

Bacterial Faecal Indicators as Proxies for Viral Gastrointestinal Illness Risk in Inland Recreational Waters:

Evidence from the Epibathe Randomised Controlled Trial

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Freshwater GI illness is mostly viral in aetiology

- Typically norovirus, rotavirus, enteric adenoviruses
- Causative pathogens rarely identified
- No routine direct viral quantification at point of sampling
- (Bacterial) Faecal Indicator Organisms as proxies for human faecal contamination

FIO proxies are poorly validated in freshwater

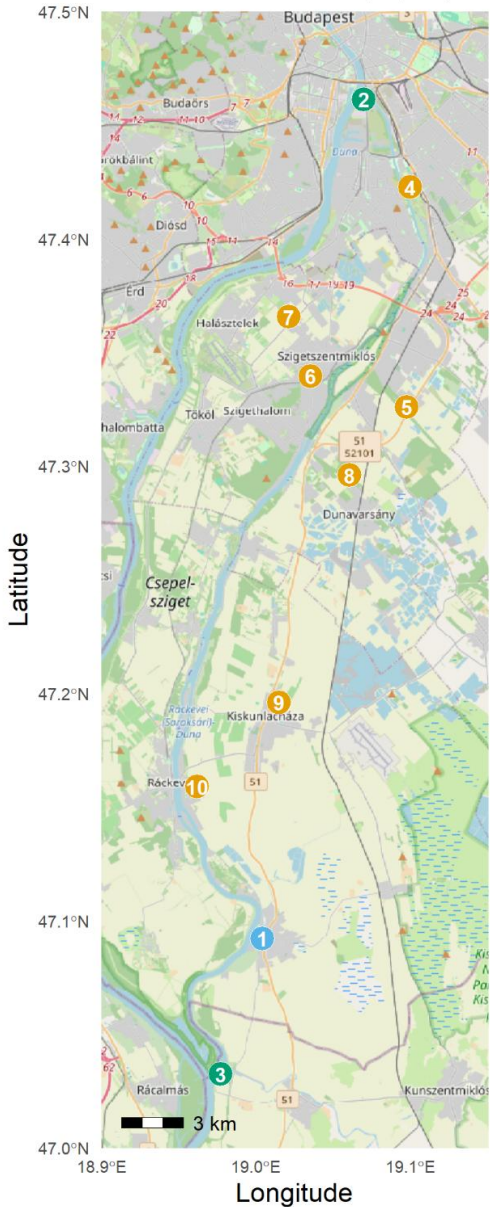
- Associations between FIO densities and GI illness outcomes are poorly characterised
- Limited individual-level exposure-response data
- Mostly observational, cohort studies
- Only one published freshwater RCT (Wiedenmann et al. 2005)

Epibathe RCT: Hungary 2006-2007

- Four lacustrine and riverine freshwater sites
- Lacustrine: relatively isolated side channels of the Danube River
- Riverine: directly connected and continuous flow from the Tisza River

