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Daily relative dog abundance, fecal density, and loading rates on intensively and minimally managed dog-friendly beaches in central California

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ABSTRACT

Due to increased concerns regarding fecal pollution at marine recreational beaches, daily relative dog abundance and fecal density were estimated on an intensively managed (Beach 1) and a minimally managed (Beach 2) dog beach in Monterey County, California. Fecal loading and factors predictive of fecal deposition also were assessed. After standardizing for beach area, daily beach use and fecal densities did not differ between beaches and yearly fecal loading estimates revealed that unrecovered dog feces likely contributes significantly to fecal contamination (1.4 and 0.2 metric tonnes/beach). Detection of feces was significantly associated with beach management type, transect position relative to mean low tideline, presence of beach wrack, distance to the nearest beach entrance, and season. Methodologies outlined in this study can augment monitoring programs at coastal beaches to optimize management, assess visitor compliance, and improve coastal water quality.

1. Introduction

Beach advisories in the United States have increased 7–8% each year since 2005, with the number of advisory and beach closure days exceeding 24,000 in recent years (Dorfman and Sinclair Rosselot, 2011). More than two-thirds of these advisories were issued because fecal indicator bacteria (FIB) levels in beach water exceeded public health standards. Because elevated FIB levels have been correlated with an increased risk of illness, culturable FIB, including *Escherichia coli* and enterococci, are monitored to assess surf zone microbiological water quality and to protect public health at recreational beaches (Wade et al., 2003).

Fecal pollution may be introduced into the aquatic environment from point sources (e.g., wastewater treatment facilities and sewer overflows), and also diffuse nonpoint sources associated with coastal and shoreline development (e.g., leaking septic tanks, urban or agricultural runoff, boat discharges, bathers, and local domestic or wild animal populations) (Halliday and Gast, 2011). Dog waste has been identified as a significant source of fecal pollution in many coastal watersheds (Whitlock et al., 2002; Kitts et al., 2010; Schriewer et al., 2010; Ervin et al., 2014). Furthermore, previous studies that have quantified markers (Silkie and Nelson, 2009) and FIB (Wright et al., 2009) in dog feces demonstrate the impact that even a small number of dogs could have on water quality (Ervin et al., 2014).

California has approximately 60 dog-friendly beaches (Foster, 2006). With few exceptions these beaches receive excellent to very good water quality grades (A or B) during months with low precipitation (Heal the Bay, 2013–2014). However, during wet weather, > 75% of these beaches earn failing grades (Heal the Bay, 2013–2014). With an estimated 85,000 dogs in Monterey County alone (United States Census Bureau, 2010), and < 10 dog-friendly beaches, dog owners and canine advocacy groups are increasingly lobbying for greater access to area beaches to enjoy recreational activities with their companions. However, strong negative feelings are sometimes expressed by communities regarding beach access for canine and park visitors, due to concerns regarding disturbance, fecal deposition, and pollution (Foster, 2006; Wright et al., 2009).

Current water quality standards in most countries focus on control of human fecal contamination and minimally assess risk posed by fecal contamination from animal sources, including pets (WHO, 2012). Although potential for transmission of fecal pathogens from domestic dogs to humans is not well characterized (Ashford and Snowden, 2000), exposure to pet feces can be a significant source of protozoal and bacterial infection for humans (Stehrgreen and Schantz, 1987; Tan, 1997; Robertson et al., 2000). Recent prevalence studies have demonstrated variable shedding of potentially pathogenic parasites (e.g.,

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Cryptosporidium parvum and *Giardia duodenalis*) and bacteria (e.g., *Campylobacter* spp., *Salmonella enterica*) from dogs in Monterey County (Oates et al., 2012a; Oates et al., 2012b). These potential pathogens could impact people, pets, and wildlife populations.

Exposure to fecal contaminated water has been linked with adverse health effects including fever, nausea, gastroenteritis, and cold and flu-like symptoms, such as nasal congestion, sore throat, fever and cough (Curriero et al., 2001). Although the majority of illnesses transmitted through recreational water use are relatively mild and self-limiting, a number of waterborne pathogens (e.g., noroviruses, adenoviruses, *C. parvum*, *G. duodenalis*, *Campylobactor* spp., *S. enterica*) can cause severe human illness, especially in immunosuppressed individuals (Pond, 2005; Yoder et al., 2008; Wyn-Jones et al., 2011).

Bacterial fecal contamination from dogs has been quantified using microbial source tracking (MST) markers (Ervin et al., 2014; Riedel et al., 2015), and based on census methods, with the assumption that 50–100% of observed dogs defecated at least once while visiting the beach (Wright et al., 2009; Wang et al., 2010). In contrast, no prior studies have estimated canine fecal loading of public beaches based on direct measurement of fecal deposition.

In response to the aforementioned data gaps, this study was designed to 1) estimate daily relative dog abundance at an intensively managed and at a minimally managed dog beach in Monterey County, California; 2) determine daily fecal density rates and estimate fecal loading for both beaches; and 3) assess risk factors that could be used to predict fecal deposition. It was hypothesized that greater canine fecal deposition would be observed on a dog-accessible beach with minimal municipal oversight, when compared to a beach with a formal municipal, dog-friendly management program. It also was thought that defined risk factors, such as distance from the nearest beach entrance and season, would be predictive of fecal deposition. Study findings may help to inform and optimize beach management, ultimately improving beach and water quality at dog-accessible beaches.

