Centre for Environment Fisheries & Aquaculture Science

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EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Menai Strait West

December 2013

Food Standards Agency

Cover photo: South Western entrance to the strait

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Statement of use

This report provides a sanitary survey relevant to bivalve mollusc beds within Menai Strait West, 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	12/12/2013
2	Draft for client/consultee comment	Simon Kershaw	12/12/2014
3	Final	Simon Kershaw	07/05/2014

Consultation

Consultee	Date of consultation	Date of response
Gwynedd CC	31/12/2014	14/02/2014
Ynys Mon CC	31/12/2014	27/02/2014
Natural Resources Wales/Cyfoeth Naturiol Cymru	31/12/2014	03/02/2014
Welsh Government Fisheries	31/12/2014	14/02/2014
Welsh Water/Dwr Cymru	31/12/2014	-
Bangor Mussel Producers Association	31/12/2014	-

Dissemination

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

Recommended Bibliographic Reference

Cefas, 2013. Sanitary survey of Menai Strait West. 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 Pacific oysters (*Crassostrea gigas*), mussels (*Mytilus* spp.) and cockles (*Cerastoderma edule*) in the Western 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 the western half of this water body, from Britannia Bridge through to Fort Belan, an area of about 19 km^2. The strong tidal streams and the net south-westerly flow of water through it (Simpson et al., 2007) mean that sources of contamination from the eastern part of the strait will also require consideration.

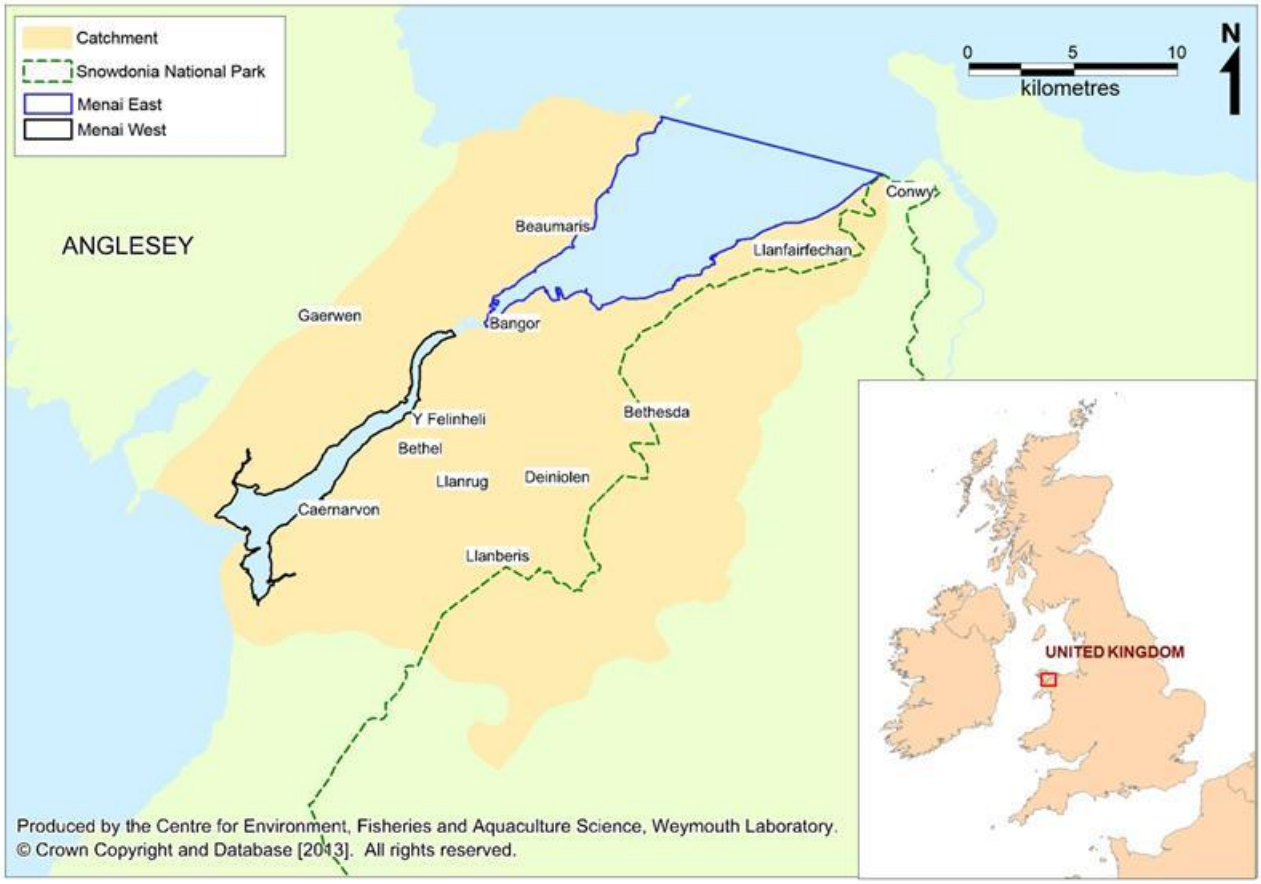


Figure 1.1: Location of the Menai Strait

The western strait lies between the south-western mouth of the strait and 'The Swellies', a constricted relatively shallow area in the middle of the strait which experiences particularly strong tidal flows. Inside the south-western entrance the strait widens significantly, and there are extensive intertidal sandbanks and flats. The intertidal areas become progressively less extensive 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 which in turn attract a variety of wildlife. 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 western strait supports a fishery for cockles on the intertidal sands, and culture fisheries for both mussels and Pacific oysters.

1.3. Catchment

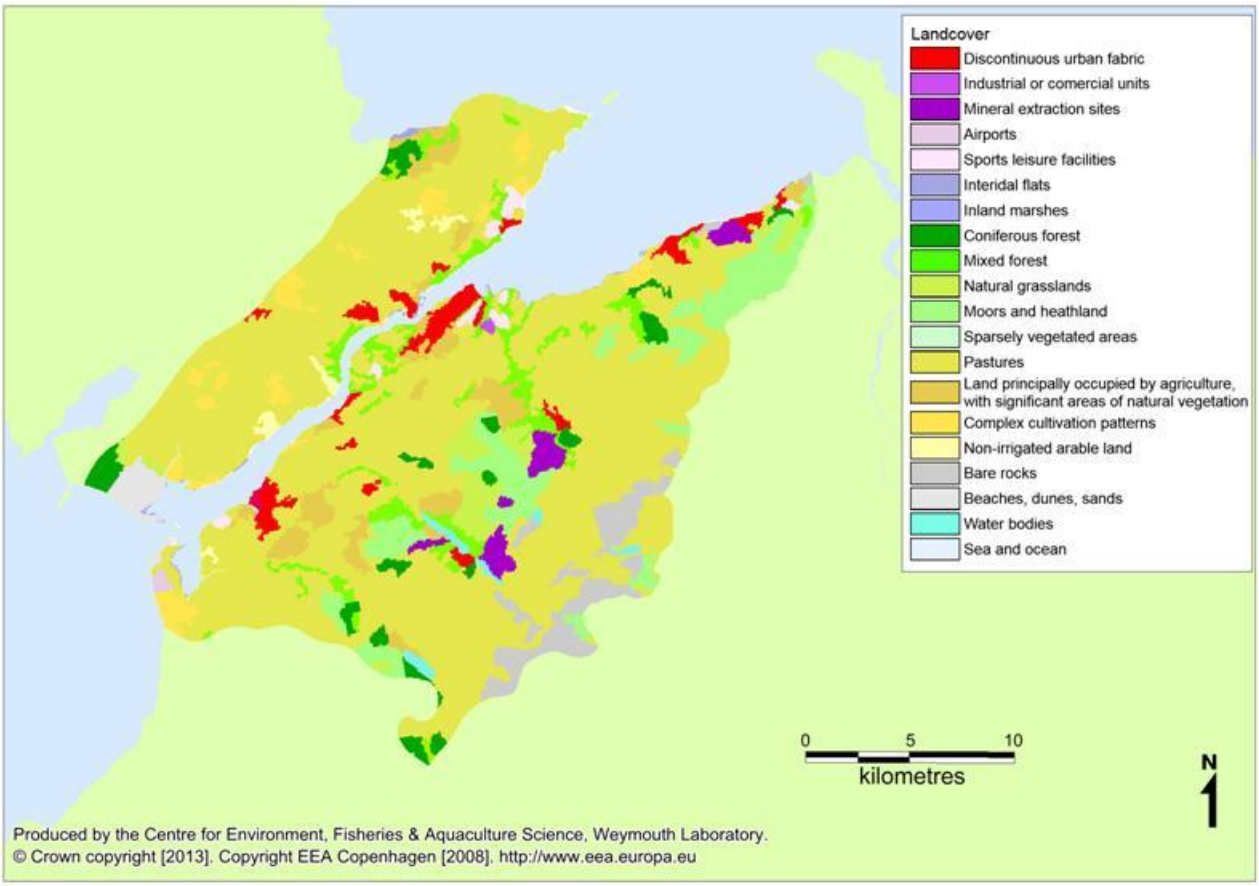


Figure 1.2: Landcover in the Menai Strait catchment area

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 urbanised pockets, which generally lie adjacent to the shore, and some natural areas (forests and moorlands). There are also a few small areas where crops are cultivated. 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 follows 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 in some cases. Any adjustments should be communicated by the LEA to the classification team at Cefas.

2.1. Mussels

The following five zones are proposed for mussels, only two of which are currently active.

Areas 1-3

This zone includes two distinct areas where mussels are cultured (Area 1 and Area 2/3). Currently there is activity in Area 2/3, so the zone will require continued monthly monitoring to maintain a classification. There are two minor watercourses discharging to the foreshore in Area 2/3, but these are not anticipated to be of major impact. Area 1 lies in relatively close proximity to the Braint estuary channel, but the ebb plume from this would generally be carried away from the mussel plot. Brynsiencyn STW discharges about 750 m from the eastern end of Area 2/3 and is likely to generate the most significant bacterial loading in this general area. Its plume will be carried across the plot as the tide ebbs, although will be subject to dilution on the way. It is therefore recommended that the RMP is established at the eastern end of this zone to best capture this. A deployment bag established on the easternmost oyster trestle here may represent a practical option.

Area 4

This zone includes one mussel plot (Area 4) which is not currently active. It is therefore appropriate to temporarily declassify this zone by reducing the sampling frequency to quarterly, until such time that reclassification is required, when monthly sampling should resume. There is a small private discharge to the centre of the plot, but it is only consented to discharge 1.2 m^3/day. There is a much larger discharge just to the east of this plot from a caravan park of up to 194.2 m^3/day, but this effluent is UV treated so should be of minor/negligible impacts assuming it is functioning correctly. The Brynsiencyn STW discharges about 750 m to the west of this plot, and the plume from this would be carried directly across the plot during the flood tide. It is therefore recommended that the RMP is located at the western end

of the zone to capture the impacts of the Brynsiencyn STW discharge. Ideally, a few water samples should be taken from the caravan park discharge to confirm the UV treatment is effective.

Sports Centre

This zone has been tentatively identified as a candidate area for establishing a mussel plot. As such a sampling plan is provided but it will only need classifying if and when a formal request for classification is made. To the west of the zone there is a cluster of private discharges some of which have sewage content. There is a small stream just to the west of this zone which receives two of these and may cause a localised hotspot of contamination. To the east of this zone is a small watercourse which receives a private sewage discharge (up to 5 m^3/day) from a nursing home which may also have some localised impacts. In the middle of the zone there are two discharges from a sports centre, one of which is a sewage discharge of up to 26m^3/day. It is therefore recommended that the RMP is located at the end of this discharge pipe, which is likely to represent the most significant hotspot within this zone.

Llanfairisgaer

This zone contains one mussel plot which is currently active and so will require continued monthly monitoring. Sources of contamination include a small stream at the eastern end of this plot, and a cluster of private discharges of various types from an industrial unit on the adjacent shore. Of these the most significant is probably the combined input of a small stream which receives two private discharges, one of which is a sewage discharge with a consented flow of up to 10 m^3/day. It is therefore recommended that the RMP is located at the eastern end of this plot, as close as possible to the drainage channel this stream cuts across the intertidal.

Fort Belan

This zone contains a site on which mussels have been grown from seed on a trestle site within a small embayment. This operation is not currently active, but may be reseeded in summer 2014. As such the zone may be temporarily declassified for the time being by reducing the sampling frequency to quarterly until a request for reclassification is received, after which monthly sampling should resume. There is little in the way of sources of contamination discharging directly to this zone. There is a small dock at the fort, and a few yacht moorings just off it. The adjacent Foryd Bay receives significant sewage and riverine inputs, so a plume of more contaminated water is likely to emanate from this while the tide ebbs. This would generally be carried in a westerly direction and so may impact on this site. The same applies to the ebb plume from the Seiont estuary, although this is further away.

It is therefore recommended that the RMP be located on the north easterly corner of the trestle site to best capture any such plume.

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 should be via hand, and so a tolerance of 10 m applies. 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. Pacific oysters

The following three zones are proposed for Pacific oysters, of which two are currently active.

Area 2/3

This zone includes a large oyster trestle farm which is currently active, so will require continued year round monthly monitoring. As discussed above (mussel Areas1-3) the most significant local contaminating influence is the Brynsiencyn STW about 750m to the east, so the RMP should be established on the easternmost trestle on this site, in the same location as the mussel RMP.

Salt Water Aquatics

This zone contains a significant Pacific oyster trestle farm which is currently active and so will require continued monthly monitoring. Sources of contamination include a small stream to the east of the trestle site, and a cluster of private discharges of various types from an industrial unit on the adjacent shore, most of which lie to the east of the trestle site. Of these the most significant is probably the combined input of a small stream which receives two private discharges, one of which is a sewage discharge with a consented flow of up to 10 m^3/day. It is therefore recommended that the RMP be established at the eastern end of the trestles to best capture the combined impacts of these various private discharges.

Fort Belan

This zone contains a site on which mussels have been grown from seed on a trestle site within a small embayment. The site operators have expressed an interest in culturing Pacific oysters here at some point in the future. A sampling plan is therefore provided, but will only require implementation on request. If and when a

fishery is established, year round monthly monitoring will be required to maintain a year round classification. As discussed above (Fort Belan mussels) the RMP should be located at the north eastern corner of the trestle site to best capture any plumes emanating from the two significant estuaries to the east.

Sampling requirements

The species sampled should be Pacific oysters of a market size. Sampling should be on a monthly and year round basis. Sampling should be via hand. A tolerance of 10 m applies.

2.3. Cockles

Only one zone is required to cover the cockle bed at Traeth Melynog. The vast majority of contamination will arrive in this zone via the river Braint, and this includes the treated effluent from Newborough STW as well as frequent storm overflow discharges from this works. As such, the RMP should be located immediately adjacent to this channel, and as far up it as stocks extend, although whether they extend to the upstream boundary of the zone is uncertain. Its location may therefore require adjustment, both initially and periodically to reflect the extent of stocks. At present there is a closed season for cockles (May to August). 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). 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. A tolerance of 50 m should allow for repeated sampling from the RMP.

3. Sampling Plan

3.1. General Information

Location Reference

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

Shellfishery

Species/culture	Mussels	Cultured
	Pacific oysters	Cultured
	Cockles	Wild
Seasonality of harvest	There is currently a closed season for cockles (May to August). 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).	

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	Gwennan Owen
Telephone number ☎	01341 424472
Fax number 🖷	01341 423984
E-mail 📧	gwennanowen@gwynedd.gov.uk
Name	Ynys Mon County Council Environmental Services Ynys Mon - Isle of Anglesey County Council Environmental Health Department Council Offices LLANGEFNI Anglesey LL77 7TW
Environmental Health Officer	Keith Rowlands
Telephone number ☎	01248 752827
Fax number 🖷	01248 752880
E-mail 📧	rkrpp@anglesey.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 West

Classification zone	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Areas 1-3	BO42L[1]	Barras Boat House	SH 4871 6570	53°10.011 'N 04°15.878'W	Mussels	Bed culture	Hand or dredge	Hand (deployment bag on trestle)	10 m	Monthly	Area currently active for this species
Area 4	BO42M[1]	Llanidan	SH 4992 6675	53°10.598'N 04°14.823'W	Mussels	Bed culture	Hand or dredge	Hand	10 m	Quarterly / monthly	Area not currently active so may be temporarily declassified and sampled quarterly until reclassification is requested. Eastern end not currently classified.
Sports Centre	BO42N[2]	Sports Centre	SH 5027 6620	53°10.307'N 04°14.493'W	Mussels	Bed culture	Hand or dredge	Hand	10 m	Monthly	Area may possibly be used in the future. Only requires sampling and classification on request.
Llanfairisgaer	BO42O[2]	Area 11 East	SH 4991 6579	53°10.080'N 04°14.804'W	Mussels	Bed culture	Hand or dredge	Hand	10 m	Monthly	Area currently active for this species
Fort Belan	BO42P[2]	Fort Belan	SH 4451 6084	53°07.320'N 04°19.503'W	Mussels	Trestle culture	Hand	Hand	10 m	Quarterly / monthly	Area not currently active so may be temporarily declassified and sampled quarterly until reclassification is requested

Classification zone	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Areas 2/3	BO42Q[1]	Barras Boat House	SH 4871 6570	53°10.011 'N 04°15.878'W	Pacific oysters	Trestle culture	Hand	Hand	10 m	Monthly	Area currently active for this species
Salt Water Aquatics	BO42R[2]	Area 11	SH 4969 6565	53°10.001'N 04°14.998'W	Pacific oysters	Trestle culture	Hand	Hand	10 m	Monthly	Area currently active for this species
Fort Belan	BO42S[2]	Fort Belan	SH 4451 6084	53°07.320'N 04°19.503'W	Pacific oysters	Trestle culture	Hand	Hand	10 m	Monthly	Area may possibly be used in the future for this species. Only requires sampling and classification on request.
Traeth Melynog	BO42T[1]	Braint Channel	SH 4383 6372	53°08.860'N 04°20.196'W	Cockles	Wild	Hand	Hand	50 m	Monthly	Inshore part of this bed not currently classified. Samples should be taken as close to the river channel and as far upstream as possible, although it is recognised that stocks do not usually extend to the upstream boundary of this zone.

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

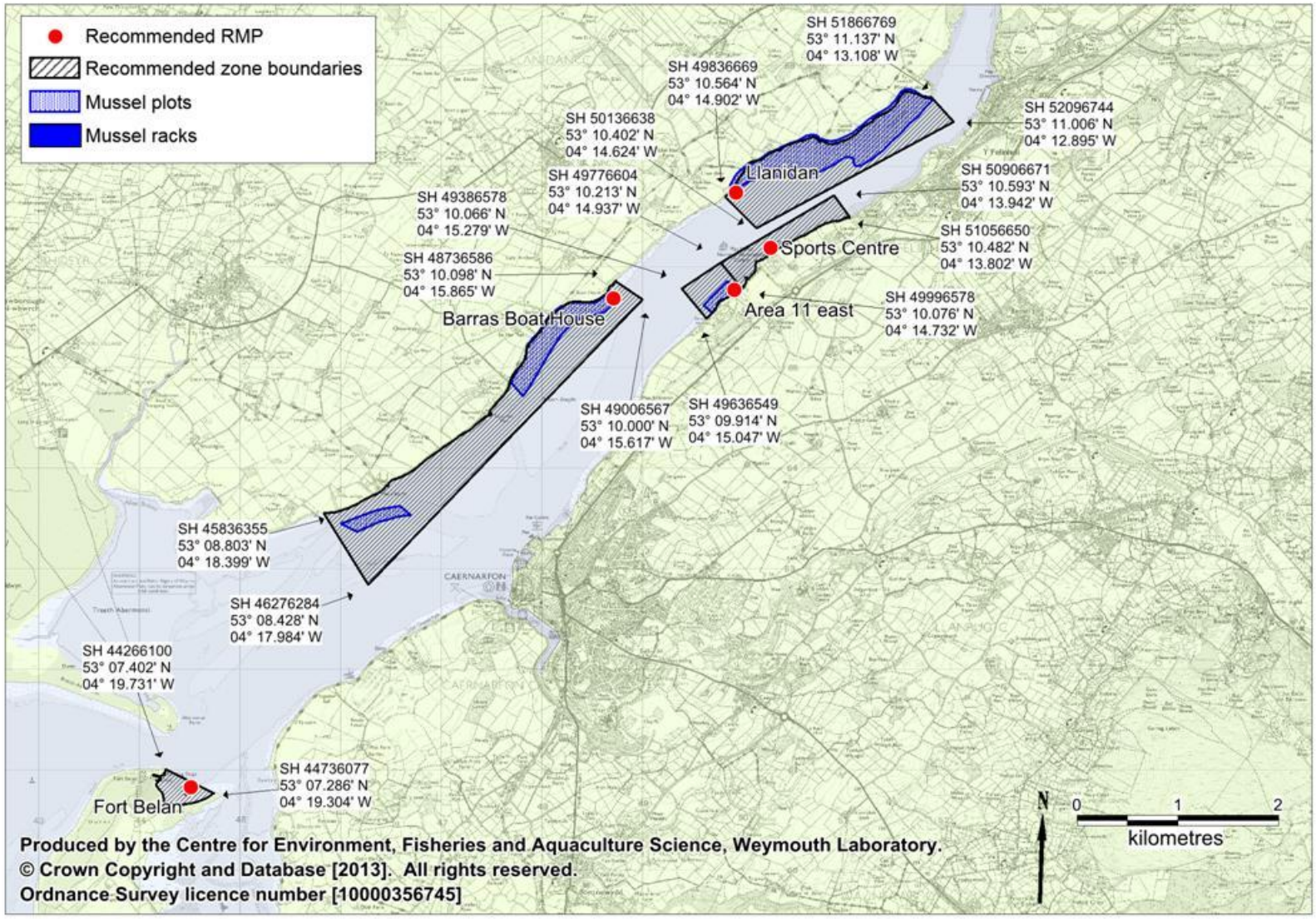


Figure 3.1: Recommended zoning and monitoring arrangements (mussels)

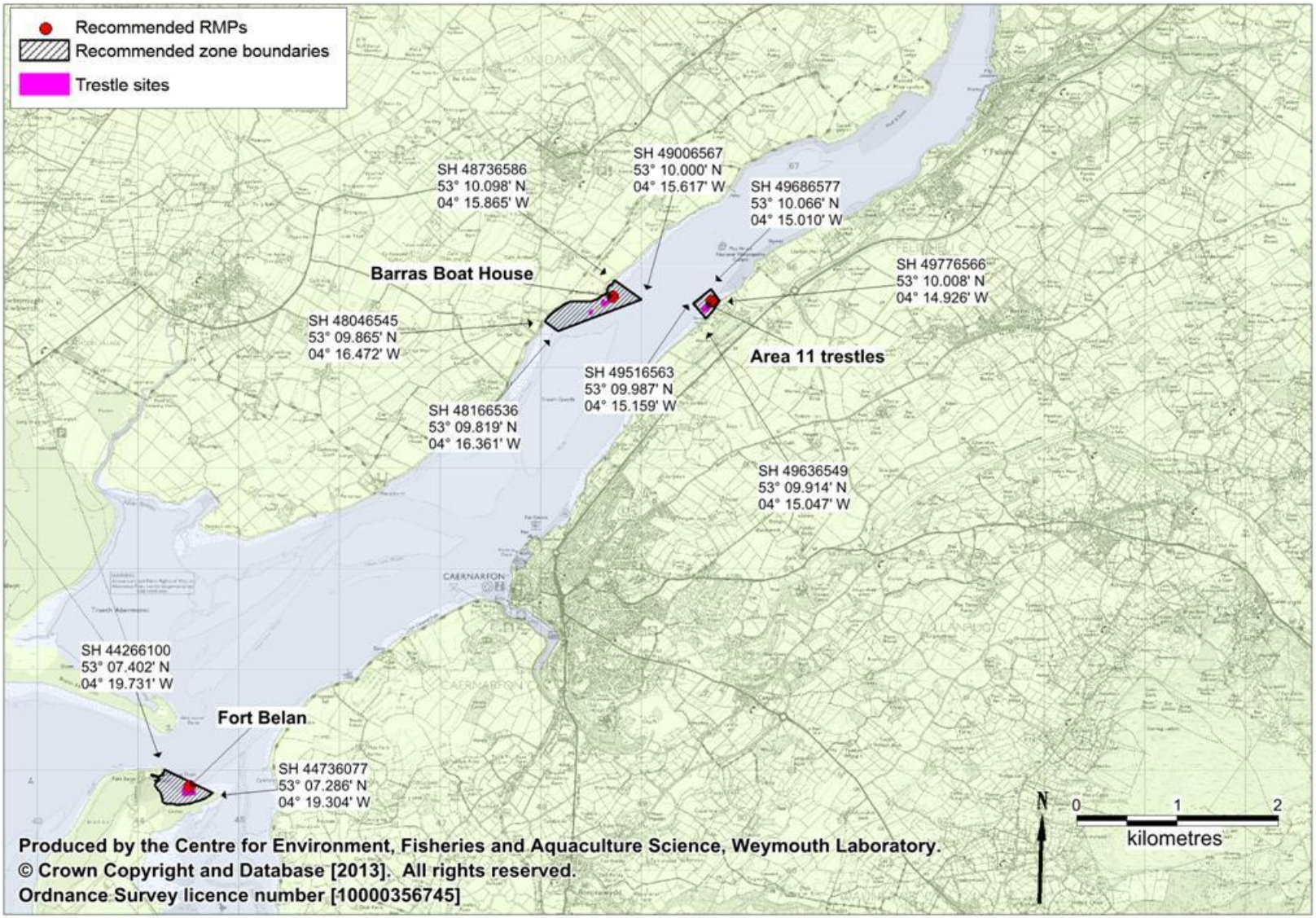


Figure 3.2: Recommended zoning and monitoring arrangements (Pacific oysters)

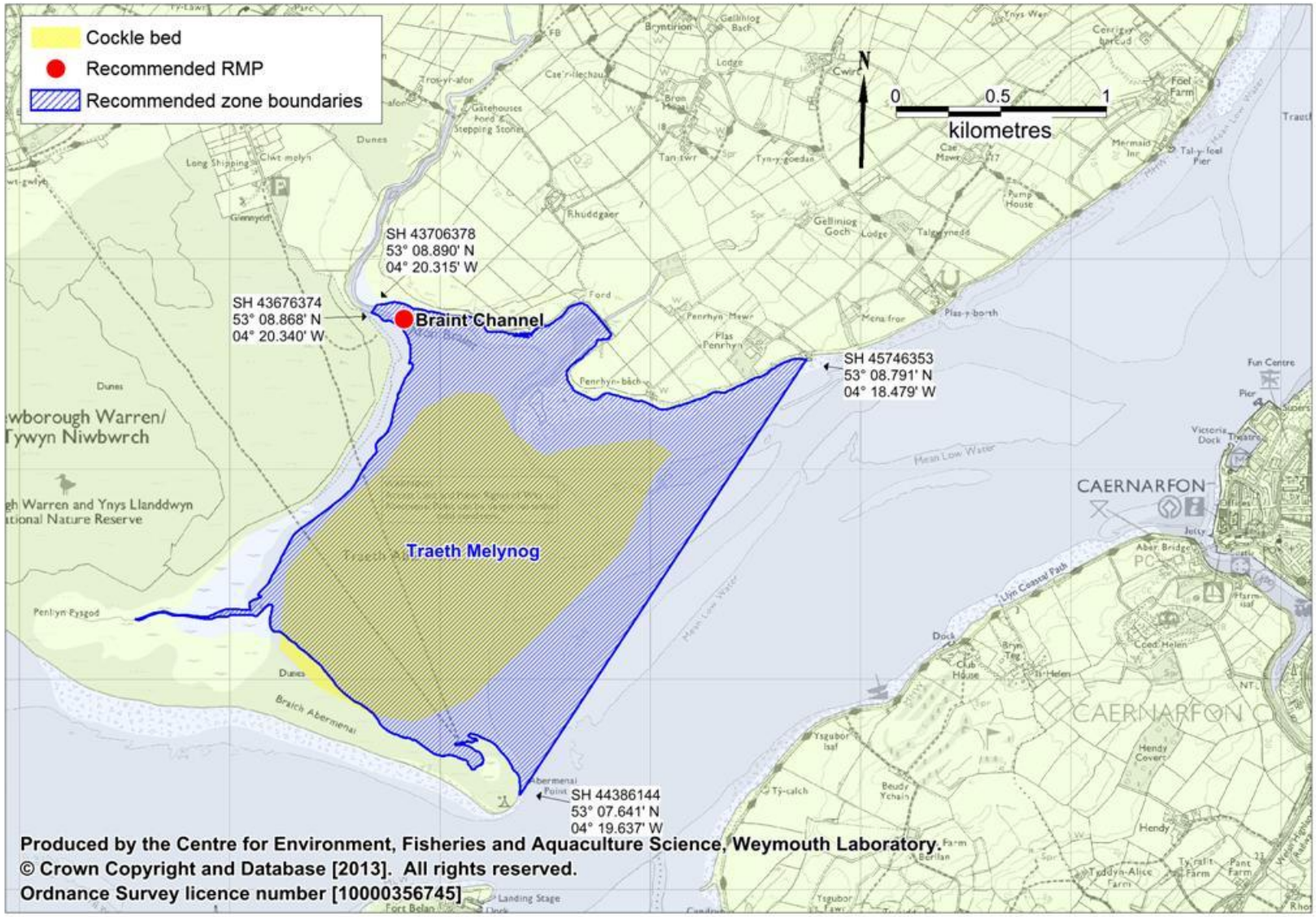


Figure 3.3: Recommended zoning and monitoring arrangements (cockles)

4. Shellfisheries

4.1. Description of fisheries

Species harvested from the western Menai Strait include mussels, Pacific oysters, and cockles.

