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EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Menai Strait East

December 2013

Food Standards Agency

Cover photo: Menai Bridge

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Statement of use

This report provides a sanitary survey relevant to bivalve mollusc beds within Menai Strait East, as required under EC Regulation 854/2004 which lays down specific rules for official controls on products of animal origin intended for human consumption. It provides an appropriate hygiene classification zoning and monitoring plan based on the best available information with detailed supporting evidence. The Centre for Environment, Fisheries & Aquaculture Science (Cefas) undertook this work on behalf of the Food Standards Agency (FSA).

Report prepared by

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Revision history

Version	Details	Approved by	Approval date
1	Draft for internal consultation	Fiona Vogt	19/12/2013
2	Draft for client/consultee comment	Simon Kershaw	20/12/2013
3	Final	Simon Kershaw	09/05/2014

Consultation

Consultee	Date of consultation	Date of response
Gwynedd CC	20/12/2013	28/03/2014
Ynys Mon CC	20/12/2013	-
Conwy CC	20/12/2013	28/03/2014
Natural Resources Wales/Cyfoeth Naturiol Cymru	20/12/2013	03/02/2014
Welsh Government Fisheries	20/12/2013	28/03/2014
Welsh Water/Dwr Cymru	20/12/2013	-
Bangor Mussel Producers Association	20/12/2013	-

Dissemination

Food Standards Agency, Gwynedd CC, Ynys Mon CC, Conwy CC. The report is available publicly via the Cefas website.

Recommended Bibliographic Reference

Cefas, 2013. Sanitary survey of Menai Strait East. Cefas report on behalf of the Food Standards Agency, to demonstrate compliance with the requirements for classification of bivalve mollusc production areas in England and Wales under EC regulation No. 854/2004.

Contents

1. Introduction

1.1. Legislative Requirement

Filter feeding, bivalve molluscan shellfish (e.g. mussels, clams, 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.

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. 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 performing 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 improve analysis of their effects on shellfish hygiene. 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 the information relevant to undertake a sanitary survey for mussels (*Mytilus* spp.), cockles (*Cerastoderma edule*) and razor clams (*Ensis* spp.) in the Eastern Menai Strait. The area was prioritised for survey in 2013-14 by a shellfish hygiene risk ranking exercise of existing classified areas.

1.2. Area description

The Menai Strait is a 30 km tidal channel which separates the Island of Anglesey from North Wales. This survey covers with the eastern half of this water body, from Menai Bridge through to the western edge of Conwy Bay, an area of about 74 km^2.

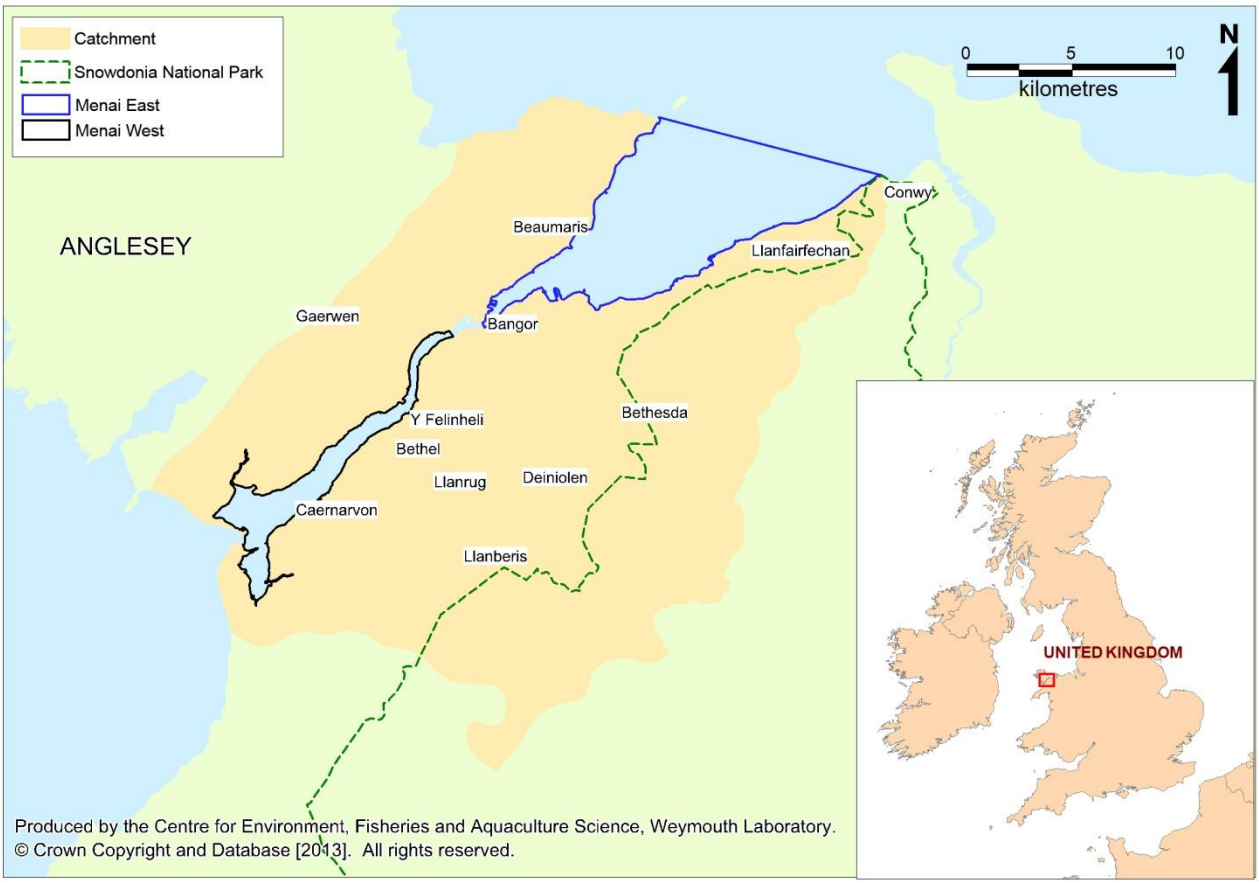

Figure 1.1: Location of the Menai Strait

The eastern end of the strait extends from Puffin Island to The Swellies, a constricted, relatively shallow area in the middle of the strait which experiences particularly strong tidal flows. The outer reaches are wide, with extensive intertidal areas, which become progressively narrower towards The Swellies where they are narrow and rocky. The Menai Strait encompasses a unique range of habitats including reefs, sandbanks, sea caves, large shallow bays and inlets, seagrass and sea cliffs. It is protected under several international and national conservation designations including the Menai Strait and Conwy Special Area of Conservation (SAC), Puffin Island SAC, seven Sites of Special Scientific Interest (SSSI), Special Protected Area (SPA), National Nature Reserves (NNR) and several Local Nature Reserves. The high primary production in Liverpool Bay, the strong tidal circulation and the shelter the strait affords from wave action result in a highly productive environment for filter feeding bivalves. The eastern strait supports a major mussel culture fishery, as well as a fishery for wild cockles.

1.3. Catchment

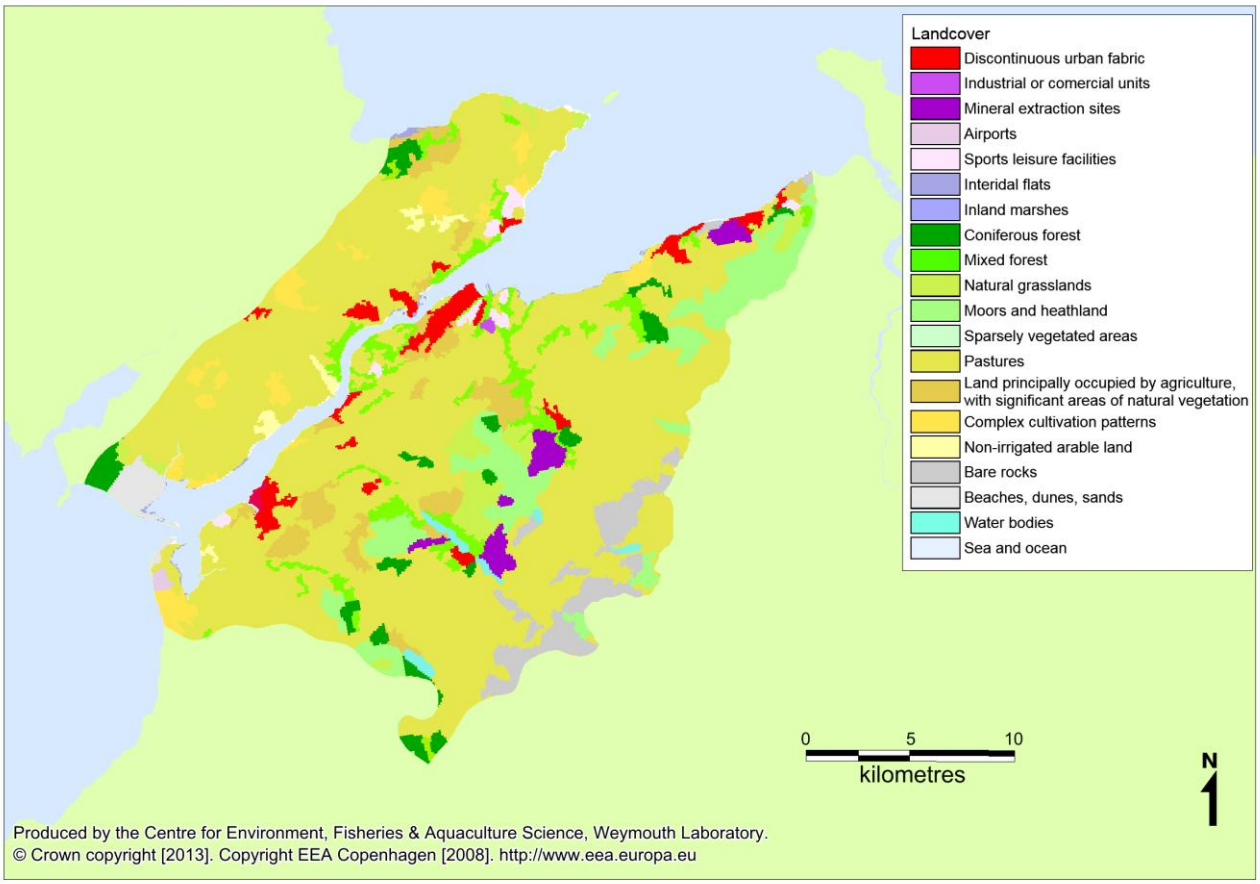

Figure 1.2: Landcover in the Menai Strait catchment area

The Menai Strait has a hydrological catchment of 522 km², of which about 70 % lies on the mainland and 30 % lies on Anglesey. Figure 1.2 shows landcover within this area. Pasture is the dominant land use on both sides of the strait, although there are some natural areas (forests and moorlands) and a few small areas where crops are cultivated. The majority or urban areas lie on the coast, with the shores of the central eastern strait by the mussel fishery representing the most heavily populated area. Different land cover types will generate differing levels of contamination in surface runoff. Highest faecal coliform contribution arises from developed areas, with intermediate contributions from the improved pastures and lower contributions from the other land types (Kay *et al*. 2008a). The contributions from all land cover types would be expected to increase significantly after marked rainfall events, particularly for improved grassland which increase up to 100 fold.

The Anglesey part of the catchment is relatively low lying, with elevations reaching about 150 m at its eastern end. The mainland catchment extends into the mountains of Snowdonia, where elevations approach 1000 m. The strait follow a geological fault line separating Anglesey from mainland Wales. The hydrogeology of the catchment is classified as of very low permeability, apart from a narrow coastal strip on both Anglesey and the mainland of moderate permeability (NERC, 2012). As

such there is unlikely to be significant groundwater flows, and a high proportion of rainfall will run off via watercourses.

2. Recommendations

It is recognised that the there are slight uncertainties about the exact distribution of some stocks, and that the recommended RMPs may require some slight adjustments to their locations following the first sampling run. Any adjustments should follow the principles identified in the recommendations (e.g. samples should be taken as far to the west as stocks extend). The use of a deployment bag may remove the need for such adjustments within the mussel fishery in some cases. Any adjustments should be communicated by the LEA to the classification team at Cefas.

2.1. Mussels

The proposed sampling plan for mussels considers not only the identified sources of contamination and their likely pattern of impacts, but also the layout of the individual lease areas which are operated by different mussel companies. This is to avoid, where possible, any possible issues of split classifications within a lease area, or even the possibility of one lease area being downgraded on the basis of sample taken from another lease area. Currently there are 8 RMPs used to monitor and classify the area, but the very similar results recorded strong class B compliance across all of them suggest a reduction may be justified. However, as described above, each lease area (of which there are six, with a further two proposed) should ideally have its own RMP (or RMPs as appropriate), and the current RMPs may not necessarily be located in the most contaminated areas. The very high volumes that are harvested also justify a relatively intensive monitoring programme to some extent. The following six zones are therefore proposed for mussels, of which five are currently active.

Area A

Sewage sources to the west include Llanfair and Treborth STWs, which lie about 4 km away on the other side of The Swellies, and Llandegfan PS, a regular spiller about 300 m to the west of the zone on the Anglesey side of the channel. The Cadnant discharges to the Anglesey shore about 750 m to the west of the zone, and there are a few more minor freshwater inputs direct to the zone. There are also two intermittent discharges direct to the zone, but there is no information available on spill frequencies from these. There is a small private discharge at the eastern end of the zone, from the Gazelle Hotel, and a few further small domestic discharges along the foreshore of this zone, of which three discharge to water in the Craig Y Don area. To the east of this zone there is little in the way of contaminating influences within 3 km. It is therefore recommended that the RMP be located at the western end of this zone at Craig Y Don. Area A is not currently active so quarterly sampling would be

appropriate until such time as reclassification is required, at which point sampling should revert to monthly.

Area 1

Sewage sources to the west include Llanfair and Treborth STWs, to the west of the Swellies, about 4 km away from this zone. There are also some intermittent discharges to the mainland side of channel between Menai Bridge and the zone, the closest of which is 850 m away. No information was available on their performance however. There is also a small private discharge from the end of Bangor pier, and an intermittent discharge direct to the zone which is reported to hardly spill at all. To the east the rivers Cegin and Ogwen, about 500 m and 2.5 km away respectively, are likely to be the principle contaminating influences. It is therefore recommended that the RMP be located on the lower intertidal, on the eastern boundary of this zone to best capture contamination arriving via the two major rivers. Sampling should be on a monthly basis to maintain a full classification.

Areas 2 & B West

This zone includes the western half of prospective Area B and the whole of Area 2. Hand gathering occurs in Area B at present so although the lease is prospective the classification will need to be maintained. Both Area B West and Area 2 are subject to similar sources of contamination, the main one being the Cegin. The Ogwen lies to the east, and there is little in the way of major sources to the west. The Beach Road PS discharges directly to this area, and although it spilled infrequently (2.2% of the time) large volumes are discharged. The low spill frequency suggests it is unlikely to be captured via monthly monitoring. On balance it is recommended that the RMP be positioned on the southern edge of Area B, immediately adjacent to the Cegin drainage channel. It is possible that this may return marginally higher results than if the RMP was moved down the channel to the edge of Area 2. This is unlikely to be a major difference and such a strategy avoids the need for two RMPs monitoring the same source. Sampling should be on a monthly basis to maintain a full classification.

Areas 3 & 4

No major sources of contamination which discharge directly to this zone have been identified. Microbiological monitoring results suggest that this is the least contaminated part of the fishery order. Immediately to the west there is a private discharge from the Gazelle Hotel, and much further away there is the Cadnant. There are also several intermittent and private sewage discharges to the west. Water company sewage works discharging to the west of this zone lie on the other side of The Swellies over 5 km away. There are two sewage works discharging to the channel to the east of the zone (Llanfaes and Llangoed STWs, about 3 and 4.5

km away, respectively). There are also some minor watercourses and intermittent discharges to the east, including a watercourse about 800 m east of Gallows Point. It is therefore recommended that the RMP be located at Gallows Point at the easternmost end of this zone. Sampling should be on a monthly basis to maintain a full classification.

Area 5 & B East

This zone includes the eastern half of prospective Area B and the whole of Area 5. Hand gathering occurs in Area B at present so although the lease is prospective the classification will need to be maintained. Both are subject to similar sources of contamination, the main one being the Ogwen. The Cegin lies to the west, and there is little in the way of major sources to the east. It is therefore recommended that the RMP be positioned on the southern edge of Area B, immediately adjacent to the Ogwen drainage channel. It is possible that this may return marginally higher results than if the RMP was moved down the channel to the edge of Area 2. This is unlikely to be a major difference and such a strategy avoids the need for two RMPs monitoring the same source. Sampling should be on a monthly basis to maintain a full classification.

Area 6

There are no major sources of contamination within 2 km of the western edge of this zone. There are two sewage works (Llanfaes and Llangoed STWs) which discharge to the channel about 1.3 and 3 km to the east. There are also several intermittent discharges and minor watercourses to the east. There are two intermittent discharges on the fringes of this zone but their performance is uncertain. There is also a minor watercourse discharging to the centre of this zone. It is reported that there are several unregistered domestic discharges to a surface water culvert that discharges by Beaumaris Pier. Microbiological monitoring results suggest an increase in contamination towards the eastern end of this zone. It is therefore recommended that the RMP is located at the north eastern corner of Area 6. Sampling should be on a monthly basis to maintain a full classification.

Sampling requirements

The species sampled should be mussels of a market size. Sampling frequencies are discussed above, and are dependent on the harvesting status of each individual zone. Sampling may be via hand or dredge and a tolerance of 50 m should be sufficient. In some cases the use of a deployment bag may be required to ensure the RMP can be sampled regularly. In such cases the mussels should be allowed to equilibrate *in situ* for at least two weeks prior to sampling.

2.2. Cockles

As the eastern end of the cockle bed at Traeth Lafan is subject to different contaminating influences to the western end the following two zones are proposed for cockles at Traeth Lafan:

Lavan Sands East

The zone will be subject to contamination discharging directly to it and also that originating from sources to the east. There are a few watercourses to the east, and the Penmaenmawr STW, although this is 6.5 km away so should be of negligible influence. The principal contaminating influences direct to this zone are four watercourses of which the largest is the Aber, and the Llanfairfechan STW, which discharges to the channel that carries the westernmost of these watercourses across the beach. In terms of bacterial loadings and concentrations, the sewage works is likely to be the most significant of these for most of the time. It is therefore recommended that the RMP be located immediately adjacent to the drainage channel conveying this effluent across the bed.

Lavan Sands West

At the western end of the bed the tide actually arrives from the north and west, then drains way in the opposite direction. As such the River Ogwen is likely to be a widespread contaminating influence, and this will be felt most acutely at the western end of the cockle bed. There are also two very small watercourses discharging directly to the zone, which may create minor hotspots of contamination. On balance it is recommended that the RMP be located at the westernmost end of the bed, by the principle east-west drainage channel to best capture the influence of the Ogwen.

Sampling requirements

Although currently there is a closed season for cockles (May to August) a review of management is underway and it is likely that the closed season will no longer apply after this review. Sampling should therefore be undertaken on a monthly basis all year round. Samples should be hand gathered and be of animals of a market size. Samples should be taken as close to the drainage channels as possible. A tolerance of 50 m should allow for repeated sampling from the RMP.

2.3. Razors

A sampling plan is provided for the razor bed off Llanfairfechan. It should only be implemented if and when a legitimate commercial fishery has been authorised by Welsh Government Fisheries.

This zone will be influenced by sources to the east and west, as well as those discharging directly to it. To the west there are several minor watercourses and the Llanfairfechan STW about 1 km away. To the east the closest significant source is the Penmaenmawr STW which is over 3 km away. The Llanfairfechan River (also known as the Afon Ddu) discharges direct to the zone and follows a drainage channel down the beach through the razor bed. This was carrying a relatively high bacterial loading at the time of shoreline survey and so is likely to create a hotspot in the vicinity of its drainage channel. The RMP should therefore be located immediately adjacent to this channel.

Sampling should be via hand using salt to extract the animals from their burrows, and animals should be of a market size (>100 mm). A tolerance of 50 m should allow for repeated sampling. Sampling should be on a monthly basis for a full classification. It is recognised that regular sampling may be problematic as the stocks are only exposed on the very largest tides. The use of a diver or snorkeller would be acceptable, but probably impractical for the LEA.

3. Sampling Plan

3.1. General Information

Location Reference

Production Area	Menai Strait - East
Cefas Main Site Reference	M042
Ordnance survey 1:25,000 map	Explorer 263
Admiralty Chart	1464

Shellfishery

Species/culture	Mussels	Cultured/wild
	Cockles	Wild
	Razors	Wild
Seasonality of harvest	There is currently a closed season for cockles (May to August) but this is currently under review and it is likely that there will be no closed season in future	

Local Enforcement Authority

Name	Gwynedd County Council Environmental Health Department Gwynedd County Council (Meirionnydd) Meirionnydd Area Office Cae Penarlag DOLGELLAU Gwynedd LL40 2YB
Environmental Health Officer	Gwenan Owen
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Fax number 🖷	01341 423984
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Name	Ynys Mon County Council Environmental ServicesYnys Mon - Isle of Anglesey County Council Environmental Health Department Council Offices LLANGEFNI Anglesey LL77 7TW
Environmental Health Officer	Keith Rowlands
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Fax number 🖷	01492 575204
E-mail 🖃	Eddie.Evans@conwy.gov.uk; Mark.D.Hughes@conwy.gov.uk; Colin.Griffiths@conwy.gov.uk

3.2. Requirement for Review

The Guide to Good Practice for the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2010) indicates that sanitary assessments should be fully reviewed every 6 years, so this assessment is due a formal review in 2019. The assessment may require review in the interim should any significant changes in sources of contamination come to light, such as the upgrading or relocation of any major discharges.

Table 3.1:
Number and location of representative monitoring points (RMPs) and frequency of sampling for classification zones within the Menai Strait East

Classification zone	RMP*	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Area A	B055R[1]	Craig-y-Don	SH 56780 73094	53°14.130'N 04°08.840'W	Mussels	Bed culture	Dredge	Hand or dredge	50 m	Monthly or quarterly	Not currently active. May be sampled quarterly until classification is required at which point revert to monthly sampling
Area 1	B055S[2]	West of Bangor Pier	SH 58334 73287	53°14.260'N 04°07.449'W	Mussels	Bed culture	Dredge	Hand or dredge	50 m	Monthly	
Areas 2 & B West	B055T[2]	Cegin Channel	SH 58678 73309	53°14.277'N 04°07.140'W	Mussels	Bed culture	Dredge	Hand or dredge	50 m	Monthly	
Areas 3 & 4	B055U[1]	Gallows Point	SH 59943 74984	53°15.200'N 4°06.048'W	Mussels	Bed culture	Dredge	Hand or dredge	50 m	Monthly	
Area 5 &B East	B055V[2]	Ogwen Channel	SH 60955 73203	53°14.256'N 04°05.092'W	Mussels	Bed culture	Dredge	Hand or dredge	50 m	Monthly	
Areas 6	B055W[1]	Beaumaris East	SH 61149 75919	53°15.723'N 04°04.989'W	Mussels	Bed culture	Dredge	Hand or dredge	50 m	Monthly	
Lavan East	B055X[3]	Lavan Sands East	SH 66242 74697	53°15.143'N 04°00.380'W	Cockles	Wild	Hand (rake)	Hand (rake)	50 m	Monthly	Now lies in Conwy district
Lavan West	B055Y[2]	Lavan Sands West	SH 62330 73458	53°14.415'N 04°03.863'W	Cockles	Wild	Hand (rake)	Hand (rake)	50 m	Monthly	

Classification zone	RMP*	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Llanfairfechan	B055Z[3]	Off Llanfairfechan	SH 67599 75997	53°15.864'N 03°59.193' W	Razors	Wild	Hand (salt)	Hand (salt)	50 m	Monthly	Only to be implemented if/when a legitimate fishery has been fully approved by Welsh Government Fisheries.

Local Enforcement Authority: [1] Ynys Mon CC [2] Gwynedd CC [3] Conwy CC

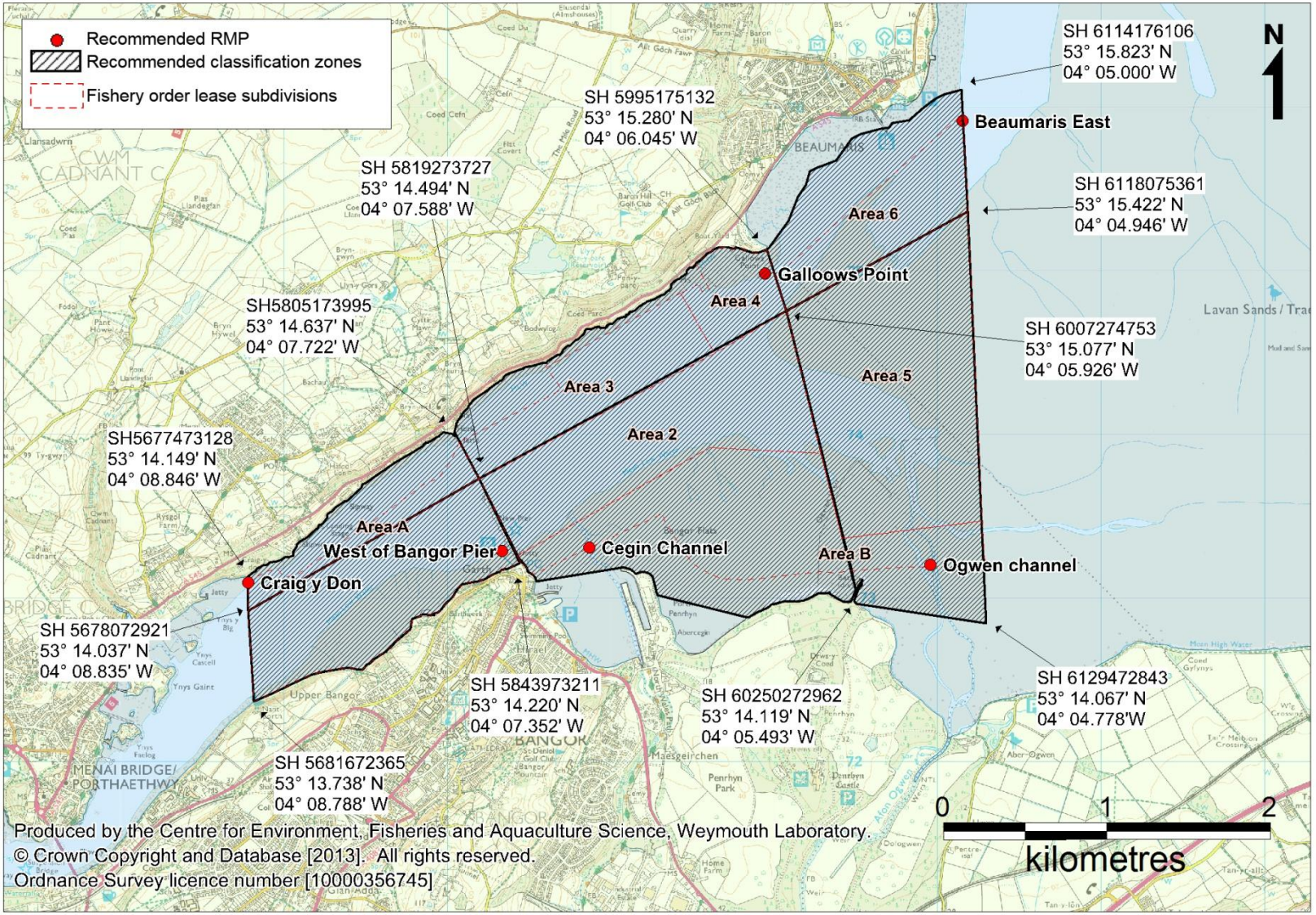


Figure 3.1: Recommended zoning and monitoring arrangements (mussels)

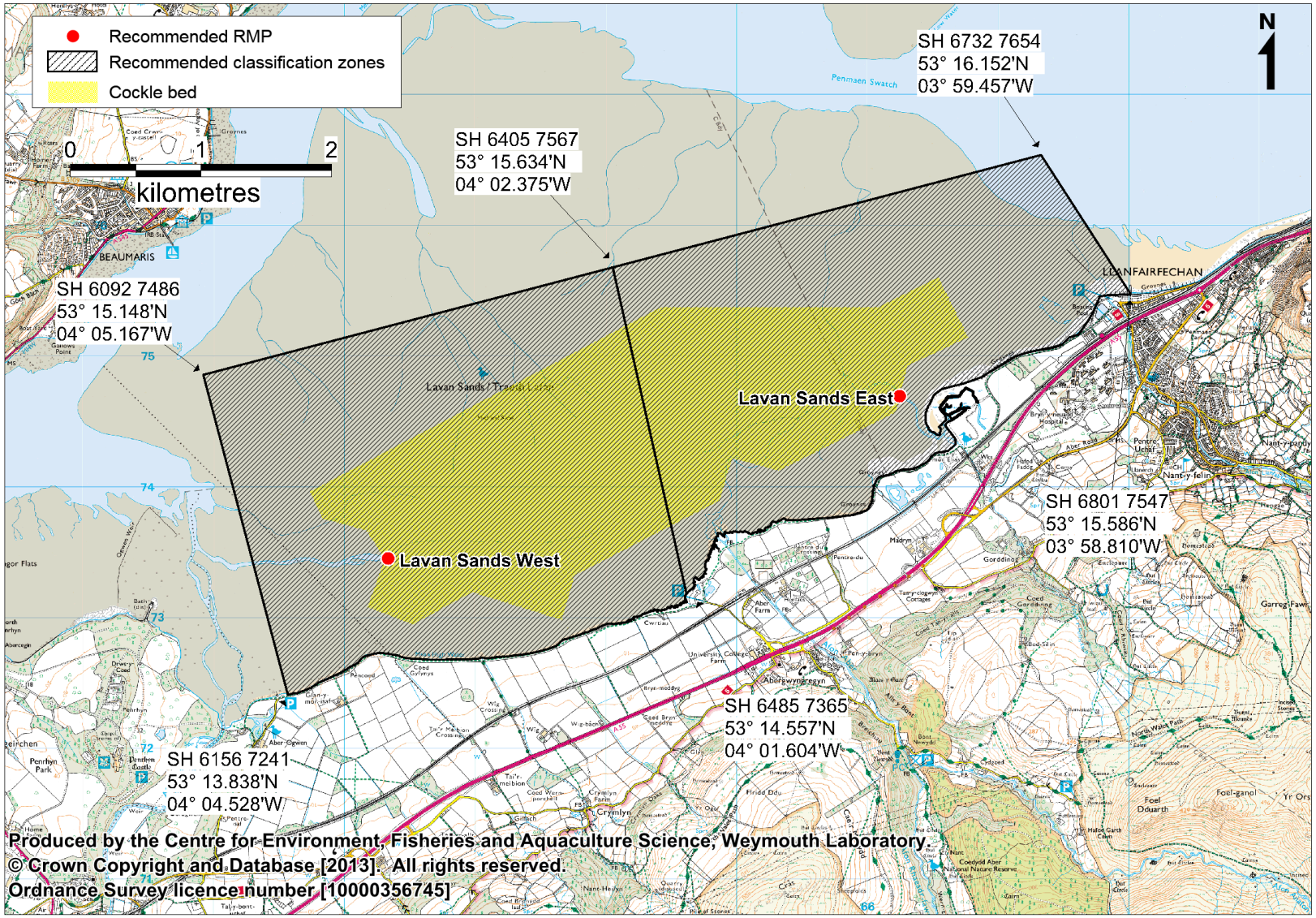


Figure 3.2: Recommended zoning and monitoring arrangements (cockles)

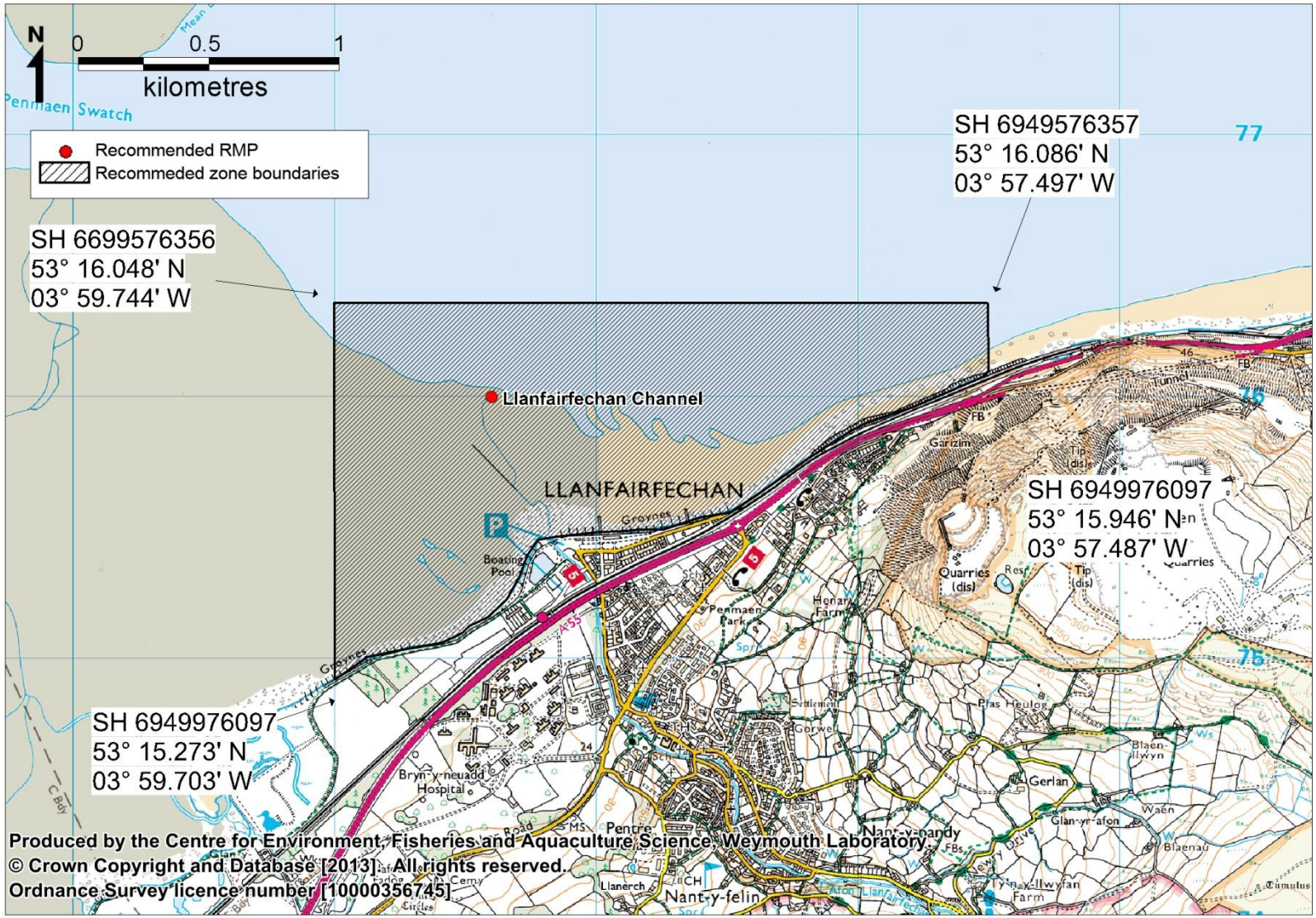


Figure 3.3: Recommended zoning and monitoring arrangements (razors)

4. Shellfisheries

4.1. Description of fisheries

The eastern strait supports the largest mussel culture operation in England and Wales, as well as significant wild cockle stocks which are subject to commercial gathering.

Mussels

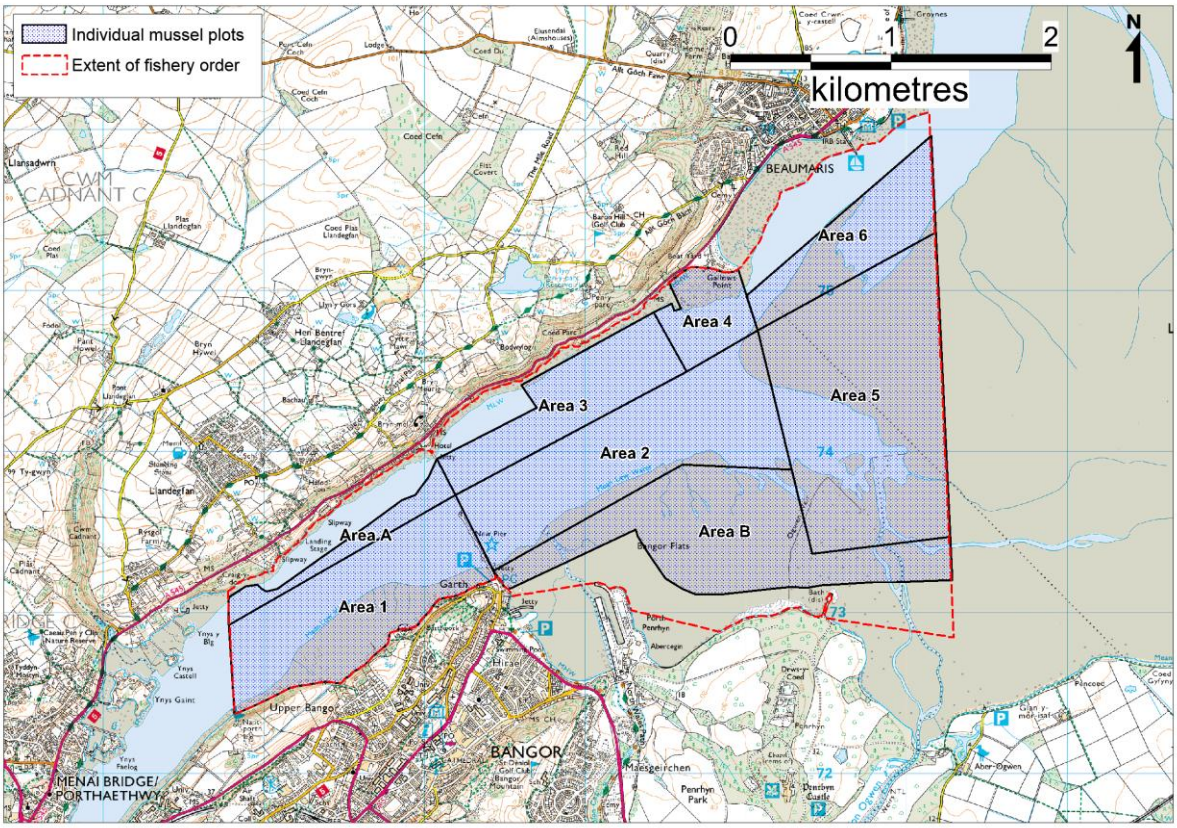


Figure 4.1: Mussel culture sites

The mussel fishery in the Menai Strait is managed through the Menai Strait Oyster and Mussel Fishery Order 1962, which covers an area of just under 8 km^2. The grantee of the order is the Menai Strait Fishery Order Management Association, which leases defined areas to the various mussel companies that operate the fishery. These companies are collectively referred to as the Bangor Mussel Producers Ltd. There are currently six established areas (Areas 1-6) and two further areas (Areas A and B) where further mussel leases have been requested from the management association.

