Fecal Indicator Bacteria (FIB) Levels During Dry Weather from Southern California Reference Streams

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Abstract

High levels of fecal indicator bacteria (FIB) in surface waters is a common problem in urban areas that often leads to impairment of beneficial uses such as swimming and fishing. Once impaired, common management and regulatory solutions include development of Total Maximum Daily Loads (TMDLs) and other water quality management plans. A critical element of these plans is establishment of a "reference" level of exceedances against which to assess management goals and TMDL compliance. Unfortunately, existing "background" or reference data on contributions of FIB from undeveloped catchments during dry weather is limited to a small number of locations measured at few time points. The goal of this study was to provide information on indicator bacteria contributions from natural streams in undeveloped catchments throughout southern California during dry weather, non-storm conditions. To help establish a regional reference data set, bacteria levels (i.e. *Escherichia coli* (*E. coli*), enterococci and total coliforms) were measured from 15 unimpaired streams in 10 southern California watersheds weekly for one full year. Concentrations measured from reference areas were typically between one to two orders of magnitude lower than levels found in developed watersheds. Nearly 82% of the samples did not exceed daily and monthly bacterial indicator thresholds, demonstrating good bacteriological water quality in natural streams throughout southern California. Indicator bacteria levels fluctuated seasonally with an average of 79% of both enterococci and total coliforms exceedances occurring during summer months (June-August). Temperature, at all sites, explained about one-half the variation in total coliforms density ($r2 = 0.5$, $p<0.001$) suggesting that stream temperatures regulated bacterial populations. Accounting for natural background levels will allow for management targets that are more reflective of the contributions from natural sources.

Study Approach

Sampling Locations & Summary

- 2006-2007 Dry Weather
- Intensive Weekly Sampling
- 15 Unimpaired Streams
- 10 southern CA Watersheds (1.4 – 99.9 km^2)
- 590 samples analyzed for *E. coli*, enterococci and total coliforms
- Data used to establish background FIB concentrations

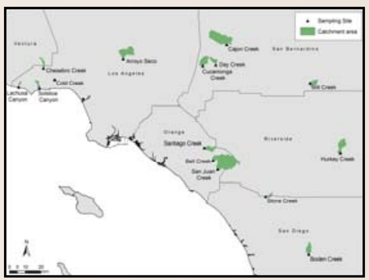

Figure 1. Map of reference bacteria sampling sites and watersheds in southern, California, USA.

Key Research Questions (?):

1. What are the "background" ranges of concentrations of FIB associated with dry weather flow from reference areas?
2. What is the frequency with which reference FIB levels exceed relevant water quality standards?
3. How do the ranges of FIB concentrations associated with reference areas compare with those associated with urban (developed) areas?
4. How does seasonality influence stream FIB levels associated with reference areas?

Background FIB Levels

1&2

Nearly 82% of the time, samples did not exceed daily bacterial thresholds (Fig. 2). *E. coli* had the lowest daily percent exceedance (1.5%).

A total of 13.7% of enterococci exceeded daily thresholds. The average enterococci level of these exceedances was 292 MPN/100 ml.

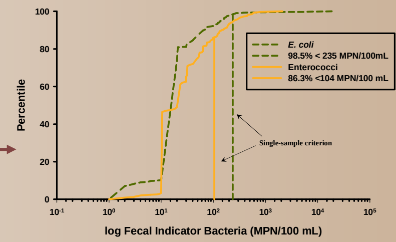

Figure 2. Dry season *E. coli* and enterococci cumulative density frequency plots (CDFs) of natural streams relative to freshwater quality standards. The CA daily (single-sample) criterion for *E. coli* = 235 MPN/100mL and enterococci = 104 MPN/100mL.

3

Natural sites were compared with data collected from watercourses draining developed areas of the Los Angeles basin to determine if significant differences existed between natural, developed and minor perturbation areas (Stein et al. 2007a, Stein et al. 2007b) (Figs 3-4).

Minor perturbation watersheds were mostly open space, but had small portions subject to agricultural or transportation related runoff. In one instance, a portion of the contributing watershed was affected by a recent fire. These small perturbations in the watershed led to dramatic changes in bacteria levels that moved sites away from reference conditions (Fig 3).

Natural streams were significantly lower than all other streams ($p < 0.001$). Minor perturbation streams were significantly lower than developed Ballona Creek ($p < 0.001$).

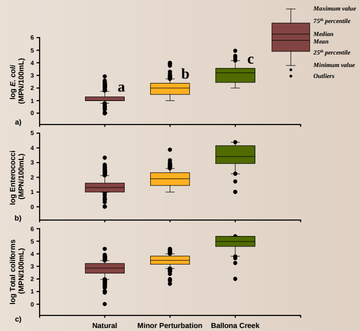

Figure 3. Distribution of log *E. coli* (a); enterococci (b); and total coliforms (c) concentrations in natural streams, streams with minor perturbations, and in developed Ballona Creek watershed in southern California, USA.

