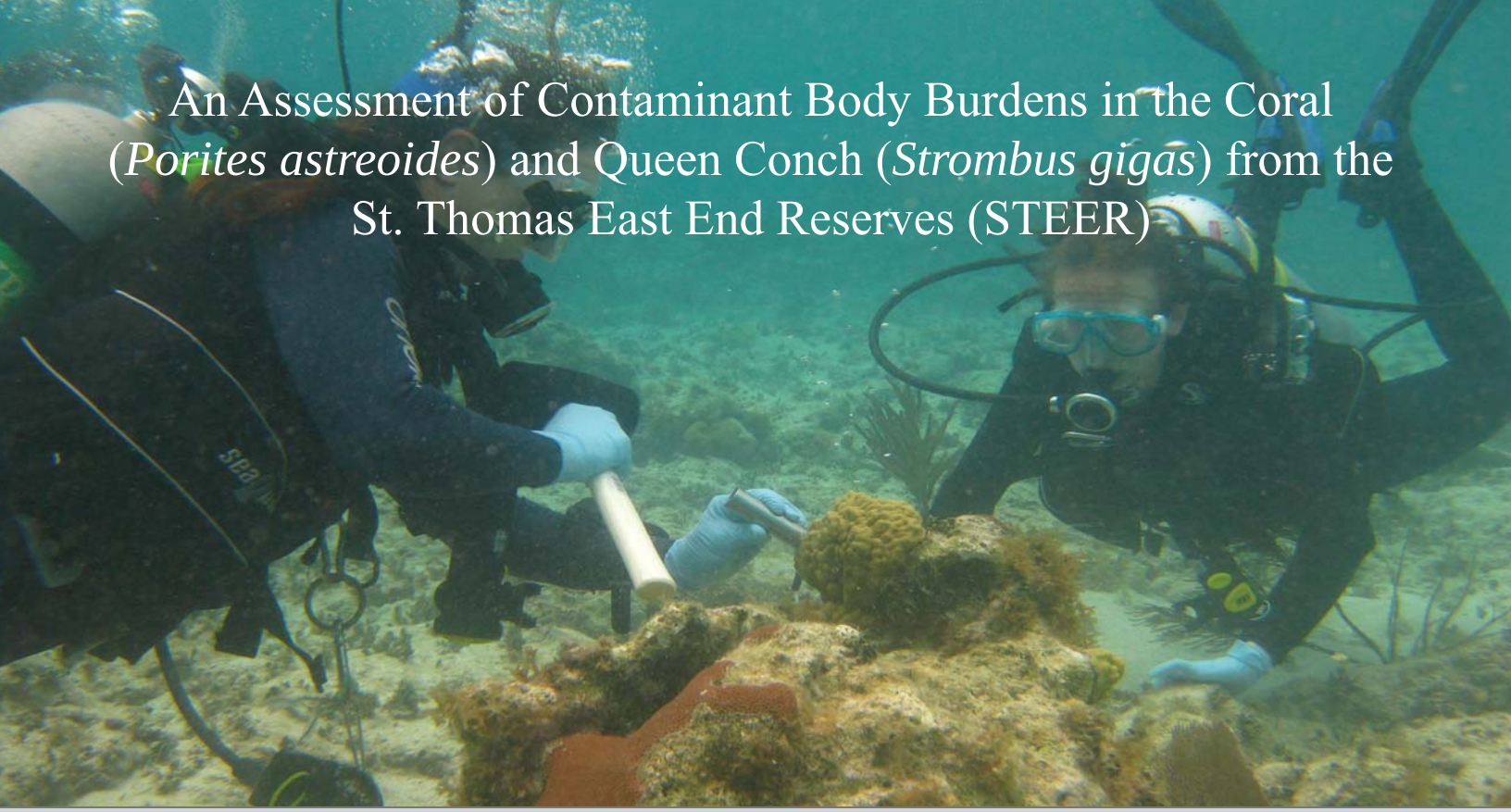
An Assessment of Contaminant Body Burdens in the Coral (*Porites astreoides*) and Queen Conch (*Strombus gigas*) from the St. Thomas East End Reserves (STEER)



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Center for Coastal Monitoring and Assessment

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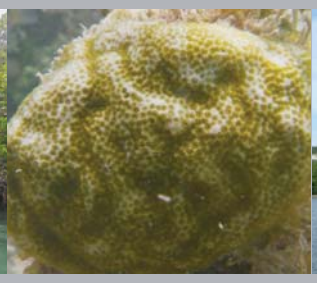


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The cover photograph of divers courtesy of NCCOS Biogeography Branch. Government contract labor was provided by CSS-Dynamac of Fairfax, Virginia under NOAA contract number DG133C11CO0019.

An Assessment of Contaminant Body Burdens in the Coral (*Porites astreoides*) and Queen Conch (*Strombus gigas*) from the St. Thomas East End Reserves (STEER)

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ABSTRACT

As part of the joint effort between the US Virgin Islands Department of Planning and Natural Resources and the NOAA Centers for Coastal and Ocean Science (NCCOS), to conduct a Reserves-wide impact assessment of land-based sources of pollution and effects in the St. Thomas East End Reserves (STEER), contaminant body burdens in coral* (Porites astreoides) *and conch* (Strombus gigas) *were assessed. Samples of coral and conch were collected from five previously identified strata and analyzed for more than 150 chemical contaminants including heavy metals (e.g. cadmium, copper, mercury and zinc) and organic contaminants (e.g. polycyclic aromatic hydrocarbons, polychlorinated biphenyls and pesticides).

Chemical body burdens varied broadly in both coral and conch tissue. Chemical body burden levels found in coral and conch from the STEER were put into context by comparing values to published data from other reef locations. The levels of contaminants found in coral from the STEER were mostly within similar concentration ranges, as reported in corals from other reef areas in the Caribbean. A strong manganese to lead correlation was seen, and may indicate terrigenous sources for this metal found in the coral.

Conch from the STEER had lower contaminant body burdens relative to published data on conch from south Florida and some other areas of the Caribbean. Where available, contaminant body burdens in conch were compared to FDA maximum permissible action levels for molluscan shellfish consumption. The conch samples from the STEER had contaminant body burdens lower than their available respective FDA action levels. A significant correlation between higher concentrations of butyltins closer to shore existed for conch, despite relatively low overall concentrations as compared to previous results from the region.

INTRODUCTION

The STEER ecosystem encompasses the largest mangrove habitat in St. Thomas, along with extensive seagrass beds and coral reef habitats, all of which provide a range of suitable environments for a highly diversified assemblage of aquatic organisms (DPNR-DFW, 2005). Typical corals in the STEER include boulder coral (*Orbicella annularis*), brain corals (*Diploria spp*.), mustard hill coral (*Porites astreoides*), branching corals such as *Porites porites*, fire corals (*Millepora spp*.) and elkhorn and staghorn corals (*Acropora palmata* and *A. cervicornus*, respectively). Seagrass beds in the STEER are extensive, covering large areas of Benner and Jersey Bays. Turtle grass (*Thalassia testudinum*) and manatee grass (*Syringodium filiforme*) are two of the major seagrass species found in the STEER (DPNR-DFW, 2005).

Image of the coral Porites astreoides in the southern portion of Mangrove Lagoon.

Draining the Red Hook and Jersey Bay watersheds with the latter feeding into Mangrove Lagoon/Benner Bay and Jersey Bay, the STEER is thought to be one of the most valuable nursery areas in St. Thomas (STEER, 2011). A variety of fish and invertebrates move between the mangroves, seagrass beds and coral reefs, either during the course of their lives (e.g., juvenile fish living in among the mangrove prop roots for protection, with adults moving out on to the reefs), or as part of a diurnal cycle (e.g., invertebrates feeding in the seagrass beds at night and returning to the protection of the reefs during the day) (STEER, 2011).

The value of the natural resources in this area has long been recognized. In 1979, the area was identified by NOAA's National Marine Sanctuary Program as a "marine area of national significance, deserving of marine sanctuary designation" (NOAA, 1981). The same year, the Mangrove Lagoon/Benner Bay area along with Vessup Bay were designated by the USVI government as Areas of Particular Concern or APC, due to the abundance of important but threatened natural resources, and the desire to preserve and

Figure 1. Map showing the boundaries of individual water bodies that comprise the STEER.

as needed, restore these resources. Threats to ecosystem quality in the STEER, are mainly anthropogenic in nature. Within the watershed is a large active landfill, numerous marinas, various commercial/industrial activities, an EPA Superfund Site, and residential areas served by individual septic systems, some of which are likely failing. On the northern side of Mangrove Lagoon is the Clinton Phipps Racetrack. During construction of the racetrack, the mangrove delta draining Turpentine Gut, the only perennial stream in St. Thomas (Nemeth and Platenberg, 2007), was altered by filling and diverting the mangrove delta, forming a single channel to Mangrove Lagoon, resulting in the sediment carried in Turpentine Gut being deposited in Mangrove Lagoon rather than in the delta (STEER, 2011). All of these have the potential of contributing land-based pollution as well as high sedimentation rates, which can cause reduced growth or die-off by reducing the amount of light reaching seagrasses and corals.

Pandolfi *et al*. (2003) noted that pollution and overfishing have resulted in massive declines in abundance, diversity and habitat structure in coral reefs and associated tropical nearshore ecosystems. Edinger *et al*. (1998) found that reefs exposed to land-based pollution in Indonesia showed a 30-50 percent reduction in coral diversity at a depth of 3 meters, and a 40-60 percent reduction in coral diversity at a depth of 10 meters.

To better understand the ecological dynamics and potential impacts of stressors within the STEER, the USVI DPNR requested a comprehensive environmental assessment in order to provide necessary information to support management of the Reserves. As part of this effort, DPNR joined with the NOAA's National Centers for Coastal and Ocean Science (NCCOS) to conduct a Reserves-wide assessment of contaminants within sediment, water and biota, bioeffects, and an assessment of the condition and status of biological resources.

A first phase of the study, conducted in 2011-2012, consisted of a comprehensive assessment of sediment quality (Pait *et al.* 2013a and 2013b). During this first phase, sediment samples were collected and measured for metal and organic chemical contamination throughout the Reserves. Sediment toxicity was also assessed using a battery of established bioassays, and the abundance and distribution of benthic infaunal communities were characterized. The first phase also included assessments of water quality in the STEER, based on evaluations of total suspended sediment (TSS) and quantification of ambient concentration of organic contaminants often linked to stormwater runoff using sediment traps and Polar Organic Chemical Sampler (POCIS) passive water sampler techniques, respectively. Results for phase one of this study were published in Pait *et al*. (2013a and 2013b). Elevated levels of chemical contaminants were

found, particularly, tributyltin or TBT, a tin-based contaminant which is particularly toxic to invertebrates, at high concentrations in Mangrove Lagoon and northern Benner Bay (Pait *et al*., 2013a).

Portions of the data from the first phase of this project have also been incorporated into the STEER Watershed Management Plan (STEER, 2013), developed to address land-based pollution impacts in the STEER. The plan outlines a series of targeted actions to reduce these sources. The Watershed Management Plan also is intended to identify key information gaps to understand the relative contributions of the various sources of LBSP into the Reserves that affect coral reefs and other resources.

A second phase (2012-2013) of the comprehensive STEER study was designed to provide baseline information on contaminant body burdens in biota, along with a biological survey of the entire STEER. As part of the second phase work, NCCOS scientists gathered additional information on ecosystem health by quantifying contaminant concentrations in coral and conch in the STEER. The significance of assessing levels of chemical contamination in biota stem not only from the need to gather environmental data, but also the necessity to evaluate ecosystem health of important marine resources. Aquatic organisms including conch and coral can bioaccumulate exogenous toxic chemicals to levels that can be detrimental (Alverez *et al*., 2008, Quinn *et al*., 2004).

High concentrations of antifouling paint-based butyltin compounds (e.g., TBT) have been linked to imposex in conch (Titley-O'Neil *et al*. 2011). Likewise, chronic exposure of coral reefs to pollutants has been identified as a factor contributing to coral reef decline in general (Garcia-Sais *et al*., 2008), and land-based sources (e.g. sediment and nutrients) have been found to increase coral susceptibility to disease (NOAA, 2013).

Delineating the extent to which STEER biological resources are exposed to chemical contamination is imperative for management, as conch are a food source, and both coral and conch have important ecological and recreational roles in the STEER. Thus, as part of the second phase of the study, *Strombus gigas* (Linnaeus) Caribbean queen conch, and mustard hill coral *Porites astreoides* (Lamarck) a colonial stony coral were collected and analyzed for tissue contamination of heavy metals and toxic organic compounds. Analytical results of phase 2 of the study are presented in this report. Information in this report will directly benefit management of the diverse habitats within the STEER, by providing complementary information on contaminant body burden and status of biological resources in the Reserves.

Information presented herein can serve as supporting material for informed coastal resource management decisions as well as providing complementary data for the Reserves-wide assessment of contaminant issues. Finally, information on pollutants (contaminants, nutrients, and sediments) will be correlated with the biological characterization data (Bauer *et al., in prep.*) to provide a holistic view of the condition of living resources within the STEER.

Study Area

The STEER comprises an area of 9.6 km^2, along with approximately 34 km of coastline, and is a collection of four Marine Reserves and Wildlife Sanctuaries (MRWS) (Figure 1). Boundaries for the STEER include the Mangrove Lagoon/Benner Bay MRWS, with Long Point as the western boundary. The St. James MRWS forms the eastern boundary of the Reserves which includes all of the island of St. James and the north shore of Little St. James Island. To the north, the boundary runs along the coastline from Cabrita Point westward to Benner Bay. At Benner Bay, the boundary follows a line offshore from Coculus Rock along Roto Cay to the northeastern entrance of Mangrove Lagoon; the marina areas within Benner Bay are outside of the Reserves (STEER, 2011).

The study area was defined during phase 1 of the project and extensively described in Pait *et al*. (2013a and 2013b). The STEER was subdivided into five relatively uniform habitat strata (Figure 2). Strata boundaries were established in consultation with regional scientists and resource managers, and were based on bathymetric, hydrographic, and regional environmental considerations. Unlike sediment sampling sites which were based on a stratified random design, sampling locations for conch and coral were based on species presence and abundance to allow replicate sampling with minimum impact on the population.

MATERIALS AND METHODS

SAMPLING METHODS

Samples of mustard hill coral were collected under DPNR permit STT-0023-12. Samples of queen conch were collected under DPNR permit STT-022-12. Specimen sampling for this study follow the standard protocols established by the NOAA National Status and Trends (NS&T) Program (Apeti *et al*., 2012). Sampling was conducted in collaboration with USVI partners on the project who also provided logistical and boat support for the fieldwork.

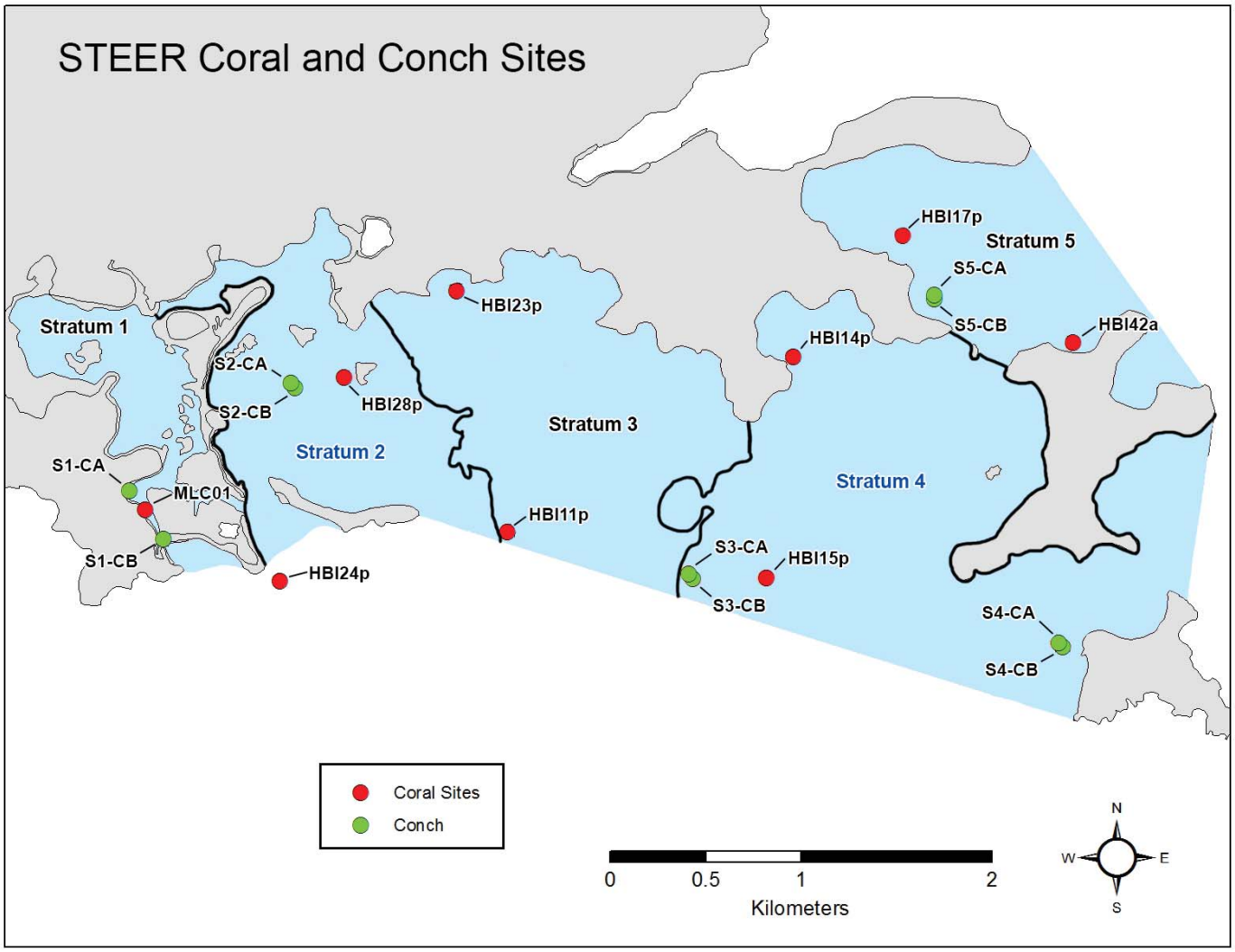

Figure 2. Coral and conch sites collected during the 2012 field mission to the St. Thomas East End Reserves (STEER).

