Cefas

EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Swansea Bay

(Wales)

2011

Cover photo: Queen's Dock looking East from Scherzer Passage.

CONTACTS:

For enquires relating to this report or further information on the implementation of Sanitary Surveys in England and Wales:

Simon Kershaw/Carlos Campos
Food Safety Group
Cefas Weymouth Laboratory
Barrack Road
The Nothe
Weymouth
Dorset
DT43 8UB

☎ +44 (0) 1305 206600
✉ shs@cefas.co.uk

For enquires relating to policy matters on the implementation of Sanitary Surveys in England and Wales:

Karen Pratt/Mariam Aleem
Hygiene Delivery Branch
Enforcement and Delivery Division
Food Standards Agency
3rd Floor Aviation House
125 Kingsway
London
WC2B 6NH

☎ +44 (0) 20 7276 8000
✉ shellfish_hygiene@foodstandards.gsi.gov.uk

STATEMENT OF USE: This report provides information from a study of the information available relevant to perform a sanitary survey of bivalve mollusc harvesting areas in Swansea Bay, Wales. Its primary purpose is to demonstrate compliance with the requirements for classification of bivalve mollusc production areas in EC Regulation 854/2004 laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption. The Centre for Environment, Fisheries & Aquaculture Science (Cefas) undertook this work on behalf of the Food Standards Agency (FSA).

CONSULTATION:

Consultee	Date of consultation	Date of response
Environment Agency	08/10/2010	08/11/2010
Swansea Bay Port Health Authority	06/10/2010	08/10/2010
Welsh Assembly Government - Food, Fisheries and Market Development Division	06/10/2010	08/10/2010

DISSEMINATION STATUS: Food Standards Agency, Swansea Bay Port Health Authority, Environment Agency, Welsh Assembly Government - Food, Fisheries and Market Development Division, Welsh Assembly Government (Fisheries Unit).

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CONTENTS

1 INTRODUCTION

1.1 LEGISLATIVE REQUIREMENT

Filter feeding, bivalve molluscan shellfish (e.g. mussels, native oysters) retain and accumulate a variety of microorganisms from their natural environments. Since filter feeding promotes retention and accumulation of these microorganisms, the microbiological safety of bivalves for human consumption depends heavily on the quality of the waters from which they are taken (Bell, 2006).

When consumed raw or lightly cooked, bivalves contaminated with pathogenic microorganisms may cause infectious diseases (e.g. Norovirus-associated gastroenteritis, Hepatitis A and Salmonellosis) in humans. Infectious disease outbreaks are more likely to occur in coastal areas, where bivalve mollusc production areas (BMPAs) are impacted by sources of microbiological contamination of human and or animal origin.

In England and Wales, fish and shellfish constitute the fourth most reported food item causing infectious disease outbreaks in humans after poultry, red meat and desserts (Hughes *et al.*, 2007).

The risk of contamination of bivalve molluscs with pathogens is assessed through the microbiological monitoring of bivalves. This assessment results in the classification of BMPAs, which determines the level of treatment (e.g. purification, relaying, cooking) required before human consumption of bivalves (Lee and Younger, 2002).

Under EC Regulation 854/2004 laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption, sanitary surveys of BMPAs and their associated hydrological catchments and coastal waters are required in order to establish the appropriate representative monitoring points (RMPs) for the monitoring programme.

The Centre for Environment, Fisheries & Aquaculture Science (Cefas) is undertaking sanitary surveys for new BMPAs in England and Wales, on behalf of the Food Standards Agency (FSA). The purposes of the sanitary surveys are to demonstrate compliance with the requirements stated in Annex II (Chapter II paragraph 6) of EC Regulation 854/2004, whereby “if the competent authority decides in principle to classify a production or relay area it must:

(a) make an inventory of the sources of pollution of human or animal origin likely to be a source of contamination for the production area;

(b) examine the quantities of organic pollutants which are released during the different periods of the year, according to the seasonal variations of both human and animal populations in the catchment area, rainfall readings, waste-water treatment, etc.;

(c) determine the characteristics of the circulation of pollutants by virtue of current patterns, bathymetry and the tidal cycle in the production area; and

(d) establish a sampling programme of bivalve molluscs in the production area which is based on the examination of established data, and with a number of samples, a geographical distribution of the sampling points and a sampling frequency which must ensure that the results of the analysis are as representative as possible for the area considered."

EC Regulation 854/2004 also specifies the use of *Escherichia coli* as an indicator of microbiological contamination in bivalves. This bacterium is present in animal and human faeces in large numbers and is therefore indicative of contamination of faecal origin.

In addition to better targeting the location of RMPs and frequency of sampling for microbiological monitoring, it is believed that the sanitary survey may serve to help to target future water quality improvements and better analyse their effects on BMPAs. Improved monitoring should lead to improved detection of pollution events and identification of the likely sources of pollution. Remedial action may then be possible either through funding of improvements in point sources of contamination or as a result of changes in land management practices.

This report documents information relevant to undertake a sanitary survey for a new production area for mussels (*Mytilus* spp.) at Queen's Dock and existing production areas for farmed and wild mussels and wild native oysters in Swansea Bay (Wales).

1.2 Site Description

Swansea Bay

Swansea Bay - national grid reference (NGR) SS 630910 - is an embayment situated in the Bristol Channel, on the coast of South Wales. The bay is approximately 12km wide (from Mumbles Head to Port Talbot) and recessed by 5km. The bay has a long shoreline (Table 1.1). It faces south to southwest and is bounded on either side by broadly east-west trending hard rock coasts.

Table 1.1 Main characteristics of Swansea Bay.

Geomorphological type	Embayment
Shoreline length (km)	22.3
Core area (ha)	785
Intertidal area (ha)	748

Data from the Estuary Guide (ABPmer and Wallingford, 2009).

Seabed sediments within the bay are varied, ranging from muddy sands through gravel material (Halcrow Group Ltd, 2002).

The bivalve mollusc production areas (BMPAs) assessed in this sanitary survey are situated in sub-tidal areas of the western bay (Figure 1.2) and in Queen's Dock in Swansea Docks (Figure 1.3).

The estuaries within the bay have been heavily modified by human activity. There are no saltmarshes or mudflats within the Afan Estuary, with sand occupying virtually the whole system. The upper part of the Neath Estuary is extensively reclaimed and industrialised, with docks and considerable navigational dredging (Halcrow Group Ltd., 2002).

The stretch of shoreline between the River Tawe and River Clyne is a low-lying area fronted by areas of dunes in places. However, seawalls define most of the coastline. From the River Clyne to Mumbles Head, the steep sloped coastline is composed of Carboniferous rocks partly covered by glacial tills and gravels with revetments and seawalls defending the frontage (Halcrow Group Ltd., 2002).

Figure 1.1 Aerial view of Swansea Bay.
Reproduced from TutorGig Encyclopedia.

Figure 1.2 Swansea Bay looking east from The Mumbles (A) and looking west from Black Pill, Swansea (B).

Photo A courtesy of Alan Bowring.

Photo B courtesy of Jonathan Billingher.

Port of Swansea

The Port of Swansea comprises the King's Dock, Queen's Dock, Prince of Wales Dock two dry docks and a ferry terminal in the River Tawe. Three transit sheds (30,000 m^2 in total area) and 16 ha open storage are available at the port. It offers facilities for handling bulks, minerals, ores, forest products and general cargo (Associated British Ports, 2007). The Prince of Wales Dock is undergoing re-development to change from a commercial dock (currently receiving marine dredged aggregate) to a marina. Current access to this dock is via a swing bridge passage from King's Dock.

Queen's Dock

Queen's Dock is a semi-enclosed large body of water covering 61km^2 (Figure 1.3). The docks' frontage is comprised of artificially made ground fronting a low-lying barrier area covered with freshwater alluvial deposits (Halcrow Group Ltd., 2002).

In the past, the docks served oil handling facilities for BP oil refinery at Llandarcy and petrochemical plant at Baglan Bay. Currently, there are no commercial uses in Queen's Dock. Thomas Vivian Ltd has made a lease agreement with Associated British Ports to operate a mussel farming area within Queen's Dock.

Figure 1.3 Map of Swansea Docks.
Modified from Associated British Ports (2007).

Figure 1.4 Aerial view of Swansea Docks.
Photo courtesy of Ivor Lewis.

CATCHMENT

The river catchments draining to Swansea Bay are shown in Figure 1.5.

Elevation in the catchment varies between 10m and 900m (weighted average = 287m) (NERC, 2005). Approximately 20% of the catchment is within the elevation range 250–350m (NERC, 2005). Steep land is expected to generate significant volumes of surface runoff and potentially microbial contamination of faecal origin, which can be drained into watercourses under heavy and/or prolonged rainfall.

Continuous and discontinuous urban fabric are the dominant land cover types in the lower reaches of these catchments, whereas agriculture land, grasslands and forests tend to occur in the upper reaches (Figure 1.5).

In the UK, urban catchments have significantly higher typical concentrations of faecal coliforms than improved pasture-dominated rural catchments under base river flow conditions (Kay *et al.*, 2008). Under high flow, urban and rural catchments have similar typical concentration of this indicator of faecal contamination.

Table 1.2 Typical geometric mean and 95% confidence intervals of faecal coliforms under base- and high-flow conditions in UK catchments.

Catchment land use	Base flow			High flow		
	GM	Lower 95% CI	Upper 95% CI	GM	Lower 95% CI	Upper 95% CI
Urban	9.7×10^3	4.6×10^3	2×10^4	1×10^5	5.3×10^4	2×10^5
Semi-urban	4.4×10^3	3.2×10^3	6.1×10^3	4.5×10^4	3.2×10^4	6.3×10^4
Rural	8.7×10^2	6.3×10^2	1.2×10^3	1.8×10^4	1.3×10^4	2.3×10^4

CI - confidence interval
GM - geometric mean
Data from Kay et al. *(2008).*

Catchment geology comprises Boulder clay and morainic drift, alluvium, peat, landslip and glacial sand and gravel (NERC, 2005). More than 50% of the solid geological formations across the catchment are of moderate permeability (NERC, 2005). Grassland on permeable soils means that sub-surface runoff could be a potentially significant route of pollution across the catchment.

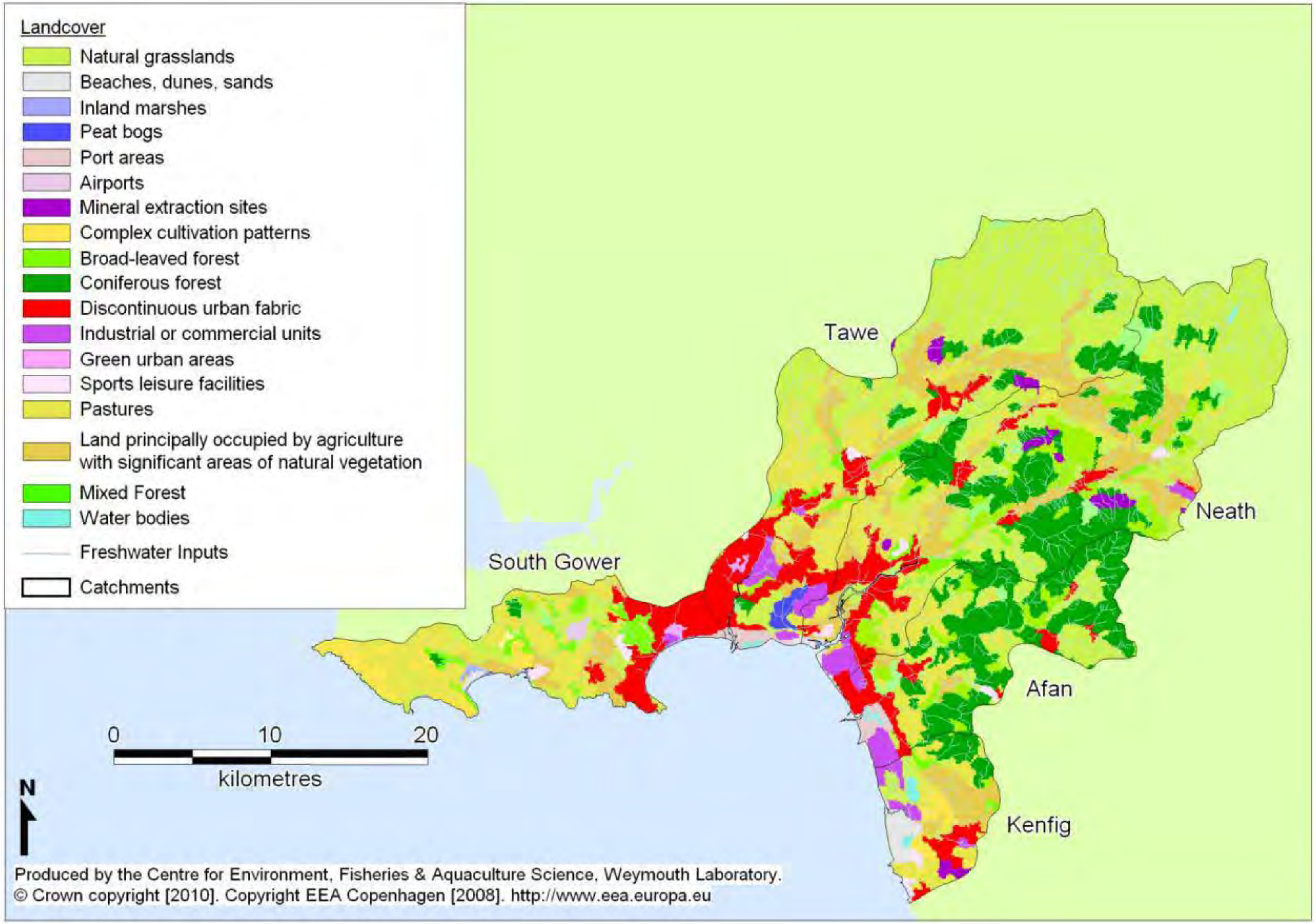


Figure 1.5 Land cover in river catchments draining to Swansea Bay.

2. SHELLFISHERIES

2.1 SPECIES, LOCATION AND EXTENT

MUSSELS

The harvesting of mussels and oysters for human consumption has a long tradition at Swansea Bay, particularly at The Mumbles (see Davidson, 1976; Herbert, 2005).

Mussels are often found in sheltered coasts and estuaries, just below the low water, where a food supply of suspended organic detritus and phytoplankton is available (Tebble 1976). In England and Wales, mussels grow well under temperatures ranging from 8°C to 28°C and salinities within the range 20–35psu in firm/solid substrata.

Both *Mytilus galloprovincialis* and *Mytilus edulis* have been recorded in the coasts of England and Wales (National Biodiversity Network Gateway, 2009). Literature indicates however that both species present large morphological, physiological and behavioural similarities and are therefore difficult to differentiate for commercial purposes due to adaptations to environmental conditions (see Wijsman and Smaal, 2006). Data from molecular analyses have highlighted high levels of hybridisation[1] and gene introgression[2] between these species in England. In the context of this sanitary survey, taxonomy of mussels is referred at genus level.

NATIVE OYSTERS

Native oysters (*Ostrea edulis*) grow under temperatures ranging from 8–27°C and salinities ranging from 25–35 psu in muddy sand and sandy substrata (Laing and Spencer, 2006).

HYGIENE CLASSIFICATION

Table 2.1 summarises the post-harvest treatment required before bivalve molluscs can be sold for human consumption. Table 2.2 summarises the historical classifications attributed to bivalve mollusc beds.

[1] The formation of a hybrid organism, e.g. by a cross between genetically dissimilar organisms.
[2] The incorporation of the genes of one species into the gene pool of another species.

Table 2.1 Criteria for classification of bivalve mollusc production areas.

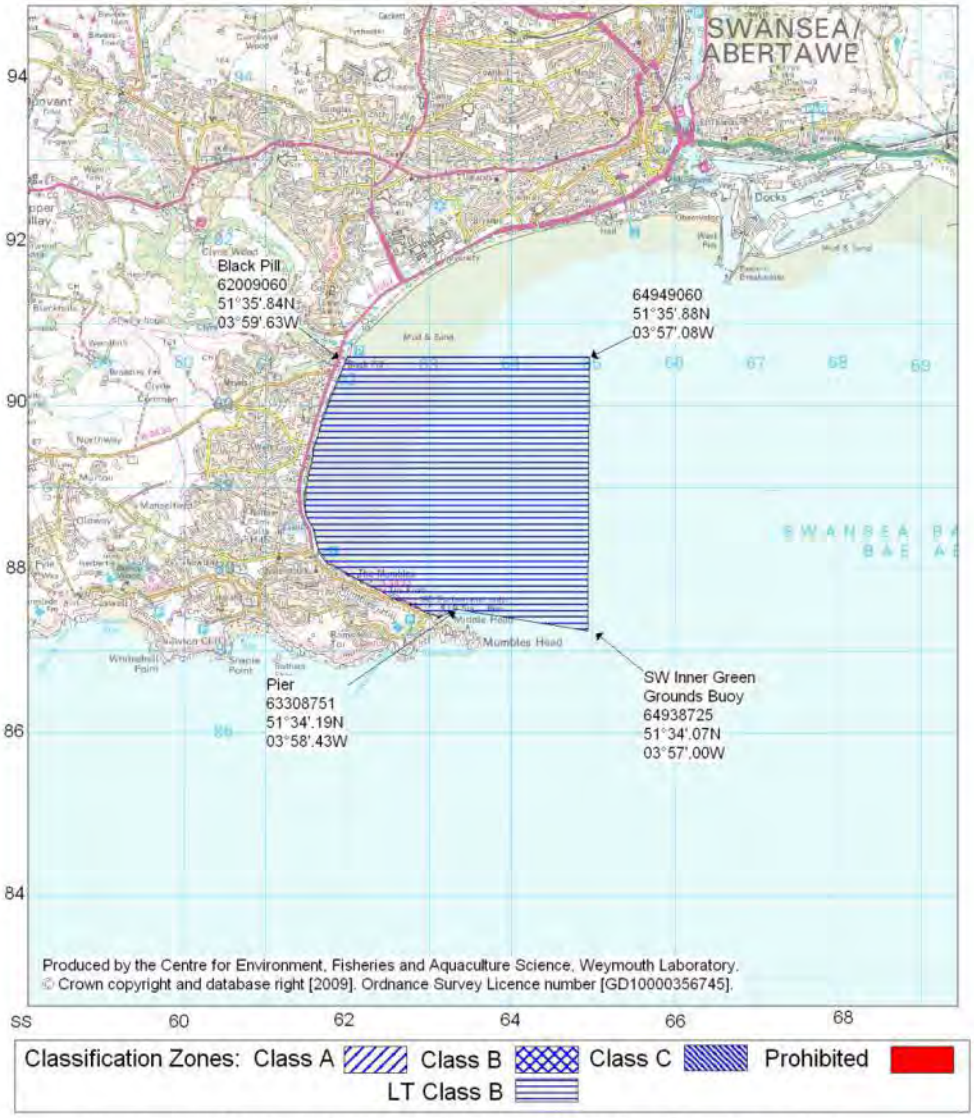
Class	Microbiological standard[1]	Post-harvest treatment required
A	Live bivalve molluscs from these areas must not exceed 230 Most Probable Number (MPN) *E. coli* $100g^{-1}$ FIL[2]	None
B	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution MPN test of 4,600 *E. coli* $100g^{-1}$ FIL in more than 10% of samples. No sample may exceed an upper limit of 46,000 *E. coli* $100g^{-1}$ FIL [3]	Purification, relaying or cooking by an approved method
C	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution MPN test of 46,000 *E. coli* $100g^{-1}$ FIL[4]	Relaying for, at least, two months in an approved relaying area or cooking by an approved method
Prohibited	>46,000 *E. coli* $100g^{-1}$ FIL[5]	Harvesting not permitted

[1] The reference method is given as ISO 16649-3.
[2] By cross-reference from EC Regulation 854/2004, via EC Regulation 853/2004, to EC Regulation 2073/2005.
[3] From EC Regulation 1021/2008.
[4] From EC Regulation 854/2004.
[5] This level is not specifically given in the Regulation but does not comply with classes A, B or C. The competent authority has the power to prohibit any production and harvesting of bivalve molluscs in areas considered unsuitable for health reasons.

The location and extent of classification zones and corresponding classification status for these species are shown in Figures 2.6–2.8.

Swansea Bay - Mytilus spp

Scale - 1:70000



Classification of Bivalve Mollusc Production Areas: Effective from 1 September 2009

The areas delineated above are those classified as bivalve mollusc production areas under EU Regulation 854/2004.

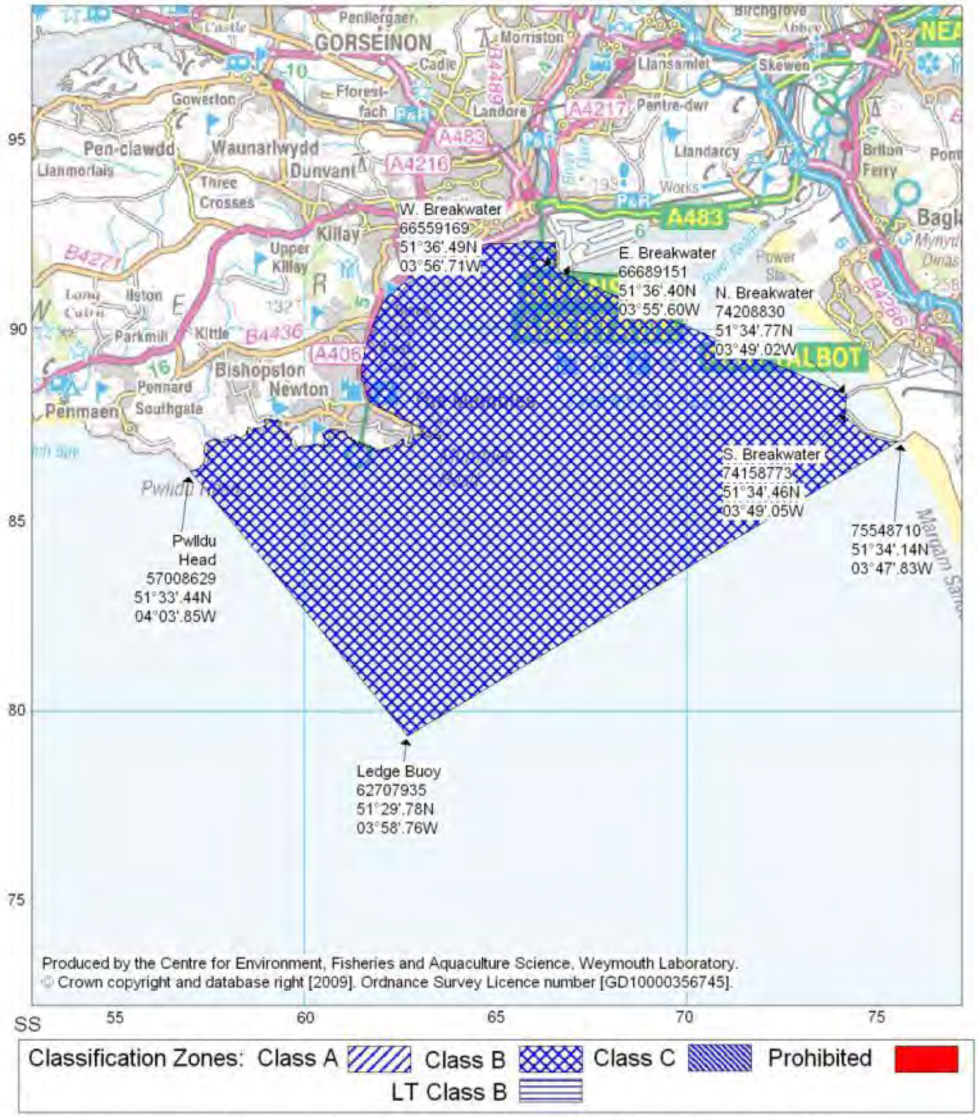
Further details on the classified species and the areas may be obtained from the responsible Food Authority. Enquiries regarding the maps should be directed to: Shellfish Microbiology, CEFAS Weymouth Laboratory, Barrack Road, The Nothe, Weymouth, Dorset DT4 8UB. (Tel: 01305 206600 Fax: 01305 206601)

N.B. Lat/Longs quoted are WGS84
Separate map available for O. edulis at Swansea Bay

Food Authorities: Swansea City & County Council Swansea Bay Port Health Authority

Figure 2.6 Classification zones for mussels in Swansea Bay.

Swansea Bay - O. edulis Scale - 1:150000



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N.B. Lat/Longs quoted are WGS84
Separate map available for Mytilus spp. at Swansea Bay

Food Authorities: Swansea City & County Council Swansea Bay Port Health Authority

Figure 2.7 Classification zones for native oysters in Swansea Bay.

Table 2.2 Historical classifications of bivalve mollusc beds in Swansea Bay.

Bed name	RMP ID	Species	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Southern Beds	B037F/G/I	*Mytilus* spp.	C	C	P	C	B	B	C	B[3]	B	B	B	B	B	B-LT	B-LT	B-LT	B-LT	B-LT
Crymlyn Burrows	B037J	*C. edule*	n/c	C[1]	C	C[1]	C[1]	B[1]	C[1]	C	C	C[1]	C	D/C	n/c	n/c	n/c	n/c	n/c	n/c
Swansea Bank	B037K	*O. edulis*	B	B	B	B	B[1]	B[1]	C	n/c	n/c	B[1]	B[1]	D/C	D/C	D/C	B[1]	D/C	B[1]	B[1]
Northern Beds		*Mytilus* spp.	C	C	C	B	B	C	n/c	B[3]	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c
Mumbles		*O. edulis*	B	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c

[1] - Classification was provisional due to insufficient sample results, either in number or period of time covered.
[2] - Area classified at higher level, although shows marginal compliance.
[3] - Area classified at higher level, due to results close to the tolerance limit. A downgrade may be possible if further failures are returned.
n/c - Not classified
LT - Long-term classification system applies. NB. Long-term (LT) classification system was introduced in England and Wales alongside the annual classification system, and applies to class B areas only. New class B areas will initially be given annual classification until they meet criteria for a long-term classification.

The extent of mussel and native oyster fisheries in the bay and location of current Representative Monitoring Points are shown in Figure 2.8.

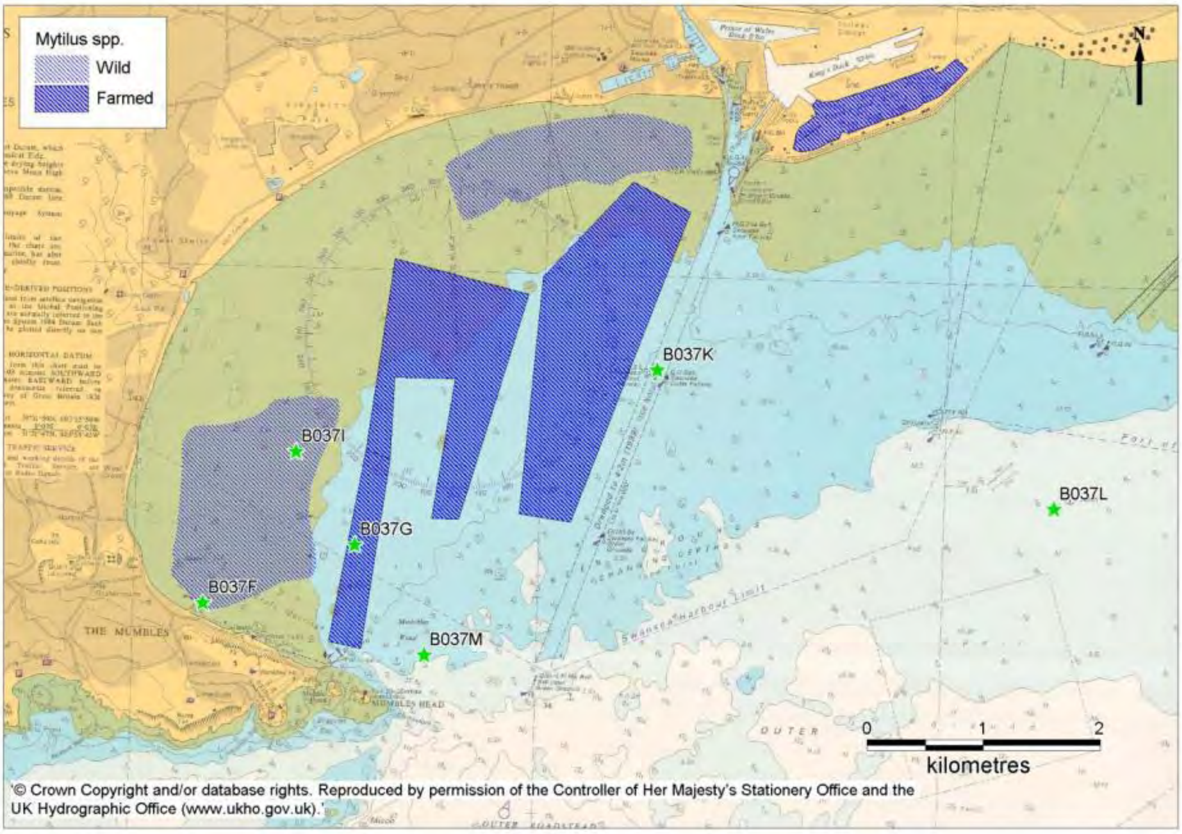

Figure 2.8 Location of wild and farmed mussel fisheries and representative monitoring points in Swansea Bay.

Information on the regulated mussel fisheries supplied by Robert Floyd (Welsh Assembly Government, Fisheries Unit).

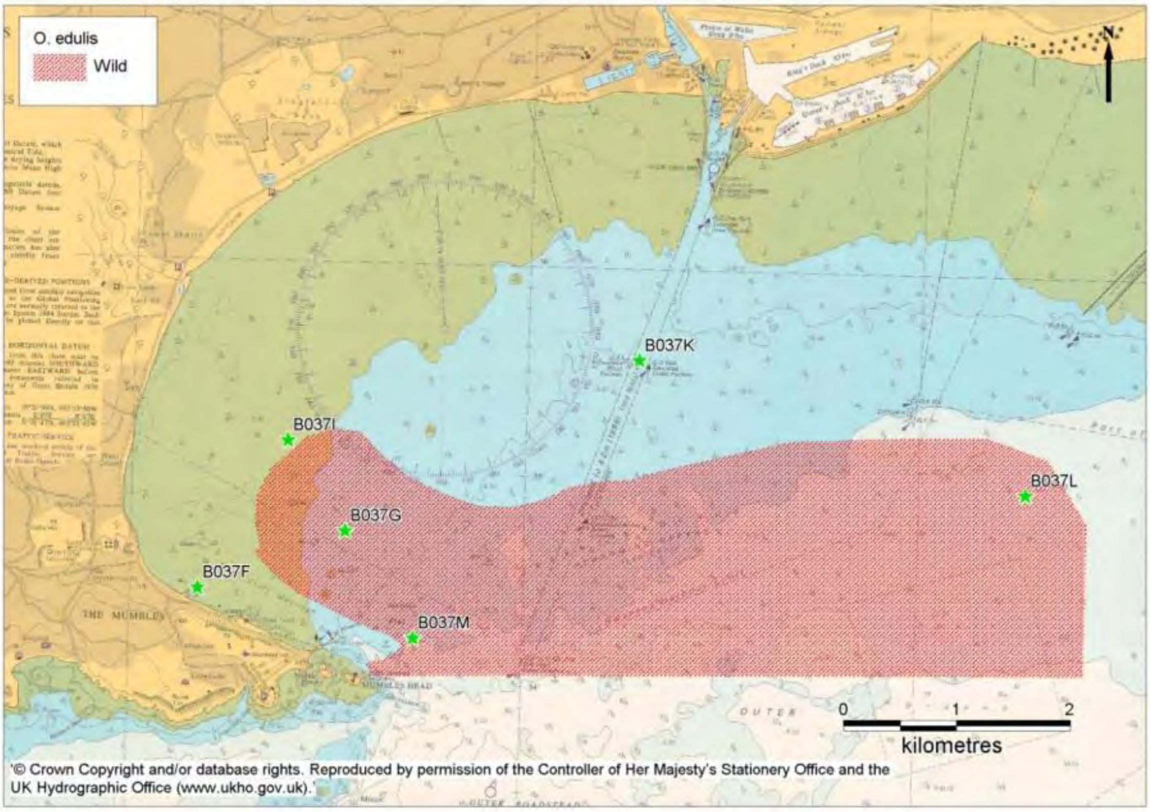

Figure 2.9 Location of wild native oyster fisheries and representative monitoring points in Swansea Bay.
Information on the regulated mussel fisheries supplied by Robert Floyd (Welsh Assembly Government, Fisheries Unit).

