How emerging science in Europe is challenging regulatory assumptions for bathing and shellfish harvesting waters

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Funders

UCD Dublin

Cardiff University / Prifysgol Caerdydd

City and County of Swansea

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Dŵr Cymru Welsh Water

C2C Cloud to Coast

Delivering Healthy Water

Environment Agency

ERDF / Llywodraeth Cymru Welsh Government
Ewrop & Chymru: Buddsoddi yn eich dyfodol
Cronfa Datblygu Rhanbarthol Ewrop
Europe & Wales: Investing in your future
European Regional Development Fund

SEPA

The Scottish Government

defra Department for Environment Food and Rural Affairs

UKWIR

YorkshireWater

Natural Environment Research Council

States of Guernsey

LCRI Marine Low Carbon Research Institute

epa Environmental Protection Agency

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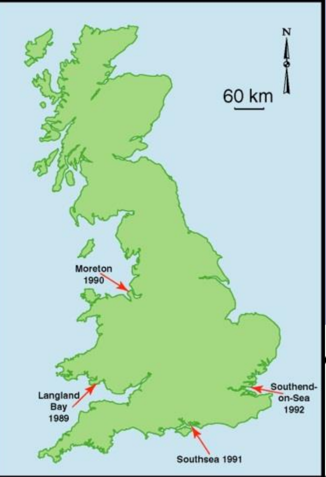
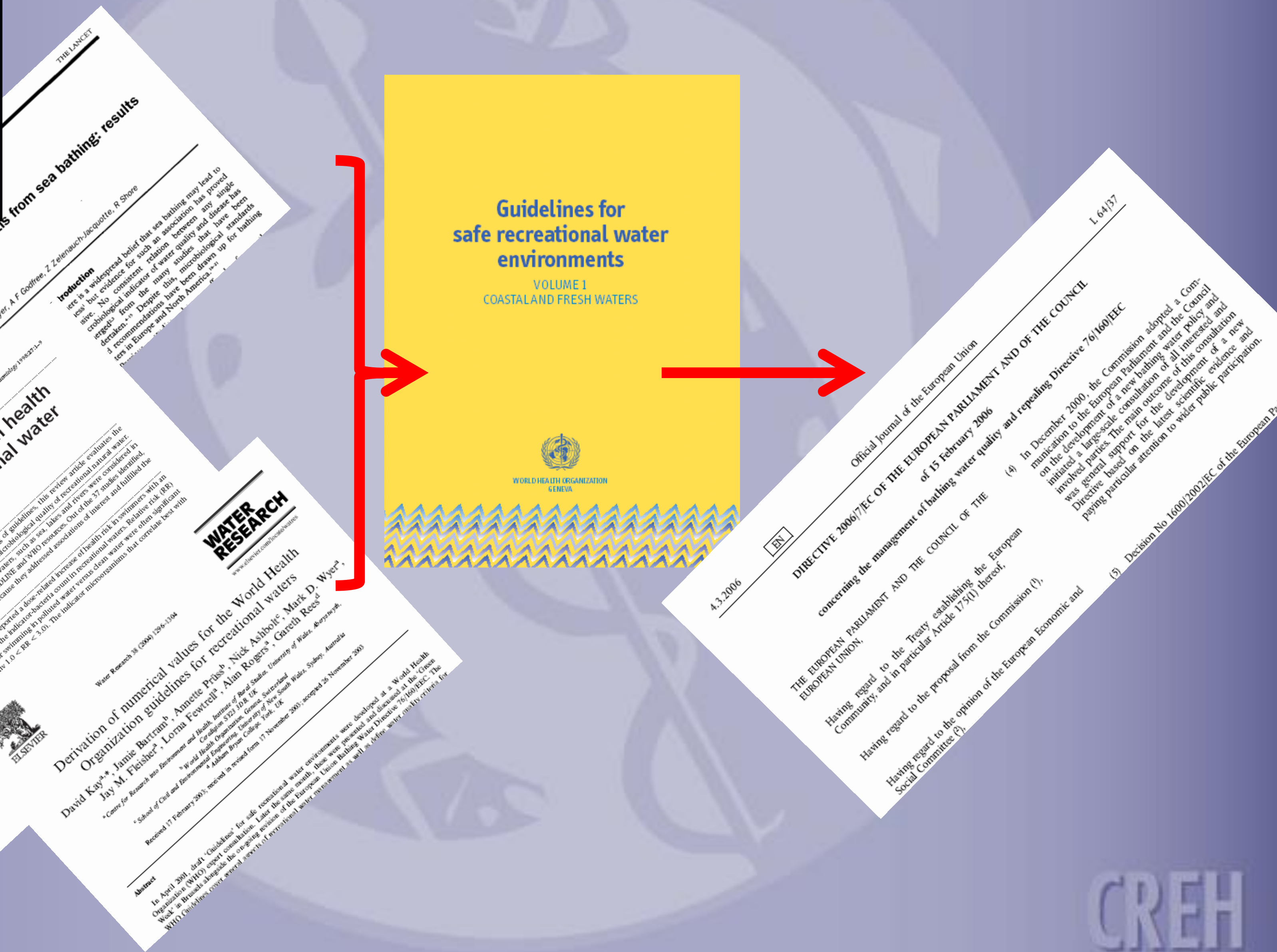
The Background

Epidemiology





UK studies 1989-1992

The WHO Microbiological Guidelines

≤40	This range is below the NOAEL in most epidemiological studies.	<1% GI illness risk <0.3% AFRI illness risk
41–**200**	The 200/100 ml value is above the threshold of illness transmission	1–**<5%** GI illness risk 0.3–<1.9% AFRI illness risk
201–500	This range represents a substantial elevation in the probability of all adverse health outcomes	**5**–10% GI illness risk 1.9–3.9% AFRI illness risk
>500	Above this level, there may be a significant risk of high levels of minor illness transmission.	>10% GI illness risk >3.9% AFRI illness rate

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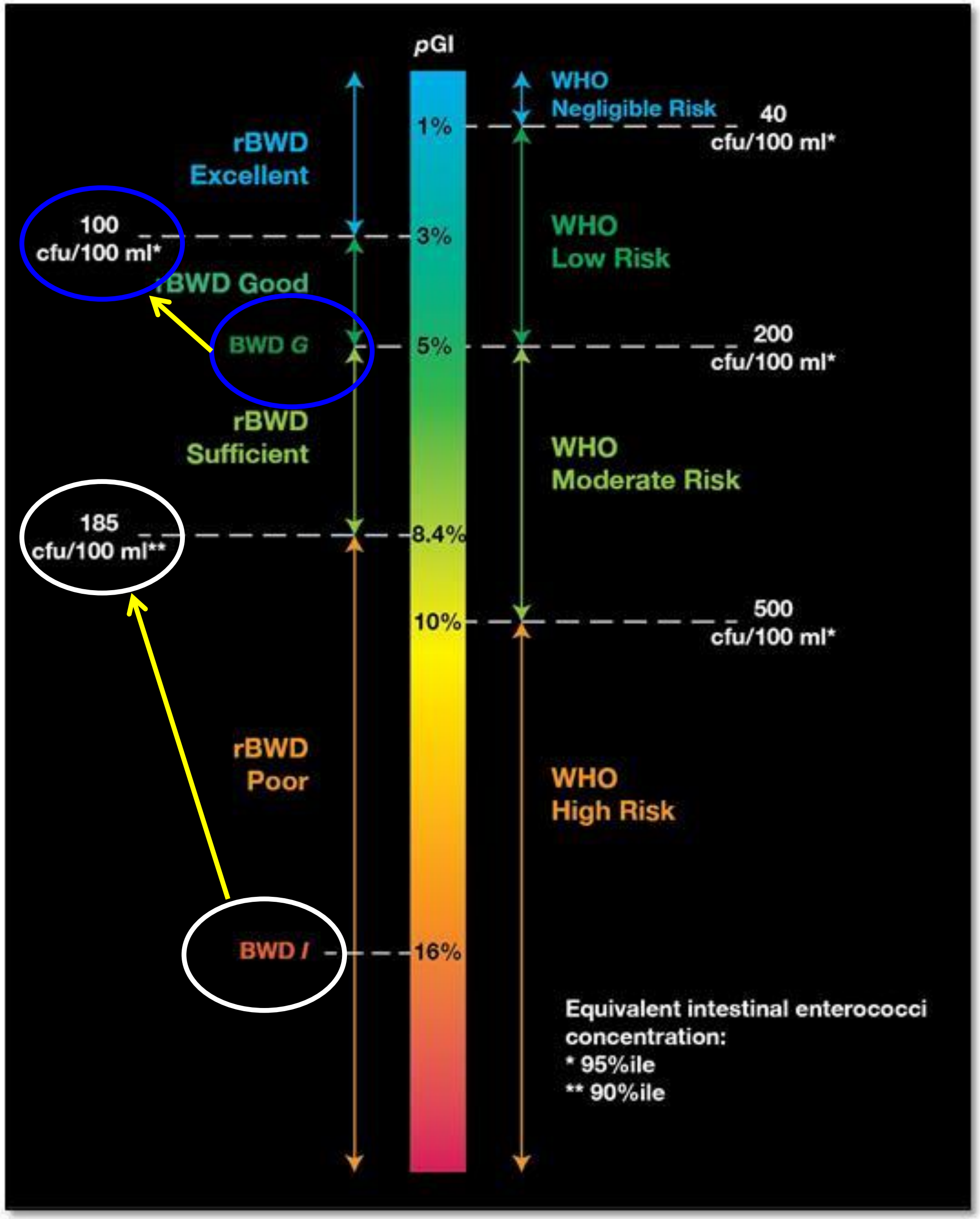
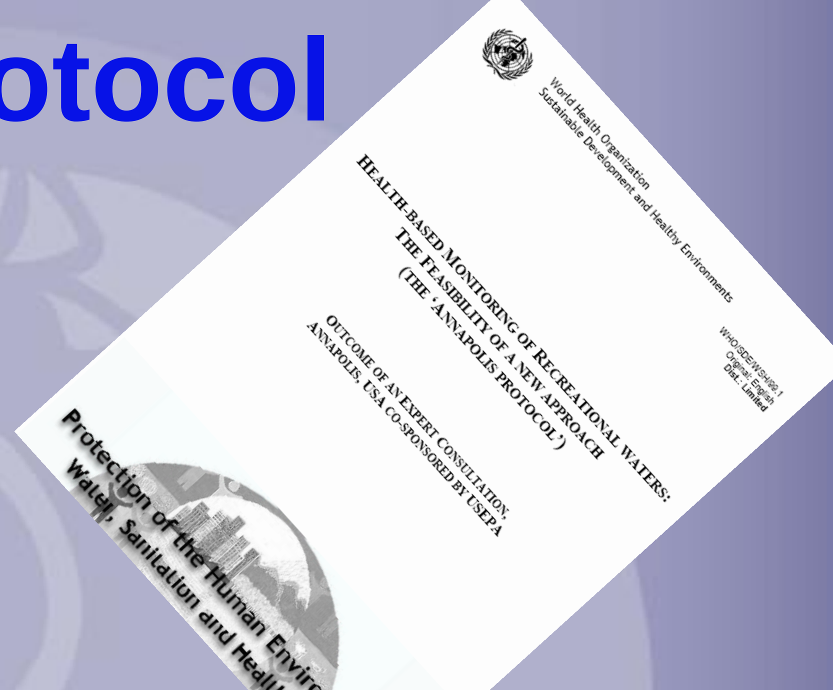


pGI
rBWD Excellent
100 cfu/100 ml*
rBWD Good
BWD G
rBWD Sufficient
185 cfu/100 ml**
rBWD Poor
BWD I
1%
3%
5%
8.4%
10%
16%
WHO Negligible Risk
40 cfu/100 ml*
WHO Low Risk
200 cfu/100 ml*
WHO Moderate Risk
500 cfu/100 ml*
WHO High Risk
Equivalent intestinal enterococci concentration:
* 95%ile
** 90%ile

The Annapolis Protocol

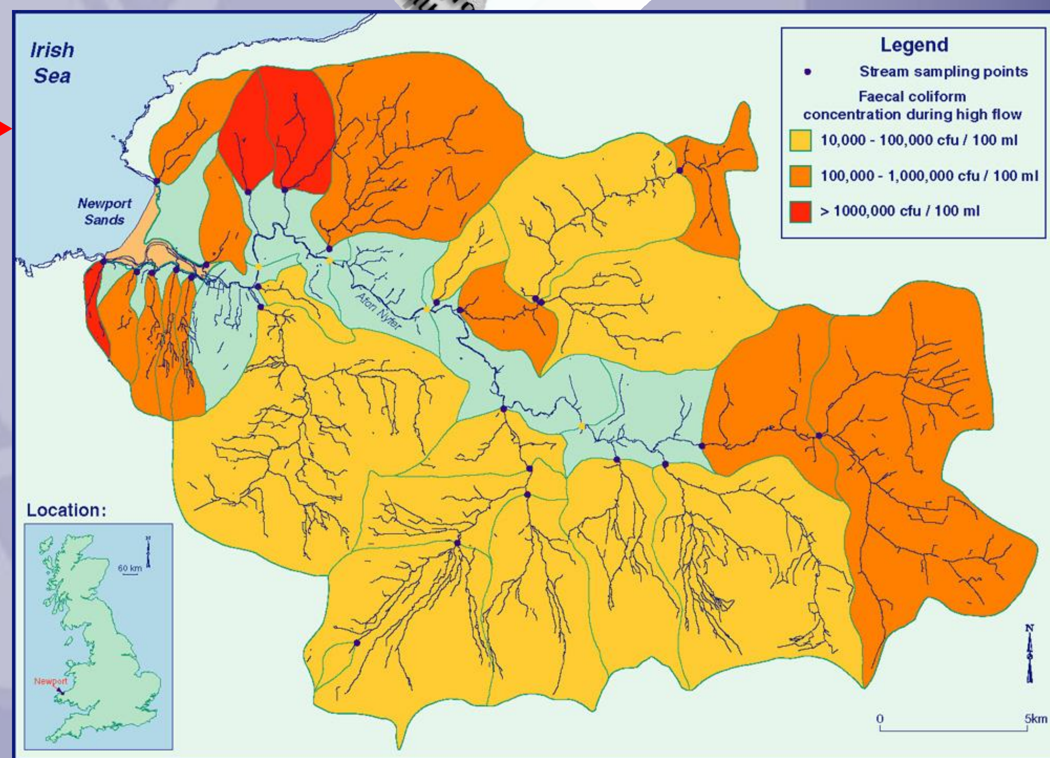

World Health Organization
Sustainable Development and Healthy Environments
WHO/SDE/WSH/99.1
Original: English
Dist.: Limited

HEALTH-BASED MONITORING OF RECREATIONAL WATERS:
THE FEASIBILITY OF A NEW APPROACH
(THE 'ANNAPOLIS PROTOCOL')

OUTCOME OF AN EXPERT CONSULTATION,
ANNAPOLIS, USA CO-SPONSORED BY USEPA

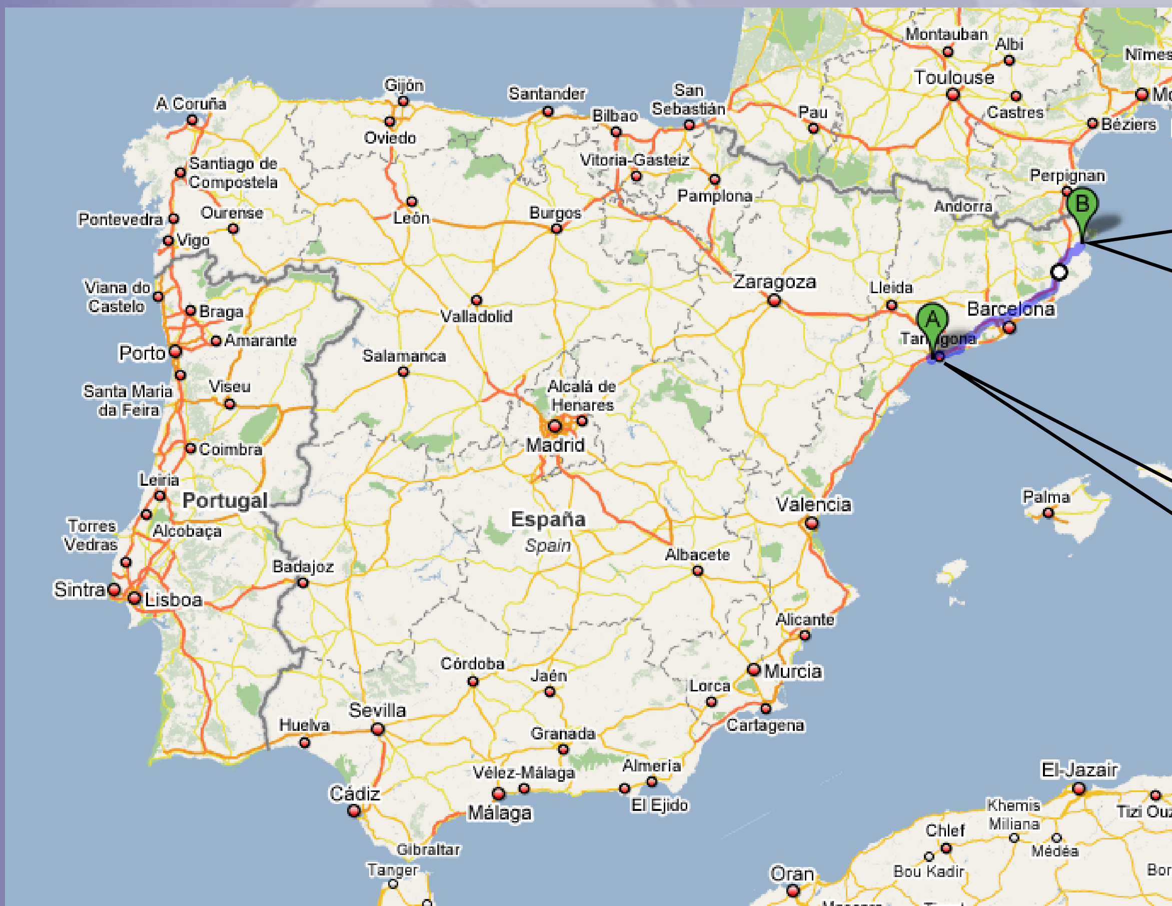
Protection of the Human
Water, Sanitation and

Norman Lowe	**DCWW**
Nick Humphrey	**DCWW**
Peter Bird	**EA**



Spanish Studies

1. Study sites



Trials 8 & 9
Sant Pere Pescador
22 & 23 Sep 07

Trials 6 & 7
Salou
24 & 30 Sep 06


MAIT
NCIA SALUT

Epibathe Hungary

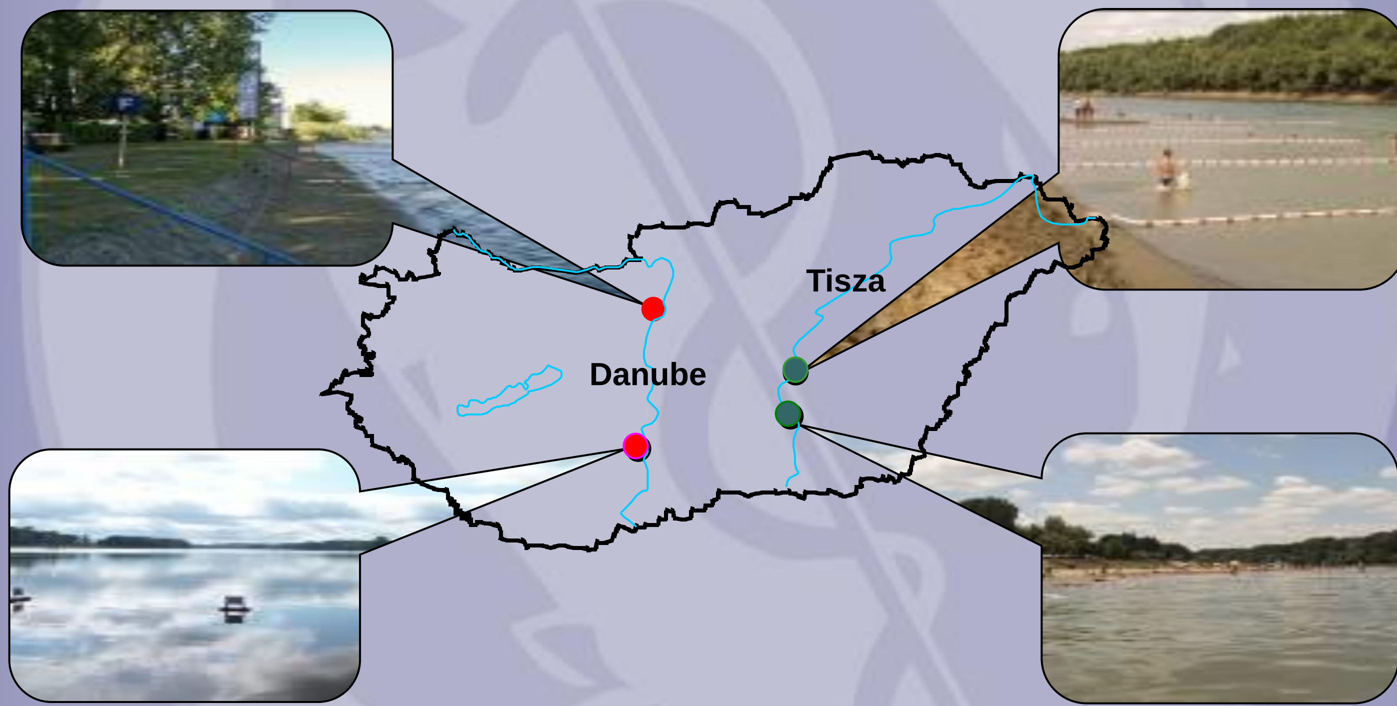
The team...

