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ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Public Health Assessment for

PUBLIC HEALTH ASSESSMENT
ISLA DE VIEQUES BOMBING RANGE
VIEQUES, PUERTO RICO
JUNE 27, 2003

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
Agency for Toxic Substances and Disease Registry

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6)), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate.

In addition, this document has previously been provided to EPA and the affected states in an initial release, as required by CERCLA section 104 (i)(6)(H) for their information and review. The revised document was released for a 30-day public comment period. Subsequent to the public comment period, ATSDR addressed all public comments and revised or appended the document as appropriate. The public health assessment has now been reissued. This concludes the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency=s opinion, indicates a need to revise or append the conclusions previously issued.

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PUBLIC HEALTH ASSESSMENT

Fish and Shellfish Evaluation

ISLA DE VIEQUES BOMBING RANGE

VIEQUES, PUERTO RICO

Prepared by:

Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

FOREWORD

In 1980, as part of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended, also known as the *Superfund* law, Congress created the Agency for Toxic Substances and Disease Registry (ATSDR). The Superfund is an amount of money used to investigate and—when necessary—clean up hazardous waste sites. The US Environmental Protection Agency (EPA) works with the individual states to investigate hazardous waste sites. The EPA can place sites on the National Priorities List (NPL), thus qualifying them for cleanup with Superfund money.

Since 1986, ATSDR has been required by the Superfund law to conduct a public health assessment at each of the sites on the National Priorities List (NPL). The assessment determines whether people are being exposed to hazardous substances and, if so, whether that exposure is harmful and should be stopped or reduced. The US Navy sites under review in this public health assessment are not NPL sites. But ATSDR can conduct public health assessments at the request of concerned individuals. Such requests are initiated through an ATSDR process known as a petition. This public health assessment, and related ATSDR public health actions currently underway in Vieques result from a petition submitted by a resident of the Isla de Vieques, Puerto Rico.

Exposure: As the first step in the assessment process, ATSDR scientists review site environmental data to determine the types of contamination, their quantity and location, and how people could come into contact with them. Generally, ATSDR does not collect its own environmental sampling data; it usually reviews information provided by EPA, other government agencies, businesses, and the public. When sufficient environmental information is not available, ATSDR scientists will indicate what further sampling data is needed.

Health Effects: If, however, the environmental data shows that people have or could come into contact with hazardous substances at the site, ATSDR scientists evaluate whether any harmful effects could result from these exposures. Their report will focus on public health, or the health impact on the community as a whole, rather than on individual risks. Again, ATSDR generally makes use of existing scientific information. This can include the results of medical, toxicologic and epidemiologic studies, as well as data collected in disease registries. Because the science of environmental health is still developing, information about the health effects of certain substances is sometimes not available. When this happens, the report will suggest what further research studies are needed.

Conclusions: The report will present conclusions about the level of health threat, if any, posed by a site and will recommend ways to stop or reduce that threat. Because ATSDR is primarily an advisory agency, the report will usually identify those actions that should be undertaken by EPA, other agencies or responsible parties, or by ATSDR's research or education divisions. If, however, the health threat is urgent, ATSDR can issue a public health advisory warning of the danger. ATSDR can also authorize health education or health effects pilot studies, full-scale epidemiology studies, disease registries, surveillance studies, or research about specific hazardous substances.

Interactive Process: The health assessment process is interactive. ATSDR solicits and evaluates information from city, state, and federal agencies, from companies responsible for cleaning up the site; and from the community. ATSDR then publicly shares its conclusions. State and federal agencies review and comment on an early version of the report to make sure the data they have provided is current and accurately presented. After learning of ATSDR's conclusions and recommendations, agencies will sometimes begin to act on them—even before the final release of the report.

Community: ATSDR also wants to learn what local citizens know about the site and what concerns they have about its effect on their health. Accordingly, throughout the evaluation process ATSDR gathers information and comments from the people who live or work near a site, including area residents, civic leaders, health professionals, and community groups. To ensure the report responds to the community's health concerns, an early version is also distributed to the public for its comments. Comments received from the public are addressed in the report's final version.

Comments: If, after reading this report, you have questions or comments, we encourage you to send them to us.

Letters should be addressed as follows:

Attention: Chief, Program Evaluation, Records, and Information Services Branch, Agency for Toxic Substances and Disease Registry, 1600 Clifton Road (E-56), Atlanta, GA 30333.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

AT	averaging time
ATSDR	Agency for Toxic Substances and Disease Registry
AFWTF	Atlantic Fleet Weapons Training Facility
BW	body weight
CDC	Centers for Disease Control and Prevention
CEL	cancer effects level
Conc.	Concentration of chemical
DHHS	US Department of Health and Human Services
DNER	Puerto Rico Department of Natural and Environmental Resources
ED	exposure duration
EF	exposure frequency
EMA	Eastern Maneuver Area
EPA	US Environmental Protection Agency
ERT	Environmental Response Team
FDA	US Food and Drug Administration
FWS	US Fish and Wildlife Service
HMX	cyclotetramethylene tetranitramine
IARC	International Agency for Research on Cancer
IR	ingestion rate
kg	kilograms
LIA	Live Impact Area
mg	milligrams
MRL	minimal risk level
NASD	Naval Ammunition Support Detachment
NOAEL	no observed adverse effects level
NTP	National Toxicology Program
PHA	public health assessment
ppm	parts per million
PRDOH	Puerto Rico Department of Health
PREQB	Puerto Rico Environmental Quality Board
QC	quality control
RDX	cyclotrimethylene trinitramine
RfD	reference dose
tetryl	methyl-2,4,6-trinitrophenylnitramine
TNT	2,4,6-trinitrotoluene
μg/day	micrograms per day
μg/dl	micrograms per deciliter
μR/h	microroentgen per hour
USGS	US Geological Survey
WHO	World Health Organization

SUMMARY

The residents of Vieques are concerned that military training activities at the Live Impact Area (LIA) are adversely affecting their health. Previous studies have reported some indication of heavy metals in fish and shellfish, which are eaten by the residents of Vieques. To address this pathway, the Agency for Toxic Substances and Disease Registry (ATSDR) worked with the US Environmental Protection Agency's Environmental Response Team (EPA/ERT) to collect and analyze fish and shellfish from the coastal waters and near shore land on Vieques to determine whether fish and shellfish muscle tissues contain levels of heavy metals and explosives compounds that would adversely affect public health. Based on research by Universidad Metropolitana (Caro et al. 2000), discussions with the petitioner and residents of Vieques, and information provided in the Vieques Special Commission Report (Government of Puerto Rico 1999 as cited in Navy 2000b), ATSDR collected grouper (*Epinephelus* sp.), snapper (*Ocyurus chrysurus* and *Lutjanus* sp.), parrotfish (Scaridae family), grunt (*Haemulon* sp.), goatfish (Mullidae family), land crabs (*Cardisoma guanhumi*), queen conch (*Strombus gigas*), and spiny lobster (*Panulirus argus*) as commonly caught and consumed species. In addition, to address a specific community concern, ATSDR collected one honeycomb cowfish (*Lactophrys polygonia*) from the fish market. For reference, Appendix E contains pictures of the fish species collected.

> ATSDR's evaluation is an assessment of public health (i.e., whether it is safe to eat Vieques fish and shellfish). This document is not an ecological assessment of the integrity of the natural systems on Vieques.

From July 16–20, 2001, these commonly consumed fish and shellfish were collected from six locations on Vieques. Fish were collected from reefs to the north of the LIA (Location 1), from a sunken Navy vessel to the south of the LIA (Location 2), from reefs to the south of Esperanza (Location 3), from reefs to the north of Isabel Segunda (Location 4), from a fish market in Isabel Segunda (Location 5), and from reefs to the west of the Laguna Kiani Conservation Zone on the west end of Vieques (Location 6). Lobsters were collected from Locations 1, 3, and 5. Conch were collected from seagrass beds located in close proximity to Locations 1, 2, 3, and 6. Land crabs were collected from Locations 1, 2, and 6. Fiddler crabs were collected from Locations 1 and 2.

During the sampling event, the EPA/ERT divers noted that all sample locations supported diverse populations of marine organisms that appeared healthy and that with very few exceptions, most of the organisms collected appeared to be healthy.

Several metals were detected in the fish and shellfish from Vieques. Using this data, ATSDR evaluated three specific exposure situations for both adults and children living on Vieques:

1. According to the survey conducted by Universidad Metropolitana, almost half the residents of Vieques eat fish one or two times a week. However, about 16% responded that they eat fish five or more times a week (Caro et al. 2000). To be most protective of the entire residential population, ATSDR evaluated whether eating fish and shellfish from Vieques on a daily basis would result in harmful health effects.

2. Individual metals in individual species of fish and shellfish varied from location to location (ATSDR 2002). Therefore, ATSDR evaluated whether eating fish and shellfish from any of the sample locations would result in harmful health effects.

3. Universidad Metropolitana reported that yellowtail snapper was the most commonly caught and consumed species of fish (Caro et al. 2000). In addition, several Vieques fishermen and residents indicated to ATSDR that snapper was more commonly sought after, caught, and consumed than any other species of fish. Therefore, ATSDR evaluated whether eating snapper on a daily basis would result in harmful health effects.

> Heavy metals were detected in the fish and shellfish, however, the concentrations were too low to pose a human health concern.

ATSDR concluded that:

1. It is safe to eat a variety of fish and shellfish every day.

2. It is safe to eat fish and shellfish from any of the locations sampled, including from around the LIA and the sunken Navy target vessel.

3. It is safe to eat the most commonly consumed species, snapper, every day.

I. INTRODUCTION

In May 1999, a resident of Isla de Vieques (Vieques), Puerto Rico, requested (petitioned) the Agency for Toxic Substances and Disease Registry (ATSDR) to determine whether hazardous substances from the detonation of munitions at the United States Navy (Navy) bombing range on the island pose a public health threat. In August 1999, ATSDR conducted an initial site visit to Vieques to meet with the petitioner, tour the island and bombing range, and gather available environmental data. As a result of this site visit, ATSDR accepted the petition and since has been investigating public health concerns related to the Navy's training activities on Vieques.

ATSDR is responding to this petition in a series of public health assessments (PHAs). PHAs examine chemicals that enter the environment, how the chemicals move through the environment, and the levels of chemicals that residents might encounter. ATSDR then uses this information to determine whether residents are exposed to levels of contamination that might cause health problems.

This PHA addresses the public health implications from eating fish and shellfish from the coastal waters and near shore land of Vieques. The fish and shellfish were analyzed for explosives compounds and heavy metals. Explosives compounds are not naturally occurring in fish and shellfish. Whereas, heavy metals are commonly detected in fish and shellfish tissue because seafood tends to accumulate metals that are naturally present in the environment (ATSDR 1999a; ATSDR 2000a; EPA 2001a). Therefore, eating fish can be a major source of one's exposure to metals. In fact, many states have issued advisories against eating fish or shellfish because of the metal content (EPA 2000). ATSDR focused this evaluation on the types of fish and shellfish that the community commonly catches and consumes (based on research by Universidad Metropolitana (Caro et al. 2000), discussions with the petitioner and residents of Vieques, and information provided in the Vieques Special Commission Report (Government of Puerto Rico 1999 as cited in Navy 2000b)).

II. BACKGROUND

Vieques is the largest offshore island in the Commonwealth of Puerto Rico. Vieques is 20 miles long, 4.5 miles at its widest point, and about 33,000 acres (or 51 square miles) in area. Figure 1 shows the location of Vieques and surrounding islands. As the figure illustrates, the nearest island to Vieques is the main island of Puerto Rico, approximately 7 miles to the west. The island of Culebra is roughly 9 miles north. St. Thomas, St. John, St. Croix, and other US Virgin Islands are all 20 miles or more northeast and southeast of Vieques.

A. Land Use

The detailed map in Figure 2 illustrates land use in Vieques. The western portion of Vieques is the former Naval Ammunition Support Detachment (NASD). Prior to May 2001, the Navy used this 8,200 acres for limited Navy operations (e.g., ammunition storage, rock quarry, communication facilities, and Navy support buildings) (IT Corporation 2000). In May 2001, the Navy transferred most of the NASD to the Isla de Vieques, the Puerto Rico Conservation Trust, and the US Department of the Interior, but retained about 100 acres of the former NASD lands for radar and communication facilities (Navy 2001a). Some NASD areas were leased to local farmers for cattle grazing and other agricultural purposes (see Picture 1).

The central 7,000 acres of Vieques houses the entire residential population of the island, mostly in the towns of Isabel Segunda and Esperanza. Vieques land uses include residential, agricultural, commercial, and industrial. In the past, sugarcane was the principal crop. Other crops have included coconuts, grains, sweet potatoes, avocados, bananas, and papayas. In the 1960s and 1970s, manufacturing was important for the economy, beginning in 1969 with the construction of the General Electric plant (Bermudez 1998). But currently, only minimal manufacturing takes place on the island. Isabel Segunda and Esperanza, however, are home to commercial fishing fleets, and recently tourism has been increasing in economic importance.

Until May 2003[1], the Navy owned roughly the eastern half of Vieques, which is divided into two sections: the Eastern Maneuver Area (EMA) and the Atlantic Fleet Weapons Training Facility (AFWTF).

- The EMA includes approximately 11,000 acres located immediately east of the residential lands. The Navy uses the EMA periodically for various combat training activities, such as conducting shore landing exercises and small arms training (CH2MHILL and Baker 1999; IT Corporation 2000). Camp Garcia, where Marine Corps and Navy personnel are

[1]As of May 2003, the former Navy portions of Isla de Vieques are under the control of the U.S. Fish and Wildlife Service.

temporarily stationed on Vieques, is within the EMA (see Picture 2). East of the EMA is the AFWTF (3,600 acres), which is further divided into three smaller sections of land:

- The western part of AFWTF was formerly known as the Surface Impact Area. Prior to 1978, the area was used as an impact area for artillery. It is heavily vegetated and almost completely undeveloped, except for dirt roads, a few observation posts and towers, and the main observation post (OP-1), located on Cerro Matias on the eastern side (see Pictures 3 and 4).

- The middle portion of AFWTF is the Live Impact Area (LIA), also commonly referred to as the bombing range. This roughly 900-acre tract contains the targets for aerial and naval bombardment. The LIA is sparsely vegetated and contains no structures—only surplus equipment (e.g., tanks, small airplanes, and trailers) the Navy uses as targets (see Pictures 5 and 6).

- The eastern tip of AFWTF is the Punta Este Conservation Zone. To preserve the unique upland forest scrub and evergreen scrub habitats, no Navy operations take place on this small piece of land. A variety of animals, including roseate terns and sea turtles, visit and nest there (see Picture 7).

B. Demographics

ATSDR examines demographic data (i.e., population information) to determine the number of people potentially exposed to environmental chemicals and to determine the presence of any sensitive populations, such as women of childbearing age, children, and the elderly. Demographic data also provide details on population mobility which, in turn, helps ATSDR evaluate how long residents might have been exposed to environmental chemicals.

Table 1 summarizes the 2000 US Census Bureau demographic data for Vieques. As the table shows, the 2000 Census reported that 9,106 people live on Vieques. This figure includes residents on both the residential lands and Navy property. Table 1 also specifies the number of residents in three potentially sensitive populations. According to several anecdotal accounts, the population of Vieques is not highly mobile; many are lifelong residents of the island.

As noted previously, most of the residents of Vieques live in the two largest towns on the island, Isabel Segunda and Esperanza (see Pictures 8 and 9). Although these towns are located relatively close to the Navy property, they are several miles removed from the LIA. Approximately 7.9 miles of Navy owned land provides a buffer zone between the LIA and populated areas of Vieques.

C. Climate

Vieques lies in the path of the easterly trade winds (i.e., winds blowing from east to west). The climate is tropical-marine, with temperatures averaging about 79° Fahrenheit (26.3° Celsius). Annually, the temperature ranges from an average of 76° Fahrenheit (24.6° Celsius) in February to 82° Fahrenheit (28° Celsius) in August. The average amount of precipitation is about 45 inches a year. The western part of the island receives a higher amount of rainfall (about 50 inches a year) than the eastern part (about 25 inches a year). The rainy season is from August through November while the remainder of the year is drier. Tropical storms are common from June to November (NCDC 1985–1994; Torres-Gonzalez 1989).

African Dust Storms

Through the natural occurrence of African dust storms, Vieques, together with the mainland of Puerto Rico and other Caribbean islands, receive an increase of airborne dust particles in the summer. Each year, large quantities of dust from the Sahara Desert and Sahel region in Africa are transported at high altitudes to the Caribbean Sea and southeastern United States. These dust storms can transport minerals, chemicals, bacteria, fungus spores, and possibly viruses and insects. Recent studies have begun to link declining coral reef health with fungi and bacteria found in African dust (e.g., the soil fungus, *Aspergillus,* causes a disease in sea fans; USGS 2000). The potential for adverse health effects to occur from African dust storms will be addressed in the Community Health Concerns Section of the Air Pathway Evaluation PHA.

D. Geology

Vieques was formed from igneous and volcanic rock, mostly granodiorite, quartz diorite, and some lavas which created the bedrock of the island. On most of the western half as well as the central portion of the eastern half of the island, the bedrock is exposed and weathered. Because of the weathering of the bedrock, gravel and sands wash downhill during storms. Over the years this material has gathered in valleys by the ocean, forming alluvial deposits (see text box for definition). Other portions of Vieques have ancient marine deposits from a time when the island was submerged. Today these deposits reveal areas with some limestone, sandstone, siltstone, and other sedimentary rocks at the surface. ATSDR's PHA focused on the soil pathway describes the geology and soils of Vieques in greater detail (ATSDR 2003).

> Alluvial deposits are sediment deposited by flowing water. They generally consist of a mixture of gravel, sand, silt, and clay.

E. Naval Operational History

The Navy has occupied portions of Vieques since 1941. In 1960, the Navy established targets on Vieques and began bombing practice (Navy 1990). The use of the LIA for air-to-ground and ship-to-shore training increased after the closing of the Culebra Island range in the mid-1970s.

Many different types of explosive and non-explosive ordnance (e.g., bombs, flares, rockets, projectiles, and small arms) have been used at Vieques. ATSDR's PHA focused on the soil pathway describes the types of military ordnance in greater detail (ATSDR 2003). Generally, Naval training exercises are most frequent in February and August with fewer exercises in April, May, November, and December. Range utilization statistics data from 1983 to1999 indicate that the Navy and other parties conducted exercises on Vieques between 159 and 228 days per year, with the total number of days not varying considerably from one year to the next. On average, 1,862 tons of ordnance were used at Vieques annually between 1983 and 1998. This ordnance, on average, contained 353 tons of high explosives (Navy 1999). ATSDR's PHA focused on the air pathway will describe ordnance use on Vieques in greater detail.

Two types of explosives were commonly used at Vieques (Young 1978). One explosive is made from organic nitrated compounds (i.e., only carbon, hydrogen, oxygen, and nitrogen). Examples include 2,4,6-trinitrotoluene (TNT), cyclotrimethylene trinitramine (RDX), cyclotetramethylene tetranitramine (HMX), tetryl, Explosive D, Composition B (RDX and TNT), Octol (HMX and TNT), and Composition A-3 (RDX and wax). The second kind of explosive contains aluminum in addition to the organic nitrated compounds. Examples include Tritonal (TNT and aluminum), H-6 (TNT, RDX, and aluminum), and Torpex (TNT, RDX, and aluminum).

Live ordnance has not been used on Vieques since April 19, 1999, when two 500-pound bombs were accidentally dropped near an observation post (OP-1) on the LIA, killing a civilian guard. In January 2000, the decision was made that the Navy could resume training on Vieques. The training is limited to 90 training days per year and the use of nonexplosive ordnance only. In May 2000, the Navy resumed training.

F. ATSDR Involvement at Vieques

Since its 1999 receipt of the petition requesting an evaluation of public health issues on Vieques, ATSDR has worked extensively to characterize the extent of environmental contamination and potential health effects and to respond to community needs. The following is a summary of ATSDR's past involvement on Vieques:

- *Site visits.* Since 1999, teams of ATSDR scientists and community involvement specialists have visited Vieques more than 10 times. These visits included site familiarization, identification of health concerns, collection of relevant site information, and collection of fish and shellfish for analysis. During two of the site visits, ATSDR personnel extensively toured the former NASD, EMA, and AFWTF, which included a ground and aerial tour of the LIA.

- *Community involvement.* Defining community concerns is an essential step in the public health assessment process. To define specific environmental health issues of concern, ATSDR met several times with individuals, families, and many other residents of Vieques. ATSDR has also met with elected officials, physicians, nurses, school educators, fishermen, leaders of women's groups, pharmacists, and businessmen. Among other discussion topics, ATSDR inquired how the agency can most effectively provide public health information to the community. ATSDR plans to continue such community involvement activities at Vieques.

- *Health education.* Throughout the community involvement process, ATSDR has worked with physicians, nurses, and school officials to provide educational materials and to support the overall public health of Vieques residents. To date, the agency has hosted four physician workshops and one nurses' training workshop covering the various aspects of environmental health, including procedures for taking an exposure history. The agency has also facilitated community education sessions on cancer. ATSDR intends to provide additional education sessions that will address topics such as air quality and asthma, nutrition and wellness, and environmental health.

In addition to the previous list of activities on Vieques, ATSDR has assessed the following public health issues:

- In October 2001, ATSDR released a PHA addressing contamination in drinking water supplies and groundwater (ATSDR 2001a). This report concluded that the public drinking water supply on Vieques poses no public health hazard. However, high nitrates and nitrites, most likely resulting from agricultural pollution, in one private drinking water well indicate a health concern for children and pregnant women if they drank water from that well. The report evaluates these health issues in greater detail. Copies are available by contacting ATSDR (1-888-42-ATSDR) and from records repositories on Vieques. The repositories are located at Biblioteca Publica (Calle Carlos Lebrum, Vieques), the Vieques Conservation and Historical Trust (Flamboyan Street, Vieques), and at the University of Puerto Rico's School of Public Health (San Juan, Puerto Rico).

- In July 2001, ATSDR, the Ponce School of Medicine, and the Centers for Disease Control and Prevention (CDC) sponsored an expert panel review to address whether an association existed between place of residence (Vieques or Ponce Playa) and morphological cardiovascular changes among fishermen. A second review by experts showed no indication of abnormal heart function attributable to pericardial thickening.

The report summarizing the expert panel review was released in October 2001 (ATSDR and PSM 2001). Copies are available by contacting ATSDR (1-888-42-ATSDR).

- ATSDR continues to evaluate the public health implications of exposure to air contaminants. In a PHA released for public comment in November 2002, ATSDR addressed potential health issues resulting from air releases from the LIA, including wind-blown dust and the use of practice bombs, live bombs, and various other munitions.

- In February 2003, ATSDR released a PHA addressing public health implications from exposures to soils on Vieques (ATSDR 2003). ATSDR addressed exposures that the residential population might typically experience as well as exposures that individuals who lived on the LIA between April 1999 and May 2000 might have experienced. This document concluded that there is no evidence that residents are being exposed to harmful levels of contamination in the soil.

III. PREVIOUS RESEARCH

This section of the PHA summarizes research previously conducted on Vieques that is directly related to the fish and shellfish sampling conducted by ATSDR and EPA/ERT. The next section of the PHA (Section IV) provides more details about ATSDR's sampling effort.

A. Biomagnification of Carcinogenic Metals in Crab Tissue, Vieques, Puerto Rico

by Arturo Massol Deyá, Ph.D. and Elba Díaz, M.S. Casa Pueblo de Adjuntas and Universidad de Puerto Rico. January 12, 2000.

Summary

In November 1999, researchers from Casa Pueblo de Adjuntas, in cooperation with the Biology Department of Recinto Mayaguez at the University of Puerto Rico, sampled male fiddler crabs (*Uca pugnax rapax*) from Icacos and Anones Lagoons in the LIA and from Puerto Mosquito just east of Esperanza. The purpose of the research was to assess the potential transport of metals from the impact area to other ecosystems.

Researchers collected "close to 35" fiddler crabs at each location. They analyzed the extremities (levers and legs) separately from the body (shell and internal contents) for cadmium, chromium, cobalt, copper, lead, manganese, nickel, and zinc. Please see Table 2 for a summary of the results. The researchers compared the levels of the heavy metals detected in fiddler crabs in Icacos Lagoon to the levels in the sediments and reported that biomagnification (see text box for definition) of cadmium was occurring. They also noted that the average cadmium concentration exceeds the critical levels of concern for cadmium ingestion according to the US Food and Drug Administration (FDA) and the World Health Organization (WHO).

Biomagnification is an increase in the concentration of a chemical as the substance moves through the food chain.

Conclusions

This research established that fiddler crabs contained evidence of heavy metals. However, fiddler crabs are not known to be a species that are eaten by the residents of Vieques. While the data from this report may be useful to evaluate ecological contamination, it has limited utility when trying to extrapolate into the human food chain. To evaluate human exposures to edible land-based shellfish, ATSDR sampled and analyzed land crabs (a species known to be consumed by the residents) during the fish and shellfish investigation in July 2001. The remainder of this PHA details ATSDR's sampling effort (Section IV) and evaluates whether eating land crabs, among other fish and shellfish species, would result in harmful health effects (Section V).

B. Toxicological Survey of Heavy Metals in Fish Populations, Vieques Island
by Doris A. Caro, Ph.D.; Mei-Ling Nazario; and Noel Diaz. Universidad Metropolitana. June 2000.

Summary

Between December 1999 and April 2000, researchers from the School of Environmental Matters, Universidad Metropolitana, collected fish from fish markets on the northern and southern (Esperanza) coasts of Vieques and from the Parquera fish market in Lajas on the western side of the mainland of Puerto Rico. The focus of the research was to identify potential heavy metal contamination in fish species that are commonly eaten by the residents of Vieques.

To identify the most frequently consumed species, researchers administered a questionnaire to Vieques residents asking about their dietary habits. Fifty-one residents responded to the questionnaire. Of these, 10 people (19.6%) reported to eat fish never or occasionally, 24 people (47%) 1–2 times a week, 9 people (17.6%) 3–4 times a week, and 8 people (15.7%) five or more times a week. Based on responses to the questionnaire, the most commonly consumed species of fish include: colirrubia (yellow tail snapper, *Ocyurus chrysurus*), mero cabrilla (red hind, *Epinephelus guttatus)*, peje puerco (triggerfish, *Balistes* sp.), sierra (cero, *Scomberomorus regalis*), capitán (not identified), cotorro (parrotfish, Scaridae family), chapín (trunkfish, *Lactophrys* sp.), bonito (skipjack tuna, *Euthynnus pelamis*), negra (blackfin snapper, *Lutjanus buccanella*), dolorado (not identified), chillo (silk snapper, *Lutjanus vivanus*), boquicolorao/ronco (white grunt, *Haemulon plumieri*), and sama (mutton snapper, *Lutjanus analis*).

Researchers collected a total of 78 fish—35 fish from fish markets in northern Vieques, 17 fish from fish markets in Esperanza, and 26 fish from fish markets in the Parquera area on the mainland of Puerto Rico. Species included: arrayao (lane snapper, *Lutjanus synagris*), boquicolorao, colirrubia, cotorro azul (blue parrotfish, *Scarus coeruleus*), cotorro rojo (stoplight parrotfish, *Sparisoma viride*), cotorro verde (redband parrotfish, *Sparisoma aurofrenatum*), mero cabrilla, mero mantequilla (coney, *Epinephelus fulvus*), and salmorete de altura (goatfish, Mullidae family). Fish fillet and skin samples were tested for arsenic, cadmium, lead, mercury, selenium, and zinc.

The researchers concluded that "based on the data obtained...we were not able to verify our hypothesis of potential bioaccumulation in the fish...there is no clear relationship between fish weight and size and their metal content" (Caro et al. 2000). They reported "high concentrations" of arsenic, mercury, selenium, and zinc; but low or no concentrations of cadmium and lead in the fish tissue samples. Please see Tables 3 and 4 for a summary of their analytical results.

Conclusions

> The use of the term "high concentration" is relative to the basis of comparison (i.e., what the concentration is being compared to). ATSDR concluded that the chemical concentrations are not high when compared to health-based values. Whereas, Universidad Metropolitana had a different basis of comparison when they reported their results.

This research provided valuable information about the dietary habits of the residents of Vieques, specifically how often people are eating fish and what species. This information was used throughout ATSDR's public health evaluation. In addition, ATSDR evaluated whether the concentrations reported would result in harmful health effects for people consuming fish from the sampled fish markets[2]. Based on this data, ATSDR determined that it is safe to eat fish from the fish markets in northern Vieques, Esperanza, and the Parquera area on the mainland of Puerto Rico on a daily basis (i.e., all of the concentrations reported by Universidad Metropolitana are too low to be of health concern). Please see Section V. Evaluation of Fish and Shellfish from Vieques and Appendix D for more details on the methods and assumptions ATSDR used to estimate human exposure doses and determine health effects.

C. **Contaminant levels in crabs from two solid waste management units on Vieques National Wildlife Refuge** (October 4, 2002)

Summary

In July 2001, US Fish and Wildlife Service (FWS) personnel sampled land crabs and fiddler crabs from two solid waste management units (SWMUs) in west Vieques (the former NASD) and from Sandy Point National Wildlife Refuge in St. Croix, as a control. The samples are whole body and were analyzed for pesticides and metals. The purpose of the research was to collect preliminary data about the level of contamination in the prey base (land crabs and fiddler crabs) for some aquatic birds (e.g., herons and egrets). FWS provided the analytical data to ATSDR for inclusion in this health assessment (FWS 2001a, 2001b). Please see Tables 5 and 6 for summaries of the fiddler crab and land crab data, respectively.

Conclusions

This research established that fiddler crabs and land crabs contained some heavy metals and pesticides. The results were not available prior to ATSDR's sampling in July 2001. In accordance with the objectives of this research, the data from the report are useful to evaluate ecological contamination. However, this research cannot easily be converted for evaluating human health

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[2]It was not noted in the study by Caro et al. 2000 if the concentrations were reported as wet weight concentrations or dry weight concentrations, ATSDR is assuming they are wet weight concentrations.

because fiddler crabs are not a species that are eaten by people. Also, the concentrations may not be applicable to what people eat because the whole body was analyzed (e.g., included in the analysis were parts that are not eaten, such as the shell)[3]. To evaluate potential exposure to people, ATSDR sampled and analyzed edible portions (i.e., the meat) of the land crabs during the July 2001 fish and shellfish investigation. The remainder of this PHA details ATSDR's sampling effort (Section IV) and evaluates whether eating land crabs, among other fish and shellfish species, would result in harmful health effects (Section V).

> It is standard protocol to analyze the whole body of organisms when evaluating ecological concerns and fillets/edible portions when evaluating human health concerns.

[3]The National Academy of Science notes that there are limitations to the usefulness of assessing human health concerns from analyses performed on nonedible portions of organisms or on the whole body (EPA 2000).

IV. ATSDR'S FISH AND SHELLFISH SAMPLING

The residents of Vieques are concerned that military training activities at the LIA are adversely affecting their health. Previous studies have reported "elevated" levels of heavy metals in fish and shellfish from Vieques (see Section III). People who regularly eat fish and shellfish may be exposed to these chemicals. The purpose of ATSDR's sampling and analysis activities was to determine whether the muscle tissues from commonly consumed fish and shellfish contain levels of heavy metals and explosives compounds that would adversely affect public health[4]. To assist in the activities, ATSDR worked with the US Environmental Protection Agency's Environmental Response Team (EPA/ERT) to collect and analyze fish and shellfish from the coastal waters and near shore land on Vieques.

A. Sample Locations

Fish and shellfish were collected from six locations on Vieques (see Figure 3). The following locations were chosen to represent productive fishing areas surrounding the island (Ecology and Environment 1986 as cited in Navy 2000b):

- *Location 1*. Fish and shellfish were collected from two small, near shore reefs to the north of the LIA on the east end of Vieques. The total area included in the sampling effort (the combined portions of each reef actually sampled by divers) was approximately 12,000 square meters. In addition, conch were collected from the sea grass bed and crabs were collected from the north end of the LIA.

- *Location 2* consisted of two sections of a former Navy vessel, located approximately 100 yards meters, that had been used for military target practice, near shore to the south of the LIA on the east end of Vieques. The total area included in the sampling effort was approximately 10,000 square meters. In addition, conch were collected from the sea grass bed and crabs were collected from the west coast of Bahia Salina del Sur in the AFWTF.

- *Location 3* consisted of three near shore reefs to the south of the town of Esperanza on the south shore of Vieques. Fish were collected at Bucky Reef and Patti Reef, and conch were collected from the seagrass bed north of Arena Reef. The total area included in the sampling effort was approximately 15,000 square meters.

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[4]The purpose of ATSDR's sampling and health evaluation is to address any potential *chemical* contamination in the fish and shellfish; therefore, this public health assessment does not focus on any potential biological conditions (e.g., naturally occurring toxins in fish, diseases, parasites, or bacteria) that may afflict the fish and shellfish of Vieques.

- *Location 4.* Fish were collected from two near shore reefs to the northwest of the town of Isabel Segunda on the north shore of Vieques and from Mosquito Pier to the west of Isabel Segunda (see Picture 10). The total area included in the sampling effort was approximately 15,000 square meters.

- *Location 5* was a fish market in the town of Isabel Segunda. No attempt was made to verify the area from which the fish and lobsters were caught, though the market staff stated that all fish and lobsters sold in the market were caught locally.

- *Location 6.* Fish were collected from an unnamed near shore reef off the southwest end of Vieques, in the vicinity of the Monte Pirata Conservation Zone. Conch were collected from a seagrass bed 500 meters northeast of the reef. The total area included in the sampling effort was approximately 15,000 square meters. In addition, land crabs were collected from the Laguna Kiani Conservation Zone on the west end of Vieques.

B. Methods

Species Collected

At each location, field personnel attempted to catch (or purchase, in the case of the fish market) five individuals from the following types of fish targeted for analysis: yellowtail snapper (*Ocyurus chrysurus*)/mutton or lane snapper (*Lutjanus* sp.), grouper/red hind/rock hind/coney (*Epinephelus* sp.), grunt (*Haemulon* sp.), parrotfish (Scaridae family), and goatfish (Mullidae family). In addition, field personnel attempted to catch or purchase five individuals of queen conch (*Strombus gigas*) and spiny lobster (*Panulirus argus*) at each sampling location. These fish and shellfish were determined to be commonly caught and consumed by the residents of Vieques, based on research by Universidad Metropolitana (Caro et al. 2000), discussions with the petitioner and residents of Vieques, information provided in the Vieques Special Commission Report (Government of Puerto Rico 1999 as cited in Navy 2000b), and visits to local fish markets. In addition, to address a specific community concern, ATSDR collected one honeycomb cowfish (*Lactophrys polygonia*) from the fish market.

Field personnel planned to collect a sufficient number of individuals of blue land crab (*Cardisoma guanhumi*) on shore, adjacent to Locations 1, 2, and 6 and fiddler crab (*Uca* sp.) adjacent to Locations 1 and 2 to meet the tissue mass requirements for five replicates of the desired chemical analyses[5]. For safety reasons, Navy technicians collected these crabs on the LIA and transferred them to field personnel the same day they were collected. Land crabs were

[5]Originally, ATSDR planned to collected blue land crabs and fiddler crabs from all six sampling locations. However, due to time constraints and logistical problems encountered during sampling, it was decided to limit the collection to these key locations.

determined to be a species eaten by the residents of Vieques, while fiddler crabs are not known to be a species that is eaten.

Table 7 summarizes the species of fish and shellfish that were collected from each sample location. For reference, Appendix E contains pictures of the species collected.

Quality Assurance and Quality Control

The data used in this investigation meets established EPA standards for adequate quality assurance and control measures for sampling procedures, chain-of-custody procedures, laboratory procedures, and data reporting. The analytical methods and detection limits established for this investigation were consistent with the study's objectives and were sufficient to enable a conservative evaluation of health implications. Appendix B contains more details concerning the sampling methods for ATSDR's fish and shellfish investigation.

C. Results

Organism General Health

All collected organisms were given a brief physical examination. However, the white grunts (*H. plumieri*) collected at the fish market had already had their gut cavities cleaned prior to sale; therefore, no internal examination was possible. All of the organisms collected from all of the sampling locations appeared to be healthy. Few had any obvious deformities or parasites, with the exception of the following.

- One french grunt from Location 6 was observed to have a deformed anal fin. The cause of the deformity (injury or growth defect) could not be determined. A graysby collected from Location 3 was observed to have a sunken belly, the cause could not be determined.

- External and internal parasites are common on reef fish, and in low numbers they are not an indication of a stressed system. A single fish was observed to have external parasites (isopods in the gill cavity of a bluestriped grunt from Location 3) and three fish were observed to have internal parasites (unidentified worms in the peritoneal cavity of two red hinds from the fish market and one coney from Location 6).

Chemical Analysis

Note of Explanation: Averages were calculated using detected concentrations only and do not take into account nondetected values. Even though this tends to overestimate the true average values, ATSDR chose to base its health evaluations on the more conservative averages to be more protective of public health.

Explosives compounds

Fish and shellfish tissues were analyzed for explosives compounds. No explosives compounds were detected in fish tissues from any sample location. Of the 42 shellfish samples, only fiddler crabs contained an explosives compound[6] (HMX; see Table 5). No explosives compounds were detected in conch, lobster, or land crab samples from any location (see Table 9).

Metals

Fish and shellfish tissues were analyzed for heavy metals. Finding heavy metals in fish and shellfish is not unique to Vieques. Depending on the geology and chemical composition of the area, a variety of metals can be found in varying concentrations (e.g., EPA 2001a). If the levels are too high and pose a health concern, health agencies issue advisories against eating fish or shellfish. Of the heavy metals, mercury is the chemical of concern in the largest number of states (EPA 2000).

- *Fish.* Calcium, magnesium, potassium, selenium, and sodium were detected in every fish sample. Chromium, copper, and zinc were also frequently detected (in greater than 90% of the samples). Aluminum, arsenic, barium, and mercury were detected in 72–78% of the samples. Manganese and iron were detected in 65% and 60% of the samples, respectively. Lead and beryllium were detected in 35% and 19% of the samples, respectively. Cadmium, cobalt, nickel, silver, and vanadium were infrequently detected (in less than 10% of the samples) and antimony and thallium were not detected in fish. The ranges, averages, and frequency of detections are summarized in Table 8.