As there is limited natural mussel settlement within the strait, seed stock is collected during the summer from ephemeral seed mussel beds from a variety of locations in north Wales, north-west England and sometimes further afield. It is deposited on the upper intertidal areas at first, and subsequently moved lower down the shore and into the subtidal as it approaches market size and becomes more predator resistant. From seed to harvest takes around three years. Husbandry and harvest is undertaken by dredge. The optimum strategies for maximising yield (e.g. stocking densities) are now well established, and the fishery produces about 10,000 tonnes a year, the vast majority of which are exported to continental Europe. There is limited scope for further expansion, and the continued supply of suitable seed stock remains a slight uncertainty facing this fishery. The culture fishery has been awarded sustainable certification by the Marine Stewardship Council (Marine Stewardship Council, 2010).

Some limited hand gathering of naturally settled mussels occurs within the fishery order area, under licences issued by the management association. Typically only a handful of individuals are issued a license each year and effort is low. Hand gathering takes place on Ballast Bank, where natural settlement does occur to varying extents, although the mussels are of a relatively low quality compared to those grown on the lays. This area largely coincides with the proposed Area B so it is uncertain whether this practice will continue.

No formal minimum landing size applies within the fishery order area, although in practice only market size animals are harvested. Harvesting may occur at any time of the year.

Cockles

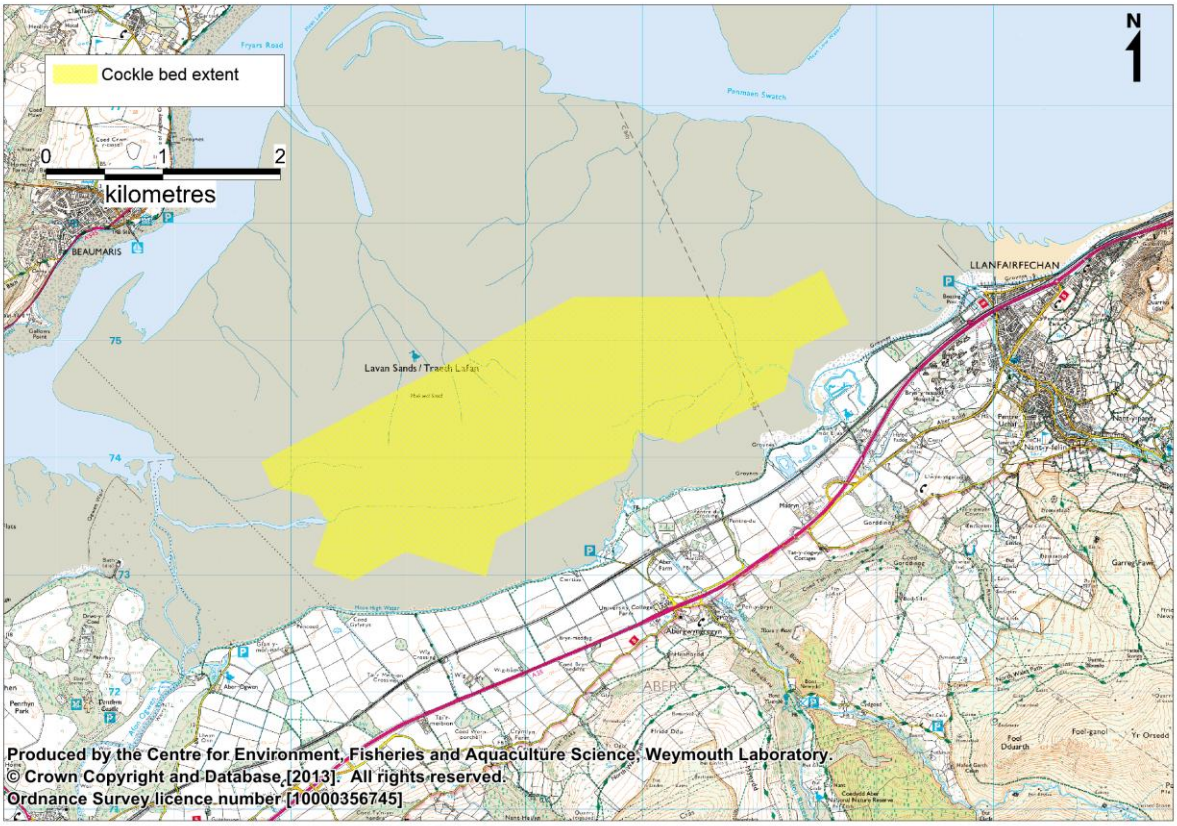


Figure 4.2: Harvestable cockle concentrations

There is a significant cockle bed on the Traeth Lafan on the mainland side of the strait. A survey undertaken earlier in 2013 indicates there are adult stocks here at exploitable densities throughout a large proportion of the bed. This fishery is currently regulated under the Cockles and Mussels (Specified Area) (Wales) Order 2011, under which only permit holders are allowed to take more than 5 kg of cockles or mussels per day. Local byelaws indicate any cockle which will not pass through a square opening of 20 mm may not be taken, and a closed season which runs from May to August inclusive. Welsh Government Fisheries may close any shellfish beds for reasons of stock conservation. The management of cockle fisheries in Wales is currently under review. Under this review, future changes to cockle fisheries are being considered including the requirement for an appropriate closed season subject to local biological and socio-economic factors (Welsh Government, 2013). The cockle bed at Traeth Lafan was opened in September 2013 but then closed in early November 2013 to conserve stocks.

Razors

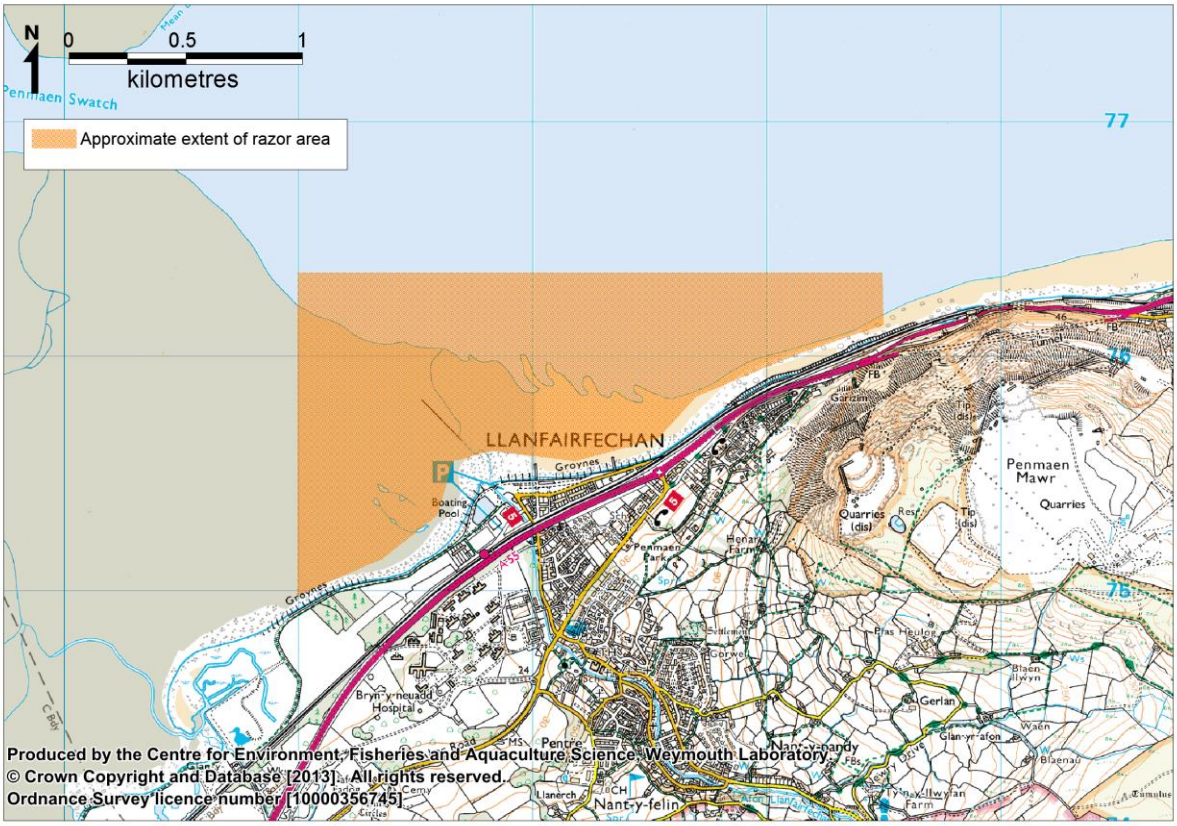


Figure 4.3: Approximate extent of known razor stocks

Razor clams are present in the low intertidal and shallow subtidal off Llanfairfechan. These have been periodically subject to gathering by large organised groups of up to over 100 people on the largest tides (e.g. BBC News, August 2013). It is unclear whether these were intended for personal consumption by the gatherers, but the volumes collected have been significant. A sampling plan will be provided for these stocks in case a legitimate commercial fishery is developed. Such a fishery would likely require regulations and management strategies to be developed by Welsh Government and ultimately may not be permitted, particularly given that there are conservation designations in the area. Currently there is no closed season for these species, and a minimum landing size of 100 mm applies.

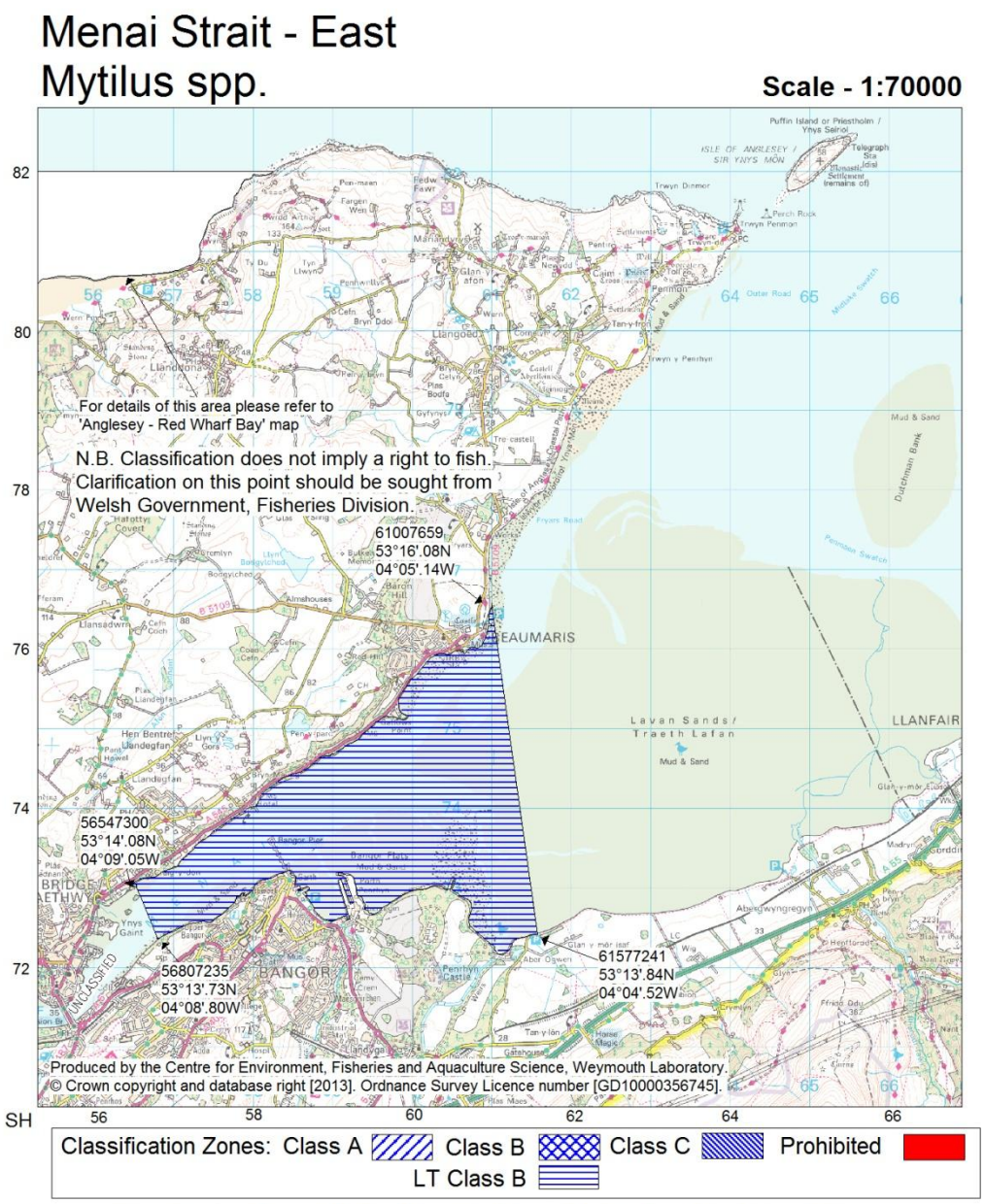
4.2. Hygiene Classification

Table 4.1 lists all classifications within the survey area since 2004.

Table 4.1: Classification history for Menai Strait East, 2004 onwards

Area	Species	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Area 1	Mussels	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Area 2	Mussels	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Area 3	Mussels	B	B-LT	B-LT	B-LT	B-LT	B-LT1	B-LT	B-LT	B-LT	B-LT
Area 4	Mussels	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Area 5	Mussels	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Area 6	Mussels	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Traeth Lafan	Cockles	B	B-LT	B-LT	B-LT	B-LT	B-LT1	B-LT	B-LT	B-LT	B-LT

LT denotes long term classification



Classification of Bivalve Mollusc Production Areas: Effective from 1 September 2013

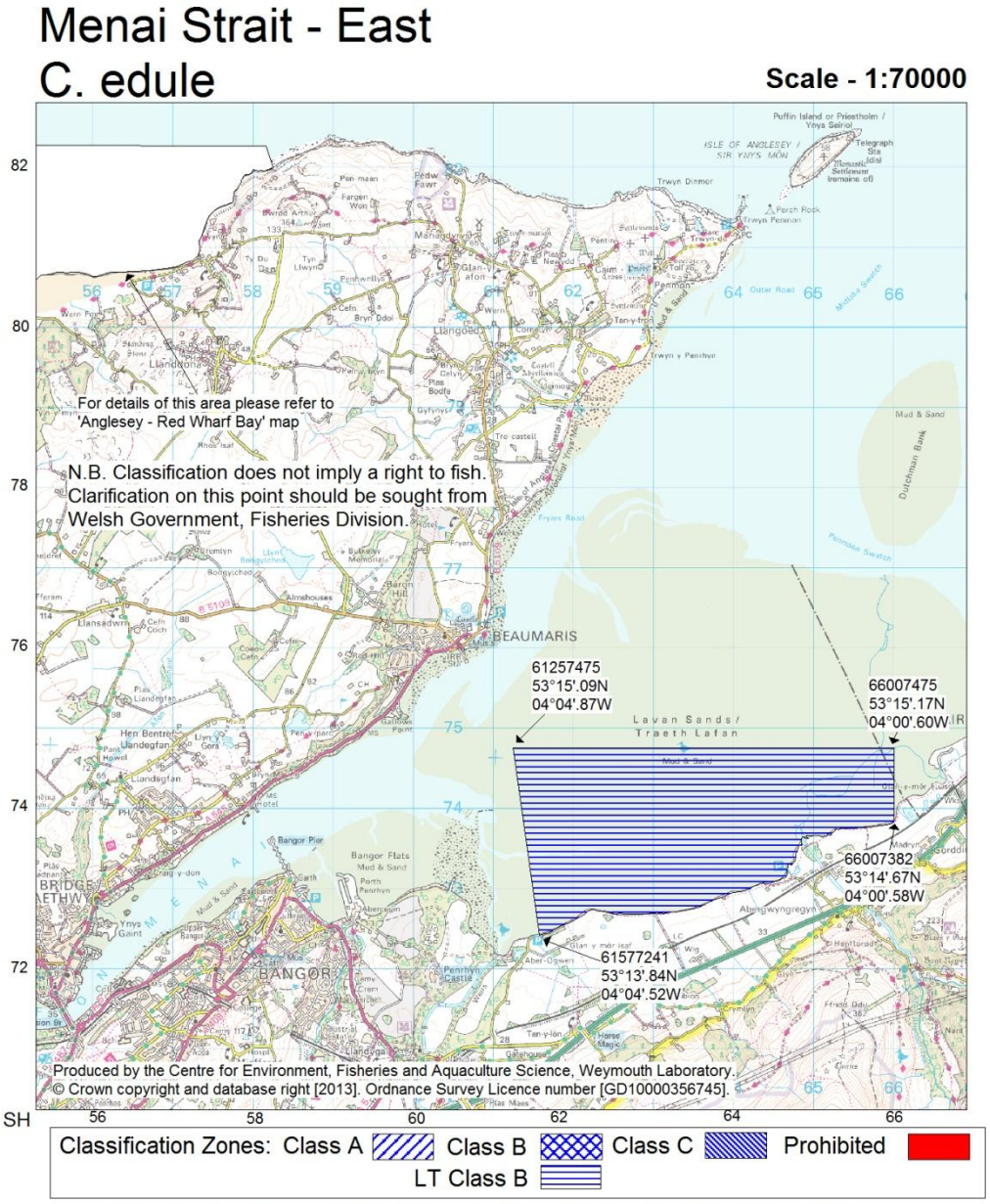
The areas delineated above are those classified as bivalve mollusc production areas under EU Regulation 854/2004.

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 C. edule at Menai Strait - East

Food Authorities: Ynys Mon - Isle of Anglesey County Council - Gannet (area 3) and Gallows Point (area 4)
Gwynedd County Council - Bangor (area 1, 2 & 5) and Horseshoe off Beaumaris (area 6)

Figure 4.4: Current mussel classifications



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(Tel: 01305 206600 Fax: 01305 206601)

N.B. Lat/Longs quoted are WGS84
Separate map available for Mytilus spp. at Menai Strait - East

Food Authority: Gwynedd County Council

Figure 4.5: Current cockle classifications

The classified area will require extending slightly to the north and east to cover the entirety of the cockle bed.

Table 4.2: Criteria for classification of bivalve mollusc production areas.

Class	Microbiological standard[1]	Post-harvest treatment required
A[2]	Live bivalve molluscs from these areas must not exceed 230 Most Probable Number (MPN) of *E. coli* $100g^{-1}$ Fluid and Intravalvular Liquid (FIL)	None
B[3]	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	Purification, relaying or cooking by an approved method
C[4]	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution Most Probable Number (MPN) test of 46,000 *E. coli* $100g^{-1}$ FIL	Relaying for, at least, two months in an approved relaying area or cooking by an approved method
Prohibited[6]	>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.
[6] Areas which are not classified and therefore commercial harvesting of LBMs cannot take place. This also includes areas which are unfit for commercial harvesting for health reasons e.g. areas consistently returning prohibited level results in routine monitoring and these are included in the FSA list of designated prohibited beds

5. Overall Assessment

5.1. Aim

This section presents an overall assessment of sources of contamination, their likely impacts, and patterns in levels of contamination observed in water and shellfish samples taken in the area under various programmes, summarised from supporting information in the previous sections and the Appendices. Its main purpose is to inform the sampling plan for the microbiological monitoring and classification of the bivalve mollusc beds in this geographical area.

5.2. Shellfisheries

The strait provides a good environment for bivalves due to the high primary productivity of adjacent Liverpool Bay, the strong tidal circulation, and the relatively sheltered environment it provides. Species harvested on a commercial basis within the eastern strait are mussels and cockles. There is also a razor bed off Llanfairfechan which may require classification at some point.

The production of mussels occurs within the Menai Strait Oyster and Mussel Fishery Order 1962, which covers an area of almost 8 km^2 between Bangor and Beaumaris. The fishery order is managed by the Menai Strait Fishery Order Management Association, who lease defined areas to several different mussel companies, collectively known as the Bangor Mussel Producers Association. Currently there are six leased areas, and there are a further two proposed lease areas. Seed mussels sourced from various locations (usually in north Wales or north west England) are laid on the seabed. The seed is laid at higher elevations in the intertidal at first to harden it, and then moved down to lower elevations, then into the subtidal from where it is harvested. This process takes around three years, and husbandry and harvest is undertaken using dredges. It is a very large fishery of considerable importance to the local economy, producing about 10,000 tonnes of mussels per year. As well as the culture fishery, a small amount of hand gathering of naturally occurring stock occurs on the Ballast Bank, off Penrhyn. This is undertaken by a small number of individuals issued licences to do so by the Menai Strait Fishery Order Management Association. The future of the hand gathered fishery is uncertain as one of the two proposed new lease areas coincides with it. The entire fishery order area therefore requires continued classification. Harvesting may occur at any time of the year so continued year round classification is required. A minimum landing size of 45 mm applies to both the culture and hand-picked mussel fisheries.

There are currently 8 active RMPs used to monitor and classify the mussel fishery, which are sampled by a combination of hand and dredge. This is a relatively intensive sampling programme in terms of the number of RMPs per unit area, although this strategy does reflect the high volumes and multiple areas operated by different companies. Results have been similar from all these RMPs over the years, so there may be some scope for reducing the number of locations sampled.

There is a commercially exploited cockle bed at Traeth Lafan which is closed until September 2014 for reasons of stock conservation. This fishery is currently managed under the permit system as well as several local byelaws. Under these measures, there is a closed season from May to August and a minimum landing size of 20 mm applies. These regulations are under review, and of relevance to the sampling plan, it is proposed that there will no longer be a closed season. As such, a year round classification will be required when the fishery re-opens. Up until September 2014 the LEA may wish to consider temporarily declassifying this cockle bed until September 2014 by reducing sampling frequency to quarterly. Monthly sampling should be resumed before the fishery re-opens, at which point the classification can be restored.

There are known to be significant razor clam stocks in the lower intertidal and shallow subtidal off Llanfairfechan. Whilst these have never been subject to a legitimate commercial fishery, significant effort has been directed at these stocks on occasion in recent years, with over 100 individuals collecting razors recorded on at least one occasion. Whether the razors were taken for personal consumption or commercial purposes is uncertain, but the volumes collected were significant. It is possible that these stocks may attract the interest of legitimate commercial harvesters. Such a fishery would require some assessment, monitoring and regulation by Welsh Government Fisheries before it can proceed. A sampling plan will therefore be provided, which the LEA can implement if and when a legitimate commercial fishery has been approved. This may be problematic to apply as the main concentrations of stocks are located low down the shore and are only accessible once a month. A minimum size of 100 mm applies to these species, and there is no closed season for this species so any classification must be on a year round basis.

5.3. Pollution Sources

Freshwater Inputs

All watercourses draining to the survey area will carry some microbiological contamination deriving from a variety of sources such as urban and agricultural runoff and sewage inputs, and so will require consideration in this assessment. The Menai Strait has a hydrological catchment of 522 km², of which 378 km^2 lies on the

mainland and 144 km^2 lies on Anglesey. These areas are drained by a series of watercourses of varying sizes. These freshwater inputs may create hotspots of contamination where they meet coastal waters. These will be most pronounced in the immediate vicinity of any drainage channels they follow across the intertidal, which may contain relatively high concentrations of faecal indicator bacteria at lower states of the tide. As such, RMPs should be located by these channels to best capture contamination from these watercourses.

The larger freshwater inputs to the eastern strait are from the mainland, but there are also a few minor watercourses which may be of local significance to the fisheries on the Anglesey side. Relevant information on these may be summarised as follows:

- The Adda is a culverted watercourse discharging just to the east of Bangor Pier. It was not possible to measure discharge rate during the shoreline survey, but a sample contained 2500 *E. coli* cfu/100ml.
- The Cegin is a minor river which discharges immediately to the west of Penrhyn docks. It was too large to measure discharge rate during the shoreline survey (~8 m wide) and contained 480 *E. coli* cfu/100ml at the time.
- The Ogwen is the largest river in the survey area, with a catchment extending up into Snowdonia. It discharges by Penrhyn Castle towards the eastern end of the fishery order. It was too large to measure discharge rate during the shoreline survey (~14m wide) and contained 7600 *E. coli* cfu/100ml. As both the largest and most heavily contaminated watercourse at the time of survey, it is likely to be one of the most significant contaminating influences to the fishery order, and also the eastern end of the cockle bed.
- A culverted stream discharges to the foreshore at the western end of the cockle bed at Traeth Lavan. At the time of shoreline survey it was discharging at a rate of about 0.09 m^3/sec, carrying 530 *E. coli* cfu/100ml, and so was generating a bacterial loading of $4.1x10^{10}$ *E. coli* cfu/day.
- The Aber discharges at Abergwyngregyn, and its drainage channel runs through the cockle bed at Traeth Lavan. At the time of shoreline survey it was discharging at a rate of about 1 m^3/sec, carrying only 30 *E. coli* cfu/100ml, and so was generating a bacterial loading of only $2.6x10^{10}$ *E. coli* cfu/day.
- Three further minor watercourses discharge between the Aber and Llanfairfechan, which were carrying bacterial loadings of (from west to east) $1.2x10^{10}$, $6.6x10^{10}$ and $2.4x10^{10}$ *E. coli* cfu/day at the time of shoreline survey.
- The Llanfairfechan (or Afon Ddu) discharges to Llanfairfechan seafront and its drainage channel cuts through the razor bed there. At the time of shoreline survey it was discharging at a rate of just over 1 m^3/sec, carrying 2600 *E. coli* cfu/100ml, and so was generating a bacterial loading of only $2.4x10^{12}$ *E. coli* cfu/day, the highest loading recorded during the survey.
- The largest watercourse discharging to the Anglesey side by some margin is the Cadnant, which discharges about 800 m to the west of the fishery order area. This could not be accessed during the shoreline survey.

- Between the Cadnant and Beaumaris, three further freshwater inputs were recorded on the shoreline survey, none of which was generating a bacterial loading exceeding 10^{10} *E. coli* cfu/day.

As well as significant day to day variation related to rainfall, there is seasonal variation in the discharge volumes of these watercourses. Precipitation is higher on average during the autumn and winter. This may fall as snow and lie for a time on the peaks during the winter although it does not persist throughout the colder months. Lower rates of evaporation and transpiration result in more rainfall running off during the colder months. Whether this results in seasonal fluctuations in the average bacterial load delivered to coastal water is uncertain.

Human Population

Total resident population within census areas contained within or partially within the entire Menai Strait catchment area was just over 92,000 at the time of the last census. Most live in coastal settlements and almost 80 % reside on the mainland. The shores of the central and eastern strait are more heavily populated than those of the western strait. The main settlement is Bangor, adjacent to the central eastern strait. There are further small towns at Menai Bridge and Beaumaris on Anglesey, and Llanfairfechan on the mainland. Other coastal areas such as the stretch between Bangor and Llanfairfechan are sparsely populated, as is the mainland away from the coast. Very few people live in the upper mainland catchment where it extends into Snowdonia.

The coastal location and proximity to Snowdonia National Park will draw an influx of tourists to the area during the summer months, although no firm quantitative information on numbers could be found. Bangor has a university attended by around 8,000 students. The majority of these will leave the area during holiday periods, of which the main one is in summer and runs from June to October. It is therefore concluded that whilst the sewage works serving most areas are likely to be serving a larger population during the summer, a significant decrease in the population of Bangor is likely to occur at these times.

Sewage Discharges

There are six water company owned sewage works which discharge direct to the eastern strait, but none of their outfalls lie within any currently classified areas. Just to the west of The Swellies there are two significant discharges which may be of some impact on the shellfisheries. The largest of these is Treborth STW, which discharges around the low water mark on the south shore of the strait about 400 m west of Britannia Bridge. It provides UV treatment for a consented dry weather flow of 9,107 m^3/day. Regular flow measurements and bacteriological testing of the final effluent from here have been undertaken in recent years from which instantaneous

estimates of the bacterial loading it was generating could be made. The geometric mean loading was relatively minor at $1.7x10^{10}$ faecal coliforms/day, with most individual measurements in the 10^9 to 10^{11} range. The maximum instantaneous loading was however more than two orders of magnitude higher than the average ($7.5x10^{12}$ faecal coliforms/day). Bacterial loadings here were slightly lower on average during the winter, but this difference was not statistically significant. The Llanfair STW discharges around the low water mark on the north shore of the strait, about 1.1 km west of the Britannia Bridge. This provides secondary treatment for a consented dry weather flow of 958 m^3/day, so an approximate estimate of the bacterial loading it generates is $3.2x10^{12}$ faecal coliforms/day.

There are two sewage works to the north of Beaumaris, both of which discharge to the subtidal channel there. Llanfaes STW provides secondary treatment for a consented dry weather flow of 703 m^3/day and generates an estimated bacterial loading of $2.3x10^{12}$ faecal coliforms/day. Llangoed STW provides secondary treatment for a dry weather flow of 475 m^3/day and generates an estimated bacterial loading of $1.6x10^{12}$ faecal coliforms/day. They lie 1.2 km and 3 km from the fishery order, and their impacts will be felt most acutely in the subtidal channel at Beaumaris, at the eastern edge of the fishery order.

The Llanfairfechan STW provides secondary treatment for a dry weather flow of 1468 m^3/day, and generates an estimated bacterial loading of $4.8x10^{12}$ faecal coliforms/day. It discharges to the upper foreshore, to a drainage channel carrying a minor watercourse. This channel then runs through the eastern edge of the cockle bed at Traeth Lafan. As such this is likely to be a significant contaminating influence to the cockle bed, and an RMP located immediately adjacent to the drainage channel would best capture its impacts. The Penmaenmawr STW provides secondary treatment for a dry weather flow of 2330 m^3/day, and generates an estimated bacterial loading of $7.7x10^{12}$ faecal coliforms per day. As it discharges about 6.5 km to the east of the Traeth Lafan cockle bed its impacts there will not be particularly acute. Greater impacts may arise towards the eastern end of the razor bed of Llanfairfechan if a fishery is developed there, although this is still over 3 km away.

The Cegin receives effluent from one sewage works (Rhiwlas STW) which generates a combined estimated bacterial loading of $1.0x10^{12}$ faecal coliforms/day. The Ogwen receives effluent from five sewage works (Bethesda STW, Llanddegai STW, Mynydd Llandegai Septic Tank, Talybont STW and Tregarth STW). Together, these generate an estimated bacterial loading of $7.9x10^{12}$ faecal coliforms/day. It can therefore be concluded that both these watercourses carry significant amounts of sewage effluent, although there is likely to be some bacterial die off in transit, particularly for the ones located further inland.

There are 61 intermittent sewage discharges which may have an impact on shellfish resources within the eastern strait. The main cluster is in the Bangor and Menai Bridge area, where the mussel fishery is located. There are also minor clusters at

Llanfairfechan and on Anglesey between Beaumaris and Llangoed. The rivers Cegin and Ogwen also both receive several intermittent discharges. A modelling study undertaken on behalf of Welsh Water estimated spill durations and volumes within several of the coastal sewage catchments. The biggest spillers in terms of both volumes discharged and the percentage of time active were all within the Treborth STW catchment. Treborth WwTW storm tank overflow was modelled to spill 359,587 m^3 annually, spilling for 16.2% of the year; Bangor Beach Road Rd with a spill volume of 259,237 m^3, predicted to spill for 2.16% of a year and Llandegfan Main Pumping Station Storm Tanks Overflow, discharging 160,113 m^3 annually, predicted to spill for 28.3% of the year. Other discharges direct to the fishery order were Merion Road PS which had a negligible annual spill volume (33.7 m^3) and two other discharges (Glyn Garth PS and Rhiana PS) neither of which featured in the study.

Other clusters of intermittent discharges relevant to water quality in the survey area that were modelled by Metoc include five assets in the Beaumaris catchment which together were predicted to have an annual spill volume of 86,008 m^3 and three assets in the Llangoed catchment with a combined annual spill volume of 2,887 m^3. Modelled spill volumes and frequencies for the Llanfairfechan STW catchment were negligible.

Intermittent discharges create issues in management of shellfish hygiene however infrequently they spill. Their impacts' are not usually captured during a year's worth of monthly monitoring from which the classification is derived as typically they only operate occasionally. Thus when they do have a significant spill, heavily contaminated shellfish may be harvested under a better classification than the levels of *E. coli* within them may merit. A reactive system alerting relevant parties to spill events in real time may therefore convey better public health protection. Welsh Water are in the process of installing spill event monitoring to all intermittent discharges likely to impact on shellfisheries within the strait.

As well as the water company owned sewerage infrastructure, there are a number of private sewage discharges in the area. There are a few relatively minor private discharges direct to the fishery order area. Bangor pier is consented to discharge up to 5 m^3/day of macerated sewage effluent. The low levels of treatment and its location suggest that it may create a small hotspot of contamination on the mussel beds. The Gazelle Hotel lies almost exactly opposite the pier and is consented to discharge up to 13.8 m^3/day of secondary treated effluent. Again this may create a small hotspot of contamination in its immediate vicinity. To the west of the Gazelle Hotel, there are a few small domestic discharges to the foreshore. Some of the watercourses draining to the eastern strait receive inputs from private discharges, but there are few of these. Also of potential relevance, it is reported that there are several unregistered domestic discharges to a surface water culvert that discharges

by Beaumaris Pier. The Cegin and the Cadnant are impacted in a minor way from such discharges.

Agriculture

The majority of land within the Menai Strait hydrological catchment is used for agriculture. Most are pastures, although there are a few small pockets where crops are cultivated, most of which lie on Anglesey. A total of 22,453 cattle and 201,495 sheep were recorded within the catchment area in the 2012 agricultural census, so significant and widespread impacts from grazing animals are anticipated. Sheep are present throughout the survey area in similar (high) densities throughout. Faecal matter from grazing livestock is either deposited directly on pastures, or collected from livestock sheds if animals are housed indoors during the colder months and then applied to agricultural lands as a fertilizer. There are also some poultry farmed in the area, mainly on Anglesey, but hardly any pigs. Manure from poultry and pigs is typically stored and applied tactically to nearby farmland. Sewage sludge is applied sporadically on a year round basis in certain areas, typically where arable farming is undertaken.

The primary mechanism for mobilisation of faecal matter from agricultural land is via land runoff, so fluxes of livestock related contamination into the estuary will be highly rainfall dependent. All significant watercourses will be affected to some extent. Therefore, RMPs should be located at points where the influence of freshwater inputs are the highest, such as adjacent to any drainage channels they follow across the intertidal. Rainfall and river flows are generally higher during the winter months, although high rainfall events may occur at any time of the year. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the ‘first flush’). Numbers of sheep and cattle will increase significantly in the spring, with the birth of lambs and calves, and decrease in the autumn when animals are sent to market. During the warmer months, livestock are likely to spend more time accessing watercourses to drink and cool off. The seasonal pattern in application of manures and slurries to agricultural land is uncertain. Cattle may be housed indoors during the winter, so applications of slurry collected from such operations is likely to be spread in the late winter and spring, depending on the storage capacities of each farm.

Boats

The survey area is used by a variety of craft, including recreational craft (yachts and cabin cruisers), fishing boats, and the occasional larger vessel. As boats may make overboard discharges of sewage they will require consideration in this assessment.

There is a small port at Penrhyn, which receives some commercial traffic and has around 75 yacht berths. There are extensive areas of yacht moorings throughout the

area between Menai Bridge and Penrhyn, and in another discrete area off Beaumaris, and the eastern strait is reported to be a heavily used recreational route. A small number of fishing boats operate out of Bangor/Penrhyn. There are no sewage pump out facilities available within the eastern strait, and the closest available are at Victoria Dock in the western strait.

Merchant shipping is not permitted to make overboard discharges in coastal waters so should be of no impact. Pleasure craft are likely to form the bulk of boat traffic within the eastern strait. It is likely that the larger of the private vessels (yachts, cabin cruisers, fishing vessels) which have onboard toilets make overboard discharges from time to time. This may occur whilst boats are in passage, and it is quite likely that any boats in overnight occupation on the moorings will make a discharge at some point during their stay. Those berthed at Penrhyn have easy access to on shore facilities so may be less inclined to make overboard discharges. The area between Penrhyn and the Menai Bridge, and the area off Beaumaris are therefore at most risk on this basis. Peak pleasure craft activity will arise in the summer, so any associated impacts are likely to follow this seasonal pattern. However, it is difficult to be more specific without any firm information about the locations, timings and volumes of such discharges, and as such boating will have little material bearing on the sampling plan.

