fish samples were sent on ice to the first laboratory (Battelle – for pesticides/PCB analysis) where the samples were homogenized. The resulting homogenate was then split and an aliquot of each sample was forwarded to the second laboratory (Brooks-Rand – for metals analysis). This process reduced the number of fish that had to be sacrificed and allowed multiple sets of data to be generated from each sample.

All necessary declaration paperwork was coordinated with the U.S. Fish and Wildlife Service officers in Hawaii so the fish could be sent to U.S. laboratories without delay.

6.5. Procedures for Community Surveys.

In addition to fish collection, biological community surveys were conducted at each islet to assess the diurnally active fish community of targeted species in order to characterize their natural abundance and habitat. These surveys helped to inform whether target species were abundant or rare, relative to the community, as well as to provide an index of similarity among study areas. Descriptive notes on the habitat (e.g., type, complexity, rugosity) were also recorded at each site following standardized protocol.

Due to the change in the number of resource agency biologists participating in the field sampling, the methods used to collect the community survey data were reduced to one method: the belt-transect method. Reef fish assemblages were surveyed and counts of all species, including those selected for tissue sampling, were quantified using a standard fish belt-transect protocol. Size-specific counts were not included in the surveys due to limitations in the field. To do this, transect lines were set in the same area as the fish and water sample collection. Reef holes, ledges, and the water column within four meters of the substratum were then searched. A pair of scuba divers, a reef fish observer and a safety diver, conducted parallel swims along two 25 meter-long transect lines, recording counts of all fishes encountered to the lowest possible taxon (to species level, where possible), within visually estimated but defined belt widths. For each replicate transect line at a station, each diver quantified fishes ≥20 cm total length (TL) encountered within a 25 m long x 4 m wide area on each side of the line on the swim-out. The swim out was followed by an analogous tally of fishes <20 cm TL within a 25 m long x 2 m wide area on each side of the line on the subsequent swim back. Fish community surveys were conducted at each site and on the day that the islet was sampled.

6.6. Procedures for Statistical Analysis.

For each analyte, several statistics were calculated to include the number/percent of individual concentrations that exceeded the appropriate screening guideline threshold, the number/percent of non-detected and detected concentrations, the maximum or range of detected values, and descriptive characteristics of the mean, standard deviation, and/or 95% one-sided upper confidence limit (UCL) of the mean where appropriate.

For each water sample analyte, ANOVA was used to compare mean analyte concentrations among the islets. If the ANOVA returned a significant result, Tukey's post-hoc test was used to determine which islet(s) were different.

For tissue samples, ANOVA was used to compare concentrations among the islets as well as between the trophic levels. Interaction between region and trophic levels were tested to determine if the results of one factor were dependent on the results of another. If the Islet main effect result was significant, Tukey's post-hoc test was used to determine which regions were different. Since trophic level only had two levels, the ANOVA main effect result was enough to conclude whether a significant difference was present between the two trophic levels. If interaction between region and trophic level was statistically significant, the marginal means were investigated to interpret significant results among islets or between trophic levels.

For both water and tissue samples, significance was defined at a p-value less than 0.05.

Primarily due to the high number of non-detected values, most analyte data failed the assumptions required to perform ANOVA. If the proportion of detected values in the total sample and each component islet/trophic level subgroup was greater than 50%, ANOVA was performed and the value assigned for any non-detects was half the limit of quantitation (LOQ). No analysis was performed where the number of detects in the total sample and each component islet/trophic level subgroup was less than 25% (non-detects greater than 75%). If the overall proportion of detected values was between 25% and 50% (non-detects between 50% and 75%), regardless of the individual islet/trophic level subgroups' levels, samples were analyzed with a test of proportions to determine if one group had more detections than another.

6.7. Procedures for Human Health Risk Assessment.

As human health risk assessments should only consider those site-specific chemical exposure scenarios that actually occur, or that could realistically occur in the future, possible exposure pathways were considered. In the Marshallese community, fish are consumed in a variety of ways based on family status, personal preference and type of fish. For example, the head of the house may consume eyes or other delicacies while the remaining family members consume only muscle tissue or the balance of the fish. One family may prefer to eat whole fish, while another may remove less desirable parts before consumption. The guts of one fish species may not be preferred, while the guts of a different fish may be considered a delicacy. No individuals consume only select portions of fish (e.g., eyeballs, liver) without also consuming muscle fillet. Thus, there is no need to know of the risks or hazards associated with the consumption of individual fish tissues given the fact that fish consumption practices are so diverse on Kwajalein and whole fish analyses include inputs from isolated tissue types. For these reasons, whole fish samples were analyzed for contaminant accumulation.

Marshallese adults who commute to Kwajalein for work may fish in the harbor and transport these fish to their homes on Ebeye. Therefore, both Marshallese adults and children were evaluated as receptors in the human health risk assessment. Although more likely to fish on the ocean side of the islet, adult U.S. residents living on Kwajalein were evaluated in the risk assessment; however, U.S. children were not considered as they do not consume fish from the harbor.

Of the possible exposure pathways considered (see Figure 6.7.1), it was determined that only the fish consumption pathway would be included in the risk assessment.

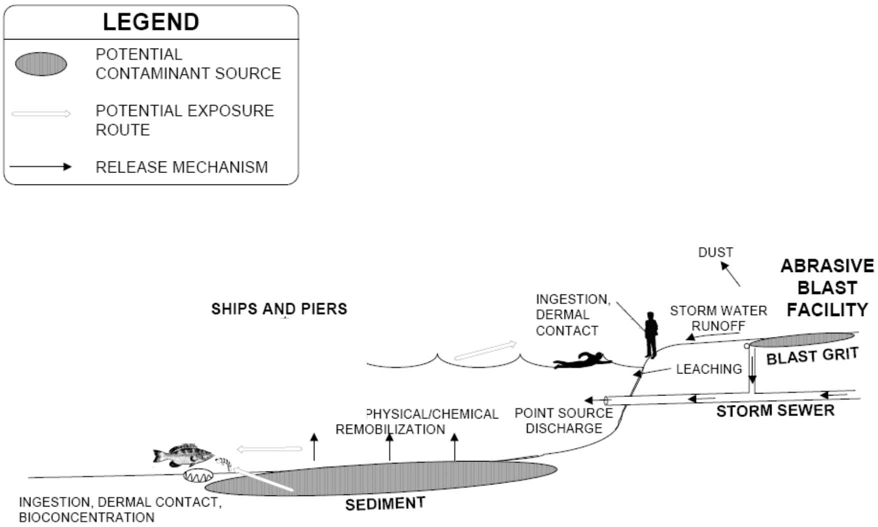

Figure 6.7.1. Conceptual Site Model for Human Health Risk Assessment.

The four-step USEPA Superfund (Comprehensive Environmental, Response, Compensation, and Liability Act or CERCLA) human health risk assessment process was used for the human health risk assessment (USEPA, 1989). Prior to the start of the field work, the Hazard Identification step had already been partially applied; a preliminary list of contaminants of potential concern, reflecting former site-specific activities at the harbor had been identified. To complete this step, concentrations of contaminants in fish tissue and water were screened against relevant risk-based benchmarks (RSLs for fish ingestion) to establish a complete COC list. The Exposure Assessment step established the exhaustive list of relevant human receptors at the study areas, as well as their complete pathways of exposure and frequency and duration of exposures. The Toxicity Assessment step identified the availability of toxicity factors (e.g., cancer slope factors) necessary for calculating risks and hazards. The Risk Characterization step estimated the magnitude of the potential adverse health effects under investigation and integrated the earlier steps to render cancer risk levels and noncancer hazard levels for the various receptors. As per CERCLA and UES requirements (section 3-6.5.8), cancer risks in excess of 1E-04 and hazard indices (HI) in excess of 1.0 are deemed unacceptable.

7. RESULTS.

7.1. Community Survey Results.

Descriptive statistics were obtained to illustrate how abundant the target fishes were at each sample site and by islet. A summary for each islet appears in the following sections; comprehensive data tables are available upon request.

7.1.1. Kwajalein.

Kwajalein islet is the largest of the USAG-KA islets, at 303 hectares (ha) (748 acres [ac]), and supports the highest human population of all the islets. The islet lies at the southern tip of the atoll and serves as the primary base of operations and distribution center for activities at USAG-KA. The reef fish sampling took place on the lagoon side of the islet, within the harbor and at the seaward end of Echo Pier. The coral reef can be characterized as patchy along the harbor floor and located within a low wave-energy environment. The reef fish survey took place on the lagoon-facing reef adjacent to the central and north side of the islet, extending between a beach west of the main harbor and a small dock farther west along the shoreline. About 400 m from shore, a steep wall (~8 m) in height has continued to support a thriving coral reef community, which included many juvenile reef fish and sponge species.

Seventy-five species of reef fish from twenty-one families were observed along the belt transects, with an average density of 0.03/m^2. This islet had the lowest reported fish density for this study, but the highest species richness. The two most common species encountered along the transect were the fusilier *Pterocaesio tile* and wrasse *Pseudocheilinus hexataenia*, neither of which were targets for the contaminants sampling. Of the target species selected before the fieldwork, five species of carnivores, three species of detritivores and four herbivores from the list were recorded along the transect.