Mussels

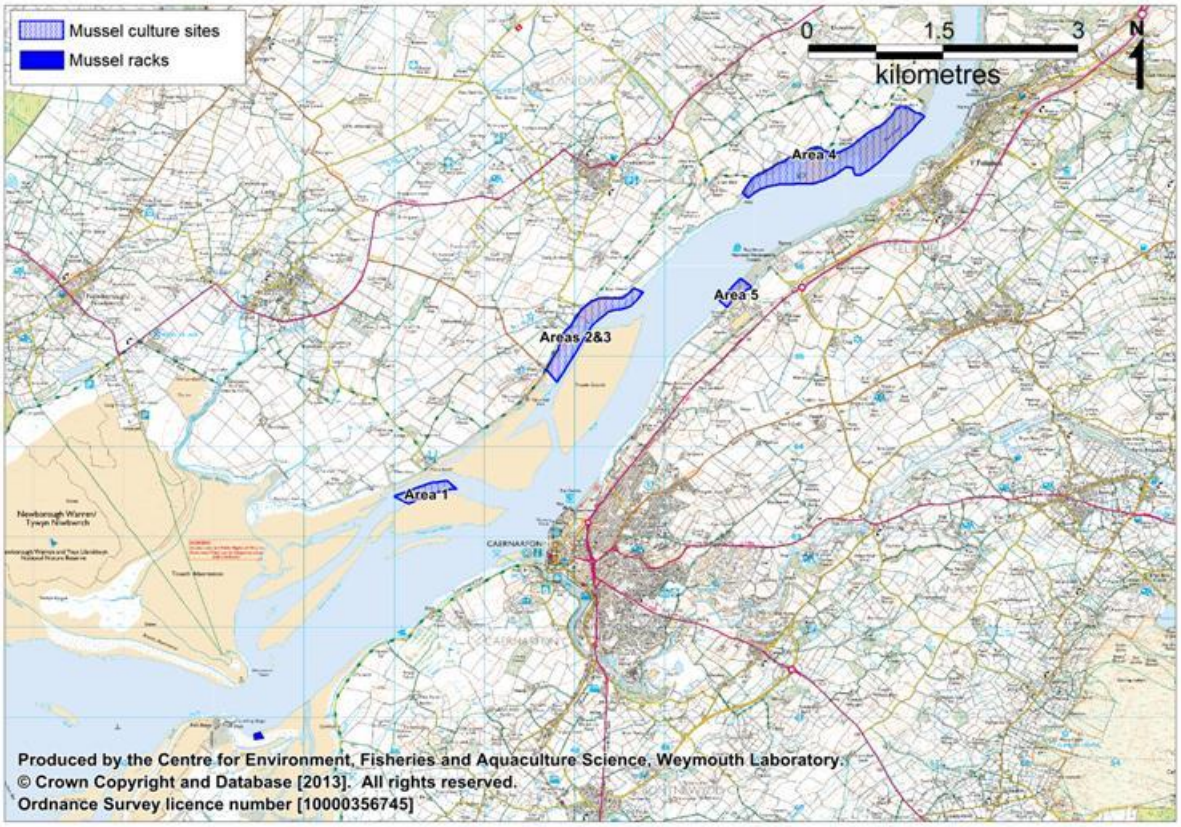


Figure 4.1: Mussel culture sites

There are four discrete areas in which mussels are cultured by various members of the Bangor Mussel Producers Association. These fell within the Menai Strait (West) Fishery Order 1978, which expired in 2008. The renewal of this order is currently being negotiated, and it is expected that a new order lasting up to 28 years will be signed off early in 2014, subject to the resolution of a minor legal issue (Welsh Government Fisheries, pers. comm.). The grantee will be the Menai Strait Fishery Order Management Association, who are also grantees of the Fishery Order in the eastern strait. During the interim period since the expiry of the previous fishery order, activity has continued on some of these plots (Areas 2/3 and Area 5). Activity will resume on the others once the fishery order has been re-established. There

may also be plans to develop a new plot off Llanfair, on the mainland shore just to the east of Area 5.

As there is little natural mussel settlement within the western 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. Harvest may be via hand or dredge.

There is an independent mussel operation at Fort Belan, where mussels have been cultivated from natural seed on racks. This site is not currently active, and there is little stock at present. The site operators intend to restock the site with seed mussels in the summer (Bluewater Shellfish, pers. comm.).

Although historical records held at Cefas indicate that there have been natural settlements of mussels at two locations on the outskirts of Traeth Melynog, Welsh Government Fisheries advise that there are no mussels present there nor any commercial interest.

Pacific oysters

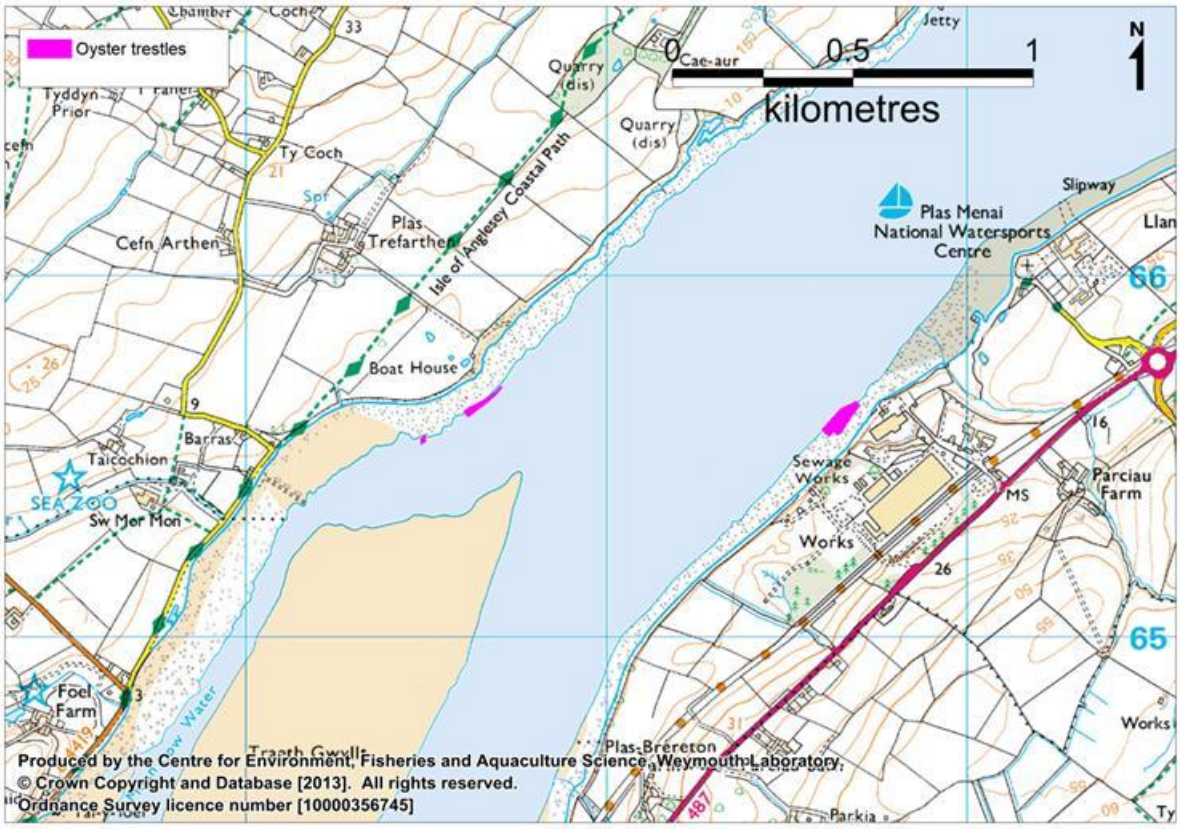


Figure 4.2: Pacific oyster culture sites

Pacific oysters are cultured over two trestle sites which lie opposite one another. They are raised from hatchery seed and raised to market size, a process which takes 2-3 years. Harvest is via hand, and the growers have their own depuration facilities. Pacific oysters are not subject to a minimum landing size, and harvest may occur at any time of the year. Bluewater Shellfish plan to culture Pacific oysters on their mussel site at Fort Belan at some point in the future, although a timescale for this is yet to be decided.

Cockles

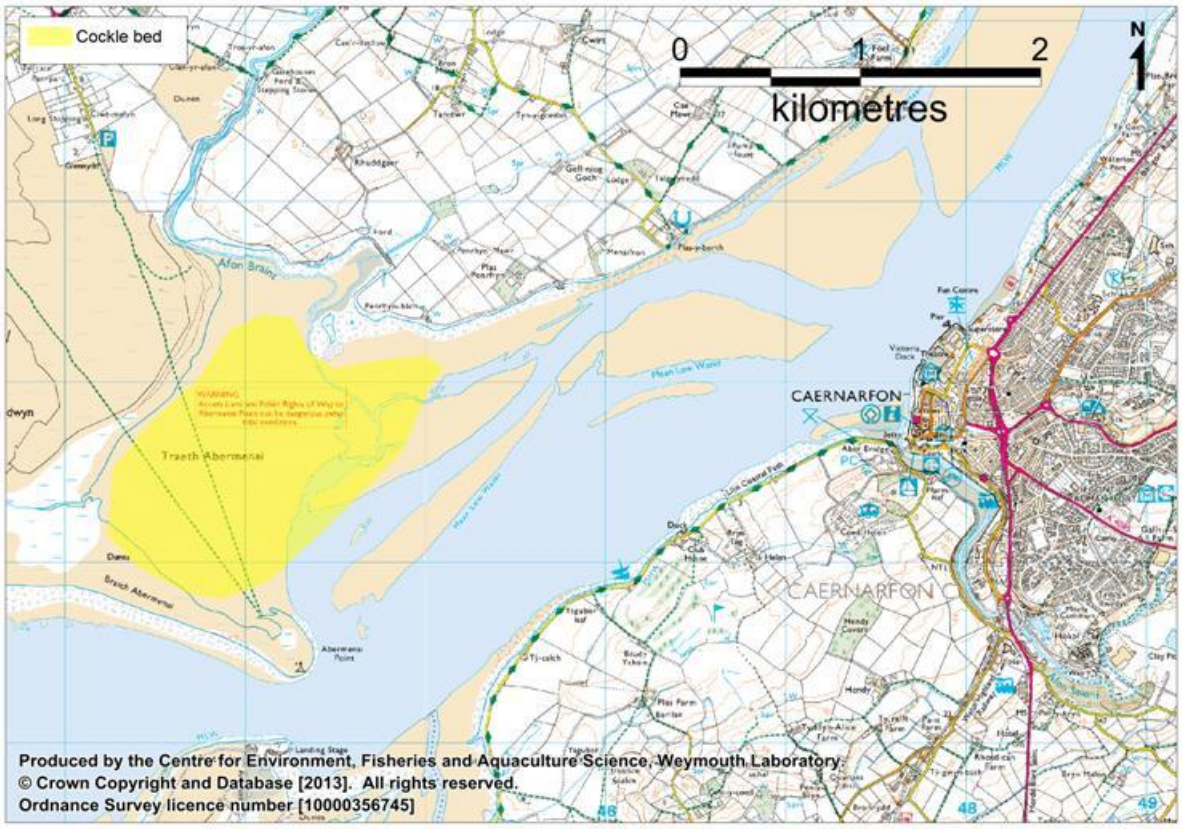


Figure 4.3: Harvestable cockle concentrations

There is a significant cockle bed on the Traeth Melynog sands on the Anglesey 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 that no cockles which can pass through a 20 mm square aperture may be taken, and there is a closed season which runs from May to August inclusive. Welsh Government Fisheries may close any shellfish beds for reasons of stock preservation. The management of cockle fisheries in Wales is currently under review (Welsh Government, 2013). 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). The cockle bed at Traeth Melynog was opened in September 2013 and remains open at the time of writing.

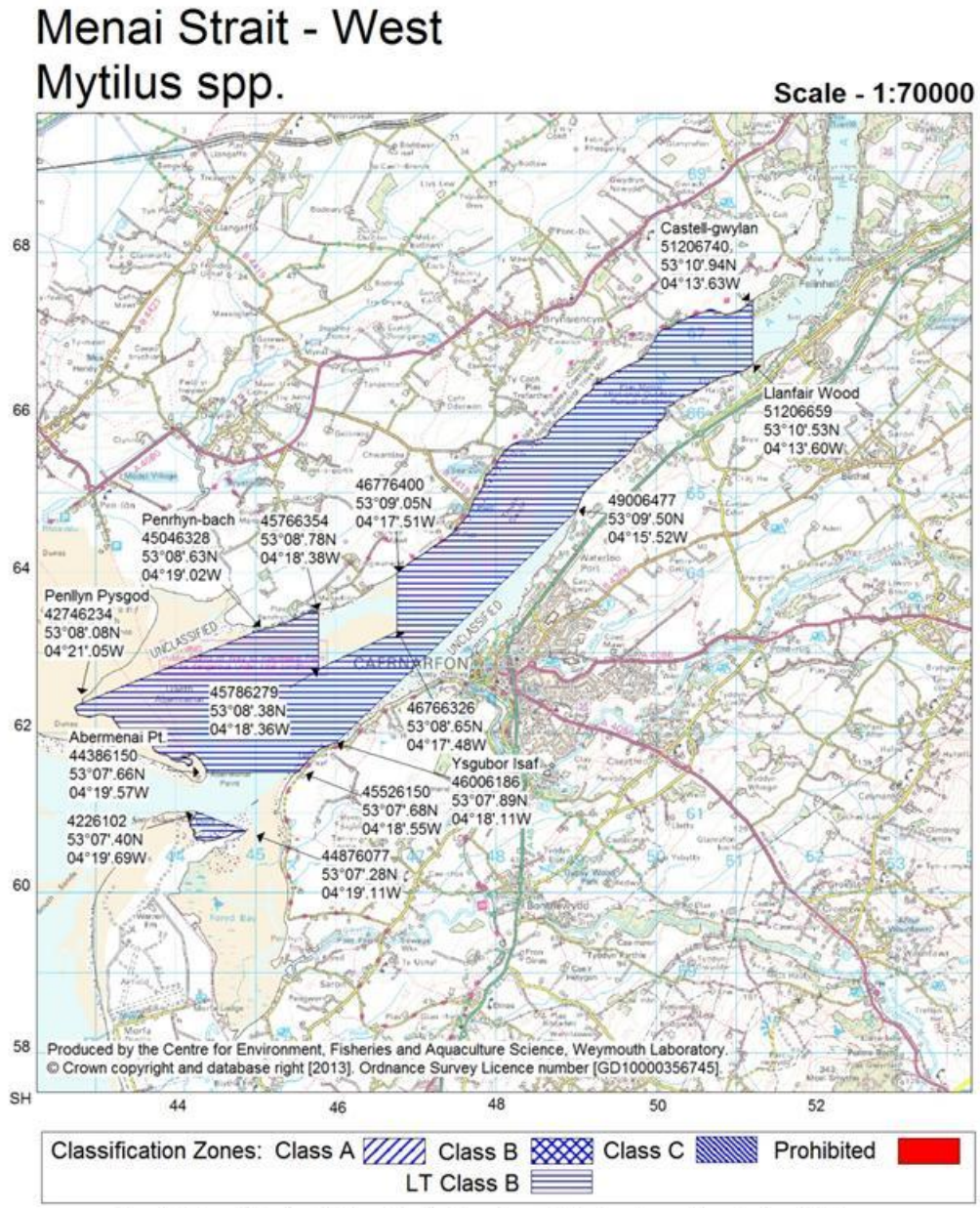
4.2. Hygiene Classification

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

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

Area	Species	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Abermenai	Mussels	B	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Traeth Melynog	Cockles	B	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Llanidan	Mussels	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	-
Llanfairsgaer	Mussels	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Barras	Mussels	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Barras	*C. gigas*	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Area 11	*C. gigas*	-	-	-	B	B	B	B	B	B	B
Fort Belan	Mussels	-	-	-	B	B	B	B-LT	B-LT	B-LT	B-LT
Plas y Borth	Mussels	-	-	-	B	B	B	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 maps available for C. edule and C. gigas at the Menai Strait - West

Food Authorities: Ynys Mon - Isle of Anglesey County Council - Northside
Gwynedd County Council - Southside

Figure 4.4: Current mussel classifications

The mussel plot off Plas y Borth is not currently classified, and the classification does not cover the western end of the innermost mussel plot.

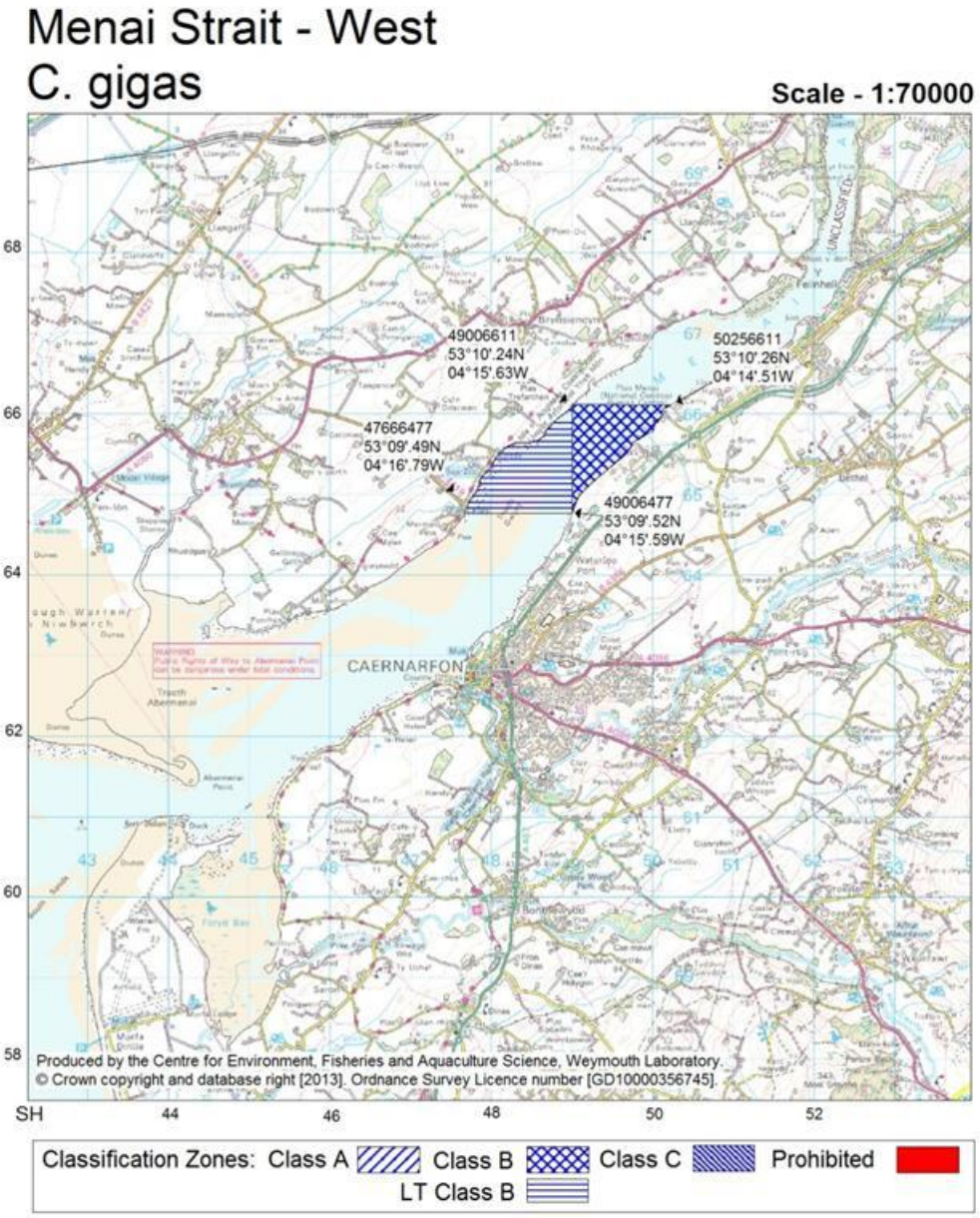
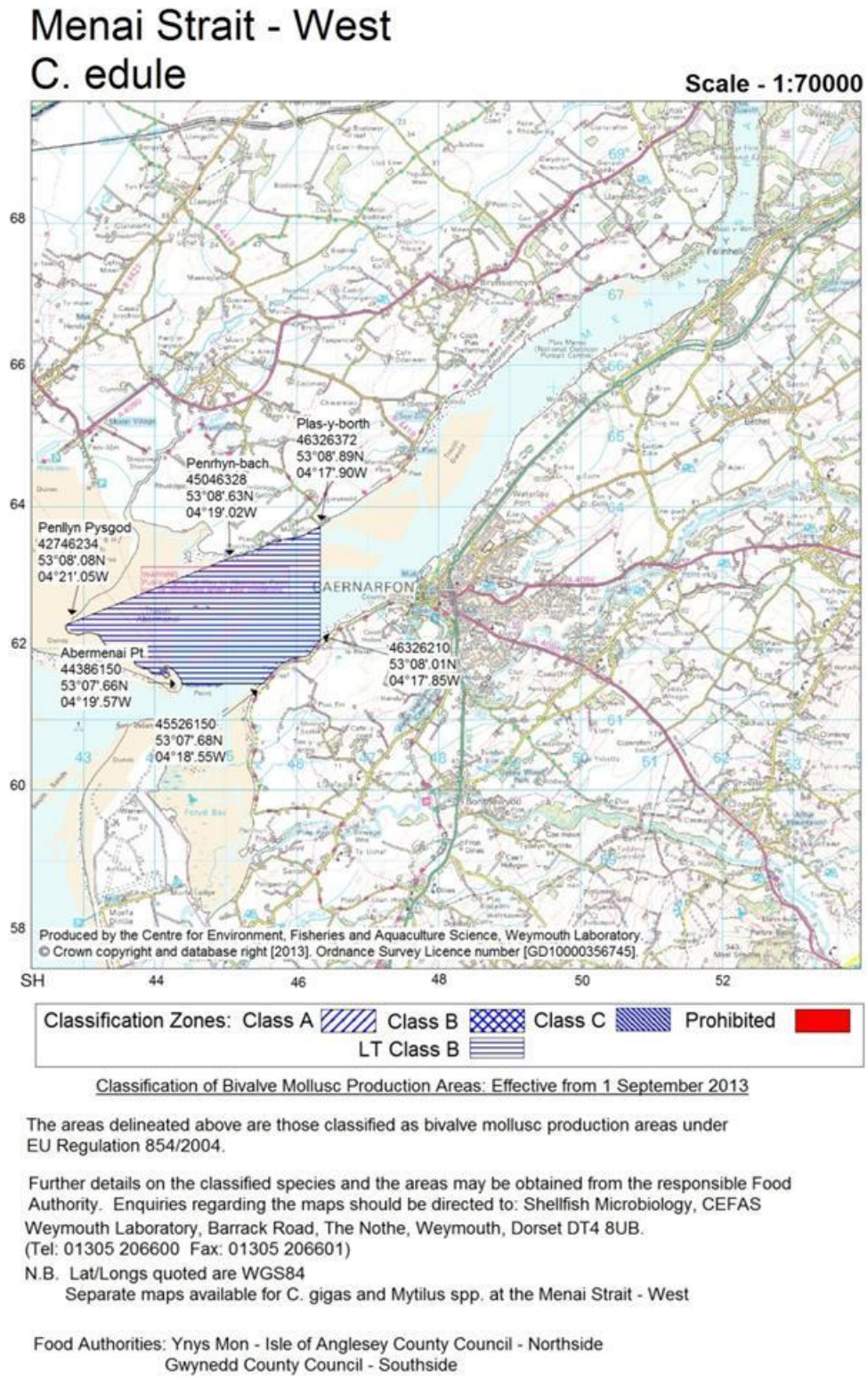


Figure 4.5: Current Pacific oyster classifications

Both Pacific oyster trestle sites are currently classified, although the classification covers a much larger area than is actually required. A sampling plan will also be required for Fort Belan, where there are plans to culture Pacific oysters in the future.



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

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N.B. Lat/Longs quoted are WGS84
Separate maps available for C. gigas and Mytilus spp. at the Menai Strait - West

Food Authorities: Ynys Mon - Isle of Anglesey County Council - Northside
Gwynedd County Council - Southside

Figure 4.6: Current cockle classifications

The classification zone at Traeth Melynog does not quite cover the entire cockle bed so will require extension further into the bay. The classification does not need to extend over to the mainland side of the strait.

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 western strait are mussels, Pacific oysters and cockles.

The production of mussels occurs or will occur in four discrete areas. Wild seed mussels sourced from outside of the strait are laid on these plots, and harvested about 3 years later. These plots formerly fell under a fishery order, which expired in 2008, and is likely to be renewed early in 2014. Two of the four discrete areas are currently active, and the other two will resume operations once the fishery order is re-established, so the LEA may wish to consider reducing sampling frequency at the latter two (Area 1 and Area 4) to quarterly and temporarily declassifying this site until commercial harvesting is resumed. The classified area will require extending westwards so the whole of the mussel plot opposite Y Felinheli is included. There is also a further, independent site at Fort Belan where mussels were cultured on trestles. Currently this site is not active, but the site operators intend to restock with some seed mussels in summer 2014. The site is temporarily declassified for the time being. Harvesting of mussels may be by hand or dredge, and no closed season applies. A minimum landing size of 45 mm applies to mussel harvesting in the district, although this does not apply to culture fisheries within a fishery order area.

There are currently two discrete sites where Pacific oysters are cultured on trestles. Both of these require continued year round classification. There are also plans to establish Pacific oyster cultivation at the mussel trestle site at Fort Belan as these are likely to offer a better return than the mussels. Seed oysters have not yet been laid at Fort Belan and the timescales for this are uncertain. A sampling plan will be provided but will only require implementation if and when a commercial scale fishery is developed.

There is a commercially active cockle bed at Traeth Melynog which requires continued classification. This 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 only animals which do not pass through a 20 mm square aperture may be removed. These regulations are under review, and of relevance to the sampling plan, the requirement for a closed season is under consideration. As such, a year round classification will be required.

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 main watercourse draining to the Anglesey side of the western strait is the Braint, which follows a valley that runs parallel to the western strait, and discharges to the head of the bay in which the Traeth Melynog cockle bed is located. A sample taken from it during the shoreline survey contained relatively high levels of *E. coli* (3900 cfu/100ml) but it was too large to safely take measurements to calculate the flow rate of the watercourse. There are a few other much smaller watercourses draining the coastal strip, the largest of which is also called the Braint and discharges just west of Britannia Bridge. This was carrying a relatively low *E. coli* concentration (210 cfu/100ml) at the time of shoreline survey, and was generating a bacterial loading of $1.2x10^{11}$ *E. coli*/day. There is also a small watercourse which discharges to the centre of one of the mussel plots by the Sea Zoo. It contained low levels of *E. coli* and was small in terms of discharge volume, generating a bacterial loading of only $2.5x10^9$ *E coli*/day at the time of shoreline survey.

On the mainland side the two main rivers are the Seiont, which drains to an enclosed estuary at Caernarfon, and the Gwyrfai, which drains to Foryd Bay. Both are relatively steep gradient rivers, which extend up into the high rainfall area of Snowdonia. These rivers will therefore respond rapidly to rainfall, although they do flow through lakes in their upper reaches which will buffer flows to some extent.

Neither of these were sampled or measured during the shoreline survey but it can be assumed they both carry a significant bacterial loading into the strait. There are numerous other smaller watercourses discharging to the western strait which drain the lower lying coastal areas. There are several smaller watercourses discharging to Foryd Bay, but this area was not visited during the shoreline survey. The Cadnant discharges to the strait at Caernarfon, and is culverted in its lower reaches. This watercourse was not observed during the shoreline survey as it drains to the Victoria Dock, an enclosed marina. There is a watercourse which drains to the eastern end of the mussel/oyster plot at Area 5, which was carrying a bacterial loading of $3.18x10^{10}$ *E. coli*/day at the time of shoreline survey. The Nant Y Garth (also known as the Nant Heulin) is another watercourse of potential significance which drains to a gated marina at Y Felinheli. This was not observed during the shoreline survey due to its location.

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 on the peaks of Snowdonia during the colder months, but the snow does not lie all winter. 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 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, where the main settlement is Caernarfon, with a population of just over 9,500. The land adjacent to the western strait on the Anglesey side is 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, the main settlement on the eastern strait 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 four sewage works discharging to tidal waters of the western Menai Strait. 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. Both these discharges lie more than 3 km to the east of the nearest mussel plot.

The only sewage works discharging directly to a classified area is the Brynsiencyn STW which discharges to the north shore in the middle of a 1.5 km gap between a mussel and a mussel/oyster plot on the same shore. Treatment is via biodisc and then reed bed for a maximum consented flow of 665 m^3/day. The additional reedbed step is likely to provide a significant reduction in the bacterial concentrations, but without any final effluent testing results it is not possible to estimate the bacterial loading it generates.

The Newborough STW discharges to tidal waters of the Braint, which subsequently flow through a drainage channel cutting through the cockle bed at Traeth Melynog. It provides secondary treatment for a consented dry weather flow of 570 m^3/day, and so an estimate of the bacterial loading it generates is about $1.9x10^{12}$ faecal coliforms/day.

In addition to the discharges to coastal waters, there are a number of sewage works discharging to watercourses which will also contribute to levels of bacterial indicators within the western strait. There is only one of these on Anglesey (Llangaffo STW) which provides secondary treatment for a consented dry weather flow of 64 m^3/day. This minor works discharges to the Braint, so will add to the bacterial loading carried by this watercourse.

On the mainland, there are a number of small to midsized water company sewage works discharging to various watercourses. The Gwyrfai, which flows into Foryd Bay receives effluent from four water company treatment works, three of which provide secondary treatment (Llanfaglan, Waunfawr and Rhyd Ddu STWs) and one of which

provides septic tank treatment (Betws Garmon STW). The combined consented dry weather flow is about 1,700 m^3/day, not including one small works for which flow rates were unspecified (Rhyd Ddu STW). About three quarters of this originates from Llanfaglan STW, located about 1 km upstream of the tidal limit of the Gwyrfai.

The Seiont receives the effluent from nine water company sewage works, of which 8 provide secondary treatment and one is a septic tank. The flow rates were only specified for six, which have a combined consented dry weather flow of about 5600 m^3/day. The largest is Caernarfon STW which discharges about 50 m upstream of the tidal limit and is consented for a dry weather flow of 2840 m^3/day.

Finally, the Nant y Garth (or Nant Heulin) watercourse which discharges at Y Felinheli receives effluent from one small works (Seion No1 New STW) which is only consented to discharge a dry weather flow of 4 m^3/day.

It can therefore be concluded that the Seiont, Gwyrfai and Braint will carry significant quantities of faecal indicator bacteria from sewage discharges into the western strait. The two sewage discharges just west of Menai Bridge may have some influence, mainly towards the eastern end of the survey area. Brynsiencyn STW may be a significant influence on the shellfish plots which lie either side of it on the north bank, perhaps to the extent that its plume results in a noticeable gradient in levels of *E. coli* in shellfish across these plots.

There are over 100 permitted intermittent water company sewage discharges within the survey area. The main coastal clusters are at Caernarfon and Bangor. The four sewage works discharging to the western strait also have overflow discharges, and there are three intermittent discharges to the strait at Y Felinheli. Event monitoring is being installed on all nearby intermittent discharges, but at the time of writing limited spill records covering varying periods were available for only four of the intermittent discharges. More comprehensive information was available on modelled spill frequencies from the intermittent discharges within the coastal sewerage catchments, which identified the main spillers in the area. The two most active discharges in the Treborth catchment were Bethel WWTW overflow (predicted to spill for 24.3 % of the time) and the Treborth STW overflow (predicted to spill for 16.2% of the time). The overflow for Newborough STW was predicted to spill for 22.5 % of the time. In the Llanfaglan catchment, Llanfaglan WWTW was predicted to spill for 4.35 % of a year. Within the Caernarfon catchment, the biggest predicted spiller was Mill Lane CSO (3.59 % of the time). The impacts of the first three assets mentioned above are likely to be captured during a year's worth of monthly monitoring, assuming the RMP is correctly positioned. Assets spilling for only 5 % of the time are likely to be captured once every two years or so under a monthly monitoring regime.

