Consideration of pathogen risks associated with uncovered finished water reservoirs

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Pathogen testing of waters

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- No ideal indicator
- Not all about *Cryptosporidium*
- Target < 0.075 oocysts /1000L or < 1 in 10,000 L need to take >>200 50-L samples (noting method recovery generally < 50% and non-normal input/distribution of oocysts in water)
- **Key issue: what is the change in relative risk due to an uncovered finished water (UCFWR)**

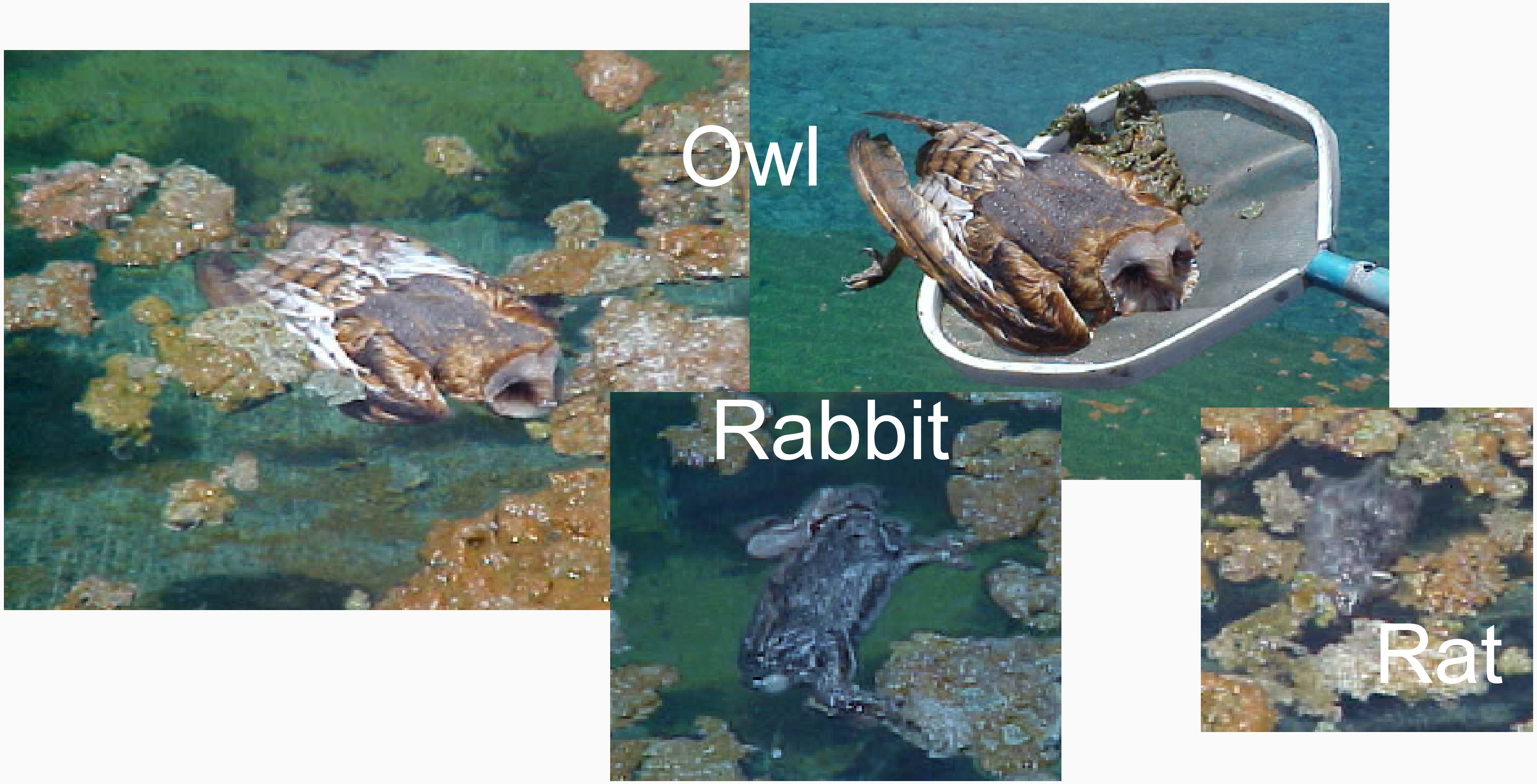
Risk = probability x consequence

- Therefore pathogen risk is based on **likelihood of occurrence** & **consequence of disease** endpoint(s); So for LT2 & in UCFWR
  - Interested in gastrointestinal (GI) disease
  - But other endpoints & sequelae possible, e.g.
    - *E. coli* O157:H7 but may also cause HUS
    - *Campylobacter jejuni* causes reactive arthritis & Guillain Barré syndrome

Models provide supporting info

- Quantitative Microbial Risk Assessment (QMRA) to inform change in risk from UCFWR:
  - Need to ID **potential sources/routes of concern** of pathogen contamination to UCFW reservoirs
  - **Model/measure fate & transport** to **provide relative risk** by pathogen that an uncovered reservoir may introduce

Animals identified in UCFWR



Photos: Staff of the California Drinking Water Program

Why Model?