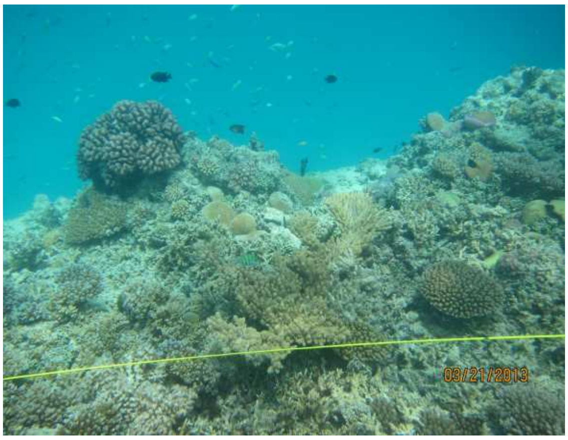

Figure 7.1.1.1. Kwajalein Harbor reef fish survey transect line and representative species from the islet.

7.1.2. Meck.

Meck is a 22.2-ha (55-ac) highly developed islet on the eastern side of the atoll. The eastern three quarters of the islet consists of an abandoned airfield and various buildings and the majority of Meck's coastline is composed of rip-rap. Reef fish sampling took place on the lagoon side (east) of the islet, and directly adjacent to the harbor. The reef fish survey took place along the south side of the harbor, along the reef flat. The reef flat supports a high density of corals, invertebrates and reef fish.

Fifty-four species of reef fish from twenty families were observed along the belt transects, with an average density of 0.03/m^2. The two most common species encountered along the transect were the damselfish *Chromis viridis* and the parrotfish *Chlororus sordidus*. *C. sordidus* was on the original list of species to be targeted because it was previously observed to be common around the islet. Of the target species selected before the fieldwork, six species of carnivores, two species of detritivores and six herbivores from the list were recorded along the transect.

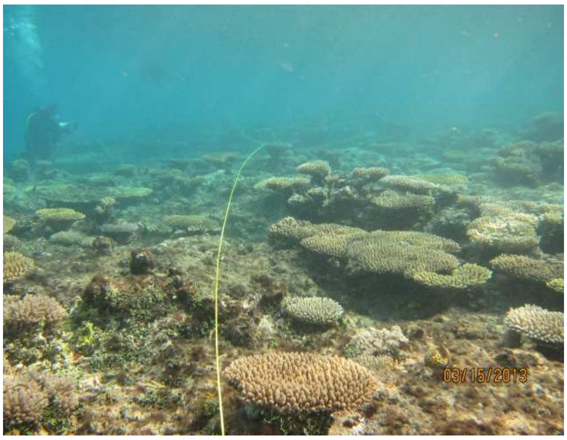

Figure 7.1.2.1. Meck reef fish survey transect line and representative species from the islet.

7.1.3. Illeginni.

Illeginni is a 12.5-ha (31-ac) islet on the western side of the atoll, that currently houses antenna towers, buildings, and a helicopter pad. The reef fish sampling and surveys were all conducted within the protected harbor. There is a northwest-facing entrance to the harbor on the lagoon side of the islet. The natural reef forms two sides of the harbor with a middle sandy bottom with patches of coral throughout. The dominant coral genus is *Acropora* spp., with the highly branched morphology providing ample habitat for targeted reef fish species.

Sixty species of reef fish from twenty-two families were observed along the belt transects, with an average density of 0.05/m^2. The two most common species encountered along the transect were the wrasse *Thalasoma quinquevittatum* and the damselfish *Dascyllus aruanus*, neither of which were targets for the study sampling. Of the target species selected before the fieldwork, five species of carnivores, one detritivore and eight herbivores from the list were recorded along the transect.

Figure 7.1.3.1. Illeginni reef fish survey transect line and representative species from the islet.

7.1.4. Ellep.

Ellep is an uninhabited islet that is not utilized by USAG-KA. It is located on the western side of the atoll between Illeginni and Legan. The reef fish sampling and survey took place along the lagoon-facing reef flat and shallow slope on the eastern side of the islet, but not within the spur and groove system. Stony coral cover was moderate to high with relatively moderate reef rugosity, including overhangs and holes. Corals present with table or plate morphology also provided habitat for the targeted reef fish species.

Forty-four species of reef fish from nineteen families were observed along the belt transects, with an average density of 0.09/m^2. This islet had the highest reported fish density for this study, but the lowest species richness. The two most common species encountered along the transect were the damselfish *Stegastes nigricans* and the cardinalfish *Apogon quinquelineatus*, neither of which were targets species. Of the target species selected before the fieldwork, three species of carnivores, three species of detritivores and seven herbivores from the list were recorded along the transect.

Figure 7.1.4.1. Ellep reef fish survey transect line and representative species from the islet.

7.1.5. Jerak.

Jerak is an uninhabited islet that is not leased by USAG-KA. It is located on the western half of the atoll and to the west of Illeginni. The reef fish sampling and survey took place along the lagoon-facing reef flat and shallow slope on the northern side of the islet, but not within the spur and groove system. Stony coral cover was moderate to high with relatively moderate reef rugosity, including overhangs and holes. Corals present with table or plate morphology also provided habitat for the targeted reef fish species.

Sixty-six species of reef fish from twenty-one families were observed along the belt transects, with an average density of 0.04/m^2. The two most common species encountered along the transect were an unidentified school of juvenile parrotfish (reported as *Scarus* spp.) and the damselfish *Amblyglyphidodon curacao*, the latter of which was not a target for the contaminants sampling. Of the target species selected before the fieldwork, four species of carnivores, three species of two species of detritivores, and seven herbivores from the list were recorded along the transect.

Figure 7.1.5.1. Jerak reef fish survey transect line and representative species from the islet.

Table 7.1.1. List of Types of Fish Sampled.

Family Name	Scientific Names	Common Name	Trophic Class
BALISTIDAE	*Rhinecanthus aculeatus, Rhinecanthus rectangulus, Sufflamen chrysoptera, Balsitapus undulates*	Triggerfishes	Carnivores
CAESONIDAE	*Pterocaesio tile*	Fusiliers	
CARANGIDAE	*Caranx melampygus, Carangoides orthogrammus, Trachinotus bailloni*	Jacks	
CHAETODONTIDAE	*Chaetodon auriga, Chaetodon citrinellus, Chaetodon ephippium, Chaetodon lunula, Chaetodon lunulatus, Chaetodon ornatissimus, Chaetodon reticulatus, Chaetodon trifascialis, Heniochus acuminatus, Heniochus chrystomus*	Butterflyfishes, bannerfishes	
HOLOCENTRIDAE	*Myripristis berndti, Neoniphon samara, Sargocentron diadema, Sargocentron spiniferum*	Squirrelfishes, soldierfishes	
KYPHOSIDAE	*Kyphosus vaigiensis*	Chubs	
LABRIDAE	*Cheilinus fasciatus, Cheilinus trilobatus, Coris aygula, Halichoeres hortulanus, Halichoeres marginatus, Oxycheilinus digrammus, Thallasoma hardwicke, Thallasoma lunare*	Wrasses	
LETHRINIDAE	*Lethrinus amboinensis, Lethrinus obsoletus, Lethrinus olivaceus, Lethrinus xanthochilus*	Emperors, breams	
LUTJANIDAE	*Aphareus rutilans, Lutjanus fulvus, Lutjanus gibbus, Lutjanus kasmira, Macolor macularis*	Snappers	
MONACANTHIDAE	*Alutera scriptus*	Filefish	

Table 7.1.1. List of Types of Fish Sampled (continued).

Family Name	Scientific Names	Common Name	Trophic Class
MULLIDAE	*Mulloidichthys vanicolensis, Parupeneus barberinus, Parupeneus cyclostomus, Parupeneus multifasciatus*	Goatfishes	Carnivores
SERRANIDAE	*Anyperodon leucogrammus, Cephalopholis cyanostigma, Cephalopholis urodeta, Epinephalus fuscoguttatus, Epinephalus melanostigmus, Epinephalus merra, Variola albimargiata*	Groupers	
ACANTHURIDAE	*Acanthurus lineatus, Acanthurus nigricans, Acanthurus nigrofuscus, Acanthurus nigroris, Acanthurus olivaceus, Acanthurus pyroferus, Acanthurus triostegus, Acanthurus xanthopterus, Ctenochaetus striatus, Zebrasoma scopas, Zebrasoma veliferum, Naso brevirostris, Naso lituratus*	Surgeons, unicorns	Herbivores
POMACANTHIDAE	*Centropyge flavissima, Pygoplites diacanthus*	Angelfish	
POMACENTRIDAE	*Abudefduf septemfasciatus, Chrysiptera traceyi, Stegastes nigricans*	Damselfish	
SCARIDAE	*Cetoscarus bicolor, Chlororus microrhinos, Chlororus sordidus, Hipposcarus longiceps, Scarus frenatus Scarus ghobban, Scarus oviceps, Scarus psittacus, Scarus rubroviolaceus, Scarus schlegeli*	Parrotfishes	
SIGANIDAE	*Siganus argenteus, Siganus puellus*	Rabbitfishes	

7.2. Analytical Results.

The analytical methods (Table 7.2.1) were chosen because they had LOQs that were less than or equal to the screening and risk assessment guidelines for most of the contaminants. Criteria for the remaining contaminants were lower than achievable quantitation limits. A large portion of the laboratory data was reported as non-detects, thus precluding the use of most statistical manipulations which require the data to be normally distributed. Also, the fact that some of the COPCs were not able to be detected at concentrations that were lower than the screening guidelines could have caused some exceedances to be missed. Some of these contaminants might have been evaluated as COCs in the human health risk assessment had their LOQs been lower than the screening guidelines to which they would have been compared. In contrast, when detected, contaminants were often present in high concentrations and were, therefore, unaffected by the higher than desired detection limits. It would not have been appropriate to carry the COPCs with higher than desired detection limits through to the risk assessment in an effort to be conservative. Only contaminants that were present in concentrations that exceeded relevant screening criteria and were detected in more than 5% of the samples were evaluated in the risk assessment.