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.

As well as the water company owned sewerage infrastructure, there are a number of private sewage discharges in the area. Those discharging to the western strait in the vicinity of the shellfisheries will be of most significance. The Plas Coch caravan park is consented to discharge up to 194.2 m^3/day of sewage effluent to the eastern edge of a mussel plot (Area 4). It provides UV disinfection so impacts should be very minor, assuming it is functioning correctly. There is also a small (1.2 m^3/day) package plant discharge to the foreshore in the centre of this plot.

There is a cluster of private discharges around Griffiths Crossing around the mussel and oyster plot (Area 5) on the mainland shore. Those carrying only trade or unspecified effluents may or may not have a bacteriological content. Those carrying sewage will likely be the most significant. As such, the inshore eastern corner of the mussel plot may lie in a hotspot derived from the sewage discharge from the meat processing plant, with a possible contribution from the unspecified industrial estate discharge. Should mussel cultivation expand towards Y Felinheli, the sewage discharge from the outdoor pursuit centre would assume the greatest significance by virtue of its higher discharge volume.

There is also a private discharge from the Anglesey Sea Zoo, which discharges to a watercourse about 100 m from where it drains into the centre of a mussel plot (Area 2/3). It is listed as an intermittent 'trade - unspecified' discharge permitted to discharge up to 20 m^3/day in the permit database.

In addition there are several smaller private discharges on the permit database, and Natural Resources Wales also advise that there are likely to be a significant number of unregistered private discharges.

Agriculture

The majority of land within the Menai Strait hydrological catchment is used for agriculture. Most are pastures, although there are a few smaller pockets where crops are cultivated, which are mainly 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 are two marinas in the Western Menai Strait, Victoria Dock and Port Dinorwic Marina, which together provide around 277 berths, and also numerous moorings in the Seiont estuary and just off the Port Dinorwic Marina. There is another area of moorings at Griffiths Crossing. Sewage pump out facilities are available at Victoria Dock but not Port Dinorwic. There are several moorings off Fort Belan, where there is also a small dock with approximately 10 berths. Three small fishing vessels are registered as operating out of Caernarfon. Although there are no commercial ports in the western Menai Strait, and passage through the Swellies is limited to a small tidal window, the occasional larger ship does navigate through the 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 western 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 in marinas have easy access to on shore facilities so may be less inclined to make overboard discharges.

The Seiont estuary, Griffiths Crossing, and the area off Y Felinheli may be most vulnerable on this basis. There may also be some lesser impacts within the small embayment at Fort Belan. 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.

Some dredging activity is proposed to maintain the Victoria Dock entrance at Caernarfon, and spoil is to be deposited in the strait outside the dock entrance. Whilst this may re-suspend faecal indicator bacteria and other sediment bound contaminants it will have no direct bearing on the sampling plan due to its occasional occurrence. It should however be given consideration if investigating the cause of unusually high *E. coli* monitoring results.

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 within the strait. 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 which is at Traeth Lavan in the eastern strait, where the average total count in recent years is just over 17,000 birds. Although no formal counts are undertaken in the western strait, this area does also attract significant numbers of wintering waterbirds. Foryd Bay for example supports peak counts of around 6,800, and large flocks of up to 500 birds were observed during the shoreline survey. 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 in the eastern strait, which supports around 6,000 individuals. There were no significant seabird colonies recorded in the western strait. These birds forage widely so are likely to have some influence on shellfish hygiene, but in the absence of any breeding colonies their impacts away from Puffin Island may be considered diffuse and as such will not influence the sampling plan.

Grey seals are a regular presence in the strait, but are most often seen in the vicinity of Puffin Island, and only in relatively small numbers (10-50). Their impacts are likely to be greatest where they haul out to rest, which typically occurs on islands and offshore sandbanks. No seal haulout sites have been identified in the western strait 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 Caernarfon. 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;

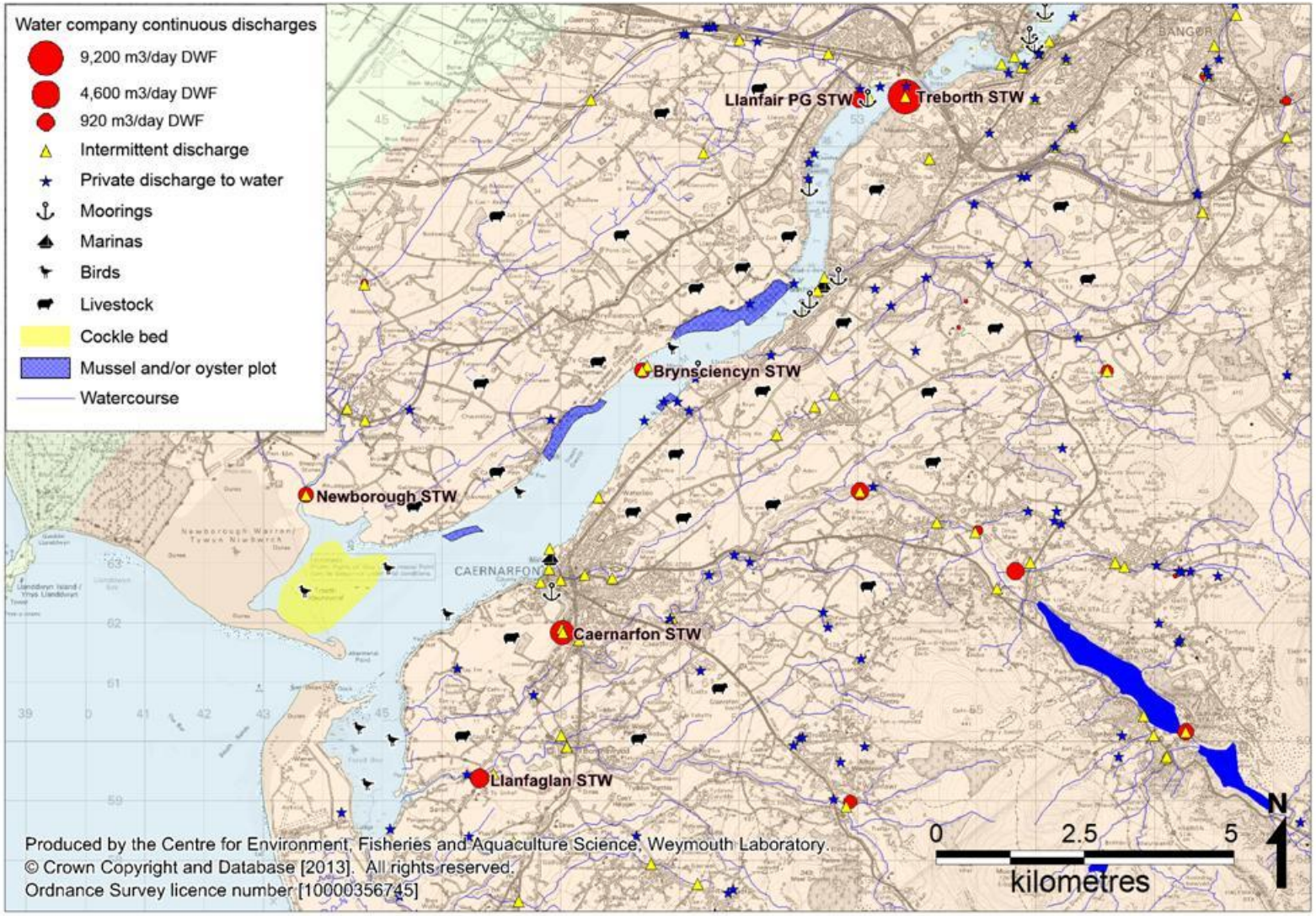

Figure 5.1: Summary of main contaminating influences

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. The eastern channel is about 7.5 km wide at its mouth, where there are extensive intertidal areas to the south of the subtidal channel. It becomes progressively narrower until The Swellies in the central reaches where it 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. This area represents a constriction where tidal flows accelerate and turbulent mixing occurs. The subtidal channel in the western strait varies in depth from about 1-20m relative to chart datum, and the intertidal areas gradually become more extensive towards its western end, and mainly lie on the Anglesey side. The western entrance is flanked by two sand spits, and this point represents another constriction where tidal flows accelerate and mixing of the water column will occur. Just inside the western entrance there are two sandy bays, one on each side of the strait, both of which form the estuaries of minor rivers and are largely intertidal. Meandering river channels cut through these bays and subsequently join the main Menai channel a short distance inside the entrance to the strait. A relatively small and enclosed river estuary (the Seiont) feeds into the southern shore of the strait just to the east of Caernarfon. Another watercourse (the Nant Y Garth or Nant Heulin) enters the southern shore of the western strait via a gated marina at Y Felinheli. All other watercourses discharging to the western strait flow directly into the intertidal areas. Channels cut across the intertidal by freshwater inputs are likely to contain relatively high concentrations of faecal indicator bacteria 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 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 enclosed estuaries and bays will fill during the flood tide, and empty during the ebb, so any plume of contamination emanating from them will generally be carried in a westerly direction.

Currents in the survey area are strongest at the western entrance and in The Swellies, where their velocities exceed 2.5 m/s on spring tides. They are slower in the subtidal channel away from these constrictions (1-2 m/s) and are likely to be slower still over intertidal areas such as Traeth Melynog. Estimates of tidal excursions within the strait are in the very approximate order of 20 km on spring

tides and 10 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, by about 7 km on average over the course of a full tidal cycle.

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. Given the enclosed nature of the strait strong wave action is not anticipated

Freshwater inputs may significantly influence circulation patterns in coastal waters via density effects. 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. 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 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.

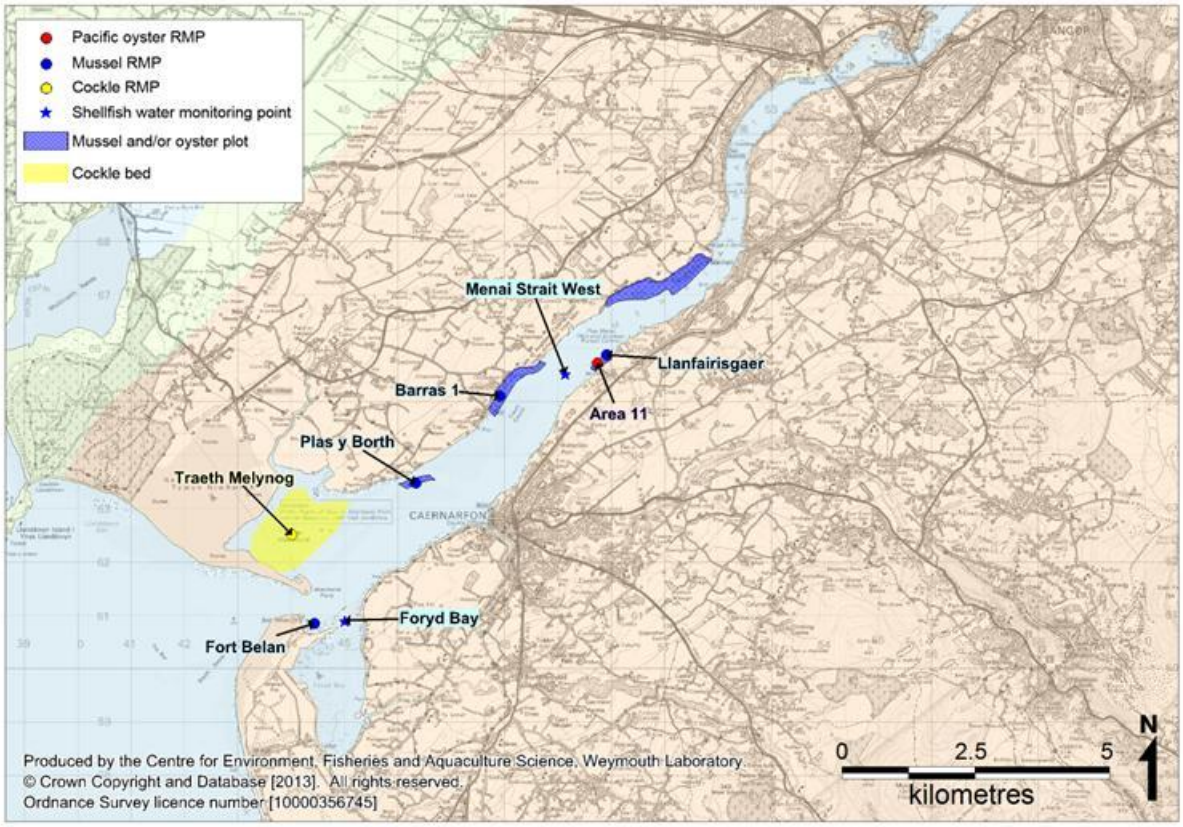

Figure 5.2: Microbiological sampling sites

Shellfish waters

There are two designated shellfish waters (Menai Strait West and Foryd Bay) within the survey area, where near surface water samples are taken on a quarterly basis and enumerated for faecal coliforms. The geometric mean result was significantly higher at Menai Strait West compared to Foryd Bay (17.4 and 6.5 faecal coliforms/100ml respectively). The results of paired (same day) samples were strongly correlated suggesting the two sites share similar sources of contamination.

Since 2003, faecal coliform levels have remained stable at Foryd Bay, but there appears to have been a slight increase on average at Menai Strait West. Significant influences of both the spring/neap and high/low tidal cycle were detected at Foryd Bay only, but no obvious pattern was apparent when the data was plotted. A statistically significant influence of rainfall was detected, and at both sites the strongest effect was following rainfall events four days prior to sampling. There were strong correlations between faecal coliform concentrations and salinity at both sites, suggesting that land runoff is a highly significant contaminating influence.

Shellfish hygiene

There are a total of six RMPs in the Menai Strait West production area that have been sampled between 2003 and 2013. Four of these RMPs are for mussels, one is for cockles and one is for pacific oysters.

Similar results were recorded across the four mussel RMPs, with geometric mean results ranging from 183 to 284 *E. coli* MPN/100g, and the proportion of results exceeding 4600 *E. coli* MPN/100g ranging from 0 to 2.7 %. There were no statistically significant differences detected between them. A comparison of paired (same day) sample results could be undertaken between Barras 1 and Plas y Borth only, and a significant correlation was found between them on a sample by sample basis. This suggests that these two RMPs are subject to similar contaminating influences. At the one cockle RMP (Traeth Melynog) the geometric mean result was 234 *E. coli* MPN/100g, and 3.9 % of results exceeded 4,600 *E. coli* MPN/100g. At the Pacific oyster RMP (Area 11[1]) the geometric mean result was 449 *E. coli* MPN/100g, and 7.7 % of results exceeded 4,600 *E. coli* MPN/100g suggesting an increased likelihood of a C classification arising here.

Since 2003*, E. coli* levels have remained stable at most mussel RMPs. However, at Plas y Borth, there was an apparent increase in *E. coli* levels before sampling stopped in 2011. *E. coli* levels remained stable at Traeth Melynog, with a slight decrease from 2011 to present. At Area 11, *E. coli* levels have fallen by almost an order of magnitude overall since 2003, suggesting that borderline class B compliance is no longer such an issue.

Across the four mussel RMPs there was a tendency for higher average results in the summer and autumn. Seasonal variation was only statistically significant at the two RMPs on the Anglesey side of the strait however, possibly suggesting that the two sides of the strait are subject to slightly different contaminating influences. At Barras 1, *E. coli* levels were significantly lower in spring than in summer and autumn. At Plas y Borth, *E. coli* levels were significantly higher in autumn than in spring and winter. A similar seasonal pattern was found for the cockle RMP at Traeth Melynog, where significantly lower levels of *E. coli* were found during spring than during any other season. At the Area 11 Pacific oyster RMP *E. coli* levels were significantly higher in autumn than winter.

A significant influence of the high/low tidal cycles was detected at two of the mussel RMPs (Barras 1 and Fort Belan). However, sampling was targeted towards low water and there are no patterns apparent in the polar plots. A significant influence of the spring/neap tidal cycle was found for mussels at Barras 1 and Plas Y Borth, and for Pacific oysters at Area 11. At these two mussel RMPs, sampling was targeted

[1] Area 11 in the expired fishery order is now referred to as Area 5 in the new proposed fishery order.

towards neap and increasing tides. A tendency for lower results on average around neap tides could be seen for both when these data were plotted, although it must be noted that only part of the cycle was represented. This may suggest that more distant sources may be of significance at these two sites. For Pacific oysters at Area 11, fewer low results were recorded as tide size increased from neaps to springs, although the reason for this is unclear.

All RMPs showed a statistically significant influence of antecedent rainfall. Across the mussel sites, the influence was strongest at Barras 1 and weakest at Plas y Borth. Cockles at Traeth Melynog responded strongly two days after a rainfall event. The influence of rainfall was relatively weak for Pacific oysters at Area 11.

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.

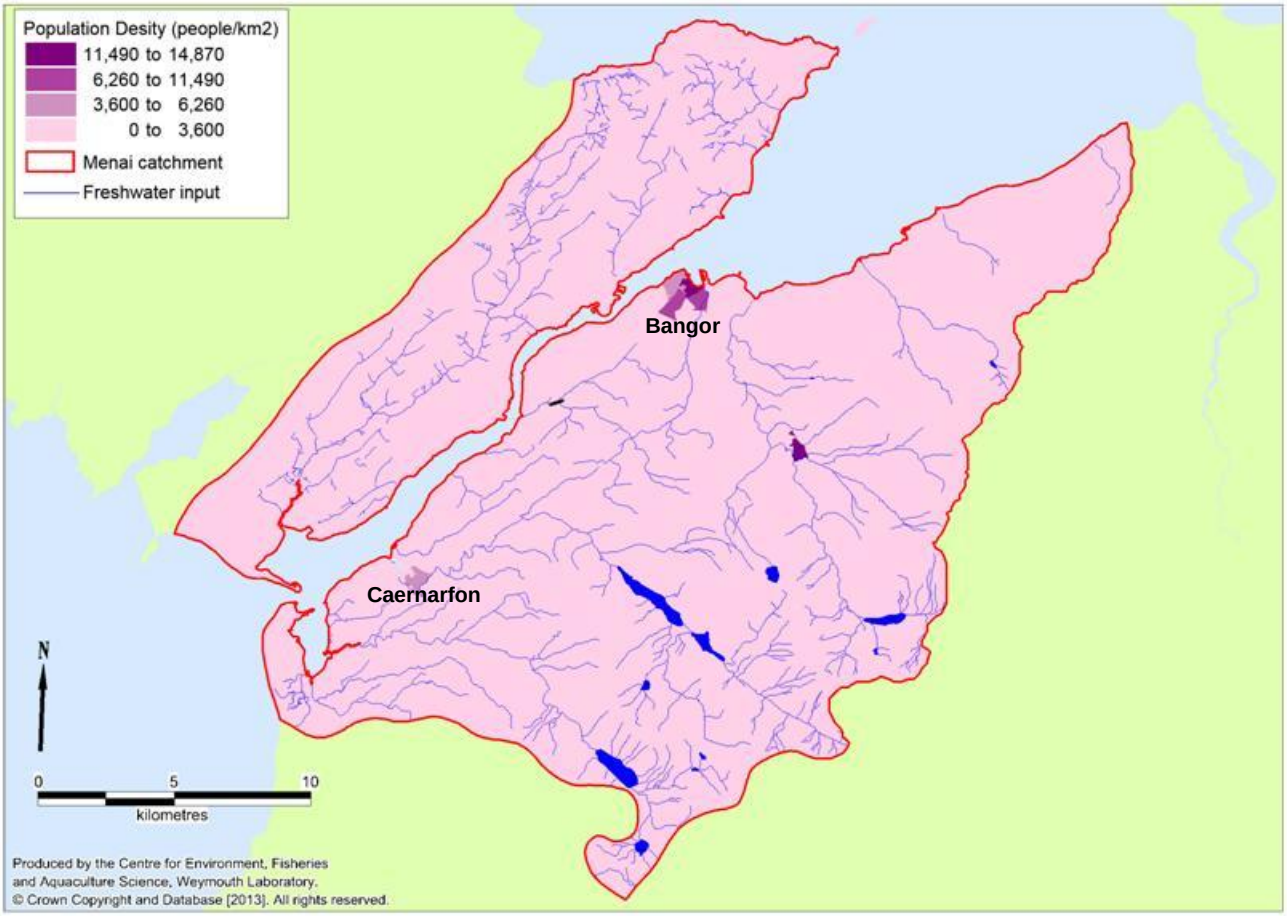

Figure I.1: Human population density in census areas in the Menai Strait catchment.

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. The main town adjacent to the western strait is Caernarfon, which had a population of just over 9,500 in 2011. 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 West shellfisheries were taken from the most recent update of the Environment Agency national permit database (March 2013). These are mapped in Figure II.1.

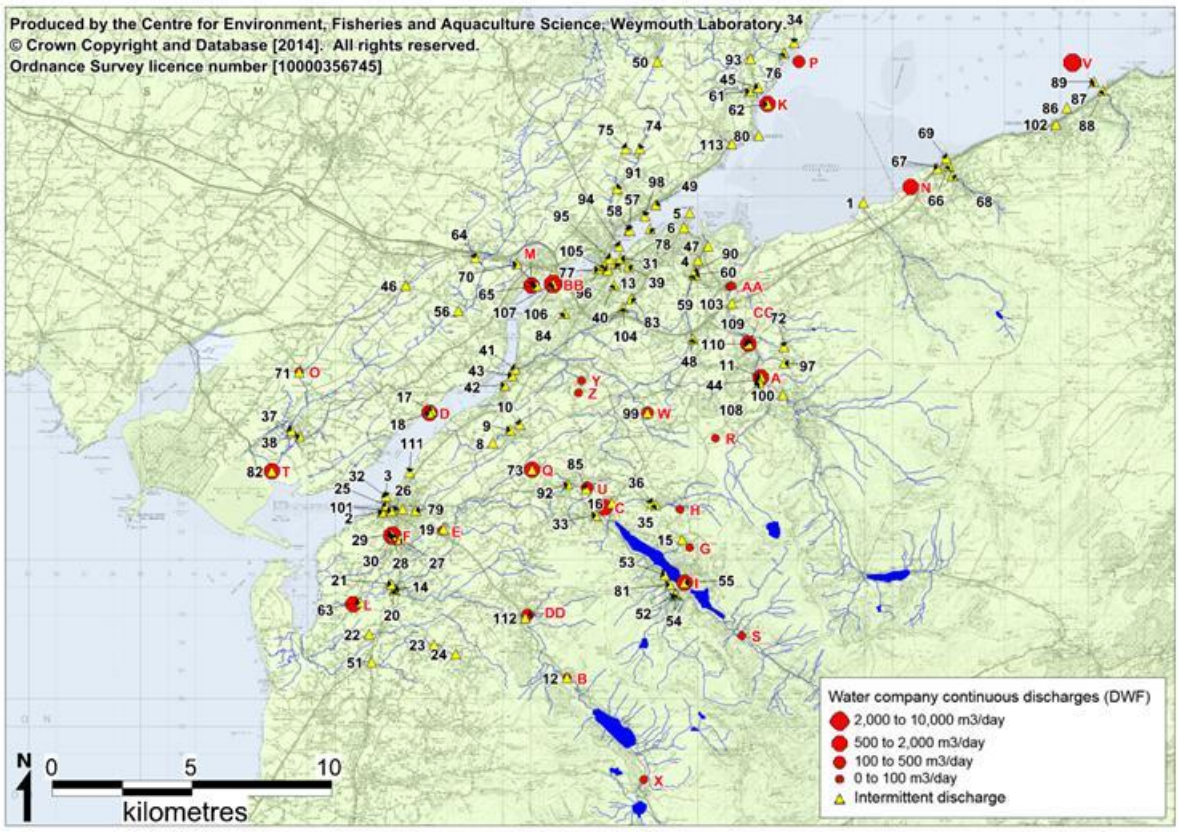

Figure II.1: Water company sewage discharges to the Menai Strait

There are 32 continuous water company discharges within the hydrological catchment for the Menai Strait, details of which are presented in Table II.1. Water company intermittent discharges within this area are listed in Table II.1.

Table II.1: Details of continuous water company sewage works within the Menai Strait catchment

Ref	Name	NGR	Treatment	Dry weather flow (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	Betws Garmon WTW	SH5429056740	Septic tank	8	$8.00x10^{11}$	Afon Gwyrfai
C	Brynrefail STW	SH5565062860	Biological Filtration	990	$3.27x10^{12}$	Caledffrwd
D	Brynsiencyn STW	SH4936066240	Biodisc & reedbed	665***	Uncertain	Menai Strait
E	Caeathro STW	SH4978062010	Biological Filtration	Not specified	Unknown	Seiont
F	Caernarfon STW	SH4802061830	Biological Filtration	2840	$9.37x10^{12}$	Afon Seiont
G	Dinorwig Chapel STW	SH5870061400	Septic Tank	Not specified	Unknown	To Land
H	Gallt-Y-Foel STW	SH5834062780	Biological Filtration	15	$4.95x10^{10}$	Caledffrwd
I	Llanberis STW (Final) Llanberis	SH5852060160	Biological Filtration	740	$2.44x10^{12}$	Afon Seiont
J	Llandegai STW	SH6013070760	Biological Filtration	8	$2.71x10^{10}$	Trib of Afon Ogwen
K	Llanfaes WWTW	SH6149477308	Biological Filtration	703	$2.32x10^{12}$	Menai Strait
L	Llanfaglan WWTW	SH4662659370	Biological Filtration	1306	$4.31x10^{12}$	Gwyrfai
M	Llanfair PG WWTW	SH5302470802	Biological Filtration	958	$3.16x10^{12}$	Menai Strait
N	Llanfairfechan WWTW	SH6663974343	Biological Filtration	1468	$4.84x10^{12}$	Menai Strait
O	Llangaffo STW	SH4469067710	Biological Filtration	64	$2.11x10^{11}$	Trib of River Braint
P	Llangoed WWTW	SH6262078820	Biological Filtration	475	$1.57x10^{12}$	Menai Strait
Q	Llanrug WWTW Final	SH5303364206	Biological Filtration	898	$2.96x10^{12}$	Afon Rhythallt
R	Mynydd Llandegai WTW	SH5963065330	Septic Tank	0.1***	$3.30x10^{8}$	Unnamed Watercourse
S	Nant Peris STW	SH6056058250	Biological Filtration	Not specified	Unknown	Seiont
T	Newborough STW	SH4370064140	Biological Filtration	570	$1.88x10^{12}$	Estuary of Afon Braint
U	Penisarwaun WWTW FE	SH5501863548	Biological Filtration	111	$3.66x10^{11}$	Afon Seiont
V	Penmaenmawr WWTW	SH7243078800	Biological Filtration	2330	$7.69x10^{12}$	Coastal Waters of Conwy Bay
W	Rhiwlas STW	SH5719066230	Biological	315	$1.04x10^{12}$	Cegin

Ref	Name	NGR	Treatment	Dry weather flow (m^3/day)	Estimated bacterial loading (cfu/day)	Receiving environment
			Filtration			
X	Rhyd DDU STW	SH5705053080	Biological Filtration	Not specified	Unknown	Gwyrfai
Y	Seion No1 New STW	SH5482067400	Biological Filtration	4	$1.35x10^{10}$	Trib of Nant Y Garth
Z	Seion No2 Septic Tank/ Soakaway	SH5469666965	Septic Tank	8***	$2.77x10^{10}$	Groundwater
AA	Talybont STW	SH6022070780	Biological Filtration	95	$3.14x10^{11}$	Afon Ogwen
BB	Treborth STW (Final) Bangor	SH5379070850	UV Disinfection	9107	$1.7x10^{10}$ **	Menai Strait
CC	Tregarth	SH6081068710	Biological Filtration	616	$2.03x10^{12}$	Ogwen
DD	Waunfawr STW (Final Effluent)	SH5287258980	Biological Filtration	387	$1.28x10^{12}$	Afon Gwyrfai

*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 flow measurements and bacteriological testing results (Table II.3)
*** 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 continuous water company discharge to the Menai Strait is Treborth STW, with a consented dry weather flow (DWF) of just over 9100 m^3/day. This discharge receives UV disinfection and effluent monitoring data suggest UV disinfection is effective. Treborth STW is located just to the west of Britannia Bridge, approximately 5 km to the east of the Menai Strait West bivalve mollusc production area. Given that it is tertiary treated and is located at some distance from the fishery, this discharge will have minimal impact on the water quality there. 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 4.5 km to the east of the production area and will generate a significant bacterial loading. The Brynsiencyn STW discharge discharges just off the Anglesey shore, about 1 km to the east of a mussel and oyster site on the same shore. It has a consented maximum flow of 665 m^3/day of

biodisc then reedbed treated effluent. The additional reedbed step is likely to result in a significant reduction in faecal indicator bacteria concentrations in the effluent, but it may nevertheless be a significant influence on the adjacent fishery sites. Towards the western end of the Menai Strait, Newborough STW has a consented DWF of 570 m^3/day, discharging secondary treated effluent to the Afon Braint. This will add significantly to the bacterial loading carried by this watercourse, which flows across the intertidal area within the cockle bed at Traeth Melynog.

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. Caernarfon STW is located about 1.6 km from the production area, with a consented DWF of 2840 m^3/day of secondary treated effluent discharging to the Afon Seiont. This discharge will make a significant contribution to the loadings in the western Menai Strait given its location and large volume. Llanfaglan has a consented DWF of 1306 m^3/day, discharging secondary treated effluent to the Afon Gwyrfai, which then enters Foryd Bay. Whilst this is located approximately 3.5 km from the nearest production area, this discharge will contribute to background loadings reaching the shellfishery at the western end of the Menai Strait.

In addition to those discharges described here, various other continuous water company discharges will contribute to loading 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.

One discharge to the Menai Strait receives UV disinfection, Treborth STW. 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).

