Microbial contamination of water and sediments

Faecal Source Tracking in the Avon / Ōtākaro River

Institute of Environmental Science and Research Ltd.
ESR

Specialist Science Solutions
Manaaki Tangata Taiao Hoki
protecting people and their environment through science

Acknowledgements

ESR

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FUNDERS

- **Environment Canterbury**
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- **Christchurch City Council**
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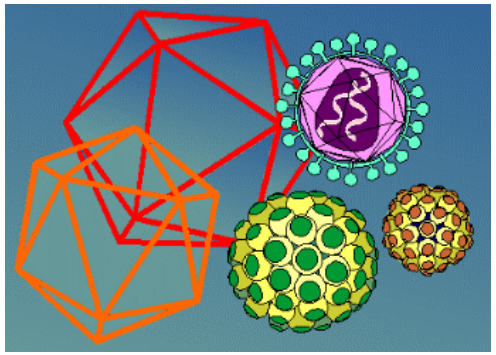
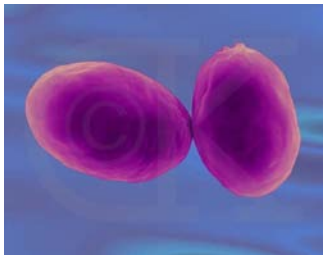
- **Ministry for the Environment**
- **FRST**
- **ESR**

Viruses

- Enteroviruses
  - -Polioviruses, Echoviruses
  - -Coxsackieviruses A & B
- Hepatitis A & E Viruses
- Adenoviruses
- Reoviruses
- Rotaviruses
- Caliciviruses
- Astroviruses
- Picornavirus/parvoviruses
- Coronaviruses





Bacteria

- *Salmonellae*
- *Shigella* spp.
- *Campylobacter* spp.
- *Yersinia enterocolytica*
- *Escherichia coli*
- *Vibrio cholerae*
- *Aeromonas* spp.
- *Helicobacter pylori*

Protozoa

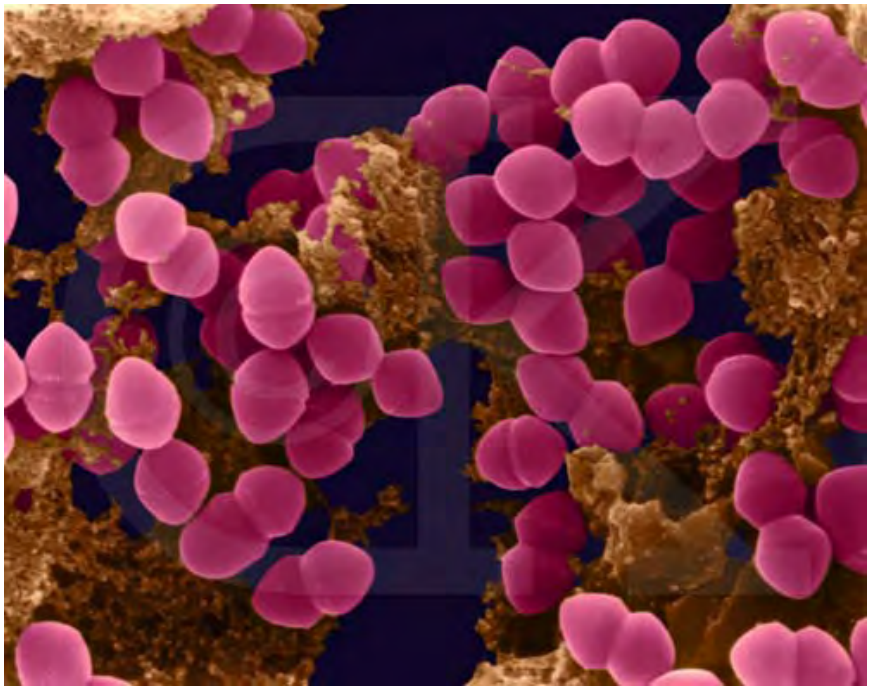
- *Giardia intestinalis*
- *Cryptosporidium parvum*
- *Entamoeba histolytica*
- *Balantidium coli*
- *Cyclospora cayatenensis*
- *Toxoplasma gondii*
- *Microsporidia*

Worms

- Roundworms (Nematodes):
  - *-Ascaris lumbricoides*
  - *-Trichuris trichuria*
- Hookworms:
  - *-Ancylostoma duodenale*
  - *-Necator americanus*
  - *-Strongyloides stercoralis*
- Cestodes (tapeworms):
  - *-Hymenolepsis nana*