Table 7.2.1. List of Analytical Methods Used.

Analyte	Method	Laboratory
PESTICIDES		
Water	Gas Chromatography/Electron Capture Detectors (EPA 8081B/8082A, modified)	ALS Environmental
Tissue	Gas Chromatography/Electron Capture Detectors (EPA 8081B/8082A, modified)	Battelle-Duxbury
PCBs		
Water	Gas Chromatography/Electron Capture Detectors (EPA 8081B/8082A, modified)	ALS Environmental
Tissue	Gas Chromatography/Electron Capture Detectors (EPA 8081B/8082A, modified)	Battelle-Duxbury
METALS		
Water	Inductively-Coupled Plasma Mass Spectrometry (EPA 1640, modified)	Brooks Rand Laboratory
Tissue	Inductively-Coupled Plasma Mass Spectrometry (EPA 1638)	Brooks Rand Laboratory

Due to the size of this sampling endeavor, full analytical results for all contaminants are not presented; however, the data are available upon request. Summary tables for the matrices and analytical groups are presented in the following sections.

7.2.1. Concentration of Metals in Surface Water

Nearly all of the five metals of interest (chromium, copper, lead, nickel and zinc) were detected in nearly all of the water samples. However, none of the metals were present in concentrations that exceeded the UES water quality criteria. There were some random differences among the five study areas, but the only significant differences were that concentrations of copper and zinc in Kwajalein Harbor water samples were higher than concentrations measured in samples from most of the other islets.

Table 7.2.1.1. Summary Concentration Ranges of Metals in Water.

Metals (µg/L)	Water Quality Criteria (µg/L)		Kwajalein Harbor	Meck	Illeginni	Jerak	Ellep	Significant differences between areas
	Chronic	Acute						
Chromium*	50	1100	0.15-0.23	0.15-0.24	0.17-0.22	0.16-0.30	0.16-0.31	None
Copper	3.1	4.8	0.21-0.68	0.08-0.15	0.07-0.09	0.05-0.06	0.05-0.07	KH > MK, IL, JE & EL; MK > JE, EL
Lead	8.1	210	0.075-2.10	0.018-0.26	0.058-4.20	0.012-5.4	0.015-1.4	None
Nickel	8.2	74	0.17-0.32	0.17-0.25	0.17-0.27	0.17-0.26	0.16-0.28	None
Zinc	81	90	0.48-2.30	ND-0.67	ND-0.55	ND-1.10	0.29-1.80	KH > MK, IL, JE

Maximum concentration detected
*Only available Cr criteria are for Cr(VI)
ND=Not detected, KH=Kwajalein, MK=Meck, IL=Illeginni, JE=Jerak, EL=Ellep

7.2.2. Concentration of Pesticides in Surface Water

There were very few pesticides detected in the water samples. Only 2 of the 31 analytes had any detected levels, and those were only detected in 3-4 of the 30 water samples for each analyte. Where there were screening guidelines, concentrations of aldrin were detected below the LOQ and there were no exceedances. For the other fourteen analytes that had screening guidelines, the LOQ was above the guideline so no comparisons or conclusions could be made from the data regarding exceedance. Table 7.2.2.1 contains the range of pesticide concentrations measured in water for each islet.

Table 7.2.2.1. Summary Concentration Ranges of Pesticides in Water.

Pesticide (ng/L)	Water Quality Criteria (ng/L)		Kwajalein Harbor	Meck	Illeginni	Jerak	Ellep
	Chronic	Acute					
beta-HCH			ND	ND-0.92	ND-1.6	ND-2.4	ND
trans-nonachlor			ND	ND	ND-0.41	ND-0.29	ND

Maximum concentration detected ND=Not detected

7.2.3. Concentration of PCBs in Surface Water

There were no detected PCBs in any of the water samples. Since the LOQ was less than the screening guideline, there is no concern that true detections were missed due to detection limit constraints.

7.2.4. Concentration of Metals in Fish Tissue.

Nearly all of the metals were detected in nearly all of the fish tissue samples; however, concentrations of metals did not exceed RSLs in any of the analyzed fish samples. Therefore, none of the metal contaminants were carried further in the risk assessment process. As there is no screening guideline for lead and children are particularly susceptible to lead exposure, a separate model was used to assess risk from lead accumulation in fish (detailed in section 7.3.3).

In general, concentrations of metals in herbivorous fish samples were consistently higher than carnivorous fish concentrations. Table 7.2.4.1 contains the range of concentrations measured in fish tissue for each islet.

Table 7.2.4.1. Summary Concentration Ranges of Metals in Fish Tissue.

Metals (mg/kg)	Regional Screening Level (mg/kg)	Kwajalein Harbor	Meck	Illeginni	Jerak	Ellep
Chromium	2000	ND-1.50	0.049-0.74	0.034-0.51	0.04-2.40	0.040-1.30
Copper	54	0.40-15.00	0.54-3.80	0.35-3.50	0.51-2.00	0.33-1.20
Lead		0.005-26.00	0.022-29.00	0.008-7.20	0.013-3.4	0.15-6.10
Nickel	27	ND-0.77	ND-1.50	ND-1.40	ND-4.10	0.06-1.10
Zinc	410	10-140.00	8.4-100.00	7.6-130.00	4.9-130.00	5.4-34.00

[shaded] Maximum concentration detected ND=Not Detected

7.2.4.1. Chromium. Concentrations in Meck fish were higher than samples from each of the other islets, accounting for trophic level. Regardless of islet, herbivorous fish concentrations were consistently higher than concentrations measured in carnivores.

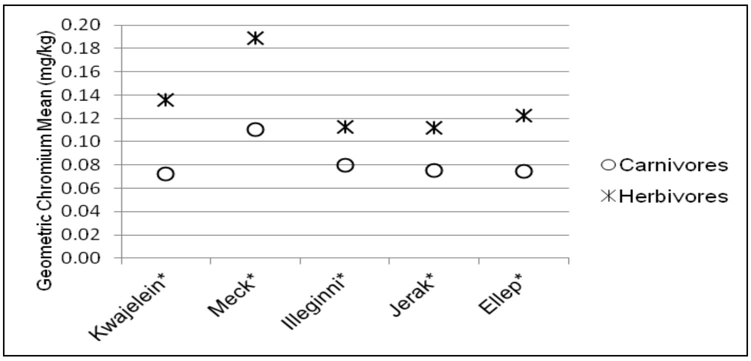

Figure 7.2.4.1.1. ANOVA Results for Chromium in Fish (*Statistical difference with at least one other islet).

7.2.4.2. Copper. Fish concentrations from every islet were higher than on Ellep, accounting for trophic level. At the greatest concentration, Meck fish concentrations were also higher than concentrations measured in fish from Jerak. Sample concentrations from Kwajalein, Meck, and Illeginni were not different from each other. There were no significant differences by trophic level.

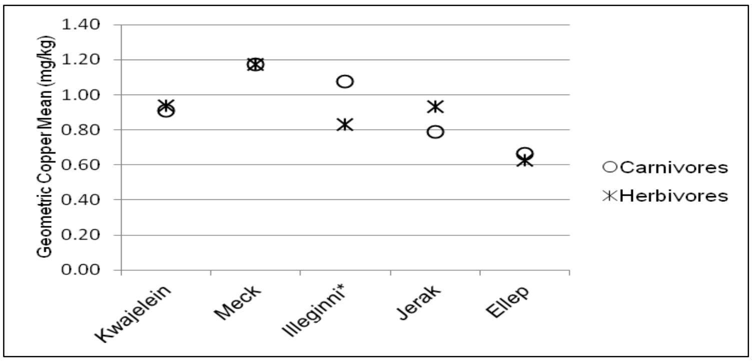

Figure 7.2.4.2.1. ANOVA Results for Copper in Fish (*Statistical difference with at least one other islet).

7.2.4.3. Lead. Within the islets, concentrations of lead in herbivores was significantly higher than carnivores in Kwajalein and Meck. This was not true for Illeginni, Jerak, or Ellep, where the carnivores showed higher concentrations, although not significantly higher than the herbivores. Within the carnivores, the lead concentration on Ellep was higher than concentrations on each of the other islets. Illeginni and Jerak were also higher than Kwajalein. For the herbivorous fish concentrations, Kwajalein, Ellep and Meck were each greater than both Illeginni and

Jerak. While Kwajalein concentrations were higher than Ellep and Meck, this difference was not statistically significant.

