Are Fecal Indicator Bacteria Like Salt?: conservative tracer modeling & resistor theory in Newport Bay, California

UCI Water - PIRE
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Megan A. Rippy*, Ashley Ciglar, Stanley B. Grant

University of California, Irvine

INTRODUCTION

- Urban estuaries like Newport Bay receive point source freshwater discharge (and associated pollutants) from upstream rivers
- Along-bay pollutant concentrations & coastal loads are a function of estuarine physics & non-conservative processes like growth/decay
- In estuaries with dispersive physical dynamics, resistor theory may provide a simple framework for modeling conservative pollutants
- Many pollutants of concern (including fecal indicator bacteria; FIB) may be "functionally" conservative over estuarine residence times

QUESTIONS

- Is physical dilution/mixing in Newport Bay dominated by dispersive or advective processes (eg. can estuaries be modeled as resistors)?
- Are FIB conservative tracers like salt?

METHODS: DATA

- Salinity & FIB were measured along 10 dry weather transects
- Each transect had 8 sites (Fig. 1)
  - 2 freshwater; SAD, SDC
  - 6 along-bay; BTO sites
- BTO sites were sampled across-shore (3x) & with depth (2x; Fig. 2)
- Salinity data were expressed as freshwater fraction (FWF)
  - 0 = saline, 1 = fresh

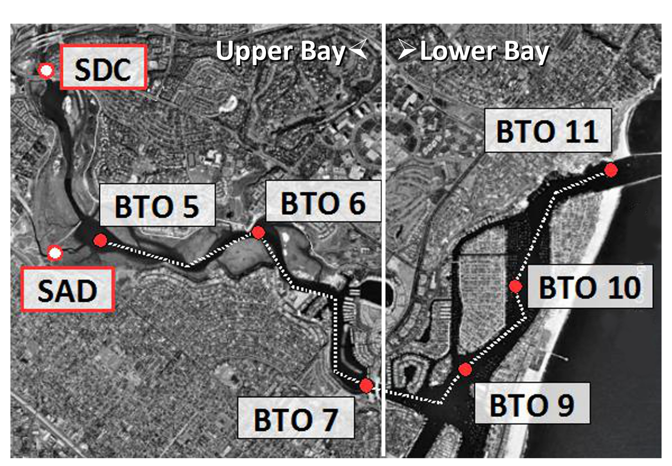


Fig. 1: (Above) Newport Bay map

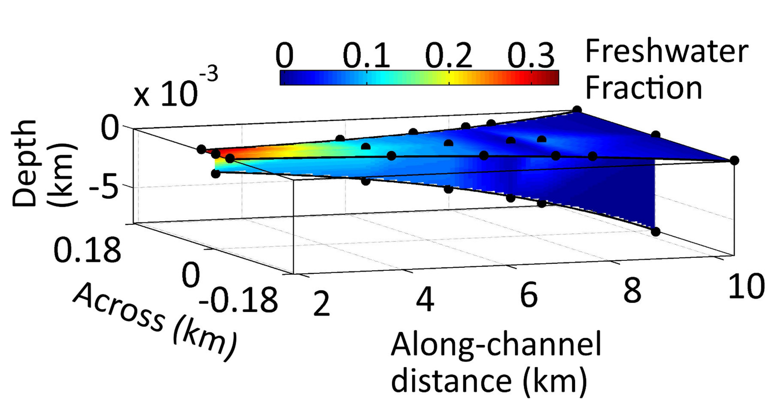
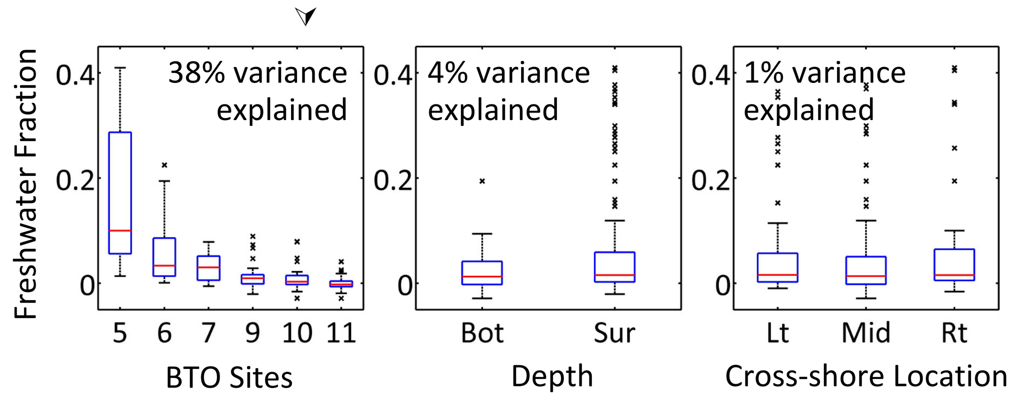