2.2 GROWING METHODS AND HARVESTING TECHNIQUES

MUSSELS

Mussels at Swansea Bay grow naturally on the seabed. At Swansea Bay N and Swansea Bay S beds, mussels are harvested by hand, using a hand held instrument, using a hand riddle or like instrument having a rigid aperture or grid or other fishing instrument of an approved pattern, as determined by WAG Fisheries Unit (formerly designated South Wales Sea Fisheries Committee) Statutory Instrument.

Within the licensed fisheries, mussels are dredged using hydraulic iron-frame dredges from vessel (Figure 2.10). A WAG Fisheries SI determines that these hydraulic dredges should consist of a maximum blade width of 75cm which must be of a batch (haul to the surface) design subject to time and area prohibitions.

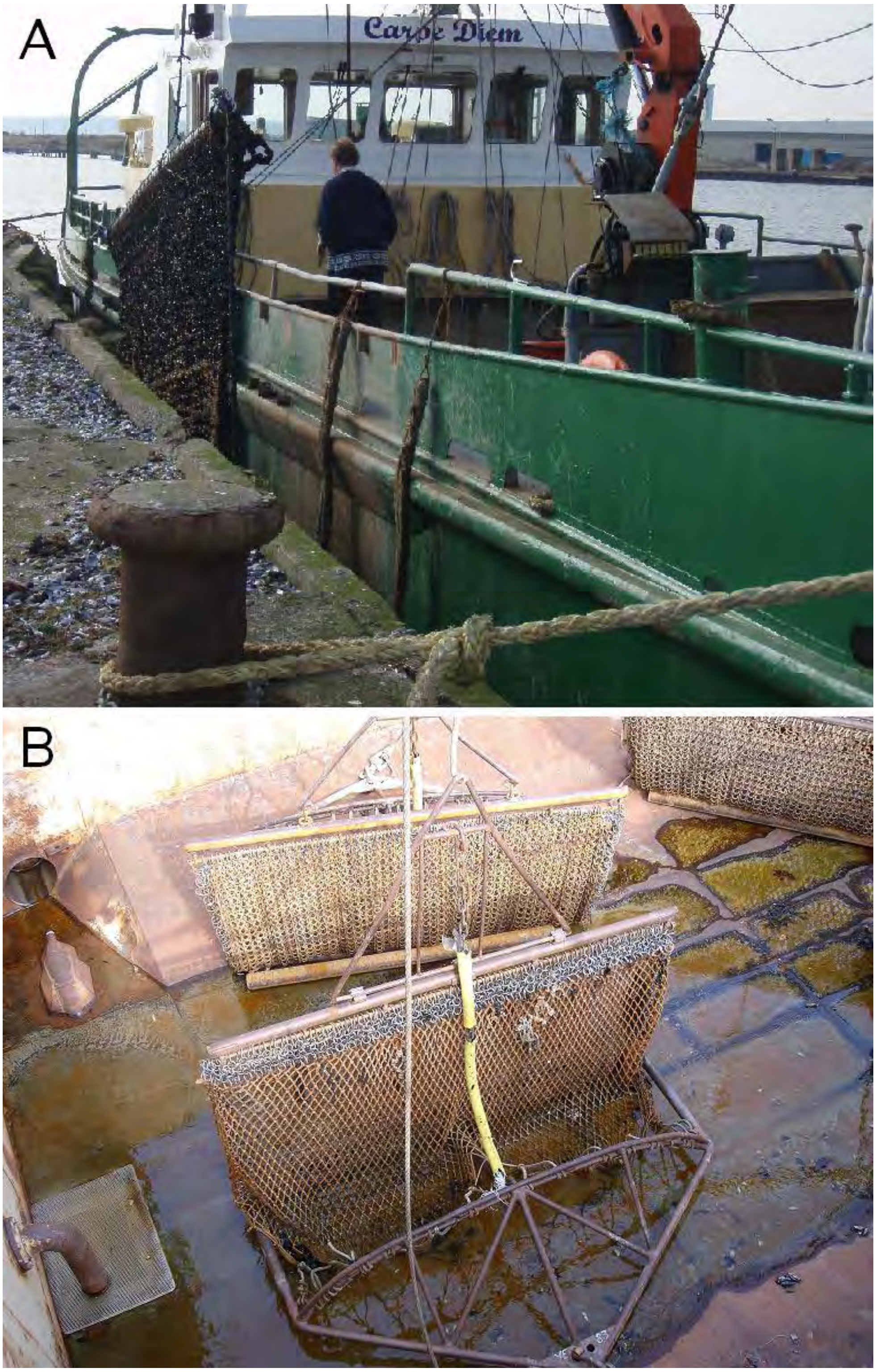

Figure 2.10 Boat used for dredging mussels in Swansea Bay (A) and iron frame dredges (B).

The application for classification of mussels in Queen's Dock proposes the use of longlines. Each longline unit consists of a PE pipe (10m length) for buoyancy (Figure 2.11A) from which a net mussel-collector is sustained running the length (Figure 2.11B). These units are anchored to the seabed from the bottom line at either end by 2-3 tonne concrete weights.

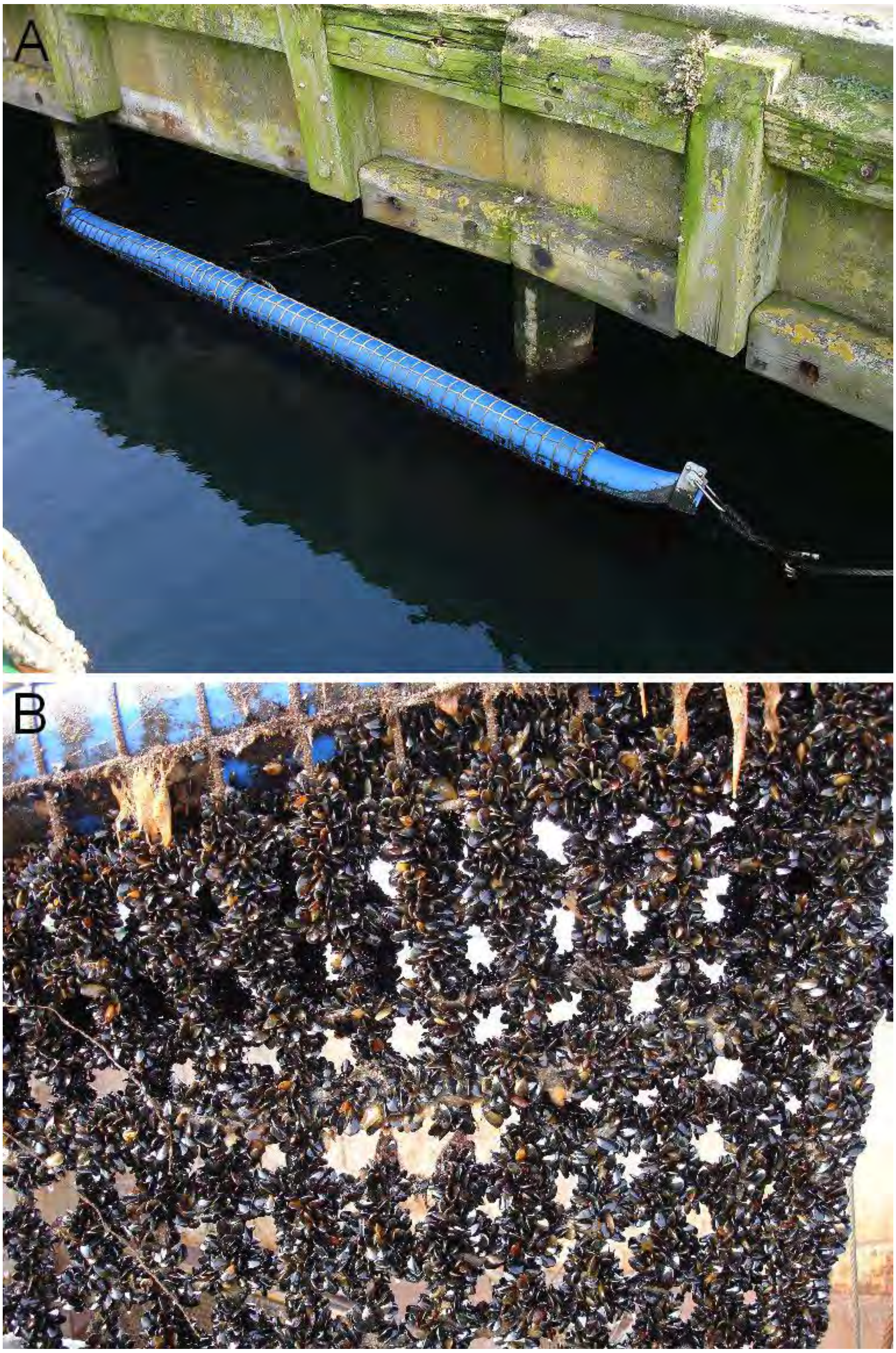

Figure 2.11 Unit for mussel cultivation in Queen's Dock showing pipe (A) and 5-month mussels attached on net (B).

The system is also designed for spat collection. Units are permanently in the water and husbandry and harvesting is done without dismantling/reassembling the net.

The applicant intends to install 78 units during the first stage of the operation. Each unit will be approximately 25m apart.

NATIVE OYSTERS

Native oysters also grow naturally on the seabed and are dredged by vessel.

2.3 SEASONALITY OF HARVEST AND CONSERVATION CONTROLS

Mussels and native oysters in Swansea Bay are harvested on a year round basis.

The minimum legal sizes for native oysters and mussels are 70mm and 37.5mm, respectively (Phil Coates, WAG, pers. comm.).

Currently, there are three Several Orders in force in Swansea Bay (see Figure 2.8):

- The Swansea Bay Mussel Fishery (C. V. & D. M. Thomas) Order 2002;
- The Swansea Bay (Woodstown Bay Shellfish Ltd) Mussel Fishery Order 2004; and
- The Swansea Bay (Penclawdd Shellfish Processing Ltd) Mussel Fishery Order 2004.

2.4 CAPACITY OF AREA AND SOCIO-ECONOMY

There has been limited commercial fishing of wild stock. For mussels, Swansea Bay S bed contains now most of the harvestable stock, although growth has been poor. This bed was last fished in the winters of 2008/2009.

The Swansea Bay N bed has been largely depleted due to a combination of factors (e.g. wave action, erosion, poor settlement). However, there is a possibility that mussels will re-settle in this bed in the foreseeable future (Phil Coates, WAG, pers. comm.).

In the past, around 1,800 tonnes of sublittoral mussel seed have been collected and laid on the licensed fishery in the bay (South Wales Sea Fisheries Committee, 2005).

In 2008, the managed mussel fishery produced approximately 145 tonnes. Currently, there are three operators dredging for mussels in the fishery (M. Gubbins, Cefas, pers. comm.).

In the past, three boats have dredged for native oysters in Swansea Bay. These have fished less than 1 tonne in each of the last 10 years (Phil Coates, WAG, pers. comm.). Nowadays, only one commercial operator is dredging for this species in the bay (Bill Arnold, pers. comm.).

3. OVERALL ASSESSMENT

AIM

This section presents an overall assessment of pollution sources on the microbiological contamination of bivalve mollusc beds in Swansea Bay as a result of a sanitary survey undertaken by Cefas on behalf of the Food Standards Agency. Its main purpose is to inform the sampling plan for the microbiological monitoring and classification of bivalve mollusc production areas (BMPAs) in this geographical area.

The present survey was prompted by an application for microbiological monitoring and classification of farmed mussels (*Mytilus* spp.) in Queen's Dock (Swansea Docks). The assessment is made in relation to this bed and existing classified beds for native oysters (*O. edulis*) and mussels in the bay.

SHELLFISHERIES

The area requiring classification for mussels at Queen's Dock covers approximately 61km^2.

The currently classified mussel and native oyster beds include much of the subtidal areas of the western bay.

These beds fall under the jurisdiction of Swansea Bay Port Health Local Enforcement Authority.

FRESHWATER INPUTS

The catchment (total area = 89.5 hectares) assessed for the purposes of this sanitary survey is drained by a river network formed by the rivers Neath (Afon Nedd), Tawe and Afan. The river network is formed by other less significant freshwater inputs such as the Clyne River. These watercourses constitute the most significant routes of contamination of faecal origin from the wider catchment to the bay.

Hydrographs for the River Neath at Resolven and River Tawe at Ynystanglws show higher flows during the autumn-winter months than those during the summer. Water levels in the rivers Neath and Tawe are characterised by a fast response to rainfall events and a relatively sharp recession limb, whereas water levels in the River Afan have no sudden peaks and will essentially depend on groundwater. Therefore, the delivery of faecal contamination to Swansea Bay via the rivers Neath and Tawe is likely to be very dependent on hydrograph events.

Correlation coefficients between salinity and levels of faecal coliforms quantified in surface waters were higher at Aberavon Beach and Swansea Bay at slipway than those at Mumbles Head, Langland Bay and Limeslade Bay. This indicates that higher salinity gradients caused by freshwater inputs would explain a significant proportion of the variation of faecal contamination at Aberavon Beach and Swansea Bay at slipway.

AGRICULTURE

The lower reaches of the catchments draining to Swansea Bay are considerably urbanised. However, significant areas in the upper reaches of these catchments are used for agricultural purposes. None of these is considered by Defra to be at risk of diffuse pollution from agricultural land.

Livestock production (total number of farmed animals is over 829,200) is based on cattle and sheep farming, predominantly in the uplands and in areas of improved and natural grassland in the valleys. Catchments of the rivers Tawe, Clyne, Neath and Afan would be the most vulnerable to diffuse pollution from agricultural land.

HUMAN POPULATION

Human population (approximately 318,400) is considerably lower than the total number of cattle and sheep in the catchment (total number is over 816,200). However, bivalve mollusc beds in Queen’s Dock and Swansea Bay are in the vicinity of the urbanised area of Swansea (resident population ≈ 271,200) and therefore will be liable to impact from point source discharges and runoff from impermeable land.

Human population in the catchment fluctuates seasonally due to tourism. Analysis of numbers of visitors to twelve of the most important tourist attractions in Swansea shows that these attractions received over 1M people in 2009. The most popular tourism-related activities are cultural, activities associated with the countryside (e.g. walking, cycling) and bathing. Bathing activities are more popular in Aberavon Beach, Langland Bay and, to a lesser extent, Swansea Bay at slipway and Mumbles Head.

Results from surveys undertaken to tourism activities show that the vast majority of visits to Swansea City occur during the period June–September, with an increase from mid-February to peak mid-July. Therefore, the contribution of human sources is expected to markedly increase during the summer tourist season.

SEWAGE DISCHARGES

A programme of work has been undertaken by the Environment Agency to upgrade a number of sewage discharges that have, or once had, the potential to influence Swansea Bay (East and West) designated Shellfish Waters. These upgrades took place in 1999 (secondary treatment and UV disinfection at Swansea Sewage Treatment Works (STW), 2002 (secondary treatment at Afan STW) and 2003 (secondary treatment at Ystradgynlais STW and Trebanos STW).

A number of continuous and intermittent water company sewage discharges representing a significant or potentially significant impact on the microbial quality of Swansea Bay occur within 10km of the bay in the urban areas of Swansea, Port Talbot and Bishopston. The most significant continuous discharge to BMPAs is Afan WwTW Port Talbot (secondary; MDV = 104,112 m^3 day^{-1}; 4.6km from BMPA). Other continuous discharges considered to have potential local significance are:

- ABP M&E Amenity Block (primary; MDV = 5 m^3 day^{-1}; 0.1km from BMPA).
- ABP Marine Control Building (primary; MDV = 3 m^3 day^{-1}; 0.3km from BMPA).
- ABP A Shed Toilet Block (primary; MDV = 3; m^3 day^{-1}; 0km from BMPA).
- National Coal Board Lab Site (primary; MDV = 5 m^3 day^{-1}; 0km from BMPA).
- Trinity House Buoy Yard (primary; MDV = 3; m^3 day^{-1}; 0km from BMPA).
- ABP Harbour Office (secondary; MDV = 11 m^3 day^{-1}; 0.3km from BMPA).
- ABP Puckey House (primary; MDV = 2; m^3 day^{-1}; 5.3km from BMPA).
- Swansea Ship Repairers STW (secondary; MDV = 5 m^3 day^{-1}; 0.3km from BMPA).
- Llandarcy District Office Site (secondary; MDV = 9 m^3 day^{-1}; 6.2km from BMPA).
- BP Oil Llandarcy Refinery (tertiary; MDV = 5; m^3 day^{-1}; 0km from BMPA).

One-hundred and eighty three intermittent discharges (combined sewer overflows, emergency overflows and overflows from pumping stations) discharge to the bay or its tributaries. Most of these discharge to the rivers Neath and Tawe and streams discharging along the stretch of coast between Swansea City and Mumbles Head.

Results from investigations carried out recently by the City and County of Swansea, the Environment Agency and Dŵr Cymru Welsh Water have identified a number of “misconnected” properties at West Cross. This is consistent with results from microbial source tracking studies along the foreshore between Mumbles and the Tawe Estuary which indicated predominance of human derived sources of contamination.

BOATS

It has long been established that sewage discharged from boats could represent a significant public health risk for bivalve mollusc beds. However, the contribution of these sources is difficult to quantify due to the intermittent nature of these discharges.

Swansea Marina situated at the mouth of the River Tawe could be the main potential source of contamination. This marina provides berths for approximately 590 boats and is accessed High Water ±4 ½h via two locks. Although shoreside toilet facilities are provided for berth holders, no pump-out facilities are available at Swansea Marina for foul water holding tanks. This increases the risk of waste discharges from boats.

Mussel beds in Swansea Bay will be vulnerable to microbial pollution from this source. RMPs situated in eastern edges of beds will monitor potential contamination from this source.

The new mussel production area at Queen's Dock would be vulnerable to sewage pollution from pleasure craft which will eventually use the Prince of Wales Dock.

SUMMARY OF POLLUTION SOURCES

An overview of sources of pollution likely to affect the levels of microbiological contamination in BMPAs in Swansea Bay is shown in Figure 3.1.

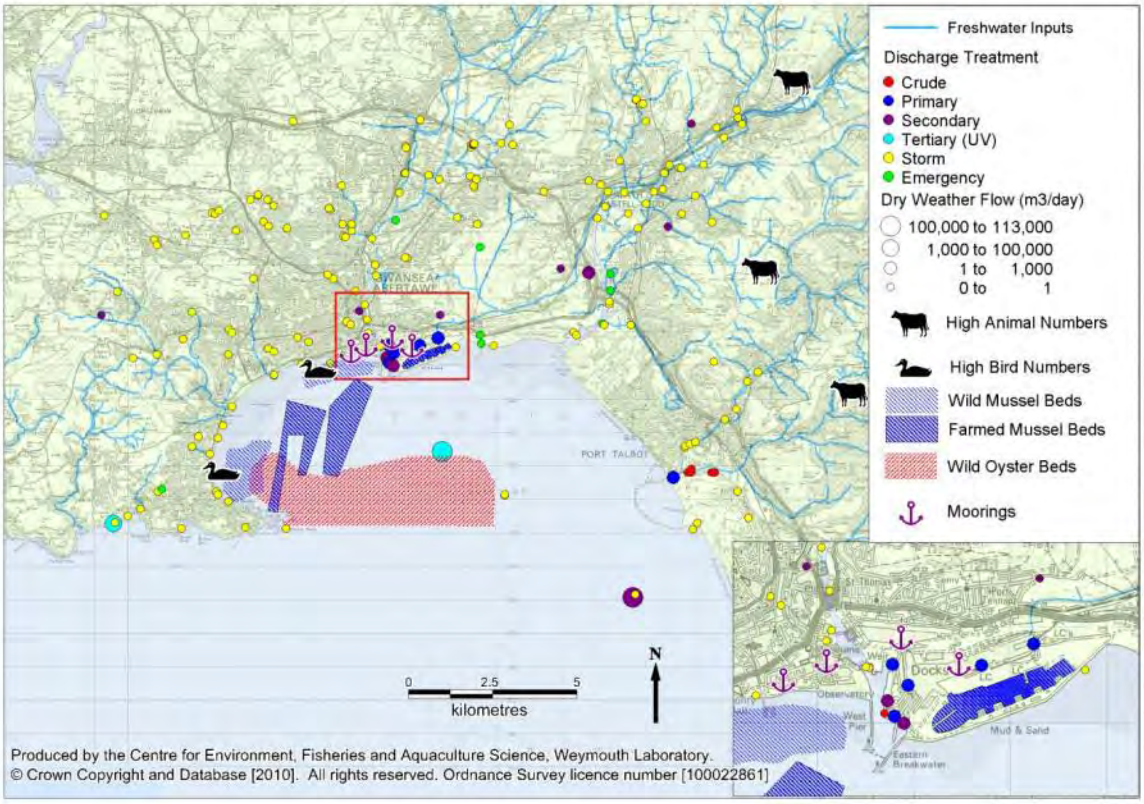

Figure 3.1 Significant sources of microbiological pollution in the vicinity of Swansea Bay.

HYDRODYNAMICS

The areas of the bay where the commercial harvesting of mussels has taken place are relatively shallow [<5.4m relative to Chart Datum (CD)]. In contrast, farmed mussel regulated fisheries and wild native oysters occur in deeper areas of the bay, where soundings increase to 21m relative to CD. This variation in the overall bathymetric profile will markedly influence the total initial dilution available in the water column between any sources of pollution at any one time due to different effects of tides and tidal currents on the transport of contamination and differences in decay rates of microorganisms. Therefore, nearshore shallow areas are likely to represent worst-case conditions.

Overall, Swansea Bay is an ebb-dominant macro-tidal bay (mean range on springs = 8.4m; mean range on neaps = 3.8m at The Mumbles). The longer and slower ebb tide is likely to promote the dispersion of pollution towards the sea, in particular that from marine outfalls situated in the centre of the bay.

Spring tide currents at Swansea range between 0.1m s^{-1} at [High Water (HW)] and 0.5m s^{-1} (at 5h before HW and 2–3h after HW). In the absence of significant wind driven currents, residual surface water movements inside the bay follow an anti-clockwise pattern, whereas the dominant longshore transport is typically in a south-eastward direction.
Salinity measurements taken across the bay suggest that, during flood tides, tidal streams run in a southwest-northeast direction across the bay, with an eddy forming on the western part of the bay due to its geographic outline.

Results from sewage plume dispersion hydrodynamic modelling for Swansea STW show that, during spring tides and under the influence of onshore south-westerly winds (10m s^{-1}), the sewage plume is carried out towards the eastern part of the bay where there is no commercial harvesting of bivalve molluscs. However, during flood tides, the plume is likely to impact on native oyster beds off Mumbles Head.
Other sewage plume hydrodynamic modelling exercises undertaken for Afan STW and Baglan PS have corroborated these general principles, indicating that sewage particles are transported easterly during the flood tide and then south-westerly during the ebb tide and are unlikely to affect the BMPA.

However, under the influence of south-easterly winds, the plume from Swansea STW is retained in inner parts of the bay over a significant proportion of the tidal cycle and is likely to significantly impact on both mussel and native oyster beds. The modelling exercise also predicted that, in the event of a storm discharge from The Mumbles, the BMPA will be significantly impacted on spring tides and under southerly winds at 10m s^{-1} between mid flood and HW-1h. The extent to which this information will inform the siting of Representative Monitoring Points is discussed in Section 4 below.

No statistically significant differences were found between levels of *E. coli* contamination in bivalves and tidal stage.

SUMMARY OF MICROBIOLOGICAL DATA

Analysis of historical data from the Bathing Waters (BW) monitoring programme indicates higher levels of faecal contamination (difference in median levels of faecal coliforms between BW is >1Log_{10}) at Swansea Bay relative to those at Bracelet Bay.
Despite achieving overall classifications of “excellent”, Bracelet Bay and Aberafan seem vulnerable to intermittent episodes of contamination. Median levels of faecal coliforms suggest a gradual deterioration in the quality of surface

waters at Swansea Bay[3] and Aberafan in recent years. However, Aberafan Bathing Water has passed the Guideline standard since 2003 (with the exception of 2006). Swansea Bay has passed the Imperative standard since 1999.

Sampling effort for the purposes of the Shellfish Waters monitoring programme has been low. Results for Swansea Bay (West) seem to indicate relatively low levels of faecal coliforms during the period 2005–2007. Median levels of faecal coliforms in shellfish flesh from Swansea Bay (South) have been equivalent to class B over the years.

Analyses of historical data (January 1999–March 2010) from the Shellfish Hygiene monitoring programme indicated:

- The highest *E. coli* results (MPN = 16,000 $100g^{-1}$ FIL) were detected in wild mussels from Knab Rock and Mumbles (Swansea Bay South);
- Similar median levels of *E. coli* in wild mussels from Mumbles (Swansea Bay South) and farmed mussels from Swansea Bay S; and
- Levels of *E. coli* in native oysters from Swansea Bank beds 1,2 and 3 have not exceeded the class B threshold (MPN ≤ 4,600 $100g^{-1}$ FIL) since 2000.

The lack of significant differences in the seasonal variation of *E. coli* in bivalves indicates that the sampling frequency currently used for the purposes of the classification programme adequately reflects the temporal variation of the microbiological indicator in bivalves.

Results of bacteriological investigations undertaken by the Environment Agency between February 2001 and October 2009 suggest a decreasing spatial trend of inputs of faecal contamination between Swansea Docks and The Mumbles. However, high concentrations of FIO have also been found in rivers/streams in the vicinity of Port Talbot.

Statistically significant positive relationships were found between daily and cumulative rainfall and levels of *E. coli* in wild mussels from Knab Rock and Swansea Bay S and native oysters from Swansea Bank 1 and Swansea Bank 2. However, correlations between variables varied according to the monitoring point and the time of sampling relative to the rainfall event.
This indicates significant impact of rainfall-dependent discharges and runoff from agricultural land from the upper catchment on bivalves.

The highest significant correlation coefficient was detected when mussels from Knab Rock were sampled after 7 days of cumulative rainfall. This hydrological lag time can be attributed to the time of travel of contamination within the bay and the time for the uptake by the bivalves to reach a maximum to produce the maximum statistically significant correlation.

[3] The dataset analysed is weighted to 2009 due to extra sampling carried out for the purposes of classification under the revised Bathing Water Directive.

Significant positive relationships were also detected between river flows in the rivers Neath and Tawe and levels of *E. coli* in mussels from Knab Rock, Mumbles (Swansea Bay South), Swansea Bay S and Swansea Bank 3. Most of the *E. coli* class C results in mussels from Knab Rock were detected when river flows were exceeding the mean flow.

4. RECOMMENDATIONS

NATIVE OYSTERS

4.1 It is recommended that the currently classified native oyster bed be represented by two classification zones (CZs) (Mumbles Head; Outer Green Grounds), each with its own representative monitoring point (RMP). This represents an increase in the number of currently classified CZs (from one to two) as is justified by the presence of sources of pollution each impacting on different areas of Swansea Bay.

4.2 The northern, southern and eastern edges of the CZs will be defined by lines approximately 10m from the edges of the bed. The western edges of the CZs will be defined by the Mean High Water Line Mark (MHWM) (Mumbles Head CZ) and the dredged channel (Green Grounds).

4.3 An RMP situated at the western edge of the Mumbles Head CZ (SS 6297 8873) for native oysters will be representative of contamination from point and diffuse sources delivered to Swansea Bay from the rivers Tawe and Clyne and streams at West Cross predominantly impacting the CZ during the ebb tide and contamination from rainfall-dependent discharges from Mumbles, Langland, Bishopston and Limeslade impacting the bed predominantly during the flood tide.

4.4 An RMP situated at the eastern edge of the Green Grounds CZ (SS 6979 8834) for native oysters will be representative of contamination from point sources in central areas of the bay (Swansea STW, Baglan SPS) and, to a lesser extent, contamination from point and diffuse sources delivered to the bay via the River Neath and contamination from Afan WwTW.

MUSSELS

Wild

4.5 It is recommended that the two wild mussel beds in inner areas of Swansea Bay be represented by two CZs (Swansea Bay N; Swansea Bay S), each with its own RMP. This is justified by the presence of sources of pollution each impacting on different areas of the bay.

4.6 Swansea Bay N CZ will be defined by a line crossing the bay at West Pier - River Clyne mouth and MHWM.

4.7 It is recommended that the location of the non-current RMP B037E for mussels at this bed be maintained as this adequately reflects the impact of contamination from the River Tawe impacting the bed during the ebb tide should mussel stock recover and the Local Enforcement Authority (LEA) request classification for this species at this site.

4.8 Swansea Bay S CZ will be defined by a line crossing the bay at landward end of Mumbles Pier-SS 6366 9112 and MHWM.

4.9 An RMP situated at the northwestern edge of Swansea Bay S (SS 6206 8909) mussel bed will be representative of contamination from pollution sources identified in 4.3.

Farmed

4.10It is recommended that the three regulated mussel fisheries in Swansea Bay be represented by two CZs, each with its own RMP.

4.11The Swansea West Fairway CZ will be defined by lines crossing the bay at West Pier-Swansea Fairway Green Grounds Buoy-SS 6455 8810-SS 6506 9144.

4.12An RMP situated on the northern edge of the Swansea West Fairway CZ (SS 6609 9126) will be representative of contamination from point and diffuse sources delivered to the bay via the River Tawe and from sewage discharges from Swansea STW during the ebb tide and from discharges at Mumbles during the flood tide.

4.13The Swansea Bay West CZ will include the regulated mussel fishery with the same name and the C. V. & D. M. Thomas regulated mussel fishery. This will be defined by lines crossing Swansea Bay at SS 6506 9144-SS 6455 8810-Landward end of Mumbles Pier-SS 6366 9112.

4.14An RMP situated on the north-western edge of Swansea Bay West CZ (SS 6390 9070) will be representative of pollution from sources impacting the mussel fisheries as described in 4.3.

4.15The Queen’s Dock CZ will include the total area of the dock at the entrance.

4.16An RMP situated at Jetty No 5 (SS 6765 9210) will be representative of any microbiological contamination entering the dock via King’s Lock and Scherzer Passage.

5. SAMPLING PLAN

GENERAL INFORMATION

Location Reference

Production Area	Swansea Bay
Cefas Main Site Reference	M037
Cefas Area Reference	FDR 2749
Ordnance survey 1:25,000 map Admiralty Chart	Admiralty Chart 1161 (Swansea Bay) OS Explorer 165 (Swansea/Abertawel; Neath and Port Talbot/Castell Nedd a Phort Talbot)

Shellfishery

Species	Culture	Seasonality of harvest
Native oysters (*O. edulis*)	Wild	Year round
Mussels (*Mytilus* spp.)	Farmed Wild	Year round Year round

Local Enforcement Authority

Name and Address	Swansea Bay Port Health Authority King's Dock Lock SWANSEA SA1 8RU
Director of Port Health Services	Roger Cork
E-mail	Swansea-bay@cieh.org.uk
Deputy Director of Port Health Services (shellfish matters)	William J. Arnold
Telephone number ☎	01792 653523
Fax number	01792 641718
E-mail	bja55@hotmail.co.uk

REQUIREMENT FOR REVIEW

The need for this sampling plan to be reviewed will be assessed by the competent authority within six years or in light of any obvious known changes in sources of pollution of human (e.g. improvements in sewage treatment works) or animal origin likely to be a source of contamination for the bivalve mollusc production area.

Table 5.1 Recommended number and location of representative monitoring points (RMPs) and frequency of sampling for bivalve mollusc classification zones in Swansea Bay.

