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Organic contamination as a driver of structural changes of hydroid's assemblages of the coral reefs near to Havana Harbour, Cuba

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A B S T R A C T

Hydroid assemblage's responses to organic contamination were evaluated using sedimentary sterols as explanatory variables. At seven coral reef sites in the Havana west coast, hydroids were collected along three 10 m × 1 m, 10 m deep transects. Five sterols were analysed, *i.e.*, coprostanol, an indicator of faecal contamination, and cholestanol, cholesterol, stigmasterol and brassicasterol, indicators of biogenic organic matter inputs. The sampling sites were classified by level of contamination. A total of 65 species comprised the hydroid assemblages. Hydroids community abundance and richness decreased in the contaminated sites. Coprostanol had the highest relative importance for these variables and also for *Plumularia floridana* and *Clytia gracilis* abundances. *Obelia dichotoma* and *Halecium bermudense* were relatively abundant in the contaminated sites. The results indicate that faecal contamination negatively affected the hydroid assemblages, highlighting the importance of integrated biological and chemical indicators to evaluate the environmental conditions of the Havana coral reef.

1. Introduction

Coastal development increases the input of pollutants to marine habitats, negatively affecting biodiversity worldwide (Johnston and Roberts, 2009) and consequently affecting human health. Monitoring environmental changes caused by organic contamination is a challenge to coastal management (Islam and Tanaka, 2004). Scientists have proposed several analyses to determine the influence of environmental and human impacts on marine benthic communities (Warwick, 1988; Anderson and Willis, 2003; Anderson et al., 2008), which are considered environmental bioindicators. They can reflect the cumulative influence of pollution by changes in the abundance, richness and diversity of their communities (Rosenberg et al., 2004; Borja and Dauer, 2008; Venturini et al., 2008).

Sterols are an important class of molecules that indicate biogenic and anthropogenic organic matter (OM), due to their relative resistance to environmental degradation, which allows them to accumulate in sediments (Takada and Eganhouse, 1998). Coprostanol (5β(H)-colestan-3β-ol) is a faecal sterol used as a chemical marker of human waste inputs by sewage effluents to coastal environments (Martins et al., 2014a; Carreira et al., 2015; Cabral et al., 2018), and it is one of the most commonly tested abiotic markers of human interference on benthic marine macrofauna (Albano et al., 2013; Barboza et al., 2015; Souza et al., 2016). Other sterols, such as cholesterol (cholest-5en-3β-ol), cholestanol (5α(H)-cholestan-3β-ol), and brassicasterol (24-methylcholesta-5,22E-dien-3β-ol), are indicators of marine biogenic OM inputs, due to their ubiquitous presence in zooplankton and phytoplankton communities (Volkman, 2005). In addition, stigmasterol (24-ethylcholesta-5,22-E-dien-3β-ol) is a vascular plant marker and also of marine diatoms, cyanobacteria and prymnesiophycean algae (Volkman et al., 1998; Martins et al., 2011).

Hydroids are one of the less distinct organisms in coral reefs, due to their small size and uncoloured exoskeleton. Nevertheless, the morphological plasticity of some hydroids makes them a key group for detecting environmental changes in benthic marine biocoenoses (Gili and Hughes, 1995). Although few studies have used hydroids as environmental bioindicators, in the tropical coral reefs of Jamaica and Siladen Island (Indonesia), stenoecious species have been suggested as indicators of light intensity and water movement (Di Camillo et al., 2008). It is known that changes in the composition and distribution of

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Table 1
Characterization of sampling sites in the west coast of Havana, Cuba.

Sampling sites	Code	Latitude & longitude	Approximate distance from shore (m)	Nearest pollution sources	Distance from Havana Harbour (km)
Havana Bay	HB	23°′08′49″N 82°21′31″W	100	Havana Harbour	0.07
Maceo park	MA	23°′08′32″N 82°22′12″W	30–50	Raw sewage input	1.65
Almendares river outfall	ALM	23°08′04″N 82°24′53″W	50–100	Raw urban and industrial waste from Almendares river	5.9
16 Street	CA16	23°07′45″N 82°25′23″W	100	Minor domestic sewage discharge	6.9
70 Street	CA70	23°06′51″N 82°26′29″W	100	–	9.2
Emissary 180 Street	EM	23°05′40″N 82°28′05″W	100	Raw wastewater from Quibú river and sewage outfall	12.6
Santana river outfall	SA	23°04′25″N 82°31′37″W	50–100	Raw wastewater from less contaminated Santana river	19.1

hydroid communities and of resilient species are entirely connected to environmental changes (Di Camillo et al., 2008; Peña Cantero and Manjón-Cabeza, 2014).