Fig. 2: (Right) Sampling design schematic. Color is freshwater fraction

Fig. 3: (Below) Freshwater fraction variability plots showing patterns along-channel, across-channel, & with depth



- 38% of FWF variance was 1D (along-channel; Fig3)
- 2, along-channel mixing models were developed

METHODS: MODEL

- Models are from mass balance theory
  - tidally averaged & steady state
- M1: advection, dispersion, & cross-sectional dilution contribute to transport (Eq1)

  M2: only dispersion & cross-sectional dilution matter (Eq2)
- Models were parametrized using freshwater fraction data (Fig. 4)
- The "best" model was selected based on parsimony & model-data fits
  - Q1: estuaries = resistors?
- The "best" model was used to predict FIB. Output was compared to data.
  - Q2: FIB are like salt?

Eq1: MODEL 1

$$C_x = C_0\left(1-e^{Pe\,e^{\left(\frac{-x}{l}\right)}}\right)$$

Eq2: MODEL 2

$$C_x = C_0\left(Pe\,e^{\left(\frac{-x}{l}\right)}\right)$$

C_0: inlet conc.

C_x: conc. at along channel distance (x)

$$Pe: \frac{\text{Adv}}{\text{Disp}} = \frac{\left(\frac{Q}{A}\right)l}{K_0}$$

Q: volumetric flow

A: cross sectional area

l: mixing length scale

K_0: dispersion

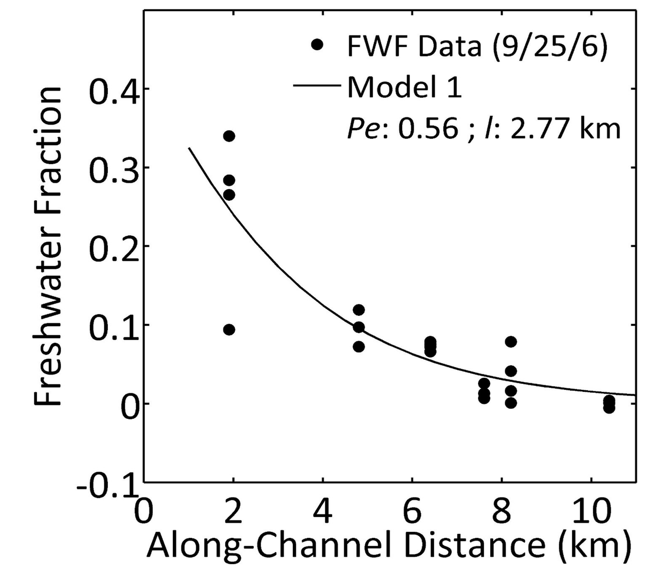
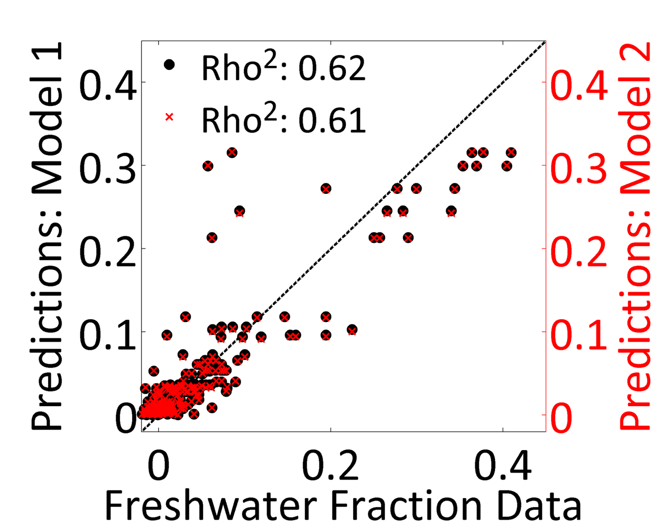


Fig. 4: (Right) Fit of Model 1 to freshwater fraction transect data (9/25/06). Estimates of the free parameters Pe & l are shown. Parameter averages (all transects) were used for FIB prediction.