Wildlife

The Menai Strait encompasses a wide range of habitats and these attract aggregations of wildlife, some of which may be an influence on shellfish hygiene. The most significant of these is likely to be the waterbird (wildfowl and waders) populations which overwinter in the area. Regular counts are undertaken at the principle site at Traeth Lafan, where the average total count in recent years is just over 17,000 birds. The grazing birds will frequent areas of pasture and saltmarsh, so contamination from these will be carried into the survey area via land runoff or tidal inundation. Therefore RMPs within or near to the drainage channels from saltmarsh areas or watercourses draining pastures will be best located to capture contamination from this source. Waders will forage (and defecate) directly on shellfish and other invertebrates in intertidal areas. Due to the diffuse and spatially unpredictable nature of contamination from wading birds it is difficult to select specific RMP locations to best capture this, although they may well be a significant influence particularly during the winter months.

Whilst most of the waterbirds will move to other areas to breed, there are resident populations of seabirds (gulls, terns, cormorants etc) within the area. The main breeding colony is located on Puffin Island where 6,424 individual seabirds including guillemots, cormorants, kittiwake, puffins and gulls were recorded during a survey in 2000. These birds forage widely so are likely to have some influence on shellfish hygiene, but in the absence of any large breeding colonies in close proximity to any

shellfish beds they may be considered a diffuse source and so will not influence the sampling plan.

Grey seals are a regular presence in the strait, but are most regularly seen in the vicinity of Puffin Island, and counts have ranged from 11 to 130, with highest numbers in the winter months. Their impacts are likely to be greatest where they haul out to rest, which mainly occurs on Puffin Island. No seal haulout sites have been identified in the immediate vicinity of any shellfisheries, so their impacts here will be minor and diffuse, and will not influence the sampling plan.

Domestic animals

Dog walking takes place on beaches and paths adjacent to the shoreline of the survey area and could represent a potential source of diffuse contamination to the near shore zone. The intensity of dog walking is likely to be higher closer to the more urban areas such as Bangor. As a diffuse source, this will have little influence on the location of RMPs.

Summary of Pollution Sources

An overview of sources of pollution likely to affect the levels of microbiological contamination to the shellfish beds is shown in Table 5.1 and Figure 5.1.

Table 5.1: Qualitative assessment of seasonality of important sources of contamination.

Pollution source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Agricultural runoff												
Continuous sewage discharges												
Intermittent sewage discharges												
Urban runoff												
Waterbirds												
Boats												

Red - high risk; orange - moderate risk; yellow - lower risk;

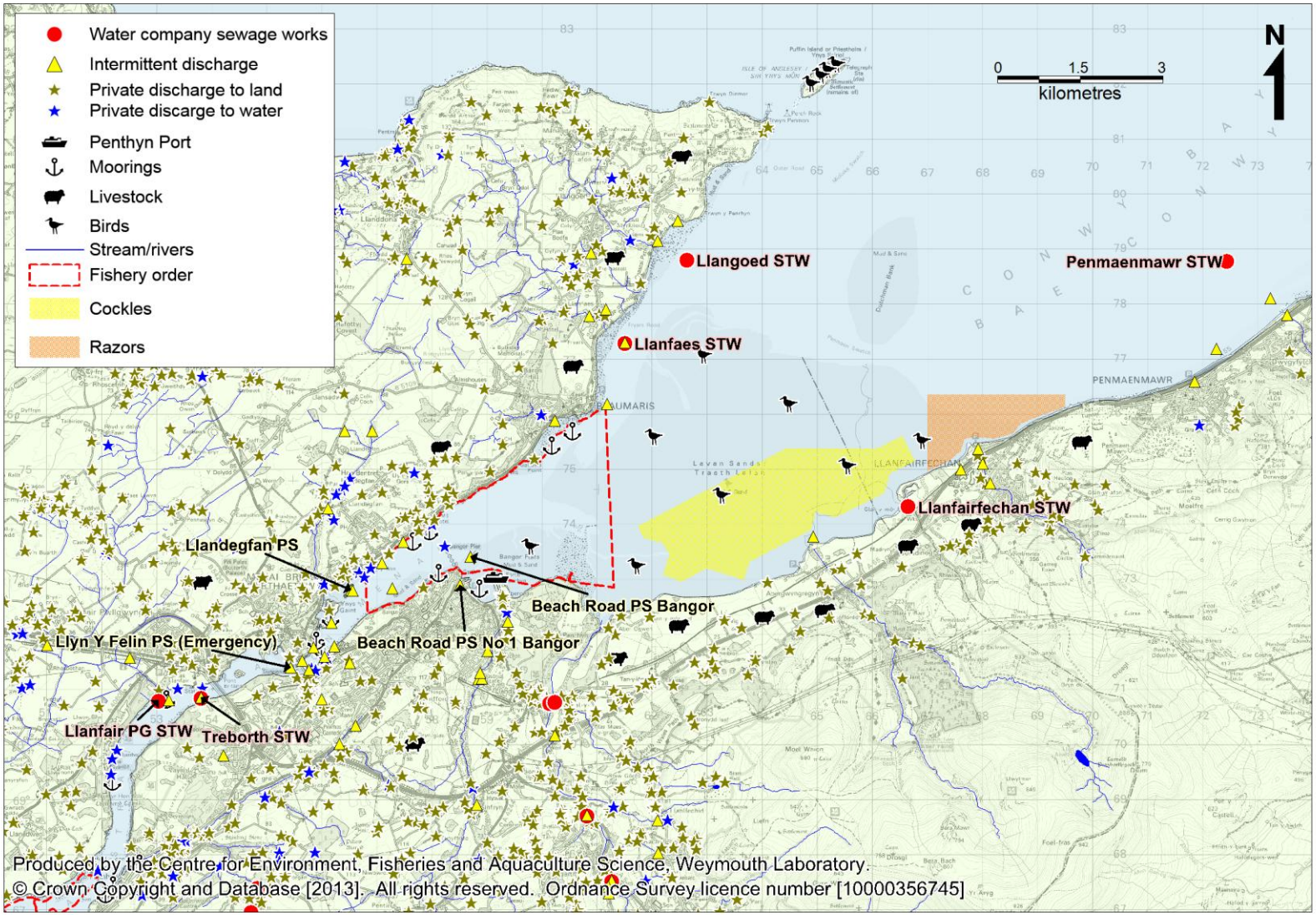

Figure 5.1: Summary of main contaminating influences

5.4. Hydrography

The Menai Strait is a tidal channel of about 30 km in length which separates mainland Wales from the Isle of Anglesey. It is characterised by a subtidal channel flanked by intertidal areas of varying width. The western entrance is flanked by two sand spits, inside each of which lie extensive intertidal sandy bays. The intertidal areas become progressively narrower and rockier towards The Swellies in the central reaches where the strait is only about 300 m in width, the bottom is rocky and uneven, and depths in the channel are as little as 1 m relative to chart datum. Significant turbulent mixing will occur here as tidal flows accelerate, so any contamination coming in from the west will be well mixed in the water column as it passes through. To the east of The Swellies, the strait widen progressively to about 7.5 km at the eastern mouth. The subtidal channel follows the Anglesey shore, with expansive intertidal flats (Traeth Lafan) to the south. A large proportion of water will therefore be exchanged on each tide, but the dilution potential will be quite low away from the main channels. Water depths in the channel at chart datum vary from only a few meters to pools over 10 m depth at Menai Bridge, off Bangor, off Gallows Point and south of Tre-castell Point. A subtidal channel (Penmaen Swatch) partially separates an offshore sandbank (Dutchman Bank) from Traeth Lafan. None of the watercourses discharging to the eastern strait have defined estuaries and drain directly to the intertidal areas so will create plumes whilst the tide is both flooding and ebbing. They follow channels cut across the intertidal areas, and within these relatively high concentrations of faecal indicator bacteria are likely to arise at lower states of the tide.

The tidal range in the area is relatively large, but is considerably smaller at the western end (4.0 m on spring tides at Fort Belan) than at the eastern end (6.8 m on spring tides at Beaumaris). The high tidal amplitude drives extensive water movements within the strait. Tidal streams enter first from the west and proceed up the strait. About 40 minutes later they enter from the east, and then the two opposing tidal streams meet somewhere in the central strait at a point dependant on local wind and tidal conditions. This pattern of circulation means that sources discharging to the shoreline of the strait in the vicinity of the main channel will impact to either side of their location and any plume will tend to remain by the same shore becoming progressively more diluted with distance. The tide is reported to flood over northern and eastern Traeth Lafan from the north and east, and over western Traeth Lafan from the north and west, with the reverse occurring on the ebb. As such, shoreline sources to the east will impact on the eastern end of the bed, and sources to the north and west (such as any in the Beaumaris area and the River Ogwen) will impact on the western end of the bed. Impacts in the central areas will largely be from local sources.

Currents in the area are strongest at The Swellies, where their velocities exceed 2.5 m/s on spring tides. They are slower in the subtidal channel away this constriction (0.5 m/s) and are slower still over intertidal areas such as Traeth Lafan. Estimates of tidal excursions within the strait are in the very approximate order of 10-13 km on spring tides and 5-7 km on neap tides. In the absence of strong winds, there is a significant residual westward flow, which equates to a net westerly current velocity of 0.15 m/s when averaged over a tidal cycle. This will result in an underlying tendency for sources of contamination to be flushed in a westerly direction along the main channel.

Superimposed on tidal streams are the effects of winds and freshwater inputs. Strong winds will modify circulation by driving surface currents, which in turn create return currents either at depth or along sheltered margins. The strait is most exposed to the prevailing south westerly winds as well as north easterly winds, which will tend to be funnelled up and down it by the surrounding land. Strong winds can significantly modify the residual south westerly water movement through the strait. Northwest winds will augment the flow, while southwest winds reduce or even reverse it when they exceed ~20 m/s and 12.5 m/s during spring and neap tides respectively. The exact effects of wind are dependent on its speed and direction as well as state of the tide and other environmental variables so a great number of scenarios may arise. Where strong winds blow across a sufficient distance of water they may create wave action, and where these waves break contamination held in intertidal sediments may be re-suspended. The eastern strait is most exposed to winds from the north east, which may at times generate significant wave action, primarily on the mainland shore in the vicinity of the cockle and razor beds.

The strait receives freshwater inputs from a number of rivers and smaller watercourses at various locations, but their combined input volumes are minor in relation to tidal exchange. As a result, salinity is usually between 32 and 34 ppt and falls below 30 ppt infrequently, and the system is considered well mixed. Density driven circulation is therefore unlikely to modify tidal circulation, except perhaps on a localised basis at times of high river flow. Repeated salinity measurements taken at Llanfairfechan in close proximity to the outfall of a small river indicated that there is normally little freshwater influence at this location, but also show that very occasionally salinities of less than 10 ppt have arisen here. It is likely that localised decreases in salinity are associated with the main freshwater inputs, and within such areas higher levels of runoff borne contamination will arise.

5.5. Summary of Existing Microbiological Data

The survey has been subject to considerable microbiological monitoring over recent years, consisting of Bathing and Shellfish Waters monitoring programmes and shellfish flesh monitoring for hygiene classification purposes. Figure 5.2 shows the

locations of the monitoring points referred to in this assessment. Results from 2003 onwards are considered in the analyses.

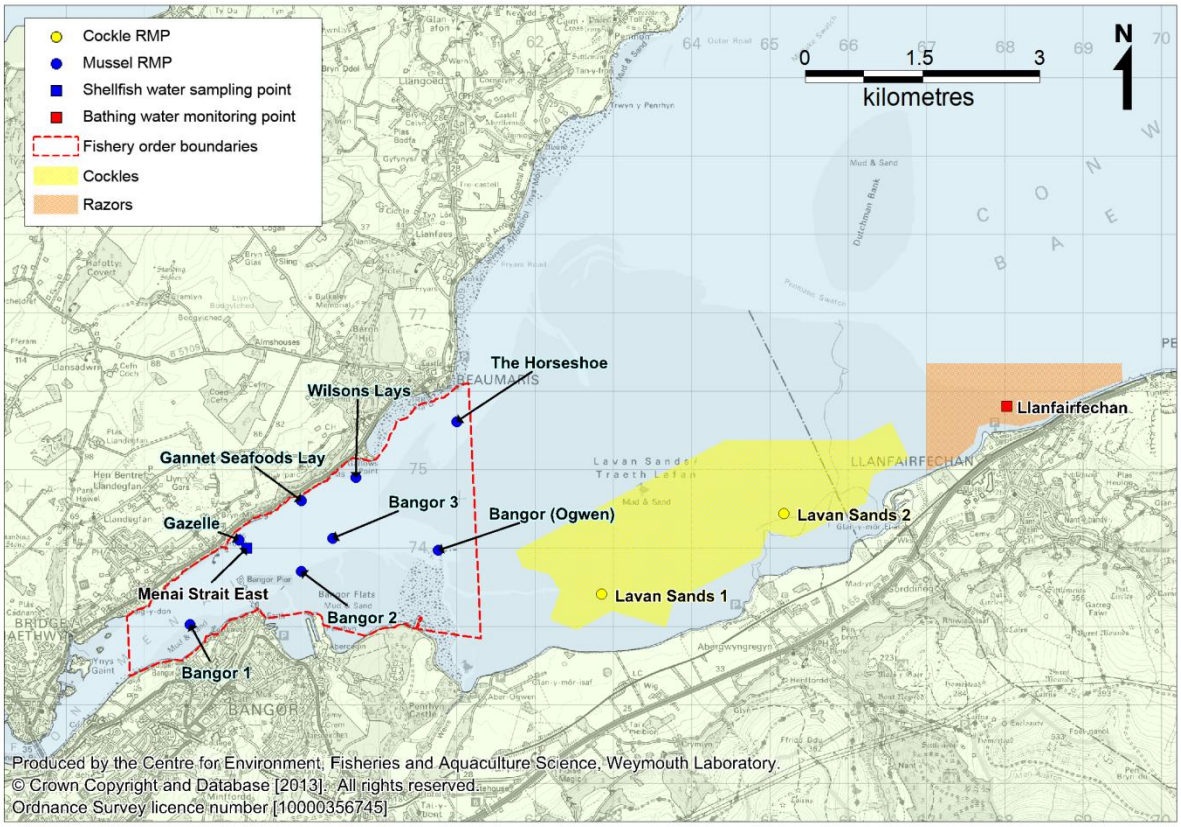

Figure 5.2: Microbiological sampling sites

Bathing waters

Around twenty water samples were taken from the bathing waters site (Llanfairfechan) during each bathing season, which runs from the 15th May to the 30th September. Faecal coliforms were enumerated in all these samples. Only data up to 2011 was included due to a recent change in analysis methods. The geometric mean result here was 26.4 faecal coliforms/100ml, and the maximum recorded result was 11,000. Faecal coliform levels have remained fairly stable on average from 2003-2011. A statistically significant influence of the spring/neap tidal cycle was detected here, and a plot of the data suggested that higher results tended to occur as the tide size increased from neap tides to spring tides. This might suggest that contamination deposited between the high water neap and high water spring tide lines may be of influence, although there is no evidence to substantiate this. Faecal coliform levels were strongly influenced by rainfall up to (and possibly beyond) seven days after an event. Similarly, a significant negative correlation between salinity and faecal coliforms was detected. It is therefore concluded that land runoff is a significant influence at this location, which is close to where a minor watercourse discharges across the beach.

Shellfish waters

There is one shellfish waters monitoring point in the eastern strait (Menai Strait East) where faecal coliforms are enumerated in near surface water samples on a quarterly basis. The average and peak results were quite low (11.9 and 231 faecal coliforms/100ml) and only 2.5 % of samples exceeded 100 faecal coliforms/100ml. Faecal coliform concentrations remained similar on average throughout the period 2003 to present. Seasonal variation was statistically significant, with significantly higher results in the winter compared to the spring and summer. A statistically significant effect was detected in relation to both the spring/neap and high/low tidal cycles. Across the high/low tidal cycle, results are generally lower around high water when dilution potential is greatest. Across the spring neap tidal cycle results tended to be higher on average as tide sizes increase from neap to spring tides. Antecedent rainfall over the week before sampling had a strong influence on levels of faecal coliforms in the water column. Similarly, a significant negative correlation was found between faecal coliform concentrations and salinity, suggesting that land runoff is a significant contaminating influence.

Shellfish hygiene

There are a total of 8 mussel RMPs and 2 cockle RMPs within the survey area where *E. coli* levels on shellfish flesh have been enumerated on a more or less monthly basis at each throughout the period 2003 to present.

Across the two cockle RMPs, the geometric mean result was marginally higher at Lavan Sands 1 than at Lavan Sands 2 (217.8 and 182.8 *E. coli* MPN/100g respectively), but the proportion of results exceeding was higher at the latter (1 % and 3 % respectively). There was no statistically significant difference between the average result at the two, and a comparison of paired (same day) samples showed that *E. coli* levels were strongly correlated between the two on a sample by sample basis. This suggests there is no need for both points to be monitored, but does not take into account that there is likely to be a hotspot at the eastern end (associated with Llanfairfechan STW) and increasing levels of contamination towards the far western end where the influence of the Ogwen and other sources to the west is likely to be greater.

Across the eight mussel RMPs, the geometric mean result was similar throughout, ranging from 119.0 to 200.2 *E. coli* MPN/100g. The difference between average results across them was not quite statistically significant. The highest average and peak result were recorded at the outermost two sites (Bangor Ogwen and Horseshoe), and these were the only locations where results of over 4600 *E. coli* MPN/100g were recorded. Results were lowest at the three sites on the Anglesey side to the west of Gallows Point (Wilsons Lays, Gannets Seafood Lays, and Gazelle). Across Bangor 1, 2 and 3, results were highest at Bangor 1, the site to the

west of Bangor Pier. Comparisons of paired (same day) samples showed that *E. coli* levels were strongly correlated between all site pairings on a sample by sample basis. These results indicate that there are broadly similar levels of contamination throughout the fishery order, and that all RMPs are mainly influenced by the same sources or by sources that respond in a similar way to environmental factors. In terms of classification thresholds, results at all sites are consistent with a solid B classification. As such there is a case for reducing the number of RMPs monitored, although this does not take into account any optimisation of RMPs to best align with hotspots of contamination. The results also tentatively suggest that on the Anglesey side sources to the north east are of influence, which include the Llanfaes and Llangoed STWs. Alternatively, the geographic pattern of results here may be due to more localised influences. The Ogwen is likely to be responsible for the slightly elevated results at Bangor (Ogwen).

During the period 2003 to present there was a slight increase in *E. coli* levels at Lavan Sands 1, but this was followed by a decrease back to levels comparable to 2003 from 2011 to present. At Lavan Sands 2, *E. coli* levels fluctuated lightly from 2003 to 2011 and there appears to have been a slight declining trend since. At all mussel RMPs except The Horseshoe there was a slight decrease *E. coli* levels from 2003 to 2006/2007 followed by relatively stable *E. coli* levels to present. At The Horseshoe, *E. coli* levels were stable until 2011 and have decreased slightly since then. Results were similar on average across the seasons at all RMPs, and no statistically significant seasonal variation was detected at any of them.

No significant influence of either the spring/neap of high/low tidal cycles were found at either of the cockle RMPs. A statistically significant influence of the high/low tidal cycle was found at all mussel RMPs except Gazelle and Gannets Seafood Lays. All six mussel RMPs where there was a significant correlation appeared to have higher results on average when the tide was flooding, but this was not a particularly strong pattern. It may suggest that in general, sources to the east are of more importance than sources to the west, which ties in to some extent with the observed geographical pattern. Significant correlations between *E. coli* results and the spring neap tidal cycle were found at all mussel RMPs except Gazelle and Bangor (Ogwen). At those RMPs where there was a correlation, there tended to be lower *E. coli* levels as the tide size decreased towards neap tides, although this pattern was barely discernible at some RMPs.

Rainfall affected the levels of *E. coli* found in shellfish to some extent in all site except Bangor 1, Bangor 3 and Bangor (Ogwen) mussel RMPs. This is surprising, particularly for Bangor (Ogwen) which lies by the Ogwen drainage channel. The strongest influence was at the Lavan Sands 2 cockle RMP which lies in close proximity to the drainage channel of a minor watercourse.

Appendices

Appendix I. Human Population

Figure I.1 shows population densities in census output areas within or partially within the Menai Strait catchment area, derived from data collected from the 2011 census.

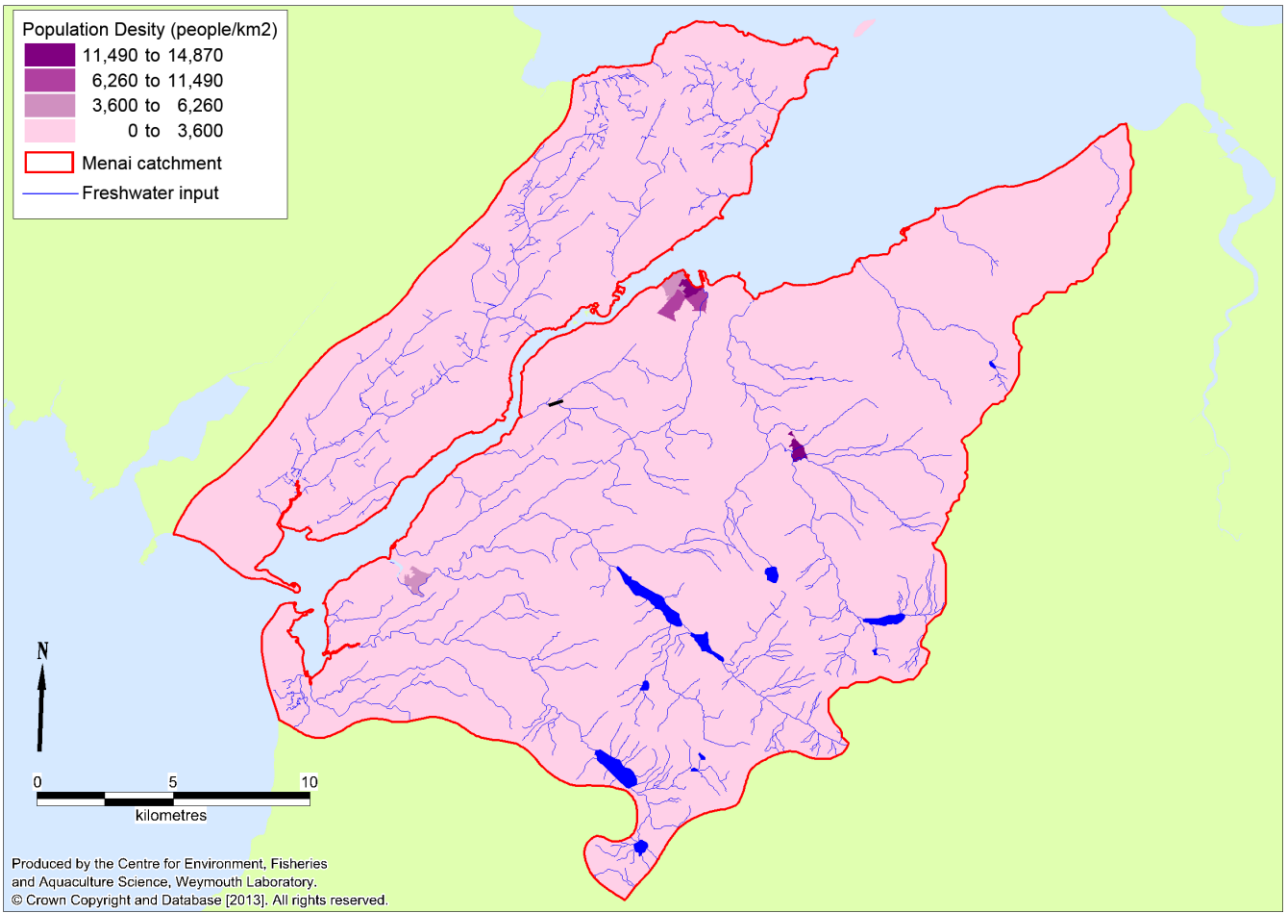

Figure I.1: Human population density in census areas in the Menai Strait catchment.

Total resident population within census areas contained within or partially within the catchment area was just over 92,000 at the time of the last census. Of these about 20,000 reside on Anglesey and 72,000 reside on the mainland. The largest settlement in the area is the university city of Bangor, which had a population of about 17,500 at the time of census. The census date fell within the University of Bangor term time, so most students should have been in residence and included in these figures. On Anglesey, most settlements are on the coast by the central and eastern strait. The rest of the catchment is generally rural, with some small settlements. Very few people reside in the upper reaches of the mainland catchment where it extends into Snowdonia.

There will be some seasonality in population within the survey area. Bangor University has around 8,000 students (Bangor University website, 2013) a large proportion of which will leave the area during holiday times (3 weeks at Christmas and Easter, and almost 4 months in summer). At the same time as the summer student exodus, there will be an influx of tourists attracted by the seaside location

and the proximity to Snowdonia National Park. It is therefore concluded that whilst there may be a decrease in the population of Bangor during the summer, increases in populations will probably occur in most other areas. The seasonal variation in population levels in the catchment will result in corresponding seasonal variations in the amount of sewage effluent received by sewage treatment works serving the areas, and the bacterial loadings they generate may be expected to fluctuate accordingly.

Appendix II. Sources and Variation of Microbiological Pollution: Sewage Discharges

Details of all consented water company sewage discharges potentially impacting on the Menai Strait East shellfisheries were taken from the most recent update of the Environment Agency national permit database (March 2013). These are mapped in Figure II.1.

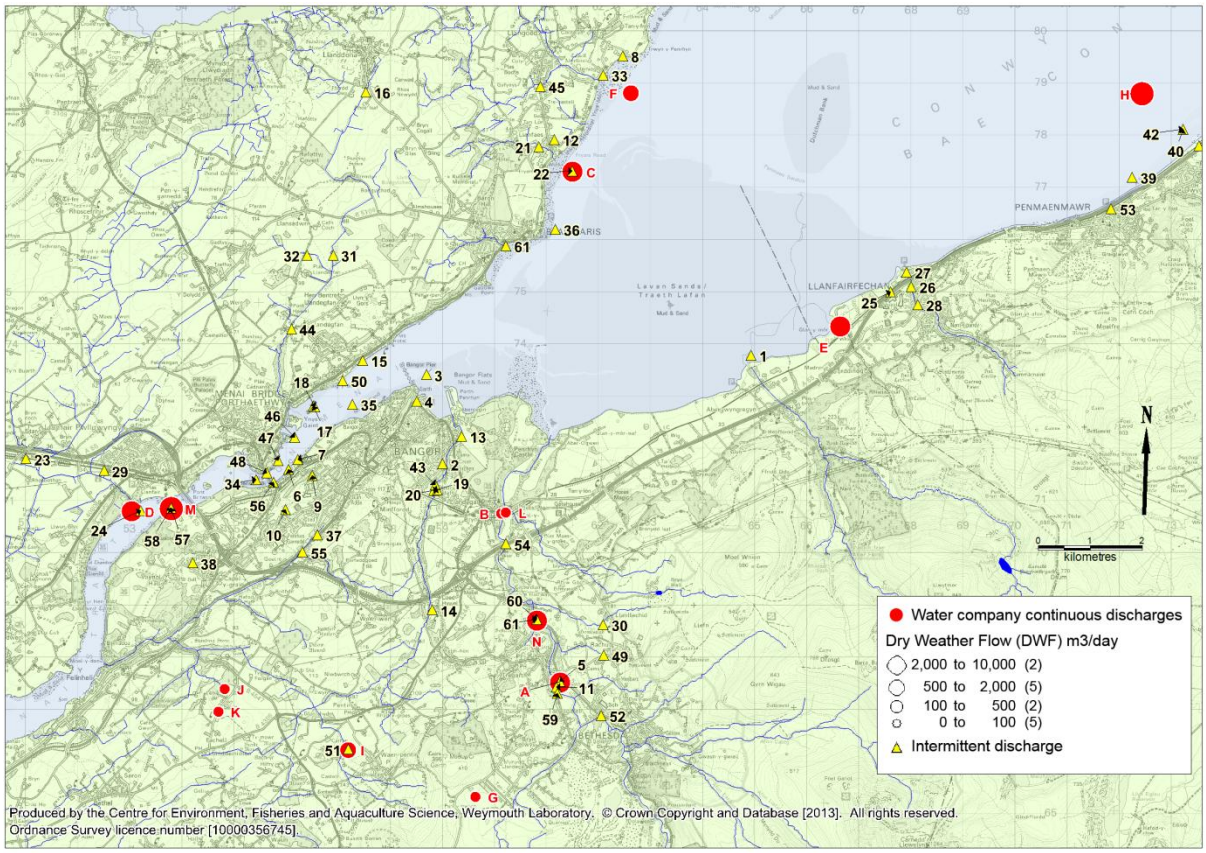

Figure II.1: Water company owned sewage discharges to the Menai Strait East
Data from the Environment Agency

There are 14 continuous water company discharges to the eastern strait, details of which are presented in Table II.1. Water company intermittent discharges within the same area are listed in Table II.4.

Table II.1: Details of continuous water company sewage works within the survey area

Ref	Name	NGR	Treatment	DWF (m^3/day)	Estimated bacterial loading (cfu/day)	Receiving environment
A	Bethesda STW (Final) Bethesda	SH6125067520	Biological Filtration	1679	$5.54x10^{12}$	River Ogwen
B	Llandegai STW	SH6013070760	Biological Filtration	8	$2.71x10^{10}$	Trib of Afon Ogwen
C	Llanfaes WWTW	SH6149477308	Biological Filtration	703	$2.32x10^{12}$	Menai Strait
D	Llanfair PG WWTW	SH5302470802	Biological Filtration	958	$3.16x10^{12}$	Menai Strait
E	Llanfairfechan WWTW	SH6663974343	Biological Filtration	1468	$4.84x10^{12}$	Menai Strait
F	Llangoed WWTW	SH6262078820	Biological Filtration	475	$1.57x10^{12}$	Menai Strait
G	Mynydd Llandegai WTW	SH5963065330	Septic Tank	0.1***	$3.30x10^{8}$	Unnamed Watercourse
H	Penmaenmawr WWTW	SH7243078800	Biological Filtration	2330	$7.69x10^{12}$	Coastal Waters of Conwy Bay
I	Rhiwlas STW	SH5719066230	Biological Filtration	315	$1.04x10^{12}$	Cegin
J	Seion No1 New STW	SH5482067400	Biological Filtration	4	$1.35x10^{10}$	Trib of Nant Y Garth
K	Seion No2 Septic Tank/ Soakaway	SH5469666965	Septic Tank	8***	$2.77x10^{10}$	Groundwater
L	Talybont STW	SH6022070780	Biological Filtration	95	$3.14x10^{11}$	Afon Ogwen
M	Treborth STW (Final) Bangor	SH5379070850	UV Disinfection	9107	$1.7x10^{10}$ **	Menai Strait
N	Tregarth	SH6081068710	Biological Filtration	616	$2.03x10^{12}$	Ogwen

Data from the Environment Agency

*Faecal coliforms (cfu/day) based on geometric base flow averages from a range of UK STWs providing secondary treatment (Table II.2)

**faecal coliform (cfu/day) based on geometric mean final effluent testing data

*** Max flow provided, not DWF

Table II.2: Summary of reference faecal coliform levels (cfu/100ml) for different sewage treatment levels under different flow conditions.

Treatment Level	Flow			
	Base-flow		High-flow	
	n	Geometric mean	n	Geometric mean
Storm overflow (53)	-	-	200	$7.2x10^{6}$
Primary (12)	127	$1.0x10^{7}$	14	$4.6x10^{6}$
Secondary (67)	864	$3.3x10^{5}$	184	$5.0x10^{5}$
Tertiary (UV) (8)	108	$2.8x10^{2}$	6	$3.6x10^{2}$

Data from Kay et al. (2008b).

n - number of samples.

Figures in brackets indicate the number of STWs sampled.

The largest discharge to the Menai Strait (Treborth STW) receives UV disinfection and its outfall is located about 3.5 km to the west of the fishery order area. Table II.3 and Figure II.2 summarise the results of bacteriological testing of the final effluent.

Table II.3: Summary statistics for final effluent testing data (faecal coliform cfu/100ml) from Treborth STW, January 2008 to November 2012

Sewage works	No.	Geometric mean result (cfu/100ml)	Minimum	Maximum
Treborth STW	131	243	0	110,000

Data from the Environment Agency

Bacteriological testing results for the final effluent from Treborth STW indicates that disinfection is consistently effective. The estimated (average) bacterial loading it generates is therefore very small, although the maximum concentration of faecal coliforms recorded is over two orders of magnitude higher than the average. It must be noted that UV disinfection is less effective at eliminating viruses than bacteria (e.g. Tree et al, 1997).

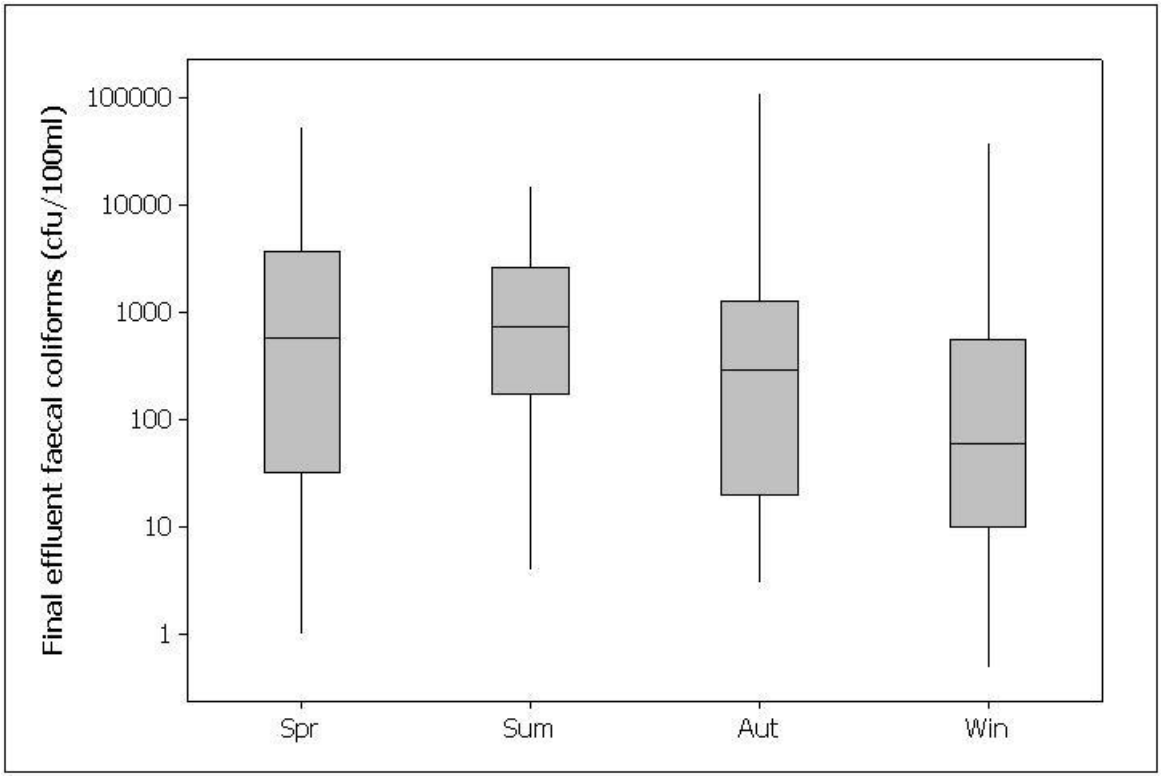

Figure II.2: Boxplot of faecal coliform concentrations in Treborth STW final effluent by season.
Data from the Environment Agency.

Some seasonality in faecal coliform concentrations was observed at Treborth STW, with significantly higher concentrations in the summer than in the winter. Each time the effluent was sampled, a spot flow reading was also taken allowing instantaneous estimates of the bacterial loading generated to be made.

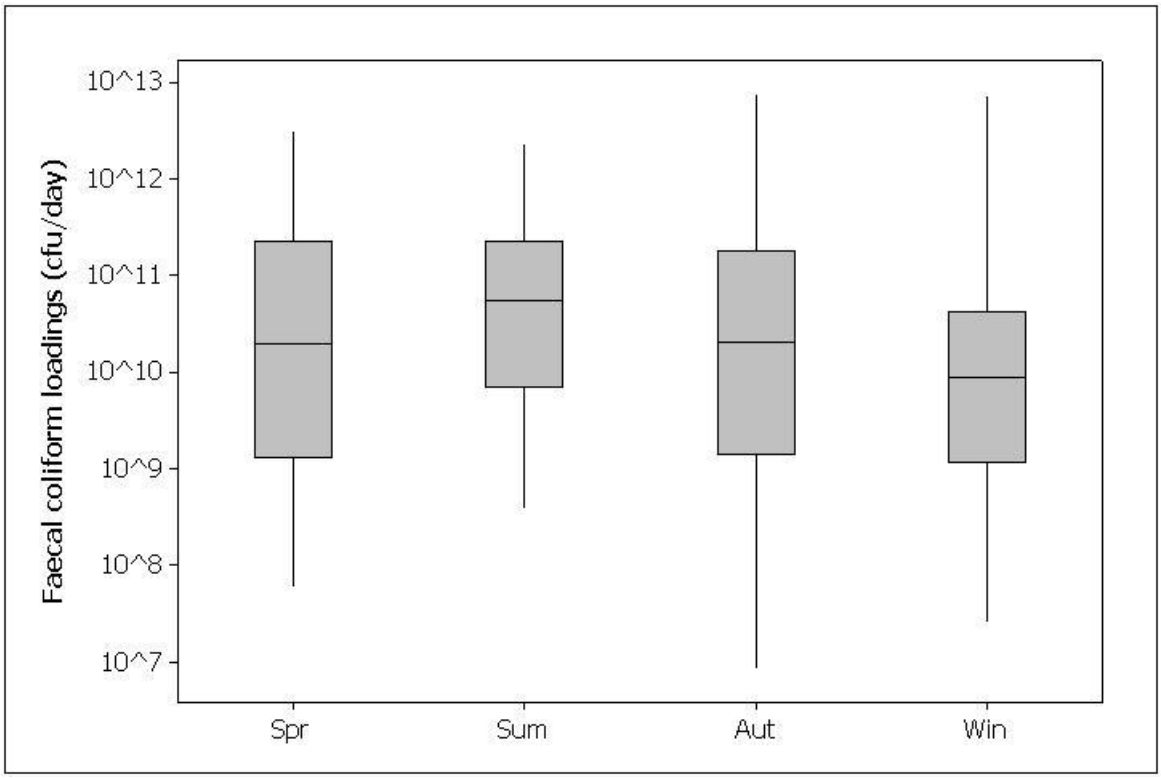

Figure II.3: Boxplot of faecal coliform daily loadings in Treborth STW final effluent by season
Data from the Environment Agency.