…and their great leader

1. Study sites

Trial 11
Dömsöd, 16 JUL 06

Trial 14
Tiszakécske, 5 AUG 07



Trial 12
Dombori, 13 AUG 06

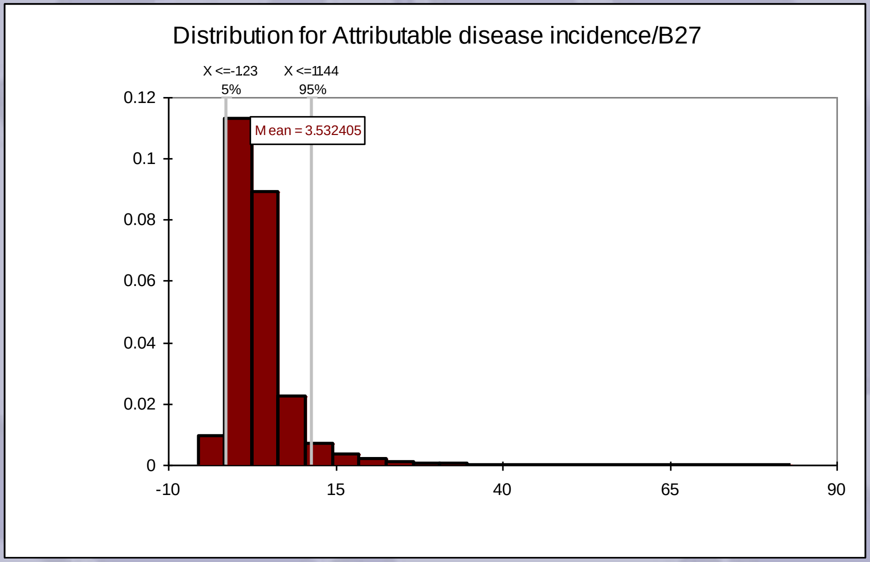
Trial 13
Csongrád, 1 JUL 07

Epibathe Combined Marine Data
UK and Spain

- More illness in bathers with lower exposure to FS.
- Very different illness rate in non-bathers
- Risk difference very different between UK and Spanish studies
- But Relative Risk/Odds Ratio are similar between UK and Spanish studies

Model outputs for a marine bathing water with 95%ile 100 IE

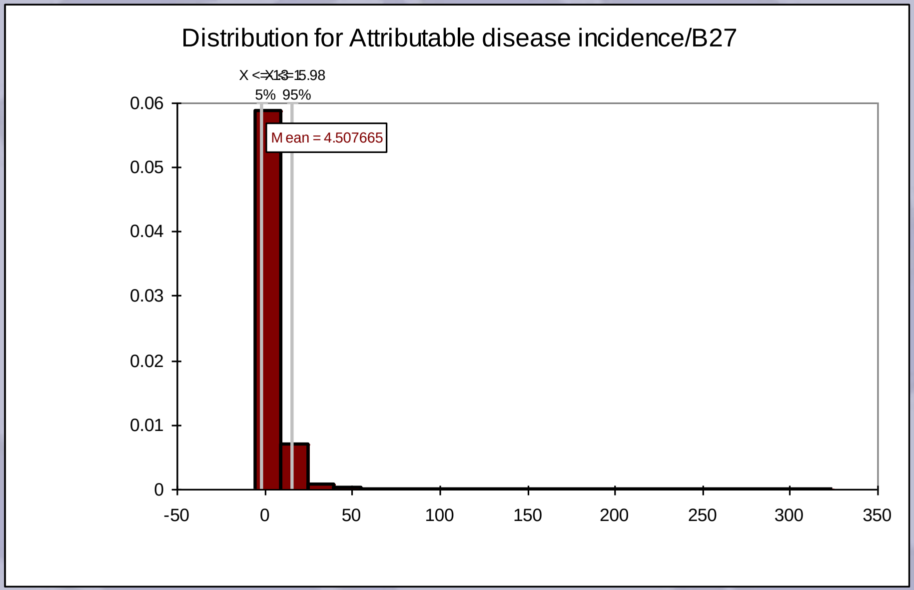
BWD Excellent



Attributable disease incidence 3.5%

EU BWD was 3% (based on Kay et al., 1994, 2004)

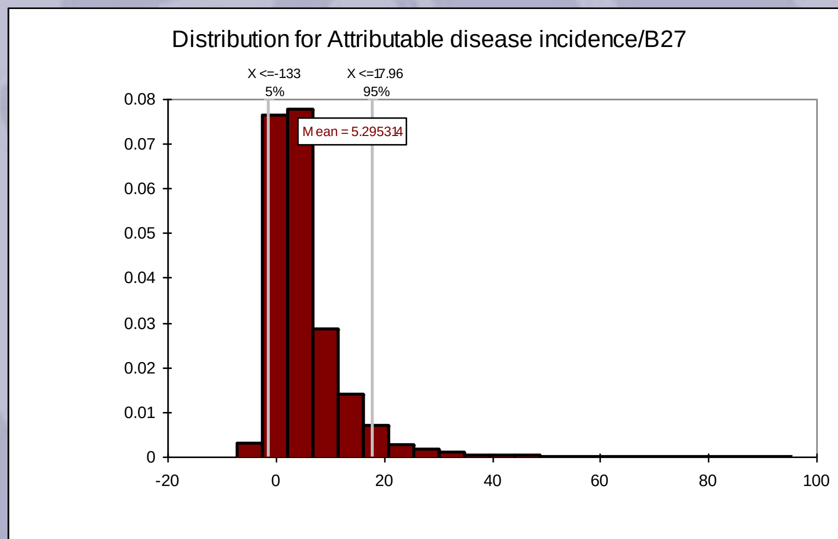
Model outputs for a marine bathing water with 95%ile 200 IE BWD Good



Attributable disease incidence 4.5%

WHO/ EU 2006 assessment was 5.0% (based on Kay et al., 1994, 2004)

Model outputs for a marine bathing water with 90%ile 185 IE BWD Sufficient



Attributable disease incidence 5.3%

EU BWD 2006 was 8.4% (based on Kay et al., 1994, 2004)

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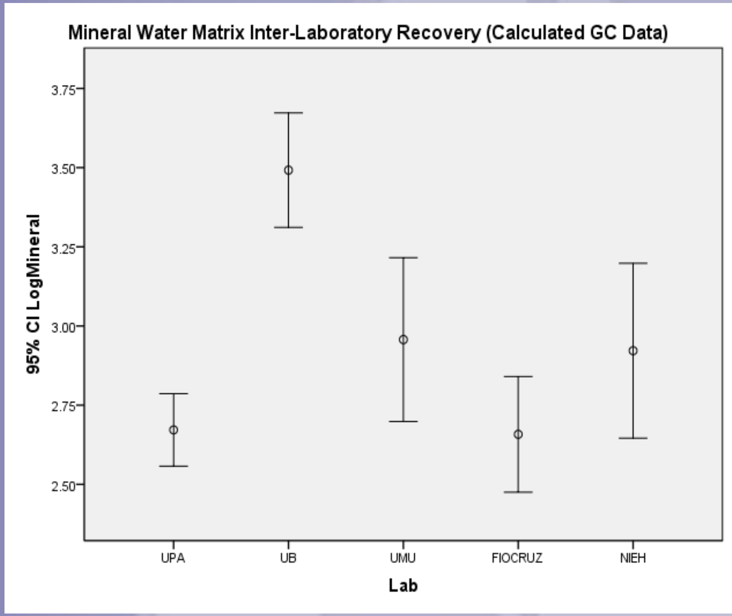
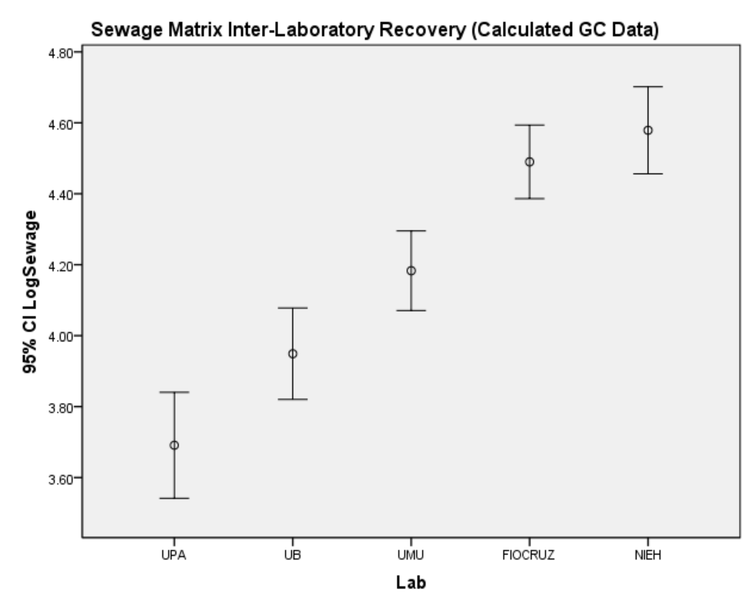
Virobathe
Viroclime

5 river basins within 5 different countries

Virobathe/Viroclime





Conclusion

Improvement on the inter-laboratory reproducibility of virological data generated by qPCR would be needed before such data could be used in a regulatory context having legal force.

Outcomes

WHO/HSE/WSH/10.04

World Health Organization

ADDENDUM TO THE

WHO GUIDELINES FOR SAFE RECREATIONAL WATER ENVIRONMENTS,

VOLUME 1, COASTAL AND FRESH WATERS

LIST OF AGREED UPDATES

DIRECTIVE 2006/7/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 15 February 2006

concerning the management of bathing water quality and repealing Directive 76/160/EEC

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 175(1) thereof,

Having regard to the proposal from the Commission (1),

Having regard to the opinion of the European Economic and Social Committee (2),

Having regard to the opinion of the Committee of the Regions (3),

Acting in accordance with the procedure laid down in Article 251 of the Treaty (4), in the light of the joint text approved by the Conciliation Committee on 8 December 2005,

Whereas:

(1) Building on the Commission's Communication on sustainable development, the European Council has singled out objectives as general guidance for future development in priority areas such as natural resources and public health.

(2) Water is a scarce natural resource, the quality of which should be protected, defended, managed and treated as such. Surface waters in particular are renewable resources with a limited capacity to recover from adverse impacts from human activities.

(3) Community policy on the environment should aim at a high level of protection, and contribute to pursuing the objectives of preserving, protecting and improving the quality of the environment and of protecting human health.

(4) In December 2000, the Commission adopted a Communication to the European Parliament and the Council on the development of a new bathing water policy and initiated a large-scale consultation of all interested and involved parties. The main outcome of this consultation was general support for the development of a new Directive based on the latest scientific evidence and paying particular attention to wider public participation.

(5) Decision No 1600/2002/EC of the European Parliament and of the Council of 22 July 2002 laying down the Sixth Community Environment Action Programme (5) contains a commitment to ensuring a high level of protection of bathing water, including by revising Council Directive 76/160/EEC of 8 December 1975 concerning the quality of bathing water (6).

(6) Pursuant to the Treaty, in preparing policy on the environment the Community is, *inter alia*, to take account of available scientific and technical data. This Directive should use scientific evidence in implementing the most reliable indicator parameters for predicting microbiological health risk and to achieve a high level of protection. Further epidemiological studies should be undertaken urgently concerning the health risks associated with bathing, particularly in fresh water.

(7) In order to increase efficiency and wise use of resources, this Directive needs to be closely coordinated with other Community legislation on water, such as Council Directives 91/271/EEC of 21 May 1991 concerning urban waste-water treatment (7), 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (8) and Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (9).

Where do we need to be?

Real-time prediction of bathing water

(1.5-5.4 billion UK£ and we keep present Blue-Flag numbers)

black box

hydrodynamic

Mitigation strategies for agricultural BMPs

(WFD Article 11 POMs for ‘Annex 4 protected areas)

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But Why does the UK need all this Modelling?

COSTS £m	From	To
Good	3163	4858
Excellent	4999	7818
Three Events	1621	2443
SAVINGS £m		
Good	1542	2415
Excellent	3378	5375

Does not include CSOs improved to one spill/season

	NPV of total benefits	NPV of total costs	
Option 1	0	9-14	
Option 2a	1104-1923	3163-4858	~Good
Option 2b	1638 -3497	4999-7818	Excellent
Option 3a	2215	2530-3846	One event
Option 3b	2215	1621-2443	Three events

eftec

Valuation of Benefits to England and Wales of a Revised Bathing Water Quality Directive and Other Beach Characteristics Using the Choice Experiment Methodology

Final report submitted to

Department for Environment, Food and Rural Affairs

by

Economics for the Environment Consultancy Ltd

25 June 2002

+

Cascade CONSULTING

Department for Environment, Food and Rural Affairs

Revision of the Bathing Water Directive: Summary of Phases 1 and 2

PROPOSAL FOR A DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL TO REVISE DIRECTIVE 76/160/EEC CONCERNING THE QUALITY OF BATHING WATER
PARTIAL REGULATORY IMPACT ASSESSMENT

1. Title

This Regulatory Impact Assessment (RIA) considers the potential impact of the proposal (COM(2002) 581 final) for a Directive of the European Parliament and of the Council to revise Directive 76/160/EEC concerning the quality of bathing water (hereafter referred to as "the revised Directive"), which the Commission agreed and published on the 24th October 2002.

2. Purpose and intended effect of measure

(i) Objective

The revised Directive updates the existing Bathing Water Directive in order to further protect public health in the EU, by limiting faecal contamination of popular bathing places.

It aims to review and streamline the parameters for setting water quality standards, focussing on fewer microbiological indicators and setting stricter standards. Better information will be also provided to the public, making use of locally and regionally available facilities and the Internet.

The revised Directive aims to be coherent with other EU water related legislation, in particular the Water Framework Directive.

(ii) Background

The 1976 Bathing Water Directive requires Member States to meet quality standards at waters within its scope. The purpose of the quality standards is to reduce the risks

Scottish Approach

(Calum McPhail and Ruth Stidson, SEPA)


Water and Environment Journal
Promoting Sustainable Solutions
Water and Environment Journal. Print ISSN

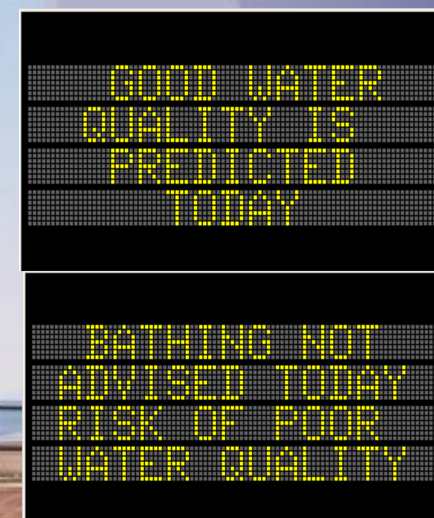
Development and use of modelling techniques for real-time bathing water quality predictions

R. T. Stidson[1], C. A. Gray[2] & C. D. McPhail[3]

[1]Scottish Environment Protection Agency, Clearwater House, Heriot Watt Research Park, Edinburgh, UK; [2]Scottish Environment Protection Agency, Bremner House, The Castle Business Park, Stirling, UK; and [3]Scottish Environment Protection Agency, East Kilbride, UK

Abstract

Real-time prediction of bathing water quality is suggested as an appropriate regulatory approach in recent WHO Guidelines and new European Union (EU)



Problems (outwith Scotland)

- **Model calibration data**
  - ‘**Bathing Day**’ is the modelling unit
  - Spot compliance samples provide the calibration data
    - **Diurnality** introduces variation and increase model error reducing explained variance
    - **Censored data** (< and >) and measurement imprecision in cfu and/or MPN counts would further reduce model utility
    - **Data precision?**

Table 5.1 Estimated count and 95% confidence intervals for the number of organisms in a 100 ml sample, where, after dilution, a subsample is examined

Organisms observed in the subsample	10-fold dilution EC	10-fold dilution CI	100-fold dilution EC	100-fold dilution CI
10	100	50-180	1000	480-1830
50	500	380-650	5000	3750-6640
100	1000	820-1200	10000	8190-12200

EC = estimated count.
CI = 95% confidence interval.

Source connectivity – tracer studies

- Microbial tracers introduced to inputs

Source dosing - river

Source dosing - offshore

Sea water sampling

Hourly sea sampling for 54 hours following tracer release

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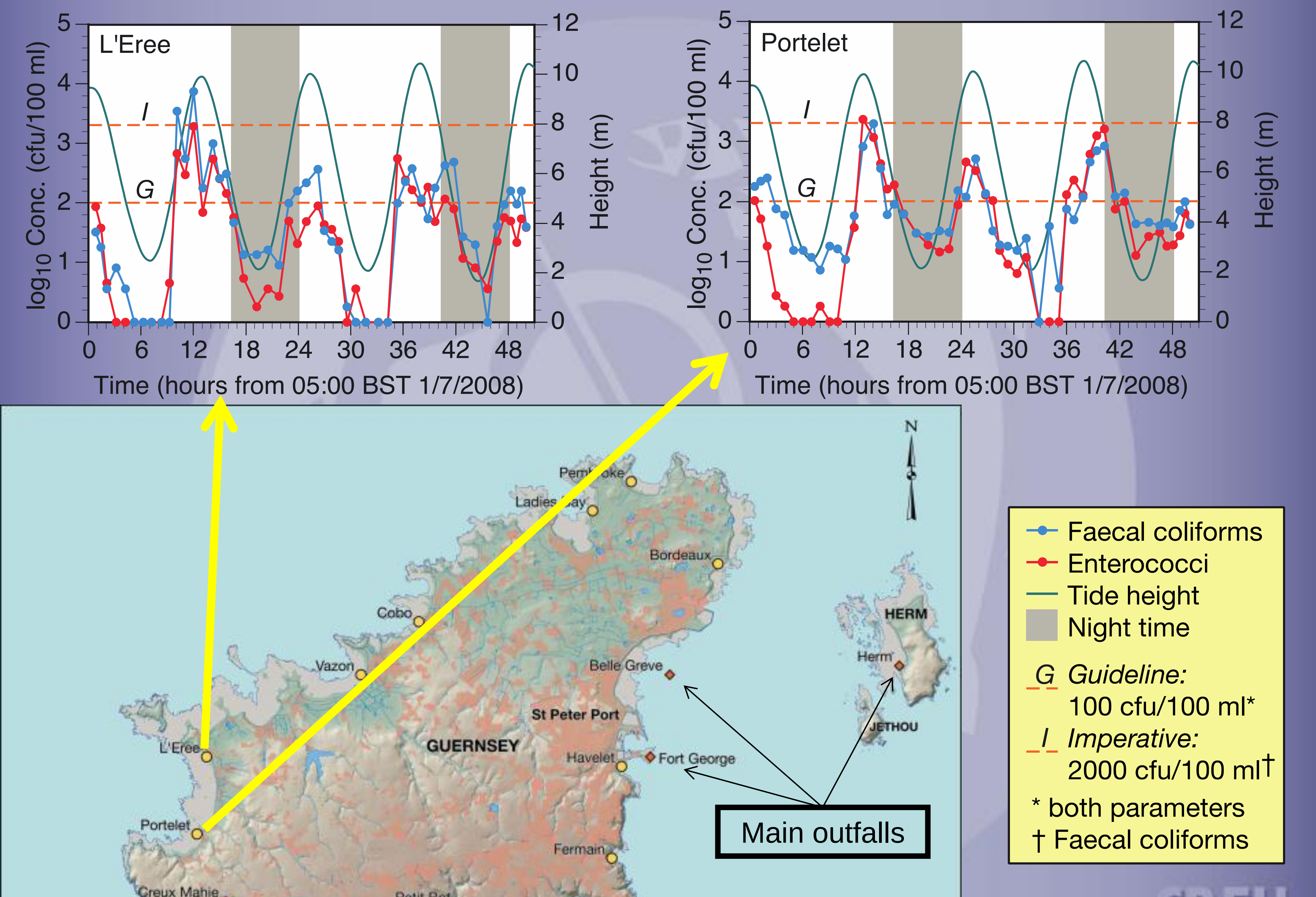
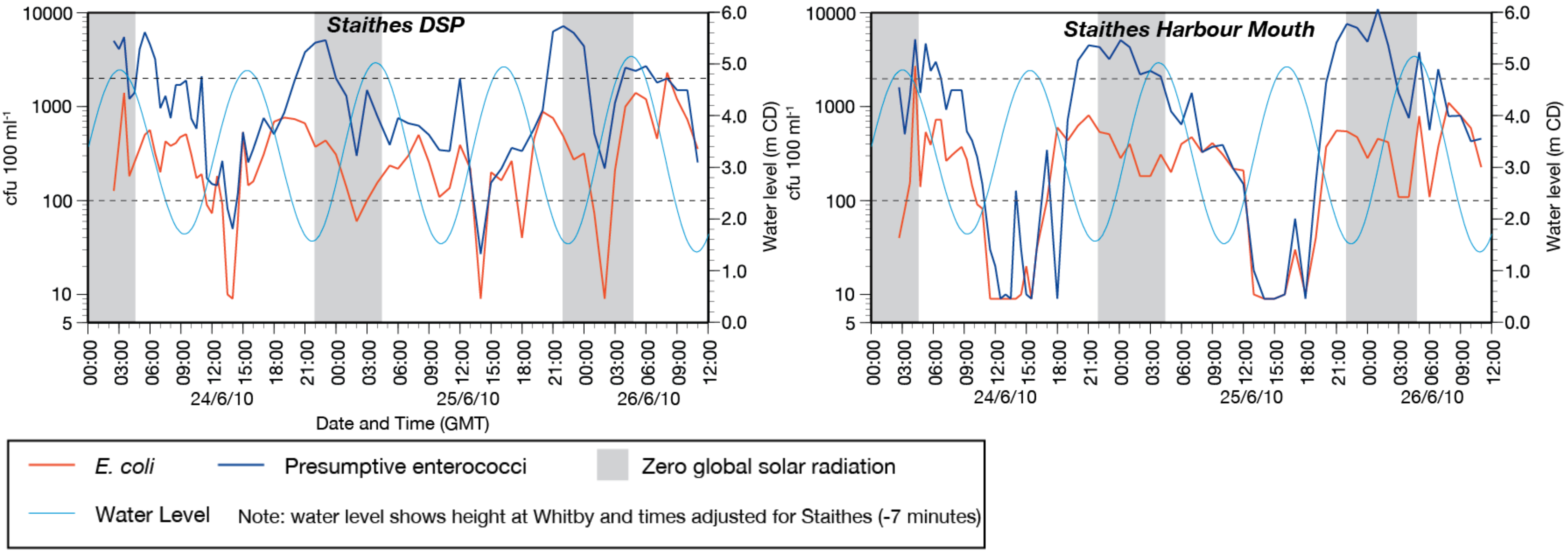
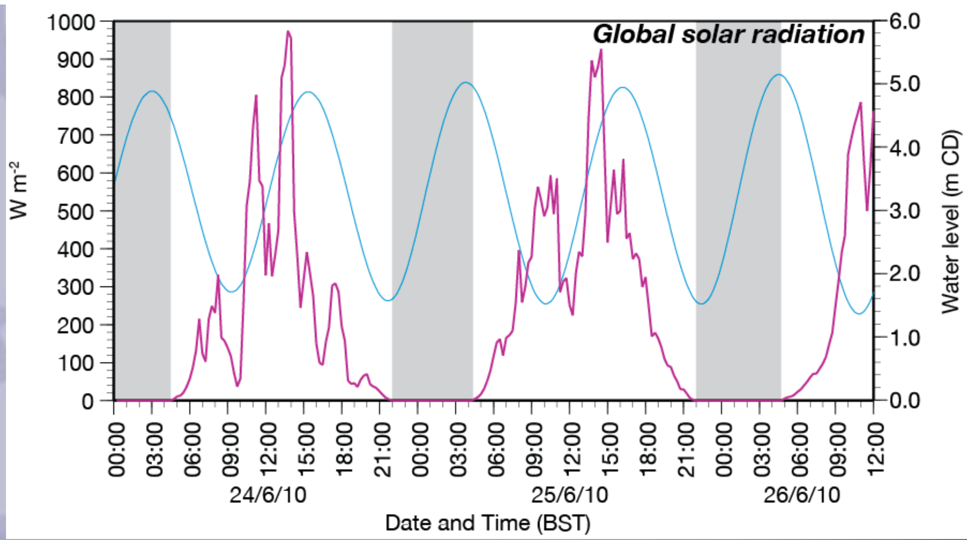