Faecal indicators

E. coli

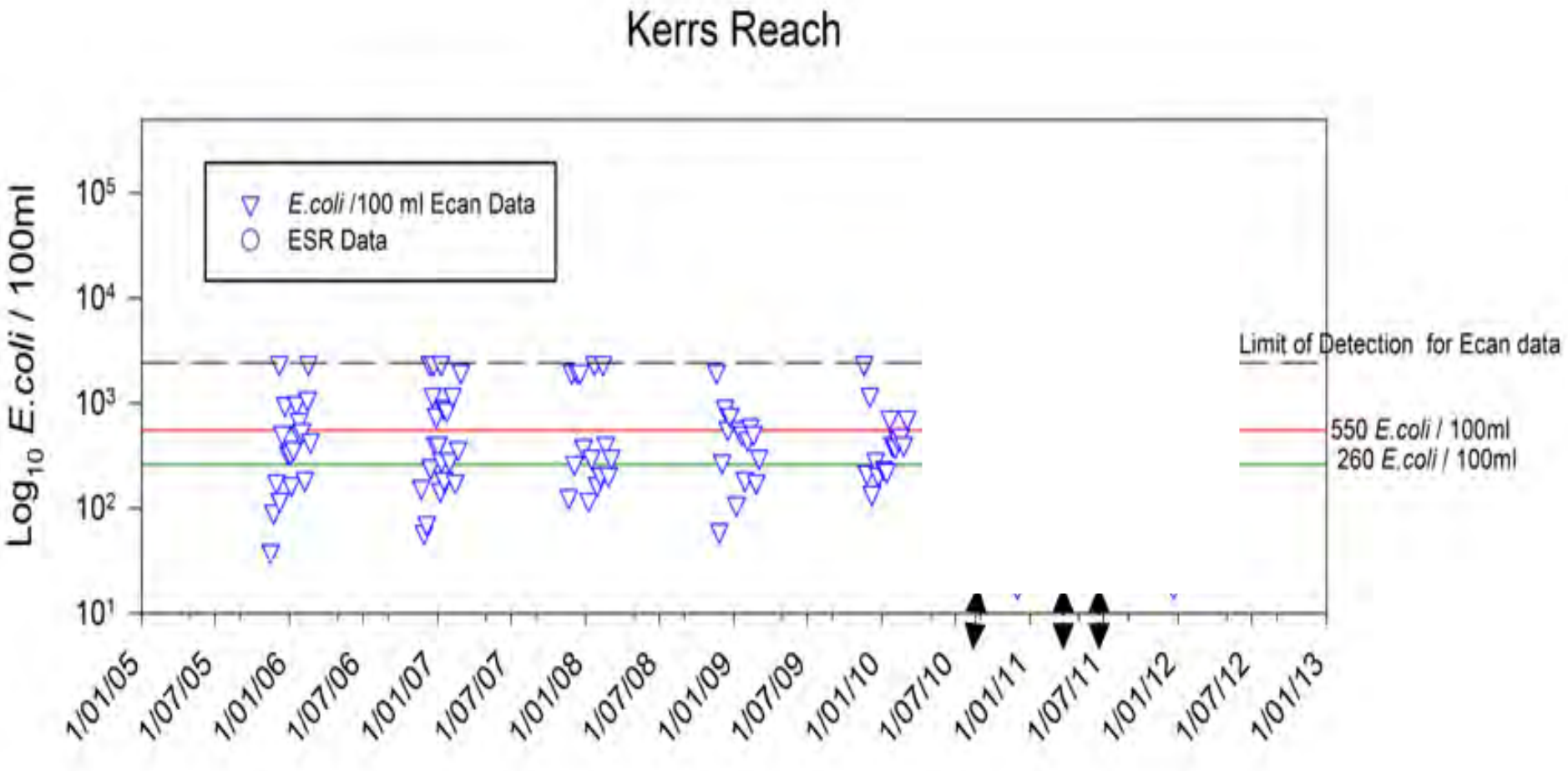


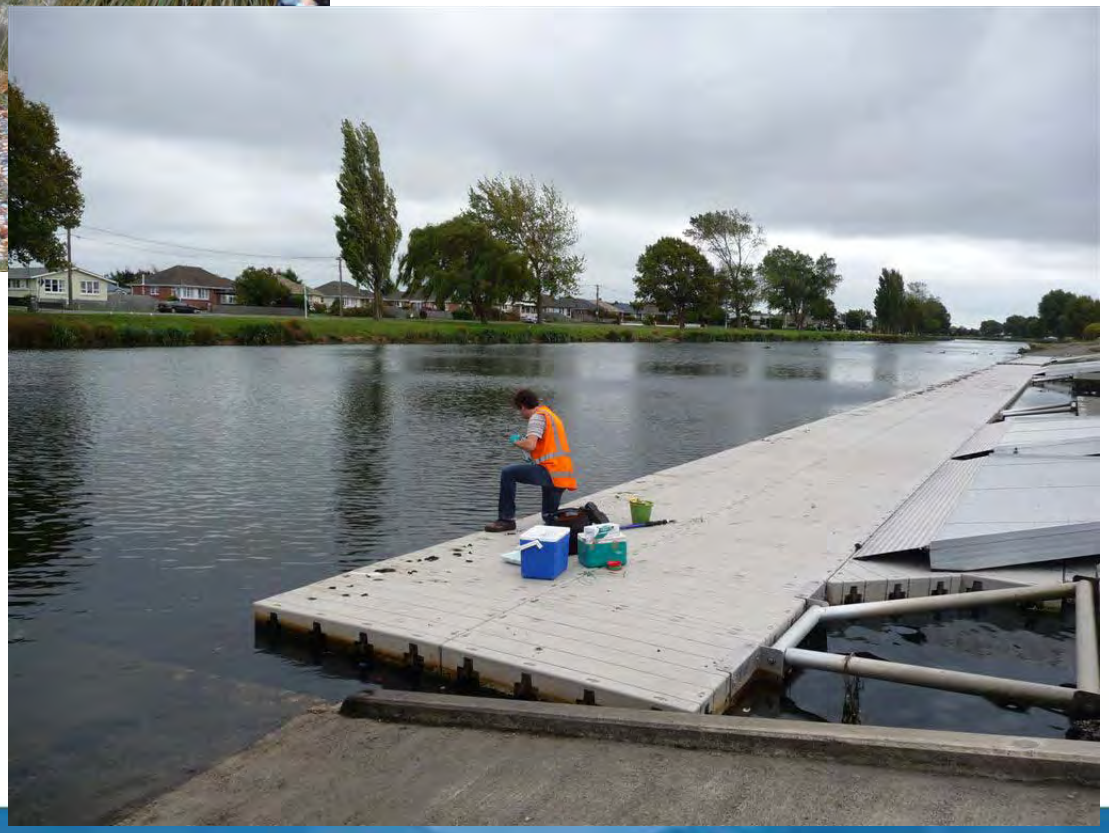
Enterocci

NZ Recreational water guidelines

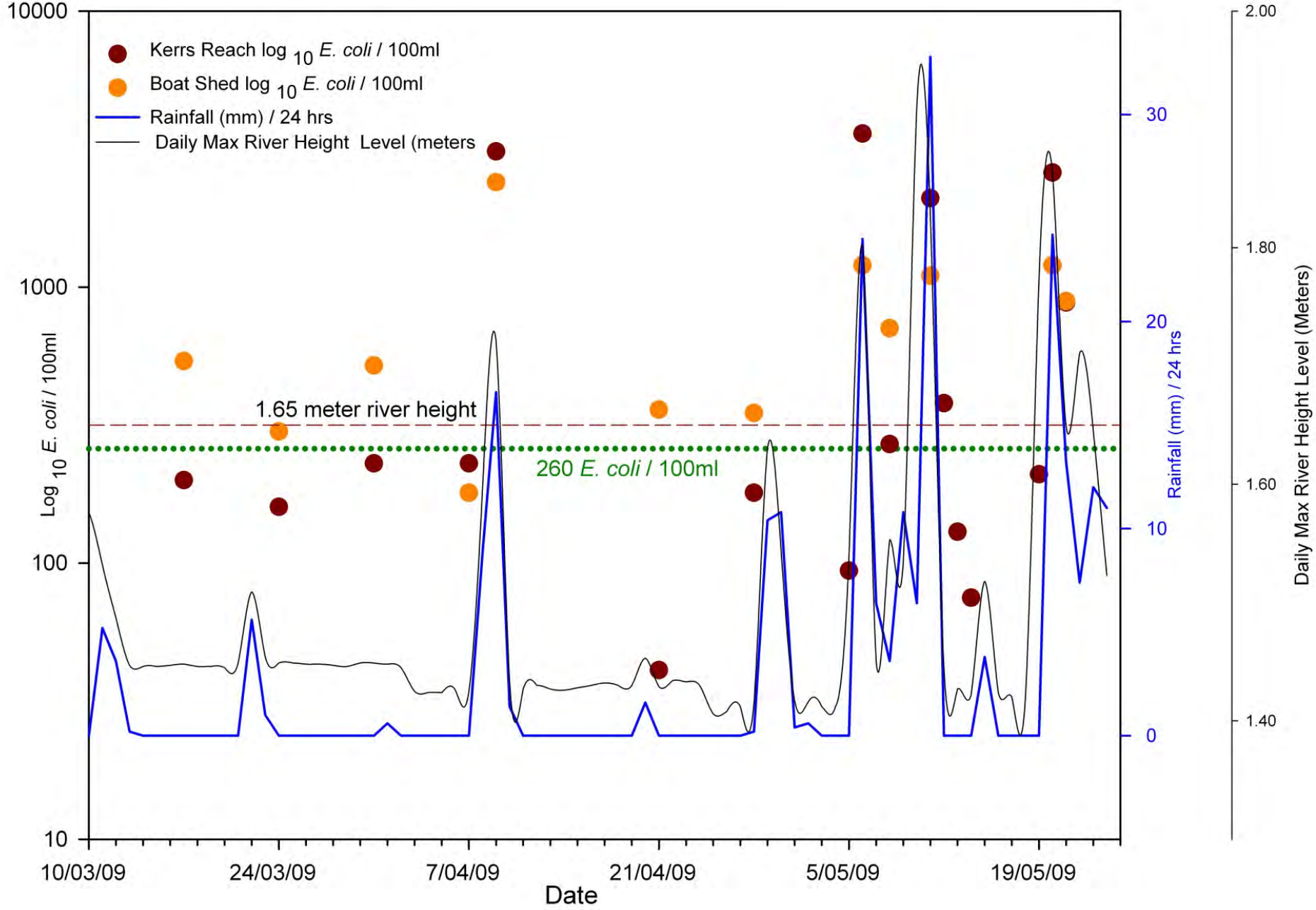
- Acceptable/Green Mode: No single sample greater than 260 *E. coli*/100 mL.
  - Continue routine (e.g. weekly) monitoring.
- Alert/Amber Mode: Single sample greater than 260 *E. coli*/100 mL.
  - Increase sampling to daily.
  - Undertake a sanitary survey, and report on sources of contamination.
- Action/Red Mode: Single sample greater than 550 *E. coli*/100 mL.
  - Increase sampling to daily
  - Undertake a sanitary survey, and report on sources of contamination.
  - Erect warning signs.
  - Inform public through the media that a public health problem exists.

