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EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Anglesey

January 2014

Food Standards Agency

Cover photo: Red Wharf Bay

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Statement of use

This report provides a sanitary survey relevant to bivalve mollusc beds within Anglesey, 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	15/01/2014
2	Draft for client/consultee comment	Simon Kershaw	16/01/2014
3	Final	Simon Kershaw	08/09/2014

Consultation

Consultee	Date of consultation	Date of response
Ynys Mon CC	16/01/2014	13/02/2014
Natural Resources Wales/Cyfoeth Naturiol Cymru	16/01/2014	14, 21 & 27/07/2014
Welsh Government Fisheries	16/01/2014	14/02/2014
Welsh Water/Dwr Cymru	16/01/2014	None
Menai Mussel Men	16/01/2014	None
Shellfish Association of Great Britain	16/01/2014	None

Dissemination

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

Recommended Bibliographic Reference

Cefas, 2014. Sanitary survey of Anglesey. 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. Infectious disease outbreaks are more likely to occur in coastal areas, where bivalve mollusc production areas (BMPAs) are impacted by sources of microbiological contamination of human and/or animal origin.

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

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

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

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

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

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

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

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

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

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

This report documents the information relevant to undertake a sanitary survey for mussels (*Mytilus* spp.), Pacific oysters (*Crassostrea gigas*), Palourdes (*Tapes* spp.) and razor clams (*Ensis* spp.) at Inland Sea; cockles (*Cerastoderma edule*) and mussels at Red Wharf Bay, and cockles at Malltraeth. The area was prioritised for survey in 2013-14 by a shellfish hygiene risk ranking exercise of existing classified areas, and the three discrete areas were assessed together in this report for efficiency reasons.

1.2. Area description

The Isle of Anglesey is located in the Irish Sea in North West Wales, and is separated from mainland Wales by the Menai Strait, a narrow tidal channel. This survey covers all commercial shellfish areas on the island apart from those in the Menai Strait, which were subject to separate surveys (Cefas 2013a and 2013b). The locations and individual hydrological catchments (estimated from topography) of these areas are illustrated in Figure 1.1.

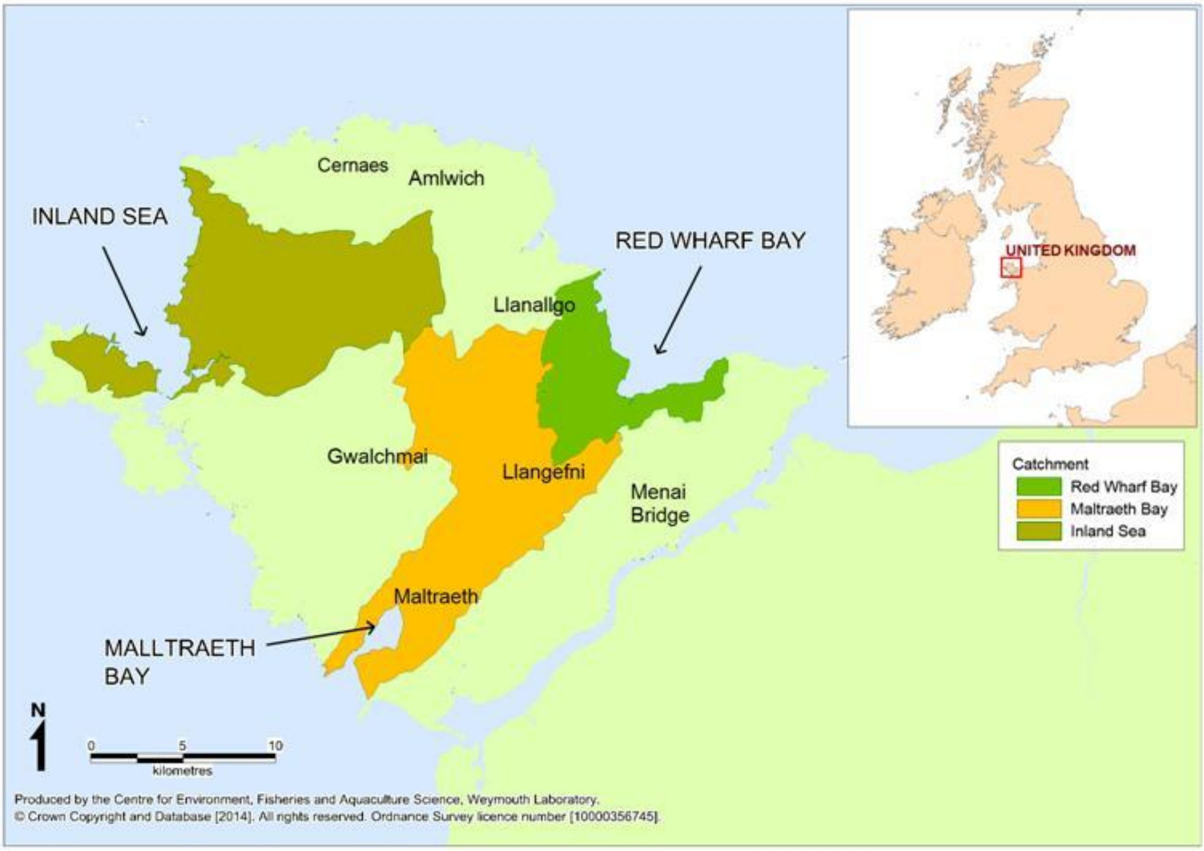


Figure 1.1: Location of Anglesey

The Anglesey coastline encompasses a wide range of marine habitats including intertidal flats, sandbanks, saltmarsh, large shallow bays, sea caves and limestone cliffs (Anglesey Heritage website, 2013). The majority of the coast is designated as an Area of Outstanding Natural Beauty (AONB) and consists of a series of Sites of Special Scientific Interest (SSSI). Inland Sea is a tidal strait separating Holy Island from Anglesey which supports a mussel fishery at its northern end. Red Wharf Bay is an open, north facing, sandy embayment supporting commercial stocks of cockles, as well as some mussel stocks at Moelfre about 5 km to the north. Malltraeth Bay is an enclosed, south facing sandy bay that has historically supported a cockle fishery, although there are insufficient stocks for a commercial fishery at present.

1.3. Catchment

Anglesey covers 716 km^2 (EA Wales, 2007), which includes Holy Island, a small island off the western coast. It is relatively low lying, reaching a maximum elevation of 220 m at Holyhead Mountain. Figure 1.2 shows landcover within this area.

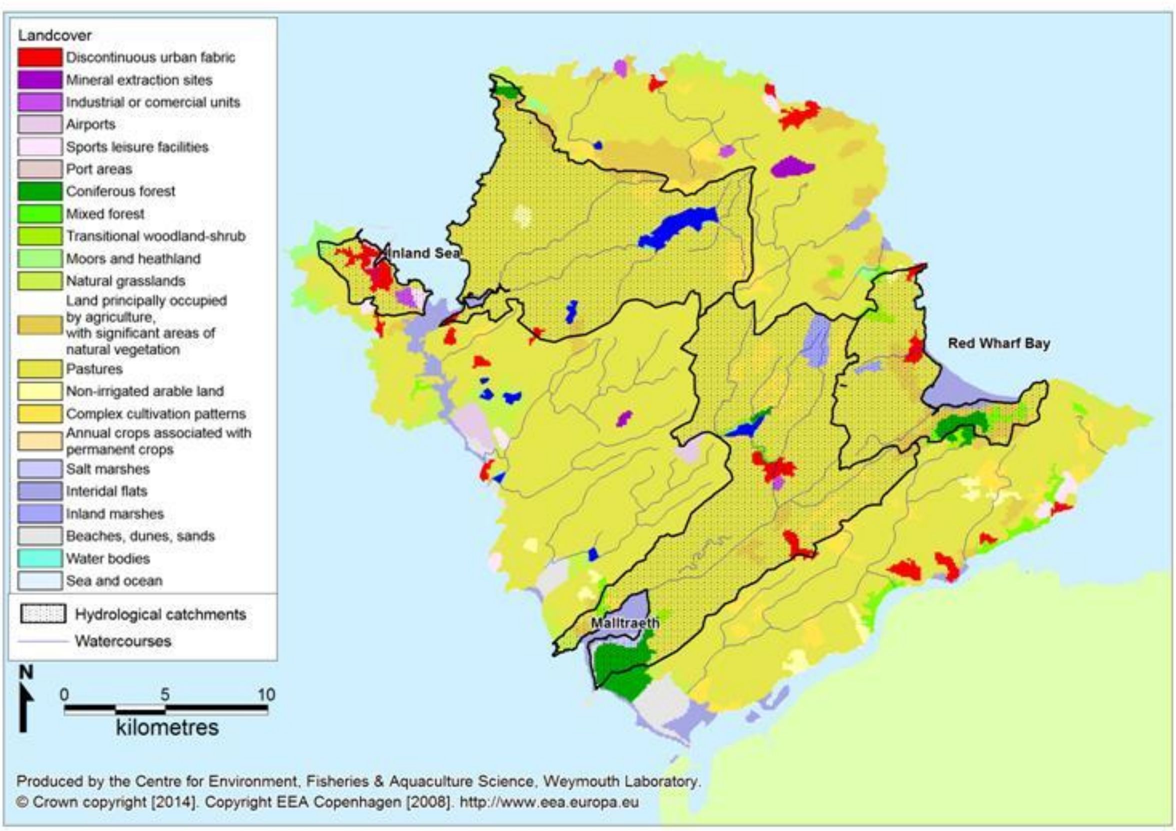


Figure 1.2: Landcover on Anglesey

Pasture is the dominant land use on Anglesey, although there are some urbanised areas, natural areas (forests, moorlands and grasslands) and a few small pockets where crops are cultivated. The hydrological catchments of the three areas considered in this survey are entirely separate so require consideration individually. The Anglesey part of the Inland Sea catchment covers 106 km^2 and is almost all pasture, but on Holy Island (catchment area 11 km^2) there are significant built up areas associated with the town of Holyhead. The Malltraeth catchment (123 km^2) is again largely pasture, but here the main settlements (Llangefni and Gaerwen) are inland, and the southern side of the bay is bordered by forest. Land within the Red Wharf Bay catchment (42 km^2) is mixture of pasture and natural areas, with two main coastal settlements (Benllech and Moelfre).

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 increases up to 100 fold. The hydrogeology of the area is classified as predominantly low permeability igneous rocks and sandstone. A band of more permeable fissured limestone is present between Malltraeth and Red Wharf Bay, and along a narrow coastal strip adjacent to the Menai Strait. As such there are unlikely to be significant groundwater flows within the Inland Sea sub-catchment, where a high proportion of rainfall will run off via watercourses. Runoff may be damped to some extent by groundwater uptake and recharge in the Malltraeth and Red Wharf Bay catchments.

2. Recommendations

It is recognised that 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 or similar sampling installation 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. Inland Sea

This area includes an established mussel lay, and a proposed aquaculture site where the culture of Pacific oysters, mussels, palourdes and razors is planned. The main source of contamination to the immediate area is the River Alaw, which receives sewage effluent as well as agricultural runoff. The Holyhead STW may have some impact at times, although this is distant and made to deep water, and it is uncertain to what extent the plume is advected into the fishery areas. There are also a number of intermittent sewage discharges and a large amount of boat traffic in the Holyhead area. It is also possible that an ebb plume of slightly more contaminated water originates from the enclosed middle section of the strait via the Stanley Embankment Culvert.

At the established mussel lay it is recommended that the RMP is located at the south eastern corner to best capture the impacts of the Alaw. Sampling should be on a monthly basis to maintain a year round classification. It may be undertaken either via hand or dredge, and samples should be of animals of a market size. As the site is not harvested from directly, it may be possible to temporarily declassify it by dropping the sampling frequency to quarterly, assuming the harvester finds this acceptable. A reversion to monthly sampling would result in an instant reclassification.

At the proposed new fishery site, it is recommended that the RMP is located at the south western corner to best capture the impacts of the Alaw as well as any contamination originating from the Holyhead seafront. This site will only require sampling towards classification once the site has been established. The harvester will need to advise the LEA on timescales by which the various species will require classification. The individual species will all require sampling if they are to be classified. Depending on the final layout of the site, it may be necessary to establish a sampling installation (e.g. a trestle) for some/all species, where bagged stock can be left for the sampling officer. This may prove problematic for the burrowing species. Any bagged samples will have to be left *in situ* to equilibrate for at least two weeks. Monthly sampling will be required for year round classifications. Sampling should be via hand, and samples should be of animals of a market size.

2.2. Red Wharf Bay

This survey area includes an extensive cockle bed within Red Wharf Bay, and a minor and sporadic mussel bed at Moelfre Island that is currently unclassified.

The main source of contamination to the cockle bed is the River Nodwydd, which receives sewage effluent as well as agricultural runoff. There are several other minor freshwater inputs which flow into the drainage channels that the Nodwydd follows across the intertidal area, but these do not flow directly through the cockle bed. The Benllech STW may have some impacts at times, although this is distant and made to deep water, and under normal conditions the plume from this would travel parallel to the coast some distance offshore from the cockle bed. It is therefore recommended that the RMP be located where the Nodwydd drainage channel enters the inshore part of the cockle bed. Monthly sampling will be required for year round classifications. Sampling should be via hand, and samples should be of animals of a harvestable size. If the fishery is closed by Welsh Government Fisheries, the LEA may wish to consider temporary or permanent declassification of the site, dependent on likely future prospects.

There is little in the way of sources of contamination direct to the mussel bed at Moelfre Island. The island hosts a colony of breeding seabirds which may be a significant contaminating influence, as evidenced by higher levels of faecal indicator bacteria observed here during the spring and summer months. The village of Moelfre lies to the south, where there is an unmonitored intermittent sewage discharge to the seafront. The Benllech STW may have some impacts at times, although this is distant and made to deep water, and under normal conditions the plume from this would travel parallel to the coast some distance offshore. Little spatial variation in levels of contamination across this relatively small site are anticipated. An RMP at the southern extremity of the bed would be suitably protective of public health. Sampling should be via hand, and samples should be of animals of a market size. Monthly sampling will be required for year round classifications. This mussel bed will only require re-classification on request from the industry or Welsh Government Fisheries.

2.3. Malltraeth Bay

This area contains a cockle bed, although this has not been subject to commercial harvest for some years due to low stock levels and is currently declassified. The vast majority of contamination to this area is likely to be delivered by the River Cefni, which enters at the head of the estuary and follows a subtidal channel out through it.

Additionally, the Malltraeth STW discharges to the river channel within the estuary, just south of Malltraeth village. The cockle beds are located on the eastern side of the estuary, away from this channel, but Welsh Government Fisheries requested that the entire estuary be classified for enforcement purposes. Whilst this strategy may aid enforcement, it will extend the classified zone into a more contaminated area than is necessary. It is concluded that the RMP should be located as close to the river channel as possible just downstream of the Malltraeth STW outfall. Whether there are sufficient stocks in this vicinity to allow regular sampling is uncertain, so some adjustment to the RMP location may be required. The cockle bed is closer to the main channel further down the estuary, where impacts from the Cefni and the sewage works are likely to be less acute. Sampling should be via hand, and samples should be of animals of a market size. Monthly sampling will be required for year round classifications. This cockle bed will only require re-classification on request from the industry or Welsh Government Fisheries.