Although there was seasonality in faecal coliform concentrations, the increased flows during the colder months resulted in broadly similar daily loading by season, although it tended to be slightly lower during the colder parts of the year. As such, Treborth STW makes a relatively consistent contribution to microbial loading to the receiving waters in the Menai Strait. Although most of the instantaneous faecal coliform loading estimates were within the 10^9 to 10^{11} per day range, the overall variation between the minimum and maximum recorded was large (8.64×10^6 and 7.51×10^{12} cfu/day). Given its typical bacterial loading and its location, Treborth STW will generally be of negligible impact to the shellfisheries.

Other water company continuous discharges that are made directly to the Menai Strait include Llanfair PG WWTW, which has a consented DWF of 958 m^3/day for secondary treated effluent and discharges about 4.25 km to the west of the production area. This discharge will contribute microbiological loading to waters reaching the shellfisheries according to water circulation along the Menai Strait. Llanfairfechan WWTW discharges off the north coast of mainland Wales, approximately 0.6 km to the east of the classified area and has a consented DWF of 1,468m^3/day secondary treated effluent. This discharge will make a significant contribution to microbiological loadings in the Menai Strait East shellfisheries. Llanfaes WWTW discharges just off the southern shore of Anglesey, approximately 1km to the east of the production area and has a consented DWF of 703 m^3/day of secondary treated effluent and this discharge will also be of significance to water quality in the eastern extent of the shellfisheries here.

Llangoed WWTW is located about 3km east of the production area, discharging off the south coast of Anglesey. This discharge has a consented DWF of 475 m^3/day, discharging secondary treated effluent which will contribute to microbiological loadings in the eastern Menai Strait. Penmaenmawr WWTW discharges to open water, about 7.5 km to the east of the fisheries and has a consented DWF of 2,330 m^3/day. Although this discharge is at some distance from the shellfisheries and it receives significant dilution in the receiving water, it is large and will contribute to loading in the Menai Strait East, potentially impacting on the fisheries according to tides and local currents.

Those inland discharges to watercourses which themselves discharge to the Menai Strait will also impact on water quality at the fisheries, to varying degrees depending on their distance from the production area, volume and treatment level. On mainland Wales, Llandegai STW and Talybont STW, discharging to the River Ogwen, all discharge just less than 2 km from the coast. The consented DWFs associated with these discharges are 8 m^3/day and 95 m^3/day respectively of secondary treated effluent. These discharges will contribute to loadings reaching the shellfisheries via these watercourses. Further inland, Tregarth STW discharges a DWF of 616 m^3/day and Bethesda STW 1679 m^3/day of secondary treated effluents to the Afon Ogwen, approximately 4.5 km and 6 km from the production area, respectively. Given the distance from the shellfisheries, there will be some bacterial die-off during transit from the works to the Menai Strait, but these discharges are likely to contribute to loadings in the production area.

As well as those discharges described here, various other continuous water company discharges will contribute to loadings in watercourses in the hydrological catchment draining to the Menai Strait. For those discharges located at some distance from the Menai Strait, a certain amount of bacterial die-off will reduce the bacterial loadings reaching the shellfisheries.

In addition to the continuous sewage discharges, there are several intermittent water company discharges associated with the sewerage networks also shown on II.1. Details of these are shown in Table II.4.

Table II.4: Intermittent discharges to the eastern strait

No.	Name	Grid reference	Receiving water	Type
1	Abergwyngregyn Pumping Station	SH6492073780	Menai Strait	Pumping Station
2	Bangor Maesgeirchen SPS	SH5900071700	Cegin	Pumping Station
3	Beach Road PS Bangor	SH5869073410	Menai Strait	Storm Overflow & Pumping Station
4	Beach Road PS No 1 Bangor	SH5850072900	Menai Strait	Pumping Station
5	Bethesda WWTW Storm	SH6125467526	Afon Ogwen	Storm Overflow/ Storm Tank
6	Bodlondeb CSO Bangor	SH5604071590	Menai Strait	Storm Overflow
7	Coleg Normal Sewage Pumping Station	SH5621971784	Menai Strait	Storm Overflow
8	Cynlai PS Llangoed Anglesey	SH6246079520	Coastal Waters	Pumping Station
9	Eithinog Phase 3A PS Off Belmont Rd	SH5650071480	Unnamed Watercourse	Pumping Station
10	Eithinog PS No 1 Penrhosgarnedd BA	SH5598070820	Unnamed Trib of Afon Menai	Pumping Station
11	Fron Ogwen PS	SH6119067420	Ogwen	Pumping Station
12	Fryars Bay PS- Screened Emerg	SH6115077910	Unnamed Ditch	Pumping Station
13	Glaentraeth Estate PS Bangor	SH5937072230	Afon Cegin	Pumping Station
14	Glasinfryn SPS	SH5880068900	Cegin	Pumping Station
15	Glyn Garth PS Llandegfan	SH5747073680	Estuary- Menai Strait	Pumping Station
16	Gorsllwyd Sewage Pumping Station	SH5752978828	The Afon Cadnant	Pumping Station
17	Llandegfan (Menai) Pumping Station	SH5652072800	Menai Strait	Pumping Station
18	Llandegfan PS (Emergency)	SH5655072790	Menai Strait	Storm Overflow
19	Llandegai Ind Estate STW	SH5883071190	Afon Cegin	Pumping Station
20	Llandygai Ind Estate PS	SH5890071200	Tributary of Afon Cegin	Pumping Station
21	Llanfaes PS (Emergency)	SH6085077780	Unnamed Watercourse	Storm Overflow
22	Llanfaes WwTW Storm Tank	SH6149477308	Menai Strait	Storm Overflow/ Storm Tank
23	Llanfair PG SPS	SH5100071800	Braint	Pumping Station
24	Llanfair PG WWTW	SH5320470802	Menai Strait	Storm Overflow
25	Llanfairfechan Hospital SPS	SH6760075000	Conway Bay	Pumping Station
26	Llanfairfechan- SSO	SH6800075100	Llanfairfechan	Storm Overflow
27	Llanfairfechan SSO No. 2	SH6791075370	Llanfairfechan	Storm Overflow
28	Llanfairfechan SSO No.1	SH6813074750	Llanfairfechan	Storm Overflow
29	Llanfairpwll SSO No. 2	SH5250071570	Trib of Braint	Storm Overflow
30	Llanllechid SPS	SH6209068620	Afon Y Llan	Storm Overflow
31	Llansadwrn PS	SH5690075700	Cadnant	Pumping Station
32	Llansadwrn PS	SH5640075700	Trib of Cadnant	Pumping Station
33	Lleiniog PS	SH6209079150	Menai Strait	Pumping Station
34	Llyn Y Felin PS (Emergency)	SH5542071400	Menai Strait	Storm Overflow & Pumping Station
35	Meirion Road PS (Storm/Emerg)	SH5727072840	Menai Strait	Storm Overflow & Pumping Station
36	Mount Field PS Beaumaris	SH6117076190	Menai Strait	Storm Overflow & Pumping Station
37	Non Food Retail Units Caernarfon Ro	SH5660070340	Afon Adda	Storm Overflow

No.	Name	Grid reference	Receiving water	Type
38	Parc Menai Park PS (Emergency)	SH5420069800	Culvert to Faenol Hall	Pumping Station
39	Penmaenmawr Promenade PS	SH7224077190	Coastal Waters	Storm Overflow & Pumping Station
40	Penmaenmawr WWTW Penmaenmawr	SH7322078110	Coastal Waters of Conwy Bay	Storm Overflow
41	Penmaenmawr WWTW Penmaenmawr	SH7353077800	Gyrach	Pumping Station
42	Penmaenmawr WWTW Penmaenmawr	SH7322078110	Coastal Waters of Conwy Bay	Storm Overflow/ Storm Tank
43	Plots 35/36 Llandegai Ind Estate	SH5886071300	Afon Cegin	Storm Overflow
44	Pont Llandegfan Sewage Pumping Station	SH5609874287	Cadnant	Pumping Station
45	Pont Y Brenin PS	SH6088078930	Y Brenin	Pumping Station
46	PS No1 (Faelog Causeway)(Emergency)	SH5616072210	Menai Strait	Storm Overflow & Pumping Station
47	PS No2 (Porth Wrach) (Emergency)	SH5584071760	Menai Strait	Storm Overflow & Pumping Station
48	PS No3 (Suspension Bridge) (Emergency)	SH5563071520	Menai Strait	Storm Overflow & Pumping Station
49	Rachub Maes Bleddyn CSO	SH6210068029	River Ogwen	Storm Overflow
	Rhiana PS Llandegfan	SH5708073300	Estuary- Menai Strait	Pumping Station
50	Rhiwlas STW	SH5719066230	Cegin	Storm Overflow/ Storm Tank
51	Rock Terrace CSO	SH6205066880	Afon Ogwen	Storm Overflow
52	Station Road CSO	SH7184276591	Coastal Waters via SW Culvert	Storm Overflow
53	Talybont STW	SH6021870166	Afon Ogwen	Storm Overflow & Pumping Station
54	Tesco Foodstore Caernarfon Road	SH5631070010	Afon Adda	Storm Overflow
55	The Antelope SPS	SH5575471351	Menai Strait	Pumping Station
56	Treborth STW (Final)	SH5379070850	Menai Strait	Storm Overflow
57	Treborth STW (Final)	SH5379070850	Menai Strait	Storm Overflow/ Storm Tank
58	Tregarth Henturnpike (from OGW)	SH6120067300	Ogwen	Storm Overflow
59	Tregarth WWTW Pumping Station EO	SH6081168713	Afon Ogwen	Pumping Station
60	Tregarth WWTW Storm Tanks	SH6081168712	Ogwen	Storm Overflow
61	West End PS Beaumaris Anglesey	SH6022075880	Estuary- Menai Strait	Pumping Station

Data from the Environment Agency

The main cluster of intermittent discharges is in the Bangor and Menai Bridge area, where the mussel fishery is located. There are also minor clusters at Llanfairfechan and on Anglesey between Beaumaris and Llangoed. The rivers Cegin and Ogwen also both receive several intermittent discharges. The only intermittent discharge listed above that has spill event monitoring records available is the Llanfaes PS (20), and these records indicate that during the last six months of 2012 the outfall spilled on 17 occasions and was active for 4.1% of the period. Welsh Water are currently installing spill event monitoring on all intermittent discharges likely to impact on shellfisheries within the strait.

In addition to the very limited spill data discussed above, intermittent discharges impacting on Shellfish Waters were modelled by Metoc (Metoc, 2008). Some of the predicted annual spill volumes and percentage of time spill durations are noticeably higher than others. Of the modelled intermittent discharges in the Treborth catchment those of most potential significance were:

- Llandegfan Main Pumping Station Storm Tanks Overflow (17) discharging 160,113 m^3 annually, predicted to spill for 28.3 % of the year, and located in the centre of the strait about 300m to the west of the fishery order
- Bangor Beach Road Rd (3 or 4) with a spill volume of 259,237 m^3, predicted to spill for 2.16 % of a year, which discharges to the east of Bangor Pier.
- Treborth WwTW storm tank overflow (56/57) was modelled to spill 359,587 m^3 annually, spilling for 16.2 % of the year, although this discharges to the west of the Britannia Bridge.
- The Lyn Y Felin PS (33) with a spill volume of 84,353 m^3/year, predicted to spill for 10.25 % of the time, which discharges just to the west of the Menai Bridge.
- The Merion Road PS (34) outfall discharges to the centre of mussel Area 1, but was predicted only to spill 33.7 m^3 annually.
- Neither of the two pumping stations discharging to Area A featured in this study (Glyn Garth PS (15) and Rhiana PS(49)).

These and other intermittent discharges in the Treborth catchment will have a significant impact on the microbiological water quality in the eastern strait from time to time. Not all of those listed in the permit database were included in the modelling report. Other clusters of intermittent discharges relevant to water quality in the survey area that were modelled by Metoc include five assets in the Beaumaris catchment which together were predicted to have an annual spill volume of 86,008 m^3 and three assets in the Llangoed catchment with a combined annual spill volume of 2,887 m^3. Modelled spill frequencies and volumes from the Llanfairfechan STW catchment were negligible. It must be noted that there are many mismatches between the permit database and the list of modelled discharges, in terms of both their names and locations, and it is uncertain which version is correct.

Although the majority of the survey area is served by water company sewerage infrastructure, there are also numerous private discharges in the area. Where specified, these are generally treated by small treatment works such as package plants, and the majority of these are small, serving one or two properties. Those holding permits, or those which have been recently registered are mapped in Figure II.4. Details of those permitted to discharge more than 3 m^3/day are shown Table II.5.

Table II.5: Details of private sewage discharges to the Menai Strait East catchment

Ref.	Property served	Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
A	Bangor Service Area A5/A55 Expressway	SH5873069220	Biodisc	36.6	Afon Cegin
B	Cabins 10 11 & 12	SH5649174837	Package Treatment Plant	3	Afon Cadnant
C	Cabins 2 3 & 4	SH5633774631	Package Treatment Plant	3	Afon Cadnant
D	Cabins 5 6 & 7	SH5640674708	Package Treatment Plant	3	Afon Cadnant
E	Cefn Farm Y Felinheli	SH5414067800	Package Treatment Plant	5	Nant Cefn
F	Ceris Newydd Nursing Home Treborth	SH5554171224	UV Disinfection	29.6	Ground
G	Conway Centre	SH5226069900	Septic Tank + reedbed	60	Menai Strait
H	Fferm Y Garth	SH5521568039	Package Treatment Plant	4	Unnamed Watercourse
I	Garth Pier Bangor	SH5822073610	Maceration	5	Menai Strait
J	Greenwood Forest Park	SH5355067330	Septic Tank	13.5	Trib of Nant Y Garth Via Soakaway
K	Henllys Farmhouse Apartments	SH5999577727	Package Treatment Plant	16	Groundwater via Soakaway
L	Indefatigable School Llanfair PG	SH5337071020	Biological Filtration	36	Menai Strait
M	Kingsbridge Caravan Park	SH6042178493	Package Treatment Plant	15	Ground
N	Kingsbridge Caravan Park	SH6056178734	Package Treatment Plant	9.4	Afon Y Brenin
O	Kingsbridge Caravan Park	SH6067078854	Septic Tank	7.5	Ground
P	Llanfairpwll Plas Newydd	SH5216069470	Package Treatment Plant	30	Menai Strait
Q	Llyn Y Gors	SH5766874947	Package Treatment Plant	12	Unnamed Watercourse
R	Pentir Substation Near Bangor	SH5585868047	Package Treatment Plant	3.19	Trib of Afon Heulyn
S	Pentre Coed Country Park	SH5413473649	Package Treatment Plant	4.7	Afon Rhyd Eilian
T	Plas Coch Caravan Park	SH5191767711	UV Disinfection	194.2	Menai Strait
U	Plas Y Coed Porth Penrhyn Bangor	SH5935072410	Unspecified	5	Afon Cegin
V	PTP Serving Visitor Centre	SH5217169746	Package Treatment Plant	9	Menai Strait
W	The Gazelle Hotel	SH5799074003	Package Treatment Plant	13.8	Menai Strait
X	Treborth Changing Rooms	SH5480570893	Septic Tank	9.12	Ground
Y	Tros Yr Afon Holiday Homes	SH6159079170	Unspecified	5	Afon Lleinog

Data from the Environment Agency.

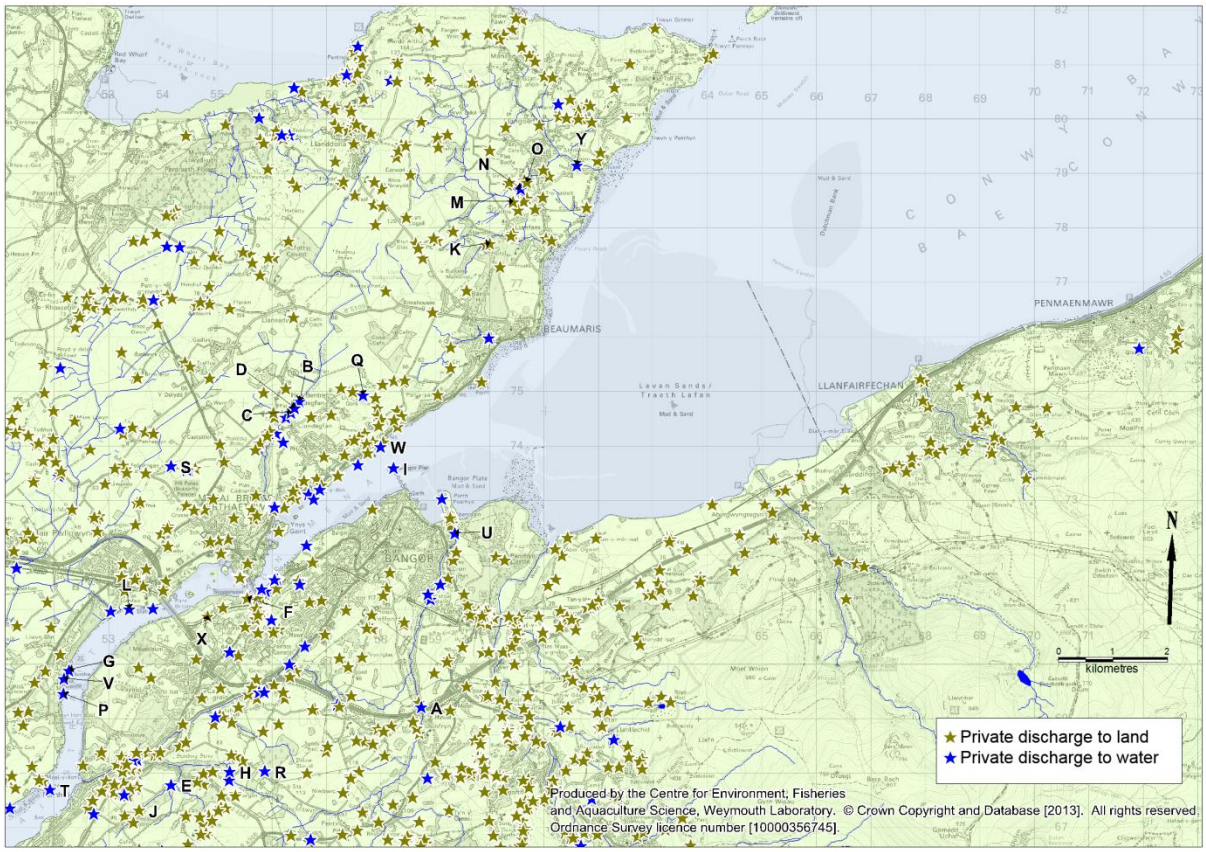

Figure II.4: Private discharges to the eastern strait
Data from the Environment Agency

There are few private discharges direct to the production area. The Gazelle Hotel (W) has a consented maximum daily flow of 13.8 m^3/day, discharging secondary treated effluent directly to the production area from the south Anglesey coast, opposite Bangor Pier. To the west of this there are a few small domestic private discharges to the foreshore. There is also a discharge from the end of Bangor Pier (I), which has a maximum consented daily flow of 5 m^3/day of macerated sewage, again direct to the production area. This level of treatment does not provide any reduction in microbial content and as such may be of some significance to the adjacent mussel beds despite its relatively small volume. Both the Gazelle Hotel and Bangor Pier discharges are likely to have a degree of seasonal influence, with potentially greater volumes and hence load, being discharged in the summer holiday season. Also of potential relevance, but not presented on the map as there are insufficient details, it is reported that there are several unregistered domestic discharges to a surface water culvert that discharges by Beaumaris Pier (NRW, pers. comm.).

Most of the larger watercourses draining to the Menai Strait also receive inputs from private discharges and collectively these will contribute to background loading to varying degrees, depending on the distance from the shellfisheries, volume of discharge and treatment level. Those discharging to soakaway, which form the majority, should not affect water quality provided they are working correctly.

Appendix III. Sources and Variation of Microbiological Pollution: Agriculture

Most of the land within the hydrological catchment is used for agriculture, the majority of which are pastures, although there are a few small pockets where crops are cultivated (Figure 1.2). Numbers and overall densities of livestock as recorded in the 2012 agricultural census are presented in Figure III.1 and Table III.1.

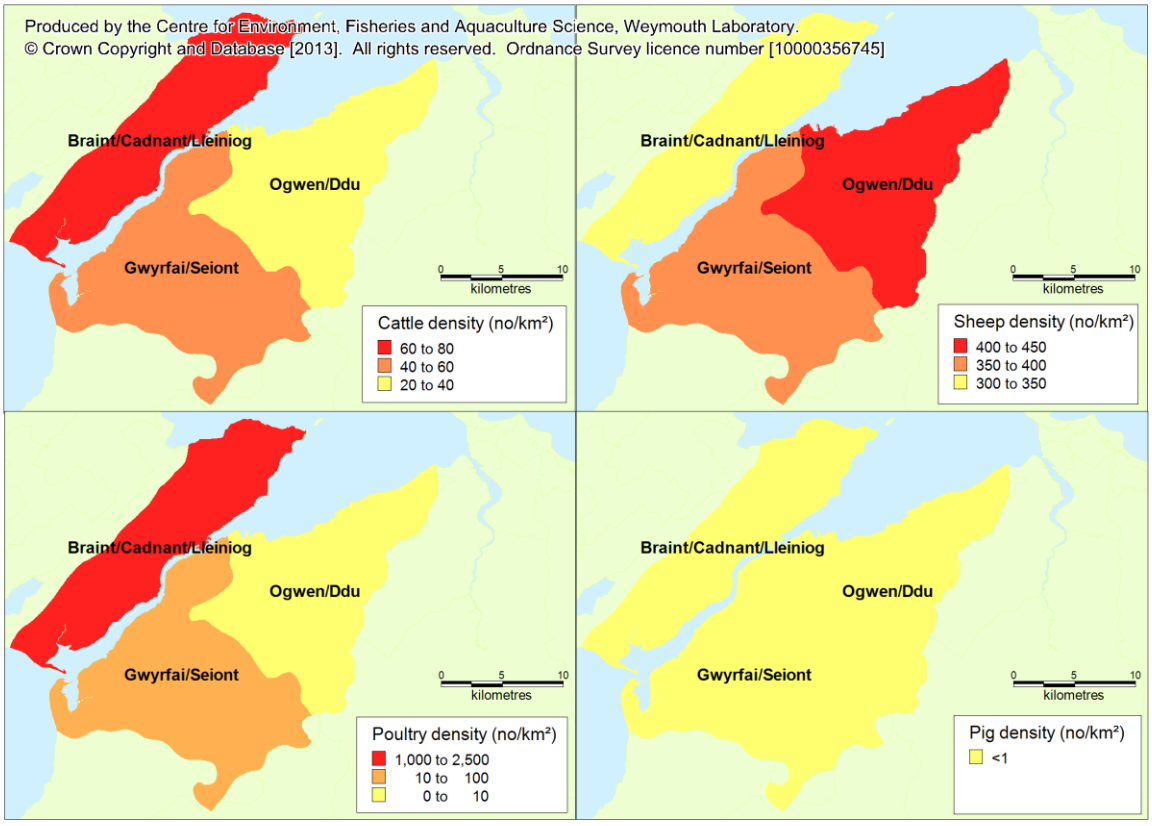

Figure III.1: Livestock densities in 2012 across the Menai sub-catchments
Data from Welsh Government.

Table III.1: Summary statistics from 2012 livestock census within the survey catchment

Catchment		Braint/Cadnant/Lleiniog	Gwyrfai/Seiont	Ogwen/Ddu	Total
Area (km^2)		144.2	200.8	177.4	522.4
Cattle	**No.**	10,046	8,590	3,817	22,453
	No./km^2	*69.7*	*42.8*	*21.5*	*43.0*
Sheep	**No.**	45,509	77,547	78,439	201,495
	No./km^2	*315.6*	*386.2*	*442.2*	*385.7*
Poultry	**No.**	313,171	7,722	1,205	322,098
	No./km^2	*2171.8*	*38.5*	*6.8*	*616.6*
Pigs	**No.**	127	105	39	271
	No./km^2	*0.9*	*0.5*	*0.2*	*0.5*

Data from Welsh Government

The concentration of faecal coliforms excreted in the faeces of animal and human and corresponding loads per day are summarised in Table III.2.

Table III.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)	Faecal coliform load (No. day^{-1})
Chicken	1,300,000	182	2.3×10^8
Pig	3,300,000	2,700	8.9×10^8
Human	13,000,000	150	1.9×10^9
Cow	230,000	23,600	5.4×10^9
Sheep	16,000,000	1,130	1.8×10^{10}

Data from Geldreich (1978) and Ashbolt et al. (2001).

Sheep farming is ubiquitous, with over 200,000 animals at similar relatively high densities throughout all three sub-catchments. There are also about 22,500 cattle, which are also widespread but are present in highest densities on Anglesey. Potentially significant numbers of poultry are farmed in the area, the vast majority of which are on Anglesey. Natural Resources Wales advise that no intensive poultry farms are located in areas draining directly to the strait. A few pigs are raised in the area, including at an indoor unit at Abergwyngregyn (Natural Resources Wales, pers comm.). During the shoreline survey several hundred sheep were seen along the coast adjacent to the Lavan Sands, and in one place here there was evidence they had accessed the intertidal zone. A few sheep (~40) were also seen on the Anglesey side to the east of Beaumaris.

Faeces from grazing animals will be deposited directly onto pastures, and subsequently washed into nearby watercourses. Cattle may be housed indoors in winter, and at these times slurry will be collected and stored for use as a fertilizer. Manure from pig and poultry operations is typically collected, stored and spread tactically on nearby farm land (Defra, 2009). Sewage sludge is also used as a fertilizer. There may therefore be some impacts arising from the periodic application of organic fertilizers to pastures and crops.

Records of sewage sludge applications were provided by Natural Resources Wales, which catalogued weekly applications within each 1 km square. The number of weeks within the period January 2009 to May 2013 when sludge was applied to farmland in each of these squares is mapped in Figure III.2.

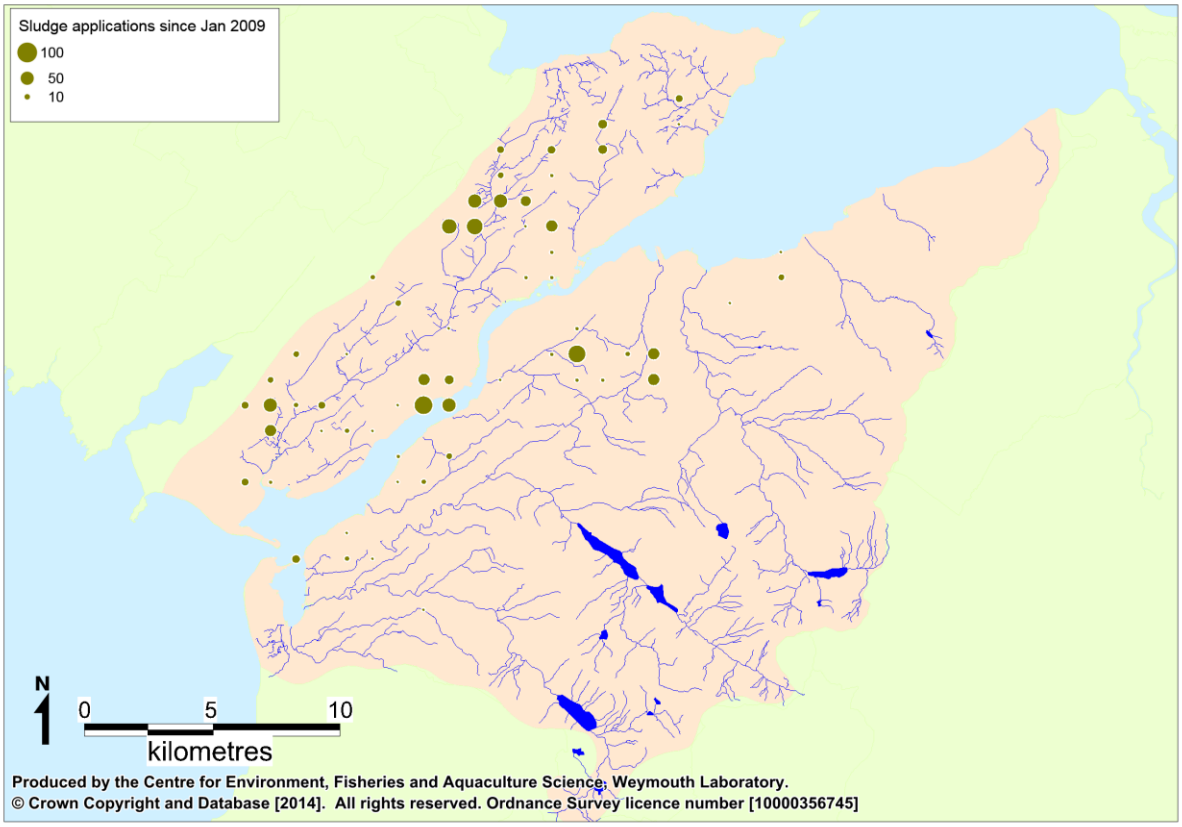

Figure III.2: Number of weeks (Jan 2009 to May 2013) during which sewage sludge was applied to fields within each square km within the Menai Strait catchment.
Data from Natural Resources Wales.

Whilst Figure III.2 provides no firm indication of the volumes or types of sludge applied, it shows that the practice occurs more frequently on certain parts of Anglesey. The areas where most spreading occurs tend to align with the locations of arable land (Figure 1.2). Numbers of applications were similar across the four seasons.

The primary mechanism for mobilisation of faecal matter deposited or spread on farmland to coastal waters is via land runoff, so fluxes of livestock related contamination into the survey area will be highly variable and depend on rainfall. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the 'first flush'). Most, if not all significant watercourses will be impacted to some extent by agriculture. The largest and most consistent fluxes of indicator bacteria into coastal waters are anticipated to arise from grazed where animals have access to watercourses, particularly if this is in close proximity to the coast.

As well as significant day to day variation driven by rainfall there is likely to be some seasonal differences in the fluxes of faecal indicator bacteria of agricultural origin into the survey area. Number of sheep and cattle will increase in the spring with the birth of lambs and calves, and then decrease in the autumn as they are sent to market. In warmer weather, grazing animals are more likely to access watercourses

to cool off and drink. It is likely that sheep are moved from the higher pastures to more sheltered areas during the colder months. During winter cattle may be transferred from pastures to indoor sheds, and at these times slurry will be collected and stored for later application to fields. Timing of these applications is uncertain, although farms without large storage capacities are likely to spread during the winter and spring. Poultry/pig manure and sewage sludge may be spread at any time of the year. Therefore peak levels of contamination from sheep and cattle may arise following high rainfall events in the summer, particularly if these have been preceded by a dry period which would allow a build up of faecal material on pastures, or on a more localised basis if wet weather follows a slurry application which is more likely in winter or spring.

Appendix IV. Sources and variation of microbiological pollution: Boats

The discharge of sewage from boats is potentially a significant source of bacterial contamination of shellfisheries within the eastern Menai Strait. There is one commercial port, and significant volumes of pleasure craft traffic (yachts and cabin cruisers) as well as a few fishing vessels. Figure IV.1 presents an overview of boating activity derived from the shoreline survey, satellite images and various internet sources.

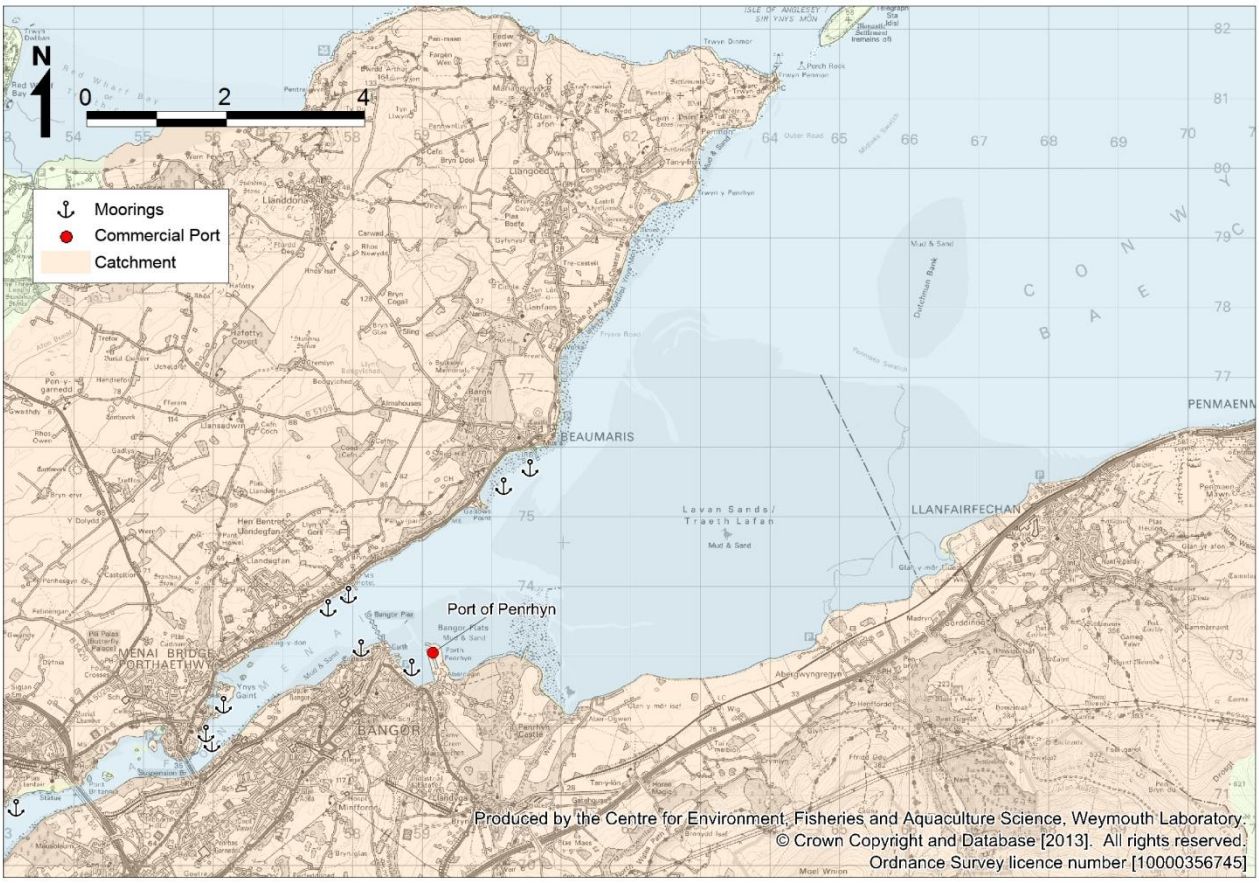

Figure IV.1: Boating activity in the eastern Menai Strait

The Port of Penrhyn is a small commercial port located in Bangor which handles a variety of cargo including slate, sand, aggregates, and scrap metal, as well as dealing with boat sales (Dickies International Ltd., 2013). It is under development to accommodate an expected expansion in the coastal shipping trade in the future (Mackintosh, 2013). Merchant shipping are not permitted to make overboard

discharges within 3 nautical miles of land[1] so such vessels transiting the area should be of no impact.

Four under 10 m fishing boats and one over 10 m are listed as having their home port as Bangor and one over 10 m vessel was listed as having its home port as Penrhyn in December 2013 (MMO, 2013). An angling charter boat also operates from here on a part time basis (Charter Boats UK, 2013).

There is significant recreational boat traffic in the Menai Strait, and the eastern strait has been categorised as a route receiving 'heavy recreational use' (RYA, 2004). There are no marinas in the east Menai but Port Penrhyn provides around 75 berths (Dickies International, 2013) and there are several extensive areas of moorings within the eastern strait. These are located throughout the area between Menai Bridge and Penrhyn, with another discrete area off Beaumaris. There are no sewage pump out facilities available within the eastern strait, and the closest available are at Victoria Dock in the western strait.

Private vessels such as yachts, motor cruisers and fishing vessels of a sufficient size are likely to make overboard discharges from time to time. This may either occur when the boats are moored or at anchor, particularly if they are in overnight occupation, or while they are navigating through the area. Occupied yachts on pontoon berths may be less likely to make overboard discharges as this is somewhat antisocial in the crowded marina setting, and facilities on land are easier to access. The areas that are at highest risk from microbiological pollution therefore include the mooring areas for larger private vessels and the main navigation routes through the area. Peak pleasure craft activity is anticipated during the summer, so associated impacts are likely to follow this seasonal pattern. It is difficult to be more specific about the potential impacts from boats and how they may affect the sampling plan without any firm information about the locations, timings and volumes of such discharges.