STATES OF GUERNSEY

Diurnality of FIO Concentrations



Diurnal pattern of low concentrations corresponding with afternoon rising tidal levels



YorkshireWater

Solutions

- Characterise the ‘**bathing day**’ water quality for model building
  - **multiple sampling events** during daylight
    - 07:00 to 19:00
  - Measure FIOs with **enhanced accuracy** through the bathing day
    - Triplicate enumeration / >100+ml filtered

Sample collection

Ireland's EU Structural Funds Programmes 2007 - 2013

Co-funded by the Irish Government and the European Union

SOUTHERN & EASTERN Regional Assembly Promoting Our Region

IRELAND WALES 2007 – 2013

EUROPEAN REGIONAL DEVELOPMENT FUND

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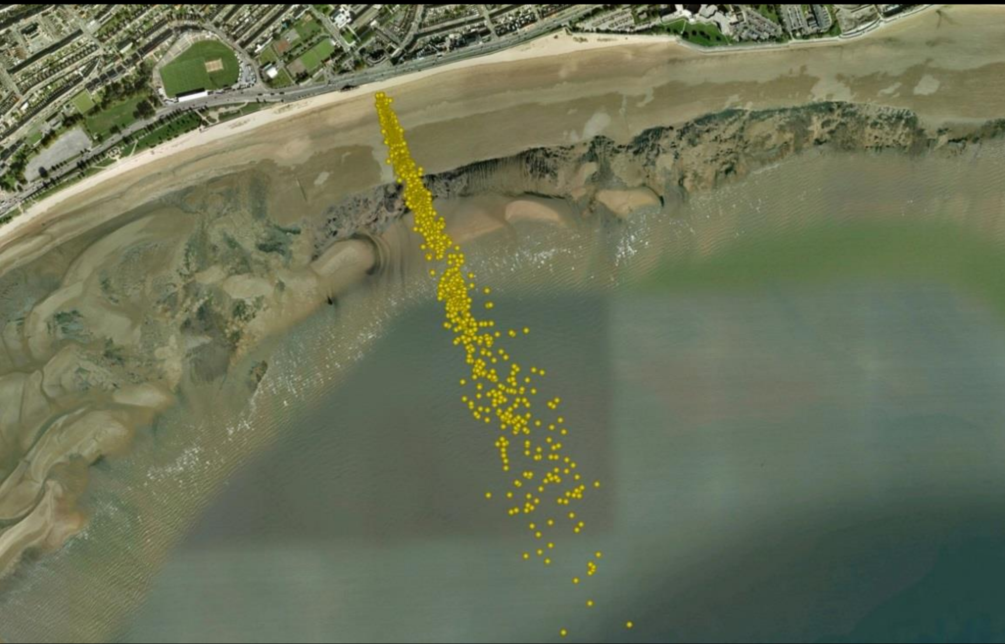
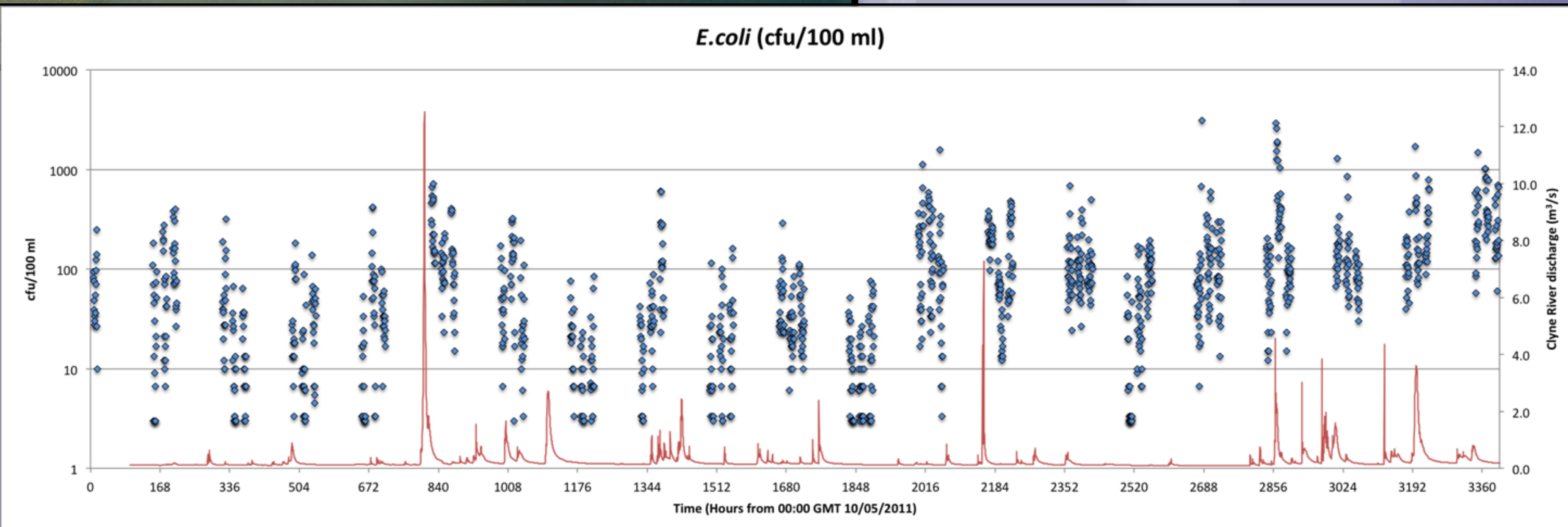
Sample collection

CREH

DSP intensive sampling





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IRELAND WALES 2007 – 2013
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Co-funded by the Irish Government and the European Union
EUROPEAN REGIONAL DEVELOPMENT FUND

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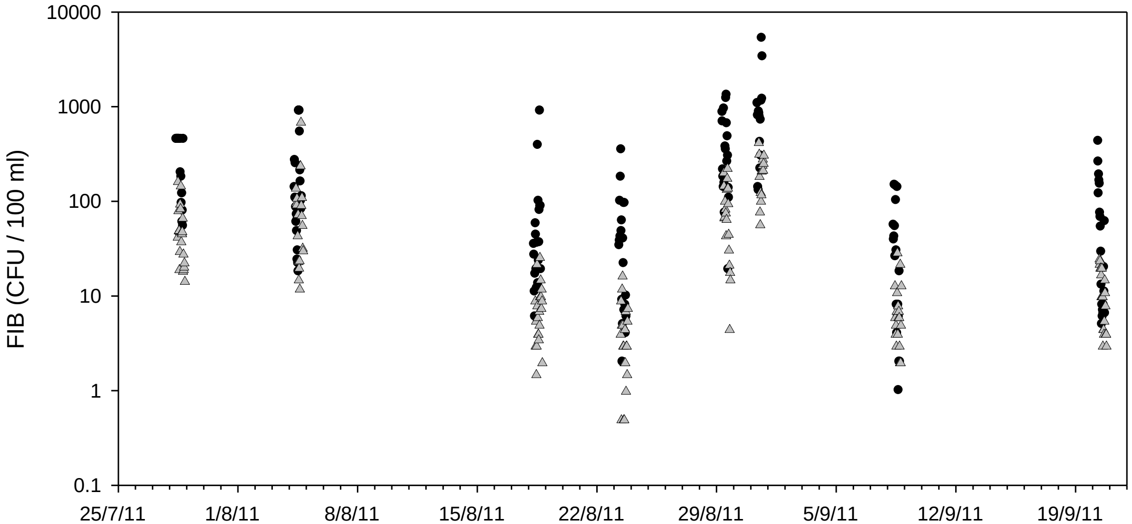
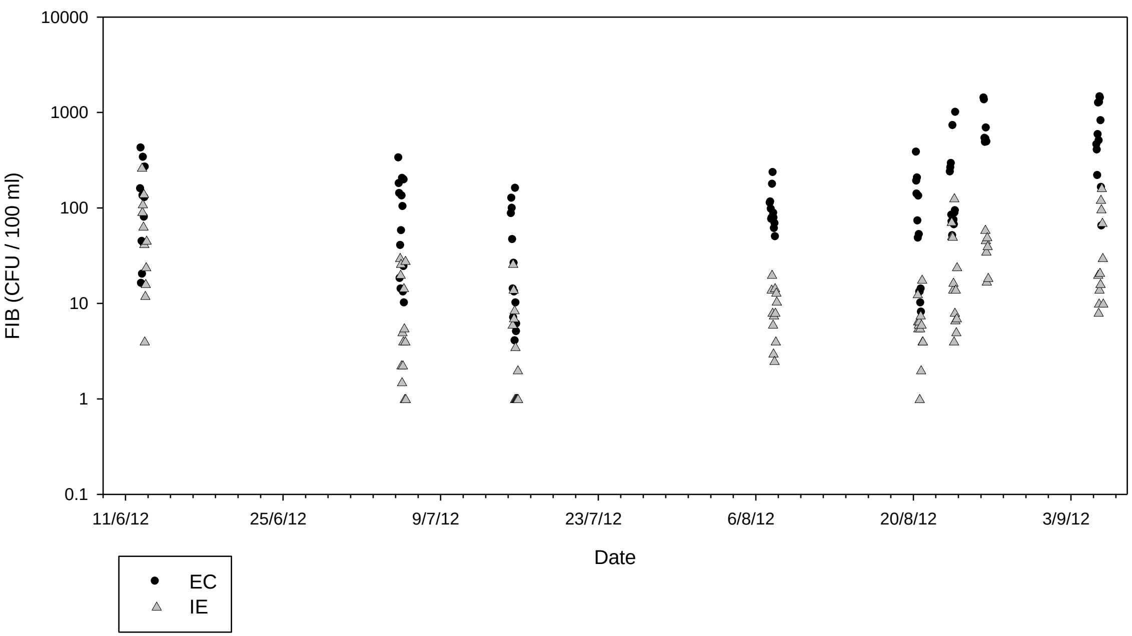
Faecal indicator bacteria concentrations at the compliance point of Bray Beach
Summer 2011



Faecal indicator bacteria concentrations at the compliance point of Bray Beach
2012



UCD Data from Bray Beach

(reproduced with permission of Prof Wim Meijer)

Confirmed enterococci – Model 1

Model 1 - Tolerance 0.0001							
Dependent (Y): Mean $\log_{10}$ Confirmed enterococci (cfu/100 ml)							
Step	**Predictor**		**r^2 (adj.)**	**Change in r^2 (%)**	**Partial r**	**Sig.**	**Tolerance**
1	**UVB Radiation on sampling day (kJ/sq. m)**	X_1	**0.440**				
2	**Log_{10} Brynmill Str. Max. Q in previous 48 Hrs (cub. m)**	X_2	0.589	**14.894**	0.528	0.000	0.916
3	Max. Tide Height on sampling day (m)	X_3	0.643	5.455	0.385	0.003	0.934
4	Log_{10} Afan STW Q in previous 48 Hrs (cub. m)	X_4	0.686	4.250	-0.368	0.006	0.509
5	Mean Wind Sp. in previous 48 Hrs (m/s)	X_5	0.742	5.615	-0.441	0.001	0.686
6	Min. Tide Ht. in previous 12 Hrs. (m)	X_6	0.775	3.329	0.382	0.005	0.081
7	Log_{10} Clyne R. Gauge Q in previous 24 Hrs (cub. m)	X_7	0.801	2.606	0.365	0.008	0.351

$$Y = 10.551 – 0.038X_1 + 0.440X_2 + 0.522X_3 – 2.992X_4 – 0.236X_5 + 0.366X_6 + 0.405X_7 \pm 0.229$$

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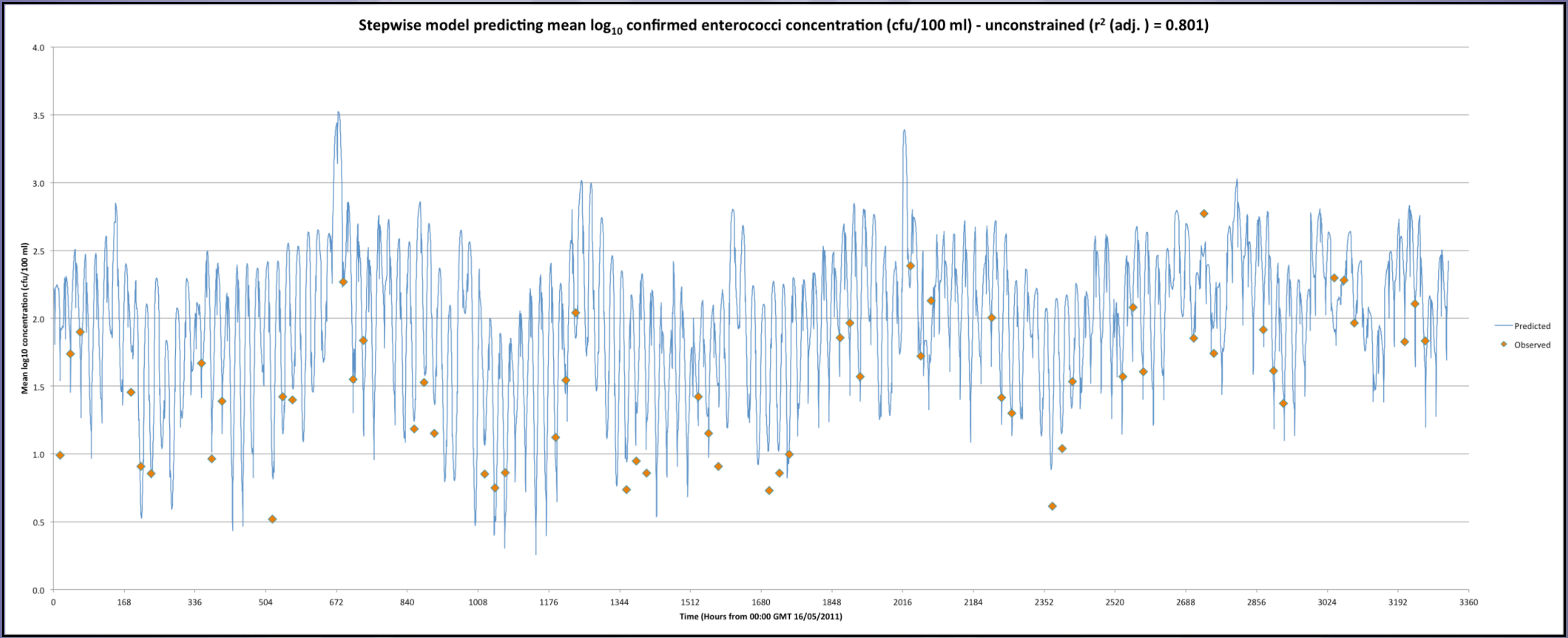
Intestinal enterococci



7 predictors

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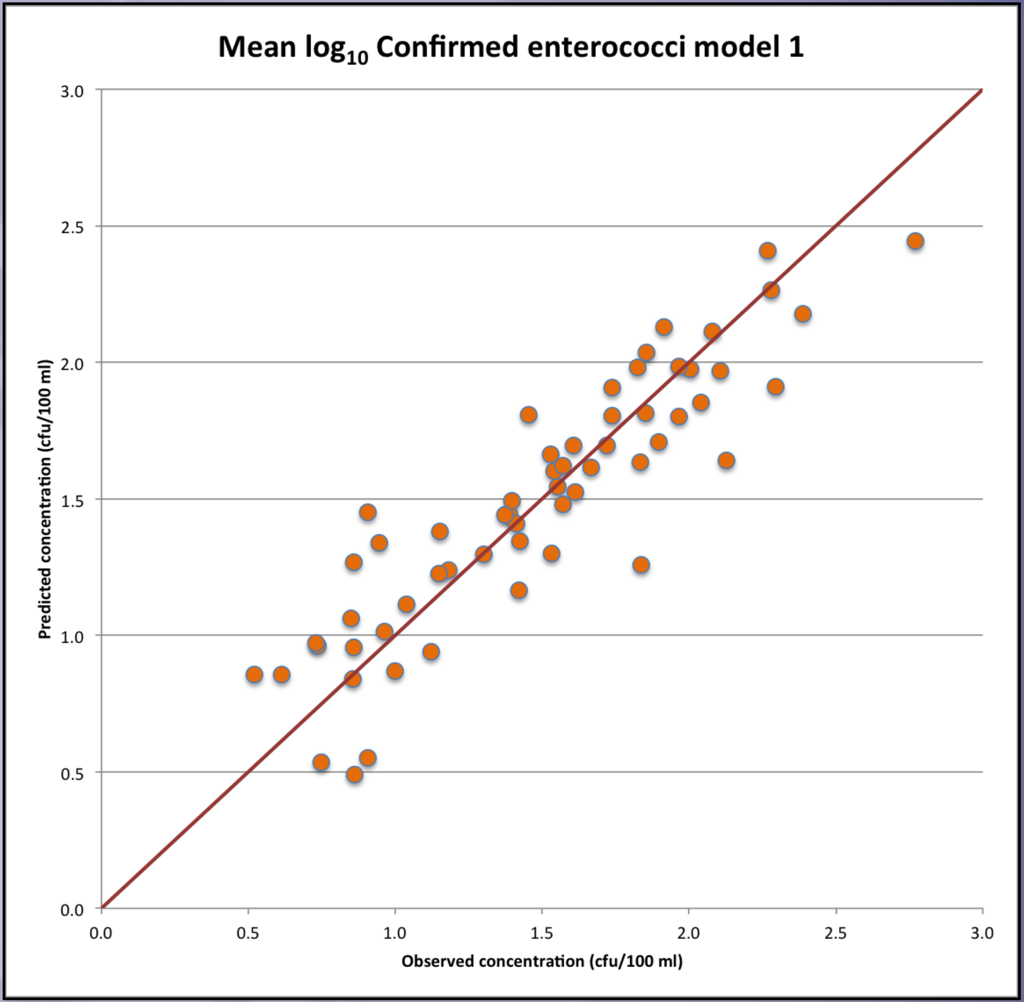
Intestinal enterococci

7 predictors

r^2 80.1%



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FIO Diurnality

- UV Irradiance is the main predictor
- Temporal pattern examination prudent
- Two sets of comparisons were made:
  - 61 days (10/05-28/09/2011), split into 07:00-11:00 and 11:30-16:00 groups – Student's t-test
  - 24 days (18/07-07/09/2011), split into 07:00-11:00, 11:30-15:00, and 15:30-19:00 groups - ANOVA

