How Does Particle Association of Fecal Indicator Bacteria Impact Microbial Persistence?

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Background

- Health risks related to recreational water contact are commonly assessed using fecal indicator bacteria (FIB)
- Both the Venice Lagoon & Hudson River Estuary are frequently impacted by human sewage contamination, which is detected via FIB
- FIB are often particle associated, so they sink
- Current models of (FIB) persistence
  - Simulate clear water columns
  - Do not incorporate sinking
- Understanding how persistence of sewage microbes differs in turbid systems like the HRE can improve predictive models intended to protect public health in other human impacted areas, like the Venice Lagoon

Research Questions

1) How does particle association impact *Enterococcus sp.* persistence?
2) How does persistence of *E. coli* vary between turbid (HRE) and clear (Venice Lagoon) water columns?

Experimental Methods

1) Conduct culture-based experiments to quantify light-induced and dark, temperature induced loss rates.
2) Set parameter values and compare values of T_{90}.
3) Run model for environmental conditions like those in the HRE and Venice Lagoon.

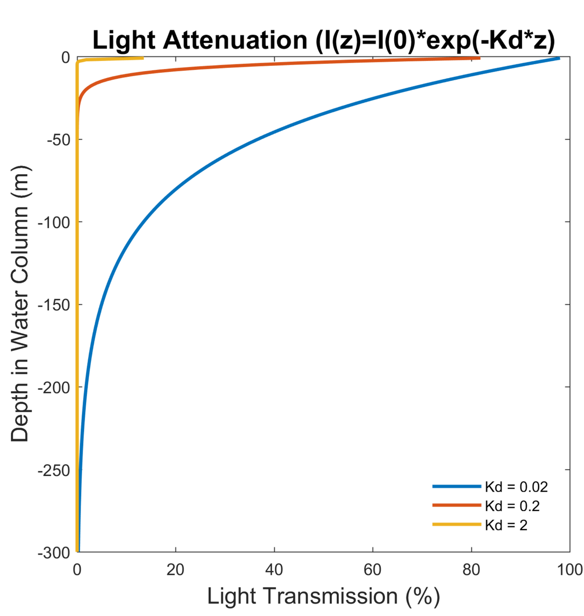
$T_{90} =$ time to decrease initial input by 90%

Representing Turbidity

- Modeled via light attenuation with depth
- Light transmission exponentially declines with depth (z) according to Kd

$$I(z) = I(0) * e^{-Kd*z}$$

- Light transmission controls light-induced loss (m_{light})

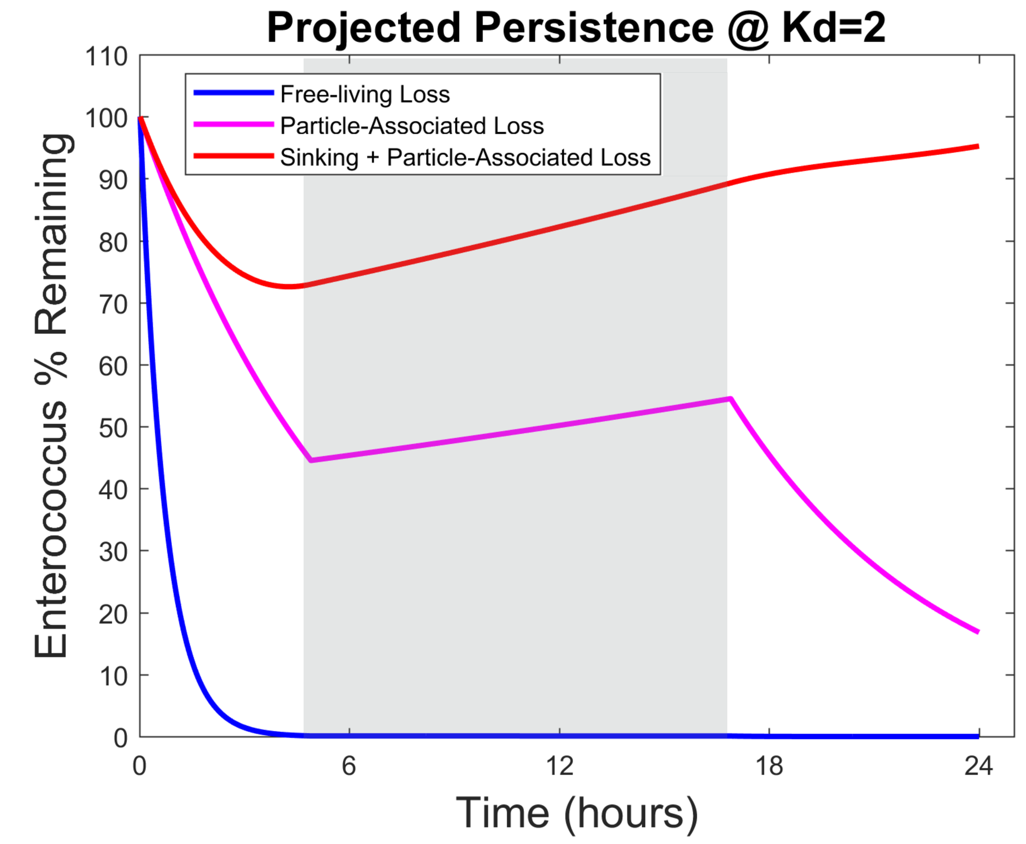


Parameter Values

Rate	Free-living	Particle-Associated	Total
Sinking ($s_{gravity}$)	N/A	1.584 m/day	N/A
Light-induced (m_{light})	-33.2614 / day	-4.37572 / day	-33.296 / day
Dark-period (m_{dark})	- 0.4141 / day	0.40418 / day	-0.09373 / day