RMP	RMP name	Classification zone	Geographic grid references of sampling points				Species	Growing method	Harvesting technique	Sampling method	Depth	Tolerance (m)	Frequency
			Easting	Northing	Latitude	Longitude							
B037U	Queen's Dock	Queen's Dock	6765	9210	51°36.73' N	03°54.77' W	*Mytilus* spp.	Longlines	Hand-picking from boat	Hand-picking from boat	2m	10	Preliminary classification: 10 samples taken over, at least, 3 months (interval between sampling not less than 1 week)
B037E	Swansea Bay N	Swansea Bay N	6550	9180	51°36.54' N	03°56.62' W	*Mytilus* spp.	Wild	Hand-picking	Hand-picking	Seabed	20	At least monthly
B037V	West Cross	Swansea Bay S	6206	8909	51°35.02' N	03°59.54' W	*Mytilus* spp.	Wild	Hand-picking	Hand-picking	Seabed	10	At least monthly
B037R	Swansea Bay West	Swansea Bay West	6390	9070	51°35.92' N	03°57.98' W	*Mytilus* spp.	Farmed	Dredging	Dredging	Seabed	50	At least monthly
B037W	Swansea West Fairway	Swansea West Fairway	6609	9126	51°36.25' N	03°56.10' W	*Mytilus* spp.	Farmed	Dredging	Dredging	Seabed	50	At least monthly
B037X	Mumbles Road	Mumbles Road	6297	8873	51°34.84' N	03°58.74' W	*O. edulis*	Wild	Dredging	Dredging	Seabed	50	At least monthly
B037Y	Green Grounds	Green Grounds	6979	8834	51°34.43' N	03°52.83' W	*O. edulis*	Wild	Dredging	Dredging	Seabed	50	At least monthly

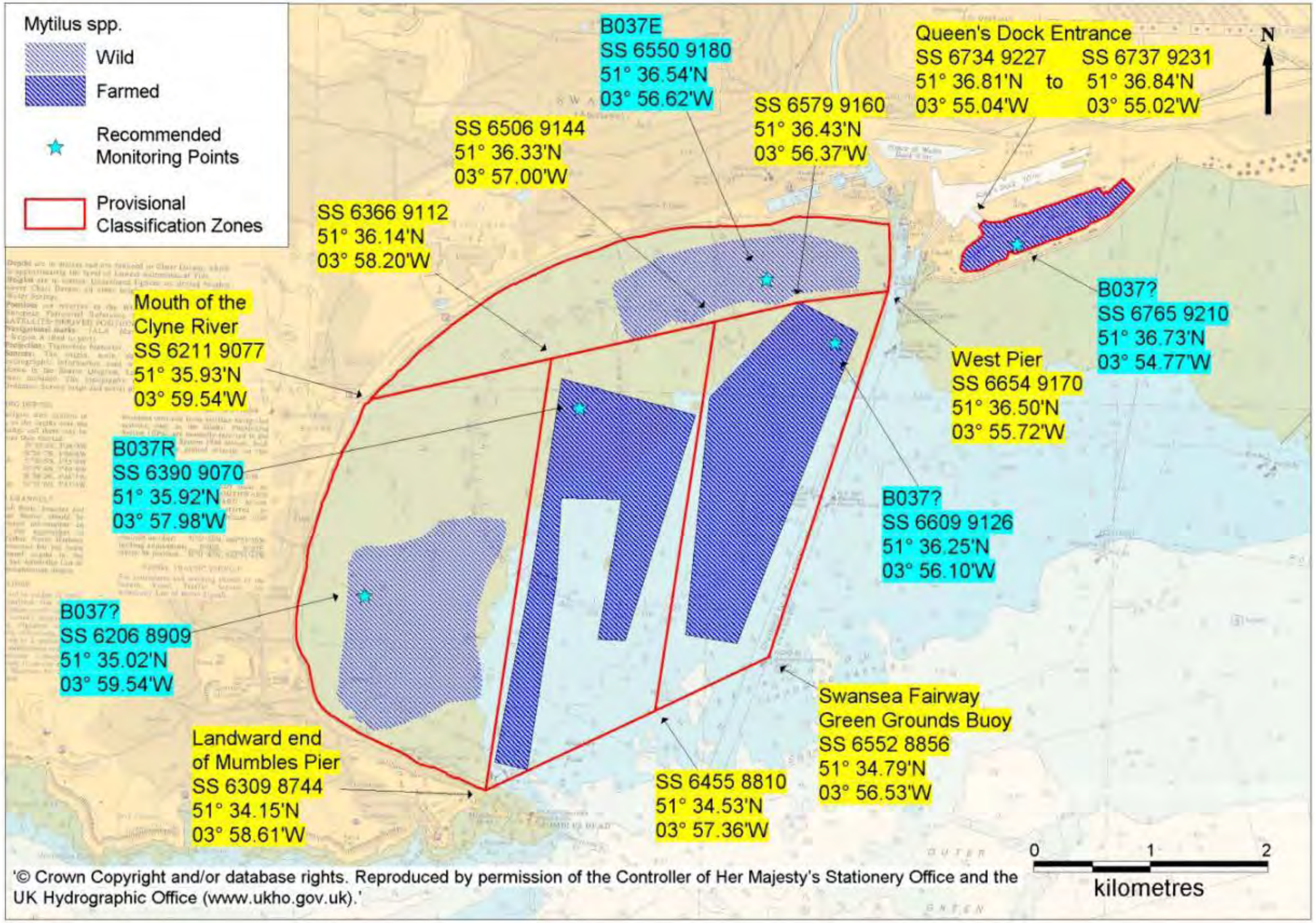

Figure 5.1 Location of recommended representative monitoring points (RMPs) and classification zone boundaries for mussels in Swansea Bay.

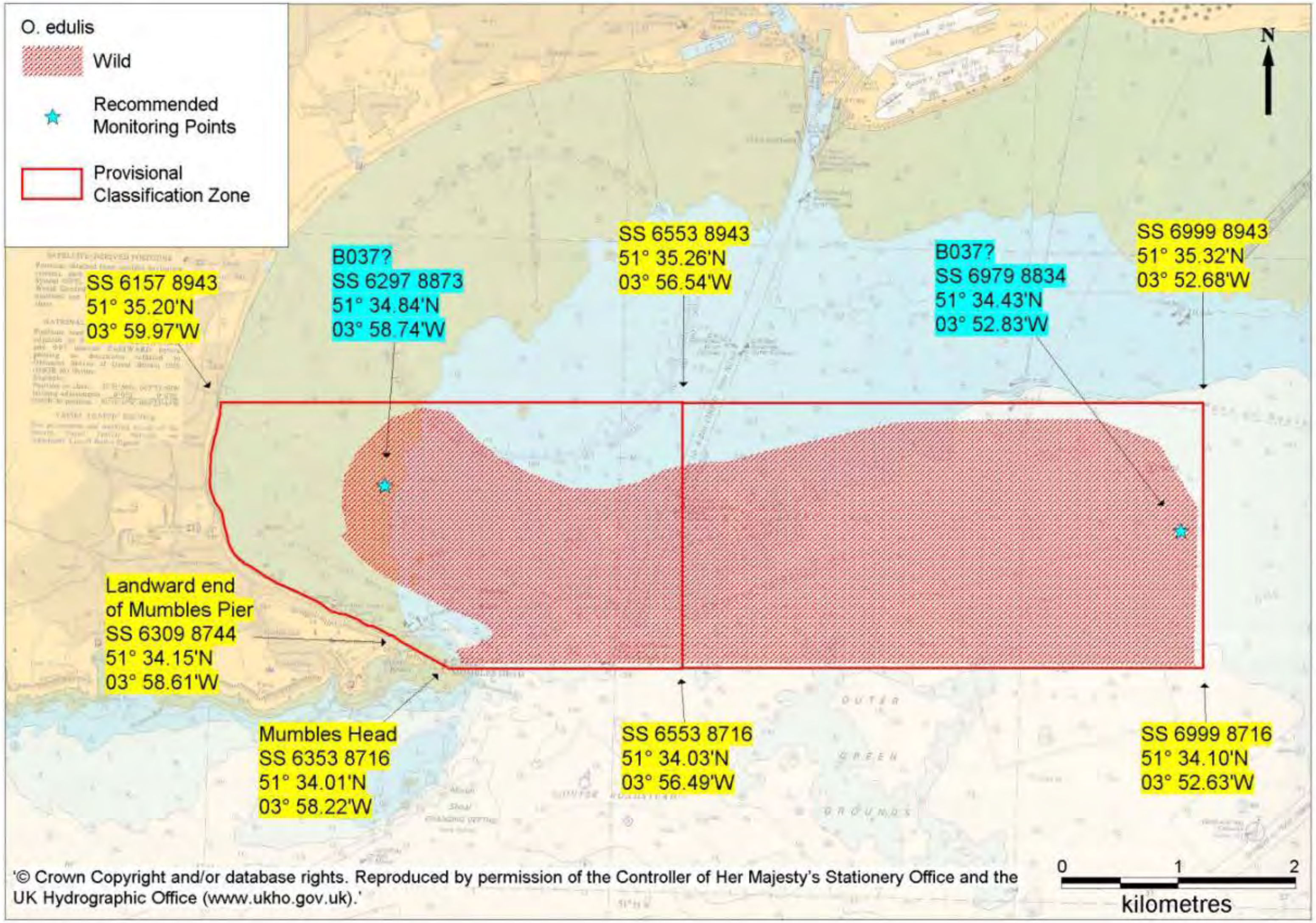

Figure 5.2 Location of recommended representative monitoring points (RMPs) and classification zone boundaries for native oysters in Swansea Bay.

APPENDIX I
HUMAN POPULATION: DENSITY AND ACTIVITIES

The distribution of resident human population totally or partially included within river catchment areas draining to Swansea Bay is shown in Figure I.1. Population density by Super Output Area Boundary[4] has its maximum value in central Swansea (103 people per hectare).

The urbanised area of Swansea has a total population of 271,202 (Office for National Statistics, pers. comm.). This urbanised area accounts for 85% of the combined population within river catchments (see Table I.1).

Table I.1 Human population in river catchments draining to Swansea Bay.

River catchment	Area (Hectare)	Resident population
South Gower	11,528	75,943
Tawe	27,752	113,545
Neath	31,687	70,732
Afan	12,711	40,768
Kenfig	5,816	17,421
Total	89,494	318,409

Source: Office for National Statistics, Crown copyright 2007.
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NB. Based on provisional mid-2005 population estimates for river catchment areas within England and Wales.

Urbanised areas contain the majority of point-sources of pollution (continuous and intermittent sewage discharges) in these catchments. An inventory of the significant sewage discharges to the estuary is presented in the Appendix VII.

Urbanised areas also contain the vast majority of impervious surfaces[5] (e.g. roads, parks, pavements), which are known to contribute with significant loads of microbiological contaminants (Ellis and Mitchell, 2006)[6]. In general, bivalve molluscs commercially harvested in the vicinity of urbanised areas tend to show deteriorated microbiological quality.

[4] Super Output Area (SOA) boundaries are in part derived from Ordnance Survey information and some SOA boundaries which follow ward or parish boundaries reproduce limited parts of the OS Boundary-Line product.
[5] In the context of the present report, impervious surfaces are any surface in the urban landscape that does not infiltrate rainfall.
[6] Concentrations of *E. coli* (MPN $100ml^{-1}$) quoted in literature are: $10–10^{3}$ for residential areas and highways and $10^{2}–10^{4}$ for roof runoff and commercial areas (Ellis and Mitchell, 2006)

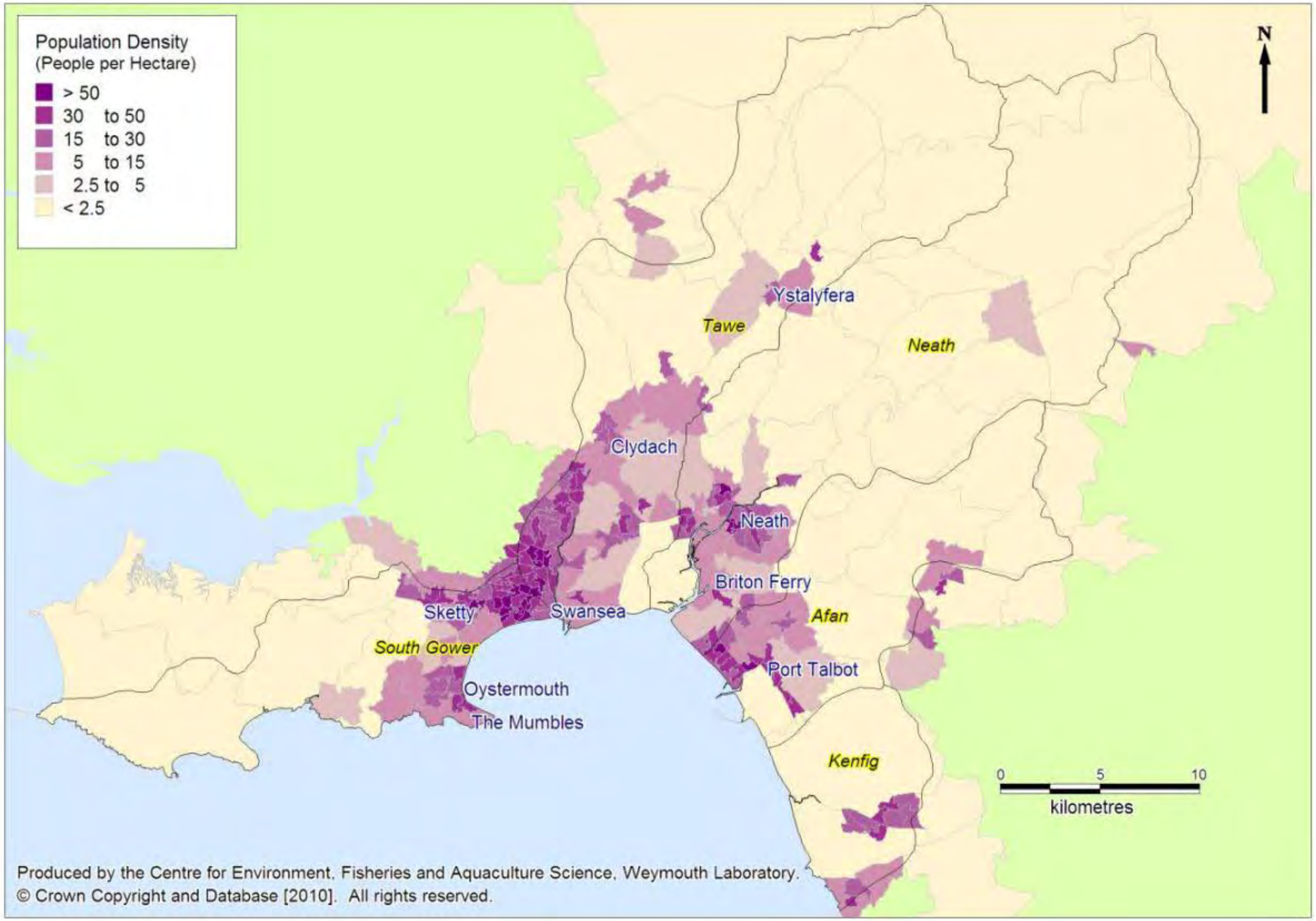

Figure A1.1 Human population density in river catchments draining to Swansea Bay.
Source: ONS, Super Output Area Boundaries. Crown copyright 2004.
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Human population in these catchments fluctuates seasonally due to tourism. Table I.2 summarises the number of visitors to twelve tourist attractions in Swansea.

Table I.2 Number of visitors to twelve tourist attractions in Swansea.

Tourist attraction	2008	2009
Swansea Bay	7,050	8,616
Swansea Museum	175,604	216,435
Swansea Museum - Floating Exhibits	11,283	7,035
Blackpill Wildlife Centre	420	200
Clyne Gardens	417,638	388,427
Cefn Coed Colliery Museum	10,029	9,259
Castle Henllys Iron Age Fort	28,949	29,484
Dylan Thomas Centre	-	102,392
Glyn-Coch Craft Centre & Farm	3,000	5,000
Glynn Vivian Art Gallery	-	43,741
Singleton Park & Botanical Gardens	59,066	56,513
Total	713,039	867,102

Data from Beaufort Research Ltd (2010).

Results from surveys undertaken by GTS (UK) Ltd and City and County of Swansea show that the vast majority of visits to Swansea City over the period 2003–2008 occurred during the period June–September, with an increase from mid-February (100,000–200,000 visitors) to peak mid-July (700,000–800,000 visitors) [GTS (UK) Ltd and City and County of Swansea, 2008]. This seasonal pattern is consistent for serviced and non-serviced accommodation and day visitors (GTS (UK) Ltd and City and County of Swansea, 2008).

Table I.3 Number of beach users counted during shoreline surveys in the 2000 and 2009 bathing seasons.

Beach	Maximum (average) number of beach users
Aberavon Beach (at slipway)	200 (10)
Bracelet Bay, Mumbles Head	30 (4)
Limeslade Bay	15 (2)
Langland Bay (West)	130 (17)
Swansea Bay (at slipway)	60 (10)

Observations made by EA Officers during bacteriological surveys.
Data supplied by the Environment Agency.

Seasonal changes in human population due to tourism will result in increased microbiological loads from sewage treatment plants on a seasonal basis (Younger *et al.*, 2003). An assessment of the impact of the most significant sewage discharges to the estuary is given in the Appendix VII.

APPENDIX II
HYDROMETRIC DATA: RAINFALL

Rainfall in Wales varies widely. The pattern of rainfall variation is heavily influenced by the topography, which forces the moisture-laden air to precipitate high levels of rainfall throughout the upper reaches of the catchments. Places along the coast receive less than 1,000 mm a year. This compares with average totals exceeding 3,000 mm in the wettest area of Snowdonia (Met Office, 2010).

Figure II.1 shows that overall the period October–February is the wettest and the late spring-summer the driest.

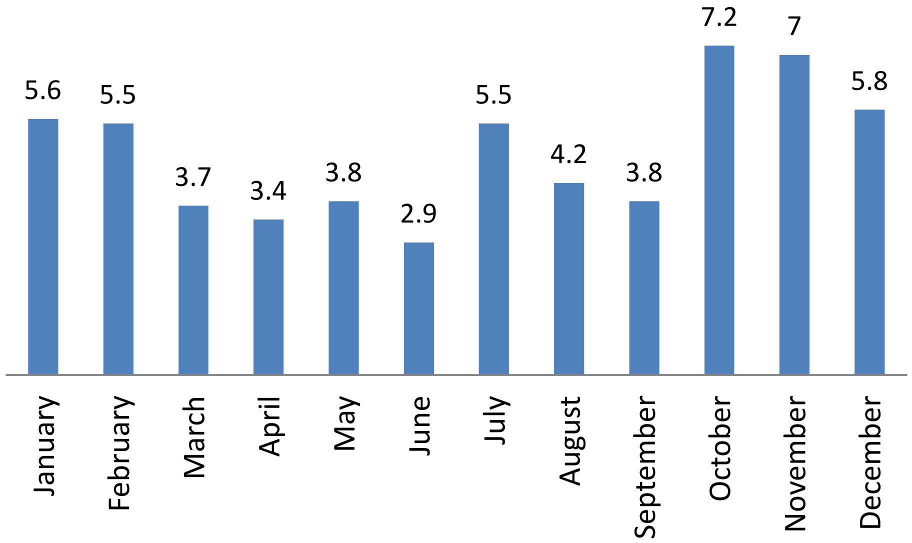


Figure II.1 Averaged monthly variation in rainfall at Resolven for the period January 2000–December 2009.

Rainfall may lead to the discharge of raw or partially treated sewage from combined sewer overflows (CSO) and other intermittent discharges as well as runoff from faecally contaminated land (Younger *et al.*, 2003). Representative monitoring points located in parts of shellfish beds closest to discharges and freshwater inputs will reflect the combined effect of rainfall on the contribution of individual pollution sources. Results from analyses of the relationships between the levels of *E. coli* in bivalve molluscs from RMPs in Swansea Bay and rainfall levels are given in the Appendix XII.

APPENDIX III
HYDROMETRIC DATA: FRESHWATER INPUTS

The rivers Neath (Affon Nedd), Tawe and Afan are the main freshwater inputs to Swansea Bay (Figure III.1). There are a number of other smaller tributaries discharging to the bay, of which the most relevant to bivalve mollusc beds is the Clyne River.

Figure III.1 Freshwater inputs to Swansea Bay and location of gauging stations mentioned in this report.

The River Neath has its headwaters in the Brecon Beacons National Park and drains an upland catchment with mixed geology (coal Measures, Millstone Grit, Carboniferous L'st and ORS) and predominantly livestock farming areas and some areas of upland heath. Minor urban development occurs in the river valley (Marsh and Hannaford, 2008).

The River Tawe drains a catchment formed by Coal Measures of mixed permeability with impermeable strata in headwaters and 30% Boulder Clay. Land uses in this river catchment include livestock farming (>60% grassland), forest and some urban and industrial development at the lower reaches (Marsh and Hannaford, 2008).

The River Afan drains a catchment formed by 40% superficial deposits with peat in uplands and Boulder Clay in valleys, 50% forested and remainder rough grazing, with some urban development and past mining activity (Marsh and Hannaford, 2008).

Table III.1 shows higher mean flows in the River Tawe than those in the rivers Neath and Afan. Table III.1 also suggests that the flow regimes in the rivers Neath and Tawe have low base-flow components and tend to respond rapidly to rainfall (Q95/Qmean<0.1), whereas flows in the River Afan have no sudden peaks and will essentially depend on groundwater (Q95/Qmean≈0.2).

Table III.1 Hydrological characteristics of freshwater inputs to Swansea Bay.

	River		
	Neath	Tawe	Afan
Name of gauging station	Resolven	Ynystanglws	Marcroft Weir
Grid reference of gauging station	SN815017	SS685998	SS771910
Catchment area (km^2)	191	228	88
Station type	Flat V triangular profile weir/velocity-area gauging station	Velocity-area gauging station	Compound crump weir
Period of record	1962–2005	1957–2005	1978–2005
Base Flow Index	0.35	0.36	0.45
Mean annual rainfall (mm)	2,000	1,922	2,128
Mean annual runoff (mm)	1,521	1,667	1,855
Mean flow ($m^3 s^{-1}$)	8.91	12.03	5.11
Q95 ($m^3 s^{-1}$)	0.70	1.42	0.85
Q70 ($m^3 s^{-1}$)	2.22	3.59	1.87
Q50 ($m^3 s^{-1}$)	4	6.20	2.96
Q10 ($m^3 s^{-1}$)	22.4	29.2	11.7
Peak flow (Q70) ($m^3 s^{-1}$) (date)	350.1 (16/10/1998)	373.4 (22/10/1998)	176.8 (27/12/1979)

Data from the UK Hydrometric Register (Marsh and Hannaford, 2008).
Base Flow Index - measure of the proportion of the river runoff that derives from stored sources.
Mean annual runoff - notional depth of water over the catchment equivalent to the mean annual flow as measured at the gauging station.
Q95 - flow which was equalled or exceeded for 95% of the flow record.

No samples of bivalve molluscs were collected immediately after the dates when peak flows were recorded and therefore no associations could be made on the effect of these hydrological extremes in the microbial quality of bivalves.

Figure III.1 shows increased flow rates in the rivers Neath and Tawe during autumn-winter months. The recession limb usually occurs between November and April. Peak flows have occurred during the period October–December and February. This represents a potentially higher risk of microbial contamination for bivalve molluscs in Swansea Bay.

Figure III.2 also depicts similar monthly variations in stream discharge between these rivers with maximum levels during the period recorded in the same month (February). This suggests that both streams would be significant in terms of delivery of microbial contaminants to Swansea Bay.

A source apportionment study undertaken by CREH found that, under dry weather conditions, the rivers Neath and Afan contribute with 9% and 6% of the load of *Enterococci* to the bay, respectively; under wet weather, these percentages increase to 51% and 21%, respectively (Kay and Wyer, pers. comm.). The same study found that, under dry weather conditions, the geometric mean concentrations of FIO from the Clyne River are similar to reference concentrations found in semi-urban catchments across the UK (Wyer and Kay, in prep.).

Results from analyses of the relationships between the levels of *E. coli* in bivalve molluscs from RMPs in Swansea Bay and river flows are given in the Appendix XII.

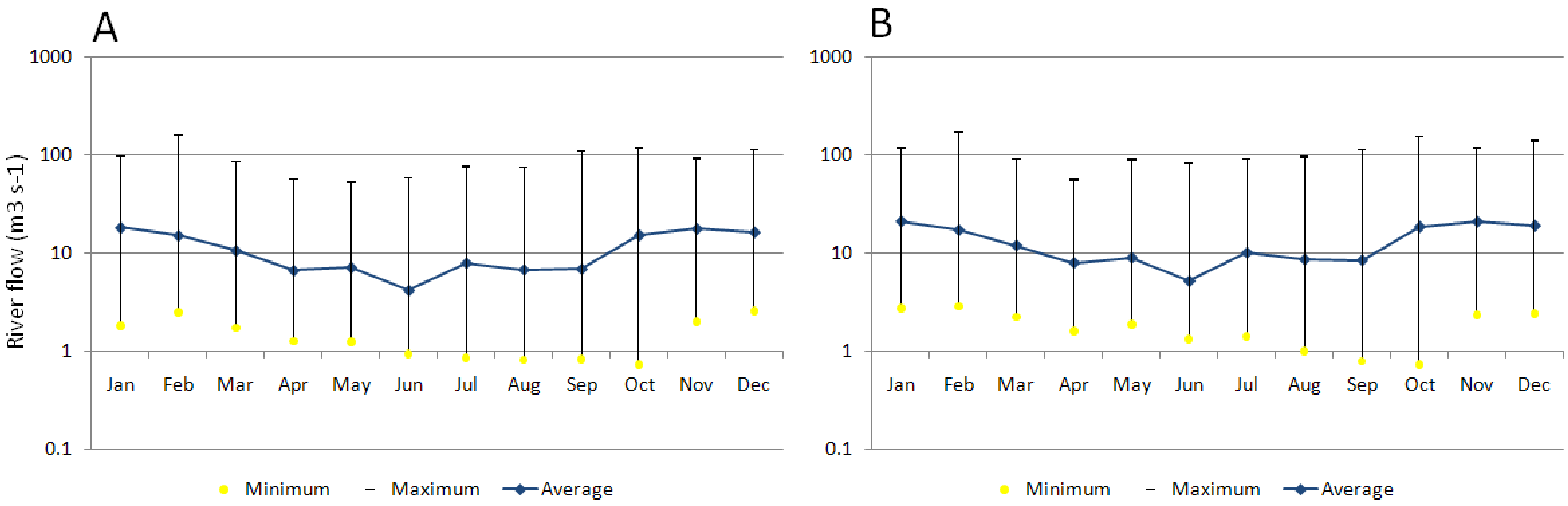


Figure III.1 Hydrographs for rivers Neath at Resolven (A) and Tawe at Ynystanglws (B) during the period January 2000–December 2009.
Data supplied by the Environment Agency.

APPENDIX IV
HYDRODYNAMIC DATA: BATHYMETRY

The stretch of coastline encompassing Swansea Bay varies in terns of bathymetry. Soundings increase to 21m just South of Mumbles Head. The gradient is considerably shallower over much of the inner bay between The Mumbles and Port of Neath, including the areas where bivalve mollusc beds are established, with the 5m bathymetric contour occurring approximately 3km (Figures IV.1 – IV.2).

Differences in bathymetry between the intertidal area and the central area of the bay may determine significant differences in terms of the effect of tides and currents on the transport of contamination and significant differences in decay rates of microorganisms. In general, less dilution of contaminants would occur in nearshore shallow waters.

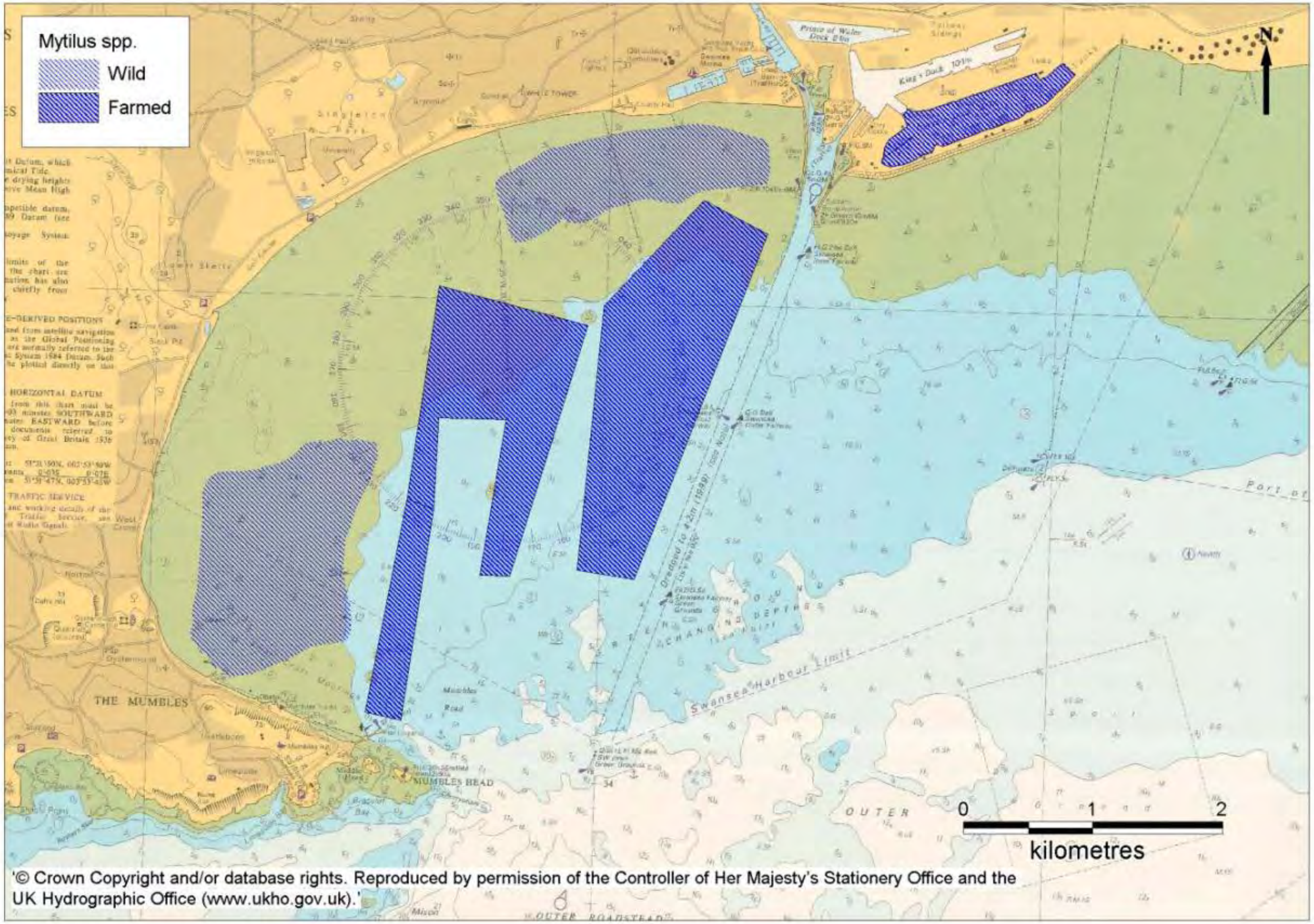


Figure IV.1 Location of wild and farmed mussel fisheries in Swansea Bay.
Information on the regulated mussel fisheries supplied by Robert Floyd (Welsh Assembly Government, Fisheries Unit).