[1] The Merchant Shipping (Prevention of Pollution by Sewage and Garbage from Ships) Regulations 2008

Appendix V. Sources and Variation of Microbiological Pollution: Wildlife

The Menai Strait encompasses a wide range of marine habitats including intertidal flats at either end of the strait, marine reefs, sandbanks, sea caves, large shallow bays and inlets, seagrass and sea cliffs which attract a variety of wildlife. Consequently the strait is protected by several international and national environmental legislations including part of the Menai Strait and Conwy Special Area of Conservation (SAC), Puffin Island SAC, seven Sites of Special Scientific Interest (SSSI), Special Protection Area (SPA), National Nature Reserves (NNR) and several Local Nature Reserves. It has also been recognised as one of seven Marine Biodiversity Hotspot in a WWF report (Hiscock & Breckels, 2007) and the Snowdonia National Park forms a large proportion of the southern catchment.

Studies in the UK have found significant concentrations of microbiological contaminants (thermophilic campylobacters, salmonellae, faecal coliforms and faecal streptococci) from intertidal sediment samples supporting large communities of birds (Obiri-Danso and Jones, 2000). Large numbers of nationally and internationally important species of overwintering birds are observed in the survey area. Traeth Lafan, on the mainland side of the eastern strait contains a large area of intertidal flats of varying substrate. It is home to a range of invertebrate species which are an important food source for a large number of waders. An average total count of 17,155 waterbirds (wildfowl and waders) was reported over five winters up to 2010/11 for Lavan Sands (Holt et. al, 2012). This area, along with the adjacent Spinnies Nature Reserve has been identified as one of the top locations in Wales for wildfowl and waders. On the shoreline survey flocks of waterbirds were regularly observed, with the largest aggregations (~500 birds) sighted in the western survey area close to Bangor Pier and on the island of Ynys y Big.

Grazers, such as geese and ducks will mainly frequent the grassland and saltmarsh, where their faeces will be carried into coastal waters via runoff into tidal creeks or through tidal inundation. Therefore RMPs within or near to the drainage channels from saltmarsh areas or watercourses draining pastures will be best located to capture contamination from this source. Waders, such as dunlin and oystercatchers forage upon shellfish and so will forage (and defecate) directly on any shellfish beds on the intertidal. They may tend to aggregate in certain areas holding the highest densities of bivalves of their preferred size and species, but this will probably vary from year to year. Contamination via direct deposition may be patchy, with some shellfish containing high levels of *E. coli* while others a short distance away are unaffected. Due to the diffuse and spatially unpredictable nature of contamination from wading birds it is difficult to select specific RMP locations to best capture this, although they may well be a significant influence particularly during the winter months.

In addition to overwintering wildfowl, seabirds (gulls, cormorants etc) are also widespread within the Menai Strait and resident all year round. Numbers are lower with 6,602 birds recorded during a survey in the early summer of 2000 (Mitchell *et al*, 2004). The vast majority of these (6,424 birds) nest on Puffin Island. Small numbers were also recorded at Bangor (160 birds) and Beaumaris (18 birds). Seabirds are likely to forage widely throughout the area so inputs could be considered as diffuse, but are likely to be most concentrated in the immediate vicinity of the nest sites. Their faeces will be carried into coastal waters via runoff from their nesting sites or via direct deposition to the adjacent intertidal. Although there is a major colony at Puffin Island, there are no shellfish resources in close proximity to it where most acute impacts are anticipated. As such, the presence of this seabird colony will have no influence on the sampling plan.

It has been estimated that there are between 5,000 and 6,000 grey seals in the Irish Sea (Kiely et. al, 2000). Grey seals are regularly seen throughout the strait particularly around their haul out location on Puffin Island (Westcott & Stringell, 2004). A survey undertaken between 2002 and 2003 reported counts ranging from 11 to 130, with highest numbers in the winter months. Consequently it forms “the most important winter assembly in North Wales” (Westcott & Stringell, 2004). Seals may create a ‘hotspot’ of contamination where they haul out but there are no reported haulout sites in close proximity to any shellfish resources so such impacts are not anticipated. They will forage widely throughout the area, and as such their impacts on the shellfisheries are likely to be minor and unpredictable in spatial terms, but may be slightly greater in winter.

Appendix VI. Meteorological Data: Rainfall

The Parc Menai weather station, received an average of 993 mm per year between 2003 and 2012. Figure VI.1 presents a boxplot of daily rainfall records by month at Parc Menai.

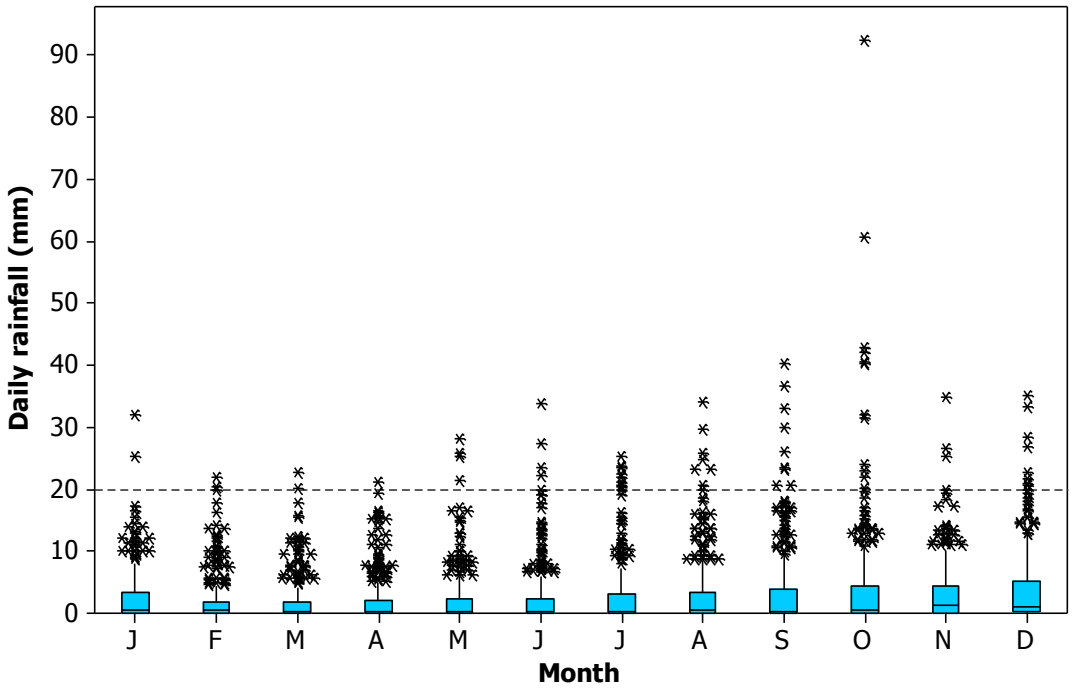

Figure VI.1: Boxplot of daily rainfall totals at Parc Menai, January 2003 to December 2012.
Data from Natural Resources Wales

Rainfall records from Parc Menai, which is representative of conditions in the vicinity of the shellfish beds indicate some seasonal variation in average rainfall with slightly higher average rainfall from late summer through winter. Rainfall was lowest on average in March and highest on average in October. Daily totals of over 20 mm were recorded on 1.7 % of days and 40 % of days were dry. High rainfall events occurred in all months, but were more frequent in the second half of the year. The hydrological catchment extends some distance inland into an area of high relief (Snowdonia). Moist air that is forced up the hills may be cooled to the dew point, which produces cloud and rain. Annual rainfall here in Snowdonia is about 3 to 4 times higher than that experienced on the coast (NERC, 2012). This may fall as snow and lie for a time on the peaks during the winter although it may not persist throughout the colder months.

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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 rainfall dependent discharges and freshwater inputs will reflect the combined effect of rainfall on the contribution of individual pollution sources. Relationships between levels of *E. coli* and faecal coliforms in shellfish and water samples and recent rainfall are investigated in detail in Appendices XI and XII.

Appendix VII. Meteorological Data: Wind

Wales is one of the windier parts of the UK, particularly its west facing coasts (Met Office, 2012). 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 are strongest (Met Office, 2012).

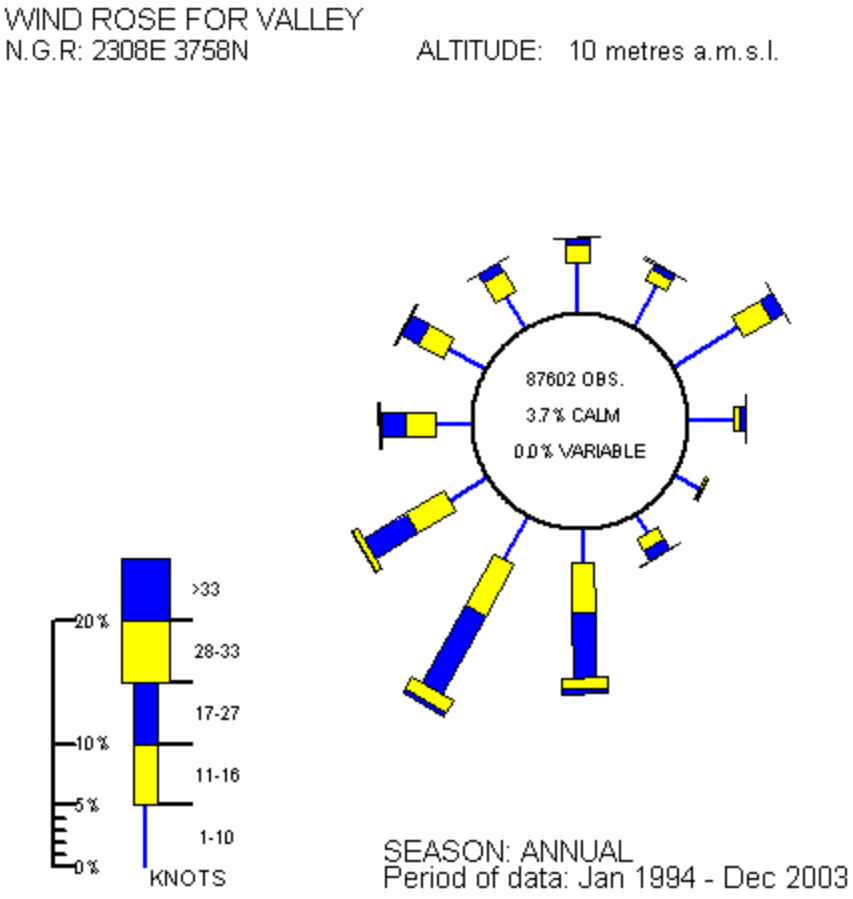


Figure VII.1: Wind rose for Valley.
Produced by the Meteorological Office. Contains public sector information licensed under the Open Government Licence v1.0

The wind rose for Valley (Anglesey) is typical of coastal locations in Wales. The prevailing wind direction is from the south west and the strongest winds usually blow from this direction. A higher frequency of north easterly winds occurs during spring. The Menai Strait is a narrow semi enclosed body of water and therefore receives some shelter from winds. The eastern strait however have a wide mouth and so the outer reaches are quite exposed to winds from the north east. The surrounding land will tend to funnel winds up and down the strait, and the orientation of the strait means that the prevailing south westerly winds will be funnelled straight up it. Strong

south westerly and north easterly winds may therefore modify circulation patterns in the area, and the latter are likely to generate significant wave action in the more exposed outer reaches of the eastern strait.

Appendix VIII. Hydrometric Data: Freshwater Inputs

The Menai Strait has a hydrological catchment of 522 km², of which 378 km^2 lies on the mainland and 144 km^2 lies on Anglesey. A series of watercourses drain to both sides of the strait, ranging from small streams through to significant spate rivers (Figure VIII.1).

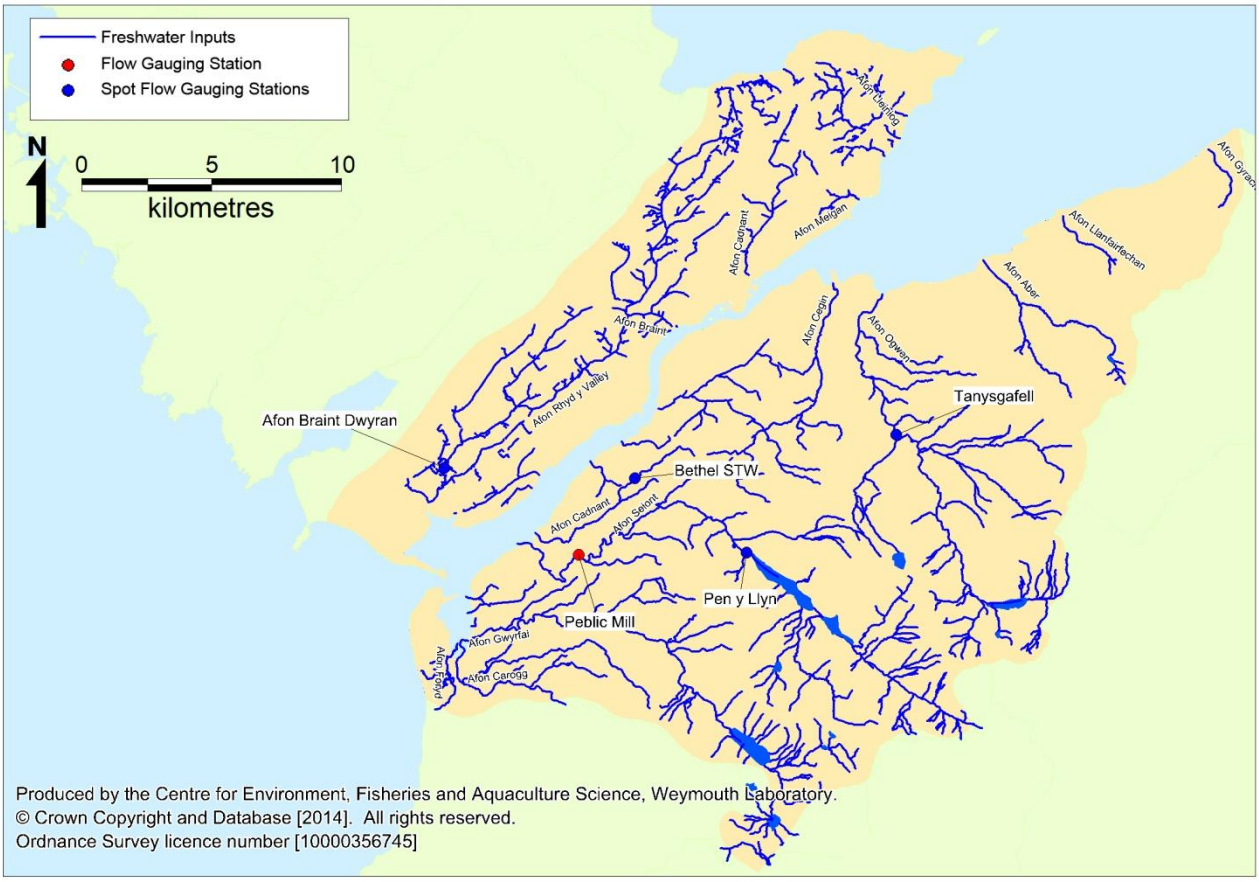


Figure VIII.1: Freshwater Inputs into the Menai Strait

There are three main watercourses which drain the Anglesey side of the Menai east catchment, the largest is the Afon Cadnant. On the mainland, watercourses are generally larger due to the greater catchment area and higher rainfall experienced in the mountainous areas. The Afon Ogwen is the largest followed by the Cegin. There are several streams and rivers discharging to the east of the catchment, including the Aber, Llanfairfechan (or Afon Ddu) and Gyrach on the mainland. As well as these watercourses there are a number of smaller streams draining at intervals along both the Anglesey and mainland coast, and several significant watercourses draining to the western strait, including the Seiont and Cadnant which discharge at Caernarfon and the Braint on the Anglesey side.

These watercourse will receive microbiological pollution from point and diffuse sources such as STW discharges and urban and agricultural runoff. They are therefore a potentially significant source of microbiological contamination to the shellfisheries in the strait. They predominantly drain pastures, with some relatively small pockets of urbanised land close to the shore such as the town of Bangor. The largest watercourses drain the mainland catchment, which is characterised by a steep mountainous region composed predominantly of impermeable mudstones and sandstones. The upper reaches of the mainland catchment experience considerably higher annual rainfall than coastal areas. Consequently, rivers draining the mainland respond quickly to rainfall which often leads to flooding in the lowland regions. The lakes in the upper reaches of Ogwen, Seiont and Gwyfrai catchments will tend to buffer flows to some extent. During the colder months snow may fall and lie on the peaks of Snowdonia for a time, although it does not persist throughout the winter. Anglesey has a more gently sloping topography so rivers in this region respond less quickly to rainfall (EA, 2007). It is underlain with impermeable carboniferous rocks so runoff rates are high. Abstraction of water from these watercourses occurs although it is limited and predominantly from surface water (EA, 2006 & EA, 2007). Summary statistics for one flow gauging station on the Afon Seiont, which discharges to the western strait, were available for the period 2003 – 2013 and are presented in Table VIII.1.

Table VIII.1 Summary flow statistics for the Peblig Mill gauging station (2003-2013)

Watercourse	Station Name	Catchment Area (Km^2)	Mean Annual Rainfall 1961-1990 (mm)	Mean Flow (m^3s^{-1})	Q95[1] (m^3s^{-1})	Q10[2] (m^3s^{-1})
Seiont	Peblig Mill	74.4	2278	5.43	0.69	12.5

[1]Q95 is the flow that is exceeded 95% of the time (i.e. low flow). [2]Q10 is the flow that is exceeded 10% of the time (i.e. high flow). Data from NERC, 2012 and Natural Resources Wales.

Boxplots showing mean daily flow records for Peblig Mill gauging station is presented in Figure VIII.2.

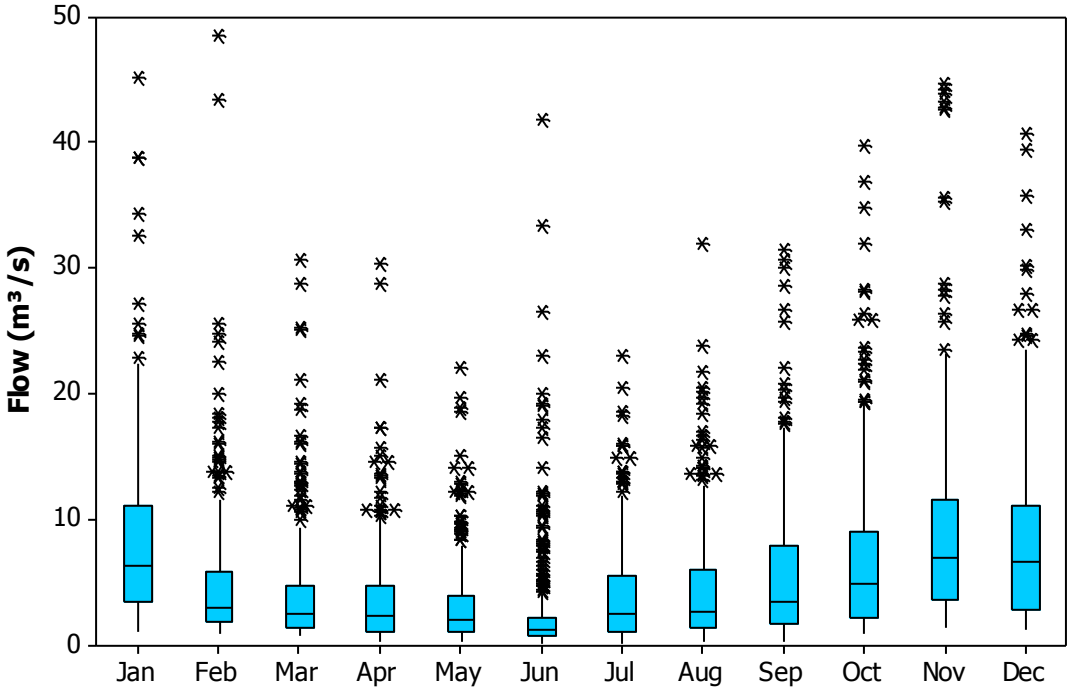


Figure VIII.2: Boxplots of mean daily flow records from the Peblig Mill gauging station on the Seiont watercourse (2003-2013)

The seasonal pattern of flows is likely to be broadly representative of other significant watercourses draining the mainland such as the Ogwen. Flows were higher on average during the colder months although high flow events were recorded during every month of the year. There does not appear to be a major peak associated with melting snow. The seasonal pattern of flows is not entirely dependent on rainfall as during the colder months there is less evaporation and transpiration, leading to a higher water table. This in turn leads to a greater level of runoff immediately after rainfall. Increased levels of runoff are likely to result in an increase in the amount of microorganisms carried into coastal waters. Additionally, higher runoff will decrease residence time in rivers, allowing contamination from more distant sources to have an increased impact during high flow events.

There are also a series of smaller watercourses discharging at intervals along the shore of the Menai West survey area. Numerous streams were observed flowing through the marshes and surface drainage pipes in the more built up areas. On the Anglesey side of the catchment the land is low lying and field drains run parallel to the sea wall. They discharge into the strait at regular intervals via engineered outfalls such as sluices and pumping stations.

Table VIII.2 presents maximum and mean spot flow results at four sampling locations within the Menai Strait catchment, the majority of which are within the western catchment.

Table VIII.2 Summary flow statistics for spot flow gauge stations on watercourses draining the Menai Strait, 1989 - 1996

Site	Watercourse	Number of Samples	Mean Flow (m^3s-1)	Max Flow (m^3s-1)	Dates
Afon Braint Dwyran	Afon Braint	4	0.193	0.359	1992 -1996
Bethel STW	Afon Cadnant	8	0.007	0.030	1990 - 1996
Pen y Llyn	Afon Rhythallt	8	2.361	4.129	1993 - 1994
Tanysgafell	Afon Ogwen	6	0.905	2.037	1995

Data from Natural Resources Wales

The highest mean flow (2.361 m^3s^{-1}) was recorded at Pen y Llyn located on the Afon Rhythallt, which is the name for the upper reaches of the Afon Seiont. The mean flow rates for the other three stations were all below 1 m^3s^{-1}. This included the Ogwen, albeit a considerable distance upstream of its tidal limit. It should be noted that only a small number of measurements were taken at each gauging location so the information should be treated with caution.

During the shoreline survey, which was conducted under dry conditions, watercourses which could be safely accessed were sampled for *E. coli* and spot flow measurements were made. The results and locations are presented in Table VIII.3 and Figure VIII.3.

Table VIII.3: *E. coli* sample results, measures discharge and calculated *E. coli* loadings

Ref.	Watercourse	*E. coli* concentration (CFU/100 ml)	Flow (m^3/s)	*E. coli* loading (CFU/day)
A	Afon Llanfairfechan	2600	1.045	$2.35x10^{12}$
B	Groundwater	350	0.005	$1.45x10^{09}$
C	Stream	260	0.109	$2.44x10^{10}$
D	Stream	880	0.086	$6.57x10^{10}$
E	Stream	380	0.036	$1.18x10^{10}$
F	Afon Aber	30	1.004	$2.60x10^{10}$
G	Stream	390	0.002	$7.64x10^{8}$
H	Culverted Stream	530	0.089	$4.07x10^{10}$
I	Stream	50	0.002	$1.03x10^{8}$
J	Afon Adda	2500	Not accessible	
K	Afon Cegin	480	Too large to measure	
L	Afon Ogwen	7600	Too large to measure	
M	Afon Meigan	97	0.091	$7.65x10^{9}$
N	Surface Drainage under road	13	0.007	$7.99x10^{7}$
O	Waterfall	9	Too large to measure	
P	Stream	Not accessible	Not accessible	
Q	Afon Cadnant	Not accessible	Not accessible	
R	Stream	2600	Not accessible	

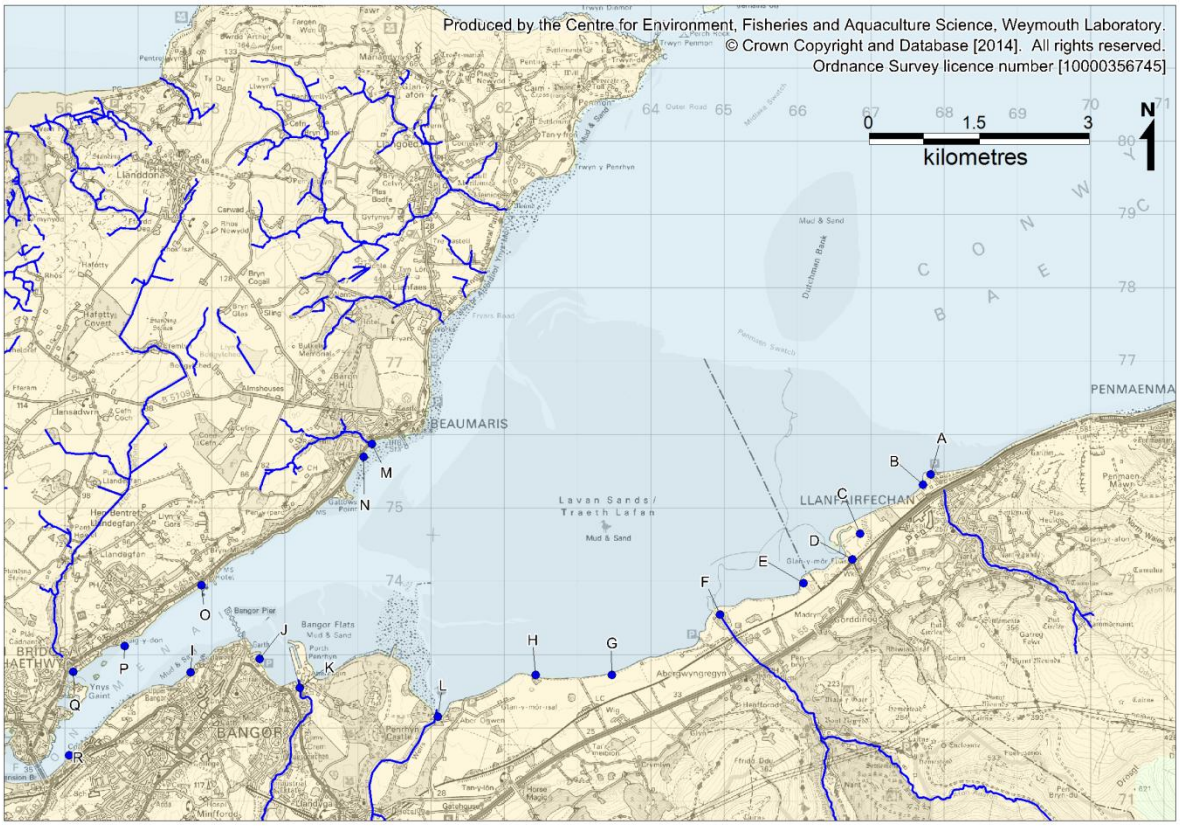


Figure VIII.3: Locations of shoreline survey stream observations

The Llanfairfechan River (or Afon Ddu) was generating the highest bacterial loading of the measured watercourses (2.35×10^{12} *E. coli*/day) by almost two orders of magnitude. The Aber was discharging a similar volume to the Llanfairfechan, but was carrying a much lower concentration of *E. coli* at the time. The discharge volumes and *E. coli* loadings being carried by other measured watercourses were not particularly high, but they may be of some local significance. A sample of river water from the Ogwen contained 7600 *E. coli*/100ml, and this combined with its relatively large size indicates that it is likely to be a highly significant influence within the fishery order area. The Cegin is also likely to be of some significance here. The Cadnant, which is the main freshwater input to the fishery order area from the Anglesey side, could not be accessed, although is likely to be of some significance.

Appendix IX. Hydrography

IX.1. Bathymetry

The Menai Strait is a tidal channel which separates mainland Wales from the Isle of Anglesey. It is approximately 30 km in length from its north-eastern entrance at Puffin Island to its south-western entrance at Abermenai Point. It is characterised by a subtidal channels flanked by intertidal areas of varying width. The western entrance is flanked by two sand spits, inside each of which lie extensive intertidal sandy bays (Traeth Melynog and Foryd Bay). The intertidal areas become progressively narrower and rockier towards The Swellies in the central reaches where the strait is only about 300 m in width, the bottom is rocky and uneven, and depths in the channel are as little as 1m relative to chart datum. Significant turbulent mixing will occur here as tidal flows accelerate, so any contamination coming in from the west will be well mixed in the water column as it passes through.

To the east of The Swellies, the strait widens progressively to about 7.5km at the eastern mouth. The subtidal channel follows the Anglesey shore, with expansive intertidal flats to the south. A large proportion of water will therefore be exchanged on each tide, but the dilution potential will be quite low away from the main channels. Water depths in the channel at chart datum vary from only a few meters to pools over 10 m depth at Menai Bridge, off Bangor, off Gallows Point and south of Tre-castell Point. There is a deep scour (26 m) in a constriction where the main channel passes between Puffin Island and Anglesey. A subtidal channel (Penmaen Swatch) partially separates an offshore sandbank (Dutchman Bank) from Traeth Lafan.

None of the watercourses discharging to the eastern strait, even the larger ones, have defined estuaries and drain directly to the intertidal areas so will create plumes whilst the tide is both flooding and ebbing. They follow channels cut across the intertidal areas, and within these relatively high concentrations of faecal indicator bacteria are likely to arise at lower states of the tide.

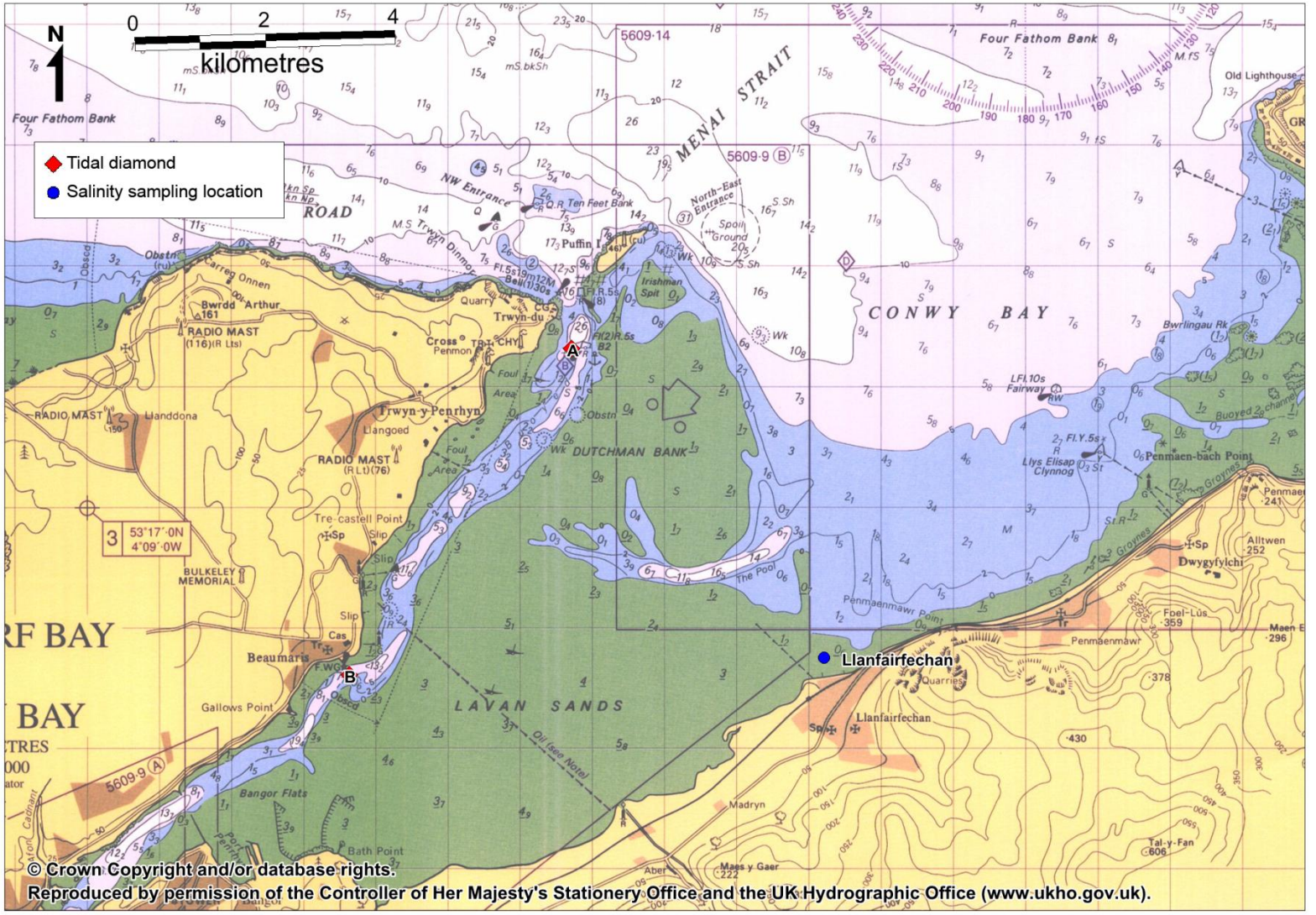


Figure IX.1: Bathymetry of the eastern strait and Conwy Bay

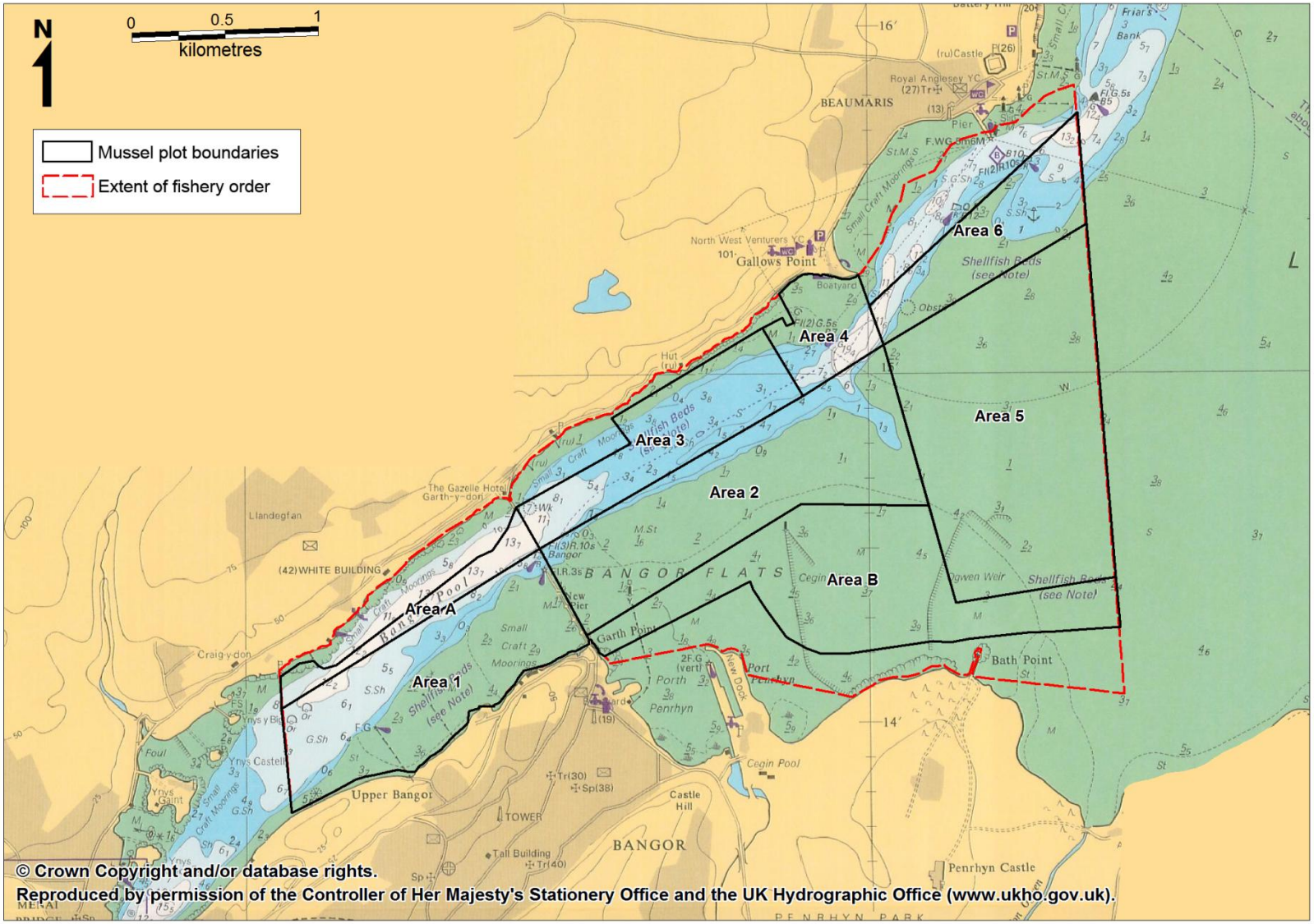


Figure IX.2: Bathymetry of the fishery order area

IX.2. Tides and Currents

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. The Menai Strait is macro-tidal having a tidal range of over 4 m on spring tides. The tidal range is greater in the eastern strait than in the western strait by about 2 m, and high water occurs about 40 minutes later at the eastern entrance (Trwyn Dinmor) compared to the western entrance (Fort Belan).

Table IX.1 Tide levels and ranges within the Menai Strait

Survey area	Port	Height above chart datum (m)				Range (m)	
		MHWS	MHWN	MLWN	MLWS	Spring	Neap
West	Fort Belan	4.6	3.5	1.8	0.6	4.0	1.7
West	Caernarfon	5.2	4.0	1.9	0.6	4.6	2.1
West	Port Dinorwic	5.6	4.4	2.0	0.8	4.8	2.4
East	Menai Bridge	7.3	5.8	2.3	0.7	6.6	3.5
East	Beaumaris	7.6	6.0	2.5	0.8	6.8	3.5
East	Trwyn Dinmor	7.5	5.9	2.5	0.9	6.6	3.4

Data from Admiralty TotalTide©

The inflowing tide enters the Menai Strait at the western end and flows in a north easterly direction. Before it can reach the other end of the strait, the tidal wave has passed around Anglesey and entered the strait for a second time at the opposite end. This results in two opposing flows meeting in a point dependant on local wind and tidal conditions. This pattern of circulation means that sources discharging to the shoreline of the strait in and around the main channel will impact to either side of their location and any plume will tend to remain by the same shore becoming progressively more diluted with distance.