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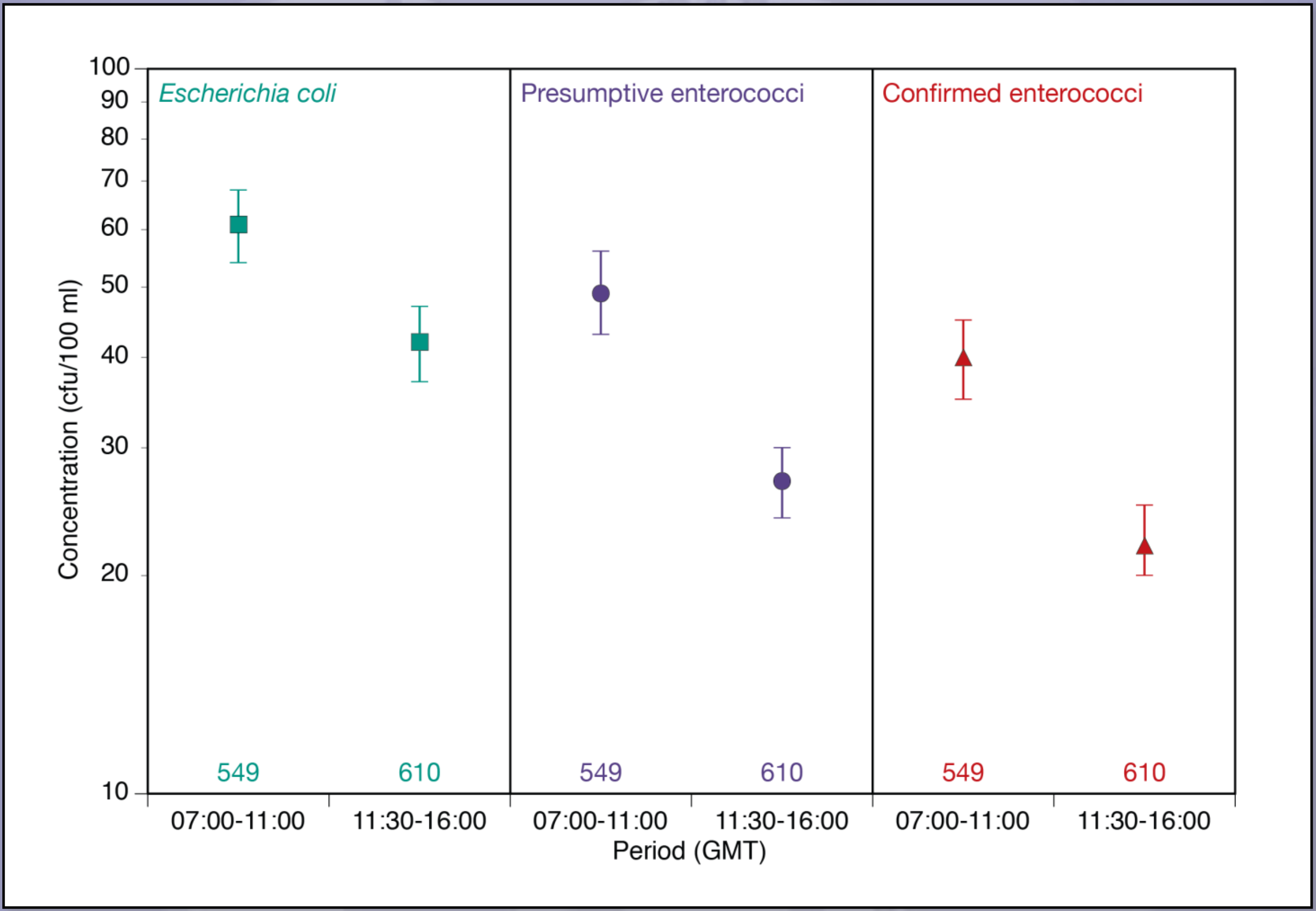
All samples – 61 days



Geometric mean±95% CI

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Compliance outcomes – All days

Period (GMT)	rBWD *E. coli* Outcome	rBWD enterococci Outcome	rBWD Overall Outcome
07:00-11:00	**Sufficient**	**Poor**	**Poor**
11:30-16:00	**Good**	**Sufficient**	**Sufficient**

On average the AM/PM difference in FIO concentrations is enough to affect the compliance outcome – which improves in the afternoon

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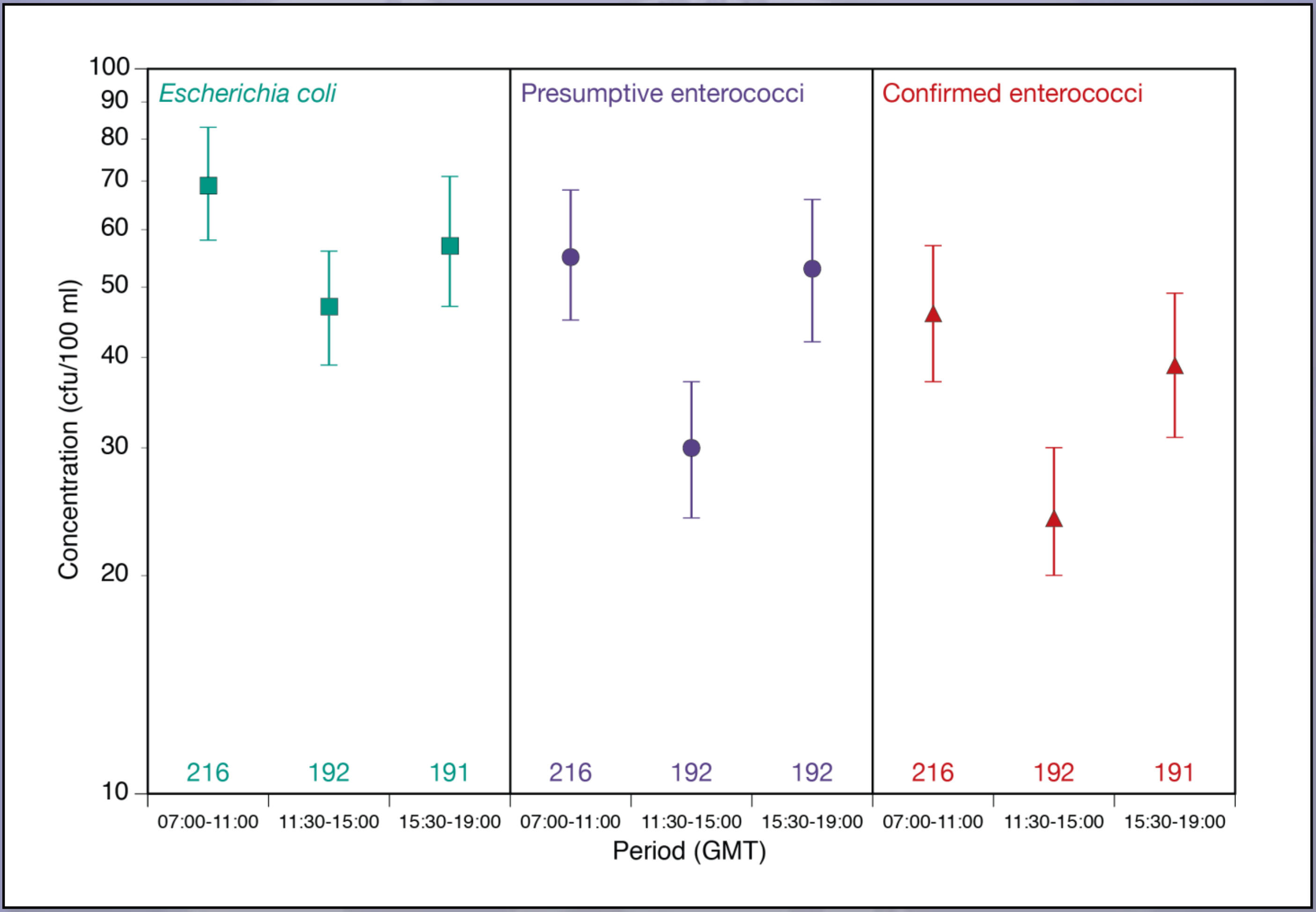
24 days with 07:00 – 19:00 data



Geometric mean±95% CI

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Compliance outcomes – Days with 07:00 to 19:00 data

Period (GMT)	rBWD *E. coli* Outcome	rBWD enterococci Outcome	rBWD Overall Outcome
07:00-11:00	Sufficient	Poor	Poor
11:30-15:00	Good	Sufficient	Sufficient
15:30-19:00	Sufficient	Poor	Poor

On average the difference in FIO concentrations is enough to affect the compliance outcome for the 3 periods

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Hourly Compliance outcomes – all data

Hour (GMT)	rBWD *E. coli* Outcome	rBWD enterococci Outcome	rBWD Overall Outcome
07:00	Sufficient	Poor	Poor
08:00	Sufficient	Poor	Poor
09:00	Sufficient	Poor	Poor
10:00	Good	Poor	Poor
11:00	Good	Sufficient	Sufficient
12:00	Good	Sufficient	Sufficient
13:00	Good	Sufficient	Sufficient
14:00	Good	Good	Good
15:00	Sufficient	Sufficient	Sufficient
16:00	Sufficient	Poor	Poor
17:00	Sufficient	Poor	Poor
18:00	Sufficient	Poor	Poor
19:00	Sufficient	Poor	Poor

Compliance outcome changes through the sampling day

Model performance tested against a new data set collected in 2014

‘no deterioration in performance’

But is Swansea an anomaly?

Acclimatize

Cemaes Bay

Results – to August 2017

Dr Mark Wyer

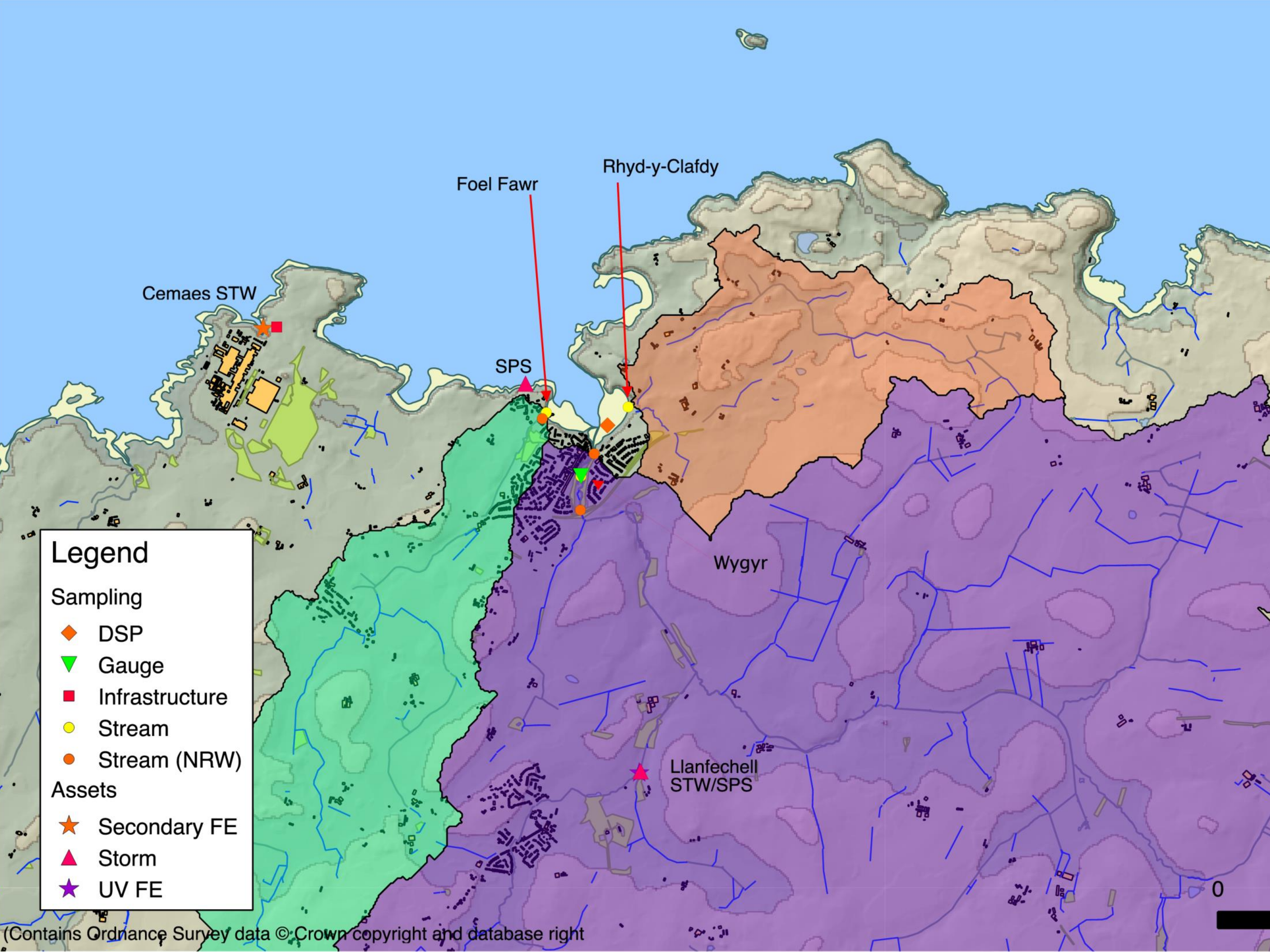
PRIFYSGOL ABERYSTWYTH UNIVERSITY

EU Funds: Ireland Wales Programme 2014-2020

Tionól Réigiúnach an Deiscirt
Southern Regional Assembly

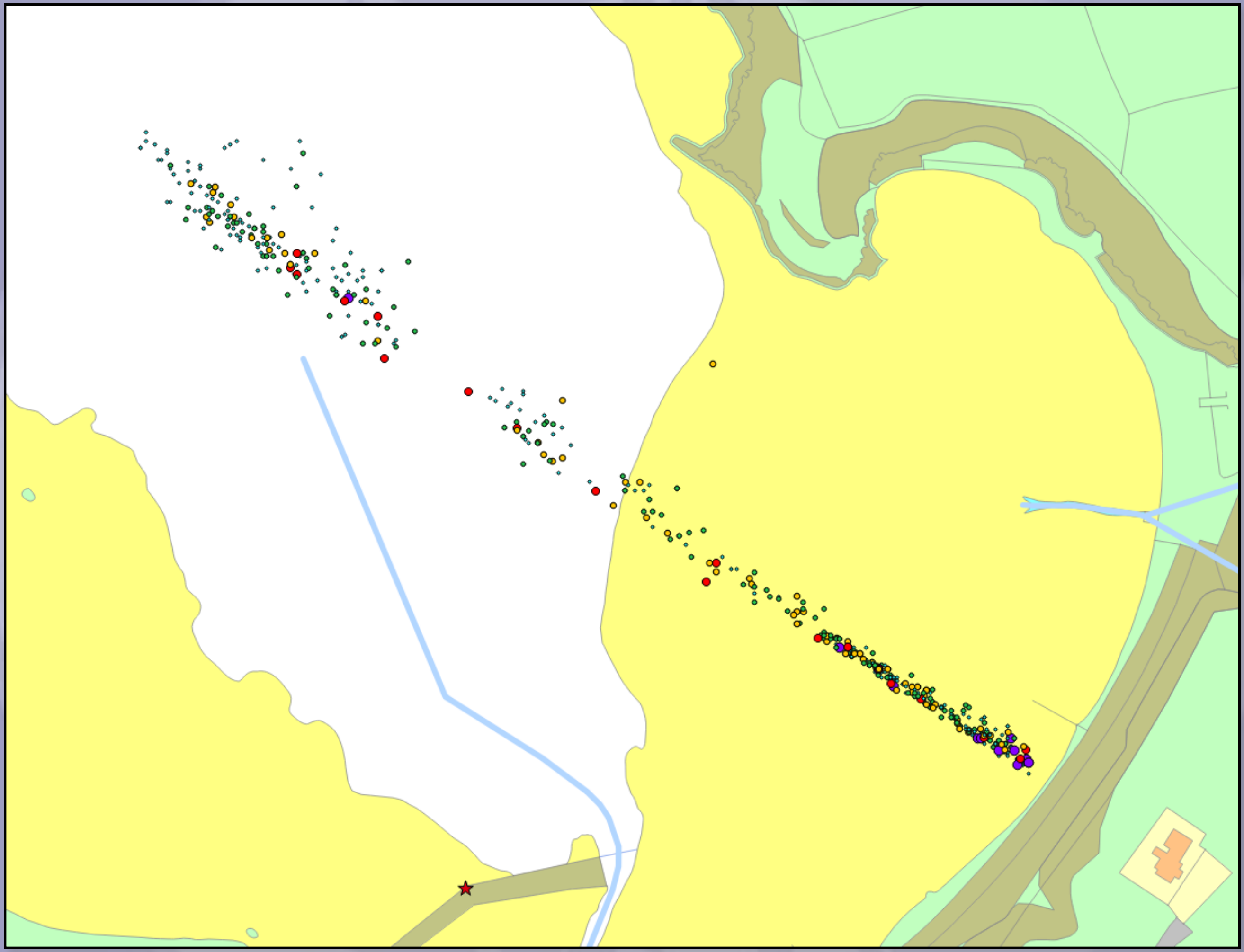
Ireland's European Structural and Investment Funds Programmes 2014-2020
Co-funded by the Irish Government and the European Union

UNDEB EWROPEAIDD
EUROPEAN UNION
Llywodraeth Cymru
Welsh Government
Cronfa Datblygu Rhanbarthol Ewrop
European Regional Development Fund



Rhyd-y-Clafdy
Foel Fawr
Cemaes STW
SPS
Wygyr
Llanfechell
STW/SPS
Legend
Sampling
DSP
Gauge
Infrastructure
Stream
Stream (NRW)
Assets
Secondary FE
Storm
UV FE
0
(Contains Ordnance Survey data © Crown copyright and database right

Spatial results DSP – *E. coli*



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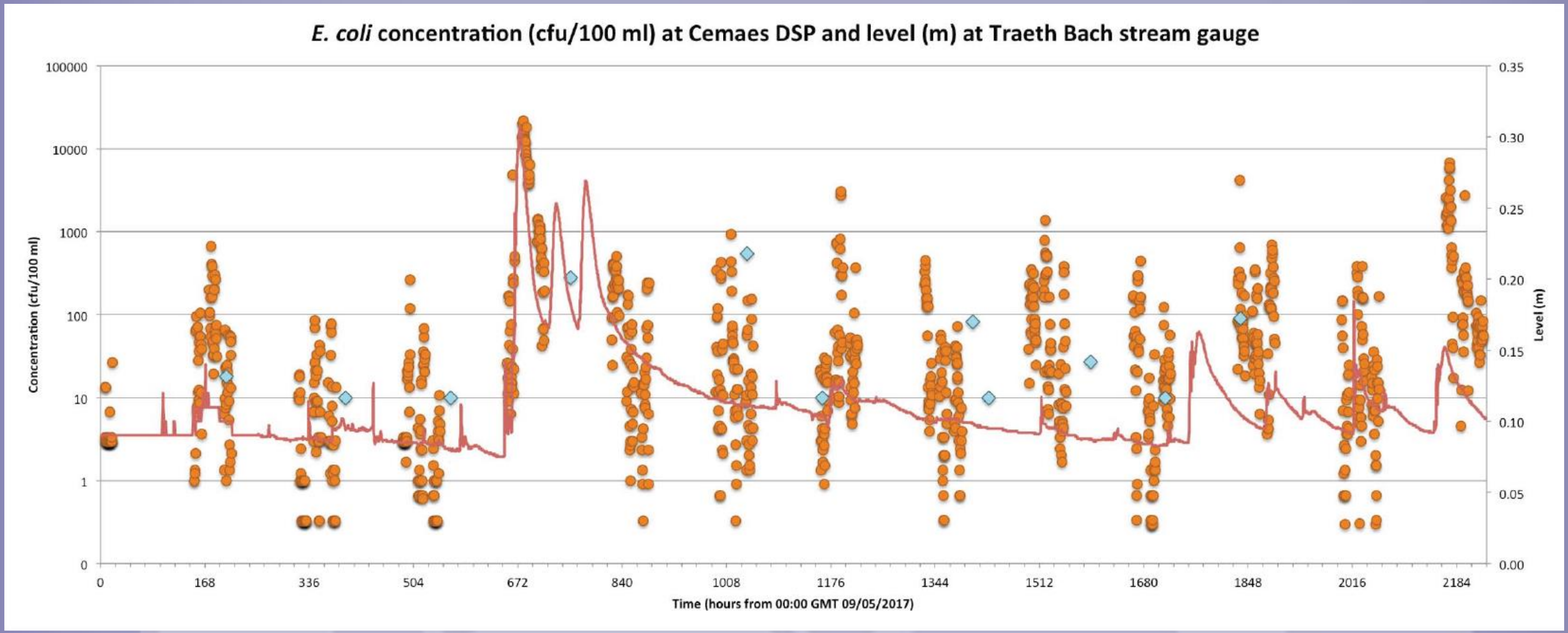
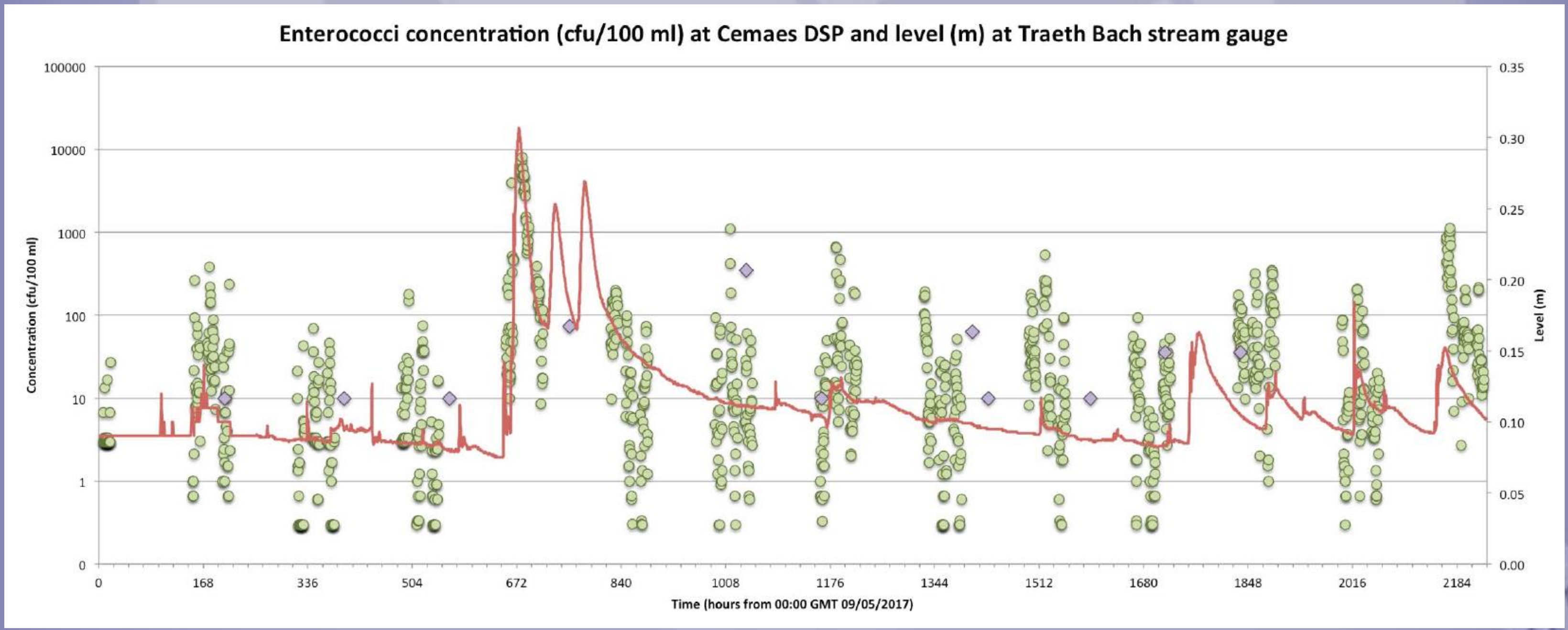
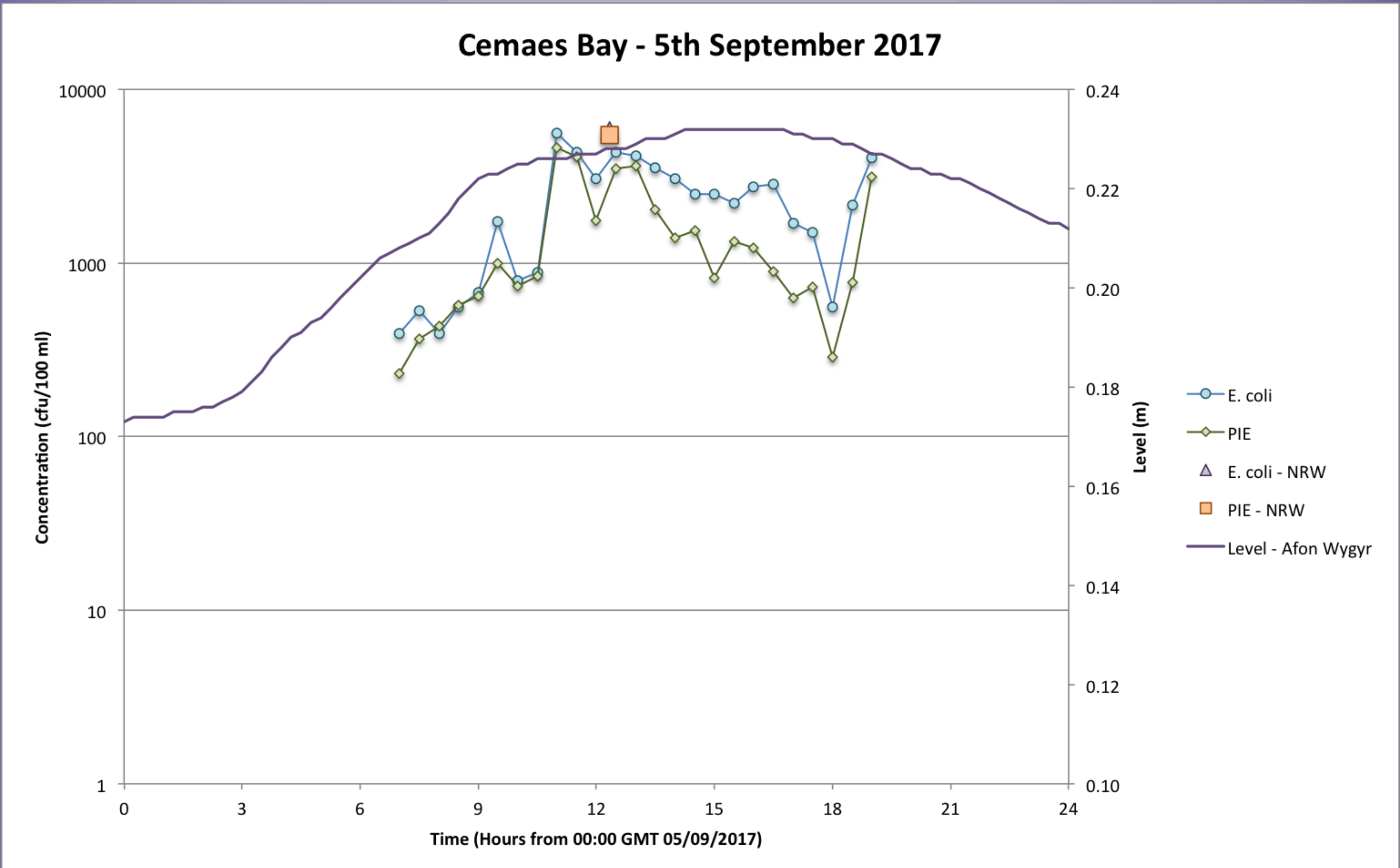
Acclimatize


