What is the relative pathogen risk to swimmers from seagull feces compared to bather shedders?

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Background

At recreational beaches in coastal California, a sign may be posted on the beach warning swimmers when the indicator bacterial concentrations exceed the regulatory limit, 104 cfu/100mL enterococci (ENT). Both seagulls and swimmers potentially shed enterococci (ENT) and pathogens into the surfzone waters, with microorganisms from seagull feces thought to be less infectious to humans than those associated with human fecal contamination. To evaluate if the seagull fecal contribution is less of a human health risk to swimmers, an initial screening-level Quantitative Microbial Risk Assessment (QMRA) of the gastro-intestinal risk to swimmers from gull feces and human feces was compared to an illness benchmark of 10 per 1000 for *Campylobacter jejuni*, *Cryptosporidium sp.*, and *Rotavirus* from human bathers and *Campylobacter jejuni* from seagulls.

Research Questions:

1. What is the predicted gastro-intestinal infection risk to swimmers from *Campylobacter jejuni*, *Cryptosporidium sp.*, and *Rotavirus* from human bathers and *Campylobacter jejuni* from seagulls when the beach water enterococci count is 104 cfu/100mL?
2. Under what fecal loading source apportionment might the predicted risk to swimmers from seagulls equal or exceed the predicted risk from bather shedders?

Figure 1. Picture of California beach and an example of a beach warning sign.

Method

Quantitative Microbial Risk Assessment (QMRA) with Monte Carlo sampling of uncertain parameters

Step 1. Estimate the distribution of pathogen dose to swimmers for a bathing water enterococci concentration of 104 cfu/100mL over the range of the possible fractions of fecal mass from human shedders and seagulls,using the parameter distributions in Table 1.

Step 2. Estimate the probability of infection resulting from either gulls or human shedders using a beta-Poisson dose-response model for *C. jejuni* and *Rotavirus*, and the exponential model for *Cryptosporidium sp.*

Step 1: Estimate Pathogen Dose μ (cfu)

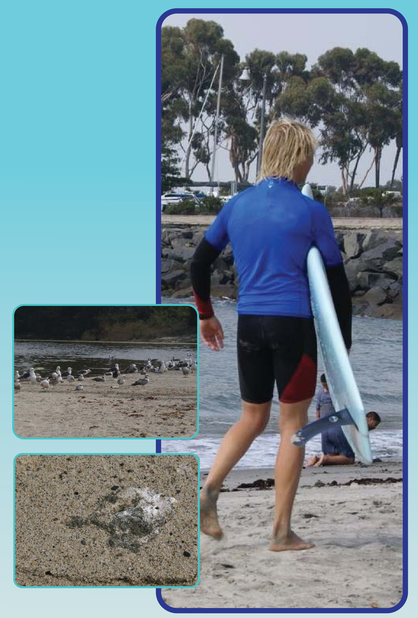
$$\mu = \sum_{S} \frac{C_{ENT}^{s} * V * F^{s}}{R_{ENT}^{s} * 100} * R_{p}^{s} * p^{s} * I^{s}$$

where
S is the source, either human (H) or seagull (G)
C_{ENT}^{s} is the surfzone concentration of ENT for source s (cfu/100mL)
R_{ENT}^{s} is the ratio of the count of ENT to the mass of feces for source s (cfu/g)
V is the volume of water ingested (mL)
R_{p}^{s} is the ratio of the count of pathogen species to the mass of feces for source s (cfu/g)
p^{s} is the proportion of infectious strains from source *s*
I^{s} is the infection rate in source s population

and

$$C_{ENT}^{s} = \frac{-F^{s}}{\frac{R_{ENT}^{s-1}}{R_{ENT}^{s}}(F^{s}-1)-F^{s}} * C_{ENT}$$

where
C_{ENT} is the total concentration of ENT (cfu/100mL)
F^{s} is the fraction of total fecal mass from source *s*



Step 2: Estimate Total Probability of Infection P_{inf}^{s} from Human Shedders and Seagulls

The probability of infection from *C. jejuni* and the *Rotavirus* was estimated using the beta-Poisson dose-response model in the form of the Kummer confluent hypergeometric function ${}_1F_1$:

$$P_{\inf} = 1 - {}_1F_1(\alpha, \alpha+\beta, -\mu) = 1 - \sum_{n=0}^{\infty} \frac{(\alpha)_n}{(\alpha+\beta)_n} \frac{(-\mu)^n}{n!}$$

where
(α,β) are model parameters

The probability of infection from *Cryptosporidium sp.* was estimated using the exponential dose-response model:

$$P_{\inf} = 1 - e^{-E(r)\mu}$$

whereE(r) is infectivity

The total probability of infection $P_{\inf}^{S}$ from either human shedders *H* or seagulls *G* was calculated using the $P_{\inf}$ from each source specific pathogen as:

$$P_{\inf}^{H} = 1 - (1 - P_{\inf}^{C.jejuni})(1 - P_{\inf}^{Rotavirus})(1 - P_{\inf}^{C.parvum})$$