The effects of environmental factors on hydroids were reviewed by Boero (1984). Some species resist poor water quality, and pollutants may even stimulate colony growth, while natural factors (salinity, temperature, turbidity, speed currents) can modulate the susceptibility of hydroid species to different pollutant concentrations. The sublethal responses of hydroids to pollutants include losses of hydrants and changes in growth and gonozooids production rates (Gili and Hughes, 1995). Otherwise, the effect of contamination on the biodiversity and structural changes of hydroid communities has been poorly studied until now.

Despite some environmental monitoring efforts, the port area of the Havana has been recognized as among the most contaminated aquatic ecosystems in the western coast of Havana city, Cuba (Aguilar et al., 2004; Yamiris et al., 2013) and in the wider Caribbean (Paz, 2004; Valdes, 2004; Villasol et al., 2010; UNEP-CEP, 2010; Romeu-Álvarez et al., 2012). In addition, several rivers without any treatment discharge contaminants from sewage and industrial activities directly to the marine ecosystem of Havana (Romeu, 2012), consequently affecting the health of benthic organisms and fish communities (De la Guardia et al., 2001; Aguilar et al., 2008; Hernández-Muñoz et al., 2008; Villiers and Alcolado, 2012; Busutil and Alcolado, 2012).

Integrated assessments of environmental conditions combined with biological indicators are still lacking in the Havana coast. In this study, we determined sterol concentrations in sediments as indicators of biogenic and anthropogenic OM inputs, in order to evaluate the influence of different OM sources on the coral reefs off the west coast of Havana. We also tested whether the gradient of sewage contamination, as indicated by faecal sterols, was a driver of variations in ecological descriptors (abundance and richness) and the spatial distribution of hydroids.

2. Study area

The study area is the subtidal coral reef zone off the west coast of Havana, Cuba. Four biotopes, Echinometra, rocky plain, terrace edge and terrace base, constitute the fringing coral reef (Aguilar et al., 2004). The similarity of the ecological zones parallel to the shore and the almost flat bottom of limestone conferee a relative homogeneity to this ecosystem in the study zone (González-Sansón and Aguilar, 2002; González-Díaz et al., 2003; Aguilar et al., 2004; Villiers and Alcolado, 2012). The sediments are sand and biogenic calcareous fragments (Pérez and Cánovas, 2006). Scleractinians, octocorals and sponges are common, and the macroalgae *Halimeda* spp. and *Lobophora* spp. were abundant and dominant in some of these sampling sites during survey.

The abundance and dominance of macroalgae change with the distance to the nutrient sources as contaminated rivers and submarine sewage outfalls. This was corroborated by studies of macroalgae community between clean and more impacted zones (González-Díaz et al., 2003) and in the determination of the environmental disturbs index between sampling sites in the coral reef of the coast of Havana Semidey (2013).

The mean sea surface temperatures (SST) in the dry (November to April) and rainy (May to October) seasons are approximately 25.7 °C and 28.8 °C, respectively, with mean surface salinities of approximately 36.2 and 35.9 PSU, respectively (Cuba Oceanology Institute, data from 2009 to 2014). The current flows < 1 km from the shore, and westward movements are caused by an anticyclone system (Arriaza et al., 2012), indicating that the fringing reef is affected by oceanic waters. To minimize the effects of these and other parameters as light exposition, heterogeneity, hydrodynamics, hydroids samples were collected at the same depth (10 m).

Contamination and overfishing have been the main impacts in this region for decades (Herrera and Martínez-Estalella, 1987; De la Guardia et al., 2001; González-Sansón and Aguilar, 2010). Two submarine sewage outfalls discharge domestic and industrial wastes in the area nearly 500 m offshore (Table 1). Effluents from these outfalls have also been released by ruptures at different depths and times (De la Guardia and González-Sansón, 2000a, 2000b; Hernández-Muñoz et al., 2008). Consequently, coral diseases, high percentages of macroalgae and low percentages of living coral cover prevail along with the dominant pollution-indicator species of gorgonians and sponges (González-Díaz et al., 2003; Hernández-Muñoz et al., 2008; Busutil and Alcolado, 2012).

The seven sampling sites were distributed within the 20 km coastline and are, from the east (near the Havana Harbour entrance) towards the west, Havana Bay (HB), Maceo Park (MA), Almendares (ALM), 16 Street (CA16), 70 Street (CA70), Emissary (EM) and Santana (SA) (Fig. 1). They are located between 30 and 100 m offshore and at different distances from the pollution sources, according to previous benthos and fish community studies in the area (De la Guardia et al., 2001; Aguilar et al., 2004; González-Sansón and Aguilar, 2010) (Table 1).

3. Material and methods

3.1. Sampling

Hydroids were collected on March 2013 by SCUBA diving, at 10 m depth. Three 10 × 1 m transects parallel to the shore and separated from each other by at least 5 m were surveyed in each of the seven sites. Along each transect, all visualized hydroids were taken with their