3. Sampling Plan

3.1. General Information

Location Reference

Production Area	Inland Sea, Red Wharf Bay, Malltraeth Bay
Cefas Main Site Reference	M043/M057/M056
Ordnance survey 1:25,000 map	Explorer 262 and 263
Admiralty Charts	5609.11, 5609.10, 5609.13 and 1970

Shellfishery

Species/culture	Mussels	Wild/cultured
	Cockles	Wild
	Pacific oysters	Cultured
	Palourdes (*Tapes* spp.)	Cultured
	Razors (*Ensis* spp.)	Cultured
Seasonality of harvest	There is currently a closed season for cockles (May to August) but this is currently under review and it is likely that there will be no closed season in future	

Local Enforcement Authority

Name	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 2020. 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 for Inland Sea, Red Wharf Bay and Malltraeth

Classification zone	RMP*	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Bedmannarch Bay	TBA	Beddmanarch Bay South	SH 2819 8068	53° 17.709'N 04° 34.761'N	Mussels	Bed culture	Dredge	Hand or dredge	10/100 m	Monthly	
Penrhos Bay	TBA	Penrhos Bay South	SH 2806 8203	53° 18.433'N 04° 34.922'N	Mussels, Pacific oysters, *Tapes* spp., *Ensis* spp. (as required)	Bouchot culture, rack culture, bed culture, experimental bed culture.	Hand	Hand (a sampling installation may need to be established to ensure stock availability)	10 m	Monthly	Will only require classification once site is established. Some species will require classification before others. Deepdock will need to advise LEA of their requirements as the situation develops
Red Wharf Bay	TBA	Nodwydd	SH 5314 8022	53° 17.911'N 04° 12.307'N	Cockles	Wild	Hand	Hand	100 m	Monthly	

Classification zone	**RMP***	**RMP name**	**NGR**	**Latitude & Longitude (WGS84)**	**Species**	**Growing method**	**Harvesting technique**	**Sampling method**	**Tolerance**	**Frequency**	**Comments**
Moelfre	TBA	Moelfre South	SH 5171 8661	53° 21.331'N 04° 13.773'N	Mussels	Wild	Hand	Hand	10 m	Monthly	Will only require classification on request of industry or Welsh Government Fisheries
Malltraeth	TBA	Cefni channel	SH 3991 6789	53° 11.037'N 04° 23.835'N	Cockles	Wild	Hand	Hand	100 m	Monthly	Will only require classification on request of industry or Welsh Government Fisheries

**RMP codes will be generated once the report has been agreed and finalised.*

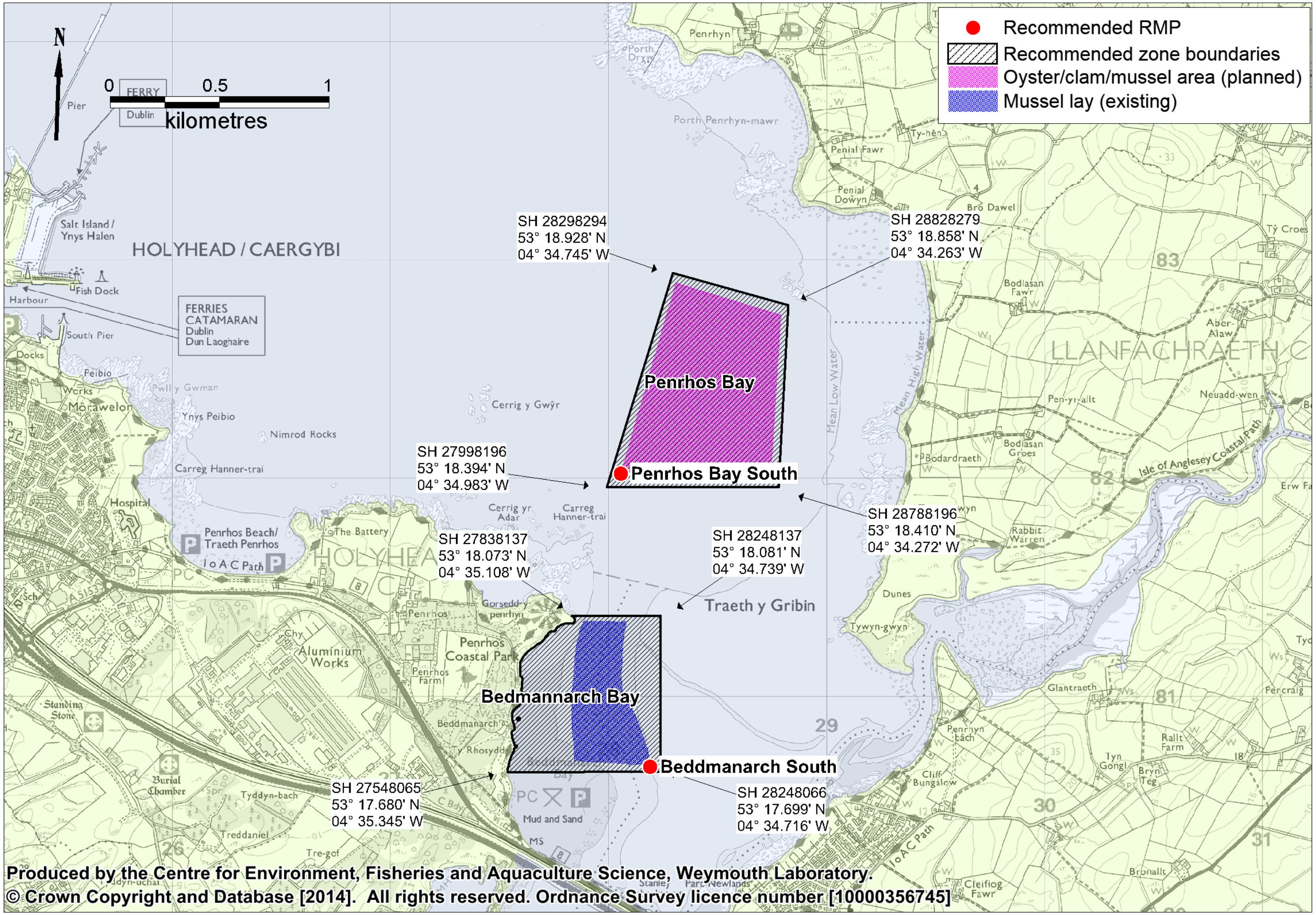


Figure 3.1: Recommended zoning and monitoring arrangements (Inland Sea all species)

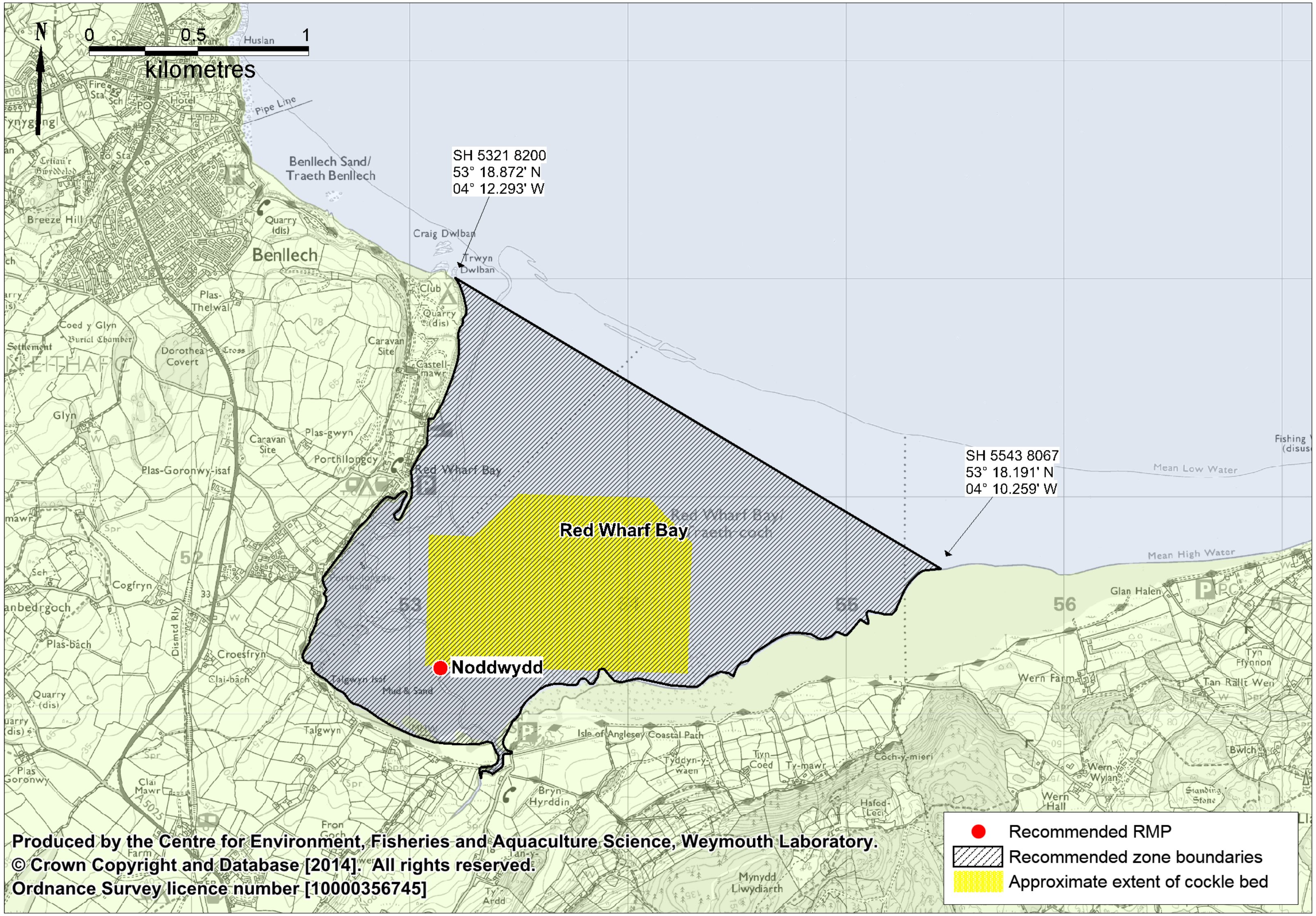


Figure 3.2: Recommended zoning and monitoring arrangements (Red Wharf Bay cockles)

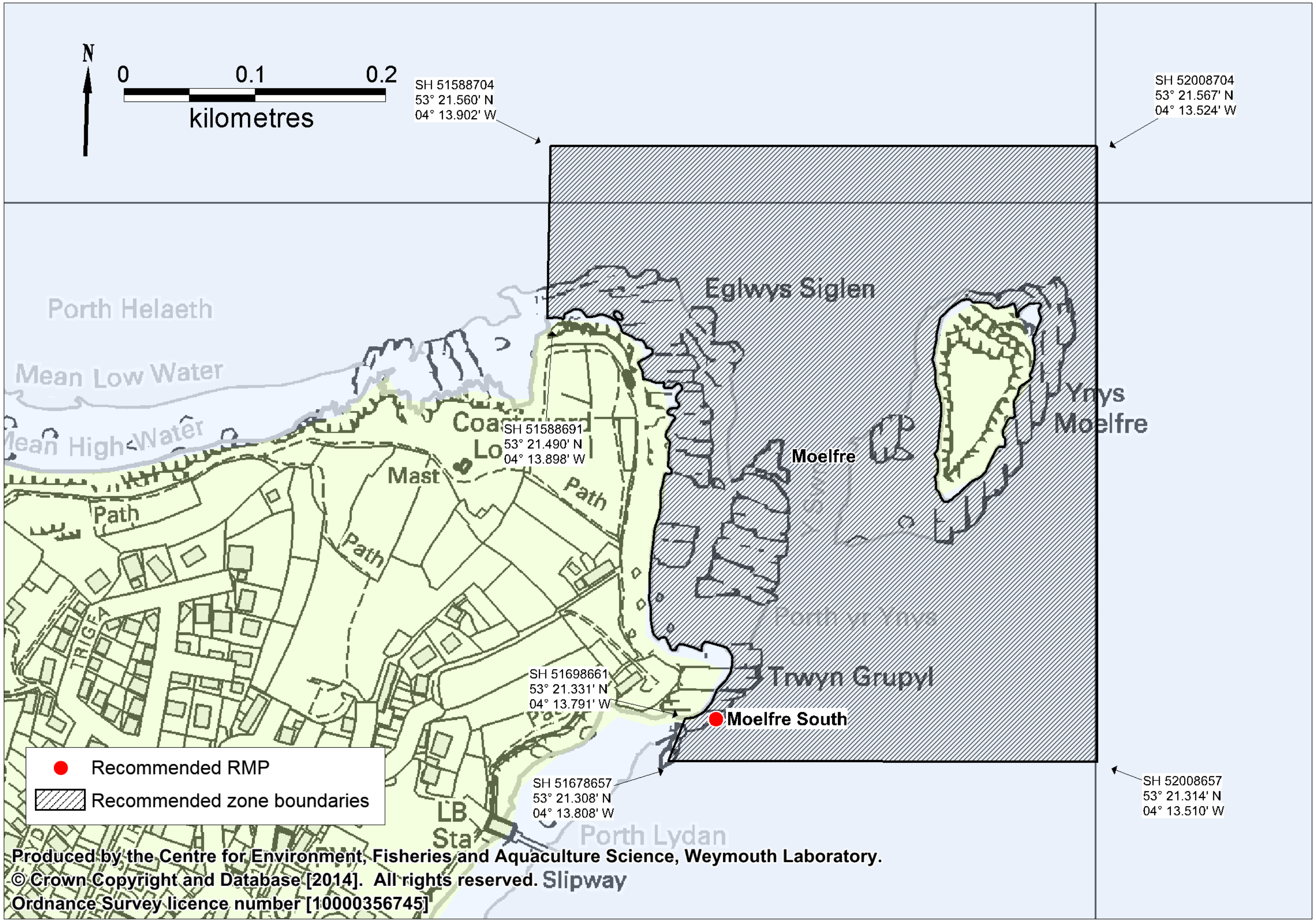


Figure 3.3: Recommended zoning and monitoring arrangements (Moelfre mussels)