2. Materials and methods

2.1. Site description

The two study beaches selected are the only marine recreational beaches in Monterey County that offer unrestricted, off-leash access for dogs (Fig. 1). Carmel City Beach (Beach 1; 36.555278, −121.923333) is an intensively managed beach characterized by an average ambient temperature of 12.8 °C (14.0 °C during summer months and 11.6 °C during winter months) and an average annual rainfall of 444 mm (5.8 mm dry/68.0 mm wet seasons). The beach is approximately 1.6 km long and 100 m wide (160,000 m^2) and is characterized by a gentle slope, fine grain sand, and large dunes with intermittent patches of vegetation. Unrestricted off-leash access is permitted along the entire beach. This beach has > 10 access points (including 6 within the study area), and each entrance features a dog waste station with a bag dispenser and a trash receptacle (Fig. 2). Signs also are posted along the pedestrian walkway parallel to the beach, advising visitors to clean up after their dogs (Fig. 1). The city provides biodegradable plastic bags for this purpose and the Carmel Police Department is responsible for enforcement. City employees maintain the beach, and a community group assists with monthly beach cleanups.

Moss Landing Sand Spit or Island Beach (Beach 2; 36.813611, −121.79055600) is a minimally managed, dog-friendly beach maintained by the County of Monterey and has an average ambient temperature of 14.4 °C (16.6 °C during summer months and 12.2 °C during winter months) and an average annual rainfall of 370 mm (21.7 mm dry/56.0 mm wet seasons). The beach is approximately 550 m long and 50 m wide (27,500 m^2) and is characterized by a gentle to medium slope, fine to coarse grain sand, and low dunes with intermittent patches of vegetation. Dogs are allowed off-leash on the beach from the south jetty to the remnants of the Moss Landing Pier. This beach has three access points (Fig. 3); during this study, none of the entrances had posted regulations or signage regarding dog waste, and only one entrance featured a waste receptacle (Fig. 1).

2.2. Beach surveys

Adjacent 100 m^2 (10 m long by 10 m wide) belt transects were established across Beach 1 (n = 1000) and Beach 2 (n = 275) parallel to the mean low tideline and extending up to the vegetation/dune lines on each beach. Transect surveys were conducted at each beach during three consecutive days, twice during the dry season (July and October 2008), and twice during the wet season (March and April 2010) (Gese, 2004). Temporal delineations for season were based on average climactic patterns for the central California coast with respect to rainfall, air and water temperature (Caffrey, 2002). Surveys were conducted at both beaches during wet and dry seasons, non-holiday week and weekend days, and between the early and late afternoon to include peak and non-peak attendance times (King and McGregor, 2012).

2.3. Daily relative dog abundance

A daily relative abundance index for dogs at each beach was determined using a modified direct-count census (Henke and Knowlton, 1995). Briefly, a single observer recorded all dogs during a one-hour period on each beach. Only unique individuals were counted, with animal identity based on natural markings, sex, and breed (Campos et al., 2007). The number of dogs recorded during each survey was then multiplied by 16, the average number of daylight hours. To account for differences in beach size, daily relative dog abundance was standardized by beach area (m^2). Daily relative abundance per unit area was calculated using the total area of each beach. Daily relative dog abundance, divided by the total beach surface area provided estimates of usage rates (dogs/m^2/day) for each beach. A two-sample *t*-test was used to analyze differences in daily relative dog abundance indices between seasons, and between beaches. Analyses were performed using Stata/LC 11.1 (Stata-Corp.) and *P*-values < 0.05 were considered statistically significant.

2.4. Daily fecal density and loading

To ensure that only freshly deposited canine feces were included in determinations of fecal density and fecal loading, all visible feces were removed from the beach surface the day before each survey. During each survey, fecal deposits had GPS coordinates logged and were then collected in tared plastic bags to be weighed to the nearest 0.1 g in the laboratory within 24 h. Daily fecal density (D_i) was calculated as $D_i = n_i / (L \times W)$, where n_i is the number of feces observed during transect i, L the length of the transect and W the width of the transect belt (Hill et al., 2005). Fecal loading per unit area was calculated using the area of each transect. The fecal mass (wet weight in g), divided by the total transect area provided estimates of daily fecal accumulation rates (g/m^2/day) for each transect, and were used to estimate fecal accumulation rates for each beach (Tate et al., 2000). To assess overall impacts on each beach, yearly fecal loading estimates were obtained by multiplying mean daily fecal loading estimates by 365 (days per year), and then multiplying by 10^{-6} to obtain weight in metric tonnes.

2.5. Risk factor analyses

Logistic regression approaches were used to investigate associations between defined risk factors in relation to the presence of feces observed on each transect quadrat (Hosmer et al., 2013). Risk factors evaluated included beach location (Beach 1, Beach 2), transect position relative to the mean low tide line (high, middle-high, middle, middle-low, low), presence or absence of beach wrack, distance to the nearest beach entrance (0–25 m, 26–50 m, 51–75 m, 76–100 m, > 100 m),