Coral

The coral *Porites astreoides* was chosen as it is abundant and has been used in a number of other NCCOS projects. Coral tissue sampling sites for this study, with the exception of the coral collected in Mangrove Lagoon (site MLC01), were chosen from a subset of preselected locations where NCCOS Biogeography divers had determined the presence of *P. astreoides*. All of the Biogeography sites were randomly generated so as to allow for spatial characterization of the study area. As such, the use of these same locations allows for spatial characterization of chemical contaminants. However, due to funding limitations, only two sites per stratum were collected, and as a result cannot be used to assess differences in coral contaminant concentrations between the strata. In stratum 1, only one *P. astreoides* colony was located. Site HBI24p, just outside of the boundary in Figure 2, was included in Stratum 2.

The coral samples were collected by SCUBA divers using a hammer and titanium coring punch. A sample location was defined as a single dive area with a 50 meter radius where enough *P. astreoides* colonies ("heads") were available for multiple sampling. A total of nine samples of *P. astreoides* were collected from five strata (Figure 2). Unlike the conch tissues, with only one set per location collected for contaminant analyses, the coral tissues were collected in two sets, one for contaminant analyses and the other for histopathology measurements. The results of the histopathology analysis of coral tissues will be covered in a later publication.

At each location, coral cores were collected from 5 different coral colonies ("heads") to constitute a site-composite. Using a hammer, the titanium coring punch was driven into the coral colonies to extract coral cores of approximately

1.5 cm in diameter and 1-1.5 cm in depth. Coral cores were dislodged with a Teflon stir stick, taking care to avoid removing large amounts of skeletal material. The cores of coral tissue were placed inside pre-labeled 250 ml IChem® jars and then capped underwater. The jars were brought to the surface, drained of water and placed on ice. The samples were then frozen at -15 ºC until shipped overnight on ice to the analytical laboratory.

Conch

Conch are herbivorous gastropods that live in sand, seagrass beds, and coral reefs, feeding on seagrass and various species of algae (Davis, 2005). It has been determined that through their feeding process, conch ingest considerable amounts of sediment particles (Brownell and Stevely, 1981), along with contaminants that may be associated with the sediment.

Collections of *S. gigas* were made either from a Nature Conservancy vessel using SCUBA or snorkeling, or off a kayak by snorkeling. A total of 10 conch were collected from five separate locations, one within each stratum identified during phase 1 of the study (Figure 2). Due to funding limitations, along with limited conch resources, only two conch were collected per stratum, and because of this, statistical comparisons of contaminant concentrations in conch between strata cannot be made.

At each location two conch were collected by hand and placed in labeled 2 gallon Ziplock™ bags. The bags containing the specimens were placed in a cooler with ice, and at the end of the day, frozen at the University of the Virgin Islands. At the end of the field mission, conch specimens were partially thawed, removed from their shells, weighed, and placed into labeled 1 liter Teflon jars and refrozen. Once completely frozen, the samples were shipped on ice to the analytical laboratory. At the analytical laboratory, the soft tissues were homogenized before contaminant analysis.

Water Quality Measurements

A series of water quality parameters (dissolved oxygen, temperature, salinity, and conductivity) were also measured at each site using a YSI® salinity/conductivity/temperature meter. The instrument probe was submerged to a depth of approximately one meter.

ANALYTICAL METHODS

The list of chemical contaminants analyzed in the coral and conch tissues for this project is shown in Table 1. This contaminant list constitutes the suite of compounds regularly quantified nationwide as part of NOAA's NS&T Program. For over 20 years, the NS&T Program has monitored the Nation's estuarine and coastal waters for chemical contaminants in bivalve mollusk tissues and in sediments. Work to characterize chemical contaminants as part of NCCOS' Center for Coastal Monitoring and Assessment (CCMA) ecological characterizations in tropical waters, represents a fairly recent expansion of NS&T activities. The compounds analyzed for the project include 59 polycyclic aromatic hydrocarbons (PAHs), 31 organochlorine pesticides, 38 polychlorinated biphenyls (PCBs), four butyltins, and 15 trace and major elements.

Organic Contaminants

Coral and conch tissues were subjected to the same procedures for the determination of the organic contaminant concentrations. Aliquots of tissue samples were chemically dried using Hydromatix®. Tissue/Hydromatix mixtures were then extracted with 100% dichloromethane using accelerated solvent extraction (ASE). Detailed analytical protocols are provided in Kimbrough and Lauenstein (2006) for organic compounds.

Measurement of PAHs and their alkylated homologues (Table 1) were conducted using gas chromatography mass spectrometry (GC/MS) in the selected ion monitoring mode (SIM). PCBs were quantitatively determined by capillary gas chromatography with an electron capture detector (ECD). The organochlorine pesticides were also quantified using capillary gas chromatography with an electron capture detector (ECD). Analysis for butyltins was based on high resolution, capillary gas chromatography using flame photometric detection (GC/FPD), which quantitatively determined tributyltin (TBT), dibutyltin (DBT), and monobutyltin (MBT). The concentration of butyltin was expressed as the concentration of tin (ng Sn/dry g).

Major and Trace Elements

The major and trace elements measured as part of this study are also presented in Table 1. Most of these elements are metals, however, antimony and arsenic are metalloids, and selenium is a nonmetal. Coral and conch were subjected to the same digestion and analytical methods (Kimbrough and Lauenstein, 2006). After freeze-drying the samples to a constant weight, aliquots (0.10-0.45 g) of dried tissue were homogenized, weighed and digested in Teflon bombs. For all metals except Hg, the tissue samples were digested with HNO_3, H_2O_2 and, HCl. After transferring the digestates into polyethylene screw cap bottles for the solution density determination by weight and volume, the digestates were prepared for inductively couple plasma mass spec-

Table 1. Chemical contaminants analyzed in STEER conch and coral samples.

PAHs - Low MW	PAHs - High MW	Organochlorine Pesticides	PCBs	PCBs (continued)	Butyltins
Naphthalene	Fluoranthene	Aldrin	PCB8/5	PCB170/190	Monobutyltin
1-Methylnaphthalene	Pyrene	Dieldrin	PCB18	PCB174	Dibutyltin
2-Methylnaphthalene	C1-Fluoranthenes/Pyrenes	Endrin	PCB28	PCB180	Tributyltin
2,6-Dimethylnaphthalene	C2-Fluoranthenes/Pyrenes	Heptachlor	PCB29	PCB183	Tetrabutyltin
1,6,7-Trimethylnaphthalene	C3-Fluoranthenes/Pyrenes	Heptachlor-Epoxide	PCB31	PCB187	
C1-Naphthalenes	Naphthobenzothiophene	Oxychlordane	PCB44	PCB194	**Major and Trace Elements**
C2-Naphthalenes	C1-Naphthobenzothiophenes	Alpha-Chlordane	PCB45	PCB195/208	
C3-Naphthalenes	C2-Naphthobenzothiophenes	Gamma-Chlordane	PCB49	PCB201/157/173	Aluminum (Al)
C4-Naphthalenes	C3-Naphthobenzothiophenes	Trans-Nonachlor	PCB52	PCB206	Antimony (Sb)
Benzothiophene	Benz[a]anthracene	Cis-Nonachlor	PCB56/60	PCB209	Arsenic (As)
C1-Benzothiophenes	Chrysene	Alpha-HCH	PCB66		Cadmium (Cd)
C2-Benzothiophenes	C1-Chrysenes	Beta-HCH	PCB70		Chromium (Cr)
C3-Benzothiophenes	C2-Chrysenes	Delta-HCH	PCB74/61		Copper (Cu)
Biphenyl	C3-Chrysenes	Gamma-HCH	PCB87/115		Iron (Fe)
Acenaphthylene	C4-Chrysenes	DDMU	PCB95		Lead (Pb)
Acenaphthene	Benzo[b]fluoranthene	2,4'-DDD	PCB99		Manganese (Mn)
Dibenzofuran	Benzo[k]fluoranthene	4,4'-DDD	PCB101/90		Mercury (Hg)
Fluorene	Benzo[e]pyrene	2,4'-DDE	PCB105		Nickel (Ni)
C1-Fluorenes	Benzo[a]pyrene	4,4'-DDE	PCB110/77		Selenium (Se)
C2-Fluorenes	Perylene	2,4'-DDT	PCB118		Silicon (Si)
C3-Fluorenes	Indeno[1,2,3-c,d]pyrene	4,4'-DDT	PCB128		Silver (Ag)
Carbazole	Dibenzo[a,h]anthracene	1,2,3,4-Tetrachlorobenzene	PCB138/160		Tin (Sn)
Anthracene	C1-Dibenzo[a,h]anthracenes	1,2,4,5-Tetrachlorobenzene	PCB146		Zinc (Zn)
Phenanthrene	C2-Dibenzo[a,h]anthracenes	Hexachlorobenzene	PCB149/123		
1-Methylphenanthrene	C3-Dibenzo[a,h]anthracenes	Pentachloroanisole	PCB151		
C1-Phenanthrene/Anthracenes	Benzo[g,h,i]perylene	Pentachlorobenzene	PCB153/132		
C2-Phenanthrene/Anthracenes		Endosulfan II	PCB156/171/202		
C3-Phenanthrene/Anthracenes		Endosulfan I	PCB158		
C4-Phenanthrene/Anthracenes		Endosulfan Sulfate			
Dibenzothiophene		Mirex			
C1-Dibenzothiophenes		Chlorpyrifos			
C2-Dibenzothiophenes					
C3-Dibenzothiophenes					

Abbreviations: MW, molecular weight; PAH, polycyclic aromatic hydrocarbons; HCH, hexachlorocyclohexane; DDMU, 1-chloro-2,2- (p-chlorophenyl)ethylene, DDT, dichlorodiphenyltrichloroethane; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; PCB, polychlorinated biphenyl

trometric (ICP-MS) analysis. NS&T routinely measures mercury (Hg) content in biota as total mercury, which is the aggregate of all forms of mercury present in the tissue matrix. For Hg quantification, tissue homogenates were acid digested based on a modified version of the Environmental Protection Agency (EPA) method 245.5. Samples were digested using concentrated H_2SO_4 and HNO_3 and the addition of $KMnO_4$ and $K_2S_2O_8$, followed by a second heated digestion step. Before analysis by cold vapor atomic absorption spectroscopy, 5mL of 10% (w/w) NH_2OH HCL were added to the digestates to reduce excess permanganate and the volumes were brought to 40 mL with distilled water.

Metals can exist in the environment in several forms, but the analytical methods used by the NS&T does not distinguish between these various forms. Instead, analytical results are reported as total metal concentration (aggregation of all species of a metal) in microgram per gram (µg/g) for dry tissue weight (dw).

STATISTICAL ANALYSES

Primary statistical analyses were conducted using the JMP-5.1TM system statistical package. Concentration values for individual compounds that were smaller than the method detection limits (MDL) were qualified as undetected and assigned a value of zero. For organics, the "totals" were derived as the arithmetic sum of all the individual congeners or homologues of the same group of compounds as listed in Table 1. Where available, contaminant body burdens of toxic metals and organic compounds in conch were compared to FDA action levels, and if possible to EPA chronic consumption limits. FDA reports concentrations on a wet weight basis. The average measured percent moisture content of the conch was 76%. A factor of four was used to convert wet weight concentrations to dry weight in order to compare to results from other studies.

A three-group classification scheme based on ArcGIS Jenks grouping method was used to assess the spatial distribution of the contaminants. Relationships between variables (e.g. inter-metal correlations) were assessed using the Pearson correlation coefficient test. Significance of statistical tests was reported at a probability level of 0.05.

Moored vessels can be a source of chemical contaminants to the STEER.

RESULTS AND DISCUSSION

FIELD DATA

Sampling for the coral and conch in the STEER occurred 18-22 June 2012. The mean water depth at the coral sites was 5.1 ± 1.67 m and the mean surface water temperature was 29.1 ± 0.34 ºC. The average surface salinity was 35.9 ± 0.07 ppt. The average surface water dissolved oxygen for coral sites was 3.96 ± 0.18 mg/L.

The mean water depth for the sites where conch were sampled was 5.97 ± 1.19 m, the mean surface water temperature was 29 ± 0.21 ºC . The average surface salinity was 36 ± 0.01 ppt. The average surface water dissolved oxygen for conch sites was 4.17 ± 0.21 mg/L. Additional field data can be found in Appendix A.

ORGANIC CONTAMINANTS

Polycyclic Aromatic Hydrocarbons

Also referred to as PAHs, polycyclic aromatic hydrocarbons are associated with the use and combustion of fossil fuels (e.g.,oil and gas) and other organic materials (e.g., wood). Natural sources of PAHs include forest fires and decaying plant material.

PAHs in Corals. The concentrations of total PAHs found in coral tissues are presented in Figure 3 and in Appendix B. The mean concentrations of total PAHs in the tissues of *P. astreoides* (22.04 ± 8.57 ng/g) were numerically lower than both those found in conch (32.7 ± 9.07 ng/g), and in sediments (142 ± 59 ng/g) (Pait *et al.*, 2013a). The mean of 22.04 ± 8.57 ng/g in STEER *P. astreoides* tissues (Table 2), was higher, but more variable, than the mean concentration of total PAHs in the tissues of *P. astreoides* (15.0 ± 0.6 ng/g) found in Vieques, Puerto Rico (Pait *et al.*, 2010) (Table 3), the closest geographical location where we have comparable data. The highest total PAH concentration in coral tissues was at site HBI23P, with 80.4 ng/g. Pait *et al*. (2013a) calculated a mean total PAH concentration of 46.9 ± 18.5 ng/g in *P. astreoides* from southwest Puerto Rico, somewhat higher than in corals from both STEER and Vieques, Puerto Rico. Looking at the means of total PAHs across NCCOS Caribbean studies, the STEER falls above the means of Guanica Bay, Jobos Bay, and Vieques, Puerto Rico, but below the mean concentration found in southwest Puerto Rico (Table 3).

Tissue data can be normalized to lipid (fat) content, which can help identify possible sources of contaminants (Lake *et al*. 1990). The results of normalizing total PAHs, however, did not reveal any further relevant information, as concentrations of PAHs in coral tissues across STEER ranged from undetected to values just above detection limits (Appendix B).