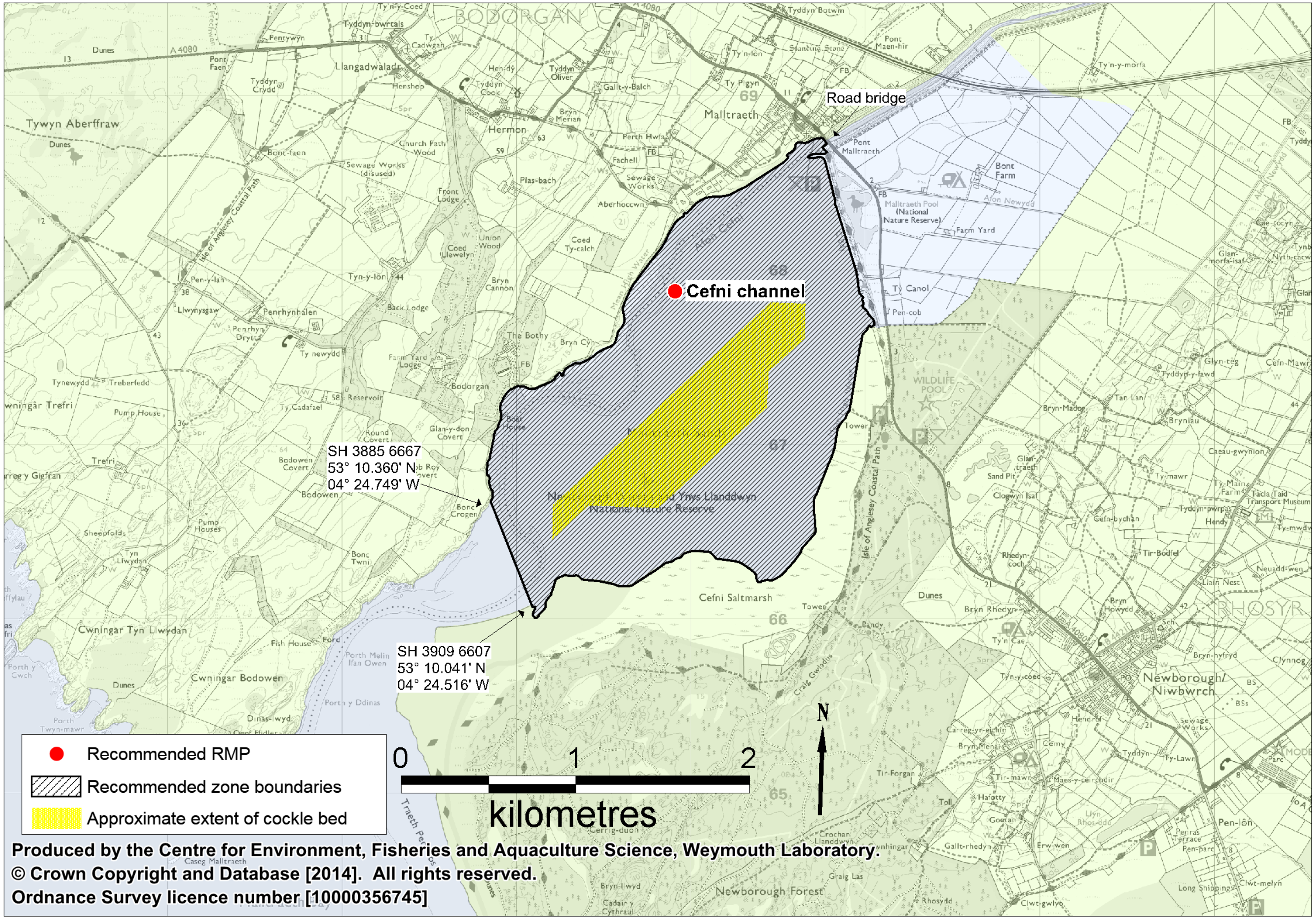


Figure 3.4: Recommended zoning and monitoring arrangements (Malltraeth)

4. Shellfisheries

4.1. Description of fisheries

Inland Sea

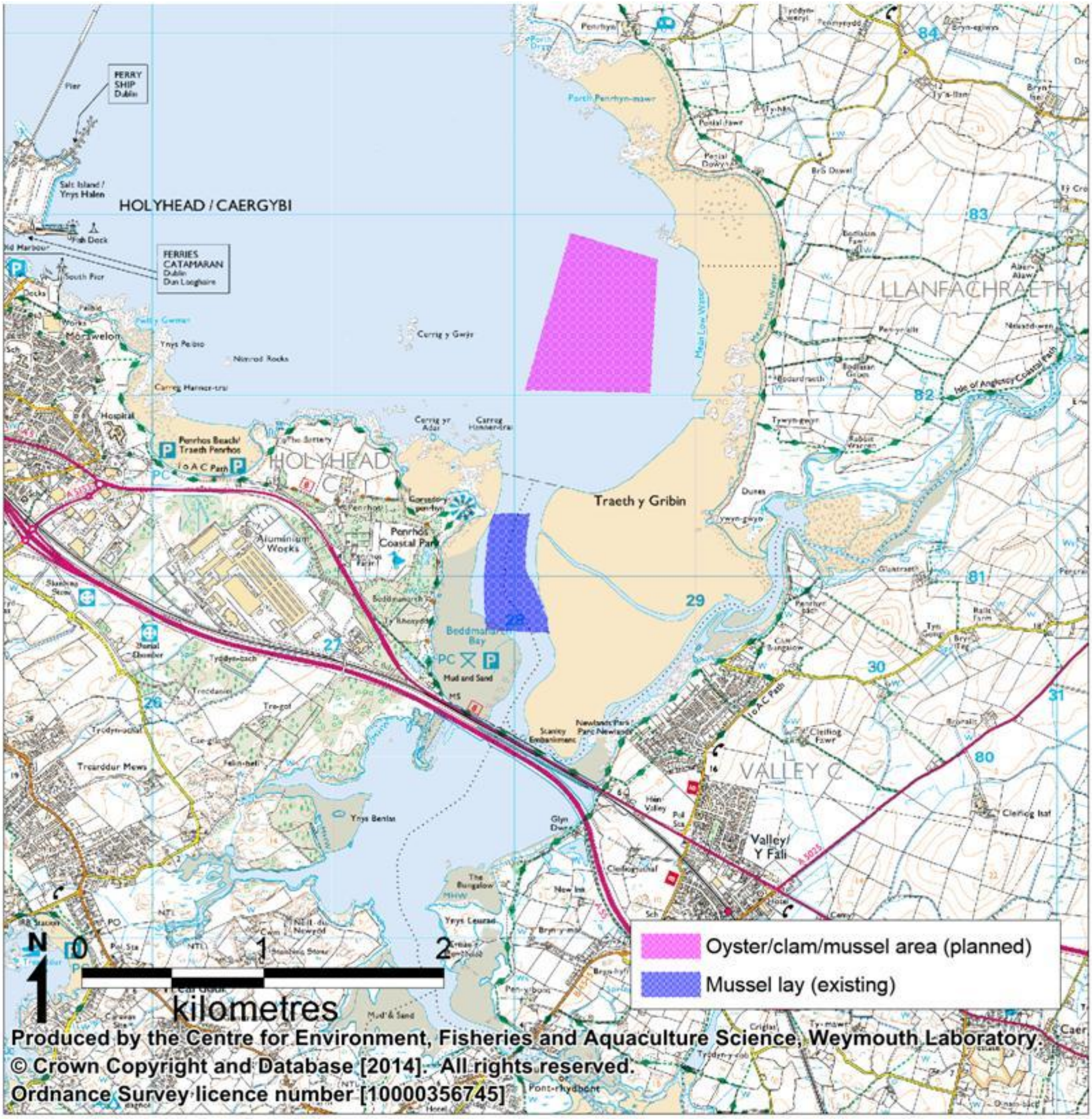


Figure 4.1: Inland Sea fishery sites

There is an active mussel fishery within this survey area, where seed stocks are laid on the lower intertidal and subtidal area, and ongrown for a period. The meat yields obtained here are not optimal at present, so stocks are then transferred to mussel lays in the eastern Menai Strait where they are fattened further then harvested. Husbandry is undertaken using dredges. Although these stocks are not harvested and sent directly to the market from this area, the site operators (Deepdock Ltd) have indicated that a continued classification is required to allow direct harvesting if required. There are currently around 500 tonnes of stock on the site. This mussel site falls within a former several order area (the Penrhos Point Mussel Fishery Order 1998) which has now expired but is in the process of renewal.

A further several order has been applied for within the survey area, where the culture of Pacific oysters, mussels, palourdes, and razor clams is planned. Pacific oysters will be cultured on a suspended longline system, where mesh bags are suspended from rows of wooden posts. Triploid seed will be used, and this will take between 9 and 24 months to reach market size, depending on the size of the seed. The wooden posts from which the oyster bags are suspended will be used as bouchots for growing mussels. Seed will be sourced either from ephemeral seed mussel beds, or through natural settlement, and it is anticipated that they will grow to a market size within 18-36 months. More extensive culture of palourdes and razor clams is also planned within the new several order area. The palourdes will be grown in the substrate from commercially sourced seed, under a cover of anti predator netting. It is estimated that they will take up to five years to reach a market size. Whilst the culture methods for palourdes are well established, there is much less known about the husbandry requirements for razor clams. Tentative plans are to use locally sourced broodstock to produce seed at the Bangor University hatchery, and this seed will then be ongrown in a similar manner to the palourdes. The techniques used will be largely experimental and the trials will be conducted in conjunction with researchers at Bangor University. How the site will be laid out exactly is uncertain, but it is anticipated that the longline/bouchot system will be established at lower elevations than the palourde plots. In the wild, razor clams are only generally found towards the extreme low water mark, so it is probable that culture of this species will be more successful at lower elevations.

Red Wharf Bay

Figure 4.2: Red Wharf Bay fisheries

The main shellfish resource within Red Wharf Bay is a cockle bed, the approximate extent of which is shown in Figure 4.2. It attracts regular settlements and is currently open for commercial harvesting. There is also a small mussel bed on the rocky outcrop around Moelfre Island, where commercial quantities of harvestable sized mussels are found periodically. Harvesting activity is uncertain but thought to be minimal and sporadic. No movement documents have been submitted to the LEA in the last few years indicating that there has been no commercial harvesting.

Malltraeth

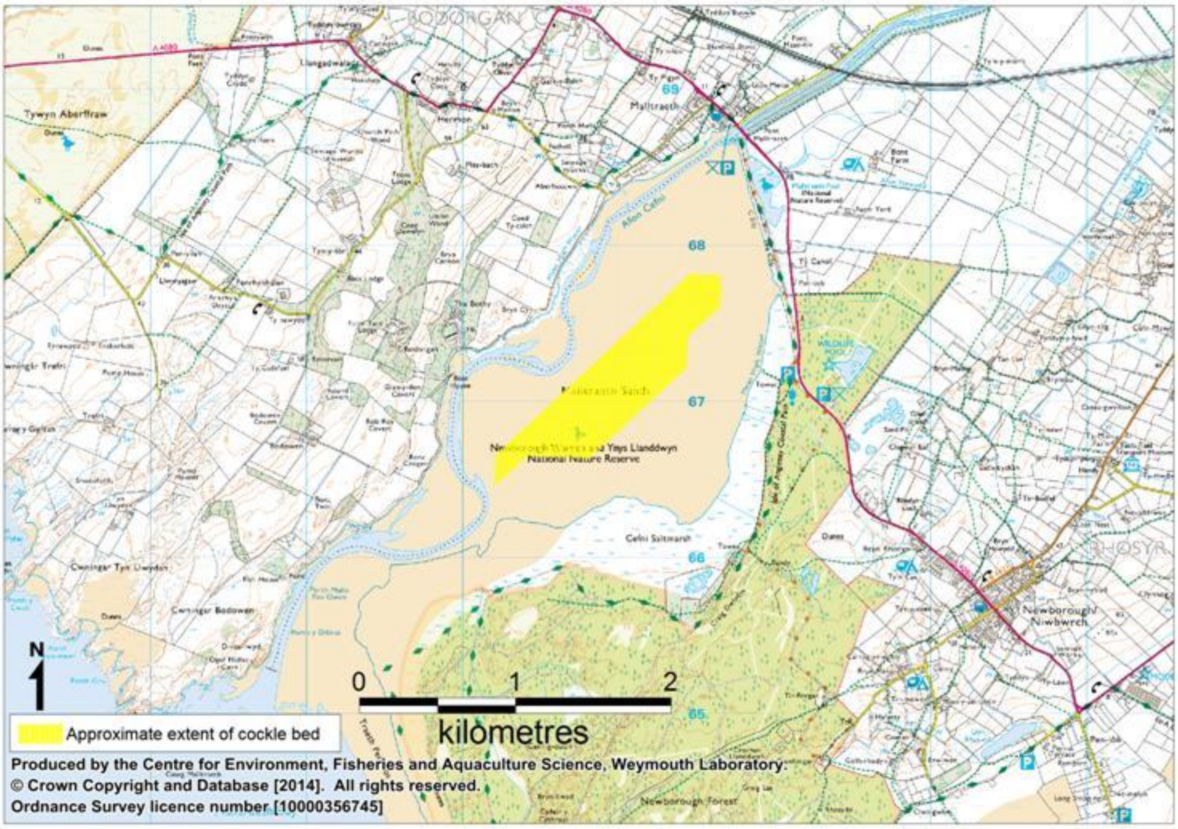


Figure 4.3: Malltraeth fisheries

Historically, there have been regular cockle settlements which have supported a commercial hand gathering fishery at Malltraeth covering the approximate area shown in Figure 4.3. However, there has been little stock present here in recent years, and it has not been opened for harvesting for several years.

4.2. Conservation controls, seasonality of harvest, and future prospects

All fisheries considered in this survey are 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 a minimum landing size of 20 mm applies to cockles, and there is a closed season which runs from May to August inclusive. The management of cockle fisheries in Wales is currently under review, and future management proposals include the removal of closed seasons (Welsh Government, 2013). No closed season applies to mussels, which have a minimum landing size of 45 mm in the district. This does not apply to movements of part grown seed from the Penrhos mussel lay, although it presumably would apply to harvesting from here until the fishery order is re-established. No minimum sizes or closed seasons will apply to any of the species cultured within fishery order areas at Inland Sea once they are established.

Welsh Government Fisheries may close shellfish beds at any time for reasons of stock preservation. Once several order(s) are (re)established at Inland Sea no minimum landing size or closed seasons will apply within them.

The mussel lay at Inland Sea is likely to remain in steady use. Within the proposed new fishery order at Inland Sea, the applicant indicates a potential annual harvest of up to 24 tonnes of oysters and 3 tonnes of palourdes. Potential annual production of mussels is uncertain, but will be on a commercial scale. The razor fishery is largely experimental so it may not develop into a commercial fishery. Both palourdes and razors occur naturally in this area, suggesting conditions are likely to be suitable. The mussel bed at Moelfre is a relatively small and sporadic resource which has not been commercially exploited in recent years. Cockle stocks will fluctuate from year to year, and in some years there will not be sufficient for a commercial fishery, as is the case currently at Malltraeth.

4.3. Hygiene Classification

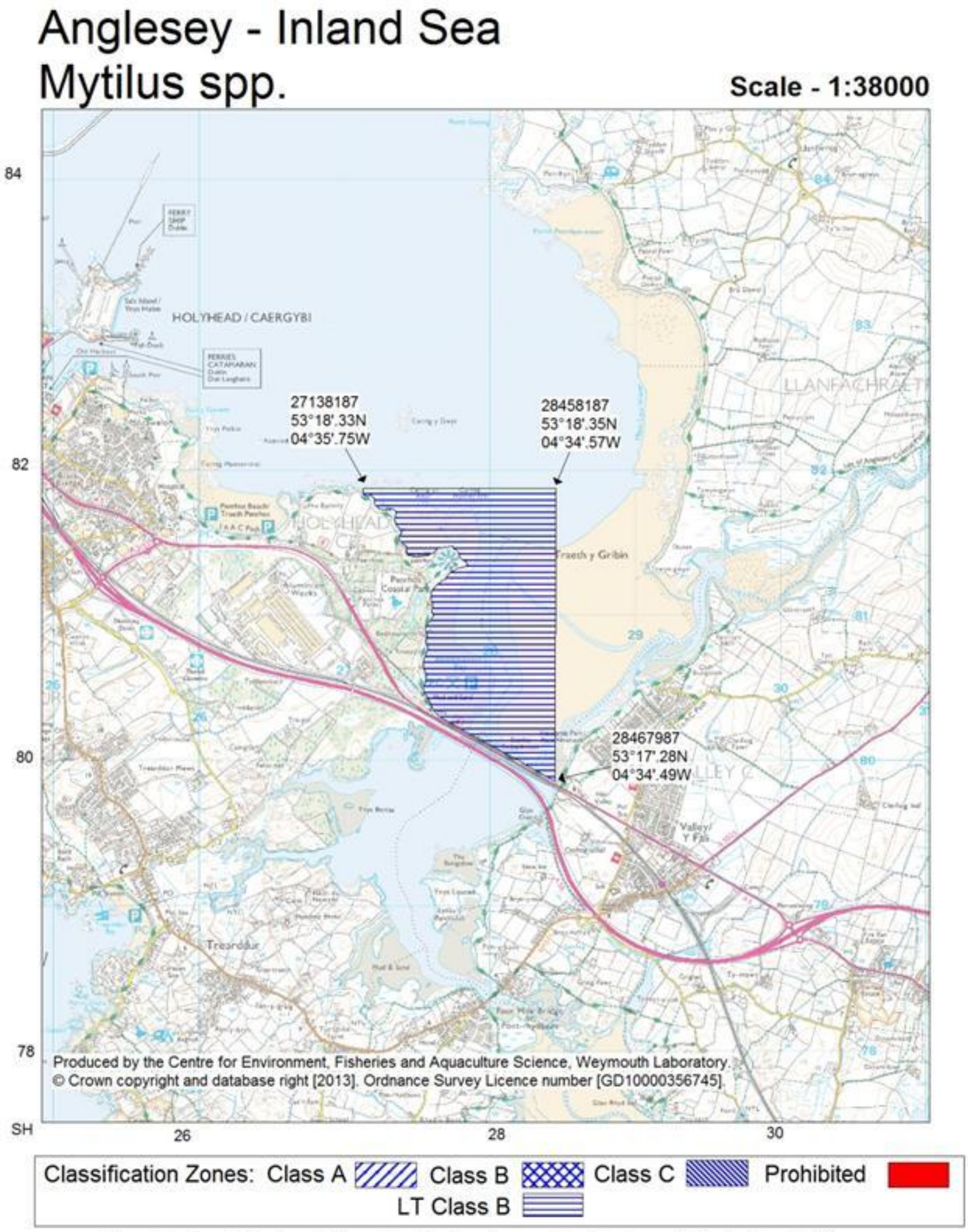
Table 4.1 lists all classifications within the survey area since 2004.