E. coli concentration (cfu/100 ml) at Cemaes DSP and level (m) at Traeth Bach stream gauge
Concentration (cfu/100 ml)
Level (m)
Time (hours from 00:00 GMT 09/05/2017)


Enterococci concentration (cfu/100 ml) at Cemaes DSP and level (m) at Traeth Bach stream gauge
Concentration (cfu/100 ml)
Level (m)
Time (hours from 00:00 GMT 09/05/2017)



Cemaes Bay - 5th September 2017
10000
1000
100
10
1
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0
3
6
9
12
15
18
21
24
Concentration (cfu/100 ml)
Level (m)
Time (Hours from 00:00 GMT 05/09/2017)
E. coli
PIE
E. coli - NRW
PIE - NRW
Level - Afon Wygyr
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Tentative Conclusions

- Spot (compliance) measurements cannot index the ‘bathing-day’ risk even on the day.
  - *Decisions to post or close a beach should not be based on the concentration of indicator bacteria in a single grab sample.* (Boehm *et al*., 2002)
  - *The results of this study show that single samples do not adequately characterize the quality of beach waters and that temporal variability must be given serious consideration when developing sampling plans for beach waters.* (Wymer *et al., 2007)*
- Bathing season compliance data may (will?) exhibit significant bias and not index bather health risk
- Compliance data are unsuitable for black box, and possibly, hydro-dynamic model calibration.

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Can hydrodynamic models approach the MLR explained variance?

Model comparison data

- 76-day numerical model run period: 16 Jul–30 Sep 2011
  - Covering the quantitative microbial source apportionment (QMSA) period providing faecal indicator organism flux estimates for inputs to Swansea Bay
  - Input sequences for: rivers, streams and continuous and intermittent discharges from sewerage infrastructure
- Intensive (half hourly) sampling on 33 days at Swansea Bay designated sampling point (DSP)
  - 3 days per week – 18/07/2011 – 28/09/2011
  - 07:00 to16:00 GMT on all 33 days – 19 samples per day
  - 07:00 to 19:00 GMT on 24 days (18/07/2011 – 07/09/2011) -25 samples per day
  - Triplicate analysis to improve measurement precision
- Parallel output from “Black Box” statistical model used for prediction at Swansea Bay DSP

Numerical model data

- The comparison focused on intestinal enterococci (IE)
  - related to probability of gastrointestinal illness (*p*GI)
  - is the parameter predicted by the Black Box model
- Two IE data sets were extracted from the model output:
  - closest of a matrix of 50 model grid points to observed sampling events spatially and temporally: “closest point”
  - closest of 29 model grid points along a transect line* to observed sampling times: “DSP transect”

* Line fitted to > 1200 sampling points

Calibration Data available

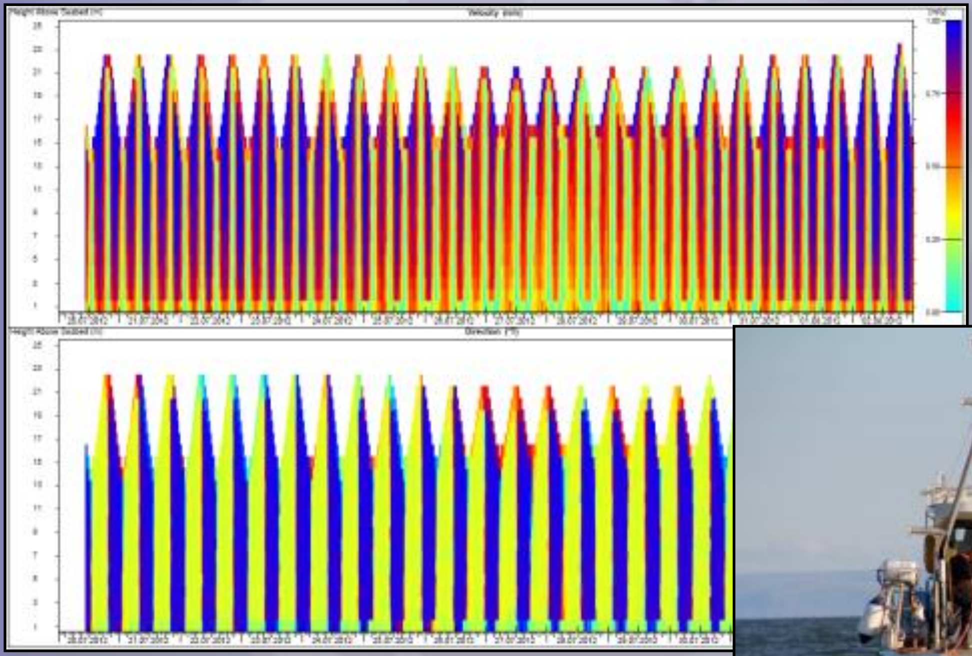
Sea-bed Mounted ADCP studies

ADCP Deployment

- Water velocity and direction profiles

Cardiff School of Engineering
Dr Reza Ahmadian and Prof Roger Falconer

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD



Calibration data

Deployment of 5 ADCPs for 31 days

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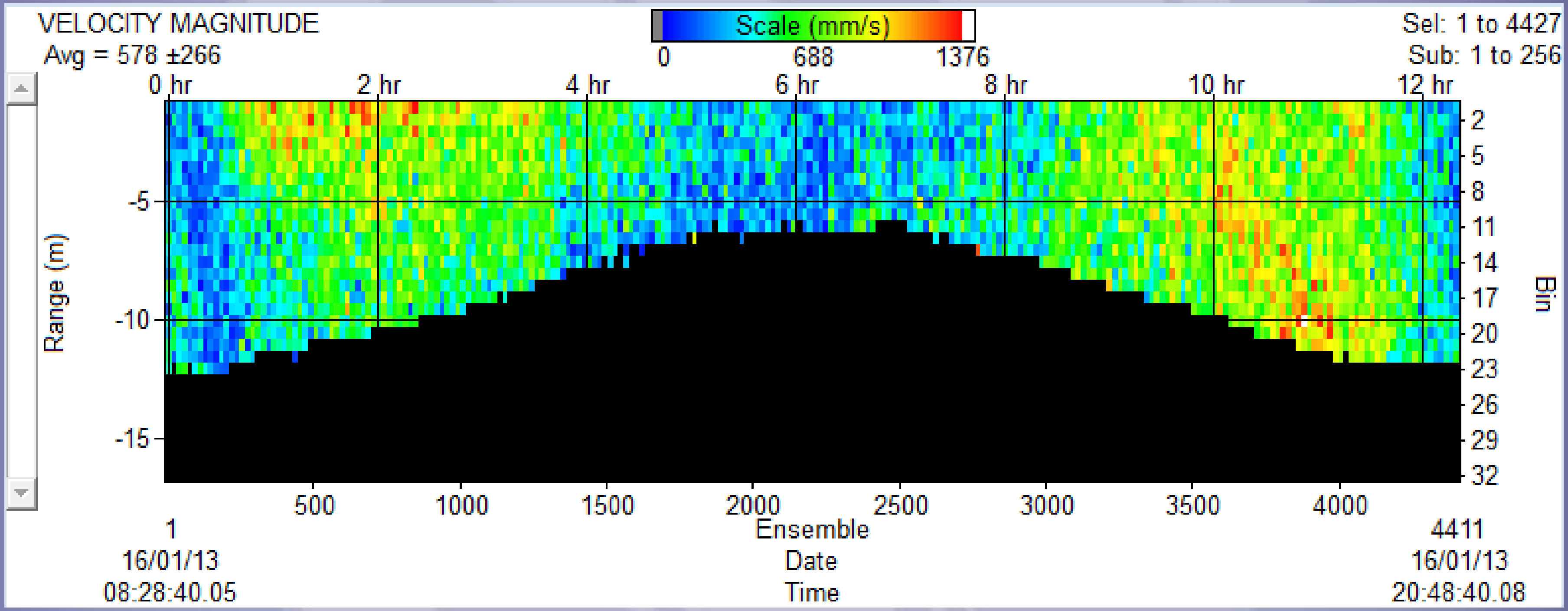
Vessel Mounted ADCP studies

Typical ADCP Data
(Black Tar Point Milford Haven)



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Multiple Synchronous Microbial Tracer Releases as Model Verification and Calibration Tools

WATER RESEARCH 44 (2010) 4783–4795
Available at www.sciencedirect.com
ScienceDirect
journal homepage: www.elsevier.com/locate/watres

Evaluating short-term changes in recreational water quality during a hydrograph event using a combination of microbial tracers, environmental microbiology, microbial source tracking and hydrological techniques: A case stud[y] Southwest Wales, UK

Mark D. Wyer [a,*], David Kay [a], John Watkins [b], Cheryl...
...nathan Porter [d], Carl M. Stapleton [a], Heather M...
...tre for Research into Environment and Health (CREH), Rive...
...te of Geography and Earth Sciences, Aberystwyth U...

Sampling: Langland

24 Hours
and cold!

Sampling: Swansea Bay

24 Hours
and cold!

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Sampling: Swansea Bay

A long way
to the sea!

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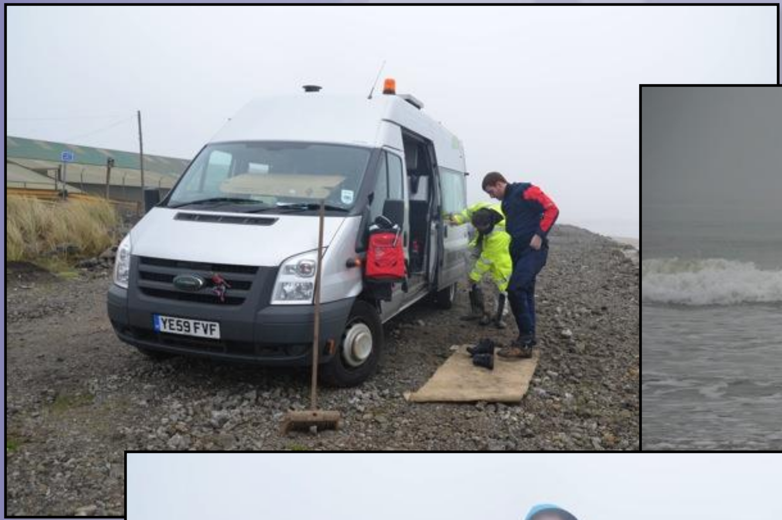
Sampling: Margam Sands



Special Guest:
Dr Louise Deering
(& low-carbon transport!)

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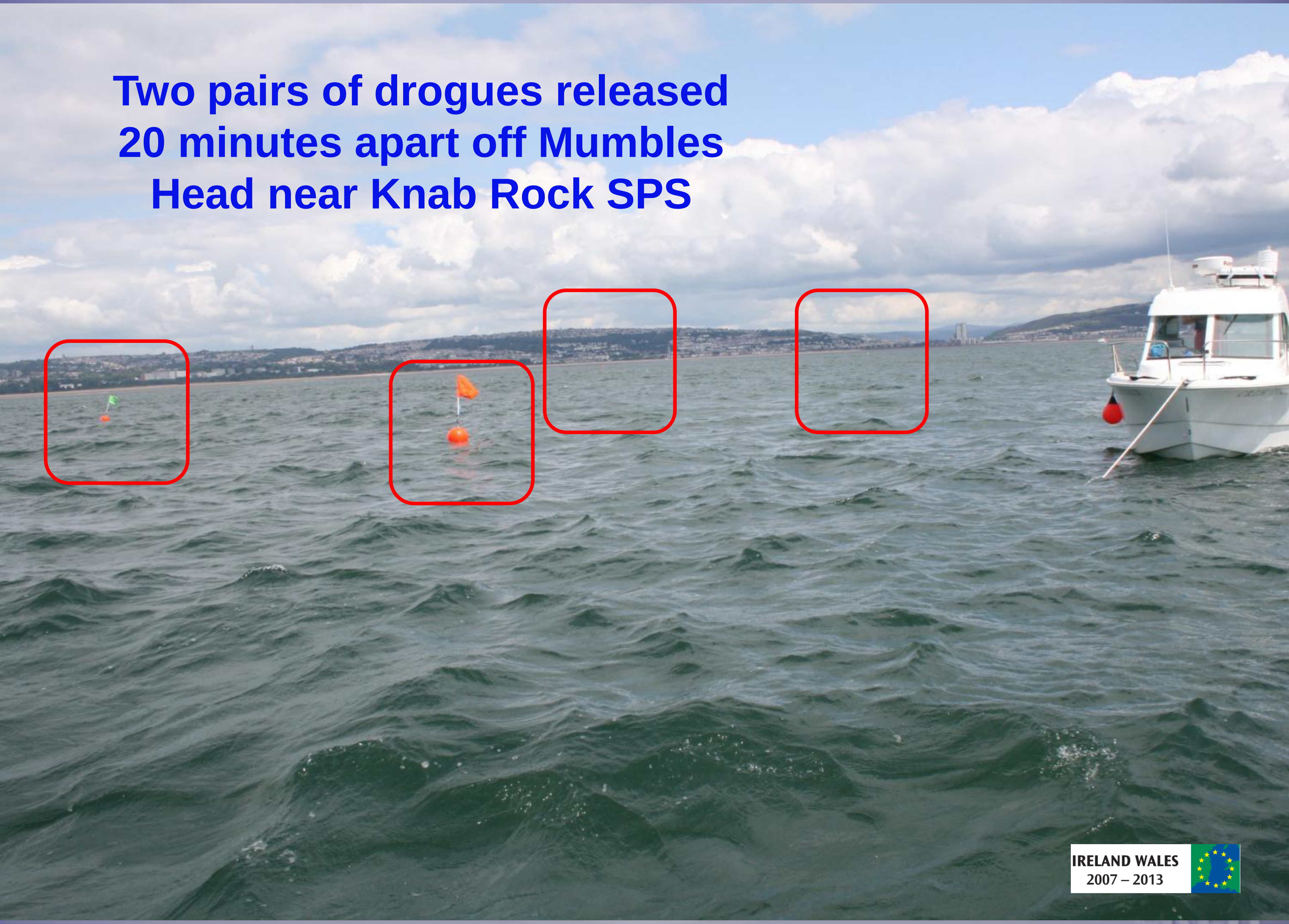
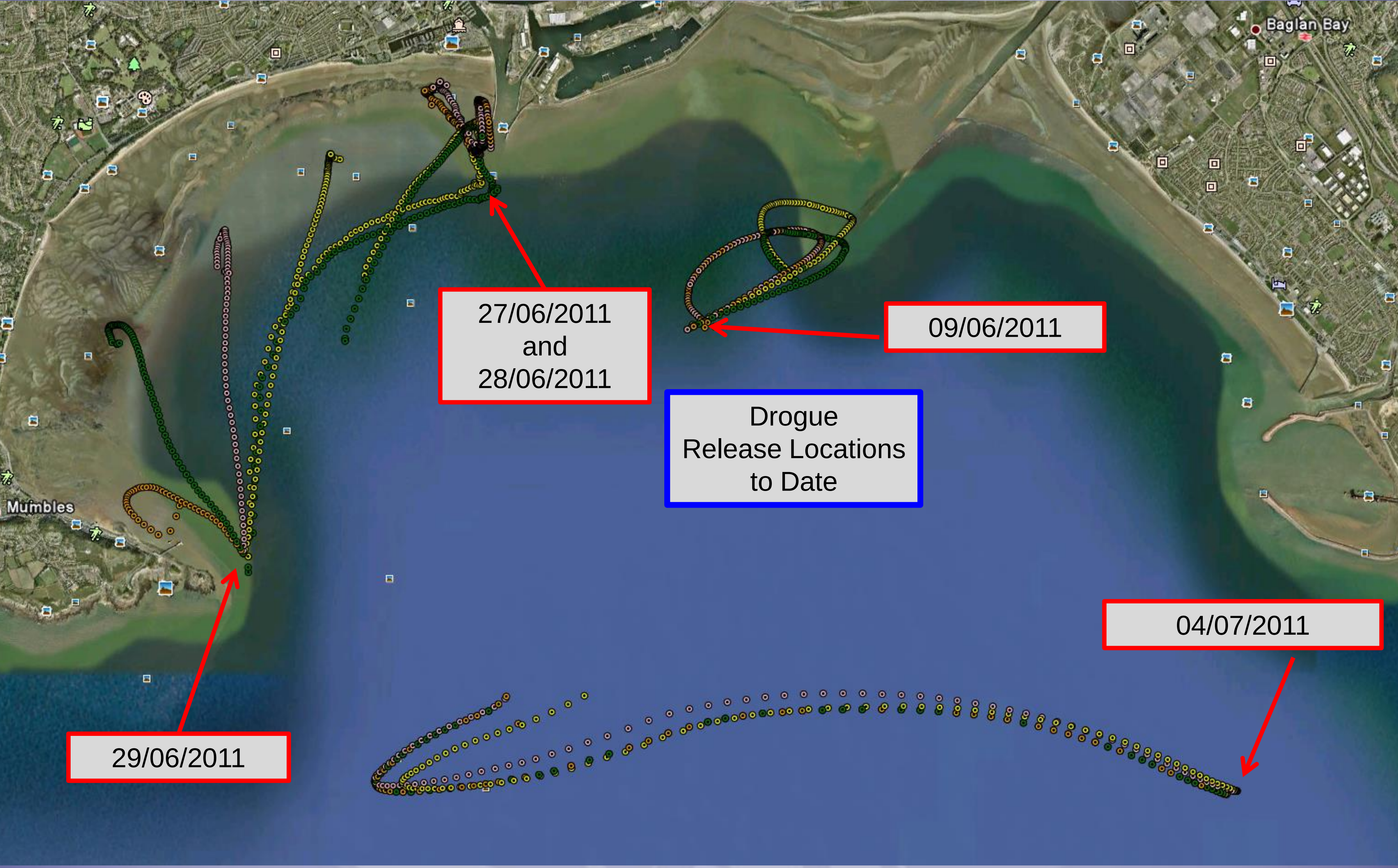
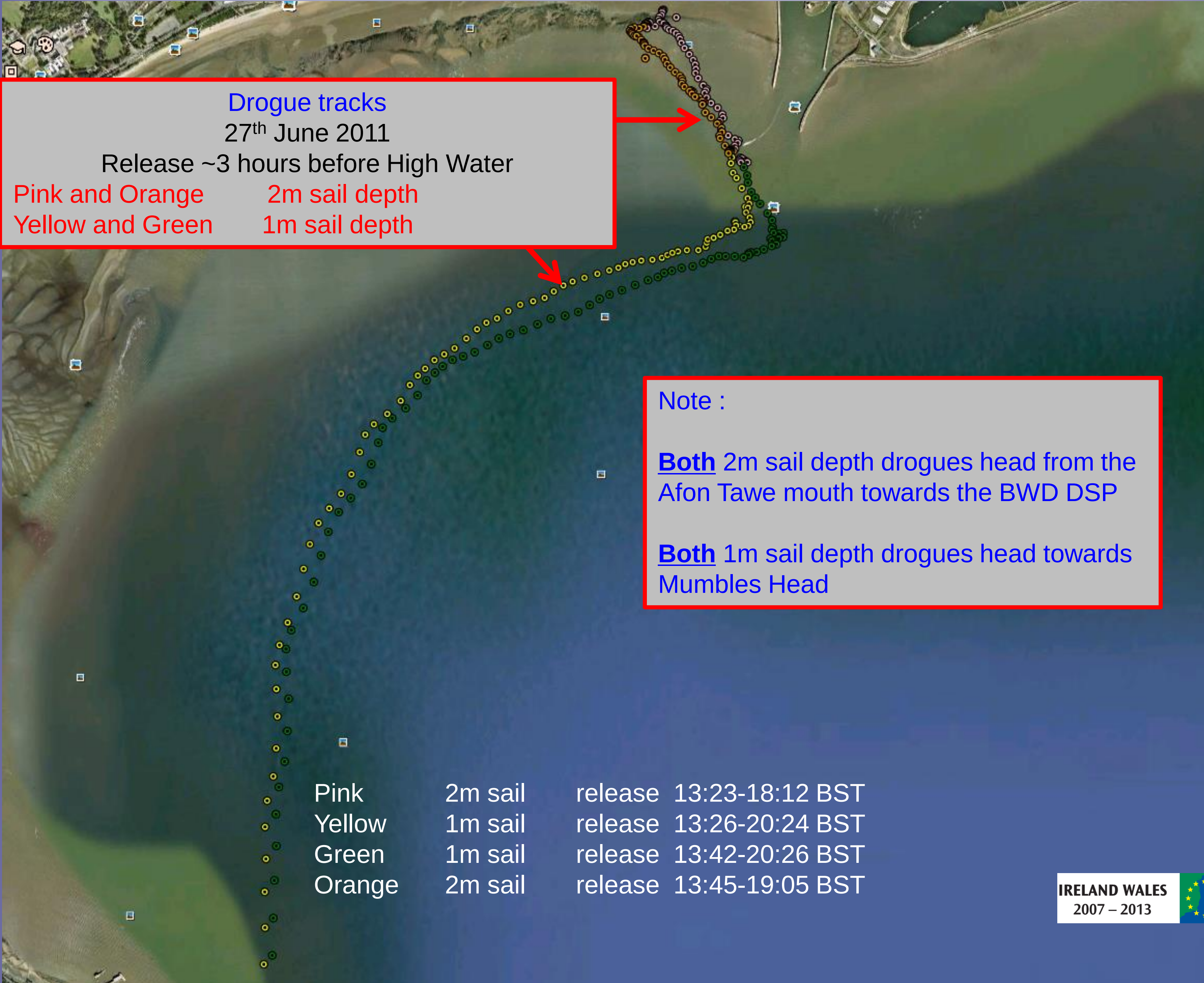
A 2 metre sail depth drogue being released