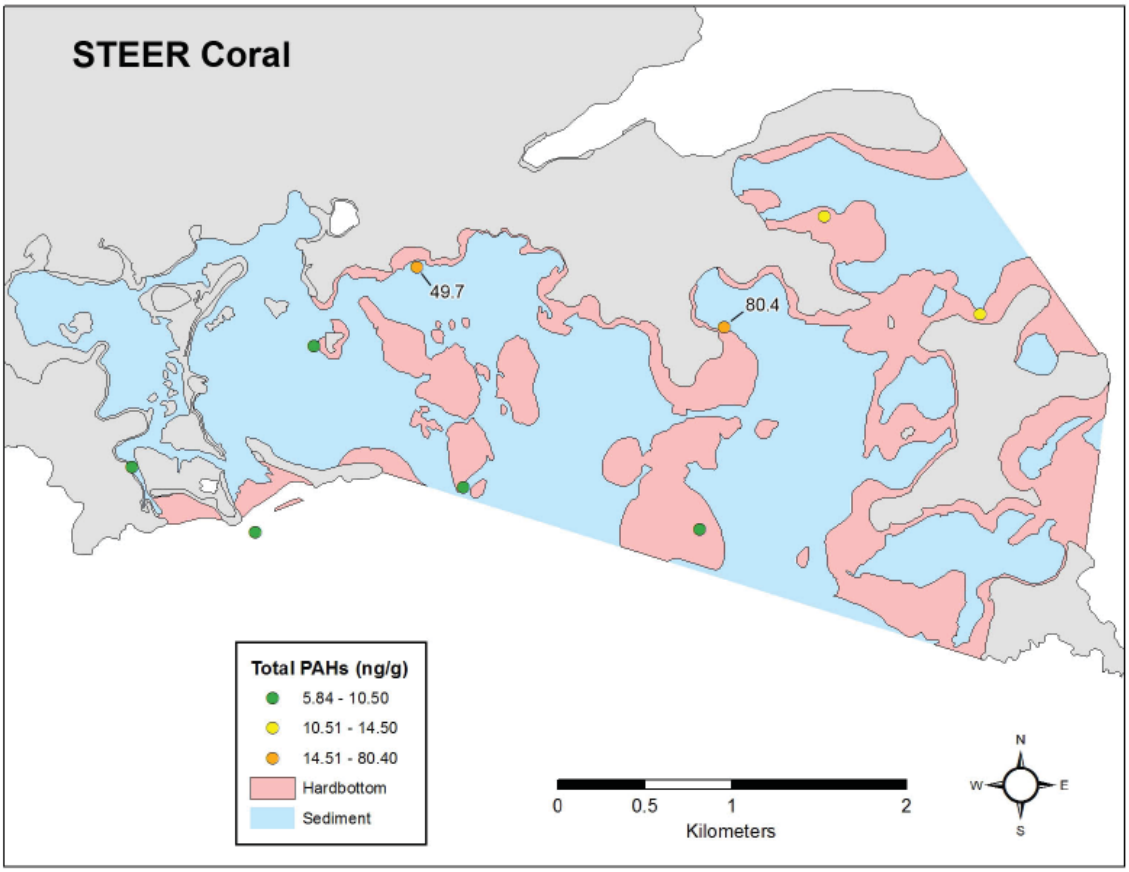

Figure 3. Total PAHs detected in t the coral *Porites astreoides*.

PAHs in Conch. The concentrations of total PAHs found in conch tissues are presented in Figure 4 and in Appendix B. The mean concentration of total PAHs in the tissues of the queen conch (32.7 ± 9.07 ng/g) were numerically lower than those found in sediments (142 ± 59 ng/g) in the STEER, but higher than those found in corals (22.04 ± 8.57 ng/g).

In their global survey of mollusk tissues, Vorkamp *et al*. (2010) found a total PAH range between 177 and 5,966 ng/ g, calculated from 30 PAHs. In the STEER, the sum of our 64 PAHs in general fell well below this range, with the highest concentration of total PAHs in *S. gigas* tissues being 113.0 ng/g at site S4-CB (Table 2 and Figure 4).

A number of PAHs including benzo[a] pyrene, benz[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, dibenzo[a,h]anthracene, and indeno[1,2,3-c,d]pyrene have been linked to carcinogenicity in vertebrates (USDHHS 1995). While an extensive body of work on the effects of PAHs has been done for fish and a number of invertebrates (Wright and Wellbourn, 2002), very little research has been carried out to address the effects of PAHs on coral or conch. Solbakken *et al*. (1984) showed that both phenanthrene and naphthalene accumulate to measurable levels in brain coral *Diploria strigosa* and green cactus coral *Madracis decatis*. While the simple accumulation of a PAH is not an impact in and of itself, the accumulation of exogenous chemicals in living tissue increases the likelihood of adverse effects. The PAHs fluoranthene and pyrene have been shown to be toxic

Table 2. Summary of means, standard error, and maximum values for organic chemical contaminants analyzed in STEER coral and conch.

Contaminant/Class	Coral (ng/g)		Conch (ng/g)	
	Mean ±SE	Maximum	Mean ±SE	Maximum
Total PAHs	22.04 ±8.57	80.4	32.7 ±9.07	113
Monobutyltin	0.13 ±0.04	0.29	5.11 ±2.77	23.2
Dibutyltin	0.03 ±0.02	0.16	1.07 ±0.45	4.27
Tributyltin	0.08 ±0.03	0.29	0.12 ±0.03	0.38
Total BTs	0.24 ±0.08	0.74	6.30 ±3.24	27.85
Total DDT	0.01 ±0.01	0.08	0	0
Mirex	0	0.04	0	0
Total Chlordane	0.01 ±0.01	0.05	0	0

BTs, butyltins; SE. standard error

Table 3. TBT and total BTs in coral tissues from NOAA Caribbean studies.

Location	PAHs			TBT			Total Butyltins		
	Mean	SE	Maximum	Mean	SE	Maximum	Mean	SE	Maximum
Guanica Bay, Puerto Rico[a]	4.96	± 0.48	10.1	ND	N/A	ND	ND	N/A	ND
Jobos Bay, Puerto Rico[b]	5.61	± 0.31	8	ND	N/A	ND	ND	N/A	ND
Southwest Puerto Rico[c]	46.9	± 18.5	158.9	ND	N/A	ND	2.62	± 0.25	3.53
Vieques, Puerto Rico[d]	15.0	± 0.64	24.9	0.08	± 0.07	2.36	4.65	± 0.45	9.37
STEER, USVI	22.04	± 8.57	80.4	0.08	± 0.03	0.29	0.24	± 0.08	0.74

[a]Whitall et al., 2013; [b]Whitall et al., 2011; [c]Pait et al., 2007; [d]Pait et al., 2010. TBT, tributyltin; SE, standard error.

to coral, particularly in the presence of increased ultraviolet radiation (phototoxicity) (Peachey and Crosby 1996; Guzman-Martinez *et al*., 2007).

Polychlorinated Biphenyls (PCBs)

PCBs or polychlorinated biphenyls are a class of synthetic compounds that have been used in numerous applications ranging from electrical transformers and capacitors, to hydraulic and heat transfer fluids, to pesticides and in paints. Although no longer manufactured in the U.S., ecosystem contamination by PCBs is widespread due to their environmental persistence and tendency to bioaccumulate. No coral or conch samples collected in the STEER, however, contained detectable concentrations of PCBs (Appendix D).

Organochlorine Pesticides

A series of manmade chlorine-containing hydrocarbon pesticides (insecticides and herbicides) were developed and used in the 1940s through the 1970s. Organochlorine pesticides are toxic to aquatic life including crayfish, shrimp and some species of fish. One of the best known organochlorine pesticides was the insecticide DDT (dichlorodiphenyltrichloroethane). The use of many of the organochlorine pesticides, including DDT, was banned in the US due to their environmental persistence and toxicity (ATSDR, 2002). Because of their persistence and heavy use in the past, residues of many organochlorine pesticides can be found in the environment, where they continue to be of environmental concern (Butler, 1973). For instance DDT and its metabolites have been found at measurable levels in coral from Puerto Rico (Whitall *et al*., 2011; Pait *et al*., 2009).

DDT in Coral. Only site, HBI14P, had a detectable concentration of DDT or any DDT metabolites, and only

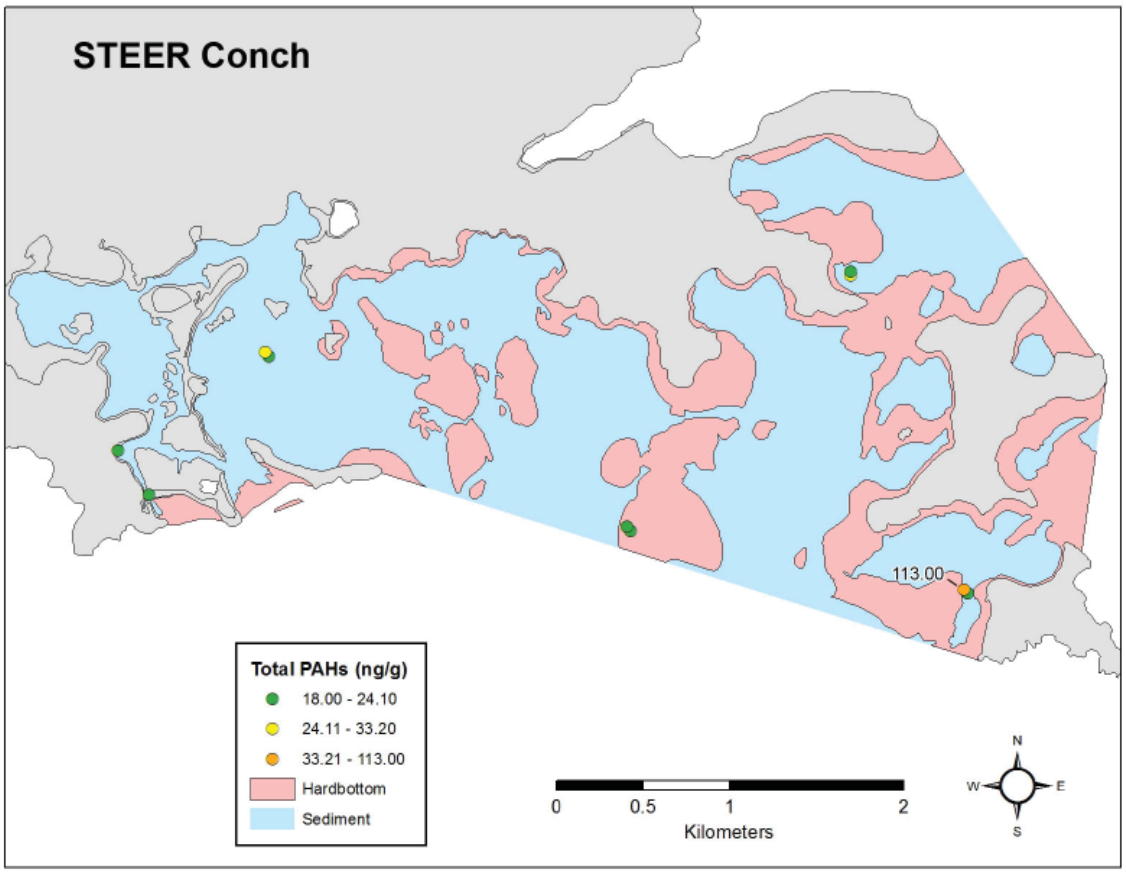

Figure 4. Total PAHs detected in the conch *Strombus gigas*.

then at a level of 0.08 ng/g (Appendix E). In comparison, the mean concentration of total DDT in coral tissues found in Vieques, Puerto Rico was 0.13 ± 0.07 ng/g. The mean concentration of total DDT in the sediments in the STEER was 0.047 ± 0.025 ng/g (Pait *et al*., 2013a).

DDT in Conch. None of the conch analyzed from the STEER contained detectable levels of total DDT. Organochlorine pesticides are typically neurotoxins, and DDT along with PCBs have also been shown to interfere with the endocrine system (ATSDR, 2002).

Other Pesticides

A number of additional chlorinated pesticides were analyzed for in coral tissues collected from the STEER, however with only one exception, there were no detectable concentrations for any other chlorinated pesticide (Appendix E). Total chlordane was detected at HBI14P at a concentration of 0.05 ng/g in coral. In comparison, the mean concentration of total chlordane detected in coral tissues in Vieques, Puerto Rico was 0.12 ± 0.03 ng/g (Pait *et al*., 2010).

Butyltins

A class of organometallic compounds, butyltins have had a variety of uses ranging from biocides in antifoulant paints to catalysts and glass coatings (Birchenough *et al*. 2002; Bennett, 1996). In the environment, tributyltin or TBT degrades to dibutyltin, then monobutyltin, and finally to inorganic tin. Tetrabutyltin is an intermediate in the manufacture of TBT. Experiments have shown that the half-life of TBT is on the order of days; degradation to monobutyltin takes approximately a month, however in deeper anoxic sediments, the half life of TBT appears to be on the order of 2-4 years or longer (Batley, 1996). Mono, di, tri, and tetrabutyltin were analyzed in coral and conch tissues from the STEER (Appendix F). In the sections below, the results for total butyltins (sum of the individual butyltin compounds analyzed) are first presented and discussed, followed by a discussion that focuses on the distribution of TBT in coral and conch.

Total Butyltins in Coral. The sum of the four butyltins (total butyltins), was calculated to better understand where they may have entered the environment (Figure 5). The mean concentration of total butyltins in coral from the STEER was 0.24 ng/g. The highest concentration of total butyltins (0.74 ng Sn/dry g) was found in stratum 2 just outside of Benner Bay at site HBI28P. The mean concentrations of total butyltins in coral tissues, however, in the STEER appeared somewhat lower than that detected in southwest and Vieques, Puerto Rico studies conducted by NOAA (Table 3).

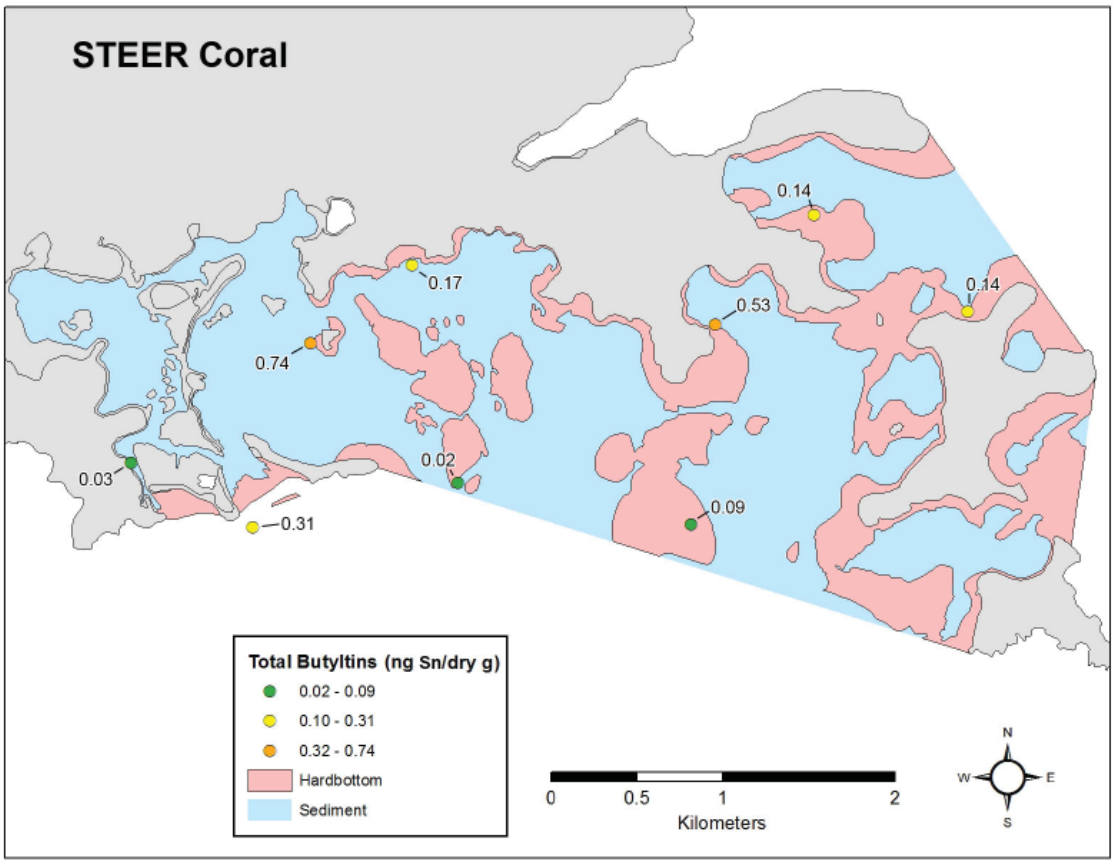

Figure 5. Total butyltins detected in the coral *Porites astreoides*.