DISPERSION DOMINATES TRANSPORT



- Both models capture a large fraction of data variability (> 60%; Fig. 5)
- Residual advection (M1) did not improve fits
- Dispersion dominates the transport of conservative tracers (freshwater) in the bay

Fig. 5: (Left) Freshwater fraction data & model predictions. Rho squared, a nonparametric R^2 equivalent, is reported.

IMPLICATIONS: NEWPORT BAY AS A RESISTOR

- Resistor theory assumptions are met:
  - advection << dispersion, steady state, no sources or sinks, & 1D mixing
- Concentrations of <u>any</u> conservative pollutant can be approximated from input loads & mass transfer resistance
- Provides a conceptual framework for evaluating mixing; processes in series or parallel (Fig. 6)

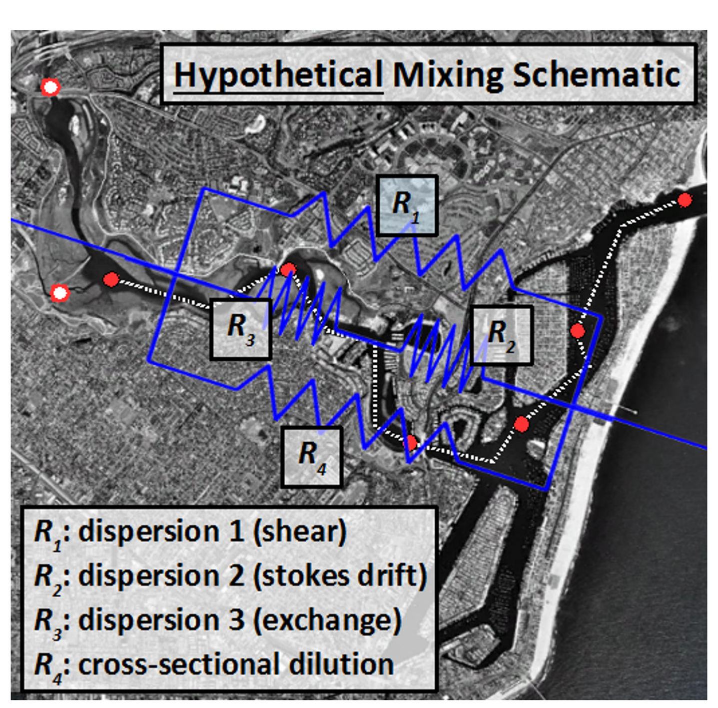


Fig. 6: (Right) Newport Bay resistor schematic (Hypothetical). Mixing processes in series (R_2 & R_3) & parallel (R_1 & R_4).

COLIFORMS ARE LIKE SALT

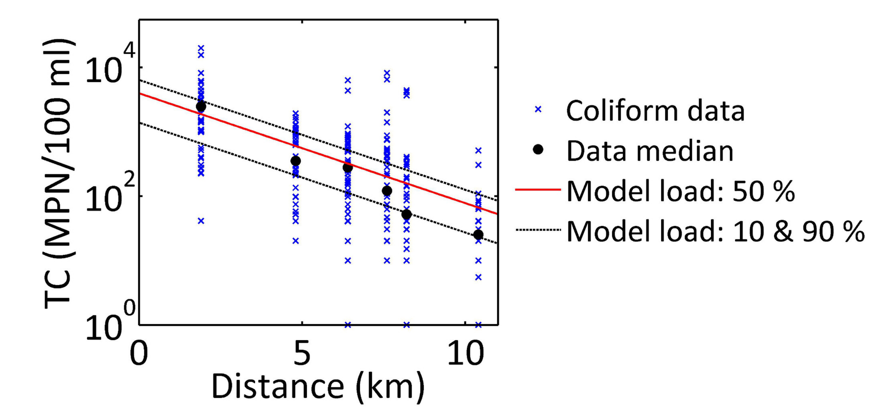


Fig. 7: Total Coliform data & Model 2 output for 10th, 50th, and 90th percentile TC loadings