- *Shellfish.* Calcium, copper, magnesium, potassium, selenium, sodium, and zinc were detected in every shellfish sample and chromium was also frequently detected (95% of the samples). Aluminum, arsenic, barium, iron, and manganese were detected in 64–89% of the samples. Cadmium, mercury, silver, and vanadium were detected in 34–55% of the

[6]Rinsing fiddler crabs of sand and dirt was inadvertently omitted prior to placing them into sample containers. The concentrations detected may not accurately represent the levels of HMX in fiddler crabs, rather the concentrations could be artificially elevated due to the external sand and dirt contamination.

samples. Beryllium, cobalt, and lead were less frequently detected (in less than 25% of the samples). Antimony, nickel, and thallium were not detected in shellfish. The ranges, averages, and frequency of detections are summarized in Table 9.

- *Fiddler crab.* Antimony, beryllium, lead, mercury, and thallium were not detected in fiddler crabs and nickel was detected in 50% of the samples[7]. The remaining metals were detected in every fiddler crab composite sample. The results are summarized under Live Impact Area in Table 5.

Methylmercury

One tissue sample from each of four species (red hind, white grunt, yellowtail snapper, and spiny lobster) collected from the fish market (Location 5) was analyzed for methylmercury. Methylmercury was detected in concentrations of 0.02–0.08 ppm (parts per million) in fish and 0.019 ppm in shellfish. Results are summarized in Tables 8 and 9.

Are the levels of mercury higher in fish from Vieques?

Because of its persistence in the environment and bioaccumulative property, mercury is the primary contaminant driving fish advisories—almost 75% of all fish advisories are related to mercury contamination (EPA 2002). In general, the levels of mercury measured in fish collected from Vieques were about the same as those from the mainland of Puerto Rico and the Virgin Islands. In Vieques, the average mercury level was 0.12 ppm. Average mercury levels found in the same species of fish from Puerto Rico and the Virgin Islands ranged from 0.07 to 0.70 (Burger et al. 1992). Average mercury levels in seafood species, collected nationwide, ranged from not detected to 1.45 ppm (FDA 2001b). It is also interesting to note that people who eat fish from Vieques would receive about as much mercury as people who eat canned tuna (according to a 1991 FDA survey, the average mercury concentration in canned tuna is 0.17 ppm; Yess 1993 as cited in ATSDR 1999a).

[7]Rinsing fiddler crabs of sand and dirt was inadvertently omitted prior to placing them into sample containers. The concentrations detected may not accurately represent the levels of metals in fiddler crabs, rather the concentrations could be artificially elevated due to the external contamination.

V. EVALUATION OF FISH AND SHELLFISH FROM VIEQUES

A. Introduction

What is meant by exposure?

ATSDR's PHAs are driven by exposure or contact. Chemicals released into the environment have the potential to cause harmful health effects. Nevertheless, *a release does not always result in exposure*. People can only be exposed to a chemical if they come in contact with that chemical. If no one comes into contact with a chemical, then no exposure occurs, thus no health effects could occur. Often the general public does not have access to the area where the environmental release occurs; however, it is important to determine whether the chemicals are moving through the environment to locations where people could come into contact with them.

The means in which a chemical moves through the environment, and how people contact the chemical, defines an exposure *pathway*. ATSDR identifies and evaluates exposure pathways by considering how people might come into contact with a chemical. In this public health assessment, ATSDR is evaluating exposures from eating potentially contaminated fish and shellfish from the coastal waters and near shore land on Vieques.

If someone is exposed, will they get sick?

Exposure does not always result in harmful health effects. The type and severity of health effects that occur in an individual as the result of contact with a chemical depend on the exposure concentration (how much), the frequency and duration of exposure (how long), and the multiplicity of exposure (combination of chemicals). Once exposure occurs, characteristics such as age, sex, nutritional status, genetics, lifestyle, and health status of the exposed individual influence how that individual absorbs, distributes, metabolizes, and excretes the chemical. Taken together, these factors and characteristics determine the health effects that can occur as a result of exposure to a chemical in the environment.

Considerable uncertainty exists regarding the true level of exposure to environmental contamination. To account for that uncertainty and to protect public health, ATSDR scientists typically use high-end, worst-case exposure level estimates to determine whether harmful health effects are possible. ATSDR used the following conservative approaches throughout this public health evaluation:

- ATSDR evaluated human exposure from consuming fish and shellfish from Vieques on a daily basis (i.e., 365 days per year) although an earlier survey by Universidad Metropolitana showed that only 16% of residents of Vieques eat fish five or more times a week (Caro et al. 2000).

- ATSDR calculated averages using detected concentrations only and did not take into account nondetected values. This tends to overestimate the true average values.

- In estimating the amount of inorganic arsenic, the most harmful form, from total arsenic in fish and shellfish, ATSDR assumed that 20% of the total arsenic detected was the inorganic form, even though FDA recommends that 10% of total arsenic be considered inorganic and as little at 1% may be inorganic (ATSDR 2000a; Francesconi and Edmonds 1997; NAS 2001b; FDA 1993).

Therefore, the estimated exposure levels are much higher than the levels to which people are really exposed. If the exposure levels indicate harmful health effects are possible, a more detailed review of exposure, combined with scientific information from the toxicologic and epidemiologic literature about the health effects from exposure to hazardous substances, is performed.

What exposure situations were evaluated in this PHA?

ATSDR focused this health evaluation on the edible samples that ATSDR worked with EPA/ERT to collect in July 2001 from six locations on and around Vieques, including five families of commonly caught and consumed fish and three species of shellfish (see Table 7). Fiddler crabs were not included in the health evaluation because it is ATSDR's understanding that fiddler crabs are not a species that people eat. Each of the other species was considered to equally represent fish or shellfish that are directly consumed by the residents of Vieques.

ATSDR evaluated several different consumption scenarios depending on a person's fish and shellfish intake. According to the survey conducted by Universidad Metropolitana, almost half the residents of Vieques eat fish one or two times a week. However, about 16% responded that they eat fish five or more times a week (Caro et al. 2000). Therefore, to account for the variability in dietary habits, ATSDR estimated exposure from eating fish or shellfish 7 days a week, 5 days a week, 4 days a week, 2 days a week, and 1 day a week. The scenario of eating fish or shellfish 7 days a week was evaluated first. If this intake level revealed a potential health hazard, ATSDR determined what a safe consumption level would be.

Individual metals in individual species varied from location to location (ATSDR 2002). Thus, it is possible that if someone were to regularly eat fish or shellfish caught from a single location rather than from a variety of locations, his/her metal intake level could be different than the average (either higher or lower than the average). Therefore, in addition to determining an overall exposure for people who eat fish and shellfish from a variety of locations surrounding Vieques, ATSDR also examined whether eating fish or shellfish from any specific location would cause people to experience adverse health effects.

Universidad Metropolitana questioned the residents of Vieques about the types of fish they eat and reported that yellowtail snapper was the most commonly consumed species of fish (Caro et al. 2000). Through talking with several Vieques fishermen and residents, including the petitioner, ATSDR confirmed that snapper were most commonly sought after, caught, and consumed than any other species of fish. Therefore, ATSDR also considered a specific situation where people ate snapper on a daily basis.

For reference, Appendix A is a glossary of environmental and health terms and Appendix D describes in greater detail the methods and assumptions ATSDR used to estimate human exposure doses and determine health effects.

B. Public Health Evaluation

Is it safe to eat fish and shellfish from Vieques?

Yes, the fish and shellfish from Vieques are safe to eat. Even though several metals were detected in some of the fish and shellfish, the concentrations that were present were too low to be of health concern in virtually all exposure situations evaluated. Appendix D describes in greater detail how ATSDR reached this conclusion.

Is it safe to eat fish and shellfish every day?

Yes, it is safe to eat a variety of fish and shellfish from Vieques on a daily basis. ATSDR evaluated this specific scenario in detail in Appendix D and determined that eating a variety of fish and shellfish would not result in adverse health effects or an increase in the risk of developing cancer.

Arsenic levels in lobsters

ATSDR evaluated arsenic concentrations in lobsters in detail in Appendix D because of their tendency to store arsenic that is naturally present in the environment (research has shown that marine organisms tend to accumulate arsenic naturally present in seawater and food, rather than only accumulating arsenic due to local pollution; Eisler 1994 as cited in ATSDR 2000a). The lobsters from Vieques did not contain higher levels of arsenic than FDA's level of concern for average consumption (76 ppm; FDA

> Arsenic levels in fish and shellfish are usually about 4–5 ppm, but may be as high as 170 ppm (Bennett 1986; NAS 1977b; Schroeder and Balassa 1966 as cited in ATSDR 2000a). According to a 1978 National Marine Fisheries Service survey, mean arsenic levels in lobsters range from 10–20 ppm (FDA 1993). However, FDA notes that in some cases arsenic levels in lobsters may exceed 100 ppm (Benson and Summons 1981; Bohn 1975; LeBlanc and Jackson 1973 as cited in FDA 1993). For comparison, arsenic levels in lobsters from Vieques ranged from 23.4–48.3 ppm and averaged 32.9 ppm.

1993). However, based upon a hypothetical exposure situation (eating lobsters from Vieques every day), using highly conservative assumptions (ATSDR assumed that 20% of the total arsenic is in the inorganic form), ATSDR found that eating more than two meals of lobster each week for 70 years could theoretically lead to harmful health effects. However, this finding is debatable because (1) there is much uncertainty surrounding the level at which health effects are seen and (2) according to the scientific research, the amount of arsenic present in lobsters from Vieques is low enough to be controlled by normal metabolic processes in the body (ATSDR 2000a). Please see the arsenic discussion in Appendix D for more details.

ATSDR concludes that lobsters from Vieques are safe to eat and only under highly unlikely, hypothetical scenarios with several levels of conservatism built into the evaluation might the arsenic levels in lobsters be a problem for people eating more than two meals of lobster a week for a lifetime.

Is it safe to eat fish and shellfish from any location?

Yes, it is safe to eat fish and shellfish from all of the areas that ATSDR sampled. Despite the fact that some metals were detected in higher concentrations at different locations, none were so much higher that ATSDR would expect to see adverse health effects in people who may solely eat fish or shellfish from a single location (e.g., only from the fish market or only from areas around the LIA). In other words, even though there are differences in fish and shellfish body burdens between locations, these differences are too small to have an impact on public health.

Is it safe to eat the most commonly caught and consumed fish every day?

ATSDR determined that it is safe to eat snapper, reportedly the most desirable and most commonly consumed species, on a daily basis. In Appendix D, under the section titled **Special Case: Snapper**, ATSDR describes in greater detail how this conclusion was reached.

VI. COMMUNITY HEALTH CONCERNS

An integral part of the public health assessment process is addressing community concerns related to environmental health. ATSDR has been working with, and will continue to work with, the community to define specific health issues of concern. On multiple trips to the island, ATSDR has met with a variety of individuals and organizations, including local officials, physicians, nurses, pharmacists, leaders of women's groups, school educators, fishermen, and business people. ATSDR has also met with individual families. Meeting with a broad spectrum of community members is critical to determine health issues of concern and to assess the environmental health issues on Vieques.

General issues of health concern related to exposure to the soil, groundwater and public drinking water on Vieques were addressed in previously released PHAs (ATSDR 2001a, 2003). Another PHA will focus on addressing potential health issues resulting from air releases from the LIA. In addition, an expert review panel discussed the issue of whether an association existed between place of residence and heart disease among fishermen (ATSDR and PSM 2001). This section of the PHA addresses additional community concerns related to the fish and shellfish evaluation.

1. Concern: Drums on Sunken Navy Vessels

In November 1999, lawyers for the Puerto Rican Government contracted the University of Georgia to examine the health of the coral reefs. During their investigation they reported seeing two sunken vessels in Bahía Salina del Sur (south of the LIA) that contained hundreds of 55-gallon drums of unknown content. The community expressed concern that unknown substances could be leaking from these drums, contaminating the marine biota, and affecting the health of island residents.

The wreckage is actually the scuttled remains of the former USS Killen (Killen), a World War II destroyer which had been used as a target vessel. To address the concern, ATSDR sampled and analyzed fish and shellfish at this site in July 2001, as sample Location 2. Despite the common occurrence of unexploded ordnance, the site was home to a diverse population of apparently healthy fish and small head corals, and were surrounded by a large halo (the halo is a typical feature of reefs and underwater structures that is caused by grazing organisms leaving the shelter of the reef at night to feed on the surrounding seagrass beds) and a healthy turtle grass bed (see Appendix C for more details). In addition, ATSDR's evaluation determined that the fish and shellfish collected from Location 2 do not contain levels of metals or explosives compounds that would adversely affect the health of someone eating fish and shellfish from this area (see the Public Health Evaluation (Section VB) and Appendix D for more details).

The Navy and the Puerto Rico Department of Natural and Environmental Resources conducted personnel interviews and reviewed the document history of the sunken vessel. Personnel noted that despite numerous fly overs, no one observed any loss of residual material, oil slicks, or plumes coming from the wrecks (Navy 2000a). The investigative committee hypothesized that the 55-gallon drums were filled with air and placed on board to enhance buoyancy to keep the vessel afloat as long as possible (Navy 2000a). A second theory is that, in addition to being used for added target buoyancy, the 55-gallon drums were filled with sand or seawater and used as ballast to redistribute the weight of the vessel (i.e., add stabilization) after several alterations were made to remove much of the superstructure, armament, and heavy engineering components (Geo-Marine 2002).

In 2001, the Navy conducted a site investigation and characterized the biological organisms to assess the health of the marine species on and around the vessel and to assess potential impacts on the surrounding biota (Geo-Marine 2002). The overall conclusion was that the sunken vessel and its contents are not having a negative effect on the coral reef ecosystem, rather they are acting as a productive artificial reef habitat. The Navy will provide these results to EPA, who along with the Puerto Rico Environmental Quality Board (PREQB), will determine if further analysis is warranted.

2. Concern: Radiological Contamination from the former USS Killen

Concern has been expressed that because the Killen was a target ship during Operation HARDTACK, it could be contaminating the waters and biota around its resting place with radiation. Operation HARDTACK consisted of underwater nuclear tests in the Pacific in 1958. ATSDR received and reviewed information from the Navy regarding Operation HARDTACK and the involvement of the Killen. During the tests, the Killen was under constant water wash before and after the blasts to remove as much of the radioactivity as possible. A few days after each test, crews went on board, surveyed the ship, and manually decontaminated those areas needing additional treatment. There is no indication that sandblasting was used as the method of decontamination. After the nuclear tests, the Killen was towed to several locations including Hawaii, the Panama Canal Zone, and Norfolk, Virginia. From 1963 until 1975 the vessel was docked at Roosevelt Roads when not in use as a target vessel. The Killen was finally scuttled in 1975.

Radiation measurements collected in 1975 showed that the radiation intensity aboard ship was less than 0.75 microroentgen per hour (μR/h) (SAIC 2002). Additional radiation readings were collected in March 2002. These readings were 0.33 μR/h above background (SAIC 2002). For comparison, typical background is approximately 10 to 17 μR/h, varying with location. Background levels of radiation result from several naturally-occurring sources, such as cosmic radiation from space and terrestrial radiation from radioactive materials in the ground.

An ATSDR health physicist also spoke with a Navy radiation scientist on this issue. As with typical nuclear tests, the predominate radioisotopes contributing to the radiation exposures was cesium 137 and strontium 90. Since the forms of cesium and strontium are reduced by half every 30 years, one can estimate that without any intervention of weather or man, the amount of these radioisotopes would be about 25% of the initial amount present on the Killen. This is seen in the data as the radiation readings taken in 2002 were more than 2 million times lower than the readings taken immediately after the tests.

Based on these observations, the radiation levels associated with the Killen are indistinguishable from the radiation associated with background levels naturally found in the environment (e.g., from cosmic and terrestrial sources) and do not pose any public health hazard to the residents of Vieques.

3. Concern: Metals Contamination from the former USS Killen

Concern was expressed regarding possible metals contamination of marine biota and of SCUBA divers visiting the remains of the Killen. Although ATSDR does not have specific water chemistry data from the vicinity of the Killen, there is no likely harmful exposure to chemicals that could result from SCUBA diving around the vessel. It should be pointed out that any sunken vessel can contain physical hazards that need to be considered in any diving activity. Also, because the area surrounding the Killen, and the Killen itself, have been targets in bombing and firing training, there could be hazard from unexploded ordnance.

There is a large body of information with which to address the concern that a sunken vessel promotes chemical contamination to the environment. Ships and other manmade objects such as defunct oil rigs, automobiles, and rail cars are frequently sought by natural resource agencies and private environmental organizations world-wide, to be used as artificial reef. Such structures form desirable habitat for marine biota and are common sites of recreational fishing and diving activities throughout the world. Although ATSDR does not endorse or recommend unauthorized diving in these waters, there is nothing unique in the construction of the former Killen that would suggest a human health hazard from exposure to metals by divers or marine biota. The following information on the environmental value of artificial reefs, including sunken vessels, was collected from publicly available Web sites.

> "Alabama has the largest artificial reef program in the United States at the present time. The natural bottom offshore of Alabama is predominately flat sand bottom. This bottom type attracts few fish that are either commercially or recreationally valuable. However, it has long been known that if vertical relief is created on this bottom, many reef fish such as snappers and groupers will be attracted. In fact artificial reefs can be created that over time will appear as natural reefs with similar communities of encrusting organisms and bait fish. As various encrusting organisms such as corals and sponges cover the artificial reef material, small animals take up residence. As these small animals become abundant larger

animals are attracted and feed upon these. Yet larger fish are attracted to these and so on until a complete reef food web is created. At that point the artificial reef functions as a natural reef. Alabama's artificial reef building program started in 1953 when the Orange Beach Charter Boat Association asked for the authority to place 250 car bodies off Baldwin County, Alabama. This proved to be very successful and in the years since, many different types of materials have been placed offshore of Alabama. These have included additional car bodies, culverts, bridge rubble, barges, boats and planes" (Alabama Dept of Conservation and Natural Resources, Marine Resources Division 2003).

"Artificial reefs rise like oases in the desert -- dotting the vast expanses of mud and sand covering the floor of the Gulf of Mexico. These underwater havens provide hard surfaces required for attachment by invertebrates such as barnacles, corals, sponges, clams, bryozoans and hydroids. These reefs are particularly important since the habitat is limited for many of them. These organisms are the beginnings of an interactive food web that supports a host of reef fish species. By providing food and shelter, artificial reefs can enhance overfished populations of resident reef fish like snapper and grouper. Transient species like mackerel, shark and billfish can also benefit by feeding on the resident fish" (Texas Parks and Wildlife Commission 2003).

"Since 1984, the bureau has been involved in an intensive program of artificial reef construction and biological monitoring. The purpose is to create a network of artificial reefs in the ocean waters along the New Jersey coast to provide a hard substrate for fish, shellfish and crustaceans, fishing grounds for anglers, and underwater structures for scuba divers. Artificial reefs are constructed by intentionally placing dense materials, such as old ships and barges, concrete ballasted tire units, concrete and steel demolition debris and dredge rock on the sea floor within designated reef sites. At present, the division holds permits for 14 artificial reef sites encompassing a total of 25 square miles of sea floor" (New Jersey Division of Fish and Wildlife 2003).

Artificial Reefs of the Keys is a non-profit group in Key West, Florida, working to bring the de-commissioned ex-*USAFS Gen. Hoyt S. Vandenberg* to Florida waters to become an artificial reef. "At over 520 feet and 13,000 tons, this will be the largest ship ever intentionally sunk for this purpose. This ship will become a world-class diving destination, but it will also offer many other benefits to the environment and to education and research" (Artificial Reefs of the Keys 2003).

4. Concern: Eating Boxfish

While on Vieques, ATSDR met with the petitioner, who at that time, specifically requested ATSDR to collect and analyze boxfish (family Ostraciidae; e.g., cowfish and trunkfish) from the fish market. At the request of ATSDR, the petitioner had compiled a list of fish caught and eaten on Vieques and reported that *Chapín* (boxfish) are the preferred fish to use as filling in *pastelillos*. Realizing that the results and conclusions would be limited, ATSDR agreed to collect a representative sample. A cowfish (honeycomb cowfish, *Lactophrys polygonia*) was purchased from the fish market for analysis. The results are presented in Table 10.

Of the fish sampled by ATSDR, the cowfish contained the highest concentrations of arsenic (29.3 ppm) and selenium (2.5 ppm). It should be noted that it is not unusual for different samples of the same species to contain varying chemical concentrations; therefore, other cowfish samples may contain higher or lower levels of these chemicals. However, consuming cowfish with the levels detected would not be expected to result in harmful health effects (see Appendix D for more details on the methods and assumptions ATSDR used to estimate human exposure doses and determine health effects).

Community members can direct additional health concerns to:

Program Evaluation, Records, and Information Services Branch
ATSDR, Division of Health Assessment and Consultation
Attn: Isla de Vieques, Puerto Rico
1600 Clifton Road, NE (E-60)
Atlanta, Georgia 30333

Community members can also telephone the ATSDR regional representatives in New York, New York, at (212) 637-4307 or call the toll-free telephone number, 1-888-42-ATSDR.

VII. CHILD HEALTH CONSIDERATIONS

ATSDR recognizes that infants and children can be more sensitive to contamination of their food than adults because children are smaller, therefore childhood exposure results in higher doses of chemical exposure per body weight. Because children can sustain permanent damage if these factors lead to toxic exposure during critical growth stages, ATSDR as part of its public health assessment process is committed to evaluating their special interests at sites such as Vieques.

ATSDR specifically evaluated the exposure to children and determined that they can safely eat fish and shellfish from Vieques.

VIII. CONCLUSIONS

Through its sampling program and public health evaluation, ATSDR has drawn the following conclusions regarding the fish and shellfish of Vieques:

- ATSDR concludes that exposures to contaminants in fish and shellfish are not at levels expected to cause adverse health effects and thus the site does not pose a public health hazard. Because exposure is still possible to these low levels, ATSDR has categorized consumption of fish and shellfish as *"no apparent public health hazard"*.

- During the July 2001 sampling, the appearance and general health of the reefs at all the sampling locations were noted. Although no quantitative data were collected, it was noted that all sample locations appeared to support diverse, healthy populations of marine organisms and that all reefs were in good condition.

- Field personnel briefly examined each fish and shellfish sample and reported that with very few exceptions, the organisms collected appeared to be healthy.

- Several metals were detected in some of the fish and shellfish from Vieques. However, the concentrations that were present were too low to be of health concern.

- Because individual metals in individual species varied from location to location, ATSDR evaluated whether eating fish or shellfish from any specific location would cause people to experience adverse health effects. The concentrations that were present at each location were too low to be of health concern.

- Universidad Metropolitana reported that yellowtail snapper was the most commonly consumed species of fish (Caro et al. 2000). In addition, several Vieques fishermen and residents indicated to ATSDR that snapper was more commonly sought after, caught, and consumed than any other species of fish. Therefore, ATSDR evaluated the specific scenario of people eating snapper every day and concluded that the chemical concentrations that were present in snapper were too low to be of health concern.

- Community members were concerned about the potential impact on marine biota in the vicinity of the former Killen located to the south of the LIA. Fish and shellfish from around the Killen were collected and analyzed during ATSDR's sampling effort. ATSDR concluded that the chemical concentrations in the fish and shellfish collected from this area were too low to be of health concern.

- The petitioner specifically requested ATSDR to collect and analyze boxfish (e.g. trunkfish, cowfish) from the fish market. A honeycomb cowfish was purchased for analysis. Based on the concentrations of chemicals detected, consuming cowfish with the levels detected would not be expected to result in harmful health effects.

IX. PUBLIC HEALTH ACTION PLAN

The Public Health Action Plan for Vieques contains a description of actions taken and those to be taken by ATSDR, the Navy, EPA, PREQB, and the Puerto Rico Department of Health (PRDOH). The purpose of the Public Health Action Plan is to ensure that this PHA not only identifies potential public health hazards, but also provides a plan of action to mitigate and prevent harmful human health effects that may be resulting from exposure to hazardous substances in the environment. The public health actions that are completed, ongoing, and recommended are as follows:

Actions Completed:

- In August 1999, ATSDR conducted an initial site visit to Vieques to meet with the petitioner, tour the island and bombing range, and gather environmental data. As a result of this site visit, ATSDR accepted the resident's petition and initiated the public health assessment process.

- In June and October 2000, ATSDR discussed with local health care providers their public health concerns and provided training regarding how to medically assess environmental exposures. During these visits ATSDR met with numerous residents of the island to discuss health concerns.

- In September 2000, ATSDR met with various agencies, including PRDOH, PREQB, EPA, the US Geological Survey, and the Navy, to gather data and to discuss the scope and nature of ATSDR investigations. ATSDR also met with the petitioner to tour various sites on Vieques and to update the petitioner on its efforts.

- In March 2001, ATSDR held a public availability session to meet individually with community members regarding the findings of the evaluation of drinking water and groundwater on Vieques.

- In April 2001, ATSDR toured Vieques both by land and by air with the principal purpose of identifying suitable areas to sample fish and shellfish off the coast of Vieques.

- In June 2001, the Navy, ATSDR, and their contractors collected air samples on Vieques to characterize levels of air contamination during air-to-ground bombing exercises.

- In July 2001, ATSDR, the Ponce School of Medicine, and CDC sponsored an expert review panel to address whether an association existed between place of residence (Vieques or Ponce Playa) and morphological cardiovascular changes among fishermen.

- ATSDR worked with EPA/ERT to collect and analyze fish and shellfish in the coastal waters and near shore areas of Vieques in July 2001. At this time, ATSDR also met with the petitioner to provide an update on ATSDR efforts.

- In September 2001, ATSDR conducted additional community involvement activities to inform participants of the scope of ATSDR investigations and seek additional community input. Continuing education and public health training was held for the nurses of Vieques and environmental health instruction was given to area parents and high school students.

- In October 2001, ATSDR released the Public Health Assessment for the Drinking Water Supplies and Groundwater Pathway Evaluation (ATSDR 2001a). This report concluded that the public drinking water supply on Vieques poses no public health hazard. However, high nitrates and nitrites, most likely resulting from agricultural pollution, in one private drinking water well indicate a health concern for children and pregnant women if they drank water from that well.

- In October 2001, ATSDR released a report summarizing the expert panel review addressing whether an association existed between place of residence and morphological cardiovascular changes among fishermen (ATSDR and PSM 2001). The panel found that the well-executed study showed no indication of abnormal heart function attributable to pericardial thickening.

- In November 2001, the Navy conducted a site investigation and characterized the biological organisms to assess the health of the marine species on and around the Killen and to assess potential impacts on the surrounding biota. EPA and PREQB will review the results and determine if further analysis is warranted.

- In February 2003, ATSDR released a PHA addressing public health implications from exposures to soils on Vieques (ATSDR 2003). This document concluded that there is no evidence that residents are being exposed to harmful levels of contamination in the soil.

Actions Ongoing:

- ATSDR continues to evaluate the public health implications of exposure to air contaminants. In a PHA released for public comment in November 2002, ATSDR addressed potential health issues resulting from air releases from the LIA, including wind-blown dust and the use of practice bombs, live bombs, and various other munitions.

- ATSDR is continuing to meet with various community members and organizations to receive concerns and exchange information. This effort will continue throughout the public health assessment process.

- ATSDR will continue to meet with local health care providers to discuss health concerns for the community and to provide educational materials for addressing the community's health needs.

- PRDOH is working on Vieques and in Puerto Rico generally to gather information regarding the incidence of cancer in Puerto Rico and on Vieques. That information will be added to the current cancer registry information.

- ATSDR will review cancer registry information and data gathered by PRDOH. The information will be evaluated as it relates to potential pathways of environmental exposure.

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TABLES

Table 1. 2000 US Census Data for Vieques

Parameter	Number of Residents	Percent of Total Residents
Total residents	9,106	100%
Men	4,512	50%
Women	4,594	50%
Women of childbearing age (15–44)	1,701	19%
Children (age 6 and under)	1,001	11%
Elderly (age 65 and over)	1,263	14%

Source: US Bureau of the Census 2000
Notes: According to the 2000 census data, 2,366 families lived on Vieques.
The 2000 census data include residents living on Navy lands and in the residential areas.

Table 2. Summary of Metal Analysis in Fiddler Crabs Sampled by Casa Pueblo de Adjuntas and the University of Puerto Rico

Metal	Average Concentration in Crab Extremities (ppm)		Average Concentration in Crab Bodies (ppm)	
	Puerto Mosquito	Icaco Lagoon	Puerto Mosquito	Icaco Lagoon
Cadmium	1.74	4.77	2.24	8.05
Chromium	25.48	23.07	40.27	40.70
Cobalt	12.17	9.82	10.32	35.69
Copper	49.94	51.18	381.75	499.91
Lead	ND	ND	ND	ND
Manganese	86.56	37.17	199.96	97.75
Nickel	17.15	7.02	21.81	18.95
Zinc	62.99	61.91	120.80	75.59

Source: Massol Deyá and Díaz 2000a
Notes: Averages are reported in dry weight concentrations.
ND = not detected

Table 3. Summary of Metal Analysis in Fish Fillets Sampled by Universidad Metropolitana

Metal	Northern Vieques			Esperanza			Parquera (mainland Puerto Rico)		
	Range (ppm)	Average (ppm)	Frequency of Detections	Range (ppm)	Average (ppm)	Frequency of Detections	Range (ppm)	Average (ppm)	Frequency of Detections
Arsenic	0.02–7.2	0.81	35/35	0.15–1.41	0.52	17/17	0.14–4.2	1.2	22/26
Cadmium	ND	ND	0/35	ND	ND	0/17	0.028	0.028	1/26
Lead	ND	ND	0/35	0.2	0.2	1/17	ND	ND	0/26
Mercury	0.004–0.1	0.024	28/35	0.008–0.38	0.02	16/17	0.002–0.052	0.011	17/26
Selenium	0.12–1.3	0.6	35/35	0.17–0.83	0.49	17/17	0.1–0.5	0.24	25/26
Zinc	1.2–9.1	3.8	35/35	3.3–8.2	5.4	17/17	0.7–6.2	3.0	26/26

Source: Caro et al. 2000

Note: It was not noted in the study if the concentrations were reported as wet weight concentrations or dry weight concentrations.
ND = not detected

Table 4. Summary of Metal Analysis in Fish Skins Sampled by Universidad Metropolitana

Metal	Northern Vieques			Esperanza			Parquera (mainland Puerto Rico)		
	Range (ppm)	Average (ppm)	Frequency of Detections	Range (ppm)	Average (ppm)	Frequency of Detections	Range (ppm)	Average (ppm)	Frequency of Detections
Arsenic	0.07–4.46	0.58	32/35	0.19–1.7	0.73	17/17	0.07–10	1.4	24/26
Cadmium	ND	ND	0/35	ND	ND	0/17	ND	ND	0/26
Lead	0.024–3.23	0.44	8/35	0.046–0.865	0.36	3/17	0.04–0.88	0.27	6/26
Mercury	0.002–0.12	0.026	22/35	0.004–0.063	0.02	10/17	0.003–0.06	0.017	14/26
Selenium	0.076–1.35	0.67	34/35	0.127–0.93	0.44	9/17	0.14–1.34	0.39	22/26
Zinc	0.5–28.7	11.4	34/35	7.2–23.3	13.1	17/17	4.4–59.2	13.2	26/26

Source: Caro et al. 2000

Note: It was not noted in the study if the concentrations were reported as wet weight concentrations or dry weight concentrations.
ND = not detected

Table 5. Summary of Chemicals Detected in Fiddler Crabs from the LIA and West Vieques

Chemical	Live Impact Area			West Vieques		
	Range (ppm)	Average (ppm)	Frequency of Detections	Range (ppm)	Average (ppm)	Frequency of Detections
Metals						
Aluminum	65–240	146	4/4	736–1,250	993	2/2
Antimony	ND	ND	0/4	NS	NS	NS
Arsenic	6.6–8.8	7.8	4/4	12.0–12.2	12.1	2/2
Barium	11–43	25.0	4/4	55.8–63.5	59.7	2/2
Beryllium	ND	ND	0/4	ND	ND	0/2
Boron	NS	NS	NS	21.4–23.2	22.3	2/2
Cadmium	0.13–1.0	0.56	4/4	0.115–1.0	0.56	2/2
Calcium	110,000–160,000	132,500	4/4	159,000–175,000	167,000	2/2
Chromium	0.49–3.8	1.59	4/4	1.11–1.56	1.34	2/2
Cobalt	0.27–0.34	0.29	4/4	0.549	0.549	1/2
Copper	78–180	131	4/4	127–203	165	2/2
Iron	33–550	328	4/4	384–1,240	812	2/2
Lead	ND	ND	0/4	0.667–11.7	6.18	2/2
Magnesium	9,300–13,000	11,325	4/4	13,700–14,800	14,250	2/2
Manganese	4.3–16	10.9	4/4	49.6–63.1	56.4	2/2
Mercury	ND	ND	0/4	0.0678–0.0725	0.0702	2/2
Molybdenum	NS	NS	NS	1.04–1.56	1.3	2/2
Nickel	0.98–1.0	0.99	2/4	ND	ND	0/2
Phosphorous	NS	NS	NS	6,750–7,900	7,325	2/2
Potassium	6,800–7,500	7,200	4/4	4,900–5,410	5,155	2/2
Selenium	1.2–2.4	1.9	4/4	1.27–1.35	1.31	2/2

Table 5. Summary of Chemical Analysis in Fiddler Crabs from the LIA and West Vieques (continued)

Chemical	Live Impact Area			West Vieques		
	Range (ppm)	Average (ppm)	Frequency of Detections	Range (ppm)	Average (ppm)	Frequency of Detections
Silver	0.21–0.37	0.32	4/4	NS	NS	NS
Sodium	12,000–14,000	13,250	4/4	154,000–177,000	165,500	2/2
Strontium	NS	NS	NS	2,480–2,550	2,515	2/2
Sulfur	NS	NS	NS	5,080–6,080	5,580	2/2
Thallium	ND	ND	0/4	NS	NS	NS
Vanadium	0.34–1.1	0.65	4/4	1.55–2.63	2.09	2/2
Zinc	86–97	91	4/4	78.6–95.0	86.8	2/2
Pesticides						
p,p'-DDE	NS	NS	NS	0.178	0.178	1/2
Explosives compounds						
HMX	0.81–0.97	0.90	4/4	NS	NS	NS

Sources: LIA: ATSDR and EPA/ERT's 2001 sampling; West Vieques: FWS 2001a, 2001b

Notes: Values are reported in dry weight concentrations.

Rinsing fiddler crabs of sand and dirt was inadvertently omitted prior to placing them into sample containers.

ATSDR also analyzed fiddler crabs in the Live Impact Area for RDX, 1,3-dinitrobenzene, 2,4-dinitrotoluene, 2,6-dinitrotoluene, 2-amino-4,6-dinitrotoluene, 4-amino-2,6-dinitrotoluene, nitrobenzene, nitroglycerin, 2-nitrotoluene, 3-nitrotoluene, 4-nitrotoluene, tetryl, 1,3,5-trinitrobenzene, and 2,4,6-trinitrotoluene. For all samples, chemicals were found below detection limits.

The US Fish and Wildlife Service also analyzed fiddler crabs in West Vieques for HCB, PCB-1242, PCB-1248, PCB-1254, PCB-1260, PCB-total, alpha BHC, alpha chlordane, beta BHC, cis-nonachlor, delta BHC, dieldrin, endrin, gamma BHC, gamma chlordane, heptachlor epoxide, mirex, o,p'-DDD, o,p'-DDE, o,p'-DDT, oxychlordane, p,p'-DDD, p,p'-DDT, toxaphene and trans-nonachlor. For all samples, chemicals were found below detection limits.

ND = not detected

NS = not sampled

Table 6. Summary of Land Crab Sampling in West Vieques by the US Fish and Wildlife Service

Chemical	West Vieques			St. Croix (control)		
	Range (ppm)	Average (ppm)	Frequency of Detections	Range (ppm)	Average (ppm)	Frequency of Detections
Metals						
Aluminum	213–399	303	4/4	128–192	160	3/3
Arsenic	1.06–1.89	1.58	4/4	1.53–2.8	2.17	3/3
Barium	15–143	68.5	4/4	6.66–10.3	8.78	3/3
Beryllium	ND	ND	0/4	ND	ND	0/3
Boron	3.75–6.89	5.03	4/4	4.38–9.55	6.46	3/3
Cadmium	0.0337–0.656	0.196	4/4	0.0228–0.0402	0.0315	2/3
Calcium	43,080–65,600	51,820	4/4	43,750–51,520	48,227	3/3
Chromium	0.365–0.699	0.556	4/4	0.284–0.342	0.321	3/3
Cobalt	0.21–0.31	0.28	3/4	ND	ND	0/3
Copper	28.2–44.4	37.2	4/4	23.5–39.7	30.6	3/3
Iron	116–306	185	4/4	17.8–23.7	21	3/3
Lead	0.291–2.05	0.799	4/4	0.287–0.366	0.333	3/3
Magnesium	3,770–5,617	4,651	4/4	3,815–4,563	4,147	3/3
Manganese	9.15–24.1	17.5	4/4	3.81–4.52	4.16	3/3
Mercury	0.0081–0.0216	0.0125	4/4	0.0091–0.0145	0.0124	3/3
Molybdenum	ND	ND	0/4	ND	ND	0/3
Nickel	0.172–0.418	0.297	4/4	ND	ND	0/3
Phosphorous	2,686–3,145	2,815	4/4	2,838–3,316	3,147	3/3
Potassium	1,920–2,175	2,023	4/4	1,903–2,240	2,092	3/3
Selenium	0.0697–0.165	0.124	4/4	0.0732–0.143	0.105	3/3
Sodium	5,019–6,027	5,336	4/4	5,040–5,710	5,301	3/3
Strontium	475–959	659	4/4	556–747	671	3/3

Table 6. Summary of land crab sampling in west Vieques by the US Fish and Wildlife Service (continued)

Chemical	West Vieques			St. Croix (control)		
	Range (ppm)	Average (ppm)	Frequency of Detections	Range (ppm)	Average (ppm)	Frequency of Detections
Sulfur	1,410–1,926	1,669	4/4	1,575–1,965	1,759	3/3
Vanadium	0.445–0.64	0.518	4/4	ND	ND	0/3
Zinc	35.5–87.5	52.3	4/4	33.6–47.6	38.7	3/3
Pesticides						
p,p'-DDE	0.13	0.13	1/4	ND	ND	0/3
p,p'-DDT	0.028	0.028	1/4	ND	ND	0/3

Sources: FWS 2001a, 2001b

Notes: Values are reported in wet weight concentrations.