TBT in Coral. The highest concentration of TBT in *P. astreoides* tissues collected from the STEER was 0.29 ng Sn/dry g at site HBI28P, just outside Benner Bay (Figure 7). The mean concentration of TBT in STEER corals was 0.08 ng Sn/dry g ± 0.03 (Table 3). The average concentration of TBT in the sediments in the STEER found by Pait *et al*. (2013a) was 1.85 ±1.30 ng Sn/dry g. The highest concentration of TBT detected in STEER sediments from the same

study using a stratified-random sampling design was in Benner Bay, at a concentration of 31 ng Sn/dry g. The mean concentration of TBT in coral tissues in the STEER was the same as that found in Vieques, Puerto Rico (Table 3). From the NOAA studies, only Vieques, Puerto Rico and STEER had detectable TBT in *P. astreoides*. The higher detection of TBT in coral in Benner, may be associated with the elevated levels found in the sediments of STEER in this same area (Pait *et al*., 2013a).

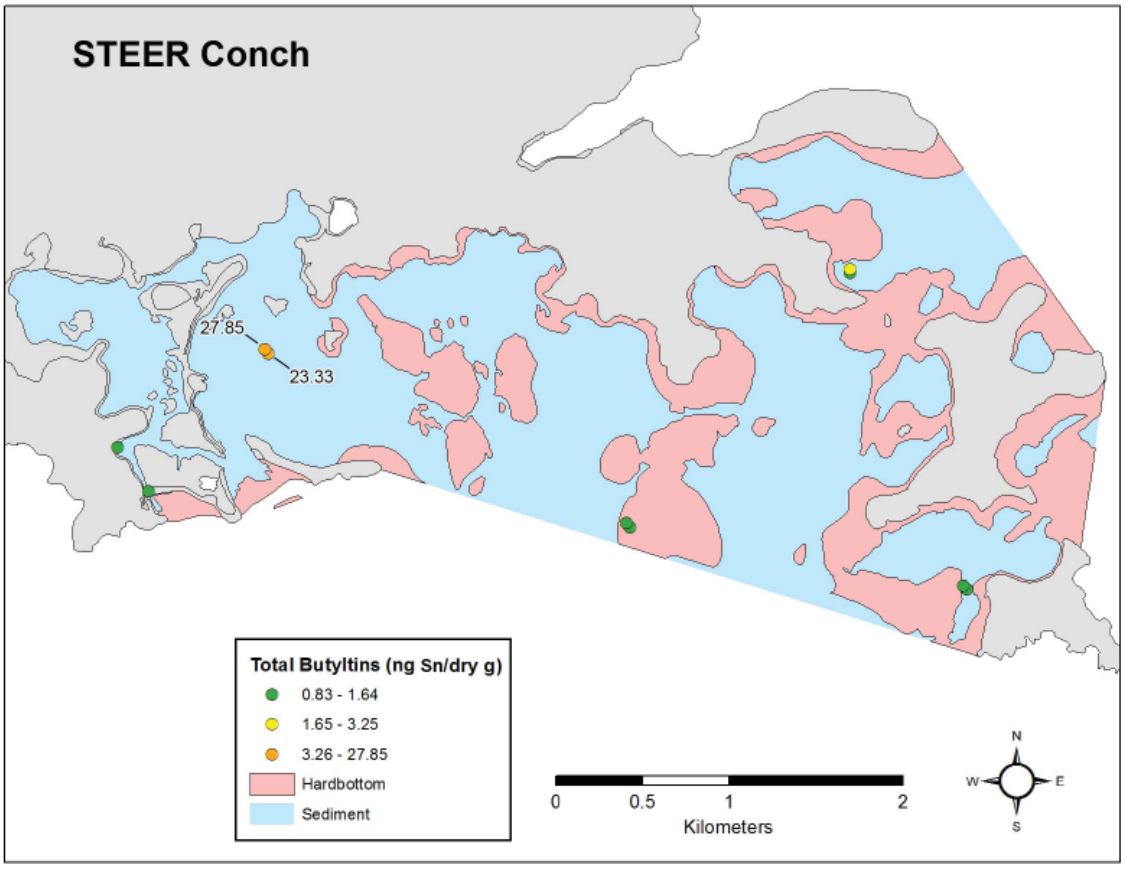

Figure 6. Total butyltins detected in the conch *Strombus gigas*.

Total Butyltins in Conch. The mean concentration of butyltins in conch tissues increased from tributyltin (0.12 ng Sn/dry g), to dibutyltin (1.07 ng Sn/dry g), and last to monobutyltin (5.11 ng Sn/dry g) (Table 2). This appears to follow the natural degradation pattern of TBT in the environment (Batley, 1996). The two highest concentrations of total butyltins of 27.85 ng Sn/dry g and 23.33 ng Sn/dry g were both found in stratum 2 in Benner Bay (Figure 6). This appears to correlate with the elevated levels of butyltins found in the sediments of STEER in Benner

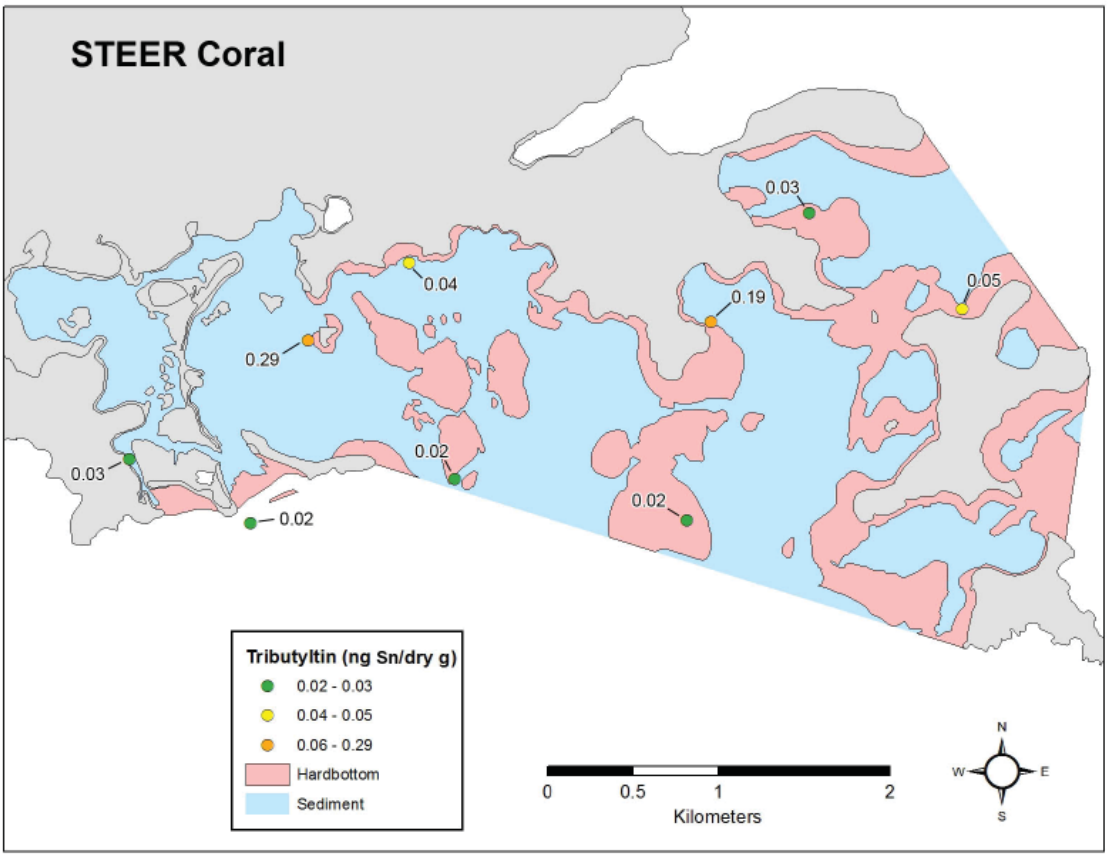

Figure 7. Tributyltin detected in the coral *Porites astreoides*.

Bay (Pait *et al*., 2013a). The two highest concentrations are at least seven times higher than the next highest concentration (3.25 ng Sn/dry g) found in stratum 5. Strand *et al*. (2009) looked at total butyltins in different non-*S. gigas* conch species in the US Virgin Islands. They found a mean concentration of total butyltins in tissues collected from St. Thomas of 104.7 ± 44.8 ng Sn/dry g. None of the samples collected by Strand *et al*. (2009) were from the STEER. In contrast, the mean concentration of total butyltins in *S. gigas* tissues from the STEER in the current study were lower, 6.30 ng Sn/dry g ± 3.24.

TBT in Conch. The highest concentration of TBT in *S. gigas* tissues in the STEER was 0.38 ng Sn/dry g in stratum 2 at site Conch 2B (Figure 8). There was a significant relationship between TBT in conch tissues in the STEER and a basic inshore vs. offshore designation, using nonparametric Wilcoxon's rank sums ($p = 0.0304$). A one-way ANOVA of TBT by inshore/offshore using TukeyKramer's HSD (honest significant difference) test on the ranked data to compare means showed that inshore concentrations of TBT in conch tissues were significantly higher than those found in offshore tissues ($p = 0.0221$). This follows the findings of Larsen *et al*. (2011) where TBT concentrations in molluscs decreased as distance from harbors increased.

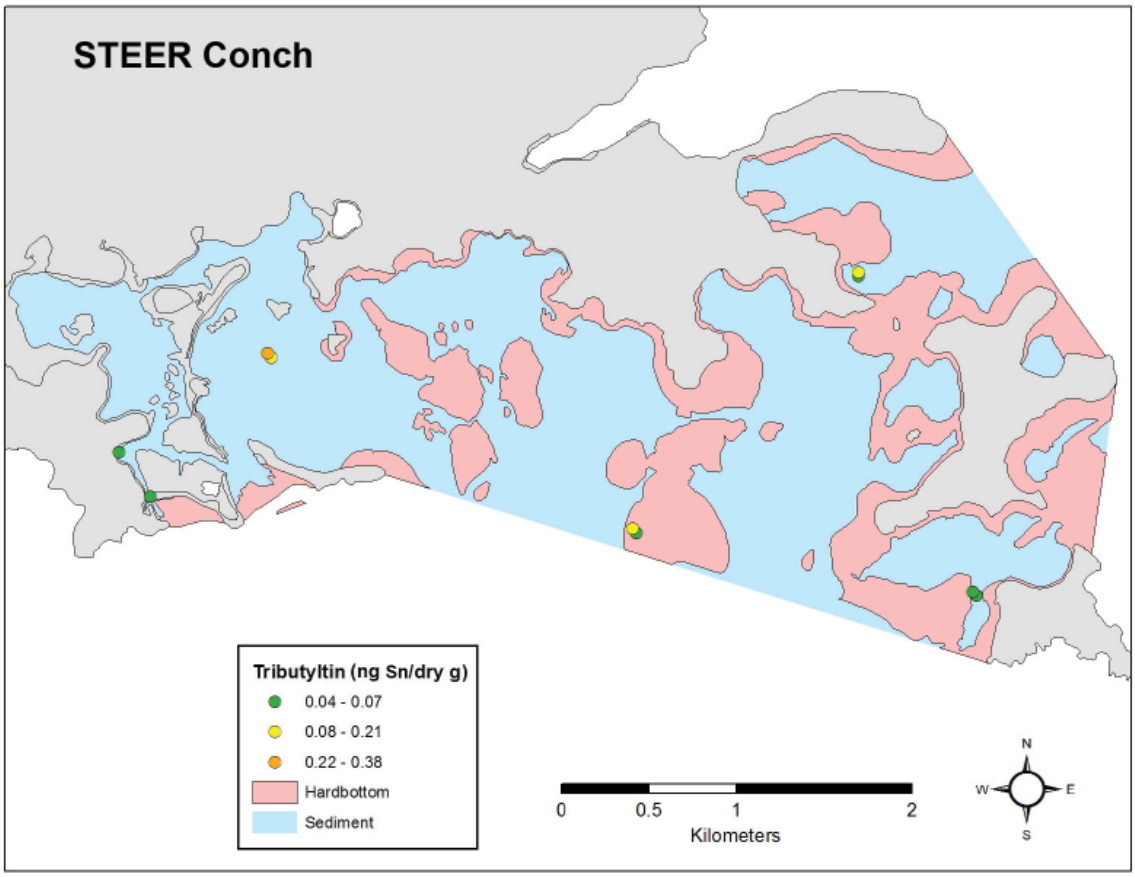

Figure 8. Tributyltin detected in the conch *Strombus gigas*.

Effects of TBT. The presence of TBT has been linked to endocrine disruption, specifically an imposex (females developing male characteristics) condition in marine gastropods, and in other mollusks (e.g., oysters), abnormal shell development, and poor weight gain (Batley, 1996; Strand *et al*. 2009). Beginning in 1989, the use of TBT as an antifouling agent was banned in the U.S. on non-aluminum vessels smaller than 25 meters in length (Gibbs and Bryan, 1996). Because of its widespread use in the past, TBT and its metabolites continue to be detected in all components of the environment.

Recent work by Titley-O'Neil *et al*. (2011) showed that high concentrations of antifouling paint-based butyltin compounds were linked to imposex in conch. Negri *et al*. (2002) investigated the effects of TBT in sediments on the coral *Acropora microphthalma*. They found that the effective concentration of TBT which caused 50 percent inhibition (EC50) of fertilization after four hours was 200 µg/L and concentration needed to inhibit 50 percent larval metamorphosis was only 2 µg/L.

TRACE AND MAJOR ELEMENTS

All 14 of the trace and major elements (Table 1) analyzed in the samples were detected in both coral and conch tissue. Coral tissue body burdens for each element varied broadly from one collection site to another within the STEER. With the exception of arsenic, copper, zinc, lead and the major elements (Al, Fe, Mn), the trace metals tissue body burden varied from below detection to the maximum values seen in Tables 4a and 4b. Detailed results of contaminant body burdens including concentrations of the major and trace

metals measured in conch are presented in Appendix G. Currently, no ecotoxicity thresholds or guidelines exist for acceptable levels of chemical contaminants in corals. However to put into context the levels found in *P. astreoides* from the STEER, results were compared to previously published studies conducted in the Caribbean (Pait *et al*, 2009 and 2010; Whitall *et al*, 2011) and elsewhere (Table 4a and 4b). A summary of average concentrations of individual trace and major elements in each stratum are presented in Figures 9-12, to show the relative abundance of each metal.

Because conch are grazers, ingesting sediment particles while feeding, elevated body burdens of major metals (aluminum, iron, manganese) were expected in the conch's soft tissue. As a result, detailed discussions are only provided for trace metals of known toxicity. When possible, levels of metal contamination of *S. gigas* from the STEER were put into context by comparing body burdens to previously published studies.

Silver

Silver in Corals. Body burdens of silver in *P. astreoides* were relatively low. Silver concentrations varied from non-detect to a maximum value of 0.0202 µg/g (Table 4a) in coral collected from HBI42A, located in stratum 5. However, on average silver concentrations in the coral tissue from the different strata across the STEER were fairly similar (Table 5). Figure 9 illustrates the relative comparison of silver body burden in coral to the other trace metals measured. Other studies (Table 4a) in diverse bays and coastal environments in Puerto Rico (Pait *et al*., 2009 and 2010; Whitall *et al*., 2011), have documented comparable ranges of silver body burdens in *P. astreoides* tissues. This implies that the observed levels of silver in *P. astreoides* tissues may represent natural background levels.

Silver in Conch. Silver body burdens in conch samples from the STEER varied from 0.16 µg/g to 3.75 µg/g, with a mean value of 0.88 µg/g (Table 6, Figure 10). Results indicated that the level of silver in conch was uniformly distributed across all strata in the STEER with the exception of stratum 5 where silver was found to be nearly an order of magnitude higher (Table 7). Glazer *et al*. (2008) investigated heavy metal concentrations in queen conch from south Florida, and found a mean body burden for silver of 1.03 µg/g in conch from the offshore habitats, and 2.54 µg/g in conch from nearshore habitats. Although causative effects were not strongly established, these authors speculated that reduced reproductive fitness of conch in the nearshore habitats in south Florida may be linked to elevated metal concentrations including silver.

Table 4a. Summary statistics for contaminants (µg/g) in coral tissue, including comparison with other studies.

