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Survey of PAH in low density residential stormwater ponds in coastal South Carolina: False dark mussels (*Mytilopsis leucophaeata*) as potential biomonitors

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ABSTRACT

The distribution of PAHs was studied in sediment and false dark mussels, *Mytilopsis leucophaeata*, of three brackish stormwater retention ponds on Kiawah Island, a gated residential community and golf resort. Impervious surface in pond watersheds ranged from 5 to 30%. Sediment concentrations were lower than those found in other studies of suburban residential areas, and there were no significant differences among ponds or seasons. Mean $\sum PAH_{16}$ values for sediments in Ponds 67, 100, and 37 were 184.7 ± 101.3 ng g^{-1}, 67.5 ± 26.0 ng g^{-1}, and 84.3 ± 75.5 ng g^{-1}, respectively. Mussel $\sum PAH_{16}$ concentrations from Pond 67 in August (mean 734.5 ± 148.1 ng g^{-1}), and from Pond 37 in December (mean 1115.1 ± 87.7 ng g^{-1}), were significantly higher than other ponds. Mean $\sum PAH_{16}$ values for mussels in Ponds 67, 100, and, 37 were 555.9 ± 219.7 ng g^{-1}, 312.5 ± 99.1 ng g^{-1} and 737.8 ± 419.8 ng g^{-1}, respectively. The mean biota-to-sediment ratio was 7.6 ± 8.1. Isomer ratios generally suggested pyrogenic sources. False dark mussels are a promising indicator species for PAH contamination because they are abundant, easy to sample, bioaccumulate PAH profiles representative of the time-integrated sediment profiles, and their PAH levels are less variable than either stormwater or sediment samples.

1. Introduction

Stormwater management ponds, including detention and retention ponds, are a commonly used best management practice for the control of stormwater runoff in the USA. In the state of South Carolina alone, it is estimated that over 8,000 ponds have been constructed (South Carolina Algal Ecology Lab, unpublished data, 2005). Their purpose is to reduce downstream impacts of stormwater runoff by reducing runoff peaks, removing sediments and pollutants, and enhancing overall stormwater quality through a variety of physical, chemical, and biological processes. However, the typical pond design results in the drainage of stormwater directly from road and street surfaces through concrete pipes into the ponds, thereby bypassing natural processes of contaminant removal. As suspended solids settle out on the pond bottom, contaminants may accumulate in the sediments. If these contaminants are bioavailable to epibenthic and pelagic organisms in the pond, they then could pose a risk to wildlife using the pond, such as wetland bird species and overwintering ducks. Pond outflows in coastal areas are often directly linked to tidal creeks and estuaries, thus they can have a significant impact on the water quality of these adjacent natural systems. Stormwater retention ponds function as the interface between development and estuarine ecological health as indicated by water quality, biodiversity and complexity, resilience, and sustainability.

One important class of contaminant associated with these stormwater management ponds are polycyclic aromatic hydrocarbons (PAHs) (Fernandez and Hutchinson, 1992; Marsalek and Marsalek, 1997; Marsalek et al., 2002; Kamalakkannan et al., 2004). PAHs are organic compounds that consist of two or more aromatic (benzene) rings. These compounds are a natural part of fossil fuels, and are formed as products of incomplete combustion. Natural sources of PAHs in the environment include forest and grass fires, volcanoes (Nagpal, 1993), and fossil fuels such as coal and oil, where PAHs have formed as result of diagenetic processes. The main anthropogenic sources of PAHs are coal combustion and vehicle emissions (Dickhut et al., 2000). Other anthropogenic sources include wood burning, industrial emissions, used motor oil and fuel drips and spills, tire wear, asphalt, tar, small engine exhaust, creosote, and waste incineration.

The PAHs quantified in this study were naphthalene (NAPT), acenapthylene (ACNY), acenapthene (ACEN), fluorene (FLUR), phenanthrene (PHEN), anthracene (ANTH), fluoranthene (FLTH), pyrene (PYR), benzo(a)anthracene (B[a]A), chrysene (CHRY), benzo(b)fluoranthene (B[b]F), benzo(k)fluoranthene (B[k]F), benzo(a)pyrene (B[a]P), dibenz(a,h)anthracene (D[ah]A), benzo(g,h,i)perylene

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(B[ghi]P), and indeno(1,2,3,c,d)pyrene (INPY). The first six PAHs listed (NAPT through ANTH) are considered low molecular weight (LMW) PAHs, and the final ten PAHs listed (FLTH through INPY) are considered high molecular weight (HMW) PAHs.

Mussels are commonly used as biomonitoring organisms for PAH contamination in both marine and freshwater environments (Utvik et al., 1999; Piccardo et al., 2001; O'Connor, 2002; Hellou et al., 2005; Oros and Ross, 2005) because they are sessile, have high filtration rates (de Lafontaine et al., 2000), bioaccumulate PAHs (D'Adamo et al., 1997), and capture PAH profiles representative of the time-integrated source in their tissues since they have limited ability to biotransform PAHs (Baumard et al., 1998a; Naes et al., 1998). Mussels are filter-feeding organisms that mainly accumulate soluble PAHs or PAHs associated with suspended solids (Baumard et al., 1998a). As such, the PAH concentrations in their tissues can be used to estimate that fraction of the total PAHs in the system which are bioavailable (Richman and Somers, 2005).