HCB, PCB-1242, PCB-1248, PCB-1254, PCB-1260, PCB-total, alpha BHC, alpha chlordane, beta BHC, cis-nonachlor, delta BHC, dieldrin, endrin, gamma BHC, gamma chlordane, heptachlor epoxide, mirex, o,p'-DDD, o,p'-DDE, o,p'-DDT, oxychlordane, p,p'-DDD, toxaphene and trans-nonachlor were also analyzed. For all samples, chemicals were found below detection limits.

ND = not detected

Table 7. Fish and Shellfish Collected by ATSDR

Taxonomic Group	Latin Name	Loc. #1	Loc. #2	Loc. #3	Loc. #4	Loc. #5	Loc. #6
Red Hind	*Epinephelus guttatus*	5	1	0	5	5	3
Rock Hind	*Epinephelus adscensionis*	0	4	4	0	0	0
Graysby	*Epinephelus cruentatus*	0	0	1	0	0	0
Coney	*Epinephelus fulvus*	0	0	0	0	0	2
Total # Serranidae family		Total = 5	Total = 5	Total = 5	Total = 5	Total = 5	Total = 5
Schoolmaster Snapper	*Lutjanus apodus*	0	3	2	0	0	0
Grey Snapper	*Lutjanus griseus*	0	2	1	0	0	0
Yellowtail Snapper	*Ocyurus chrysurus*	0	0	1	2	5	3
Total # Lutjanidae family		Total = 0	Total = 5	Total = 4	Total = 2	Total = 5	Total = 3
Stoplight Parrotfish	*Sparisoma viride*	4	1	5	4	0	5
Redband Parrotfish	*Sparisoma aurofrenatum*	1	3	0	1	0	0
Redfin Parrotfish	*Sparisoma rubripinne*	0	1	0	0	0	0
Total # Scaridae family		Total = 5	Total = 5	Total = 5	Total = 5	Total = 0	Total = 5
White Grunt	*Haemulon plumieri*	0	2	0	0	5	0
Spanish Grunt	*Haemulon macrostomum*	0	0	1	0	0	0
Bluestriped Grunt	*Haemulon sciurus*	5	3	4	0	0	0
French Grunt	*Haemulon flavolineatum*	0	0	0	0	0	4
Total # Haemulidae family		Total = 5	Total = 5	Total = 5	Total = 0	Total = 5	Total = 4
Yellow Goatfish	*Mulloidichthys martinicus*	0	0	3	0	0	1
Spotted Goatfish	*Pseudupeneus maculatus*	1	0	0	0	0	0
Total # Mullidae family		Total = 1	Total = 0	Total = 3	Total = 0	Total = 0	Total = 1
Honeycomb Cowfish	*Lactophrys polygonia*	0	0	0	0	1	0
Queen Conch	*Strombus gigas*	5	5	5	0	0	5
Spiny Lobster	*Panulirus argus*	1	0	1	0	5	0
Blue Land Crab	*Cardisoma guanhumi*	5	5	0	0	0	1
Fiddler Crab	*Uca* sp.	2	2	0	0	0	0

Note: Blue land crabs and fiddler crabs are listed by the number of tissue samples analyzed, not by the number of individuals captured. The meat from several land crabs was composited until a sufficient quantity of meat was obtained. Fiddler crabs were analyzed *en masse* to ensure a sufficient sample was collected for analysis.

Table 8. Summary of Chemical Analysis in Fish Sampled by ATSDR

Chemical	Range (ppm)	Average (ppm)	Frequency of Detections
Metals			
Aluminum	2.59–14	7.66	75/104
Antimony	ND	ND	0/104
Arsenic	0.5–29.3	3.95	76/104
Barium	0.06–6.59	0.24	80/104
Beryllium	0.01–0.02	0.016	20/104
Cadmium	0.08	0.08	1/104
Calcium	71.3–5,330	777	104/104
Chromium	0.05–1.99	0.16	98/104
Cobalt	0.06–0.11	0.08	7/104
Copper	0.11–8.21	0.56	97/104
Iron	1.9–57.8	6.81	62/104
Lead	0.16–1.94	0.27	36/104
Magnesium	257–648	330	104/104
Manganese	0.11–3.09	0.33	68/104
Mercury	0.02–0.33	0.12	81/104
Methylmercury	0.02–0.08	0.05	3/3
Nickel	0.35–1.28	0.81	2/104
Potassium	3,230–7,340	3,870	104/104
Selenium	0.63–2.48	0.98	104/104
Silver	0.07–0.11	0.08	4/104
Sodium	214–2,590	468	104/104
Thallium	ND	ND	0/104
Vanadium	0.09	0.09	1/104
Zinc	0.54–24.7	3.13	99/104

Table 8. Summary of Chemical Analysis in Fish Sampled by ATSDR (continued)

Chemical	Range (ppm)	Average (ppm)	Frequency of Detections
Explosives compounds			
1,3-Dinitrobenzene	ND	ND	0/104
2,4-Dinitrotoluene	ND	ND	0/104
2,6-Dinitrotoluene	ND	ND	0/104
2-amino-4,6-Dinitrotoluene	ND	ND	0/104
4-amino-2,6-Dinitrotoluene	ND	ND	0/104
HMX	ND	ND	0/104
Nitrobenzene	ND	ND	0/104
Nitroglycerin	ND	ND	0/104
2-Nitrotoluene	ND	ND	0/104
3-Nitrotoluene	ND	ND	0/104
4-Nitrotoluene	ND	ND	0/104
RDX	ND	ND	0/104
Tetryl	ND	ND	0/104
1,3,5-Trinitrobenzene	ND	ND	0/104
2,4,6-Trinitrotoluene	ND	ND	0/104

Notes: Averages were calculated using detected values only.
Values are reported in wet weight concentrations.
ND = not detected

Table 9. Summary of Chemical Analysis in Shellfish Sampled by ATSDR

Chemical	Range (ppm)	Average (ppm)	Frequency of Detections
Metals			
Aluminum	3.2–43.9	15.5	26/38
Antimony	ND	ND	0/38
Arsenic	1.15–48.3	11.1	28/38
Barium	0.09–7.25	2.21	26/38
Beryllium	0.014–0.018	0.016	5/38
Cadmium	0.2–0.69	0.36	21/38
Calcium	146–7,020	2,090	38/38
Chromium	0.076–1.29	0.19	36/38
Cobalt	0.063–0.088	0.079	7/38
Copper	1.35–17.6	7.83	38/38
Iron	1.62–162	36.3	14/22
Lead	0.17–0.57	0.25	9/38
Magnesium	251–4,350	1,820	38/38
Manganese	0.16–5.06	2.49	34/38
Mercury	0.018–0.049	0.031	16/38
Methylmercury	0.019	0.019	1/1
Nickel	ND	ND	0/38
Potassium	2,510–4,540	3,440	38/38
Selenium	0.43–1.16	0.8	38/38
Silver	0.07–0.19	0.1	13/38
Sodium	1,140–4,100	2,330	38/38
Thallium	ND	ND	0/38
Vanadium	0.051–0.27	0.11	16/38
Zinc	5.41–96.6	30.1	38/38

Table 9. Summary of Chemical Analysis in Shellfish Sampled by ATSDR (continued)

Chemical	Range (ppm)	Average (ppm)	Frequency of Detections
Explosives compounds			
1,3-Dinitrobenzene	ND	ND	0/38
2,4-Dinitrotoluene	ND	ND	0/38
2,6-Dinitrotoluene	ND	ND	0/38
2-amino-4,6-Dinitrotoluene	ND	ND	0/38
4-amino-2,6-Dinitrotoluene	ND	ND	0/38
HMX	ND	ND	0/38
Nitrobenzene	ND	ND	0/38
Nitroglycerin	ND	ND	0/38
2-Nitrotoluene	ND	ND	0/38
3-Nitrotoluene	ND	ND	0/38
4-Nitrotoluene	ND	ND	0/38
RDX	ND	ND	0/38
Tetryl	ND	ND	0/38
1,3,5-Trinitrobenzene	ND	ND	0/38
2,4,6-Trinitrotoluene	ND	ND	0/38

Notes: This table only includes the results for edible species of shellfish. Please see Table 5 for a summary of the fiddler crab data.
Averages were calculated using detected values only.
Values are reported in wet weight concentrations.
The non-detected results for sixteen iron samples were regarded as unusable during the validation process because iron displayed a strong interference in the analysis of the samples (probably due to the high concentration of calcium).
ND = not detected

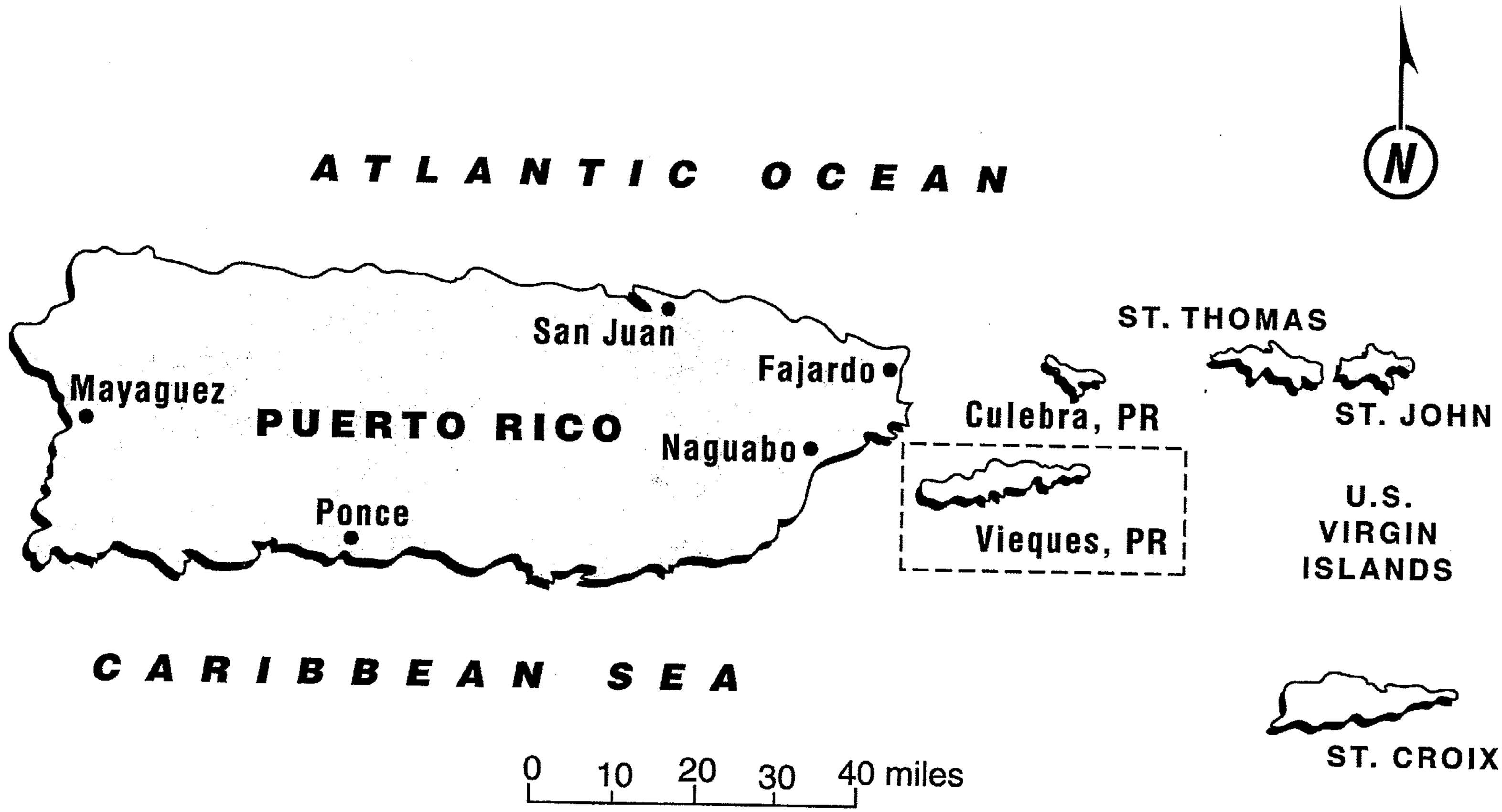
Table 10. Summary of Chemical Analysis in Cowfish

Chemical	Concentration (ppm)	Frequency of Detections	Chemical	Concentration (ppm)	Frequency of Detections
Metals			*Explosives compounds*		
Aluminum	4.3	1/1	1,3-Dinitrobenzene	ND	0/1
Antimony	ND	0/1	2,4-Dinitrotoluene	ND	0/1
Arsenic	29.3	1/1	2,6-Dinitrotoluene	ND	0/1
Barium	0.15	1/1	2-amino-4,6-Dinitrotoluene	ND	0/1
Beryllium	ND	0/1	4-amino-2,6-Dinitrotoluene	ND	0/1
Cadmium	ND	0/1	HMX	ND	0/1
Calcium	360	1/1	Nitrobenzene	ND	0/1
Chromium	0.08	1/1	Nitroglycerin	ND	0/1
Cobalt	ND	0/1	2-Nitrotoluene	ND	0/1
Copper	0.36	1/1	3-Nitrotoluene	ND	0/1
Iron	ND	0/1	4-Nitrotoluene	ND	0/1
Lead	ND	0/1	RDX	ND	0/1
Magnesium	338	1/1	Tetryl	ND	0/1
Manganese	ND	0/1	1,3,5-Trinitrobenzene	ND	0/1
Mercury	ND	0/1	2,4,6-Trinitrotoluene	ND	0/1
Nickel	ND	0/1			
Potassium	3,825	1/1			
Selenium	2.5	1/1			
Silver	ND	0/1			
Sodium	743	1/1			
Thallium	ND	0/1			
Vanadium	ND	0/1			
Zinc	3.2	1/1			

Notes: Values are reported in wet weight concentrations.
ND = not detected

FIGURES

Figure 1. Location of Isla de Vieques



Reference: Torres-Gonzalez, 1989

Figure 2. Vieques Land Use

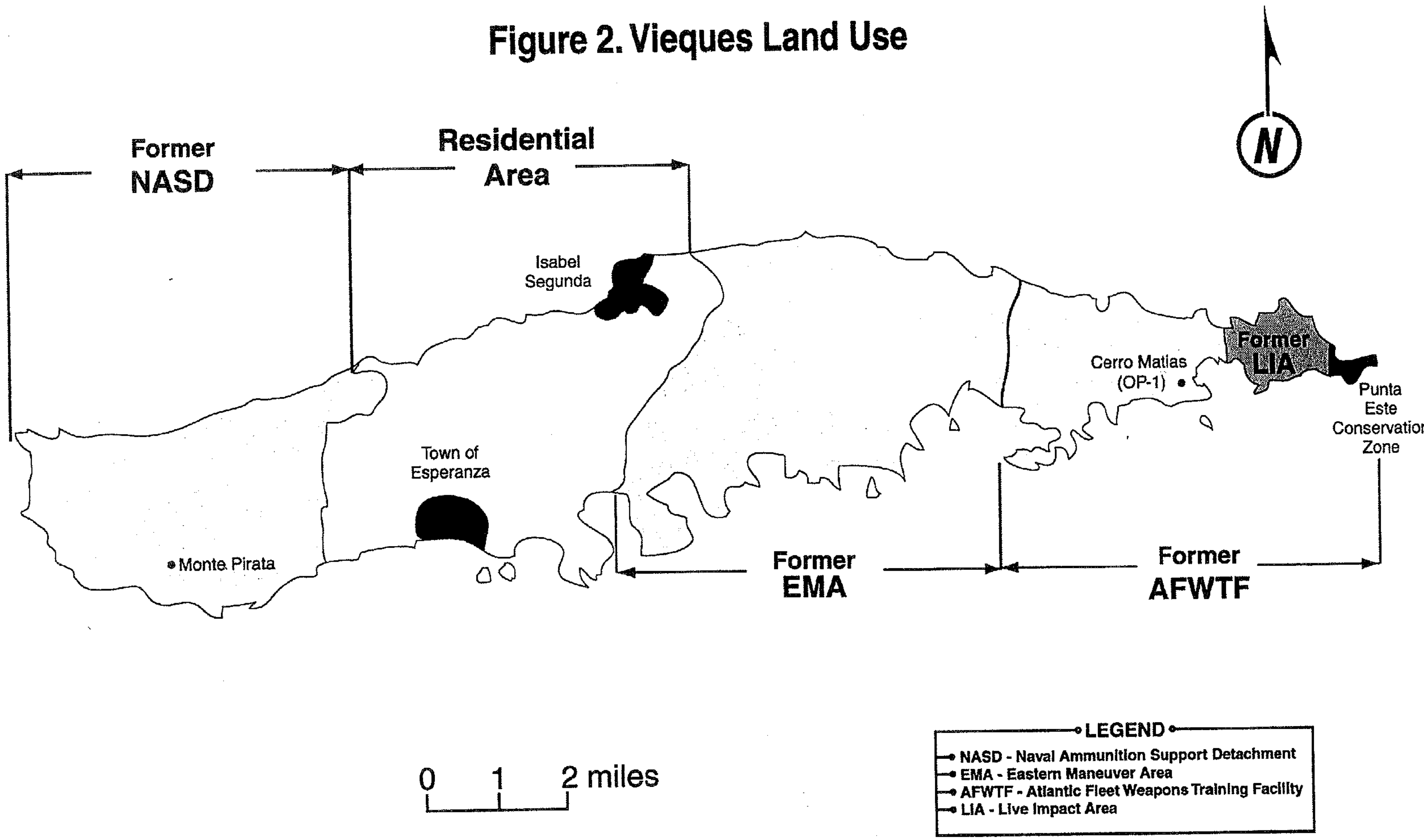
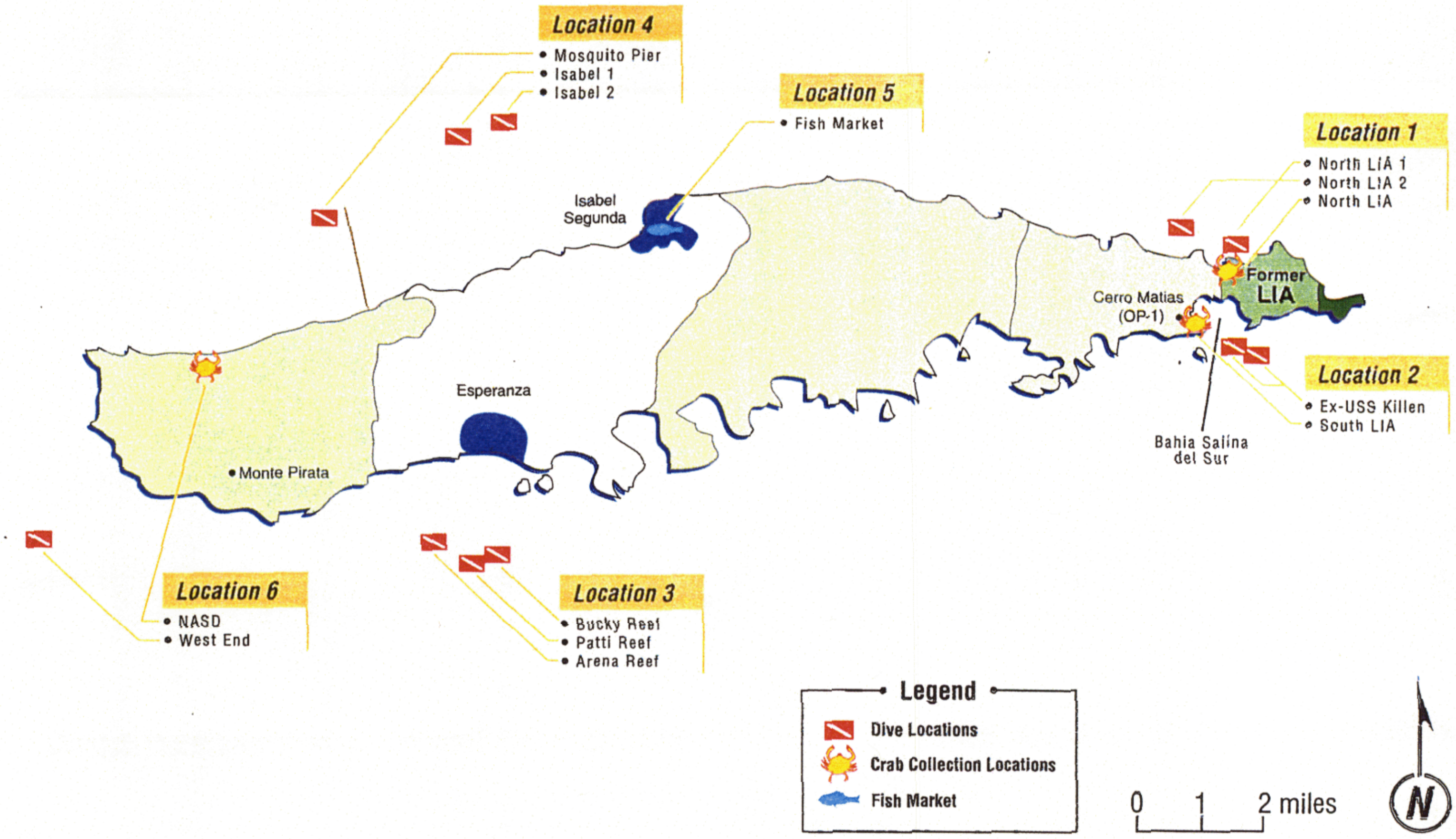


Figure 3. ATSDR Fish & Shellfish Sample Locations



Appendix A

ATSDR Glossary of Environmental Health Terms

ATSDR Glossary of Environmental Health Terms

Absorption: How a chemical enters a person's blood after the chemical has been swallowed, has come into contact with the skin, or has been breathed.

Acute Exposure: Contact with a chemical that happens once or only for a limited period of time. ATSDR defines acute exposures as those that might last up to 14 days.

Additive Effect: A response to a chemical mixture, or combination of substances, that might be expected if the known effects of individual chemicals, seen at specific doses, were added together.

Adverse Health Effect: A change in body function or the structures of cells that can lead to disease or health problems.

Antagonistic Effect: A response to a mixture of chemicals or combination of substances that is **less** than might be expected if the known effects of individual chemicals, seen at specific doses, were added together.

ATSDR: The **A**gency for **T**oxic **S**ubstances and **D**isease **R**egistry. ATSDR is a federal health agency in Atlanta, Georgia that deals with hazardous substance and waste site issues. ATSDR gives people information about harmful chemicals in their environment and tells people how to protect themselves from coming into contact with chemicals.

Background Level: An average or expected amount of a chemical in a specific environment. Or, amounts of chemicals that occur naturally in a specific environment.

Biota: Used in public health, things that humans would eat – including animals, fish and plants.

Cancer: A group of diseases which occur when cells in the body become abnormal and grow, or multiply, out of control.

CEL: **C**ancer **E**ffects **L**evel. Dose that produces significant increases in the incidence of cancer or tumors.

Carcinogen: Any substance shown to cause tumors or cancer in experimental studies.

Chronic Exposure: A contact with a substance or chemical that happens over a long period of time. ATSDR considers exposures of more than one year to be *chronic*.

Completed Exposure Pathway: See **Exposure Pathway**.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA): **CERCLA** was put into place in 1980. It is also known as **Superfund**. This act concerns releases of hazardous substances into the environment, and the cleanup of these substances and hazardous waste sites. ATSDR was created by this act and is responsible for looking into the health issues related to hazardous waste sites.

Concern: A belief or worry that chemicals in the environment might cause harm to people.

Concentration: How much or the amount of a substance present in a certain amount of soil, water, air, or food.

Contaminant: See **Environmental Contaminant**.

Dose: The amount of a substance to which a person may be exposed, usually on a daily basis. Dose is often explained as "amount of substance(s) per body weight per day."

Dose / Response: The relationship between the amount of exposure (dose) and the change in body function or health that result.

Duration: The amount of time (days, months, years) that a person is exposed to a chemical.

Environmental Contaminant: A substance (chemical) that gets into a system (person, animal, or the environment) in amounts higher than that found in **Background Level**, or what would be expected.

Environmental Media: Usually refers to the air, water, and soil in which chemicals of interest are found. Sometimes refers to the plants and animals that are eaten by humans. **Environmental Media** is the second part of an **Exposure Pathway**.

US Environmental Protection Agency (EPA): The federal agency that develops and enforces environmental laws to protect the environment and the public's health.

Epidemiology: The study of the different factors that determine how often, in how many people, and in which people will disease occur.

Exposure: Coming into contact with a chemical substance.(For the three ways people can come in contact with substances, see **Route of Exposure**.)

Exposure Assessment: The process of finding the ways people come in contact with chemicals, how often and how long they come in contact with chemicals, and the amounts of chemicals with which they come in contact.

Exposure Pathway: A description of the way that a chemical moves from its source (where it began) to where and how people can come into contact with (or get exposed to) the chemical.

ATSDR defines an exposure pathway as having 5 parts:

1. Source of Contamination,
2. Environmental Media and Transport Mechanism,
3. Point of Exposure,
4. Route of Exposure, and
5. Receptor Population.

When all 5 parts of an exposure pathway are present, it is called a **Completed Exposure Pathway**. Each of these 5 terms is defined in this Glossary.

Frequency: How often a person is exposed to a chemical over time; for example, every day, once a week, twice a month.

Hazardous Waste: Substances that have been released or thrown away into the environment and, under certain conditions, could be harmful to people who come into contact with them.

Health Effect: ATSDR deals only with **Adverse Health Effects** (see definition in this Glossary).

Indeterminate Public Health Hazard: The category is used in Public Health Assessment documents for sites where important information is lacking (missing or has not yet been gathered) about site-related chemical exposures.

Ingestion: Swallowing something, as in eating or drinking. It is a way a chemical can enter your body (See **Route of Exposure**).

Inhalation: Breathing. It is a way a chemical can enter your body (See **Route of Exposure**).

MRL: **M**inimal **R**isk **L**evel. An estimate of daily human exposure – by a specified route and length of time -- to a dose of chemical that is likely to be without a measurable risk of adverse, noncancerous effects. An MRL should not be used as a predictor of adverse health effects.

NPL: The **N**ational **P**riorities **L**ist. (Which is part of **Superfund**.) A list kept by the US Environmental Protection Agency (EPA) of the most serious, uncontrolled or abandoned hazardous waste sites in the country. An NPL site needs to be cleaned up or is being looked at to see if people can be exposed to chemicals from the site.

NOAEL: **N**o **O**bserved **A**dverse **E**ffect **L**evel. The highest dose of a chemical in a study, or group of studies, that did not cause harmful health effects in people or animals.

No Apparent Public Health Hazard: The category is used in ATSDR's Public Health Assessment documents for sites where exposure to site-related chemicals may have occurred in the past or is still occurring but the exposures are not at levels expected to cause adverse health effects.

No Public Health Hazard: The category is used in ATSDR's Public Health Assessment documents for sites where there is evidence of an absence of exposure to site-related chemicals.

PHA: Public Health Assessment. A report or document that looks at chemicals at a hazardous waste site and tells if people could be harmed from coming into contact with those chemicals. The PHA also tells if possible further public health actions are needed.

Plume: A line or column of air or water containing chemicals moving from the source to areas further away. A plume can be a column or clouds of smoke from a chimney or contaminated underground water sources or contaminated surface water (such as lakes, ponds and streams).

Point of Exposure: The place where someone can come into contact with a contaminated environmental medium (air, water, food or soil). For examples: the area of a playground that has contaminated dirt, a contaminated spring used for drinking water, the location where fruits or vegetables are grown in contaminated soil, or the backyard area where someone might breathe contaminated air.

Population: A group of people living in a certain area; or the number of people in a certain area.

Public Health Hazard: The category is used in PHAs for sites that have certain physical features or evidence of chronic, site-related chemical exposure that could result in adverse health effects.

Public Health Hazard Criteria: PHA categories given to a site which tell whether people could be harmed by conditions present at the site. Each are defined in the Glossary. The categories are:

1. Urgent Public Health Hazard
2. Public Health Hazard
3. Indeterminate Public Health Hazard
4. No Apparent Public Health Hazard
5. No Public Health Hazard

Receptor Population: People who live or work in the path of one or more chemicals, and who could come into contact with them (See **Exposure Pathway**).

Reference Dose (RfD): An estimate, with safety factors (see **safety factor**) built in, of the daily, life-time exposure of human populations to a possible hazard that is <u>not</u> likely to cause harm to the person.

Route of Exposure: The way a chemical can get into a person's body. There are three exposure routes:

- breathing (also called inhalation),
- eating or drinking (also called ingestion), and
- or getting something on the skin (also called dermal contact).

Safety Factor: Also called **Uncertainty Factor**. When scientists don't have enough information to decide if an exposure will cause harm to people, they use "safety factors" and formulas in place of the information that is not known. These factors and formulas can help determine the amount of a chemical that is <u>not</u> likely to cause harm to people.

Source (of Contamination): The place where a chemical comes from, such as a landfill, pond, creek, incinerator, tank, or drum. Contaminant source is the first part of an **Exposure Pathway**.

Special Populations: People who may be more sensitive to chemical exposures because of certain factors such as age, a disease they already have, occupation, sex, or certain behaviors (like cigarette smoking). Children, pregnant women, and older people are often considered special populations.

Statistics: A branch of the math process of collecting, looking at, and summarizing data or information.

Synergistic effect: A health effect from an exposure to more than one chemical, where one of the chemicals worsens the effect of another chemical. The combined effect of the chemicals acting together are greater than the effects of the chemicals acting by themselves.

Toxic: Harmful. Any substance or chemical can be toxic at a certain dose (amount). The dose is what determines the potential harm of a chemical and whether it would cause someone to get sick.

Toxicology: The study of the harmful effects of chemicals on humans or animals.

Tumor: Abnormal growth of tissue or cells that have formed a lump or mass.

Uncertainty Factor: See **Safety Factor**.

Urgent Public Health Hazard: This category is used in ATSDR's Public Health Assessment documents for sites that have certain physical features or evidence of short-term (less than 1 year), site-related chemical exposure that could result in adverse health effects and require quick intervention to stop people from being exposed.

Appendix B

Sampling Methods for ATSDR's Fish and Shellfish Investigation

Sampling Methods for ATSDR's Fish and Shellfish Investigation

Sampling Techniques

At each location, field personnel collected fish and shellfish using the following methods:

- *Spearfishing.* Divers used spearguns, aided by self-contained underwater breathing apparatus (SCUBA), to collect fish. Where possible, the divers aimed for the fish's abdomen to avoid damaging the body meat (see Picture 11).
- *Fishing poles.* While on board the surface support boat, field personnel used fishing poles baited with squid.
- *Hand capture.* Lobster and conch were collected by hand, while snorkeling or while using SCUBA. Fiddler crabs were also collected by hand.
- *Traps.* Large wooden traps baited with fruit (e.g., mangos) were used to capture land crabs (see Picture 12).
- *Field purchase.* Field personnel purchased fish and lobsters from a local fish market. No attempt was made to verify the area from which the fish and lobsters were caught, though the market staff stated that all fish and lobsters sold in the market were caught locally.

Fish identifications were made using the field guide "Reef Fish Identification; Florida, Caribbean, Bahamas" (Humann 1994) and invertebrate identifications were made using the field guide "Caribbean Reef Invertebrates and Plants" (Colin 1978).

An attempt was made to collect organisms of the same approximate size (by species) at each location so that final tissue concentrations would be comparable. Because the reefs around Vieques are heavily fished, many of the fish and shellfish collected by field personnel were small, and it was not possible to collect five individuals of each of the species at every sampling location, as originally planned. Though yellowtail snapper was listed as the most commonly caught and consumed fish in Vieques (Caro et al. 2000), few yellowtail snappers were seen at any of the sampling locations, and those that were approachable were quite small (less than 30 cm).

Species	Regulation
yellowtail snapper	minimum total length = 12 inches [30 centimeters (cm)]
queen conch	minimum total length = 9 inches (23 cm), with greater than 3/8 inch (1 cm) lip thickness
spiny lobster	minimum carapace length = 3.5 inches (9 cm)

The Caribbean Fishery Management Council size regulations were observed where possible (see text box for details). Because the field sampling trip was scheduled for mid-July, during the closed season for collecting queen conch and land crabs, field personnel were not able to abide by the seasonal regulations. The Puerto Rico Department of Natural and Environmental Resources (DNER), however, granted permission to collect these specimens.

Organism Collection

Fish and shellfish were collected using the commercial dive charter boat, "Moonglow," operated by the Blue Caribe Dive Center, in Esperanza, Vieques (see Picture 13). The captain made suggestions regarding specific reefs at the desired sampling locations. Reef names, where known, were supplied by the boat captain. Areas unfamiliar to the captain, and/or not named on nautical charts, were named (for the purposes of this study) by field personnel. The latitude and longitude of the approximate center of each sampling location was determined using a global positioning system (GPS) unit made available on the chartered dive boat. Fish and shellfish were collected from July 16–20, 2001. Sample locations are depicted in Figure 3.

- On the first sampling day, field personnel traveled to Location 3. Dives were made on Bucky Reef and Patti Reef, which are regularly visited by recreational divers and fisherman. Fish were collected using spearguns and a single lobster was collected by hand.

- On the second sampling day, field personnel traveled to Location 2. Dives were made on the former USS Killen. Fish were collected using spearguns and fishing poles, and conch were collected by hand. Field personnel were unsuccessful in their attempt to collect lobster from Location 2. Land crabs and fiddler crabs were collected from the shore area adjacent to the former USS Killen.

- On the third sampling day, field personnel traveled to Location 1. Dives were made on two small, unnamed reefs. The first small unnamed patch reef (North LIA 1) was visible from the surface, since the reef crest was partially emergent at low tide. The other reef (North LIA 2) was located by towing a diver behind the boat (see Picture 14). Fish were collected using spearguns and fishing poles, lobster and conch were collected by hand. Land crabs and fiddler crabs were collected from the shore area adjacent to the patch reef at North LIA 1.

- On the fourth sampling day, field personnel traveled to Location 4. Dives were made on two unnamed reefs (Isabel 1 and Isabel 2) and under a dock near the end of the Mosquito Pier. Fish were collected using spearguns and fishing poles. Field personnel were unsuccessful in their attempt to collect lobster and conch from Location 4.

- On the fifth sampling day, field personnel split into two teams. The first team traveled to Locations 3, 5, and 6. At Location 6, dives were made on an unnamed reef (West End). Fish were collected using spearguns and conch were collected from a nearby seagrass bed by hand. Field personnel were unsuccessful in their attempt to collect lobster from Location 6. On the return trip from Location 6 to Esperanza, field personnel stopped at Location 3 (Arena Reef) to collect conch. The second team retrieved land crabs from traps that had been set the previous day on land near Location 6 and purchased fish from a fish market in Isabel Segunda (Location 5).

Tissue Sampling

Fish were processed according to EPA's Standard Operating Procedure # 2039 *Fish Handling and Processing* (EPA/ERT 1998). Each fish was weighed, measured for total length, and observed both externally and internally for obvious abnormalities (e.g., neoplasms, parasites, deformities) (see Pictures 15 and 16). Fish were filleted, taking care not to include any portion of the meat that had been damaged by the spear, and a sample of the fillet was wrapped in plastic wrap, placed in a sealable plastic bag, and placed on wet ice until it could be frozen (in less than 6 hours). Sometimes fillets from both sides of the fish were collected in order to obtain sufficient tissue mass for analytical requirements.

> ATSDR is aware that some residents of Vieques may eat more than the fillet of a fish (e.g., residents may use the whole fish to make soup stock). However, the bones and organs of the fish are typically not consumed. ATSDR chose to sample fish fillets to evaluate the maximum exposure potential to chemicals in the fish. This procedure tends to be more sensitive than analyzing the whole fish, which may cause the concentrations to be diluted. In addition, by sampling fish fillets, ATSDR is following standard protocol for human health evaluations and allowing for a comparison of these results to other studies.

Each lobster was weighed whole, measured for carapace length, and observed externally for obvious abnormalities. Lobster abdomens (i.e., tails) were separated from the carapace and the meat removed. The entire tail meat sample was wrapped in plastic wrap, placed in a plastic bag, and placed on wet ice until it could be frozen (in less than 6 hours).

Each conch was weighed (in its shell), measured for total shell length, and observed externally and internally for obvious abnormalities (see Pictures 17 and 18). Conch were removed from their shells by punching a hole in the shell at the second or third spire whorl, cutting the animal's attachment with a fillet knife, and pulling the animal out of the shell by its operculum. The conch meat was then separated from the operculum, mouth and eyes, and internal organs, wrapped in plastic wrap, placed in a plastic bag, and placed on wet ice until it could be frozen (in less than 6 hours).

The sex of the land crabs was recorded and the crab meat was "picked" from the chelipeds and the body (see Pictures 19 and 20). Since a single crab could not supply enough easily picked meat to meet the sample quantity needed for chemical analyses, the meat from several crabs was composited until a sufficient quantity of meat was obtained. Land crab composite samples were made from an equal number of male and female crabs. The meat was wrapped in plastic wrap, placed in a plastic bag, and placed on wet ice until it could be frozen (in less than 6 hours).

Fiddler crabs were analyzed for whole body burdens; therefore, they were weighed *en masse* to ensure a sufficient sample was collected for analysis. Though fiddler crabs were not individually weighed or measured, notes were made of obvious external abnormalities. Rinsing fiddler crabs of sand and dirt was inadvertently omitted prior to placing them into sample containers. The composite sample of crabs was placed in a plastic bag and placed on wet ice until it could be frozen (in less than 6 hours).