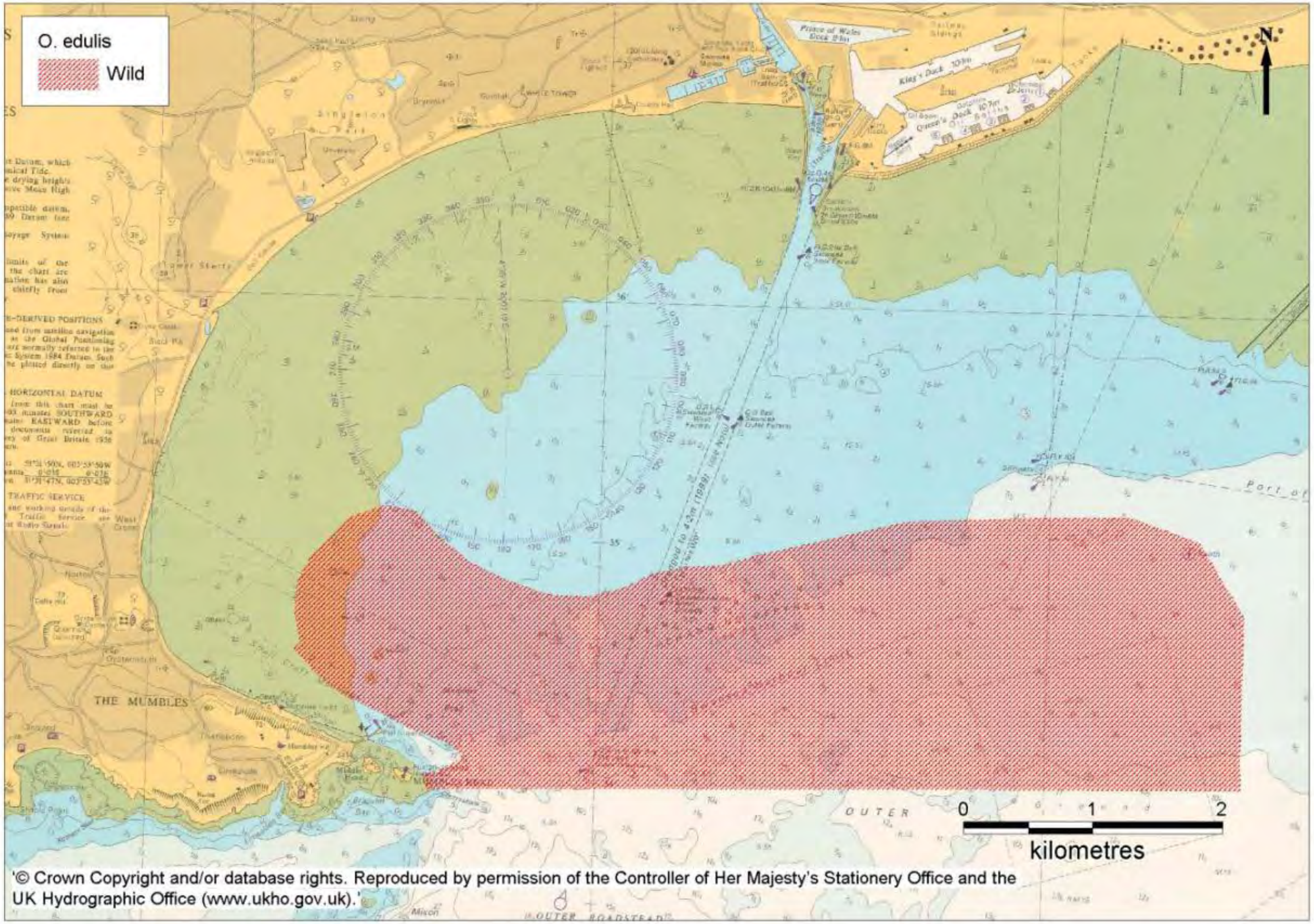


Figure IV.2 Location of wild native oyster fisheries in Swansea Bay.
Information on the regulated mussel fisheries supplied by Robert Floyd (Welsh Assembly Government, Fisheries Unit).

APPENDIX V
HYDRODYNAMIC DATA: TIDES AND CURRENTS

Swansea Bay has an asymmetrical macro-tidal regime with semi-diurnal tides (i.e. two tidal cycles per day). Table V.1 displays information on predicted tides and ranges for three ports in the bay.

Table V.1 Tidal constants for Swansea Bay.

	Height (m) above Chart Datum				Range (m)	
Port	MHWS	MHWN	MLWN	MLWS	Spring	Neap
Mumbles	9.3	6.9	3.1	0.9	8.4	3.8
Swansea	9.5	7.2	3.1	1.0	8.5	4.1
Port Talbot	9.8	7.4	3.5	1.2	8.6	3.9

Data from Imray Chart 2600.5 - The Bristol Channel (Ilfracombe to Nash Point).

Table V.2 summarises predicted tidal streams referred to Swansea.

Table V.2 Approximate direction and rate of tidal streams at Swansea.

	Hours before HW						HW	Hours after HW					
	6	5	4	3	2	1		1	2	3	4	5	6
Direction (°)	090	103	109	114	122	135	270	274	275	289	297	350	081
Rate (knots)													
Springs	0.3	0.5	0.4	0.4	0.2	0.1	0.1	0.3	0.5	0.5	0.3	0.1	0.2
Neaps	0.1	0.2	0.2	0.2	0.1	0.0	0.1	0.1	0.2	0.2	0.1	0.0	0.1

Data from Imray Chart 2600.5 - The Bristol Channel (Ilfracombe to Nash Point).

The dominant longshore transport is typically in a south-eastward direction to the east of Port Talbot (Halcrow Group Ltd., 2002). However, residual currents within the 5m bathymetric contours are anti-clockwise with some tidal residuals to the North in the centre of the bay (Figure V.1).

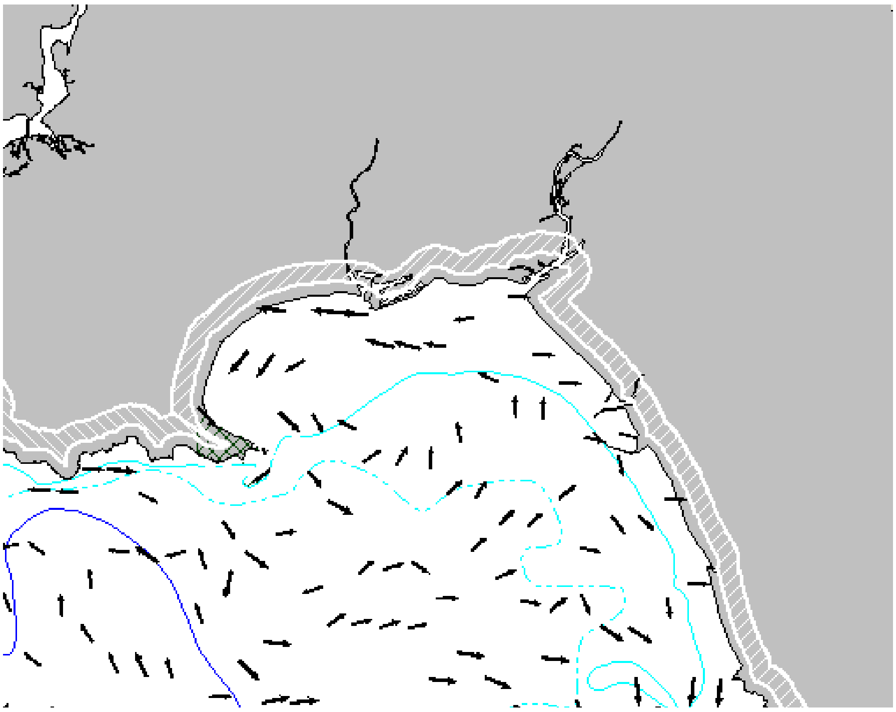


Figure V.1 Tidal residuals in Swansea Bay.
Modified from Futurecoast, Halcrow Group Ltd (2002). Database copyright.

The bay is thought to receive significant quantities of sand from offshore (Halcrow Group Ltd., 2002). Surface circulation based on salinity measurements shown in Figure V.2 shows the dominance of ebb flood currents inside the bay directed to the west and an eddy on the western part of the bay during flood tides. These conditions are likely to displace the River Tawe plume and its load of suspensions to the westward coast leading to the deposition of fine sediments in southwestern parts of the bay, where bivalve mollusc beds occur.

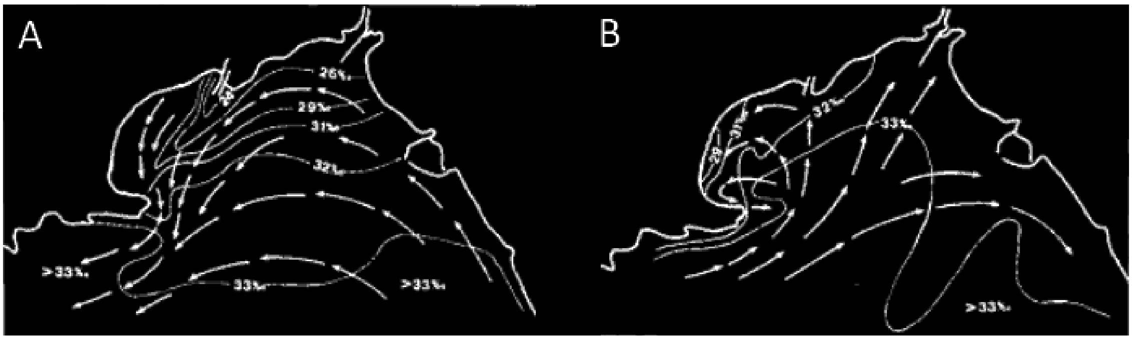


Figure V.2 Surface circulation in Swansea Bay determined by analysis of isohalines during ebb (A) and flood (B) tides.
Modified from Huntley (1980).

Figure V.3 shows results from hydrodynamic modelling of Swansea STW for the following conditions: *E. coli* concentration = 1 x 10^6 $100ml^{-1}$; total volume discharged = $84,474m^3$ discharged over complete spring tidal cycle, when ebb and flood currents are fastest and available dilution over the outfall is lowest and onshore wind at $10m\ s^{-1}$.

Figure V.3A shows the sewage plume being carried out towards the eastern part of the bay aided by the on-shore wind after the low water release. The plume reaches the beach off Port Talbot after a further 3h (Figure V.3B).

On the mid ebb and at low water (Figures V.3C–D), the plume is drawn offshore around Mumbles Head and the bacterial concentrations are reduced with dispersion and dilution effects.

On the returning flood tide, the same transport processes dominating in Figures V.3A–C are repeated with overall bacterial concentrations at Port Talbot decreasing to levels below 750 $100ml^{-1}$ with the cessation of the discharge (Figure V.3E–F).

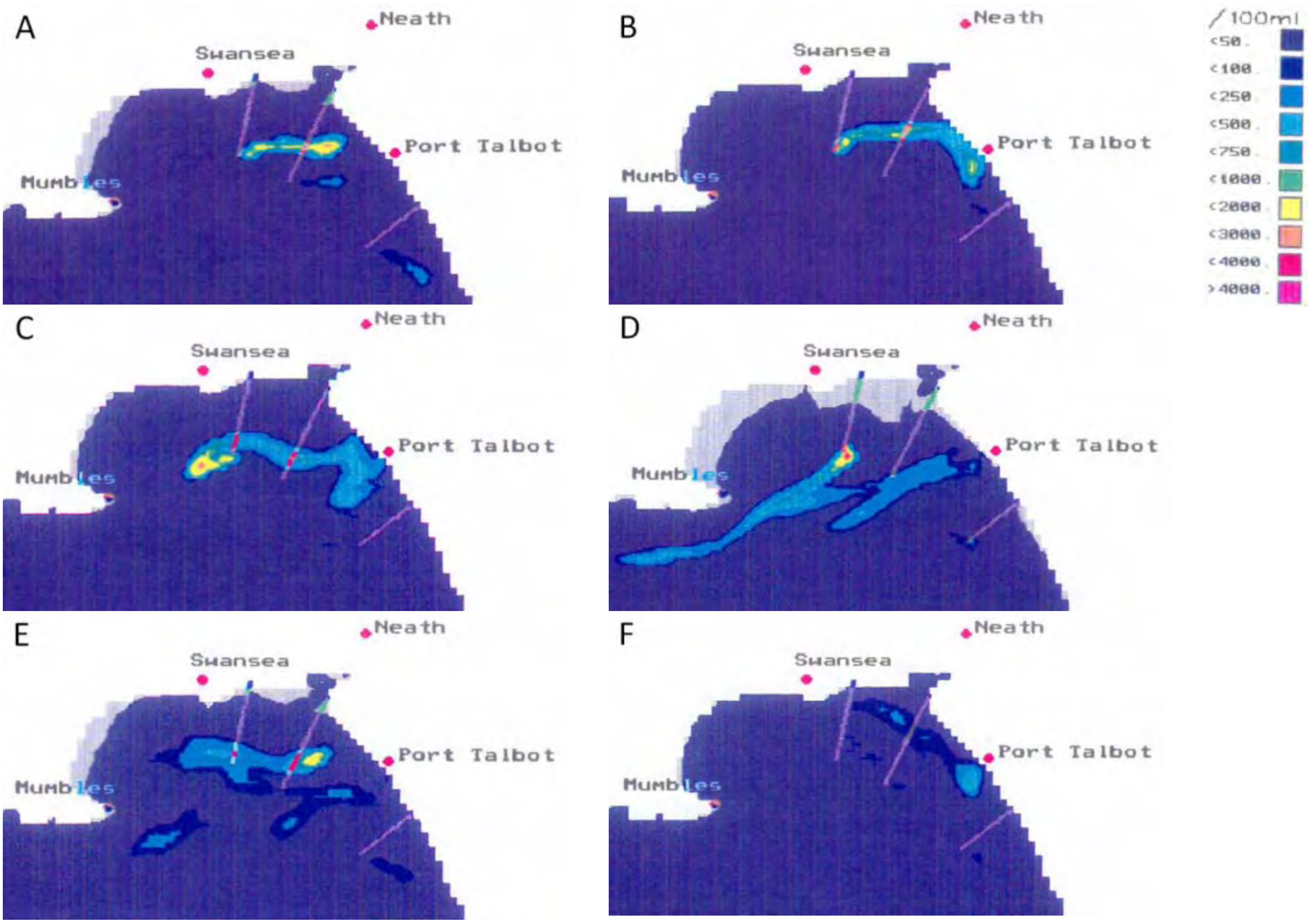


Figure V.3 Sewage plume dispersion from Swansea STW (13h storm discharge, spring tide and under low water release and 10m s^{-1} South-westerly winds).
Into STW event: A – 3h; B – 6h; C – 9h; D – 12h. After STW event: E – 2h; F – 5h.
Modified from Wallace Evans Ltd (1994).

Figure V.4 shows results from hydrodynamic modelling of Swansea STW for 13h sewage plume discharge at maximum flows, commencing at low water during the night, over complete tidal spring tidal cycle and 10m s^{-1}south-easterly winds.

Figure V.4A shows that, under these wind conditions and 3h after release, the sewage plume is pushed across the outfall end. At mid ebb tide (Figure V.4C), the sewage plume is pulled further into the inner bay. At the end of the ebb tide and high water (Figure V.4D), the plume is dispersed around Mumbles Head. The plume is retained inshore due to the influence of south-easterly wind.

With the returning flood tide, the plume is carried towards Swansea and dispersed to concentrations below 500 *E. coli* 100ml^{-1} (Figures V.4E–F).

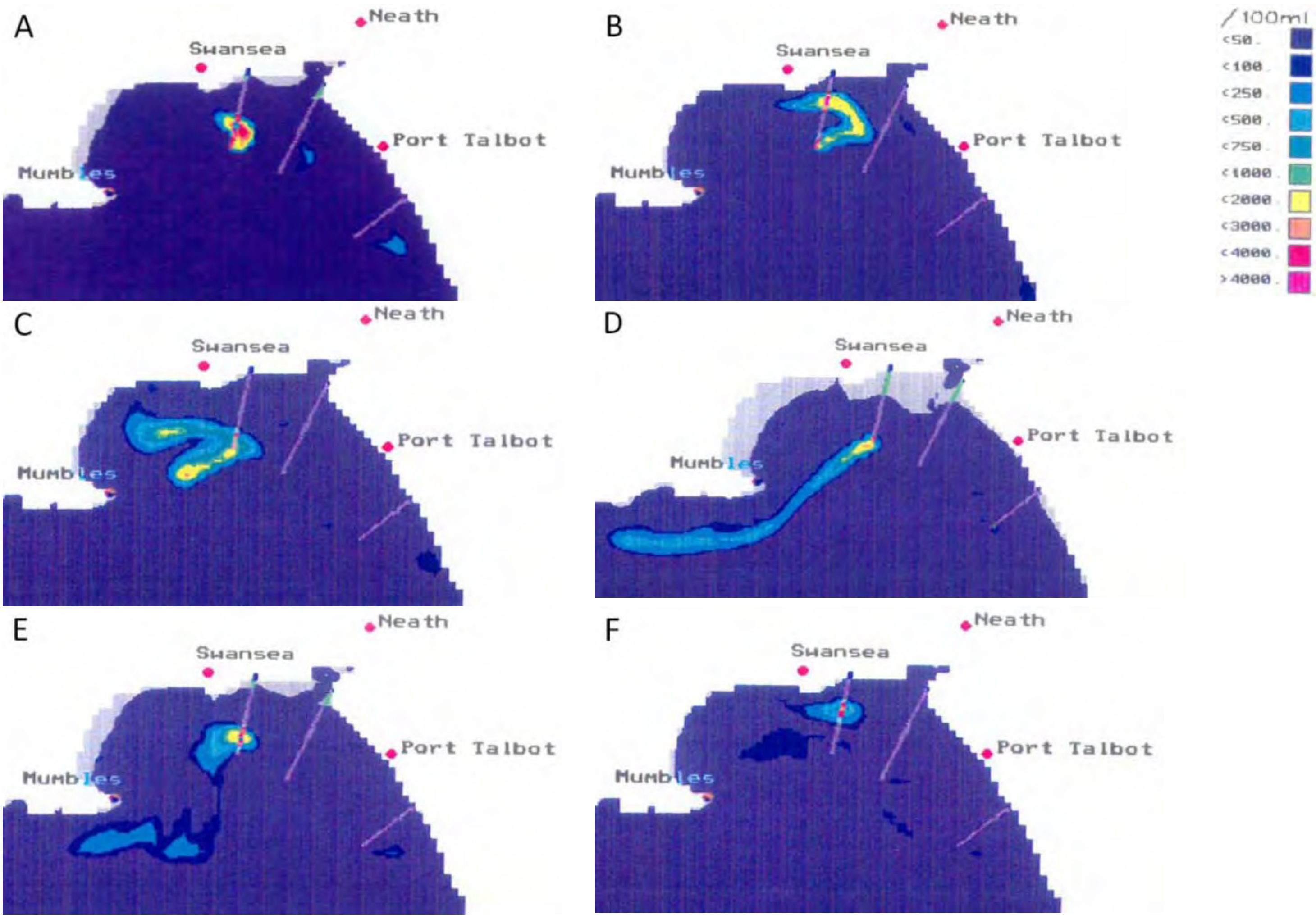


Figure V.4 Sewage plume dispersion from Swansea STW (13h storm discharge, spring tide and under low water release and 10m s^{-1} South-easterly winds).
Into STW event: A – 3h; B – 6h; C – 9h; D – 12h. After STW event: E – 2h; F – 5h.
Modified from Wallace Evans Ltd (1994).

Figure V.5 represents results from hydrodynamic modelling of mumbles Tanks for the following conditions: *E. coli* concentration = 1 x 10^6 100ml^{-1}; total volume discharged = 38,578m^3 discharged over complete spring tidal cycle, when ebb and flood currents are fastest and available dilution over the outfall is lowest and southerly wind set at 10m s^{-1}.

Figure V.5A shows the plume from Mumbles 2h after the storm discharge commenced on the mid ebb tide. The modelling exercise indicates that the southerly wind pushes the plume close to the Mumbles Head, as the ebb tide draws it westwards along the coast.

In Figure V.5B, the discharge is about to cease 1h before low water. With the limited available dilution over the outfall end, *E. coli* concentrations are slightly elevated. However, the main plume moves further along the coast with the ebb tide.

With the tide turning, the stormwater plume is brought back along the coast to Mumbles Head (Figure V.5C). By this time, the plume is well dispersed and bacterial concentrations are on average less than 500 $100ml^{-1}$.

By mid flood (Figure V.5D), the plume is advected around Mumbles Head into the inner Swansea Bay. At this stage, all the bacterial concentrations along the shore are less than 250 $100ml^{-1}$.

At 1h before High Water (Figure V.5E), the remainder of the storm water plume is directed along the Swansea shore. However, the bacterial levels at this stage are less than 250 $100ml^{-1}$ and the peal concentration in the plume is les than 500 $100ml^{-1}$.

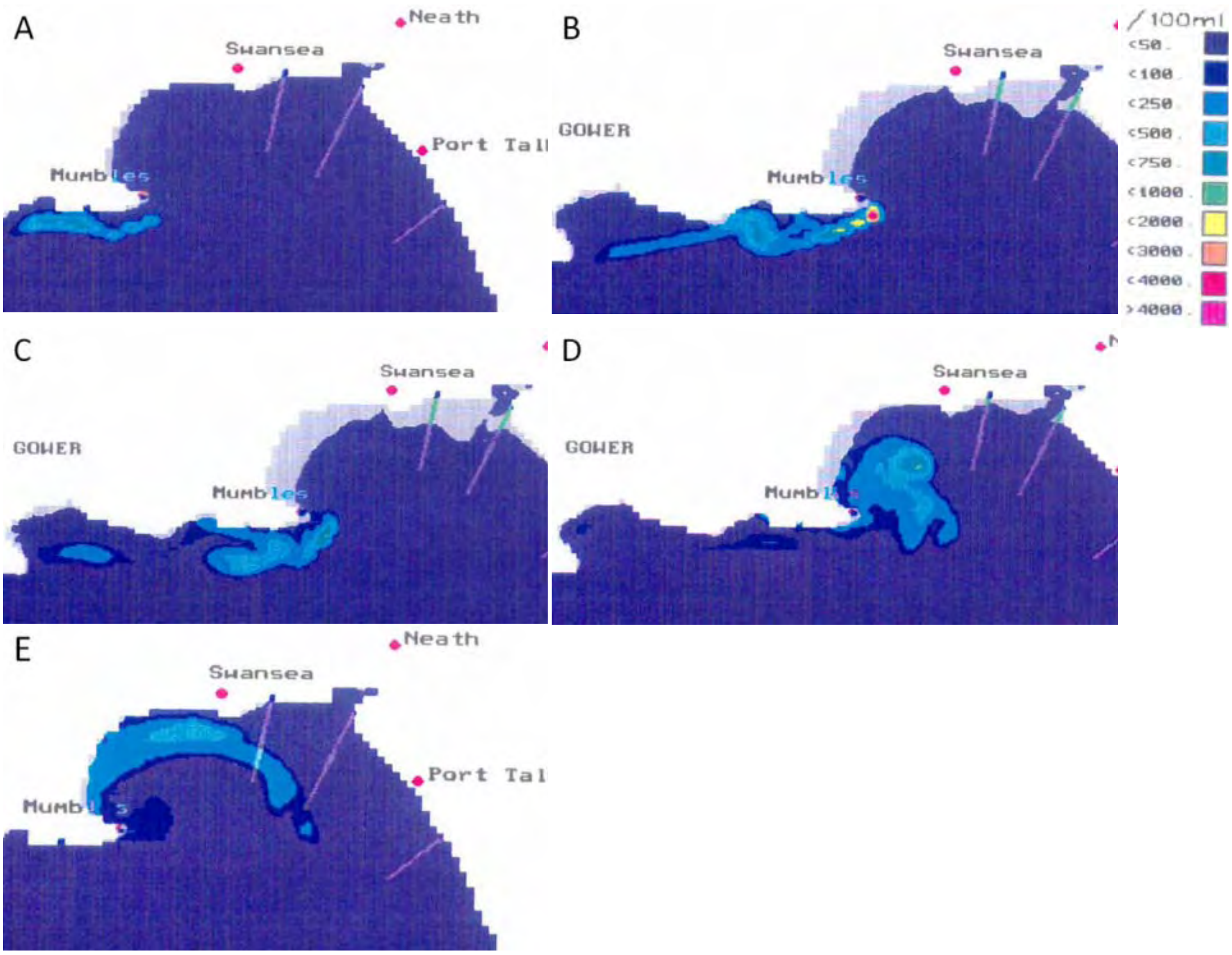


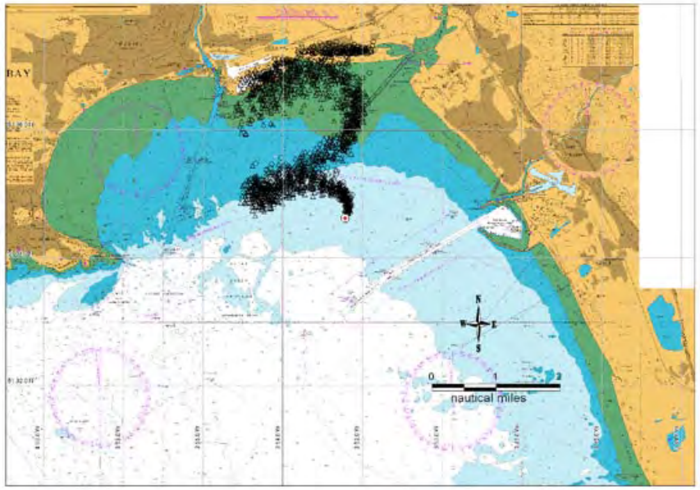
Figure V.5 Sewage plume dispersion from Mumbles (13h storm discharge, spring tide and under low water release and 10m s^{-1} south-westerly winds).
Into Mumbles storm event: A – 2h; B – 4h; After Mumbles storm event: C – 2h; D – 4h. E – 6h. Modified from Wallace Evans Ltd (1994).

Wave exposure changes as a result of the orientation of the bay. The western side of the bay (Mumbles Head), where BMPAs are established, tends to be more sheltered from westerly storms. Therefore, the embayment would be exposed to easterly-propagated waves and locally generated waves (Halcrow Group Ltd., 2002).

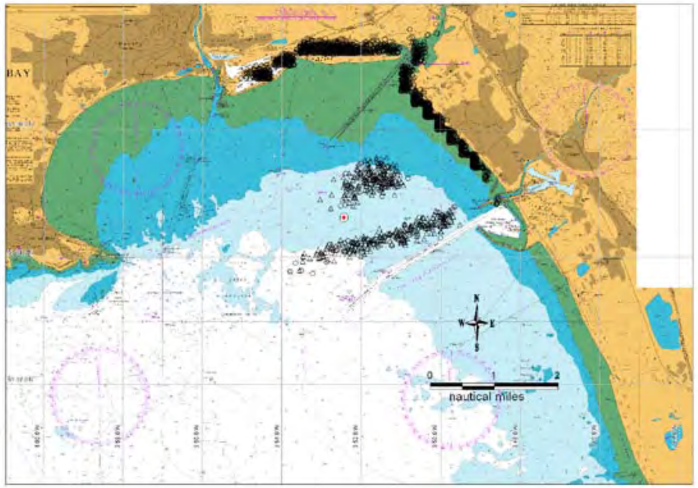
Figure V.6 represents results from a modelling exercise undertaken by Cefas to simulate the dispersion of 2,500 particles from Baglan PS, which discharges to Swansea Bay. The model assumed an *E. coli* concentration of 10^7 $100ml^{-1}$ in the discharge.

Results indicated that, during the first 24h, the particles were transported northwards and reached the stretch of coast between Swansea and Port Talbot. As the wind turns, particles are then transported more easterly and then south-westerly (Figure V.6B–C). The sewage plume did not extend further south-westerly as expected. This was probably due to the fact that wind speed was lower than predicted (Jon Rees, pers. comm.).

A



B



C

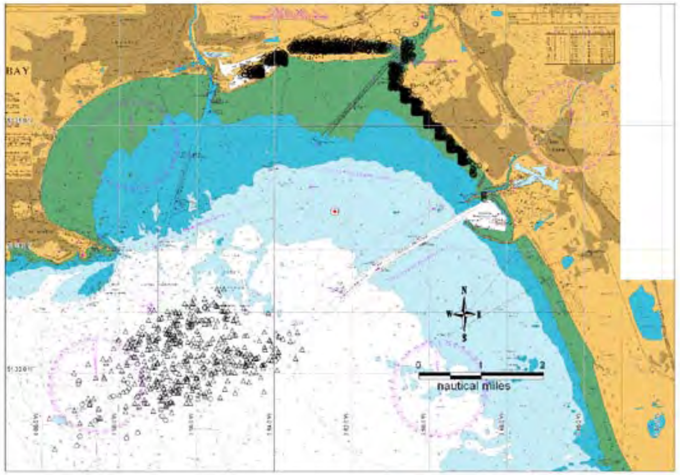


Figure V.6 Simulation of sewage plume dispersion from Baglan PS [spill commencing on 24/04/2007 after 24h (A), 48h (B) and 72h (C)].
Reproduced from Admiralty Chart 1161 by permission of the Controller of Her Majesty's Stationery Office and the UK Hydrographic Office (www.ukho.gov.uk). Not to be used for navigation.

Figure V.7 shows relationships between salinity and levels of faecal coliforms in surface waters sampled in 7 sites across Swansea Bay. None of the relationships is linear. As expected, the variation in salinity explains a higher proportion of the levels of the microbiological indicator in sites situated in the proximity of freshwater inputs and sewage discharges (Aberafon Beach; Swansea Bay at Slipway) than at sites less vulnerable to contamination of faecal origin (e.g. Langland Bay).

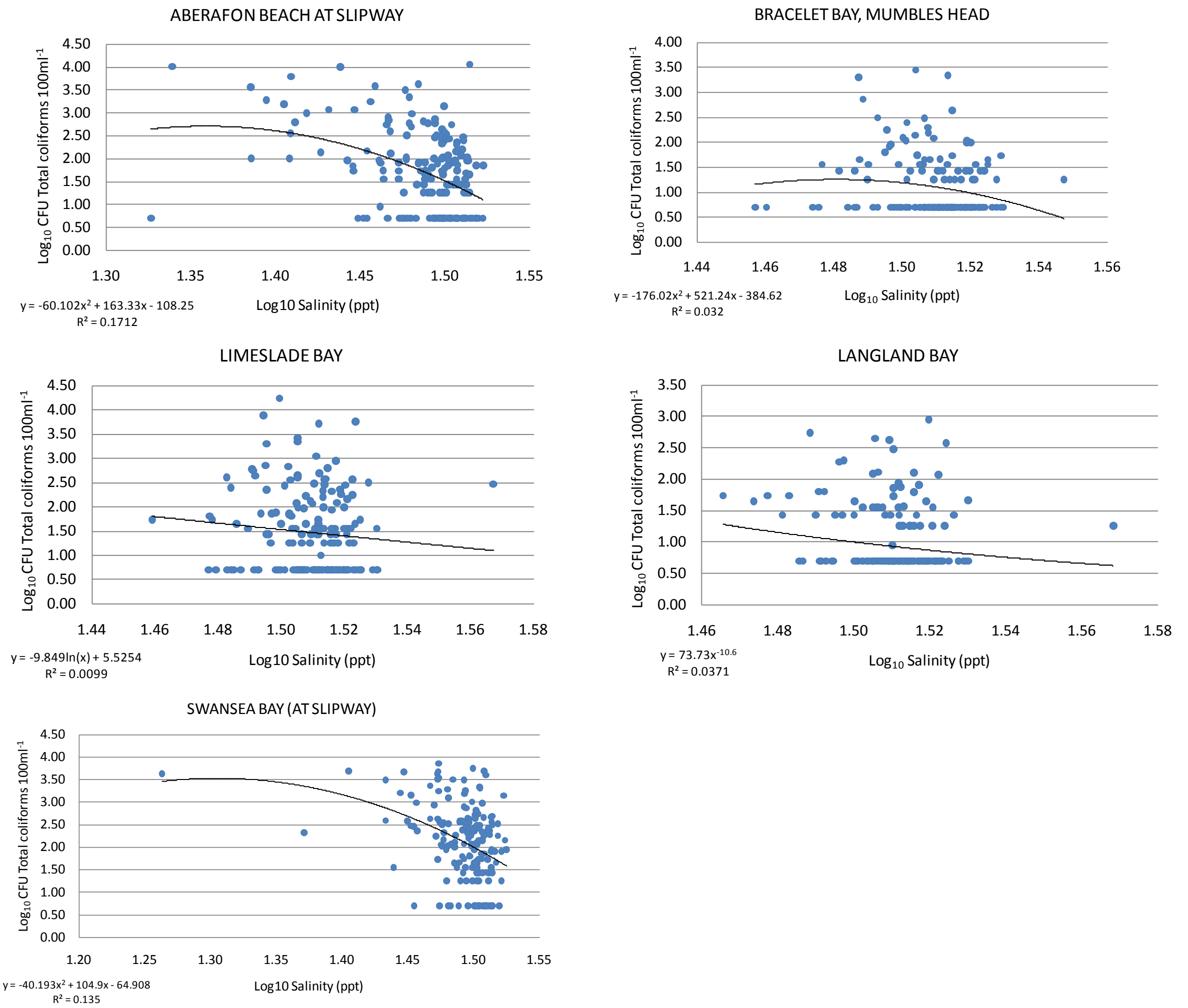


Figure V.7 Scatterplots of levels of total coliforms versus salinity in surface waters at five sites across Swansea Bay.
Data supplied by the Environment Agency.