650
ANTARES
IRELAND WALES
2007 – 2013


Two pairs of drogues released
20 minutes apart off Mumbles
Head near Knab Rock SPS
IRELAND WALES
2007 – 2013


Baglan Bay
Mumbles
27/06/2011
and
28/06/2011
09/06/2011
Drogue
Release Locations
to Date
04/07/2011
29/06/2011



Drogue tracks
27th June 2011
Release ~3 hours before High Water

Pink and Orange	2m sail depth
Yellow and Green	1m sail depth

Note :

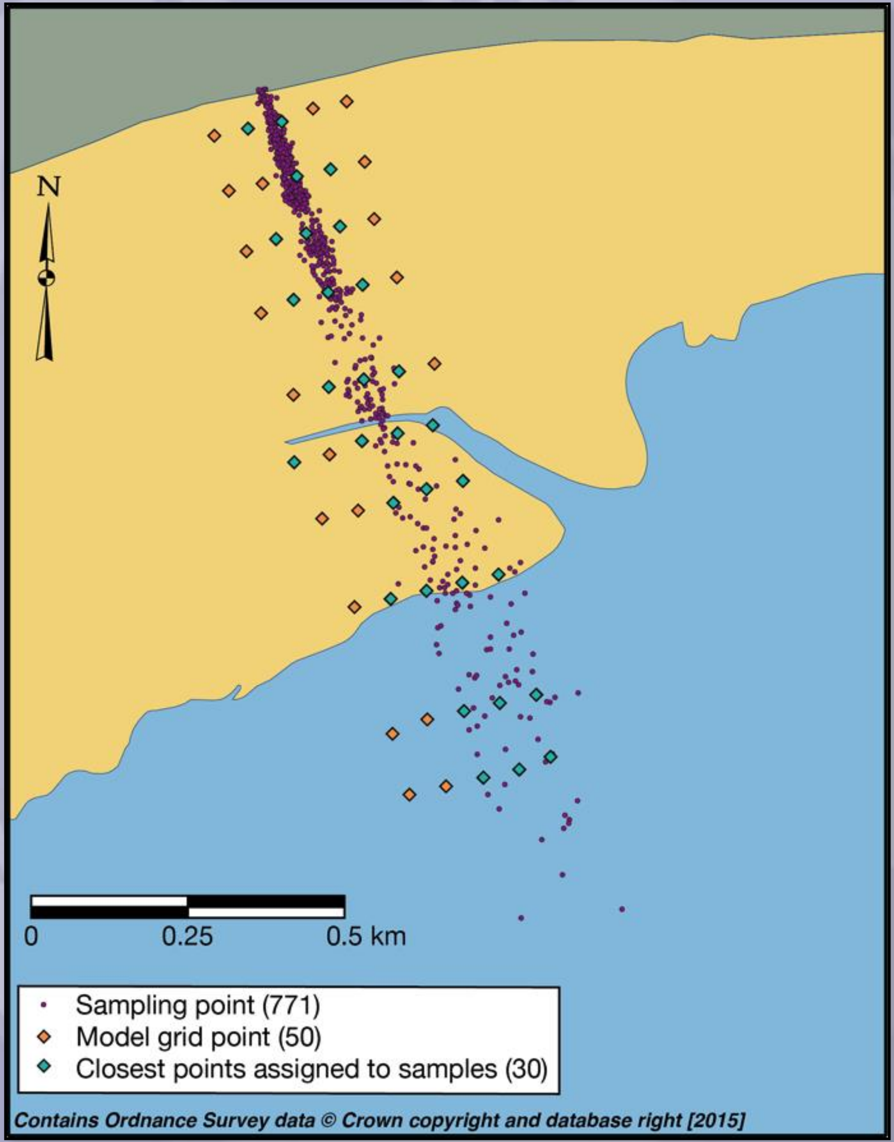
Both 2m sail depth drogues head from the Afon Tawe mouth towards the BWD DSP

Both 1m sail depth drogues head towards Mumbles Head

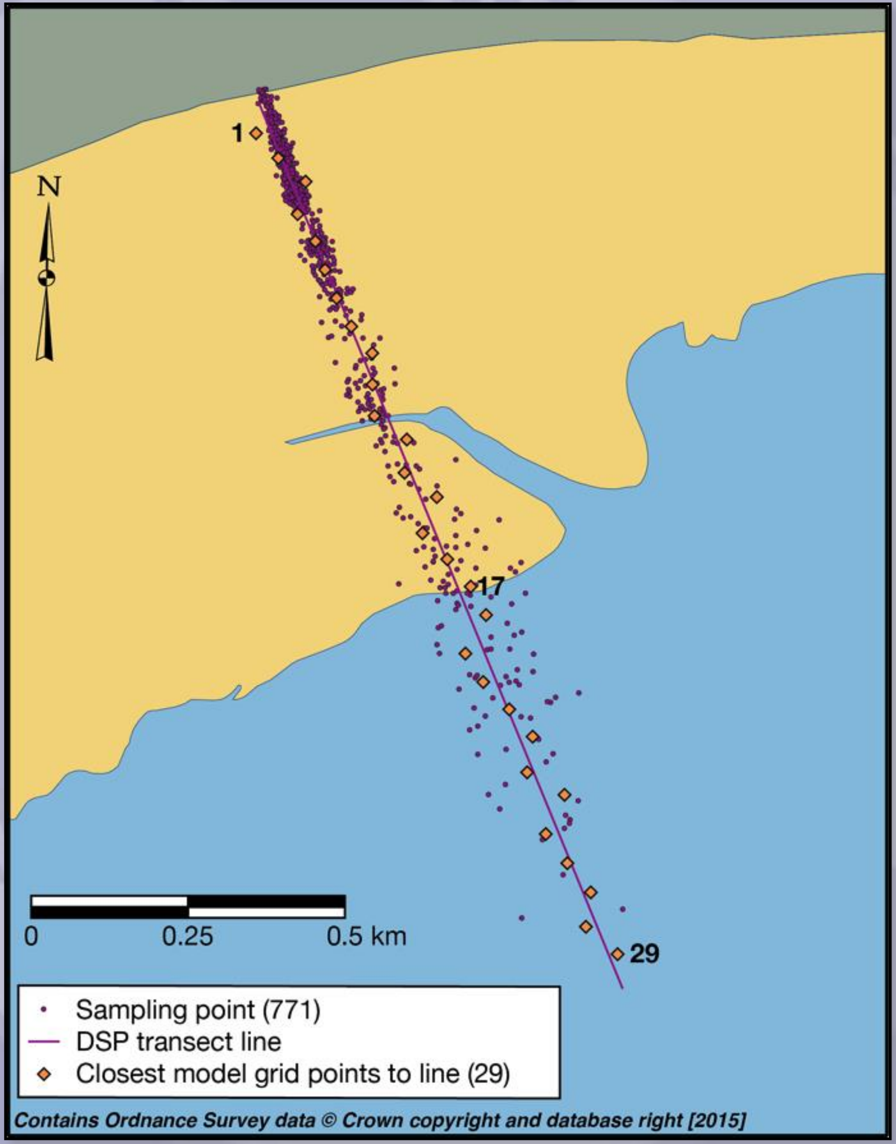
Pink	2m sail	release	13:23-18:12 BST
Yellow	1m sail	release	13:26-20:24 BST
Green	1m sail	release	13:42-20:26 BST
Orange	2m sail	release	13:45-19:05 BST

IRELAND WALES
2007 – 2013

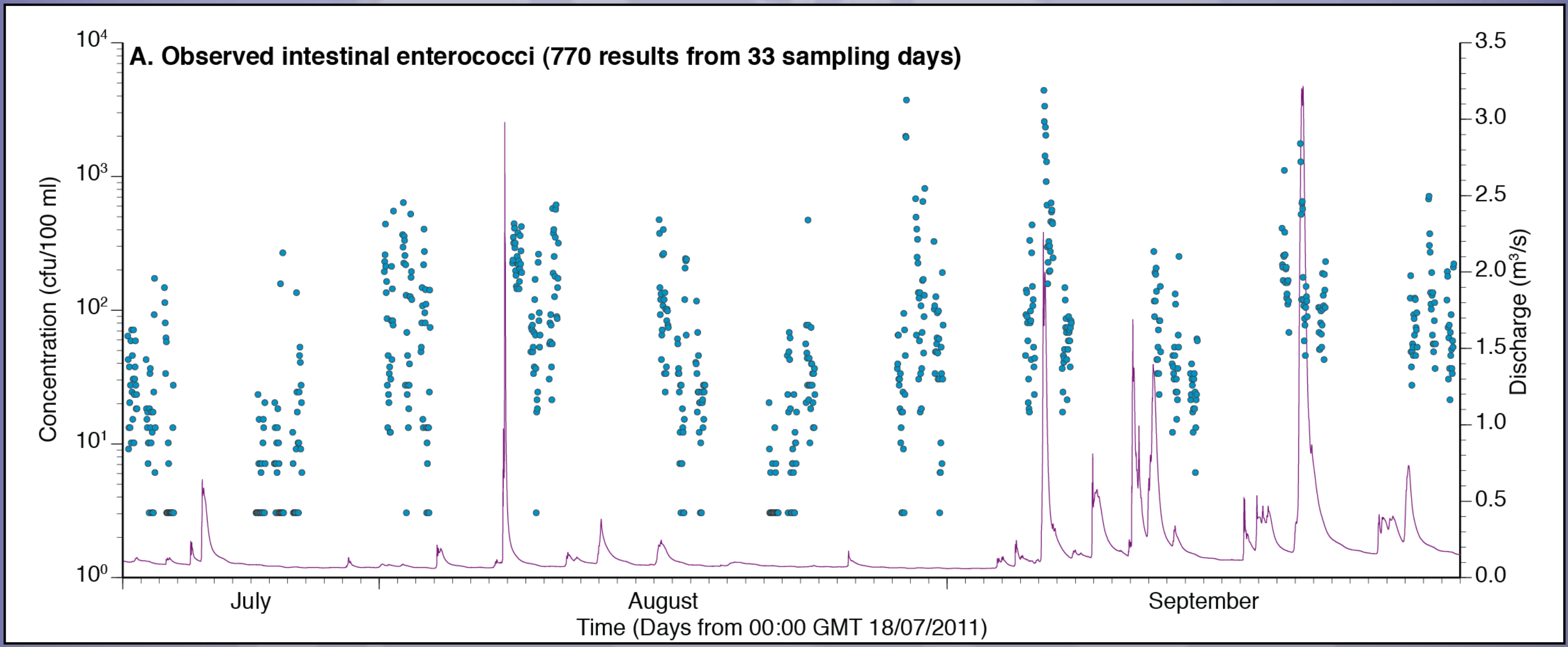
Swansea Bay DSP - Closest Point Grid



Swansea Bay - DSP Transect



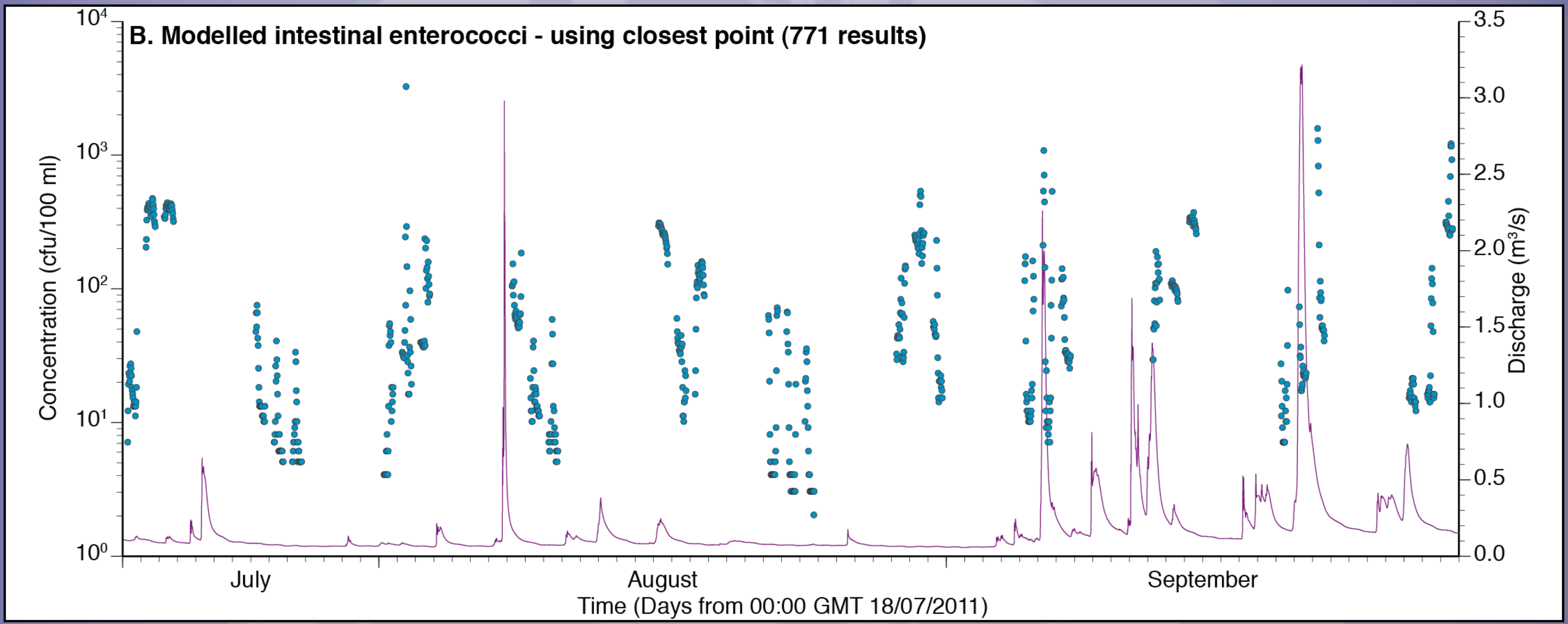
Measured – Individual samples



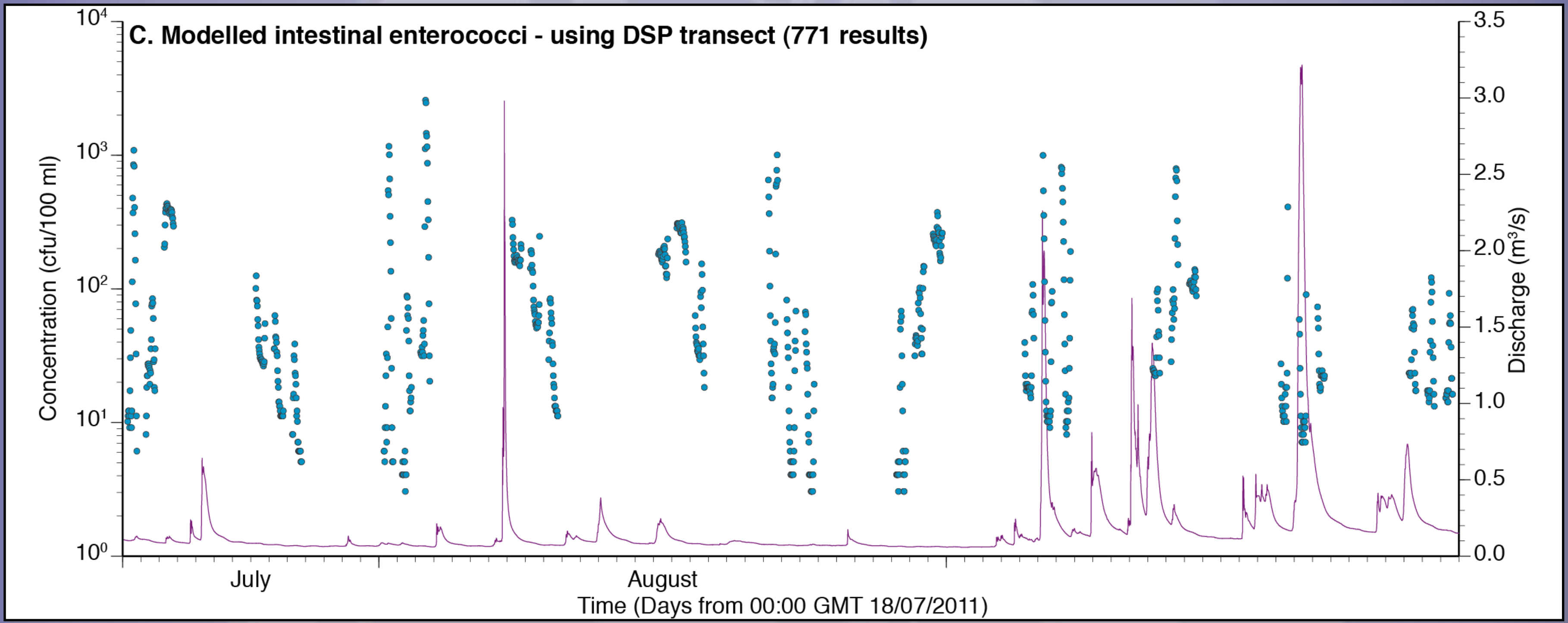
Variation in IE concentration within each sampling day

Observed and modelled IE concentrations showed a better approximation to normality when $\log_{10}$ transformed

Modelled – Closest Point



Modelled – DSP Transect



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Overall Statistics (cfu/100 ml)