Figure 4. Cucamonga Creek, (a) San Bernardino, CA; a natural site and developed Ballona Creek (b), Los Angeles, CA.

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Dry weather FIB levels were one to two orders of magnitude lower than those observed in natural streams during storm conditions ($p < 0.001$) (Fig 5).

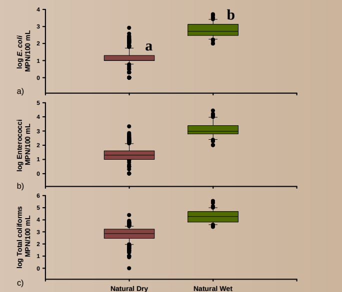

Figure 5. Distribution of log *E. coli* (a); enterococci (b); and total coliforms (c) concentrations in natural streams during dry weather (present study) compared to wet weather (natural loadings; 2003–2005 and Los Angeles River watershed; 2001–2005) studies in southern California, USA.

What Spatial and Temporal Patterns Were Observed?

4

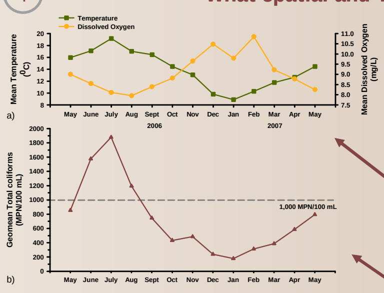

Figure 6. Mean monthly temperature (°C) and dissolved oxygen (mg/l) comparison (a) and geomean total coliform densities in natural streams in southern CA (b) between May 2006 and May 2007. The *dashed line* indicates the 30-day geomean for total coliforms equal to 1,000 MPN/100 ml. *All points above the line* represent bacteria water quality exceedances.

Significant differences in median annual FIB densities existed between perennial and non-perennial streams mainly due to high levels in the period immediately prior to streams drying up; but ranges generally overlapped ($p < 0.05$) (Fig 7).

Temperature explained about one-half the variation in total coliforms density suggesting that stream temperatures regulated bacterial populations (Fig 6a).

Summer months (June to August) were significantly higher than all other seasons ($p < 0.01$) (Fig 6b).

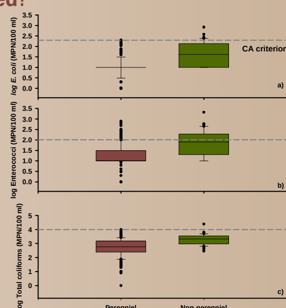

Figure 7. Perennial and non-perennial stream comparison of log10 *E. coli* (a), enterococci (b) and total coliform (c) densities (MPN/100 ml) in southern California. The *dotted line* indicates CA single-sample bacterial criterion.

Summary

1. Annual mean concentrations (both single sample and 30-day geometric mean) were below established water quality criteria for all three bacteria indicators.

   Approximately 1.5%, 14%, and 3% of *E. coli*, enterococci, and total coliforms, respectively, from the natural sites exceeded single sample water quality criteria.

2. Dry weather FIB in natural streams are typically **two** orders of magnitude **lower** than those observed in streams draining developed watersheds.

   Minor perturbations (i.e. agricultural and transportation runoff, and recent fires) can cause streams to move away from "unimpacted" conditions.

3. Dry weather FIB levels were **one to two** orders of magnitude **lower** than those observed in natural streams during **storm** conditions.

4. Fecal indicator bacteria levels exhibit seasonal patterns. Mean bacteria levels and frequency of exceedance of water quality standards were **higher** during the **warmer summer months (June-August)** for all three FIB.

   Median annual FIB densities were **higher in non-perennial** than in perennial streams mainly due to high levels in the period immediately prior to streams drying up; but ranges generally overlapped ($p < 0.05$)

Accounting for natural background levels will allow for management targets that are more reflective of the contributions from natural sources.

Southern CA Reference Streams (Fig. 8)

Figure 8. Dry weather FIB sampling at Solstice Creek, (a) Los Angeles, CA; Boden Creek, (b) San Diego, CA; and Silverado Creek, (c) Orange County, CA.

References

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Stein ED, Tiefenthaler LL, Schiff KC. 2007b. Sources, patterns and mechanisms of storm water pollutant loading from watersheds and land uses of the greater Los Angeles area, California, USA. Southern California Coastal Water Research Project Technical Report 510. March 2007. pp. 77. Southern California Coastal Water Research Project Costa Mesa, CA, USA.

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