Species	Location	Value	Ag	Al	As	Cd	Cr	Cu	Fe	Reference
Porites astreoides	STEER	Maximum	0.0202	201	1.76	0.0467	1.52	4.07	275	This study
Porites astreoides	STEER	Mean	0.01293	22.33333	1.255	0.011867	0.389111	2.692222	72.31111	This study
Porites astreoides	STEER	Minimum	0	0	0.611	0	0	1.96	27.9	This study
Porites astreoides	Southwest Puerto Rico	Mean	0	37.8	0	0	0	2.06	90.8	Pait et al. 2009
Porites astreoides	Vieques, Puerto Rico	Mean	0.013	30.75	0.241	0.194	0.183	0.757	51.2	Pait et al. 2010
Porites astreoides	Jobos Bay, Puerto Rico	Range	0	100-333	0.94-2.44	0.21-0.31	0	2.37-97.2	110-480	Whitall et al
Porites astreoides	Punta brava, Venezuela	Range							1.32-369	Bastidas and Garcia 1999
	Bajo Caiman, Venezuela	Range							nd-88.7	
Porites sp.	Misima Island, Papua NG									Falom et al, 2002
Porites lobata	Ulan Reef, Philipines	Mean						3.1		David, 2003
Porites sp.	Dafangji Island, China									Peng et al. 2006
Porites sp.	Daya Bay, China	Range							41.4-226.4	Chen et al. 2010

Table 4b. Summary statistics for contaminants (µg/g) in coral tissue, including comparison with other studies.

Species	Location	Value	Hg	Mn	Ni	Pb	Se	Sn	Zn	Reference
Porites astreoides	STEER	Maximum	0.003	19.6	8.33	0.42	0.116	0.0393	14.8	This study
Porites astreoides	STEER	Mean	0.001	10.1	2.18	0.16	0.012889	0.004367	5.983333	This study
Porites astreoides	STEER	Minimum	0	7.25	0	0.07	0	0	1.87	This study
Porites astreoides	Southwest Puerto Rico	Mean	0	3.01	1.32	0	0.05	0.02	6.09	Pait et al. 2009
Porites astreoides	Vieques, Puerto Rico	Mean		2.66	0.9	0.07	0.096	0.246	3.43	Pait et al. 2010
Porites astreoides	Jobos Bay, Puerto Rico	Range	0.001-.004	8.33-24.6	0.8-6.84	0.08-12.5	0.13-0.26	nd-0.10	2.56-16.9	Whitall et al
Porites astreoides	Punta brava, Venezuela	Range							3.59-42.5	Bastidas and Garcia 1999
	Bajo Caiman, Venezuela	Range							0.83-23.1	
Porites sp.	Misima Island, Papua NG			0.19-1.6					0.68-36.5	Falom et al, 2002
Porites lobata	Ulan Reef, Philipines	Mean		1					1.8	David, 2003
Porites sp.	Dafangji Island, China			2.76-6.85					4.2-55.1	Peng et al. 2006
Porites sp.	Daya Bay, China	Range		0.79-5.38					0.02-22.3	Chen et al. 2010

Aluminum

Aluminum in Corals. In the STEER, *P. astreoides* had aluminum body burdens ranging from non-detect to a maximum value of 201 µg/g (Table 4a). Figure 11 shows the overall mean of aluminum body burden in the coral tissue, however, the results indicated that aluminum concentrations were below the detection limit at most of the sampling locations in the STEER except at HBI28P where the maximum value was detected. Pait *et al.* (2010) and Whitall *et al.* (2011) have respectively reported maximum values of 37 µg/g in coral from Vieques, Puerto Rico and 333 µg/g in Jobos Bay, Puerto Rico indicating that levels found in the STEER were within the range of aluminum concentration in coral from the Caribbean.

Table 5. Mean metal body burden (µg/dry g) in coral by stratum.

Element	Stratum 1	Stratum 2	Stratum 3	Stratum 4	Stratum 5
Ag	0.0138	0.0134	0.0131	0.0169	0.0134
Al	0	201	0	0	0
As	0.611	1.76	1.57	0.984	1.11
Cd	0	0	0	0.0177	0.0205
Cr	0	0	0	0	1.52
Cu	2.37	4.07	2.06	2.44	2.77
Fe	54.7	275	82.6	32.3	42
Hg	0	0.00227	0	0	0
Mn	8	19.6	11.8	8.07	7.25
Ni	1.58	2.3	0.954	1.78	2.28
Pb	0.111	0.415	0.217	0.0693	0.0741
Se	0	0	0.116	0	0
Sn	0	0.0393	0	0	0
Zn	2.04	14.8	10.2	1.87	2.38

n = 2 for each stratum except for stratum 1 (only one site located).

Aluminum in Conch. In *S. gigas*, aluminum ranged from 38.5 to 828 µg/g (Table 6). The highest concentration of aluminum occurred in one of the conch collected from stratum 4.

Aluminum is generally not considered to be a pollutant, but its relationship with other metals in conch tissue could provide insight to the sources of these metals. Strong aluminum - metal correlations would indicate that metals in conch tissues may be of natural terrigenous sources derived from land-based erosion and deposition. Further assessment of this observation could be conducted using aluminum-to-metal ratios, however due to lack of replication and low level of aluminum, the data was not conducive for ratio calculation.

Arsenic

Arsenic in Corals. Arsenic body burdens in *P. astreoides* varied from 0.61 µg/g to 1.76 µg/g (Appendix G). Table 4a indicates that the overall range of arsenic concentrations were similar to those reported elsewhere in southwest Puerto Rico and Jobos Bay, Puerto Rico (Pait *et al.*, 2009 and Whitall *et al.*, 2011). Like a number of the other metals measured, the highest arsenic concentration was found at HBI28P within stratum 4, although the average arsenic coral body burdens were higher in stratum 2 and 3. This coral site is located in Benner Bay, adjacent to Roto Cay. A number of metals were higher in coral at this site, and may be related to the input from point and nonpoint sources in this area, including runoff from terrestrial areas (e.g., roads and boatyard activities), and the resuspension of sediments as a result of boat traffic. Sublethal thresholds of arsenic on coral have not been established, but Pichler *et al.* (1999) found that coral in Ambide Island, Papua New Guinea, exposed to elevated concentrations of arsenic in seawater from hydrothermal vents did not show any obvious toxic effects.

Arsenic in Conch. Arsenic was detected in the tissue of all *S. gigas* collected in the STEER. Overall, arsenic body burdens in queen conch varied from 17.6 µg/g to 67.6 µg/g (Table 6). The highest levels in conch were found in stratum 4 (Table 7). With a mean value of 32.7 µg/g, arsenic had the second highest concentration of the trace metals measured in conch after copper (Figure 10). Said *et al.* (2013) assessed metal concentrations including arsenic in the conch *S. canarium* in the western region of Johor Straits, Malaysia, and reported an arsenic value of 0.125 µg/g wet weight (Table 6). Using the average 76% moisture content measured in the conch from the STEER, we derived an equivalence maximum concentration of 16.9 µg/g wet weight (ww) and minimum of 8.2 µg/g ww of arsenic in *S. gigas*. Despite the species differences, these results indicate that the arsenic body burden in conch was numerically elevated in the STEER. The sublethal threshold of arsenic for conch is unknown at this time. For human protection however, the U.S. FDA (FDA, 2009) has set the maximum permissible action level of 86 µg/g arsenic wet weight (ww) in shellfish. Using the measured 76% moisture content in conch, the derived wet weight equivalence of the maximum arsenic concentration value found in conch from the STEER (16.9 µg/g ww) was low relative to the FDA criterion.

Cadmium

Cadmium in Corals. Cadmium concentrations in coral tissues ranged from non-detect to a maximum of 0.047 µg/g (Table 4a), which was found in stratum 5, at HBI42A. Like other trace metals, the coral body burdens of cadmium were relatively low (Figure 9). Compared to other studies, the cadmium body burden in coral from the STEER was virtually an order of magnitude lower than levels reported by Whitall *et al*. (2011) in Jobos Bay, Puerto Rico (Table 4a). These authors linked the high cadmium levels observed in coral from Jobos Bay to elevated concentrations observed in bed sediment in the vicinity of the reef. Laboratory studies have shown that low levels of cadmium can affect coral metabolic processes by inhibiting the photosynthetic electron transport in the symbiotic zooxanthellae (Kuzminov *et al*., 2013). Additionally, cadmium, used in metal plating and solders, has been shown to impair development and reproduction in several invertebrate species including coral (Eisler, 1985; Mitchelmore *et al*., 2007).

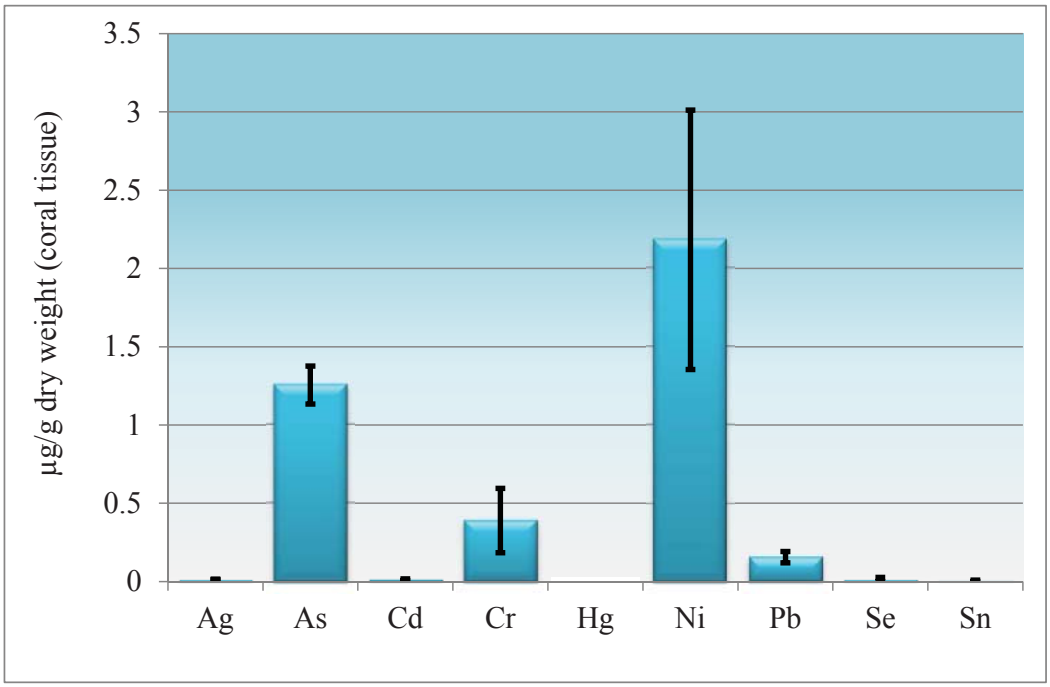

Figure 9. Concentrations (mean ±SE) of metals detected in the coral *Porites astreoides*.

Cadmium in Conch. Cadmium body burdens in conch tissues ranged from 0.89 µg/g to a maximum value of 3.75 µg/g (Table 6) found in stratum 3. The results showed little variation between strata for cadmium body burden in conch with a STEER-wide mean value of 1.96 µg/g (Table 7; Figure 10). Cadmium body burdens found in the STEER were similar to levels reported by Glazer *et al*. (2008) in *S. gigas* collected from the offshore environment in south Florida. However, the same authors reported levels of 31.9 µg/g in conch collected from nearshore environments in Florida (Table 6). Cadmium's toxicity to aquatic organisms is well documented (Lin and Dunson, 1993; Omer *et al*., 2012). However, threshold guidelines for cadmium ecotoxicity or sublethal effects in conch are unknown at this time. The FDA action level for cadmium in molluscan shellfish is 4 µg/g wet weight. Using the measured 76% moisture content in conch, we derived an FDA equivalence value of 0.94 µg/g (ww) cadmium in STEER conch. The concentra-

Table 6. Summary statistics for contaminants (µg/g) in conch tissue (n=10), including comparison with mean concentration values derived from study of conch contamination in South Florida (Glazer et al. 2008) and Johor Straits, Malaysia (Said et al., 2013).

Metal	STEER			Glazer, 2008 (ww)		Said et al., 2013 (ww)
	Mean	Min. Conc.	Max. Conc.	PS (offshore)	TI (nearshore)	Johor Straits, Malaysia
Ag	0.88	0.16	3.75	1.03 (1.4)	2.54 (3.4)	
As	32.7	17.6	67.6			0.125 (0.17)
Cd	1.96	0.89	3.75	2.62 (3.5)	24.14 (31.9)	0.01 (0.01)
Hg	0.24	0.05	0.88	0.01 (0.01)	0.00 (0)	
Al	229	38.5	828			
Cr	3.41	1.45	8.57			
Fe	785	284	1720			
Mn	113	40	355			
Ni	5.79	3.03	13.6	16.28 (21.53)	9.59 (12.7)	
Zn	484	170	1320	30.53 (40.39)	660.32 (873.6)	
Cu	84.7	36	122	14.06 (18.6)	84.34 (111.6)	1.36 (1.8)
Pb	0.61	0.21	1.32			
Se	1.19	0.68	2.38			
Sn	5	0.03	12.7	0.00 (0)	0.00 (0)	

Min. Conc., minimum concentration; Max. Conc., maximum concentration; TI, Tingler Island; PS = Pelican Shoal. Values in parentheses are dry weight equivalence of the wet weight concentrations; ww, wet weight.

tions of cadmium in conch from the STEER were below applicable safety thresholds.

Chromium

Chromium in Corals. The average concentration of chromium in *P. astreoides* was 0.39 µg/g (Table 4a), and ranged from below detection to a maximum of 1.52 µg/g, at sampling location HBI7P in stratum 5. Chromium body burdens in coral tissue from the STEER were similar to the concentration ranges reported by a previous study in the Puerto Rico (Table 4a), although the maximum level found at HBI7P was nearly an order of magnitude higher than levels found in Vieques, Puerto Rico.

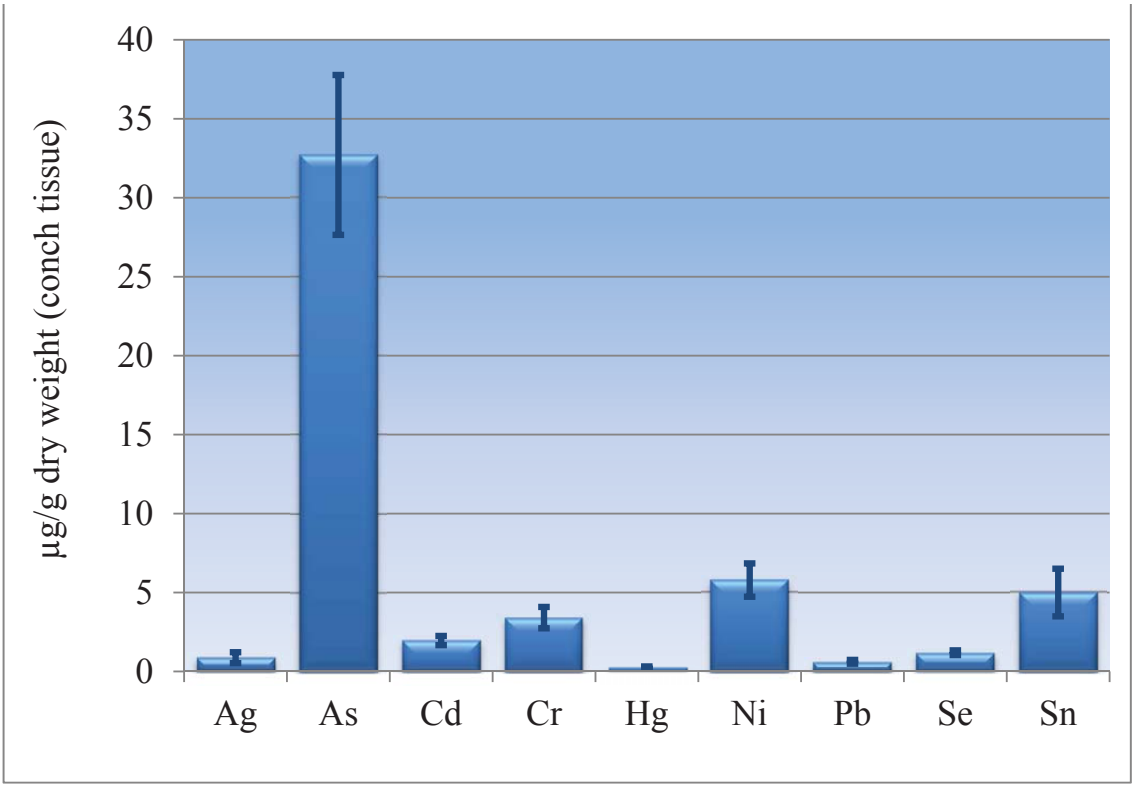

Figure 10. Concentrations (mean ±SE) of metals detected in the conch *Strombus gigas.*

Chromium in Conch. Summary statistics for the levels of chromium body burdens in *S. gigas* from the STEER are presented in Table 6. Chromium levels in conch varied from 1.45 µg/g to a maximum value of 8.57 µg/g. With a mean concentration of 3.41 µg/g, chromium was fairly evenly distributed across the strata in the STEER except in Stratum 4 where the maximum values were measured (Table 6).

