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Variability of fecal indicator bacteria in flowing and ponded waters in southern California: Implications for bacterial TMDL development and implementation

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A B S T R A C T

Recreational water quality is assessed by using water quality objectives for fecal indicator bacteria (FIB) including total coliform, fecal coliform (or *E. coli*), and/or *Enterococcus*. It is required under the Clean Water Act that a TMDL be developed for a bacteria-impaired water body. The development and implementation of bacterial TMDLs has proven challenging and often difficult due to unknown source(s) of FIB. This study found that FIB levels varied significantly in flowing water, ponded water, and associated sediment. FIB levels in isolated ponded water in waterways were significantly higher than in flowing water. Sediment under ponded water contained a great amount of FIB. Furthermore, FIB concentrations in ponded water tended to increase with increasing water temperature and to decrease with increasing water salinity. The result provides the field evidence of survival/growth of FIB in water and sediment under ambient conditions in southern California. A holistic approach including natural sources (e.g., a reference system) should be considered for practical and applicable purposes while developing and implementing bacterial TMDLs for pathogen-impaired waterbodies.

1. Introduction

California's beaches receive more visitors than the beaches of all other states combined and coastal water pollution remains a significant public health concern in southern California. More than 5000 beach closing and health advisory days were reported across California in 2005. Health advisories are usually posted on a beach where fecal indicator bacteria (FIB), including total coliform, fecal coliform (or *E. coli*), and *Enterococcus*, exceed recreational water quality standards established by the State of California. When the bacterial concentration in a waterbody exceeds the FIB water quality criteria, the waterbody may be identified on the Clean Water Act Section 303(d) list of impaired waters. Section 303(d) requires the development and implementation of total maximum daily loads (TMDLs) for the impaired waterbody. Bacteria have been listed as the priority pollutant with regard to impairments reported for the nation, with a total of ~2700 bacterial TMDLs being developed (USEPA, 2005). In California, about 300 waterbodies have been 303(d) listed as impaired by FIB. Among these listed waterbodies, some 40 TMDLs for FIB have been developed and approved by USEPA in 2002, which placed FIB TMDLs at the top of all TMDLs developed so far in California.

It is challenging and often difficult to address water quality impairment effectively while developing and implementing TMDLs without knowing the source of contamination, and the identification and elimination of sources of fecal pollution have become major priorities in California. The sources of FIB

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are generally believed to be from the wastes of humans or animals due to accidental sewage spills, leaking sewage infrastructure, inappropriate disposal of pet/livestock wastes, or waste droppings from wildlife (Boehm et al., 2003; Grant et al., 2000, 2001; Haack et al., 2003; Noble et al., 2004). However, the fact that high FIB levels have been found in areas where there were no external inputs indicates sources other than humans or animals. This implies that a natural entity such as ambient water or sediment may serve as FIB sources (Ishii et al., 2007; Lee et al., 2006). Presented here are the study results of FIB concentrations in flowing water, ponded water, and collected in San Diego, CA, indicating significant variability of FIB in those environments and implications to FIB TMDL development and implementation.

2. Description of study area and methods

The study area included 10 watersheds within the San Diego region in southern California (Fig. 1). Most of the surface water streams of the region are interrupted in character, having both perennial and ephemeral components. This is a result of the regional rainfall pattern and the development of surface water impoundments. The region has an average annual rainfall of ~250 mm in the coastal area with distinct climatic periods: a dry (semi-arid) period from late April to mid-October, and a wet period from mid-October through late April. The wet period typically provides 85–90% of the annual average rainfall. The San Diego region coastal climate is generally mild with annual average temperatures near 18 °C, but the temperature is high in August and September, particularly in inland areas. As the whole or portions of a creek dried out in late August through October, there was no flowing water in the waterway, with ponded water remaining at some sampling locations for a period of time before disappearance.