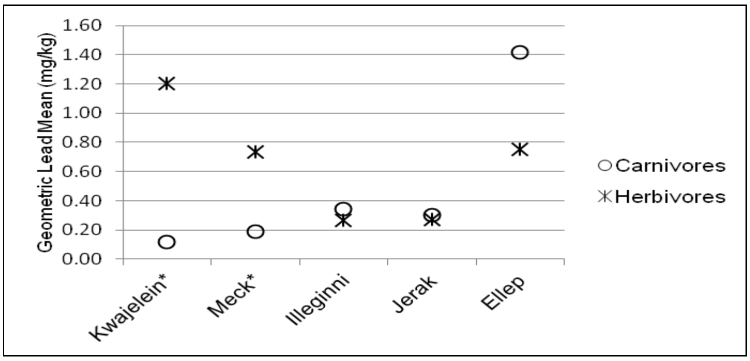

Figure 7.2.4.3.1. ANOVA Results for Lead in Fish (*Statistical difference with at least one other islet).

7.2.4.4. Nickel. Among the islets, herbivores had significantly higher nickel concentrations than carnivores in Jerak and carnivores were higher than herbivores collected from Illeginni. Within the carnivores, the nickel concentrations on Meck and Illeginni were not significantly different than each other, but were both higher than concentrations on each of the three other islets. In the herbivores, Kwajalein Harbor fish had the lowest concentrations and each of the other four islets was significantly higher. In addition, with the greatest concentration, Meck was also higher than Illeginni and Jerak.

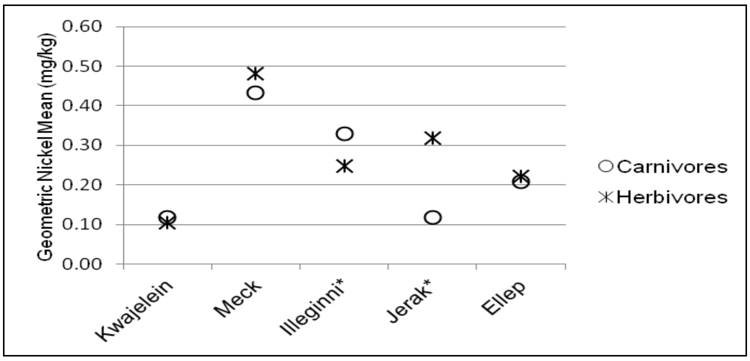

Figure 7.2.4.4.1. ANOVA Results for Nickel in Fish (*Statistical difference with at least one other islet).

7.2.4.4. Zinc. Within each islet, concentrations of zinc in carnivorous fish were significantly higher than those measured in herbivores. Within the carnivores, there were no significant differences by islet, but within herbivores, Kwajalein, Meck, and Illeginni were all higher than Ellep and Jerak.

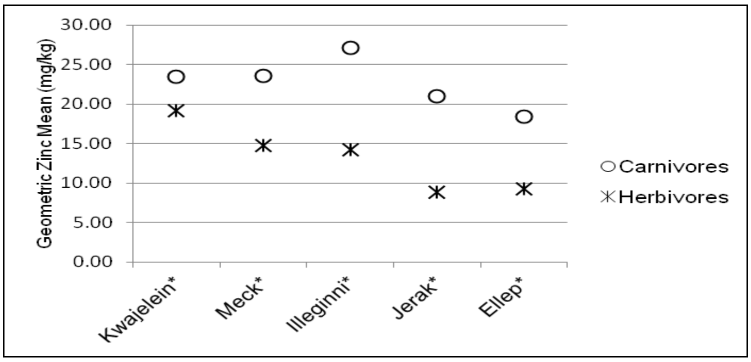

Figure 7.2.4.5.1. ANOVA Results for Zinc in Fish (*Statistical difference with at least one other islet).

7.2.5. Concentrations of Pesticides in Fish Tissue

Of the 31 pesticides analyzed for this study, 15 were not detected in the majority of the samples (percent non-detects greater than 90% of the 360 samples overall and 75% of any particular islet-trophic level subgroup). Among the 16 pesticides with a sufficient number of detections, proportion tests showed that Kwajalein Harbor fish data had a higher percent of detects than Meck, Illeginni, or both in about half of the analytes. In two cases (heptachlor epoxide and hexachlorobenzene), fish data from other islets had a higher proportion of detects than what was calculated for Kwajalein Harbor fish samples.

Table 7.2.5.1. Summary of Pesticide Comparisons in Fish Tissue.

Analytes with Total Non-Detects >90%	**Analytes with 50-90% Non-Detects**	
(No Analysis)	**Analyte**	**Proportion Test General Findings**
Aldrin alpha-HCH beta-HCH delta-HCH Endosulfan I Endosulfan II Endrin Endrin ketone gamma-HCH Heptachlor Methoxychlor Mirex 2,4'-DDE 2,4'-DDT Toxaphene	Chlorpyrifos Endosulfan sulfate 2,4'-DDD 4,4'-DDD 4,4'-DDT	KH > all others; no other significant differences
	cis-Nonachlor	KH > IL & MK >JE, EL
	alpha-chlordane	KH & IL > MK, JE, EL
	Chlordane Trans-Nonachlor	KH, MK & IL > JE, EL
	Dieldrin	KH > IL, JE, EL; MK> JE, EL
	Endrin aldehyde	KH & MK > IL, JE, EL
	gamma-Chlordane	KH > IL > MK, JE, EL
	Heptachlor epoxide	IL > MK, KH, EL; JE > KH, EL
	Hexachlorobenzene	MK & IL > JE, KH, EL
	Oxychlordane	KH & IL > MK > JE, EL
	4,4'-DDE	KH all others; MK > IL, JE, EL; IL > EL

KH=Kwajalein, MK=Meck, IL=Illeginni, JE=Jerak, EL=Ellep

Screening guidelines were only available for 15 of the 31 pesticides and eight of these pesticides showed detections above the RSLs. Overall, there were few detects in the pesticide data and very few exceedances. Since concentrations of nine pesticides exceeded RSLs for fish ingestion, they were carried into the risk assessment process. The ranges of fish tissue data are presented in Table 7.2.5.2; the analytes with reported concentrations that exceeded screening guidelines are listed in bold.

Table 7.2.5.2. Summary Concentration Ranges of Pesticides in Fish Tissue.

Pesticides (µg/kg)	Regional Screening Level (µg/kg)	Kwajalein Harbor	Meck	Illeginni	Jerak	Ellep
Aldrin	0.19	ND-8.6	ND-0.11	ND-0.38	ND	ND-0.16
a-BHC		ND	ND	ND-1.1	ND-3.4	ND
b-BHC		ND-0.16	ND-0.41	ND-0.67	ND-0.67	ND
d-BHC		ND-7.2	ND-5	ND-1.2	ND	ND
alpha-Chlordane		ND-25	ND-0.52	ND-6.8	ND-0.19	ND
gamma-Chlordane		ND-5.4	ND-0.46	ND-0.94	ND-3.1	ND
Chlordane	9	ND-360	ND-15	ND-54	ND-17	ND-9
Chlorpyrifos	1400	ND-9.2	ND-0.78	ND-14	ND-3.6	ND-4.2
2,4'-DDD		ND-20	ND-0.24	ND-1.7	ND	ND
2,4'-DDE		ND-2.7	ND	ND-2.7	ND	ND-4.5
2,4'-DDT		ND-6.2	ND-2	ND-0.41	ND	ND
4,4'-DDD	13	ND-18	ND-0.17	ND-3.6	ND	ND
4,4'-DDE	9.3	ND-36	ND-1.1	ND-1.7	ND-0.15	ND
4,4'-DDT	9.3	ND-160	ND-1.2	ND-1.6	ND-120	ND-4.1
Dieldrin	0.2	ND-14	ND-1.4	ND-1.3	ND-0.05	ND
Endosulfan I	8100	ND-2.3	ND-1.4	ND-2.2	ND	ND
Endosulfan II		ND-2.7	ND-0.24	ND-0.66	ND-1.4	ND-5.2
Endosulfan sulfate		ND-31	ND-0.23	ND-0.12	ND-1.2	ND
Endrin	410	ND-4	ND-0.24	ND	ND	ND
Endrin aldehyde		ND-2.4	ND-4.5	ND-0.55	ND	ND
Endrin ketone		ND-2.9	ND-0.28	ND	ND-4.7	ND
Heptachlor	0.7	ND-0.77	ND-0.58	ND-0.37	ND-6	ND-0.89
Heptachlor epoxide	0.35	ND-0.53	ND-0.97	ND-0.71	ND-0.32	ND
Hexachlorobenzene	2.0	ND-0.93	ND-1.1	ND-0.57	ND-0.56	ND-0.22
Lindane		ND-0.38	ND-0.28	ND-1.7	ND-0.23	ND
Methoxychlor	6800	ND-11	ND-8.2	ND-7.2	ND-0.68	ND
Mirex	0.18	ND-0.17	ND-0.2	ND	ND	ND
cis-Nonachlor		ND-20	ND-1.3	ND-6.1	ND	ND
trans-Nonachlor		ND-76	ND-4.1	ND-14	ND-0.39	ND-3.2
Oxychlordane		ND-27	ND-0.93	ND-5	ND	ND
Toxaphene	2.9	ND	ND	ND	ND	ND

Maximum concentration detected (light blue)
Maximum concentrations exceeded screening guideline for fish ingestion (red)

ND=Not detected

Laboratory analysis of chlordane is difficult because of variations in both the number and composition of constituents in weathered chlordane and due to interferences with other organic compounds. Chlordane was analyzed in the laboratory by first quantifying a chlordane standard then comparing the results of individual isomers in a standard calibration curve (a-chlordane, g-chlordane, trans-nonachlor, cis-nonachlor, and heptachlor) to the mixture. From this comparison, a multiplier was determined in order to relate the response factors of these individual components back to the chlordane. The multiplier related the response in the chlordane standard back to the specific peaks selected to be representative of the chlordane mixture. Therefore, the concentrations of chlordane were calculated and not directly measured. This led to times when chlordane was detected in a given sample even though some of the main isomers were not detected.