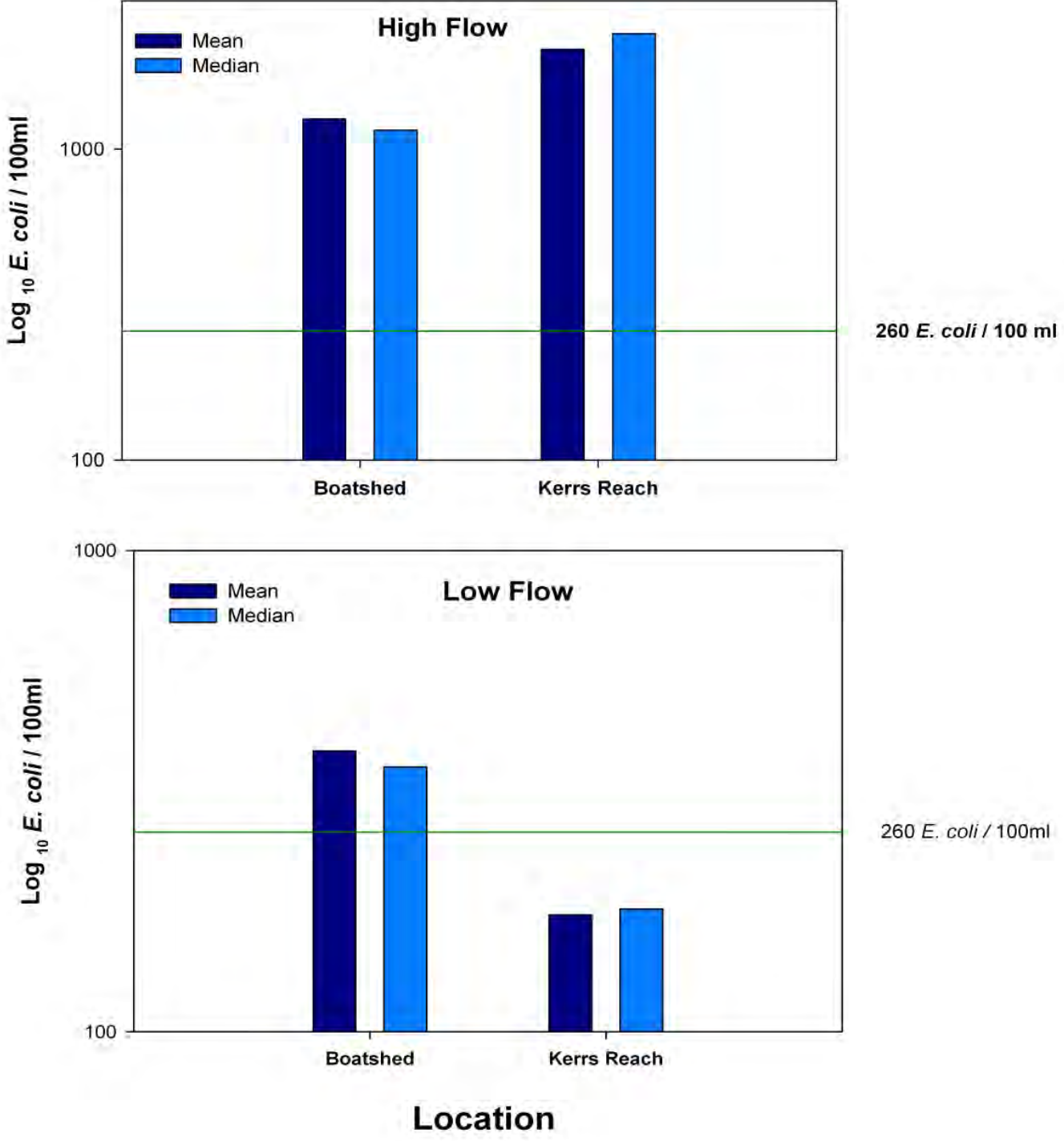
Avon River *E. coli* levels



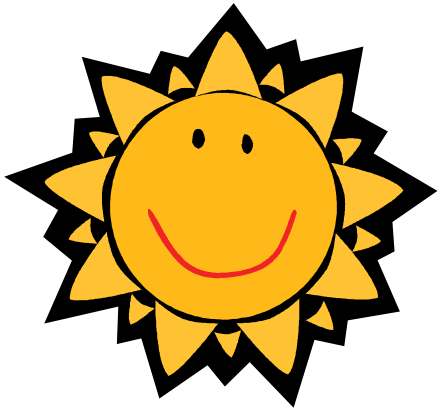


March-May 2009

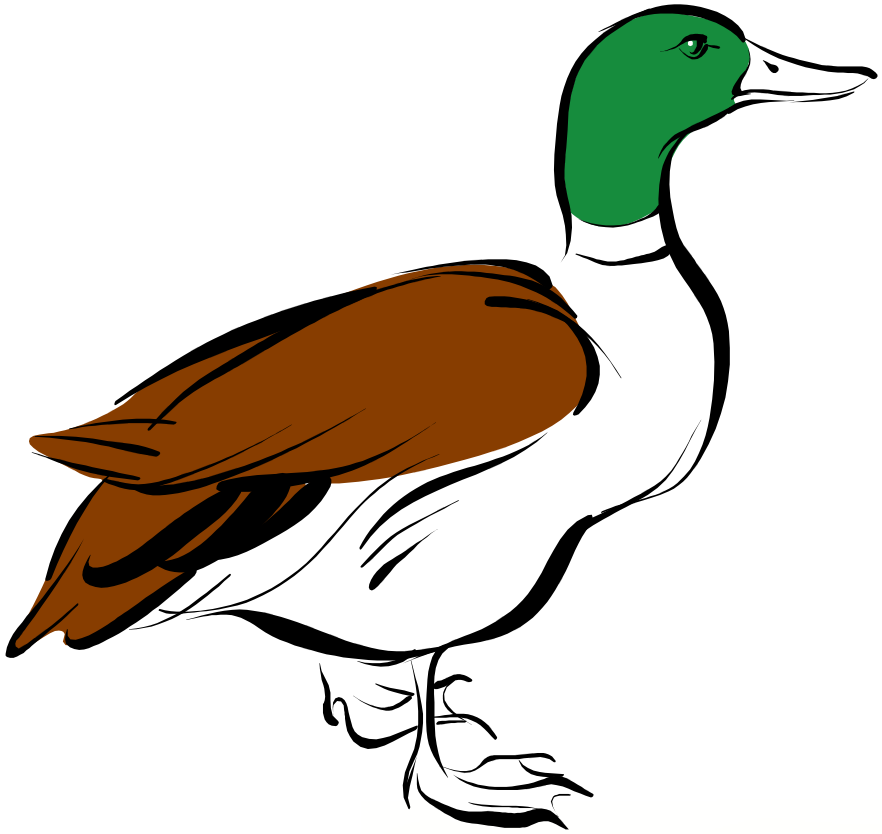

Kerrs Reach log 10 E. coli / 100ml
Boat Shed log 10 E. coli / 100ml
Rainfall (mm) / 24 hrs
Daily Max River Height Level (meters
1.65 meter river height
260 E. coli / 100ml
Log 10 E. coli / 100ml
Rainfall (mm) / 24 hrs
Daily Max River Height Level (Meters)
Date
10000
1000
100
10
30
20
10
0
2.00
1.80
1.60
1.40
10/03/09
24/03/09
7/04/09
21/04/09
5/05/09
19/05/09


High Flow
Mean
Median
Log 10 E. coli / 100ml
1000
100
Boatshed
Kerrs Reach
260 E. coli / 100 ml
Low Flow
Mean
Median
Log 10 E. coli / 100ml
1000
100
Boatshed
Kerrs Reach
260 E. coli / 100ml
Location