Table 4.1: Classification history for Anglesey, 2004 onwards

Area	Species	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Inland Sea - Gorsedd y Penrhyn	Mussels	-	-	B	B	B	B	B-LT	B-LT	B-LT	B-LT
Red Wharf Bay - All beds	Cockles	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Red Wharf Bay - Y Swnt Moelfre	Mussels	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	-
Malltraeth - All beds	Cockles	B	-	B	B	B	B	B-LT	B-LT	B-LT	-

LT denotes long term classification

All shellfisheries have held B classifications in recent years. The mussel bed at Moelfre and the cockle bed at Malltraeth were declassified in 2013 due to a lack of commercial activity.



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

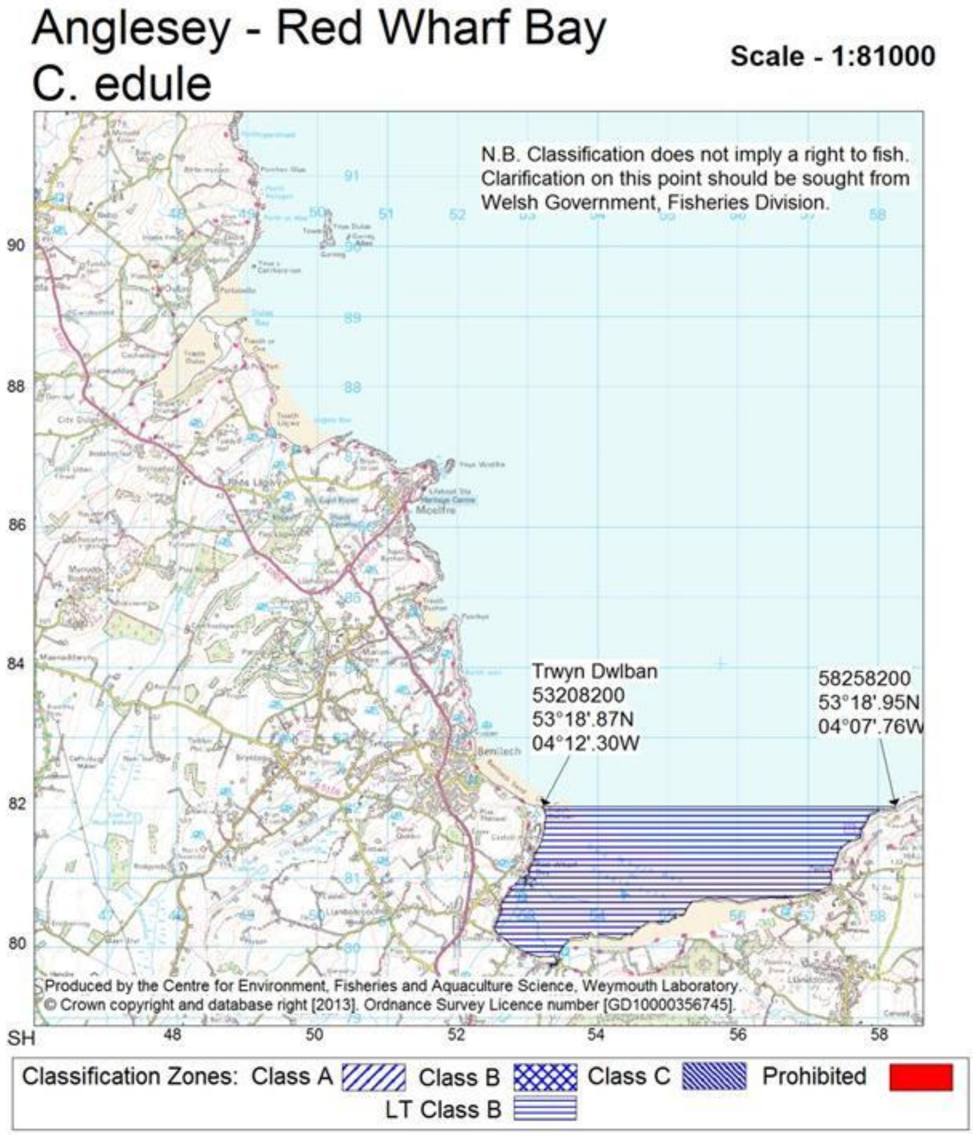
The areas delineated above are those classified as bivalve mollusc production areas under EU Regulation 854/2004.

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

Food Authority: Ynys Mon - Isle of Anglesey County Council

Figure 4.4: Current classifications (Inland Sea mussels)



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Food Authority: Ynys Mon - Isle of Anglesey County Council

Figure 4.5: Current classifications (Red Wharf Bay cockles)

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

Inland Sea

Currently, there is an area at Penrhos where seed mussels are laid and ongrown. This site was formerly within a fishery order which has now expired and is in the process of being renewed. Mussels are not harvested directly from this area as meat yields obtained here are not optimal. Instead, they are transported in a part grown state to the eastern Menai Strait, where they are subsequently grown to market size and harvested. Husbandry is undertaking using dredges. The site operator indicated that there are about 500 tonnes of mussels on this site, and that continued classification will be necessary to ensure that the site may be harvested directly if required. There is no closed season for mussels so continued year round classification is needed. Until the fishery order is re-established, a minimum landing size of 45 mm applies to any stock harvested directly from here.

There is a further proposed several order within this survey area, where the same operator intends to culture Pacific oysters, mussels, palourdes and razor clams. Pacific oysters will be cultured on net bags suspended from a longline system, and the wooden stakes used to support these longlines will be employed for the bouchot style culture of mussels. Palourdes will be grown in the substrate from hatchery seed, with a covering of anti predator netting. Methods for razor clam culture are less well established, and this fishery is largely experimental. Tentative plans involve the collection of broodstock locally, the production of seed stock at the Bangor University hatchery, and then the seed will be ongrown on the several order site in a similar manner to the palourdes. The site operator estimates that Pacific oysters may be harvestable within 9 months of setup, mussels may be produced within 18 months, and palourdes may take about 5 years. The annual production of oysters may be up to 24 tonnes, and of palourdes around 3 tonnes. Commercial quantities of mussels will also be produced, but the prospects for the razor fishery are uncertain. The uncertainty surrounding the possible geographical extent of these stocks within the proposed fishery order area creates difficulties in selecting an appropriate RMP. All that is known at this stage is that it is likely that the palourde culture will be undertaken at higher elevations than the oyster/mussel culture. Razors are normally found only around the extreme low water mark, so it is likely that culture of this species will be more successful lower down the foreshore. It is therefore assumed that the site operator will be able to maintain stocked sampling installations at the specified RMP locations. Sufficient notice will need to be given by the site operator to the LEA to ensure a classification is established by the time stocks are ready for harvesting. There is no closed season for any of these species so year round classifications will be required. No minimum landing size will apply within the area once the fishery order is established.

Red Wharf Bay

The principle shellfishery within this survey area is an intertidal cockle bed within the western part of Red Wharf Bay. This cockle bed is currently open for commercial harvesting, and so requires continued classification. The fishery is currently managed under the permit system as well as several local byelaws. Under these measures, there is a closed season from May to August inclusive and a minimum landing size of 20 mm applies. These regulations are under review, and of relevance to the sampling plan, it is proposed that there will no longer be a closed season. As such, a year round classification will be required.

There is also a patch of mussels on the rocks between the headland at Moelfre and Moelfre Island which has on occasion been subject to commercial harvesting via hand gathering. Mussels of a harvestable size and quantity are only sporadically present, and a lack of movement documents indicates it has not been harvested in recent years. It is currently declassified and will only require reclassification on request from either a harvester or Welsh Government Fisheries. There is no closed season for mussels in the district so any classification would have to be year round. A minimum size of 45 mm applies.

Malltraeth

Historically, Malltraeth has supported a commercial fishery for cockles, but currently stocks are low, the fishery here is closed, and the area was declassified in 2013. At some point in the future it is likely that there will be a significant settlement, and the commercial fishery will continue. Cockle fisheries in the district are currently managed under the permit system as well as several local byelaws. Under these measures, there is a closed season from May to August inclusive and a minimum landing size of 20 mm applies. These regulations are under review, and of relevance to the sampling plan, it is proposed that there will no longer be a closed season. As such, a year round classification will be required if and when a viable commercial fishery is re-established here.

5.3. Pollution Sources

Inland Sea

Freshwater Inputs

Rivers and streams are significant pathways by which faecal indicator bacteria are delivered to coastal waters and so require consideration in this assessment. Livestock grazing is ubiquitous throughout the catchment so most watercourses will be impacted by agricultural runoff, and some will receive contamination from urban runoff and sewage discharges. The survey area has two main watercourses draining to it (the rivers Alaw and the Tan-yr-Allt) both of which enter the area via a small enclosed estuary which they share. As such, they will be subject to significant dilution before entering the survey area. The drainage channel from this estuary then follows the mainland shore southwards and joins the main subtidal channel running through the strait immediately north of the Stanley Embankment. No flow gauging data were available for these watercourses. A water sample taken from just downstream of the Alaw/Tan-yr-Allt confluence during the shoreline survey contained 1,200 *E. coli* cfu/100ml. The relatively large sizes of these freshwater inputs, which have a catchment area of about 80 km^2, combined with the observed level of faecal indicator bacteria suggest they are a highly significant contaminating influence to the area. There are no other significant watercourses which discharge directly to this survey area, although there was a freshwater outfall pipe to the foreshore at Valley which was carrying a very high concentration of *E. coli* at the time of shoreline survey (280,000 cfu/100ml). This suggests it was receiving some sewage input at the time. However, measured discharge from this outlet was very low so the bacterial loading it was delivering at the time was only 6.7x109 *E. coli*/day. NRW have commented that bacterial monitoring of freshwater inputs and of the sea water in the area around the Inland Sea was carried out by NRW during 2013 in order to see if there were any areas or inputs that needed investigation in order to protect the shellfishery. Nothing exceptional was found.

As well as day to day variations in river flows (and the bacterial loadings they deliver to coastal waters) in response to rainfall, there is likely to be significant seasonal variation in the average discharge rate from watercourses draining to the area. There is a flow gauging station located in the upper reaches of the Cefni which should be reasonably representative of watercourses on the island. Flows are highest on average here from October to December, and the peak flow events tend to occur during this period. Peak and average flows in the summer months tended to be much lower. Whether this translates to a seasonal variation in the average bacterial loadings they deliver is uncertain.

Human Population

The survey area lies adjacent to some of the more heavily populated areas of Anglesey. The main settlement is the town of Holyhead (population ~11,000) which extends along the north shore of Holy Island. On the east shore of the Holy Island Strait the main settlement is Valley (population ~2,000). Some urban runoff will enter coastal waters from these built up areas, but the pattern of impacts from sewage will depend on the nature of the sewerage infrastructure serving the population. Anglesey attracts significant tourism, with about 1.1 million visitors recorded in 2007. The majority of visits were from April to October, peaking in July and August. It is therefore concluded that sewage works in the area are likely to be serving a larger population during the summer.

Sewage Discharges

Holyhead STW (improved in 2005) is the largest sewage discharge in the area. It discharges to between 15 and 20 m of water about 3 km to the west of the end of the Holyhead Breakwater on Anglesey and generates a very large estimated bacterial loading ($3.6x10^{13}$ faecal coliforms/day). The spatial profile of its impacts will depend on water circulation patterns in the area, which are discussed under the hydrography heading. The Alaw and its' tributaries receive effluent from three sewage works, and the Alaw estuary receives effluent from a fifth sewage discharge in its very upper reaches. All of these provide secondary treatment and the combined bacterial loading they deliver to this watercourse is about $1.2x10^{12}$ faecal coliforms/day. These will contribute to the bacterial loading delivered by the Alaw to the Inland Sea area. The Llanerchymedd STW (and associated storm overflows) has been re-routed so it actually discharges to the Afon Goch Dulas which drains to the east coast of Anglesey.

There are various water company intermittent discharges on Holy Island and Anglesey that may impact on the shellfisheries in the Inland Sea from time to time. The main cluster of these is along the Holyhead seafront, and there are two discharging to the foreshore at Valley. There are also a small number feeding to the enclosed area between the Stanley Embankment and the Four Mile Bridge. No spill information was available for any of these so it is difficult to assess their likely impacts on the shellfisheries aside from noting their location and potential to deliver large volumes of untreated sewage. Usually (but not always) intermittent discharges spill relatively infrequently and so their impacts are unlikely to be captured during a year of monthly monitoring from which the classification is derived. Thus when they do have a significant spill, heavily contaminated shellfish may be harvested under a better classification than the levels of *E. coli* within them may merit. A reactive system alerting relevant parties to spill events in real time may therefore convey better public health protection. Welsh Water are nearing completion of a project to install telemetry to record spills on all their assets that discharge near designated shellfish and EC bathing waters. Once completed this will provide a significant improvement in the amount of information available

Whilst the majority of properties in the survey catchment are served by the water company sewerage network, there are a small number of private sewage discharges. Most are small, serving one or a small number of properties, and providing treatment via package plant or septic tank. They may contribute to levels of faecal indicator bacteria in watercourses such as the Alaw, but none are in such a position or of such a size that they will have any influence on the sampling plan.

Agriculture

The vast majority of land on the Anglesey side of the survey area is pasture, whereas the much smaller hydrological catchment on the Holy Island side is largely built up. Sheep farming is ubiquitous on Anglesey, with over 275,000 animals recorded in the 2012 census, as well as almost 57,000 cattle. Livestock densities were notably lower on Holy Island compared to the rest of Anglesey. Significant and widespread impacts from grazing animals are therefore anticipated, and the vast majority of contamination of agricultural origin will be delivered to the survey area via the Alaw estuary. 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 on Anglesey, but hardly any pigs. Manure from poultry and pigs is typically stored and applied tactically to nearby farmland.