Correlation analyses between the levels of *E. coli* in bivalves monitored at six current RMPs in Swansea Bay and tidal levels (high/low tide)/ranges (springs/neaps) were performed using circular statistics. In most cases, no statistically significant differences were found between tidal stage and levels of *E. coli* in bivalves.

Figure V.8 represents two graphical displays for which significant correlations were detected between levels of *E. coli* in wild mussels and spring-neap tidal cycle. In both cases, class C results appear to be associated with spring tides. However, it is apparent that the *E. coli* results are not representative of the full range of tidal variation. A more robust dataset would be needed to support a recommendation on a modified sampling regime based on tidal range.

A B

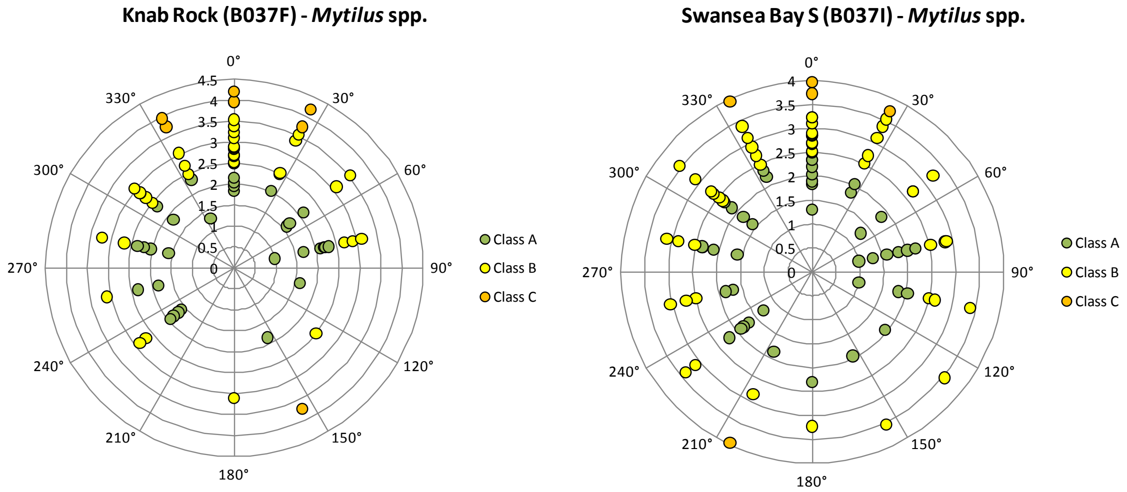


Figure V.8 Circular scatterplots of levels of* $\log_{10}$-transformed E. coli *in mussels from two representative monitoring points in Swansea Bay according to tidal range.
A - correlation coefficient = 0.3; p = 2.7 x 10^{-4}.
B - correlation coefficient = 0.17; p = 0.04.

APPENDIX VI
METEOROLOGICAL DATA: WIND

Wales is one of the windier parts of the UK, with the windiest areas being over the highest grounds and along the coasts, particularly those facing directions between north-west and south (Met Office, 2010).

The strongest winds are associated with the passage of deep areas of low pressure close to or across the UK. The frequency and strength of these depressions is greatest in the winter half of the year, especially from November to February, and this is when mean speeds and gusts (short duration peak values) are strongest (Met Office, 2010).

Wind roses for the period 2005–2006 for Swansea show that the prevailing wind is south-westerly.

A B

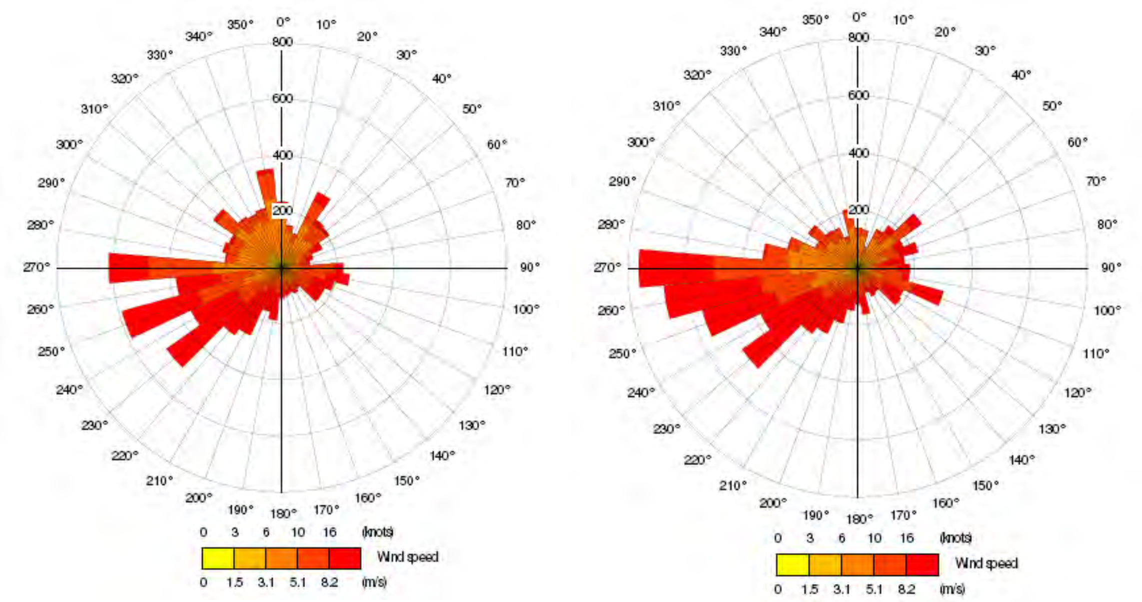


Figure VI.1 Wind roses for Swansea in 2005 (A) and 2006 (B).
Modified under permission of Geotechnical Engineering Ltd (2007).

Wind driven currents are expected to significantly influence water movements and hence circulation of contaminants within Swansea Bay. Strong wind conditions from west-southwest are expected to impinge effluent plumes upon the shore in the broader and shallower areas of the bay. As with tides, wind effects will depend on the location of the bivalve mollusc bed with respect to the source of contamination. Literature suggests that *E. coli* concentrations in bivalves are often higher when the sampling point lay downwind of a sewage outfall (Smith *et al.*, 1998).

APPENDIX VII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: SEWAGE DISCHARGES

Sewage discharges pose a significant risk of contamination of faecal origin to bivalve molluscs. The risk varies depending on the characteristics and absolute levels of the domestic and trade effluent components and volume of discharge. Sewage effluents in the catchment draining to Swansea Bay are treated in a number of sewage treatment works (STWs).

Figure VII.1 shows the locations of continuous and intermittent sewage discharges likely to be a source of microbiological contamination to bivalve mollusc beds in Swansea Bay and Queen’s Dock. The larger Dwr Cymru Welsh Water (DCWW) discharges are associated with the urbanised areas of Swansea, Port Talbot and the village of Bishopston. Smaller discharges are located in King’s Dock and the mouth of the River Tawe at Swansea.

Effluents from Bishopston STW and Swansea STW receive UV disinfection; effluents from Afan Port Talbot are secondary treated.

The Environment Agency considers that Afan WwTW Port Talbot, Swansea STW, Ystradgynlais STW and Trebanos STW represent a significant or potentially significant impact on designated Shellfish Waters (Environment Agency, 2008, 2009, 2009a). However, Ystradgynlais STW and Trebanos STW are outside the catchment and more than 10km from Swansea Bay.

Under dry weather conditions, Afan STW is known to contribute with approximately 82% of the load of enterococci to Swansea Bay whereas under wet weather conditions, this source contributes with approximately 10% of the load of these microorganisms to the bay (Kay and Wyer, pers. comm.). Swansea STW was found to have a negligible contribution to the load of the indicator at approximately 0.04% under wet weather conditions (Kay and Wyer, pers. comm.).

The sewerage infrastructure is also served by 183 intermittent discharges, which include combined sewer overflows (CSO), emergency overflows (EO), storm overflows (SO) and overflows from sewage pumping stations (PS).

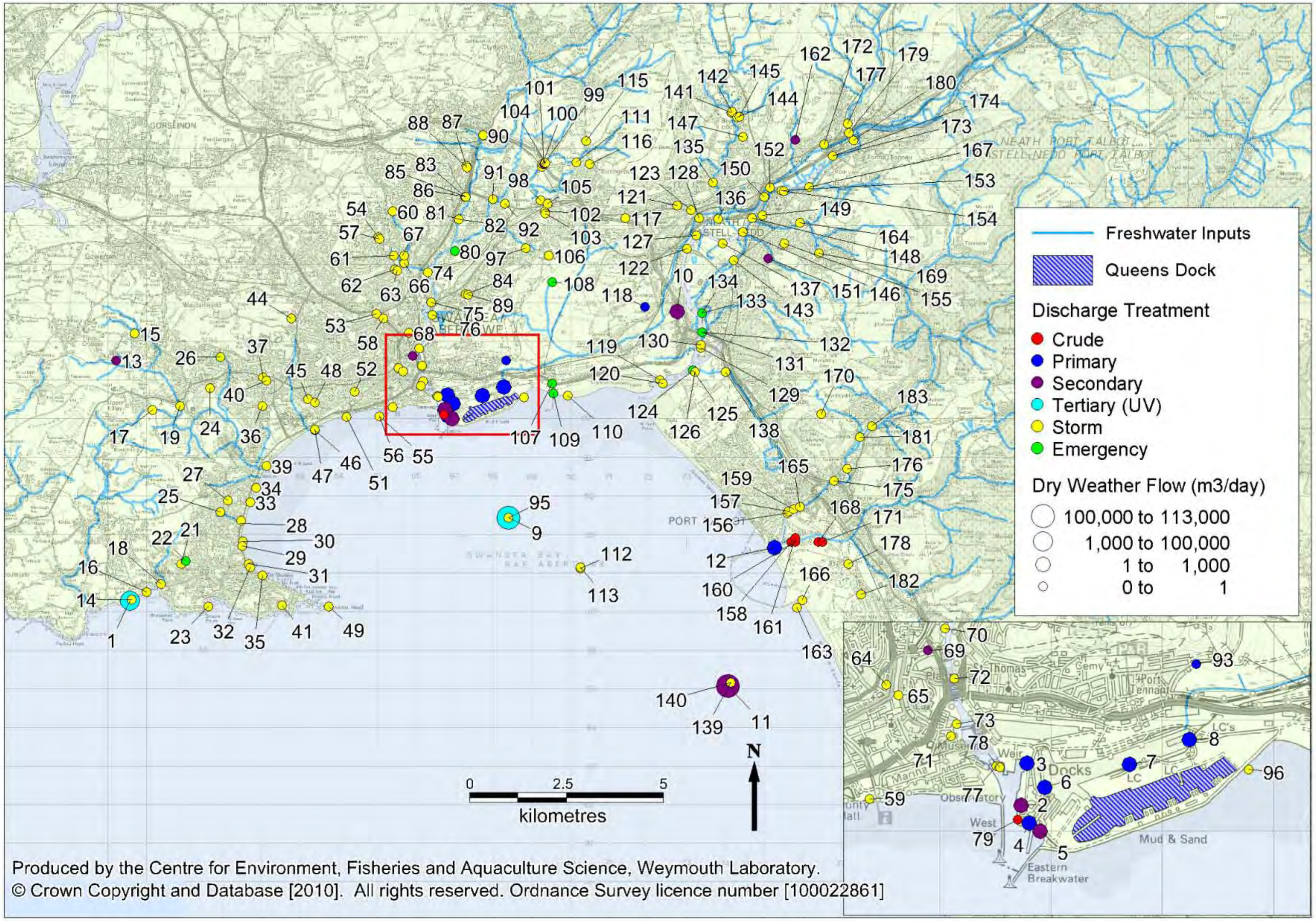


Figure VII.1 Significant sewage discharges to Swansea Bay and Queen's Dock.

Table VII.1 Continuous sewage discharges to Swansea Bay.

Map Ref. ID	Name	Treatment	MDV (m^3 day^{-1})	Population equivalent	Approx. distance to nearest bivalve mollusc bed	NGR of outfall
1	Bishopston STW	Tertiary (UV)	2,813	3,700	5.2	SS58568728
2	ABP Harbour Office	Secondary	11	62	0.3	SS66739223
3	ABP M&E Amenity Block	Primary	5	28	0.1	SS66789261
4	ABP Marine Control Building	Primary	3	17	0.3	SS66809207
5	Swansea Ship Repairers STW	Secondary	5	28	0.3	SS66909200
6	ABP A Shed Toilet Block	Primary	3	17	0	SS66949239
7	National Coal Board Lab Site	Primary	5	28	0	SS67709260
8	Trinity House Buoy Yard	Primary	3	12	0	SS68249282
9	Swansea STW Fabian Way	Tertiary (UV)	112,320	184,921	0.26	SS68378943
10	Llandarcy District Office Site	Secondary	9	51	6.2	SS72749478
11	Afan WwTW Port Talbot	Secondary	104,112	125,462	4.6	SS74058507
12	ABP Puckey House	Primary	2	9	5.3	SS75278865

MDV = Maximum Daily Volume (of effluent to be discharged).
NGR = National Grid Reference.
ABP = Associated British Ports.
STW = Sewage Treatment Works.

Table VII.2 Intermittent sewage discharges to Swansea Bay.

Map Ref. ID	Name	Type	NGR of outfall
13	3 Ddol Cottages Dunvant	Secondary	SS58209350
14	Bishopston STW Brandy Cove Lane	Storm	SS58608730
15	Cefn Celyn Pen-Y-Fro Dunvant	Storm	SS58679420
16	PS at Redcliffe Apartments Caswell	Storm	SS58998750
17	Hen Parc Lane PS	Storm	SS59149222
18	Caswell Bay Car Park SPS	Storm	SS59368771
19	Killay SPS Off Gower Road	Storm	SS59859233
20	Waunarlwydd Caravan Site CSO	Storm	SS59869560
21	Briarwood Gardens PS	Storm	SS59898823
22	EO from PS Woolacot	Emergency	SS60008830
23	Langland SPS	Storm	SS60588712
24	Killay House PS	Storm	SS60639279
25	Elmgrove Road CSO	Storm	SS60908957
26	Devt off Donvant Road Hendrefoilan	Storm	SS60909360
27	Fairwood Road / Lynden Tree Public House	Storm	SS61108988
28	Outfall E From CSO 14	Storm	SS61448935
29	Outfall D1 From CSO 10	Storm	SS61478870
30	SWO Near Norton Avenue	Storm	SS61488881
31	Outfall C From CSO 4A	Storm	SS61638823
32	Outfall B From CSO 3	Storm	SS61678815
33	Off Lliput Lane Point 130 CSO	Storm	SS61688983
34	Outfall G From CSO 16	Storm	SS61829021
35	Outfall A (CSO 201) Junction of Mumbles	Storm	SS61998794
36	CSO No 21 Derwen Fawr Road Sketty	Storm	SS61999233
37	CSO No 33 Glan Yr Afon Road Sketty	Storm	SS62009307
38	CSO Sketty Park Drive	Storm	SS62016267
39	Outfall H From CSO 17	Storm	SS62109077
40	CSO No 34 Rear of Furzeland Drive	Storm	SS62109298
41	Limeslade PS	Storm	SS62508716
42	Cwmbach Road CSO Cockett	Storm	SS626195217
43	Cadle Mill Point 47 CSO	Storm	SS62649696
44	Station Road CSO Pen Y Cwm	Storm	SS62749459
45	SWO Singleton Park (Point 30)	Storm	SS63179250
46	SWO Singleton Park (Point 25)	Storm	SS63359170
47	Outfall J From CSO 24	Storm	SS63359171
48	SWO Singleton Park (Point 23)	Storm	SS63359241
49	Mumbles SPS Knab Rock	Storm	SS63708713
51	Outfall K From CSO 264	Storm	SS64179204
52	Point 28 Brynmor/Westbury	Storm	SS64389270
53	Cwmbwrla CSO	Storm	SS64949472
54	Rear 61 Gwyrossydd (Point 52)	Storm	SS64999670
55	SWO Near H.M. Prison (Point 6)	Storm	SS65029206
56	Outfall L From CSO 121 Sandfields PS	Storm	SS65029206

57	Penlan Crescent (Point 52A)	Storm	SS65029666
58	CSO 60 Gors Avenue	Storm	SS65129459
59	Swansea (Oxford St/Union St) point 129	Storm	SS65379229
60	Mynyddgarnllwyd CSO	Storm	SS65379737
61	SWO Treboeth (Point 68)	Storm	SS65399622
62	CSO 64A Penlanfach Brynhyfryd	Storm	SS65429586
63	Brynhyfryd CSO Llangyfelach Road	Storm	SS65499584
64	Point 118 Grove Place	Storm	SS65529331
65	Swansea (High St/Welcome Lane) Point 1	Storm	SS65639322
66	CSO 69 Trwyddfa Road	Storm	SS65669603
67	CSO 69A Heol Nant Gelli	Storm	SS65679623
68	CSO 119 Cwm Road Hafod	Storm	SS65789422
69	Cambrian Service Station Restaurant/Café	Secondary	SS65899362
70	SWO Outlet of Burlais Brook	Storm	SS66059382
71	Point 120 Cambrian Place	Storm	SS66109285
72	Morris Lane Pentreguinea Rd St Thomas	Storm	SS66139337
73	SWO Dock Area (Point 59)	Storm	SS66159296
74	CSO 70 A4067 Nthbnd Landore	Storm	SS66279579
75	White Rock PS Storm Overflow	Storm	SS66379501
76	Pentre Chwyth SWO (Point 100)	Storm	SS66409469
77	Outfall M High St/Kingsway/E Burrows CSOs	Storm	SS66519258
78	Swansea Marina Barrage SSO	Storm	SS66549257
79	Harbour Office Lockhead Kings Dock	Crude	SS66709210
80	Matrix Park PS	Emergency	SS66989634
81	Wychtree Street CSO Morrsiton	Storm	SS67089716
82	Fendrod PS Ferryboat Close	Storm	SS67089716
83	CSO 81 Cwm Bath Road Morriston	Storm	SS67259775
84	Swansea (Bonymaen Road) Point 101A	Storm	SS67269522
85	CSO 73 Crown St Morriston	Storm	SS67269775
86	CSO 72 Slate St Morriston	Storm	SS67269775
87	SWO Near Chemical Road Morriston	Storm	SS67289855
88	CSO 80 Pentrpoeth Rd Morriston	Storm	SS67299851
89	Bonymaen Road Near Dartford Road	Storm	SS67329520
90	SSO Ynysforgan Roundabout	Storm	SS67719935
91	Llansamlet PS	Storm	SS67969768
92	CSO 103 Samlet Road Llansamlet	Storm	SS68289756
93	Tir John Civic Amenity Site	Primary	SS68309350
94	SWO Ynystawe (Point 86)	Storm	SS68370024
95	Swansea STW Storm Overflow	Storm	SS68378943
96	SWO Queens Dock (Point 92)	Storm	SS68779255
97	The Old Ammunition Dump Trallwn	Storm	SS68829641
98	Peniel Green CSO Peniel Green Road	Storm	SS69219765
99	SWO Llansamlet (Point 107)	Storm	SS69239852
100	Felin Fran CSO Walters Road Llansamlet	Storm	SS69259860
101	Nythfa 1 Felin Fran Heol Las Llansamlet	Secondary	SS69309860
102	CSO 104 Bethel Road Llansamlet	Storm	SS69319737

103	CSO 106 Trallwyn Community Centre	Storm	SS69329732
104	Ynysallen Road PS	Storm	SS69339862
105	Llansamlet SWO (Point 105)	Storm	SS69389756
106	SSO Halfway Crymlyn Road PS	Storm	SS69419622
107	Emergency Overflow A Crymlyn	Emergency	SS69509290
108	Halfway Scheme Emergency Overflow	Emergency	SS69509553
109	Baldwins Crescent SPS	Emergency	SS69539265
110	Temp. Discharge from Neath Port Talbot	Storm	SS69909260
111	CSO Off Heol Las Llansamlet	Storm	SS70139864
112	Baglan SPS Briton Ferry Neath	Storm	SS70248811
113	Baglan SPS Briton Ferry Neath	Storm	SS70248814
114	PS Outfall Residential Devt Birchgrove Road	Storm	SS70300030
115	Drumau Farm Birchgrove Road PS SSO	Storm	SS70389920
116	CSO 109 Birchgrove	Storm	SS70489860
117	SSO Skewen PS Lonlas	Storm	SS71409720
118	Gellibwch Farm	Primary	SS71909490
119	Penstocks Jersey Marine PS	Storm	SS72309300
120	Fabian Way SPS	Storm	SS72379291
121	CSO 34 Rear 38 Caenant Terrace	Storm	SS72759752
122	Dynevor Junction PS	Storm	SS73009640
123	CSO 31 opposite New Road Skewen	Storm	SS73109740
124	Baglan SPS Briton Ferry	Storm	SS73159325
125	Baglan SPS Briton Ferry	Emergency	SS73159325
126	Baglan PS SSO	Storm	SS73209320
127	Pentreffynnon PS	Storm	SS73249674
128	Neath Abbey PS	Storm	SS73319719
129	Briton Ferry SPS inner Dock	Storm	SS73359384
130	Briton Ferry SPS	Storm	SS73369391
131	George’s Row SPS	Storm	SS73399424
132	George’s Row SPS	Emergency	SS73399424
133	Giants Grave SPS Pill Terrace	Storm	SS73399473
134	Giants Grave SPS Pill Terrace	Emergency	SS73399473
135	Longford SWO 8	Storm	SS73679812
136	Neath Abbey PS	Storm	SS73809718
137	Penrhiwtyn PS	Storm	SS73939653
138	Baglan PS SSO Northern Boundary	Storm	SS74009320
139	Afan WWTW SO/EO	Storm	SS74138516
140	Afan WWTW Phoenix Wharf Harbour Road	Storm	SS74138516
141	Farmers Road PS	Storm	SS74159993
142	Farmers Road PS Bryncoch	Storm	SS74169995
143	Penrhiwtyn PS	Storm	SS74209610
144	Bryncoch SWO Nr Junction 7	Storm	SS74309980
145	CSO No. 10 30m U/S roadbrdge	Storm	SS74369982
146	Melincryddan PS	Storm	SS74449684
147	CSO 8 Bryncoch SWO 7b	Storm	SS74449930
148	Roman Way SWO	Storm	SS74689720

149	Gunsight Overflow (SWO 11)	Storm	SS74969727
150	Quay Road PS	Storm	SS75009775
151	The Grove Eaglesbush	Secondary	SS75109615
152	Vale of Neath Retail Park PS	Storm	SS75159799
153	Farfield PS Prince of Wales Drive	Storm	SS75449791
154	Dyfed Road O/S Public Health Office	Storm	SS75519789
155	CSO 32 Nr St Josephs Church	Storm	SS75529654
156	Gasworks Sewer Junction Chamber	Storm	SS75608955
157	CSO 104 Newbridge Road PS	Storm	SS75638959
158	The Small Boat Club Site ABP	Crude	SS75708880
159	Water St. CJC Port Talbot	Storm	SS75768965
160	The Sea Cadets Club ABP Drain D3	Crude	SS75808880
161	The Sea Cadets Club ABP Drain D4	Crude	SS75808890
162	Neath Golf Club	Secondary	SS75819923
163	Abbey SPS British Steel Site	Storm	SS75858709
164	CSO 33 Cimla Road	Storm	SS75929708
165	CSO 126 Moors St Culvert Afan	Storm	SS75938971
166	Afan WWTW Phoenix Wharf Harbour Road	Storm	SS75988729
167	Llantwit Church PS	Storm	SS76179800
168	John Nicholas Timber Site ABP Drain D21	Crude	SS76408880
169	CSO 9 Cimla Common	Storm	SS76419628
170	CSO 125 Cwmafan RFC	Storm	SS76489211
171	Metal Mend Site ABP Drain D20	Crude	SS76508880
172	CSO 49 Llangatwg School Aberdulais	Storm	SS76559911
173	Abbey PS	Storm	SS76779880
174	Abbey PS	Emergency	SS76779880
175	CSO 136 Afan Street Velindre	Storm	SS76819039
176	CSO 115 Scotts Yard Cwmafan	Storm	SS77159070
177	SWO below Brynamlwg House	Storm	SS77169964
178	CSO 123 Margam PS Near Brombill Street	Storm	SS77188823
179	CSO 17 under Old Road Bridge Aberdulais	Storm	SS77209940
180	CSO 48 Neath River Bridge Adj Calor	Storm	SS77319921
181	CSO 135 below Pantdu Cwmafan	Storm	SS77479152
182	CSO 122 18 Duke Street Afan	Storm	SS77518744
183	CSO 102 100m D/S Footbridge	Storm	SS77799180

PS/SPS = pumping station/sewage pumping station
CSO = combined sewer overflow
SO = storm overflow
EO = emergency overflow
SWO = sewage works overflow

Geometric means of faecal coliforms monitored in the final effluent post UV disinfection from Bishopston STW (Table VII.3) are lower than the average levels given in the literature for a range of UV-treated effluents in the UK (Kay *et al*., 2008). Maximum levels of the microbial indicator indicate the existence of periods when the quality of the final effluent had deteriorated.

Table VII.3 Summary statistics of presumptive levels of faecal coliforms in the final effluent post UV disinfection monitored in Bishopston STW for the period May 1998–October 2000.

No. of samples	Minimum	Maximum	Median	Geometric mean
63	<1	>30,000	96	120

Data from Environment Agency Wales.

Side-by-side box-and-whisker plots of faecal coliform data amalgamated by season show that this deterioration essentially occurred during the period late autumn-winter and that the microbial quality of the effluent is improved during the summer (Figure VII.3). Median levels of faecal coliforms in effluent discharges from this STW increase more than $1Log_{10}$ between June and November (not shown).

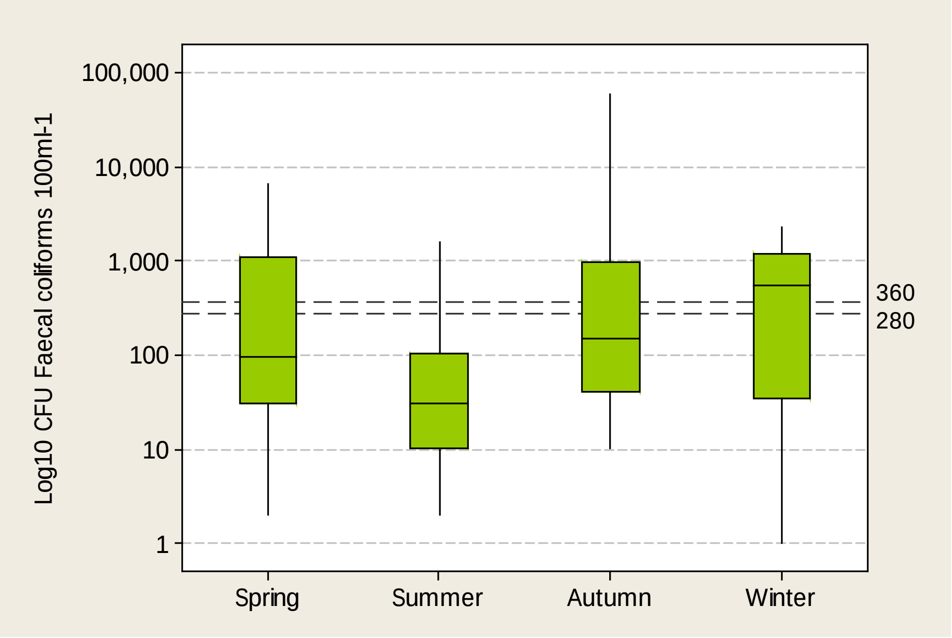


Figure VII.3 Box-and-whisker plots of seasonal levels of faecal coliforms in the final effluent post UV disinfection monitored in Bishopston STW during the period May 1998–October 2000.
N.B. Spring: March–May; Summer: June–August; Autumn: September–November; Winter: December–February.
Reference lines correspond to typical levels of faecal coliforms in UV-treated effluents under base-flow and high flow conditions as observed in a range of effluents by Kay et al. *(2008a).*
Data from the Environment Agency Wales.

APPENDIX VIII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: AGRICULTURE

Although large areas of the catchment draining to Swansea Bay are urbanised or serve industrial activities, agricultural activities are also significant (Environment Agency, 2007; 2010), particularly in the valley of the river Neath (Neath Port Talbot Regeneration Partnership, 2009).

There are over 829,200 farmed animals in these catchments (Table VIII.1). Cattle represents 91% of the total number of farmed animals.

Table VIII.1 Numbers of farmed animals in the catchment draining to Swansea Bay.

Sheep	756,068
Cattle	60,185
Chickens	7,536
Horses	4,568
Pigs	525
Goats	386

Data from June 2006 Welsh Agricultural Survey. Agricultural Small Area Statistics (aggregations of Communities within Local Authorities and Old Counties).

Densities of cattle, sheep and chickens are higher within catchments draining to the eastern part of Swansea Bay (Figure VIII.1).

Farmyards can significantly contribute to loads of faecal indicator microorganisms to watercourses or coastal waters when they have a ready and renewable source of faecal material, a direct hydrological connection with open water channels exists and a sufficient proportion of livestock farms are present in the catchment (Edwards *et al*., 2008).

The concentration of faecal coliforms excreted in the faeces of humans and farm animals and corresponding excretion rates are summarised in Table VIII.2.

Table VIII.2 Levels of faecal coliforms and corresponding loads excreted in the faeces of warm-blooded animals.

Farm animal	Faecal coliforms (No. g^{-1} wet weight)	Excretion rate (g day^{-1} wet weight)
Human	13,000,000	150
Pig	3,300,000	2,700
Cow	230,000	23,600
Sheep	16,000,000	1,130

Data from Geldreich (1978).

Diffuse pollution from rural areas discharged into the bay via the rivers Tawe, Clyne, Neath and Afan is considered by the Environment Agency to be a potentially significant source of microbial contamination affecting the quality of designated Shellfish and Bathing Waters (Environment Agency, 2008, 2009, 2009a).