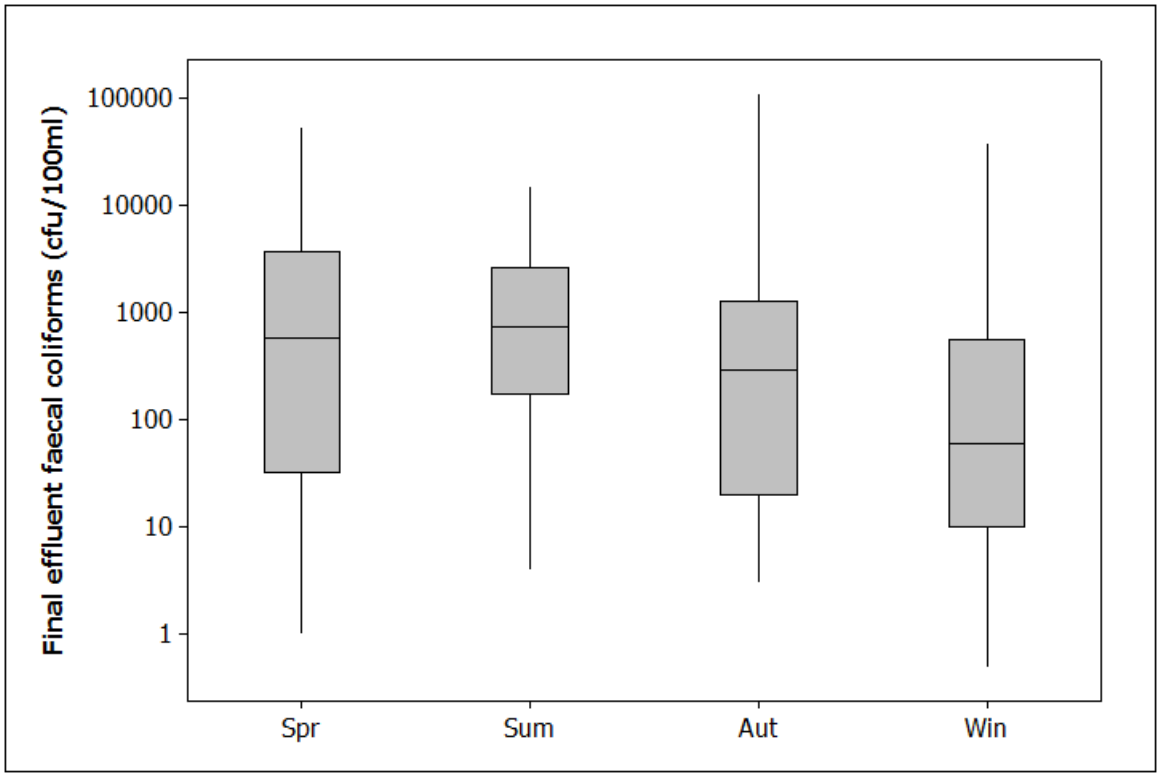

Figure II.2: ***Boxplot of faecal coliform concentrations in Treborth STW final effluent by season.***
Data from the Environment Agency.

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.

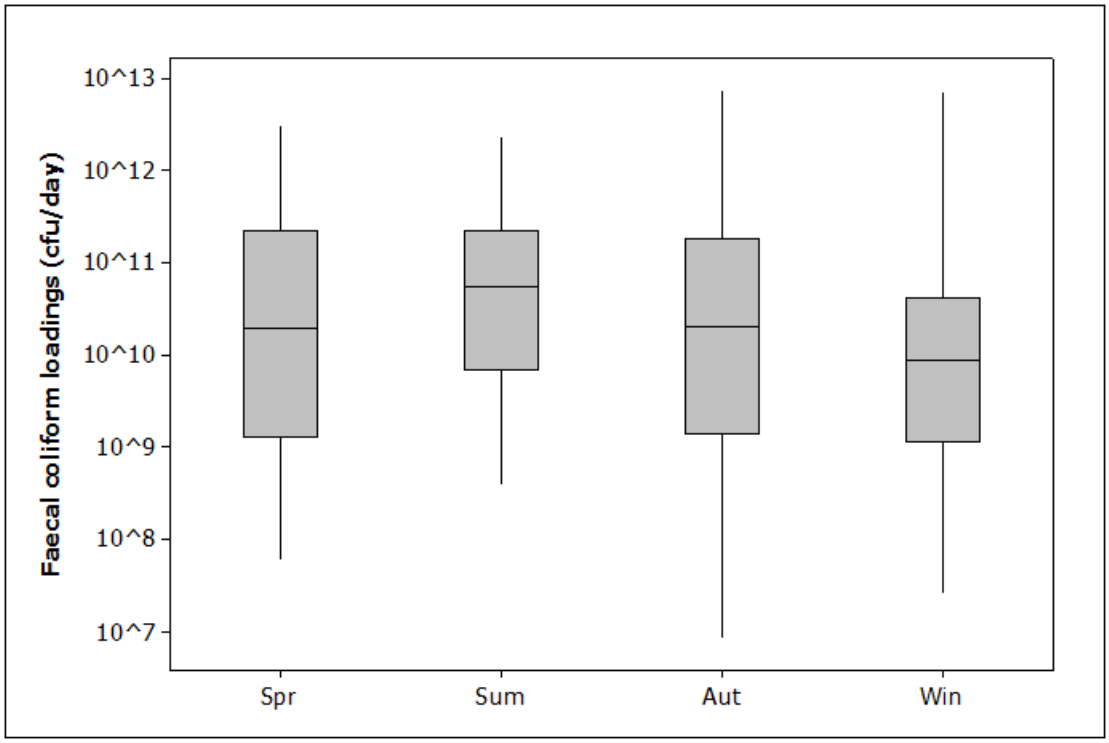

Figure II.3: Boxplot of faecal coliform daily loadings in Treborth STW final effluent by season
Data from the Environment Agency.

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).

In addition to the continuous sewage discharges, there are numerous intermittent water company discharges associated with the sewerage networks also shown on Figure II.1. Details of these are shown in Table II.4, where discharges highlighted in yellow have spill event monitoring records available. In the future, Welsh Water intends to install event monitoring on all intermittent discharges likely to impact on shellfish waters in the area.

Table II.4: Intermittent discharges within the Menai Strait catchment

No.	Name	Grid reference	Receiving water	Type
1	Abergwyngregyn Pumping Station	SH6492073780	Menai Strait	Pumping Station
2	Anglesey Arms Pumping station	SH4765062680	Estuary- Afon Siont	Pumping Station
3	Balaclava Road SPS	SH4780663233	Menai Strait	Pumping Station
4	Bangor Maesgeirchen SPS	SH5900071700	Cegin	Pumping Station
5	Beach Road PS Bangor	SH5869073410	Menai Strait	Storm Overflow & Pumping Station
6	Beach Road PS No 1 Bangor	SH5850072900	Menai Strait	Pumping Station
7	Bethel CSO Bethel Near Caernarfon	SH5163065160	Afon Cadnant	Storm Overflow
8	Bethel Sewage Transfer PS	SH5163365156	Unnamed Trib of Afon Cadnant	Pumping Station
9	Bethel SSO No. 2	SH5227065630	Cadnant	Pumping Station
10	Bethel SSO No. 3	SH5260065830	Cadnant	Pumping Station
11	Bethesda WWTW Storm	SH6125467526	Afon Ogwen	Storm Overflow/ Storm Tank
12	Betws Garmon WTW	SH5429056740	Afon Gwyrfai	Pumping Station
13	Bodlondeb CSO Bangor	SH5604071590	Menai Strait	Storm Overflow
14	Bontnewydd SSO Ysgol Gynradd Bontne	SH4810059910	Afon Gwyrfai	Storm Overflow
15	Bro Elidir STW Dinorwic	SH5842061700	Trib of Afon Fachwen	Pumping Station
16	Brynrefail Main SPS	SH5590063000	Caledffrwd	Pumping Station
17	Brynsiencyn PS	SH4945066320	Menai Strait	Storm Overflow & Pumping Station
18	Brynsiencyn STW	SH4936066240	Menai Strait	Storm Overflow/ Storm Tank
19	Caethro STW	SH4986062080	Seiont	Storm Overflow/ Storm Tank
20	Caernarfon- Bontnewydd SSO No	SH4810059900	Gwyrfai	Storm Overflow
21	Caernarfon- Bontnewydd SSO No	SH4800060100	Beuno	Storm Overflow
22	Caernarfon- Glanrhyd SSO No.	SH4720058300	Rhyd	Storm Overflow
23	Caernarfon- Rhostryfan SSO No.	SH4951857930	Carrog	Storm Overflow
24	Caernarfon- Rhostryfan SSO No.	SH5030057600	Trib of Afon Carrog	Storm Overflow
25	Caernarfon Bank Quay PS	SH4780062900	Menai Strait	Storm Overflow
26	Caernarfon Margaret Street -S	SH4840062800	Unnamed Watercourse	Storm Overflow
27	Caernarfon Pont seiont PS	SH4830061700	Seiont	Pumping Station
28	Caernarfon WWTW Inlet Pump St 6mm	SH4801061891	Afon Seiont	Pumping Station
29	Caernarfon WWTW Inlet Pump St 6mm	SH4800961890	Afon Seiont	Pumping Station
30	Caernarfon WWTW Storm Tanks	SH4803461826	Afon Seiont	Storm Overflow/ Storm Tank
31	Coleg Normal Sewage Pumping Station	SH5621971784	Menai Strait	Storm Overflow
32	Crossville CSO	SH4780563232	Menai Strait	Storm Overflow
33	Cwmyglo SSO	SH5534062570	Rhythallt	Storm Overflow
34	Cynlai PS Llangoed Anglesey	SH6246079520	Coastal Waters	Pumping Station
35	Deiniolen- Clwt Y Bont- SSO	SH5748062940	Caledffrwd	Storm Overflow
36	Deiniolen- SSO	SH5732663003	Caledffrwd	Storm Overflow
37	Dwyran by School- SSO	SH4440065600	Braint	Storm Overflow

No.	Name	Grid reference	Receiving water	Type
38	Dwyran Rhydwyn- SSO	SH4470065400	Braint	Storm Overflow
39	Eithinog Phase 3A PS Off Belmont Rd	SH5650071480	Unnamed Watercourse	Pumping Station
40	Eithinog PS No 1 Penrhosgarnedd BA	SH5598070820	Unnamed Trib of Afon Menai	Pumping Station
41	Felinheli PS (Adj to Quay Toilets)	SH5243067800	Menai Strait	Storm Overflow
42	Felinheli PS (Opp Sea Cadet Corp)	SH5206067240	Menai Strait	Storm Overflow
43	Felinheli PS (Quay Cottage)	SH5232067580	Menai Strait	Pumping Station
44	Fron Ogwen PS	SH6119067420	Ogwen	Pumping Station
45	Fryars Bay PS- Screened Emerg	SH6115077910	Unnamed Ditch	Pumping Station
46	Gaerwen Station SPS	SH4850070800	Trib Braint	Pumping Station
47	Glaentraeth Estate PS Bangor	SH5937072230	Afon Cegin	Pumping Station
48	Glasinfryn SPS	SH5880068900	Cegin	Pumping Station
49	Glyn Garth PS Llandegfan	SH5747073680	Estuary- Menai Strait	Pumping Station
50	Gorsllwyd Sewage Pumping Station	SH5752978828	The Afon Cadnant	Pumping Station
51	Hen Gastell No. 5- SSO	SH4728357305	Carrog	Storm Overflow
52	Llanberis- SWO at Maes Padarn	SH5817059710	Afon Hwch	Storm Overflow
53	Llanberis PS	SH5781060430	Llyn Padarn	Storm Overflow
54	Llanberis SSO No.2	SH5820059740	Afon Hwch	Storm Overflow
55	Llanberis STW (Storm) Llanberis	SH5852060160	Afon Y Bala	Storm Overflow/ Storm Tank
56	Llanddaniel Pont Y Crug SPS	SH5040069900	Afon Braint	Storm Overflow
57	Llandegfan (Menai) Pumping Station	SH5652072800	Menai Strait	Pumping Station
58	Llandegfan PS (Emergency)	SH5655072790	Menai Strait	Storm Overflow
59	Llandegai Ind Estate STW	SH5883071190	Afon Cegin	Pumping Station
60	Llandygai Ind Estate PS	SH5890071200	Tributary of Afon Cegin	Pumping Station
61	Llanfaes PS (Emergency)	SH6085077780	Unnamed Watercourse	Storm Overflow
62	Llanfaglan WWTW Storm Tank	SH4686459447	Menai Strait	Storm Overflow/ Storm Tank
63	Llanfaglan WWTW Storm Overflow	SH4686459447	Gwyrfai	Storm Overflow/ Storm Tank
64	Llanfair PG SPS	SH5100071800	Braint	Pumping Station
65	Llanfair PG WWTW	SH5320470802	Menai Strait	Storm Overflow
66	Llanfairfechan- SSO	SH6800075100	Llanfairfechan	Storm Overflow
67	Llanfairfechan Hospital SPS	SH6760075000	Conway Bay	Pumping Station
68	Llanfairfechan SSO No.1	SH6813074750	Llanfairfechan	Storm Overflow
69	Llanfairfechan SSO No. 2	SH6791075370	Llanfairfechan	Storm Overflow
70	Llanfairpwll SSO No. 2	SH5250071570	Trib of Braint	Storm Overflow
71	Llangaffo STW SSO	SH4469067690	Braint	Storm Overflow/ Storm Tank
72	Llanllechid SPS	SH6209068620	Afon Y Llan	Storm Overflow
73	Llanrug WWTW Storm	SH5303364206	Afon Seiont	Storm Overflow/ Storm Tank
74	Llansadwrn PS	SH5690075700	Cadnant	Pumping Station
75	Llansadwrn PS	SH5640075700	Trib of Cadnant	Pumping Station
76	Lleiniog PS	SH6209079150	Menai Strait	Pumping Station
77	Llyn Y Felin PS (Emergency)	SH5542071400	Menai Strait	Storm Overflow &

No.	Name	Grid reference	Receiving water	Type
				Pumping Station
78	Meirion Road PS (Storm/Emerg)	SH5727072840	Menai Strait	Storm Overflow & Pumping Station
79	Min-Y-Nant CSO	SH4885662742	Cadnant	Storm Overflow
80	Mount Field PS Beaumaris	SH6117076190	Menai Strait	Storm Overflow & Pumping Station
81	Near Castle Gift Shop Llanberis	SH5798060100	Goch bach	Storm Overflow
82	Newborough STW	SH4370064140	Afon Braint (Estuary)	Storm Overflow/ Storm Tank
83	Non Food Retail Units Caernarfon Ro	SH5660070340	Afon Adda	Storm Overflow
84	Parc Menai Park PS (Emergency)	SH5420069800	Culvert to Faenol Hall	Pumping Station
85	Penisarwaun WWTW	SH5497663514	Seiont	Storm Overflow/ Storm Tank
86	Penmaenmawr Promenade PS	SH7224077190	Coastal Waters	Storm Overflow & Pumping Station
87	Penmaenmawr WWTW Penmaenmawr	SH7322078110	Coastal Waters of Conwy Bay	Storm Overflow
88	Penmaenmawr WWTW Penmaenmawr	SH7353077800	Gyrach	Pumping Station
89	Penmaenmawr WWTW Penmaenmawr	SH7322078110	Coastal Waters of Conwy Bay	Storm Tank
90	Plots 35/36 Llandegai Ind Estate	SH5886071300	Afon Cegin	Storm Overflow
91	Pont Llandegfan Sewage Pumping Station	SH5609874287	Cadnant	Pumping Station
92	Pont Rhythallt Pumping Station	SH5432963677	Afon Seiont	Storm Overflow & Pumping Station
93	Pont Y Brenin PS	SH6088078930	Y Brenin	Pumping Station
94	PS No1 (Faelog Causeway)(Emergency)	SH5616072210	Menai Strait	Storm Overflow & Pumping Station
95	PS No2 (Porth Wrach) (Emergency)	SH5584071760	Menai Strait	Storm Overflow & Pumping Station
96	PS No3 (Suspension Bridge) (Emergency)	SH5563071520	Menai Strait	Storm Overflow & Pumping Station
97	Rachub Maes Bleddyn CSO	SH6210068029	River Ogwen	Storm Overflow
98	Rhiana PS Llandegfan	SH5708073300	Estuary- Menai Strait	Pumping Station
99	Rhiwlas STW	SH5719066230	Cegin	Storm Overflow/ Storm Tank
100	Rock Terrace CSO	SH6205066880	Afon Ogwen	Storm Overflow
101	SSO at Mill Lane Caernarfon	SH4799162715	Cadnant- Caernarfon	Storm Overflow
102	Station Road CSO	SH7184276591	Coastal Waters via SW Culvert	Storm Overflow
103	Talybont STW	SH6021870166	Afon Ogwen	Storm Overflow & Pumping Station
104	Tesco Foodstore Caernarfon Road	SH5631070010	Afon Adda	Storm Overflow
105	The Antelope SPS	SH5575471351	Menai Strait	Pumping Station
106	Treborth STW (Final)	SH5379070850	Menai Strait	Storm Overflow
107	Treborth STW (Final)	SH5379070850	Menai Strait	Storm Tank
108	Tregarth Henturnpike (from OGW)	SH6120067300	Ogwen	Storm Overflow
109	Tregarth WWTW Pumping Station	SH6081168713	Afon Ogwen	Pumping Station

No.	Name	Grid reference	Receiving water	Type
	EO			
110	Tregarth WWTW Storm Tanks	SH6081168712	Ogwen	Storm Overflow
111	Waterloo Port Sewage Pumping Station	SH4863164109	Estuary- Menai Strait	Pumping Station
112	Waunfawr (Storm)	SH5280358901	The Afon Gwyrfai	Storm Overflow/ Storm Tank
113	West End PS Beaumaris Anglesey	SH6022075880	Estuary- Menai Strait	Pumping Station

Data from the Environment Agency

The majority of the intermittent discharges to the strait are in the Bangor area. Most of those by the western strait discharge to watercourses. The main cluster here is around Caernarfon of which four discharge directly to the western strait and several others discharge to the Seiont estuary. There is a further cluster of three intermittent discharges direct to the western strait at Y Felinheli. All four of the sewage works discharging to saline waters in the western strait also have intermittent overflows.

For those without spill information it is difficult to assess their impacts aside from noting their location and potential to spill untreated sewage. Although Welsh Water are in the process of installing spill monitoring on all intermittent discharges likely to impact on the shellfisheries, limited spill records were only available for four of these 113 discharges, as summarised in Table II.5.

Table II.5: Summary of spill records, January 2008 to March 2012.

	2008		2009		2010		2011		2012	
Discharge Name	**No. events**	**% of period active**	**No. events**	**% of period active**	**No. events**	**% of period active**	**No. events**	**% of period active**	**No. events**	**% of period active**
Crossville CSO	32	0.64	33	0.51	23	0.35	31	0.67	50	0.89
Llanfaes PS	No data prior to 2012								17*	4.11
Llanfaglan WWTW storm	92	18.2	37	7.1	15	1	38	2.65	101**	19.3
Waterloo Port SPS			4	0.14	1	0.002	8	1.62	4***	0.13

Data from the Environment Agency
* 6 months of data only
** up to 06/01/2013 as was spilling continuously over the new year
*** 2012-13 data already compiled by the EA

Of the four discharges with event duration monitoring data available, the most active by far was Llanfaglan WWTW storm overflow, which spilled for almost 20 % of the time in 2008 and 2012, although for a much lower proportion of the time during the years in between (7.1 %, 1 % and 2.65 % for 2009, 2010 and 2011 respectively). This discharge is therefore likely to be a sporadic but significant influence on water quality in Foryd Bay and possibly beyond. Llanfaes PS is located on the southern shore of Anglesey, discharging to the eastern strait and as such will be of limited relevance to this assessment. Crossville CSO and Waterloo Port SPS intermittent discharges spilled much less frequently and so whilst they may be of occasional

influence their impacts are very unlikely to be captured during monthly shellfish monitoring.

In addition to the actual spill data discussed above, the performance of the intermittent discharges impacting on Shellfish Waters were investigated by a modelling study (Metoc, 2008). This report covered the coastal sewerage catchments only, and presented modelled data rather than actual spill records. Some of the predicted annual spill volumes and percentage of time spill durations are considerably higher than others. Modelled annual spill volumes (m^3) for the cluster of intermittent discharges in the Caernarfon catchment total 181,415 m^3, for the 13 assets. Of these, Mill Lane CSO (Table II.4, line 100) is predicted to spill for the greatest proportion of the time (3.59 % annual spill duration) with a modelled annual spill volume of 87, 408 m^3. As such, impacts from intermittent discharges in this part of the Menai Strait West will be of sporadic significance to microbiological water quality. In the Llanfaglan catchment, Llanfaglan WWTW (Table II.4, line 61) is predicted to spill for 4.35 % of a year, discharging 18,165 m^3 annually. The total of all the modelled assets in the Llanfaglan catchment discharge 43,144 m^3 annually and will be of intermittent influence in Foryd Bay and the western end of the Menai Strait West. The intermittent discharge from Newborough STW storm tank (Table II.4, line 81) is modelled to discharge 138,195 m^3 annually and to spill for 22.48 % of the year. This discharge would be a significant influence on microbiological water quality at the cockle bed at Traeth Melynog. Of the intermittent discharges in the Treborth catchment, Bethel WWTW (Table II.4, lines 8 or 9 or 10) has a modelled annual spill volume of 116,585 m^3, spilling for 24.3 % of a year and Treborth WWTW storm overflow (Table II.4, lines 105 and/or 106) was modelled to spill 359,587 m^3 over 16.2 % of the year. These discharges will contribute significantly to concentrations of faecal indicators in the western strait at times. It must be borne in mind that these are modelled predictions, and were used to inform work on assets in the Asset Management Programme 4 (AMP4) and as such, improvements may have resulted in the reduction in the impact from these assets more recently.

During the shoreline survey the presumed outfalls for Waterloo PS, and two of the Felinheli PS overflows were observed to be discharging, although this could not be confirmed as the outfalls were not labelled and no corresponding enclosures were seen. The concentrations of *E. coli* they were carrying at the time were lower than would generally be expected for storm sewage (Table XII.2).

Although the vast majority of the survey area is served by water company sewerage infrastructure, there are also a number of private discharges in the area. Where specified, these are generally treated by small treatment works such as package plants. The majority of these are small, serving one or two properties. Details of the larger private discharges which hold permits are presented in Table II.6 and mapped in Figure II.4. As well as the larger private discharges there are numerous smaller

permitted ones (<3 m^3/day) and there are also likely to be unregistered private discharges which are not listed on the permit database.

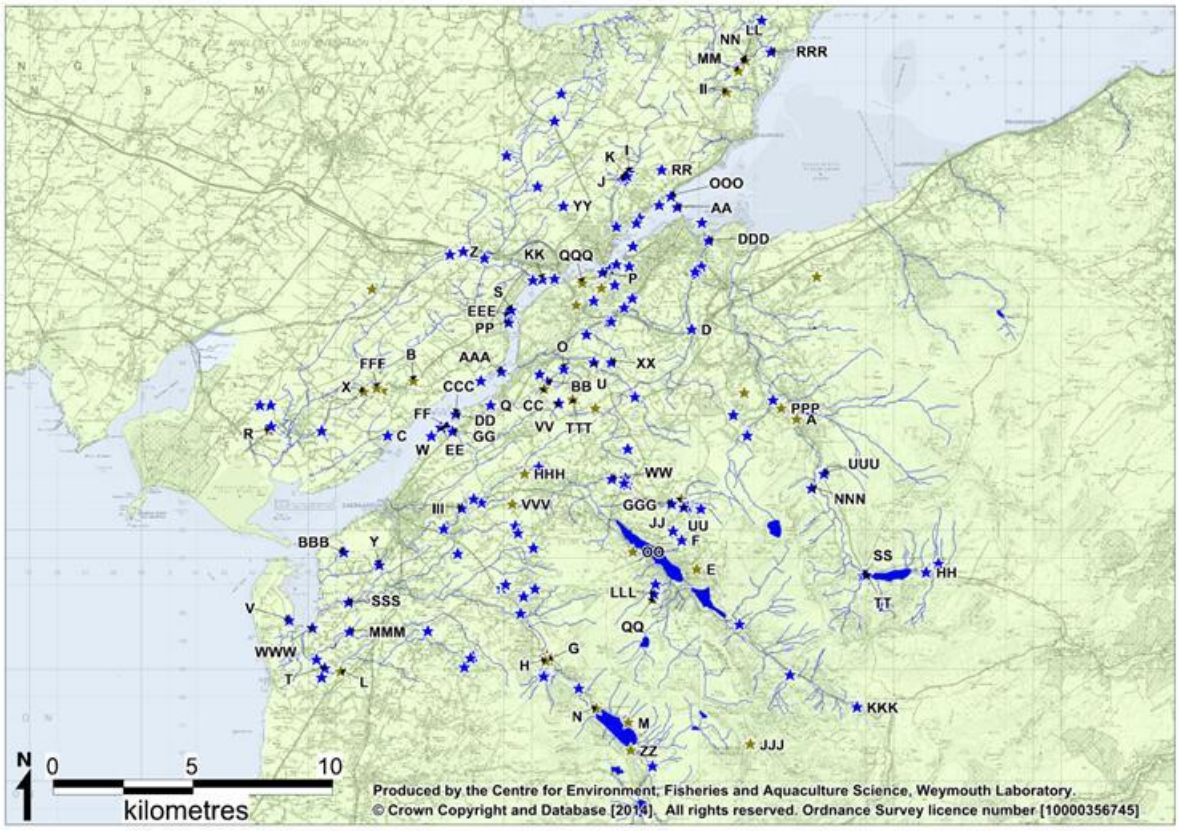

Figure II.4: Private discharges to the Menai Strait
Data from the Environment Agency

Table II.6*:* Details of private sewage discharges to the Menai Strait catchment

Ref.	Property served	Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
A	1-6 Tai Pont Twr	SH6248865957	Septic Tank	3.42	Soakaway
B	6 Bryn Llewelyn	SH4872867381	Septic Tank	3.8	Soakaway
C	Anglesey Sea Zoo Brynsiencyn Angl	SH4774565383	Unspecified	20	Unnamed Ditch
D	Bangor Service Area A5/A55 Expressw	SH5934669383	Biodisc	36.6	Afon Cegin
E	Blue Peris Mountain Centre	SH5888260805	Package Plant	5	Soakaway
F	Bro Elidir Stw Dinorwic ,	SH5840161655	Unspecified	20	Trib of Afon Fachwen
G	Bryn Gloch Caravan And Camping Park	SH5357257572	Septic Tank	15	Soakaway
H	Bryn Gloch Caravan And Camping Park	SH5357257570	Septic Tank	3.6	Soakaway
I	Cabins 10 11 & 12	SH5649174837	Package Plant	3	Afon Cadnant
J	Cabins 2 3 & 4	SH5633774631	Package Plant	3	Afon Cadnant
K	Cabins 5 6 & 7	SH5640674708	Package Plant	3	Afon Cadnant
L	Cae Berllan Holiday Units	SH4621256968	Septic Tank	5	Soakaway
M	Cae'R Orsaf	SH5646455137	Septic Tank	5	Soakaway
N	Castell Cidwm Hotel	SH5533955648	Septic Tank	5	Soakaway

Ref.	Property served	Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
O	Cefn Farm Y Felinheli	SH5403067762	Package Plant	5	Nant Cefn
P	Ceris Newydd Nursing Home Treborth	SH5559771207	Uv Disinfection	29.6	Soakaway
Q	Cerrig Yr Afon Nursing Home	SH5156566514	Biodisc	5	Unnamed Watercourse
R	Clynnog	SH4360365741	Package Plant	5	Soakaway
S	Conway Centre	SH5207869941	Septic Tank & reedbed	60	Menai Strait
T	Dol Meredydd Stw Llandwrog ,	SH4561957056	Unspecified	3	Carrog
U	Fferm Y Garth	SH5530367995	Package Plant	4	Unnamed Watercourse
V	Foryd Bay Morfa Lodge ,	SH4418658606	Package Plant	86	Menai Strait
W	Friction Products Factory Caernarfo	SH4972665351	Biological Filtration	83.5	Menai Strait
X	Fron Caravan And Camping Park	SH4696966993	Septic Tank	20	Soakaway
Y	Fron Goch Garden Centre	SH4759160820	Package Plant	5.17	Unnamed Watercourse
Z	Garnedd Ddu (Holiday Cottages) Star	SH5054172092	Biodisc	5	Unnamed Watercourse
AA	Garth Pier Bangor	SH5823173601	Maceration	5	Menai Strait
BB	Greenwood Forest Park	SH5326067035	Septic Tank	13.5	Trib Of Nant Y Garth
CC	Greenwood Forest Park	SH5326067035	Package Plant	13.5	Trib Of Nant Y Garth
DD	Griffiths Cross Out Purs Cent	SH5026066110	Unspecified	4.54	Menai Strait
EE	Griffiths Crossing	SH4979965608	Unspecified	15	Menai Strait
FF	Griffiths Crossing	SH4982665611	Biodisc	10.8	Unnamed Watercourse
GG	Griffiths Crossing Ind Estate	SH5008365547	Unspecified	4.5	Unnamed Watercourse
HH	Gwern Gof Uchaf Nant Y Benglog	SH6726060373	Package Plant	3.36	Trib of Afon Denau
II	Henllys Farmhouse Apartments	SH5999577727	Package Plant	16	Soakaway
JJ	Hostel Noddfa	SH5840263121	Septic Tank	4	Soakaway
KK	Indefatigable School Llanfair Pg	SH5324571232	Biological Filtration	36	Menai Strait
LL	Kingsbridge Caravan Park	SH6056178734	Package Plant	9.4	Afon Y Brenin
MM	Kingsbridge Caravan Park	SH6056178734	Package Plant	15	Soakaway
NN	Kingsbridge Caravan Park	SH6056178734	Septic Tank	7.5	Soakaway
OO	Lake View Hotel - Sewage Effluent	SH5660261226	Septic Tank	5	Soakaway
PP	Llanfairpwll Plas Newydd	SH5207269580	Package Plant	30	Menai Strait
QQ	Llwyn Celyn Bach Septic Tank	SH5728259612	Septic Tank And Filter	5	Soakaway
RR	Llyn Y Gors	SH5767474938	Package Plant	12	Unnamed Watercourse
SS	Nant Ffrancon Ogwen Cottage	SH6493160360	Unspecified	7	Idwal
TT	Ogwen Lake Ogwen Cottage Nr Bethes	SH6501060396	Package Plant	7.5	Afon Ogwen

Ref.	Property served	Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
UU	Old School Deiniolen Caernarfon	SH5846562856	Package Plant	5	Trib Of Afon Caladffrwd
VV	Parciau Rhos	SH5394466469	Biological Filtration	4.9	Unnamed Watercourse
WW	Penisarwaun Nursing Home	SH5586263887	Biodisc	8	Trib Of River Seiont
XX	Pentir Substation Near Bangor	SH5582067747	Package Plant	3.19	Trib Of Afon Heulyn
YY	Pentre Coed Country Park	SH5413473649	Package Plant	4.7	Afon Rhyd Eilian
ZZ	Planwydd Campsite	SH5682053920	Package Plant	4.95	Soakaway
AAA	Plas Coch Caravan Park	SH5123168601	Uv Disinfection	194.2	Menai Strait
BBB	Plas Llanfaglan Llanfaglan Caernar	SH4621361247	Unspecified	5	Unnamed Watercourse
CCC	Plas Menai Outdoor Purs Centre Ca	SH5029366052	Package Plant	27	Menai Strait
DDD	Plas Y Coed Porth Penrhyn Bangor ,	SH5937072467	Unspecified	5	Afon Cegin
EEE	PTP Serving Visitor Centre At	SH5174669821	Package Plant	9	Menai Strait
FFF	Quality Care Nursing Home Glan Rhos	SH4743567186	Package Plant	15	Partial Soakaway
GGG	Rhydfadog Stw Deiniolen ,	SH5804262989	Unspecified	25	Afon Marchlyn Bach
HHH	Seiont Manor Hotel Llanrug	SH5283963859	Package Plant	20	Soakaway
III	Seiont Nurseries Pontrug Caernarfon	SH5060862858	Package Plant	15	Afon Seiont
JJJ	Snowdon Summit Cafe	SH6094654353	Septic Tank	10.9	Soakaway
KKK	STP @ Pen-Y-Pass Youth Hostel	SH6470655656	Package Plant	24	Trib of Afon Nant Peris
LLL	STP @ Yha Llanberis	SH5735759751	Package Plant	10	Trib of Afon Goch
MMM	STP Serving Ysgol Felinwnda	SH4652158250	Package Plant	3.35	Trib of Afon Rhyd
NNN	Tai Newyddion	SH6304963484	Package Plant	6.2	Trib of Afon Ogwen
OOO	The Gazelle Hotel Glyngarth	SH5800974028	Package Plant	13.8	Menai Strait
PPP	The Joys Of Life	SH6195166389	Package Plant	3.12	Soakaway
QQQ	Treborth Changing Rooms	SH5480570893	Septic Tank	9.12	Soakaway
RRR	Tros Yr Afon Holiday Homes Penmon	SH6148179126	Unspecified	5	Afon Lleiniog
SSS	Tyddyn Dafydd Llanfaglan Caernarfo	SH4641159478	Septic Tank	5	Afon Gwyrfai
TTT	Ty'N Rhos Country House & Cottage	SH5449466738	Septic Tank And Filter	4.9	Soakaway
UUU	Tyn Y Maes Motel Tyn-Y-Maes Bethesd	SH6350164036	Package Plant	13.63	Afon Berthon
VVV	Tyn-Y-Coed Caravan Park	SH5241762959	Septic Tank	5	Soakaway
WWW	White Tower Caravan Park Llanwrog	SH4524158144	Package Plant	25	Foryd Bay

Data from the Environment Agency.