In absence of rainfall

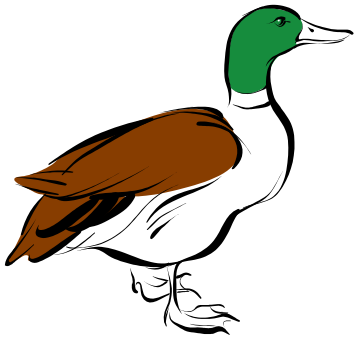


- ***E. coli*** **levels of up to 540** ***E. coli*****/100ml**

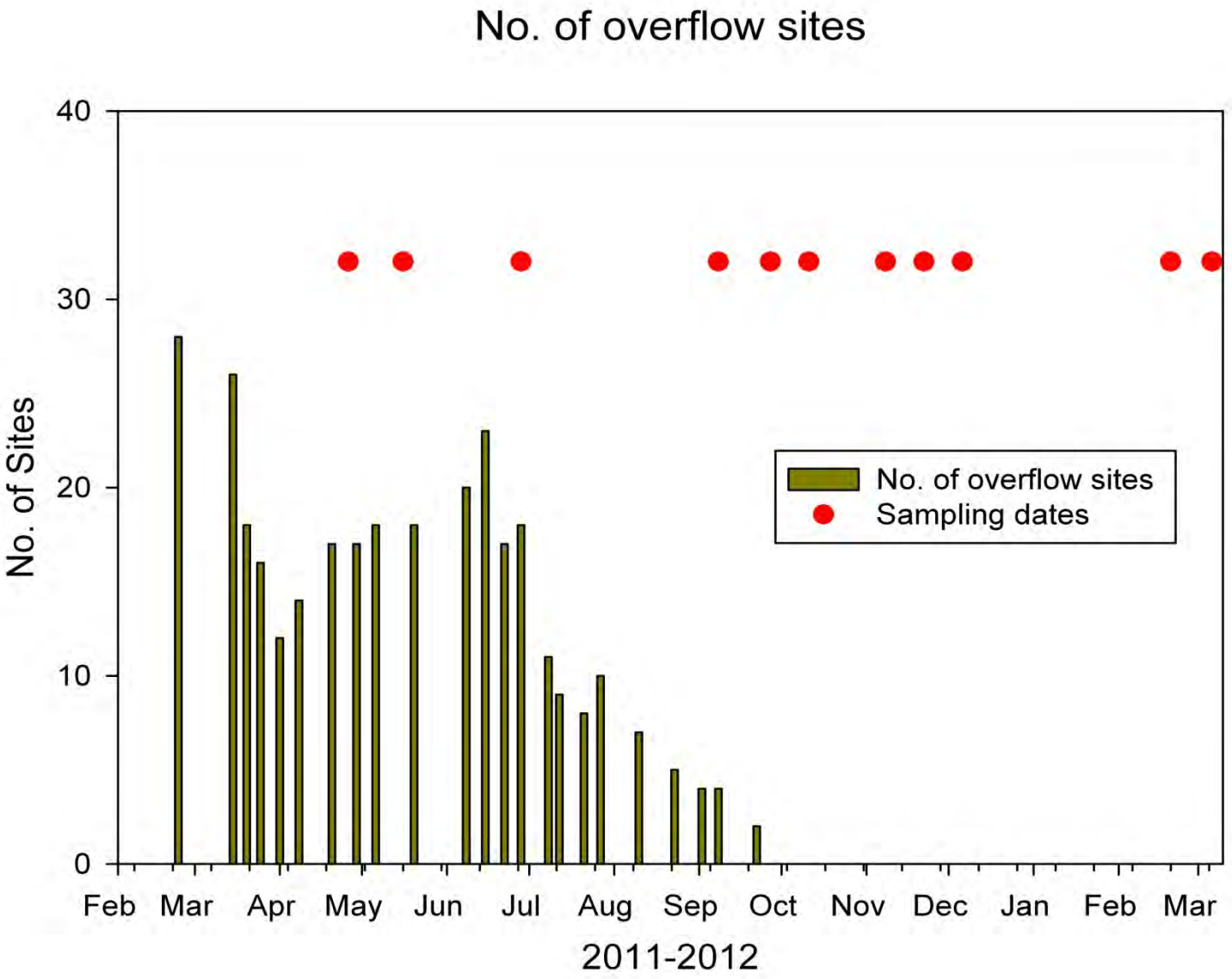


Following rainfall

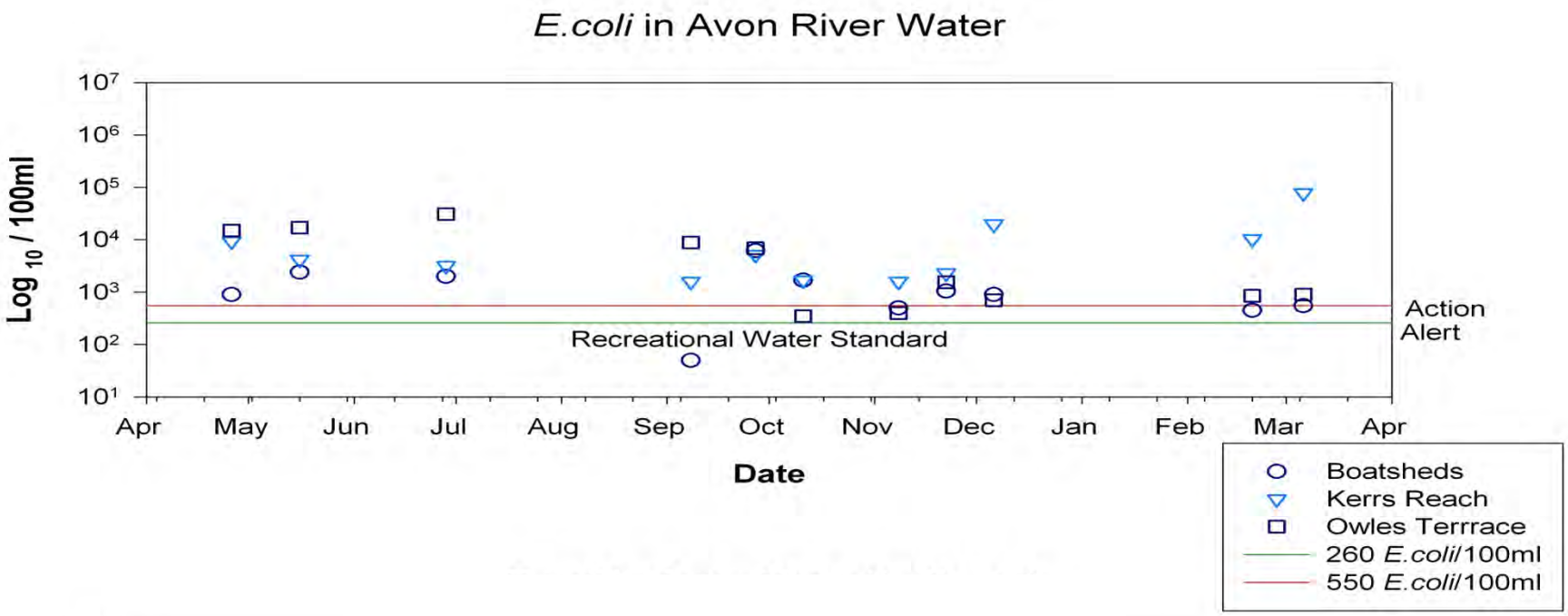
- **Up to 3,600 *E. coli*/100ml.**

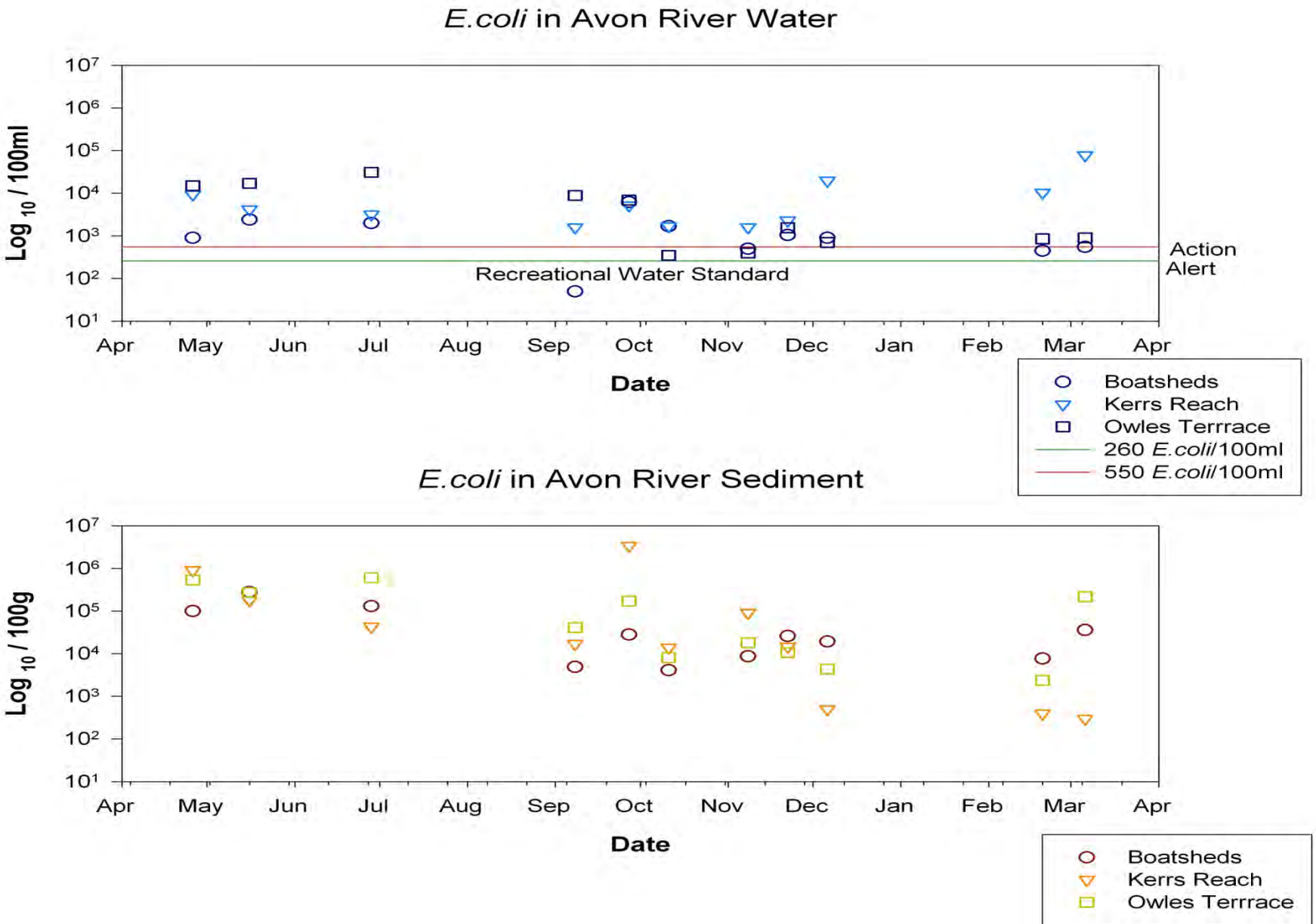


Post-Earthquake sampling




Owles Terrace
Kerrs Reach
Antigua Boatsheds
Humphreys Drive
Penguin Street
Cave Rock
Map
Photos


E.coli in Avon River Water
Log 10 / 100ml
10⁷
10⁶
10⁵
10⁴
10³
10²
10¹
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
Date
Recreational Water Standard
Action Alert
Boatsheds
Kerrs Reach
Owles Terrrace
260 *E.coli*/100ml
550 *E.coli*/100ml


E.coli in Avon River Water
Log 10 / 100ml
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10²
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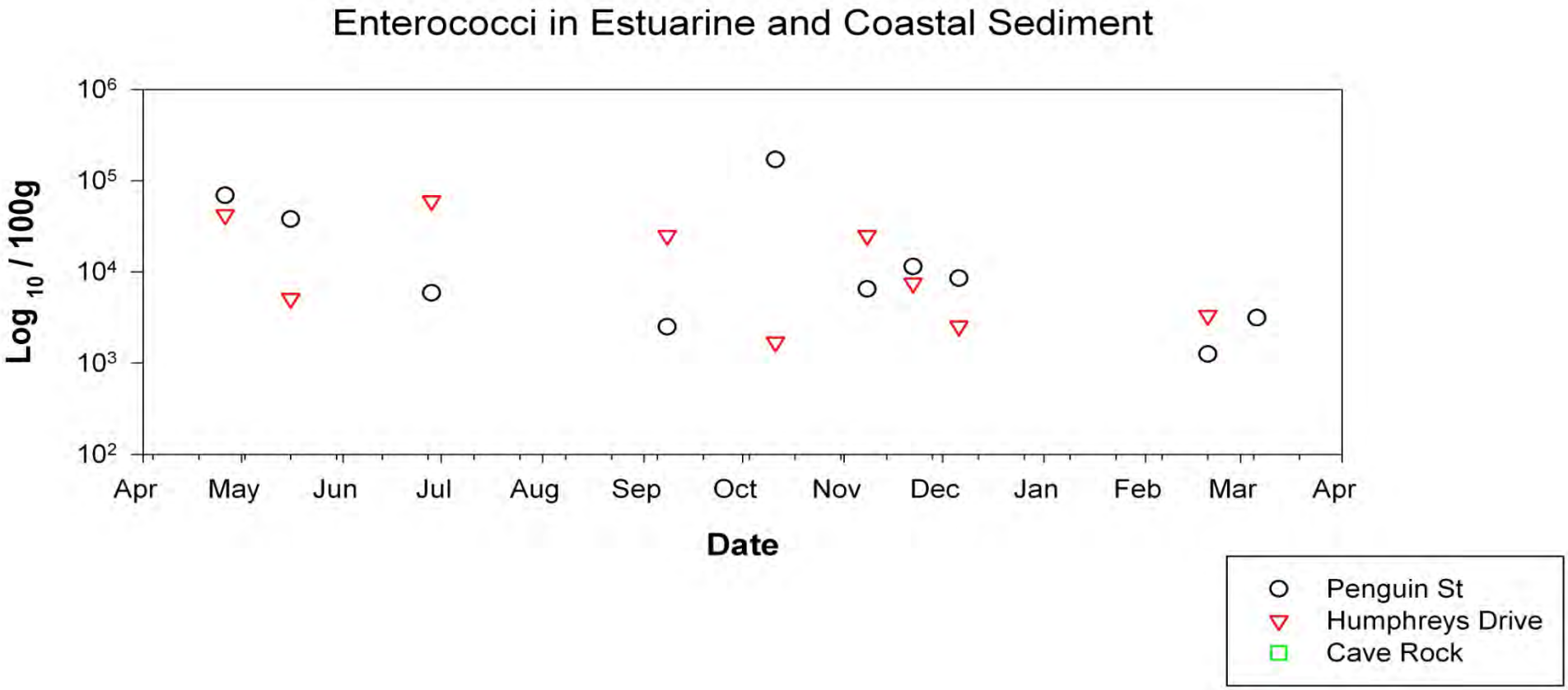
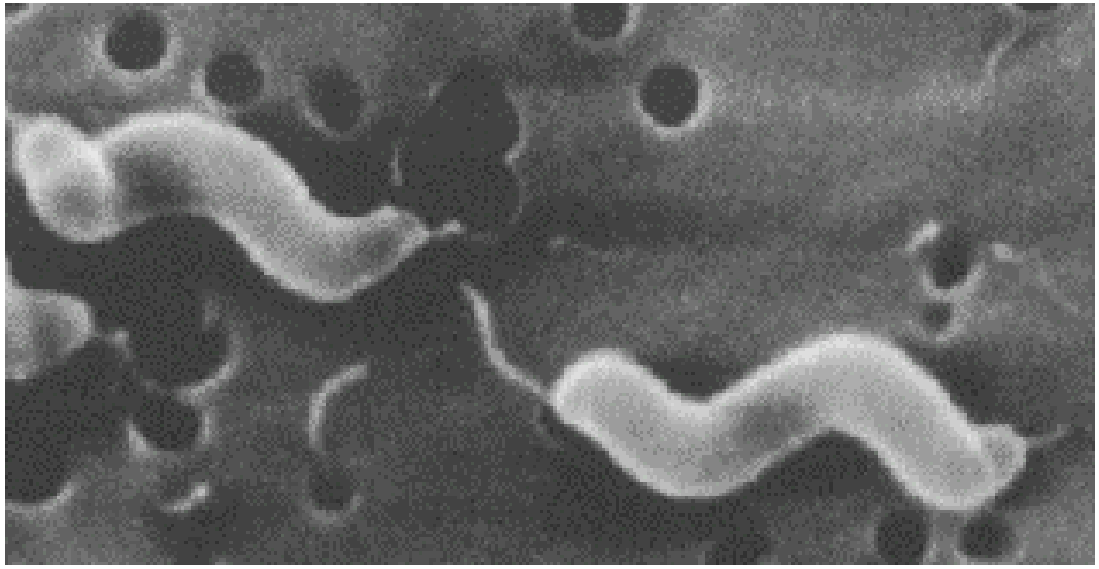
Date
Recreational Water Standard
Action
Alert
Boatsheds
Kerrs Reach
Owles Terrrace
260 E.coli/100ml
550 E.coli/100ml
E.coli in Avon River Sediment
Log 10 / 100g
10⁷
10⁶
10⁵
10⁴
10³
10²
10¹
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
Date
Boatsheds
Kerrs Reach
Owles Terrrace