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

There is significant boat traffic near the shellfishery associated with the port of Holyhead. This includes around 8,500 ferry and freighter movements each year, a fleet of 33 resident fishing vessels, a few angling charter boats, and large volumes of recreational traffic (yachts and cabin cruisers) associated with the 500 berth Holyhead Marina. As such there is significant potential for overboard sewage discharges to be made in the area. Merchant shipping is not permitted to make overboard discharge in near shore waters so the ferries and freighters should be of no impact. It is likely that the larger private vessels (yachts, cabin cruisers, and fishing vessels) which have onboard toilets make overboard discharges from time to time. This may occur whilst boats are in passage, and possibly while they are berthed at the marina or on the adjacent moorings, particularly for vessels in overnight occupation. Given that the vast majority of boat traffic will be to and from Holyhead, and will not venture into the survey area, any impacts are likely to be heaviest towards the northern end of the mussel lay. 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.

Wildlife

The survey area encompasses a range of coastal habitats and these attract aggregations of wildlife, some of which may be an influence on shellfish hygiene. The most significant of these is likely to be the waterbird (wildfowl and waders) populations which overwinter in the area. Although not subject to any organised counts in recent years, invertebrates within the sand and intertidal flats are reported to provide an important food source for large numbers of overwintering waders. Grazing wildfowl such as geese are also reported to overwinter on Anglesey. Foraging waders will defecate directly on the intertidal parts of the shellfishery. They may tend to aggregate in certain areas holding the highest densities of their preferred size and species of prey, but this may vary from year to year. They will therefore represent a diffuse input and may be a significant contaminating influence at times. RMPs on the parts of the mussel lay that are exposed for the longest time each tide are likely to be more vulnerable. Grazing waterbirds such as ducks and geese will mainly frequent areas of saltmarsh and coastal grasslands, where their faeces will be carried into coastal waters via runoff into tidal creeks or through tidal inundation. As such, the Alaw estuary is likely to be most impacted by grazing wildfowl.

Although the majority of waterbirds migrate elsewhere to breed, seabird species such as gulls and cormorants are present throughout the entire year and aggregate at certain areas to breed during the summer. A total of 6,559 individual breeding seabirds were recorded around the coast of Holy Island during a detailed survey in 2000. The majority of these were at South Stack, on the north east tip of the island. Natural Resources Wales indicate that about 11,000 individuals now use the island as a breeding site. Impacts from seabird colonies will be diffuse, although they will be more concentrated in the vicinity of their nesting sites. As such, although they may be a contaminating influence, seabirds will have no material bearing on the positioning of RMPs within this survey area.

The grey seal population in the Irish Sea numbers 5-6,000 and seals are regularly sighted around the Anglesey Coast. The nearest significant haul out site is North Stack on Holy Island where up to 37 animals have been recorded at any one time. There are further haul out sites at the Skerries, Carmel Head, and Ynys Llanddwvn. None of these locations coincide with that of the shellfisheries, so no acute impacts are anticipated. 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, so their presence will not influence the sampling plan. No other wildlife species which may be of significance to shellfish hygiene in the survey area have been identified.

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 Holyhead and Valley. 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 5.1and 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;

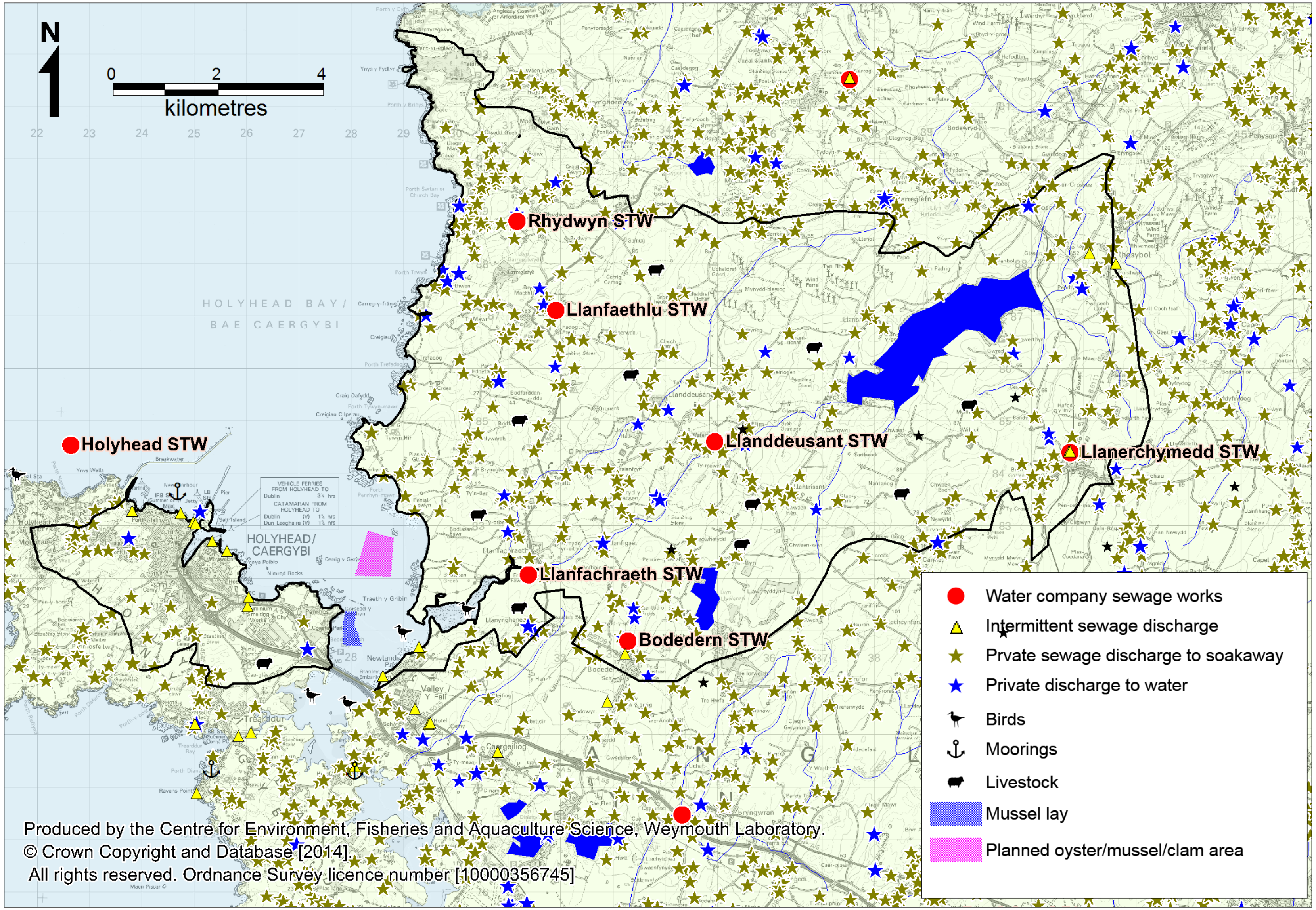


Figure 5.1: Summary of main contaminating influences (Inland Sea)

Red Wharf Bay

Freshwater Inputs

Rivers and streams are significant pathways by which faecal indicator bacteria are delivered to coastal waters and so require consideration in this assessment. Livestock grazing is ubiquitous throughout the catchment so most watercourses will be impacted by agricultural runoff, and some will receive contamination from urban runoff and sewage discharges. The hydrological catchment for this stretch of coast is small so freshwater inputs are limited to a number of small streams discharging at regular intervals along the foreshore. The largest of these in terms of discharge volume and the bacterial loading it delivers is the Nodwydd, which discharges in the eastern corner of the Bay and subsequently follows a drainage channel which cuts through the cockle bed in places. It was carrying a bacterial loading of 1.7×10^{12} *E. coli*/day at the time of shoreline survey. This intertidal drainage channel also receives two other smaller freshwater inputs, one of which was carrying the second highest measured bacterial loading in the area at the time of shoreline survey (2.5×10^{11} *E. coli*/day). As such, this drainage channel is likely to represent the most significant hotspot of runoff borne contamination within the cockle bed.

At Moelfre, there are no freshwater inputs direct to the mussel bed. There is a small stream about 750 m to the south of the mussel bed, whilst the nearest watercourse to the north lies about 2.5 km away. Together with the open coastal aspect and relatively deep water inshore suggests freshwater inputs are not likely to be a major contaminating influence at Moelfre, and it is highly unlikely that they will be responsible for any spatial variation in levels of contamination across the mussel bed.

As well as day to day variations in river flows (and the bacterial loadings they deliver to coastal waters) in response to rainfall, there is likely to be significant seasonal variation in the average discharge rate from watercourses draining to the area. There is a flow gauging station located in the upper reaches of the Cefni which should be reasonably representative of watercourses on the island. Flows are highest on average here from October to December, and the peak flow events tend to occur during this period. Peak and average flows in the summer months tended to be much lower. Whether this translates to a seasonal variation in the average bacterial loadings they deliver is uncertain.

Human Population

The two largest settlements here are the coastal villages of Benllech and Moelfre. The rest of the catchment is generally rural, with some small scattered settlements. Some urban runoff will enter coastal waters from built up areas, but the pattern of impacts from sewage will depend on the nature of the sewerage infrastructure serving the population.

Anglesey attracts significant tourism, with about 1.1 million visitors recorded in 2007. The majority of visits were from April to October, peaking in July and August. There are several caravan parks adjacent to Red Wharf Bay for example, which is a popular seaside holiday destination. It is therefore concluded that sewage works in the area are likely to be serving a larger population during the summer

Sewage Discharges

The main sewage discharge in the survey area is Benllech STW, which generates an estimated bacterial loading of around $4.1x10^{12}$ faecal coliforms/day and discharges 1.6 km off Benllech in about 6 m of water. Whilst this discharge is likely to be a significant contaminating influence to the area as a whole, the extent of its impacts on the shellfisheries at Red Wharf Bay and Moelfre will depend on the pattern of water circulation in the area. There is a second water company owned sewage works (Pentraeth STW) which discharges an estimated bacterial loading of $7.8x10^{11}$ faecal coliforms/day to the Nodwydd. This will make a significant contribution to the bacterial loading carried by this watercourse, which drains across the intertidal through the western end of the cockle bed at Red Wharf Bay but will be of negligible impact at Moelfre.

There are only five intermittent discharges to the survey area. Two of these discharge to the Nodwydd, one discharges to the Benllech seafront, one discharges via the Benllech STW long sea outfall, and one discharges to the seafront at Moelfre. No spill information was available for any of these so it is difficult to assess their likely impacts on the shellfisheries. Usually (but not always) intermittent discharges spill relatively infrequently and so their impacts are unlikely to be captured during a year of monthly monitoring from which the classification is derived. 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.

Although most properties in the survey area are served by water company sewerage networks, there are 34 consented private sewage discharges within the survey catchment. Most are small, serving one or a small number of properties, and providing treatment via package plant or septic tank. The majority (28) discharge to soakaway so should not affect water quality in coastal areas assuming they are functioning correctly. Those discharging to watercourses will make a minor contribution to the bacterial loadings they carry into coastal waters.

Agriculture

Most of the land within the survey catchment is pasture, although there is a forested area by the southern shore of Red Wharf Bay and a small pocket of arable land behind Moelfre. Sheep farming is ubiquitous, with over 275,000 animals recorded on Anglesey in the 2012 census, as well as almost 57,000 cattle. Significant and widespread impacts from grazing animals are therefore anticipated, although little livestock was seen by the shore during the shoreline survey. 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 on Anglesey, but hardly any pigs. Manure from poultry and pigs is typically stored and applied tactically to nearby farmland.

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

Boats may make overboard sewage discharges, so require consideration in this assessment. There are around 30 drying moorings for small yachts at the eastern end of Red Wharf Bay, and a navigation route to the eastern Menai Strait further offshore. Merchant ships shelter off the east coast of Anglesey at times. It is likely that fishing vessels work the area from time to time. It is therefore concluded boat traffic within the area is minor and mainly consists of pleasure craft, and some merchant ships further offshore. The latter are not permitted to make overboard discharges within 3 nautical miles of land so should be of no impact. It is likely that the larger 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. Levels of overnight occupancy on the drying moorings in Red Wharf Bay are uncertain however. Peak pleasure craft activity will arise in the summer, so any associated impacts are likely to follow this seasonal pattern. However, it is difficult to be more specific without any firm information about the locations, timings and volumes of such discharges, and as such boating will have little material bearing on the sampling plan.

Wildlife

The survey area encompasses a range of coastal habitats and these attract aggregations of wildlife, some of which may be an influence on shellfish hygiene. The most significant of these is likely to be the waterbirds (wildfowl and waders) populations which overwinter in the area. Although not subject to any organised counts in recent years, invertebrates within the sand and intertidal flats are reported to provide an important food source for large numbers of overwintering waders. Grazing wildfowl such as geese are also reported to overwinter on Anglesey. Waders feeding on intertidal invertebrates will defecate directly on the intertidal area in which the Red Wharf Bay cockle bed is located. They may tend to aggregate in certain areas holding the highest densities of their preferred size and species of prey, but this may vary from year to year. They will therefore represent a diffuse input and whilst they may be a significant contaminating influence at times, they will not influence the positioning of any RMPs. Grazing waterbirds such as ducks and geese will mainly frequent areas of saltmarsh and coastal grasslands, where their faeces will be carried into coastal waters via runoff into tidal creeks or through tidal inundation. As such they may also be an influence at Red Wharf Bay. RMPs positioned in or by creeks and channels draining from such areas would be best positioned to capture contamination from these.

Although the majority of waterbirds migrate elsewhere to breed, other species such as gulls and terns are present throughout the entire year and aggregate at certain areas to breed during the summer. The main aggregations were at Moelfre Island and the adjacent cliffs (228 pairs) and along the cliffs just to the east of Red Wharf Bay (211 pairs). Puffin Island located 6 km south east of Red Wharf Bay has a major nesting colony (4,687 pairs) including guillemots, razorbills, cormorants, kittiwakes, puffins and various gulls. These birds will forage widely so their inputs can be considered as diffuse. Impacts will be most concentrated in the immediate vicinity of the nesting sites, so may be a significant influence at Moelfre Island during the breeding season, although they will not influence the location of the RMP.

The grey seal population in the Irish Sea numbers 5-6,000 and seals are regularly sighted around the Anglesey Coast. The nearest significant haul out site is Puffin Island, where counts of between 11 and 130 animals have been recorded. Seals may create a localised ‘hotspot’ of contamination where they haul out on sandbanks and islands, but none of their known haulout sites coincides with any shellfish resources. 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, so their presence will not influence the sampling plan. No other wildlife species which may be of significance to shellfish hygiene in the survey area have been identified.

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 settlements such as Benllech and Moelfre. 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 5.2 and Figure 5.2.