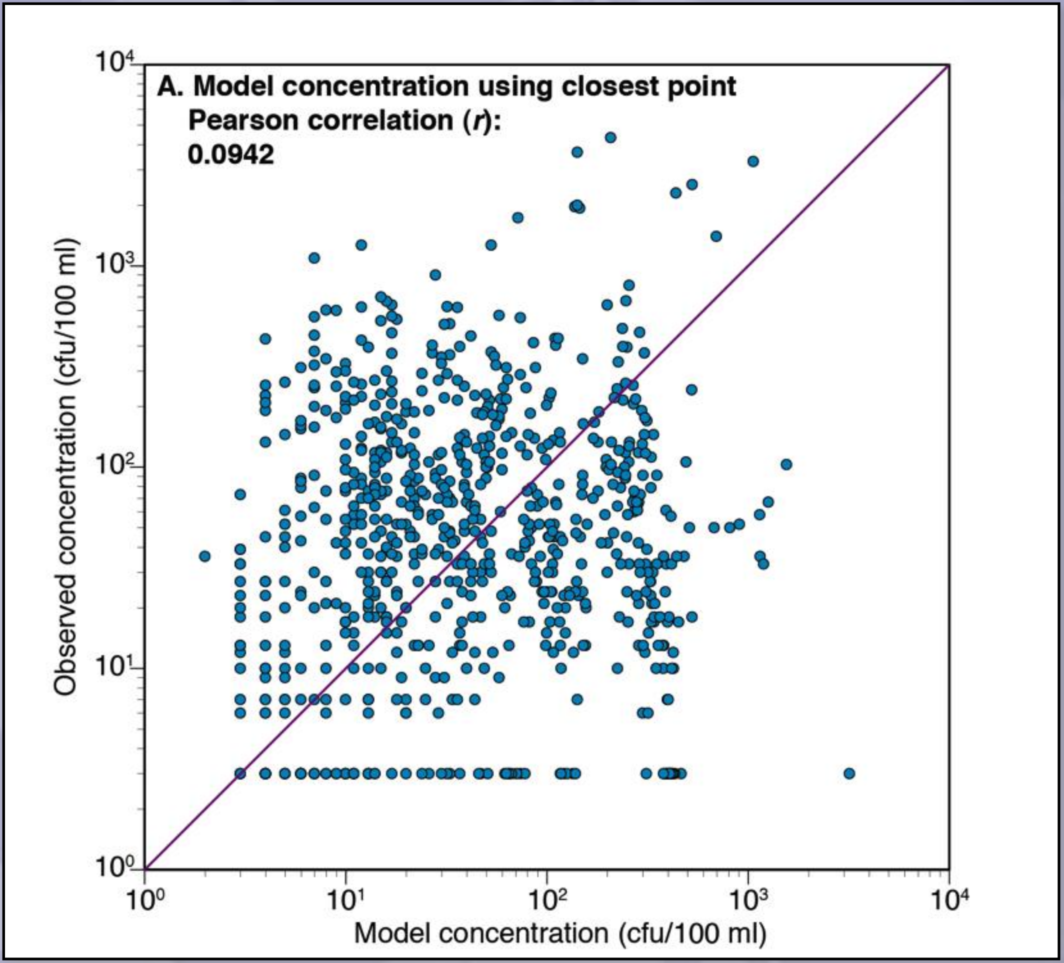
Source	Geo. Mean	L95%CI	U95% CI	SD[a]	Min.	Max.	*n*
Observed	43	38	48	0.658	3	4333	770
Closest point	39	36	44	0.632	2	3198	771
DSP Transect	44	40	49	0.601	3	2534	771

a. Standard deviation of $\log_{10}$ IE concentrations

Model showed similar GM to that observed – no statistically significant difference

SD and ranges were also similar

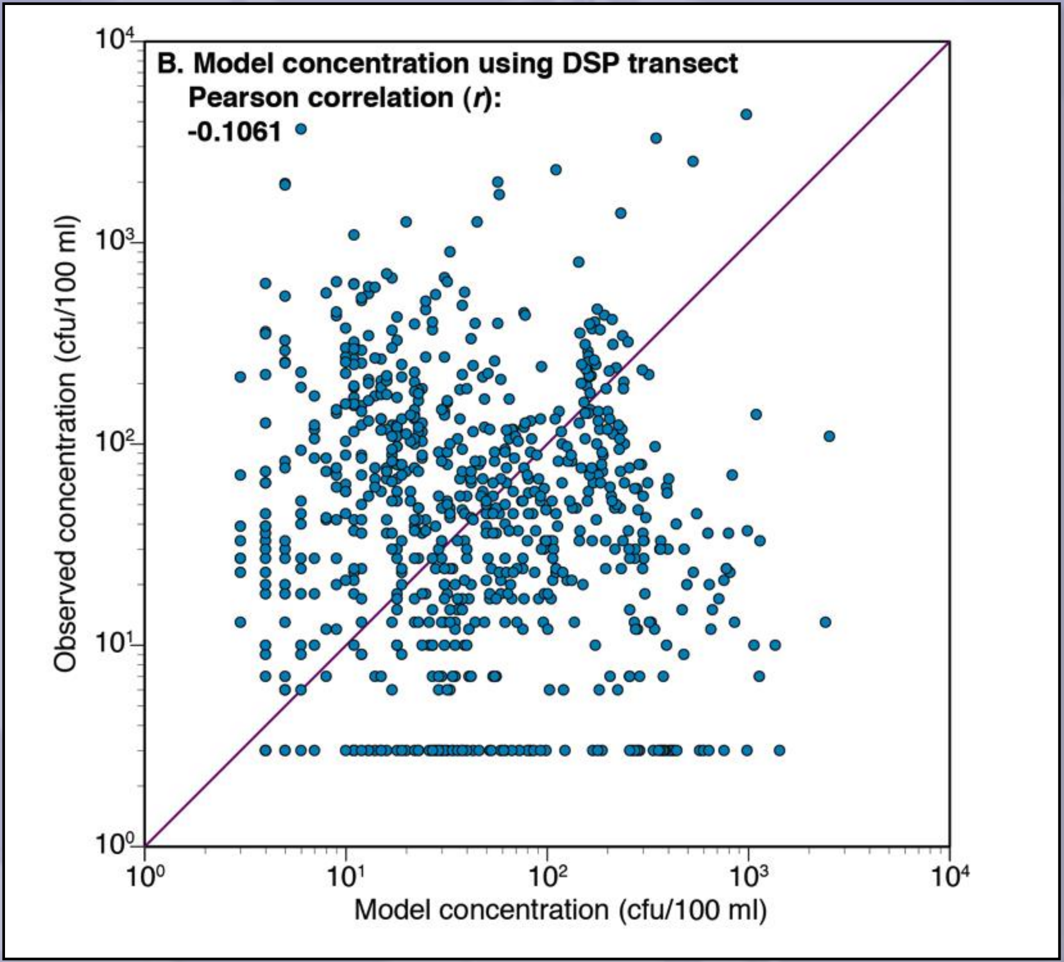
Pairwise comparisons – Closest Point



Statistically significant but weak +ve correlation

No apparent positive trend

Pairwise comparisons – DSP Transect



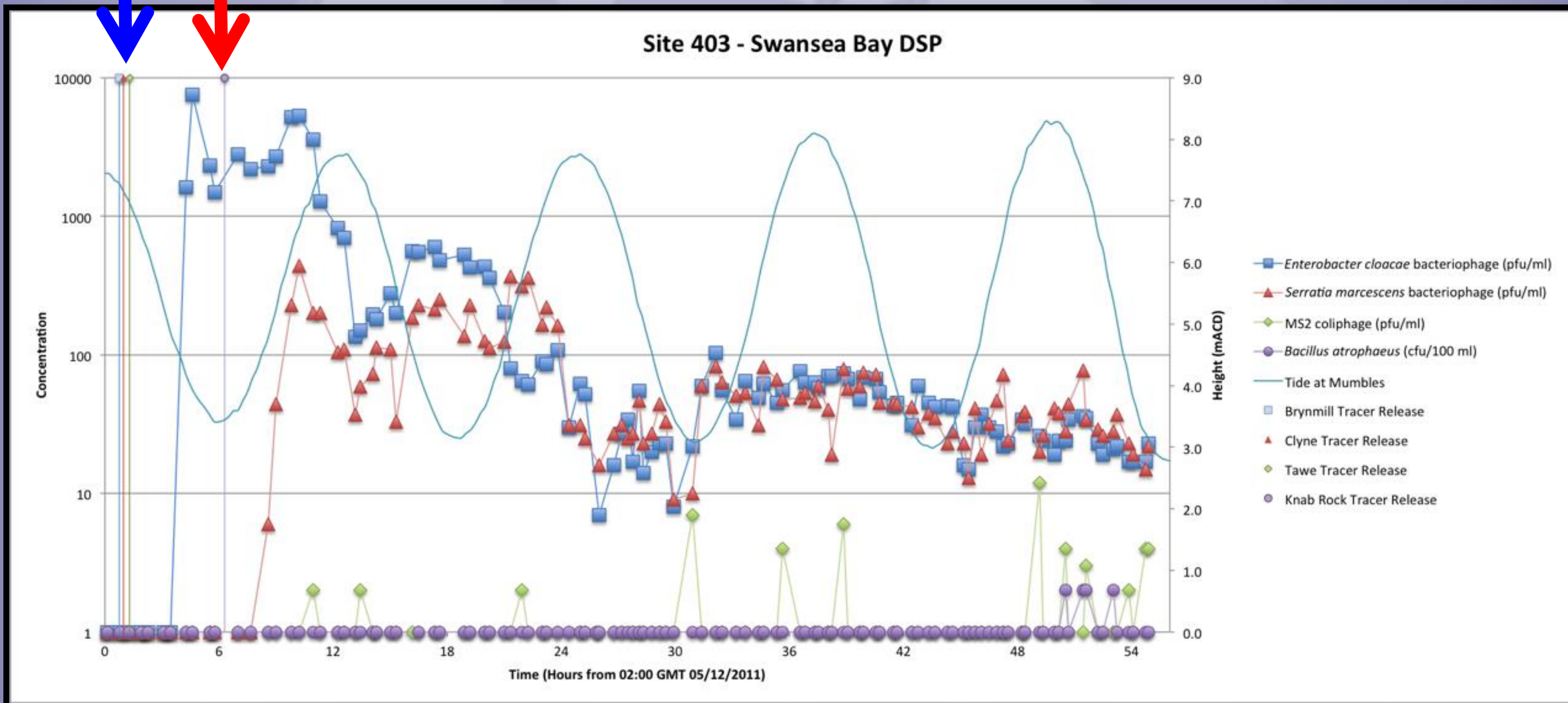
Statistically significant but weak –ve correlation
No apparent positive trend

But MLR is only Association
NOT
Causation

Confirmation of Connectivity

Results Swansea - DSP

02:00 **08:00**



Brynmill *Enterobacter* tracer arrived at 3.2 hrs – peak at 3.5 hrs
Clyne *Serratia* River tracer arrived at 7.6 hrs – peak at 9.2 hrs
Max MS2 coliphage (Tawe) = 12 pfu/ml – 47.9 hrs
Knab Rock Max *B. atrophaeus* = 2 cfu/100 ml – 44.2 hrs

Wider use of the tracer approach

Menai East
Rhyl/Dee
Menai West
Aberdyfi
Aberystwyth
New Quay
Newport
Milford Haven
Three Rivers
0
25
50
75
100 km

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Aberystwyth to Aberdyfi tracer Study
8th to 10th Feb 2016

8th February 2016

Tan-y-Cae Pumping Sta. Aberystwyth Marina tracer insertion

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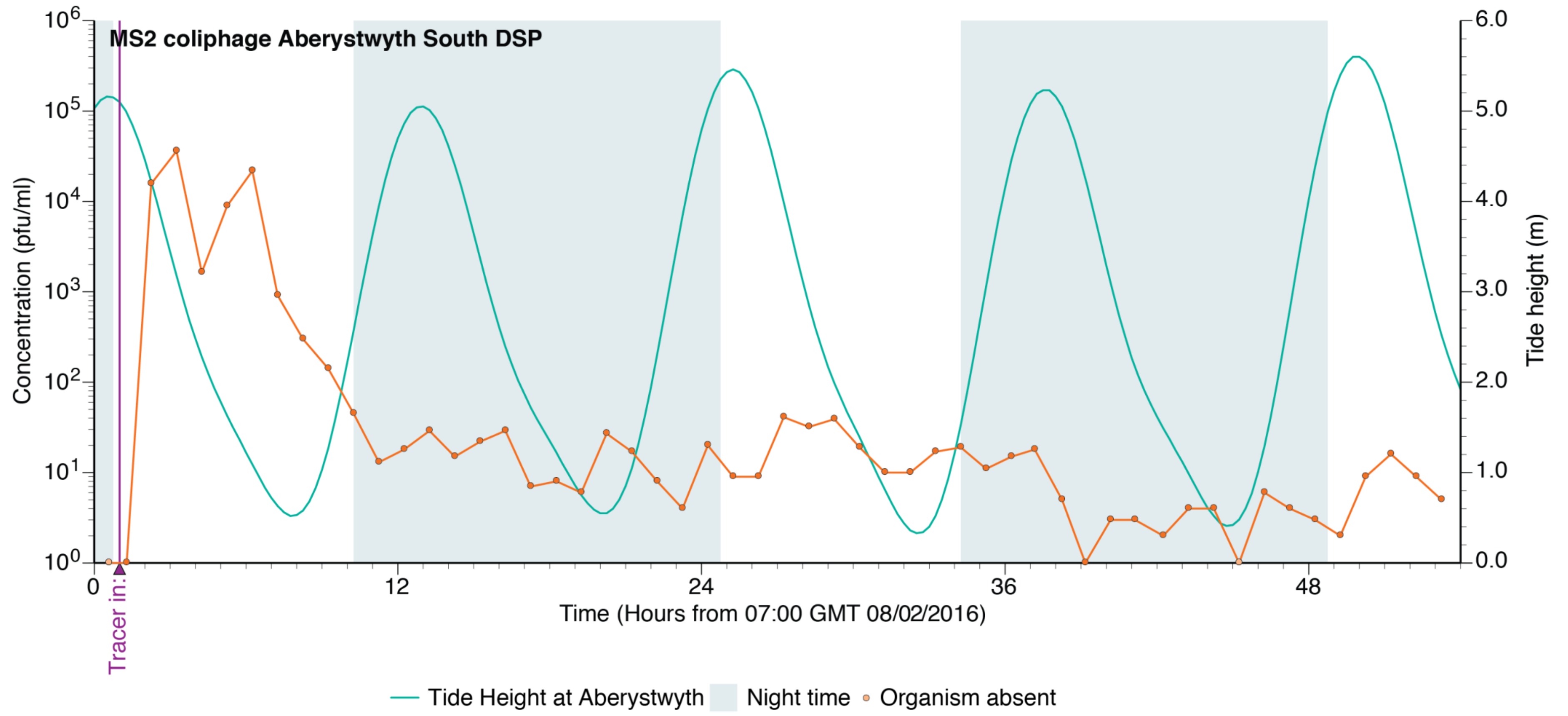
HAVE OU
PAID AND
DISPLAYED
Aberystwyth
De / South

Hourly sampling at Aberystwyth South Beach for 54 Hours post-tracer release



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Results

- MS2 coliphage tracer released at Tan-y-Cae PS which discharges into Aberystwyth Harbour (10^{17} pfu)
- Wind peaking at Bf 10 WSW
- Phage located at

– Tanybwlch Beach	3.00hrs	140,800 pfu/ml
– Aberystwyth S	2.25hrs	36,000 pfu/ml
– Aberystwyth N	2.25hrs	10,100 pfu/ml
– Borth	9.02hrs	1,960 pfu/ml
– Aberdyfi	13.10hrs	390 pfu/ml
– Tywyn	17.37hrs	676 pfu/ml

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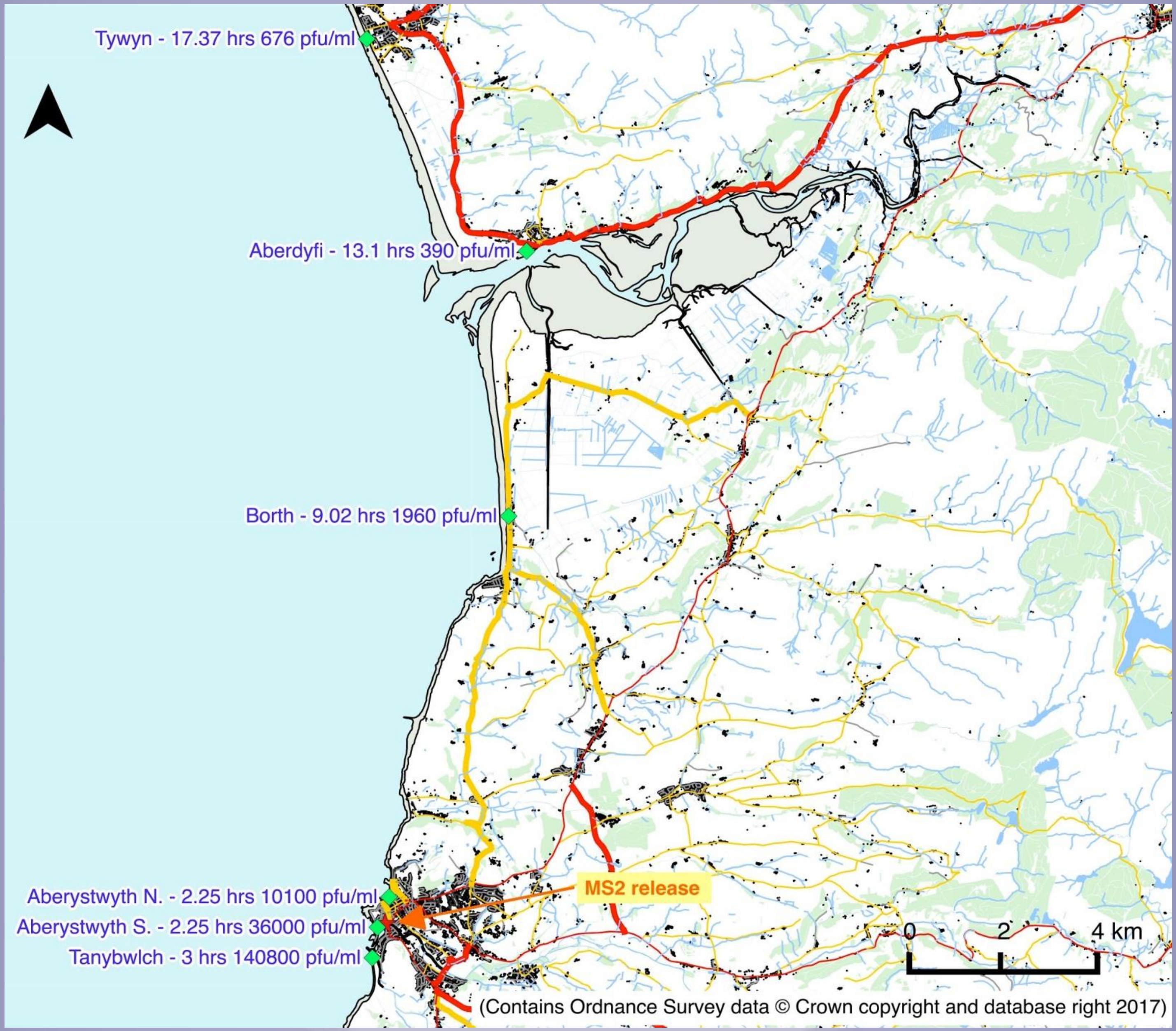

Tywyn - 17.37 hrs 676 pfu/ml
Aberdyfi - 13.1 hrs 390 pfu/ml
Borth - 9.02 hrs 1960 pfu/ml
MS2 release
Aberystwyth N. - 2.25 hrs 10100 pfu/ml
Aberystwyth S. - 2.25 hrs 36000 pfu/ml
Tanybwlch - 3 hrs 140800 pfu/ml
0
2
4 km
(Contains Ordnance Survey data © Crown copyright and database right 2017)

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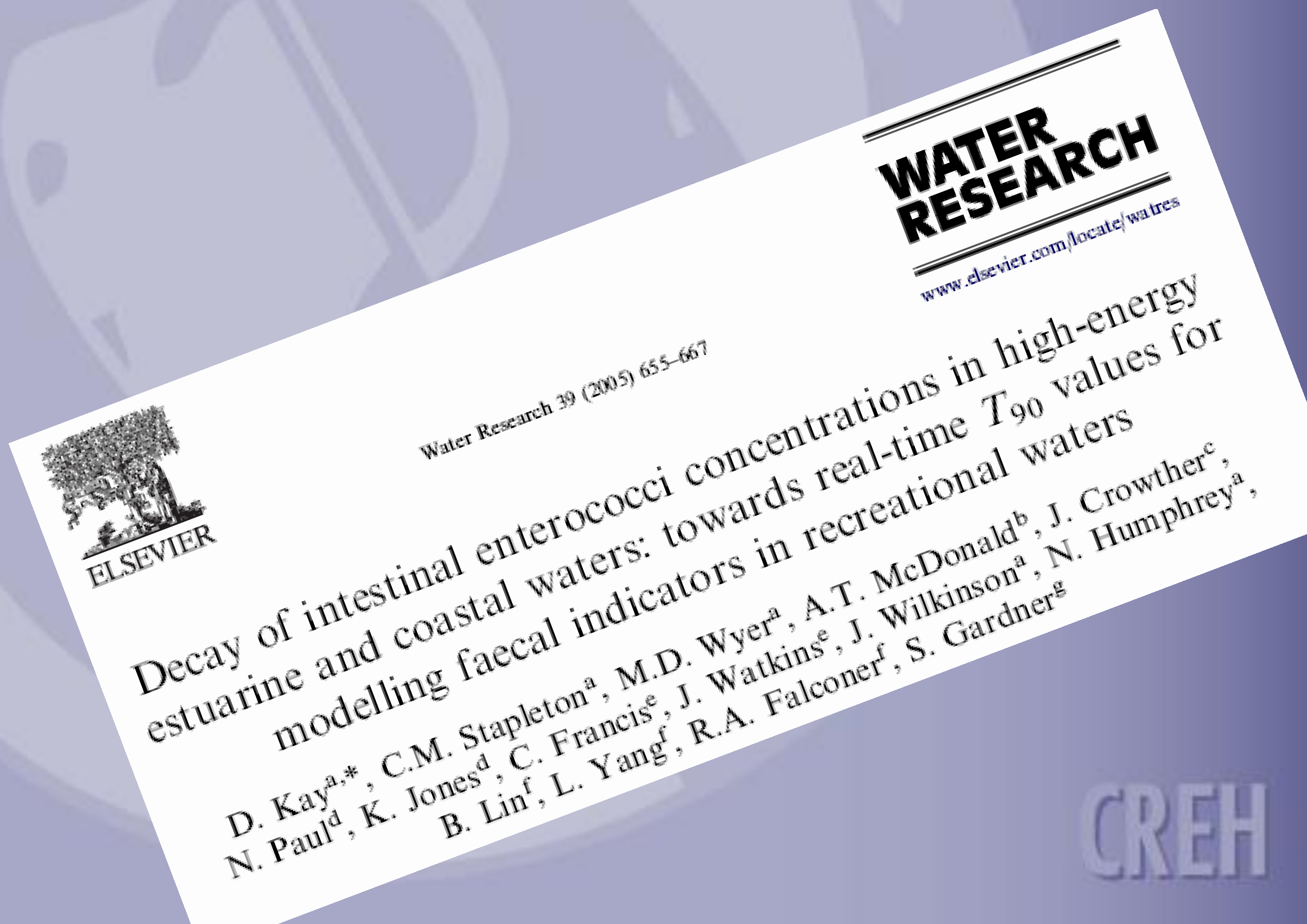
T_{90} values and microbial Decay