Based on the fact that cis-chlordane and trans-nonachlor are the most abundant and persistent of the chlordane components measured in fish (Ribbick and Zajicek, 1983), chlordane fish data were re-examined upon receipt. Samples with calculated chlordane concentrations that did not show detection of both alpha-chlordane and trans-nonachlor were discounted and were removed from the data set prior to inclusion in the risk assessment. Of the 360 fish samples collected for pesticide analysis, 189 chlordane samples were removed in this data validation step. Chlordane concentrations were, therefore, biased on the high side. The extent to which this may have affected the risk assessment results is minimal.

7.2.6. Concentrations of PCBs in Fish Tissue

In examining the PCB levels among the fish tissue samples, there was a very high level of non-detects. Of the nine Aroclor PCBs analyzed, five of them had non-detects for the entire sample set, likely due to the fact that the LOQ was relatively high compared to concentrations. Furthermore, the LOQ exceeded the screening guidelines in nearly all cases so no conclusions about the degree of contamination could be determined. In general, however, of the four islets where PCBs were detected, the percentage of detections was higher in Kwajalein. Carnivores had a significantly higher proportion of detects than herbivores for Aroclor 1242, 1254 and 1260 in Kwajalein Harbor.

Table 7.2.6.1. Summary of PCB Comparisons in Fish Tissue.

Characteristic	Aroclors 1221, 1232, 1248, 1262, 1268	Aroclor 1016	Aroclor 1242	Aroclor 1254	Aroclor 1260
Detection	No Detections	KH only	KH only	KH, MK, IL, JE	KH, MK, IL
Percent of Samples Detected (%)		3.3	30.8	KH: 70.0 MK: 50.0 IL: 33.3 JE: 7.4	KH: 83.3 MK: 8.0 IL: 1.1
Significant Differences in Proportion of Detects		N/A	KH > all other	KH > all other; MK not > IL; MK, IL > JE , EL; JE > EL	KH > all other

KH=Kwajalein, MK=Meck, IL=Illeginni, JE=Jerak, EL=Ellep

Of the PCB compounds, four were present in concentrations that exceeded the screening guidelines for fish ingestion. The highest concentrations were detected for Aroclor 1254 and 1260. As these PCBs were present in concentrations that exceeded the associated RSLs, they were carried through to the risk assessment as COCs along with Aroclor 1016 and 1242 for Kwajalein. No PCBs were detected in Ellep fish and only Aroclor 1254 was detected in fish collected from the other uninhabited islet, Jerak. The ranges of fish tissue data are presented in Table 7.2.6.2; the four analytes with reported concentrations that exceeded screening guidelines are highlighted in bold.

Table 7.2.6.2. Summary Concentration Ranges of PCBs in Fish Tissue.

PCBs (µg/kg)	Regional Screening Level (µg/kg)	Kwajalein Harbor	Meck	Illeginni	Jerak	Ellep
Aroclor 1016	45	ND-1500	ND	ND	ND	ND
Aroclor 1221	1.6	ND	ND	ND	ND	ND
Aroclor 1232	1.6	ND	ND	ND	ND	ND
Aroclor 1242	1.6	ND-1200	ND	ND	ND	ND
Aroclor 1248	1.6	ND	ND	ND	ND	ND
Aroclor 1254	1.6	ND-3200	ND-120	ND-55	ND-140	ND
Aroclor 1260	1.6	ND-1500	ND-130	ND-33	ND	ND
Aroclor 1262		ND	ND	ND	ND	ND
Aroclor 1268		ND	ND	ND	ND	ND

[red box] Maximum concentration exceeded screening guideline for fish ingestion
ND=Not detected

The highest Aroclor 1254 concentrations from Kwajalein Harbor fish were ranked to determine if data from certain fish species indicated a trend in accumulation. Seven of the top 10 concentrations were measured in lei triggerfish (*Rhinecanthus aculeatus*), two were from honeycomb grouper samples (*Epinephalus merra*) and the remaining high concentration was detected in a blacktail snapper (*Lutjanus fulvus*) sample. Figure 7.2.6.1 shows these three carnivorous species.

Figure 7.2.6.1. Kwajalein Harbor Species with Highest PCB Contamination (Top left – Lei triggerfish (*Rhinecanthus aculeatus)*, Top right – Honeycomb grouper (*Epinephalus merra*), Bottom – Blacktail snapper (*Lutjanus fulvus*)).

7.2.7. Percent Lipids. In an effort to determine the correlation between fat content in fish and the concentration of accumulated contaminants, the percent lipid content of each sample was measured. The average percent lipids ranged from 2.24 to 3.88 however this number varied widely among the samples, with standard deviations as large as the means. Overall herbivores had a significantly greater percent of lipids in their tissue than carnivores. Due to the variance in the data, strong correlations between percent lipids and organic contaminant concentrations were not calculated.

7.3. Human Health Risk Assessment.

The previous Results sections highlighted the contaminants that were present in fish samples in concentrations that exceeded screening guidelines for fish ingestion. These contaminants were further considered in the human health risk assessment; however, contaminants for which there are no available RSLs were not able to be evaluated.

The first step in the risk assessment, the Exposure Assessment, established the list of relevant human receptors, as well as their specific pathways of exposure and frequency and duration of exposures. Although fishing is prohibited in Kwajalein Harbor, anecdotal evidence indicates that some Marshallese workers and Kwajalein residents continue to fish. It is said that the Americans who fish in the harbor do so to a far lesser degree than the Marshallese workers, who may fish before/after work or during their lunch break. Opportunities do not really exist for either population to have extensive contact with harbor water or sediment; consequently, the fish consumption pathway was most important in the risk assessment. Marshallese children may ingest harbor-caught fish, but they do not usually travel to Kwajalein and do not generally come in contact with harbor sediment or water. Instead, they may consume fish that were brought home to them from Kwajalein. Marshallese adults may also travel to non-developed islets such as Ellep and Jerak, but the American adults will likely only consume fish from one of the three USAG-KA-utilized islets. Most American adults living on Kwajalein do not have the opportunity to travel to Meck or Illeginni with any regularity, so the fraction of fish deriving from these islets was reduced compared to the Kwajalein models. Table 7.3.1 summarizes the inputs used in the assessment of risk for all receptors.

Table 7.3.1. Exposure Assumptions Used in the Human Health Risk Assessment for the Fish Ingestion Pathway.

Exposure Variable	Receptors		
	Marshallese Adult	Marshallese Child	U.S. Adult
Fish Ingestion Rate (grams/day)	54, 132	16	54
Fraction of Fish Diet Deriving from Contaminated Source (%)	50, 75	50, 75	10 – Kwajalein, 5 – Meck/Illeginni
Exposure Duration (years)	30, 70	6	1
Exposure Frequency (meals/year)	350	350	350
Body Weight (kg)	70	15	70

As a second component of the Exposure Assessment, the list of contaminants of potential concern was determined. This was accomplished through several contaminant screening exercises. First, contaminants were evaluated to determine the frequency of detection (FOD) of each contaminant in fish tissue data. Only contaminants that were detected in more than 5% of the sample set were carried further in the risk assessment process. For example, in the Kwajalein Harbor data set, there were four samples in which the concentration of Aroclor 1016 was detected. Given that there were 120 fish samples collected from the harbor, this indicated that the contaminant was detected in only 3% of the samples. Therefore, this contaminant and others that did not pass this initial 5% FOD screening requirement, were not considered further in the risk assessment. Secondly, the maximum detected concentration of each contaminant that passed the FOD requirement was compared to the RSL for fish ingestion. Only contaminants with maximum concentrations that exceeded the available screening guidelines were carried through to the risk assessment as contaminants of concern.

