Environ Monit Assess (2009) 156:343–360
DOI 10.1007/s10661-008-0489-x

# Multi-scale landscape factors influencing stream water quality in the state of Oregon

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Received: 14 January 2008 / Accepted: 24 July 2008 / Published online: 30 August 2008


**Abstract** Enterococci bacteria are used to indicate the presence of human and/or animal fecal materials in surface water. In addition to human influences on the quality of surface water, a cattle grazing is a widespread and persistent ecological stressor in the Western United States. Cattle may affect surface water quality directly by depositing nutrients and bacteria, and indirectly by damaging stream banks or removing vegetation cover, which may lead to increased sediment loads. This study used the State of Oregon surface water data to determine the likelihood of animal pathogen presence using enterococci and analyzed the spatial distribution and relationship of biotic (enterococci) and abiotic (nitrogen and phosphorous) surface water constituents to landscape metrics and others (e.g. human use, percent riparian cover, natural covers, grazing, etc.). We used a grazing potential index (GPI) based on proximity to water, land ownership and forage availability. Mean and variability of GPI, forage availability, stream density and length, and landscape metrics were related to enterococci and many forms of nitrogen and phosphorous in standard and logistic regression models. The GPI did not have a significant role in the models, but forage related variables had significant contribution. Urban land use within stream reach was the main driving factor when exceeding the threshold (≥35 cfu/100 ml), agriculture was the driving force in elevating enterococci in sites where enterococci concentration was <35 cfu/100 ml. Landscape metrics related to amount of agriculture, wetlands and urban all contributed to increasing nutrients in surface water but at different scales. The probability of having sites with concentrations of enterococci above the threshold was much lower in areas of natural land cover and much higher in areas with higher urban land use within 60 m of stream. A 1% increase in natural land cover was associated with a 12% decrease in the predicted odds of having a site exceeding the threshold. Opposite to natural land cover, a one unit change in each of manmade barren and urban land use led to an increase of the

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likelihood of exceeding the threshold by 73%, and 11%, respectively. Change in urban land use had a higher influence on the likelihood of a site exceeding the threshold than that of natural land cover.

**Keywords** Nutrients · Nitrogen · Phosphorus · Enterococci · Grazing potential index · GPI · Logistic regression · Oregon

## Introduction

Composition of land use and land cover in a watershed has a direct effect on the condition of streams. Surface water quality is influenced by the extent of anthropogenic and animal (domestic livestock, feral animals and wildlife) inputs within a watershed. Commercial livestock grazing comprises approximately 70% of the land use in the arid western United States (Fleischner 1994). Over the years, lack of adequate grazing management has damaged more than 80% of the stream and wetland riparian ecosystems (Belsky et al. 1999, 2002). Livestock tend to be located in areas where food and water are available (Kauffman and Krueger 1984). Extreme disturbance (both from grazing and trampling) and livestock waste can be found adjacent to the water with disturbance (primarily from grazing) progressively decreasing as distance increases away from the water source. This pattern of disturbance has been shown an effect on vegetation characteristics (Lange 1969; Graetz and Ludwig 1978; Andrew and Lange 1986; Fusco et al. 1995), vegetation patterns (deSoyza et al. 1997; Nash et al. 1999), and soil microtopography (Nash et al. 2003).

The amount of nutrients and pathogens originating from livestock is dependent on terrestrial hydraulic transport mechanisms to surface water. In the arid part of Eastern Oregon, the water table can be contaminated by infiltration of nutrients and pathogens through the overlying soil. This infiltration process is a function of the vegetation cover and structure, evapotranspiration, soil properties, and the number of grazing animals (e.g., horses, cows, wildlife). In the western part of Oregon, streams are more abundant, and livestock tend to concentrate in areas adjacent to streams depending on season, age class and type (VanWagoner et al. 2006). Input of nutrients and pathogens from livestock delivered to surface water is a function of livestock abundance and the proximity of their forage to stream (MacLusky 1960; Marsh and Campling 1970; Betteridge et al. 1986).

A need has been recognized to develop a method(s) for the assessment and evaluation of surface water nutrient and pathogen levels in the Western United States as a result of urbanization, livestock grazing and agriculture activities. Because information on location and number of cattle grazing is limited, this effort focuses on creating a grazing potential index (GPI) map of Oregon as a case study (Wade et al. 1998). The GPI uses, a combination of land cover, land ownership, distance to water, and slope to map the relative likelihood of presence of grazing cattle. GPI values range from 0 to 100, with higher values representing greater grazing potential.

Fecal bacteria (coliforms and streptococci) live in human and animal digestive systems and are used as indicators of possible sewage and nonpoint source contamination. Drinking or coming in contact (i.e., ingested and/or enter the skin through a cut or sore) with surface water contaminated with fecal material can infect humans with many diseases (e.g. skin rashes, urinary tract infections, meningitis). Certain types of bacteria are indicators of fecal material in the water column. Fecal coliform bacteria is normally measured in surface water to determine the level of contamination. Recently, the United States Environmental Protection Agency (USEPA) recommended using enterococci bacteria to indicate the presence of human and/or animal fecal materials (USEPA 2000). Water is safe for drinking when a single sample contains no more than 104 colony formed units (cfu) per 100 ml, or for multiple samples (from at least 24 h time intervals) a geometric mean of 35 cfu/100 ml for freshwater (APHA 1998).

The concentration of nitrogen and phosphorous in surface waters are also found to be related with human or animal presence. Nitrogen and phosphorous in water may come from sources such as runoff from agriculture land, rural and urban areas, waste water and auto exhausts, as well as livestock. The role and magnitude of each