Table 5.2: 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 (cockle bed)												
Seabirds (mussel bed)												
Boats												

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

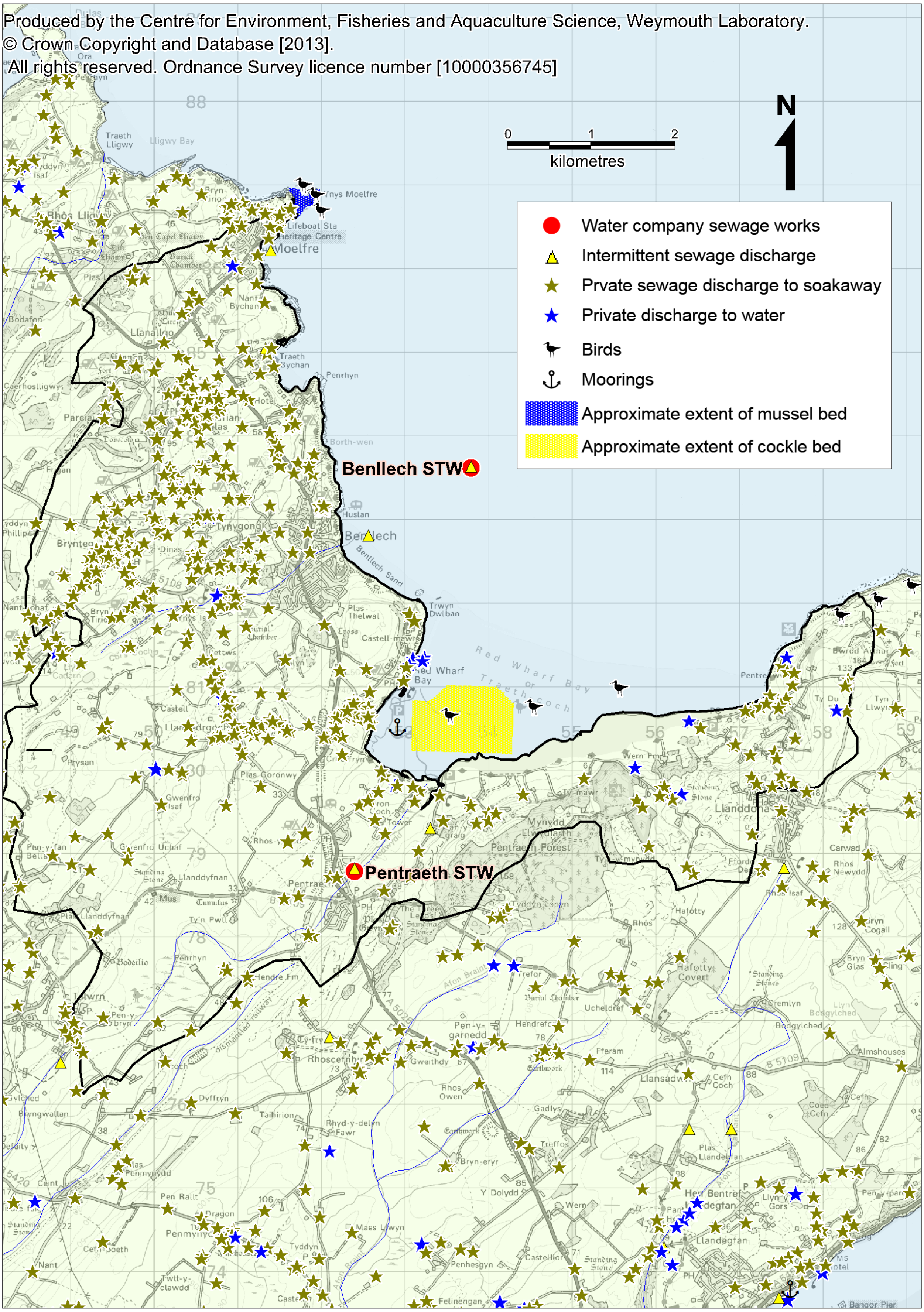


Figure 5.2: Summary of main contaminating influences (Red Wharf Bay)

Malltraeth

Freshwater Inputs

Rivers and streams are significant pathways by which faecal indicator bacteria are delivered to coastal waters and so require consideration in this assessment. Livestock grazing is ubiquitous throughout the catchment so most watercourses will be impacted by agricultural runoff, and some will receive contamination from urban runoff and sewage discharges. The survey area forms the estuary of the Cefni, which has a catchment area of 123 km^2 and is the largest river on Anglesey. This watercourse has been embanked in its tidal reaches and discharges to the head of the estuary, together with two adjacent marsh drains via a set of sluice gates. There is a gauging station in the upper reaches of this river, where the mean flow over the last decade was 0.44 m^3/sec, and the highest recorded flow was 13.8 m^3/sec. Flows recorded here only represent runoff from about 20% of the catchment, so the average discharge from this river is likely to be in the approximate order of 2.2 m^3/sec. A water sample taken from this watercourse during the shoreline survey contained high levels of *E. coli* (8,200 cfu/100ml) but the watercourse was too large to measure. Using the estimated mean river discharge from the whole catchment together with the measured *E. coli* concentration would give an estimated bacterial loading of 1.6×10^{13} *E. coli*/day. Although such an estimate should clearly be treated with caution, it does indicate that the Cefni is a highly significant contaminating influence to the estuary.

Aside from this there are a few very minor streams discharging to the foreshore of the estuary, none of which was carrying a bacterial loading exceeding 10^{10} *E. coli*/day at the time of shoreline survey. It is therefore concluded that there is likely to be a gradient of increasing average levels of runoff borne contamination towards the head of the estuary. Also, the highest concentrations of faecal indicator bacteria are likely to arise in the river channel, particularly the upper reaches, at lower states of the tide.

As well as day to day variations in river flows (and the bacterial loadings they deliver to coastal waters) in response to rainfall, there is likely to be significant seasonal variation in the average discharge rate from watercourses draining to the area. Flows at the gauging station on the Cefni are highest on average from October to December, and the peak flow events tend to occur during this period. Peak and average flows in the summer months tended to be much lower. Whether this translates to a seasonal variation in the average bacterial loadings they deliver is uncertain.

Human Population

Aside from the small village of Malltraeth, at the head of the estuary, there are no coastal settlements within the survey catchment. The main settlement in the area is Llangefni, which has a population of around 5,100 and lies on the banks of the Cefni about 10 km upstream from the sluice gates at Malltraeth. The rest of the catchment is generally rural, with some small scattered settlements. Some urban runoff will enter the Cefni in the

Llangefni area, but the pattern of impacts from sewage will depend on the nature of the sewerage infrastructure serving the population.

Anglesey attracts significant tourism, with about 1.1 million visitors recorded in 2007. The majority of visits were from April to October, peaking in July and August. It is therefore concluded that sewage works in the area are likely to be serving a larger population during the summer, although there are no significant coastal settlements in the survey area.

Sewage Discharges

There is only one sewage discharge direct to the survey area, Malltraeth STW (improved in 2004) which generates an estimated bacterial loading of 7.1×10^{11} faecal coliforms/day and discharges to the main estuary channel just downstream from Malltraeth village. The impacts from this discharge will principally be felt in this channel both upstream and downstream of the outfall. There are also three inland sewage works discharging to the Cefni and its tributaries. The smallest of these (Bodffordd STW) discharges to the Cefni reservoir bypass channel in the upper catchment. Llangefni STW (improved in 2003) discharges to the Cefni about 8 km upstream of the tidal gates at Malltraeth, and generates an estimated bacterial loading of 1.9×10^{13} faecal coliform/day. Gaerwen STW discharges to the canalised section of the Cefni, about 6.5 km upstream of the tidal gates and generates an estimated bacterial loading of 3.9×10^{12} faecal coliforms/day. These two discharges will make a very significant contribution to the bacterial loading delivered to the survey area by the Cefni.

There are 14 intermittent discharges associated with the water company sewerage network within the survey catchment. Of these, 12 discharge to the Cefni and tributaries, none of which have available spill records. It is therefore concluded that these 12 discharges may contribute to the bacterial loading carried by the Cefni at times, although it is not possible to assess how often and to what extent this may occur. A sampling plan designed to capture the impacts of the Cefni may therefore capture the impacts of these discharges. The other two intermittent discharges are both from the Malltraeth STW outfall. An examination of spill records indicated that one of these hardly spills at all (active for 0.2% of the time in recent years) whereas the other was active for 13.4% of the time during the same period. Its impacts would therefore probably be captured during the course of a year or two of monitoring and given this and its potential to deliver large bacterial loadings it should be considered in the sampling plan. The spill records indicated that it was most active in the autumn and winter.

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.

Although the majority of properties in the survey catchment are served by the water company sewerage network, there are 28 consented private sewage discharges within the survey catchment, of which 10 discharge to land and 18 discharge to watercourses. Most are small, serving one or a small number of properties, and providing treatment via package plant or septic tank. Those discharging to ground should not affect water quality in coastal waters, provided systems are working correctly. All but one of those discharging to water are to the Cefni and tributaries, so they will make a minor contribution to the bacterial loading carried by this watercourse.

Agriculture

Most of the land within the survey catchment is pasture, although there is a forested area by the eastern shore of the estuary and a few small cultivated areas further inland. Sheep farming is ubiquitous, with over 275,000 animals recorded on Anglesey in the 2012 census, as well as almost 57,000 cattle. Significant and widespread impacts from grazing animals are therefore anticipated. During the shoreline survey, the main livestock aggregation observed was around 500 sheep on the reclaimed pastures by the north east shore of the estuary. There were also about 70 cattle on a cliff-top field by the western shore. No animals were observed grazing on the saltmarsh area. 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 on Anglesey, but hardly any pigs. Manure from poultry and pigs is typically stored and applied tactically to nearby farmland. Significant amounts of sludge, deriving from both municipal sewage works and plants treating creamery, abattoir and chicken processing units are also applied to arable land in this catchment.

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, namely towards the head of the main river channel running through the estuary. 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. Records of sewage sludge applications indicate that they are spread throughout the year. 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

There are no ports, marinas, moorings, or other boating facilities within the survey area. No boats were seen in the area either on satellite imagery or during the shoreline survey. It is therefore concluded that whilst the occasional small vessel may venture into the estuary, overboard discharges from boats will not generally be made here and as such boats will have no bearing on the sampling plan.

Wildlife

The survey area encompasses a range of coastal habitats including saltmarsh, sandflats and grazing marshes. These attract aggregations of wildlife, some of which may be an influence on shellfish hygiene. The most significant of these is likely to be the waterbirds (wildfowl and waders) populations of which overwinter in the area. Although not subject to any organised counts in recent years, invertebrates within the sand and intertidal flats are reported to provide an important food source for large numbers of overwintering waders. Grazing wildfowl such as geese are also reported to overwinter on Anglesey, and are likely to frequent the saltmarsh and reclaimed pastures by the estuary. Waders feeding on intertidal invertebrates will defecate directly on the intertidal area in which the cockle bed is located. They may tend to aggregate in certain areas holding the highest densities of their preferred size and species of prey, but this may vary from year to year. They will therefore represent a diffuse input and whilst they may be a significant contaminating influence at times, they will not influence the positioning of any RMPs. Grazing waterbirds such as ducks and geese will mainly frequent areas of saltmarsh and coastal grasslands, where their faeces will be carried into coastal waters via runoff into tidal creeks or through tidal inundation. As such they may also be an influence at Red Wharf Bay. RMPs positioned in or by creeks and channels draining from such areas would be best positioned to capture contamination from these.

Although the majority of waterbirds migrate elsewhere to breed, other species such as gulls and terns are present throughout the entire year and aggregate at certain areas to breed during the summer. The closest identified breeding colonies were on the rocky islands and cliffs either side of the mouth of the estuary, where a total of 224 pairs of cormorants, shags and fulmars were recorded during a survey in 2000. Since this survey, Natural Resources Wales indicate that the colony to the south of the estuary mouth (35 pairs of shags) is no longer present. Impacts from these seabirds will be most concentrated in the immediate vicinity of the nesting sites, which are not in close proximity to the cockle bed. As such some diffuse impacts may arise but these will have no influence on the sampling plan.

The grey seal population in the Irish Sea numbers 5-6,000 and seals are regularly sighted around the Anglesey Coast. Seals may create a localised ‘hotspot’ of contamination where they haul out on sandbanks and islands, but none of their known haulout sites are in the vicinity of the Malltraeth survey area. 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, so their presence will not influence the sampling plan. No other wildlife species which may be of significance to shellfish hygiene in the survey area have been identified.

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 settlements such as Malltraeth village. 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 5.3 and Figure 5.3.

Table 5.3: 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												

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

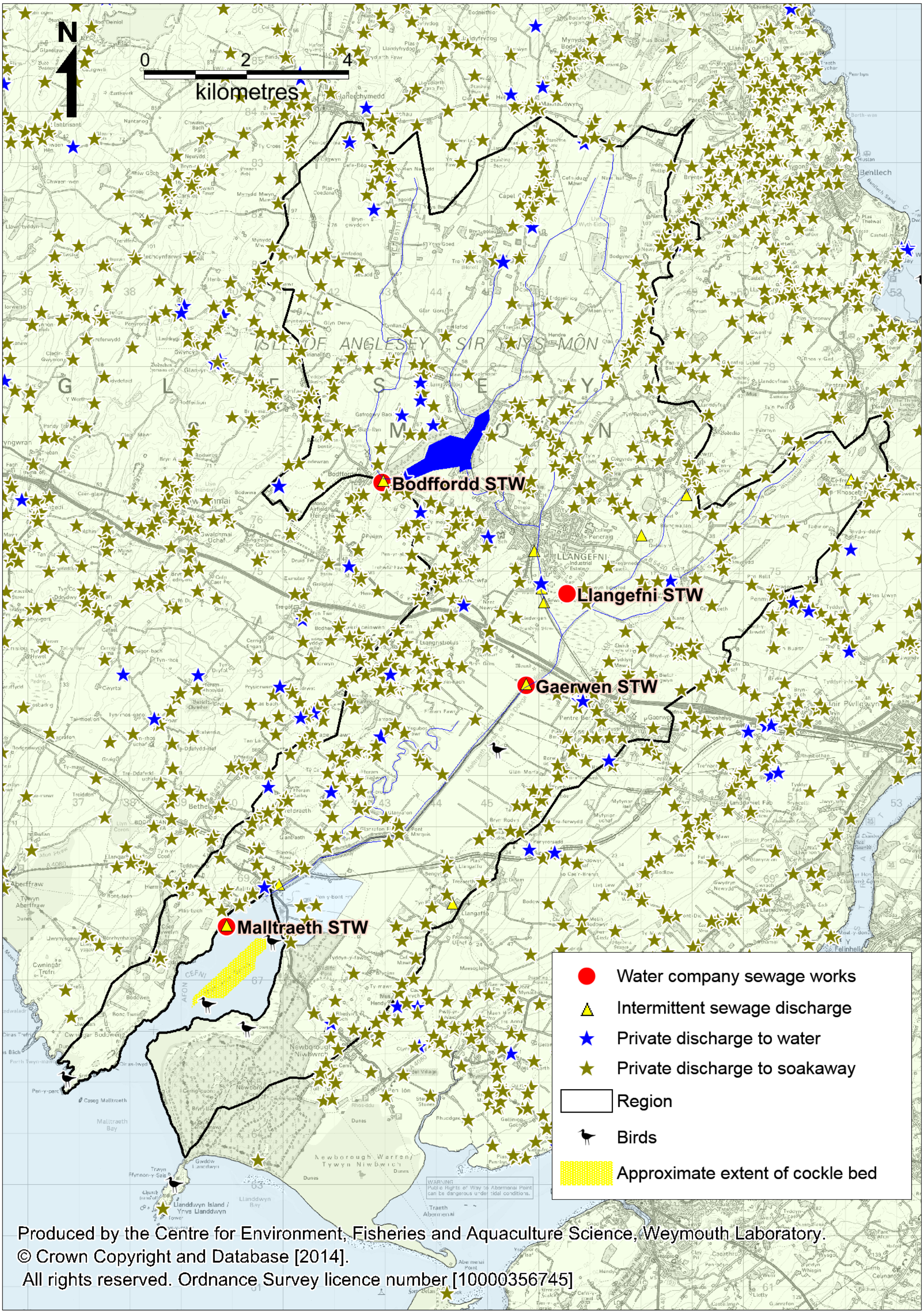


Figure 5.3: Summary of main contaminating influences (Malltraeth)

5.4. Hydrography

Inland Sea

Inland Sea is a 10 km strait located between Anglesey and Holy Island, which is effectively divided into three distinct zones by two man-made causeways (Stanley Embankment and Four Mile Bridge). These are solid structures with narrow culverts that impede the flows of water through the strait as well as causing mixing of the water column as it passes through. The shellfishery is located in the northernmost of these zones. Here the strait is characterised by a subtidal channel flanked by relatively extensive intertidal areas. The intertidal areas then gently slope away into the subtidal and the straits open out into Holyhead Bay. A 2.4 km breakwater extends from Holyhead in an easterly direction, which will provide some shelter from north westerly winds and swells. There is a small enclosed estuary of a minor river (the Alaw) feeding into the eastern shore which represents the main freshwater input to the area. The main drainage channel extending from the mouth of this estuary runs in a southerly direction adjacent to the Anglesey coast before joining the main channel through the strait just north of the Stanley Embankment. There is also a secondary drainage channel which emanates from the mouth of the estuary in a north westerly direction and feeds into the main subtidal channel near the northern extremity of the mussel lay.