Land use in the region is distinctive and dominated by undeveloped vacant lands and park/recreational areas. These two land uses encompass nearly 75% of the total land area in the region. Residential and agricultural land uses

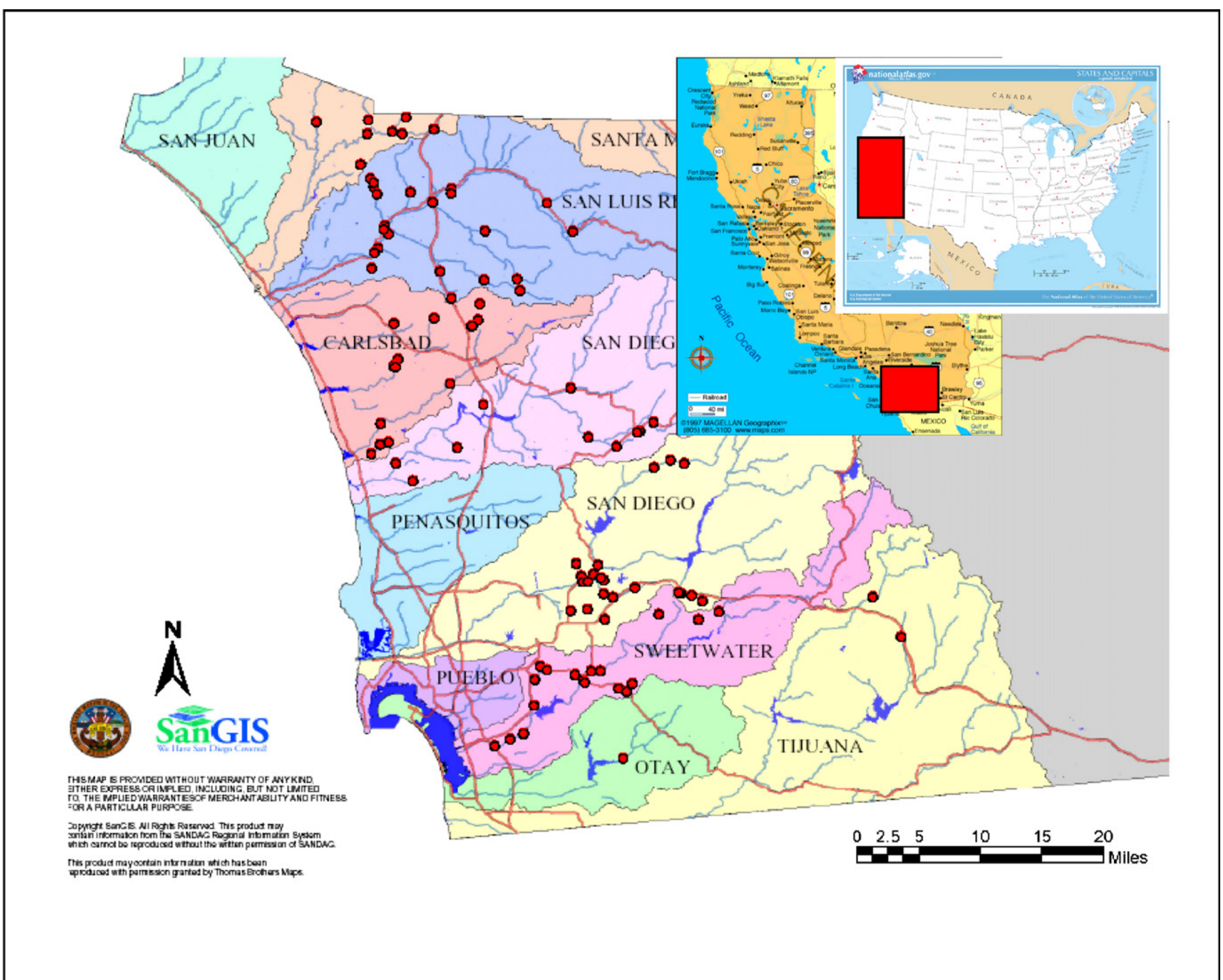

Fig. 1 – San Diego Region. Major watersheds from north to south include Santa Margarita, San Luis Rey, Carlsbad, San Dieguito, San Diego, Sweetwater, Otay, and Tijuana Rivers. Select monitoring stations are shown in red dots.