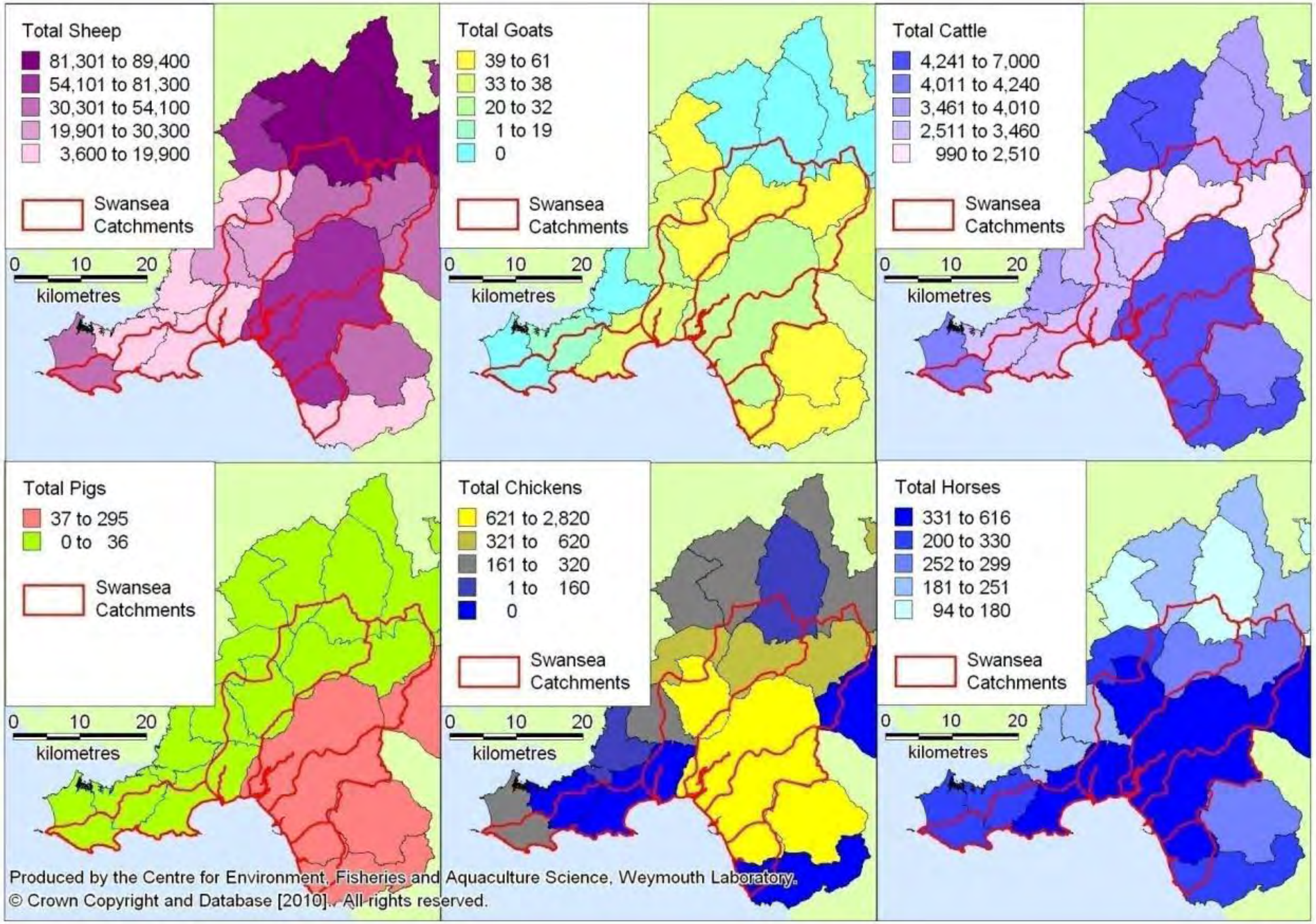


Figure VIII.1 Numbers of farmed animals in catchments draining to Swansea Bay.

APPENDIX IX
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: BIRDS

Swansea Bay provides a diversity of habitats for large communities of birds. Waterbirds have been surveyed by BTO/WeBS in sectors across the bay. The most abundant species are the Oystercatcher and Dunlin (Table IX.1).

Table IX.1 Low tide counts of waterbird species in Swansea Bay in 2003/04.

Species	Peak Number	Mean Number	Mean density
Shelduck	1	0	+
Oystercatcher	2,857	1,757	1.44
Ringed Plover	70	51	0.04
Grey Plover	17	9	0.01
Dunlin	1,093	646	0.53
Bar-tailed Godwit	7	5	+
Curlew	59	44	0.04
Redshank	24	14	0.01
Turnstone	23	8	0.01

+ indicates non-zero densities of <0.01 birds per hectare.
Peak number of a species over the whole site counted in any one month.
Mean number is an estimate over the winter for the whole site, obtained by summing mean counts of each species for each count section).
Mean density over the site is the mean number divided by the total area surveyed.
Data from Colier et al. *(2005).*

Figure IX.1 shows that most oystercatchers exploit intertidal flats in the western part of the bay around The Mumbles. Concentrations of this species have also been recorded in the area adjacent to Guildhall, with further aggregations at the mouth of the Nedd and a few individuals at Margam Sands. Peak counts of this species usually occur in November–December and decline in February.

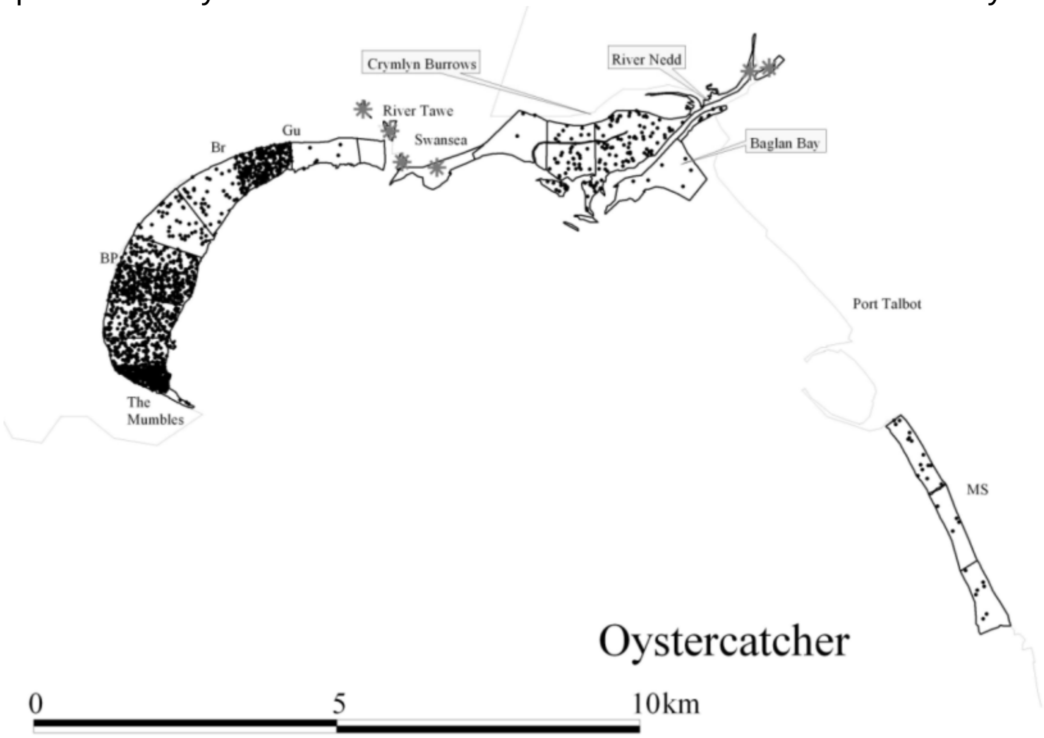


Figure IX.1 WeBS Low Tide Count distributions of Oystercatcher in Swansea Bay for the winter of 2003/04. BP–Black Pill; Br–Brynmill; Gu–Guildhall; MS–Margam Sands.
Modified from Collier et al. *(2005) under permission of Andy Musgrove.*

Dunlin also prefers The Mumbles area and some of the areas near the mouth of the Nedd. This species tends to be more abundant during the period November–February (Collier *et al.*, 2005).

Other species were recorded at high numbers in the winter 2003/04, such as the Black-headed Gull (peak count = 3,647 in December), Herring Gull (peak count = 2,800 in December) and Common Gulls (peak count = 718 in December).

Bird counts undertaken during the bathing season confirm that the intertidal area in the vicinity of the slipway and Aberavon Beach are the preferred sites for these birds (Table IX.2).

Table IX.2 Number of birds counted as part of shoreline surveys undertaken by the EA in the 2000 and 2009 bathing seasons.

Beach	Maximum (average) number of birds
Swansea Bay (at slipway)	100 (16)
Aberavon Beach (at slipway)	70 (12)
Bracelet Bay, Mumbles Head	20 (2)
Langland Bay (West)	20 (4)
Limeslade Bay	5 (0.47)

Observations made by EA Officers at the time of bacteriological investigations. Data supplied by the Environment Agency.

Previous studies in the UK have found significant concentrations of microbial contaminants in intertidal sediment samples collected from bays supporting large communities of birds (Obiri-Danso and Jones, 2000). Table IX.3 shows concentrations of faecal coliforms excreted by wild birds in Morecambe Bay, in the northwest of England. Feare (2001) suggested that approximately 10% of faecal matter could be deposited under a roost, indicating the potentially significant contribution of contamination in these areas.

Table IX.3 Concentrations of faecal coliforms in bird faeces.

Species	CFU Faecal coliforms g^{-1} faeces
Bar-tailed Godwit	7.1×10^{11}
Oystercatcher	4.7×10^{11}
Shellduck	7.4×10^{8}
Gulls (bay)	1.8×10^{7}
Gulls (waste tip)	1×10^{10}

Data from Jones (2002).

Figure IX.2 shows that, during the 2000 bathing season, birds were present on 67% of the sampling occasions when the Guideline value of faecal coliforms (100 CFU $100ml^{-1}$; $Log_{10} = 2$) was exceeded in Aberavon Beach.

Linear relationships between levels of faecal indicator microorganisms and numbers of birds are rarely found because of the sporadic and unpredictable nature of faecal inputs from birds. Representative monitoring points situated in inshore positions of wild mussel beds will be well placed to reflect any contamination from these sources.

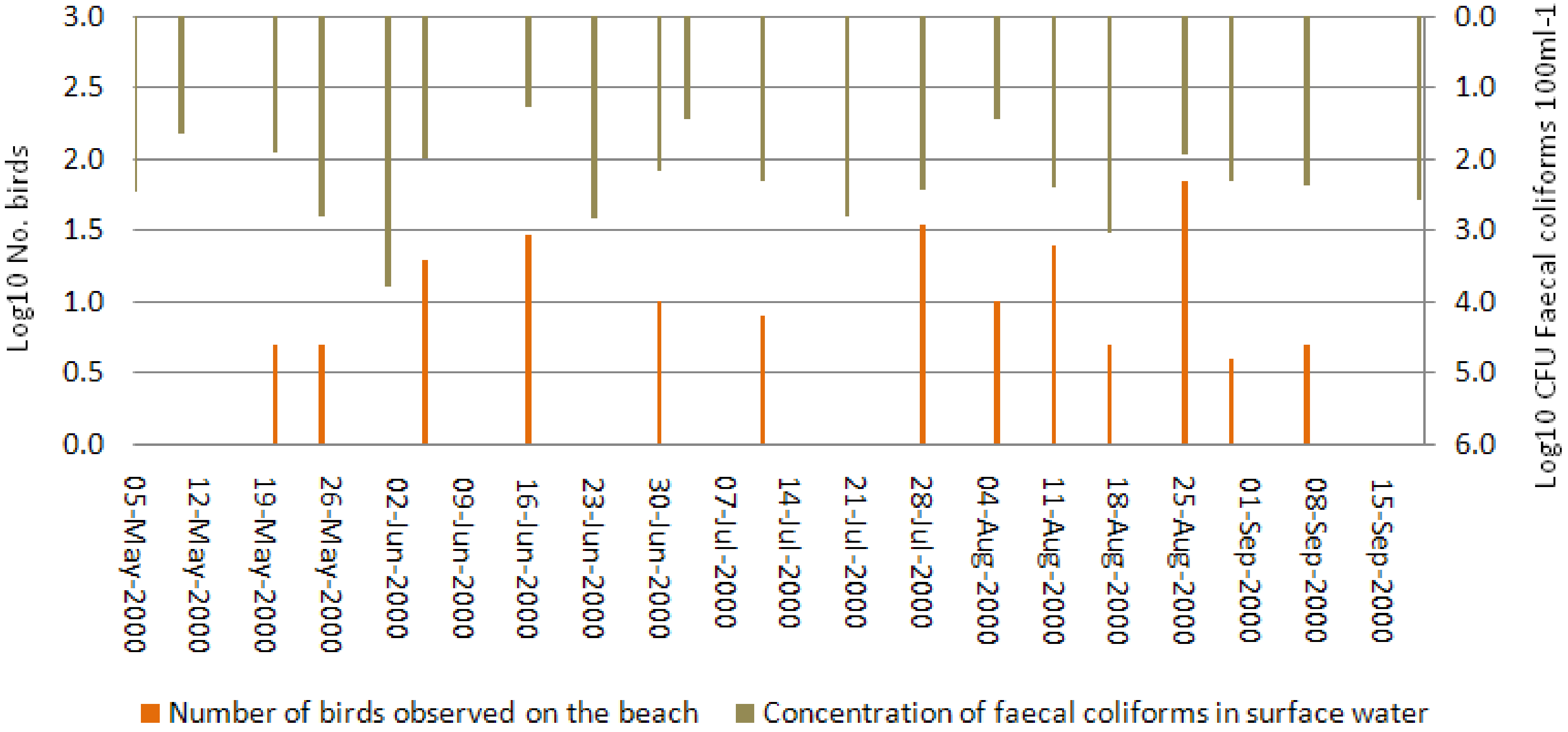


Figure V.1 Time series of levels of faecal coliforms in surface water and number of birds observed on Aberavon Beach during the 2000 bathing season.

APPENDIX X
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: BOATS

The Port of Swansea consists of two main docks, King's and Queen's Docks and a third Dock - the Prince of Wales - which is now used as a marina and no longer accepts commercial traffic (ABP, 2007).

On the north-east of the bay lies Port Talbot's enclosed dock, which consists of a single dock with several branches. On the East is the entrance to Port Talbot Tidal Harbour, which contains a large deep-water jetty for handling bulk cargoes of coal and iron ore (ABP, 2007).

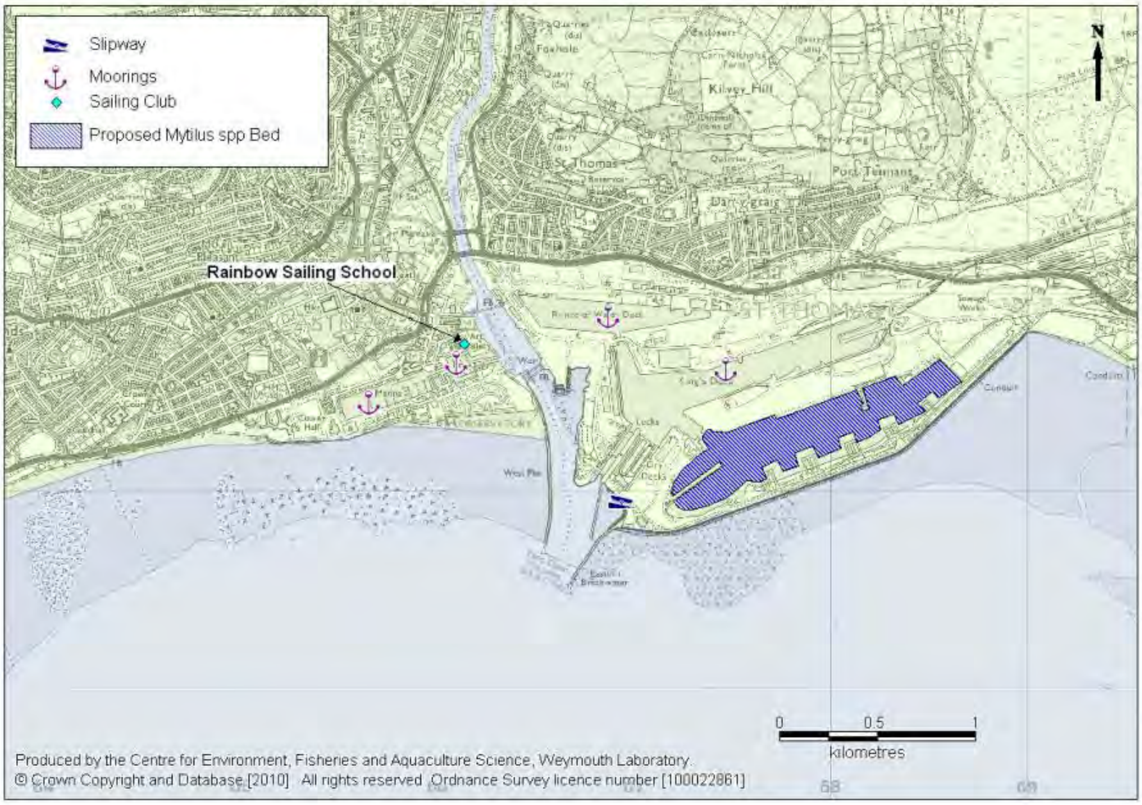


Figure X.1 Location of mooring areas, sailing clubs and slipways in Swansea Docks.

Marinas and ports have historically been identified as major sources of faecal contamination (see Sobsey *et al*., 2003). This is based on the assumption that some boat owners will, at some time, illegally discharge their head (onboard toilet) into harbour waters.

Swansea Marina provides berths for approximately 590 boats and does not provide pump-out facility (Adlard Coles Nautical, 2008). As part of a mix of residential, commercial and leisure development scheme for Swansea Waterfront, the Prince of Wales Dock will change its use to a commercial marina capable of berthing in excess of 400 vessels (Rees, 2010). This will increase the total berthing capacity in Swansea to approximately 1,000 boats. These will constitute an additional risk of microbial contamination from pleasure craft to the mussel production area at Queen's Dock.

APPENDIX XI
MICROBIOLOGICAL DATA: WATER

BATHING WATERS

There are six bathing waters in the proximity of classified bivalve mollusc beds designated under the Directive 2006/7/EC (European Communities, 2006a)[7]: Swansea Bay, Aberafan, Bracelet Bay, Caswell Bay, Limeslade Bay and Langland Bay (Figure XI.1).

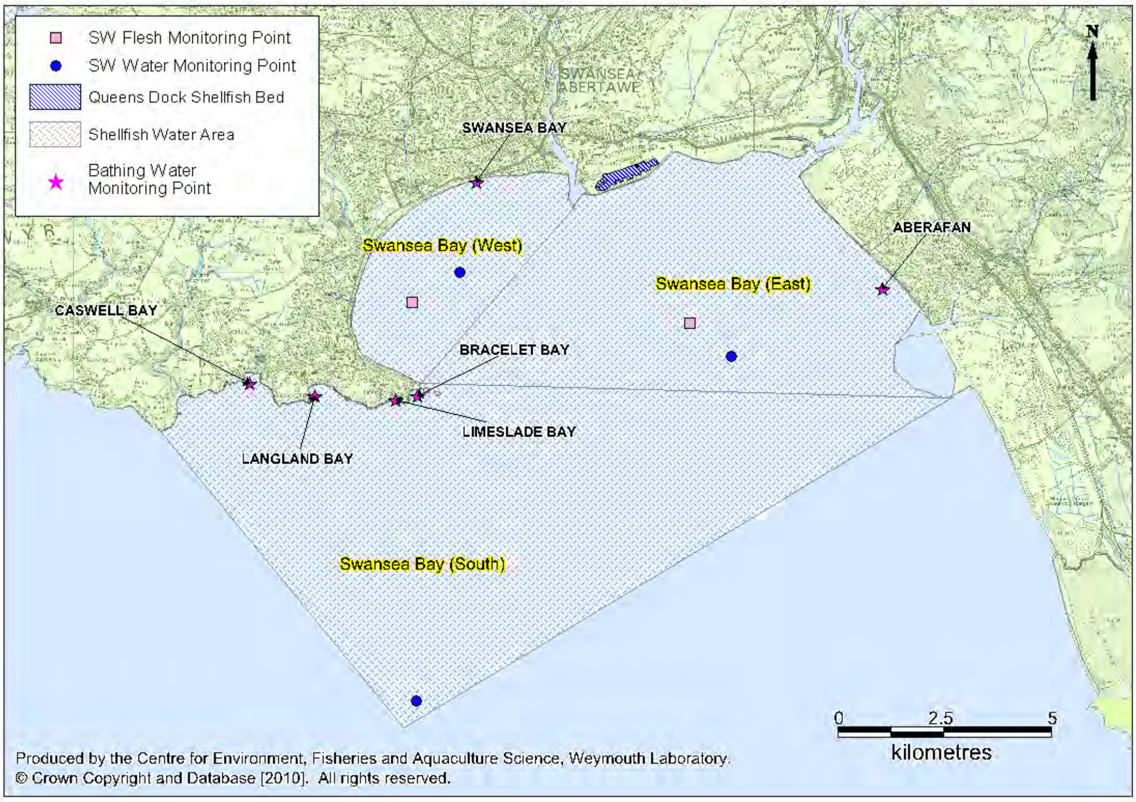


Figure XI.1 Location of designated Bathing Waters and Shellfish Waters in Swansea Bay.

In 2009, Aberafan and Bracelet achieved "excellent" status. The overall quality of these Bathing Waters under the revised BW Directive is summarised in Table XI.1. Swansea Bay would achieve "poor" status.

Table XI.2 shows summary statistics during the bathing seasons 1999–2009. Median levels of faecal coliforms in surface waters at Swansea Bay and Aberafan seem to show a gradual deterioration in the quality of surface waters at these sites during the period 2005–2009. Median levels of the microbial indicator in Caswell Bay remained below 7 during the monitoring period.

[7] The bathing season runs from 15 May to 30 September. Water is sampled throughout the season. Levels of bacteria must not exceed the Imperative (I) value (2,000 faecal coliforms 100ml^{-1}) and the Guideline (G) value (100 faecal coliforms 100ml^{-1}) represents the ideal maximum value. Bathing waters in England and Wales are classified as:
Poor - fails at least one coliform I standard;
Good - passes coliform I standards but fails at least one coliform G standard;
Excellent - passes coliform G standard and faecal streptococci standards.

Table XI.1 Overall quality of designated Bathing Waters for the period 2005−2009.

Bathing Water	Bathing season 2005–2009
Swansea Bay	Poor
Aberafan	Good
Bracelet Bay	Excellent
Caswell Bay	Excellent
Limeslade Bay	Excellent
Langland Bay	Excellent

Data from the Environment Agency (2010). Based on full results; no discounting.

Table XI.2 Summary statistics of levels of faecal coliforms in Gyllyngvase and Swanpool Bathing Waters for the period 1999–2009.

	CFU Faecal coliforms 100ml^{-1}																	
	Swansea Bay			Aberafan			Bracelet Bay			Caswell Bay			Limeslade Bay			Langland Bay		
Bathing season	Min.	Max.	Median	Min.	Max.	Median	Min.	Max.	Median	Min.	Max.	Median	Min.	Max.	Median	Min.	Max.	Median
1999	<10	610	164	5	560	82	<10	27	5	<10	182	5	<10	2,600	23	<10	127	21
2000	<10	3,700	187	18	6,160	217	<10	55	5	<10	270	5	<10	6,800	36	<10	736	36
2001	<10	790	66	5	2,400	36	<10	176	5	<10	82	5	<10	310	28	<10	146	5
2002	<10	2,500	23	5	2,100	23	<10	793	5	<10	82	5	<10	15,200	5	<10	18	5
2003	<10	1,280	61	<2	538	23	<2	22	5	<2	263	5	<2	224	5	<2	42	5
2004	<2	500	68	<2	1,872	14	<2	52	4	<2	38	1	<2	692	7	<2	74	2
2005	<2	3,023	35	<2	728	10	<2	74	1	<2	41	4	<2	140	9	<2	13	1
2006	4	972	70	<2	4,770	10	<2	96	4	<2	120	3	<2	928	8	<2	70	1
2007	2	196	32	<2	346	17	<2	577	2	<2	67	4	<2	1,680	5	<2	98	2
2008	<2	3,308	128	<2	756	13	<2	560	5	<2	1,680	7	<2	654	13	<2	80	3
2009	<2	3,493	57	<2	896	21	<2	1,800	1	<2	192	3	<2	323	2	<2	19	2

Data from the Environment Agency (2010).
Total number of samples per season = 20.
Min. - minimum.
Max. - maximum.

The symmetric distribution of the levels of faecal coliforms in surface waters of all Bathing Waters is represented by the similar sizes of top and bottom box halves in Figure XI.2.

The outlier values represented by asterisks for Bracelet Bay and Aberafan suggest the existence of periods when the microbial quality of the waters had deteriorated at these bathing waters.

Surface waters at Swansea Bay are significantly more contaminated (>1Log_{10}) than those at Bracelet Bay, Caswell Bay, Langland Bay and Limeslade Bay (Figure XI.2).

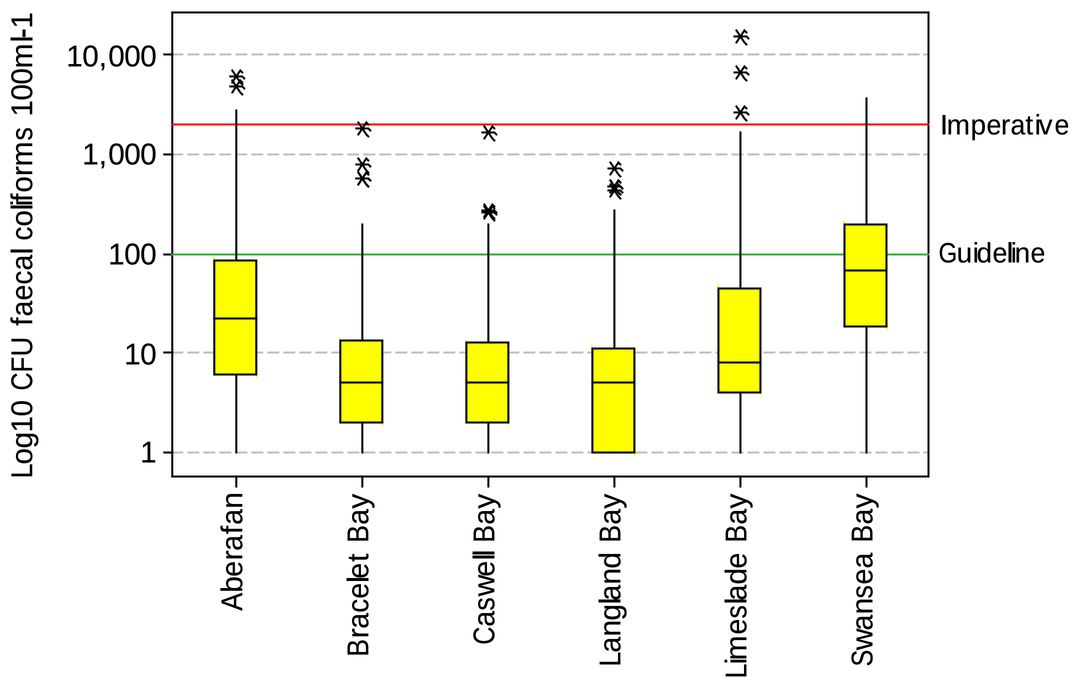


Figure XI.2 Box-and-whisker plots of levels of faecal coliforms in designated Bathing Waters in Swansea Bay for the period 1999–2009.
Data from the Environment Agency (2010).

Shellfish Waters

There are three Shellfish Waters in Swansea Bay designated under the Directive 2006/113/EC (European Communities, 2006b): Swansea Bay West, Swansea Bay East and Swansea Bay South (Figure XI.1).

Table XI.3 shows summary statistics for levels of faecal coliforms in surface waters at Swansea Bay (West) during the period January 2000–November 2009. Median levels of the microbiological indicator remained relatively low during the period 2005–2007.
Sampling effort at this shellfish water has been low in recent years. Median levels of the microbiological indicator were considerably high during the period 2000–2004 and in 2008.

Table XI.3 Summary statistics of levels of faecal coliforms (CFU 100ml^{-1}) in Swansea Bay (West) for the period 2000−2009.

Year	Minimum	Maximum	Median	Number of samples
2000	<10	430	96	8
2001	<10	405	16	12
2002	<10	924	12	12
2003	10	192	36	5
2004	<2	94	46	4
2005	<2	219	7	4
2006	<2	63	7	4
2007	<2	10	6	4
2008	24	369	71	4
2009	<2	114	3	1

Table XI.4 shows summary statistics for levels of faecal coliforms in shellfish flesh at Swansea Bay (East) and Swansea Bay (South). No comparisons can be made between these sites due to the low sampling effort at Swansea Bay (East) over the years.

Median levels of faecal coliforms at Swansea Bay (South) have been consistently equivalent to class B over the years.

Table XI.4 Summary statistics of levels of faecal coliforms (CFU 100g^{-1}) in shellfish flesh in two designated Shellfish Waters in Swansea Bay for the period 2000−2009.

	Swansea Bay (East)				Swansea Bay (South)			
Year	Minimum	Maximum	Median	Number of samples	Minimum	Maximum	Median	Number of samples
2000	-	-	-	0	-	-	-	0
2001	-	750	-	1	-	1,300	-	1
2002	-	1,700	-	1	310	2,400	500	3
2003	-	-	-	0	20	430	110	3
2004	-	-	-	0	290	1,700	1,300	3
2005	-	-	-	0	160	750	405	4
2006	-	-	-	0	750	3,500	1,300	4
2007	-	-	-	0	50	2,400	255	4
2008	10	490	490	3	80	1,300	700	7
2009	330	2,800	1,300	4	20	1,100	360	4

Data from the Environment Agency (2010).
All samples collected under wet weather conditions.

APPENDIX XII
MICROBIOLOGICAL DATA: SHELLFISH FLESH

The programme of work drawn up by the Environment Agency for the purposes of giving effect to Article 5 of the Shellfish Waters Directive 2006/113/EC lists the proposed actions to Dwr Cymru Welsh Water (DCWW) continuous and intermittent discharges that have or once had the potential to influence the microbial quality of the Shellfish Water (Environment Agency, 2009).

Cumulative sum analyses (CUSUM) were conducted for Shellfish Hygiene monitoring data to identify any step changes in *E. coli* concentrations in bivalve molluscs[8] that could be associated with any improvements to the sewerage system.

One step change was detected in *E. coli* contamination in mussels from Swansea Bay S (B037I) in January 1999. The geometric mean of *E. coli* decreased from 1,308 before the step change to 303 after the change.

This improvement in the quality of mussels is temporally coincident with the implementation of secondary treatment and UV disinfection in Swansea STW (completed in 1999). Therefore, analyses of historical microbiological data are only relevant and confined to the period following this improvement.

Table XII.1 shows summary statistics for levels of *E. coli* in bivalves from thirteen current and non-current RMPs.

The sampling effort for Native oysters at Swansea Bank beds has been consistent over the years. In contrast, there has not been a consistent sampling effort for mussels and there are very few beds with a robust series of data that could be used for comparison purposes.

The highest *E. coli* results (MPN = 16,000 $100g^{-1}$ FIL) were obtained in wild mussels from Knab Rock and Mumbles (Swansea Bay South).

The similarities in terms of central tendencies of the levels of *E. coli* in wild mussels from Mumbles (Swansea Bay South) and farmed mussels from Swansea Bay S should be highlighted. Bearing in mind the differences in terms of proximity to pollution sources and differences in the overall bathymetric profile between these beds, this suggests that the currently established RMPs for this species may not adequately reflect the spatial variation of contamination across the western part of the bay.

Of relevance is also the fact that *E. coli* results for native oysters from Swansea Bank beds 1,2 and 3 have not exceeded the class B threshold (MPN ≤ 4,600 $100g^{-1}$ FIL) since 2000. The 50^{th} percentile of *E. coli* concentrations in native oysters from these beds is below the class A threshold (MPN≤230 *E. coli* $100g^{-1}$ FIL) (Figure XII.1). The distribution of these datasets is relatively symmetric, as indicated by the similar sizes of top and bottom box halves and similar sizes of whiskers.

[8] Only datasets for beds in which there are more than 50 results were assessed.

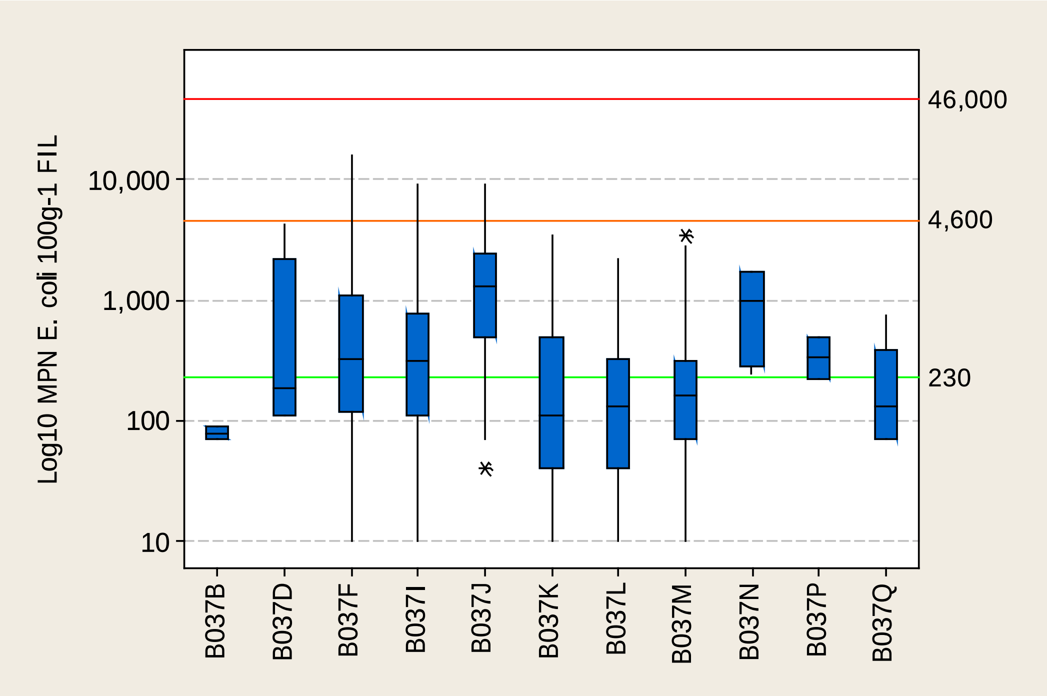


Figure XII.1 Box-and-whisker plots of levels of* E. coli *in bivalves from eleven RMPs in Swansea Bay for the period January 1999–March 2010.