Water Research 39 (2005) 655–667

WATER RESEARCH

www.elsevier.com/locate/watres

ELSEVIER

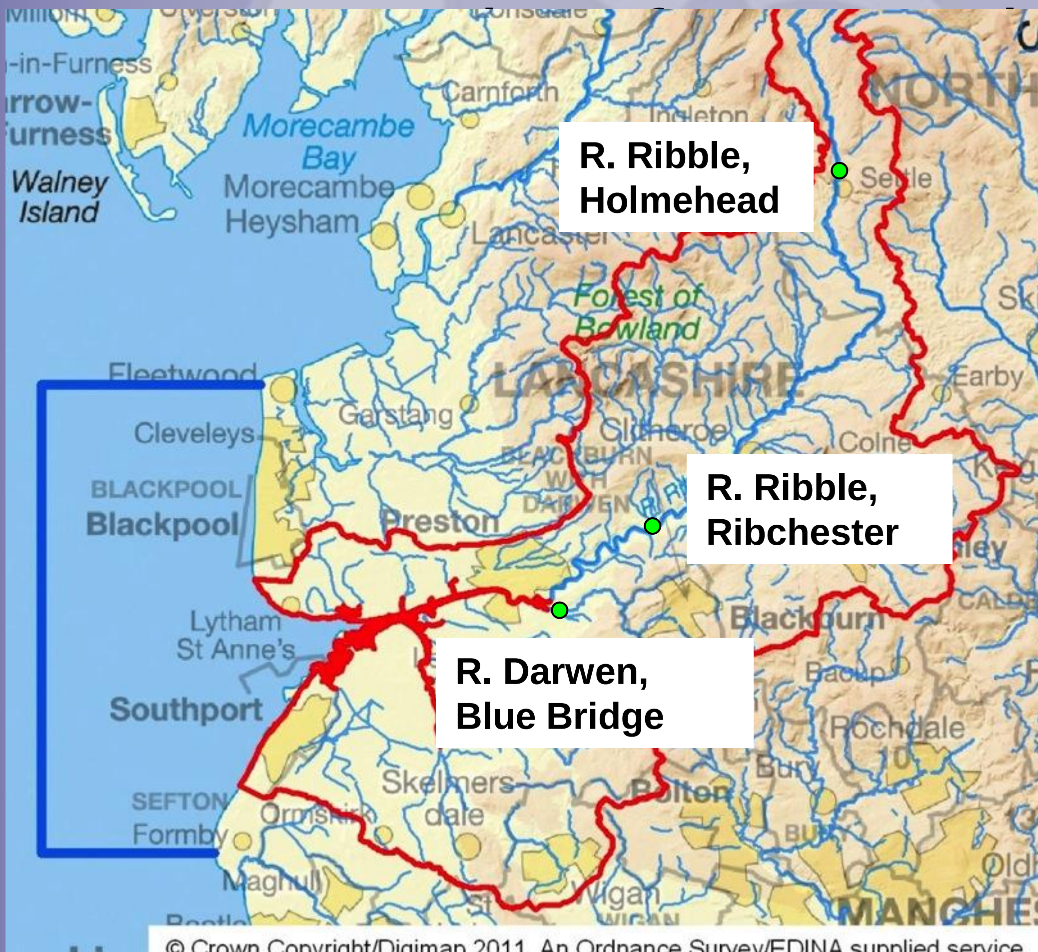
Decay of intestinal enterococci concentrations in high-energy estuarine and coastal waters: towards real-time T_{90} values for modelling faecal indicators in recreational waters

D. Kay[a,*], C.M. Stapleton[a], M.D. Wyer[a], A.T. McDonald[b], J. Crowther[c], N. Paul[d], K. Jones[d], C. Francis[e], J. Watkins[e], J. Wilkinson[a], N. Humphrey[a], B. Lin[f], L. Yang[f], R.A. Falconer[f], S. Gardner[g]

Light rig

Mixture of visible (metal halide) and UV lamps

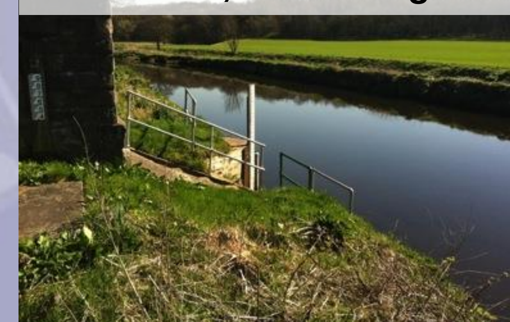
T_{90} experiments:
Freshwater



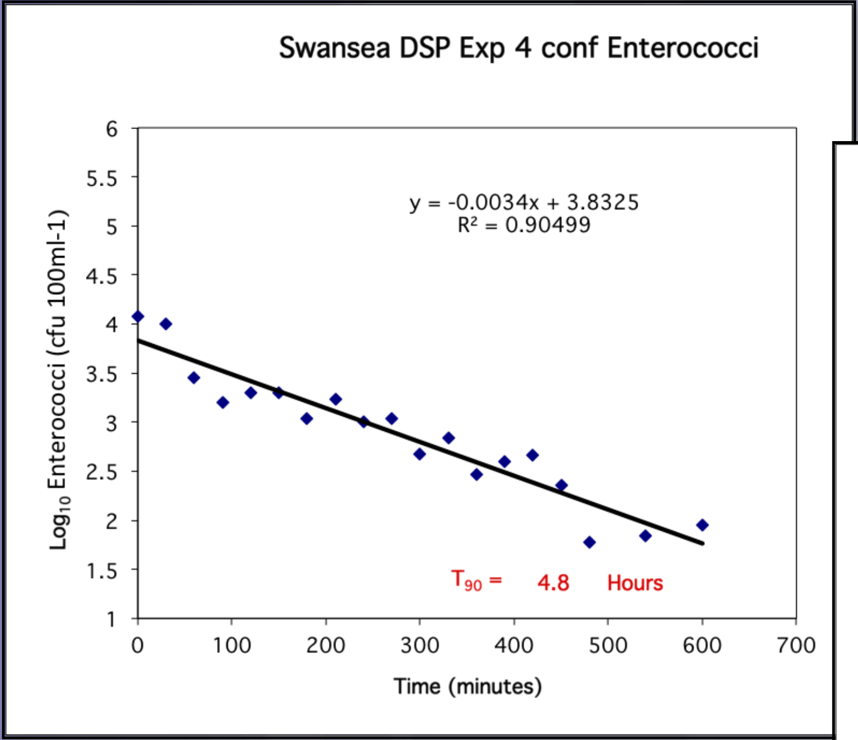
R. Ribble, Holmehead

R. Ribble, Ribchester

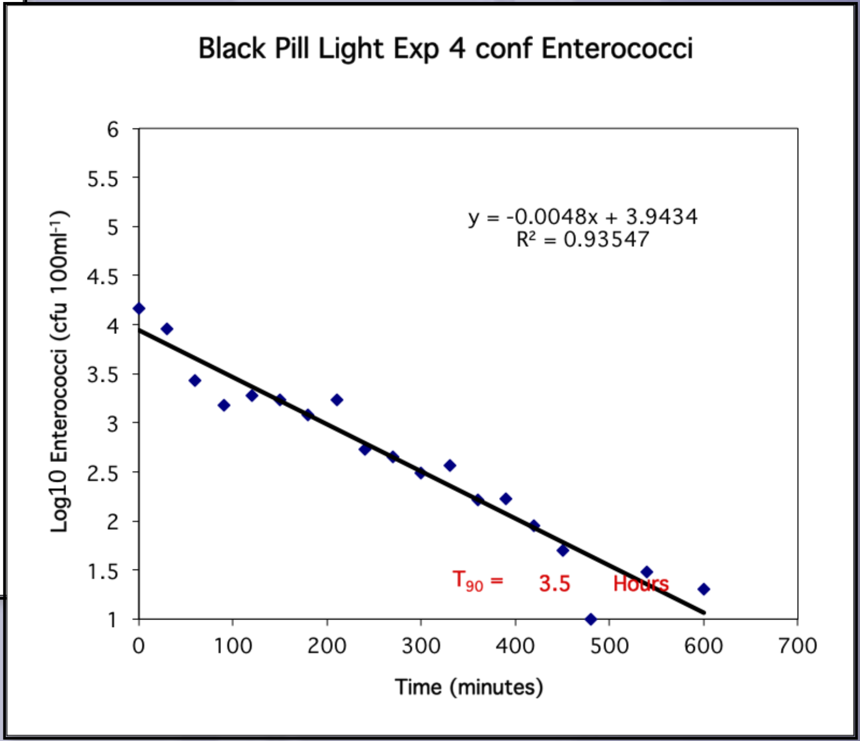
R. Darwen, Blue Bridge



T_{90} Experiments



9 sets of light/dark experiments using Swansea Bay water



Water from a range of locations

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Range of T_{90}: Freshwaters

	Irradiated T_{90} (hours)	Dark T_{90} (hours)	Turbidity (NTU)
E. Coli	4.1 — 43.4	23.5— 829.6	2 — 30.2
Confirmed Enterococci	4.4 — 65.3	32.2 — 279.6	1.5 — 39.3

Turbidity during field surveys 10/7/12 – 2/9/12

Ribble, Ribchester:
Average: 49 NTU; Maximum 220 NTU

Darwen Blue Bridge
Average: 30 NTU; Maximum 130 NTU

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Range of T_{90}: Seawater

Swansea and Severn	Irradiated T_{90} (hours)	Dark T_{90} (hours)	Turbidity (NTU)
E. Coli	1.3 — 2.5	3.1 — 44.0	1.5 — 290
Confirmed Enterococci	3.5 — 5.1	6.3 — 84.0	1.5 — 290

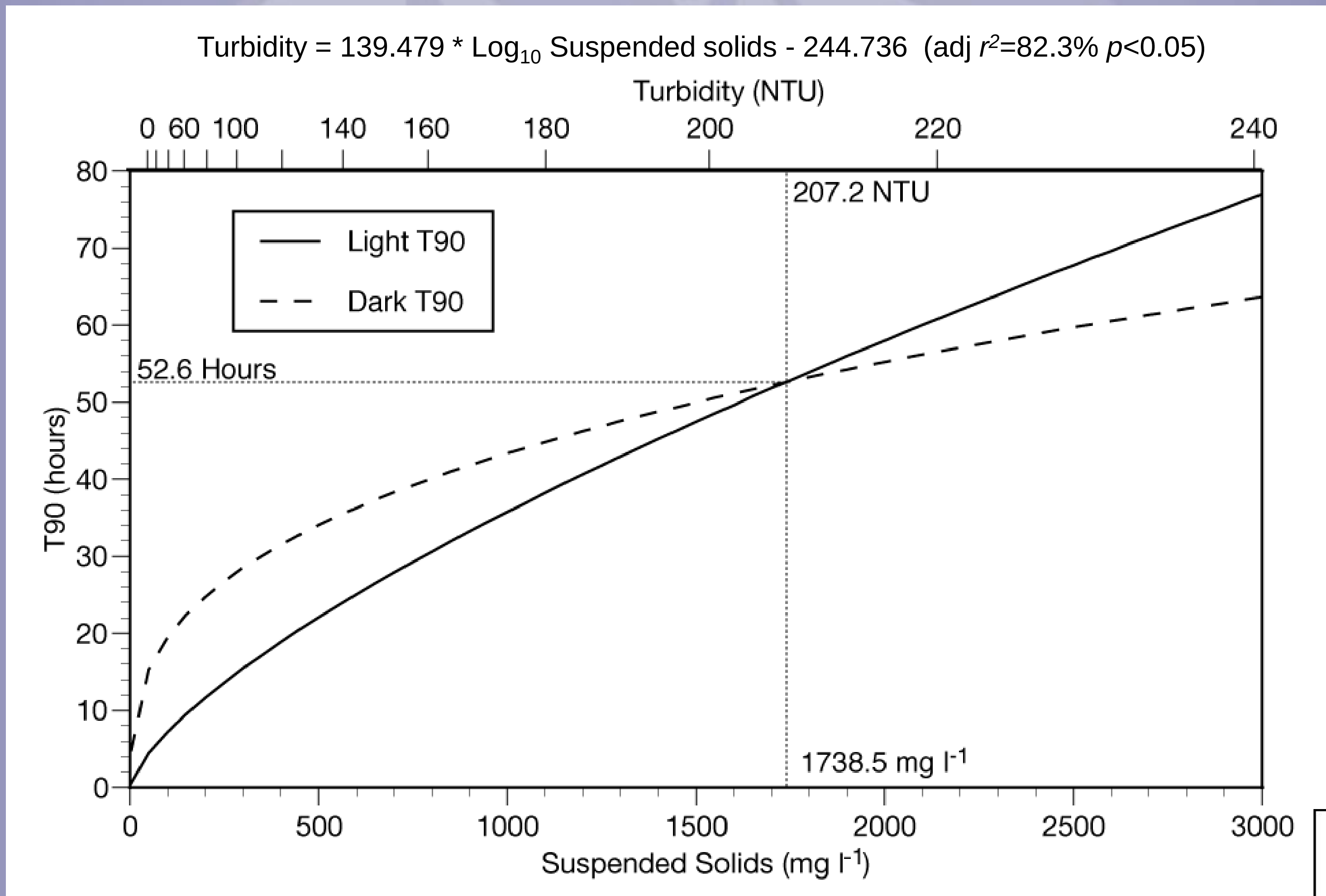
EA† (Fate & Transport)	Irradiated T_{90} (hours)	Dark T_{90} (hours)	Turbidity (NTU)
Presumptive Enterococci	4.2 — 12.8	18.7 — 73.8	14 — 95

* Swansea samples: Swansea DSP, Mumbles Pier, Mumbles Slip, Black Pill

† EA and LCRI Fate & transport samples: Beachley Penarth, Porthcawl, Minehead, Langland

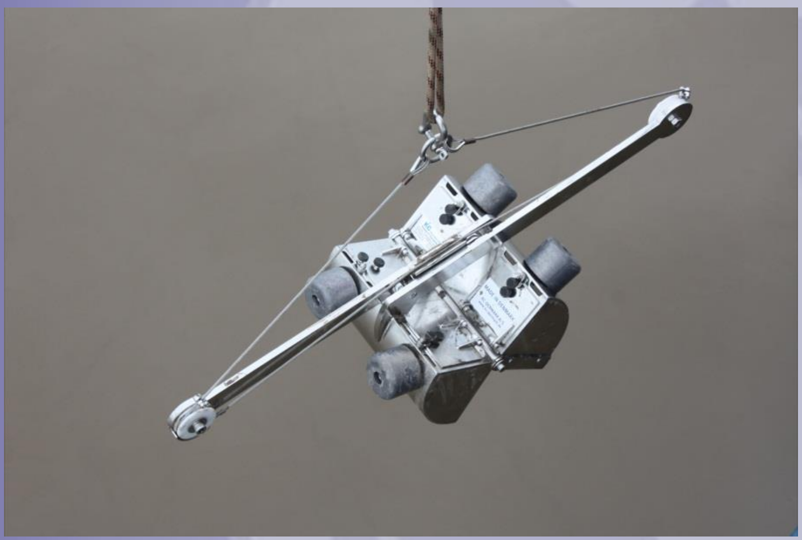

Environment Agency
using science to create a better place
Fate and transport of particles in estuaries

Relationship with turbidity & s. solids – saline & brackish T_{90}



99% of incident radiation absorbed in first 1cm of optical path through the water column at 200 NTU (Joyce *et al*., 1996)

What of Sediment Sources?



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c2c CLOUD TO COAST

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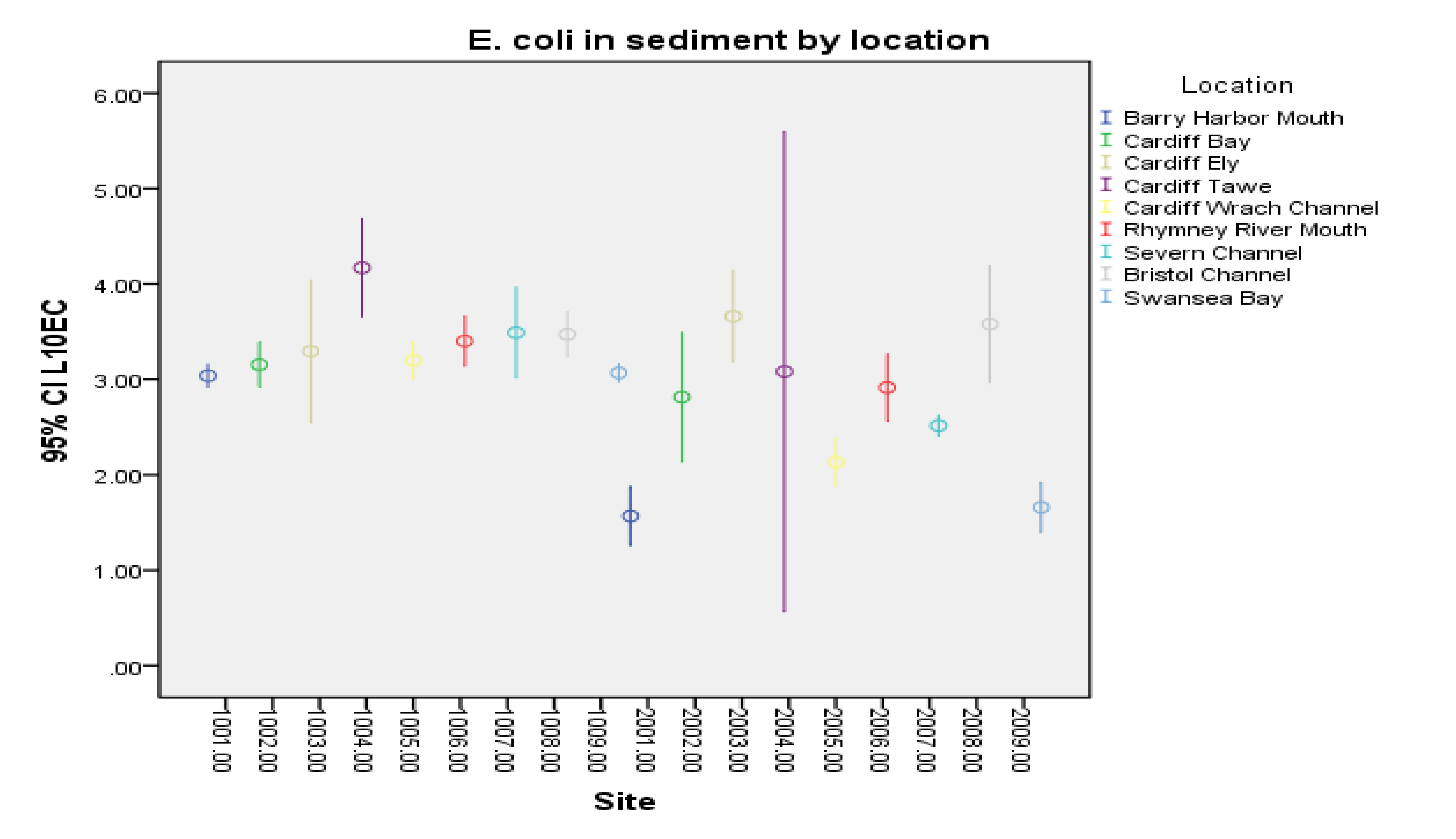
Severn Estuary Results



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Bridlington Harbour FIO Investigation

December 2011

to

April 2012

YorkshireWater

CREH

13th December 2011

YorkshireWater

13th December 2011

YorkshireWater

CREH

YorkshireWater

13th December 2011

Results

Sediment near Gypsey Race	GM *E. coli*	16,698 /100g	Water	GM 859 /100ml
	GM IE	42,679 /100g		GM 1,081 /100ml
Remainder of Harbour	GM *E. coli*	3,409 /100g		GM 190 /100ml
	GM IE	10,583 /100g		GM 173 /100ml

Importantly, a speciation study indicated ‘intestinal enterococci, the elevated concentrations were therefore compliance relevant and not indicative of environmental strains re-growing in the sedimentary environment

YorkshireWater

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BMPs
Catchment
Control efforts

do they work for FIO flux?


Further information, reports and papers
email to
dave@crehkay.demon.co.uk