- Models help us explore questions that we might not be able to address in the laboratory or field; for example:
  - What is the waterfowl risk to reservoir waters under condition X?
  - What is the impact of reservoir turn-over?
  - When may it be safe to restart service after an event for an UCFWR?

Pathogen hazards: mostly zoonotic

Portland reservoir urination raises a few concerns (Oregon *Live.com*, 6/15/11)

- 21 year-old’s event let to draining 7.8 MG Mt. Tabor R
- Risk was human access ‘thought it was a sewer plant’

Zoonosis – pathogen from animal-to-human

- A few are viral (HEV wild pigs, H5N1 virus in birds), range of pathogenic bacterial & parasitic protozoa

Which animal groups of concern:

- **Birds** (e.g. H1N1, *Cryptosporidium meleagridis, Giardia lamblia, Salmonella enterica, Campylobacter jejuni*), **rodents** (most as above) **rabbits** (*C. cuniculus*)

Understanding (fecal) sources

- Animal surveys / by season / risk periods
- qPCR for various pathogens / indicators
- Microbial Source Tracking (MST)
  - *Bacteroidales* targets, yet poorly developed for non-ruminants & birds
  - Emerging use whole genome sequencing
- Chemical biomarkers to ID sources
  - Fecal sterols, biomass assays

Increasing risk?

Source (g feces/d)	**Pathogens**	**Counts/gram**	**D-R**
Birds, e.g. ducks (30-360)	H5N1, *Cryptosporidium meleagridis, Giardia lamblia,* microsporidia*, *Salmonella, Campylobacter & Mycobacterium* spp.	P/A, ranges 10^2-10^4/g	H5N1 Sal Campy
Rodents (2-30)	*Cryptosporidium parvum, Salmonella, E. coli* O157:H7	10^2-10^4/g P/A	?
Rabbits (20-80)	*Cryptosporidium cuniculus, Staphylococcus aureus* (+ARG), *Francisella tularensis*	3000/g P/A	illness
Feral cats	*Toxoplasma gondii,*	P/A	-
Environ-mental	*Schistosoma* spp., *Mycobacterium avium* (↑virulent strains from animals)	P/A	-

P/A presence/absent data only, ARG – antibiotic-resistant genes

**Encephalitozoon hellem, E. intestinalis*, & *Enterocytozoon bieneusi*

Model/measure fate & transport

- Various model components can be estimated with surrogates:
  - Fecal loadings (*E. coli,* enterococci, MST) & HRT
  - Environmental inactivation (light intensity + temp)
  - Algae-association, reservoir turn-over (re-suspension) of sediment-bound pathogens
- Role of algae?
  - May lead to growth of some bacterial pathogens & indicators
  - Toxins?

Reservoir water QMRA model

Goal: estimate the relative risk increase (for water in vs out of the UC reservoir)

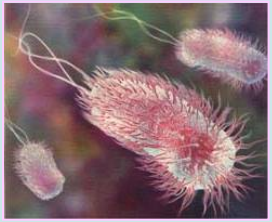
STEP 1

SETTING

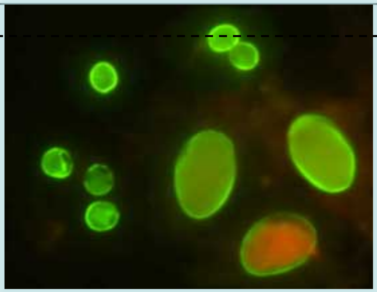
Hazard identification & pathways

Describe physical system, selection of **reference pathogens** & identification of **hazardous events**