Table XII.1 Summary statistics of* E. coli *levels in bivalve molluscs from thirteen RMPs in Swansea Bay for the period January 1999–March 2010.

RMP	Bed name	Species	n	Date of first sample	Date of last sample	MPN *E. coli* 100g^{-1} FIL Min.	Max.	GM	Median
B037J	Crymlyn Burrows	*C. edule*	24	11/01/99	09/09/03	40	9,100	992	1,300
B037F	Knab Rock	*Mytilus* spp.	89	17/10/01	17/03/10	<20	16,000	395	330
B037N	Knab Rock	*C. edule*	6	24/04/02	09/10/02	250	1,700	1,025	767
B037B	Mumbles	*O. edulis*	2	25/02/99	04/03/99	70	90	79	80
B037P	Mumbles	*Mytilus* spp.	2	21/02/01	07/03/01	220	500	332	360
B037G	Mumbles (Swansea Bay South)	*Mytilus* spp.	49	20/05/03	16/03/10	<20	16,000	310	310
B037Q	Several Order A	*Mytilus* spp.	6	19/05/04	12/10/05	70	750	165	135
B037K	Swansea Bank 1	*O. edulis*	64	13/11/00	23/03/10	<20	3,500	124	110
B037L	Swansea Bank 2	*O. edulis*	59	20/11/00	23/03/10	<20	2,200	116	130
B037M	Swansea Bank 3	*O. edulis*	61	13/11/00	23/03/10	<20	3,500	144	160
B037I	Swansea Bay S	*Mytilus* spp.	137	11/01/99	17/03/10	<20	9,200	333	310
B037R	Woodstown Bay/Several Order D	*Mytilus* spp.	1	20/09/07	-	5,400	-	-	-
B037D	Swansea Bay N	*Mytilus* spp.	4	27/01/99	20/06/00	110	4,300	356	210

n - number of samples.
GM - geometric mean.
FIL - flesh and intravalvular liquid.

SEASONALITY OF *E. COLI* IN BIVALVE MOLLUSCS

All bivalve molluscs in Swansea Bay are subject to year-round classification. This section presents the results of an assessment of the seasonal variation in levels of *E. coli* in currently classified mussel and native oyster beds.

Data from the Shellfish Hygiene monitoring programme were amalgamated by season, considering spring (March–May), summer (June–August), autumn (September–November) and winter (December–February). Side-by-side box-and-whisker plots were computed to summarise the distribution of these datasets. All analyses were conducted for datasets with more than 50 results.

Figures XII.2–XII.3 show that the 75th percentile of seasonal *E. coli* concentrations in mussels and native oysters are below the class B threshold (MPN≤4,600 *E. coli* 100g^{-1} FIL).

Figure XII.2 shows that median (50th percentile) levels of contamination in mussels tend to increase between summer and winter. These differences in seasonal *E. coli* contamination are more pronounced at Mumbles and less pronounced at Swansea Bay South, although these are less than 1 Log_{10}.

The symmetry of *E. coli* data from Swansea Bay S and Knab Rock is highlighted by the similar sizes of top and bottom box halves and relatively similar lengths of whiskers.

Figure XII.3 shows fairly stable seasonal distributions of *E. coli* data in native oysters from Swansea Bank 1 and Swansea Bank 2 during the period spring–autumn and lower levels of contamination detected during the winter. Median levels of the microbial indicator in oysters from these beds are above the class A threshold (MPN≤230 *E. coli* 100g^{-1} FIL) during the whole year. Native oysters from Swansea Bank 3 show higher median levels of *E. coli* contamination in spring and autumn relative to those in summer and winter. However, as observed for mussels, these are minor differences that do not support a recommendation for a modified sampling frequency relative to that being used to date.

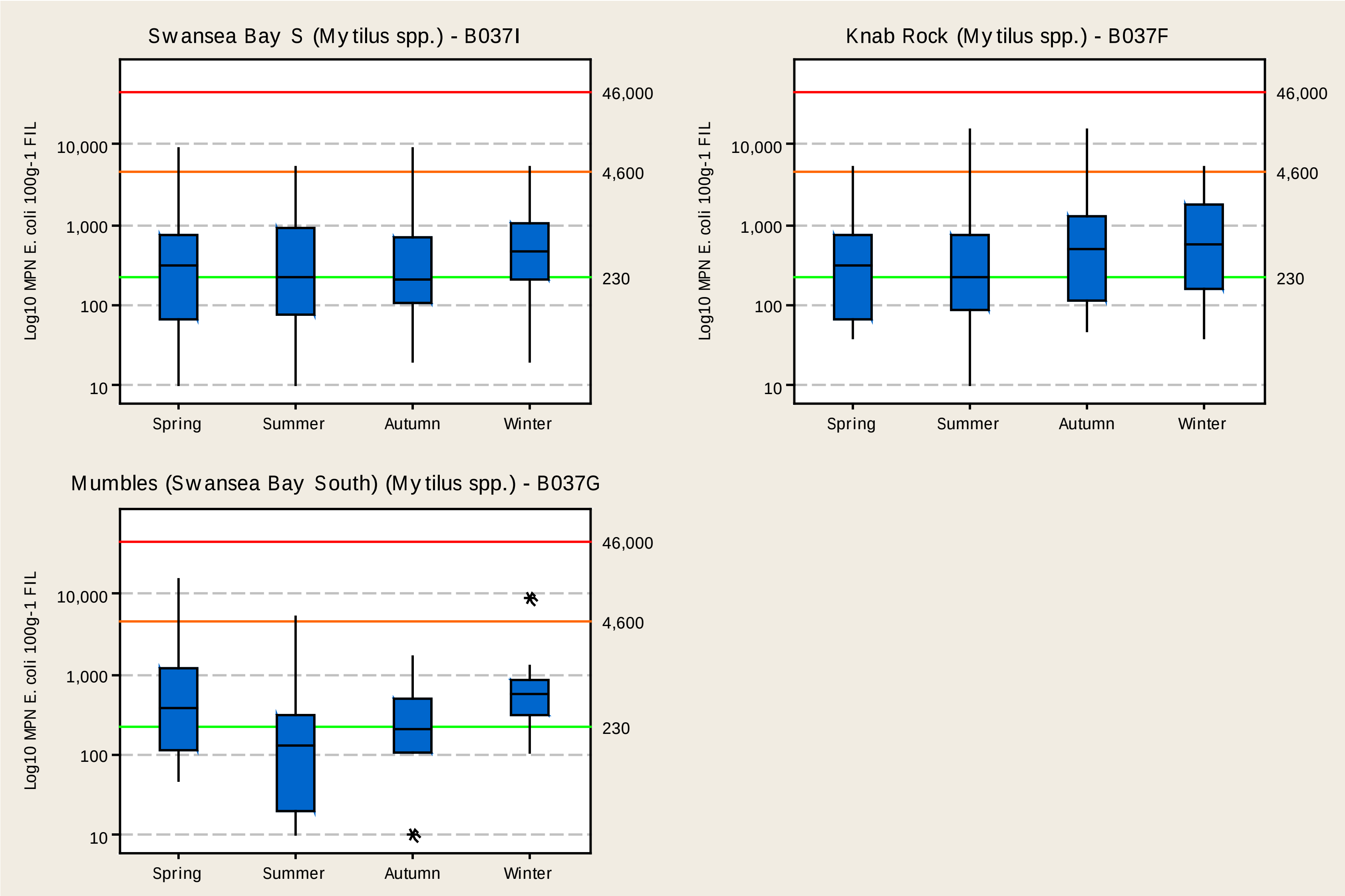


Figure XII.2 Box-and-whisker plots of seasonal variation of E. coli **levels in mussels from three RMPs in Swansea Bay.**

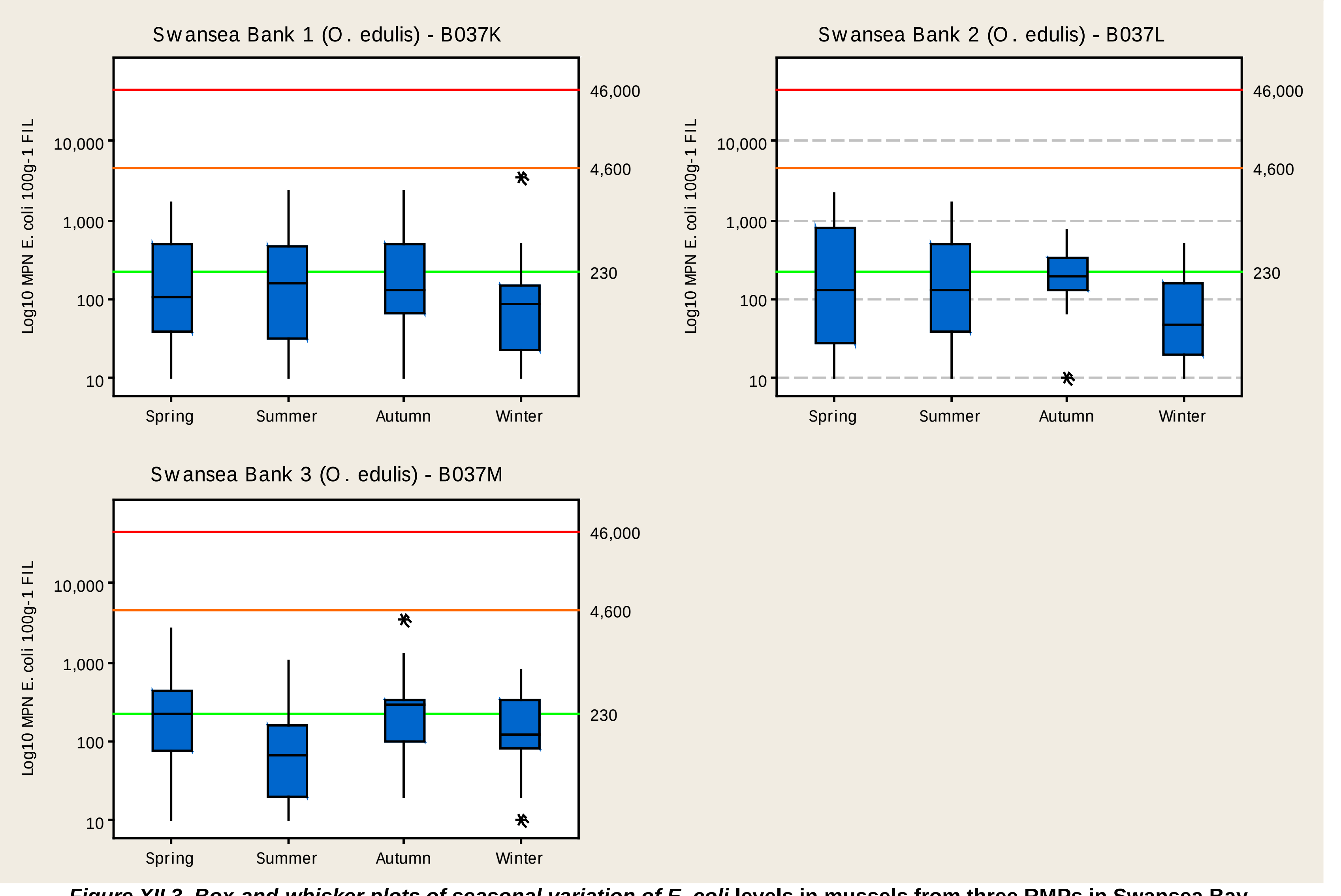


Figure XII.3 Box-and-whisker plots of seasonal variation of E. coli **levels in mussels from three RMPs in Swansea Bay.**

LEVELS OF *E. COLI* AND RAINFALL

The association between levels of *E. coli* in bivalves sampled from six current RMPs in Swansea Bay and rainfall levels in the catchment was examined for the period January 2000–March 2010.

Spearman's rank correlation coefficient (*rho*) [9] was used to estimate correlations between MPN of *E. coli* 100g^{-1} FIL and daily/cumulative rainfall monitored at two gauging stations (Figure II.1).

Significant positive relationships were detected between daily and cumulative rainfall and levels of the indicator in wild mussels from Knab Rock and Swansea Bay S and native oysters from Swansea Bank 1 and Swansea Bank 2. Statistically significant correlations between variables varied according to the monitoring point and the time of sampling relative to the rainfall event (Table XII.2).

The highest significant correlation coefficient was detected when mussels from Knab Rock were sampled after 7 days of cumulative rainfall.

A two dimensional scatterplot of levels of rainfall and *E. coli* in mussels from this RMP with superimposed LOcally WEighted Scatterplot Smoothing (LOWESS) for the maximum correlation coefficient is shown in Figure XII.4. This plot indicates that the relationship between the two variables is linear within the range of rainfall values below 30mm.

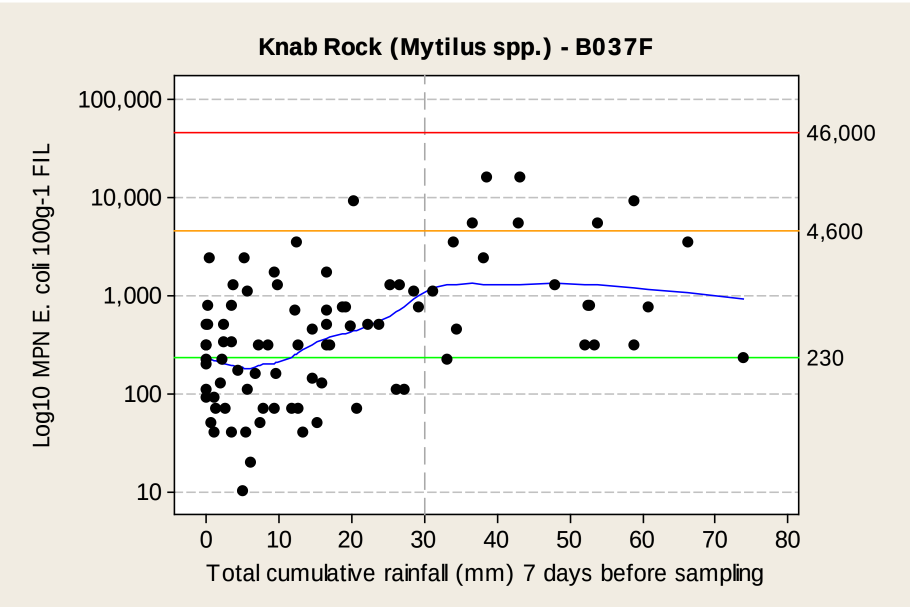


Figure XII.4 Scatterplot of rainfall recorded at Victoria Park gauging station and levels of E. coli in mussels from Knab Rock (Swansea Bay).

[9] This statistical test is usually defined as the linear correlation coefficient determined on the ranks of the data, in which differences between data values ranked further apart are given more weight (Helsel and Hirsch, 2002).

Table XII.2 Spearman's rho coefficients between rainfall recorded at two gauging stations and MPNs of* E. coli *100g^{-1} FIL in bivalves from six monitoring points in Swansea Bay during the period January 2000−March 2010.

Rainfall	MPN *E. coli* 100g^{-1} FIL					
Gauging station: Victoria Park	Knab Rock (B037F) (n=88)	Mumbles (Swansea Bay South) (B037G) (n=48)	Swansea Bay S (B037I) (n=113)	Swansea Bank 1 (B037K) (n=63)	Swansea Bank 2 (B37L) (n=58)	Swansea Bank 3 (B337M) (n=60)
Time	*Mytilus* spp.	*Mytilus* spp.	*Mytilus* spp.	*O. edulis*	*O. edulis*	*Mytilus* spp.
Daily rainfall						
Day of sampling	0.308*	0.166	0.041	0.004	0.203	-0.003
-1 day	0.199	0.221	0.072	0.205	0.230	0.214
-2 days	0.301*	0.078	0.154	0.143	0.255	-0.059
-3 days	0.167	0.017	0.246*	0.344*	0.386*	0.176
-4 days	0.349*	-0.213	0.241*	0.187	0.229	0.027
-5 days	0.343*	-0.065	0.190	0.167	0.100	0.093
-6 days	0.177	-0.016	0.197*	-0.042	-0.011	0.209
-7 days	0.146	0.090	0.086	-0.058	0.078	0.176
Cumulative rainfall						
-2 days	0.284*	0.189	0.068	0.112	0.214	0.113
-3 days	0.355*	0.224	0.145	0.109	0.272*	0.055
-4 days	0.355*	0.214	0.199*	0.165	0.308*	0.102
-5 days	0.409*	0.158	0.225*	0.147	0.299*	0.052
-6 days	0.441*	0.087	0.267*	0.148	0.258	0.035
-7 days	0.444*	0.065	0.277*	0.133	0.210	0.069
Gauging station: Resolven						
Daily rainfall	(n=85)	(n=45)	(n=108)	(n=60)	(n=55)	(n=57)
Day of sampling	0.200	0.133	0.010	0.066	0.218	0.079
-1 day	0.250*	0.062	0.161	0.213	0.154	0.210
-2 days	0.249*	0.014	0.176	0.208	0.211	0.085
-3 days	0.210	-0.205	0.235*	0.320*	0.338*	0.275*
-4 days	0.307*	-0.145	0.218*	0.090	0.192	0.051
-5 days	0.296*	-0.032	0.202*	0.164	0.143	0.224
-6 days	0.184	0.160	0.178	-0.020	0.010	0.268*
-7 days	0.074	0.172	0.062	0.030	0.097	0.179
Cumulative rainfall						
-2 days	0.240*	0.108	0.106	0.142	0.186	0.157
-3 days	0.330*	0.127	0.172	0.195	0.232	0.109
-4 days	0.352*	0.064	0.212*	0.304*	0.296*	0.187
-5 days	0.398*	0.091	0.249*	0.245	0.294*	0.152
-6 days	0.419*	0.055	0.268*	0.237	0.264	0.162
-7 days	0.437*	0.124	0.285*	0.213	0.211	0.212

** Statistically significant.*
Values <20 E. coli MPN 100g^{-1} were assigned values of 10 E. coli MPN 100g^{-1}

No statistically significant correlations were found between levels of *E. coli* in mussels from Mumbles (Swansea Bay South) and rainfall.

These results suggest that mussels and native oysters commercially harvested in the western part of the bay are vulnerable to contamination of faecal origin from local diffuse sources and/or the effect of rainfall-dependent discharges.

The fact that statistically significant correlations were obtained for the gauging station in the upper catchment (Resolven) suggests that a significant proportion of microbial contamination accumulated by bivalves may have its origin at the headwaters.

LEVELS OF *E. COLI* AND RIVER FLOWS

The association between levels of *E. coli* in bivalves sampled from six current RMPs in Swansea Bay and river flows in the rivers Neath and Tawe was examined for the period January 2000–March 2010.

Spearman's rank correlation coefficient (*rho*) [10] was used to estimate correlations between MPN of *E. coli* 100g^{-1} FIL and total daily rainfall monitored at two gauging stations (Figure II.1).

Table XII.2 shows consistent statistically significant positive correlations between levels of *E. coli* in mussels from Knab Rock, Mumbles (Swansea Bay South), Swansea Bay S and Swansea Bank 3 and water levels in the rivers Neath and Tawe.

Significant correlations were also found for native oysters from Swansea Bank 1 when the sampling occasion occurred 2–3 days after the increase in river flows. No statistically significant positive correlations were found for native oysters from Swansea Bank 2.

The highest correlation coefficient was obtained for wild mussels from Knab Rock. The scatterplot of river flows and *E. coli* in mussels from this RMP for the maximum correlation coefficient shown in Figure XII.5 indicates a fairly linear relationship between the minimum flow level recorded (1.3m^3 s^{-1}) and 27 m^3 s^{-1}. Furthermore, most of the *E. coli* results within the range for class C (MPN≤46,000 100g^{-1} FIL) were detected when river flows were exceeding the mean flow.

Overall, these results suggest that the rivers Neath and Tawe constitute important routes of contamination of faecal origin influencing the quality of mussels.

[10] This statistical test is usually defined as the linear correlation coefficient determined on the ranks of the data, in which differences between data values ranked further apart are given more weight (Helsel and Hirsch, 2002).

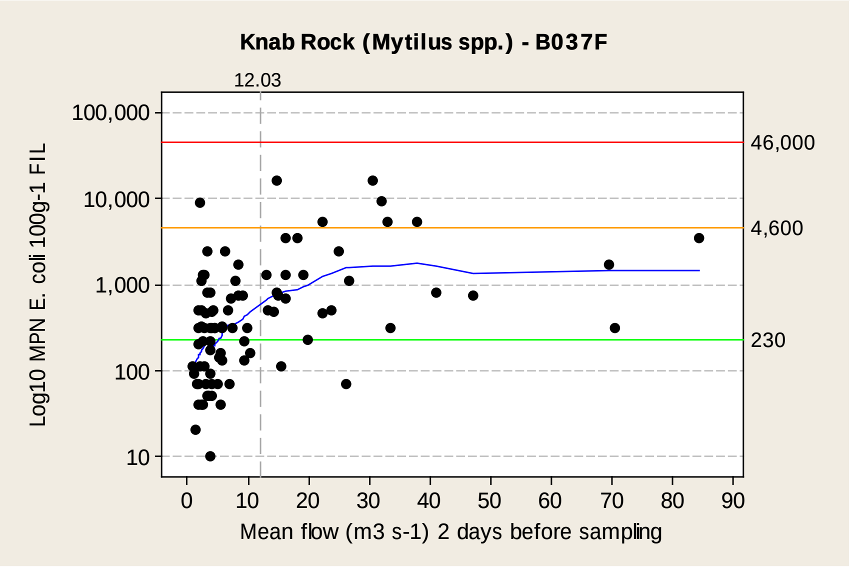


Figure XII.5 Scatterplot of river flows in the River Tawe at Ynystanglws and levels of E. coli in mussels from Knab Rock (Swansea Bay).

Table XII.2 Spearman's rho coefficients between river flows in the rivers Neath and Tawe recorded at two gauging stations and MPNs of* E. coli *100g^{-1} FIL in bivalves from six monitoring points in Swansea Bay during the period January 2000−March 2010.

Rainfall	MPN *E. coli* 100g^{-1} FIL					
Gauging station: River Neath (Resolven)	Knab Rock (B037F) (n=86)	Mumbles (Swansea Bay South) (B037G) (n=45)	Swansea Bay S (B037I) (n=111)	Swansea Bank 1 (B037K) (n=63)	Swansea Bank 2 (B37L) (n=58)	Swansea Bank 3 (B337M) (n=60)
Time	*Mytilus* spp.	*Mytilus* spp.	*Mytilus* spp.	*O. edulis*	*O. edulis*	*Mytilus* spp.
Daily rainfall						
Day of sampling	0.431*	0.360*	0.284*	0.211	0.131	0.302*
-1 day	0.453*	0.360*	0.309*	0.237	0.168	0.320*
-2 days	0.479*	0.316*	0.336*	0.305*	0.234	0.341*
-3 days	0.395*	0.285	0.285*	0.204	0.156	0.312*
-4 days	0.374*	0.297*	0.290*	0.123	0.090	0.264
-5 days	0.337*	0.356*	0.268*	0.075	0.011	0.272*
-6 days	0.272*	0.425*	0.224*	0.062	0.052	0.314*
-7 days	0.266*	0.404*	0.237*	0.061	0.026	0.226
Cumulative rainfall						
-2 days	0.439*	0.364*	0.294*	0.232	0.151	0.309*
-3 days	0.457*	0.353*	0.312*	0.256*	0.176	0.306*
-4 days	0.456*	0.350*	0.318*	0.244	0.165	0.303*
-5 days	0.457*	0.350*	0.327*	0.230	0.167	0.300*
-6 days	0.451*	0.345*	0.331*	0.198	0.146	0.297*
-7 days	0.440*	0.358*	0.331*	0.187	0.141	0.312*
Gauging station: River Tawe (Ynystanglws)						
Daily rainfall	(n=89)	(n=45)	(n=114)	(n=64)	(n=59)	(n=61)
Day of sampling	0.425*	0.351*	0.247*	0.211	0.143	0.246
-1 day	0.470*	0.304*	0.295*	0.225	0.162	0.294*
-2 days	0.503*	0.264	0.325*	0.310*	0.236	0.331*
-3 days	0.414*	0.215	0.286*	0.192	0.129	0.280*
-4 days	0.387*	0.262	0.252*	0.135	0.112	0.241*
-5 days	0.350*	0.315*	0.241*	0.108	0.017	0.287*
-6 days	0.279*	0.354*	0.187*	0.079	0.070	0.322*
-7 days	0.277	0.365	0.219	0.051	0.025	0.236
Cumulative rainfall						
-2 days	0.455*	0.310*	0.277*	0.235	0.160	0.276*
-3 days	0.474*	0.304*	0.295*	0.246*	0.172	0.296*
-4 days	0.477*	0.296*	0.298*	0.246*	0.158	0.288*
-5 days	0.472*	0.290*	0.304*	0.243	0.174	0.290*
-6 days	0.471*	0.304*	0.307*	0.211	0.132	0.275*
-7 days	0.461*	0.320*	0.304*	0.208	0.138	0.294*

** Statistically significant.*
Values <20 E. coli MPN 100g^{-1} were assigned values of 10 E. coli MPN 100g^{-1}.

APPENDIX XIII
MICROBIOLOGICAL DATA: BACTERIOLOGICAL SURVEYS

The Environment Agency considers leakage from private sewers or unauthorised connection of private sewers to stormwater drainage a significant source of faecal contamination impacting on the designated Shellfish Waters (Environment Agency, 2008, 2009, 2009a).

The City and County of Swansea (CCS), in partnership with the Environment Agency and Dŵr Cymru Welsh Water have investigated contamination sources affecting the bathing water quality of Swansea Bay. The first area of investigation identified is that being served by the outfall East of Lilliput Lane (Figure XIII.1). Results indicated that a number of properties (7% of the properties in the locality) were "misconnected", i.e. foul waste was found to be connected to the public surface water sewer rather than the foul water sewer (Environment Agency *et al.*, 2010).

Further investigations focused on significant storm water outlets discharging into the beach in order to ascertain a long-term strategy for reducing the levels of contamination in Swansea Bay. The experimental protocol included the collection of water samples from 19 outlets and streams receiving storm water discharges further upstream for quantification of faecal indicator microorganisms. These sites are shown in Figure XIII.1. Table XIII.1 shows ranked *E. coli* concentrations obtained for these samples.

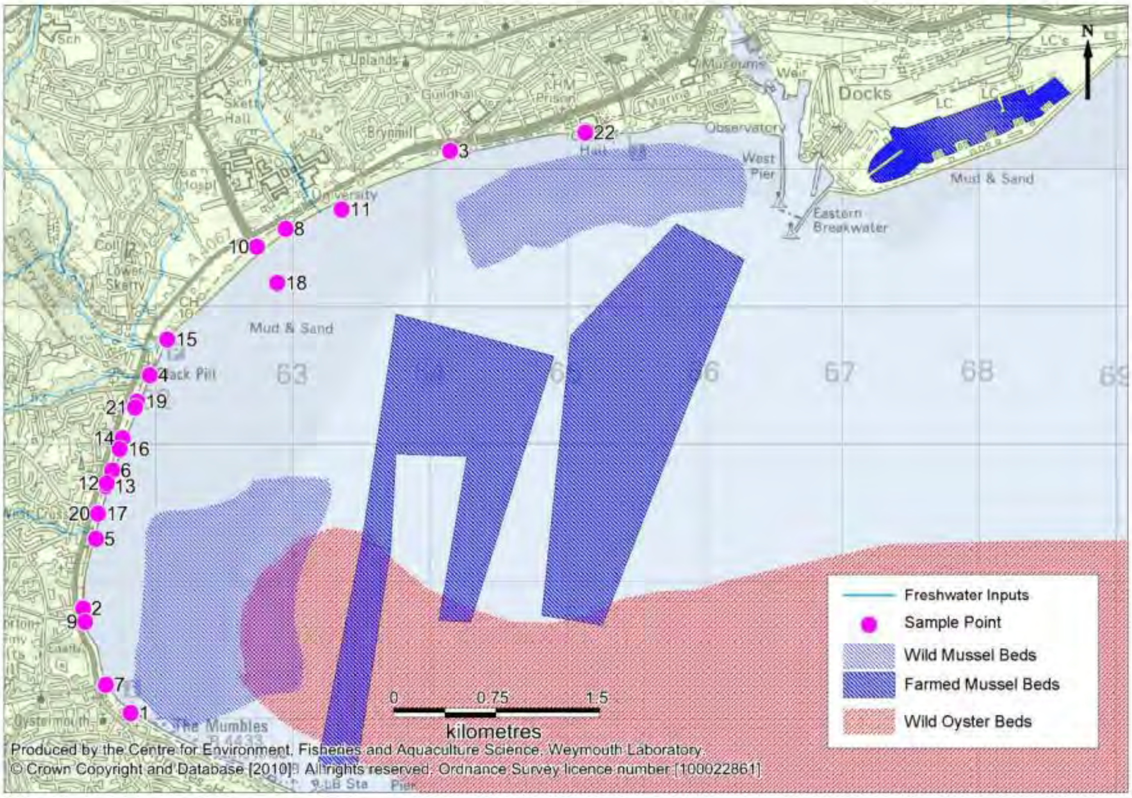


Figure XIII.1 Location of sites sampled by the City and County of Swansea during bacteriological investigations on significant storm water outlets discharging to Swansea Bay.

The highest concentrations of the microbiological indicator are associated with samples collected in the western part of the bay along the stretch of coast between West Cross and The Mumbles. Other very significant inputs of *E. coli* contamination occur at Black Pill, Lilliput Lane and, to a lesser extent, sites in the vicinity of Swansea University and Brynmill.

Table XIII.1 Concentrations of* E. coli *in water samples collected on 17 March 2010 in significant storm water outlets and streams discharging to Swansea Bay.

Figure XIII.1 ID	Sampling point	CFU *E. coli* 100ml^{-1}
1	Opposite Cornwall Place	14,800
2	Opposite Norton Avenue	14,800
3	Patti pavilion short	8,400
4	Culvert by Texaco garage Black Pill	6,300
5	West Cross Inn - Washing House Brook	3,200
6	Opposite Lilliput Lane	2,600
7	By Square Café in car park (opposite Newton Road)	1,600
8	Stream opposite 'Pub on the Pond'	1,600
9	Opposite Norton Road	1,500
10	Opposite Sketty Lane	1,200
11	Between Brynmill Lane and University entrance	1,100
12	c. 20–30m North of TA entrance	1,000
13	Opposite TA entrance	700
14	c. 90m North Llwynderw Drive (60m North)	700
15	Clyne	700
16	Opposite Llwynderw Drive	500
17	c. 12" pipe opposite Fairwood Road	420
18	Patti pavilion long	50
19	c. 250m South of Mayals Road	20
20	c. 3" pipe opposite Fairwood Road	0
21	c. 300 South of Mayals Road	0
22	Civic Centre steps (West side)	0

Data supplied by Adrian Johnson and Andrew Cook (City and County of Swansea).

Tables XIII.2 and XIII.3 summarise results of bacteriological investigations undertaken by the Environment Agency for time periods February 2001–October 2009 and May 2006–September 2009. The locations of sites sampled are shown in Figure XIII.2. The spatial pattern of contamination suggested by these results is consistent with that discussed above, i.e. areas at West Cross, Norton and Mumbles contribute significantly to loadings of FIO to the bay.