There is a cluster of private discharges at Griffiths Crossing (discharges Q, W, DD, EE, FF, GG, CCC) around the Area 5 mussel and oyster plot (Figure II.5). Those carrying only trade or unspecified effluents may or may not have a bacteriological content. Those carrying sewage will likely be the most significant. As such, the inshore eastern corner of the mussel plot may lie in a hotspot derived from the sewage discharge from the meat processing plant, with a possible contribution from the unspecified industrial estate discharge. Should mussel culture operations expand eastwards towards Y Felinheli, the sewage discharge from the outdoor pursuit centre would assume the greatest significance by virtue of its higher discharge volume.

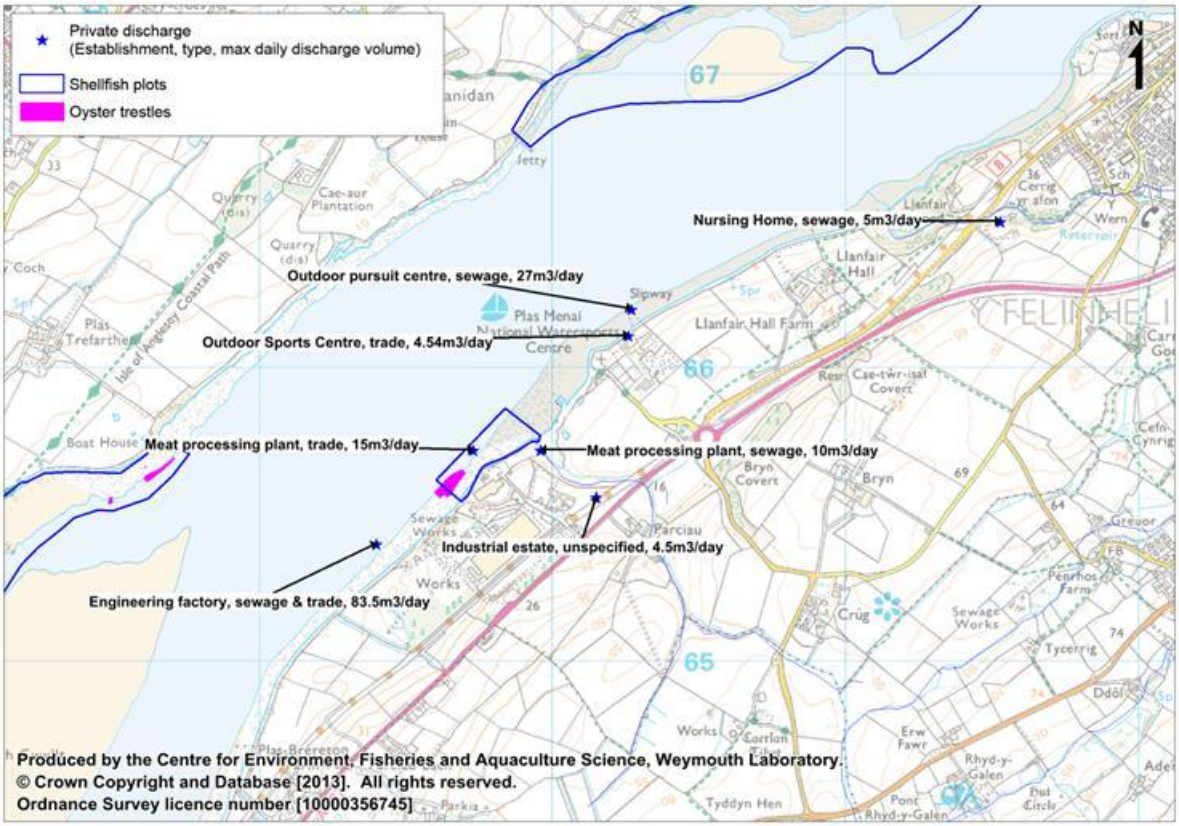

Figure II.5: Private discharges at Griffiths Crossing

Other private discharges which may have some bearing on the sampling plan include Plas Coch Caravan Park (AAA) which has a consented maximum daily volume of 194.2 m^3/day and discharges <1 km east of the production zone. However, this effluent receives UV disinfection and as such should not impact adversely at the fisheries provided the plant is operating effectively. Anglesey Sea Zoo (C) discharges a maximum of 20 m^3/day of effluent within 200 m of the strait. The treatment level is unspecified and it may be that there is some microbiological content. Foryd Bay Morfa Lodge (V) discharges a maximum consented volume of 86 m^3/d of secondary treated effluent to the west coast of Foryd Bay. As such, this discharge may be of significance to the fisheries in Foryd Bay and the western end

of the strait. The Conway Centre (S) has a consented maximum daily volume of 60 m^3/d, which is treated via septic tank then reedbed before discharging to the strait approximately 3 km east of the production area.

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. Those discharging to ground should not affect water quality provided systems 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.

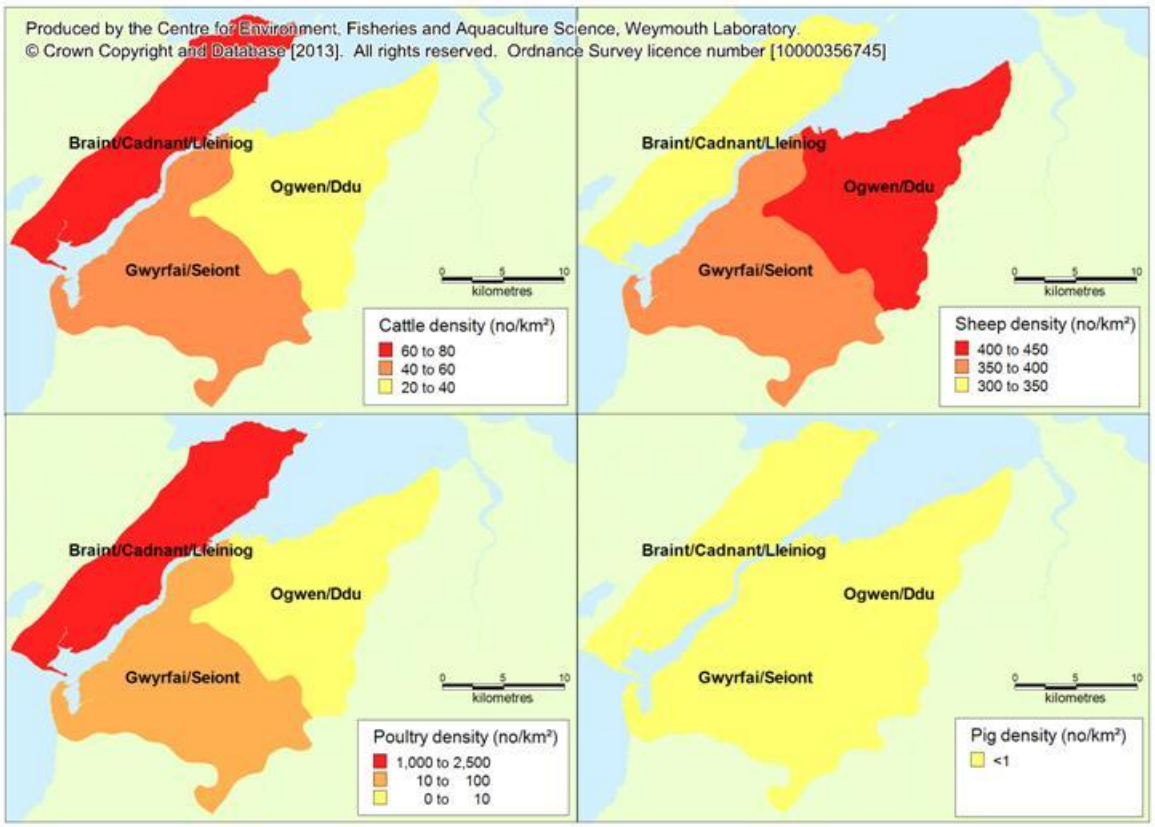

Figure III.1: Livestock densities in 2012 across the Menai sub-catchments
Data from Welsh Government.

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. There are not any intensive poultry operations in the areas draining direct to the Menai Strait (Environment Agency, pers. comm.). A few pigs are farmed in the area. During the shoreline survey the presence of sheep was noted in several fields adjacent to the shore on both sides of the strait, although the local topography would have obscured much of the land behind the shoreline from view. No areas of grazed saltmarsh were recorded.

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 the Environment Agency, 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.

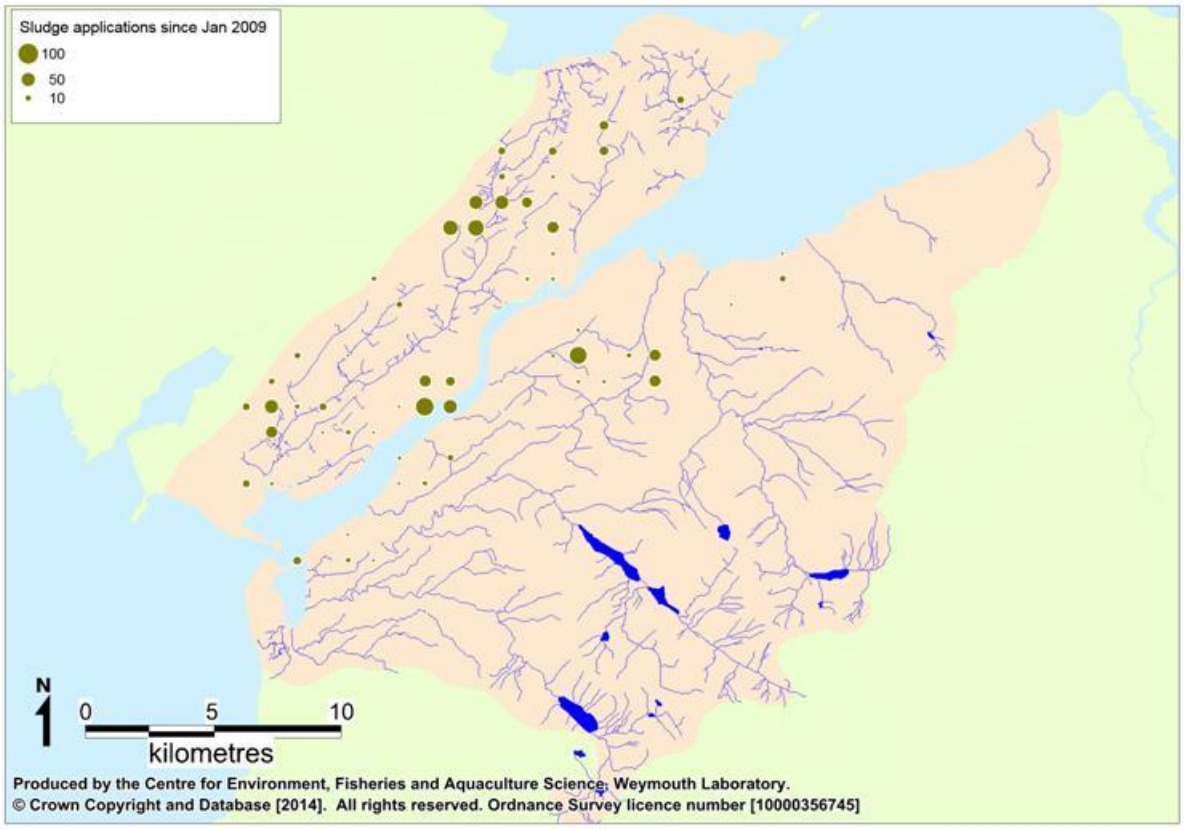

Figure III.2: Number of weeks (Jan 2009 to May 2013) during which sewage sludge was applied to fields within each square km within the Menai Strait catchment.
Data from the Environment Agency.

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 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 may be 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 western Menai Strait. There are no commercial ports in the survey area, and traffic consists mainly of pleasure craft (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.

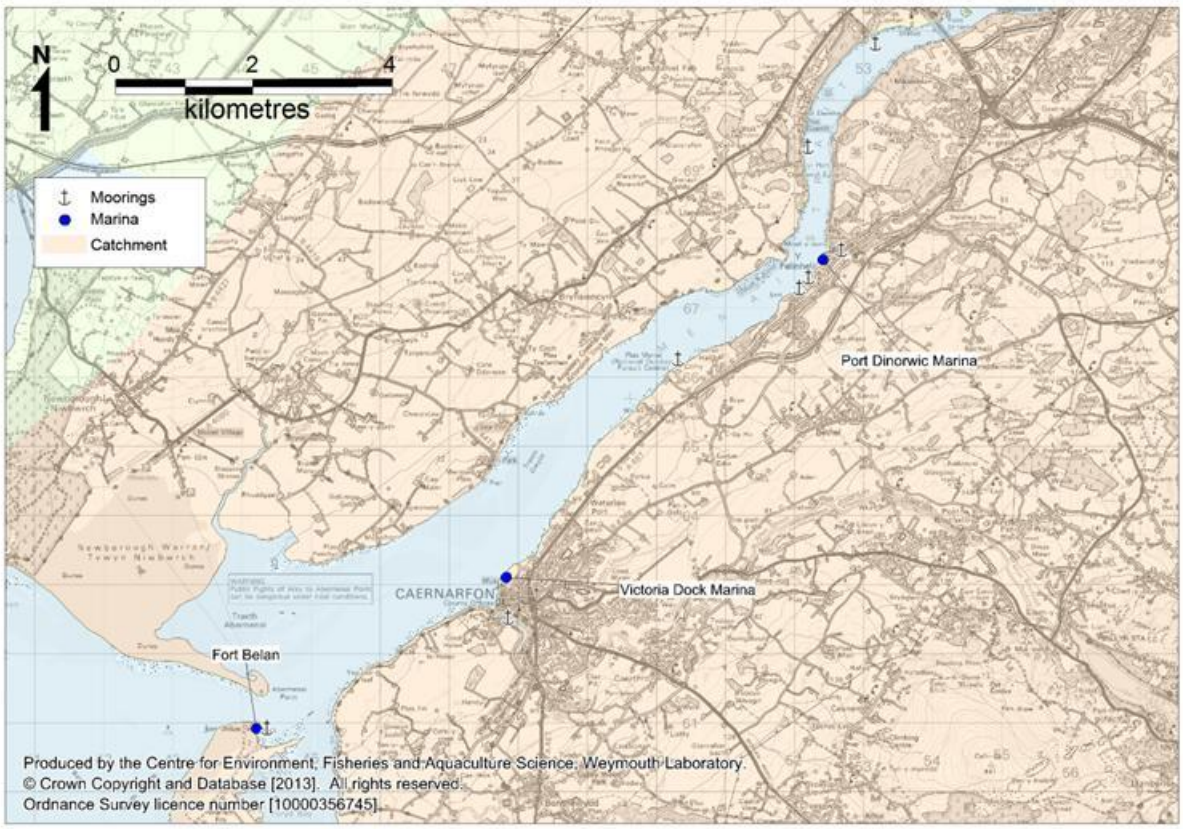

Figure IV.1 Boating activity in the West Menai

There is significant recreational boat traffic in the Menai Strait however in recent years there has been a decline in the number of boats that moor in the strait due to improvements at local marinas. There are two marinas in the western strait, Victoria Dock and Port Dinorwic Marina, which together provide around 277 berths and there are also numerous moorings in the Seiont estuary and just off the Port Dinorwic Marina (Reeds Almanac, 2012 & Caernarfon Harbour Trust, 2013a). In addition to this there are several other areas of moorings positioned throughout the survey area including several moorings at Fort Belan, where there is also a small dock with approximately 10 berths. Landerne Pier adjacent to Victoria Dock can berth larger

vessels up to 75 m in length. Sewage pump out facilities are available at Victoria Dock but are not available in Port Dinorwic.

Three under 10 m fishing boats are listed as having their home port as Caernarfon in November 2013 (MMO, 2013). An angling charter boat also operates from here on a part time basis (Charter Boats UK, 2013).

Racing and courses for yachts and dinghies are available through the Royal Welsh Yacht Club and Caernarfon Sailing Club. There is also a watersports centre, Plas Menai watersports centre, which offers a variety of watersports including windsurfing, kayaking and powerboating (Plas Menai website, 2013). However, the smaller recreational boats are not large enough to contain onboard toilet facilities and are therefore unlikely to make overboard discharges.

Although there are no commercial ports in the western strait, and passage through The Swellies can be hazardous, the occasional larger vessel does navigate through the strait (Caernarfon Harbour Trust, 2013b). Merchant shipping are not permitted to make overboard discharges within 3 nautical miles of land[2] so such vessels transiting the area should be of no impact.

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.

Some dredging activity is proposed to maintain the Victoria Dock entrance at Caernarfon (Natural Resources Wales, pers. comm.). The dredgings are to be deposited in the strait outside the dock entrance. Whilst this may resuspend faecal indicator bacteria and other sediment bound contaminants it will be an occasional occurrence. Although this may be a consideration if investigating the cause of high results, it will have no direct bearing on the sampling plan.

[2] 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). Bird counts are routinely undertaken at Traeth Lavan, in the eastern strait under the Wetland Bird Survey co-ordinated by the British Trust for Ornithology. Here, an average total count of 17,155 birds was recorded over the five winters up to 2010/11 (Holt et al, 2012). The most recent five year peak mean at Foryd Bay was 6,808 individuals (Natural Resources Wales, pers comm.). On the shoreline survey flocks of waterbirds were regularly observed, with the largest aggregation (~500 birds) on the Anglesey side just north of Caernarfon.

Grazers, such as geese and ducks will mainly frequent the grassland and saltmarsh, where their faeces will be carried into coastal waters via runoff 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 and wildfowl flocks, seabirds (gulls, cormorants etc) are also widespread within the Menai Strait and resident all year round. The main breeding colony is on Puffin Island at the eastern mouth of the strait where there are around 6,000 birds (Natural Resources Wales, pers comm.). A survey in the early

summer of 2000 recorded only small numbers of breeding seabirds within the western strait, with 35 pairs of Shags off Llanddwyn Headland and one pair of the Lesser Black-backed Gulls at Caernarfon (Mitchell et al, 2004). 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. As there are no large colonies within the western strait the presence of seabirds will have no bearing 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 Menai Strait particularly around Puffin Island in the east. A survey undertaken between 2002 and 2003 revealed numbers ranging from between 11 and 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 on sandbanks and islands, but no regular haulout sites have been identified within the western strait. Given the large area they are likely to forage over impacts are likely to be minor, and unpredictable in spatial terms outside of haul out sites.

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.

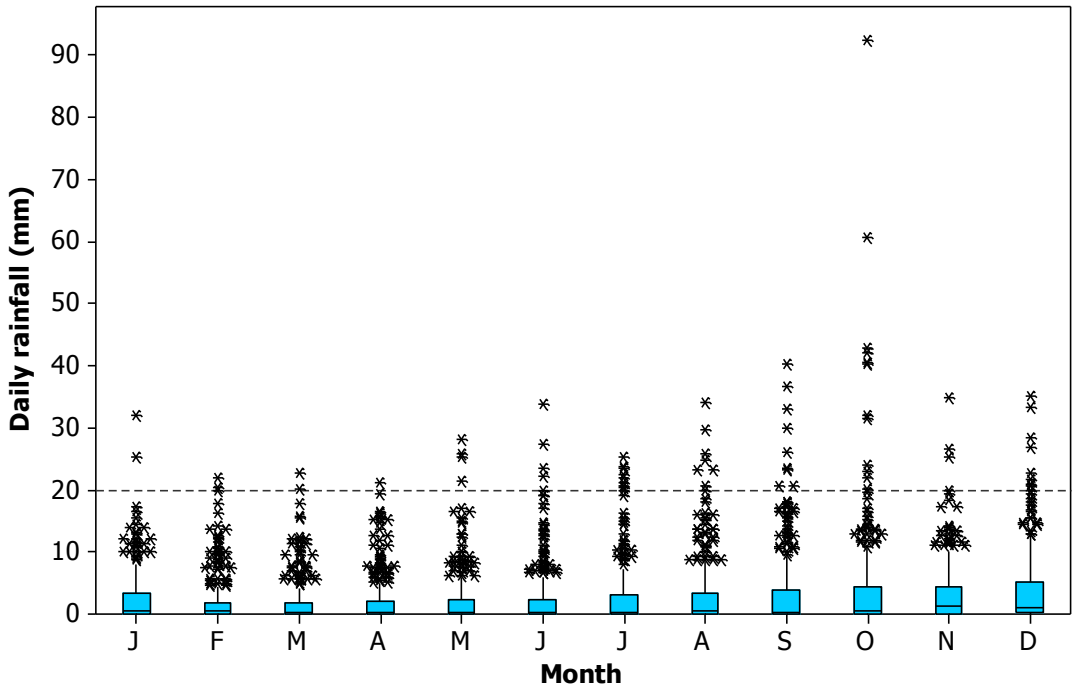

Figure VI.1: Boxplot of daily rainfall totals at Parc Menai, January 2003 to December 2012.
Data from the Environment Agency

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 at higher altitudes during the colder months of the year, although the snow covering does not persist on the peaks throughout the winter.

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).

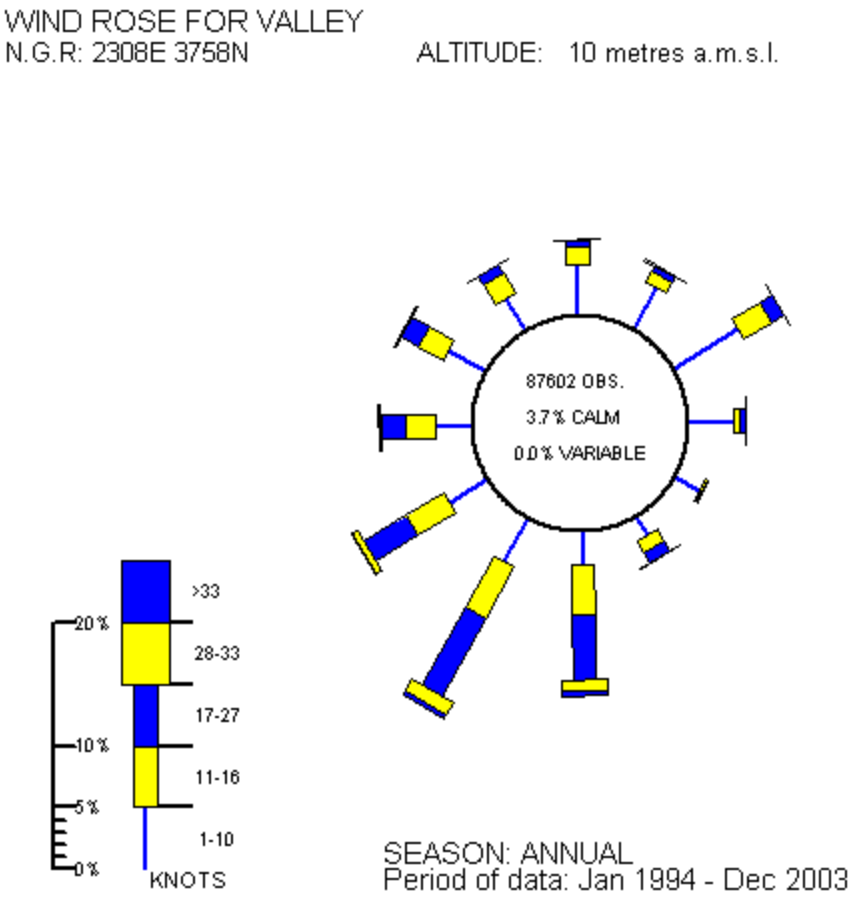

Figure VII.1: Wind rose for Valley.
Produced by the Meteorological Office. Contains public sector information licensed under the Open Government Licence v1.0

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 strait is a narrow semi enclosed body of water and therefore receives some shelter from winds. The surrounding land will tend to funnel winds up and down the strait, and the orientation of the western strait means that the prevailing south westerly winds will be funnelled straight up it. Strong south westerly winds may

therefore modify circulation patterns in the strait, particularly in areas where tidal streams are weaker.

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).

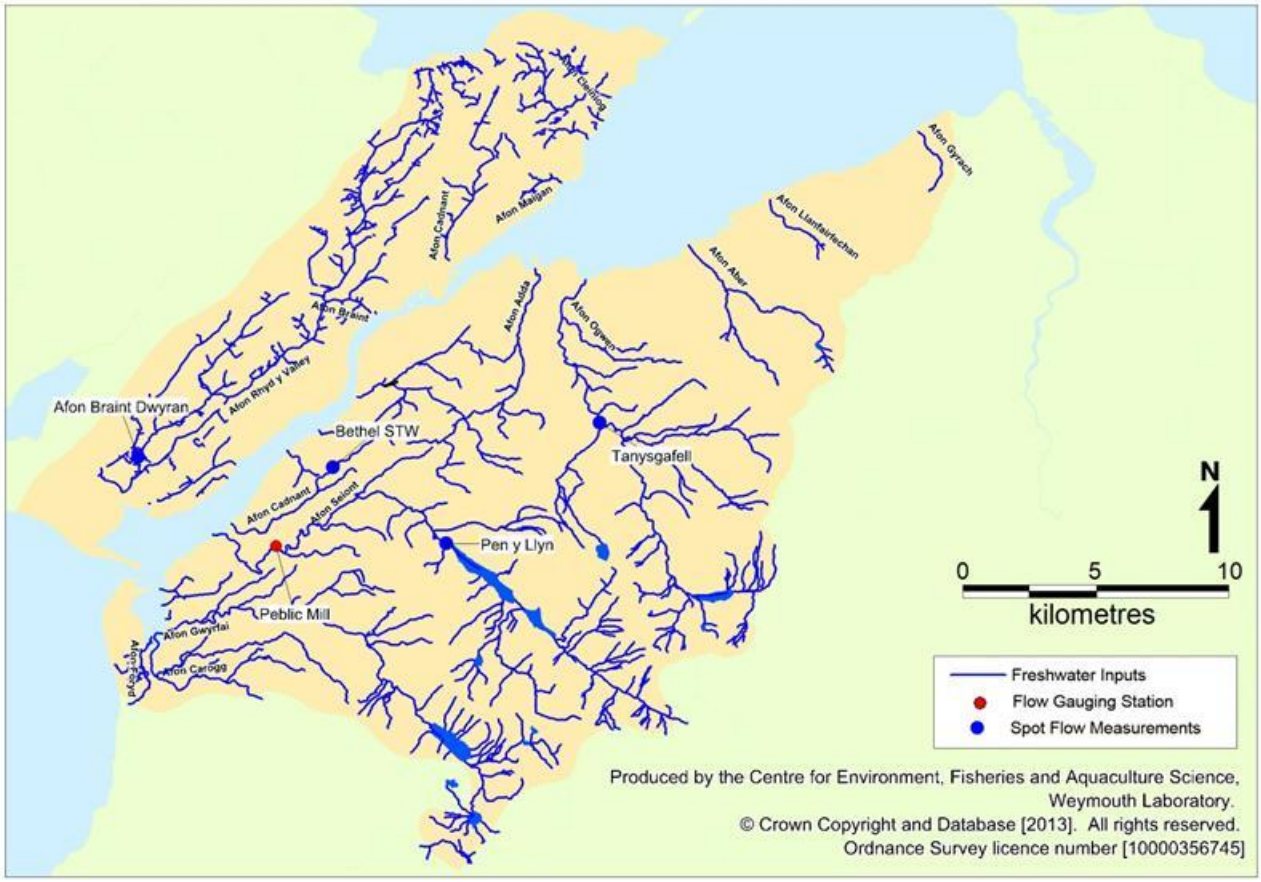

Figure VIII.1: Freshwater Inputs into the Menai Strait

On the Anglesey side, the largest freshwater input is the Braint which discharges to the bay in which the Traeth Melynog cockle bed is located. There is another significant watercourse, also called the Braint, which discharges about 1 km to the west of Britannia Bridge. On the mainland, watercourses are generally larger due to the greater catchment area and higher rainfall experienced in the mountainous areas. There are several streams and rivers discharging to Foryd Bay, including the Gwyrfai. The Seiont and Cadnant discharge at Caernarfon, the former of which has a defined estuary and represents the largest freshwater input to the western strait, and the latter is culverted in its lower reaches (Environment Agency Wales, 2010). The Nant y Garth (or Nant Heulin) is a smaller stream which discharges to the strait through a gated marina at Y Felinheli. 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 eastern strait, including the Ogwen.