Plots of modelled tidal vectors indicate that the tide floods over the eastern part of Traeth Lafan from the east, and over the northern part from the north. On the western end of this sandbank the tide actually floods in from the north west (Metoc, 2008). The opposite occurs on the ebb.

The higher tidal range in the eastern strait, combined with the shallow nature of The Swellies results in a net (residual) westerly flow. In the absence of wind, this residual flow is considerable, and has been estimated at about 800 m^3/s during spring tides and 330 m^3/s during neap tides (Simpson *et al*., 1971). This will result in a tendency for sources of contamination to be flushed in a westerly direction. For comparison with other tidal stream information, the average residual current velocity is about 0.15 m/s (Harvey, 1968).

Table IX.2 presents the direction and rate of tidal streams at two locations in the eastern strait on spring and neap tides, at hourly intervals before and after high water.

Table IX.2 The direction and rate of tidal streams at two locations within the eastern strait on spring and neap tides and at hourly intervals before and after high water.

Time before /after High Water	Station A			Station B		
	Direction	Rate (m/s)		Direction	Rate (m/s)	
		Spring	Neap		Spring	Neap
HW-6	1	0.51	0.26	61	0.67	0.36
HW-5	234	0.05	0.05	60	0.67	0.36
HW-4	188	0.87	0.46	22	0.05	0.00
HW-3	196	1.03	0.57	248	0.31	0.15
HW-2	203	0.93	0.51	244	0.57	0.31
HW-1	204	0.57	0.31	240	0.62	0.36
HW	283	0.05	0.05	240	0.62	0.36
HW+1	14	0.26	0.15	237	0.57	0.31
HW+2	25	0.46	0.26	246	0.26	0.15
HW+3	25	0.62	0.36	62	0.10	0.05
HW+4	26	0.72	0.41	65	0.67	0.36
HW+5	17	0.62	0.31	63	0.67	0.36
HW+6	5	0.57	0.31	63	0.67	0.36
Excursion (flood)		12.6	7.0		10.5	5.9
Excursion (ebb)		13.5	7.4		23.1	12.6

Data from Admiralty Chart 1464

The tidal diamonds indicate that tide floods into the eastern strait in a south westerly direction from Liverpool Bay and ebbs in the opposite direction, with tidal streams reversing on the ebb tide. The relative speeds of the flood and ebb streams at diamond B (off Beaumaris Pier) suggest that the main ebb and flood streams here follow differing paths. Tidal currents are particularly rapid at The Swellies where they may reach 2.5 m/s (Rippeth *et al*., 2002). Current velocities are around 50 % smaller on neap tides, and are slower over the shallower and intertidal areas such as Traeth Lafan. The estimates of tidal excursions based on these diamonds suggest that contamination may be carried considerable distances. There is some asymmetry in the tidal curve, with a slightly faster moving but shorter duration flood tide.

Strong winds can modify tidal circulation within the strait. Winds typically drive surface water at about 3 % of the wind speed (Brown, 1991) so gale force wind (34 knots or 17.2 m/s) would drive a surface water current of around 0.5 m/s. Surface currents will create return currents which may travel lower in the water column or along sheltered margins. Given its orientation, winds from the north east and south west will be of most effect as they will blow up/down the strait. Strong winds can significantly modify the residual south westerly water movement through the strait. Northwest winds will augment the flow, while southwest winds reduce or even reverse it. A reversal may be expected for winds from the southwest of ~20 m/s and 12.5 m/s for spring and neap tides respectively (Simpson et al. 1971). Exact effects

are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great number of scenarios may arise. Where strong winds blow across a sufficient distance of water they may create wave action, and where these waves break contamination held in intertidal sediments may be resuspended. The eastern strait is most exposed to winds from the north east, which may at times generate significant wave action, primarily on the mainland shore of the outermost reaches of the strait.

Freshwater inputs may significantly influence circulation patterns in coastal waters via density effects. The strait receive freshwater inputs from a number of rivers and smaller watercourses at various locations, but their combined input volumes are minor in relation to tidal exchange. This results in a well mixed system within which density driven circulation is unlikely to modify tidal circulation, except perhaps on a localised basis at times of high river flow. Salinity is usually between 32 and 34 ppt and falls below 30 ppt infrequently (Buchan et al., 1967). Repeated salinity measurements taken between 2006 and 2011 at Llanfairfechan (Figure I.2) in close proximity to the outfall of a small river. These indicate that there is normally little freshwater influence at this location, but also show that occasional low salinities may be recorded in the vicinity of river mouths. Localised decreases in salinity will be more extensive at times of high river discharge, and within such areas higher levels of runoff borne contamination are likely to arise.

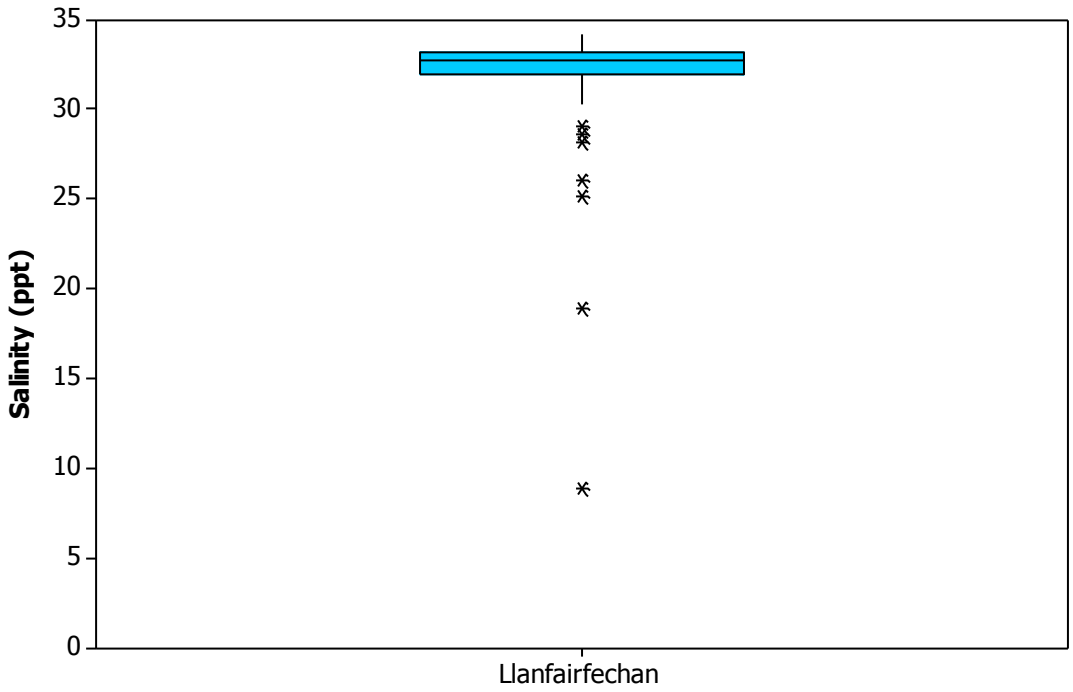


Figure IX.1: Boxplot of salinity readings taken from Llanfairfechan in the East Menai (2006-2011)

Data from Natural Resources Wales

Appendix X. Microbiological Data: Seawater

X.1. Bathing Waters

Due to changes in the analyses of bathing water quality by the Environment Agency/ (Natural Resources Wales) from 2012, only data produced up to the end of 2011 were used in these analyses. There is one bathing water in the Menai Strait (Llanfairfechan) designated under the Directive 76/160/EEC (Council of the European Communities, 1975).

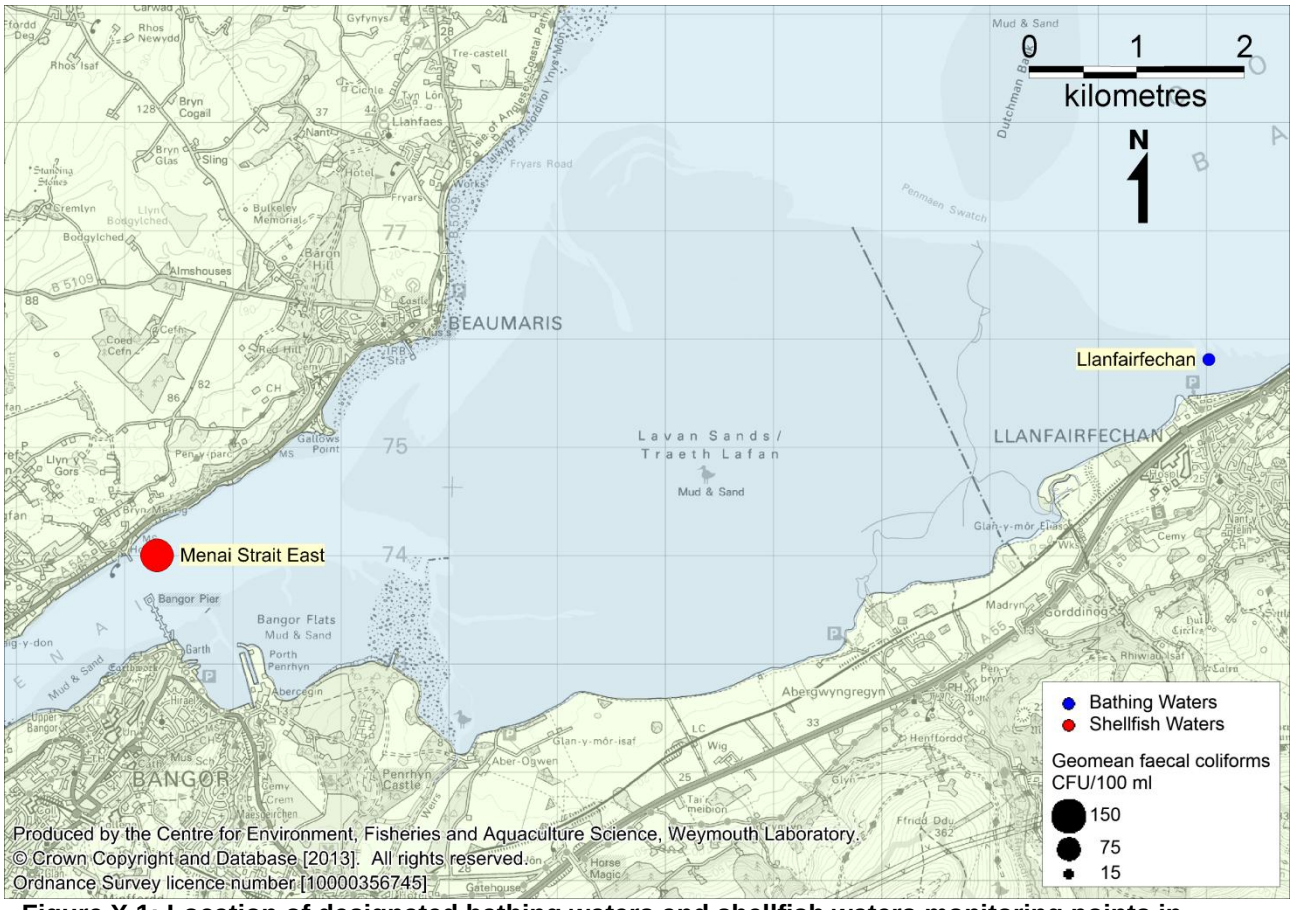


Figure X.1: Location of designated bathing waters and shellfish waters monitoring points in the eastern Menai Strait.
Data from Natural Resources Wales

Around twenty water samples were taken from the bathing waters site during each bathing season, which runs from the 15th May to the 30th September. Faecal coliforms were enumerated in all these samples. Summary statistics of all results are presented in Table X.1, and Figure X.2 presents box plots of these data.

Table X.1: Summary statistics for bathing waters faecal coliforms results, 2003-2011 (cfu/100ml).

Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1,000	% over 10,000
Llanfairfechan	163	07/05/2003	18/09/2011	26.4	2	11000	22.1	2.5	0.6

Data from Natural Resources Wales

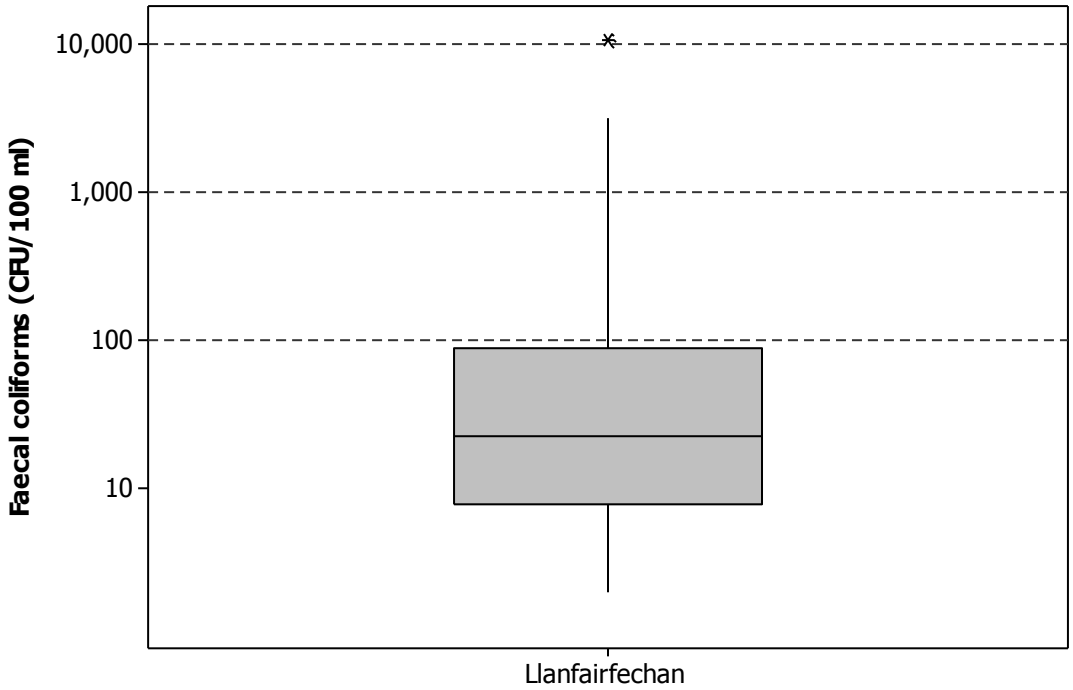


Figure X.2: Box-and-whisker plots of all faecal coliforms results
Data from Natural Resources Wales

Faecal coliform levels exceeded 1,000 cfu/100 ml in 2.5 % of samples and 10,000 cfu/100 ml in a single sample (0.6 %).

X.2. Overall temporal pattern in results

The overall variation in faecal coliform levels found at Llanfairfechan is shown in Figure X.3.

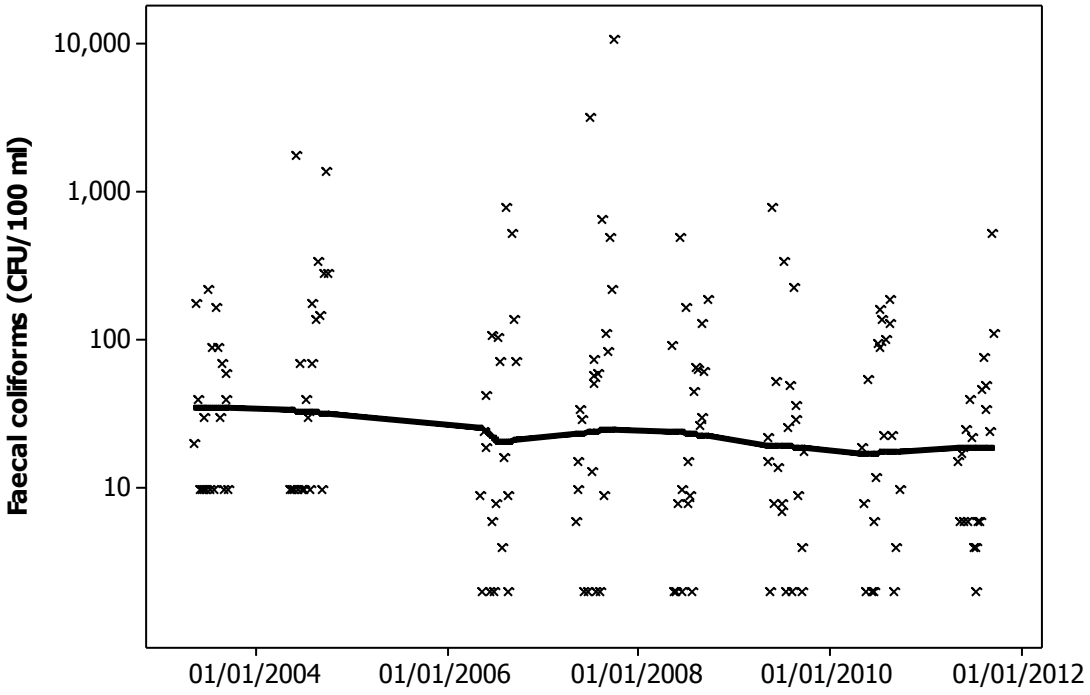


Figure X.3: Scatterplot of faecal coliform results for bathing waters at Llanfairfechan overlaid with loess lines.
Data from Natural Resources Wales

Faecal coliform levels have remained fairly stable since 2003.

X.3. Influence of tides

To investigate the effects of tidal state on faecal coliform results, circular-linear correlations were carried out against both the high/low and spring/neap tidal cycles for each of these bathing waters sampling points. Correlation coefficients are presented in Table X.2, with statistically significant correlations highlighted in yellow.

Table X.2: Circular linear correlation coefficients (r) and associated p values for faecal coliform results against the high low and spring/neap tidal cycles

	High/low tides		Spring/neap tides	
Site Name	**r**	**p**	**r**	**p**
Llanfairfechan	0.087	0.297	0.147	0.031

Data from Natural Resources Wales

No influence of the high/low tidal cycle was detected at Llanfairfechan. Figure X.4 presents polar plots of faecal coliform results against the lunar spring/neap cycle. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 100 faecal coliforms/100ml or less are plotted in green, those from 101 to 1000 are plotted in yellow, and those exceeding 1000 are plotted in red.

Figure X.4: Polar plots of log_{10} faecal coliforms against tidal state on the spring/neap tidal cycle for bathing waters monitoring points with significant correlations
Data from Natural Resources Wales

At Llanfairfechan, higher results tended to occur as the tide size increased from neap tides to spring tides.

X.4. Influence of Rainfall

To investigate the effects of rainfall on levels of contamination at the bathing waters sites Spearman's rank correlations were carried out between rainfall recorded at the Parc Menai weather station (Appendix II for details) over various periods running up to sample collection and faecal coliforms results. These are presented in Table X.3 and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table X.3: Spearmans Rank correlation coefficients for faecal coliforms results against recent rainfall

	Site	Llanfairfechan
	n	163
24 hour periods prior to sampling	1 day	0.274
	2 days	0.438
	3 days	0.312
	4 days	0.242
	5 days	0.215
	6 days	0.239
	7 days	0.148
Total prior to sampling over	2 days	0.443
	3 days	0.486
	4 days	0.474
	5 days	0.438
	6 days	0.437
	7 days	0.428

Data from Natural Resources Wales

Faecal coliform levels rapidly increase after rainfall, and remain higher for several days.

Influence of salinity

Salinity was recorded on most sampling occasions. Figure X.5 shows a scatter-plot of faecal coliforms against salinity. A Pearson's correlation was run to determine the effect of salinity on faecal coliforms at the bathing waters site.

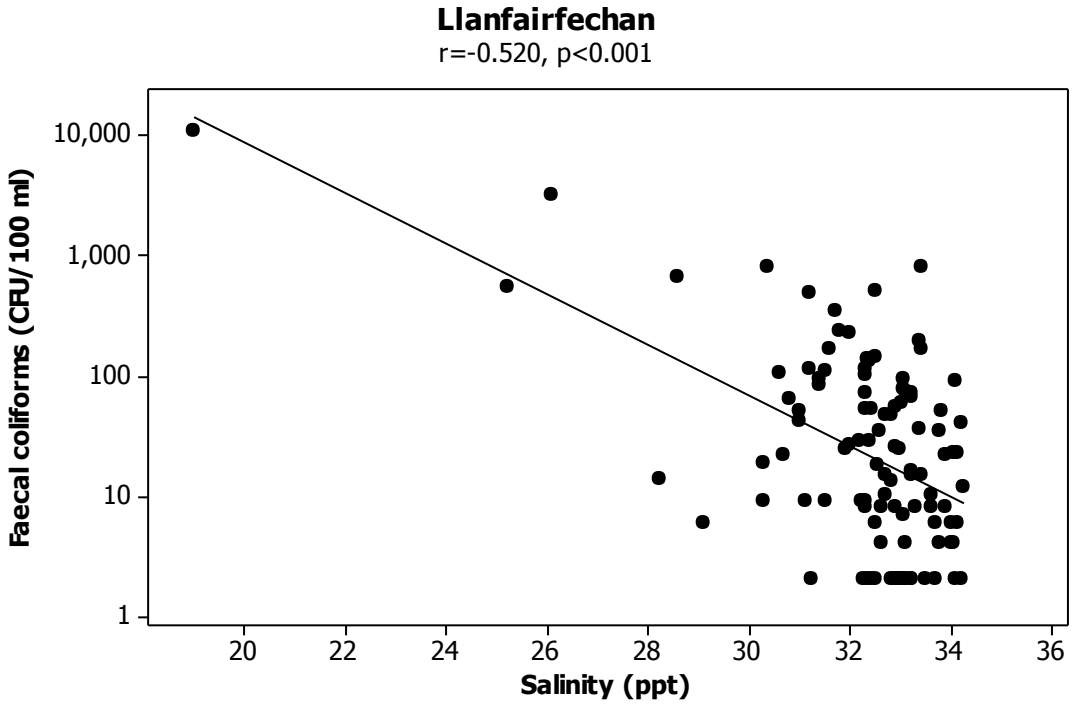


Figure X.5: scatter-plot of salinity against faecal coliform.
Data from Natural Resources Wales

A strong negative correlation was found between faecal coliform concentrations and salinity. The highest individual result was recorded at the same time as the lowest salinity.

X.5. Shellfish Waters

Summary statistics and geographical variation

There is one shellfish waters site designated under Directive 2006/113/EC (European Communities, 2006) in the eastern Menai Strait. Figure X.1 shows the location of this site. Table X.4 presents summary statistics for bacteriological monitoring results and Figure X.6 presents a boxplot of faecal coliforms levels from the monitoring point.

Table X.4: Summary statistics for shellfish waters faecal coliform results, 2003 to 2013 (cfu/100ml).

Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100
Menai Strait East	50	07/01/2003	15/10/2013	11.9	<2	231	2.5%

Data from Natural Resources Wales

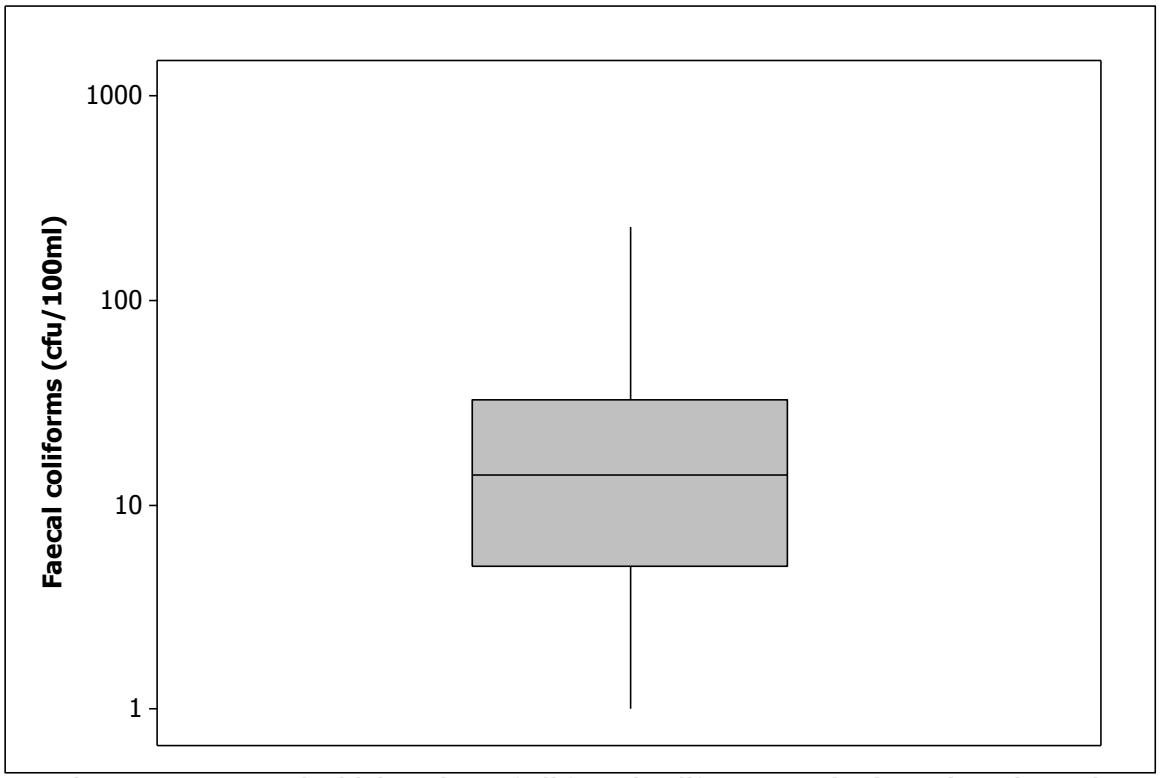


Figure X.6: Box-and-whisker plots of all faecal coliforms results (Menai Strait East)
Data from Natural Resources Wales

The average and peak results were quite low, and only 2.5 % of samples exceeded 100 faecal coliforms/100ml.

Overall temporal pattern in results

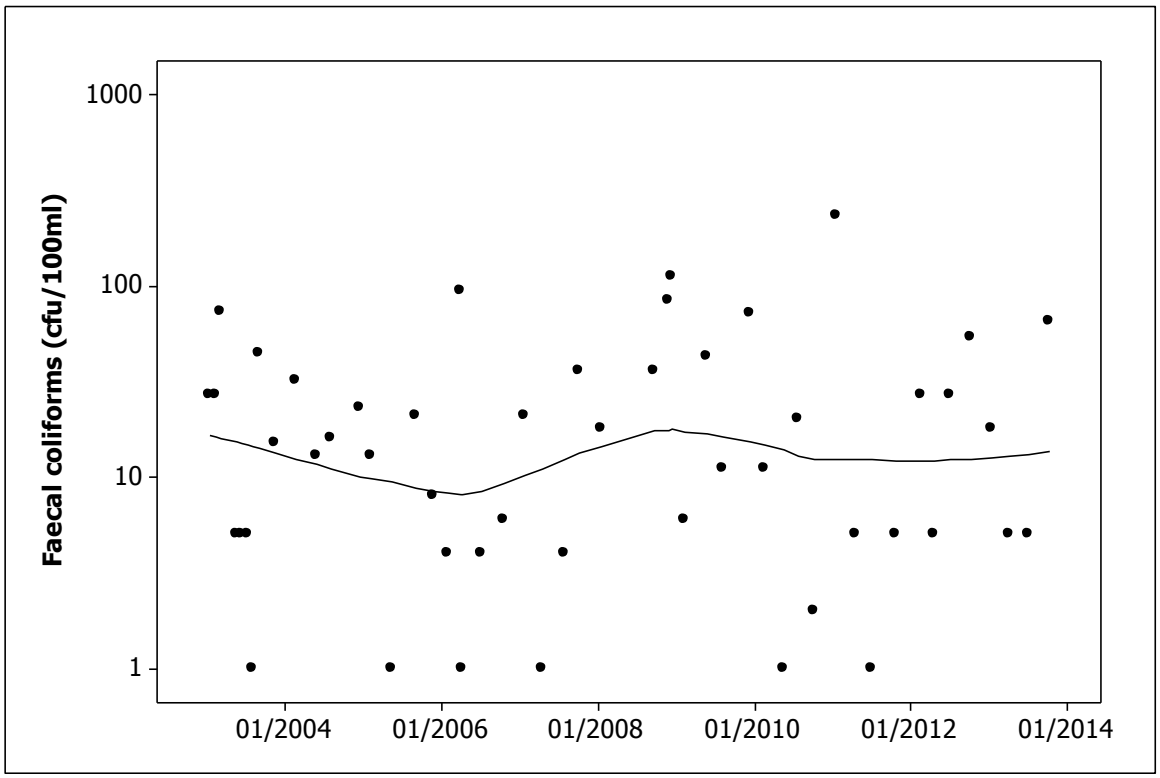


Figure X.7: Scatterplot of faecal coliform results by date, overlaid with loess lines
Data from Natural Resources Wales

Faecal coliform concentrations have remained similar on average throughout this period.

Seasonal patterns of results

Figure X.8 shows the variation in faecal coliform levels at the Menai East Shellfish waters monitoring point between seasons.

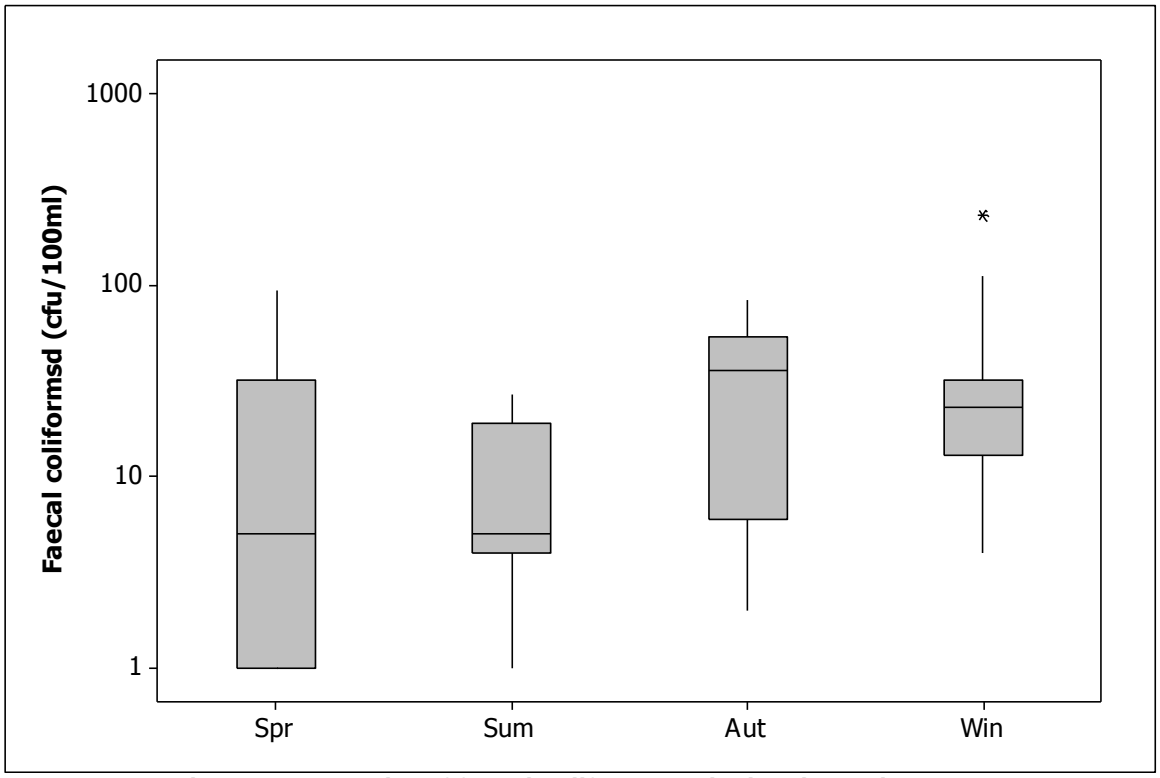


Figure X.8: Boxplot of faecal coliform results by site and season
Data from Natural Resources Wales

Seasonal variation was statistically significant (One-way ANOVA, p=0.011). Post ANOVA testing (Tukeys comparison) revealed that results were significantly higher in the winter compared to the spring and summer.

Influence of tide

To investigate the effects of tidal state on faecal coliform results, circular-linear correlations were carried out against the high/low and spring/neap tidal cycles. The results of these correlations are summarised in Table X.5.

Table X.5: Circular linear correlation coefficients (r) and associated p values for faecal coliform results against the high/low and spring/neap tidal cycles

	High/low tides		Spring/neap tides	
Site Name	**r**	**p**	**r**	**p**
Menai Strait East	0.478	<0.001	0.344	0.004

Data from Natural Resources Wales

A significant effect was detected in relation to both tidal cycles. Figure X.9 presents polar plots of $\log_{10}$ *E. coli* results against tidal state. For the high/low cycle plot, high water at Menai Bridge is at 0° and low water is at 180°. For the spring/neap plot, full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides.

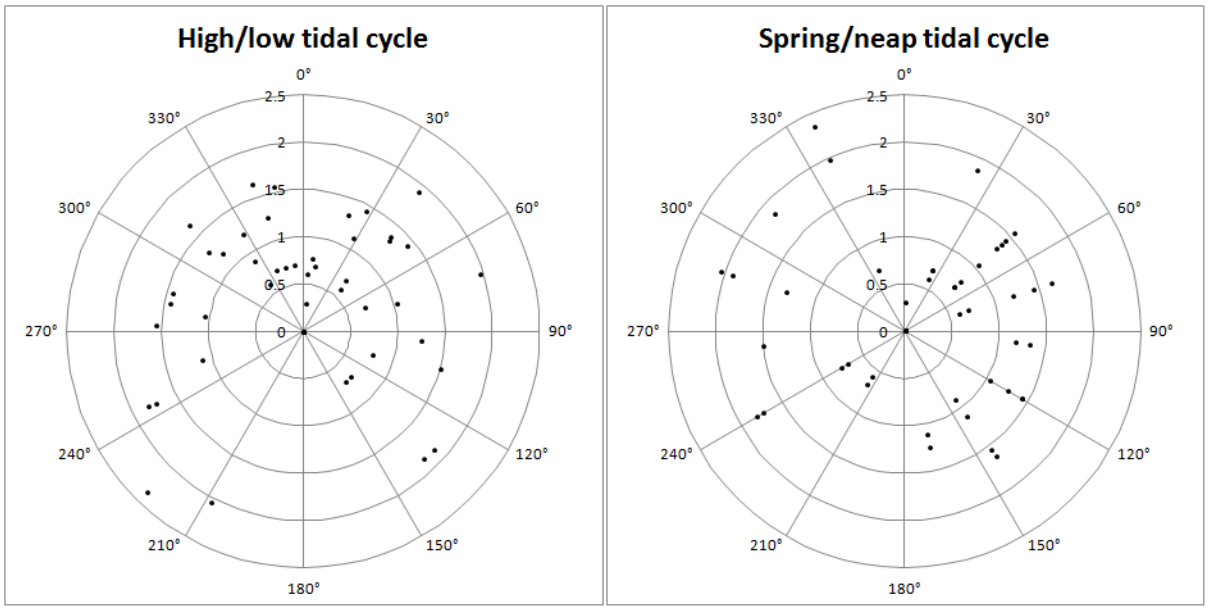


Figure X.9. Polar plots of log_{10} faecal coliforms across the spring/neap and high/low tidal cycles.
Data from Natural Resources Wales

Across the high/low tidal cycle, results are generally lower around high water when dilution potential is greatest. Across the spring neap tidal cycle results tended to be higher on average as tide sizes increase from neap to spring tides.

Influence of rainfall

To investigate the effects of rainfall on levels of contamination at the water quality monitoring sites Spearman's rank correlations were carried out between rainfall recorded at the Parc Menai weather station (Appendix II for details) over various periods running up to sample collection and faecal coliform results. These are presented in Table X.6 and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table X.6: Spearmans Rank correlation coefficients for faecal coliform results against recent rainfall

		Site	Menai Strait East
		n	47
24 hour periods prior to sampling	1 day		0.315
	2 days		0.311
	3 days		0.232
	4 days		0.319
	5 days		0.103
	6 days		0.312
	7 days		0.291
Total prior to sampling over	2 days		0.396
	3 days		0.424
	4 days		0.388
	5 days		0.437
	6 days		0.355
	7 days		0.413

Data from Natural Resources Wales

Antecedent rainfall over the week before sampling had a strong influence on levels of faecal coliforms in the water column.

Influence of salinity

Salinity was recorded on most sampling occasions. Figure X.10 shows a scatter-plots of faecal coliforms against salinity. Pearson's correlations were run to determine the effect of salinity on faecal coliforms at shellfish waters sites.

