Quantitative analysis of *Campylobacter* sources in rural streams

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Campylobacter is considered to survive poorly in river water and yet it is consistently identified in river water samples collected in New Zealand. This observation is surprising and indicates that the source of *Campylobacter* must be frequent fresh inputs to rivers during base-flow conditions. Obvious sources of *Campylobacter* in rural streams during base-flow conditions are dairy cows, farm dairy effluent management and water fowl.

We used a Monte Carlo modelling approach to predict the number of Campylobacter discharged to a stream from a number of different dairy farm managements and from ducks. The daily discharge to the stream was converted to stream concentrations using a hypothetical farm and stream reach based on data from the well studied Toenepi catchment. Modelling analysis indicated that the daily load discharged to the stream would need to be $>10^6$ *Campylobacter* ha^{-1}, to generate the measured median stream concentrations of 2.3 *Campylobacter* $100mL^{-1}$.

The predicted daily loads of *Campylobacter* discharged from the dairy cows and farm dairy effluent managements were all highly skewed as there are a number of days each year where the load is zero. The highest predicted 95^{th} percentile of load was c. 10^8 ha^{-1} from cows having access to the stream for drinking water. The highest predicted median load was c. 10^5 ha^{-1} day^{-1} from a 2-pond farm dairy effluent management system discharging to the stream. Scenario analysis indicated that animal access to the stream and/or a 2-pond effluent discharge would generate stream concentrations similar to the measured concentrations. Preventing animal access to the stream and converting the 2-pond effluent system to a deferred irrigation strategy will significantly reduce the farm impact on stream *Campylobacter* concentrations.

The predicted *Campylobacter* load from the ducks, based on recently published shedding data from NZ, was lower than expected with a 95^{th} percentile of c. 10^3 ha^{-1} day^{-1}. Scenario testing indicated that an unrealistic density of 400,000 ducks km^{-1} of stream would be required to achieve the measured stream concentrations using these duck faecal concentrations of $<10^3$ *Campylobacter* g^{-1} fresh weight. International literature of *Campylobacter* shedding in duck faeces has reported concentrations of 10^4-10^6 g^{-1}. Using the higher duck faecal concentrations from the international literature generate a median load of c. 10^5 ha^{-1} day^{-1} similar to that produced by the 2-pond discharge from the farm dairy effluent management system. The duck loading rates calculated using faecal concentrations from the international literature could account for the concentrations of *Campylobacter* measured in the Toenepi stream.

This quantitative modelling analysis indicates that some farm managements have the potential to explain the concentrations of *Campylobacter* measured in the Toenepi stream and that the appropriate mitigations should be applied on farms. The potential

impact of ducks on the stream is not clear as there appears to be a large difference in the reported *Campylobacter* shedding rates between the New Zealand and international studies. The impact of water fowl on stream water quality requires further investigation.