Tissue Analysis

All tissue samples were shipped on dry ice, *via* overnight delivery to EPA's subcontracted laboratory, Compuchem, for analysis of heavy metals, explosives compounds, percent lipids, and percent moisture. One gram tissue samples were analyzed for heavy metals according to EPA Method 6010B (utilizing inductively coupled argon plasma-atomic emission spectrometry and co-vapor atomic absorption; the method description can be found at the following URL: http://www.epa.gov/epaoswer/hazwaste/test/6010b.pdf). Two gram tissue samples were analyzed for explosives compounds according to EPA Method 8330 (utilizing high performance liquid chromatography; the method description can be found at the following URL: http://www.epa.gov/epaoswer/hazwaste/test/8330.pdf). One specimen of each of the four species purchased from the fish market (red hind, white grunt, yellowtail snapper, and spiny lobster) was submitted to Brooks Rand Ltd. for separate methylmercury analysis. Methylmercury was determined using Brooks Rand method BR-0011 (utilizing aqueous phase ethylation, Tenax trap collection, gas chromatograph separation, isothermal decomposition, and cold vapor atomic fluorescence spectroscopic detection).

Quality Control

A qualified third party validator, the Response, Engineering and Analytical Contract (REAC), validated the results from the labs.

Metals analysis. Matrix spike/matrix spike duplicates were performed for the metals analysis. Percent recoveries ranged from 42 to 118; all 272 values were within acceptable quality control (QC) limits. The relative percent differences ranged from zero to two; all 136 values were within the acceptable QC limits. Laboratory duplicates were analyzed; relative percent differences ranged from zero to 154. A laboratory control sample standard was analyzed for each data package; percent recoveries ranged from 54 to 116.

Explosives Analysis. Matrix spike/matrix spike duplicates were performed for the explosives analysis. Percent recoveries ranged from 0 to 142; 178 or 192 values were within acceptable QC limits. The relative percent differences ranged from zero to 101; 88 of 93 values were within the acceptable QC limits. A laboratory control sample standard was analyzed for each batch. Percent recoveries ranged from 8 to 154; 90 of 96 values were within the acceptable QC limits. Each sample was spiked with 1,4-dinitrobenzene (surrogate) prior to extraction. The surrogate percent recoveries ranged from 63 to 158; 153 of 154 vales were within acceptable QC limits. The data associated with the only explosives compound detected, HMX, in fiddler crabs, fell within acceptable QC limits.

Appendix C

Condition of the Reefs

Condition of the Reefs

The following general reef conditions were noted by the lead Marine Scientist during ATSDR and EPA/ERT's fish and shellfish sampling. He is a certified diver with over 20 years experience diving on coral reefs, with formal training at the West Indies Laboratory (St. Croix, US Virgin Islands) in scientific diving, coral reef biology, and tropical marine ecology. Throughout his career he has made more than 500 dives on Caribbean reefs and seagrass beds in the Florida Keys, the US and British Virgin Islands, the Cayman Islands, St. Martin, and Vieques. His Master's degree focused on natural and anthropogenic stresses to seagrass beds and assessing population dynamics of resident green sea turtles. In addition, he managed an aquatic toxicology laboratory that studied the effects of environmental pollution to freshwater and marine fish, invertebrates, and plants and assisted the National Park Service and EPA with coral disease monitoring studies in St. John and St. Croix, respectively.

General

When comparing the sampling locations, it is important to note that the different locations exhibited varied depths, bottom structures (e.g., reef, rubble, wreck), currents, and fishing pressures. All descriptions of the appearance and general health of the sampling locations are subjective. No quantitative data were collected on the numbers of species or the number of individuals of each coral or fish species observed. In general, it appeared that all sample locations supported diverse, healthy populations of marine organisms. The impression of each of the divers was that the reefs were in good condition and that the fish appeared healthy.

All of the reefs and structures that were bordered by seagrass beds were surrounded by a sandy "halo" and then a healthy seagrass bed that was dominated by turtle grass (*Thalassia testudinum*). The halo is a typical feature of reefs and underwater structures that is caused by grazing organisms (most commonly the sea urchin, *Diadema antillarum*) leaving the shelter of the reef at night to feed on the surrounding seagrass beds (see Picture 21). Lack of a halo would have been indicative that grazers were not present. Turtle grass is the climax species in the succession from bare sand to algae to seagrass, and a dense bed of turtle grass is an indication of a mature, healthy system (McRoy and Helfferich 1977; Zieman and Zieman 1989).

At Locations 1, 2, and 6, many conch shells were found that had holes punched out by fishermen who pulled the meat out and threw the shells back before leaving the area. A number of holed shells were clearly not of legal size. Location 3 had a healthy population of conch, most likely because it was significantly deeper and; therefore, less accessible than the other locations.

At all sampling locations fish were plentiful and appeared to be in good health, but were generally small and wary of divers. Larger individuals appeared to be heavily fished from the reefs around Vieques.

At the Mosquito Pier location, the remains of a freshly butchered green sea turtle (*Chelonia mydas*) were found. The turtle was quite small, definitely immature, and all that was left was the neatly cut away plastron, still attached to the foreflippers. Since the green sea turtle is an endangered species and is protected by federal law, the finding was reported to the Puerto Rico Department of Natural and Environmental Resources (DNER). While green sea turtles are a common inhabitant of seagrass beds throughout the Caribbean, they were conspicuously absent from the seagrass beds during the dives conducted for this study.

Location 1

The first unnamed reef visited on the north shore of the LIA was a small, shallow, well developed patch reef, labeled "North LIA 1" by field personnel. The reef appeared to be in good health, with a diverse population of corals and fish. The reef was shallow, from 5 meters to emergent, composed of large head corals (e.g., *Montastrea* sp. and *Diploria* sp.) and soft corals (e.g., gorgonians and sea fans), with a lot of structure (hiding places for reef organisms) (see Pictures 22, 23, and 24). The reef was surrounded by a halo and a healthy turtle grass bed. Conch were collected in the turtle grass, but were very sparse and only a few legal sized specimens were found. Unexploded ordnance was visible in the seagrass bed.

The second unnamed reef visited on the north shore of the LIA was a small barrier type reef, extending east to west for approximately 250 meters from a small island, and labeled "North LIA 2" by field personnel. The reef was shallow, to a depth of 7 meters, but had relatively high relief (3 to 5 meters off the sand) and good structure. The reef appeared to be in good health, with a diverse population of corals and fish. On the shore side of the reef, there was a narrow halo and a healthy turtle grass bed. No ordnance was observed in this area. Field personnel did not dive on the seaward side of the reef.

Location 2

The first section of the former Navy vessel visited, on the south shore of the LIA, is in approximately 8 meters of water and is home to a diverse population of fish, all of which appeared to be healthy. One section had high relief (approximately 5 meters off the sand) but the smooth sides and top offered no habitat. Nonetheless, dozens of several different kinds of fish were seen inside that section. The other sections ranged from flat plates to broken sections with a lot of structure for fish habitat. There was a spotty distribution of small head corals (e.g., *Montastrea* sp., and *Diploria* sp.) growing on the surfaces of the wreck exposed to current and sunlight. All corals observed appeared to be in good health. The wreck was surrounded by a large halo and a healthy turtle grass bed. Unexploded ordnance was a common sight around the wreck and in the surrounding seagrass bed.

The second portion of the vessel was a large structure which provided habitat for fish. Located approximately 100 meters southeast of the first portion, it is also in about 8 meters of water and is home to a diverse population of apparently healthy fish. The ship offered high relief (approximately 5 to 6 meters off the sand), with a lot of structure for fish habitat. There was a spotty distribution of small, healthy head corals growing on the surfaces of the wreck which were exposed to current and sunlight (see Pictures 25 and 26). The wreck was surrounded by a large halo and a healthy turtle grass bed. Conch were collected in the halo area and the seagrass bed. Unexploded ordnance was a common sight around the wreck and in the surrounding seagrass bed.

Location 3

The first reef visited on the south shore near the town of Esperanza was Bucky Reef. The reef was approximately 18 meters deep and had high relief (5 to 7 meters off the sand), with a lot of structure. The reef appeared to be in good health, with a diverse population of both corals and fish. The top of the reef was mainly soft corals (e.g., gorgonians and sea fans) interspersed with small head corals, while the base of the reef had numerous holes and undercut ledges for fish habitat. The ocean bottom near the reef was coarse sand with some coral rubble.

The second reef visited on the south shore near Esperanza was Patti Reef. The reef was approximately 10 meters deep and had a lower profile than Bucky Reef, with isolated head corals and less structure. There were many healthy soft corals and a wide diversity of fish. The reef was spread out over a large area and the ocean bottom was sand and rubble. Most of the fish observed on this reef were small, probably a result of the lack of hiding places suitable for use as refuge from predators.

The third area visited was the seagrass area inshore of Arena Reef, in approximately 15 meters of water. The seagrass bed was sparse, but there were quite a few large conch present.

Location 4

The first reef visited on the north shore near the town of Isabel Segunda was an unnamed reef that field personnel labeled "Isabel 1." The reef was shallow, from 5 meters to emergent, and it was similar in structure to Patti Reef, with a low profile and many healthy soft corals. The isolated head corals and numerous fish all appeared healthy. The reef was spread out over a large area and the bottom was sand and rubble (see Picture 27).

The second reef visited on the north shore near the town of Isabel Segunda was also unnamed, and was called "Isabel 2" by field personnel. The reef was growing on a gradual slope that rose from a sand flat at approximately 13 meters deep to approximately 3 meters deep. The sand flat demonstrated the typical halo away from the reef into a seagrass bed. The reef had a lot of structure and supported a diverse, healthy population of hard and soft corals and fish (see Pictures 28 and 29).

The third location visited on the north shore near the town of Isabel Segunda was Mosquito Pier. The pier is a large earthen structure extending approximately one-half mile to the north from land. In order to accommodate large vessels a dock extends to the west, near the end of the pier, into approximately 13 meters of water. Diving to collect fish was limited to the area under the dock. The dock had a lot of structure, mostly concrete rubble, at its origin and supported a large population of small fish. Toward the end of the dock, there was very little bottom structure except for the dock pilings. There were no hard corals present, though the pilings displayed nearly complete encrustation with a diverse population of invertebrate and plant life.

Location 6

The unnamed reef visited on the west end of the island was southwest of the Monte Pirata Conservation Zone, labeled "West End" by field personnel, and was in 20 meters of water. The reef was a spur and groove type reef with low relief (less than 3 meters off the sand), but had a lot of structure for fish. Spur and groove reefs are characterized by a series of long (≥100 meters), usually narrow (≤7 meters wide) coral spurs, with a narrow (≤7 meters wide) bare sand channel between each spur. The reef had diverse, apparently healthy, populations of corals and fish. The tops of the spurs had many soft corals and small head corals, and the bottom of the spurs had many small holes and undercuts for fish habitat.

Conch were collected from a healthy turtle grass bed approximately 500 meters northeast of the reef in approximately 7 meters of water. Conch were plentiful, but most visible animals were below legal size.

Appendix D

Estimates of Human Exposure Doses and Determination of Health Effects

Estimates of Human Exposure Doses and Determination of Health Effects

Overview of ATSDR's Methodology for Evaluating Potential Public Health Hazards

To evaluate exposures of eating fish and shellfish from Vieques, ATSDR derived exposure doses and compared them against health-based guidelines. ATSDR also reviewed relevant toxicologic data to obtain information about the toxicity of chemicals of interest. Exposure to a certain chemical does not always result in harmful health effects. The type and severity of health effects expected to occur depend on the exposure concentration, the toxicity of the chemical, the frequency and duration of exposure, and the multiplicity of exposures.

Deriving exposure doses

Exposure doses are expressed in milligrams per kilogram per day (mg/kg/day). When estimating exposure doses, health assessors evaluate chemical concentrations to which people could be exposed, together with the length of time and the frequency of exposure. Collectively, these factors influence an individual's physiological response to chemical exposure and potential outcomes. ATSDR used site-specific information regarding the frequency and duration of exposures. In addition, ATSDR employed several conservative exposure assumptions to estimate exposures.

The following equation was used to estimate ingestion of chemicals by eating fish and shellfish:

$$\text{Estimated exposure dose} = \frac{\text{Conc. x IR x EF x ED}}{\text{BW x AT}}$$

where:

Conc.: Concentration of chemical in parts per million (ppm, which is also mg/kg)
IR: Ingestion rate: adult = 0.227 kilograms (kg)* of fish or shellfish per day; child = 0.1135 kg of fish or shellfish per day**
EF: Exposure frequency, or number of exposure events per year of exposure:
365 days/year for people who eat fish or shellfish 7 times a week
260 days/year for people who eat fish or shellfish 5 times a week
208 days/year for people who eat fish or shellfish 4 times a week
104 days/year for people who eat fish or shellfish 2 times a week
52 days/year for people who eat fish or shellfish 1 time a week
ED: Exposure duration: adult = 70 years; child = 6 years
BW: Body weight: adult = 70 kg; child = 16 kg
AT: Averaging time, or the period over which cumulative exposures are averaged (6 years or 70 years x 365 days/year)

*0.227 kg is the equivalent of an 8-ounce meal.
**0.1135 kg is the equivalent of an 4-ounce meal.

Using exposure doses to evaluate potential health hazards

ATSDR analyzes the weight of evidence of available toxicologic, medical, and epidemiologic data to determine whether exposures might be associated with harmful health effects (noncancer and cancer). As part of this process, ATSDR examines relevant health effects data to determine whether estimated doses are likely to result in harmful health effects. As a first step in evaluating noncancer effects, ATSDR compares estimated exposure doses to conservative health guideline values, including ATSDR's minimal risk levels (MRLs) and EPA's reference doses (RfDs). The MRLs and RfDs are estimates of daily human exposure to a substance that are unlikely to result in noncancer effects over a specified duration. *Estimated exposure doses that are less than these values are not considered to be of health concern.* To maximize human health protection, MRLs and RfDs have built in uncertainty or safety factors, making these values considerably lower than levels at which health effects have been observed. The result is that even if an exposure dose is higher than the MRL or RfD, it does not necessarily follow that harmful health effects will occur.

But if health guideline values are exceeded, ATSDR examines the health effects levels discussed in the scientific literature and more fully reviews exposure potential. ATSDR reviews available human studies as well as experimental animal studies. This information is used to describe the disease-causing potential of a particular chemical and to compare site-specific dose estimates with doses shown in applicable studies to result in illness (known as the margin of exposure). For cancer effects, ATSDR compares an estimated lifetime exposure dose to available cancer effects levels (CELs), which are doses that produce significant increases in the incidence of cancer or tumors, and reviews genotoxicity studies to understand further the extent to which a chemical might be associated with cancer outcomes. This process enables ATSDR to weigh the available evidence in light of uncertainties and offer perspective on the plausibility of harmful health outcomes under site-specific conditions.

When comparing estimated exposure doses to actual health effects levels in the scientific literature, ATSDR estimates doses based on more realistic exposure scenarios to use for comparison. In this level of the evaluation, *an average concentration*[8] is used to calculate exposure doses to estimate a more probable exposure. This approach is taken because it is highly unlikely that anyone would ingest fish or shellfish with the maximum concentration on a daily basis and for an extended period of time because not every fish or shellfish contains the maximum detected concentration of any given chemical. Therefore, it is more likely that fish or shellfish containing a range of concentrations would be ingested over time. In addition, several chemicals (e.g., arsenic, iron, and lead) were not detected in all samples collected. Therefore, fish or shellfish without any chemical contamination could also be consumed.

[8] Averages were calculated using detected concentrations only and do not take into account nondetected values. Even though this tends to overestimate the true average values, ATSDR chose to base its health evaluations on the more conservative averages to be more protective of public health.

Using other methods to evaluate potential health hazards

When dealing with exposure to lead, ATSDR uses a second approach in addition to the traditional methodologies described above. A substantial part of human health effects data for lead are expressed in terms of blood lead level rather than exposure dose. Thus, ATSDR developed a secondary approach to utilize regression analysis with media-specific uptake parameters to estimate what cumulative blood lead level might result from exposure to a given level of contamination. This is accomplished by multiplying the detected concentration by a media-specific slope factor, which is 0.24 micrograms per deciliter (µg/dl) per ppm of lead in fish ingested (ATSDR 1999c). The Centers for Disease Control and Prevention (CDC) have determined that health effects are more likely to be observed if blood lead levels are at or above 10 µg/dl.

Sources for health-based guidelines

By Congressional mandate, ATSDR prepares toxicological profiles for hazardous substances found at contaminated sites. These toxicological profiles were used to evaluate potential health effects from ingestion of fish and shellfish from Vieques. ATSDR's toxicological profiles are available on the Internet at http://www.atsdr.cdc.gov/toxpro2.html or by contacting the National Technical Information Service (NTIS) at 1-800-553-6847. EPA also develops health effects guidelines, and in some cases, ATSDR relied on EPA's guidelines to evaluate potential health effects. These guidelines are found in EPA's Integrated Risk Information System (IRIS)—a database of human health effects that could result from exposure to various substances found in the environment. IRIS is available on the Internet at http://www.epa.gov/iris. For more information about IRIS, please call EPA's IRIS hotline at 1-301-345-2870 or e-mail at Hotline.IRIS@epamail.epa.gov.

Evaluation of Health Hazards Associated with Eating Fish and Shellfish from Vieques

Chemicals not detected

Antimony, thallium, RDX, HMX, 1,3,5-trinitrobenzene, 1,3-dinitrobenzene, 2,4,6-dinitrobenzene, 2,4,6-trinitrotoluene, tetryl, nitrobenzene, 2,4-dinitrotoluene, 2,6-dinitrotoluene, 2-amino-4,6-dinitrotoluene, 4-amino-2,6-dinitrotoluene, 2-nitrotoluene, 3-nitrotoluene, 4-nitrotoluene, and nitroglycerin were analyzed for but not detected in any fish or shellfish sample (see Tables 8 and 9). In addition, nickel was not detected in shellfish (see Table 9). Therefore, none of these chemicals are of health concern for people consuming fish and shellfish around Vieques and will not be discussed further.

Chemicals without health-based guidelines

Essential nutrients (e.g., calcium, magnesium, potassium, and sodium) are important minerals that maintain basic life functions; therefore, certain doses are recommended on a daily basis. Because these chemicals are necessary for life, MRLs and RfDs do not exist for them. They are found in many foods, such as milk, bananas, and table salt. Ingestion of these essential nutrients at the concentrations found in the fish and shellfish from Vieques will not result in harmful health effects and will not be discussed further.

Chemicals below health guidelines for all exposure scenarios

ATSDR derived conservative exposure doses for the metals that were detected in edible samples by using the maximum concentrations found in fish and shellfish in the equation provided above in the *Deriving exposure doses* section and by comparing the estimated exposure doses to standard health guideline values (MRLs and RfDs). Using the maximum detected concentration for the daily exposure scenario, the resulting exposure doses for aluminum, barium, beryllium, cobalt, manganese, silver, and vanadium were below health guidelines for both fish and shellfish. In addition, cadmium, nickel, and zinc were below the health guidelines in fish[9] (see Tables D-1 and D-2 for fish and shellfish, respectively). Therefore, none of these chemicals were detected at a level of health concern in fish and shellfish from Vieques and will not be discussed further.

Chemicals above health guidelines for one or more exposure scenarios

One or more exposure scenarios for arsenic, cadmium (in shellfish), chromium, copper, iron, mercury, selenium, and zinc (in shellfish) resulted in exposure doses higher than the health guideline for that chemical (see Tables D-3 and D-4 for the estimated doses of these metals in fish and shellfish, respectively). However, calculated exposure doses higher than the health guidelines do not automatically mean harmful health effects will occur. Rather, they are an indication that ATSDR should further examine the harmful effect levels reported in the scientific literature and more fully review exposure potential. The remainder of this appendix further evaluates these metals and their realistic exposure potential. Lead is also included in this analysis because a health guideline is not available for lead. The chemical-specific evaluations follow.

Arsenic

Although elemental arsenic sometimes occurs naturally, arsenic is usually found in the environment in two forms—inorganic (arsenic combined with oxygen, chlorine, and sulfur) and organic (arsenic combined with carbon and hydrogen). The organic forms of arsenic are usually

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[9]Nickel was not detected in shellfish. Estimated doses for zinc were above health guidelines in shellfish.

less toxic than the inorganic forms (ATSDR 2000a). Arsenic can be found in most foods, with seafood, particularly shellfish, containing the highest concentrations (FDA 1993). Therefore, ingesting fish and shellfish containing arsenic is one way arsenic can enter the body. However, most of the arsenic in fish and shellfish is the less harmful organic form (Cullen 1998; Dabeka et al. 1993; Eisler 1994; Gebel et al. 1998b as cited in ATSDR 2000a; FDA 1993).

Once in the body, the liver changes some of the inorganic arsenic into the less harmful organic form (i.e., by methylation). This process is effective as long as the dose of inorganic arsenic remains below 0.05 mg/kg/day (ATSDR 2000a). Both inorganic and organic forms of arsenic leave the body in urine. Studies have shown that 45–85% of the arsenic is eliminated within one to three days (Buchet et al. 1981a; Crecelius 1977; Mappes 1977; Tam et al. 1979b as cited in ATSDR 2000a); however, some will remain for several months or longer.

Because inorganic arsenic is much more harmful than organic arsenic, ATSDR based its health assessment on the levels of inorganic arsenic that are present. In fish and shellfish, generally about 1–20% of the total arsenic is in the more harmful inorganic form (ATSDR 2000a; Francesconi and Edmonds 1997; NAS 2001b; FDA 1993). The US Food and Drug Administration (FDA) proposes that 10% of the total arsenic be estimated as inorganic arsenic rather than specifically analyze for inorganic arsenic (FDA 1993). To be conservative, ATSDR used a conversion factor of 20% in the numerator of the dose equation described in the *Deriving exposure doses* section to calculate the estimated dose from exposure to inorganic arsenic in fish and shellfish from Vieques (i.e., ATSDR conservatively assumed that 20% of the total arsenic detected was inorganic arsenic).

<u>Noncancer health effects</u>

Daily exposure to the average concentrations of arsenic (averages = 4.0 ppm in fish and 11.1 ppm in shellfish) in fish and shellfish from a variety of locations would result in exposure doses of 0.0026–0.0072 mg/kg/day for adults and 0.0057–0.0157 mg/kg/day for children. Consuming the average concentration of arsenic from any one location would result in exposure doses ranging from 0.0008–0.0206 mg/kg/day for adults and from 0.0018–0.045 mg/kg/day for children (see Table D-5). As noted above, the metabolism (i.e., how it is broken down in the body) of inorganic arsenic has been extensively studied in humans and animals. ATSDR's estimated doses are well below those that inhibit the body's ability to detoxify or change it to non-harmful forms (doses greater than 0.05 mg/kg/day inhibit detoxification). Therefore, the amount of arsenic that a person consumes in fish and shellfish from Vieques should be controlled by normal metabolic processes in the body.

There is some indication in the scientific literature, however, that some dermal health effects could result from ingesting a lower dose of arsenic—hyperkeratosis and hyperpigmentation were reported in humans exposed to 0.014 mg/kg/day of arsenic in their drinking water for more than

45 years (Tseng et al. 1968 as cited in ATSDR 2000a). However, there is much uncertainty surrounding the reported dose. Because estimates of water intake and dietary arsenic are highly uncertain in this and similar studies, some scientists argue that reported effects may actually be associated with doses higher than 0.014 mg/kg/day. Specifically, the full extent of arsenic intake from dietary sources and the health status of the study population are not well documented.

The estimated exposure doses for every day consumption of shellfish with the average concentration of arsenic exceed the health effects level of 0.014 mg/kg/day for the fish market (Location 5) and overall exposure scenarios (see Table D-5). The disproportionally high arsenic average observed at the fish market is due to the lobsters collected from that location. As shown in the text box, shellfish caught from Vieques displayed noticeably different levels of total arsenic contamination, with lobsters containing by far the highest arsenic body burdens. Therefore, ATSDR evaluated exposure to inorganic arsenic for each individual species. As shown in Table D-6, all estimated doses are within the body's capability to metabolize arsenic (i.e., doses are lower than 0.05 mg/kg/day), although some of the more frequent consumption scenarios for lobster are above the health effects level of 0.014 mg/kg/day. Hence, ATSDR determined how much lobster could safely be consumed given the average concentration of arsenic in lobsters from Vieques. Based on the use of highly conservative assumptions, ATSDR does not expect noncancer health effects to occur in people consuming up to two meals of lobster a week.

Species	Range of Arsenic Concentrations
Lobster*	23.4–48.3 ppm
Conch	1.2–7.1 ppm
Land Crab	0.0–2.6 ppm

*According to a 1978 National Marine Fisheries Service survey, mean arsenic levels in lobsters range from 10–20 ppm (FDA 1993). However, FDA notes that in some cases arsenic levels may exceed 100 ppm because lobsters tend to store arsenic in their bodies (Benson and Summons 1981; Bohn 1975; LeBlanc and Jackson 1973 as cited in FDA 1993).

Given the fact that the metabolism of arsenic has been well studied in people and the estimated exposure doses for consumption of fish and shellfish are within the body's capability to metabolize arsenic, ATSDR does not expect that people who eat arsenic-contaminated fish and shellfish from Vieques would experience adverse noncancer health effects.

<u>Cancer health effects</u>

The US Department of Health and Human Services (DHHS), the International Agency for Research on Cancer (IARC), the National Toxicology Program (NTP), and EPA have all independently determined that inorganic arsenic is carcinogenic to humans (ATSDR 2000a). Skin cancer was reported for people exposed to 0.014 mg/kg/day of arsenic in their water for more than 45 years (Tseng et al. 1968 as cited in ATSDR 2000a). As explained above, scientists argue that this CEL may be underestimated (i.e., doses associated with cancer may actually be higher). Additional CELs in the literature generally ranged from 0.01–0.05 mg/kg/day (ATSDR 2000a).

Consuming the average concentration of inorganic arsenic in fish and shellfish from Vieques on a daily basis is estimated to result in lifetime doses of 0.0008–0.0052 mg/kg/day for fish and 0.0018–0.0206 mg/kg/day for shellfish (see adult exposure in Table D-5). Eating arsenic-contaminated fish would not increase your risk of developing cancer. However, some of the exposure scenarios presented in Table D-5 for shellfish resulted in doses higher than some of the CELs. As explained in the noncancer health effects section, lobsters had substantially higher arsenic burdens than conch and land crabs. Therefore, ATSDR evaluated exposure to inorganic arsenic for each individual species of shellfish. As shown in Table D-6, eating conch and land crab would not increase your risk of developing cancer. However, some of the more frequent consumption scenarios for lobster are above the health effects level of 0.01 mg/kg/day. Hence, ATSDR determined how much lobster could safely be consumed given the average concentration of arsenic in lobsters from Vieques. Based on the use of highly conservative assumptions (ATSDR assumed that 20% of the total arsenic is in the inorganic form), ATSDR does not expect cancer health effects to occur in people consuming up to two meals of lobster a week.

It should be noted that the levels of arsenic in lobsters collected from Vieques are below FDA's guidance for total arsenic (i.e., 76 ppm; FDA 1993). Why then, does ATSDR's evaluation show the potential for health effects to occur if lobsters are eaten more than twice a week? This apparent contradiction is a function of the exposure assumptions used by each agency, primarily different ingestion rates. FDA assumes that the general population eats a certain amount of lobster every week and bases their action level (76 ppm) on that assumption. In general terms, their assumption is that people will, on average, eat an 8-ounce serving of lobster every other week. ATSDR approached it slightly differently—we determined the average concentration (32.9 ppm) and from there decided how much lobster with this level of arsenic could safely be consumed under our own *highly conservative* evaluation (two 8-ounce servings a week).

Cadmium

Generally, the main sources of cadmium exposure are through smoking cigarettes and, to a lesser extent, eating foods contaminated with cadmium. However, only about 5 to 10% of ingested cadmium is actually absorbed by the body; the majority is passed out of the body in feces (McLellan et al. 1978; Rahola et al. 1973 as cited in ATSDR 1999b). Cadmium that is absorbed goes to the kidneys and liver. Once absorbed, however, cadmium tends to remain in the body for years. The body changes most of the cadmium into a form that is not harmful, but if too much cadmium is absorbed, the liver and kidneys cannot convert all of it into the harmless form (Goyer et al. 1989; Kotsonis and Klaassen 1978; Sendelbach and Klaassen 1988 as cited in ATSDR 1999b).

Noncancer health effects

Cadmium was only detected above health guidelines in shellfish (i.e., fish did not contain levels of cadmium above health concern). The oral health guideline for cadmium is based on a toxicokinetic model which predicts that no adverse health effects would result in people chronically exposed to 0.01 mg/kg/day of cadmium in their food (USEPA 1985 as cited in EPA 1991a).

Daily exposure to the average concentration of cadmium (overall average = 0.36 ppm) in shellfish from a variety of locations would result in exposure doses of 0.0012 mg/kg/day for adults and 0.0026 mg/kg/day for children. Consuming the average concentration in shellfish from any one location would result in exposure doses ranging from 0.0009–0.0016 mg/kg/day for adults and from 0.0019–0.0035 mg/kg/day for children (see Table D-7). Even consuming the highest concentration of cadmium detected in shellfish on a daily basis would result in estimated doses lower than the NOAEL mentioned above (exposure doses = 0.0022 mg/kg/day for adults and 0.0049 mg/kg/day for children; see Table D-4). Therefore, cadmium concentrations in fish and shellfish from Vieques are below levels of health concern for noncancer effects.

Cancer health effects

Studies of cadmium in humans and animals have not found an increase in cancer, however, more research is needed before a definitive conclusion can be reached regarding whether cadmium does or does not cause cancer. As a conservative approach, IARC has determined that cadmium is carcinogenic to humans. DHHS reasonably anticipates that cadmium is a carcinogen. EPA has determined that cadmium, when inhaled, is a probable human carcinogen (ATSDR 1999b). Lifetime exposure to the average concentration of cadmium in fish and shellfish from Vieques is also not expected to result in an increase in cancer because the expected lifetime doses (0.00026 mg/kg/day for fish—see adult exposure in Table D-1; and 0.0009–0.0016 mg/kg/day for shellfish—see adult exposure in Table D-7) are lower than the CEL (increased rates of prostatic adenomas resulted in rats from exposure to 3.5 mg/kg/day of cadmium in food; Waalkes and Rehm 1992 as cited in ATSDR 1999b). Therefore, cadmium concentrations are also below levels of health concern for cancer effects.

Chromium

Chromium can be found in three main forms—chromium 0, chromium III (also known as trivalent chromium), and chromium VI (also known as hexavalent chromium). Chromium VI is more harmful than chromium III, an essential nutrient required by the body. Although some or all of the chromium detected in fish and shellfish from Vieques could be chromium III; as a conservative approach to the health evaluation, ATSDR assumed that all of the chromium was the more harmful chromium VI.

The National Research Council recommends that adults take 50–200 µg of chromium III every day and has established safe and adequate daily dietary intakes of 10–80 µg for children (NRC 1989 as cited in ATSDR 2000b).

Chromium VI is more easily absorbed than chromium III; therefore, ingesting fish and shellfish containing chromium can lead to harmful forms of chromium entering the body. However, once inside the body, the more harmful chromium VI is converted into the essential nutrient, chromium III. In addition, most of the chromium ingested will exit the body in feces within a few days and never enter the bloodstream. Only a very small amount (0.4 to 2.1%) of chromium can pass through the walls of the intestine and enter the bloodstream (Anderson et al. 1983; Anderson 1986; Donaldson and Barreras 1966 as cited in ATSDR 2000b).

<u>Noncancer health effects</u>

The oral health guideline for chromium VI is based on a study in which no adverse health effects were reported in animals exposed to 2.5 mg/kg/day of chromium VI in their drinking water (MacKenzie et al. 1958 as cited in EPA 1998). Eating fish or shellfish from Vieques on a daily basis would result in chromium doses much lower than this NOAEL, and would not result in harmful health effects.

Daily exposure to the average concentrations of chromium (averages = 0.16 ppm in fish and 0.19 ppm in shellfish) in fish and shellfish from a variety of locations would result in exposure doses of 0.0005–0.0006 mg/kg/day for adults and 0.0011–0.0013 mg/kg/day for children. Consuming the average concentration of chromium from any one location would result in exposure doses ranging from 0.0003–0.0012 mg/kg/day for adults and from 0.0007–0.0027 mg/kg/day for children (see Table D-8). Even consuming the highest concentration of chromium detected in fish and shellfish on a daily basis would result in estimated doses orders of magnitude lower than the NOAEL mentioned above (exposure doses = 0.0042–0.0065 mg/kg/day for adults and 0.0092–0.0141 mg/kg/day for children; see Tables D-3 and D-4). Therefore, chromium concentrations in fish and shellfish from Vieques are well below levels of health concern for noncancer effects.

<u>Cancer health effects</u>

DHHS has determined that certain chromium VI compounds are known human carcinogens when inhaled. IARC has determined that chromium VI is carcinogenic to humans and chromium 0 and chromium III are not classifiable as to their carcinogenicity. EPA has determined that chromium VI in air is a human carcinogen, but insufficient evidence exists to determine whether chromium VI and chromium III in food and water are human carcinogens (ATSDR 2000b). Therefore, despite its carcinogenicity classification, consuming fish and shellfish with chromium is not expected to result in an increase in cancer because the available scientific evidence suggests that oral exposure to chromium would not result in cancer. Animal studies involving chromium ingestion have found no evidence of carcinogenicity. Therefore, chromium concentrations are also below levels of health concern for cancer effects.

Copper

Once ingested, copper is absorbed by the stomach and small intestines as ionic copper or bound to amino acids. Many factors affect the absorption of copper: (1) competition with other metals, such as cadmium and zinc (Davies and Campbell 1977; Hall et al. 1979 as cited in ATSDR 1990); (2) the amount of copper in the stomach (Farrer and Mistilis 1967; Strickland et al. 1972 as cited in ATSDR 1990); (3) certain dietary components; and (4) the form of copper. After being absorbed, copper is transported to the liver by loosely binding to plasma albumin and amino acids (Marceau et al. 1970 as cited in ATSDR 1990). The liver transforms copper into a glycoprotein (ceruloplasmin) and releases it into plasma. About 72% of copper is excreted in feces through bile (Bush et al. 1955 as cited in ATSDR 1990).

Copper is essential for good health because it aids in the absorption and utilization of iron and in the production of hemoglobin, which transports oxygen in the body (ANR 2001). However, even though the body is very good at regulating how much copper enters the bloodstream, very large single or daily intakes can cause harmful health effects (ATSDR 1990). The National Academy of Sciences reports that no adverse effects were observed at doses of 10 mg/day (NAS 2001a).

Group	Recommended Copper Dietary Allowance
adult men	0.90 mg/day
adult women	0.90 mg/day
pregnant women	1.00 mg/day
children (1-3 years)	0.34 mg/day
children (4-8 years)	0.44 mg/day
children (9-13 years)	0.70 mg/day
children (14-18 years)	0.89 mg/day

Group	Adequate Intake
infants (0-6 months)	0.20 mg/day
infants (7-12 months)	0.22 mg/day

Source: NAS 2001a

Very few toxicological and epidemiological studies are available for copper and those that are available suffer from design flaws and involve only a few subjects (NAS 2001a). Therefore, for comparison, ATSDR calculated a daily consumption of copper in fish and shellfish using a modification of the dose equation described in the *Deriving exposure doses* section (Dose = Conc. x IR) and compared this daily dose to the level determined by the National Academy of Sciences to be safe (10 mg/day).

Exposure to the average concentrations of copper (averages = 0.56 ppm in fish and 7.8 ppm in shellfish) in fish and shellfish from a variety of locations would increase a child's daily consumption of copper by 0.06–0.89 mg/day and an adult's daily consumption by 0.13–1.77

mg/day. Consuming the average concentration of copper from any one location would result in daily dose increases from 0.1–2.36 mg/day for adults and from 0.05–1.18 mg/day for children (see Table D-9). Even consuming the maximum concentration of copper would only increase a child's daily consumption by 0.9–2.0 mg/day and an adult's daily consumption by 1.9–4.0 mg/day.

The median copper intake in the United States from food is approximately 1.0–1.6 mg/day (NAS 2001a). Therefore, the relatively small daily increases in consumption (from eating fish and shellfish from Vieques) are not likely to increase a person's daily dose above the National Academy of Sciences' NOAEL of 10 mg/day. Additionally, eating fish and shellfish would help a person consume the recommended dietary intake for copper. Therefore, copper concentrations in fish and shellfish from Vieques are not expected to cause adverse health effects.

Iron

Iron is an important mineral, assisting in the maintenance of basic life functions. It combines with protein and copper to make hemoglobin, which transports oxygen in the blood from the lungs to other parts of the body, including the heart. It also aids in the formation of myoglobin, which supplies oxygen to muscle tissues (ANR 2001). Without sufficient iron, the body cannot produce enough hemoglobin or myoglobin to sustain life. Iron deficiency anemia is a condition occurring when the body does not receive enough iron.

The oral health guideline for iron is based on dietary intake data collected as part of EPA's Second National Health and Nutrition Examination Survey in which no adverse health effects were associated with average iron intakes of 0.15–0.27 mg/kg/day. These levels were determined to be sufficient for protection against iron deficiency, but also low enough to not cause harmful health effects.

National Academy of Science

Group	Recommended Iron Dietary Allowance
children	10 mg/day
adults >50 yrs	10 mg/day
adult men	10 mg/day
women <50 yrs	15 mg/day
pregnant women	30 mg/day

US Food and Drug Administration (FDA)

Group	Reference Daily Intake
Adults	18 mg/day
Children ≥4 yrs	18 mg/day

Sources: FDA 1997; Kurtzweil 1993

Daily exposure to the average concentrations (averages = 6.8 ppm in fish and 36.3 ppm in shellfish) of iron in fish and shellfish from a variety of locations would result in exposure doses of 0.022–0.118 mg/kg/day for adults and 0.048–0.258 mg/kg/day for children. Consuming the average concentration of iron from any one location would result in exposure doses ranging from 0.005–0.169 mg/kg/day for adults and from 0.011–0.37 mg/kg/day for children (see Table D-10). Some of the estimated doses for shellfish slightly exceed the NOAELs of 0.15–0.27 mg/kg/day.