Viruses



Bacteria



Parasitic protozoa

STEP 1

SETTING

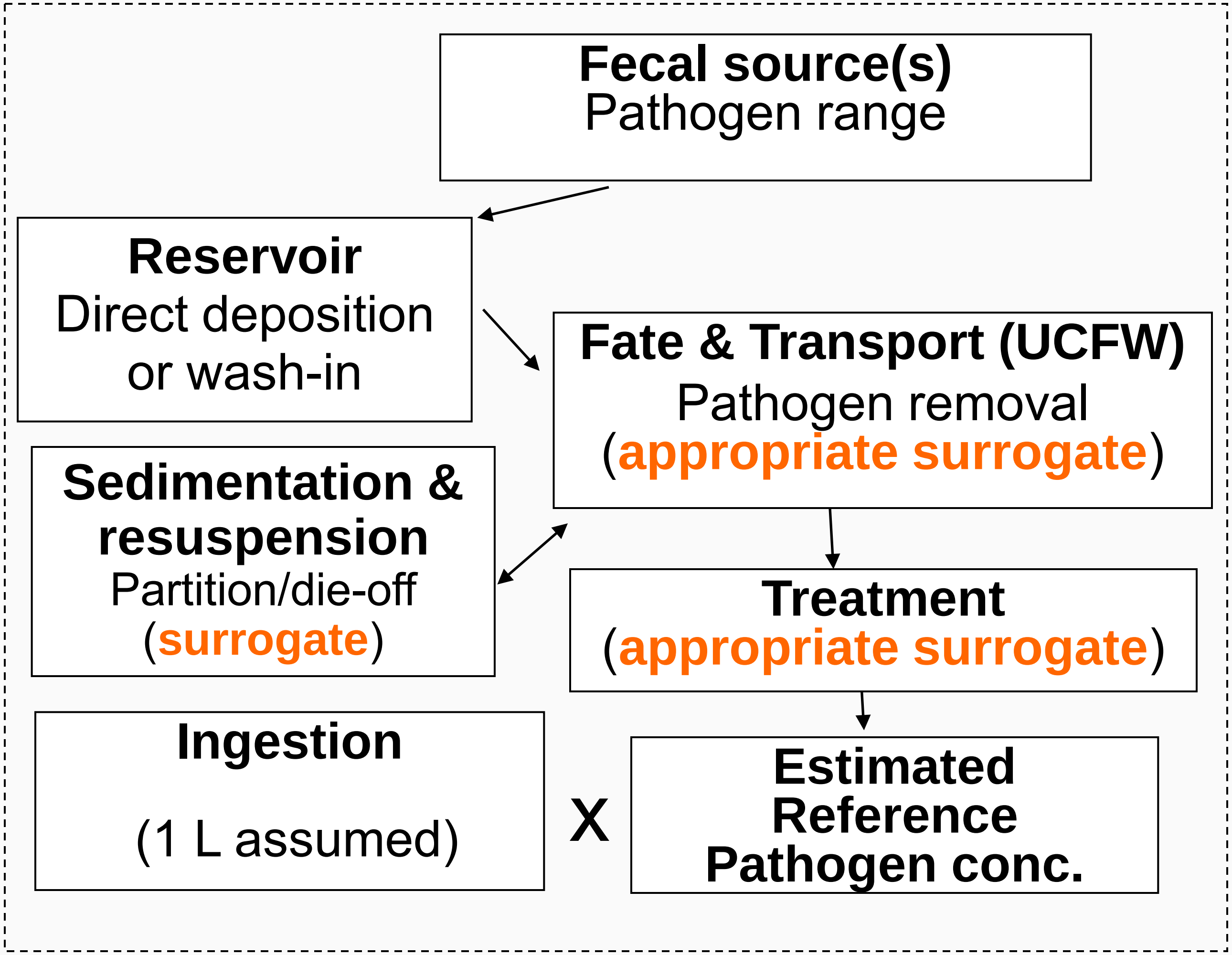
Hazard identification & its setting
Describe physical system, selection of reference pathogens and identification of hazardous events

Reservoir QMRA model

STEP 2

EXPOSURE

For each reference pathogen:



Fecal source(s)
Pathogen range

Reservoir
Direct deposition or wash-in

Fate & Transport (UCFW)
Pathogen removal
(**appropriate surrogate**)

Sedimentation & resuspension
Partition/die-off
(**surrogate**)

Treatment
(**appropriate surrogate**)

Ingestion

(1 L assumed)

X

Estimated Reference Pathogen conc.