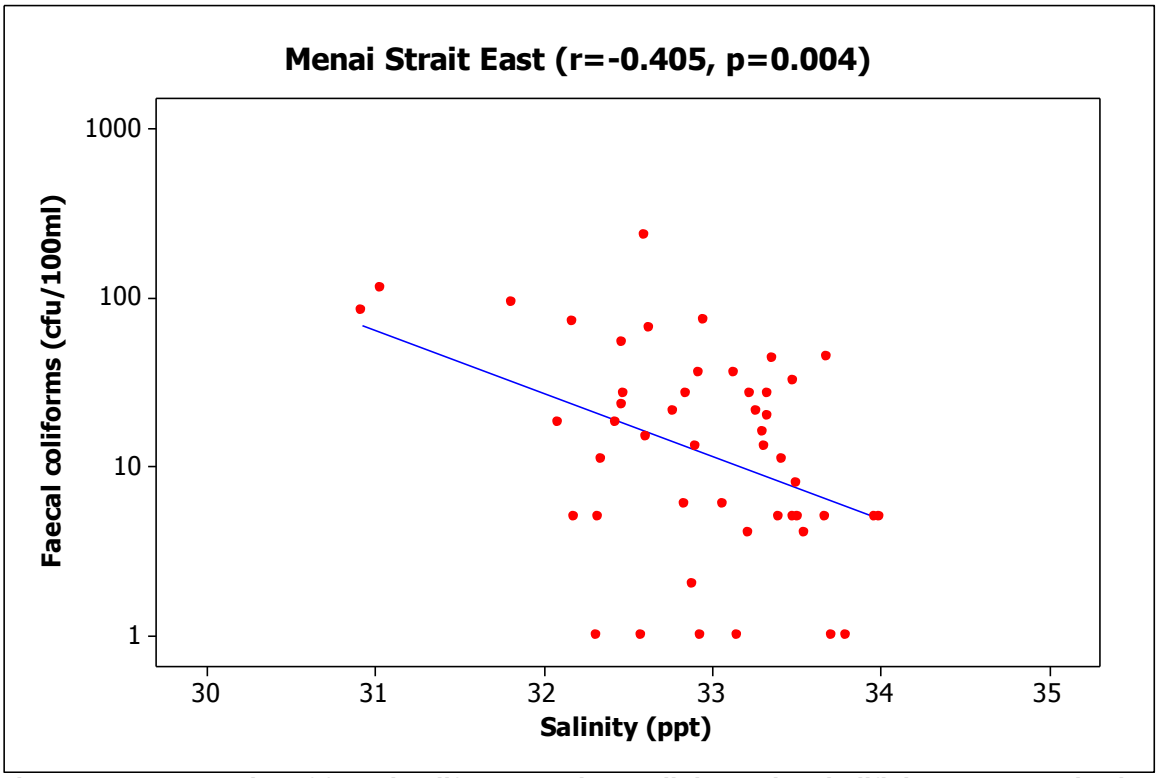


Figure X.6 Scatterplot of faecal coliforms against salinity at the shellfish waters monitoring point.

Data from Natural Resources Wales.

A significant negative correlation was found, suggesting that land runoff is a significant contaminating influence.

Appendix XI. Microbiological Data: Shellfish Flesh

There are a total of 10 RMPs in the Menai Strait East production area that have been sampled between 2003 and 2013. Eight of these RMPs are for mussels and two for cockles. The geometric mean results of shellfish flesh monitoring from all RMPs sampled from 2003 onwards are presented in Figure XI.1. Summary statistics are presented in Table XI.1 and boxplots for sites are show in Figure XI.2 and Figure XI.3.

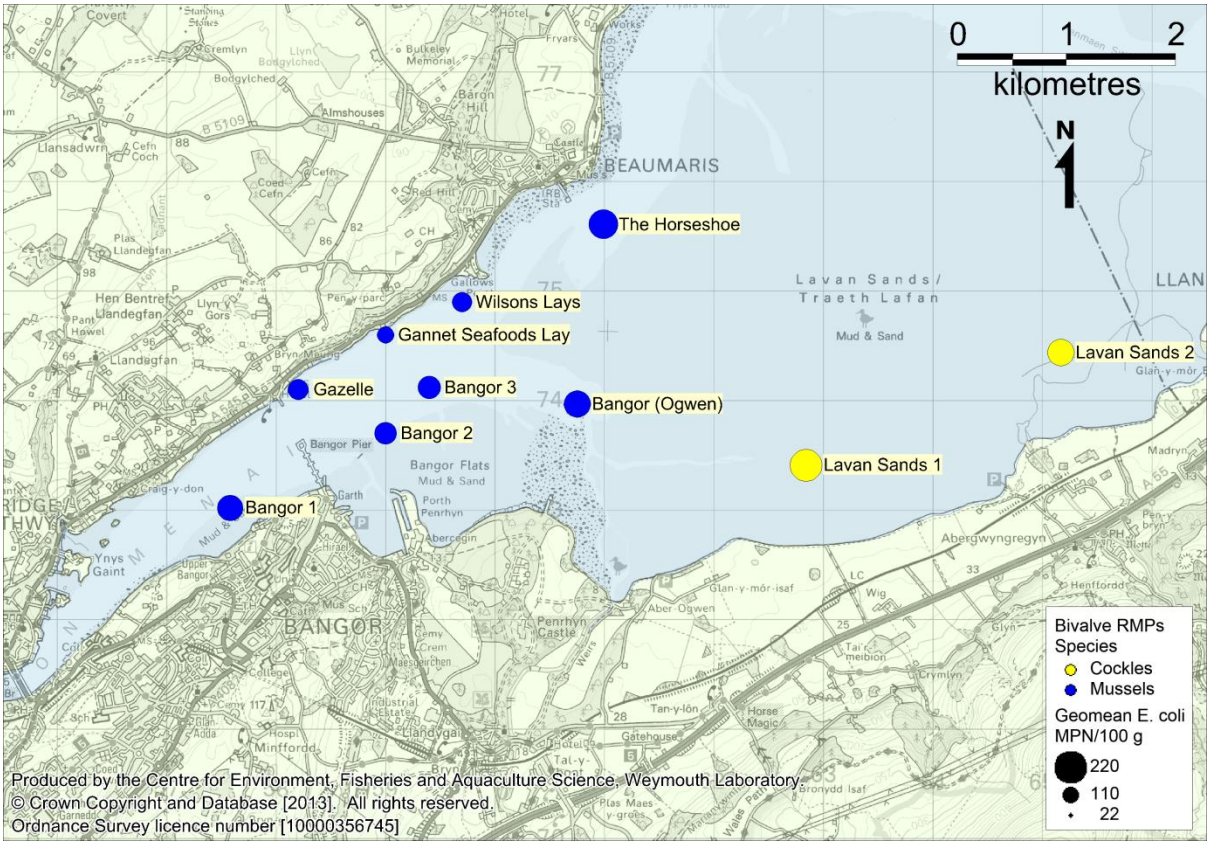


Figure XI.1: Bivalve RMPs active since 2003

Table XI.1: Summary statistics of *E. coli* results (MPN/100 g) from RMPs sampled from 2003 onwards

Site	Species	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 230	% over 4,600
Lavan Sands 1	Cockle	100	27/01/2003	03/09/2013	217.8	<20	9200	54.0	1.0
Lavan Sands 2		99	27/01/2003	03/09/2013	182.8	<20	5400	45.5	3.0
Bangor 1	Mussel	99	07/01/2003	11/11/2013	176.4	<20	3500	40.4	0.0
Gazelle		101	07/01/2003	11/11/2013	141.1	<20	1700	41.6	0.0
Bangor 2		99	07/01/2003	11/11/2013	154.8	<20	3500	40.4	0.0
Gannet Seafoods Lay		101	07/01/2003	11/11/2013	119.0	<20	2200	29.7	0.0
Bangor 3		101	07/01/2003	11/11/2013	158.3	<20	1300	43.6	0.0
Wilsons Lays		105	07/01/2003	11/11/2013	135.6	<20	2400	35.2	0.0
Bangor (Ogwen)		99	07/01/2003	11/11/2013	184.4	<20	>18000	44.4	2.0
The Horseshoe		101	07/01/2003	11/11/2013	200.2	<20	9100	45.5	1.0

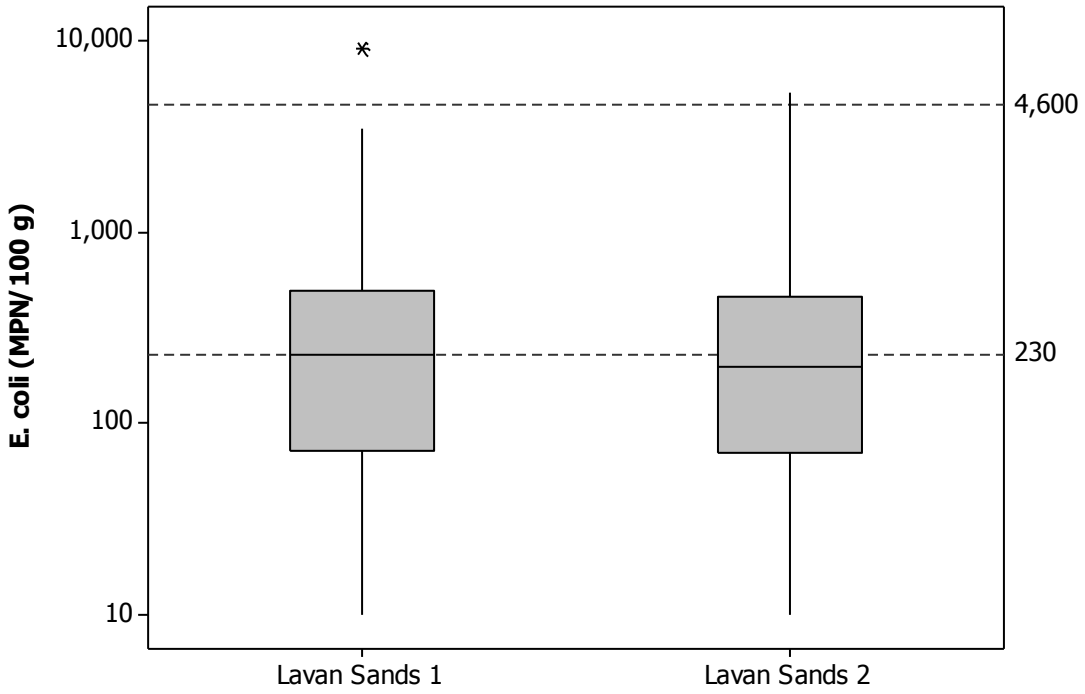


Figure XI.2: Boxplots of *E. coli* results from cockle RMPs from 2003 onwards.

E. coli levels at Lavan Sands 1 and Lavan Sands 2 exceeded 230 MPN/100g in 54 % and 45.5 % of samples respectively and exceeded 4,600 *E. coli* MPN/100 g in 1 % and 3 % of samples. The geometric mean result was marginally higher at Lavan Sands 1, but two-sample t-tests revealed no significant differences in average *E. coli* levels between them (p=0.374). A comparison of paired (same day) samples showed a very strong correlation in *E. coli* levels at the two RMPs (Pearsons correlation, r=0.493, p=0.000) suggesting they are both subject to similar contaminating influences.

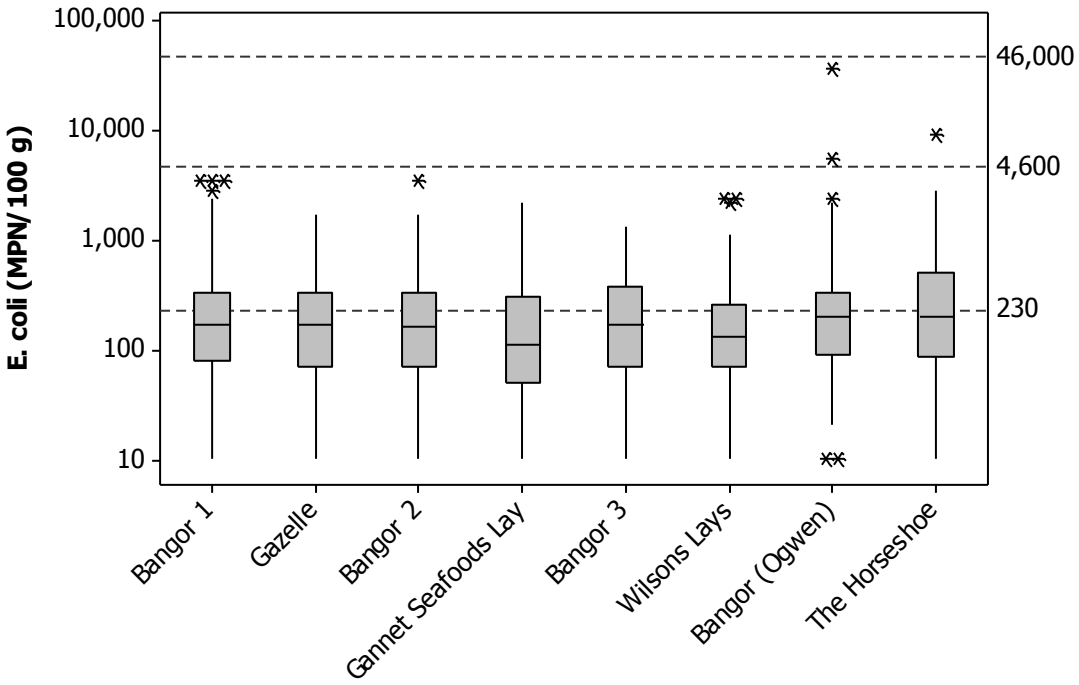


Figure XI.3: Boxplots of *E. coli* results from mussel RMPs from 2003 onwards.

The geometric mean *E. coli* levels across the 8 mussel RMPs were similar, ranging from 119 to 200 MPN/100g. *E. coli* levels only exceeded 4,600 MPN/100g at two RMPs, Bangor (Ogwen) and The Horseshoe, which also had the two highest geometric mean result. Bangor (Ogwen) recorded the highest individual result of >18,000 MPN/100g. The differences in average *E. coli* levels across these RMPs were not quite significant at the 0.05 level (One-way ANOVA, p=0.051). Comparisons of paired (same day) samples showed very strong correlations in *E. coli* levels between all mussel RMP pairings (Pearsons correlation, p<0.001 in all cases) suggesting they are all subject to similar contaminating influences. These analyses suggest that there is a case for reducing the number of RMPs currently used to classify mussels within the fishery order area.

XI.1. Overall temporal pattern in results

The overall variation in *E. coli* levels found in bivalves is shown in Figure XI.4 and XI.5.

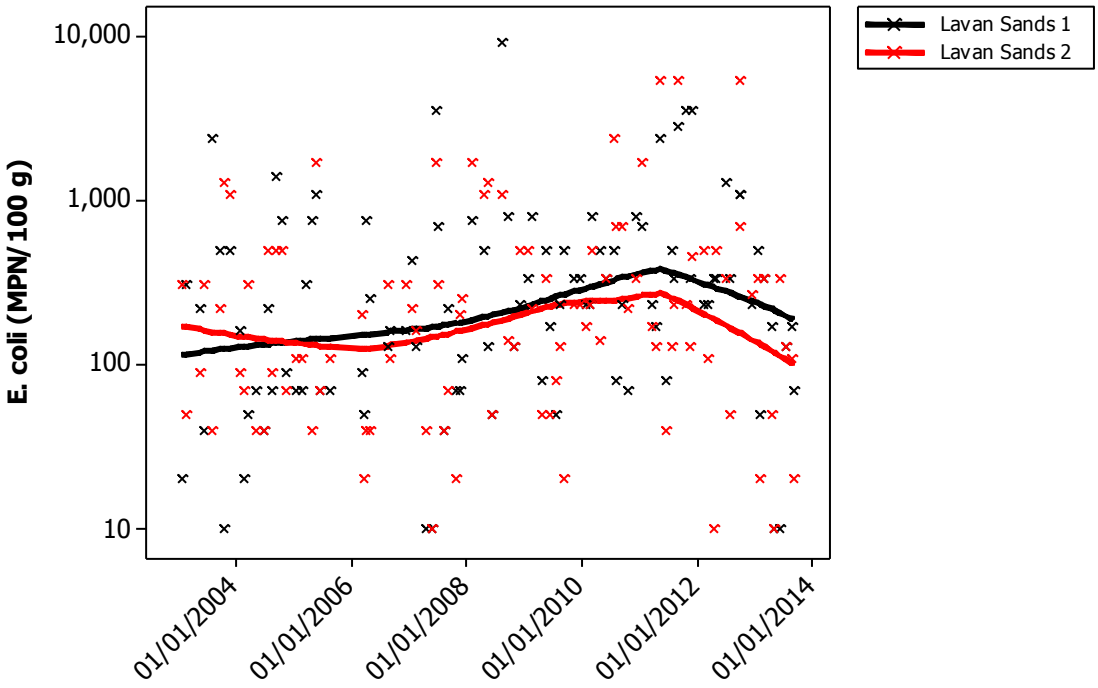


Figure XI.4: Scatterplot of E. coli results for cockles overlaid with loess line.

There was a slight increase in *E. coli* levels at Lavan Sands 1, but this was followed by a decrease back to levels comparable to 2003 from 2011 to present. At Lavan Sands 2, *E. coli* levels fluctuated lightly from 2003 to 2011 and there appears to have been a slight declining trend since.

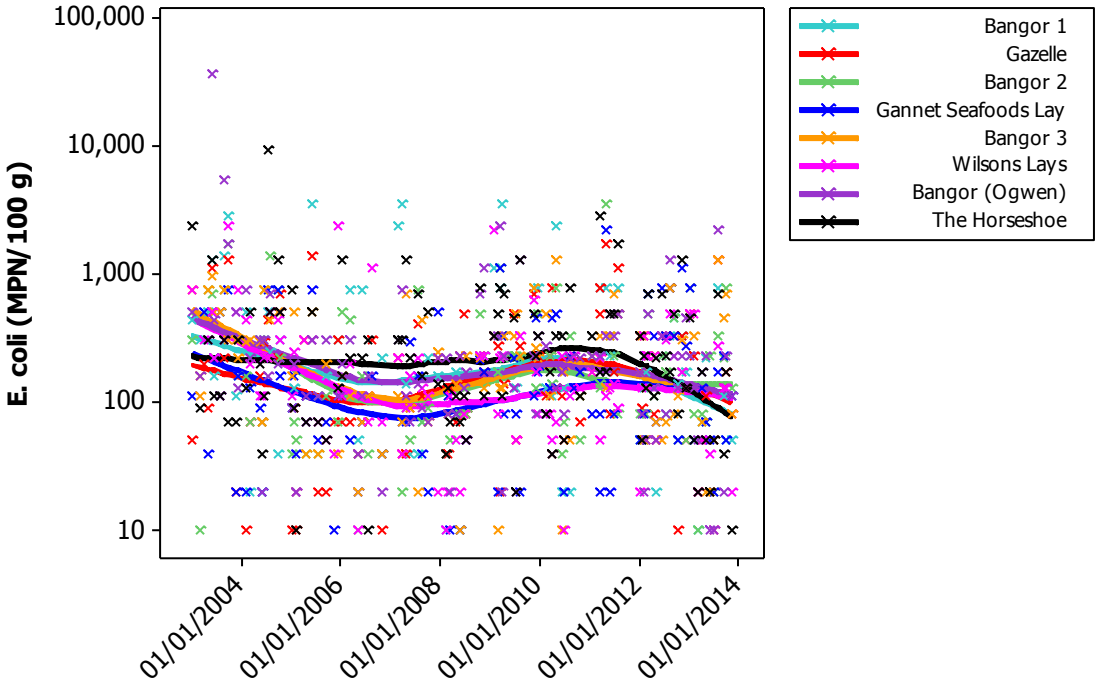


Figure XI.5: Scatterplot of E. coli results for mussels overlaid with loess line.

At all mussel RMPs except The Horseshoe there was a slight decrease *E. coli* levels from 2003 to 2006/2007 followed by relatively stable *E. coli* levels to present. At The Horseshoe, *E. coli* levels were stable until 2011 and have decreased slightly since then.

XI.2. Seasonal patterns of results

The seasonal patterns of results from 2003 to 2013 were investigated by RMP. Figure XI.6 and XI.7 show box plots of *E. coli* levels at each RMP by season.

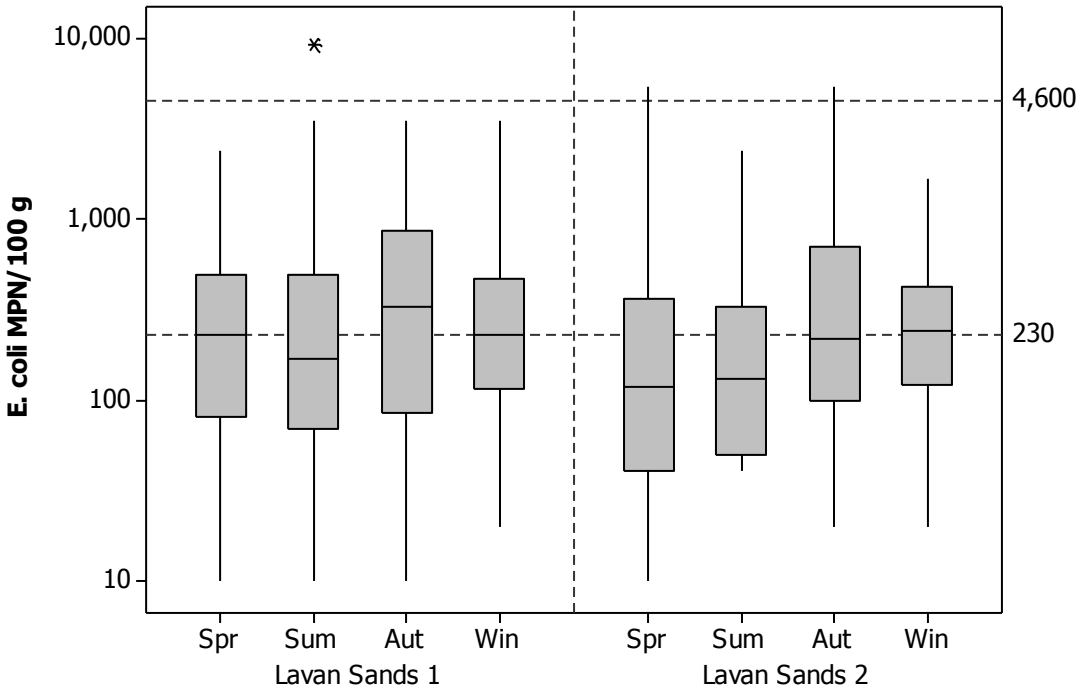


Figure XI.6: Boxplot of *E. coli* results for cockles by RMP and season

E. coli results at both cockle RMPs were similar throughout the year. One-way ANOVAs showed that there were no significant variations in *E. coli* levels between seasons at either (p=0.648 and 0.303 for Lavan Sands 1 and Lavan Sands 2 respectively).

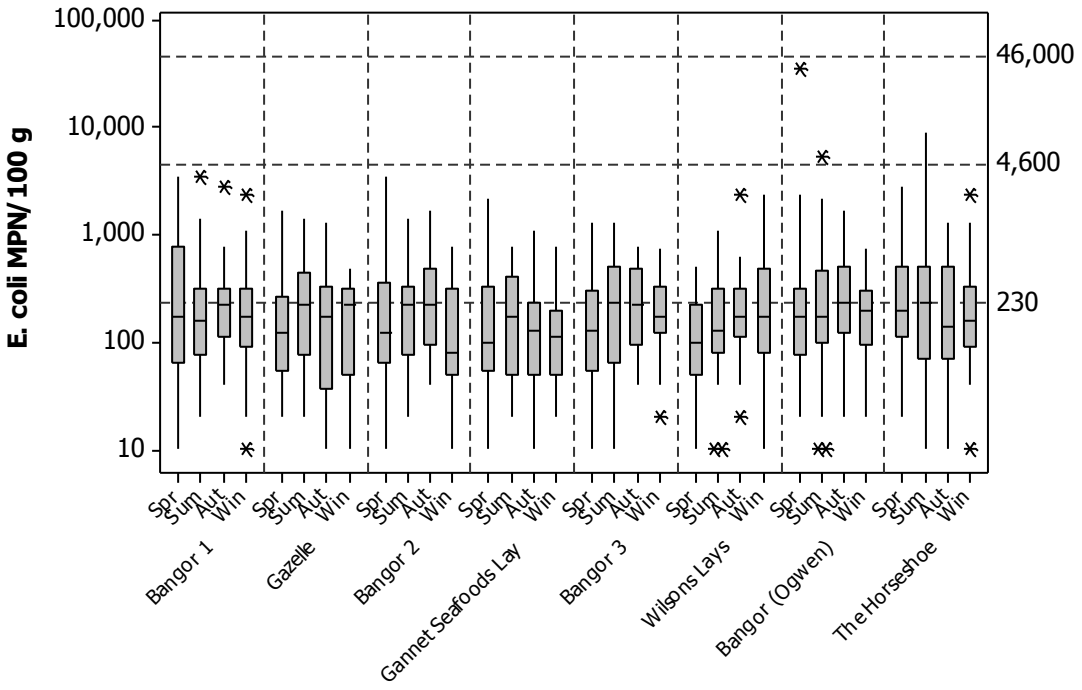


Figure XI.7: Boxplot of *E. coli* results for mussels by RMP and season

All eight mussel RMPs showed little seasonal variation in *E. coli* results. One-way ANOVAs showed that there were no significant variation in between seasons at any of them (p=0.158 to 0.941).

XI.3. Influence of tide

To investigate the effects of tidal state on *E. coli* results, circular-linear correlations were carried out against the high/low and spring/neap tidal cycles for each RMP where more than 30 samples had been taken. Results of these correlations are summarised in Table XI.2, and significant results are highlighted in yellow.

Table XI.2: Circular linear correlation coefficients (r) and associated p values for *E. coli* results against the high/low and spring/neap tidal cycles

		High/low tides		Spring/neap tides	
Site Name	**Species**	**r**	**p**	**r**	**p**
Lavan Sands 1	Cockle	0.145	0.128	0.131	0.190
Lavan Sands 2		0.131	0.190	0.127	0.211
Bangor 1	Mussel	0.450	<0.001	0.253	0.002
Gazelle		0.130	0.193	0.099	0.384
Bangor 2		0.291	<0.001	0.289	<0.001
Gannet Seafoods Lay		0.175	0.050	0.258	0.001
Bangor 3		0.342	<0.001	0.219	0.009
Wilsons Lays		0.355	<0.001	0.252	0.002
Bangor (Ogwen)		0.298	<0.001	0.054	0.754
The Horseshoe		0.213	0.012	0.221	0.008

Figure XI.8 presents polar plots of $\log_{10}$ *E. coli* results against tidal states on the high/low cycle for the correlations indicating a statistically significant effect. High water at Menai Bridge is at 0° and low water is at 180°. Results of 230 *E. coli* MPN/100g or less are plotted in green, those from 231 to 4,600 are plotted in yellow, and those exceeding 4,600 are plotted in red.

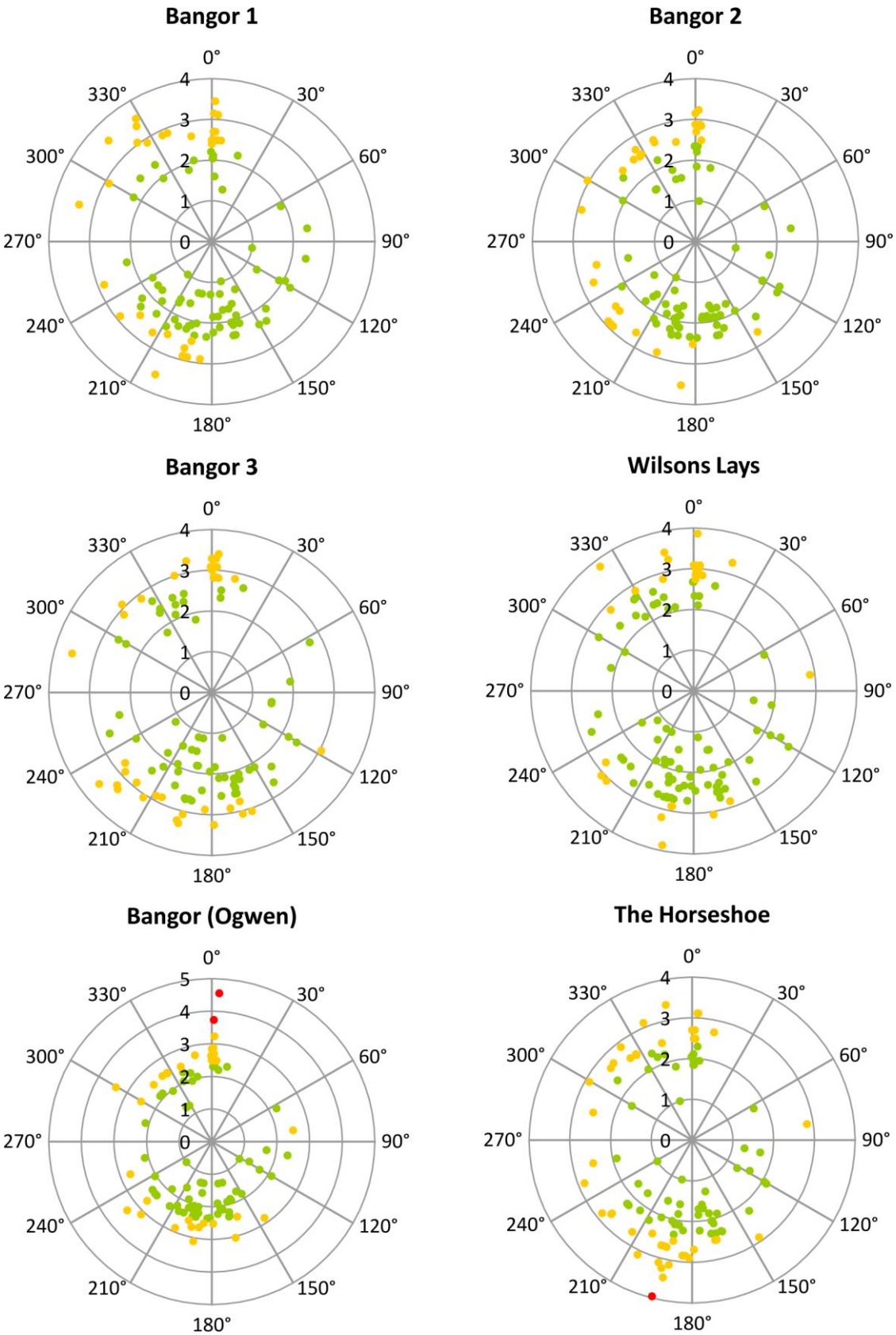


Figure XI.8: Polar plot of log_{10} *E. coli* results (MPN/100g) at mussel RMPs against high/low tidal state

The majority of the sampling effort for mussels occurred during the flood tide. However, it appears that proportionally more higher results occurred during the flood tide than during the ebb at all sites.

Figure XI.9 presents polar plots of $\log_{10}$ *E. coli* results against the spring neap tidal cycle for each RMP. Full/new moons occur at 0º, and half moons occur at 180º, and the largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 230 *E. coli* MPN/100g or less are plotted in green, those from 231 to 4600 are plotted in yellow, and those exceeding 4600 are plotted in red.

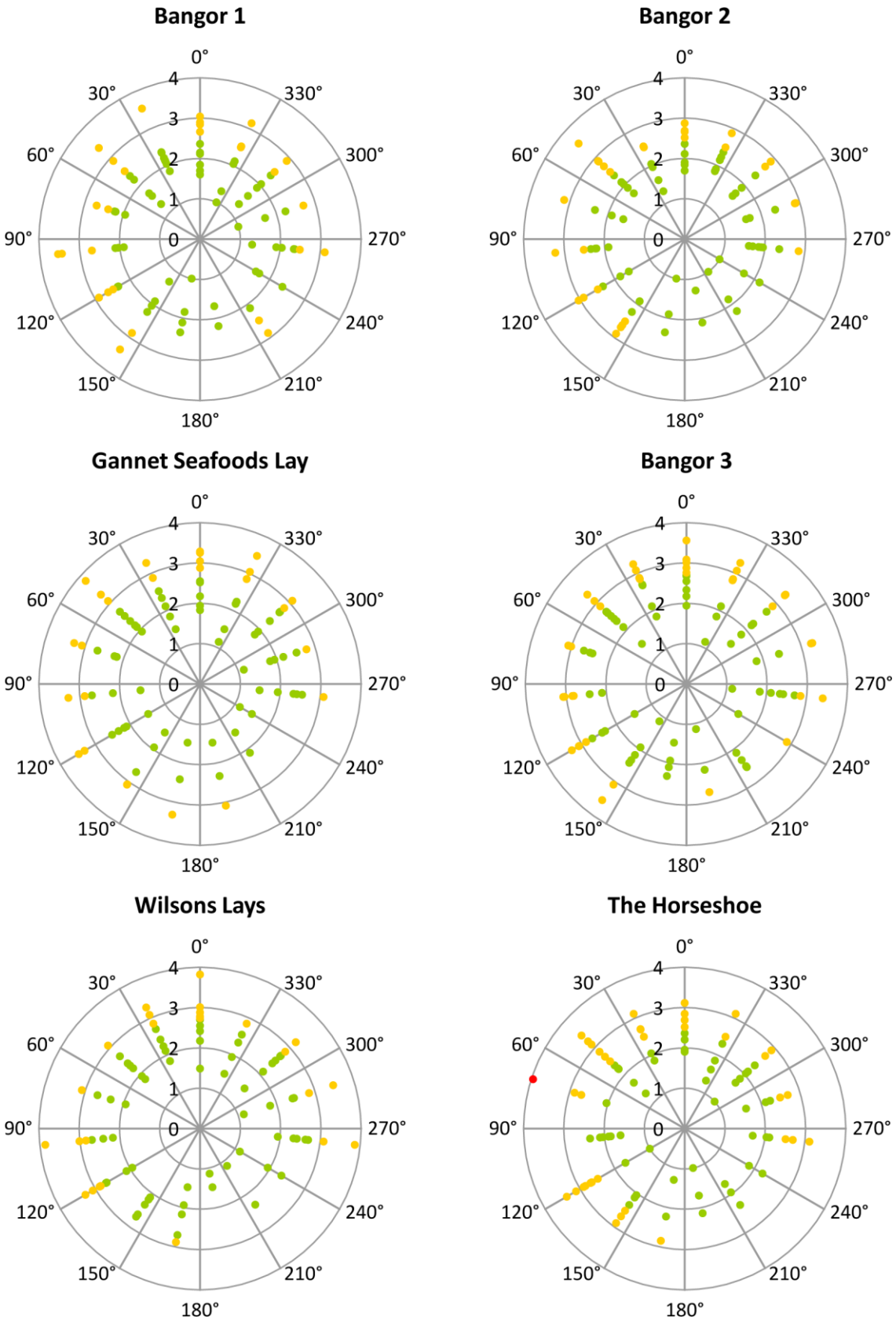


Figure XI.9: Polar plot of $\log_{10}$ *E. coli* results (MPN/100g) at mussel RMPs against spring/neap tidal state

At all mussel RMPs, there tended to be lower *E. coli* levels as the tide size decreased towards neap tides, although this pattern is barely discernible at some RMPs.

XI.4. Influence of rainfall

To investigate the effects of rainfall on levels of contamination within shellfish samples Spearman's rank correlations were carried out between *E. coli* results and rainfall recorded at the Parc Menai weather station (Appendix II for details) over various periods running up to sample collection. These are presented in Table XI.3, and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table XI.3: Spearman's Rank correlations between rainfall recorded at Parc Menai and shellfish hygiene results

	Species	Cockle		Mussel							
	Site	Lavan Sands 1	Lavan Sands 2	Bangor 1	Gazelle	Bangor 2	Gannet Seafoods Lay	Bangor 3	Wilsons Lays	Bangor (Ogwen)	The Horseshoe
	n	95	94	91	94	92	94	93	98	92	92
24 hour periods prior to sampling	1 day	0.109	0.179	0.145	0.329	0.291	0.251	0.066	0.183	0.134	0.228
	2 days	0.205	0.280	0.145	0.122	0.132	0.034	0.021	0.145	0.048	0.130
	3 days	0.059	0.215	0.001	0.085	0.002	-0.038	0.067	0.113	0.007	-0.001
	4 days	0.029	0.254	-0.026	0.215	0.116	0.159	-0.044	0.165	-0.038	0.053
	5 days	0.100	0.079	0.167	0.088	0.096	0.035	0.134	0.091	0.121	0.040
	6 days	0.088	0.201	0.108	0.061	0.017	0.145	0.042	0.146	0.049	0.161
	7 days	0.242	0.224	0.160	0.158	0.125	0.238	0.050	0.239	0.040	0.174
Total prior to sampling over	2 days	0.148	0.259	0.133	0.261	0.245	0.200	0.038	0.200	0.156	0.169
	3 days	0.125	0.250	0.032	0.236	0.137	0.156	-0.024	0.175	0.045	0.127
	4 days	0.117	0.301	0.001	0.272	0.161	0.190	-0.047	0.194	0.036	0.150
	5 days	0.143	0.302	0.041	0.220	0.152	0.137	-0.014	0.194	0.070	0.143
	6 days	0.136	0.295	0.063	0.164	0.147	0.149	0.034	0.239	0.132	0.160
	7 days	0.172	0.328	0.055	0.145	0.126	0.170	0.040	0.254	0.116	0.183

Rainfall affected the levels of *E. coli* found in shellfish to some extent in all site except Bangor 1, Bangor 3 and Bangor (Ogwen) mussel RMPs. This is surprising, particularly for Bangor (Ogwen) which lies by the Ogwen drainage channel. The strongest influence was at the Lavan Sands 2 cockle RMP which is close to the River Aber.

Appendix XII. Shoreline Survey Report

Date (time):
29th October 2013 (09:10-13:30)
30th October 2013 (09:00-14:30)
13th November 2013 (09:00-15:00)

Cefas Officers:
David Walker (29/10/2013)
David Walker & Owen Morgan (30/10/2013)
Simon Kershaw & Rachel Parks (13/11/2013)

Survey Partners:
Gwenan Owen (Gwynedd Council, 29/10/2013)
Deiniol Gwyn Jones (Gwynedd Council, 13/11/2013)

Area surveyed:
Eastern end of the Menai Strait, from the Menai Suspension Bridge to Porth Penmon (Anglesey) and Llanfairfechan (mainland). Excluding Penrhyn Estate.