However, estimated doses that slightly exceed the NOAELs do not indicate that an adverse health effect will occur because NOAELs indicate a level in which **no** adverse health effects were observed. Additionally, it is highly unlikely that anyone would eat shellfish on a daily basis, rather a variety of different foods would be consumed. Further, the body uses a homeostatic mechanism to keep iron burdens at a constant level despite variations in the diet (Eisenstein and Blemings 1998).

Generally, iron is not considered to cause harmful health effects except when swallowed in extremely large doses, such as in the case of accidental drug ingestion. Acute iron poisoning has been reported in children under 6 years of age who have accidentally overdosed on iron-containing supplements for adults. According to the FDA, doses greater than 200 mg per event could poison or kill a child (FDA 1997). However, doses of this magnitude are generally the result of children ingesting iron pills. For comparison, ATSDR calculated a daily consumption from exposure to the average concentration of iron in fish and shellfish using a modification of the dose equation described in the *Deriving exposure doses* section (Dose = Conc. x IR).

Exposure to the average concentration of iron (averages = 6.8 ppm in fish and 36.3 ppm in shellfish) in fish and shellfish from a variety of locations would increase a child's daily consumption of iron by 0.8–4.1 mg/day and an adult's daily consumption by 1.5–8.2 mg/day. Consuming the average concentration of iron from any one location would result in daily dose increases from 0.4–11.8 mg/day for adults and from 0.2–5.9 mg/day for children (see Table D-11).

The median daily intake of dietary iron is roughly 11–13 mg/day for children 1 to 8 years old, 13–20 mg/day for adolescents 9 to 18 years old, 16–18 mg/day for adult men, and 12 mg/day for adult women (NAS 2001a). Therefore, the daily increases in consumption (from eating fish and shellfish from Vieques) are not likely to cause a person's daily dose to exceed levels known to induce poisoning (e.g., greater than 200 mg/event). In addition, eating fish and shellfish would help a person meet the recommended dietary intakes for iron. Therefore, ATSDR does not expect that people who eat fish and shellfish from Vieques would experience adverse health effects.

Lead

Ingesting lead in fish and shellfish will cause some lead to enter the body and bloodstream. The amount of lead that enters the body depends on how old you are because more lead enters the blood in children than in adults (Alexander et al. 1974; Blake et al. 1983; James et al. 1985; Rabinowitz et al. 1980; Ziefler et al. 1978 as cited in ATSDR 1999c). Within a few weeks, 99% of the amount of lead absorbed by adults will exit in urine and feces (Rabinowitz et al. 1977 as cited in ATSDR 1999c), whereas only about 68% of the lead taken into children will leave their bodies (Ziegler et al. 1978 as cited in ATSDR 1999c). Once in the body, lead will travel to soft tissues, such as the liver, kidneys, lungs, brain, spleen, muscles, and heart. After several weeks of continual exposure, most of the lead moves from the soft tissue into bones and teeth. In adults, about 94% of the total amount of lead in their bodies can be found in bones. In children, about 73% of lead in their bodies is stored in their bones (Barry 1975 as cited in ATSDR 1999c).

Noncancer health effects

Health effects from chronic exposure to lead have not been documented in humans. However, no adverse effects were observed in animals chronically exposed to 0.57–27 mg/kg/day of lead (ATSDR 1999c). Eating fish and shellfish from Vieques on a daily basis would result in lead doses much lower than these NOAELs.

Daily exposure to the average concentrations of lead (averages = 0.27 ppm in fish and 0.25 ppm in shellfish) in fish and shellfish from a variety of locations would result in exposure doses of 0.0008–0.0009 mg/kg/day for adults and 0.0018–0.0019 mg/kg/day for children. Consuming the average concentration of lead from any one location would result in exposure doses ranging from 0.0006–0.0034 mg/kg/day for adults and from 0.0012–0.0075 mg/kg/day for children (see Table D-12). Even consuming the highest concentration of lead detected in fish and shellfish on a daily basis would result in estimated doses much lower than the NOAELs of 0.57–27 mg/kg/day (exposure doses = 0.0018–0.0063 mg/kg/day for adults and 0.0040–0.0138 mg/kg/day for children; see Tables D-3 and D-4).

To more fully evaluate chronic exposure in adults and children, ATSDR determined the blood lead level expected to result from exposure to lead in fish and shellfish from Vieques using the formula described in the *Using other methods to evaluate potential health hazards* section. Exposure to the average concentrations of lead in fish and shellfish from a variety of locations is estimated to result in blood lead levels of 0.06 µg/dl—well below CDC's level of concern (10 µg/dl). Consuming the average concentration of lead from any one location would result in blood lead levels ranging from 0.04–0.25 µg/dl (see Table D-13). Even consuming the highest concentration of lead on a daily basis would result in very low blood lead levels (0.14–0.47 µg/dl). Therefore, lead concentrations in fish and shellfish from Vieques are well below levels of health concern for noncancer effects.

Cancer health effects

Although some animal testing has shown that kidney tumors develop if animals are given large doses of lead, no evidence exists that lead causes cancer in humans. Based on the available research, however, DHHS has determined that lead acetate and lead phosphate can reasonably be expected to cause cancer. To evaluate potential increases in cancer from exposure to lead, ATSDR compared the lifetime exposure doses for adults (0.0006–0.0034 mg/kg/day for fish and 0.0006–0.0009 mg/kg/day for shellfish; see adult exposure in Table D-12) to the CELs reported in the literature (renal tubular adenomas and carcinomas resulted in animals exposed to 27 to 371 mg/kg/day of lead in food and water; ATSDR 1999c). But because of the high doses of lead used, ATSDR cautions against using these animal studies to predict whether cancer will actually occur in humans. Even so, the CELs are much higher than the doses expected to result from lifetime exposure to lead in fish and shellfish from Vieques. Therefore, lead concentrations are also below levels of health concern for cancer effects.

Mercury

Mercury exists naturally in the environment in several different forms: metallic mercury (also known as elemental mercury), inorganic mercury, and organic mercury. Metallic mercury is the pure form of mercury. Inorganic mercury is formed when metallic mercury combines with elements such as chlorine, sulfur, or oxygen. Organic mercury is formed when mercury combines with carbon. Microorganisms (bacteria and fungi) and natural processes can change mercury from one form to another. The most common organic mercury compound generated through these processes is methylmercury.

The different forms of mercury are absorbed and distributed differently in the body.

- When small amounts of metallic mercury are ingested, only about 0.01% of the mercury will enter the body through the stomach or intestines (Sue 1994; Wright et al. 1980 as cited in ATSDR 1999a). More metallic mercury can be absorbed if one suffers from a gastrointestinal tract disease. The small amount of metallic mercury that enters the body will accumulate in the kidneys and the brain, where it is readily turned into inorganic mercury. It can stay in the body for weeks or months, but most mercury is eventually excreted through urine, feces, and exhaled breath.

- Typically, less than 10% of inorganic mercury is absorbed through the stomach and intestines. But it has been reported that up to 40% can be absorbed in the intestinal tract (Clarkson 1971; Morcillo and Santamaria 1995; Nielson and Anderson 1990, 1992; Piotrowski et al. 1992 as cited in ATSDR 1999a). Once in the body, a small amount of the inorganic mercury can be converted into metallic mercury, which will be excreted or stored as described above. Inorganic mercury enters the bloodstream and moves to many different tissues, but will mostly accumulate in the kidneys. Inorganic mercury does not easily enter the brain. It can remain in the body for several weeks or months and is excreted through urine, feces, and exhaled breath.

- Methylmercury is the most studied organic mercury compound. It is readily absorbed in the gastrointestinal tract (about 95% absorbed) and can easily enter the bloodstream (Aberg et al 1969; Al-Shahristani et al. 1976; Miettinen 1973 as cited in ATSDR 1999a). It moves rapidly to various tissues and the brain, where methylmercury can be turned into inorganic mercury, which can remain in the brain for long periods. Slowly, over months, methylmercury will leave the body, mostly as inorganic mercury in the feces.

The organic form of mercury is much more harmful than the metallic and inorganic forms. In fish tissue, mercury is present predominantly as methylmercury (about 85%), the more toxic form (Jones 1996). Therefore, to be conservative, ATSDR assumed that all the mercury detected in fish and shellfish was methylmercury. The oral health guideline for methylmercury is based on a study in which people who were exposed to 0.0013 mg/kg/day of methylmercury in their food did not experience any adverse health effects[10] (Davidson et al. 1998 as cited in ATSDR 1999a). Eating fish and shellfish from Vieques would result in mercury doses much lower than this NOAEL and would not result in harmful health effects.

Daily exposure to the average concentrations of mercury (averages = 0.12 ppm in fish and 0.03 ppm in shellfish) in fish and shellfish from a variety of locations on a daily basis would result in estimated doses of 0.0001–0.0004 mg/kg/day for adults and 0.0002–0.0009 mg/kg/day for children. Consuming the average concentration of mercury from any one location would result in exposure doses ranging from 0.0001–0.0005 mg/kg/day for adults and from 0.0001–0.0011 mg/kg/day for children (see Table D-14). All of the exposure doses are below the NOAEL of 0.0013 mg/kg/day.

Furthermore, this is a very conservative estimation of mercury exposure because typically about 85% of total mercury in fish is methylmercury, the most prevalent organic form of mercury (Jones 1996). However, in this sampling, only 36-78% of total mercury was methylmercury (three fish and one lobster were analyzed for both total mercury and methylmercury). People who eat fish and shellfish from Vieques are actually being exposed to a lower amount of the harmful form of mercury than what ATSDR calculated. Therefore, the mercury concentrations present in the fish and shellfish from Vieques are well below levels of health concern.

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[10]The chronic oral MRL for methylmercury is based upon the Seychelles Child Development Study (SCDS), in which over 700 mother-infant pairs have, to date, been followed and tested from parturition through 66 months of age. The Seychellois regularly consume a large quantity and variety of ocean fish, with 12 fish meals per week representing a typical methylmercury exposure. The results of the 66-month testing in the SCDS revealed no evidence of adverse effects attributable to chronic ingestion of low levels (median total mercury concentration in 350 fish sampled from 25 species consumed by the Seychellois was <1 ppm (range, 0.004–0.75 ppm)) of methylmercury in fish. In this study, developing fetuses were exposed in utero through maternal fish ingestion before and during pregnancy. Neonates continued to be exposed to maternal mercury during breastfeeding (i.e., some mercury is secreted in breast milk), and methylmercury exposure from the regular diet continued after the gradual post-weaning shift to a fish diet (Davidson et al. 1998 as cited in ATSDR 1999a).

Selenium

Selenium is an essential nutrient that protects cell membranes, is an antioxidant in Vitamin E, and decreases the risk of cancer and heart disease (ANR 2001). The Dietary Reference Intake for maintenance of good health is 55 µg/day (NAS 2000 as cited in ATSDR 2001b). However, consuming too much selenium could lead to harmful health effects.

Absorption studies in humans reported that 80–97% of ingested selenium is absorbed in the gastrointestinal tract (Griffiths et al 1976; Martin et al. 1989a; Thomson 1974; Thomson and Stewart 1974; Thomson et al. 1977 as cited in ATSDR 2001b). Therefore, consuming fish or shellfish with elevated levels will cause some selenium to enter the body and bloodstream. Once in the body, selenium tends to be found at the highest concentrations in the liver and kidneys (Cavalieri et al. 1966; Heinrich and Kelsey 1955; Jereb et al. 1975; Thomson and Stewart 1973 as cited in ATSDR 2001b). Within 24 hours, most of the selenium will leave the body in urine, feces, and to a lesser extent though sweat (Kuikka and Nordman 1978; Levander et al. 1987; Thomson and Stewart 1974 as cited in ATSDR 2001b). Throughout the first week of exposure, about half the selenium will leave the body every day. After the first week, selenium is eliminated more slowly (Thomson and Stewart 1974 as cited in ATSDR 2001b).

The oral health guideline for selenium is based on two studies in which no adverse health effects were reported in people who were exposed to 0.015 mg/kg/day of selenium in their food over their lifetime and dermal health effects (selenosis: sloughing of nails and brittle hair) were observed when the people were exposed to 0.023 mg/kg/day of selenium (Yang and Zhou 1994 as cited in ATSDR 2001b; Yang et al. 1989b as cited in EPA 1991b). Eating fish or shellfish from Vieques on a daily basis would result in selenium doses lower than the NOAEL and health effects level, and would not result in harmful health effects.

Daily exposure to the average concentrations of selenium (averages = 0.98 ppm in fish and 0.8 ppm in shellfish) in fish and shellfish from a variety of locations would result in exposure doses of 0.0026–0.0032 mg/kg/day for adults and 0.0057–0.007 mg/kg/day for children. Consuming the average concentration of selenium from any one location would result in exposure doses ranging from 0.0024–0.0037 mg/kg/day for adults and from 0.0052–0.0082 mg/kg/day for children (see Table D-15). All of these exposure doses are well below the NOAEL mentioned above (0.015 mg/kg/day). Therefore, selenium concentrations in fish and shellfish from Vieques are below levels of health concern.

Zinc

Zinc is an essential nutrient that is needed by the body for normal growth, bone formation, brain development, behavioral response, reproduction, fetal development, sensory function, immune function, membrane stability, and wound healing. Too little zinc can lead to poor health, reproductive problems, and a lowered resistance to disease (ATSDR 1994).

Group	Recommended Zinc Dietary Allowance
infants (0-1 year)	5 mg/day
children (1-10 years)	10 mg/day
men (11-51+ years)	15 mg/day
women (11-51+ years)	12 mg/day
pregnant women	15 mg/day
lactating women	19 mg/day (first 6 months) 16 mg/day (next 6 months)

Source: NAS/NRC 1989b as cited in ATSDR 1994

Zinc absorption in humans (8–81%) varies with the amount of zinc ingested and the amount and kind of food eaten (Aamodt et al. 1983; Hunt et al. 1991; Istfan et al. 1983; Reinhold et al. 1991; Sandstrom and Abrahamson 1989; Sandstrom and Cederblad 1980; Sandstrom and Sandberg 1992 as cited in ATSDR 1994). The body uses a homeostatic mechanism to control zinc absorption in the gastrointestinal tract (Davies 1980 as cited in ATSDR 1994). People with adequate nutritional levels of zinc tend to absorb 20–30% of ingested zinc, whereas people with zinc deficiencies absorb more (Johnson et al. 1988; Spencer et al. 1985 as cited in ATSDR 1994). Zinc is one of the most abundant trace metals in the body. Muscle and bone contain about 90% (60% and 30%, respectively) of the total amount of zinc in the body (Wastney et al. 1986 as cited in ATSDR 1994). Zinc can also be found in the liver, gastrointestinal tract, kidney, skin, lung, brain, heart, pancreas, prostate, retina, and sperm (Bentley and Gribb 1991; Drinker and Drinker 1928; Forssen 1972; He et al. 1991; Llobet et al. 1988a as cited in ATSDR 1994).

Zinc was only detected above health guidelines in shellfish (i.e., fish did not contain levels of zinc above health concern). The oral health guideline for zinc is based on a study in which hematological health effects (e.g., decreased superoxide dismutase activity, hematocrit, and ferritin) were observed when people were given doses of 0.83 mg/kg/day of zinc in capsule form for 10 weeks (Yadrick et al. 1989 as cited in ATSDR 1994 and EPA 1992) and is supported by several other studies that investigated effects from zinc supplementation (Black et al. 1988; Chandra 1984; Festa et al. 1985; Fischer et al. 1984; Hooper et al. 1980; L'Abbe and Fischer 1984a,b; Pennington et al. 1989; Prasad et al. 1978; Simko et al. 1984 as cited in EPA 1992). Eating shellfish from Vieques on a daily basis would result in zinc doses lower than this health effects level, and would not result in harmful health effects.

Daily exposure to the average concentration of zinc in shellfish (overall average = 30.1 ppm) from a variety of locations would result in exposure doses of 0.098 mg/kg/day for adults and 0.214 mg/kg/day for children. Consuming the average concentration of zinc from any one location would result in exposure doses ranging from 0.026–0.147 mg/kg/day for adults and from 0.057–0.321 mg/kg/day for children (see Table D-16). All of these exposure doses are below the health effects level mentioned above (0.83 mg/kg/day). Further, as cited above, the body controls zinc absorption to keep body burdens at a constant level. Therefore, zinc concentrations in fish and shellfish from Vieques are below levels of health concern.

Multiple Chemicals

Several studies, including those conducted by the National Toxicology Program in the United States and the TNO Nutrition and Food Research Institute in the Netherlands, among others, generally support the conclusion that if each individual chemical is at a concentration not likely to produce harmful health effects (as is the case on Vieques), exposures to multiple chemicals are also not expected to be of health concern (for reviews, see Seed et al. 1995; Feron et al. 1993).

Special Case: Snapper

Universidad Metropolitana reported that yellowtail snapper was the most commonly consumed species of fish (Caro et al. 2000). Through talking with several Vieques fishermen and residents, including the petitioner, ATSDR also found that snapper were more commonly sought after, caught, and consumed than any other species of fish. Therefore, ATSDR also considered a situation where people ate snapper on a daily basis and evaluated this special scenario using the same methodology that was used previously for people who consume a variety of fish species.

Chemicals not detected

Antimony, cadmium, thallium, vanadium, HMX, RDX, 1,3,5-trinitrobenzene, 1,3-dinitrobenzene, 2,4,6-dinitrobenzene, 2,4,6-trinitrotoluene, tetryl, nitrobenzene, 2,4-dinitrotoluene, 2,6-dinitrotoluene, 2-amino-4,6-dinitrotoluene, 4-amino-2,6-dinitrotoluene, 2-nitrotoluene, 3-nitrotoluene, 4-nitrotoluene, and nitroglycerin were analyzed for but not detected in snapper. Therefore, none of these chemicals are of health concern for people consuming snapper from Vieques.

Chemicals without health-based guidelines

Essential nutrients (e.g., calcium, magnesium, potassium, and sodium) are important minerals that maintain basic life functions; therefore, certain doses are recommended on a daily basis. Because these chemicals are necessary for life, MRLs and RfDs do not exist for them. They are found in many foods, such as milk, bananas, and table salt. Ingestion of these essential nutrients at the concentrations found in snapper will not result in harmful health effects.

Chemicals below health guidelines

Using the maximum concentration detected in snapper and assuming that snapper is consumed every day, the resulting exposure doses for aluminum, barium, beryllium, chromium, cobalt, iron, manganese, nickel, silver, and zinc were below the conservative health guidelines (see Table D-17). Therefore, none of these chemicals were detected at a level of health concern in snapper.

Chemicals above health guidelines

Eating snapper with the maximum concentration of arsenic, copper, mercury, and selenium every day resulted in exposure doses higher than the health guidelines (see Table D-17). In addition, because a health guideline is not available for lead, ATSDR further examined the harmful effect levels reported in the scientific literature and more fully reviewed exposure potential for these four chemicals and lead. The toxicology and health effects of each of these chemicals have been explained in greater detail previously in this appendix.

Arsenic

Eating snapper from Vieques every day would result in arsenic exposure doses of 0.0037 mg/kg/day for adults and 0.008 mg/kg/day for children (see Table D-18). These doses are within the body's capacity (i.e., less than 0.05 mg/kg/day) to metabolize arsenic into non-harmful forms and are lower than the health effect level of 0.014 mg/kg/day. In addition, the lifetime exposure dose for adults (0.0037 mg/kg/day) is well below the CELs reported in the literature (0.01 to 0.05 mg/kg/day). Therefore, arsenic concentrations in snapper are well below levels of health concern for noncancer and cancer health effects.

Copper

Eating snapper from Vieques would increase a child's daily consumption of copper by 0.12 mg/day and an adult's daily consumption by 0.23 mg/day (see Table D-18). These relatively small daily increases in consumption are not likely to increase a person's daily dose above the National Academy of Sciences' NOAEL of 10 mg/day. Therefore, copper concentrations in snapper are not expected to cause adverse health effects.

Lead

Eating snapper from Vieques every day would result in exposure doses lower than the NOAELs of 0.57–27 mg/kg/day (0.0007 mg/kg/day for adults and 0.0015 mg/kg/day for children; see Table D-18). In addition, the resulting blood lead level is estimated to be 0.05 µg/dl, well below CDC's level of concern (10 µg/dl). Finally, the lifetime exposure dose for adults (0.0007 mg/kg/day) is orders of magnitude below the CELs reported in the literature (27 to 371 mg/kg/day). Therefore, lead concentrations in snapper are well below levels of health concern for noncancer and cancer health effects.

Mercury

Eating snapper from Vieques every day would result in exposure doses to mercury (0.0002 mg/kg/day for adults and 0.0004 mg/kg/day for children; see Table D-18) lower than the NOAEL of 0.0013 mg/kg/day. Therefore, mercury concentrations in snapper are well below levels of health concern.

Selenium

Eating snapper from Vieques every day would result in exposure doses to selenium (0.0036 mg/kg/day for adults and 0.0079 mg/kg/day for children; see Table D-18) below the NOAEL of 0.015 mg/kg/day. Therefore, selenium concentrations in snapper are well below levels of health concern.

Special Case: Boxfish

While on Vieques, ATSDR met with the petitioner, who at that time, specifically requested ATSDR to collect and analyze boxfish from the fish market. At the request of ATSDR, the petitioner had compiled a list of fish caught and eaten on Vieques and reported that *Chapín* (boxfish; e.g., trunkfish and cowfish) are the preferred fish to use as filling in *pastelillos*. Realizing that the results and conclusions would be limited[11], ATSDR purchased a honeycomb cowfish (*Lactophrys polygonia*) from the fish market for analysis.

Chemicals not detected

Antimony, beryllium, cadmium, cobalt, iron, lead, manganese, mercury, nickel, silver, thallium, vanadium, HMX, RDX, 1,3,5-trinitrobenzene, 1,3-dinitrobenzene, 2,4,6-dinitrobenzene, 2,4,6-trinitrotoluene, tetryl, nitrobenzene, 2,4-dinitrotoluene, 2,6-dinitrotoluene, 2-amino-4,6-dinitrotoluene, 4-amino-2,6-dinitrotoluene, 2-nitrotoluene, 3-nitrotoluene, 4-nitrotoluene, and nitroglycerin were analyzed for but not detected (see Table 10). Therefore, none of these chemicals were detected at a level of health concern in this representative sample.

Chemicals without health-based guidelines

Essential nutrients (e.g., calcium, magnesium, potassium, and sodium) are important minerals that maintain basic life functions; therefore, certain doses are recommended on a daily basis. Because these chemicals are necessary for life, MRLs and RfDs do not exist for them. They are

[11] It is not unusual for different samples of the same species or family to contain varying chemical concentrations; therefore, other boxfish samples may contain higher or lower levels of these chemicals. There are not enough data from this one sample upon which to base any meaningful health decisions for consumption of boxfish.

found in many foods, such as milk, bananas, and table salt. Ingestion of these essential nutrients will not result in harmful health effects.

Chemicals below health guidelines

Using the detected concentration in the representative cowfish sample and assuming that boxfish are consumed every day, the resulting exposure doses for chromium and copper were below the conservative health guidelines (see Table D-19). Therefore, none of these chemicals were detected at a level of health concern.

Chemicals above health guidelines

Eating boxfish every day with the concentrations of arsenic and selenium detected in the representative cowfish sample resulted in exposure doses higher than the health guidelines (see Table D-19). Therefore, ATSDR further examined the harmful effect levels reported in the scientific literature and more fully reviewed exposure potential for these two chemicals. The toxicology and health effects of each of these chemicals have been explained in greater detail previously in this appendix.

Arsenic

Eating boxfish every day with arsenic levels similar to those found in the representative cowfish sample would result in arsenic exposure doses of 0.019 mg/kg/day for adults and 0.042 mg/kg/day for children (see Table D-19). These doses are within the body's capacity (i.e., less than 0.05 mg/kg/day) to metabolize arsenic into non-harmful forms, but are slightly higher than the health effect level of 0.014 mg/kg/day. However, as stated previously, there is much uncertainty surrounding this reported dose and some scientists argue that reported effects may actually be associated with doses higher than 0.014 mg/kg/day. The lifetime exposure dose for adults is within the range of CELs reported in the literature (0.01 to 0.05 mg/kg/day). However, this estimated dose is based upon a hypothetical exposure situation (eating boxfish from Vieques every day), using highly conservative assumptions (ATSDR assumed that 20% of the total arsenic is in the inorganic form.

Given the fact that the metabolism of arsenic has been well studied in people and the estimated exposure doses are within the body's capability to metabolize arsenic, ATSDR does not expect that people who eat boxfish with similar arsenic levels would experience adverse health effects. Furthermore, the representative cowfish sample did not contain higher levels of arsenic than FDA's level of concern for average consumption (76 ppm; FDA 1993). Based upon this one cowfish sample, boxfish are safe to eat and only under highly unlikely, hypothetical scenarios with several levels of conservatism built into the evaluation would the arsenic levels be a problem for people eating more than two meals of boxfish a week for a lifetime.

Selenium

Eating boxfish every day with concentrations of selenium similar to the representative cowfish sample would result in exposure doses of 0.008 mg/kg/day for adults and 0.018 mg/kg/day for children (see Table D-19). Both doses are below the health effects level of 0.023 mg/kg/day. Therefore, selenium concentrations are below levels of health concern.

Evaluating Health Concerns Using Fish Fillet Data from Universidad Metropolitana

Universidad Metropolitana (Caro et al. 2000) sampled fish fillets for arsenic, cadmium, lead, mercury, selenium, and zinc (see Table 3).

Chemicals below health guidelines

Using the maximum concentration detected by Universidad Metropolitana and assuming that fish is consumed every day, the resulting exposure doses for cadmium and zinc were below the conservative health guidelines (see Table D-20). Therefore, these two chemicals were not detected at a level of health concern.

Chemicals above health guidelines

Eating snapper with the maximum concentration of arsenic, mercury, and selenium every day resulted in exposure doses higher than the health guidelines (see Table D-20). In addition, because a health guideline is not available for lead, ATSDR further examined the harmful effect levels reported in the scientific literature and more fully reviewed exposure potential for these three chemicals and lead. The toxicology and health effects of each of these chemicals has been explained in greater detail previously in this appendix.

Arsenic

Eating fish from fish markets on Vieques and the Parquera area on the mainland of Puerto Rico every day would result in exposure doses to arsenic of 0.0008 mg/kg/day for adults and 0.0017 mg/kg/day for children (see Table D-21). These doses are within the body's capacity (i.e., less than 0.05 mg/kg/day) to metabolize arsenic into non-harmful forms and are lower than the health effect level of 0.014 mg/kg/day. In addition, the lifetime exposure dose for adults (0.0008 mg/kg/day) is well below the CELs reported in the literature (0.01 to 0.05 mg/kg/day). Therefore, arsenic concentrations are well below levels of health concern for noncancer and cancer health effects.

Lead

Eating fish every day would result in exposure doses lower than the NOAELs of 0.57–27 mg/kg/day (0.0006 mg/kg/day for adults and 0.0014 mg/kg/day for children; see Table D-21). In addition, the resulting blood lead level is estimated to be 0.05 µg/dl, well below CDC's level of concern (10 µg/dl). Finally, the lifetime exposure dose for adults (0.0006 mg/kg/day) is orders of magnitude below the CELs reported in the literature (27 to 371 mg/kg/day). Therefore, lead concentrations in fish collected from fish markets on Vieques and the Parquera area on the mainland of Puerto Rico are well below levels of health concern for noncancer and cancer health effects.

Mercury

Eating fish from fish markets on Vieques and the Parquera area on the mainland of Puerto Rico every day would result in exposure doses to mercury (0.0001 mg/kg/day for adults and 0.0002 mg/kg/day for children; see Table D-21) lower than the NOAEL of 0.0013 mg/kg/day. Therefore, mercury concentrations are well below levels of health concern.

Selenium

Eating fish every day would result in exposure doses to selenium (0.0019 mg/kg/day for adults and 0.0043 mg/kg/day for children; see Table D-21) below the NOAEL of 0.015 mg/kg/day. Therefore, selenium concentrations in fish from fish markets on Vieques and the Parquera area on the mainland of Puerto Rico are well below levels of health concern.

Table D-1. Exposure Doses for Chemicals Below the Oral Health Guideline in Fish

Chemical	Maximum Detected Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)		Oral Health Guideline (mg/kg/day)	Basis for Health Guideline
		Adult	Child		
Aluminum	13.5	0.0438	0.0958	1.0	chronic RfD
Barium	6.59	0.0214	0.0467	0.07	chronic RfD
Beryllium	0.02	0.00006	0.00014	0.001	chronic MRL
Cadmium	0.08	0.00026	0.00057	0.001	chronic RfD (food)
Cobalt	0.11	0.0004	0.0008	0.02	chronic RfD
Manganese	3.09	0.0100	0.0219	0.14	chronic RfD (food)
Nickel	1.28	0.0042	0.0091	0.02	chronic RfD
Silver	0.11	0.0004	0.0008	0.005	chronic RfD
Vanadium	0.09	0.0003	0.0006	0.007	chronic RfD
Zinc	24.7	0.0801	0.1752	0.3	chronic MRL/RfD

Notes: Exposure doses were calculated using 365 days/year for EF in the formula described in the *Deriving exposure doses* section of this appendix: (Conc. x IR x EF x ED) / (BW x AT).

Table D-2. Exposure Doses for Chemicals Below the Oral Health Guideline in Shellfish

Metal	Maximum Detected Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)		Oral Health Guideline (mg/kg/day)	Basis for Health Guideline
		Adult	Child		
Aluminum	43.9	0.1424	0.3114	1.0	chronic RfD
Barium	7.25	0.0235	0.0514	0.07	chronic RfD
Beryllium	0.02	0.00006	0.00014	0.001	chronic MRL
Cobalt	0.09	0.0003	0.0006	0.02	chronic RfD
Manganese	5.06	0.0164	0.0359	0.14	chronic RfD (food)
Silver	0.19	0.0006	0.0013	0.005	chronic RfD
Vanadium	0.27	0.0009	0.0019	0.007	chronic RfD

Note: Exposure doses were calculated using 365 days/year for EF in the formula described in the *Deriving exposure doses* section of this appendix: (Conc. x IR x EF x ED) / (BW x AT).

Table D-3. Estimated Exposure Doses from Ingestion of Fish

Metal	Level of Exposure	Maximum Detected Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)		Oral Health Guideline (mg/kg/day)	Basis for Health Guideline
			Adult	Child		
Arsenic	7 days/week	29.25	0.095*	0.207*	0.0003	chronic MRL/RfD
	5 days/week	29.25	0.068*	0.148*	0.0003	chronic MRL/RfD
	4 days/week	29.25	0.054*	0.118*	0.0003	chronic MRL/RfD
	2 days/week	29.25	0.027*	0.059*	0.0003	chronic MRL/RfD
	1 day/week	29.25	0.014*	0.030*	0.0003	chronic MRL/RfD
Chromium	7 days/week	1.99	0.0065*	0.0141*	0.003	chronic RfD (CrVI)
	5 days/week	1.99	0.0046*	0.0101*	0.003	chronic RfD (CrVI)
	4 days/week	1.99	0.0037*	0.0180*	0.003	chronic RfD (CrVI)
	2 days/week	1.99	0.0018	0.0040*	0.003	chronic RfD (CrVI)
	1 day/week	1.99	0.0009	0.0020*	0.003	chronic RfD (CrVI)
Copper	7 days/week	8.21	0.027	0.058*	0.04	chronic RfD
	5 days/week	8.21	0.019	0.041*	0.04	chronic RfD
	4 days/week	8.21	0.015	0.033	0.04	chronic RfD
	2 days/week	8.21	0.008	0.017	0.04	chronic RfD
	1 day/week	8.21	0.004	0.008	0.04	chronic RfD
Iron	7 days/week	57.78	0.19	0.41*	0.3	chronic RfD
	5 days/week	57.78	0.13	0.29	0.3	chronic RfD
	4 days/week	57.78	0.11	0.23	0.3	chronic RfD
	2 days/week	57.78	0.05	0.12	0.3	chronic RfD
	1 day/week	57.78	0.03	0.06	0.3	chronic RfD
Lead	7 days/week	1.94	0.0063	0.0138	NA	NA
	5 days/week	1.94	0.0045	0.0098	NA	NA
	4 days/week	1.94	0.0036	0.0078	NA	NA
	2 days/week	1.94	0.0018	0.0039	NA	NA
	1 day/week	1.94	0.0009	0.0020	NA	NA

Table D-3. Estimated Exposure Doses from Ingestion of Fish (continued)

Metal	Level of Exposure	Maximum Detected Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)		Oral Health Guideline (mg/kg/day)	Basis for Health Guideline
			Adult	Child		
Mercury, total	7 days/week	0.33	0.00107*	0.00234*	0.0003	chronic MRL (MeHg)
	5 days/week	0.33	0.00076*	0.00167*	0.0003	chronic MRL (MeHg)
	4 days/week	0.33	0.00061*	0.00133*	0.0003	chronic MRL (MeHg)
	2 days/week	0.33	0.00030	0.00067*	0.0003	chronic MRL (MeHg)
	1 day/week	0.33	0.00015	0.00033*	0.0003	chronic MRL (MeHg)
Methylmercury	7 days/week	0.082	0.00027	0.00058*	0.0003	chronic MRL
	5 days/week	0.082	0.00019	0.00042*	0.0003	chronic MRL
	4 days/week	0.082	0.00015	0.00033*	0.0003	chronic MRL
	2 days/week	0.082	0.00008	0.00017	0.0003	chronic MRL
	1 day/week	0.082	0.00004	0.00008	0.0003	chronic MRL
Selenium	7 days/week	2.48	0.0080*	0.0176*	0.005	chronic MRL/RfD
	5 days/week	2.48	0.0057*	0.0125*	0.005	chronic MRL/RfD
	4 days/week	2.48	0.0046	0.0100*	0.005	chronic MRL/RfD
	2 days/week	2.48	0.0023	0.0050	0.005	chronic MRL/RfD
	1 day/week	2.48	0.0011	0.0025	0.005	chronic MRL/RfD

* Estimated exposure exceeds health guideline; however, an exposure dose that is higher than the MRL or RfD does not necessarily result in harmful health effects. These metals are further evaluated.

Note: Exposure doses were calculated using the formula described in the *Deriving exposure doses* section of this appendix: (Conc. x IR x EF x ED) / (BW x AT).

Table D-4. Estimated Exposure Doses from Ingestion of Shellfish

Metal	Level of Exposure	Maximum Detected Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)		Oral Health Guideline (mg/kg/day)	Basis for Health Guideline
			Adult	Child		
Arsenic	7 days/week	48.28	0.157*	0.342*	0.0003	chronic MRL/RfD
	5 days/week	48.28	0.112*	0.244*	0.0003	chronic MRL/RfD
	4 days/week	48.28	0.0892*	0.195*	0.0003	chronic MRL/RfD
	2 days/week	48.28	0.045*	0.098*	0.0003	chronic MRL/RfD
	1 day/week	48.28	0.022*	0.049*	0.0003	chronic MRL/RfD
Cadmium	7 days/week	0.69	0.0022*	0.0049*	0.001	chronic RfD (food)
	5 days/week	0.69	0.0016*	0.0035*	0.001	chronic RfD (food)
	4 days/week	0.69	0.0013*	0.0028*	0.001	chronic RfD (food)
	2 days/week	0.69	0.0006	0.0014*	0.001	chronic RfD (food)
	1 day/week	0.69	0.0003	0.0007	0.001	chronic RfD (food)
Chromium	7 days/week	1.29	0.0042*	0.0092*	0.003	chronic RfD (CrVI)
	5 days/week	1.29	0.0030	0.0065*	0.003	chronic RfD (CrVI)
	4 days/week	1.29	0.0024	0.0052*	0.003	chronic RfD (CrVI)
	2 days/week	1.29	0.0012	0.0026	0.003	chronic RfD (CrVI)
	1 day/week	1.29	0.0006	0.0013	0.003	chronic RfD (CrVI)
Copper	7 days/week	17.6	0.057*	0.124*	0.04	chronic RfD
	5 days/week	17.6	0.041*	0.089*	0.04	chronic RfD
	4 days/week	17.6	0.032	0.071*	0.04	chronic RfD
	2 days/week	17.6	0.016	0.035	0.04	chronic RfD
	1 day/week	17.6	0.008	0.018	0.04	chronic RfD
Iron	7 days/week	162	0.52*	1.15*	0.3	chronic RfD
	5 days/week	162	0.37*	0.82*	0.3	chronic RfD
	4 days/week	162	0.30	0.65*	0.3	chronic RfD
	2 days/week	162	0.15	0.33*	0.3	chronic RfD
	1 day/week	162	0.07	0.16	0.3	chronic RfD

Table D-4. Estimated Exposure Doses from Ingestion of Shellfish (continued)

Metal	Level of Exposure	Maximum Detected Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)		Oral Health Guideline (mg/kg/day)	Basis for Health Guideline
			Adult	Child		
Lead	7 days/week	0.57	0.0018	0.0040	NA	NA
	5 days/week	0.57	0.0013	0.0029	NA	NA
	4 days/week	0.57	0.0011	0.0023	NA	NA
	2 days/week	0.57	0.0005	0.0012	NA	NA
	1 day/week	0.57	0.0003	0.0006	NA	NA
Mercury, total	7 days/week	0.05	0.00016	0.00036*	0.0003	chronic MRL (MeHg)
	5 days/week	0.05	0.00012	0.00025	0.0003	chronic MRL (MeHg)
	4 days/week	0.05	0.00009	0.00020	0.0003	chronic MRL (MeHg)
	2 days/week	0.05	0.00005	0.00010	0.0003	chronic MRL (MeHg)
	1 day/week	0.05	0.00002	0.00005	0.0003	chronic MRL (MeHg)
Methylmercury	7 days/week	0.019	0.00006	0.00014	0.0003	chronic MRL
	5 days/week	0.019	0.00004	0.00010	0.0003	chronic MRL
	4 days/week	0.019	0.00004	0.00008	0.0003	chronic MRL
	2 days/week	0.019	0.00002	0.00004	0.0003	chronic MRL
	1 day/week	0.019	0.00001	0.00002	0.0003	chronic MRL
Selenium	7 days/week	1.16	0.0038	0.0082*	0.005	chronic MRL/RfD
	5 days/week	1.16	0.0027	0.0059*	0.005	chronic MRL/RfD
	4 days/week	1.16	0.0021	0.0047	0.005	chronic MRL/RfD
	2 days/week	1.16	0.0011	0.0023	0.005	chronic MRL/RfD
	1 day/week	1.16	0.0005	0.0012	0.005	chronic MRL/RfD

Table D-4. Estimated Exposure Doses from Ingestion of Shellfish (continued)

Metal	Level of Exposure	Maximum Detected Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)		Oral Health Guideline (mg/kg/day)	Basis for Health Guideline
			Adult	Child		
Zinc	7 days/week	96.6	0.31*	0.69*	0.3	chronic MRL/RfD
	5 days/week	96.6	0.22	0.49*	0.3	chronic MRL/RfD
	4 days/week	96.6	0.18	0.39*	0.3	chronic MRL/RfD
	2 days/week	96.6	0.09	0.20	0.3	chronic MRL/RfD
	1 day/week	96.6	0.04	0.10	0.3	chronic MRL/RfD

* Estimated exposure exceeds health guideline; however, an exposure dose that is higher than the MRL or RfD does not necessarily result in harmful health effects. These metals are further evaluated.

