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Chemical contaminants in surficial sediment in Coral and Fish Bays, St. John, U.S. Virgin Islands

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ABSTRACT

Land based sources of pollution have the potential to negatively impact coral reef ecosystems. Many coral systems, including environmentally sensitive marine protected areas, do not have assessments of their chemical contaminant status (magnitude and extent). Without a status assessment, it is impossible to measure change in a system. This study presents surficial sediment data from Coral and Fish Bays (St. John, US Virgin Islands (USVI)). Portions of these bays are included in Virgin Islands National Park, and Virgin Islands Coral Reef National Monument. A suite of analytes (PCBs, PAHs, pesticides, heavy metals, butyltins) was quantified and compared against other regional data and against previously published sediment quality guidelines (SQG). Contamination from toxic contaminants in the system was generally low when compared to other similar studies and potential toxicity thresholds (SQG). Exceptions to this were copper and total chlordane which exceeded the Effects Range Low (ERL) sediment quality guideline, indicating possible sediment toxicity. This assessment will be useful to coastal managers for tracking environmental change, and ensuring that this marine protected area remains relatively free from toxic contamination.

1. Introduction

1.1. Land based sources of pollution

A variety of anthropogenic stressors, such as climate change, overfishing and land based sources of pollution, have the potential to adversely impact corals reef ecosystems. Although pollution is frequently cited as adversely affecting coral reef health (Fabricius, 2005; Dubinsky and Stambler, 1996), the concentration of chemical contaminants present in coral reef ecosystems is not well characterized, and typically even less is known regarding linkages between contaminants and coral condition. Developing an understanding of which chemical contaminants are present, how and to what extent they affect the health of corals and coral reefs would help focus management efforts, especially in marine protected areas such as national parks.

1.2. Contaminants in the marine environment

Since 1986, NOAA's National Status and Trends Program (NS&T) has monitored and assessed the nation's estuarine and coastal waters for chemical contaminants in a variety of matrices (e.g. bivalve tissues, sediments). Characterization of contaminants in coral reef ecosystems, including in the water column, sediments and coral tissues, represents a relatively recent expansion of NS&T activities. An assessment of environmental contamination is critical to the management of ecosystems; it is impossible to detect change, or understand how well management actions are working without an initial assessment.

The suite of NS&T chemical contaminants analyzed for this project is shown in Table 1. The analytes include 58 polycyclic aromatic hydrocarbons (PAHs), 31 organochlorine pesticides, 38 polychlorinated biphenyls (PCBs), four butyltins, and 16 trace and major elements. These analytes represent a broad spectrum of potential sources (transportation, agriculture, industry) and potential impacts. The nature, sources and environmental significance of each of the contaminant classes to coral reef ecosystems have been discussed in detail previously (Pait et al., 2007, 2010). In

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Table 1
List of analytes.