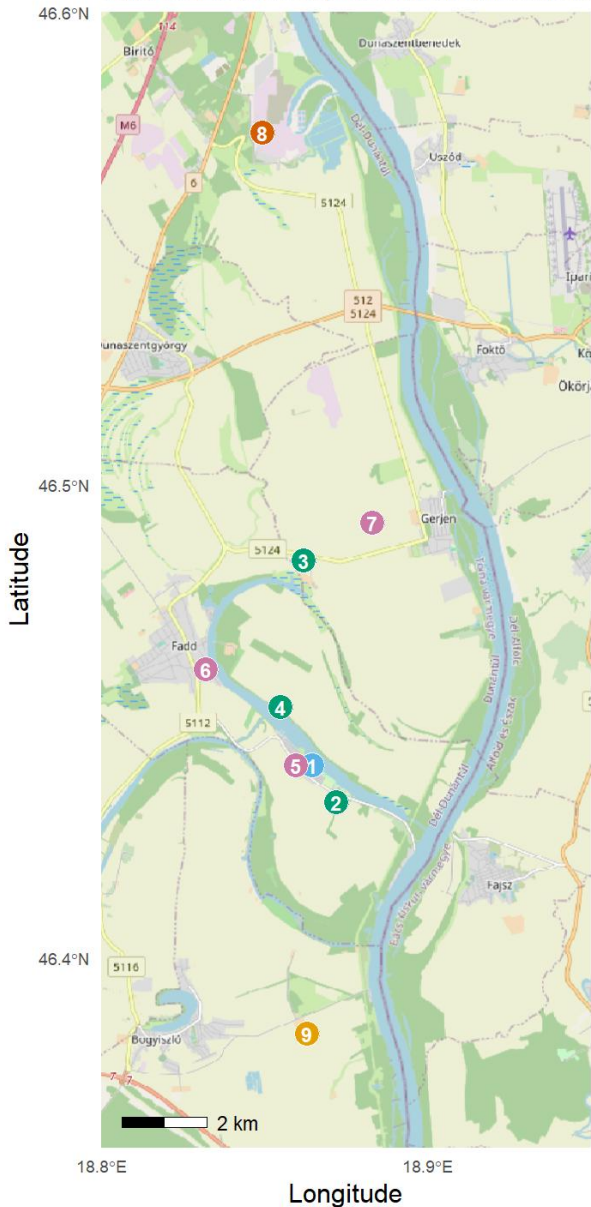
Dömsödi Strandfürdő

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Tiszakécskei Szabadstrand

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Körös-toroki Partfürdő

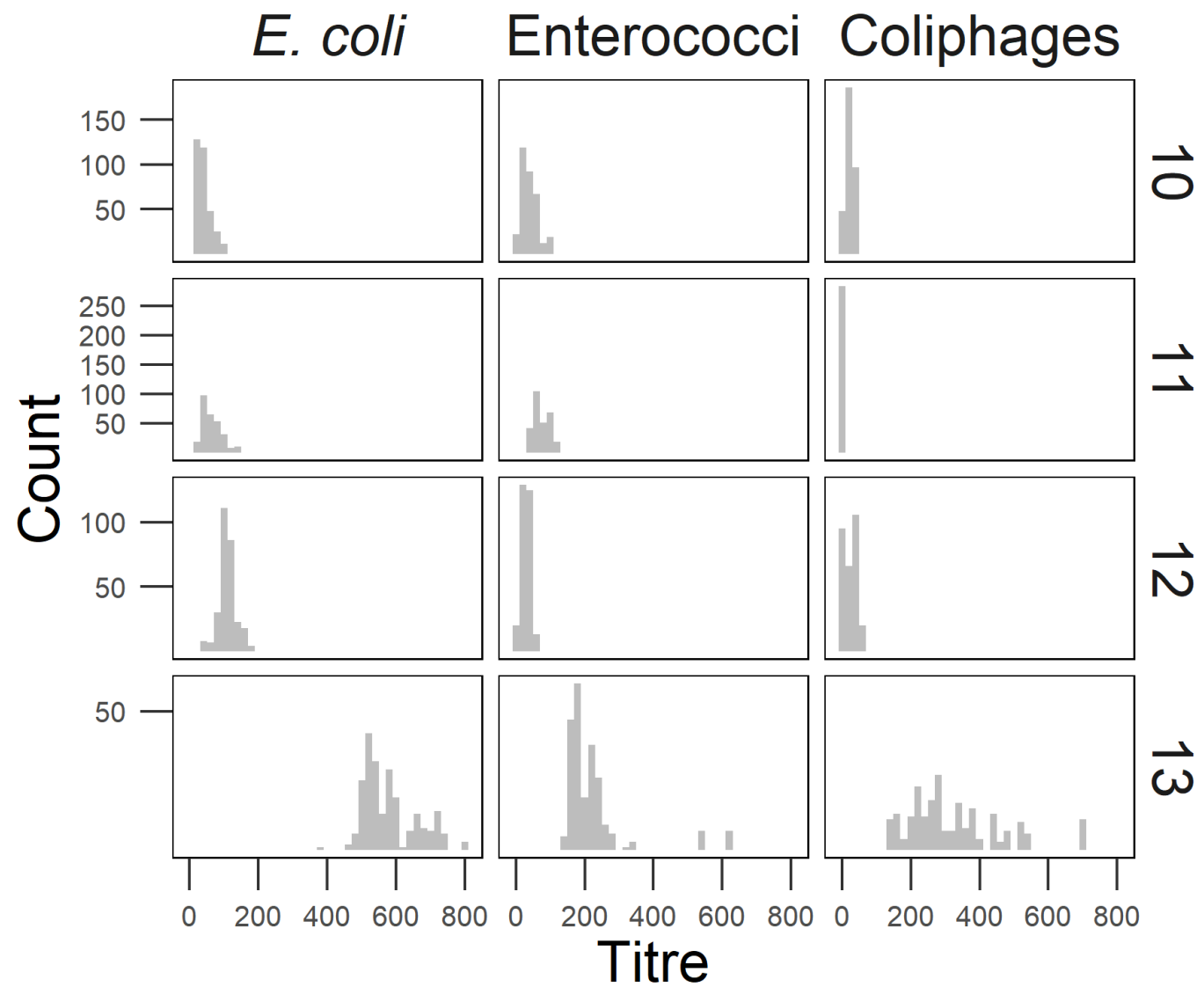
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- Bathing site
- Inflow
- Nuclear Power Plant
- Pollution source
- Wastewater Treatment Plant