Microbial source tracking (*Bacteroidales* DNA analysis) results from 13 samples collected from 26 sites along the foreshore between Mumbles and the Tawe Estuary on 22 July 2009 all suggested human (i.e. sewage related) derived pollution sources (Wyer and Kay, in prep.).

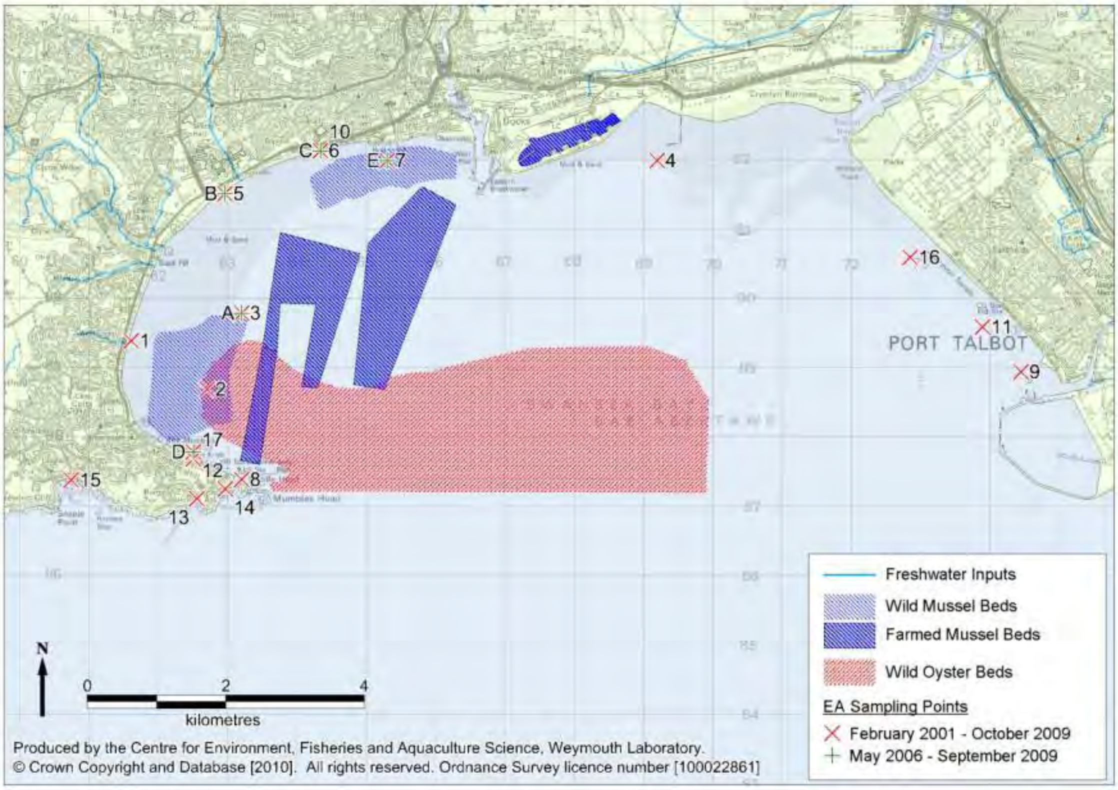


Figure XIII.2 Location of sites sampled by the Environment Agency during bacteriological investigations in Swansea Bay.

Table XIII.2 Results of bacteriological surveys undertaken by the Environment Agency in Swansea Bay during the period February 2001–October 2009.

Figure XIII.1 ID	Site	Easting	Northing	n	Total coliforms (CFU 100ml^{-1}) Minimum	Maximum	Median	Geometric mean
1	High Water Mark (West Cross, S)	261600	189400	20	37	11,000	600	582
2	Swansea Bay (opposite Norton Road)	262700	188700	20	22	5,400	515	368
3	Swansea Bay (opposite Black Pill)	263200	189800	41	9	18,400	450	379
4	Jersey Marine (West)	269200	192000	84	<10	180,000	300	266
5	Swansea Bay (100m E of Clyne)	262955	191517	20	58	16,700	240	310
6	Swansea Bay (at Slipway) (May 2000–September 2009)	264336	192137	203	5	7,300	146	130
7	Swansea Bay	265300	192000	40	9	10,200	100	167
8	Swansea Bay (Mumbles Head Pier)	263200	187400	20	9	600	98	84
9	Aberavon Beach (East)	274450	188950	42	<10	8,900	91	111
10	Swansea Bay (at slipway) (May 2009–September 2009)	264336	192137	103	<2	9,600	79	76
11	Aberavon Beach (at slipway)	273900	189600	210	<10	11,291	45	47
12	Swansea Bay (Mumbles Knab Rock)	262500	187800	40	2	450	34	28
13	Limeslade Bay	262546	187124	205	<10	17,400	27	30
14	Bracelet Bay, Mumbles Head	262964	187262	221	<10	2,800	5	12
15	Langland Bay (West)	260732	187391	202	<10	884	5	11
16	Aberavon Beach (West)	272850	190600	1	574	-	-	-
17	Swansea Bay (Yacht Club Slipway)	262500	187700	1	<10	-	-	-

Data supplied by the Environment Agency.

Table XIII.3 Results of bacteriological surveys undertaken by the Environment Agency in Swansea Bay during the period May 2006–September 2009.

Figure XIII.1 ID	Site	Easting	Northing	n	Presumptive *E. coli* (CFU 100ml^{-1}) Minimum	Maximum	Median	Geometric mean
A	Swansea Bay (opposite Black Pill)	263200	189800	80	<2	30,000	280	262
B	Swansea Bay (100m E of Clyne)	262955	191517	60	6	11,600	170	163
C	Swansea Bay (at slipway)	264336	192137	206	<2	14,000	96	93
D	Swansea Bay (Mumbles Knab Rock)	262500	187800	80	1	3,300	29	37
E	Swansea Bay	265300	192000	80	4	4,300	73	85

Data supplied by the Environment Agency.

APPENDIX XIV
SHORELINE SURVEY

Date (time): 16 March 2010 (13:30−17:00 GMT); 17 March 2010 (09:00–13:00)
Applicant: Colin Thomas (Thomas Vivian Ltd)
Cefas Officers: Carlos Campos, Lesley Bickerstaff
Local Enforcement Authority Officer: Bill Arnold (Swansea Bay Port Health Authority).

Objectives: (a) confirm the existence of pollution sources identified during the desk study likely to constitute sources of microbiological contamination for the mussel beds; (b) identify any additional pollution sources in the area; and (c) confirm the extent of the new production area.

Area surveyed: boat survey was conducted in the western part of King's Dock and Queen's Dock. This was followed by shoreline walks in parts of Swansea Bay, between The Mumbles and Swansea Marina (Figure XIII.2a and XIII.2b).

Tides: the predicted times and heights of high and low waters and tidal curve on the day of the survey are given in Table XIII.1 and Figure XIII.1.

Table XIII.1 Predicted high and low water times and heights for Swansea on 16–17 March 2010.

	Time (height)	
	16th March 2010	17th March 2010
Low Water	00:28 (1.1m)	00:59 (1.1m)
High Water	06:44 (9.2m)	07:15 (9.2m)
Low Water	12:43 (1.0m)	13:13 (1.0m)
High Water	18:56 (9.1m)	19:26 (9.1m)

Predicted heights are in metres above Chart Datum.
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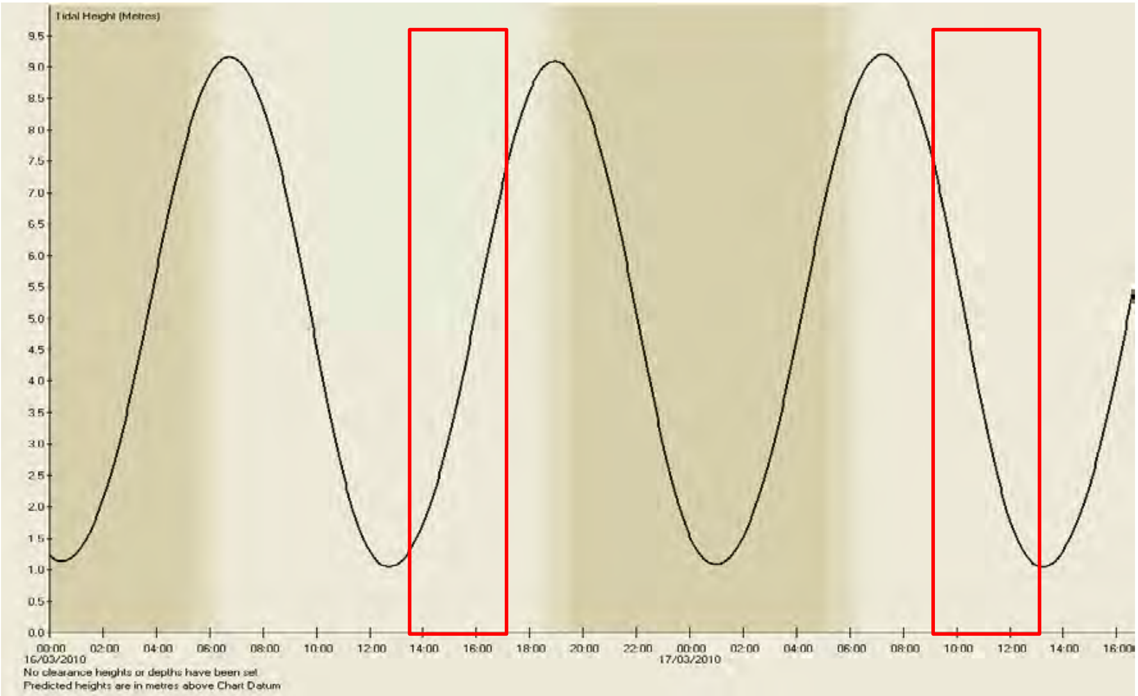

Figure XIII.1 Tidal curve at Swansea on 16–17 March 2010.
Red boxes indicate periods when shoreline surveys were carried out.
Times given in local time (GMT). Predicted heights are in metres above Chart Datum
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Figure XIII.2a Location of sites sampled in Swansea on 16–17 March 2010.

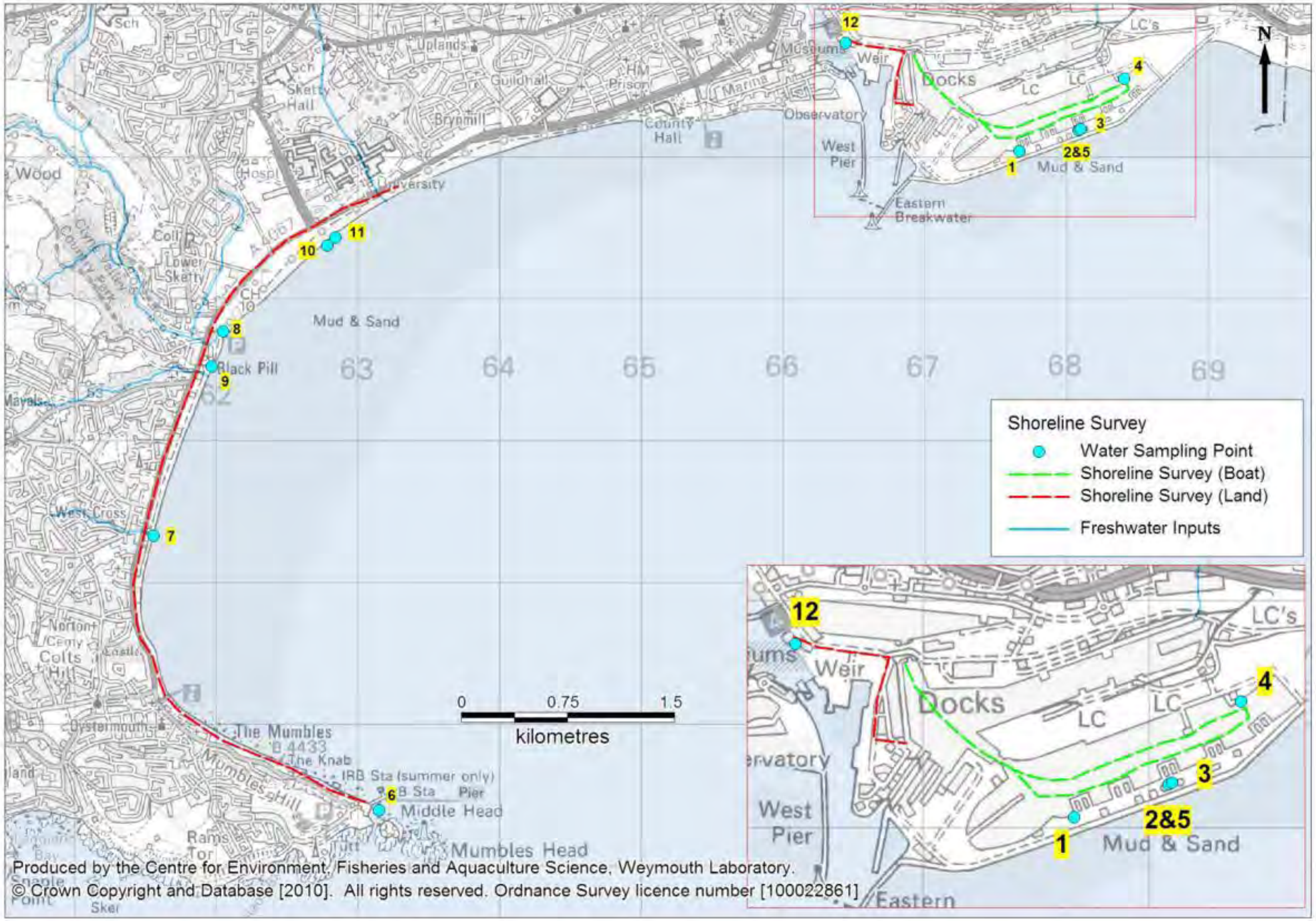

Figure XIII.2b Location of sites sampled in Swansea on 16–17 March 2010.
Red lines indicate areas where shoreline walks were carried out. Green line indicates areas where boat survey was carried out.

Table XIII.2 summarises information relevant to the production site and observations made during the survey.

Table XIII.2 Site data and observations and results made during the shoreline survey.

Production area	Swansea Bay
Existing beds and species classified	Swansea Bay - Southern Beds (*Mytilus* spp.)/ Swansea Bank (*O. edulis*)
Area of bed	Queen's Dock (*Mytilus* spp.): 0.30km^2 (proposed) Swansea Bank (*O. edulis*): 10.19km^2 Several Order (*Mytilus* spp.): two beds (0.40km^2 + 3.26km^2)
SWD Flesh Point	SS 6290 8930 (Swansea Bay West) SS 6940 8880 (Swansea Bay East)
SWD Water Point	SS 6400 9000 (Swansea Bay West) SS 7035 8804 (Swansea Bay East) SS 6300 8000 (Swansea Bay South)
BWD Sampling point(s)	SS 6440 9211 (Swansea Bay) SS 6300 8711 (Bracelet Bay) SS 6250 8701 (Limeslade Bay)
Applicant's details	Colin Thomas (Thomas Vivian Ltd) Nant-Y-Wrach Farm, Llanrhidian, Gower, Swansea. SA3 1EU Tel: 01792 391584 Fax: 01792 391584
Map/Chart references	Admiralty Chart 1161 (Swansea Bay) OS Explorer 165 (Swansea/Abertawel; Neath and Port Talbot/Castell Nedd a Phort Talbot)

Weather forecast	Met Office (Inshore Waters) (15 March 2010) Wind: variable 3 or less, becoming southerly or south-easterly 3 or 4, increasing 5 or 6 in west later. Sea state: smooth or slight, increasing moderate. Weather: mainly fair, rain or drizzle later. Visibility: moderate or good, occasionally poor at first close inshore.
Air temperature (recorded)	16 March: 15.4°C 17 March: 11°C
Wind (recorded)	16 March: 16 km/h 17 March: 0 km/h
Precipitation	None at time of survey
Rivers/Streams/springs	Springs at NE corner of Prince of Wales Dock (not sampled; discharge point below water level) Springs at Norton (Oystermouth Castle) Springs at West Cross (sampled) Clyne River (sampled) Springs at Brynmill (boating lake) (sampled) Springs (Swansea University) (sampled) River Tawe (Afon Tawe) (sampled)
River flows (spot readings)	Springs at West Cross: 1.027m s^{-1} Clyne River: 0.297m s^{-1}; 0.619m s^{-1} Springs at Brynmill (boating lake): 0.112m s^{-1}; 0.369 m s^{-1}
Significant sewage discharges (Cefas database)	Afan STW Swansea STW (observed; marine outfall discharges directly to the middle of Swansea Bay approximately 3.7km offshore in 5.3m of water at Chart Datum) Ystradgynlais STW Trebanos STW
Discharges (observed)	No significant point discharges were observed within Queen's Dock itself.
Boats/port	One ship moored at Rose Wharf (King's Dock) (Figure XIII.3) Two ships moored at A&B Shed Wharf (King's Dock) Two ships moored at Scherzer Passage (King's Dock) It was noted that the Prince of Wales Dock is used as a marina and no longer serves commercial purposes.
Dogs	Two dogs at Westcross slipway (Figure XIII.4) Two dogs on beach at Brynmill
Other animals	Flocks of seabirds at Jetty No. 5 Approx. 30 Cormorants at north shores of Queen's Dock (Figure XIII.5) Flocks of seabirds on beach at the mouth of the Clyne River
Samples taken	See table XIII.2
Bivalve harvesting activity	None at time of survey. Mussel shells at Jetty No. 5 (Figure XIII.6)
Sewage related debris	Dozens of cotton buds along Swansea Beach shoreline from the mouth of Clyne River to Boating Lake (Figure XIII.7)
Other debris	Plastics and cans along the shores within Queen's Dock between Jetty no. 5 and Coastal Tanker Jetty (Figure XIII.8)

Water appearance	Clear within King's and Queen's Docks. Turbid in Swansea Bay. Turbid/brown in Clyne River Hydrocarbons film in surface waters inside terminal tank at Jetty No 3 (Figure XIII.9). Tank corrosion evident. Source of this pollution not identified at time of survey. High turbidity observed at Queen's Dock when mussel rope kept at Jetty no. 3 was lifted suggesting high levels of sedimentation (Figure XIII.10).
Hydrodynamics	Water levels within Queen's Dock regulated by lock gates at King's Dock. In the absence of significant tidal currents within Queen's Dock, wind driven currents are likely to be a major mechanism in the transport and distribution of microbial contaminants.
Human population	Swansea is the second most populous city and the third most populous county in Wales. Water and land based tourism activities are noted to play an important role to local economy. Parks and gardens occur along the waterfront. Restaurants and coffees occur at Mumbles. Sailing, water-skiing and surfing. Walking and cycling were noted at time of survey.
Topography	Topography of the area surveyed increases to 29m in places at The Mumbles and 39m at Oystermouth.
Land Use	Urban and suburban between The Mumbles and Swansea, with an interspersed woodland area (Clyne Valley County Park).
Other comments	ABP has a waste management plan in place by which sewage is disposed of via arrangements made between the ship (or an agent action on behalf) and an approved waste management contractor. There are 5 reception points for ship-generated waste at King's Dock. Fences around the perimeter of Queen's Dock restrict the access of dogs to the dock. The applicant kindly provided test reports of three investigative mussel samples collected from Jetty no. 3 in advance of the shoreline survey. The results of these samples are: 02 September 2009 (10:00): 330 *E. coli* MPN $100g^{-1}$ FIL 05 October 2009 (09:00): 130 *E. coli* MPN $100g^{-1}$ FIL 15 February 2010 (10:30): <20 *E. coli* MPN $100g^{-1}$ FIL (Time between sample collection and arrival at the laboratory was less than 24h in all samples). The applicant informed Cefas Officer that he intends to collect further mussel samples for quantification of trace metals. A network of iron pipes was observed at Queen's Dock. These appear to be left from the time when the dock supported the refinery (Figure XIII.8). There was no sign of sewage or any other discharge from these pipes at time of survey. The LEA Officer informed that the currently classified native oyster bed (Swansea Bank) does not extend south of The Mumbles.

Figure XIII.3 Ship moored at Rose Wharf, King's Dock.
Note bulk coal at the wharf.

Figure XIII.4 Dogs at West Cross slipway.

Figure XIII.5 Cormorants at Queen's Dock.

Figure XIII.6 Mussel shells at Jetty No. 5, Queen's Dock.

Figure XIII.7 Sewage related debris on Swansea Beach at the mouth of Clyne River.
Cotton buds marked on map.

Figure XIII.8 Plastics and unidentified East of Coastal Tanker Jetty, Queen's Dock.

Figure XIII.9 Oil spill at Jetty No. 3, Queen's Dock.

Figure XIII.10 Turbid water at Jetty No. 3, Queen's Dock after lifting mussel rope.

Table XIII.2 Results of samples collected during the shoreline survey on 16–17 March 2010.

Figure XIII.2b ID	Figure XIII.11 ID	Site name	Matrix	Collection Date/time	Easting	Northing	*E. coli*		Salinity (ppt)	Temperature (°C)	Water appearance	(*E*
1	-	Queen's Dock (Jetty No. 5)	Seawater	16 March 2010 (15:00)	67650	92101	0	CFU 100ml^{-1}	29	6.5	Clear	
2	A	Queen's Dock (Jetty No. 3)	Seawater	16 March 2010 (15:20)	68085	92191	0	CFU 100ml^{-1}	29.1	6.5	Clear	
3	B	Queen's Dock (Jetty No. 3 terminal tank)	Seawater	16 March 2010 (15:25)	68103	92198	0	CFU 100ml^{-1}	28.9	7.2	Clear	
4	-	Queen's Dock at Coastal Tanker Jetty	Seawater	16 March 2010 (15:47)	68406	92555	6	CFU 100ml^{-1}	29.1	7.1	Clear	
5	A	Queen's Dock (Jetty No. 5)	Mussels	16 March 2010 (15:00)	67650	92101	<20	MPN 100g^{-1}	n/a	n/a	n/a	
6	C	Mumbles Head at Middle Head	Seawater	17 March 2010 (10:03)	63146	87387	74	CFU 100ml^{-1}	31.3	6.7	Clear	
7	D	Springs at West Cross	Freshwater	17 March 2010 (10:40)	61552	89329	4800	CFU 100ml^{-1}	0	7.4	Clear	
8	E	Clyne River	Freshwater	17 March 2010 (10:57)	62045	90770	1800	CFU 100ml^{-1}	0	6.6	Clear	
9	F	Springs at Brynmill (Boating Lake)	Freshwater	17 March 2010 (11:09)	61963	90522	4000	CFU 100ml^{-1}	0	7.5	Turbid (brown)	
10	G	Springs at Brynmill (Swansea University)	Freshwater	17 March 2010 (11:38)	62780	91377	300	CFU 100ml^{-1}	0.5	9.6	Clear	
11	H	Springs at Brynmill (Swansea University)	Freshwater	17 March 2010 (11:47)	62837	91434	100	CFU 100ml^{-1}	0.1	7.8	Clear	
12	I	Mouth of River Tawe	Seawater	17 March 2010 (12:11)	66438	92810	2100	CFU 100ml^{-1}	6.4	7.6	Clear	

E. coli *loadings based on flows recorded at time of survey.*

Figure XIII.11 Sites sampled during the shoreline survey.

CONCLUSIONS

QUEEN'S DOCK

No evidence of significant sources of microbiological pollution impacting on Queen's Dock was evident from observations made during the shoreline survey. Information supporting this conclusion:

1. There are no significant sewage discharges directly into Queen's Dock.

2. Freshwater inputs are limited to a small stream discharging to Prince of Wales Dock and therefore the potential for diffuse microbial contamination from catchment sources to enter Queen's Dock is minimal.

3. No *E. coli* was found in the seawater sample collected from Jetty No. 3 at the time of the survey. The mussel sample collected from the same location returned an *E. coli* result below the limit of detection of the MPN test. Low levels of microbial contamination were also reported from investigative samples previously collected by the applicant.

4. The salinity measurements taken at various points across the dock are indicative of a fully saline body of water, similar to reference values measured at The Mumbles (western Swansea Bay). This suggests that despite being a semi-enclosed system, Queen's Dock is subjected to a tidal flushing similar to that typical of many estuaries and bays supporting shellfisheries.

5. King's Dock separates Queens Dock and Prince of Wales Dock. All three docks are served by lock into King's Dock (Figure XIII.2a). Other than the proposed mussel aquaculture operation, there are no commercial or leisure uses at Queen's Dock. The only dock where commercial ships are permitted to moor is King's Dock. The Prince of Wales Dock is now being used as a marina (745m between Queen's Dock entrance and Prince of Wales Dock entrance). The marina represents a potential source of microbial contamination should sewage be discharged from recreational boats moored at Prince of Wales. However toilets facilities ashore are provided for berth holders and illegal discharges should not occur if the waste management plan is respected by the dock users.

6. The quantities of plastic debris found in the south and eastern margins of Queen's Dock and the hydrocarbon film observed at Jetty No. 3 cause some concern. The applicant and the LEA informed Cefas that ABP would be able to deploy a floating oil containment boom at Queen's Dock entrance in the event of an emergency. However, it must be stressed that this report is not intended to assess chemical contamination.

7. Birds roosting in Queen's Dock could represent a source of faecal contamination.

SWANSEA BAY

The following conclusions can be drawn from the shoreline survey undertaken in Swansea Bay:

8. The *E. coli* concentrations calculated for freshwater samples indicate that, under dry weather conditions, the Clyne River is, at least, one order of magnitude more contaminated than other small streams discharging into the bay. Daily loads calculated from these data and flows observed at the time of sampling indicates that The Clyne River imparts a load at least an order of magnitude more than other small streams discharging into the bay.

9. The presence of sewage related debris on the beach at the mouth of the river also suggests that the Clyne River can have an adverse microbiological impact on the western part of Swansea Bay.

10. The *E. coli* concentration found in the seawater sample at the mouth of the River Tawe was also high indicating that this river is potentially the second largest freshwater source of faecal contamination to the western part of the bay.

11. The presence of birds and dogs on the beach indicates that faecal matter from these animals may be a source of contamination.

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List of Abbreviations

BMPA	Bivalve Mollusc Production Area
CD	Chart Datum
Cefas	Centre for Environment, Fisheries & Aquaculture Science
CFU	Colony Forming Units
CSO	Combined Sewer Overflow
CZ	Classification Zone
Defra	Department for Environment, Food and Rural Affairs
DWF	Dry Weather Flow
EA	Environment Agency
E. coli	*Escherichia coli*
EC	European Community
EEC	European Economic Community
EO	Emergency Overflow
FIL	Fluid and Intravalvular Liquid
FSA	Food Standards Agency
GM	Geometric Mean
ISO	International Organization for Standardization
km	Kilometre
LEA (LFA)	Local Enforcement Authority formerly Local Food Authority
M	Million
m	Metres
ml	Millilitres
mm	Millimetres
MPN	Most Probable Number
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
OSGB36	Ordnance Survey Great Britain 1936
PS	Pumping Station
RMP	Representative Monitoring Point
SAC	Special Area of Conservation
SSSI	Site of Special Scientific Interest
UV	Ultraviolet
WGS84	World Geodetic System 1984

GLOSSARY

Bathing Water	Element of surface water used for bathing by a large number of people. Bathing waters may be classed as either EC designated or non-designated OR those waters specified in section 104 of the Water Resources Act, 1991.
Bivalve mollusc	Any marine or freshwater mollusc of the class Pelecypoda (formerly Bivalvia or Lamellibranchia), having a laterally compressed body, a shell consisting of two hinged valves, and gills for respiration. The group includes clams, cockles, oysters and mussels.
Classification of bivalve mollusc production or relaying areas	Official monitoring programme to determine the microbiological contamination in classified production and relaying areas according to the requirements of Annex II, Chapter II of EC Regulation 854/2004.
Coliform	Gram negative, facultatively anaerobic rod-shaped bacteria which ferment lactose to produce acid and gas at 37°C. Members of this group normally inhabit the intestine of warm-blooded animals but may also be found in the environment (e.g. on plant material and soil).
Combined Sewer Overflow	A system for allowing the discharge of sewage (usually dilute crude) from a sewer system following heavy rainfall. This diverts high flows away from the sewers or treatment works further down the sewerage system.
Discharge	Flow of effluent into the environment.
Dry Weather Flow (DWF)	The average daily flow to the treatment works during 7 consecutive days without rain following 7 days during which rainfall did not exceed 0.25mm on any one day (excludes public or local holidays). With a significant industrial input the dry weather flow is based on the flows during five working days if production is limited to that period.
Ebb tide	The falling tide, immediately following the period of high water and preceding the flood tide. Ebb-dominant estuaries have asymmetric tidal currents with a shorter ebb phase with higher speeds and a longer flood phase with lower speeds. In general, ebb-dominant estuaries have an amplitude of tidal range to mean depth ratio of less than 0.2.
EC Directive	Community legislation as set out in Article 189 of the Treaty of Rome. Directives are binding but set out only the results to be achieved leaving the methods of implementation to Member States, although a Directive will specify a date by which formal implementation is required.
EC Regulation	Body of European Union law involved in the regulation of state support to commercial industries, and of certain industry sectors and public services.
Emergency Overflow	A system for allowing the discharge of sewage (usually crude) from a sewer system or sewage treatment works in the case of equipment failure.
Escherichia coli (*E. coli*)	A species of bacterium that is a member of the faecal coliform group (see below). It is more specifically associated with the intestines of warm-blooded animals and birds than other members of the faecal coliform group.
E. coli O157	E. *coli* O157 is one of hundreds of strains of the bacterium *Escherichia coli*. Although most strains are harmless, this strain produces a powerful toxin that can cause severe illness. The strain O157:H7 has been found in the intestines of healthy cattle, deer, goats and sheep.
Faecal coliforms	A group of bacteria found in faeces and used as a parameter in the Hygiene Regulations, Shellfish and Bathing Water Directives, *E. coli* is the most common example of faecal coliform. Coliforms (see above) which can produce their characteristic reactions (e.g. production of acid from lactose) at 44°C as well as 37°C. Usually, but not exclusively, associated with the intestines of warm-blooded animals and birds.
Flood tide	The rising tide, immediately following the period of low water and preceding the ebb tide.

Flow ratio	Ratio of the volume of freshwater entering into an estuary during the tidal cycle to the volume of water flowing up the estuary through a given cross section during the flood tide.
Geometric mean	The geometric mean of a series of N numbers is the N^{th} root of the product of those numbers. It is more usually calculated by obtaining the mean of the logarithms of the numbers and then taking the anti-log of that mean. It is often used to describe the typical values of a skewed data such as one following a log-normal distribution.
Hydrodynamics	Scientific discipline concerned with the mechanical properties of liquids.
Hydrography	The study, surveying, and mapping of the oceans, seas, and rivers.
Lowess	LOcally WEighted Scatterplot Smoothing, more descriptively known as locally weighted polynomial regression. At each point of a given data set, a low-degree polynomial is fitted to a subset of the data, with explanatory variable values near the point whose response is being estimated. The polynomial is fitted using weighted least squares, giving more weight to points near the point whose response is being estimated and less weight to points further away. The value of the regression function for the point is then obtained by evaluating the local polynomial using the explanatory variable values for that data point. The LOWESS fit is complete after regression function values have been computed for each of the *n* data points. LOWESS fit enhances the visual information on a scatterplot.
Secondary Treatment	Treatment to applied to breakdown and reduce the amount of solids by helping bacteria and other microorganisms consume the organic material in the sewage or further treatment of settled sewage, generally by biological oxidation.
Sewage	Sewage can be defined as liquid, of whatever quality that is or has been in a sewer. It consists of waterborne waste from domestic, trade and industrial sources together with rainfall from subsoil and surface water.
Sewage Treatment Works (STW)	Facility for treating the waste water from predominantly domestic and trade premises.
Sewer	A pipe for the transport of sewage.
Sewerage	A system of connected sewers, often incorporating inter-stage pumping stations and overflows.
Storm Water	Rainfall which runs off roofs, roads, gulleys, etc. In some areas, storm water is collected and discharged to separate sewers, whilst in combined sewers it forms a diluted sewage.
Waste water	Any waste water but see also “sewage”.

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