Wherever possible, the risk assessors used site-specific information to derive the exposure inputs. USEPA default fish consumption rates (national average of 17.5 grams/day for recreational fishers) were not used in the risk assessment in an effort to be protective of two unique ethnic groups and lifestyles. The risk assessor used best professional judgment to select a fish ingestion rate (IR) of 54 grams/day that would accurately reflect the cultural and regional affinity for fish, since fish is so prevalent in the diet of both U.S. citizens living on Kwajalein and Marshallese workers. The 95th percentile fish consumption rate for the general U.S. population is 63 grams/day, so the fish ingestion rate used in the risk assessment was a conservative one. To be protective of Marshallese individuals who may follow a subsistence lifestyle, a subsistence fish consumption scenario (IR of 132 grams/day) was also evaluated. In a 2006 survey of the Republic of the Marshall Islands, 1% of working age residents of Ebeye responded that they did some type of subsistence activity while 10% of households said they rely primarily on local sources of protein. Ebeye residents were shown to be more dependent on imported sources of food than any other island in the Marshall Islands (RMI, 2006). This is likely due to the fact that Ebeye and Majuro are more modern, urban areas while the outer islands tend to be more rural, subsistence sectors. Despite the results of the survey, the risk assessor chose to err on the side of caution by evaluating risk using the USEPA default subsistence fish consumption rate.

The fraction of fish ingested (FI) that derived from Kwajalein Harbor was 10% for American adults while Marshallese adults were assigned 50% and 75% figures based on the fact that they commute to Kwajalein 5 of 7 days and consume harbor fish with greater frequency than the American population. These FI values were evaluated for both the default and higher subsistence fish consumption scenarios.

To be even more conservative, both a 30- and 70-year lifespan for the Marshallese worker were evaluated. One year and 30-year exposure durations were evaluated for U.S. citizens to reflect both short term and long term assignments on Kwajalein. Risk was assessed for each of the five islets using fish tissue data generated from the separate islets.

When the data were integrated to calculate cancer risks or noncancerous hazard**s** associated with the consumption of fish, risk outputs for consumption of fish from each islet were calculated. All results from the human health risk assessment are shown in Appendix D; summary information is provided in this section.

7.3.1. Assessment of Cancer Risks by Islet.

Table 7.3.1.1. Summary Results of Cancer Risk Assessment - Kwajalein.

Receptor	Variable Exposure Assumptions - Kwajalein			ILCR*
	Ingestion Rate (grams/day)	Dietary Fraction of Fish Ingested from Contaminated Source (%)	Exposure Duration (years)	
Marshallese Adult	54	50	30	**2.99E-04**
			70	**7.11E-04**
		75	30	**4.57E-04**
			70	**1.07E-03**
	132	50	30	**7.45E-04**
			70	**1.74E-03**
		75	30	**7.45E-04**
			70	**2.61E-03**
Marshallese Child	16	50	6	6.02E-05
		75		9.03E-05
U.S. Adult	54	10	1	7.26E-07
			30	2.18E-05

*Bold face values indicate unacceptable cancer risk (i.e., ILCR > 1.0E-04)

Table 7.3.1.2. Summary Results of Cancer Risk Assessment - Meck.

Receptor	Variable Exposure Assumptions - Meck			ILCR*
	Ingestion Rate (grams/day)	Dietary Fraction of Fish Ingested from Contaminated Source (%)	Exposure Duration (years)	
Marshallese Adult	54	50	30	2.84E-05
			70	6.63E-05
		75	30	4.26E-05
			70	9.94E-05
	132	50	30	6.94E-05
			70	**1.62E-04**
		75	30	6.94E-05
			70	**2.43E-04**
Marshallese Child	16	50	6	5.61E-06
		75		8.41E-06
U.S. Adult	54	10	1	3.38E-08
			30	1.10E-06

*Bold face values indicate unacceptable cancer risk (i.e., ILCR > 1.0E-04)

Table 7.3.1.3. Summary Results of Cancer Risk Assessment - Illeginni.

Receptor	Variable Exposure Assumptions - Illeginni			ILCR*
	Ingestion Rate (grams/day)	Dietary Fraction of Fish Ingested from Contaminated Source (%)	Exposure Duration (years)	
Marshallese Adult	54	50	30	3.38E-06
			70	7.78E-05
		75	30	5.06E-06
			70	1.18E-05
	132	50	30	8.25E-05
			70	**1.93E-04**
		75	30	8.25E-05
			70	**2.89E-04**
Marshallese Child	16	50	6	6.67E-06
		75		1.00E-05
U.S. Adult	54	10	1	4.02E-08
			30	1.21E-06

*Bold face values indicate unacceptable cancer risk (i.e., ILCR > 1.0E-04)

Table 7.3.1.4. Summary Results of Cancer Risk Assessment - Ellep.

Receptor	Variable Exposure Assumptions - Ellep			ILCR*
	Ingestion Rate (grams/day)	Dietary Fraction of Fish Ingested from Contaminated Source (%)	Exposure Duration (years)	
Marshallese Adult	54	50	30	4.92E-08
			70	6.56E-07
		75	30	7.38E-08
			70	1.72E-07
	132	50	30	1.20E-07
			70	2.81E-07
		75	30	1.20E-07
			70	4.21E-07
Marshallese Child	16	50	6	1.13E-07
		75		1.70E-07

*Bold face values indicate unacceptable cancer risk (i.e., ILCR > 1.0E-04)

Table 7.3.1.5. Summary Results of Cancer Risk Assessment - Jerak.

Receptor	Variable Exposure Assumptions - Jerak			ILCR*
	Ingestion Rate (grams/day)	Dietary Fraction of Fish Ingested from Contaminated Source (%)	Exposure Duration (years)	
Marshallese Adult	54	50	30	1.30E-05
			70	3.03E-05
		75	30	1.95E-05
			70	4.55E-05
	132	50	30	3.18E-05
			70	7.41E-05
		75	30	3.18E-05
			70	**1.11E-04**
Marshallese Child	16	50	6	3.00E-05
		75		4.49E-05

*Bold face values indicate unacceptable cancer risk (i.e., ILCR > 1.0E-04)

7.3.2. Assessment of Noncancer Risks by Islet. Many of the contaminants pose noncancer-related risks in addition to being carcinogenic. There are a wide variety of possible noncancer endpoints ranging from mild skin conditions to severe developmental delays. In addition to being a probable carcinogen, PCB exposure has been linked to cases of liver disease, adult onset jaundice, compromised immunity, low birth weight and thyroid disease (USEPA, 2013). Another contaminant of concern, chlordane, is a neurotoxin and exposure effects can include problems with memory, learning, thinking, sleeping, personality changes, depression, numbness in the extremities and headaches. It has been suggested that chronic exposure to chlordane can cause blood disorders (ATSDR, 1994).

An assessment of noncancer risks was conducted for the three USAG-KA-leased islets and Jerak. A noncancer evaluation was not needed for Ellep given that there were no contaminants for this endpoint that passed the quantitative assessment (i.e., were present in concentrations that exceeded screening guidelines for noncarcinogenic effects).

Table 7.3.2.1. Summary Results of Noncancer Risk Assessment - Kwajalein.

Receptor	Variable Exposure Assumptions - Kwajalein			HI*
	Ingestion Rate (grams/day)	Dietary Fraction of Fish Ingested from Contaminated Source (%)	Exposure Duration (years)	
Marshallese Adult	54	50	30	**1.72E+01**
			70	**1.72E+01**
		75	30	**2.58E+01**
			70	**2.58E+01**
	132	50	30	**4.20E+01**
			70	**4.20E+01**
		75	30	**4.20E+01**
			70	**6.3E0+01**
Marshallese Child	16	50	6	**1.70E+01**
		75		**2.55E+01**
U.S. Adult	54	10	1	**1.23E00**
			30	**1.23E00**

*Bold face values indicate unacceptable noncancer hazard (HI > 1.0)

Table 7.3.2.2. Summary Results of Noncancer Risk Assessment - Meck.

Receptor	Variable Exposure Assumptions - Meck			HI*
	Ingestion Rate (grams/day)	Dietary Fraction of Fish Ingested from Contaminated Source (%)	Exposure Duration (years)	
Marshallese Adult	54	50	30	**1.42E00**
			70	**1.42E00**
		75	30	**2.14E00**
			70	**2.14E00**
	132	50	30	**3.48E00**
			70	**3.48E00**
		75	30	**3.48E00**
			70	**5.22E00**
Marshallese Child	16	50	6	**1.41E00**
		75		**2.11E00**
U.S. Adult	54	10	1	5.09E-02
			30	5.09E-02

*Bold face values indicate unacceptable noncancer hazard (HI > 1.0)

Table 7.3.2.3. Summary Results of Noncancer Risk Assessment - Illeginni.

<table>
<tr><th rowspan="2">Receptor</th><th colspan="3">Variable Exposure Assumptions - Illeginni</th><th rowspan="2">HI*</th></tr>
<tr><th>Ingestion Rate (grams/day)</th><th>Dietary Fraction of Fish Ingested from Contaminated Source (%)</th><th>Exposure Duration (years)</th></tr>
<tr><td rowspan="8">Marshallese Adult</td><td rowspan="4">54</td><td rowspan="2">50</td><td>30</td><td>2.59E-01</td></tr>
<tr><td>70</td><td>2.59E-01</td></tr>
<tr><td rowspan="2">75</td><td>30</td><td>3.88E-01</td></tr>
<tr><td>70</td><td>3.88E-01</td></tr>
<tr><td rowspan="4">132</td><td rowspan="2">50</td><td>30</td><td>6.33E-01</td></tr>
<tr><td>70</td><td>6.33E-01</td></tr>
<tr><td rowspan="2">75</td><td>30</td><td>6.33E-01</td></tr>
<tr><td>70</td><td>9.49E-01</td></tr>
<tr><td rowspan="2">Marshallese Child</td><td rowspan="2">16</td><td>50</td><td rowspan="2">6</td><td>2.56E-01</td></tr>
<tr><td>75</td><td>3.84E-01</td></tr>
<tr><td rowspan="2">U.S. Adult</td><td rowspan="2">54</td><td rowspan="2">10</td><td>1</td><td>9.25E-03</td></tr>
<tr><td>30</td><td>9.25E-03</td></tr>
</table>

*Bold face values indicate unacceptable noncancer hazard (HI > 1.0)

Table 7.3.2.4. Summary Results of Noncancer Risk Assessment - Jerak.