Tidal amplitude is relatively large, at 4.9 m on spring tides and 2.4 m on neap tides at Holyhead, and this drives extensive water movements through the survey area. Tidal streams flood along the west coast of Anglesey in a north westerly direction. They enter the strait through both the southern entrance, and a short while later through the northern entrance. They then pass through the two causeways, meeting in the middle section. The reverse occurs on the ebb tide. The water level difference through the culverts results in the formation of a race and standing waves. The impeded flows through these constrictions result in reduced water exchange and tidal range within the central section. The reduced flushing may result in a build up of faecal indicator bacteria in this section, and potentially an ebb plume of more contaminated water through the culverts, although sources of contamination to this section are few and minor.

There is considerable uncertainty as to the extent of impacts from Holyhead STW, which discharges to 15-20 m of water about 3 km to the west of the end of the Holyhead Breakwater. The main tidal stream will progress northwards along the Anglesey coast, whereas the more near shore stream will split from this and flood into the survey area. Whether the plume from Holyhead STW largely passes up the coast or is carried into the strait is uncertain, and the situation may be complicated by the formation of eddy currents at certain states of the tide. The deep water and relatively strong tidal streams at the point of discharge will provide high potential for dilution and dispersion.

The other major source of contamination in the area is the Alaw, which discharges via an enclosed estuary to the eastern shore of the northern section of the straits. There will be significant dilution of this input in the estuary, but it is likely that there is an ebb plume of more contaminated water from the estuary mouth. This will ultimately be carried out of the survey area as the tide drains away to the north. During the early part of the ebb the plume is likely to be carried in a northerly direction, but at lower states of the tide it is likely that it will follow the main drainage channel in a southerly direction before it enters the main channel through the straits just north of the Stanley Embankment. It is therefore anticipated that it will have wide ranging impacts over the intertidal on the eastern shore, but its most acute impacts will arise within the main drainage channel and to a lesser extent along the eastern side of the main channel through the straits.

Tidal exchange is large in relation to freshwater input so the system is likely to be well mixed with salinities usually approaching that of full strength seawater outside of the enclosed Alaw estuary under normal conditions. There is likely to be an area of decreased salinity associated with the mouth of the Alaw estuary, particularly at times of high river flow. This and corresponding increases in levels of faecal indicator bacteria is likely to be most acute in its drainage channel around low water. The area is sheltered from winds from all directions apart from the north, which will tend to push surface water in a southerly direction, and so may advect any buoyant plume from the Holyhead STW into the strait. Given its relatively sheltered aspect strong wave action which may resuspend contamination in the sediment is not generally anticipated although swells may enter the area from the north at times.

Red Wharf Bay

The bathymetry of Red Wharf Bay is relatively uncomplicated. It is comprised of a large area (approximately 7 km^2) of intertidal sand flats which gently slope away into the subtidal. There are several drainage channels cutting across the intertidal area which carry freshwater inputs where relatively high concentrations of faecal indicator bacteria are likely to arise at lower states of the tide. Either side of the bay the foreshore becomes steeper and depths increase more rapidly in the subtidal. At Moelfre, the mussel beds are located on a rocky intertidal reef protruding from the Moelfre Headland which has a small island at its tip. The depth drops away rapidly to over 10m off the island so the dilution potential here is large.

Tidal amplitude is large, at 6.6 m on spring tides and 3.3 m on neap tides at Moelfre, and this drives extensive water movements through the survey area. Tidal streams flood parallel to the east coast of Anglesey in a south easterly direction, and travel in the opposite direction on the ebb. It is concluded that, in general, plumes from shoreline sources of contamination will travel parallel to the coast becoming progressively more diluted. The plume from the Benllech STW outfall, which lies 1.6 km off Benllech in about 6m of water will tend to remain offshore and will not generally impact on shellfisheries in the intertidal. However, within indentations and either side of headlands it is possible that eddy currents form at certain states of the tide and such effects are difficult to predict. Estimates of tidal excursion made from an offshore tidal diamond are in the order of ~8 km on spring tides and ~5 km on neap tides. Tidal streams in more nearshore areas are likely to be slower, particularly in shallow indentations to the coast such as Red Wharf Bay. It is possible that they accelerate slightly around Moelfre headland.

The survey area is an open coastal location with little in the way of freshwater inputs, so density driven circulation is unlikely to be of significance and salinities are likely to be that of full strength seawater throughout. Repeated salinity measurements taken at three locations within the survey area appear to confirm this. A density effect of some relevance is the tendency for sewage effluent to float on seawater, so any plume from the Benllech STW will tend to be buoyant. There may be localised areas of decreased salinity in near shore areas associated with freshwater inputs, the magnitude of which will vary with discharge rates. The most acute influences of land runoff will be felt in the immediate vicinity of drainage channels which carry freshwater inputs across the intertidal, where relatively high concentrations of faecal indicator bacteria may arise at lower states of the tide. Very little freshwater influence is anticipated at Moelfre as freshwater inputs to this stretch of coast are very minor and the dilution potential is very high.

The survey area is most exposed to winds blowing from the north and east. Strong winds will modify tidal circulation patterns, particularly where such circulation is weakest in the inner reaches of Red Wharf Bay. Winds from the north east quadrant will tend to advect any buoyant plume from the Benllech STW towards the shore and under such conditions it is likely to have a greater contaminating influence on shellfish at both Red Wharf Bay and Moelfre. Such winds are also likely to generate energetic wave action, which may resuspend contamination entrained in intertidal sediments.

Malltraeth

The survey area at Malltraeth consists of the enclosed estuary of the Cefni, which is characterised by a large area of intertidal sand flats bisected by a meandering river channel, which mainly follows the western shore. The mouth faces south west and is flanked on either side by rocky outcrops. Sand dunes have accreted on the eastern side resulting in a narrowing of the estuary just inside the mouth. There is some saltmarsh inside of the dunes on the eastern shore. There are several drainage channels from these saltmarsh areas that cut across the intertidal before joining the main river channel. The estuary has been subject to significant land reclaim and the upper reaches have been embanked and canalised to reclaim the Malltraeth Marshes. The canalised section discharges to the main body of the estuary via sluice gates.

Tidal amplitude is relatively large, at 4.2 m on spring tides and 2 m on neap tides at Llanddwyn Island, and this drives extensive water movements through the survey area. Tides will flood up this estuary, firstly up the main channel the spreading out over the intertidal as water levels rise. After high water the estuary will drain in the opposite manner. Currents are likely to be weaker away from the main river channel, but no information on current velocities within the estuary could be found. Apart from the Malltraeth STW which discharges to the main river channel just south of Malltraeth Village, the main contaminating influences arrive via the Cefni. Contamination from the catchment sources will tend to be carried out of the estuary along the course of the main river channel. Contamination from the Malltraeth STW will also tend to remain in the main river channel, but will be carried up the channel during the flood tide. Contamination from minor shoreline sources such as minor watercourses will tend to impact on either side of their location at higher tidal states, whilst at lower states of the tide it will follow drainage channels across the intertidal and into the main estuary channel. The highest concentrations of faecal indicator bacteria are therefore likely to arise in the main river channel and other minor drainage channels the around low water, and RMPs should be located accordingly.

The ratio of average river flow to tidal exchange is low, suggesting that salinity will generally be approaching that of full strength seawater, and that stratification and density driven circulation is unlikely to be of significance apart from at times of high river flow. Repeated salinity measurements taken from the estuary mouth appear to confirm this, although a greater freshwater influence is anticipated further up-estuary. In such estuaries there is typically a gradient of decreasing average salinity towards its head which is usually accompanied by corresponding increases in the average concentration of faecal indicator bacteria originating from catchment sources. It is therefore concluded that the RMP should not only be located as close to the main river channel as possible, but also as far up-estuary as possible.

The estuary faces south west into the prevailing winds, which will tend to push surface water up the estuary. The dunes just inside the mouth will largely prevent energetic wave action from arising in the estuary, which could otherwise potentially re-suspend contamination within sediments.

5.5. Summary of Existing Microbiological Data

The survey areas have been subject to some microbiological monitoring over recent years, consisting of Bathing Waters and Shellfish Waters monitoring programmes, as well as shellfish flesh monitoring for hygiene classification purposes.

Inland Sea

Within this survey area microbiological monitoring results are only available for one monitoring point (Figure 5.4) where levels of *E. coli* have been enumerated under the hygiene classification programme on a monthly basis from 2004 to present.

Figure 5.4: Microbiological sampling sites

The geometric mean result at Gorsedd y Penrhyn was 137 *E. coli* MPN/100g, and the maximum recorded result in 117 samples was 5400 *E. coli* MPN/100g. Only 1.7% of samples exceeded 4600 *E. coli* MPN/100g. There appears to have been an overall trend of decreasing average results during the period sampled. Statistically significant seasonal variation was found, and levels of *E. coli* were significantly higher on average in the autumn compared to the spring. No statistically significant influence of tide across either the high/low or spring/neap cycles was found. There were significant positive correlations with antecedent rainfall, but the effect did not extend further than two days after a rainfall event.

Red Wharf Bay

Within the Red Wharf Bay survey area, there are three bathing waters monitoring points and two RMPs sampled under the shellfish hygiene classification programme. Figure 5.5 shows the locations of the monitoring points referred to in this assessment. Results from 2003 onwards are considered in the analyses.

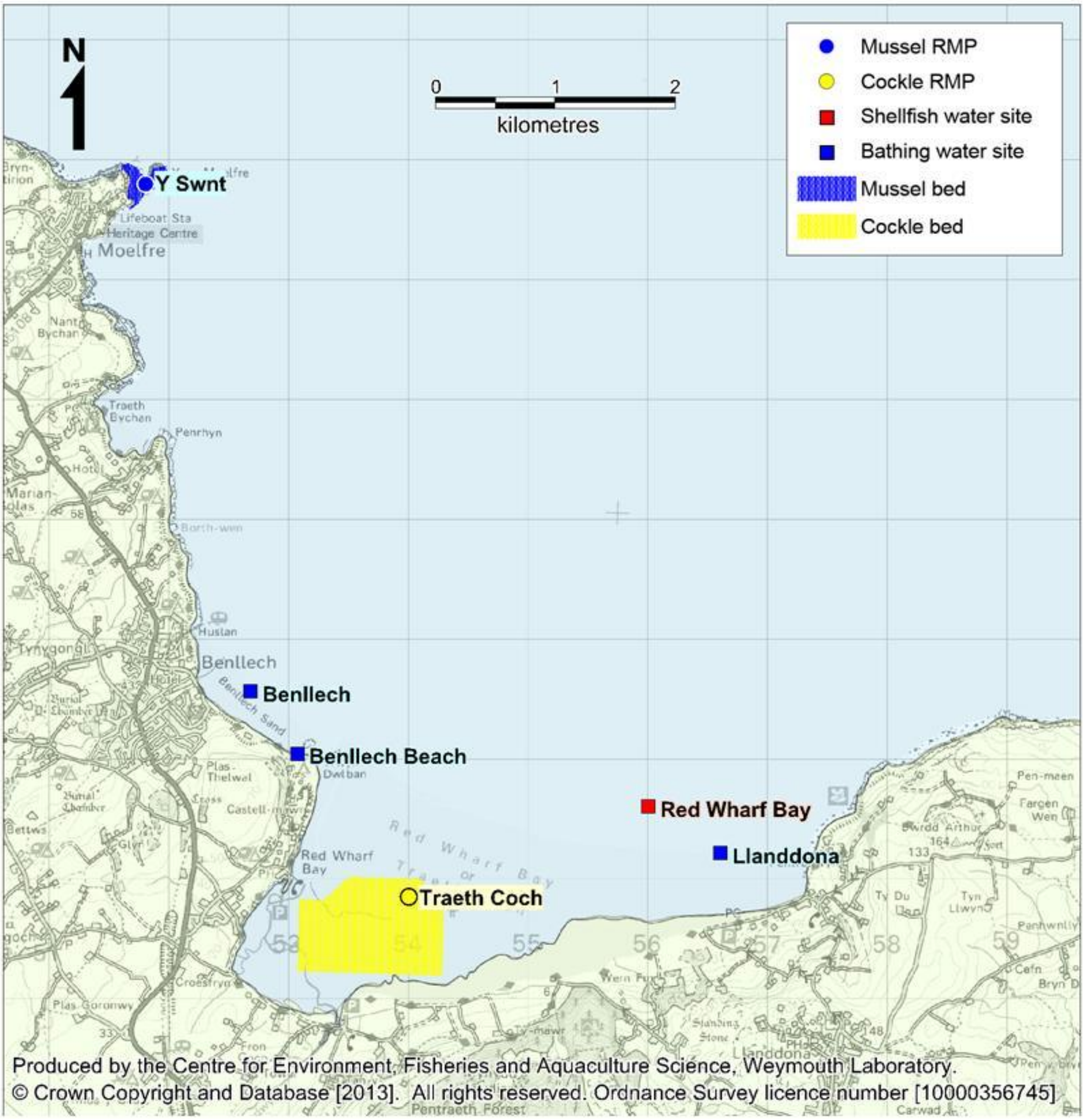


Figure 5.5: Microbiological sampling sites

At the three bathing waters sites, around 20 samples were taken and enumerated for faecal coliforms each bathing season (May-September). The geometric mean result was low at all three, ranging from 7.1 to 8.9 faecal coliforms/100ml, and there was no significant difference between them. Comparisons paired (same day) sample results revealed very strong correlations between all three site pairings indicating that they are subject to similar sources of contamination. Since 2003, results have been relatively stable at all three locations, although there appears to have been a slight improvement in results at Benllech Beach between 2003 and 2006. Significant correlations with tidal state across the high/low tidal cycle were found at Benllech and Llanddona, where higher results tended to occur at higher states of the tide. There were significant correlations with tidal state across the spring/neap tidal cycle at all three bathing sites, where there was a tendency for higher results on average during spring tides. Rainfall affected faecal coliform levels at all three sites to some extent. The influence was most rapid and consistent at Llanddona, whereas elevated levels of faecal coliforms at Benllech and Benllech Beach only arose after a delay of several days following a rainfall event.

At the shellfish waters monitoring point, water samples were collected on a quarterly basis and enumerated for faecal coliforms. It is located further offshore than the bathing waters monitoring points, and the geometric mean concentration of faecal coliforms was lower (3.5 cfu/100ml). The highest individual result was 38 faecal coliforms/100ml, which suggests that the plume from the Benllech STW does not impact acutely here. Faecal coliform levels have remained stable since 2003. Results were highest on average during the winter, and lowest on average during the spring, but the seasonal variation was not statistically significant. No statistically significant influence of either the high/low or spring/neap tidal cycle was detected. Should the Benllech STW be an influence, some variation across the high/low tidal cycle would be anticipated. There was very little influence of antecedent rainfall on faecal coliform levels, nor was there any correlation with salinity at the time of sampling. This suggests that the influence of local rainfall dependent sources observed at the bathing waters sites does not extend far from the intertidal areas.