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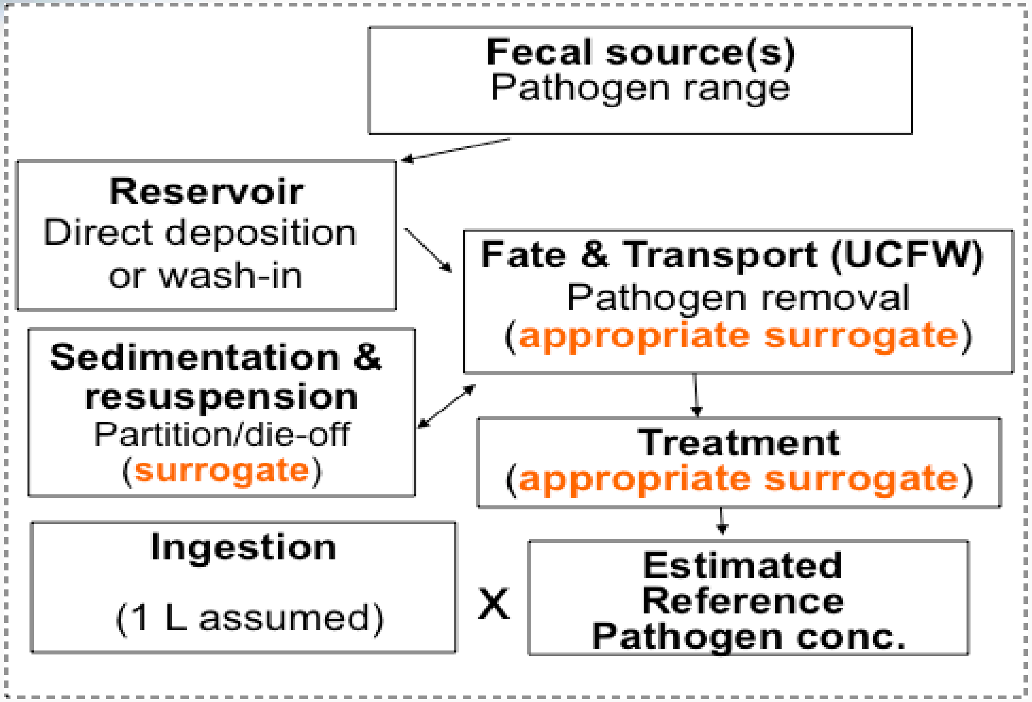

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STEP 3

HEALTH EFFECTS

Dose-Response (P_{inf})

Selection of appropriate model & dose for each pathogen and scenario

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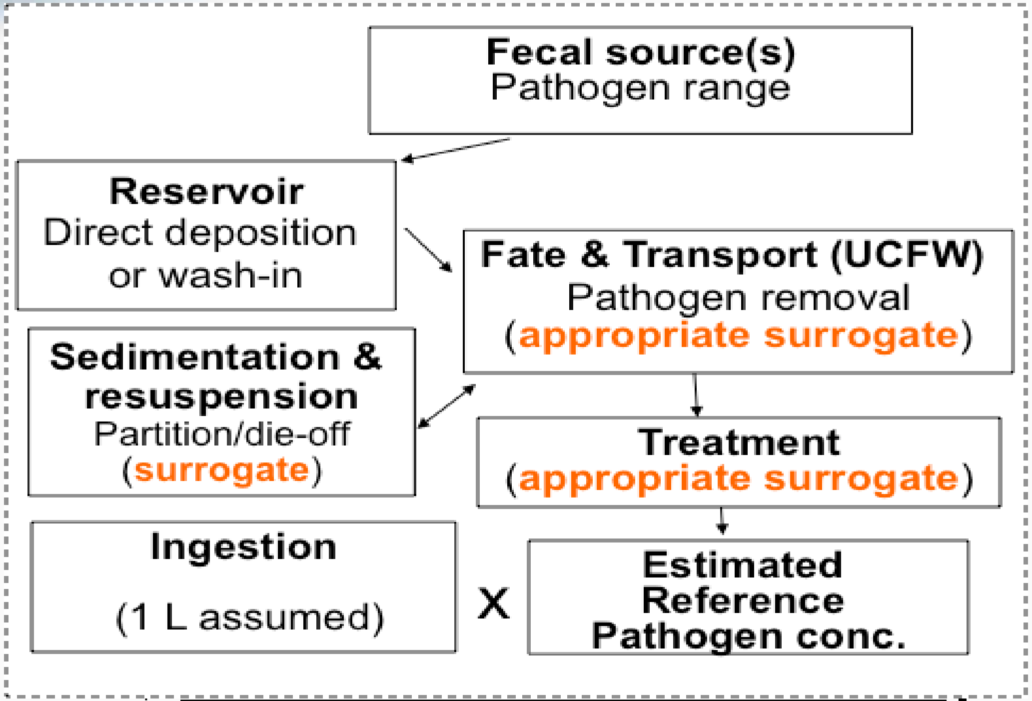

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HEALTH EFFECTS

Dose-Response (P_{inf})
Selection of appropriate models for each pathogen and scenario examined

STEP 4

RISK

Characterisation of Risk

Simulations for each pathogen baseline and event infection risks with variability & uncertainty identified

Conclusions

- Uncovered finish water reservoirs are vulnerable to fecal inputs, in decreasing order of likely pathogen risks as follows:
  - Birds
  - Rodent
  - Feral cats (& dogs)
- Additional treatment could negate risks
- Very large numbers of samples required to measure pathogen risk impacts due to UCFWR