Note: Exposure doses were calculated using the formula described in the *Deriving exposure doses* section of this appendix: (Conc. x IR x EF x ED) / (BW x AT).

Table D-5. Inorganic Arsenic Exposure Doses According to Location

Location	Fish			Shellfish		
	Average Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)		Average Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)	
		Adult	Child		Adult	Child
1 - North LIA	3.8	0.0025	0.0054	9.9	0.0064	0.0140
2 - South LIA	1.3	0.0008	0.0018	5.3	0.0034	0.0075
3 - Esperanza	4.4	0.0029	0.0062	8.3	0.0054	0.0118
4 - Isabel Segunda	1.9	0.0012	0.0027	NS	NS	NS
5 - Fish Market	8.0	0.0052	0.0114	31.7	0.0206	0.0450
6 - West Vieques	3.9	0.0025	0.0055	2.7	0.0018	0.0038
All Locations	4.0	0.0026	0.0057	11.1	0.0072	0.0157

Notes:
Averages were calculated using detected values only.
Exposure doses were calculated using 365 days/year for EF in the formula described in the *Deriving exposure doses* section of this appendix: (Conc. x IR x EF x ED x 0.2) / (BW x AT).
The body metabolizes arsenic into a less harmful form at doses of 0.05 mg/kg/day.
Health effects were reported from exposure to 0.014 mg/kg/day.
Cancer effects were reported from exposures to 0.01–0.05 mg/kg/day.
NS = not sampled

Table D-6. Inorganic Arsenic Exposure Doses for Species of Shellfish

Species	Level of Exposure	Average Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)	
			Adult	Child
Lobster	7 days/week	32.9	0.0213	0.0467
	5 days/week	32.9	0.0152	0.0332
	4 days/week	32.9	0.0122	0.0266
	2 days/week	32.9	0.0061	0.0133
	1 day/week	32.9	0.0030	0.0066
Conch	7 days/week	3.9	0.0025	0.0055
Land Crab	7 days/week	2.6	0.0017	0.0037

Notes:
Averages were calculated using detected values only.
Exposure doses were calculated using 365 days/year for EF in the formula described in the *Deriving exposure doses* section of this appendix: (Conc. x IR x EF x ED x 0.2) / (BW x AT).
The body metabolizes arsenic into a less harmful form at doses of 0.05 mg/kg/day.
Health effects were reported from exposure to 0.014 mg/kg/day.
Cancer effects were reported from exposures to 0.01–0.05 mg/kg/day.

Table D-7. Cadmium Exposure Doses According to Location

Location	Shellfish		
	Average Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)	
		Adult	Child
1 - North LIA	0.34	0.0011	0.0024
2 - South LIA	0.27	0.0009	0.0019
3 - Esperanza	0.49	0.0016	0.0035
4 - Isabel Segunda	NS	NS	NS
5 - Fish Market	ND	ND	ND
6 - West Vieques	0.34	0.0011	0.0024
All Locations	0.36	0.0012	0.0026

Notes:
Averages were calculated using detected values only.
Exposure doses were calculated using 365 days/year for EF in the formula described in the *Deriving exposure doses* section of this appendix: (Conc. x IR x EF x ED) / (BW x AT).
No adverse health effects were reported from exposure to 0.01 mg/kg/day.
Cancer effects were reported from exposure to 3.5 mg/kg/day.
ND = not detected
NS = not sampled

Table D-8. Chromium Exposure Doses According to Location

Location	Fish			Shellfish		
	Average Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)		Average Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)	
		Adult	Child		Adult	Child
1 - North LIA	0.14	0.0005	0.0010	0.16	0.0005	0.0011
2 - South LIA	0.25	0.0008	0.0018	0.38	0.0012	0.0027
3 - Esperanza	0.23	0.0007	0.0016	0.12	0.0004	0.0009
4 - Isabel Segunda	0.10	0.0003	0.0007	NS	NS	NS
5 - Fish Market	0.13	0.0004	0.0009	0.13	0.0004	0.0009
6 - West Vieques	0.11	0.0003	0.0008	0.10	0.0003	0.0007
All Locations	0.16	0.0005	0.0011	0.19	0.0006	0.0013

Notes:

Averages were calculated using detected values only.
Exposure doses were calculated using 365 days/year for EF in the formula described in the *Deriving exposure doses* section of this appendix: (Conc. x IR x EF x ED) / (BW x AT).
No adverse health effects were reported from exposure to 2.5 mg/kg/day.
NS = not sampled

Table D-9. Copper Daily Doses According to Location

Location	Fish			Shellfish		
	Average Concentration (ppm)	Estimated Daily Dose (mg/day)		Average Concentration (ppm)	Estimated Daily Dose (mg/day)	
		Adult	Child		Adult	Child
1 - North LIA	0.45	0.10	0.05	9.5	2.16	1.08
2 - South LIA	0.54	0.12	0.06	10.0	2.27	1.14
3 - Esperanza	0.55	0.12	0.06	3.8	0.86	0.43
4 - Isabel Segunda	0.46	0.10	0.05	NS	NS	NS
5 - Fish Market	0.92	0.21	0.10	10.4	2.36	1.18
6 - West Vieques	0.44	0.10	0.05	3.2	0.73	0.36
All Locations	0.56	0.13	0.06	7.8	1.77	0.89

Notes: Averages were calculated using detected values only.
Daily doses were calculated using the following formula: Dose = Conc. x IR.
No adverse health effects were reported from exposure to 10 mg/day.
NS = not sampled

Table D-10. Iron Exposure Doses According to Location

Location	Fish			Shellfish		
	Average Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)		Average Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)	
		Adult	Child		Adult	Child
1 - North LIA	6.4	0.021	0.045	18.0	0.058	0.128
2 - South LIA	10.3	0.033	0.073	52.1	0.169	0.370
3 - Esperanza	4.8	0.016	0.034	1.6	0.005	0.011
4 - Isabel Segunda	1.9	0.006	0.013	NS	NS	NS
5 - Fish Market	5.0	0.016	0.035	ND	ND	ND
6 - West Vieques	6.8	0.022	0.048	NA	NA	NA
All Locations	6.8	0.022	0.048	36.3	0.118	0.258

Notes:
Averages were calculated using detected values only.
Exposure doses were calculated using 365 days/year for EF in the formula described in the *Deriving exposure doses* section of this appendix: (Conc. x IR x EF x ED) / (BW x AT).
No adverse health effects were reported from exposure to 0.15–0.27 mg/kg/day.
NA = not available
ND = not detected
NS = not sampled

Table D-11. Iron Daily Doses According to Location

Location	Fish			Shellfish		
	Average Concentration (ppm)	Estimated Daily Dose (mg/day)		Average Concentration (ppm)	Estimated Daily Dose (mg/day)	
		Adult	Child		Adult	Child
1 - North LIA	6.4	1.5	0.7	18.0	4.1	2.0
2 - South LIA	10.3	2.3	1.2	52.1	11.8	5.9
3 - Esperanza	4.8	1.1	0.5	1.6	0.4	0.2
4 - Isabel Segunda	1.9	0.4	0.2	NS	NS	NS
5 - Fish Market	5.0	1.1	0.6	ND	ND	ND
6 - West Vieques	6.8	1.5	0.8	NA	NA	NA
All Locations	6.8	1.5	0.8	36.3	8.2	4.1

Notes:
Averages were calculated using detected values only.
Daily doses were calculated using the following formula: Dose = Conc. x IR.
Childhood poisoning was reported from exposure to 200 mg/event.
NA = not available
ND = not detected
NS = not sampled

Table D-12. Lead Exposure Doses According to Location

Location	Fish			Shellfish		
	Average Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)		Average Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)	
		Adult	Child		Adult	Child
1 - North LIA	1.06	0.0034	0.0075	ND	ND	ND
2 - South LIA	0.23	0.0007	0.0016	0.27	0.0009	0.0019
3 - Esperanza	0.21	0.0007	0.0015	0.18	0.0006	0.0013
4 - Isabel Segunda	0.17	0.0006	0.0012	NS	NS	NS
5 - Fish Market	0.24	0.0008	0.0017	0.20	0.0006	0.0014
6 - West Vieques	ND	ND	ND	ND	ND	ND
All Locations	0.27	0.0009	0.0019	0.25	0.0008	0.0018

Notes:
Averages were calculated using detected values only.
Exposure doses were calculated using 365 days/year for EF in the formula described in the *Deriving exposure doses* section of this appendix: (Conc. x IR x EF x ED) / (BW x AT).
No adverse health effects were reported from exposure to 0.57–27 mg/kg/day.
Cancer health effects were reported from exposure to 27 to 371 mg/kg/day.
ND = not detected
NS = not sampled

Table D-13. Blood Lead Levels According to Location

Location	Fish		Shellfish	
	Average Concentration (ppm)	Estimated Blood Lead Level (µg/dl)	Average Concentration (ppm)	Estimated Blood Lead Level (µg/dl)
1 - North LIA	1.06	0.25	ND	ND
2 - South LIA	0.23	0.06	0.27	0.06
3 - Esperanza	0.21	0.05	0.18	0.04
4 - Isabel Segunda	0.17	0.04	NS	NS
5 - Fish Market	0.24	0.06	0.20	0.05
6 - West Vieques	ND	ND	ND	ND
All Locations	0.27	0.06	0.25	0.06

Notes:
Averages were calculated using detected values only.
Blood lead levels were calculated by multiplying the concentration by a media-specific slope factor (0.24 µg/dl per ppm) as described in the *Using other methods to evaluate potential health hazards* section of this appendix.
CDC's blood lead level of concern is 10 µg/dl.
ND = not detected
NS = not sampled

Table D-14. Mercury Exposure Doses According to Location

Location	Fish			Shellfish		
	Average Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)		Average Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)	
		Adult	Child		Adult	Child
1 - North LIA	0.13	0.0004	0.0009	0.03	0.0001	0.0002
2 - South LIA	0.09	0.0003	0.0006	0.02	0.0001	0.0001
3 - Esperanza	0.15	0.0005	0.0011	0.04	0.0001	0.0003
4 - Isabel Segunda	0.09	0.0003	0.0006	NS	NS	NS
5 - Fish Market	0.09	0.0003	0.0006	0.03	0.0001	0.0002
6 - West Vieques	0.13	0.0004	0.0009	0.03	0.0001	0.0002
All Locations	0.12	0.0004	0.0009	0.03	0.0001	0.0002

Notes: Averages were calculated using detected values only.
Exposure doses were calculated using 365 days/year for EF in the formula described in the *Deriving exposure doses* section of this appendix: (Conc. x IR x EF x ED) / (BW x AT).
No adverse health effects were reported from exposure to 0.0013 mg/kg/day.
NS = not sampled

Table D-15. Selenium Exposure Doses According to Location

Location	Fish			Shellfish		
	Average Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)		Average Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)	
		Adult	Child		Adult	Child
1 - North LIA	0.82	0.0027	0.0058	0.80	0.0026	0.0057
2 - South LIA	1.05	0.0034	0.0074	0.80	0.0026	0.0057
3 - Esperanza	1.03	0.0033	0.0073	0.85	0.0028	0.0060
4 - Isabel Segunda	0.84	0.0027	0.0060	NS	NS	NS
5 - Fish Market	1.15	0.0037	0.0082	0.74	0.0024	0.0052
6 - West Vieques	0.93	0.0030	0.0066	0.79	0.0026	0.0056
All Locations	0.98	0.0032	0.0070	0.80	0.0026	0.0057

Notes: Averages were calculated using detected values only.
Exposure doses were calculated using 365 days/year for EF in the formula described in the *Deriving exposure doses* section of this appendix: (Conc. x IR x EF x ED) / (BW x AT).
No adverse health effects were reported from exposure to 0.015 mg/kg/day.
NS = not sampled

Table D-16. Zinc Exposure Doses According to Location

Location	Shellfish		
	Average Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)	
		Adult	Child
1 - North LIA	45.2	0.147	0.321
2 - South LIA	44.1	0.143	0.313
3 - Esperanza	11.2	0.036	0.079
4 - Isabel Segunda	NS	NS	NS
5 - Fish Market	18.3	0.059	0.130
6 - West Vieques	8.0	0.026	0.057
All Locations	30.1	0.098	0.214

Notes:
Averages were calculated using detected values only.
Exposure doses were calculated using 365 days/year for EF in the formula described in the *Deriving exposure doses* section of this appendix: (Conc. x IR x EF x ED) / (BW x AT).
Fish did not contain levels of zinc above health concern at any location.
Health effects were reported from exposure to 0.83 mg/kg/day.
NS = not sampled

Table D-17. Estimated Exposure Doses from Ingestion of the Maximum Snapper Concentration

Metal	Maximum Detected Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)		Oral Health Guideline (mg/kg/day)	Basis for Health Guideline
		Adult	Child		
Aluminum	10.8	0.0350	0.0766	1.0	chronic RfD
Arsenic	21.4	0.0694*	0.1518*	0.0003	chronic MRL/RfD
Barium	0.19	0.0006	0.0013	0.07	chronic RfD
Beryllium	0.01	0.00003	0.00007	0.001	chronic MRL
Chromium	0.37	0.0012	0.0026	0.003	chronic RfD (CrVI)
Cobalt	0.09	0.0003	0.0006	0.02	chronic RfD
Copper	8.21	0.0266	0.0582*	0.04	chronic RfD
Iron	6.51	0.0211	0.0462	0.3	chronic RfD
Lead	0.37	0.0012	0.0026	NA	NA
Manganese	2.02	0.0066	0.0143	0.14	chronic RfD (food)
Mercury	0.09	0.0003*	0.0006*	0.0001	chronic RfD
Methylmercury	0.018	0.00006	0.00013*	0.0001	chronic RfD
Nickel	0.35	0.0011	0.0025	0.02	chronic RfD
Silver	0.11	0.0004	0.0008	0.005	chronic RfD
Selenium	1.94	0.0063*	0.0138*	0.005	chronic MRL/RfD
Zinc	21.0	0.0681	0.1490	0.3	chronic MRL/RfD

* Estimated exposure exceeds health guideline; however, an exposure dose that is higher than the MRL or RfD does not necessarily result in harmful health effects. These metals are further evaluated.

Notes: Exposure doses were calculated using 365 days/year for EF in the formula described in the *Deriving exposure doses* section of this appendix: (Conc. x IR x EF x ED) / (BW x AT).
NA = not available

Table D-18. Estimated Exposure Doses from Ingestion of the Average Snapper Concentration

Metal	Average Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)	
		Adult	Child
Arsenic, inorganic	5.64	0.0037	0.0080
Lead	0.21	0.0007	0.0015
Mercury	0.05	0.0002	0.0004
Selenium	1.12	0.0036	0.0079
		Estimated Daily Dose (mg/day)	
Copper	1.02	0.23	0.12
		Estimated Blood Lead Level (µg/dl)	
Lead	0.21	0.05	0.05

Notes:

Averages were calculated using detected values only.

Exposure doses were calculated using 365 days/year for EF in the formula described in the *Deriving exposure doses* section of this appendix: (Conc. x IR x EF x ED) / (BW x AT). To calculate the exposure dose for inorganic arsenic the total arsenic concentration was used along with a conversion factor of 0.2 in the numerator.

Daily doses were calculated using the following formula: Dose = Conc. x IR.

The body metabolizes arsenic into a less harmful form at doses of 0.05 mg/kg/day.

Health effects were reported from exposure to arsenic at doses of 0.014 mg/kg/day.

Cancer effects were reported from exposures to arsenic at doses of 0.01–0.05 mg/kg/day.

No adverse health effects were reported from exposure to lead at doses of 0.57–27 mg/kg/day.

CDC's blood lead level of concern is 10 µg/dl.

No adverse health effects were reported from exposure to mercury at doses of 0.0013 mg/kg/day.

No adverse health effects were reported from exposure to selenium at doses of 0.015 mg/kg/day.

No adverse health effects were reported from exposure to copper at doses of 10 mg/day.

Table D-19. Estimated Exposure Doses from Ingestion of Boxfish

Metal	Detected Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)		Oral Health Guideline (mg/kg/day)	Basis for Health Guideline
		Adult	Child		
Arsenic	29.3	0.0190*	0.0416*	0.0003	chronic MRL/RfD
Chromium	0.08	0.0003	0.0006	0.003	chronic RfD (CrVI)
Copper	0.36	0.0012	0.0026	0.04	chronic RfD
Selenium	2.5	0.0080*	0.0176*	0.005	chronic MRL/RfD

* Estimated exposure exceeds health guideline; however, an exposure dose that is higher than the MRL or RfD does not necessarily result in harmful health effects. These metals are further evaluated.

Notes: Exposure doses were calculated using 365 days/year for EF in the formula described in the *Deriving exposure doses* section of this appendix: (Conc. x IR x EF x ED) / (BW x AT). To calculate the exposure dose for inorganic arsenic the total arsenic concentration was used along with a conversion factor of 0.2 in the numerator.
The body metabolizes arsenic into a less harmful form at doses of 0.05 mg/kg/day.
Health effects were reported from exposure to arsenic at doses of 0.014 mg/kg/day.
Cancer effects were reported from exposures to arsenic at doses of 0.01–0.05 mg/kg/day.
Health effects were reported from exposure to selenium at doses of 0.023 mg/kg/day.

Table D-20. Estimated Exposure Doses from Ingestion of the Maximum Concentrations Detected by Universidad Metropolitana

Metal	Maximum Detected Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)		Oral Health Guideline (mg/kg/day)	Basis for Health Guideline
		Adult	Child		
Arsenic	7.2	0.0047*	0.0102*	0.0003	chronic MRL/RfD
Cadmium	0.028	0.00009	0.00019	0.001	chronic RfD (food)
Lead	0.2	0.0006	0.0014	NA	NA
Mercury	0.38	0.0012*	0.0027*	0.0001	chronic RfD
Selenium	1.3	0.0042	0.0092*	0.005	chronic MRL/RfD
Zinc	9.1	0.0295	0.0646	0.3	chronic MRL/RfD

* Estimated exposure exceeds health guideline; however, an exposure dose that is higher than the MRL or RfD does not necessarily result in harmful health effects. These metals are further evaluated.

Source: Caro et al. 2000

Notes: Exposure doses were calculated using 365 days/year for EF in the formula described in the *Deriving exposure doses* section of this appendix: (Conc. x IR x EF x ED) / (BW x AT).
NA = not available

Table D-21. Estimated Exposure Doses from Ingestion of the Average Concentrations Detected by Universidad Metropolitana

Metal	Average Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)	
		Adult	Child
Arsenic, inorganic	1.2	0.0008	0.0017
Lead	0.2	0.0006	0.0014
Mercury	0.024	0.0001	0.0002
Selenium	0.6	0.0019	0.0043
		Estimated Blood Lead Level (µg/dl)	
Lead	0.2	0.05	0.05

Source: Caro et al. 2000

Notes: Averages were calculated using detected values only.

Exposure doses were calculated using 365 days/year for EF in the formula described in the *Deriving exposure doses* section of this appendix: (Conc. x IR x EF x ED) / (BW x AT). To calculate the exposure dose for inorganic arsenic the total arsenic concentration was used along with a conversion factor of 0.2 in the numerator.

The body metabolizes arsenic into a less harmful form at doses of 0.05 mg/kg/day.

Health effects were reported from exposure to arsenic at doses of 0.014 mg/kg/day.

Cancer effects were reported from exposures to arsenic at doses of 0.01–0.05 mg/kg/day.

No adverse health effects were reported from exposure to lead at doses of 0.57–27 mg/kg/day.

CDC's blood lead level of concern is 10 µg/dl.

No adverse health effects were reported from exposure to mercury at doses of 0.0013 mg/kg/day.

No adverse health effects were reported from exposure to selenium at doses of 0.015 mg/kg/day.

Appendix E

Pictures of Species Collected by ATSDR

Image 1: Snapper

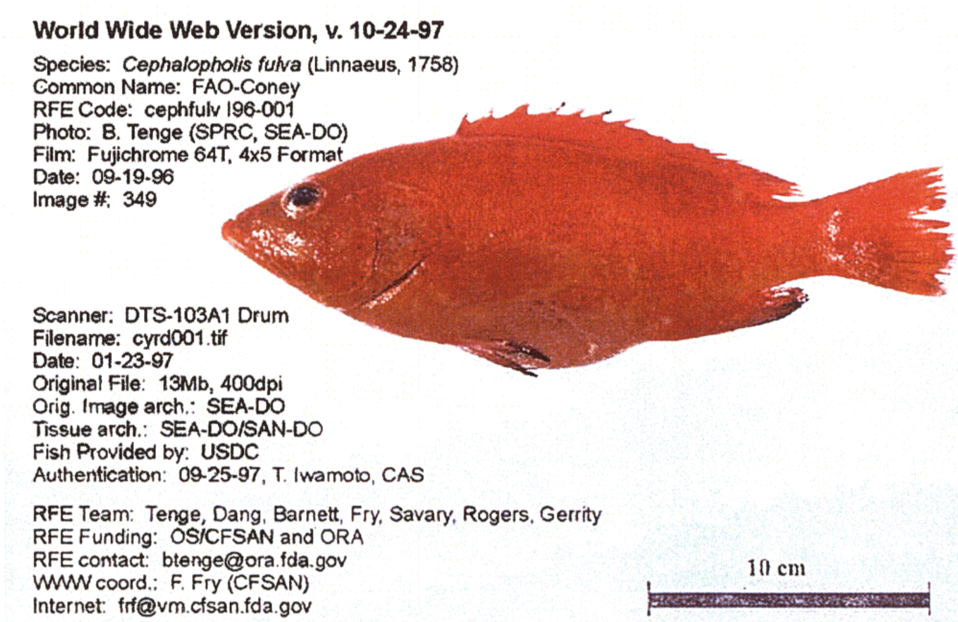


Image 2: Coney

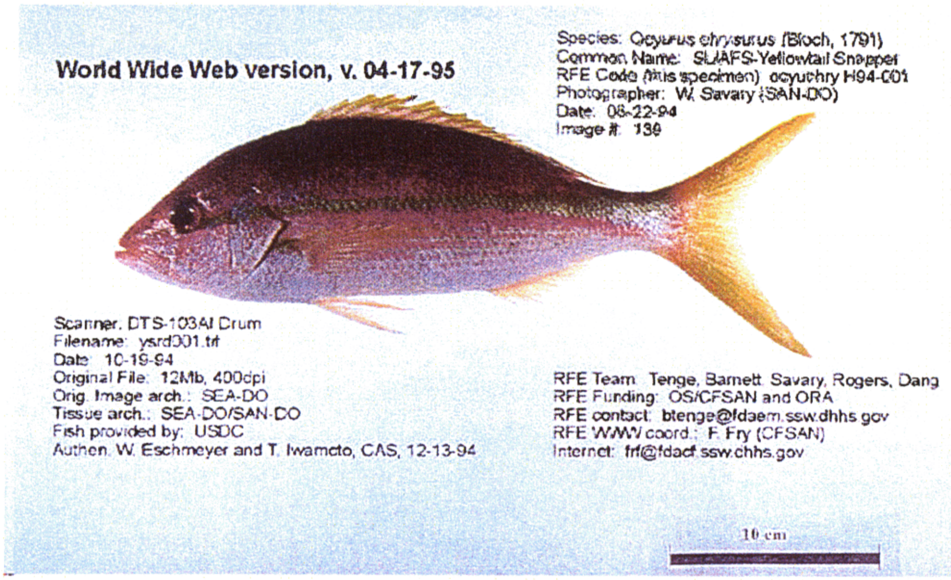


Image 3: Yellowtail Snapper

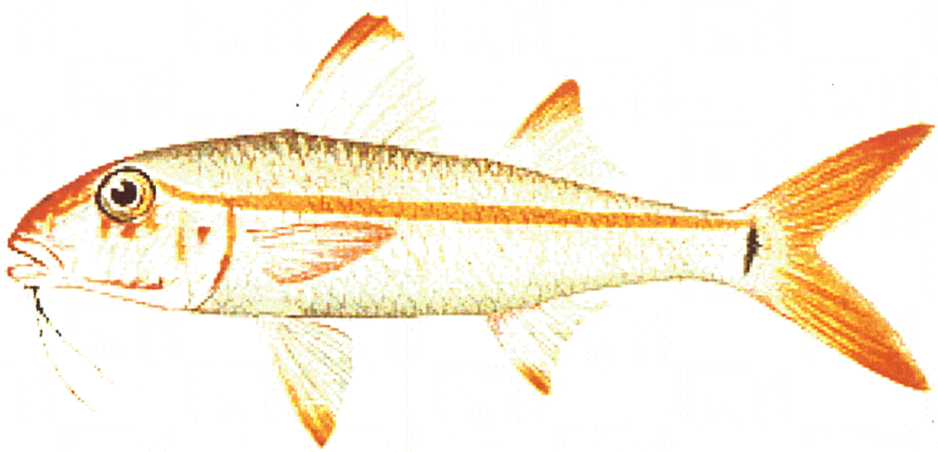


Image 4: Goatfish

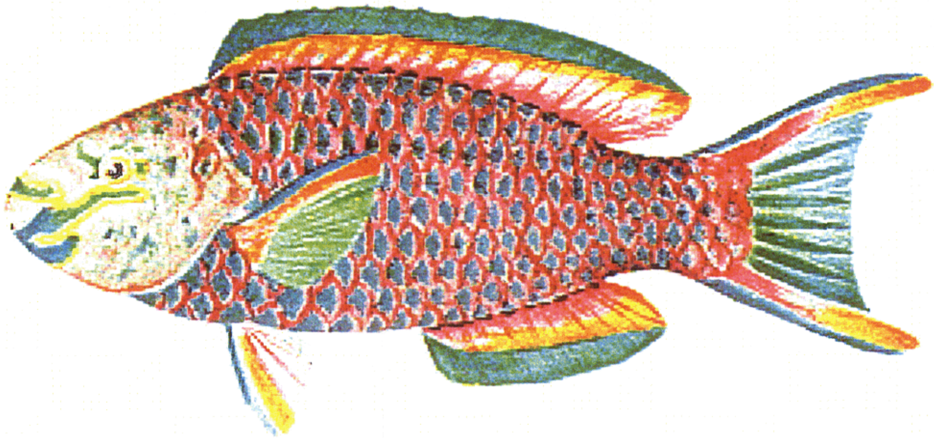


Image 5: Parrotfish

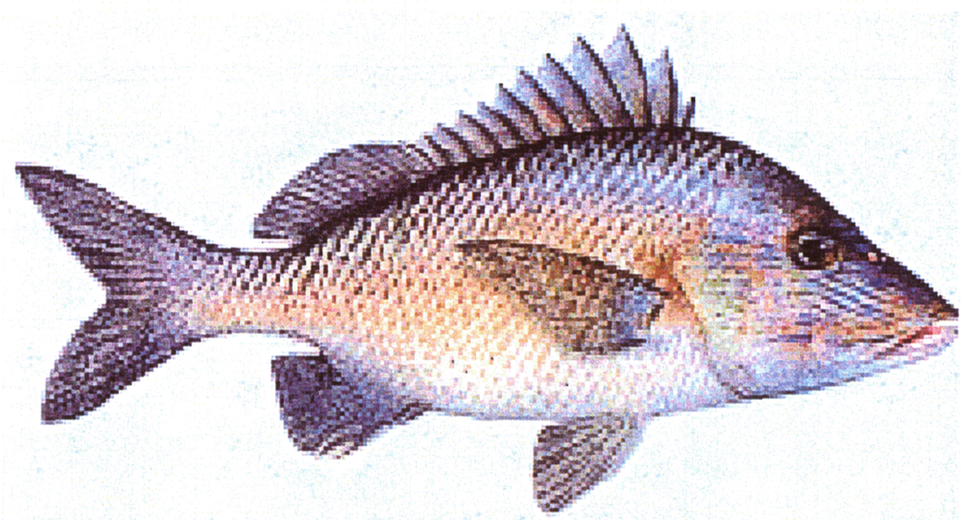


Image 6: Grunt

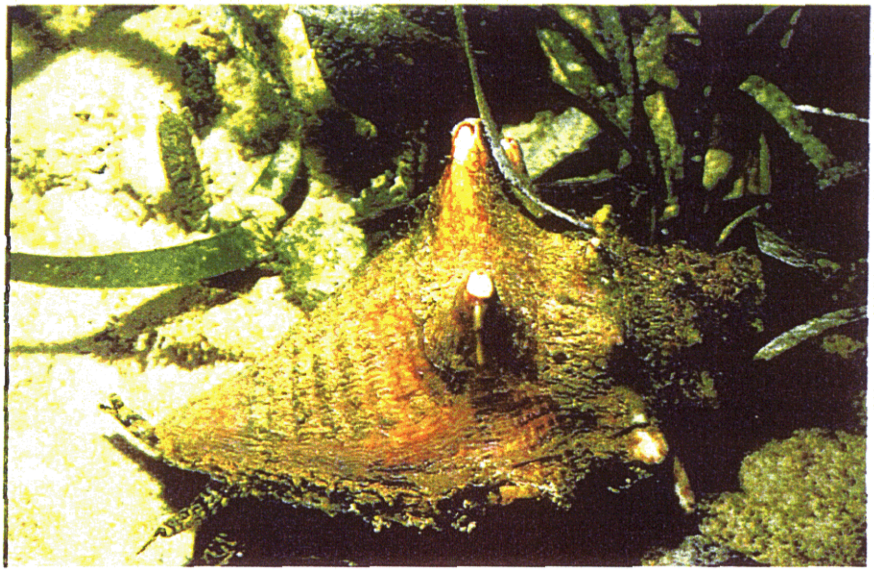


Image 7: Queen Conch

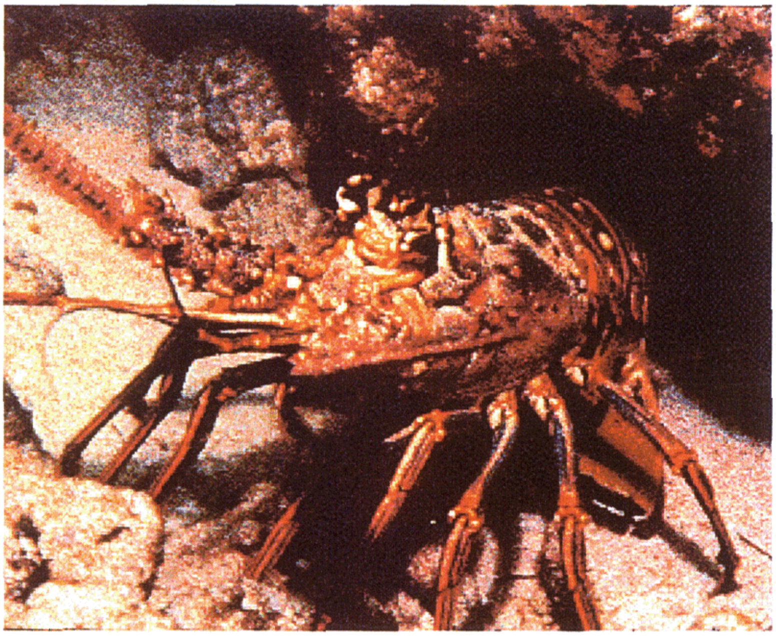


Image 8: Spiny Lobster

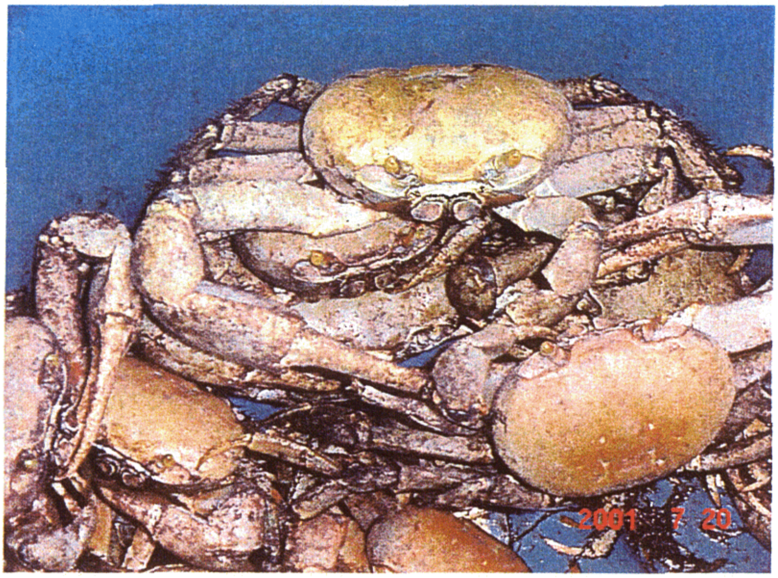


Image 9: Land Crab

Images 1, 2, 3: U.S. Food & Drug Administration, Seafood Products Research Center, Center for Food Safety & Applied Nutrition, Regulatory Fish Encyclopedia, http://www.cfsan.fda.gov
Image 4, 5: National Marine Fisheries Service http://www.sefsc.noaa.gov/ from: Everman, B.W. and M.C. Marsh. 1902. The fishes of Porto Rico. Bulletin of the United States Fish Commission, Volume 10 for 1900. Plate 5, Plate 31
Image 6: Smithsonian Marine Station Web site, www.sms.si.edu
Image 7: University of North Carolina Web site, http://www.unc.edu/depts/oceanweb
Image 8: National Marine Fisheries Service, Office of Protected Resources, http://www.nmfs.noaa.gov
Image 9: land crabs collected for this study

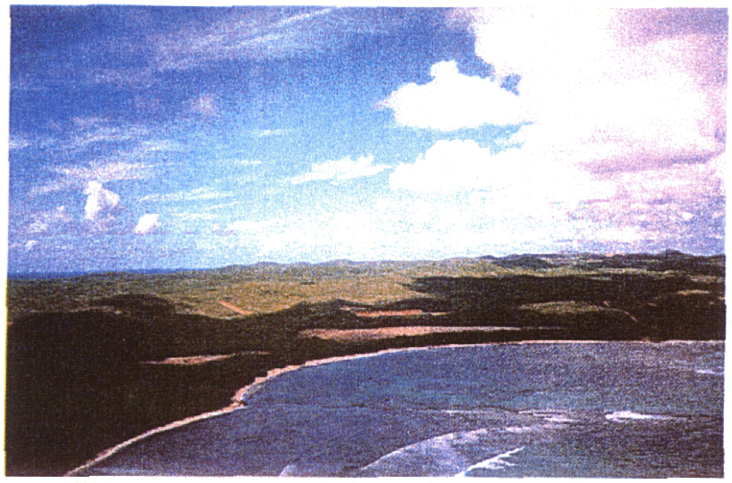
Appendix F

Pictures Referenced in the Public Health Assessment

Picture 1. West Vieques

Picture 2. Former Eastern Maneuver Area

Picture 3. OP-1 in the former Atlantic Fleet Weapons Training Facility



Picture 4. Former Atlantic Fleet Weapons Training Facility

Picture 5. Former Live Impact Area

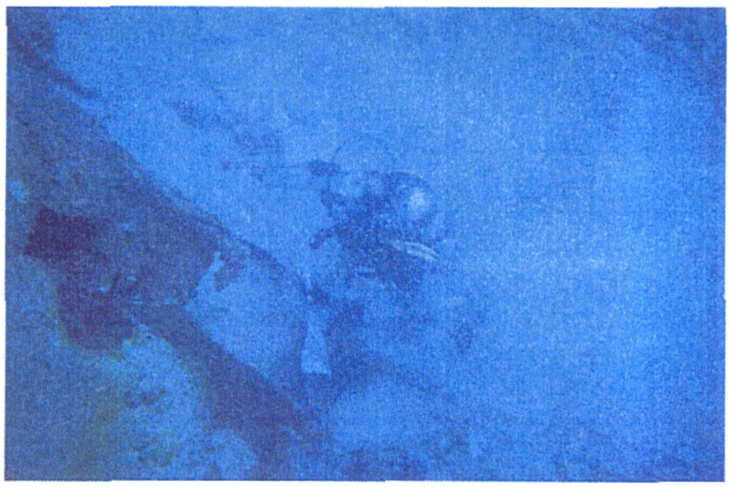
Picture 6. Targets in the former Live Impact Area