PAHs – Low Molecular Weight	PAHs – High Molecular Weight	PCBs	Organochlorine Pesticides
Naphthalene	Fluoranthene	PCB8/5	Aldrin
1-Methylnaphthalene	Pyrene	PCB18	Dieldrin
2-Methylnaphthalene	C1-Fluoranthenes/Pyrenes	PCB28	Endrin
2,6-Dimethylnaphthalene	C2-Fluoranthenes/Pyrenes	PCB29	Heptachlor
1,6,7-Trimethylnaphthalene	C3-Fluoranthenes/Pyrenes	PCB31	Heptachlor-Epoxide
C1-Naphthalenes	Naphthobenzothiophene	PCB44	Oxychlordane
C2-Naphthalenes	C1-Naphthobenzothiophenes	PCB45	Alpha-Chlordane
C3-Naphthalenes	C2-Naphthobenzothiophenes	PCB49	Gamma-Chlordane
C4-Naphthalenes	C3-Naphthobenzothiophenes	PCB52	Trans-Nonachlor
Benzothiophene	Benz(a)anthracene	PCB56/60	Cis-Nonachlor
C1-Benzothiophenes	Chrysene	PCB66	Alpha-HCH
C2-Benzothiophenes	C1-Chrysenes	PCB70	Beta-HCH
C3-Benzothiophenes	C2-Chrysenes	PCB74/61	Delta-HCH
Biphenyl	C3-Chrysenes	PCB87/115	Gamma-HCH
Acenaphthylene	C4-Chrysenes	PCB95	2,4′-DDT
Acenaphthene	Benzo(b)fluoranthene	PCB99	4,4′-DDT
Dibenzofuran	Benzo(k)fluoranthene	PCB101/90	2,4′-DDD
Fluorene	Benzo(e)pyrene	PCB105	4,4′-DDD
C1-Fluorenes	Benzo(a)pyrene	PCB110/77	2,4′-DDE
C2-Fluorenes	Perylene	PCB118	4,4′-DDE
C3-Fluorenes	Indeno(1,2,3-c,d)pyrene	PCB128	DDMU
Anthracene	Dibenzo(a,h)anthracene	PCB138/160	1,2,3,4-Tetrachlorobenzene
Phenanthrene	C1-Dibenzo(a,h)anthracenes	PCB146	1,2,4,5-Tetrachlorobenzene
1-Methylphenanthrene	C2-Dibenzo(a,h)anthracenes	PCB149/123	Hexachlorobenzene
C1-Phenanthrene/Anthracenes	C3-Dibenzo(a,h)anthracenes	PCB151	Pentachloroanisole
C2-Phenanthrene/Anthracenes	Benzo(g,h,i)perylene	PCB153/132	Pentachlorobenzene
C3-Phenanthrene/Anthracenes		PCB156/171/202	Endosulfan II
C4-Phenanthrene/Anthracenes	**Trace Elements (cont.)**	PCB158	Endosulfan I
Dibenzothiophene	Copper	PCB170/190	Endosulfan Sulfate
C1-Dibenzothiophenes	Iron	PCB174	Mirex
C2-Dibenzothiophenes	Lead	PCB180	Chlorpyrifos
C3-Dibenzothiophenes	Manganese	PCB183	
	Mercury	PCB187	**Butyltins**
Trace Elements	Nickel	PCB194	Monobutyltin
Aluminum	Selenium	PCB195/208	Dibutyltin
Antimony	Silver	PCB199	Tributyltin
Arsenic	Tin	PCB201/157/173	Tetrabutyltin
Cadmium	Zinc	PCB206	
Chromium		PCB209	

summary these pollutants can have a variety of deleterious effects on corals (including coral zooxanthelle), aquatic plants, fish, macroinvertebrates and benthic infauna. Furthermore, because NS&T quantifies these analytes around the country, it is easy to put newly measured values into a larger (regional and national) context.

Surface sediments were selected as the analytical matrix because they tend to integrate contaminants from the water column. Unlike water chemistry, which can change on the order of hours, sediment chemistry is representative of the system over a much longer period of time (i.e. years).

1.3. Study site description

The island of St. John has a topography characterized by steep slopes with over half the island having a slope greater than 30% (Anderson, 1994). The island is volcanic in origin, resulting in geology dominated by volcanic rocks (Rankin, 2002) overlain with shallow, well drained gravelly clay loam soils (USDA, 1995).

Precipitation on the island is driven by tropical storms from May to November and by cold fronts from December to April (Calversbert, 1970); precipitation ranges across the island from 90 to 140 cm yr^{-1}. Owning to the relatively impermeable bedrock, there is very little groundwater on the island and precipitation events results in very flashy hydrographs (MacDonald et al., 1997) for the intermittent streams (ghuts) resulting in large runoff events that transport sediments and sediment associated toxins to the coastal zone.

The island is mostly covered by second generation forest growth. Almost the entire island was clear-cut to make way for sugar cane production during the colonial era, and this had dramatic impacts to hydrology and soil composition of the island. Most of the vegetation on St. John today consists of both native and nonnative species competing for space.

The seascape surrounding the island of St. John consists of coral reefs, seagrass beds, algal meadows, rock outcrops and sand plains. It too has seen dramatic changes caused by anthropogenic and natural disturbances. Intensive fishing has caused the loss of several spawning aggregations, as well as severe declines in size and abundance of important fish species (Beets and Friedlander, 1999; Beets and Rogers, 2002). Coral and seagrass habitat loss due to hurricanes and coral diseases has led to an ecosystem that is now dominated by macroalgae (Beets and Rogers, 2002). Nutrients and sediments have also been identified as important pollutants to these two ecosystems (Ramos-Scharron et al., 2007; CWP, 2008), and global climate change is affecting reefs worldwide (Rogers, 2013).

Virgin Islands National Park (VIIS) was established in 1956 to protect significant marine and terrestrial resources on the island of St. John. Submerged lands were added to the park in 1962 to further protect and preserve coral reefs and seascapes. The park consists of almost 30 square kilometers including approximately 2/3 of the island of St. John. The need to protect reefs from further degradation led to a Presidential Proclamation establishing Virgin Islands Coral Reef National Monument (VICR) in January 2001, which