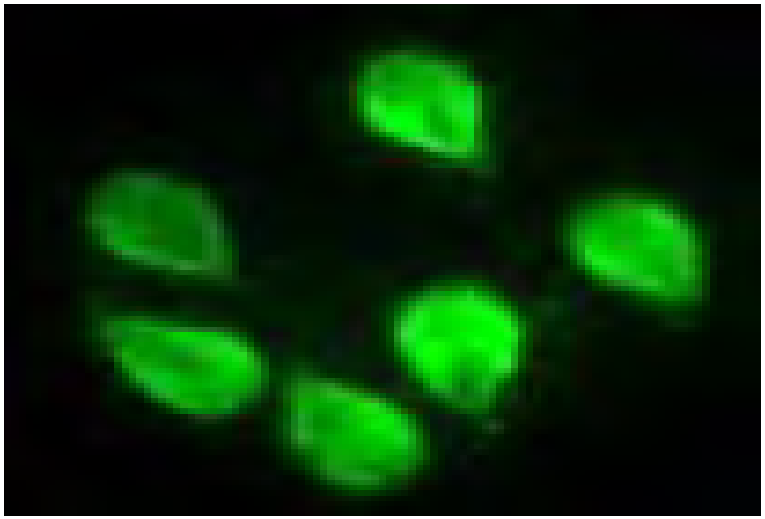

Enterococci in Estuarine and Coastal Sediment
Log 10 / 100g
10^6
10^5
10^4
10^3
10^2
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
Date
Penguin St
Humphreys Drive
Cave Rock

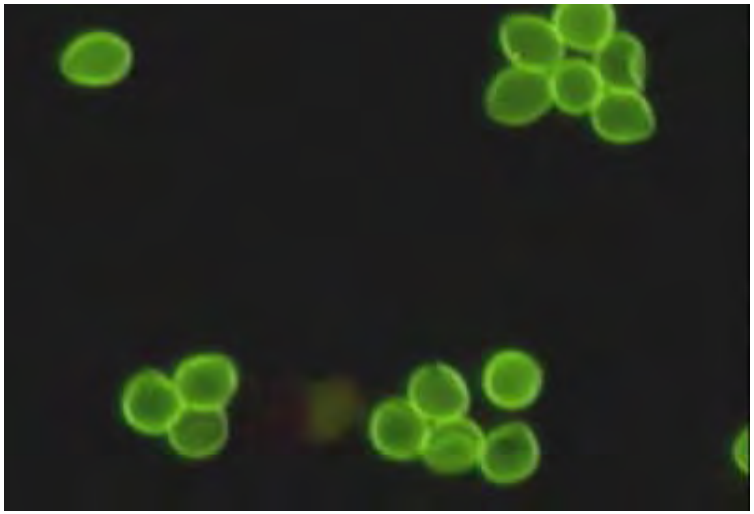
Campylobacter

- **Up to 110 Campylobacter/100ml**

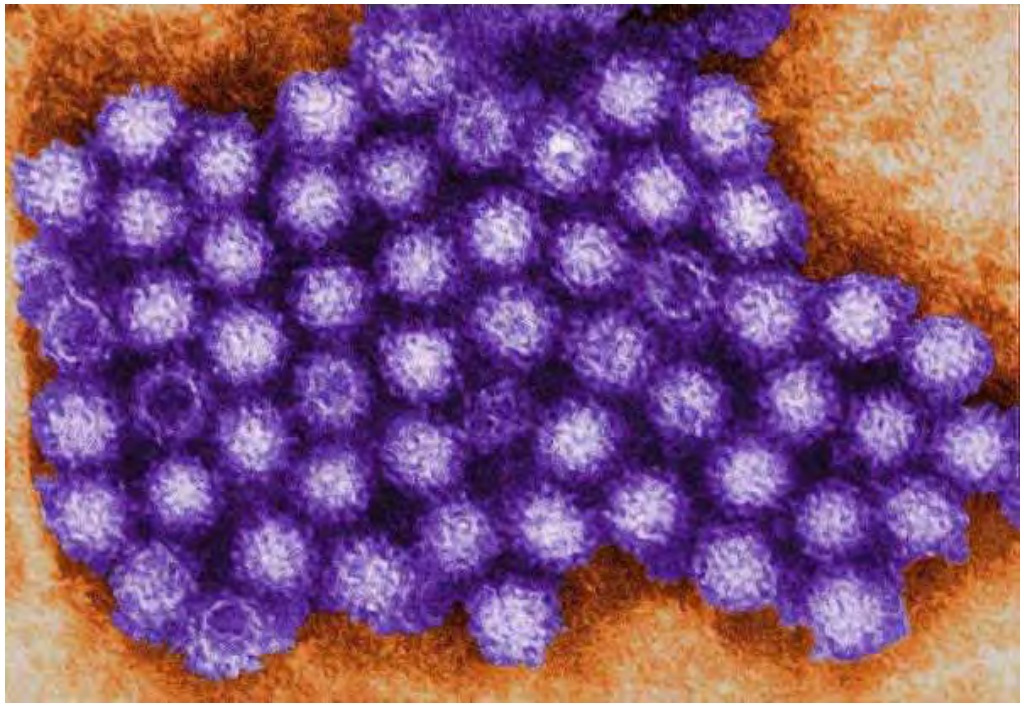


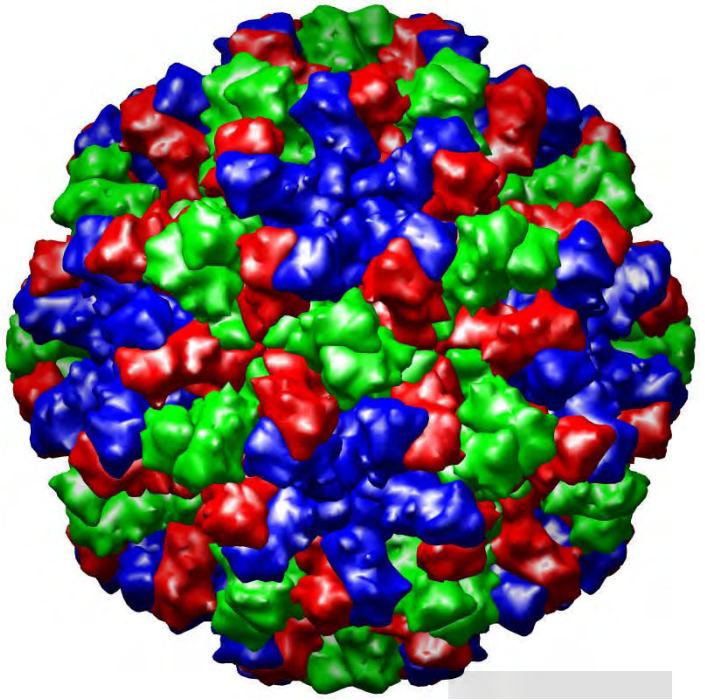
Protozoa





Viruses





Key findings

- During discharges high levels of indicator bacteria and presence pathogens in the water
  - Inform health risk estimates
- Accumulation of micro-organisms in sediments
  - Lack of correlation between water and sediments
  - Tidal influenced sites less accumulation
  - Heavy rainfall “wash” microorganisms out of sediments
- Sumner Beach sediments no evidence of pathogens in beach sand

Faecal Source Tracking in the Avon / Ōtākaro River

Methods for identifying faecal sources of contamination in waterways

Megan Devane, Brent Gilpin,
Beth Robson, Susan Lin, Paula Scholes

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ESR

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Manaaki Tangata Taiao Hoki
protecting people and their environment through science

What does it mean when you identify high levels of microbial indicators??

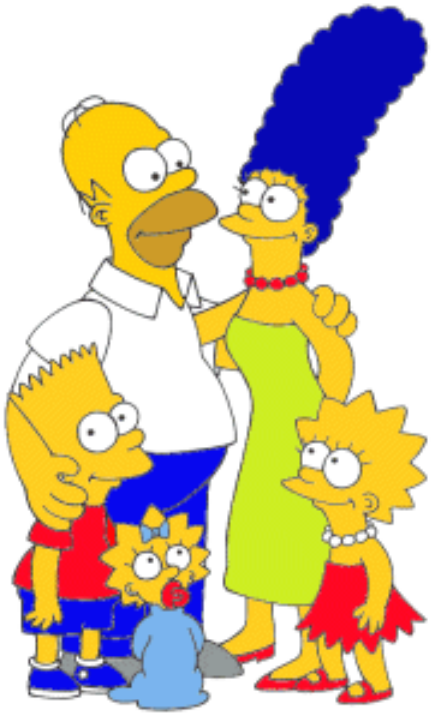
E. coli, Enterococci

Sources of faecal contamination

What does it mean when you identify high levels of microbial indicators??