Epibathe RCT: Hungary 2006-2007

- 2,368 participants
- **Bathers** (≥ 3 head immersions, 10 min) **vs** shoreside **Non-bathers**
- **Individual-level exposure** from concurrent water sampling
- GI and other health outcomes at **one-week follow-up**



Health problem	Overall (n=2368)	Non-bather (n=1235)	Bather (n=1133)
Gastrointestinal	48 (2.03%)	24 (1.94%)	24 (2.12%)
Skin	47 (1.98%)	16 (1.30%)	31 (2.74%)
Respiratory	9 (0.38%)	2 (0.16%)	7 (0.62%)
Ear	13 (0.55%)	5 (0.40%)	8 (0.71%)
Eye	13 (0.55%)	4 (0.32%)	9 (0.79%)

- Generalised Estimating Equation Models with exchangeable working correlation
- Adjusted for sociodemographic covariates and clustering by site
- Robustness to missing data was assessed by multiple imputation.

E. Coli and coliphages predict GI Illness

GI Illness Indicator	Adjusted			Adjusted +MI		
	RR	95% CI	p-value	RR	95% CI	p-value
Non-bathers	1	-	-	1	-	-
Bathers	1.13	0.63-2.02	0.68	1.12	0.63-2.00	0.7
Log. <i>E. coli</i>	1.77	1.15-2.73	0.01	1.73	1.13-2.65	0.01
Log. <i>I. Enterococci</i>	1.20	0.75-1.94	0.45	1.18	0.74-1.88	0.49
Log. <i>S. phage</i>	1.48	1.05-2.06	0.02	1.45	1.05-2.04	0.03

Skin Ailments Indicator	Adjusted			Adjusted +MI		
	RR	95% CI	p-value	RR	95% CI	p-value
Non-bathers	1	-	-	1	-	-
Bathers	2.17	1.55-3.03	0.00	2.30	1.57-3.37	0.00
Log. <i>E. coli</i>	0.61	0.26-1.44	0.26	0.50	0.21-1.16	0.11
Log. <i>I. Enterococci</i>	0.63	0.24-1.68	0.36	0.50	0.19-1.28	0.15
Log. <i>S. phage</i>	1.31	0.88-1.93	0.18	1.26	0.79-2.00	0.34

Sensitivity analyses (Site 13 excluded)

GI Illness Indicator	Adjusted			Adjusted +MI		
	RR	95% CI	p-value	RR	95% CI	p-value
Non-bathers	1	-	-	1	-	-
Bathers	1.07	0.57-2.02	0.83	1.06	0.57-1.98	0.843
Log. <i>E. coli</i>	1.77	1.38-2.28	0.00	1.72	1.33-2.23	0.00
Log. <i>I. Enterococci</i>	1.28	0.76-2.17	0.36	1.25	0.75-2.09	0.388
Log. <i>S. phage</i>	1.58	1.14-2.18	0.01	1.56	1.12-2.17	0.01

Implications

- *E. coli* and somatic coliphages are better predictors for GI illness risk than enterococci in freshwater contexts
- WHO 2021 Guidelines: enterococci only justified?
- Coliphages parallel human enteric viruses structurally and ecologically
- Wider panel of source-specific viral markers and FIOs

Acknowledgements

- Paul Hunter; Julii Brainard
- Epibathe Consortium: Márta Vargha, Daniel Thomas, Roland Salmon, Mihály Kádár, Maria José Figueras, Jamie Bartram, Zsolia Barna, David Kay
- 6th Research Framework Program of the European Union (grant no. 022618) and the UK NIHR HPRU in Gastrointestinal Infections (grant no. NIHR207399)