Weather:
29th October 13:00, partially cloudy, 13°C, wind bearing 315° at 3 km/h
30th October 13:00, partially cloudy, 11°C, wind bearing 168° at 16 km/h
13th November 13:00, partially cloudy, 10°C, wind bearing 230° at 9 km/h

Tides:
Admiralty TotalTide© predictions for Menai Bridge (53°13'N 4°10'W). All times in this report are GMT.

29/10/2013			30/10/2013			13/11/2013		
High	06:21	5.8 m	High	07:23	6.1 m	High	07:12	6.5 m
High	18:38	6.1 m	High	19:36	6.5 m	High	19:23	6.9 m
Low	00:26	2.5 m	Low	01:30	2.2 m	Low	01:09	1.6 m
Low	12:46	2.7 m	Low	13:47	2.4 m	Low	13:37	1.9 m

Objectives:

The shoreline survey aims to obtain samples of freshwater inputs to the area for bacteriological testing; confirm the location of previously identified sources of potential contamination; locate other potential sources of contamination that were previously unknown and find out more information about the fishery. A full list of recorded observations is presented in Table XII.1 and the locations of these observations are shown in Figure XII.2.

While every effort was made to survey the entire shoreline, the coastline around the Penrhyn Estate was not surveyed. This was due to restrictions of time and access. There are no discharges on the EA consented discharge to controlled waters database in the estate, and no significant watercourses are evident on the maps.

The shoreline survey required two separate fieldwork trips, one in October and another in November. The October trip incorporated pedestrian surveys for Anglesey and the Menai Strait West and East production areas. The boat survey, originally planned to be conducted in parallel with the pedestrian survey, was postponed due to unfavourable weather and then completed in November.

XII.1. Fishery

Razor clam, cockle and scallop deadshell were observed along the shore adjacent to Lavan Sands (observations 2 and 10). During the survey eight people were seen on Lavan Sands with quad bike, harvesting cockles. Large parts of Lavan Sands are restricted for cockling as they are part of the Y Fenai a Bae Conwy/ Menai Strait and Conwy Bay special area of conservation. To access Lavan Sands cockle gatherers must stay on a designated route as shown in Figure XII.1.

Around the Garth area of Bangor a mussel dredger was observed in the strait (observation 36). Along the same stretch of shoreline large amounts of cockle and mussel deadshell were observed (observation 39 and 40).

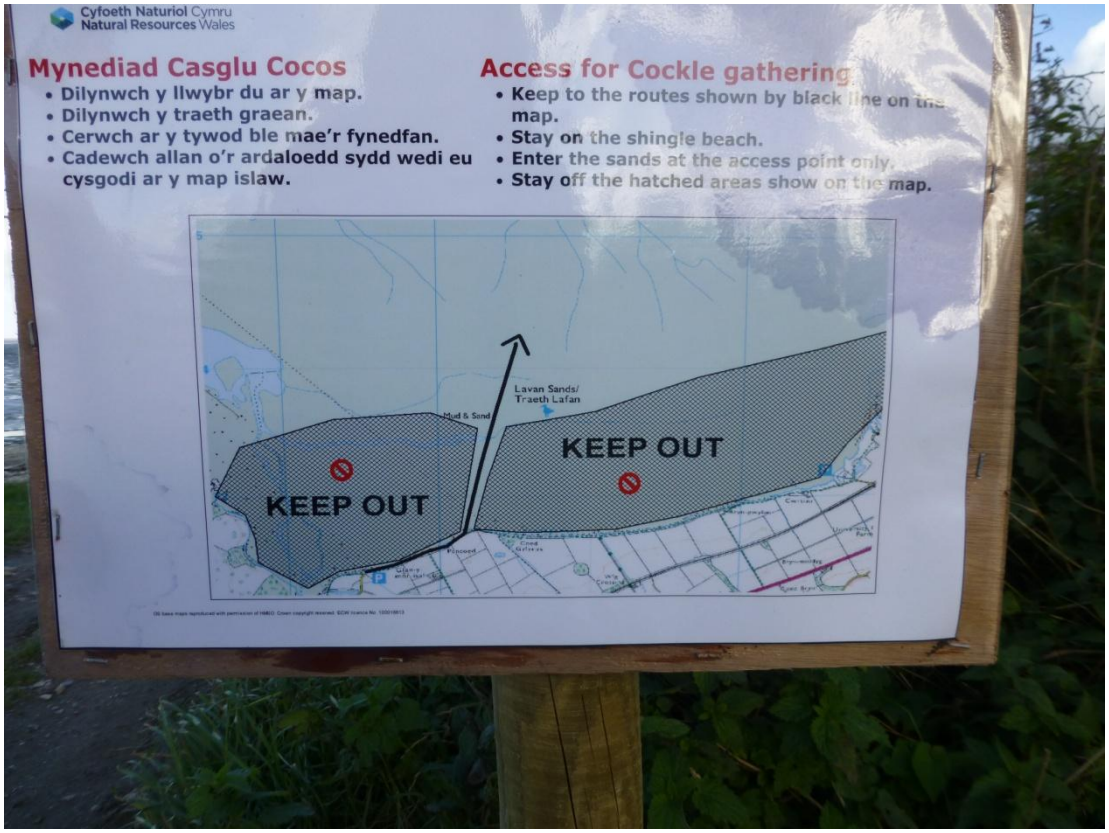


Figure XII.1

XII.2. Sources of contamination

Sewage discharges

The locations of several intermittent discharges were confirmed. These were the Abergwyngregyn pumping station (PS) discharge (observation 20), the Merion Road PS discharge (observation 38), the Beach Road PS (observation 45), the Glaentraeth Estate PS and the Antelope Sewage PS (observation 78). Three other intermittent discharges may have been observed, but it was not possible to confirm whether these discharges matched the EA consented discharge to controlled waters database. These were the Llanfairfechan Hospital PS (observation 4 or 5), the West End PS (observation 58) and the Glyn Garth PS (observation 68). Of all of the intermittent discharges observed during this survey, it was only possibly to sample one. This was the Llanfairfechan Hospital PS, which was outputting either 1.59×10^7 or 9.03×10^6 *E. coli* cfu/day. The concentration of *E. coli* in both these outfalls was very low (5 cfu/100ml) compared to what may be expected for storm sewage. The location of the Llanfairfechan sewage treatment works (STW) was confirmed (observation 8). but no discharge could be seen coming out of the site.

Freshwater inputs

Six of the rivers flowing into the strait were observed as well as nine smaller streams. Afon Cegin (observation 53) and Afon Ogwen (observation 55) were too deep to measure flow and therefore daily bacterial load. However, Afon Ogwen was found to have an *E. coli* concentration of 7,600 cfu/100 ml, which was the highest concentration for any of the samples in the survey. Given the size of the river (14 m width) and the high *E. coli* concentration this is likely to represent a significant source of contamination.

Afon Llanfairfechan had a measured *E. coli* loading of 2.35×10^{12} CFU/day. This means that this river had the highest *E. coli* loading of any of the measured observations by two orders of magnitude (although it had a lower *E. coli* concentration than Afon Ogwen). There are three intermittent storm overflows upstream on this river. This survey was conducted shortly after heavy rainfall and so these overflows may have been flowing, possibly contributing to the high levels of *E. coli*.

There were several pipes throughout the survey area which were not listed in the EA consented discharges to controlled waters database (including current and revoked consents), and are therefore assumed to be ground/surface water drainage.

Livestock

Several hundred sheep were seen throughout the coast adjacent to the Lavan Sands cockle beds (observations 14, 15, 27, 29 and 35). The presence of sheep faeces on the shoreline at observation 11 indicates that sheep have access to the intertidal zone at this point.

Additionally 20 cattle were seen in a field (observation 35) and 20 chickens were seen on the footpath directly adjacent to the intertidal zone (observation 23).

Wildlife

Large concentrations of wild birds were seen across the survey area (observations 6, 43, 50, 57, 72 and 83).

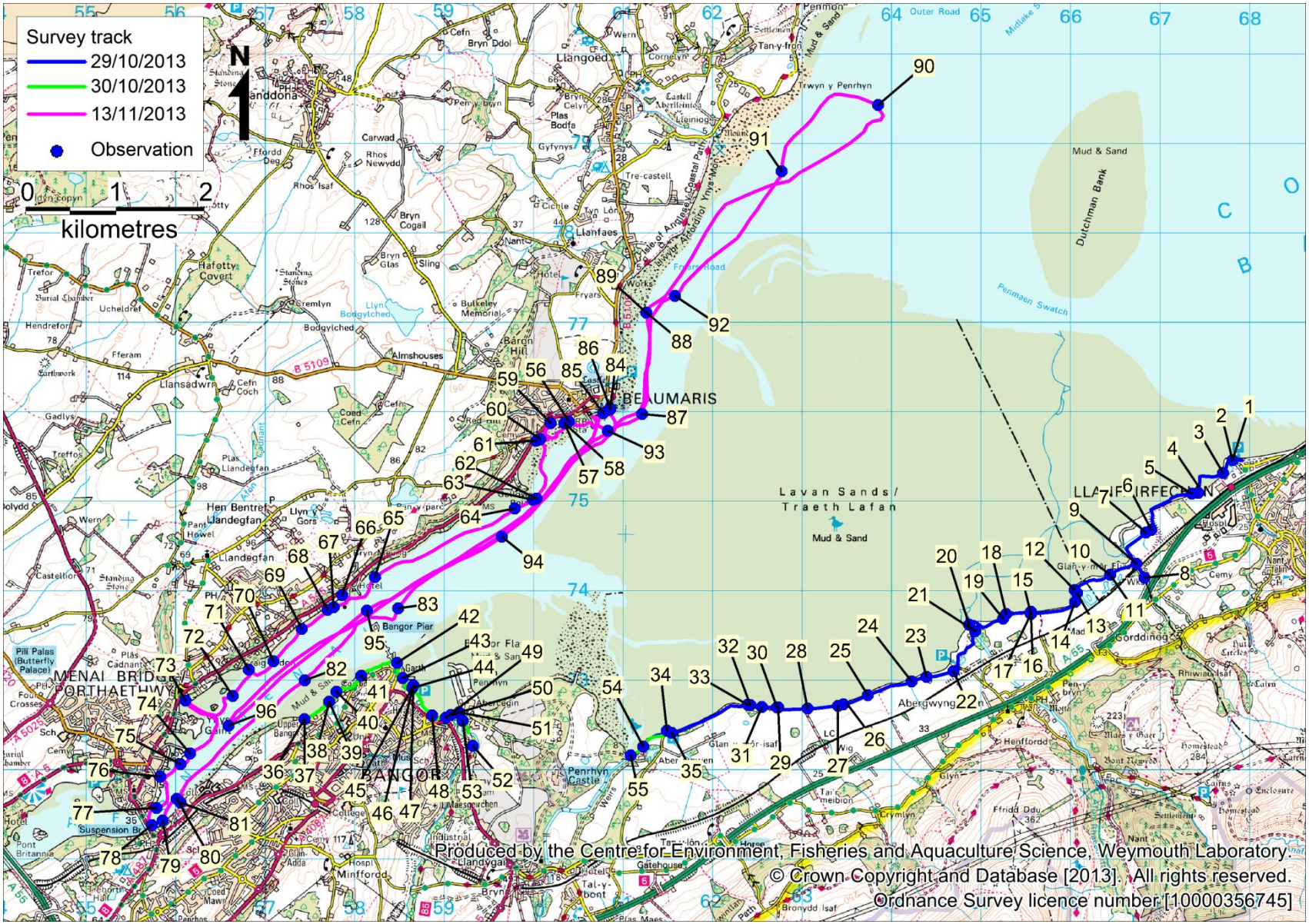


Figure XII.2: Locations of Shoreline Observations (Table XII.1 for details)

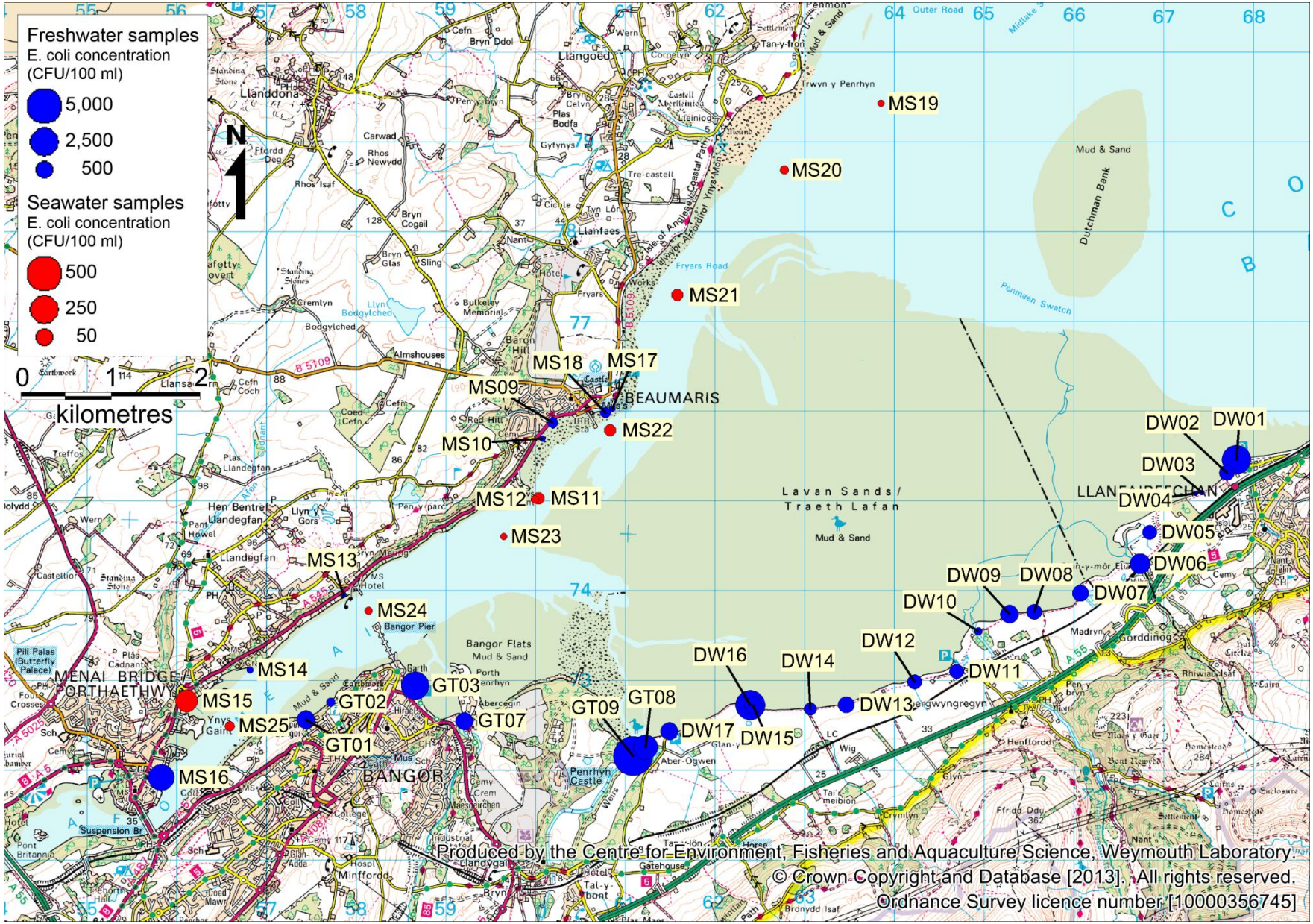
Table XII.1: Details of Shoreline Observations

Observation no.	NGR	Date	Time	Description	Photo
1	SH 67813 75458	29/10/2013	09:13	River Afon Llanfairfechan (0.2 x 3.5 m) (sample DW01)	Figure XIII.5
2	SH 67813 75458	29/10/2013	09:13	Razor clam dead shell	
3	SH 67706 75314	29/10/2013	09:23	Ground water pipe. (0.04 x 0.3 m) (sample DW02)	Figure XIII.6
4	SH 67430 75093	29/10/2013	09:32	Concrete pipe. Possible ground water drainage (0.03 x 0.42 m) (sample DW03)	Figure XIII.7
5	SH 67358 75083	29/10/2013	09:36	Concrete pipe. (0.07 x 0.15 m) (sample DW04)	Figure XIII.8
6	SH 66906 74678	29/10/2013	09:52	300 ducks on marsh	
7	SH 66847 74648	29/10/2013	09:56	Stream through marsh (0.2 x 0.55 m) (sample DW05)	Figure XIII.9 & 10
8	SH 66828 74143	29/10/2013	10:09	Llanfairfechan sewage treatment works. No visible outfall. Stream running alongside	
9	SH 66741 74300	29/10/2013	10:14	Stream - downstream from sewage works (0.2 x 2 m) (sample DW06)	Figure XIII.11
10	SH 66446 74175	29/10/2013	10:22	Cockle dead shell along bay. Also some scallop shell (king).	
11	SH 66446 74175	29/10/2013	10:22	Sheep faeces along bay	
12	SH 66050 74005	29/10/2013	10:31	Broken pipe (concrete culvert). Flow reading not possible (not laminar and too spread further on)	Figure XIII.12
13	SH 66075 73971	29/10/2013	10:39	Stream running to pipe at observation 10 (0.3 x 1 m) (sample DW07)	Figure XIII.13
14	SH 66053 73873	29/10/2013	10:42	100 sheep in field	
15	SH 65558 73738	29/10/2013	10:51	100 sheep in filed and another 100 sheep 200 metres west	
16	SH 65558 73762	29/10/2013	10:54	Valved pipe (0.3 m diameter x 0.04 m flow depth) (sample DW08)	Figure XIII.14
17	SH 65558 73762	29/10/2013	10:54	Start of seagrass	
18	SH 65281 73735	29/10/2013	11:06	Valved pipe (0.3 m diameter). Flow reading not possible (valve cover jammed shut) - flow rate is an estimate (sample DW09)	Figure XIII.15
19	SH 65249 73684	29/10/2013	11:11	Around 8 cocklers on quads (~1 km bearing 270°)	
20	SH 64867 73617	29/10/2013	11:24	Inspection cover for pipeline (access to end of pipe too dangerous due to mud)	Figure XIII.16&17
21	SH 64936 73543	29/10/2013	11:32	River – Afon Aber (average 0.33 x 7 m) (sample DW10)	Figure XIII.18
22	SH 64694 73097	29/10/2013	11:50	Pipe under track. Probable culvert. (0.5 m diameter 0.1 m flow depth) (sample DW11)	Figure XIII.19
23	SH 64391 73031	29/10/2013	11:55	20 chickens	
24	SH 64225 72984	29/10/2013	12:00	Plastic pipe (0.45 m diameter 0.1 m flow depth) (sample DW12)	Figure XIII.20
25	SH 63735 72827	29/10/2013	12:10	Ground seepage	
26	SH 63463 72725	29/10/2013	12:17	Stream or ground water (0.09 x 0.15 m) (sample DW13)	Figure XIII.21

27	SH 63401 72711	29/10/2013 12:22	200 sheep in fields	
28	SH 63062 72678	29/10/2013 12:28	Culvert. 2 black plastic pipes - combined flow data (1.1 m diameter 0.15 and 0.1 m flow depths) (sample DW14)	Figure XIII.22
29	SH 62733 72693	29/10/2013 12:38	300 sheep in fields (up to western tree line)	
30	SH 62721 72691	29/10/2013 12:38	Iron pipe. Flow too low to sample and measure	Figure XIII.23
31	SH 62551 72698	29/10/2013 12:41	Iron pipe. Flow too low to sample and measure	Figure XIII.24
32	SH 62421 72719	29/10/2013 12:46	Culvert (0.11 x 0.7 m) (sample DW15)	Figure XIII.25
33	SH 62391 72723	29/10/2013 12:50	Iron pipe. (0.25 m diameter 0.07 m flow depth) (sample DW16)	Figure XIII.26
34	SH 61488 72434	29/10/2013 13:10	Pipe (0.15 x 1 m) (sample DW17)	Figure XIII.27
35	SH 61544 72407	29/10/2013 13:20	20 cows, 50 sheep	
36	SH 57436 72560	30/10/2013 08:58	Mussel dredger offshore	Figure XIII.28
37	SH 57436 72560	30/10/2013 08:58	Pipe flowing over beach (0.07 x 0.27) (sample GT01)	Figure XIII.29
38	SH 57714 72755	30/10/2013 09:09	Submerged pipe with stream next to pipe (measurements for stream, 0.03 x 0.15 m) (sample GT02)	Figure XIII.30
39	SH 57714 72755	30/10/2013 09:09	Mussel and cockle deadshell all along this stretch of shoreline	
40	SH 57793 72865	30/10/2013 09:15	Large amounts of deadshell. Cockle, mussel & whelks	
41	SH 58070 73045	30/10/2013 09:21	Boatyard (~30 small boats)	
42	SH 58470 73191	30/10/2013 09:38	Public toilets (no discharge)	
43	SH 58536 73021	30/10/2013 09:46	100 gulls (200m bearing 100°)	
44	SH 58642 72909	30/10/2013 09:50	Inspection cover (on beach)	
45	SH 58642 72908	30/10/2013 09:50	Pumping station	Figure XIII.31&32
46	SH 58654 72939	30/10/2013 09:55	Other side of pumping station. Lots of toilet paper stuck on embankment	Figure XIII.33
47	SH 58654 72939	30/10/2013 09:55	Afon Adda and CSO outfall. Flow measurement not possible (not accessible for meter) (sample GT03)	Figure XIII.34
48	SH 58862 72603	30/10/2013 10:06	Ground water. Flow too low to measure	Figure XIII.35
49	SH 59018 72578	30/10/2013 10:10	Old broken ceramic pipe coming out of bank. Disused.	Figure XIII.36
50	SH 59071 72605	30/10/2013 10:12	200 bird on flats	
51	SH 59165 72636	30/10/2013 10:16	Non-return valve on side of brick building	Figure XIII.37
52	SH 59318 72262	30/10/2013 13:20	Pumping station	Figure XIII.38
53	SH 59203 72544	30/10/2013 13:39	River – Afon Cegin. Too deep to measure (~8 m wide) (sample GT07)	Figure XIII.39
54	SH 61225 72251	30/10/2013 14:31	Pipe in mud flats, 60 cm. Flow too fast to measure safely (sample GT08)	Figure XIII.40
55	SH 61084 72156	30/10/2013 14:37	River - Afon Ogwen. Too deep to measure (14 m) (sample GT09)	Figure XIII.42

56	SH 60394 75889	13/11/2013 09:42	16 pipes in wall. Not flowing	Figure XIII.43
57	SH 60344 75873	13/11/2013 09:44	200 birds	
58	SH 60344 75873	13/11/2013 09:44	Valved pipe. Not flowing	Figure XIII.44
59	SH 60188 75873	13/11/2013 09:51	River – Afon Meigan (average 0.2 x 1 m) (sample MS09)	Figure XIII.45
60	SH 60073 75693	13/11/2013 10:06	Drainage under road (0.05 x .18 m) (sample MS10)	Figure XIII.46
61	SH 60026 75676	13/11/2013 10:12	Surface drainage. Not flowing	Figure XIII.47
62	SH 60033 75026	13/11/2013 10:19	Sea water sample (sample MS11)	
63	SH 59989 75015	13/11/2013 10:23	Sea water sample (sample MS12)	
64	SH 59789 74918	13/11/2013 10:26	Surface drainage pipes outside ABC marina	
65	SH 58222 74148	13/11/2013 10:31	Surface water drainage under hill and houses	
66	SH 57858 73948	13/11/2013 10:36	Waterfall (0.03 x 0.36 m) (sample MS13)	Figure XIII.48
67	SH 57762 73812	13/11/2013 10:43	Large white pipe under houses. Not flowing	Figure XIII.49
68	SH 57694 73783	13/11/2013 10:44	Pipe into sea under houses	Figure XIII.50
69	SH 57405 73568	13/11/2013 10:46	Pipe coming down wall into sea under block of flats	Figure XIII.51
70	SH 57092 73206	13/11/2013 10:48	Surface drainage under houses. Not flowing	
71	SH 56814 73115	13/11/2013 10:49	Water flowing from garden (sample MS14)	Figure XIII.52
72	SH 56636 72821	13/11/2013 10:56	500 seabirds on Ynys y Big	
73	SH 56107 72767	13/11/2013 11:03	Sample from river (Afon Cadnant) - not accessible for flow reading (sample MS15)	Figure XIII.53
74	SH 56155 72175	13/11/2013 11:12	Pipe running down wall into sea	Figure XIII.54
75	SH 56051 72058	13/11/2013 11:13	Pipe running across rocks. Not flowing	Figure XIII.55
76	SH 55825 71915	13/11/2013 11:18	Pipe (17.2 s to fill 1 litre) (sample MS16)	Figure XIII.56
77	SH 55783 71566	13/11/2013 11:29	Pipe from boat house	Figure XIII.57
78	SH 55729 71377	13/11/2013 11:31	Pipe running down beach (likely private discharge). Covered by tide	Figure XIII.58
79	SH 55849 71427	13/11/2013 11:33	Larger pipe down cliff and beach (likely private discharge).	Figure XIII.59
80	SH 56009 71669	13/11/2013 11:35	2 pipes (likely private discharges).	Figure XIII.60
81	SH 56050 71625	13/11/2013 11:37	Dripping stream	Figure XIII.61
82	SH 57441 72994	13/11/2013 11:42	Pipe along beach	
83	SH 58482 73800	13/11/2013 11:48	500 gulls	
84	SH 60855 76027	13/11/2013 12:40	Valved pipe (1 metre diameter 2 cm flow depth) (sample MS17)	Figure XIII.62
85	SH 60779 75981	13/11/2013 12:43	Pipe (53cm diameter 4cm flow depth) (sample MS18)	Figure XIII.63
86	SH 60855 76036	13/11/2013 12:58	Pipe running along beach. Submerged	

87	SH 61212 75973	13/11/2013 13:08	Valved pipe (50 cm diameter). Not flowing
88	SH 61260 77107	13/11/2013 13:13	Pipes either end of slipway (possible sluice)
89	SH 61260 77107	13/11/2013 13:13	40 sheep
90	SH 63850 79429	13/11/2013 13:24	Sea water sample (sample MS19)
91	SH 62772 78687	13/11/2013 13:41	Sea water sample (sample MS20)
92	SH 61579 77294	13/11/2013 13:48	Sea water sample (sample MS21)
93	SH 60829 75785	13/11/2013 14:03	Sea water sample (sample MS22)
94	SH 59643 74603	13/11/2013 14:16	Sea water sample (sample MS23)
95	SH 58135 73776	13/11/2013 14:23	Sea water sample (sample MS24)
96	SH 56587 72489	13/11/2013 14:30	Sea water sample (sample MS25)


Freshwater samples
E. coli concentration
(CFU/100 ml)
5,000
2,500
500
Seawater samples
E. coli concentration
(CFU/100 ml)
500
250
50
N
0
1
2
kilometres
MS09
MS10
MS11
MS12
MS13
MS14
MS15
MS16
MS17
MS18
MS19
MS20
MS21
MS22
MS23
MS24
MS25
BEAUMARIS
BANGOR
MENAI BRIDGE
PORTHAETHWY
Llanddona
Llanfaes
Llangoed
Bangor Pier
Bangor Flats
Mud & Sand
Lavan Sands/
Traeth Lafan
Dutchman Bank
Penmaen Swatch
Fryars Road
Outer Road
GT01
GT02
GT03
GT07
GT08
GT09
DW01
DW02
DW03
DW04
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DW12
DW13
DW14
DW15
DW16
DW17
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Ordnance Survey licence number [10000356745]

Figure XII.3: Water sample results (Table XII.2 and

Table XII.3 for details)

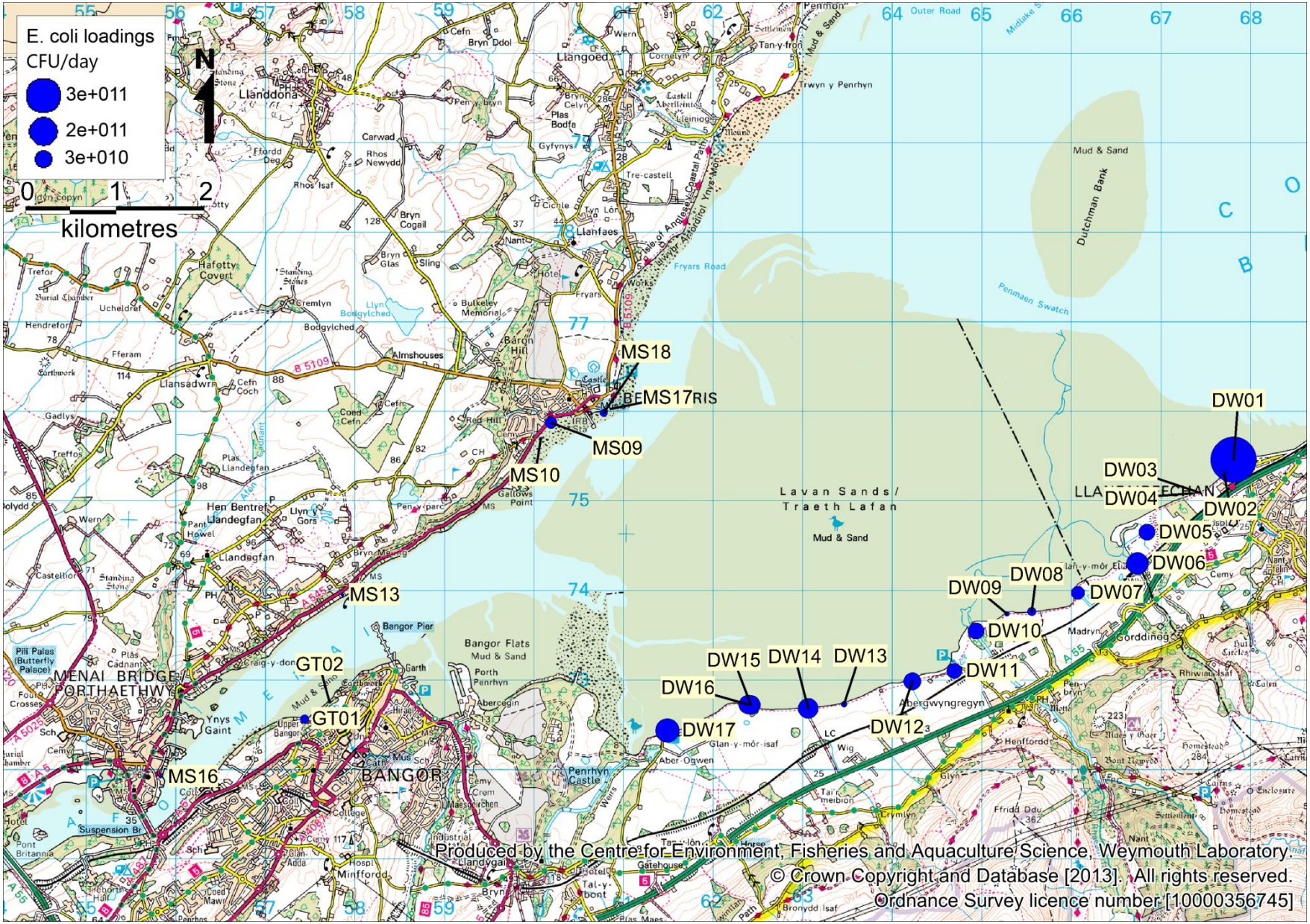

Figure XIII.4: *E. coli* stream loadings (Table XII.2 for details).

Table XII.2: Freshwater *E. coli* results, spot flow gauging results and estimated stream loadings (where applicable).

Sample ID	Observation number	Date and time	Description	Flow (m^3/s)	*E. coli* concentration (cfu/100 ml)	*E. coli* loading (cfu/day)	NGR
DW01	1	29/10/2013 09:13	River – Afon Llanfairfechan	1.045	2,600	$2.35x10^{12}$	SH 67813 75458
DW02	3	29/10/2013 09:23	Pipe	0.005	350	$1.45 x10^{9}$	SH 67706 75314
DW03	4	29/10/2013 09:32	Pipe	0.004	5	$1.59 x10^{7}$	SH 67430 75093
DW04	5	29/10/2013 09:36	Pipe	0.002	5	$9.03 x10^{6}$	SH 67358 75083
DW05	7	29/10/2013 09:56	Stream	0.109	260	$2.44 x10^{10}$	SH 66847 74648
DW06	9	29/10/2013 10:14	Stream (downstream of STW)	0.086	880	$6.57 x10^{10}$	SH 66741 74300
DW07	13	29/10/2013 10:39	Stream	0.036	380	$1.18 x10^{10}$	SH 66075 73971
DW08	16	29/10/2013 10:54	Pipe	0.010	310	$2.61 x10^{9}$	SH 65558 73762
DW09	18	29/10/2013 11:06	Pipe	0.001	620	$5.36 x10^{8}$	SH 65281 73735
DW10	21	29/10/2013 11:32	River – Afon Aber	1.004	30	$2.60 x10^{10}$	SH 64936 73543
DW11	22	29/10/2013 11:50	Culvert	0.082	260	$1.84 x10^{10}$	SH 64694 73097
DW12	24	29/10/2013 12:00	Pipe	0.122	280	$2.95 x10^{10}$	SH 64225 72984
DW13	26	29/10/2013 12:17	Stream or ground water	0.002	390	$7.64 x10^{8}$	SH 63463 72725
DW14	28	29/10/2013 12:28	2 large pipes	0.310	180	$4.82 x10^{10}$	SH 63062 72678
DW15	32	29/10/2013 12:46	Culvert	0.089	530	$4.07 x10^{10}$	SH 62421 72719
DW16	33	29/10/2013 12:50	Pipe	0.015	3,100	$4.00 x10^{10}$	SH 62391 72723
DW17	34	29/10/2013 13:10	Pipe	0.208	470	$8.44 x10^{10}$	SH 61488 72434
GT01	37	30/10/2013 08:58	Pipe	0.007	560	$3.37 x10^{9}$	SH 57436 72560
GT02	38	30/10/2013 09:09	Stream	0.002	50	$1.03 x10^{8}$	SH 57714 72755
GT03	47	30/10/2013 09:55	Afon Adda and CSO		2,500		SH 58654 72939
GT07	53	30/10/2013 13:39	River – Afon Cegin		480		SH 59203 72544
GT08	54	30/10/2013 14:31	Pipe		1,600		SH 61225 72251
GT09	55	30/10/2013 14:37	River – Afon Ogwen		7,600		SH 61084 72156
MS09	59	13/11/2013 09:51	River – Afon Meigan	0.091	97	$7.65 x10^{9}$	SH 60188 75873
MS10	60	13/11/2013 10:06	Drainage	0.007	13	$7.99 x10^{7}$	SH 60073 75693
MS13	66	13/11/2013 10:36	Waterfall	0.010	9	$7.92 x10^{7}$	SH 57858 73948
MS14	71	13/11/2013 10:49	Groundwater		22		SH 56814 73115
MS16	76	13/11/2013 11:18	Pipe	$5.8x10^{-5}$	2,000	$1.00 x10^{8}$	SH 55825 71915
MS17	84	13/11/2013 12:40	Pipe	0.002	13	$2.22 x10^{7}$	SH 60855 76027
MS18	85	13/11/2013 12:43	Pipe	0.021	94	$1.67 x10^{9}$	SH 60779 75981

Table XII.3: Seawater *E. coli* results.

Sample	Observation number	Date and time	Description	*E. coli* concentration (cfu/100 ml)	NGR
MS11	62	13/11/2013 10:19	Sea water sample	14	SH 60033 75026
MS12	63	13/11/2013 10:23	Sea water sample	4	SH 59989 75015
MS15	73	13/11/2013 11:03	Sample from near river (Afon Cadnant)	107	SH 56107 72767
MS19	90	13/11/2013 13:24	Sea water sample	2	SH 63850 79429
MS20	91	13/11/2013 13:41	Sea water sample	5	SH 62772 78687
MS21	92	13/11/2013 13:48	Sea water sample	12	SH 61579 77294
MS22	93	13/11/2013 14:03	Sea water sample	13	SH 60829 75785
MS23	94	13/11/2013 14:16	Sea water sample	2	SH 59643 74603
MS24	95	13/11/2013 14:23	Sea water sample	4	SH 58135 73776
MS25	96	13/11/2013 14:30	Sea water sample	6	SH 56587 72489

Figure XIII.5

Figure XIII.6

Figure XIII.7

Figure XIII.8

Figure XIII.9

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Figure XIII.12

Figure XIII.13

Figure XIII.14

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Figure XIII.58

Figure XIII.59

Figure XIII.60

Figure XIII.61

Figure XIII.62

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List of Abbreviations

AONB	Area of Outstanding Natural Beauty
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
IFCA	Inshore Fisheries and Conservation Authority
ISO	International Organization for Standardization
km	Kilometre
LEA (LFA)	Local Enforcement Authority formerly Local Food Authority
M	Million
m	Metres
ml	Millilitres
mm	Millimetres
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MPN	Most Probable Number
NM	Nautical Miles
NRA	National Rivers Authority
NWSFC	North Western Sea Fisheries Committee
OSGB36	Ordnance Survey Great Britain 1936
mtDNA	Mitochondrial DNA
PS	Pumping Station
RMP	Representative Monitoring Point
SAC	Special Area of Conservation
SHS	Cefas Shellfish Hygiene System, integrated database and mapping application
SSSI	Site of Special Scientific Interest
STW	Sewage Treatment Works
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 seven consecutive days without rain following seven days during which rainfall did not exceed 0.25 mm 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.
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 Nth 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 skewed data such as those 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 dataset, 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.
Telemetry	A means of collecting information by unmanned monitoring stations (often rainfall or river flows) using a computer that is connected to the public telephone system.
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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