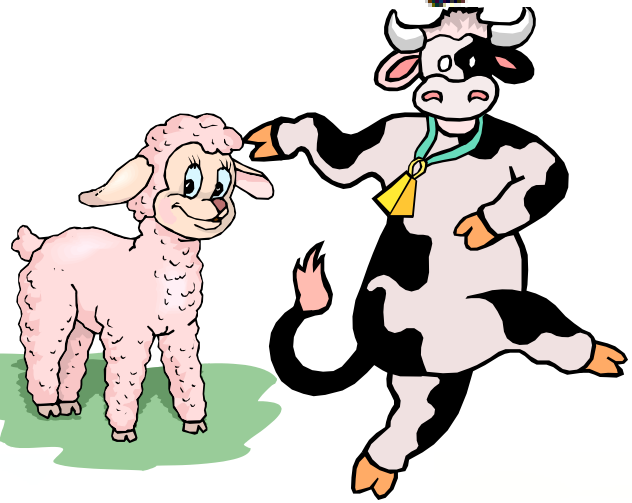
E. coli, Enterococci

Sources of faecal contamination

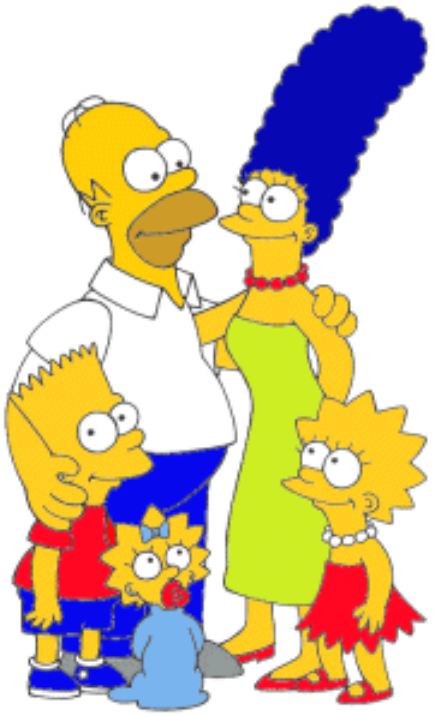


High levels of microbial indicators

E. coli, Enterococci

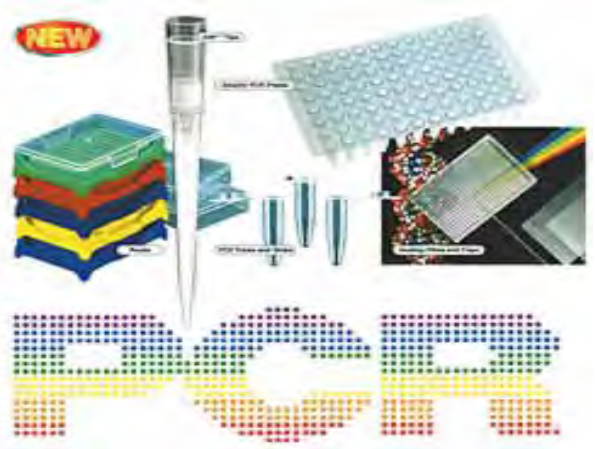


Sources of faecal contamination



Toolbox for faecal source tracking

Molecular markers

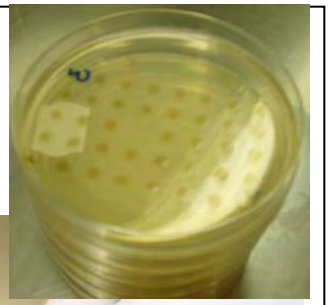


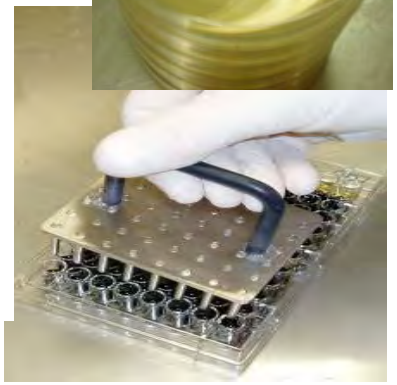
Indicative:
human,
ruminants
pigs, dog,
horses,
possum
ducks,

Library based methods

REP -PCR

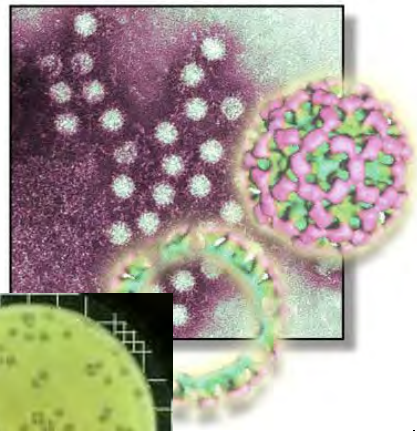
Multiple Antibiotic Resistance analysis





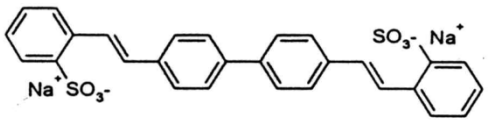
Pathogen Analysis

Noroviruses
Campylobacter typing
Cryptosporidium typing

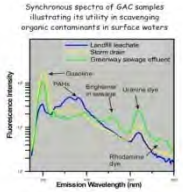


Chemical methods

FWAs



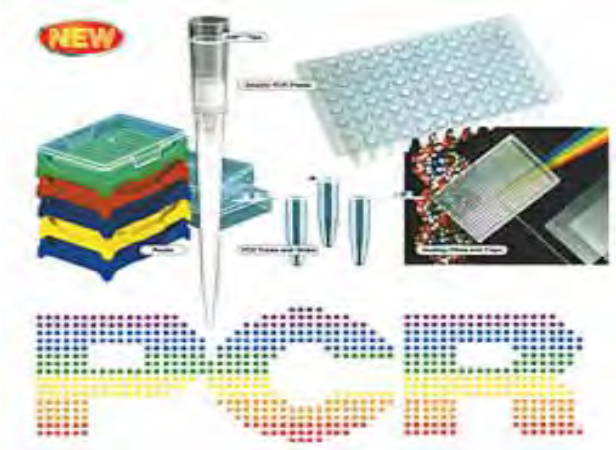
A1557 (FWA1)



Faecal sterol analysis

Toolbox for faecal source tracking

Molecular markers



Indicative:
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ruminants
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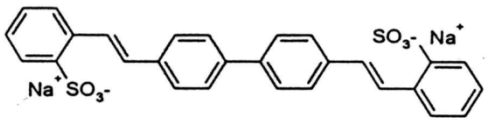
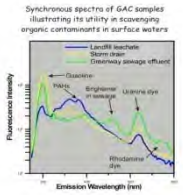
Chemical methods

FWAs



A1557 (FWA1)



Faecal sterol analysis

Chemical Markers:
Faecal Sterols

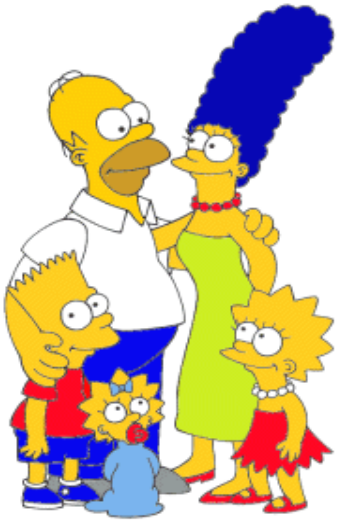
Each animal type has a similar range of sterols but at different concentrations

Sterol ratio analysis

Coprostanol / 24-ethylcoprostanol

>1.0 indicative of human pollution

<1.0 indicative of pollution from herbivores



Chemical Marker

Fluorescent Whitening Agents (FWAs)

- Absorb UV-light and emit blue visible light
- Used “whiten” paper, plastic and fabrics.
- FWAs are added to washing powders
- FWAs in grey water mixed with sewage outflow
- specific indicator of human faecal contamination

Polymerase Chain Reaction (PCR)

Bacterial target	Target faecal source
Bifidobacterium adolescentis	Human
Bacteroidales -Human	Human
Bacteroidales - Herbivore	Ruminant
Bacteroidales– Dog	Dog
Bacteroidales– Pig	Pig
Bacteroidales– Horse	Horse
Rhodococcus coprophilus	Dairy effluent
E2 *Desulphovibrio*	Duck (Wildfowl)

Owles Terrace

A comparison of

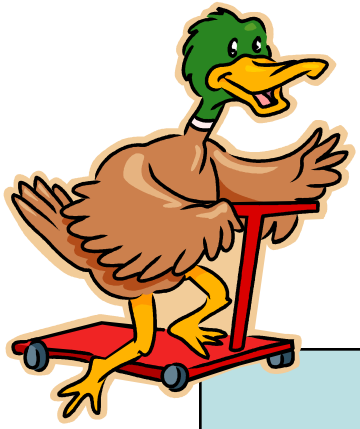
FST markers from sediments and overlying water samples

Why sample the sediments for FST markers?

- Evaluate whether sediments provide a historical record of faecal pollution
- Assess methods for aging faecal pollution

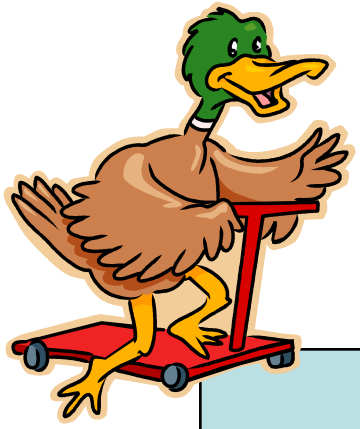
Question:

Whether resuspended sediments are likely to contribute to the FST markers identified in water samples?