Chromium has been shown to reduce survival and fecundity in the cladoceran *Daphnia magna,* and result in reduced growth in fingerling chinook salmon (*Oncorhynchus tshawytscha*) (Eisler, 1986). However, chromium effects in conch are unknown. To limit human exposure to chromium through seafood consumption, the U.S. FDA (FDA, 2009) has set a chromium action level in molluscan shellfish at 2.14 µg/g wet wt. Using the measured 76% moisture content in conch we derived an FDA equivalence value of 17.2 µg/g chromium (dry weight) in mollusks. Levels

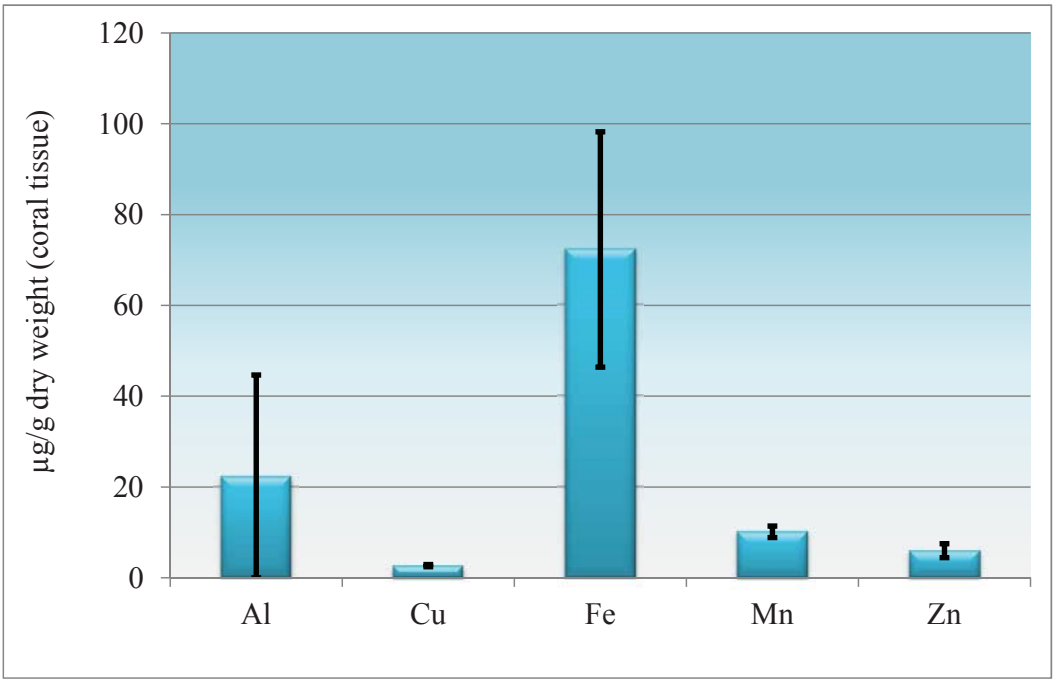

Figure 11. Concentrations (mean ±SE) of metals detected in the coral *Porites astreoides*.

of chromium found in conch tissue from the STEER (maximum of 8.57 µg/g) are well below the FDA action levels.

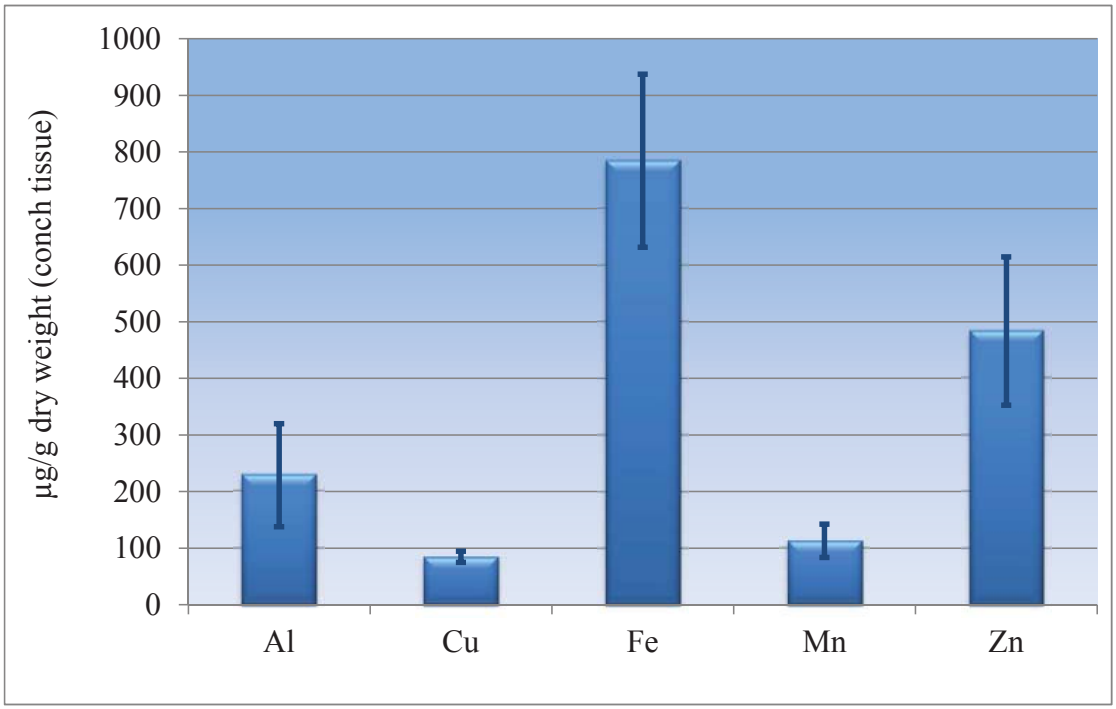

Figure 12. Concentrations (mean ±SE) of metals detected in the conch *Strombus gigas.*

Copper

Copper in Corals. Copper body burdens in *P. astreoides* ranged from 1.96 µg/g to 4.07 µg/g with a mean of 2.69 µg/g (Table 4a and Figure 11). Copper body burdens in *P. astreoides* from the STEER were in the range of levels found in southwest and in Vieques, Puerto Rico (Table 4a). However, in *P. astreoides* from Jobos Bay, Puerto Rico, Whitall *et al*., (2011) reported a median value as high as 69 µg/g. These authors suggested there have been copper contamination problems in Jobos Bay.

The toxicity of copper to corals is well demonstrated (Downs *et al* 2005; Reichelt-Brushett and Harrison, 1999, Goh and Chou, 1997; Reichelt-Brushett and Michalek-Wagnerm, 2005). Downs *et al.* (2005) also showed that copper as cuprous oxide affects cell vitality and mitochondrial function. Reichelt-Brushett and Michalek-Wagner (2005) investigated the effects of copper on the soft coral *Lobophytum compactum*. A significant difference in fertilization success was found at a copper concentration of 117 µg/L. Also, in corals, Reichelt-Brushett and Harrison (2004) found that a copper concentration of 20 µg/L significantly reduced fertilization success in brain coral *Goniastrea aspera*. Goh and Chou (1997) found that a copper concentration of 40 µg/L in the zooxanthellae *Symbiodinium microadriaticum*, isolated from the rice coral *Montipora verrucosa* resulted in growth inhibition in the symbiotic dinoflagellate. Goh and Chou (1997) noted a

Table 7. Mean metal body burden in conch collected from the five strata. in the STEER (ug/g).

Element	Stratum 1	Stratum 2	Stratum 3	Stratum 4	Stratum 5
Ag	0.238	0.172	0.8755	0.985	2.116
Al	113	141.5	38.65	767.5	77.1
As	25.3	19.9	32.25	51.4	38.1
Cd	1.45	1.044	2.66	2.725	1.745
Cr	3.03	1.81	3.085	6.33	3.16
Cu	48.8	113	62.2	114.5	85.5
Fe	783	776	389	1625	380
Hg	0.0544	0.09725	0.2975	0.196	0.5485
Mn	55.8	258	86.2	103.9	69.55
Ni	5.18	6.06	4.08	11.045	3.545
Pb	0.424	1.26	0.29	0.7415	0.3305
Se	0.758	0.962	1.22	1.19	1.845
Sn	1.74	4.75	12.25	4.011	0.03765
Zn	307	920.5	670	235.5	288.5

n = 2 from each stratum.

synergistic effect when the zooxanthellae were exposed to both copper and zinc.

Copper in Conch. Copper body burdens in *S. gigas* from the STEER ranged from 36 µg/g to 122 µg/g with a mean of 84.7 µg/g (Table 4a and Figure 12). Copper body burdens in conch from the STEER were similar to levels found in conch collected from nearshore environments in south Florida (Table 6). However, the mean copper value measured in conch from the STEER was elevated compared to published values by Glazer *et al*. (2008) and Said *et al*. (2013), in the offshore environments of south Florida and Johor Straits, Malaysia (Table 6), respectively.

While an essential element, especially for mollusks which use copper as the oxygen carrier in their blood, elevated levels of copper can impact aquatic organisms, including the functioning of gills, along with reproduction and development in fish and mollusks (Eisler, 1998; Spade *et al*., 2010). Spade *et al*., (2010) found copper concentrations of 34.77 µg/g ww (46 µg/g dw) and 83.96 µg/g (111 µg/g dw) respectively in testis and digestive gland of conch from south Florida, and speculated that copper may be contributing to testis regression, and hence to reproductive failure of the conch in the nearshore environment of south Florida. Note, our data is whole body burden, and not tissue specific.

Iron

Iron in Coral. Iron in *P. astreoides* ranged from a minimum of 27.9 µg/g to maximum value of 275 µg/g (Appendix G and Table 4b). Similarly to copper, the maximum iron body burden in coral was found at the HBI28P in stratum 2. The STEER-wide mean of iron of 72.3 µg/g indicates that iron is the most abundant metal in coral from the STEER, which can also be seen in Figure 11.

Similar iron coral body burden ranges were reported in southwest and Vieques, Puerto Rico and in Daya Bay, China (Table 4b). Like aluminum, iron is regarded as a marker of metals from terrestrial sources (Chen *et al*. 2010). The presence of iron in coral tissue at elevated concentrations could indicate that other observed metals in coral tissues in this area may be from natural sources as well.

Iron in Conch. Iron detected in conch ranged from 284 to 1,720 µg/g, with a mean of 785 µg/g. As with coral, iron had the highest mean concentration of any element measured in conch in this study, supporting the notion that the iron may be derived from natural terrigenous sources.

Mercury

Mercury in Coral. Coral body burdens of mercury in the STEER ranged from below detection to 0.003 µg/g (Table 4b). In general mercury was detected at very low concentrations in *P. astreoides* (Figure 9). Similar concentration ranges were reported for mercury in coral from Puerto Rico (Table 4b). The ecotoxicity of mercury includes neurological diseases in vertebrates, which are well documented (Murphy *et al*. 2008), but its effects on coral are unknown.

Mercury in Conch. Mercury body burdens in conch were relatively higher in the STEER (ranging from 0.05 µg/g to 0.88 µg/g) compared to other studies (Table 6). Mercury was detected in all strata, with an overall mean of 0.24 µg/g indicating that conch in the STEER have slightly higher concentrations of mercury than conch from south Florida, which averaged 0.01 µg/g (Glazer *et al*., 2008).

Mercury has no known biological function, and is potentially hazardous to exposed organisms. Accumulation of mercury above background levels in aquatic systems can pose serious environmental threats to wildlife (EPA, 1997; Murphy *et al*., 2008). Signs of neurological diseases including abnormal behavior, convulsion, reduced fitness and death, have been observed in wildlife exposed to mercury (EPA, 1997; Murphy *et al*., 2008). There is no FDA action level for mercury in shellfish.

Manganese

Manganese in Coral. Manganese body burdens in *P. astreoides* varied from a minimum value of 7.25 µg/g to a maximum value of 19.6 µg/g (Table 4b). In the STEER, manganese was detected in all of the coral samples with the maximum concentration measured in stratum 2. Manganese body burdens were similar in range to reported values in *P. astreoides* from Puerto Rico. However, these values were virtually an order of magnitude higher than levels reported in Misima Island, Papua New Guinea, Ulan Reef, Philippines, and Daya Bay, China (Table 4b). With a mean body burden value of 10.1 µg/g, manganese had the third highest concentration in coral after iron and aluminum.

Along with iron, manganese is considered as a marker of terrigenous metal inputs (Chen *et al*., 2010). The manganese-to-metal ratio in coral tissue could indicate the possible origin of its presence in coral. The results of an analysis of the STEER data showed, however, that manganese was not correlated with any other metals except lead. The positive correlation ($p < 0.05$) between manganese and lead (Figure 13) may indicate that the likely sources of lead

contamination in the coral is of natural land erosion and transport dynamics present in the STEER watershed. This interpretation should be approached cautiously, because of the small sample size. More research is needed to understand uptake processes of metals in coral species.

Manganese in Conch. In *S. gigas*, manganese was also detected in all samples analyzed. The highest concentration detected was 355 µg/g, in conch from stratum 2 (Appendix G). Unfortunately, there does not appear to be much data on the presence of manganese in conch.

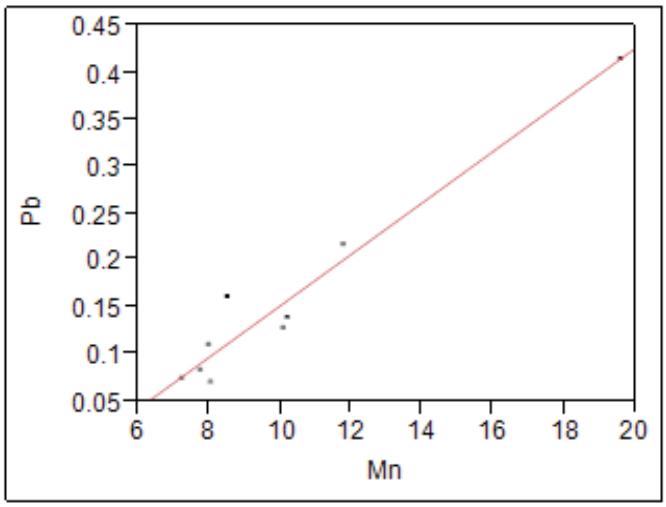

Figure 13. Scatter plot showing relationship between manganese and lead in coral.

Nickel

Nickel in Coral. Body burdens of nickel in coral tissues ranged from below detection to a maximum value of 8.33 µg/g found at the HBI42A in stratum 5. Nickel was detected in all coral samples with levels that were relatively higher than all the other trace metals measured (Figure 9). Whitall *et al*., (2011) reported a maximum body burden of 6.84 µg/g in *P. astreoides* for nickel indicating that levels found in the STEER were within the regional range.

In experimental settings, nickel was found to cause serious toxicity to the anemones *Condylactis gigantea* and *Stichodactyla helianthus* (Shimek, 2008). The author reported that nickel ambient concentrations as low as 4 ppb could induce toxic effects such as reduced carbonic anhydrase activity in coral. Anemones have sometimes been used as a lab model for coral.

Nickel in Conch. Body burdens of nickel in conch tissues ranged from 3.03 µg/g to 13.6 µg/g (Table 6). Nickel was detected in conch from all of the strata. The mean concentrations of nickel in *S. gigas* tissue from the different strata are shown in Table 7. While in all other strata, nickel body burdens in conch were fairly similar, relatively higher nickel levels (~14 µg/g) were observed in stratum 4. Glazer *et al*. (2008) reported levels of 9.59 µg/g ww in conch from the nearshore coastal environment in Florida. Using the measured 76% moisture content in conch, we derived a maximum wet weight value of 3.4 µg/g, indicating that nickel concentrations in conch from the STEER were numerically lower than values reported by Glazer *et al*. (2008). For nickel, the FDA action level in shellfish of 80 µg/g (ww), is much higher than the wet weight nickel concentration of 3.4 µg/g derived for conch from the STEER.