These watercourses 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 Menai Strait. They predominantly drain pastures, with some relatively small pockets of urbanised land close to the shore such as the town of Caernarfon. 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 Seiont, Gwyrfai and Ogwen catchments will tend to buffer flows to some extent. Snow lies in the mountains through the winter and the spring melt will add to flows in the mountain rivers at these times. Anglesey has a more gently sloping topography so rivers in this region respond less quickly to rainfall (Environment Agency Wales, 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 (Environment Agency Wales, 2006 & 2007). Summary statistics for one flow gauging station on the Afon Seiont 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 Environment Agency

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

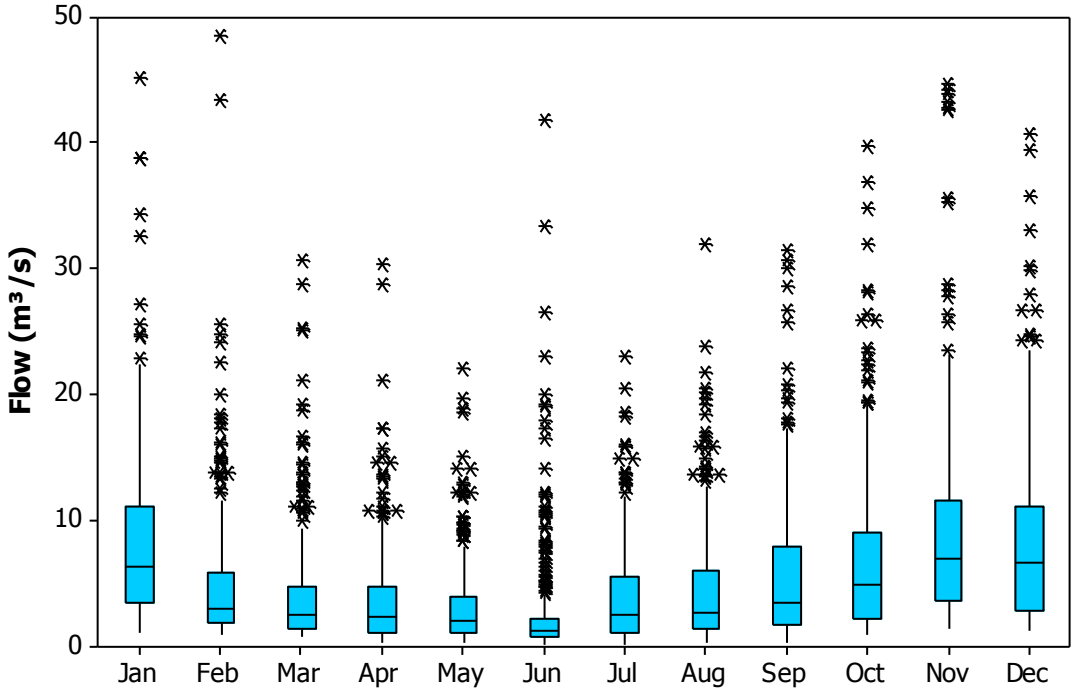

Figure VIII.2: Boxplots of mean daily flow records from the Peblig Mill gauging station on the Seiont watercourse (2003-2013)

Flows were generally highest in the colder months. The maximum flow rate (48.6 m^3s^{-1}) was recorded in February 2004 after periods of heavy rainfall and flooding (Met Office, 2012). 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 Strait West survey area. Numerous streams were observed flowing through the marshes and surface drainage pipes in the more built up areas during the shoreline survey. 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 estuary at regular intervals via engineered outfalls such as sluices and pumping stations.

Table VIII.2 presents maximum and mean spot flow results at 4 sampling locations within the Menai Strait catchment, the majority of which are within the western catchment. The highest mean flow (2.361 m^3s^{-1}) was recorded at Pen y Llyn located on the Afon Rhythallt, the name for the upper reaches of the Afon Seiont, and situated downstream of the Llyn Padarn Lake. The mean flow rates for the other three stations were all below 1 m^3s^{-1}.

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 the Environment Agency

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	Culverted stream	480	0.006	$2.50x10^9$
B	Culverted stream	21,000	0.01	$1.76 x10^{11}$
C	River (Afon Braint)	3,900	Too deep to measure	
D	Culverted outfall	530	Not possible to access	
E	Stream	310	0.067	$1.80 x10^{10}$
F	Stream	210	0.654	$1.19 x10^{11}$
G	Stream	490	0.075	$3.18 x10^{10}$

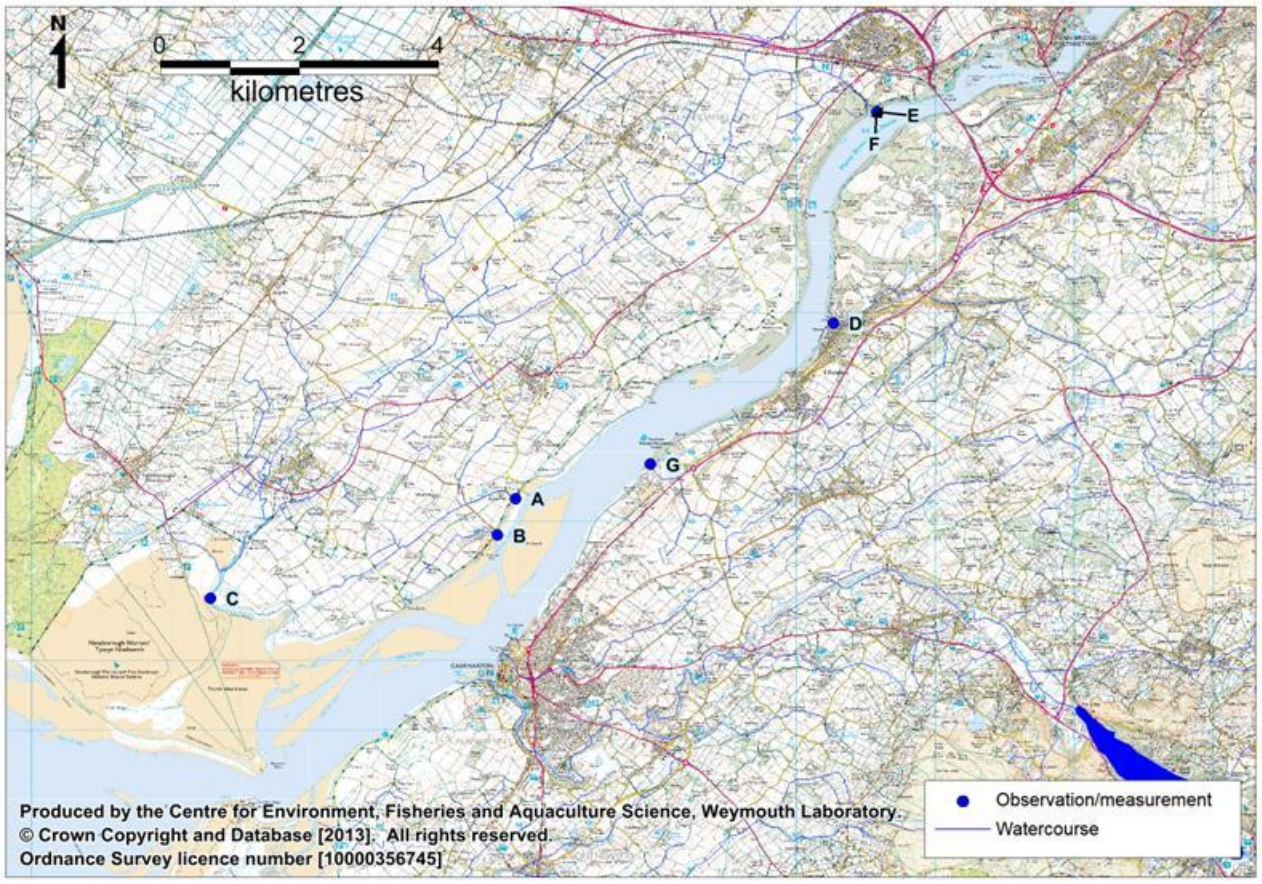

Figure VIII.3: Locations of shoreline survey stream observations

The *E. coli* loadings being carried by these watercourses at the time of shoreline survey were not particularly high, but high enough to be of some local significance. The Braint could not be measured due to its size, but a water sample contained 3900 *E. coli* cfu/100ml. This combined with its large size suggests that it is a highly significant contaminating influence on the cockle bed at Traeth Melynog, and quite likely beyond. None of the watercourses discharging in the Caernarfon area or to Foryd Bay were investigated but given their sizes and in some cases the urbanised nature of their lower reaches these are also likely to be of significant impact.

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 to the south of Puffin Island to its south western entrance at Abermenai Point. The eastern channel is about 7.5 km wide at its mouth, where there are extensive intertidal areas to the south of the subtidal channel. It becomes progressively narrower until The Swellies in the central reaches where it 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. The survey area lies to the west of The Swellies and its bathymetry is shown in (Figure IX.1).

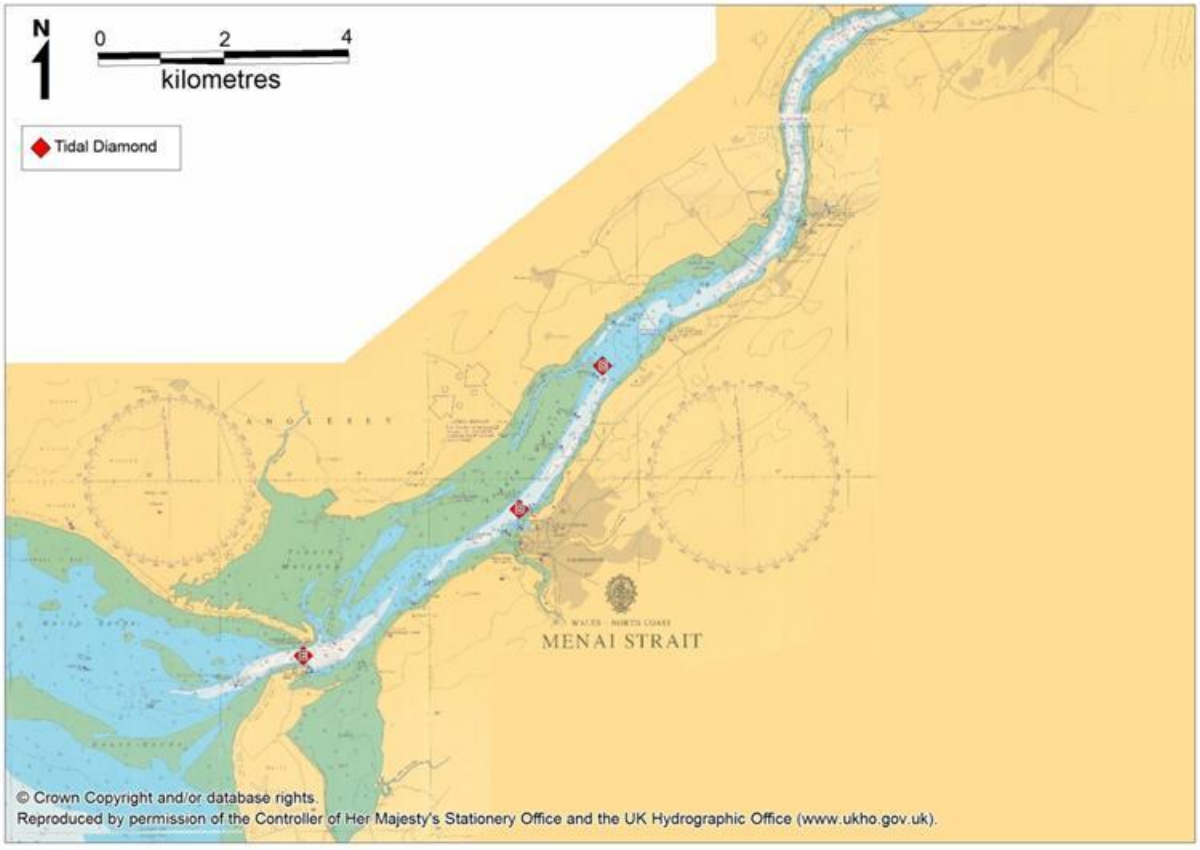

Figure IX.1: Bathymetry of the Menai Strait West

The subtidal channel in the western strait varies in depth from about 1-20 m relative to chart datum, and the intertidal areas gradually become more extensive towards its western end, and mainly lie on the Anglesey side. The western entrance is flanked by two sand spits, inside which lie two extensive intertidal sandy bays (Traeth Melynog and Foryd Bay), both of which form the estuaries of minor rivers (the Braint,

and the Gwyrfai respectively). Meandering river channels cut through these bays and subsequently join the main Menai channel a short distance inside the entrance to the strait. Within these river channels, relatively high concentrations of faecal indicator bacteria are likely to arise at lower states of the tide. There is a much narrower enclosed estuary where the River Seiont joins the strait just east of Caernarfon. The Nant y Garth (or Nant Heulin) watercourse at Y Felinheli discharges through an enclosed marina with lock gates that are generally kept closed at lower states of the tide. Both the western entrance and The Swellies represent constrictions in the strait, so increased tidal flows and turbulent mixing will occur in these areas. Contamination originating from outside of the western strait will therefore be well mixed in the water column as it enters the survey 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 IXX.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 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 Seiont estuary will fill during the flooding tide and empty during the ebbing tide, so any plume from here will mainly impact to the west of its mouth. A similar principle will apply to sources within Traeth Melynog and Foryd Bay. The Nant Y Garth (or Nant Heulin) at Y Felinheli will discharge intermittently as it flows into a gated marina, although if the gates are left open around high water, a west moving plume will arise as it drains during the early ebb tide.

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 three locations in the western strait on spring and neap tides and at hourly intervals before and after high water.

Table IX.2: The direction and rate of tidal streams at three locations within Menai Strait West on spring and neap tides and at hourly intervals before and after high water.

Time relative to high water	Station C			Station D (Caernarfon)			Station E (Fort Belan)		
	Direction	Rate (m/s)		Direction	Rate (m/s)		Direction	Rate (m/s)	
		Spring	Neap		Spring	Neap		Spring	Neap
HW-6	40	0.10	0.05	30	0.15	0.05	68	0.21	0.10
HW-5	30	0.77	0.36	44	0.87	0.41	83	0.82	0.41
HW-4	28	1.23	0.62	46	1.39	0.67	79	2.16	1.08
HW-3	31	1.29	0.62	52	1.85	0.93	82	2.62	1.29
HW-2	32	1.13	0.57	50	1.29	0.62	90	2.36	1.18
HW-1	33	0.51	0.26	51	0.57	0.26	95	1.03	0.51
HW	218	0.72	0.36	223	0.57	0.26	267	1.80	0.87
HW+1	218	1.08	0.51	235	1.03	0.51	267	2.21	1.08
HW+2	212	1.18	0.57	236	1.49	0.72	262	2.00	0.98
HW+3	206	0.93	0.46	224	1.39	0.67	259	1.64	0.82
HW+4	206	0.67	0.36	225	0.93	0.46	262	1.18	0.57
HW+5	204	0.36	0.21	226	0.62	0.31	280	0.51	0.26
HW+6		0.00	0.00		0.00	0.00		0.00	0.00
Excursion (flood)		18.1	8.9		22	10.5		33.1	16.5
Excursion (ebb)		17.8	8.9		21.7	10.5		33.7	16.5

Data from Admiralty Chart 1464 (maximum rates highlighted in yellow)

The tidal diamonds indicate that tide floods into the western strait in a north easterly direction from the Irish Sea and ebbs in the opposite direction, with tidal streams reversing just before high water. Currents in western strait are strongest at its entrance (Station E), recorded as 2.62 m/s on flood spring tides. Tidal currents are also 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 will be slower over the shallower and intertidal areas, particularly in Foryd Bay and Traeth Melynog. The estimates of tidal excursions based on these diamonds suggest that contamination may be carried considerable distances. They also suggest 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 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. Given the enclosed nature of the western strait strong wave action is not anticipated.

Freshwater inputs may significantly influence circulation patterns in coastal waters via density effects. 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. 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). It is however likely that localised decreases in salinity are associated with the main freshwater inputs, and within such areas higher levels of runoff borne contamination are likely to arise.

Appendix X. Microbiological Data: Seawater

X.1. Bathing Waters

There are no bathing waters designated under the Directive 76/160/EEC (Council of the European Communities, 1975) which are relevant to the survey area.

X.2. Shellfish Waters

Summary statistics and geographical variation

There are two shellfish water sites designated under Directive 2006/113/EC (European Communities, 2006) in the western strait. Figure X.1 shows their location. Table X.1 presents summary statistics for bacteriological monitoring results and Figure X.2 presents a boxplot of faecal coliforms levels from the two monitoring points.

Figure X.1: Location of shellfish waters sampling points in the western Menai Strait

Table X.1: 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
Foryd Bay	47	07/01/2003	11/07/2013	6.5	<2	677	4.3%
Menai Strait West	50	07/01/2003	15/11/2013	17.4	<2	342	12.0%

Data from the Environment Agency

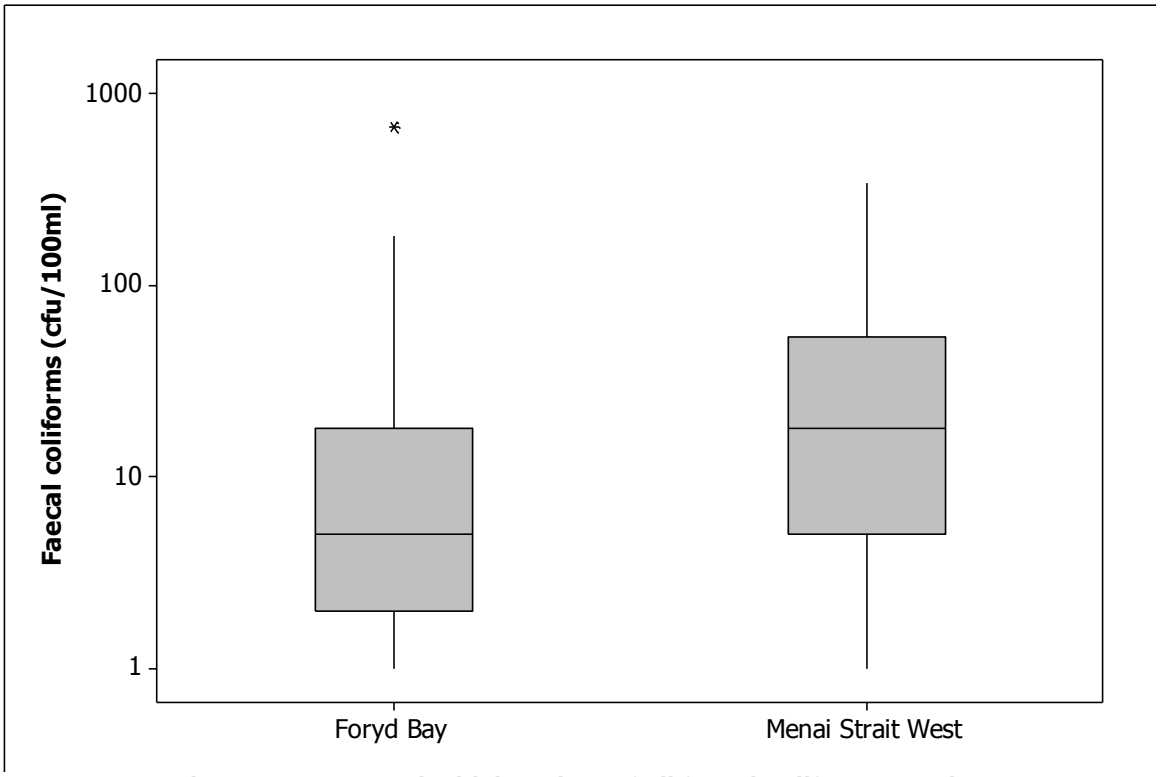

Figure X.2: Box-and-whisker plots of all faecal coliforms results
Data from the Environment Agency

Results were significantly higher on average at Menai Strait West (One-way ANOVA, p=0.002). A comparison of paired (same day) sample results revealed a strong correlation (Pearsons correlation, r=0.531, p=0.000) suggesting that the two locations share similar sources of contamination.

Overall temporal pattern in results

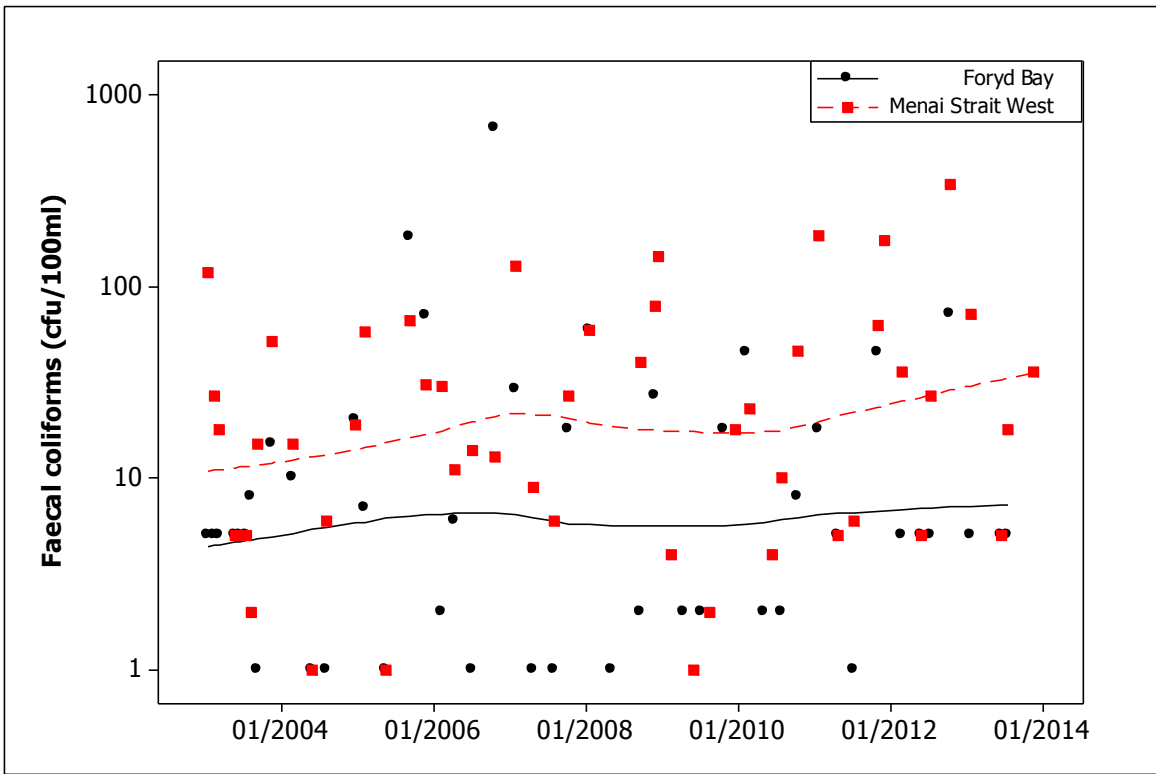

Figure X.3: Scatterplot of faecal coliform results by date, overlaid with loess lines
Data from the Environment Agency

Figure X.3 shows that faecal coli form levels remained stable at Foryd Bay throughout the period considered, but there appears to have been a slight increase on average at Menai Strait West.

Seasonal patterns of results

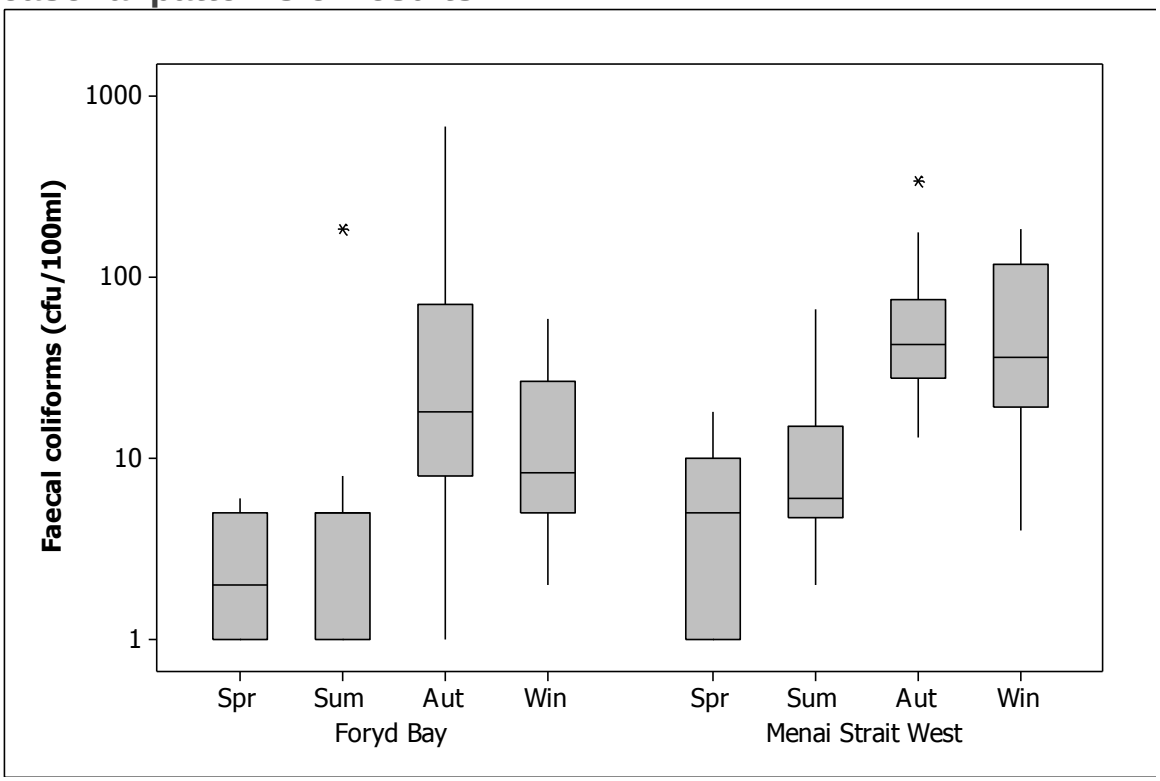

Figure X.4: Boxplot of faecal coliform results by season
Data from the Environment Agency

Similar patterns of higher results in the autumn and winter are apparent at both locations. The seasonal variation was statistically significant at both (One-way ANOVA, p=0.001 or less). At Foryd Bay results were significantly higher in the autumn and winter compared to the spring and summer. At Menai Strait West results were significantly higher in the autumn than in the spring and summer, and significantly higher in the winter than in the spring.

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.2, where significant correlations are 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**
Foryd Bay	0.392	0.001	0.313	0.013
Menai Strait West	0.058	0.852	0.203	0.145

Data from the Environment Agency

Figure X.5 presents polar plot of $\log_{10}$ *E. coli* results against tidal states on the high/low cycle for Foryd Bay. High water at Menai Bridge is at 0° and low water is at 180°.

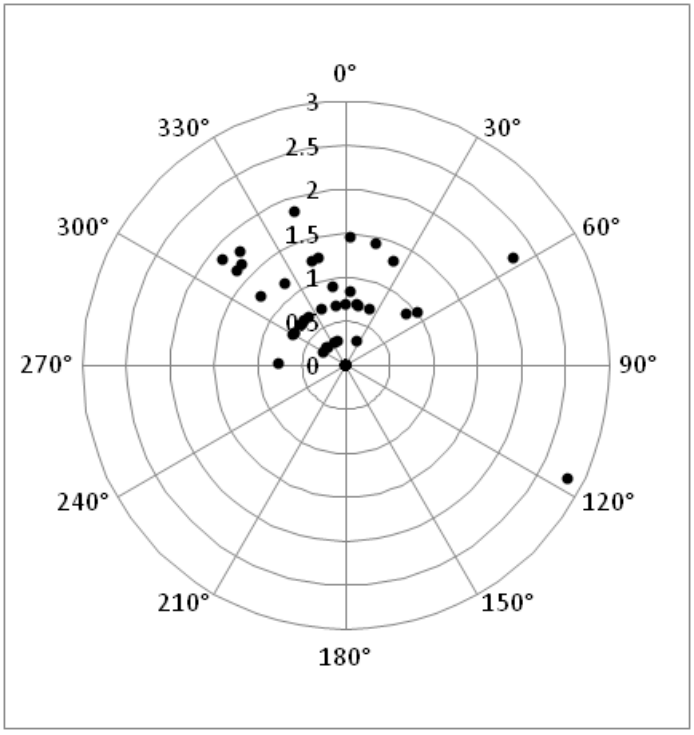

Figure X.5: Polar plot of $\log_{10}$ faecal coliforms at Foryd Bay against tidal state on the high/low tidal cycle

Sampling was targeted towards high water and no strong patterns are apparent in the plot.

Figure X.6 presents a polar plot of $\log_{10}$ *E. coli* results against the spring neap tidal cycle for Foryd Bay. 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.

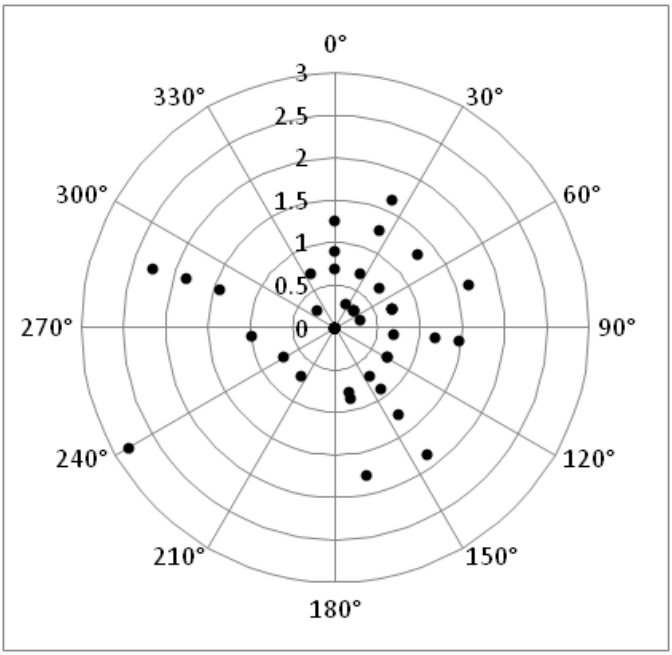

Figure X.5: Polar plot of log_{10} faecal coliforms at Foryd Bay against tidal state on the high/low tidal cycle

Despite the significant correlation there is no strong pattern apparent in the polar plot.

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.3.

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

	Site	Foryd Bay	Menai Strait West
	n	47	49
24 hour periods prior to sampling	1 day	0.118	0.263
	2 days	0.210	0.215
	3 days	0.073	0.141
	4 days	0.272	0.342
	5 days	0.079	0.213
	6 days	0.079	0.230
	7 days	0.231	0.276
Total prior to sampling over	2 days	0.312	0.294
	3 days	0.285	0.289
	4 days	0.318	0.313
	5 days	0.313	0.335
	6 days	0.307	0.353
	7 days	0.289	0.362

Data from the Environment Agency

Some influence of rainfall was detected, and at both sites the strongest effect was following rainfall events four days prior to sampling.

Influence of salinity

Salinity was recorded on most sampling occasions. Figure X.6 shows scatter-plots of faecal coliforms against salinity at the two monitoring points. Pearson's correlations were run to determine the effect of salinity on faecal coliforms at shellfish waters sites.