The false dark mussel, *Mytilopsis leucophaeata,* is a member of the family Dreissenidae and is closely related to the invasive zebra mussel, *Dreissena polymorpha* (Therriault et al., 2004). Although false dark mussels have not previously been used to study PAH contamination, they are an ideal indicator organism for coastal stormwater retention ponds because they are widespread and able to colonize these brackish ponds quickly (Rajagopal et al., 2005a). This mussel is epibenthic and is easy to collect because it uses byssal threads to attach itself to solid substrates like concrete pipes or submerged wood (Rajagopal et al., 2005b). The false dark mussel is a euryhaline species that is native to North America and is found in estuarine environments of the east coast from Florida to Massachusetts (Marelli and Gray, 1983). It is most commonly found in water with salinity ranging from 3 to 15 ppt (Claudi and Mackie, 1994). The false dark mussel grows quickly, approximately 1 mm per month (Laine et al., 2006), their average size is 1 to 3 cm when mature, and their life span is 3 to 5 years (Therriault et al., 2004). Because of their high lipid content (up to 15 percent) (Bruner et al., 1994), Dreissenidae mussels are especially well suited to capturing PAHs, many of which are lipophilic. *D. polymorpha* filters particles from 1 to 35 μm in size and feeds on the organic fraction (Gossiaux et al., 1998; Sprung and Rose, 1998). *D. polymorpha*, and other mussels commonly used for mussel watch such as the blue mussel, *Mytilus edulis* (O'Connor, 2002), generally prefer particles from 15 to 40 μm (Winkel and Davids, 1982). The particle size most efficiently filtered by these mussels corresponds to the particle size of soot particles, to which high molecular weight PAHs are commonly adsorbed (Vo-dinh, 1989).

The objective of this study was to investigate sediment PAH concentrations in three residential stormwater retention ponds on Kiawah Island (South Carolina) and evaluate the utility of false dark mussels as a biomonitor of PAH contamination. These stormwater ponds were chosen because the land use in the pond watersheds represented different intensities of primarily residential development. The relative abundance of PAH analytes in sediments was used to investigate probable PAH sources, and the relationship between sediment and mussel tissue PAH concentrations was explored.

2. Materials and methods

2.1. Study area

The three brackish stormwater retention ponds (Ponds 67, 100, and 37) are located on Kiawah Island, a barrier island in southeastern South Carolina (Fig. 1). Kiawah Island is a gated community characterized by large residences, numerous golf courses and

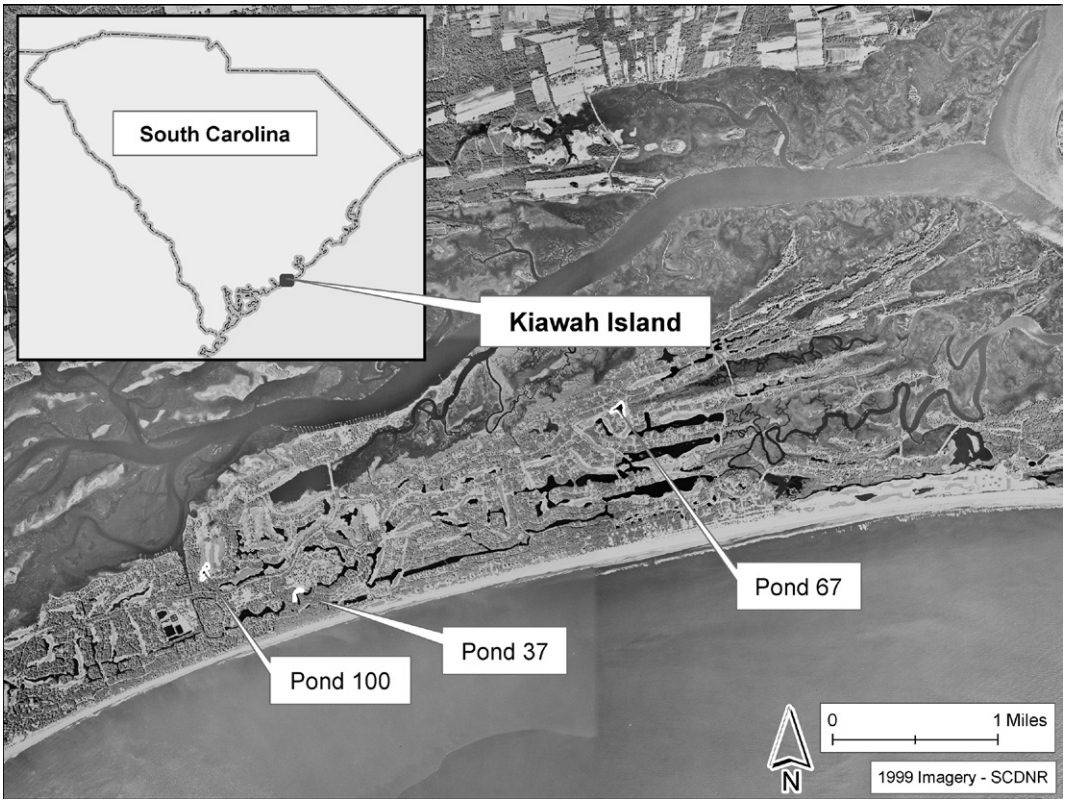

Fig. 1. Project Location - Kiawah Island, a barrier island on the southeastern South Carolina coast. Sediment and mussel tissue PAH concentrations were studied at three sites each in the three highlighted brackish retention ponds; Pond 67, Pond 37, and Pond 100.