Boatshed Water

	E. Coli		PCR Markers		
Date	***CFU/ 100 ml***	**Sterols**	**Human**	**Bird**	**Dog**
23 Apr 2011	7,500	Wildfowl	ND	POS	POS
16 May 2011	2,350	Human	POS	POS	POS
8 Nov 2011	500	Wildfowl	ND	POS	ND
20 Feb 2012	450	Human	POS	POS	POS



Boatshed Sediment

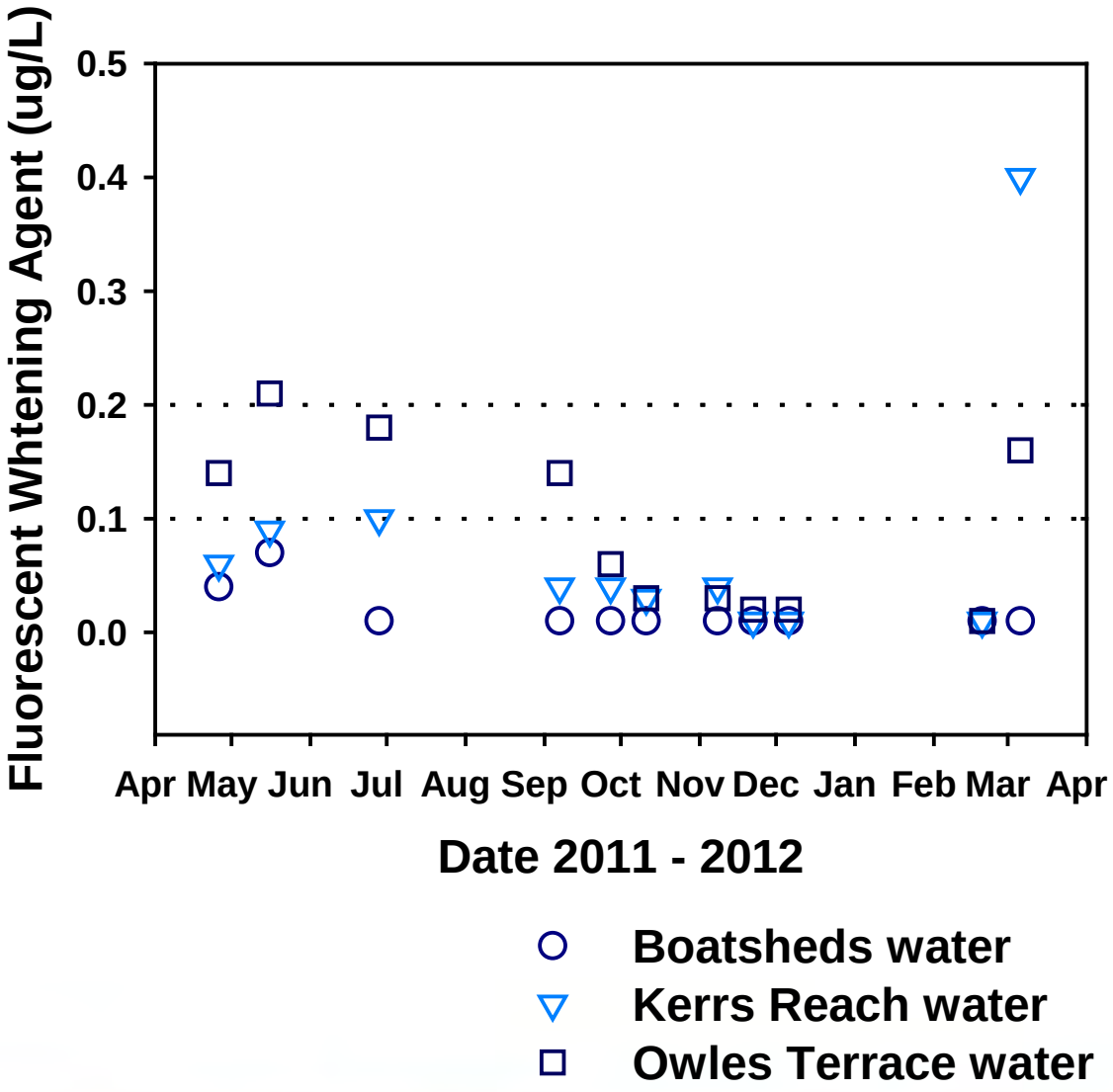
	E. Coli		PCR Markers		
Date	***CFU/ 100 ml***	**Sterols**	**Human**	**Bird**	**Dog**
23 Apr 2011	222,000	Wildfowl	ND	ND	ND
16 May 2011	277,000	ND	Low level	ND	ND
8 Nov 2011	8,700	ND	ND	ND	ND
20 Feb 2012	10,300	ND	ND	ND	ND

Sterol concentrations and sterol ratio analysis for Owles Terrace

26 April 2011- 20 Feb 2012

Sterol ratio analysis	Type of faecal indicator	Sediment	Water
coprostanol/cholestanol	Non-specific indicators of faecal contamination	**faecal**	**faecal**
24-ethylcoprostanol/ 24-ethylcholestanol		**faecal**	**faecal**
%Coprostanol/total sterols	Human faecal indicators 	**human**	**human**
Coprostanol/(coprostanol cholestanol)		**human**	**human**
coprostanol/24-ethylcoprostanol		**human**	**human**
%coprostanol/ coprostanol+24-ethylcoprostanol	Human versus herbivore indicator	**human**	**human**
% 24-ethylcoprostanol/total sterols	Herbivore specific indicator	**ND**	**ND**
24-ethylcholestanol/ (24-ethylcholestanol+24-ethylcoprostanol +24-ethylepicoprostanol)	Wildfowl	**ND**	**ND**