RESULTS

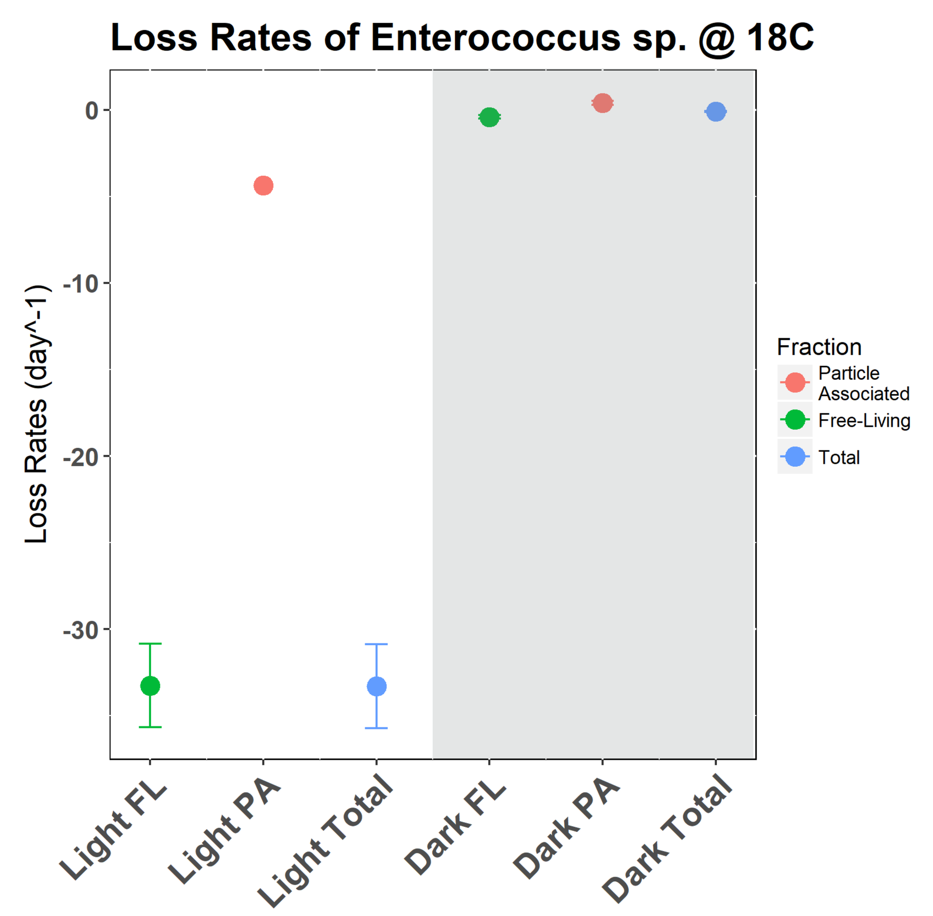
Model Results

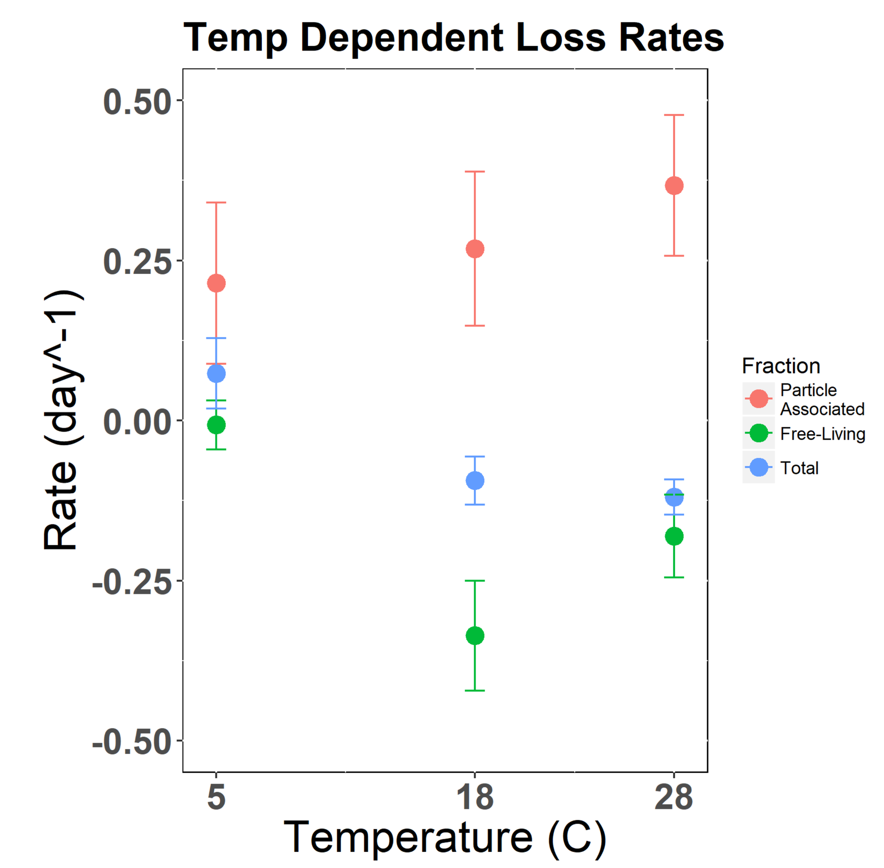


- T_{90} for free-living fraction ~ 3 hours
- T_{90} from particle-associated loss rates ~ 28 hours
- By including sinking, particle-associated *Enterococcus sp.* T_{90} is effectively infinite

**shaded region denotes 12-hour dark-period*

Empirical Results





- Light-induced loss >> dark, temperature-dependent loss
  - 100x's greater for free-living fraction
  - 10x's greater for particle-associated fraction
- Particle association reduces light loss 6x's
- Minimal temperature dependence of dark loss

Model System

1) Exponential Loss Model with First-order Decay Rates

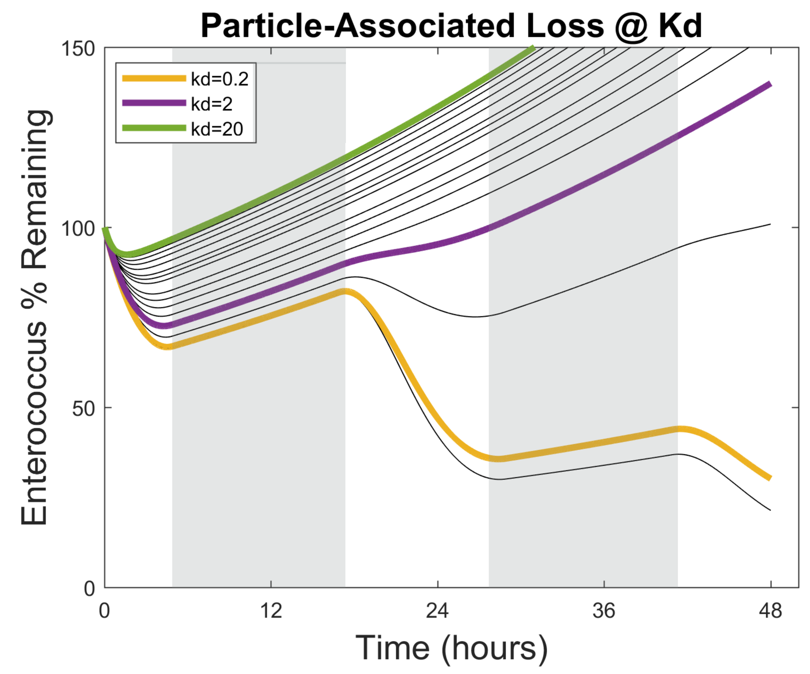
2) Sinking of particle-associated *Enterococcus* represented through light-induced loss adjustment

3) Diurnal signal in light represented via a sinusoidal function

$$(1)\quad \frac{de}{dt} = \text{Input} - (m_{light} + m_{dark}) * e$$

$$(2)\quad m_{light_{pass}}(z) = m_{light_{pass}}(0) * e^{-kd*z}$$

Simulating Varying Turbidity



- Simulations of particle-associated *Enterococcus* shows:
  - > Kd~1, growth
  - < Kd ~1, decay to 0
- Increased turbidity increases persistence and causes growth at high levels

Conclusions

- Greatest loss of *Enterococcus sp.* is due to sunlight (m_{light})
  - Free-living *Enterococcus* ~ -32/day
  - Particle-associated *Enterococcus* ~ -5/day
- Particle-associated *Enterococcus* grows, while free-living fraction decays
- Particle association decreases light-induced loss (~6 x's)
- Sinking critically increases persistence of particle associated *Enterococcus sp.* ($T_{90} \rightarrow \infty$)
- Higher turbidity waters like the HRE have greater persistence of *Enterococcus* than clearer waters like the Venice Lagoon
- Diurnal cycles increase persistence
  - Sinking, particle-associated cells escape sunlit waters and reduce light-exposure

Future Work

- Complete measurements of m_{light} for *Enterococcus* in different Kd conditions as a groundtruth
- Incorporate turbidity impacts on sinking
- Simulate different input conditions (frequency, time of day, duration)