- Model 2 captures the decline in coliform conc.
- Data medians fall within 10 & 90% model bounds
- Data spread far exceeds model bounds
- Model 2 (50% load) & data have the same down-bay extent of the 10^3 MPN/100 ml TC contour; 3.9 km
- Model 2 predicts that TC contamination is confined to a < 5 km stretch of upper bay (see 90% load)

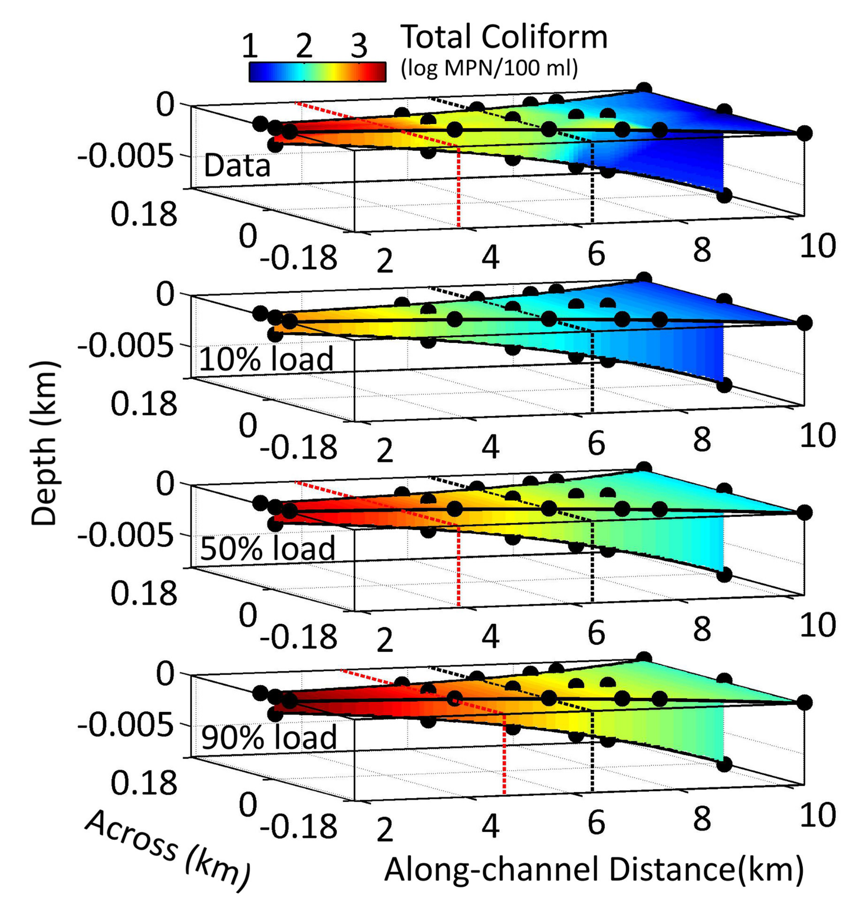


Fig. 8: Spatial distributions of coliform data (top) & Model 2 outputs for 10th, 50th, & 90th % TC loads. Black dashed line: boundary between upper & lower bay. Red dashed line: max extent of the 1000 MPN/100 ml contour (EPA geometric mean standard).

CONCLUSIONS

- Simple, 1D, physical models can capture a significant fraction of freshwater variability in Newport Bay
- Dispersive processes dominate transport suggesting that conservative tracers (like freshwater) can be modeled using resistor theory
- Total coliforms behave like salt. This implies that <u>some</u> FIB are "functionally conservative" from a modeling perspective
- Passive tracer modeling of Newport Bay coliforms suggests that coliform plumes are limited to upper bay during dry weather flows

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