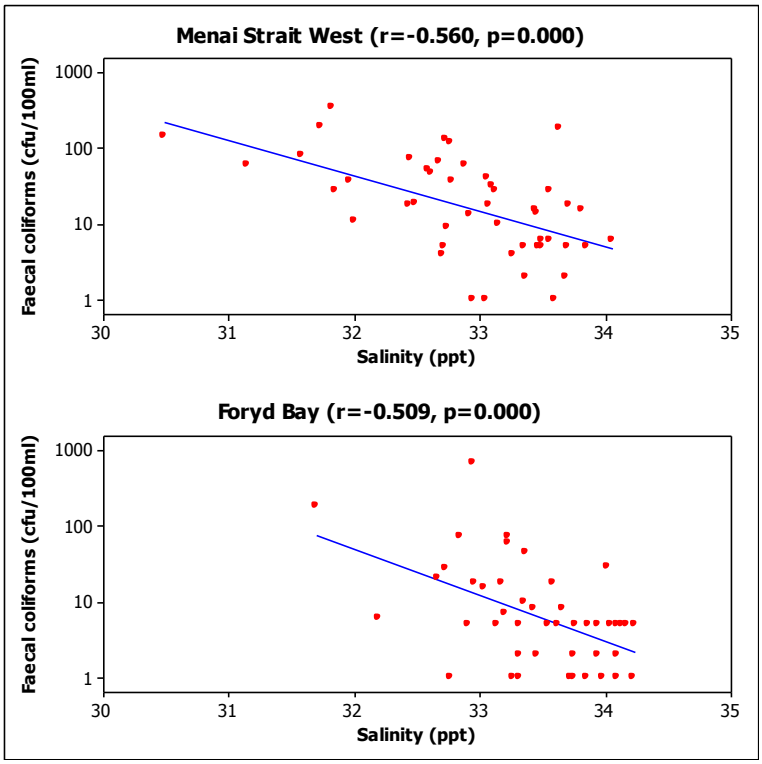

Figure X.6 Scatterplots of faecal coliforms against salinity at the shellfish waters monitoring points.
Data from the Environment Agency.

There were significant correlations between salinity and faecal coliform concentrations at both sites. These correlations were very strong suggesting that land runoff is a highly significant contaminating influence.

Appendix XI. Microbiological Data: Shellfish Flesh Hygiene

XI.1. Summary statistics and geographical variation

There are a total of six RMPs in the Menai Strait West production area that have been sampled between 2003 and 2013. Four of these RMPs are for mussels, one is for cockles and one is for pacific oysters. 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 shown in Figure XI.2 to Figure XI.4.

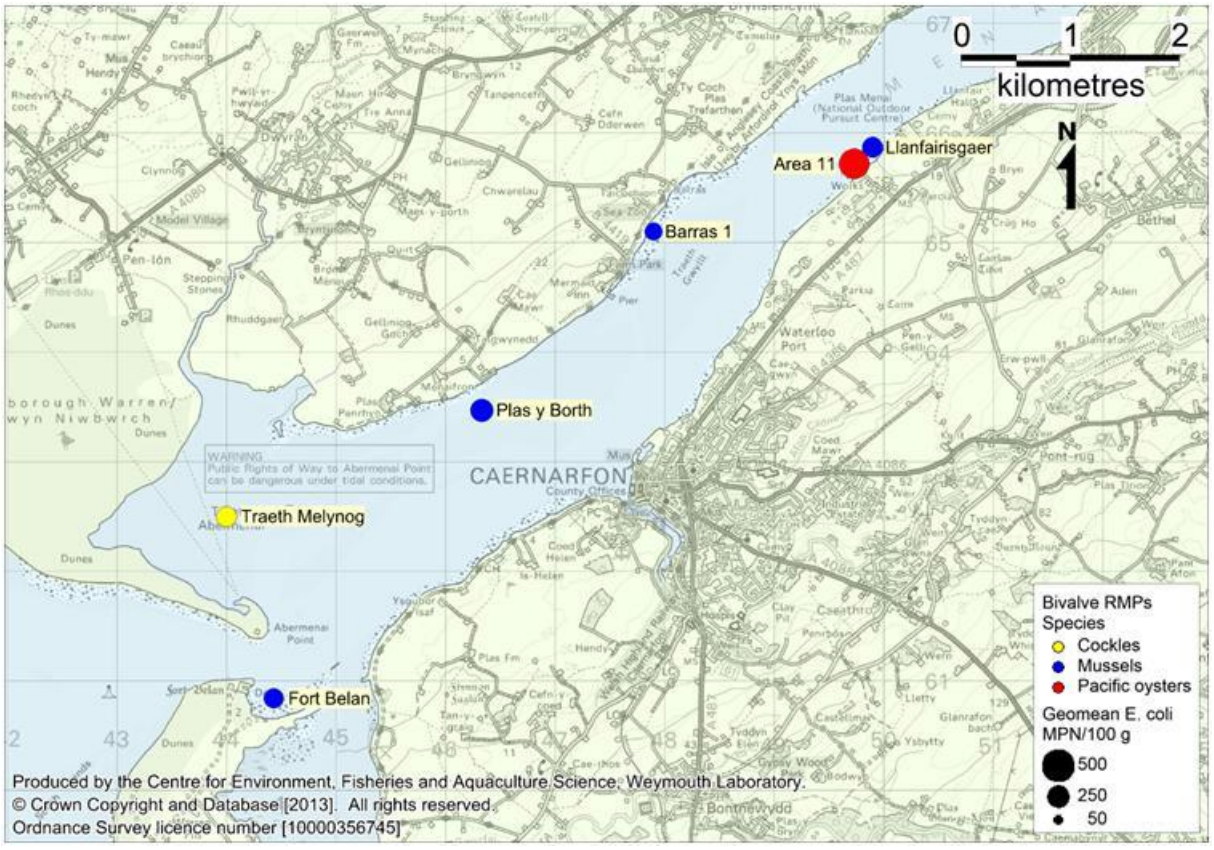

Figure XI.1: Bivalve RMPs active since 2003

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
Traeth Melynog	Cockle	103	28/01/2003	21/10/2013	234.1	<20	>18000	47.6	3.9
Llanfairisgaer	Mussel	101	07/01/2003	11/11/2013	221.4	20	3500	47.5	0.0
Barras 1	Mussel	149	28/01/2003	14/10/2013	183.4	<20	16000	42.3	1.3
Plas y Borth	Mussel	75	19/07/2006	13/04/2011	284.4	<20	16000	61.3	2.7
Fort Belan	Mussel	76	08/08/2006	11/11/2013	206.8	20	9200	50.0	1.3
Area 11	Pacific oyster	78	23/08/2005	23/09/2013	449.3	20	>18000	75.6	7.7

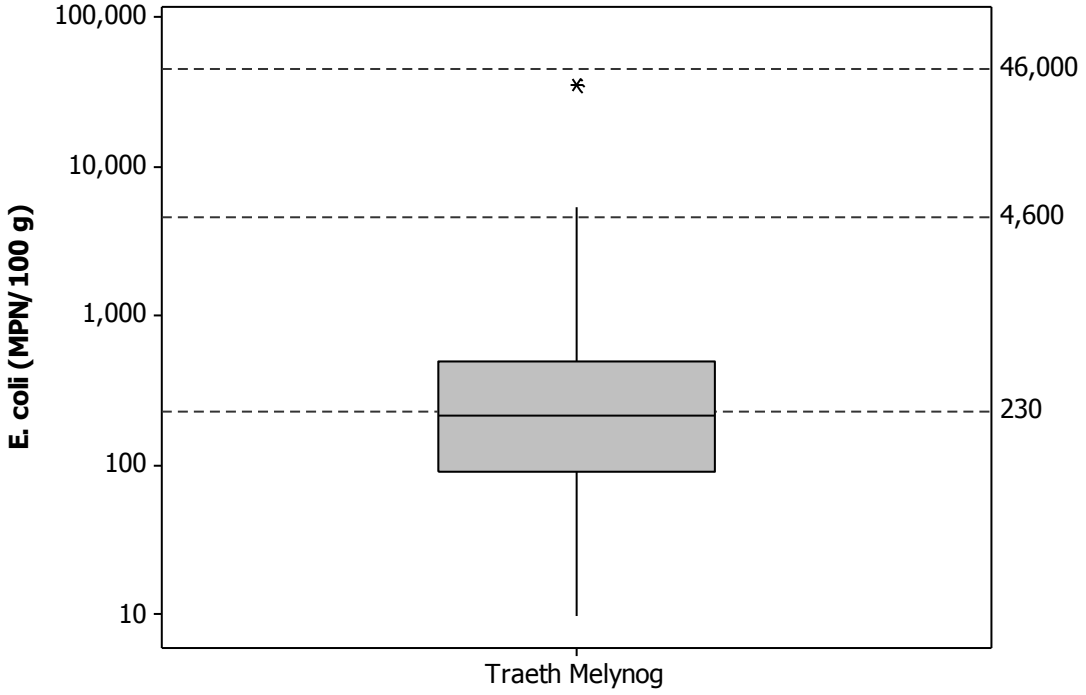

Figure XI.2: Boxplots of *E. coli* results from cockle RMPs from 2003 onwards.

At Traeth Melynog, *E. coli* numbers in cockles exceeded 4,600 MPN/100g in 3.9 % of samples, and the maximum recorded result was >18,000 MPN/100g.

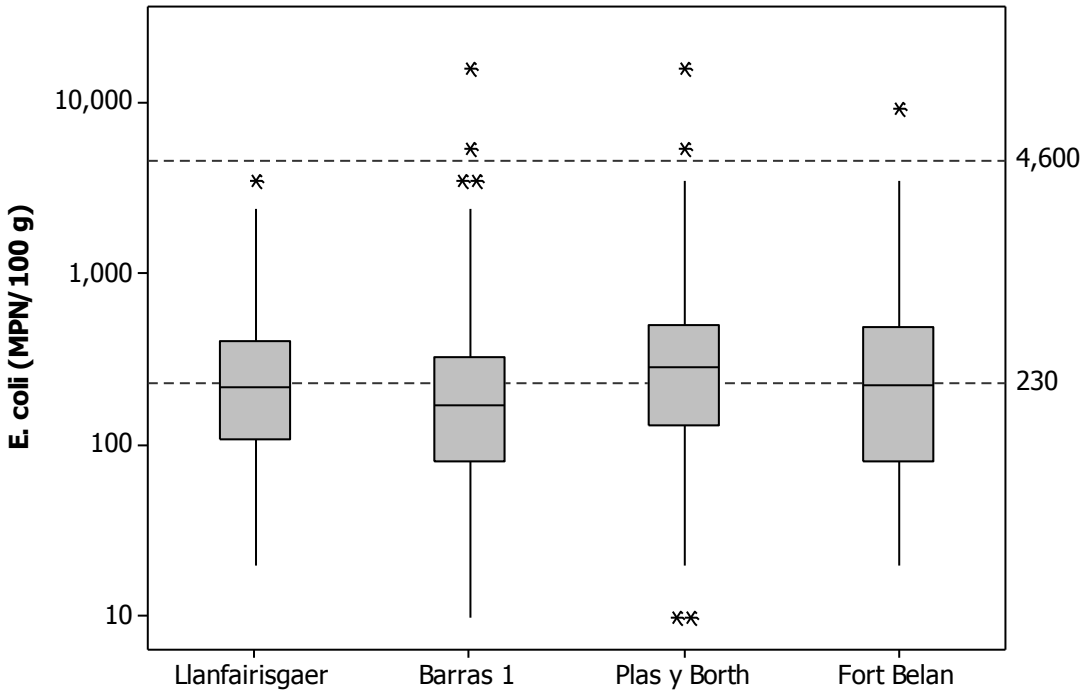

Figure XI.3: Boxplots of *E. coli* results from mussel RMPs from 2003 onwards.

The distribution of results was very similar across all four of these RMPs, and no evidence of an overall gradient of increasing or decreasing contamination towards the central part of

the strait. The highest average result (284 MPN/100g) and proportion of results exceeding 4600 MPN/100g (2.7 %) was recorded Plas y Borth, although the results cover a slightly shorter period than the others. A one-way ANOVAs showed no significant differences in average *E. coli* levels between sites (p=0.118).

Comparisons of RMPs were carried out on a pair-wise basis by running correlations (Pearson's) between sites that shared sampling dates, and therefore environmental conditions, on at least 20 occasions. Only two sites (Barras 1 and Plas y Borth) shared 20 or more sampling dates. There was a significant correlation between *E. coli* results at these sites, indicating that they share similar contamination sources.

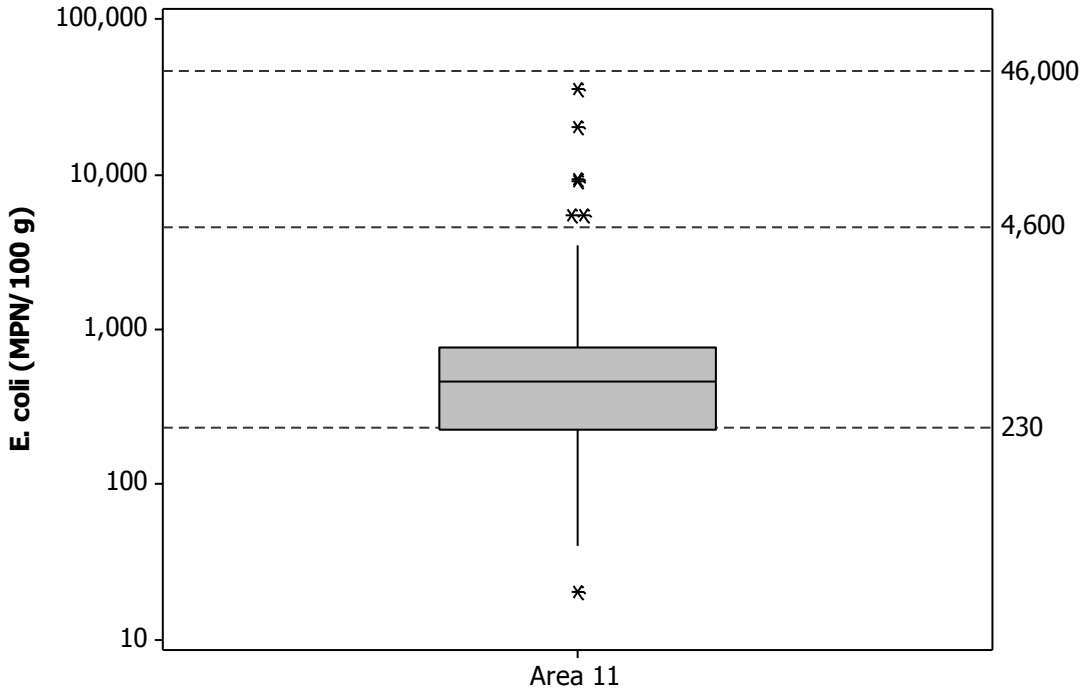

Figure XI.4: Boxplots of *E. coli* results from Pacific oyster RMPs from 2003 onwards.

At Area 11, *E. coli* numbers in Pacific oysters were higher on average and in terms of the percentage exceeding 4600 MPN/100g than at any of the cockle or mussel RMPs. Whether this is attributable to the species or the location sampled, or a combination of the two, is uncertain. This RMP is also used to classify both Area 11 and another oyster trestle site on the opposite bank. The high proportion of results exceeding 4600 MPN/100g (7.7 %) suggests that class B compliance may be borderline at times. Separate monitoring of the two sites may therefore be advisable to ensure the unmonitored site is compliant with class B, and to avoid any issues whereby it may be downgraded on the basis of results from Area 11.

XI.2. Overall temporal pattern in results

The overall variation in *E. coli* levels found in bivalves is shown in Figure XI.5 to Figure XI.7.

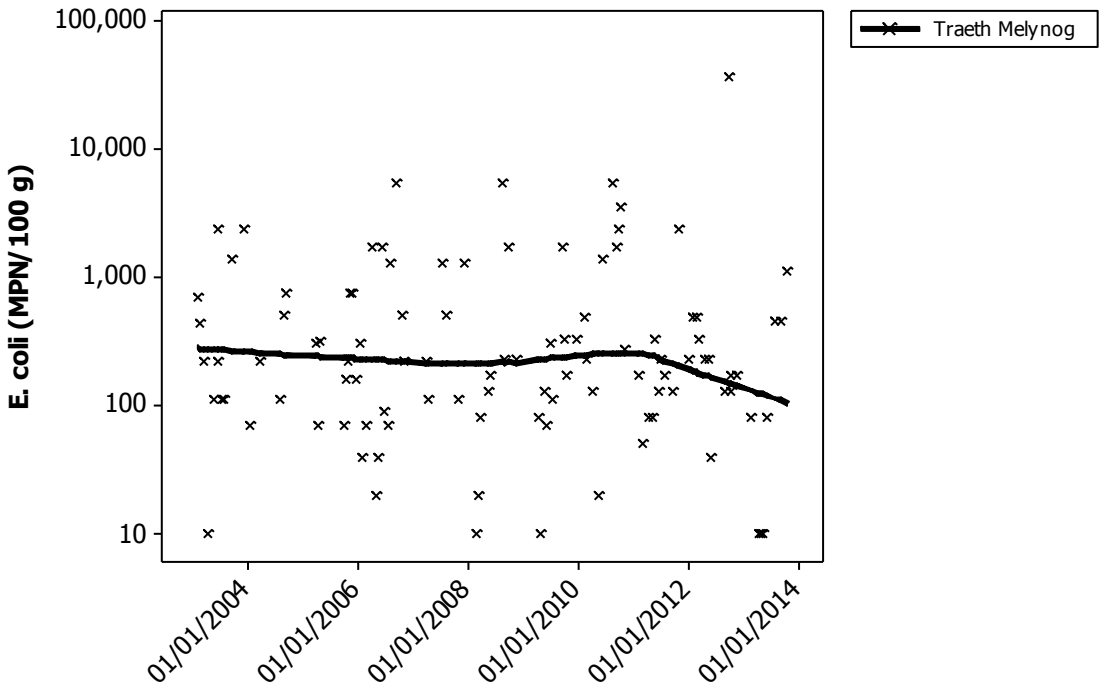

Figure XI.5: Scatterplot of *E. coli* results for cockles overlaid with loess line.

E. coli levels have remained stable at Traeth Melynog with a slight decrease from 2011 to present.

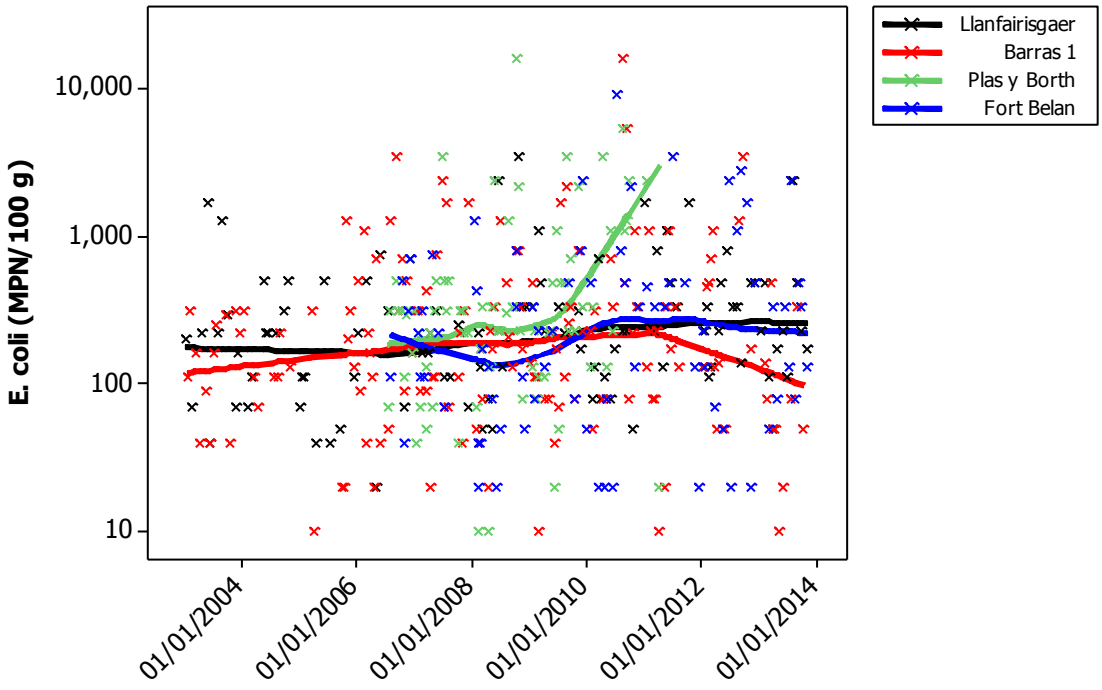

Figure XI.6: Scatterplot of *E. coli* results for mussels overlaid with loess line.

E. coli levels have remained stable at most mussel RMPs. However, at Plas y Borth, there was an increase in *E. coli* levels before sampling stopped in 2011.

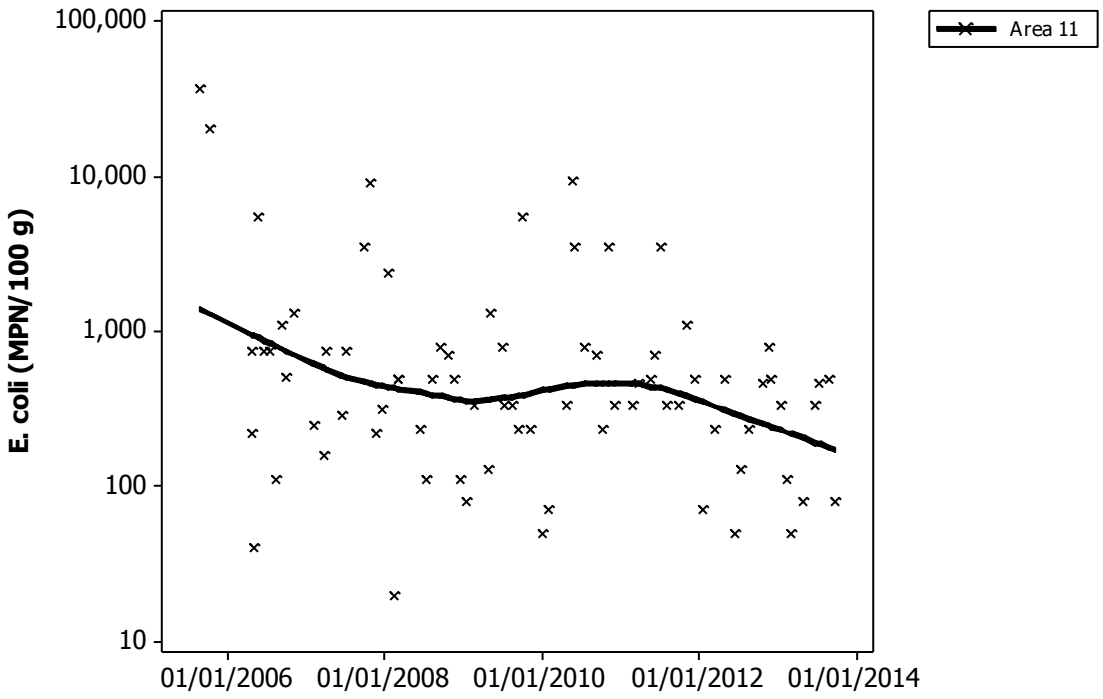

Figure XI.7: Scatterplot of *E. coli* results for Pacific oysters overlaid with loess line.

At Area 11, *E. coli* levels have fallen by almost an order of magnitude overall since 2003, suggesting that borderline class B compliance is no longer such an issue.

XI.3. Seasonal patterns of results

The seasonal patterns of results from 2003 to 2013 were investigated by species and RMP. Figure XI.8 to Figure XI.10 show the variation in *E. coli* levels between seasons at different RMPs.

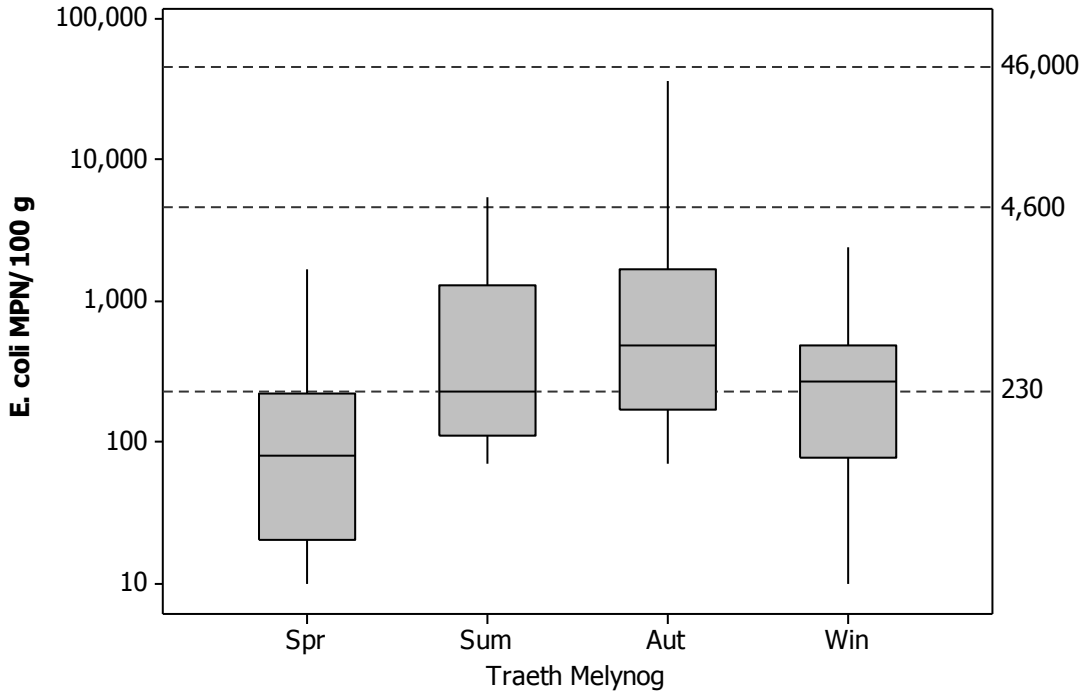

Figure XI.8: Boxplot of *E. coli* results for cockles by RMP and season

At Traeth Melynog, there were significant differences in *E. coli* levels found in cockles between seasons (one-way ANOVA, p<0.001). Post ANOVA Tukey tests showed that significantly lower levels of *E. coli* were found during spring than during any other season.

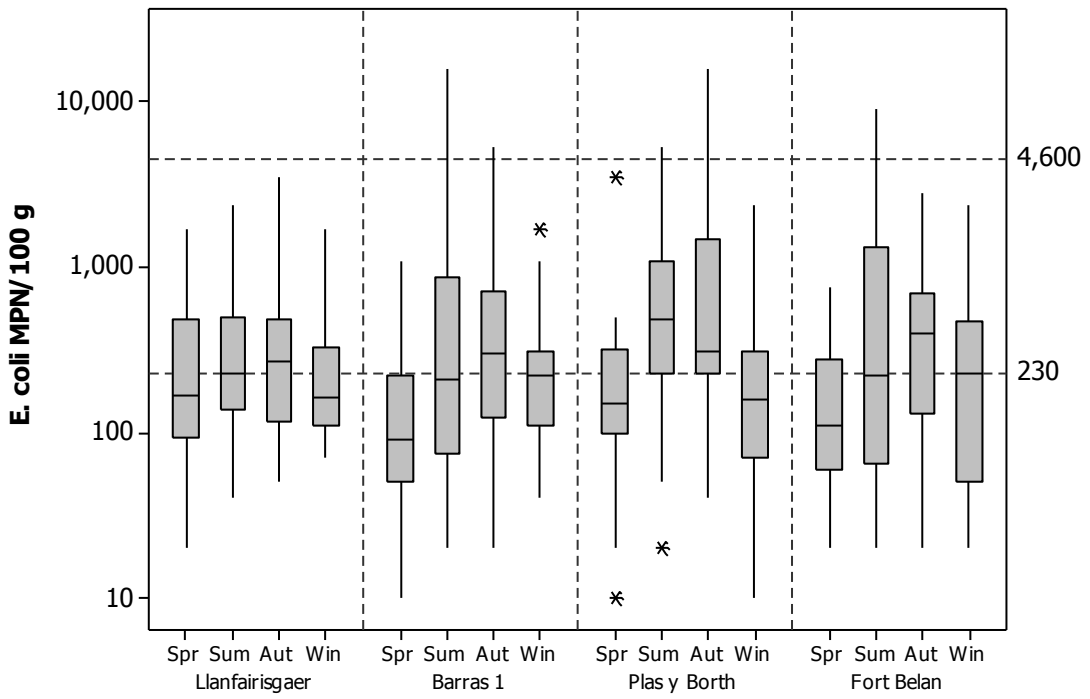

Figure XI.9: Boxplot of *E. coli* results for mussels by RMP and season

The Llanfairisgaer and Fort Belan mussel RMPs did not have significant variation between seasons (one-way ANOVA, p=0.292 and 0.134 respectively). At the Barras 1 and Plas y

Borth mussel RMPs significant variation in *E. coli* level between seasons was found (p = 0.001 and 0.005 respectively). At Barras 1, *E. coli* levels were lower in spring than in summer and autumn. At Plas y Borth, *E. coli* levels were higher in autumn than in spring and winter.

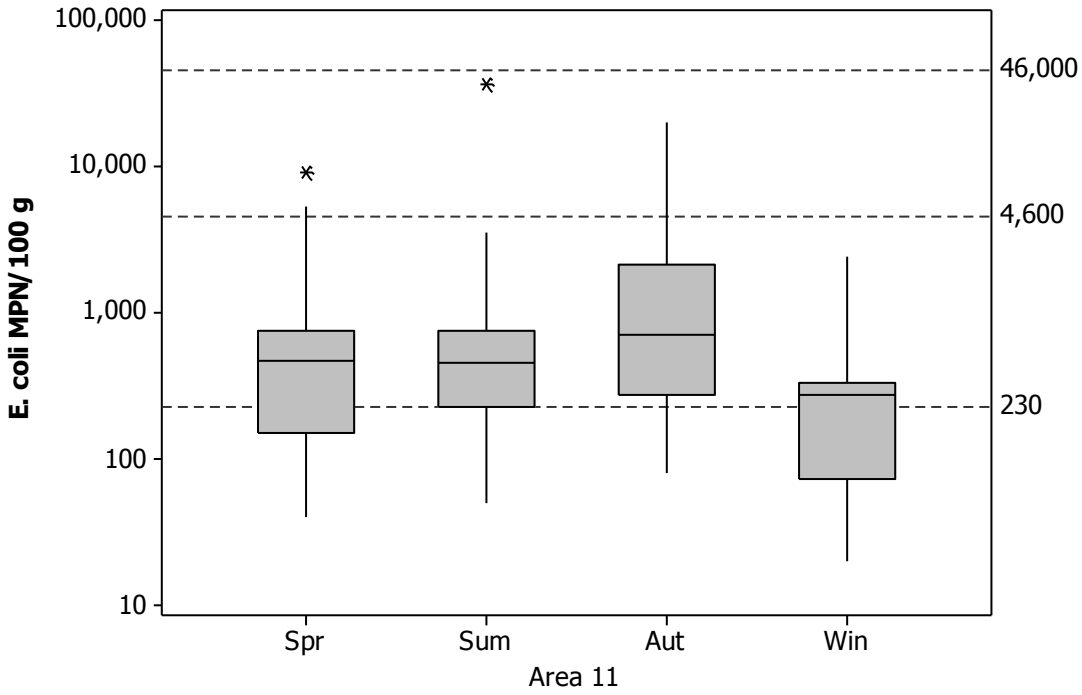

Figure XI.10: Boxplot of *E. coli* results for Pacific oysters by RMP and season

At Area 11, *E. coli* levels in Pacific oyster were found to vary significantly between seasons (one-way ANOVA, p=0.010). Post ANOVA Tukey tests showed that *E. coli* levels were higher in autumn than winter.