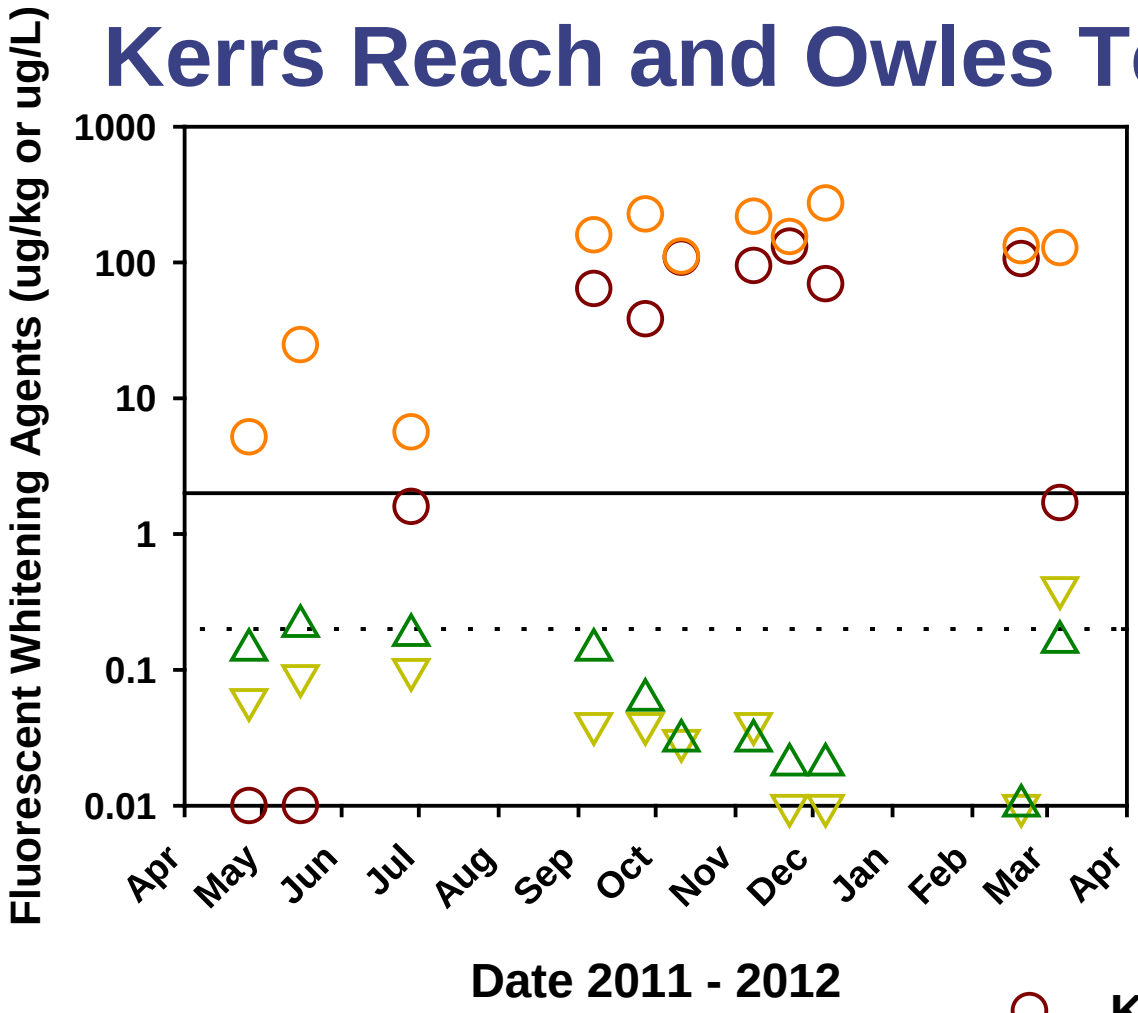
FWAs in Avon / Ōtākaro River water



indicates human faecal pollution

suggests human faecal pollution

Accumulation of FWA in sediments at Kerrs Reach and Owles Terrace



indicates sewage in sediment

indicates sewage in water

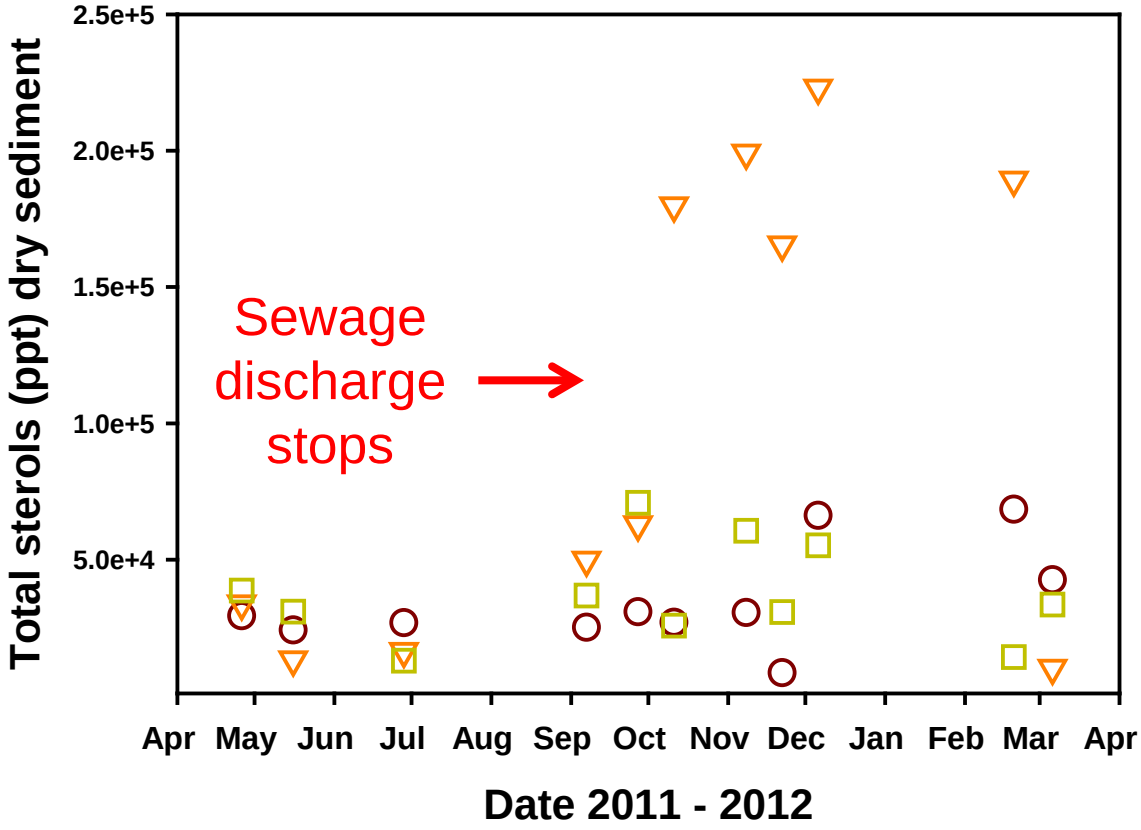
Kerrs Reach sediment

Owles Terrace sediment

Kerrs Reach water

Owles Terrace water

Sterols in Avon / Ōtākaro River sediments



>10 fold less total sterols in water column

Boatshed sediments
Kerrs Reach sediments
Owles Terrace sediments

Faecal Aging Methods

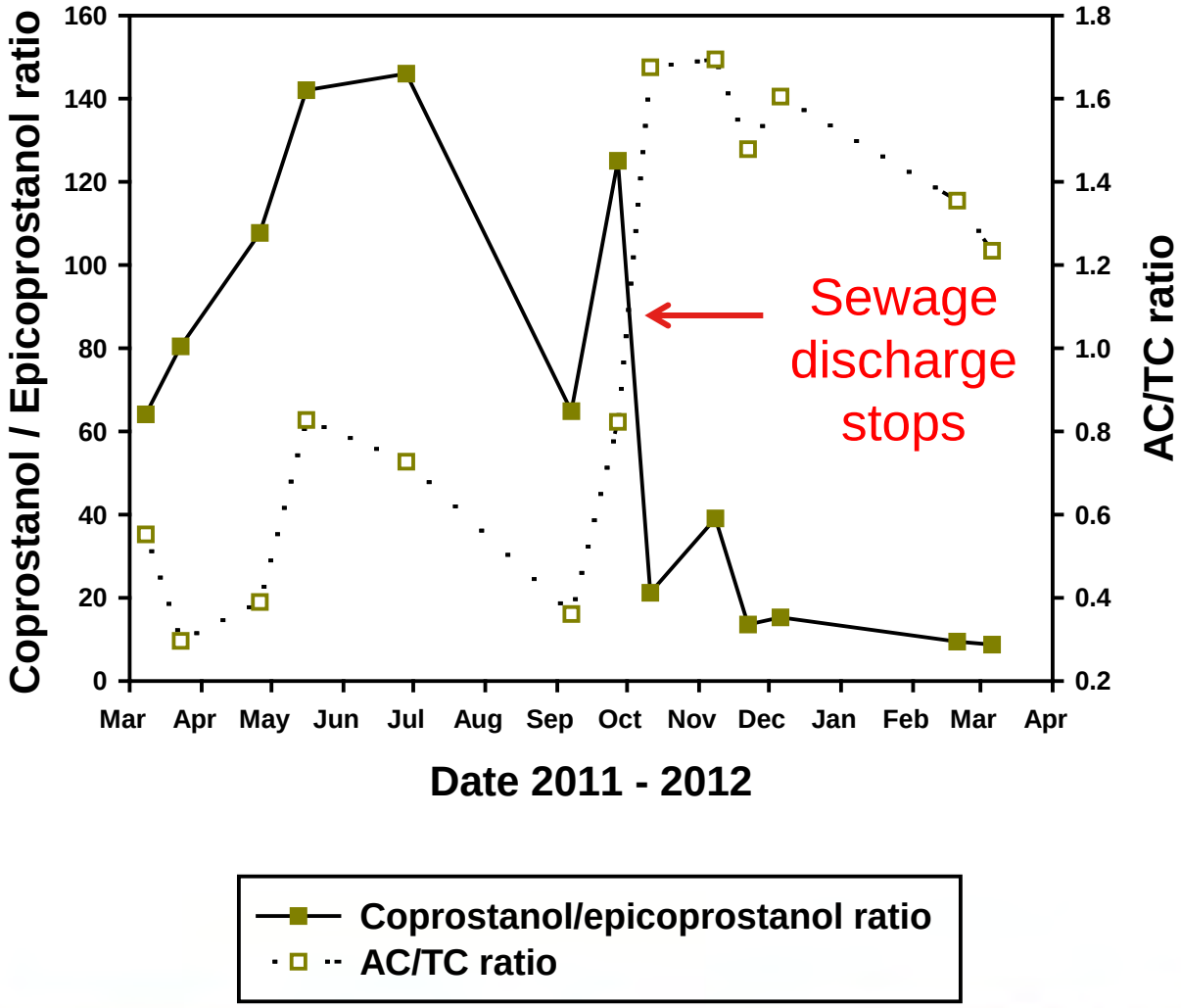
- **Bacterial Ratio** $\frac{\text{Atypical colonies}}{\text{Total Coliforms}}$

Low ratios = fresh sewage

- **Sterol ratio** $\frac{\text{Coprostanol}}{\text{Epicoprostanol}}$

high ratios = fresh sewage

Faecal aging ratios in water at Owles Terrace



Finding from this study: Faecal aging ratios

For water impacted by human sewage:

A negative corrrelation was identified between the sterol aging ratio and the Total coliform ratio based on bacterial enumeration

Sterol ratio : Bacterial ratio (P = 0.013)

Conclusions for FST markers in Avon / Ōtākaro River sediments

	Marker accumulating in sediment
Faecal Sterols	
PCR markers	
Fluorescent Whitening Agents	

Faecal Source Tracking Conclusions

- Sediments provide a historical record of faecal pollution
- Disconnect between FST markers identified in sediment and overlying water
- Two promising methods for aging human faecal pollution

ESR

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FST markers for Avon River

	Water	Sediment	Marker accumulating in sediment
Faecal Sterols	★	★	★
PCR markers	★	✖	✖
Fluorescent Whitening Agents	✖	★	★

Faecal Source Tracking

Using science to help inform water management decisions

Home | Decision Trees | Toolbox | Case Studies | Research | Publications | Contacts

An information source for those interested in identifying sources of faecal contamination

Faecal Source Tracking:

www.waterquality.org.nz

Sophisticated Techniques to Identify and Mitigate Water Contamination Issues

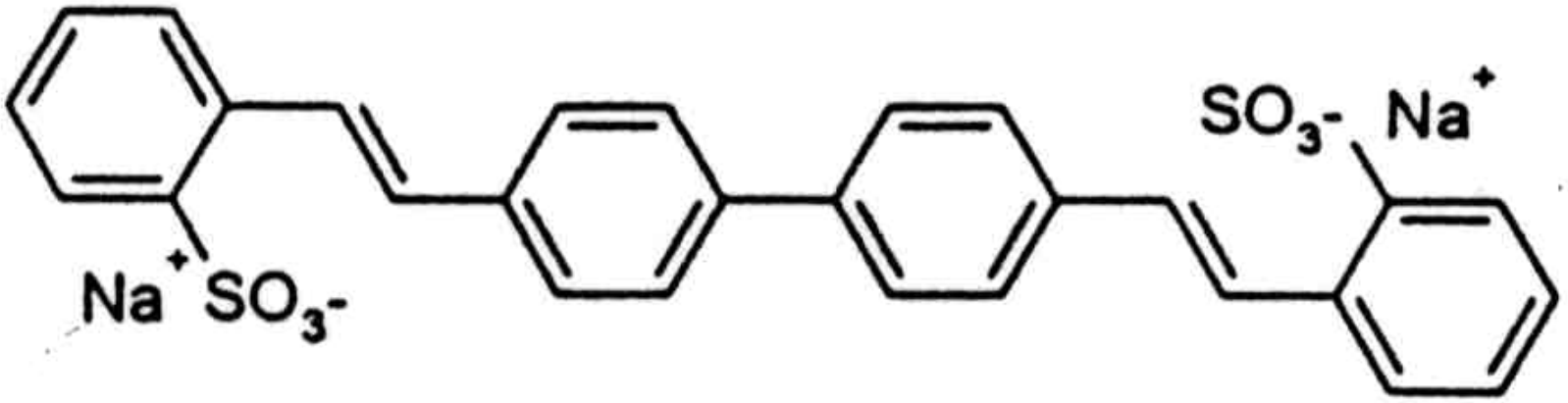
Waters clean enough for humans to drink, swim in, process food with and collect food from, are indicative of a wider healthy environment. However, access to such pristine waters is diminishing as urbanisation expands and agricultural production increases, leading to faecal contamination and reduced microbiological water quality. Issues surrounding factors that may compromise water quality must be addressed and resolved.

When waterways become contaminated with faeces, an important step in contamination management is identifying the source of the pollution. A research team at ESR is developing tools that will improve the microbial quality of water by discriminating among different sources of faecal contamination of water, leading to targeted environmental management interventions.

Scientists use molecular and chemical techniques to help identify the source of faecal contamination of water whether it is from farm, domestic or feral animals, humans or birds. If an initial Colilert® test indicates the presence of high counts of Escherichia coli, one or more assays from a 'tool box' of

FWA1

FWA 1



4,4’-bis(2-sulfostyryl)biphenyl

- **Photodegradation with half life several hours**
- **Below photic zone, persistent since biodegradation not been observed.**

Faecal Aging Methods

Second marker: Sterol Ratio

- Based on faecal sterols
- Coprostanol / Epicoprostanol

- Higher ratios are associated with high levels of coprostanol, the major human sterol
- The ratio reduces over time as sterols are degraded to epicoprostanol.