$$P_{\inf}^{G} = P_{\inf}^{C.jejuni}$$

Table 1. Parameter Inputs for Human Shedders and Seagulls

Parameter	Distribution	Units	Parameters	Data Source
R_{ENT}^{H}	Uniform	cfu/g	$a = 2E3 \quad b = 3E8$	(Slanetz and Bartley 1957)
R_{ENT}^{G}	Uniform	cfu/g	$a = 1E6 \quad b = 1E8$	(Fogarty, Haack et al. 2003; Haack, Fogarty et al. 2003)
$R_{C.jejuni}^{H}$	Uniform	cfu/g	$a = 1E6 \quad b = 1E9$	(Hindiyeh, Jense et al. 2000)
$R_{C.spp}^{G}$	Uniform	cfu/g	$a = 2E3 \quad b = 1E6$	(Lévesque, Brousseau et al. 2000)
R_{Rota}^{H}	Uniform	ffu/g	$a = 1E5 \quad b = 1E10$	(Gerba 2000)
$R_{C.parvum}^{H}$	Uniform	oocyts/g	$a = 1E4 \quad b = 8E8$	(Okhuysen, Chappell et al. 1999)
ln(*V*)	Normal	mL	$\mu = 2.7 \quad \sigma = 1.1$	(Dufour et al. 2006)
I (C. h)	NA	NA	0.001	(Yoder and Beach 2007)
I (R)	NA	NA	0.0071	(HMSO 2000)
I(C. j)	NA	NA	0.0015	(HMSO 2000)
$(\alpha,\beta)_{C.\ jejuni}$	NA	NA	(0.024,0.011)	(Teunis, Van den Brandhof et al. 2005)
$(\alpha,\beta)_{Rota}$	NA	NA	(0.253,0.422)	(Teunis and Havelaar 2000)
$E(r)_{Crypto}$	NA	NA	0.09	(EPA 2005)

Results

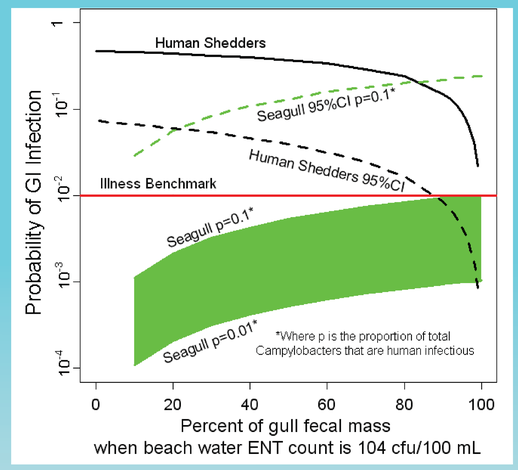


Figure 2. Probability of Infection (P_{inf}) to Swimmers from *Cryptosporidium sp.*, *C. jejuni* and *Rotavirus* from Human Shedders and *C. jejuni* from Seagulls. The probability of infection P_{inf} is plotted on the *y*-axis for the range of percent of total fecal mass (human shedder plus seagull fecal mass) in the bathing water attributed to the seagulls on the *x*-axis. The red line represents the illness risk benchmark of 10/1000 or 0.01. The solid lines represent the median predicted P_{inf} from human shedders (black) and seagulls (green) from 10,000 Monte Carlo runs of uncertain variables for surfzone ENT concentration of 104 cfu/100mL. The green series show predicted P_{inf} from seagulls for alternative values of the uncertain variable *p*, the proportion of the infectious campylobaters from seagulls (p = 0.01 to 0.1). The dashed series represents the upper 95% CI P_{inf} from seagulls with p=0.1 (green) and the lower 95% CI P_{inf} from human shedders (black).

Table 2. Predicted Median Concentration of Pathogens in Bathing Water for Alternative Apportionment of Fecal Mass between Human Shedders and Seagulls when Bathing Water ENT Concentration is 104 cfu/100mL

Fecal Mass Apportionment		Reference Pathogen		
Percent of fecal mass from seagulls*	Percent of fecal mass from humans	*C. jejuni* (cfu/100mL)	*Cryptosporidium sp.* (oocysts/100mL)	*Rotavirus* (ffu/100mL)
100%	0%	1.0E-02	0	0
50%	50%	2.7E-01	1.4E-01	12
0%	100%	5.2E-01	2.8E-01	24

*Proportion of the total campylobacters that are human infectious is 0.01

Conclusions

1. When human bathers are present in the bathing water, the median predicted risk of gastro-intestinal infection from accidental ingestion of bathing water containing human fecal matter is greater than that from seagulls – given a mean enterococci count of 104 cfu/100 mL in bathing waters.
2. The predicted probability of infection from accidental ingestion of bathing water containing human fecal matter is dominated by *Rotavirus* then followed by *Campylobacter jejuni*.
3. The predicted probability of infection from accidental ingestion of bathing water containing *Campylobacter jejuni* from bather shedders is comparable to that predicted from seagulls when the proportion of human infectious *Campylobacter* strains from seagulls is equal to or greater than 10%.
4. The median predicted probability of infection from accidental ingestion of bathing water containing gull feces is generally low with median predictions less than the illness benchmark of 0.01 for waters with enterococci concentrations below the recreation standard of 104 CFU/100mL if the proportion of infections *Campylobacter* strains from seagulls is less than 0.1.
5. There remains considerable uncertainty in the estimation of pathogen dose in the QMRA model, particularly resulting from estimating the density of pathogens in human feces, the background rate of infection in the general population (here possibly underestimated), and the proportion of human infectious *Campylobacter* strains from seagulls.

Future Work

- Modify approach to account for enterococci loads from beach sand and differences in persistence between pathogens and the fecal indicator
- Estimate risk to swimmers at Doheny Beach using field data and site specific parameters for seagull population
- Compare results to ongoing epidemiological study

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