Picture 7. Punta Este Conservation Zone

Picture 8. Isabel Segunda

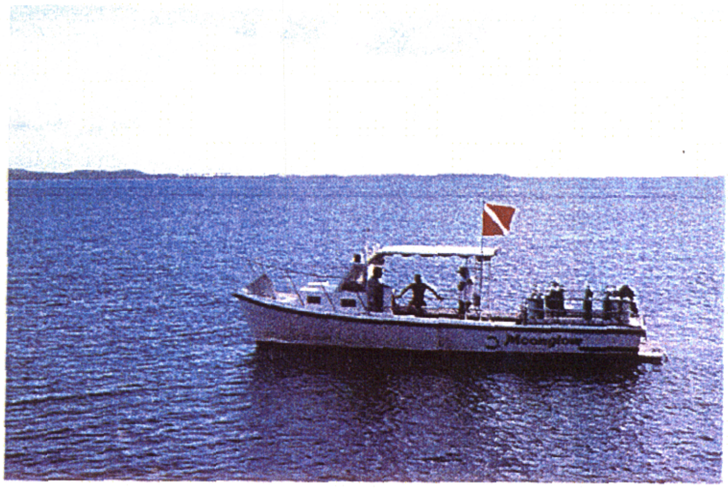
Picture 9. Esperanza

Picture 10. Mosquito Pier

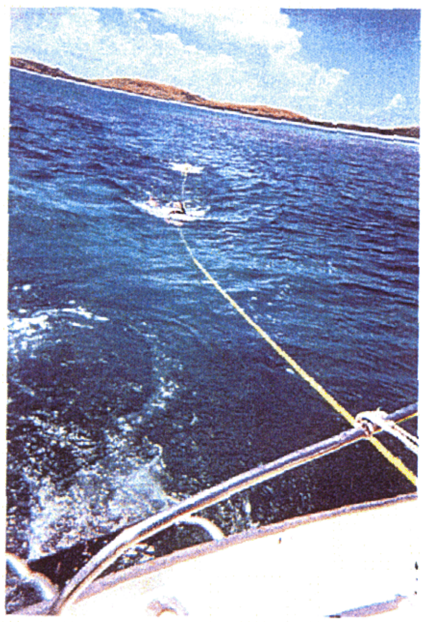


Picture 11. EPA/ERT Diver Spearfishing

Picture 12. Land Crab Trap

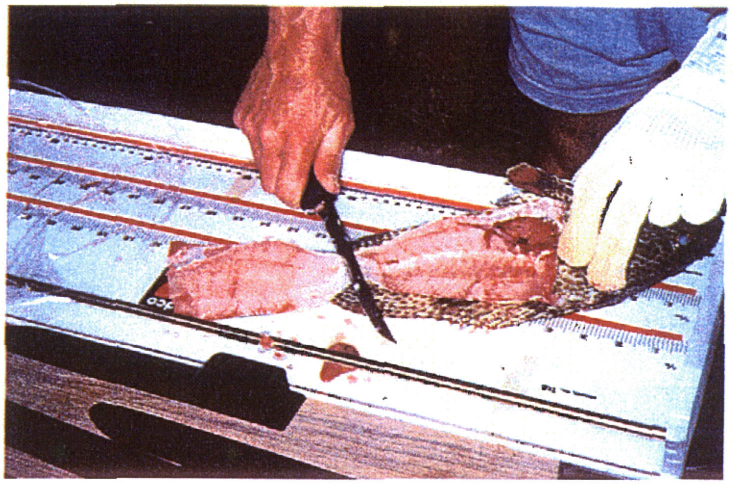


Picture 13. The Moonglow



Picture 14. Diver Tow

Picture 15. Measuring Fish Length

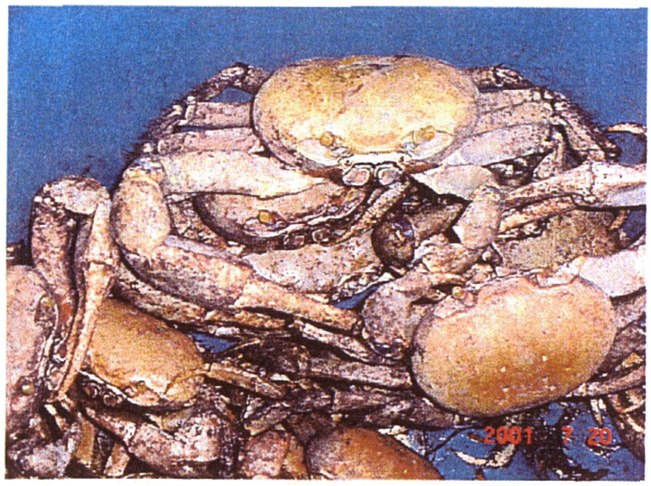


Picture 16. Filleting Fish

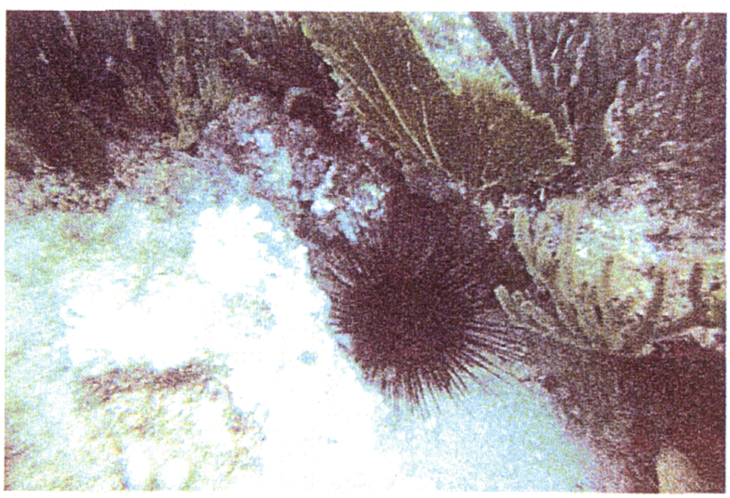
Picture 17. Measuring Conch Length

Picture 18.
Weighing Conch

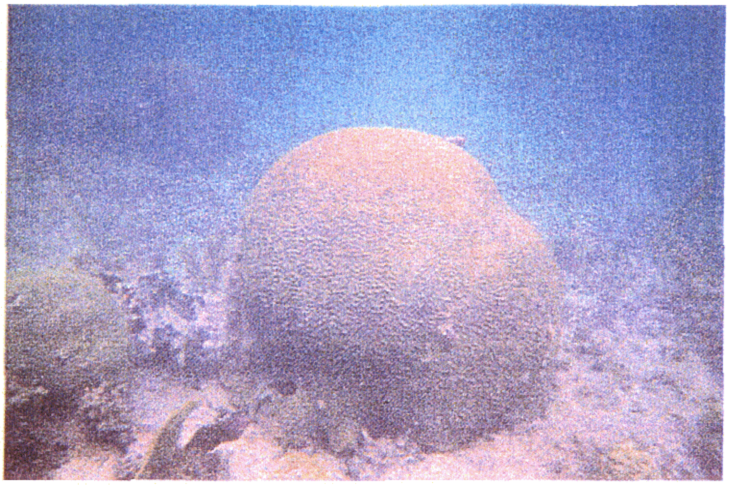
Picture 19. "Picking" Land Crabs



Picture 20. Land Crabs

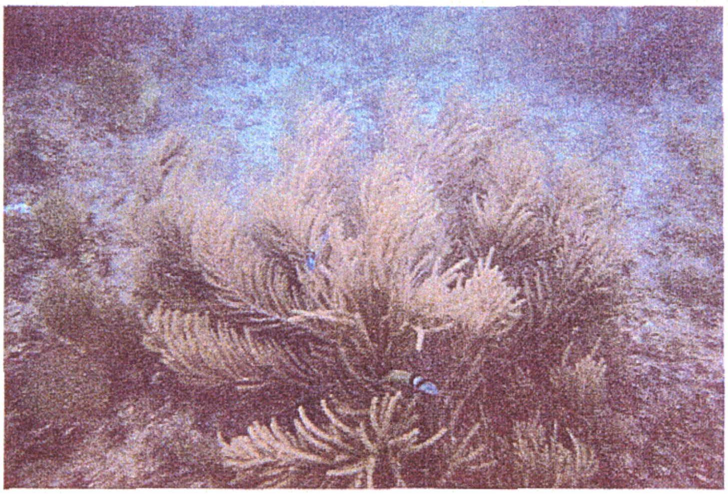


Picture 21. Sea Urchin

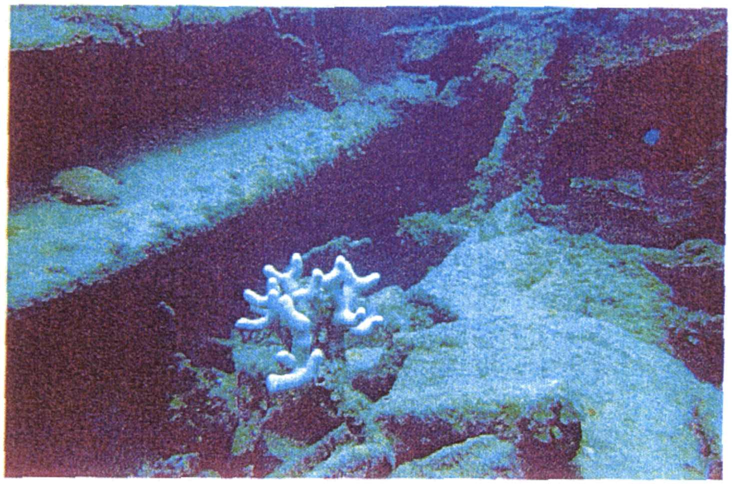


Picture 22. Hard Coral

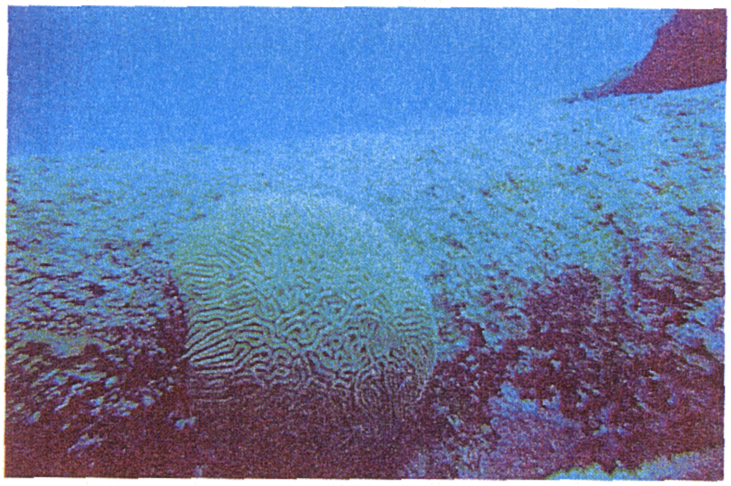
Picture 23. Hard Coral



Picture 24. Soft Coral

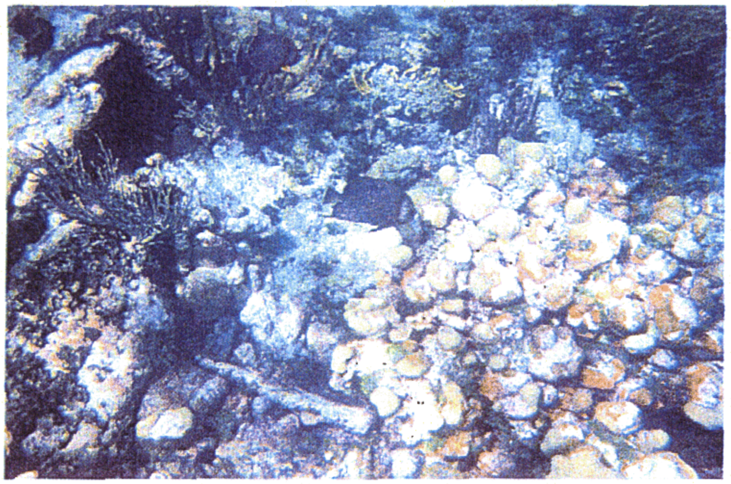


Picture 25. Coral on the former USS Killen

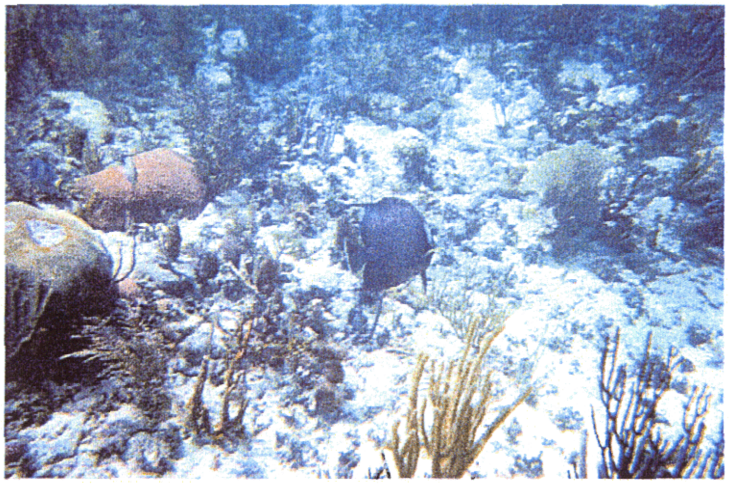


Picture 26. Coral on the former USS Killen

Picture 27. Fish around Coral Reef



Picture 28. Corals and Fish from Location 4



Picture 29. Corals and Fish from Location 4

Appendix G

Responses to Public Comments

4. **Comment:** *The importance of how explicit appear the text is to determine the existence or not of the contamination and the pathways.*

   Response: ATSDR agrees that it is important to explicitly present the findings about the existence of contamination and the possibility of exposure pathways.

5. **Comment:** *The PHA is strongly based on Dr. Caro's research, Metropolitan University. While Dr. Caro's report determines that her research is a starting point; inclusive without having access to the complete methodology of the research, I question that epidemiologically, 51 residents are a representative percentage of the total population of Vieques Island.*

   Response: At the time of ATSDR's sampling, Dr. Caro's research provided the most detailed and relevant information about consumption habits of Vieques residents (Caro et al. 2000). However, it was not the only source consulted by ATSDR. We also relied on information provided by (1) the petitioner, (2) the Vieques Special Commission Report (Government of Puerto Rico 1999 as cited in Navy 2000b), (3) ATSDR's community involvement program, and (4) visits to local fish markets by ATSDR staff. Taken together, these sources provided ATSDR with a good indication of how often residents of Vieques eat fish and shellfish and what species they eat.

6. **Comment:** *Epidemiologically does not establish the absence of risk.*

   Response: ATSDR assumes that this comment is in reference to Dr. Caro's research of a representative sampling (51 people) of Vieques residents' consumption habits (Caro et al. 2000). Dr. Caro's research helped ATSDR determine which species of fish and shellfish to collect and helped determine how often residents of Vieques ate fish and shellfish. The information provided in the report was substantiated by information collected by the petitioner, ATSDR's community involvement program, the Vieques Special Commission Report (Government of Puerto Rico 1999 as cited in Navy 2000b), and visits to local fish markets.

   To determine whether it is safe to eat the fish and shellfish from around Vieques, ATSDR collected 104 fish and 38 shellfish and analyzed them for heavy metals and explosive compounds. The results of the sampling and analysis indicated what levels of chemicals are present in the fish and shellfish around Vieques. ATSDR used these data to determine that it is safe for people to eat fish and shellfish with the detected levels of chemicals.

Responses to Public Comments

The Agency for Toxic Substances and Disease Registry (ATSDR) received the following comments during the public comment period (November 14, 2002 to January 27, 2003) for the Fish and Shellfish Evaluation for the Isla de Vieques Bombing Range Public Health Assessment (PHA) (November 2002). For comments that questioned the validity of statements made in the PHA, ATSDR verified or corrected the statements. The list of comments does not include editorial comments, such as word spelling or sentence syntax.

1. **Comment:** *Between this fish and shellfish evaluation and the earlier groundwater and drinking water pathways et al studies I consider the inhabitants of Isla de Vieques to be in a reasonably safe environment.*

   Response: Thank you for the comment. After thoroughly evaluating the drinking water and groundwater supplies, the soil pathway, the fish and shellfish, and the air pathway, ATSDR agrees that the residents of Vieques are not being exposed to harmful levels of chemicals from the Live Impact Area (LIA).

2. **Comment:** *While stated in different parts of the document, the document summary should name the metals found in the fish and shellfish and conclude that while the following compounds were found to be present in the fish and shellfish of Vieques, they are found at levels low enough as not to pose a threat to human health. The individual metals found should also be included in Part VIII, Conclusion.*

   Response: ATSDR agrees with the statement that while metals were detected in the Vieques fish and shellfish, they were found at levels too low to present a public health concern. However, since very few metals were <u>not</u> detected in Vieques fish and shellfish, listing all of them would not be efficient. Instead, please refer to Tables 8 and 9 which identify the ranges, averages, and frequency of detections for the metals that were detected in the fish and shellfish, respectively. It should be noted that heavy metals are commonly detected in fish and shellfish tissue because seafood tends to accumulate metals that are naturally present in the environment.

3. **Comment:** *The report should have one or two sentences stating that the findings of this report are directed solely at human health and cannot be used to infer ecological integrity of the natural systems on Vieques. The results of an ATSDR report should not be used to imply that there are no environmental impacts on Vieques.*

   Response: ATSDR agrees that this evaluation is a <u>public health</u> assessment, not an ecological assessment.

7. **Comment:** *The methodology by which the nutritional information is obtained is unclear.*

Response: To determine which species of commonly consumed fish should be sampled, ATSDR compiled consumption information from the questionnaire administered by the Universidad Metropolitana researchers (Caro et al. 2000), the petitioner, the Vieques Special Commission Report (Government of Puerto Rico 1999 as cited in Navy 2000b), ATSDR's community involvement program, and visits to local fish markets by ATSDR staff.

1. *Some of the information regarding the relative frequency of consumption by Viequenses was obtained from the study done by Metropolitan University (Caro et al. 2000). As quoted by the ATSDR, a total of 51 Viequenses was surveyed in Dr. Caro's study and the frequency of fish consumption was derived from this survey. The age and sex distribution of the 51 subjects is not known.*

Response: The 51 residents of Vieques who were questioned by Universidad Metropolitana were comprised of 20 females (39.2%) and 31 males (60.8%). While the researchers did not report the actual ages of the residents who participated in the questionnaire, they did ask how long they lived in Vieques. Eleven people (21.5%) reported that they lived in Vieques 1–10 years, 9 people (17.6%) lived in Vieques 11–20 years, 10 people (19.6%) lived in Vieques 21–35 years, and 21 people (41.2%) lived in Vieques 36 or more years. This information is provided in the original report (Caro et al. 2000).

2. *The potential consumption of seafood (fish, mollusks, and/or crustaceans) more than once daily is not contemplated in the Dr. Caro study:*

fish consumed % (of subjects)	*frequency*
47.05	*1-2 times per week*
17.60	*3-4 times per week*
15.60	*5 or more times per week*
19.60	*0 or occasional*

Response: It appears that the Universidad Metropolitana researchers asked how many times a week the residents ate seafood. This seems to imply that a person could respond with a number greater than seven if they ate fish or shellfish more than once a day. The category of "5 or more times per week" would; therefore, include anyone who eats fish or shellfish more than once a day.

8. **Comment:** *The methodology and questionnaire by which ATSDR interviewed Viequenses regarding their nutritional habits are not stated.*

Response: ATSDR did not formally interview or circulate questionnaires to the residents of Vieques asking about their nutritional habits. To determine which species of commonly consumed fish should be sampled, ATSDR compiled consumption information from the questionnaire administered by the Universidad Metropolitana researchers (Caro et al. 2000), the petitioner, the Vieques Special Commission Report (Government of Puerto Rico 1999 as cited in Navy 2000b), ATSDR's community involvement program, and visits to local fish markets by ATSDR staff.

9. **Comment:** *Our study done during 2000-2002, included among other subjects, a detailed questionnaire of nutritional habits. These were completed by 102 volunteers. Among our findings are the following:*

1. *Seafood (fish, mollusks and crustaceans) consumption is highly variable.*
2. *The frequency of fish consumption varies significantly with the age variable.*
3. *The weekly total seafood consumption for the 102 studied Viequenses was 5.9 +/- 1.1 times per week. The upper limit of the 95% confidence interval was 9.7 times per week. Thus some Viequenses consume seafood more frequently than once daily.*
4. *In contrast, weekly chicken consumption average 3.5 +/- 0.2 times per week, with a 95% CI limit of 3.8 and did not exhibit a statistically significant correlation with the age variable.*

Response: ATSDR requested, but was not given, the opportunity to view this particular study. ATSDR and US Environmental Protection Agency's Environmental Response Team (EPA/ERT) collected commonly caught and consumed species based on several sources of information that were available at the time of the sampling (prior to July 2001): (1) the questionnaire administered by the Universidad Metropolitana researchers (Caro et al. 2000), (2) the petitioner, (3) the Vieques Special Commission Report (Government of Puerto Rico 1999 as cited in Navy 2000b), (4) ATSDR's community involvement program, and (5) visits to local fish markets by ATSDR staff. Taken together, these sources provided ATSDR with a good indication of how often residents of Vieques eat fish and shellfish and what species they eat.

According to the consumption information provided by the commenter, the majority of residents of Vieques were considered during ATSDR's evaluation of eating fish and shellfish once a day, every day for 70 years. To evaluate whether the small percentage of people who eat fish and shellfish 9.7 times a week would expect to experience adverse health effects, ATSDR adjusted the exposure frequency to 505 days a year in the exposure dose equations provided in Appendix D. The results are provided in the following table. All of these doses are below levels of health concern for anyone eating fish and shellfish 9.7 times a week.

Chemical	Fish			Shellfish		
	Average Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)		Average Concentration (ppm)	Estimated Exposure Dose (mg/kg/day)	
		Adult	Child		Adult	Child
Inorganic Arsenic	4.0	0.0036	0.0079	11.1	0.0100	0.0218
Cadmium	0.08	0.0004	0.0008	0.36	0.0016	0.0035
Chromium	0.16	0.0007	0.0016	0.19	0.0009	0.0019
Lead	0.27	0.0012	0.0026	0.25	0.0011	0.0025
Mercury	0.12	0.0005	0.0012	0.03	0.0001	0.0003
Selenium	0.98	0.0044	0.0096	0.80	0.0036	0.0079
Zinc	3.1	0.014	0.031	30.1	0.135	0.295
Chemical	**Average Concentration (ppm)**	**Estimated Daily Dose (mg/day)**		**Average Concentration (ppm)**	**Estimated Daily Dose (mg/day)**	
Copper	0.56	0.18	0.09	7.8	2.5	1.2
Iron	6.8	2.2	1.1	36.3	11.5	5.8
Chemical	**Average Concentration (ppm)**	**Estimated Blood Lead Level (µg/dl)**		**Average Concentration (ppm)**	**Estimated Blood Lead Level (µg/dl)**	
Lead	0.27	0.09	0.09	0.25	0.08	0.08

10. **Comment:** *The rationale for sampling the chosen species and the number of individuals sampled for each species has not been determined. To our knowledge, prior to our study, the frequency or relative frequency of local consumption of each species had not been determined. For illustration, a rank of the most commonly consumed species is provided. The number of individuals sampled for each species (as per ATSDR reports) is also listed.*

Species	*sampled by ATSDR*	*sampled by UMET*
colirubia (Ocyurus chrysurus)	*10*	*12*
chapin (Lactophyrys trigonus)	*1*	*0*
sierra (Scomberomorus regalis)	*0*	*0*
carrucho (Strombus gigas)	*4*	*0*
pulpo (Octopus vulgaris)	*0*	*0*
caracol-Burgao (Cittarium pica)	*0*	*0*
sama (lutjamus analis)	*0*	*0*
"chopa" (multiple species)	*information not available*	*information not available*
tiburon (Shark) (several species)	*0*	*0*
pargo (Lutjanus apodus)	*0*	*0*
chillo (lutjanus vivanus)	*0*	*0*
rabalo	*N/A*	*N/A*

Thus, the only commonly consumed species for which more than 3 individuals were sampled was colirubia (Ocyurus chrysurus). Any conclusion about other species or variety of seafood is unfounded.

Response: ATSDR requested, but was not given the opportunity to view this particular study. ATSDR and EPA/ERT collected commonly caught and consumed species based on several sources of information that were available at the time of the sampling (prior to July 2001): (1) the questionnaire administered by the Universidad Metropolitana researchers (Caro et al. 2000), (2) the petitioner, (3) the Vieques Special Commission Report (Government of Puerto Rico 1999 as cited in Navy 2000b), (4) ATSDR's community involvement program, and (5) visits to local fish markets by ATSDR staff.

It should be noted that the table provided by the commenter is inaccurate in the number of fish ATSDR collected for each species identified. As Table 7 shows, ATSDR collected more than three individuals for three of the species specifically identified by the commenter (*colirubia, carrucho,* and *pargo).* During the July 2001 sampling, ATSDR and EPA/ERT collected 104 fish and 38 shellfish, representing 17 different species of fish and three different species of shellfish—30 groupers (*Epinephelus* sp.), 19 snappers (*Ocyurus chrysurus* and *Lutjanus* sp.), 25 parrotfish (Scaridae family), 24 grunts (*Haemulon* sp.), 5 goatfish (Mullidae family), 1 cowfish (*Lactophrys polygonia*), 20 conch (*Strombus gigas*), 7 lobster (*Panulirus argus*), and 11 land crab (*Cardisoma guanhumi*) composite samples.

Because not every species of fish and shellfish can be realistically sampled (nor is it expected or recommended[12]), ATSDR and EPA/ERT focused the sampling effort on species of commonly consumed fish and shellfish that would be expected to have a higher exposure to potential contamination from Navy training exercises at the LIA. Therefore, ATSDR and EPA/ERT choose to sample non-migratory, reef-dwelling species that tended to reside locally (rather than migratory, open-water fish that would have less exposure to local contamination).

11. **Comment:** *The distinction between seafood locally consumed and seafood fished for commercial purposes in Vieques is not clarified.*

    Response: The purpose of ATSDR's sampling and analysis activities was to determine whether the muscle tissues from commonly consumed fish and shellfish, collected from the coastal waters and near shore land on Vieques, contain levels of heavy metals and explosives compounds that would adversely affect public health. ATSDR's public health evaluation assesses potential exposures from eating fish and shellfish from Vieques, regardless of where a person is when they eat the fish and shellfish.

12. **Comment:** *The primary research question being addressed is whether military operations on the island have contaminated fish consumed by Island residents. The ATSDR sampling design employed to detect chemicals in fish did not produce data that would allow ATSDR to answer this question with statistical significance. The ideal sampling design would grow from an understanding of where chemicals have been released to the environment, their movement, and fate. It would permit the testing of hypotheses regarding relations between fish contamination levels and their proximity to known sites of release and contamination. The design would further test the hypothesis that certain species of fish may accumulate some elements or compounds more efficiently than others. It should also consider the behavior patterns of the various species, and their*

[12] EPA's Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories suggests collecting one species of fish and one species of shellfish when trying to assess whether a potential human health risk exists for estuarine/marine environments (EPA 2000).

tendency to remain proximate to contaminated areas, or to migrate longer distances, perhaps to cleaner waters. The ATSDR choice of "productive fishing areas surrounding the island" (p. 18) as a criterion for sampling is necessary but insufficient to understand possible associations between chemical concentrations in fish and military contamination. The ATSDR sampling effort is especially difficult to understand absent a map of the Island and offshore areas, designating sampling locations, numbers of fish and shellfish samples collected at each location. Current maps do not provide this information.

Response: The purpose of ATSDR's sampling and analysis activities was to determine whether the muscle tissues from commonly consumed fish and shellfish contain levels of heavy metals and explosives compounds that would adversely affect public health. Therefore, ATSDR's sampling and analysis was sufficient for the public health evaluation that was conducted. While it may be a useful environmental/ecological exercise to conduct a sampling program similar to the one described by the commenter, it would have been a strictly academic exercise. The primary purpose of determining that the fish and shellfish are safe to eat was accomplished—the levels of metals that were detected in the fish and shellfish are below levels of health concern.

During the July 2001 sampling, ATSDR and EPA/ERT collected 104 fish and 38 shellfish, representing 17 different species of fish and three different species of shellfish (see Table 7). The types of fish and shellfish collected were previously identified through several sources as species that are commonly caught and consumed by the residents of Vieques. This methodology is in accordance with EPA's Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories (EPA 2000).

Because not every species of fish and shellfish can be realistically sampled (nor is it expected or recommended[13]), ATSDR and EPA/ERT focused the sampling effort on species of commonly consumed fish and shellfish that would be expected to have a higher exposure to potential contamination from Navy training exercises at the LIA. Therefore, ATSDR and EPA/ERT choose to sample non-migratory, reef-dwelling species that tended to reside locally (rather than migratory, open-water fish that would have less exposure to local contamination).

ATSDR agrees that, for a variety of reasons, different areas around Vieques may contain varying levels of chemicals. To evaluate whether eating fish and shellfish from different locations around Vieques would adversely affect public health, ATSDR and EPA/ERT

[13]EPA's Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories suggests collecting one species of fish and one species of shellfish when trying to assess whether a potential human health risk exists for estuarine/marine environments (EPA 2000).

caught fish and shellfish from five "preferred" fishing locations around Vieques—north of the LIA, south of the LIA, south of Esperanza, north of Isabel Segunda, and west of the former NASD—as well as from a local fish market in Isabel Segunda (see Figure 3). Table 7 provides the types and number of species collected at each location.

The fish and shellfish collected from around the LIA (areas of presumed highest contamination) do not contain levels of metals or explosives compounds that would adversely affect the health of someone eating fish and shellfish from this area (see the Public Health Evaluation (Section VB) and Appendix D for more details). In addition, despite the common occurrence of unexploded ordnance, the site was home to a diverse population of apparently healthy fish and small head corals, and were surrounded by a large halo (the halo is a typical feature of reefs and underwater structures that is caused by grazing organisms leaving the shelter of the reef at night to feed on the surrounding seagrass beds) and healthy turtle grass bed (see Appendix C for more details).

13. **Comment:** *Contaminants in fish are likely to be higher than recorded by ATSDR's sampling and analyses, if fish are collected closer to the time, and nearer the location of military activity. Sampling efforts should be timed to follow intense periods of bombardment, when hazardous chemicals are released and mobilized. Rains, winds, currents and tides will all work to dilute pollutants across space and time.*

    Response: Because ATSDR's involvement began in May 1999, after the Navy ceased military training with live munition, it was not possible for fish and shellfish to be collected during live bombing exercises. From July 16–20, 2001, ATSDR and EPA/ERT collected commonly consumed fish and shellfish from six locations on Vieques. The Navy conducted training exercises with inert ordnance from June 12–29, 2001, less than three weeks before ATSDR and EPA/ERT's sampling (personal communication with Navy personnel, February 2003).

    ATSDR agrees that dilution will decrease the likelihood of exposure at some point in time and distance from the bombing range. Therefore, ATSDR sampled two locations immediately to the north and south of the LIA, areas of presumed highest contamination. Fish and shellfish from these two locations did not show levels high enough to be of health concern.

14. **Comment:** *The ATSDR sample sizes, admittedly constrained by available time and financial resources, are nevertheless grossly insufficient to capture likely variance in chemical concentrations across space, time, and among species. For example only 11 yellowtail snappers were collected by ATSDR, despite the fact that it was estimated to be the most commonly consumed fish by island residents (Caro et al. 2000). The most commonly consumed shellfish include blue land crab (n=11), spiny lobster (n=7) and*

queen conch (n=20) where n is the number of individual fish tested. Since elements and compounds are likely to behave differently in different species, the small ATSDR sample sizes are clearly insufficient to predict exposures, and to reach conclusions regarding the safety or absence of health hazard associated with chronic human fish consumption.

Response: During the July 2001 sampling, ATSDR and EPA/ERT collected 104 fish and 38 shellfish, representing 17 different species of fish and three different species of shellfish—30 groupers, 19 snappers, 25 parrotfish, 24 grunts, 5 goatfish, 1 cowfish, 20 conch, 7 lobster, and 11 land crab composite samples (see Table 7). The types of fish and shellfish collected were previously identified through several sources as species that are commonly caught and consumed by the residents of Vieques. This methodology is in accordance with EPA's Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories (EPA 2000).

Because the purpose of ATSDR's sampling and analysis activities was to determine whether commonly consumed fish and shellfish contain levels of heavy metals and explosives compounds that would adversely affect public health, ATSDR chose to sample a "typical sized species" as identified at the market and in the waters on the reefs near the island. Since Navy bombing activities are conducted on the LIA, ATSDR sampled two locations immediately to the north and south of the LIA, areas of presumed highest contamination.

15. **Comment:** *The Agency claims that its calculation of averages using only detects results in a conservative overestimation of health effects. This may not be the case when the data are disaggregated by chemical and fish species, which will reduce the sample size. It is also likely that if the Agency sampled more intensively, considering factors such as time-from-release date, proximity to release, and species behavior, the high end of detects would be substantially higher than those reported. By not releasing individual data points the public is left uncertain regarding the shape of the distribution of findings, and this knowledge is critical to estimate probable human exposure levels.*

Response: There are two general methods to incorporate nondetected values—one way is to include them as zero and the other is to include them using one half the detection limit. Either way, the average would be lower than the number used by ATSDR to calculate exposure doses since ATSDR only used values higher than the detection limits (i.e., detected values). Since the detected concentrations within a group fell within the expected or normal distribution, it is likely that the average sample of fish collected is representative of the rest of the population (of that fish size).

The Navy conducted training exercises with inert ordnance from June 12–29, 2001, less than three weeks before ATSDR and EPA/ERT's fish and shellfish sampling activities from July 16–20, 2001 (personal communication with Navy personnel, February 2003).

ATSDR and EPA/ERT focused the sampling effort on species of commonly consumed fish and shellfish that would be expected to have a higher exposure to potential contamination from Navy training exercises at the LIA by choosing non-migratory, reef-dwelling species that tended to reside locally (rather than migratory, open-water fish that would have less exposure to local contamination). In addition, ATSDR sampled two locations immediately to the north and south of the LIA, areas of presumed highest contamination.

16. **Comment:** *Actual levels of methylmercury in Vieques fish may be higher than reported levels due to the type of fish sampled and the small sample size surveyed by ATSDR.*

    Response: ATSDR and EPA/ERT sampled commonly consumed fish and shellfish that would be expected to have a higher exposure to potential contamination from Navy training exercises at the LIA by choosing non-migratory, reef-dwelling species that tended to reside locally (rather than migratory, open-water fish that would have less exposure to local contamination).

    In general, the levels of mercury measured in fish collected from Vieques were about the same as those from the mainland of Puerto Rico and the Virgin Islands. In Vieques, the average mercury level was 0.12 ppm. Average mercury levels found in the same species of fish from Puerto Rico and the Virgin Islands ranged from 0.07 to 0.70 (Burger et al. 1992). Average mercury levels in seafood species, collected nationwide, ranged from not detected to 1.45 ppm (FDA 2001b). It is also interesting to note that people who eat fish from Vieques would receive about as much mercury as people who eat canned tuna (according to a 1991 FDA survey, the average mercury concentration in canned tuna is 0.17 ppm; Yess 1993 as cited in ATSDR 1999a).

    ATSDR and EPA/ERT sampled 104 fish and 38 shellfish. Collecting more fish will not likely increase the levels of methylmercury found in the Vieques fish and shellfish. While it is probable that some fish may have higher levels, it is also equally likely that some fish would contain lower levels. Since the detected concentrations within a group fell within the expected or normal distribution, it is likely that the average sample of fish collected is representative of the rest of the population (of that fish size).

17. **Comment:** *Despite limitations in sampling design and sample size, ATSDR reached three aggressive and I believe unsupportable conclusions:*
    - *"It is safe to eat a variety of fish and shellfish every day."*

- *"It is safe to eat fish and shellfish from any of the locations sampled, including from around the LIA and the sunken Navy target vessel."*
- *"It is safe to eat the most commonly consumed species, snapper, every day." (ATSDR 2003 pp. 2-3).*

It is my opinion that the data presented do not justify ATSDR's conclusions that fish intake by Vieques residents poses no health threat. There is evidence of significant contamination of the Vieques landscape and marine ecosystems, resulting from intensive U.S. military activities over the past 60 years. Does ATSDR's surveillance demonstrate safety? Unequivocally, the answer is no. The absence of evidence should not be used by ATSDR to claim the absence of a health hazard, given important defects in the Agency's environmental surveillance. A far more ambitious sampling effort, stratified by species, location and time would be necessary before conclusions such as those presented in this report could be viewed as credible science.

Response: ATSDR disagrees. The purpose of ATSDR's sampling and analysis activities was to determine whether the muscle tissues from commonly consumed fish and shellfish contain levels of heavy metals and explosives compounds that would adversely affect public health. ATSDR's sampling and analysis was sufficient for determining that the fish and shellfish are safe to eat.

Heavy metals were found in the tissues of the fish and shellfish collected by ATSDR and EPA/ERT (see Tables 8 and 9). This is not uncommon—heavy metals are commonly detected in fish and shellfish tissue because seafood tends to accumulate metals that are naturally present in the environment. However, all of the concentrations were detected at levels too low to present a public health concern to people who eat fish and shellfish from Vieques.

ATSDR and EPA/ERT collected 104 fish and 38 shellfish, representing 17 different species of fish and three different species of shellfish—30 groupers, 19 snappers, 25 parrotfish, 24 grunts, 5 goatfish, 1 cowfish, 20 conch, 7 lobster, and 11 land crab composite samples (see Table 7). The types of fish and shellfish collected were previously identified through several sources as species that are commonly caught and consumed by the residents of Vieques. To evaluate whether eating fish and shellfish from different locations around Vieques would adversely affect public health, ATSDR and EPA/ERT caught fish and shellfish from five "preferred" fishing locations around Vieques—north of the LIA, south of the LIA, south of Esperanza, north of Isabel Segunda, and west of the former NASD—as well as from a local fish market in Isabel Segunda (see Figure 3). This methodology is in accordance with EPA's Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories (EPA 2000).

The Navy conducted training exercises with inert ordnance from June 12–29, 2001, less than three weeks before ATSDR and EPA/ERT's fish and shellfish sampling from July 16–20, 2001 (personal communication with Navy personnel, February 2003).