XI.4. Influence of tide

To investigate the effects of tidal state on *E. coli* results, circular-linear correlations were carried out against the high/low tides at Menai Bridge 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**
Traeth Melynog	Cockle	0.140	0.140	0.059	0.708
Llanfairisgaer	Mussel	0.158	0.088	0.080	0.536
Barras 1	Mussel	0.222	0.001	0.351	0.000
Plas y Borth	Mussel	0.157	0.171	0.251	0.011
Fort Belan	Mussel	0.231	0.020	0.192	0.068
Area 11	Pacific oyster	0.097	0.493	0.288	0.002

Figure XI.11 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 4600 are plotted in yellow, and those exceeding 4600 are plotted in red.

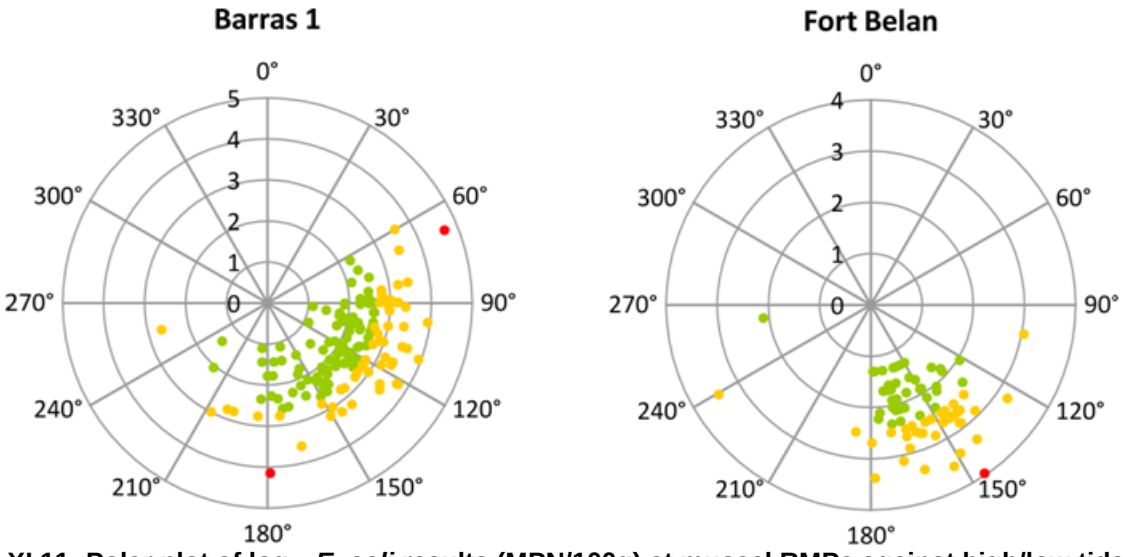

Figure XI.11: Polar plot of $\log_{10}$ *E. coli* results (MPN/100g) at mussel RMPs against high/low tidal state

Although significant correlations were detected, sampling was targeted towards low water and there are no patterns apparent in the polar plots.

Figure XI.12 and Figure XI.13 present polar plots of $\log_{10}$ *E. coli* results against the spring neap tidal cycle for each RMP where a significant correlation was detected. 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.

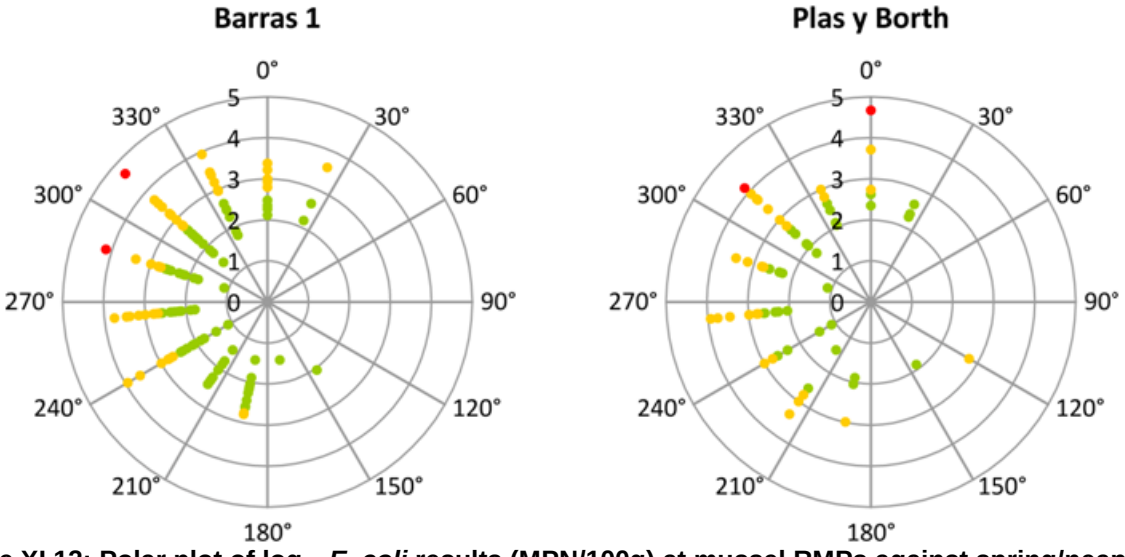

Figure XI.12: Polar plot of $\log_{10}$ *E. coli* results (MPN/100g) at mussel RMPs against spring/neap tidal state

At both these mussel RMPs, sampling was targeted towards neap and increasing tides. Both plots appear to show a tendency for lower results on average around neap tides, although it must be noted that only part of the cycle is represented.

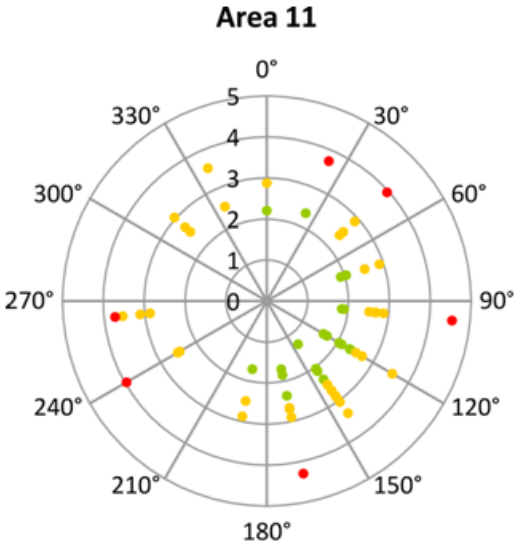

Figure XI.13: Polar plot of log10 *E. coli* results (MPN/100g) at Pacific oyster RMPs against spring/neap tidal state

At Area 11, fewer low results were recorded as tide size increased from neaps to springs.

XI.5. 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

	Site	Traeth Melynog	Llanfairisgaer	Barras 1	Plas y Borth	Fort Belan	Area 11
	Species	Cockle		Mussel			Pacific oyster
	n	98	94	144	75	68	72
24 hour periods prior to sampling	1 day	0.137	0.125	0.158	0.180	0.261	0.134
	2 days	0.316	0.184	0.303	0.148	0.434	0.197
	3 days	0.198	0.250	0.334	0.220	0.410	0.118
	4 days	0.066	0.224	0.247	0.142	0.140	0.170
	5 days	0.021	0.219	0.139	0.072	0.016	0.064
	6 days	0.099	0.037	0.066	0.041	0.119	0.114
	7 days	0.065	0.162	0.193	0.079	0.181	-0.020
Total prior to sampling over	2 days	0.297	0.127	0.299	0.199	0.404	0.303
	3 days	0.280	0.185	0.377	0.232	0.453	0.242
	4 days	0.281	0.227	0.418	0.267	0.436	0.278
	5 days	0.232	0.249	0.418	0.247	0.375	0.226
	6 days	0.203	0.230	0.384	0.251	0.336	0.214
	7 days	0.225	0.220	0.372	0.295	0.328	0.196

All sites showed some influence of antecedent rainfall. Traeth Melynog responded strongly two days after a rainfall event. Across the mussel sites, the influence was strongest at Barras 1 and weakest at Plas y Borth. The influence was relatively weak at Area 11.

Appendix XII. Shoreline Survey Report

Date (time):
30th October 2013 (11:15-12:30
12th November 2013 (10:00-14:40)

Cefas Officers:
Simon Kershaw & Rachel Parks

Area surveyed:
Western end of the Menai Strait, from Britannia Bridge to Abermenai Point.

Weather:
30th October 13:00, partially cloudy, 11°C, wind bearing 168° at 16 km/h
12th November 13:00, partially cloudy, 10°C, wind bearing 305° at 14 km/h

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

30/10/2013			12/11/2013		
High	07:23	6.1 m	High	06:02	6.3 m
High	19:36	6.5 m	High	18:16	6.7 m
Low	01:30	2.2 m	Low	12:28	2.1 m
Low	13:47	2.4 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.1.

The shoreline survey required two separate fieldwork trips, one in September and another in November. The September trip incorporated pedestrian surveys for Anglesey and the Menai Strait East production area, when spot samples were taken at points not accessible by boat. 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. Description of Fishery

A meeting was held with a representative of the Bangor Mussel Producers Association during the September visit. Information was received on the location of the culture fisheries and their *modus operandus*, which is presented in the shellfisheries section (section 4) of this report.

XII.2. Sources of contamination

Sewage discharges

Two possible intermittent water company discharges for the Felinheli pumping station were seen (observations 5 and 7). The discharges were discharging approximately $1.40x10^{11}$ and $3.57x10^{9}$ *E. coli* cfu/day when measured. The location of another possible intermittent water company discharge, Waterloo Port pumping station was also identified (observation 27). This pumping station was found to be discharging approximately $1.02x10^{10}$ *E. coli* CFU/day. None were carrying the high *E. coli* levels typically associated with storm sewage however.

The locations of two sewage treatment works (STW) discharges were confirmed. Both discharges were submerged and so it was not possible to measure flow rates. However a sample of the seawater adjacent to the Treborth STW outfall (observation 11) was taken and was found to contain 310 *E. coli* cfu/100 ml. No sample was taken from the Brynsiencyn STW outfall (observation 20).

The locations of two private consents were confirmed (observations 28 and 29) but no measurements or samples were possible from these discharges as one was submerged and the other went to ground. Both were trade waste water discharges. Observation 18 was possibly an overflow from the Conwy Centre septic tank, but no sample was possible from this outfall.

Freshwater inputs

Four of the watercourses flowing into the strait were observed. One of these (observation 3) was too deep for flow and depth measurements to be taken, but had an *E. coli* concentration of 3,900 cfu/100 ml. The relatively high level of *E. coli* in this watercourse is probably due to the outfalls from the Newborough STW that are located approximately 300m upstream of this observation.

A culverted stream (observation 4) was found to have an *E. coli* concentration of 21,000 cfu/100 ml and a loading of $1.76x10^{11}$ cfu/day. There are no consented discharges flowing into this watercourse; however it does flow through agricultural land.

Another watercourse (observation 14) split into two separate streams (observation 15 and 16) that ran into the strait. These streams were found to have a combined loading of $1.37x10^{11}$ *E. coli* cfu/day.

Observation 31 was a stream which has a discharge from a meat processing operation flowing into it. It had and *E. coli* concentration of 490 cfu/100 ml and a loading of $3.18x10^{10}$ cfu/day.

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

Sheep were observed in fields on both the mainland (observation 9) and on Anglesey (observations 10, 19 and 21).

Wildlife

Flocks of birds were seen throughout the survey area, these are detailed in table I.1 below.

Figure XII.1: 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 47952 65323	30/10/2013	11:16	Culverted stream (valved pipe) (sample GT04)	Figure XII.4
2	SH 47690 64800	30/10/2013	11:33	Culverted stream (valved pipe) (sample GT05)	Figure XII.5
3	SH 43560 63896	30/10/2013	12:07	River. Too deep to measure (sample GT06)	Figure XII.6
4	SH 42974 64939	30/10/2013	12:29	Pumping station	Figure XII.7
5	SH 52319 67540	12/11/2013	10:15	Felinheli PS† discharge, pipe (38cm diameter 3cm flow depth) (sample MW01)	Figure XII.8
6	SH 52306 67639	12/11/2013	10:23	2 pipes in wall not flowing	Figure XII.9
7	SH 52453 67813	12/11/2013	10:26	Felinheli PS overflow, Pipe (6 seconds to fill bucket 8 litres) (sample MS02)	Figure XII.10
8	SH 52526 67847	12/11/2013	10:31	Culverted outflow, flowing rapidly, not possible to access (sample MS03)	Figure XII.11
9	SH 52805 70329	12/11/2013	10:51	30 sheep in field on mainland	
10	SH 53326 70822	12/11/2013	10:55	50 sheep in field on Anglesey	
11	SH 53792 70882	12/11/2013	10:57	Treborth STW‡, underwater discharge (sample taken from bubbling water) (sample MS04)	
12	SH 54089 71089	12/11/2013	11:10	Surface water pipe	
13	SH 53159 70883	12/11/2013	11:18	Pipe from house. Not flowing	Figure XII.12
14	SH 53154 70889	12/11/2013	11:18	Stream splits into 2 streams	
15	SH 53154 70889	12/11/2013	11:18	Stream 1 (observation 14) (sample MS05)	
16	SH 53154 70889	12/11/2013	11:18	Stream 2 (observation 14) (sample MS06)	
17	SH 53123 70891	12/11/2013	11:25	2 pipes under water	Figure XII.13
18	SH 52313 69965	12/11/2013	11:59	Possibly Conwy Centre septic tank overflow. Pipe. Covered with seaweed and raised.	Figure XII.14
19	SH 51047 66890	12/11/2013	12:12	100 sheep in field on Anglesey	
20	SH 49356 66260	12/11/2013	12:18	Brynsiencyn STW. Outfall underwater. Green marker	Figure XII.15
21	SH 48873 65269	12/11/2013	12:22	500 birds, 100 sheep (on Anglesey)	
22	SH 44370 61231	12/11/2013	12:35	Entrance to the strait	Figure XII.16
23	SH 44889 61128	12/11/2013	12:42	30 birds onshore, 40 birds on sand flats	
24	SH 47293 62963	12/11/2013	12:53	100 birds onshore in front of castle	
25	SH 47607 63066	12/11/2013	12:58	Pipe into sea	
26	SH 48055 63402	12/11/2013	13:03	3 valved pipes, not flowing	Figure XII.17
27	SH 48599 64147	12/11/2013	13:09	Waterloo Port PS. Pipe 2.5 seconds to fill bucket (sample MS07)	Figure XII.18

28	SH 49416 65368	12/11/2013	13:27	Trade waste. Large pipe, half submerged	Figure XII.19
29	SH 49746 65749	12/11/2013	10:01	Trade waste. Concrete structure with pipes going to ground	Figure XII.20
30	SH 49746 65749	12/11/2013	10:57	60 birds	
31	SH 49890 65821	12/11/2013	11:21	Stream with meat processing discharge upstream. (sample MS08)	Figure XII.21
32	SH 49990 66044	12/11/2013	14:14	Surface water pipe, not flowing	

†PS is pumping station. ‡STW is sewage treatment works.

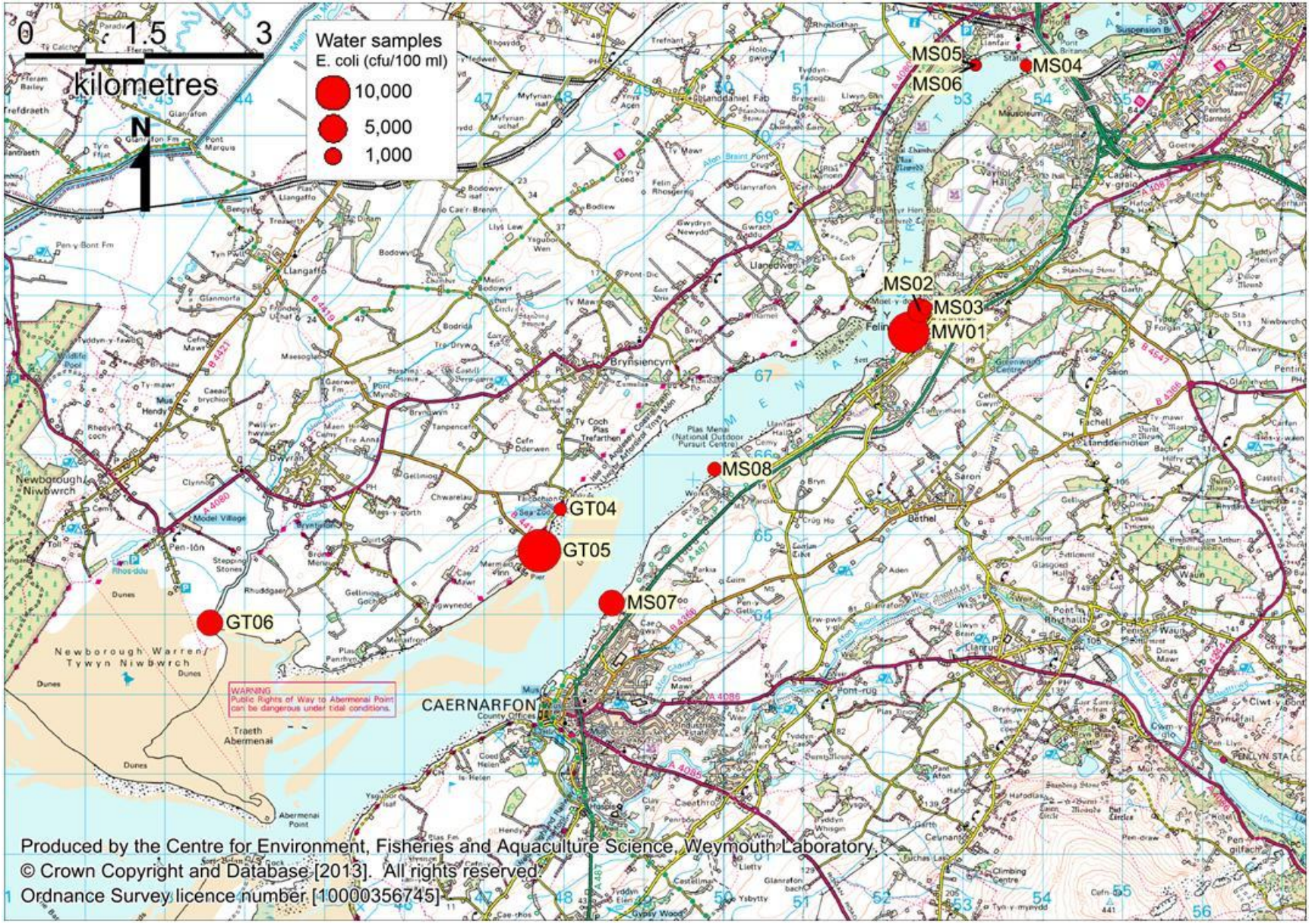

Figure XII.2: Water sample results (Table XII.2 for details)

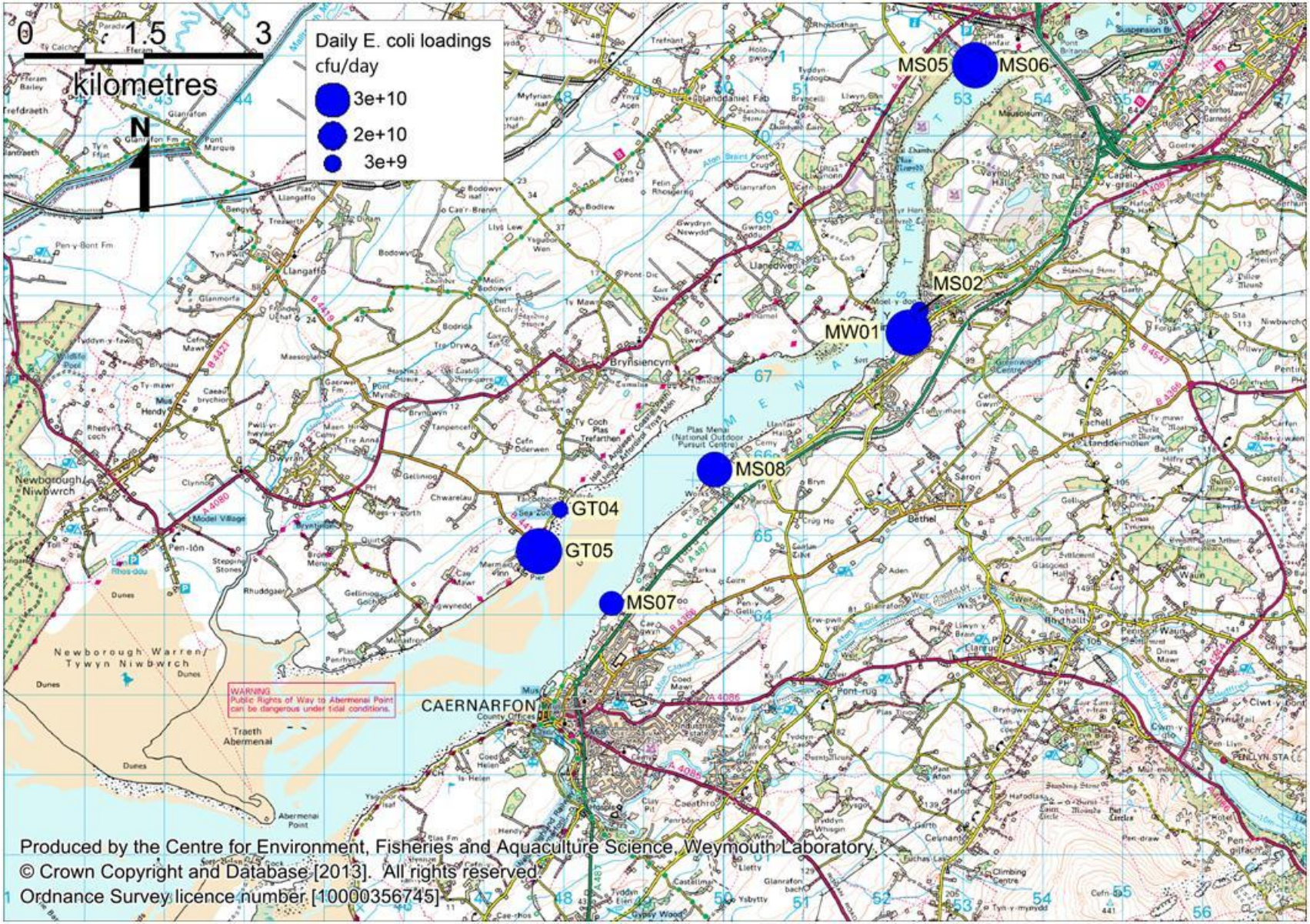

Figure XII.3: *E. coli* stream loadings (Table XII.2 for details).

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

Sample ID	Observation number	Date and time	Water type	Description	Flow (m^3/s)	*E. coli* concentration (CFU/100 ml)	*E. coli* loading (CFU/day)	NGR
GT04	1	30/10/2013 11:16	FW	Culverted stream	0.006	480	$2.50x10^{9}$	SH 47952 65323
GT05	2	30/10/2013 11:33	FW	Culverted stream	0.010	21,000	$1.76 x10^{11}$	SH 47690 64800
GT06	3	30/10/2013 12:07	FW	River		3,900		SH 43560 63896
MW01	5	12/11/2013 10:15	FW	Possible PS outfall	0.009	18,000	$1.40 x10^{11}$	SH 52319 67540
MS02	7	12/11/2013 10:26	FW	Possible PS outfall	0.001	3,100	$3.57 x10^{9}$	SH 52453 67813
MS03	8	12/11/2013 10:31	FW	Flow from lock		530		SH 52526 67847
MS04	11	12/11/2013 10:57	SW	Adjacent to STW outfall		310		SH 53792 70882
MS05	15	12/11/2013 11:18	FW	Stream	0.067	310	$1.80 x10^{10}$	SH 53154 70889
MS06	16	12/11/2013 11:18	FW	Stream	0.654	210	$1.19 x10^{11}$	SH 53154 70889
MS07	27	12/11/2013 13:09	FW	Possible PS outfall		3,700	$1.02 x10^{10}$	SH 48599 64147
MS08	31	12/11/2013 13:34	FW	Stream	0.075	490	$3.18 x10^{10}$	SH 49890 65821

Figure XII.4

Figure XII.5

Figure XII.6

Figure XII.7

Figure XII.8

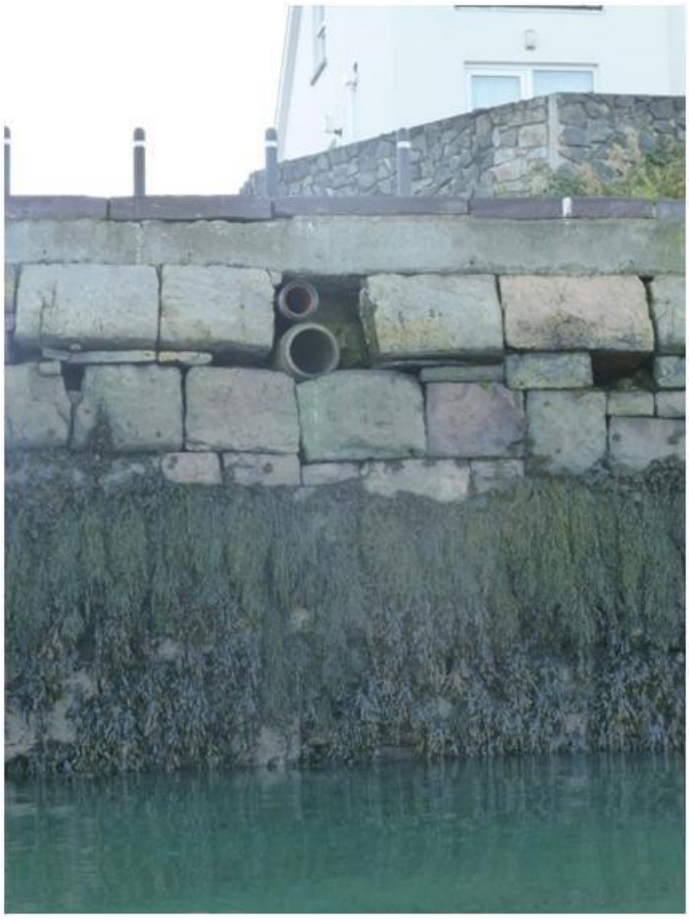

Figure XII.9

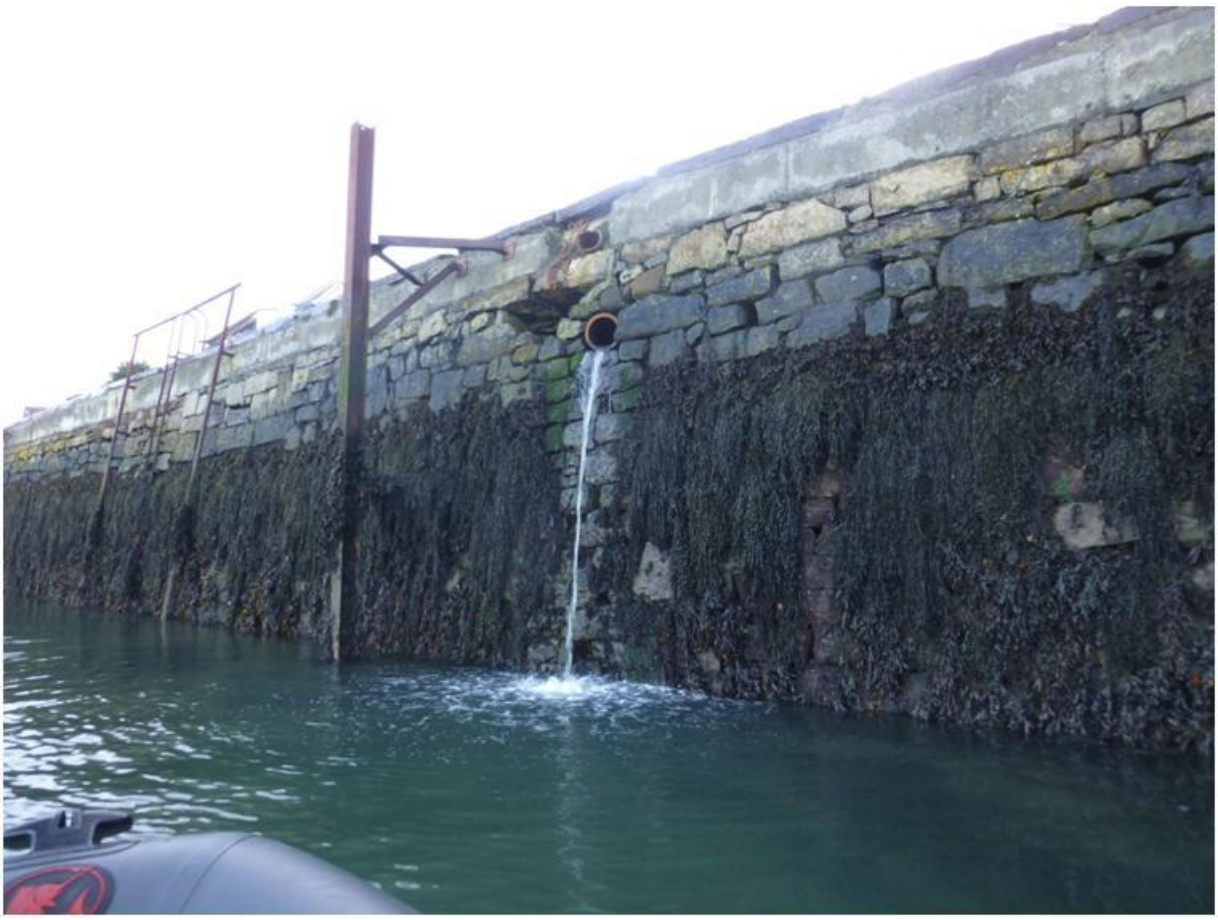

Figure XII.10

Figure XII.11

Figure XII.12

Figure XII.13

Figure XII.14

Figure XII.15

Figure XII.16

Figure XII.17

Figure XII.18

Figure XII.19

Figure XII.20

Figure XII.21

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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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