Receptor	Variable Exposure Assumptions - Jerak			HI*
	Ingestion Rate (grams/day)	Dietary Fraction of Fish Ingested from Contaminated Source (%)	Exposure Duration (years)	
Marshallese Adult	54	50	30	7.58E-01
			70	7.58E-01
		75	30	**1.14E00**
			70	**1.14E00**
	132	50	30	**1.85E00**
			70	**1.85E00**
		75	30	**1.85E00**
			70	**2.78E00**
Marshallese Child	16	50	6	7.49E-01
		75		**1.12E00**

*Bold face values indicate unacceptable noncancer hazard (HI > 1.0)

In scenarios with unacceptable cancer risks, the two main risk drivers were Aroclors 1254 and 1260 with a combined contribution of nearly 90% in each case. In the case of Illeginni's risk assessment, chlordane concentrations drove the risk for the Marshallese adult scenarios. Likewise, the Aroclors drove the risk in the noncancer hazard analysis for most of the islets while high concentrations of chlordane found in Illeginni fish played a significant role.

7.3.3. Special Assessment of Lead.

Although lead is extremely toxic to children (they absorb more than 50% of their consumed lead), the metal has no available RSL for fish ingestion. Therefore, lead risk was assessed using a specially-designed uptake model to determine what the blood-lead level would be for children who consume harbor fish. Prior to the initiation of field work, it was determined that in order for lead to be pose a health concern, the model would have to result in a predicted geometric mean blood-lead level of 10 micrograms per deciliter (µg/dL) in greater than 5 percent of the potentially exposed (child) population.

When the lead model was run for the Marshallese child scenario, fish concentrations alone and fish concentrations in addition to default dietary sources were considered. The results shown in Table 7.3.3.1 were obtained which indicate that lead concentrations in fish pose unacceptable risks to children regardless of the area from which the fish were harvested. Concentrations used in the model were the arithmetic mean lead concentrations of each data set.

Table 7.3.3.1. Model Outputs for Lead Modeling. Values shown are the percentages of Marshallese children populations with estimated blood lead concentrations in excess of 10 µg/dL given the mean lead concentrations shown.

	FI (%)	Kwajalein	Illeginni and Jerak	Meck	Ellep
		Concentration 3.13 µg/g	Concentration 1.25 µg/g	Concentration 4.41 µg/g	Concentration 1.69 µg/g
Fish plus other dietary sources	50	56	16	74	25
	75	74	28	87	42
Fish as the only dietary source	50	54	13	73	23
	75	73	25	86	39

8. DISCUSSION.

8.1. Correlation with Previous Fish Concentrations.

Concentrations of contaminants in fish tissue from the current study were compared to concentrations that were measured in the 2009 Kwajalein Harbor Release Area PA/SI. In the PA/SI, concentrations of contaminants in fish tissue exceeded screening guidelines for aldrin and dieldrin (pesticides) and Aroclor compounds. In the Southern USAG-KA Fish Study, several more contaminants were included as COCs in the human health risk assessment. It should be noted that aldrin was not evaluated in the current risk assessment since it was not detected in more than 5% of the samples for any given islet although, when detected, it was measured in concentrations that exceeded its screening guideline. Table 8.1.1 lists all contaminants that were detected in more than 5% of the data and were present in concentrations that exceeded available screening guidelines in the recent data set.

Table 8.1.1. Contaminants of Potential Concern in the 2013 Human Health Risk Assessment.

Contaminants of Potential Concern	Specific Contaminants of Concern	Pertaining to Islet(s)
Pesticides	4,4'-DDD	Kwajalein
	4,4'-DDE	Kwajalein
	4,4'-DDT	Kwajalein
	Dieldrin	Kwajalein, Illeginni, Meck
	Heptachlor epoxide	Illeginni, Meck
	Chlordane	Kwajalein, Illeginni, Meck
PCBs	Aroclor 1242	Kwajalein,
	Aroclor 1254	Kwajalein, Illeginni, Meck, Jerak
	Aroclor 1260	Kwajalein, Meck

The fact that different types of samples were collected makes it difficult to compare contaminant tissue concentrations from the PA/SI with those collected for the recent study. In 2008, collected fish were dissected and only the muscle fillets were sent to the laboratories for analysis. The use of fillet contaminant concentrations for risk assessment may be insufficient when assessing risk to certain populations. In the current investigation, whole fish samples were analyzed since information became known that Marshallese citizens commonly consume more than just the muscle tissue. Also, there are contaminant-specific differences in affinities for and accumulation in various tissue compartments so analyzing muscle fillet concentration alone may not accurately predict concentrations in the whole body.

As an example, the highest reported concentration of lead in muscle tissue was 1.5 mg/kg in the previous study (USAPHC, 2009). In the Southern USAG-KA Fish Study, the highest concentration in fish was detected as 29 mg/kg, a value which is approximately 20 times higher than what was previously reported. There are no indications that lead contamination in Kwajalein Harbor has increased since 2008 when the initial fish samples were collected. Instead, the difference is likely due to the fact that lead has high affinity for hard tissues such as bone and scales (Bowen 1979) and also accumulates in internal organs such as the liver and kidneys (ATSDR, 2007). None of these tissue types were assessed in the PA/SI.

A similar discussion can be presented for the accumulation of organic contamination. The maximum concentration of Aroclor 1254 contamination in Kwajalein Harbor fish (3200 mg/kg) is approximately 24 times higher than what was reported in the PA/SI. Ongoing remediation of PCB-contaminated buildings should effectively reduce the amount of PCBs that enter the harbor. The difference in accumulation may be due, in part, to the fact that organic contaminants tend to accumulate in fatty tissues (i.e., liver, brain, fat ribbon) which were not included in the previous fish sampling.

8.2. Metals

In general, concentrations of metals in fish were higher in herbivorous fish which was expected given the way in which these contaminants accumulate. Algae readily accumulate metals and serve as a primary source of food for most herbivorous species. The concentration of lead is usually highest in benthic organisms and algae and lowest in higher order carnivores. The reported bioconcentration factor (BCF) for lead in marine algae is 725, but it is only 42 for fish (ATSDR, 2007). It can be concluded, then, that lead does not readily biomagnify up the food chain to higher level organisms.

When the percentage of Marshallese children with predicted blood lead levels higher than guidelines was modeled, the results were unexpectedly high. Based on these results, Marshallese children are at risk of exposure to harmful levels of lead from ingestion of contaminated fish. The absorption of lead may slow cognitive development, increase blood pressure and increase incidence of cardiovascular disease in adults (ATSDR, 2007). Sources of lead on island may include batteries, ammunition, fishing weights, older layers of paint and aviation fuel.

Although not a screening guideline for this project, the joint World Health Organization/Food and Agricultural Organization (WHO/FAO) Committee on Food Additives published an acceptable lead level of 0.3 mg/kg in fish (WHO/FAO, 2011). The maximum observed concentration at every islet in this investigation exceeded this threshold and did so by two orders of magnitude for Meck and Kwajalein fish.

As metals most often accumulate to higher concentrations in skin, bone and certain organs, removing these fish parts prior to consumption would reduce the total exposure.

8.3. Pesticides.

Of the pesticides of interest in this study, chlordane is the only analyte that significantly contributed to the overall calculation of risk. Used as an agricultural pesticide until 1983, chlordane was also used to control termites in homes before it was banned in the United States in 1988 (ATSDR, 1994). Chlordane consists of more than 45 components, five of which comprise most of the compound: cis-chlordane (19%), trans-chlordane (24%), heptachlor (10%), cis- and trans-nonachlor (7%). Oxychlordane and heptachlor epoxide are significant degradation products. Atmospheric transport is the major route of dissemination, but chlordane is also distributed in water. It is thought that chlordane is ubiquitously distributed (Eisler, 1990) and data from the Southern USAG-KA Fish Study support this notion.

Chlordane bioconcentrates in fish (with BCFs ranging from 3,000 to 12,000 in marine species) and can biomagnify in animals that consume fish (Zaroogian et al., 1985). Chlordane is usually found in higher concentrations in tissues with high lipid content. According to the literature, in some U.S. fish species, chlordane levels are high enough to endanger the health of the fish (100 µg/kg) or the humans who consume the fish (300 µg/kg) (Eisler, 1990). The 300 µg/kg level corresponds to the U.S. Food and

Drug Administration action level in edible tissue (USFDA, 2000). The maximum concentration measured in the current study was 360 µg/kg in a Kwajalein Harbor sample.