18. **Comment:** *Why were no analyses conducted to search for the presence of radionuclides?*

Response: Radiological contamination around the former USS Killen was not an issue when ATSDR initiated fish and shellfish sampling activities at Vieques. After the concern was raised, ATSDR spoke with a Navy radiation scientist about the presence of radioactivity and evaluated radiation measurements from 1975 and 2002. The radiation levels associated with the former USS Killen are indistinguishable from the radiation associated with background and do not pose any public health hazard to the residents of Vieques. Please refer to the Community Health Concerns section (Section VI) for a discussion of the concern about possible radiological contamination around the former USS Killen.

19. **Comment:** *Table D-3 (Estimated exposure doses from ingestion of fish), pages D-36 to 37 and Table D-4 (Estimated exposure doses from ingestion of shellfish) pages D-38 to 40, shows contaminants that exceed the health guides; even with that ATSDR justify itself saying that this does not necessarily result in an adverse health effect.*

Response: Table D-3 and Table D-4 within the PHA compare estimated exposure doses to the oral health guidelines (e.g., minimal risk levels (MRLs) and reference doses (RfDs)). In these tables ATSDR identified which chemicals required further evaluation, noted with an asterisk. However, as mentioned at the end of the tables, "An exposure dose that is higher than the MRL or RfD does not necessarily result in harmful health effects. These metals are further evaluated." Exposure to a level above the MRL or RfD does not mean that adverse health effects will occur. MRLs and RfDs are intended only to serve as screening tools to help public health professionals decide whether to conduct a more comprehensive assessment of potential health effects. This concept is further explained in the *Using exposure doses to evaluate potential health hazards* section in Appendix D.

20. **Comment:** *The RfD is defined as the estimated daily consumption that is likely to be without deleterious effects during the lifetime for humans (2). MRL is not pertinent to mercury as this is not a known carcinogen.*

Response: Both the MRL and RfD are estimates of daily human exposure to a substance that are unlikely to result in <u>noncancer</u> effects over a specified duration. Therefore, the MRL is applicable to mercury as a noncarcinogen. Definitions of the MRL and RfD can be found in Appendix A, ATSDR Glossary of Environmental Health Terms.

21. **Comment:** *The U.S. National Academy of Sciences (NAS) concluded in 2000 that the most scientifically defensible RfD for human consumption of methylmercury is 0.1 ug/kg/day. The ATSDR MRL is 0.3 ug/kg/day, permitting a level 3 times higher than the NAS supports. ATSDR should explain the knowledge they possess that justifies their conclusion that humans may be safely exposed to methylmercury at levels 3 times higher than the NAS recommends.*

Response: ATSDR's MRLs undergo a rigorous review process: Health Effects/MRL Workgroup reviews within ATSDR's Division of Toxicology, expert panel peer reviews, and agency wide MRL Workgroup reviews, with participation from other federal agencies and comments from the public. MRLs are derived for hazardous substances using the no-observed-adverse-effect level (NOAEL)/uncertainty factor approach. The derivation for mercury is explained in detail within Appendix A of ATSDR's Toxicological Profile for Mercury (ATSDR 1999a).

The chronic oral MRL for methylmercury is based on the Seychelles Child Development Study, in which over 700 mother-infant pairs have, to date, been followed and tested from parturition through 66 months of age. The Seychellois regularly consume a large quantity and variety of ocean fish, with 12 fish meals per week representing a typical methylmercury exposure. In this study, developing fetuses were exposed to methylmercury *in utero* through maternal fish ingestion before and during pregnancy. Neonates continued to be exposed to maternal mercury during breast feeding, and methylmercury exposure from the regular diet continued after the gradual post-weaning shift to a fish diet. The results revealed no evidence of adverse effects attributable to chronic ingestion of low levels of methylmercury in fish (Davidson et al. 1998 as cited in ATSDR 1999a). ATSDR derived the chronic-duration MRL for mercury (0.0003 mg/kg/day) by dividing the NOAEL from the Seychelles Child Development Study (0.0013 mg/kg/day) by an uncertainty factor of 3 to account for human pharmacokinetic and pharmacodynamic variability and by a modifying factor of 1.5.

22. **Comment:** *Table D-3 reveals that the RfD for mercury (0.0001 mg/kg/day) was exceeded even if an individual (child – 0.00033 or adult – 0.00015) consumed fish only once daily according to ATSDR samples. This is 330% and 150% higher than the sanitary standard.*

Response: Table D-3 compares the estimated exposure doses from ingestion of fish collected by ATSDR to the chemical-specific oral health guidelines. In this table ATSDR identified which chemicals required further evaluation, noted with an asterisk. However, as mentioned at the end of the table, "An exposure dose that is higher than the MRL or RfD does not necessarily result in harmful health effects. These metals are further evaluated." Exposure to a level above the MRL or RfD does not mean that adverse health effects will occur. MRLs and RfDs are intended only to serve as screening tools to help public health professionals decide whether to conduct a more comprehensive assessment of potential health effects. This concept is further explained in the *Using exposure doses to evaluate potential health hazards* section in Appendix D. ATSDR further evaluated mercury exposure (as well as the other chemicals identified with an asterisk) in both children and adults within the *Mercury* section of Appendix D. Table D-14 presents the exposure doses expected to result from eating fish and shellfish from Vieques on a daily basis. All of the estimated exposure doses were below toxicological doses reported in the scientific literature in which no adverse health effects were reported. Therefore, the levels of mercury found in the fish and shellfish collected from Vieques are not of health concern.

As a note, all of the fish and shellfish collected from Vieques contained levels of total mercury below the US Food and Drug Administration's (FDA's) guidance for methylmercury in fish, shellfish, and crustacea (1 ppm). The maximum concentration of total mercury in fish was a third of this guidance (maximum = 0.33 ppm, see Table 8), while the maximum concentration in shellfish was even lower (maximum = 0.049 ppm, see Table 9).

23. **Comment:** *Table D-20 revealed that the maximum detected mercury fish concentrations resulted in exposure dosages exceeding the RfD for mercury (child 0.0027 and adult 0.0012). Similarly, the child exposure exceeds the RfD by 27000% and the adult exposure will exceed the RFD by 1200%.*

Response: Table D-20 compares the estimated exposure doses from ingestion of fish collected by Universidad Metropolitana to the chemical-specific oral health guidelines. In this table ATSDR identified which chemicals required further evaluation, noted with an asterisk. However, as mentioned at the end of the table, "An exposure dose that is higher than the MRL or RfD does not necessarily result in harmful health effects. These metals are further evaluated." Exposure to a level above the MRL or RfD does not mean that adverse health effects will occur. MRLs and RfDs are intended only to serve as screening tools to help public health professionals decide whether to conduct a more comprehensive assessment of potential health effects. This concept is further explained in the *Using exposure doses to evaluate potential health hazards* section in Appendix D. ATSDR further evaluated adult and child exposures to all of the chemicals with an asterisk, including mercury, within Appendix D, specifically within the *Evaluating Health Concerns Using Fish Fillet Data from Universidad Metropolitana* section. Table D-21 presents the exposure doses expected to result from eating fish on a daily basis. All of the estimated exposure doses were below toxicological doses reported in the scientific literature in which no adverse health effects were reported. Therefore, the levels of mercury found in the fish collected by Universidad Metropolitana from the fish markets in northern Vieques, Esperanza, and the Parquera area on the mainland of Puerto Rico are not of health concern.

As a note, all of the fish collected by Universidad Metropolitana contained levels of mercury below FDA's guidance for methylmercury in fish, shellfish, and crustacea (1 ppm). The maximum concentration was about a third of this guidance (maximum = 0.38 ppm, see Tables 3 and 4).

24. **Comment:** *The RfD (and MRL) for arsenic oral consumption is 0.0003 mg/kg/day. Table D-3 revealed that ATSDR sampled fish will produce exposure that by far exceed the RfD.*

Child 0.03/0.0003 = 100 times higher or 10000%
Adult 0.014/0.0003 = 46.7 times higher or 4,667%

Response: Table D-3 compares the estimated exposure doses from ingestion of fish collected by ATSDR to the chemical-specific oral health guidelines. In this table ATSDR identified which chemicals required further evaluation, noted with an asterisk. However, as mentioned at the end of the table, "An exposure dose that is higher than the MRL or RfD does not necessarily result in harmful health effects. These metals are further evaluated." Exposure to a level above the MRL or RfD does not mean that adverse health effects will occur. MRLs and RfDs are intended only to serve as screening tools to help public health professionals decide whether to conduct a more comprehensive assessment of potential health effects. This concept is further explained in the *Using exposure doses to evaluate potential health hazards* section in Appendix D. ATSDR further evaluated arsenic exposure (as well as the other chemicals identified with an asterisk) in both children and adults within the *Arsenic* section of Appendix D. Tables D-5 and D-6 present the exposure doses expected to result from eating fish and shellfish from Vieques on a daily basis. All of the estimated exposure doses were within the body's capability to metabolize arsenic. Therefore, the levels of arsenic found in the fish and shellfish collected from Vieques are not of health concern.

As a note, all of the fish and shellfish collected from Vieques contained levels of arsenic below FDA's guidance for arsenic in crustacea (76 ppm) and molluscan bivalves (86 ppm). The maximum concentration in fish was about a third of this guidance (maximum = 29.3 ppm, see Table 8) and the maximum concentration in shellfish was also below this guidance (maximum = 48.3 ppm, see Table 9).

25. **Comment:** *Table D-20 revealed that ATSDR sampled fish will produce exposure that by far exceed the RfD for arsenic.*

Child 0.0102/0.0003 = 34 times higher or 3,400%
Adult 0.0047/0.0003 = 15.7 times higher or 1,570%

Response: Table D-20 compares the estimated exposure doses from ingestion of fish collected by Universidad Metropolitana to the chemical-specific oral health guidelines. In this table ATSDR identified which chemicals required further evaluation, noted with an asterisk. However, as mentioned at the end of the table, "An exposure dose that is higher than the MRL or RfD does not necessarily result in harmful health effects. These metals are further evaluated." Exposure to a level above the MRL or RfD does not mean that adverse health effects will occur. MRLs and RfDs are intended only to serve as screening tools to help public health professionals decide whether to conduct a more comprehensive assessment of potential health effects. This concept is further explained in the *Using exposure doses to evaluate potential health hazards* section in Appendix D. ATSDR further evaluated adult and child exposure to all of the chemicals with an asterisk, including arsenic, within Appendix D, specifically within the *Evaluating Health Concerns Using Fish Fillet Data from Universidad Metropolitana* section. Table D-21 presents the exposure doses expected to result from eating fish on a daily basis. All of the estimated exposure doses were within the body's capability to metabolize arsenic and are below the noncancer and cancer health effects levels reported in the scientific literature. Therefore, the levels of arsenic found in the fish collected by Universidad Metropolitana from the fish markets in northern Vieques, Esperanza, and the Parquera area on the mainland of Puerto Rico are not of health concern.

As a note, all of the fish collected by Universidad Metropolitana contained levels of arsenic below FDA's guidance for arsenic in crustacea (76 ppm) and molluscan bivalves (86 ppm). The maximum concentration was only a fraction of this guidance (maximum = 10 ppm, see Tables 3 and 4).

26. **Comment:** *Sanitary standards are established as guidelines. In the case of mercury, this guideline is based on the concentrations that are neurotoxic to the developing human fetus. Exposures at or below the standard are believed to be without deleterious health effects. The safety of exposures ABOVE the standard has not been determined. Conclusions about the safety of exposures above the RfD are unfounded. Given the magnitude of the potential exposures even at low frequency of consumption by Viequenses, the conclusions of the ATSDR report are unfounded and contradictory.*

Response: MRLs and RfDs are intended only to serve as screening tools to help public health professionals decide whether to conduct a more comprehensive assessment of potential health effects. To maximize human health protection, MRLs and RfDs have built in uncertainty or safety factors, making these values considerably lower than levels at which health effects have been observed. The result is that even if an exposure dose is higher than the MRL or RfD, it does not necessarily follow that harmful health effects will occur. This concept is further explained in the *Using exposure doses to evaluate potential health hazards* section in Appendix D.

If health guideline values (MRLs and RfDs) are exceeded, ATSDR examines the health effects levels discussed in the scientific literature and more fully reviews exposure potential. This information is used to describe the disease-causing potential of a particular chemical and to compare site-specific dose estimates with doses shown in applicable studies to result in illness (known as the margin of exposure). This process enables ATSDR to weigh the available evidence in light of uncertainties and offer perspective on the plausibility of harmful health outcomes under site-specific conditions.

The chronic oral MRL for methylmercury is based on the Seychelles Child Development Study, in which over 700 mother-infant pairs have, to date, been followed and tested from parturition through 66 months of age. The Seychellois regularly consume a large quantity and variety of ocean fish, with 12 fish meals per week representing a typical methylmercury exposure. The results revealed no evidence of adverse effects attributable to chronic ingestion of low levels[14] of methylmercury in fish (NOAEL = 0.0013 mg/kg/day). In this study, developing fetuses were exposed *in utero* through maternal fish ingestion before and during pregnancy. Neonates continued to be exposed to maternal mercury during breast feeding, and methylmercury exposure from the regular diet continued after the gradual post-weaning shift to a fish diet (Davidson et al. 1998 as cited in ATSDR 1999a). All of the exposure doses estimated by ATSDR for daily consumption of the average concentrations of mercury in fish and shellfish from Vieques were lower than the level at which no adverse health effects were observed in this long-term, subsistence-based study (i.e., lower than the NOAEL of 0.0013 mg/kg/day) (see Table D-14). Therefore, it can confidently be concluded that the mercury concentrations found in the fish and shellfish from Vieques are not at levels of health concern.

27. **Comment:** *In the case of mercury, the ATSDR at no point refers to the criteria published since 1999 by: National Research Council, US Environmental Protection Agency (EPA) Centers for Disease Control and Prevention (CDC), Surgeon General of the United States, and FDA. Namely, recommending women of reproductive age in the USA to not consume more than 6 ounces of fish per week to decrease exposure to mercury to the developing fetus. This is an overt contradiction to ATSDR conclusions (page 16 English/18 Spanish versions):*

"Based on these data, ATSDR determined that it is safe to eat fish from the fish market in northern Vieques, Esperanza, and the Parquera on the mainland of Puerto Rico on a daily basis."

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[14] Median total mercury concentration in 350 fish sampled from 25 species consumed by the Seychellois was <1 ppm (range, 0.004–0.75 ppm).

Response: FDA states that pregnant women and women of child-bearing age can safely eat 12 ounces per week of cooked fish, however, "some kinds of fish are known to have much lower than average levels of methylmercury and can be safely eaten more frequently and in larger amounts." FDA recommends contacting an appropriate food safety authority for specific consumption recommendations about fish caught or sold in a person's local area (FDA 2001a). CDC and EPA concur with this guidance (EPA 2001b; personal communication with CDC personnel, February 2003). This national guideline is published as general guidance for women living in areas where site-specific information is not readily available. ATSDR's conclusions for local consumption concerns are based on site-specific sampling data and; therefore, are preferable to this generic guidance.

As a note, all of the fish and shellfish collected from Vieques contained levels of total mercury below FDA's guidance for methylmercury in fish, shellfish, and crustacea (1 ppm). The maximum concentration of total mercury in fish was a third of this guidance (maximum = 0.33 ppm, see Table 8), while the maximum concentration in shellfish was even lower (maximum = 0.049 ppm, see Table 9).

28. **Comment:** *The data obtained in relation to the Fiddler Crabs are different from those obtained by Dr. Massol (Ecological Assessment of Heavy Metals in Vieques, Puerto Rico). The Fiddler Crab is within the feeding chain of the Blue Crab, which is consumed by humans (the Vieques population).*

Response: Dr. Massol and ATSDR analyzed fiddler crabs differently. Dr. Massol sampled and analyzed the extremities (levers and legs) of the fiddler crabs separately from the body (shell and internal contents). ATSDR analyzed the whole fiddler crab in one analysis. Therefore, one would expect differences in the results. Additionally, ATSDR acknowledged that rinsing fiddler crabs of sand and dirt was inadvertently omitted prior to placing them in sample containers. The washing methods were not stated in the report by Dr. Massol.

ATSDR agrees that fiddler crabs are eaten by the blue land crab, and chemicals present in the fiddler crabs may then be transferred to the human food chain when people eat blue land crabs. To address this exposure pathway, ATSDR collected and analyzed blue land crabs (a species known to be consumed by the residents) from Vieques and evaluated whether eating them would result in harmful health effects (see Section V); rather than sample fiddler crabs (a species that is not eaten by the residents of Vieques). ATSDR determined that it is safe to eat blue land crabs from Vieques.

29. **Comment:** *The disposition of contaminant products is not similar; it is necessary to enhance the research methodology from an epidemiological perspective.*

Response: ATSDR worked with the EPA/ERT to collect and analyze fish and shellfish from the coastal waters and near shore land on Vieques to determine whether fish and shellfish muscle tissues contain levels of heavy metals and explosives compounds that would adversely affect public health. During the July 2001 sampling, ATSDR and EPA/ERT collected 104 fish and 38 shellfish, representing 17 different species of fish and three different species of shellfish (see Table 7). The types of fish and shellfish collected were previously identified through several sources as species that are commonly caught and consumed by the residents of Vieques. This methodology is in accordance with EPA's Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories (EPA 2000).

30. **Comment:** *Different environmental characteristics could affect the disposition and deposit of contaminants.*

Response: ATSDR agrees that, for a variety of reasons, different areas around Vieques may contain varying levels of chemicals. To evaluate whether eating fish and shellfish from different locations around Vieques would adversely affect public health, ATSDR and EPA/ERT caught fish and shellfish from five "preferred" fishing locations around Vieques—north of the LIA, south of the LIA, south of Esperanza, north of Isabel Segunda, and west of the former NASD—as well as from a local fish market in Isabel Segunda (see Figure 3). ATSDR determined that it is safe to eat fish and shellfish from all of the areas that ATSDR sampled. Even though there are differences in fish and shellfish body burdens between locations, these differences are too small to have an impact on public health.

31. **Comment:** *Dr. Massol detected that the plant "Syringodium filiforme", which is consumed by the Manatee, was contaminated with lead. Therefore sea life contamination is present.*

Response: ATSDR's evaluation is a public health assessment, not an ecological assessment. Therefore, ATSDR's focus is on seafood that is eaten by the residents of Vieques. Fish and shellfish collected by ATSDR and EPA/ERT in July 2001 contained heavy metals, including lead, in their tissues (see Tables 8 and 9). This is not uncommon—heavy metals are commonly detected in fish and shellfish tissue because seafood tends to accumulate metals that are naturally present in the environment. However, all of the concentrations were detected at levels too low to present a public health concern to people who eat fish and shellfish from Vieques.

32. **Comment:** *There has been no evaluation of specimens during exercises. In this case, the sea life could be greatly affected and enter to the human pathway.*

Response: Because ATSDR's involvement began in May 1999, after the Navy ceased military training with live munition, it was not possible for fish and shellfish to be collected during live bombing exercises. From July 16–20, 2001, ATSDR and EPA/ERT collected commonly consumed fish and shellfish from six locations on Vieques. The Navy conducted training exercises with inert ordnance from June 12–29, 2001, less than three weeks before ATSDR and EPA/ERT's sampling (personal communication with Navy personnel, February 2003). In addition, if fish contained higher levels of metals during a bombing exercise, the cumulative presence of the metals would have been detected during ATSDR and EPA/ERT's sampling.

33. **Comment:** *The fish malformations are not evaluated.*

Response: Only two of 104 fish collected by ATSDR and EPA/ERT had any obvious deformities. One french grunt (*Haemulon flavolineatum*) had a deformed anal fin and a graysby (*Epinephelus cruentatus*) had a sunken belly. While the causes of these two malformations were not determined, it is <u>not</u> at all alarming or indicative of an unhealthy system to see so few fish with deformities.

34. **Comment:** *I am not in accordance with the ATSDR conclusions, the methodology of the research must be changed in order to research for the proposed objectives.*

Response: ATSDR believes that the sampling and analyses conducted for this report completely address the important issue of whether contaminants are present in commonly consumed species of fish and shellfish at levels of health concern. During the July 2001 sampling, ATSDR and EPA/ERT collected 104 fish and 38 shellfish, representing 17 different species of fish and three different species of shellfish (see Table 7). The types of fish and shellfish collected were previously identified through several sources as species that are commonly caught and consumed by the residents of Vieques. This methodology is in accordance with EPA's Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories (EPA 2000). ATSDR concluded that it is safe to eat fish and shellfish from Vieques using standard public health evaluation procedures, which are described in greater detail in Appendix D.

35. **Comment:** *Were samples collected at other times of the year to rule out if African dust storms had any influence on the presence of heavy metals detected?*

Response: It is important to look at the worst-case scenario in fish to be protective of public health. Despite being collected during a time when African dust storms could potentially cause an increase in the amount of chemicals around Vieques, the fish and shellfish are safe to eat (i.e., the concentrations detected in the fish and shellfish were not at a level of public health concern).

36. **Comment:** *It should be clearly stated that the agricultural pollution resulting in water contamination is NOT related to Navy activities.*

    Response: ATSDR acknowledges that the Navy does not engage in agricultural practices on Vieques.

37. **Comment:** *Add to Table 2 a column titled "Frequency of Detection" to be consistent with Tables 3, 4, 5, 6, 7, and 8. It should be noted how many crabs out of approximately 140 crabs were detected to contain of the constituents noted.*

    Response: ATSDR cannot add a frequency of detection column to Table 2, since the report produced by Casa Pueblo de Adjuntas and the University of Puerto Rico did not identify how many crabs contained each heavy metal.

38. **Comment:** *What are "high concentrations" in reference to?*

    Response: "High concentrations" was a term used by the authors of the report by Universidad Metropolitana (Caro et al. 2000) to describe the levels of arsenic, mercury, selenium, and zinc found in the fish they sampled. As explained in the text box, ATSDR determined that the levels of the metals detected in the fish are not high when compared to health-based values.

39. **Comment:** *It can be concluded that Navy activities do not impact the mercury concentration levels in fish.*

    Response: Based on ATSDR's evaluation, <u>no</u> activities on Vieques, including Navy activities, have resulted in levels of chemicals that would present a public health hazard to people eating the fish and shellfish.

40. **Comment:** *Chain of custody forms and analytical results should be included as appendices.*

    Response: ATSDR does not typically include chain of custody forms in appendices of PHAs. The analytical results, however, are summarized in the PHA. Chain of custody forms and analytical results are included in the *Field Data Summary, Vieques Fish Assessment* (EPA/ERT 2001), which establishes that the data used during ATSDR's public health assessment meet established EPA standards.

41. **Comment:** *ATSDR should release all data in both tabular and electronic form identified by fish species, chemical species, date, sample location, detection limits and detection methods for both detects and non-detects. The Agency should also include its calculations*

for all exposure estimates that provide a basis for its claims of "no adverse health effects."

Response: For clarity of presentation, within the PHA, ATSDR summarizes the analytical data generated during ATSDR and EPA/ERT's sampling and analysis activities. Table 8 summarizes the analytical results of the fish analyses and Table 9 summarizes the analytical results of the shellfish analyses. The fish species, chemical species, locations, detection limits, dates of collection, and methods are thoroughly discussed in this public health assessment.

The calculations that ATSDR used to estimate exposures and to determine that it is safe to eat fish and shellfish from Vieques are included throughout Appendix D. The basic exposure dose equation and assumptions are provided on page D-1, as well as at the end of each of the tables within Appendix D.

42. **Comment:** *I have reviewed the ATSDR fish and shellfish evaluation concerning Vieques Island. I remain concerned about the public health risks involving the residents of Vieques Island. While the ATSDR reaches the conclusion that there is no substantial risk from consuming fish and shellfish caught on and around Vieques Island, their sampling was not satisfactory. For example, the ATSDR purchased one cowfish from a fish market. This is problematic since, as the ATSDR stated in their report, "the cowfish contained the highest concentrations of arsenic (29.3 ppm) and selenium (2.5 ppm)." Cowfish is used as a food source as a filling in pastelillos.*

Response: The circumstances surrounding the collection of the one cowfish sample is explained in the Community Health Concerns section (Section VI). While conducting the sampling on Vieques, ATSDR met with the petitioner, who at that time, specifically requested that ATSDR collect and analyze boxfish (family Ostraciidae; e.g., cowfish and trunkfish). Realizing that the results and conclusions would be limited, ATSDR agreed to collect a representative sample from the fish market. Using the data from this limited sampling, ATSDR determined that consuming *this* cowfish and any others that contain similar levels of metals would not be expected to result in harmful health effects. Even though this one sample contained the highest concentrations of arsenic and selenium, it is not unusual for different samples of the same species to contain varying chemical concentrations—other cowfish samples may contain higher or lower levels of these chemicals. In addition, because of the specific uses of cowfish, this one fish would not be the only source of fish in a person's diet (i.e., other fish and non-seafood items would be eaten).

During the July 2001 sampling, ATSDR and EPA/ERT collected 104 fish and 38 shellfish, representing 17 different species of fish and three different species of shellfish (see Table 7). The types of fish and shellfish collected were previously identified through several sources as species that are commonly caught and consumed by the residents of Vieques. This methodology is in accordance with EPA's Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories (EPA 2000).

43. **Comment:** *The other area of concern is the presence of contaminates in fiddler crabs that the ATSDR would consider a risk if used for human consumption. However, the ATSDR does not consider fiddler crab contamination a serious public health concern since it is their understanding that the inhabitants of Vieques do not eat fiddler crabs. This is problematic for the following reasons.*

Response: As fiddler crabs are not a species that is consumed by the residents of Vieques, ATSDR did not evaluate them. Therefore, nowhere in the report does ATSDR identify that the presence of contaminants in fiddler crabs would be a risk *if* used for human consumption.

a. *Fiddler crabs may be a food source for other animals on Vieques Island that may form part of the food chain leading to ultimate human consumption. For example, birds may eat the fiddler crabs and humans may then eat the birds or their eggs. This type of analysis was not conducted in this report.*

Response: In discussions with the Fish and Wildlife Service (FWS), ATSDR was informed that herons and egrets eat fiddler crabs. However, many of these species are considered a Department of Interior trust resource and are protected under the Migratory Bird Treaty Act and Puerto Rican law and are; therefore, not likely to be consumed (personal communication with Fish and Wildlife Service personnel, February 2003).

ATSDR acknowledges that fiddler crabs are eaten by the blue land crab, and chemicals present in the fiddler crabs may then be transferred to the human food chain when people eat blue land crabs. To address this exposure pathway, ATSDR collected and analyzed blue land crabs (a species known to be consumed by the residents) from Vieques and evaluated whether eating them would result in harmful health effects (see Section V); rather than sample fiddler crabs (a species that is not eaten by the residents of Vieques).

b. *The presence of contamination in the fiddler crabs makes it very likely that other food sources including fish and shellfish are contaminated. The ATSDR does not explain why fiddler crabs are the only animal life suffering from contamination on or around Vieques Island. If fiddler crabs are contaminated, it is difficult to see how the ATSDR can responsibly conclude that there is not risk to human health from daily consumption of fish or shellfish given the limited extent of testing conducted by the ATSDR.*

Response: Fiddler crabs are not the only species in which chemicals were detected. Other fish and shellfish species collected by ATSDR and EPA/ERT in July 2001 also contained heavy metals (see Table 8 and 9). This is not uncommon—heavy metals are commonly detected in fish and shellfish tissue because seafood tends to accumulate metals that are naturally present in the environment. However, all of the concentrations were detected at levels too low to present a public health concern to people who eat fish and shellfish from Vieques.

44. **Comment:** *I do not feel comfort from the ATSDR report and would not personally consume indigenous food products from Vieques. I may have greater faith in the report if the personnel that drafted this report agreed to be stationed with their families, including minor children, on Vieques and ate an indigenous diet including daily consumption of local fish and shellfish.*

Response: ATSDR took great care to ensure that an objective evaluation was conducted to determine that the fish and shellfish are safe to eat. ATSDR's evaluation of whether fish and shellfish muscle tissues contain levels of heavy metals and explosives compounds that would adversely affect public health is conducted independent of the resident location of the researchers.

45. **Comment:** *ATSDR compares the levels of methlymercury in fish from Vieques with the average level of methylmercury in canned tuna. ATSDR does not mention the concerns associated with consuming methylmercury in canned tuna, particularly for pregnant women, women of childbearing age, and children. The statement, "People who eat fish from Vieques would receive about as much mercury as people who eat canned tuna" implies that consumption of tuna and mercury contaminants is insignificant.*

Response: Information about the amount of mercury in canned tuna is supplied in the health assessment to provide perspective to the levels of mercury detected in Vieques fish and shellfish. According to FDA, consumption advice is unnecessary for canned tuna, since the methylmercury levels are less than 0.2 ppm (which is comparable to the average levels of total mercury in Vieques fish and shellfish) (FDA 2000). In addition, the average level of mercury in canned tuna (0.17 ppm) is a fraction of FDA's guidance for methylmercury in fish, shellfish, and crustacea (1 ppm).

46. **Comment:** *The ATSDR does not address the potential for Vieques residents to exceed safe levels of exposure to contaminants such as methylmercury in fish caught nearby in addition to other sources such as canned tunafish. ATSDR should explain why it believes that pregnant women and children are safe from typically detected levels of methylmercury in tuna, in addition to mercury detected in Vieques fish. Cumulative*

exposure should be addressed for other contaminants released by the U.S. military on the island.

Response: ATSDR's evaluation determines whether it is safe to eat fish and shellfish from Vieques. The information about canned tuna is supplied in the health assessment to provide perspective on the levels of mercury detected in Vieques.

According to FDA, consumption advice is unnecessary for seafood species that have methylmercury levels less than 0.2 ppm (FDA 2000). The average mercury levels in fish and shellfish from Vieques and canned tuna are below this level (Vieques fish = 0.12 ppm, Vieques shellfish = 0.031 ppm, canned tuna = 0.17 ppm). In addition, the average levels of mercury in fish and shellfish from Vieques, as well as canned tuna, are a fraction of FDA's guidance for methylmercury in fish, shellfish, and crustacea (1 ppm).

ATSDR's evaluation of eating fish and shellfish with the detected levels of mercury specifically takes into consideration pregnant women and women of child-bearing age. The health effects level used to determine that one could safely eat fish and shellfish from Vieques is based on the Seychelles Child Development Study, where no health effects were observed in children born to women who ate fish while pregnant and nursing (Davidson et al. 1998 as cited in ATSDR 1999a).

Several studies, including those conducted by the National Toxicology Program in the United States and the TNO (Netherlands Organization for Applied Scientific Research) Nutrition and Food Research Institute in the Netherlands, among others, generally support the conclusion that if each individual chemical is at a concentration not likely to produce harmful health effects (as is the case on Vieques), exposures to multiple chemicals are also not expected to be of health concern (for reviews, see Seed et al. 1995; Feron et al. 1993).

47. **Comment:** *The Agency does not include a discussion of the sources and magnitude of uncertainty—including error—surrounding estimates of exposure. Nor does the Agency present quantitative estimates of uncertainty and statistical significance. The sources and magnitudes of uncertainty are so high in this case that the Agency should use Monte Carlo simulation techniques that employ full distributions of detected values and ranges of possible food intake to estimate distributions of exposure. This would allow the Agency to identify the proportion of the population likely to be exposed beyond the RfD.*

Response: The purpose of ATSDR's sampling and analysis activities was to determine whether the muscle tissues from commonly consumed fish and shellfish contain levels of heavy metals and explosives compounds that would adversely affect public health. The purpose was not to conduct a statistical evaluation. Therefore, ATSDR's analyses were sufficient for the public health evaluation that was conducted.

To evaluate potential health hazards, ATSDR compared the oral health guideline values to exposure doses that were calculated using the maximum concentrations. A Monte Carlo simulation would not change this part of ATSDR's evaluation. If health guidelines were exceeded, ATSDR examined the health effects levels discussed in the scientific literature and more fully reviewed exposure potential, accounting for uncertainty in the assumptions used. During this part of the evaluation, ATSDR calculated exposure doses using average concentrations that were calculated using detected values only. To account for variability in the amount of fish people consumed, ATSDR calculated exposure doses for both adults and children who eat fish 7 times a week, 5 times a week, 4 times a week, 2 times a week, and once a week. Using this technique to account for uncertainty and variability is more transparent to the reader than a Monte Carlo simulation.

Exposure to a dose above the MRL or RfD does not mean that adverse health effects will occur. MRLs and RfDs are intended only to serve as screening tools to help public health professionals decide whether to conduct a more comprehensive assessment of potential health effects. To maximize human health protection, MRLs and RfDs have built in uncertainty or safety factors (e.g., to account for human variability), making these values considerably lower than levels at which health effects have been observed. The result is that even if an exposure dose is higher than the MRL or RfD, it does not necessarily follow that harmful health effects will occur. This concept is further explained in the *Using exposure doses to evaluate potential health hazards* section in Appendix D.

ATSDR further evaluated exposures to the chemicals detected above the MRL or RfD for both children and adults. All of the estimated exposure doses were below health effects levels reported in the scientific literature. ATSDR concluded that it is safe to eat fish and shellfish from Vieques using standard public health evaluation procedures, which are described in greater detail in Appendix D.

48. **Comment:** *The Agency has not yet established a convincing "control" by taking fish samples from relatively pristine and undisturbed waters. This should be supplemented by a literature review of chemicals detections in highly consumed species from areas with no known anthropogenic source of the chemicals in question. The absence of systematic comparison species by species, and chemical by chemical, makes it more difficult to support the ATSDR "no adverse health effects" conclusion.*

Response: ATSDR's evaluation of Vieques fish and shellfish is a <u>public health</u> assessment, not an ecological assessment. The purpose was to determine whether the muscle tissues from commonly consumed fish and shellfish, collected from the coastal waters and near shore land on Vieques, contain levels of heavy metals and explosives compounds that would adversely affect public health. Therefore, the levels detected in the fish and shellfish were compared to health-based guidelines. Knowing whether the concentrations in Vieques fish and shellfish are higher or lower than other "pristine" areas would not change the conclusion that eating Vieques fish and shellfish would not result in adverse health effects.

49. **Comment:** *ATSDR should clearly distinguish between the NOELs and NOAELs it relies upon to establish RfDs or MRLs, and all safety factors employed. In 1996, following recommendations of the National Academy of Sciences report, Pesticides in the Diets of Infants and Children, Congress enacted the Food Quality Protection Act to limit childrens' exposure to pesticides. This statute required the use of an additional 10 fold safety factor to account for the unusually high exposure of infants and children to pesticides, and their elevated susceptibility, related to their rapid rates of growth and development, and immature detoxification capacity. Given ATSDR's policy statement at the outset of their report, "As a policy, unless data are available to suggest otherwise, ATSDR considers children to be more sensitive and vulnerable to hazardous substances." (ATSDR 2003, Foreword), why would the Agency not adopt the more health protective safety factor suggested by NAS for pesticides? The level of food contamination and associated exposure levels are uncertain enough to justify a higher margin of safety.*

Response: Proposed MRLs undergo a rigorous review process: Health Effects/MRL Workgroup reviews within ATSDR's Division of Toxicology, expert panel peer reviews, and agency wide MRL Workgroup reviews, with participation from other federal agencies and comments from the public.

MRLs are derived for hazardous substances using the NOAEL/uncertainty factor approach. They are below levels that might cause adverse health effects in the people most sensitive to such chemical-induced effects. MRLs are derived for acute (1–14 days), intermediate (15–364 days), and chronic (365 days and longer) durations and for the oral and inhalation routes of exposure. MRLs are generally based on the most sensitive chemical-induced end point considered to be of relevance to humans. Exposure to a level above the MRL does not mean that adverse health effects will occur.

MRLs are intended only to serve as screening tools to help public health professionals decide whether to conduct a more comprehensive assessment of potential health effects. They may also be viewed as a mechanism to identify those hazardous waste sites that are not expected to cause adverse health effects. Most MRLs contain a degree of uncertainty because of the lack of precise toxicological information on the people who might be most sensitive (e.g., children, pregnant women) to the effects of hazardous substances. ATSDR uses a conservative (i.e., protective) approach to address this uncertainty consistent with the public health principle of prevention. Although human data are preferred, MRLs often must be based on animal studies because relevant human studies are lacking. In the absence of evidence to the contrary, ATSDR assumes that humans are more sensitive to the effects of a hazardous substance than animals and that certain persons may be particularly sensitive. Thus, the resulting MRL may be as much as a hundredfold below levels that have been shown to be nontoxic in laboratory animals.

Specific details about the derivation of each chemical-specific MRL are provided in Appendix A of ATSDR's Toxicological Profiles. These Toxicological Profiles are available from the following URL: http://www.atsdr.cdc.gov/toxpro2.html.

50. **Comment:** *Regarding the conch samples, it seems they were weighed with the shell on, did they weigh the animal once extracted from the shell? If not, this may skew your data since the shell is a considerable weight when compared to the animal tissue that is consumed by the public.*

Response: Yes, conch tissue samples were weighed without the shell for the chemical analyses. The laboratory analyzed one-gram tissue samples for the heavy metal analysis and two-gram tissue samples for the explosive compound analysis.

51. **Comment:** *The Public Health Assessment Conclusions seem to be directed at a healthy population. It does not take into account persons consuming these food items that may already have debilitating diseases such as cancer or are undergoing medical treatment. A separate analysis should be done to see if this segment of the population could be at risk from regular consumption of fish and shellfish.*

Response: ATSDR does consider certain sensitive populations in the public health evaluation (e.g., children, pregnant women). However, this evaluation is intended for the general population of Vieques and does not address individual health concerns. If a person has specific concerns about their own personal health needs, the person should consult the local health department or a private physician.

52. **Comment:** *Given the political ramifications of the desired departure of the Navy/Marine Corps from the island I think the basis for the petition is somewhat suspect; however, that is only supposition on my part.*

Response: Thank you for the comment.

53. **Comment:** *Since the Navy is in fact stopping all activity on the Isla de Vieques in May, your study is coming out at a good time. Suggest it be in final form and promulgated as soon as possible.*

Response: Thank you for the comment.

54. **Comment:** *The "Agency for Toxic Substances and Disease Registry" (ATSDR) presents the "Public Health Assessment" in a coordinated manner.*

Response: Thank you for the comment.