Lead

Lead in Coral. Lead body burdens in *P. astreoides* from the STEER ranged from 0.07 µg/g to 0.42 µg/g (Table 4b). With a mean value 0.16 µg/g, lead was detected in coral from all the five strata (Figure 9; Table 5). Lead body burden as high as 12.50 µg/g was reported in *P. astreoides* from Jobos Bay, Puerto Rico (Whitall *et al*., 2011). However, other studies in southwest and Vieques, Puerto Rico have reported lead mean values of below detection to 0.07 in *P. astreoides* (Pait *et al*., 2009 and 2010), implying that results from the STEER are within the regional concentration range for lead in coral. In a laboratory experiment, Reichelt-Burshett and Harrison (2004) demonstrated that a seawater concentration of lead of around 2,900 µg/L seriously impacted coral larvae survival. When lead concentrations in algae exceeded 500 ppb, enzymes needed for photosynthesis were inhibited (Taub, 2004).

Lead in Conch. The lead body burden in *S. gigas* from the STEER ranged from 0.21 µg/g to 1.32 µg/g (Table 6). With a mean value of 0. 61 µg/g, lead was detected in conch from all five strata at a relatively constant concentration (Table 6). The highest lead body burden in conch from the STEER was found in stratum 2 at 1.32 µg/g. Lead is a toxic heavy metal; its toxic effects (inhibited development) have been observed in sea urchins and in oysters (Eisler, 1988). The FDA action level for lead in molluscan shellfish is 1.7 µg/g (ww). Using the measured 76% moisture content in conch we derived an equivalence maximum value of 0.33 µg/g lead ww, indicating that lead concentrations in conch from the STEER were lower the FDA action level for shellfish.

Selenium

Selenium in Coral. The body burden in *P. astreoides* varied from below detection to 0.12 µg/g. Selenium was only detected in coral samples from stratum 3 (Table 5), and the relatively low concentrations were similar to those ob-

served elsewhere in *P. astreoides* from the Caribbean (Pait 2009 and 2010; Whitall *et al*., 2011).

Selenium in Conch. Selenium body burdens in *S. gigas* varied from 0.68 µg/g to 2.38 µg/g in the STEER (Table 6). Selenium was detected in conch tissue, with the highest found in stratum 5 (Table 7). There is no FDA action level for selenium in shellfish tissue.

Zinc

Zinc in Coral. In the STEER, *P. astreoides* body burdens of zinc ranged from 1.87 µg/g to a maximum value of 14.8 µg/g (Table 4b). With an overall average of 5.98 µg/g, zinc was detected in all five strata (Table 5, Figure 11). Zinc body burdens in *P. astreoides* from the STEER were similar to reported values (Table 4b). Mean zinc body burdens of 6.09 µg/g and 8.59 µg/g have been reported by Pait *et al*. (2009) and Whitall *et al*. (2011) in *P. astreoides* from southwest Puerto Rico and Jobos Bay, Puerto Rico, respectively. These published data indicate that zinc levels found in the coral from the STEER are within the concentration range seen in the region. However, numerically higher zinc body burdens (Table 4b) have been reported elsewhere in Punta Brava, Venezuela (Bastidas and Garcia, 1999), Misima Island, Papua New Guinea (Fallon *et al*, 2002), Dafangji Island, China (Peng *et al*. 2006). Zinc is an essential element, however at elevated concentrations, it can be toxic to coral (Chen *et al*., 2010). Several studies have linked excess zinc to harmful effects in zooxanthellae (Goh and Chou, 1997) and fertilization impairments in coral (Reichelt-Brushett and Harrison, 2005).

Zinc in Conch. In the STEER, *S. gigas* body burdens for zinc ranged from 170 µg/g to maximum value of 1,320 µg/g (Table 6). With an overall average of 484 µg/g, zinc was detected in all of the five strata (Figure 12; Table 7). Zinc body burdens in *S. gigas* from the STEER are similar to reported values (Table 6). Mean zinc body burdens of 40.4 µg/g and 874 µg/g have been reported by Glazer *et al*. (2008) in *S. gigas* from south Florida. These published data indicated that zinc levels found in the conch from the STEER are within the concentration range seen in Florida (Glazer, *et al*., 2008).

Although zinc is an important biological element, at elevated concentrations, it can be toxic to aquatic organisms (Spade *et al*., 2010 ; Chen *et al*., 2010). Zinc has been associated with reproductive inhibition in mollusks including gastropods such as *S. gigas* (Spade *et al*., 2010). A zinc concentration of 832 µg/g in the digestive gland, and 84 ng/mg in testis have been linked to testis regression in conch from the Florida Keys (Spade *et al*., 2010).

SUMMARY AND CONCLUSIONS

In general, organic contaminant levels in the tissues of coral and conch in the STEER appear to be relatively low, and similar to results seen in other studies from the region. Mean total PAHs (sum of all PAHs measured) in corals were in the range of mean total PAH concentrations from studies in the region (Strand *et al*., 2009). Conch total PAH levels appeared low when compared with other mollusk studies from the region. Butyltins for both coral and conch tissues, including TBT and total (sum) of butyltins were relatively low or comparable to previous results from the region. A significant correlation between higher concentrations closer to shore (inshore vs. offshore) existed for conch. The correlation was not significant for coral tissues.

Trace and major elements are incorporated into corals and conch tissue by a variety of pathways. In coral, metal accumulation can occur by direct replacement of calcium by dissolved metals in the aragonite lattice, inclusion of detritus materials into skeletal pore spaces, uptake of organic materials incorporation of metals into coral skeletons, or coral feeding (Howard and Brown, 1984). Bioaccumulation of metal in conch can occur via exposure to dissolved metals in the gills and through feeding. Conch have been shown to ingest considerable amounts of sediment particles (Brownell and Stevely, 1981). Hence, elevated body burdens of major metals such aluminum, iron, and manganese were expected. It has been observed that corals (David, 2003; Chen *et al*., 2010) and conch (Glazer et al. 2008 and Said et al., 2013) from polluted areas show a much higher concentration of trace metals in their tissues than corals from unpolluted areas. In the STEER, the most elevated metal concentrations in corals were found in strata 1 and 2, which are the strata where sediments had the most elevated concentration of metals. This pattern was not however observed in conch. The most elevated metal concentrations were observed in conch from stratum 4 instead of strata 1 and 2 which also had elevated metal concentrations in sediment. Based on the levels of metal body burdens found, the coral and conch tissues do not appear to be very contaminated.

All of the major and trace elements occur naturally to some extent in the environment. Iron for instance is a major element in the Earth's crust. As their name implies, trace elements such as chromium, cadmium, lead and nickel occur at lower concentrations in crustal material, however,

mining and manufacturing processes along with the use and disposal of products containing trace elements can lead to elevated concentrations in the environment. Some trace and major elements (e.g. iron, copper, selenium) in the appropriate concentrations are biologically essential, but above certain concentration thresholds, a number of trace elements are toxic. Because no threshold or guidelines of toxicity exist for metals in coral tissue, it is not possible to evaluate impacts. Coral organisms may be subjected, however, to sublethal effects from low metal concentrations of toxic metals.

Since there are currently no ecotoxicity thresholds and the fact that trace and major element levels were similar to published data from many other coastal areas in the Caribbean, we conclude that levels of the trace and major elements in the coral and conch tissue were background levels. More research is needed to understand uptake processes of metals in coral species.

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Appendix A. Field data collected during the June 2012 mission to the STEER

Site	Stratum	Date Collected	Matrix	Longitude (DD)	Latitude (DD)	Depth (m)	Temp (°C)	Salinity (‰)	DO (mg/L)
HBI28p	2	6/18/2012	Coral	-64.86575	18.31337	1.2	29.8	36.12	4.49
HBI42a	5	6/18/2012	Coral	-64.82964	18.31538	3.0	28.6	35.82	3.89
HBI14p	4	6/18/2012	Coral	-64.84351	18.31455	4.0	28.6	35.88	3.54
HBI7p	5	6/18/2012	Coral	-64.83813	18.32036	2.4	28.6	35.53	3.43
HBI24p	2	6/18/2012	Coral	-64.86886	18.30371	5.2			
HBI11p	3	6/18/2012	Coral	-64.85760	18.30615	14.3	28.7	35.91	4.01
HBI15p	4	6/18/2012	Coral	-64.84471	18.30409	12.8	28.6	35.9	3.52
HBI23p	3	6/18/2012	Coral	-64.86024	18.31753	1.5	29.2	35.99	3.95
MLC01	1	6/22/2012	Coral	-64.87556	18.30700	1.2	31.3	36.16	4.87
Conch 1A	1		Conch	-64.87637	18.30791	3.7			
Conch 1B	1		Conch	-64.87463	18.30565	2.4			
Conch 2A	2	6/20/2012	Conch	-64.86820	18.31287	2.4	30	35.98	5.09
Conch 2B	2	6/20/2012	Conch	-64.86820	18.31287	2.4	30	35.98	5.09
Conch 3A	3	6/20/2012	Conch	-64.84837	18.30402	12.2	28.7	36	3.91
Conch 3B	3	6/20/2012	Conch	-64.84837	18.30402	12.2	28.7	36	3.91
Conch 4A	4	6/20/2012	Conch	-64.82999	18.30095	6.7	28.7	35.98	4.01
Conch 4B	4	6/20/2012	Conch	-64.82999	18.30095	6.7	28.7	35.98	4.01
Conch 5A	5	6/20/2012	Conch	-64.37737	18.31737	6.1	28.7	36.01	3.67
Conch 5B	5	6/20/2012	Conch	-64.37737	18.31737	6.1	28.7	36.01	3.67

Appendix B. Polycyclic aromatic hydrocarbons detected in STEER coral and conch samples (ng/g dw).

Compound	HBI28P	HBI42A	HBI14P	HBI7P	HBI24P	HBI11P	HBI15P	HBI23P	MLC01
					Coral				
Naphthalene	3.05	3.97	3.99	2.41	3.50	3.17	3.63	3.39	4.47
C1-Naphthalenes	0.730	0.768 J	0.936 J	0.714 J	0.685 J	0.890 J	0.752 J	0.924 J	0.743 J
C2-Naphthalenes	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C3-Naphthalenes	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C4-Naphthalenes	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Benzothiophene	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C1-Benzothiophenes	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C2-Benzothiophenes	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C3-Benzothiophenes	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C4-Benzothiophenes	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Biphenyl	0.849	0.965 J	1.22 J	0.978 J	1.11 J	1.38 J	0.888 J	1.42 J	1.03 J
Acenaphthylene	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Acenaphthene	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Dibenzofuran	0.484	0.577 J	0.586 J	0.00 U	0.00 U	0.00 U	0.00 U	0.452 J	0.635 J
Fluorene	0.296	0.496 J	0.732 J	0.00 U	0.00 U	0.00 U	0.00 U	0.665 J	0.00 U
C1-Fluorenes	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C2-Fluorenes	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C3-Fluorenes	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Carbazole	0.292	0.706 J	0.876 J	0.746 J	0.764 J	3.51	0.00 U	1.31	0.262 J
Anthracene	0.222	0.411 J	0.728 J	0.326 J	0.00 U	0.00 U	0.00 U	0.428 J	0.00 U
Phenanthrene	0.861	2.04 J	3.04	1.26 J	0.574 J	0.710 J	0.570 J	1.86 J	0.867 J
C1-Phenanthrenes/Anthracenes	0.00	0.00 U	3.87 J	1.17 J	0.00 U	0.00 U	0.00 U	2.24 J	<4.5 U
C2-Phenanthrenes/Anthracenes	0.00	0.00 U	9.22	2.97 J	0.00 U	0.00 U	0.00 U	8.07	0.00 U
C3-Phenanthrenes/Anthracenes	0.00	0.00 U	6.44	0.00 U	0.00 U	0.00 U	0.00 U	3.54 J	0.00 U
C4-Phenanthrenes/Anthracenes	0.00	0.00 U	10.9	0.00 U	0.00 U	0.00 U	0.00 U	6.50	0.00 U
Dibenzothiophene	0.177	0.384 J	0.473 J	0.320 J	0.137 J	0.400 J	0.00 U	0.331 J	0.500 J
C1-Dibenzothiophenes	0.00	0.463 J	0.823 J	0.00 U	0.00 U	0.00 U	0.00 U	0.658 J	0.00 U
C2-Dibenzothiophenes	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C3-Dibenzothiophenes	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C4-Dibenzothiophenes	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Fluoranthene	0.437	1.33	2.89	1.13	0.00 U	0.269 J	0.00 U	1.96	0.222 J
Pyrene	0.428	1.24 J	2.53	0.881 J	0.00 U	0.208 J	0.00 U	1.44 J	0.00 U
C1-Fluoranthenes/Pyrenes	0.00	0.00 U	3.70	0.00 U	0.00 U	0.00 U	0.00 U	2.81 J	0.00 U
C2-Fluoranthenes/Pyrenes	0.00	0.00 U	3.34 J	0.00 U	0.00 U	0.00 U	0.00 U	2.40 J	0.00 U
C3-Fluoranthenes/Pyrenes	0.00	0.00 U	4.00	0.00 U	0.00 U	0.00 U	0.00 U	2.34 J	0.00 U
C4-Fluoranthenes/Pyrenes	0.00	0.00 U	3.14 J	0.00 U	0.00 U	0.00 U	0.00 U	2.27 J	0.00 U
Naphthobenzothiophene	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C1-Naphthobenzothiophenes	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C2-Naphthobenzothiophenes	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C3-Naphthobenzothiophenes	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C4-Naphthobenzothiophenes	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Benz(a)anthracene	0.270	0.612	1.53	0.278 J	0.00 U	0.00 U	0.00 U	0.589	0.00 U
Chrysene/Triphenylene	0.261	0.551 J	1.61	0.459 J	0.00 U	0.00 U	0.00 U	1.04	0.00 U
C1-Chrysenes	0.00	0.00 U	3.04	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C2-Chrysenes	0.00	0.00 U	3.12	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C3-Chrysenes	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C4-Chrysenes	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Benzo(b)fluoranthene	0.00	0.00 U	1.38 J	0.00 U	0.00 U	0.00 U	0.00 U	0.636 J	0.00 U
Benzo(k,j)fluoranthene	0.00	0.00 U	0.600 J	0.00 U	0.00 U	0.00 U	0.00 U	0.314 J	0.00 U
Benzo(a)fluoranthene	0.00	0.00 U	0.273 J	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Benzo(e)pyrene	0.00	0.00 U	1.12 J	0.00 U	0.00 U	0.00 U	0.00 U	0.548 J	0.00 U
Benzo(a)pyrene	0.00	0.00 U	1.21 J	0.00 U	0.00 U	0.00 U	0.00 U	0.463 J	0.00 U
Perylene	0.00	0.00 U	1.56 J	0.00 U	0.00 U	0.00 U	0.00 U	0.934 J	0.00 U
Indeno(1,2,3-c,d)pyrene	0.00	0.00 U	0.633 J	0.00 U	0.00 U	0.00 U	0.00 U	0.119 J	0.00 U
Dibenzo(a,h)anthracene	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C1-Dibenzo(a,h)anthracenes	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C2-Dibenzo(a,h)anthracenes	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C3-Dibenzo(a,h)anthracenes	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Benzo(g,h,i)perylene	0.00	0.00 U	0.87 J	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Total PAHs	8.4	14.5	80.4	13.6	6.8	10.5	5.8	49.7	8.7

Appendix B. Polycyclic aromatic hydrocarbons detected in STEER coral and conch samples (ng/g dw) (cont.).