Total pesticides in fish can be reduced by trimming those portions of the fish with the highest lipid concentrations, such as the skin, dorsal fat and bellyflap. One study reduced the chlordane concentration in bluefish by 29% by removing these fatty portions (Sanders and Haynes, 1988).

8.4. PCBs.

As is the case with pesticides, PCBs are soluble in lipids and slowly metabolized which leads to accumulation in fatty tissues. The lipid content of the collected fish specimens was calculated by the laboratory as an ancillary parameter. When the concentrations of detected organics in a fish specimen were normalized to their percent lipid fractions, lei triggerfish and honeycomb grouper showed the highest concentration of Aroclor 1254 per unit fat in comparison with the other species. Concentrations of Aroclor 1254 in these species proved to be significant in the human health risk assessment (section 7.3).

Some species store much of their lipid reserves within the abdominal cavity instead of in muscle tissue; therefore, the concentration of fat soluble organic contaminants would likely be higher in whole body samples than fillets (Lockheed Martin, 1997). To reduce exposure to PCBs and other organic contaminants, steps can be taken prior to fish consumption. The first step is the removal of fatty areas such as the skin, fat belly meat along bottom of the fish, fat above the backbone and the wedge of fat along the lateral line on each side of the fish. Baking or broiling the remaining fish parts on a rack or grill and allowing any remaining fat to drip away and be discarded will further reduce contaminant concentrations. Data from the PA/SI and the pilot study indicate that concentrations of contaminants in muscle fillets still exceed screening guidelines for the protection of human health. Although these fish preparation measures may reduce the total amount of PCBs in a given fish, consumption of the remaining fillet portion still poses an unacceptable cancer and noncancer risk.

8.5. Islet Comparisons

In addition to determining if there were any human health concerns associated with fish consumption, a secondary objective of the study was to determine if contaminant concentrations observed in Kwajalein fish were the result of industrial activities on Kwajalein or if there is widespread contamination of the southern atoll.

Although there were random differences among the islets with regard to metal contaminants in water, the only significant difference was that Kwajalein copper and zinc data were higher than most of the other islets. Mean metal concentrations were often higher in fish collected from Meck than the other islets, particularly for lead. Additionally, concentrations of nickel in Kwajalein Harbor fish were significantly lower than fish from the other islets and were often not detected. There was no trend indicating that metal contamination derives solely from activities on Kwajalein. Therefore, metal contamination appears to be distributed throughout the southern atoll and cannot be directly attributed to Kwajalein activities.

In general, concentrations of organic contaminants were higher in Kwajalein fish when compared to the four other islets under investigation. Due to the high proportion of non-detects in the pesticide fish data, the islets could not be definitively compared with the exception of chlordane which was present in higher concentrations in Kwajalein fish. Kwajalein Harbor fish had a higher percentage of detections in some of the other pesticide analytes, but no clear patterns could be found. In examining PCB levels among the fish samples, the percentage of detections was higher in Kwajalein fish. It was not possible to determine statistical significance given the large number of non-detects; however, the highest reported PCB concentrations were all from the Kwajalein data set. Of the four Aroclor compounds that were detected in fish, two were detected only in Kwajalein fish and two were also detected in the other USAG-KA-utilized islets. One of the four compounds was also detected in a few fish collected from Jerak. As a non-developed islet, it was not hypothesized that PCBs would be found in fish from this location. Detection of PCBs in fish from Jerak suggests that although historical or ongoing Kwajalein activities are contributing to the contamination in the southern atoll, the distribution of these contaminants may be part of a ubiquitous problem.

The study work plan (Appendix B) indicated that the following findings would result in a “initiate second phase of Southern USAG-KA Fish Study” decision:

- Concentrations of pesticides/PCBs/metals in Kwajalein Harbor fish samples are higher than concentrations measured in the other study areas.

- Concentrations in fish pose an unacceptable risk to human receptors.

Since both of these findings were realized to some extent, a second phase of the fish study is proposed. The follow on investigation should involve the collection of fish samples from Ebeye, an islet not used by USAG-KA that is located near Kwajalein Islet. The proximity of Ebeye to Kwajalein Islet could be influencing the observed pesticide/PCB/metal accumulation in Kwajalein Harbor fish. Additional fish collection and analysis are necessary to discern if observed accumulation in Kwajalein Harbor fish stems only from industrial activities on USAG-KA or if other sources might be contributing to the contaminant loading.

8.6. Human Health Risk Assessment.

ILCRs reflect the frequency with which cancer is anticipated to arise in a given receptor population (e.g., Marshallese adults), attributable to their fish ingesting behavior at discrete portions on the Kwajalein Atoll. The risk calculations should not be interpreted to mean that people who consume fish from the contaminated areas <u>will</u> get cancer, but rather the calculation express the likelihood they will get cancer over and above background cancer risk levels. Likewise, noncancer risk assessment resulting in high HIs does not guarantee that a health effect outcome will actually appear in the affected site population.

Fish consumption poses unacceptable cancer risk to Marshallese adults who draw fish from Kwajalein Harbor, Illeginni and Meck. There is borderline unacceptable cancer risk for this receptor at Jerak. Noncancer hazard is unacceptable for Marshallese Republic adults and children at Kwajalein Harbor, Meck, and Jerak. Of three Kwajalein Atoll islets considered for U.S. adults with dietary exposure to contaminated fish (Kwajalein Harbor, Illeginni, and Meck), there is only borderline unacceptable noncancer hazard at Kwajalein Harbor.

PCB Aroclors, and in particular Aroclor 1254, account for nearly all of the instances of unacceptable cancer and hazard observed. Due to the toxicity of PCBs, the screening guidelines are extremely low for the protection of human health and concentrations measured in some of the fish samples were more than three orders of magnitude higher than the RSLs.

9. CONCLUSIONS.

- Contaminant concentrations or the proportion of detected concentrations are often higher in fish/water collected from Kwajalein Harbor when compared to samples from two other USAG-KA-utilized islets and two non-developed islets.

- Concentrations of PCBs and pesticides in fish tissue exceed available screening guidelines for the protection of human health.

- High concentrations of lead in fish pose risk to Marshallese children who consume fish from the southern atoll.

- Fish ingestion poses unacceptable cancer risk to Marshallese adults who draw fish from Kwajalein and Meck harbors. Risks are attributable to PCB Aroclor concentrations, particular Aroclor 1254. Unacceptable cancer risk for Marshallese adults at Illeginni is attributable to the pesticide, chlordane. Borderline unacceptable cancer risk was calculated for Marshallese adults using contaminant concentrations from Jerak fish samples. Noncancer hazard is unacceptable for Marshallese adults and children engaging in subsistence fishing at Kwajalein, Meck and Jerak.

- Of the three USAG-KA-utilized islets where fish consumption was considered for U.S. adults (Kwajalein, Meck and Illeginni), there is only borderline unacceptable noncancar hazard at Kwajalein.

- Contaminant concentrations in lagoon reef fish may adversely affect public health, the marine environment, and protected beneficial uses of surface waters (e.g., fishing).

10. RECOMMENDATIONS.

10.1. Fishing Prohibition.

Continue the existing fishing prohibition in Kwajalein Harbor until such a time that medical personnel have determined whether a consumption advisory should be developed and implemented. Current warning signs state: “Per USAKA Regulation 385-9 potential health risks exist from heavy metals in the fish, water, and sediments.” The warning sign should be updated with the results of this risk assessment and explicitly state that consuming fish caught in these waters poses an increased risk of cancer and potentially other adverse health effects.

Modify wording on existing signs to emphasize the cancer risks associated with the consumption of fish due to high concentrations of PCBs in fish tissue. USAKA Regulation Number 385-9 Section 4.4 (Fishing) states that “Fishing is prohibited at certain areas around Kwajalein Island due to a build-up of heavy metals in the tissues of certain species.” This regulation should be updated with the results of the risk assessment and explicitly state that consuming fish caught in Kwajalein Harbor poses an increased risk of cancer and adverse noncancer health effects.

Establish a similar fishing ban at Meck and Illeginni harbors to prevent the consumption of fish from these areas.

10.2. Eliminate Ongoing Sources of Contamination.

Eliminate the discharge of contaminants to Kwajalein Harbor. Continue to remediate known sources of PCBs on land. Determine possible on land sources of contamination stemming from Meck and Illeginni activities.

10.3. Further Investigation.

Initiate a second phase of the study to include collection of fish samples from Ebeye as the proximity of Ebeye to Kwajalein Islet could be contributing to the observed pesticide/PCB/metal accumulation in Kwajalein Harbor fish.

Conduct an epidemiological investigation to determine if consumption of fish from the contaminated areas is, in fact, resulting in negative health outcomes in the Marshallese population.

10.4. Risk Communication. A comprehensive education and outreach program should be conducted to explain the results of this study, the hazards of fish consumption and the necessity of maintaining the fishing prohibition.

APPENDIX A

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APPENDIX B

SOUTHERN USAKA FISH STUDY WORK PLAN

APPENDIX C

STATISTICAL TREATMENT OF THE DATA

APPENDIX D

HUMAN HEALTH RISK ASSESSMENT