Compound	S1-CA	S1-CB	S2-CA	S2-CB	S3-CA	S3-CB	S4-CA	S4-CB	S5-CA	S5-CB
	Conch									
Naphthalene	7.12	7.42	8.73	13.9	8.71	9.27	10.5	12.2	11.1	10.6 U
C1-Naphthalenes	1.56 J	1.40 J	2.24 J	2.72 J	1.75 J	1.63 J	2.47 J	3.81 J	3.09 J	3.12
C2-Naphthalenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	5.03	4.26	0.00 J
C3-Naphthalenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C4-Naphthalenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Benzothiophene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C1-Benzothiophenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C2-Benzothiophenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C3-Benzothiophenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C4-Benzothiophenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Biphenyl	2.93 J	3.01 J	2.12 J	3.59 J	1.82 J	1.96 J	4.15 J	2.83 J	2.80 J	2.66 U
Acenaphthylene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 J
Acenaphthene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Dibenzofuran	1.38 J	1.62 J	1.73 J	1.77 J	1.17 J	1.20 J	2.16 J	2.52	1.36 J	1.19 U
Fluorene	1.09 J	0.882 J	0.00 U	0.729 J	1.77	0.800 J	0.554 J	1.44 J	0.635 J	0.00 J
C1-Fluorenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C2-Fluorenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C3-Fluorenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Carbazole	0.00 U	0.00 U	1.46	1.21 J	0.644 J	0.836 J	0.00 U	1.81	1.48	1.62 U
Anthracene	0.00 U	0.00 U	0.00 U	0.00 U	0.359 J	0.640 J	0.00 U	4.31	3.14	0.00
Phenanthrene	0.00 U	2.366	2.00 J	2.42 J	1.47 J	4.15	2.96 J	9.29	2.35	2.49 U
C1-Phenanthrenes/Anthracenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	7.05	0.00 U	0.00 J
C2-Phenanthrenes/Anthracenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	9.26	0.00 U	0.00 U
C3-Phenanthrenes/Anthracenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C4-Phenanthrenes/Anthracenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Dibenzothiophene	0.00 U	0.00 U	0.402 J	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C1-Dibenzothiophenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C2-Dibenzothiophenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C3-Dibenzothiophenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C4-Dibenzothiophenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Fluoranthene	0.631	0.655	0.00 U	0.00 U	0.00 U	1.57	0.00 U	10.9	0.00 U	0.00 U
Pyrene	0.516 J	0.684 J	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	6.32	0.00 U	0.00 U
C1-Fluoranthenes/Pyrenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	7.81	0.00 U	0.00 U
C2-Fluoranthenes/Pyrenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	5.32	0.00 U	0.00 U
C3-Fluoranthenes/Pyrenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C4-Fluoranthenes/Pyrenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Naphthobenzothiophene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C1-Naphthobenzothiophenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C2-Naphthobenzothiophenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C3-Naphthobenzothiophenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C4-Naphthobenzothiophenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Benz(a)anthracene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	2.91	0.00 U	0.00 U
Chrysene/Triphenylene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	4.82	0.00 U	0.00 U
C1-Chrysenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C2-Chrysenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C3-Chrysenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C4-Chrysenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Benzo(b)fluoranthene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	3.84	0.00 U	0.00 U
Benzo(k,j)fluoranthene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	2.03 J	0.00 U	0.00 U
Benzo(a)fluoranthene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.675 J	0.00 U	0.00 U
Benzo(e)pyrene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	1.98 J	0.00 U	0.00 U
Benzo(a)pyrene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	1.32 J	0.00 U	0.00 U
Perylene	3.44 J	0.00 U	2.50 J	6.86 J	3.85 J	2.03 J	0.00 U	3.24 J	2.67 J	0.00 U
Indeno(1,2,3-c,d)pyrene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.672 J	0.00 U	0.00 U
Dibenzo(a,h)anthracene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C1-Dibenzo(a,h)anthracenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C2-Dibenzo(a,h)anthracenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C3-Dibenzo(a,h)anthracenes	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Benzo(g,h,i)perylene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	1.68 J	0.00 U	0.00 U
Total PAHs	18.7	18.0	21.2	33.2	21.5	24.1	22.8	113	32.8	21.7

Appendix C. Individual alkyl isomers and hopanes detected in STEER coral and conch samples (ng/g dw).

Compound	HBI28P	HBI42A	HBI14P	HBI7P	HBI24P	HBI11P	HBI15P	HBI23P	MLC01
					Coral				
2-Methylnaphthalene	0.741	0.812	0.945	0.628	0.565 J	0.820	0.661	0.835	0.644
1-Methylnaphthalene	0.368	0.352 J	0.478 J	0.464 J	0.486 J	0.538 J	0.490 J	0.577 J	0.494 J
2,6-Dimethylnaphthalene	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
1,6,7-Trimethylnaphthalene	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
1-Methylfluorene	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
4-Methyldibenzothiophene	0.00	0.335 J	0.571 J	0.00 U	0.00 U	0.00 U	0.00 U	0.477 J	0.00 U
2/3-Methyldibenzothiophene	0.00	0.248 J	0.549 J	0.00 U	0.00 U	0.00 U	0.00 U	0.346 J	0.00 U
1-Methyldibenzothiophene	0.00	0.127 J	0.140 J	0.00 U	0.00 U	0.00 U	0.00 U	0.184 J	0.00 U
3-Methylphenanthrene	0.00	0.00 U	0.964 J	0.359 J	0.00 U	0.00 U	0.00 U	0.454 J	0.00 U
2-Methylphenanthrene	0.00	0.00 U	0.999 J	0.269 J	0.00 U	0.00 U	0.00 U	0.705 J	0.00 U
2-Methylanthracene	0.00	0.00 U	0.582 J	0.153 J	0.00 U	0.00 U	0.00 U	0.390 J	0.00 U
4/9-Methylphenanthrene	0.00	0.00 U	1.03 J	0.432 J	0.00 U	0.00 U	0.00 U	0.546 J	0.00 U
1-Methylphenanthrene	0.00	0.00 U	1.15 J	0.216 J	0.00 U	0.00 U	0.00 U	0.634 J	0.00 U
3,6-Dimethylphenanthrene	0.00	0.00 U	0.915 J	0.467 J	0.00 U	0.00 U	0.00 U	0.654 J	0.00 U
Retene	0.00	0.00 U	21.5	0.00 U	0.00 U	0.00 U	0.00 U	13.2	0.00 U
2-Methylfluoranthene	0.00	0.00 U	0.427 J	0.00 U	0.00 U	0.00 U	0.00 U	0.247 J	0.00 U
Benzo(b)fluorene	0.00	0.00 U	0.685	0.00 U	0.00 U	0.00 U	0.00 U	0.348 J	0.00 U
C29-Hopane	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
18a-Oleanane	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C30-Hopane	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C20-TAS	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C21-TAS	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C26(20S)-TAS	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C26(20R)/C27(20S)-TAS	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C28(20S)-TAS	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C27(20R)-TAS	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C28(20R)-TAS	0.00	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U

Appendix C. Individual alkyl isomers and hopanes detected in STEER coral and conch samples (ng/g dw) (cont.).

Compound	S1-CA	S1-CB	S2-CA	S2-CB	S3-CA	S3-CB	S4-CA	S4-CB	S5-CA	S5-CB
	Conch									
2-Methylnaphthalene	1.33	1.53	2.13	2.64	1.57	1.76	2.77	3.81	3.15	3.26
1-Methylnaphthalene	1.05 J	0.599 J	1.29	1.51	1.10	0.720 J	0.960 J	1.98	1.54	1.46
2,6-Dimethylnaphthalene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	2.38	2.00	0.00 U
1,6,7-Trimethylnaphthalene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
1-Methylfluorene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
4-Methyldibenzothiophene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
2/3-Methyldibenzothiophene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
1-Methyldibenzothiophene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
3-Methylphenanthrene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	1.39 J	0.00 U	0.00 U
2-Methylphenanthrene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	2.93 J	0.00 U	0.00 U
2-Methylanthracene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.958 J	0.00 U	0.00 U
4/9-Methylphenanthrene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	1.84 J	0.00 U	0.00 U
1-Methylphenanthrene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	1.50 J	0.00 U	0.00 U
3,6-Dimethylphenanthrene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	1.73 J	0.00 U	0.00 U
Retene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
2-Methylfluoranthene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	1.38	0.00 U	0.00 U
Benzo(b)fluorene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.906	0.00 U	0.00 U
C29-Hopane	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
18a-Oleanane	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C30-Hopane	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C20-TAS	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C21-TAS	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C26(20S)-TAS	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C26(20R)/C27(20S)-TAS	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C28(20S)-TAS	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C27(20R)-TAS	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
C28(20R)-TAS	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U

Appendix D. Polychlorinated biphenyls detected in STEER coral and conch samples (ng/g dw).

Compound	HBI28P	HBI42A	HBI14P	HBI7P	HBI24P	HBI11P	HBI15P	HBI23P	MLC01
					Coral				
PCB8/5	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB18	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB28	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB29	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB31	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB44	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB45	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB49	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB52	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB56/60	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB66	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB70	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB74/61	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB87/115	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB95	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB99	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB101/90	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB105	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB110/77	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB118	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB128	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB138/160	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB146	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB149/123	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB151	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB153/132	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB156/171/202	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB158	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB170/190	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB174	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB180	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB183	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB187	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB194	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB195/208	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB199	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB201/157/173	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB206	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB209	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Total PCB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix D. Polychlorinated biphenyls detected in STEER coral and conch samples (ng/g dw) (cont.).

Compound	S1-CA	S1-CB	S2-CA	S2-CB	S3-CA	S3-CB	S4-CA	S4-CB	S5-CA	S5-CB
	Conch									
PCB8/5	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB18	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB28	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB29	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB31	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB44	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB45	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB49	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB52	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB56/60	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB66	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB70	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB74/61	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB87/115	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB95	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB99	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB101/90	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB105	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB110/77	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB118	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB128	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB138/160	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB146	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB149/123	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB151	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB153/132	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB156/171/202	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB158	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB170/190	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB174	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB180	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB183	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB187	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB194	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB195/208	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB199	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB201/157/173	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB206	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
PCB209	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Total PCB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix E. Organochlorine compounds detected in STEER coral and conch samples (ng/g dw).

Compound	HBI28P	HBI42A	HBI14P	HBI7P	HBI24P	HBI11P	HBI15P	HBI23P	MLC01
					Coral				
Aldrin	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Dieldrin	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Endrin	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Heptachlor	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Heptachlor-Epoxide	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Oxychlordane	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Alpha-Chlordane	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Gamma-Chlordane	0.00 U	0.00 U	0.05 J	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Trans-Nonachlor	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Cis-Nonachlor	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Alpha-HCH	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Beta-HCH	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Delta-HCH	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Gamma-HCH	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
DDMU	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
2,4'-DDD	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
4,4'-DDD	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
2,4'-DDE	0.00 U	0.00 U	0.03 J	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
4,4'-DDE	0.00 U	0.00 U	0.06 J	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
2,4'-DDT	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
4,4'-DDT	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
1,2,3,4-Tetrachlorobenzene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
1,2,4,5-Tetrachlorobenzene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Hexachlorobenzene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Pentachloroanisole	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Pentachlorobenzene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Endosulfan II	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Endosulfan I	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Endosulfan Sulfate	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Mirex	0.00 U	0.00 U	0.04 J	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Chlorpyrifos	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Total HCH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Chlordane	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Total DDT	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00

Appendix E. Organochlorine compounds detected in STEER coral and conch samples (ng/g dw) (cont.).

Compound	S1-CA	S1-CB	S2-CA	S2-CB	S3-CA	S3-CB	S4-CA	S4-CB	S5-CA	S5-CB
						Conch				
Aldrin	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Dieldrin	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Endrin	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Heptachlor	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Heptachlor-Epoxide	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Oxychlordane	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Alpha-Chlordane	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Gamma-Chlordane	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Trans-Nonachlor	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Cis-Nonachlor	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Alpha-HCH	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Beta-HCH	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Delta-HCH	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Gamma-HCH	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
DDMU	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
2,4'-DDD	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
4,4'-DDD	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
2,4'-DDE	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
4,4'-DDE	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
2,4'-DDT	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
4,4'-DDT	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
1,2,3,4-Tetrachlorobenzene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
1,2,4,5-Tetrachlorobenzene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Hexachlorobenzene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Pentachloroanisole	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Pentachlorobenzene	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Endosulfan II	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Endosulfan I	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Endosulfan Sulfate	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Mirex	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Chlorpyrifos	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U	0.00 U
Total HCH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Chlordane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total DDT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix F. Butyltins detected in coral and conch samples collected from the STEER (ng Sn/dry g).

Site	Matrix	Monobutyltin	Dibutyltin	Tributyltin	Tetrabutyltin	Total Butyltins
HBI28p	Coral	0.29	0.16	0.29	0	0.74
HBI42a	Coral	0.09	0	0.05	0	0.14
HBI14p	Coral	0.29	0.05	0.19	0	0.53
HBI7p	Coral	0.09	0.02	0.03	0	0.14
HBI24p	Coral	0.25	0.04	0.02	0	0.31
HBI11p	Coral	0	0	0.02	0	0.02
HBI15p	Coral	0.07	0	0.02	0	0.09
HBI23p	Coral	0.09	0.04	0.04	0	0.17
MLC01	Coral	0	0	0.03	0	0.03
S1-CA	Conch	1.13	0.44	0.07	0	1.64
S1-CB	Conch	0.6	0.22	0.06	0	0.88
S2-CA	Conch	20.1	3.02	0.21	0	23.33
S2-CB	Conch	23.2	4.27	0.38	0	27.85
S3-CA	Conch	1.07	0.45	0.04	0	1.56
S3-CB	Conch	0.44	0.26	0.13	0	0.83
S4-CA	Conch	1.05	0.24	0.04	0	1.33
S4-CB	Conch	1	0.29	0.07	0	1.36
S5-CA	Conch	0.6	0.33	0.07	0	1
S5-CB	Conch	1.92	1.19	0.14	0	3.25

Appendix G. Trace and major elements detected in STEER coral and conch samples (µg/g dw).

Element	HBI28P	HBI42A	HBI14P	HBI7P	HBI24P
	Coral				
Al	201	0 U	0 U	0 U	0 U
Cr	0 U	1.25	0 U	1.52	0.732
Fe	275	53.7	31.9	42	50.7
Mn	19.6	7.76	8.52	7.25	10.1
Ni	2.3	8.33	0 U	2.28	2.43
Zn	14.8	9.77	5.88	2.38	3.62
Hg	0.00227	0.00248	0 U	0 U	0.00164
Ag	0.0134	0.0202	0 U	0.0134	0.0133
As	1.76	1.54	1.22	1.11	1.48
Cd	0 U	0.0467	0 U	0.0205	0 U
Cu	4.07	3.06	1.96	2.77	3.43
Pb	0.415	0.0842	0.161	0.0741	0.128
Se	0 U	0 U	0 U	0 U	0 U
Sn	0.0393	0 U	0 U	0 U	0 U

Qualifiers (Q): J=Below the MDL; U=Not detected

Element	HBI11P	HBI15P	HBI23P	MLC01
	Coral			
Al	0 U	0 U	0 U	0 U
Cr	0 U	0 U	0 U	0 U
Fe	27.9	32.3	82.6	54.7
Mn	10.2	8.07	11.8	8
Ni	0 U	1.78	0.954	1.58
Zn	3.29	1.87	10.2	2.04
Hg	0 U	0 U	0 U	0 U
Ag	0.0123	0.0169	0.0131	0.0138
As	1.02	0.984	1.57	0.611
Cd	0.0219	0.0177	0 U	0 U
Cu	2.07	2.44	2.06	2.37
Pb	0.14	0.0693	0.217	0.111
Se	0 U	0 U	0.116	0 U
Sn	0 U	0 U	0 U	0 U

Qualifiers (Q): J=Below the MDL; U=Not detected

Appendix G. Trace and major elements detected in STEER coral and conch samples (µg/g dw) (cont.)

Element	S1-CA	S1-CB	S2-CA	S2-CB	S3-CA
			Conch		
Al	113	128	157	126	38.8
Cr	3.03	2.3	1.45	2.17	4.64
Fe	783	731	808	737	493
Mn	55.8	40	355	161	122
Ni	5.18	3.25	7.89	4.23	5.08
Zn	307	299	1320	521	1170
Hg	0.0544	0.0606	0.0949	0.0996	0.259
Ag	0.228	0.241	0.164	0.18	0.421
As	25.3	18.5	21.5	18.3	46.9
Cd	1.45	1.78	1.2	0.887	3.75
Cu	48.8	47.9	121	105	36
Pb	0.424	0.454	1.32	1.2	0.368
Se	0.758	0.682	1.11	0.814	1.2
Sn	1.74	6.18	6.83	2.67	11.8

Qualifiers (Q): J=Below the MDL; U=Not detected

Element	S3-CB	S4-CA	S4-CB	S5-CA	S5-CB
			Conch		
Al	38.5	707	828	67.7	86.5
Cr	1.53	8.57	4.09	2.08	4.24
Fe	284	1720	1530	324	435
Mn	50.4	113	94.8	77	62.1
Ni	3.08	13.6	8.49	3.03	4.06
Zn	170	297	174	252	325
Hg	0.336	0.197	0.195	0.215	0.882
Ag	1.33	1.12	0.85	0.482	3.75
As	17.6	67.6	35.2	39.7	36.5
Cd	1.57	3.43	2.02	1.76	1.73
Cu	88.4	122	107	70	101
Pb	0.212	0.674	0.809	0.243	0.418
Se	1.24	1.24	1.14	1.31	2.38
Sn	12.7	7.7	0.322	0.034	0.0413

Qualifiers (Q): J=Below the MDL; U=Not detected

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Rebecca Blank, *Deputy Secretary*

National Oceanic and Atmospheric Administration
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National Ocean Service
Holly Bamford, *Assistant Administrator for Ocean Service and Coastal Zone Management*

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