There are two shellfish hygiene RMPs in the Red Wharf Bay production area which have been sampled on a more or less monthly basis from 2003 to 2013. One is for mussels and one is for cockles. At the Traeth Coch cockle RMP the geometric mean *E. coli* result was 370 *E. coli* MPN/100g and results exceeded 4,600 MPN/100 g in 4.3% of samples. At the Y Swnt mussel RMP *E. coli* results were approaching that of a class A area, with a geometric mean of 42.1 *E. coli* MPN/100g. They only exceeded 230 MPN/100 g in 15.5% of samples and did not exceed 4,600 MPN/100 g in any sample. Results have remained stable at both RMPs since 2003, although the time series plot did suggest a recent run of higher than average results at Y Swnt.

Statistically significant seasonal variation was found at both RMPs. At the Traeth Coch cockle RMP results were significantly higher in summer than in winter. At Y Swnt results were higher on average in spring and summer compared to autumn and winter, but post ANOVA testing did not reveal which seasons were statistically distinct from one another. Across the two RMPs the only statistically significant influence of the spring/neap and high/low tidal cycles detected was the influence of the spring/neap tidal cycle on the Traeth Coch cockle RMP. The majority of sampling here was conducted while tide sizes increased from the neap tides to the spring tides, and across this part of the cycle lower results tended to occur just before spring tides. Rainfall affected *E. coli* levels at the Traeth Coch cockle RMP, but this influence was only detected 5-6 days after a rainfall event. No influence of antecedent rainfall was found at the Y Swnt mussel RMP.

Malltraeth

Figure 5.6 shows the locations of the monitoring points referred to in this assessment. Results from 2003 onwards are considered in the analyses.

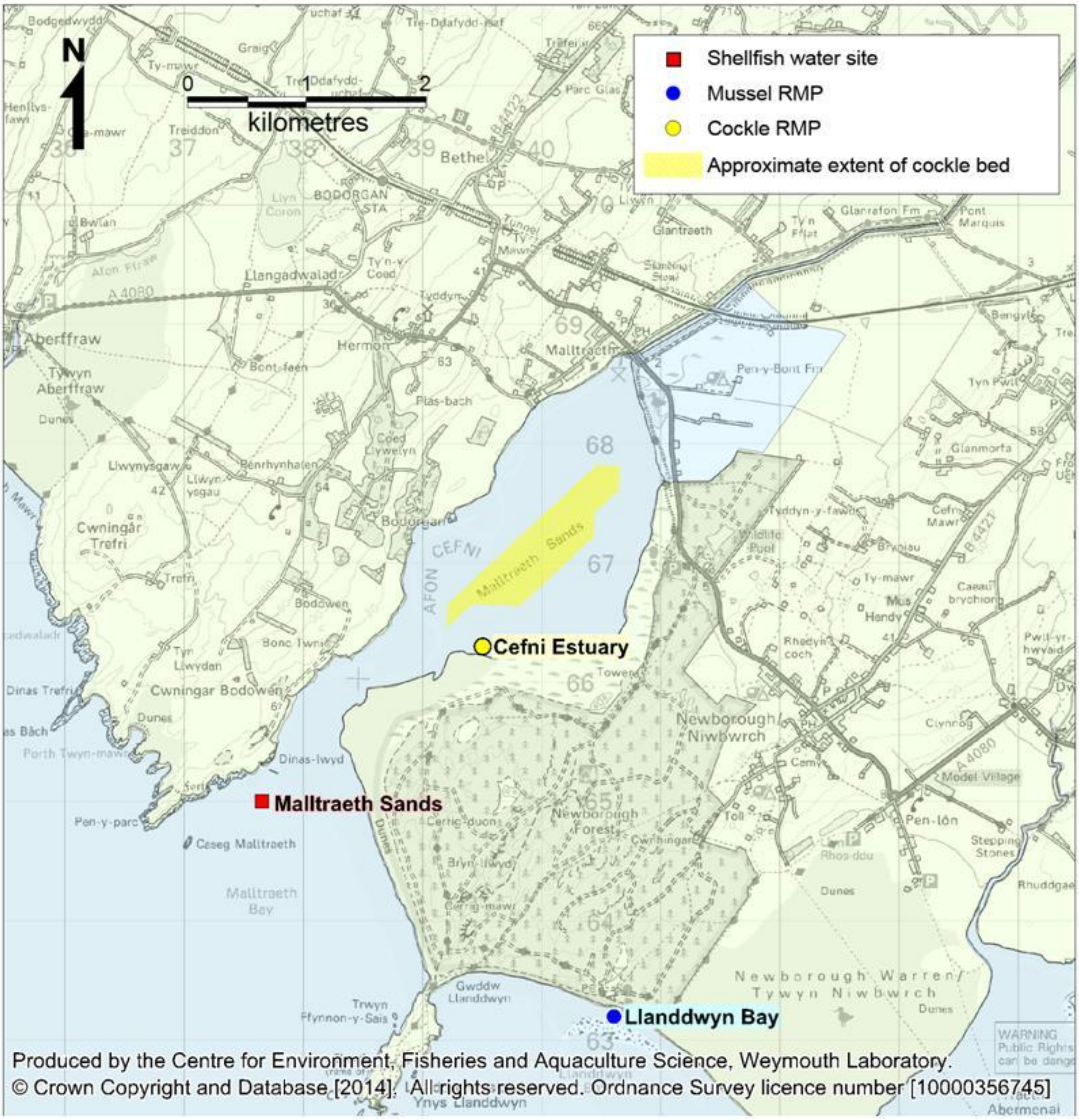


Figure 5.6: Microbiological sampling sites

At the Malltraeth shellfish waters site, which actually lies in a more open coastal situation than the cockle beds, water samples were collected on a quarterly basis and enumerated for faecal coliforms. The geometric mean faecal coliform concentration here was low (8.3 cfu/100ml), and only 4.3% of samples returned results exceeding 100 cfu/100ml. Levels of faecal coliforms have remained steady since 2003. There were significant differences between seasons, with significantly higher levels of faecal coliforms in winter than any other season. No significant influence of the high/low tidal cycle was detected, but a significant correlation between faecal coliform concentrations and the spring/neap tidal cycle was found. A plot of these data suggested that the lower results tended to occur as the tide size decreased from springs to neaps. A significant influence of antecedent rainfall was found, as well as a strong negative correlation between salinity and faecal coliform levels. It is therefore concluded that land runoff is an important contaminating influence at this monitoring point.

There are two hygiene RMPs which have been active in the area since 2003. Only six samples were taken at the Llanddwyn Bay mussel RMP, where the geometric mean and maximum results were 82.6 and 310 *E. coli* MPN/100g respectively. The low number of samples precluded any more detailed analyses of results from this RMP, which is of limited relevance to the cockle bed at Malltraeth due to its location. The Cefni Estuary cockle RMP is located away from the main river channel and towards the lower reaches of the estuary. The geometric mean result here was 440 *E. coli* MPN/100g and 6.4% of samples exceeded 4600 *E. coli* MPN/100g. Time series plots suggest a slight decrease in average levels of *E. coli* from 2003 to 2008. Results were highest on average during the autumn and lowest on average during the spring, but these differences were not particularly marked, and were not found to be statistically significant. A weak correlation between *E. coli* levels and the spring/neap tidal cycle was found. The majority of sampling was conducted while tide sizes increased from the neap tides to the spring tides, and across this part of the cycle the highest results tended to occur just after neap tides. A significant influence of rainfall was detected two days after a rainfall event, but not before or after this. The limited nature of this influence is surprising given that the cockle bed lies in an enclosed estuary, although the RMP is not located in such as position to capture the effects of land runoff.

Appendices

Appendix I. Human Population

Figure I.1 shows population densities in census output areas within Anglesey, derived from data collected from the 2011 census.

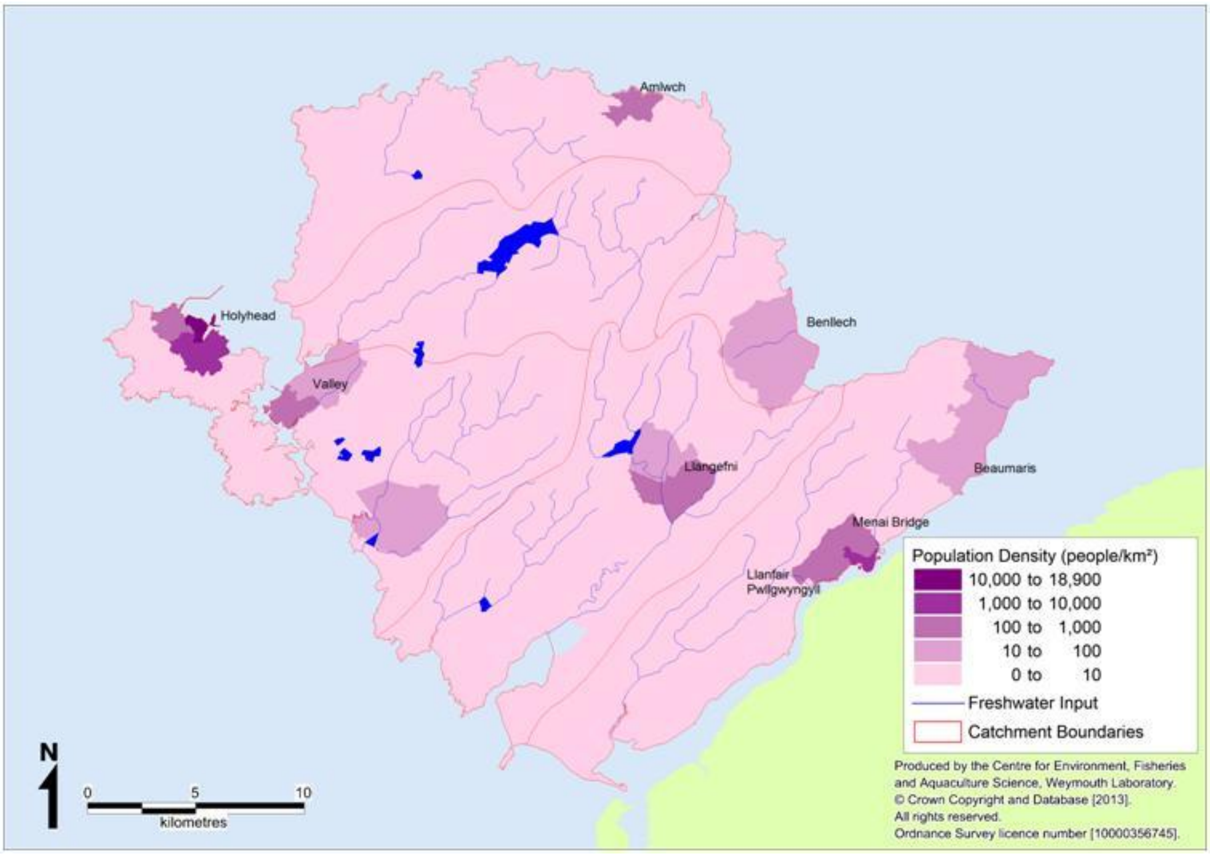


Figure I.1: Human population density in census areas in the Anglesey catchments.

The total resident population of Anglesey was just under 70,000 at the time of the last census. Of these about 14,000 people reside on Holy Island and 56,000 reside on the Isle of Anglesey. The largest settlement in the area is Holyhead, which had a population of about 11,400 at the time of census. Valley is located directly adjacent to the Inland Sea production area and had a population of around 2,400 at the time of the census. The village of Benllech lies adjacent to the Red Wharf Bay production area and had a population of around 3,400 at the last census. The smaller village of Moelfre lies immediately adjacent to the mussel bed around the headland. The rest of the catchment is generally rural, with some small scattered settlements. The main settlement in the Malltraeth catchment is the town of Llangefni which lies some distance inland and has a population of around 5,100. Malltraeth village lies at the head of the estuary.

Anglesey attracted approximately 1.1 million visitors in 2007 (Tourism Partnership North Wales. 2008; GTS, 2008) and so there will be some seasonality in population within the survey area. Figure I.2 shows the variation in visitor numbers to Anglesey in 2007.

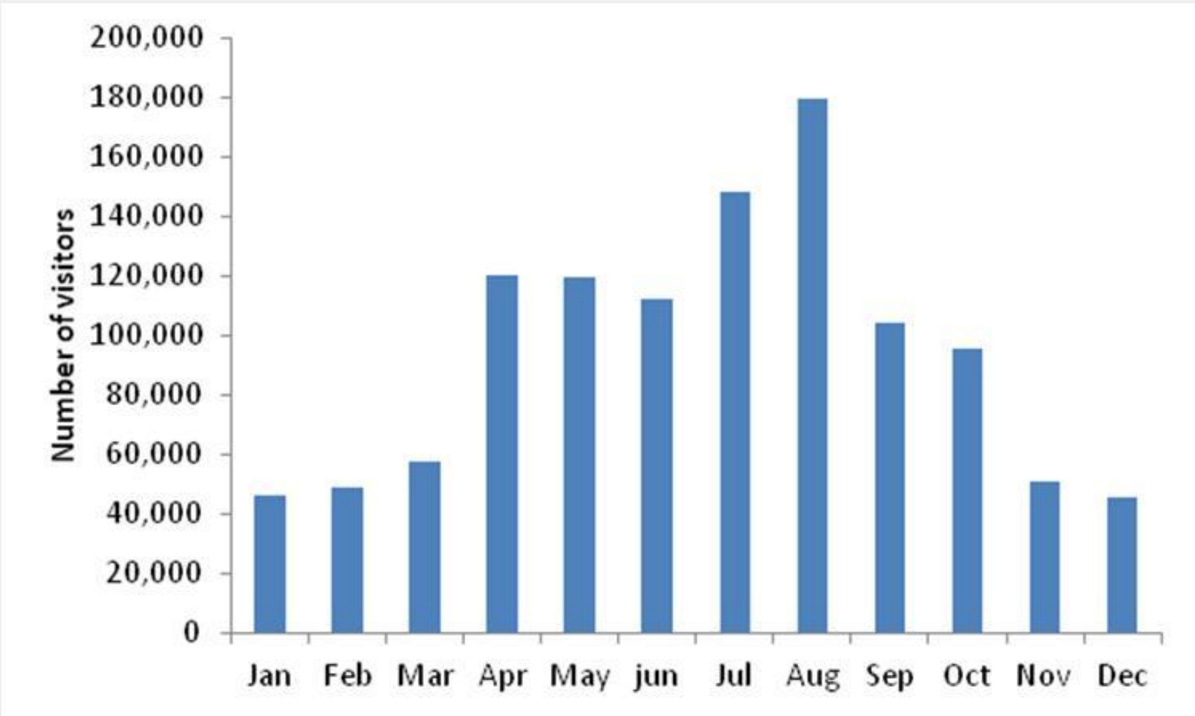


Figure I.2: Numbers of tourists visiting Anglesey in 2007 by month.
Data from Tourism Partnership North Wales. 2008 & GTS, 2008

During the summer there is an influx of tourists attracted by the seaside location and the proximity to Snowdonia National Park. The Red Wharf Bay area is a popular seaside holiday destination, and there are a number of caravan parks in this area. 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

As there are three entirely separate areas considered in this survey, this section presents an inventory of all sewage discharges on Anglesey, and discusses their likely impacts for the three individual areas.

II.1. Overview of sewerage arrangements on Anglesey

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

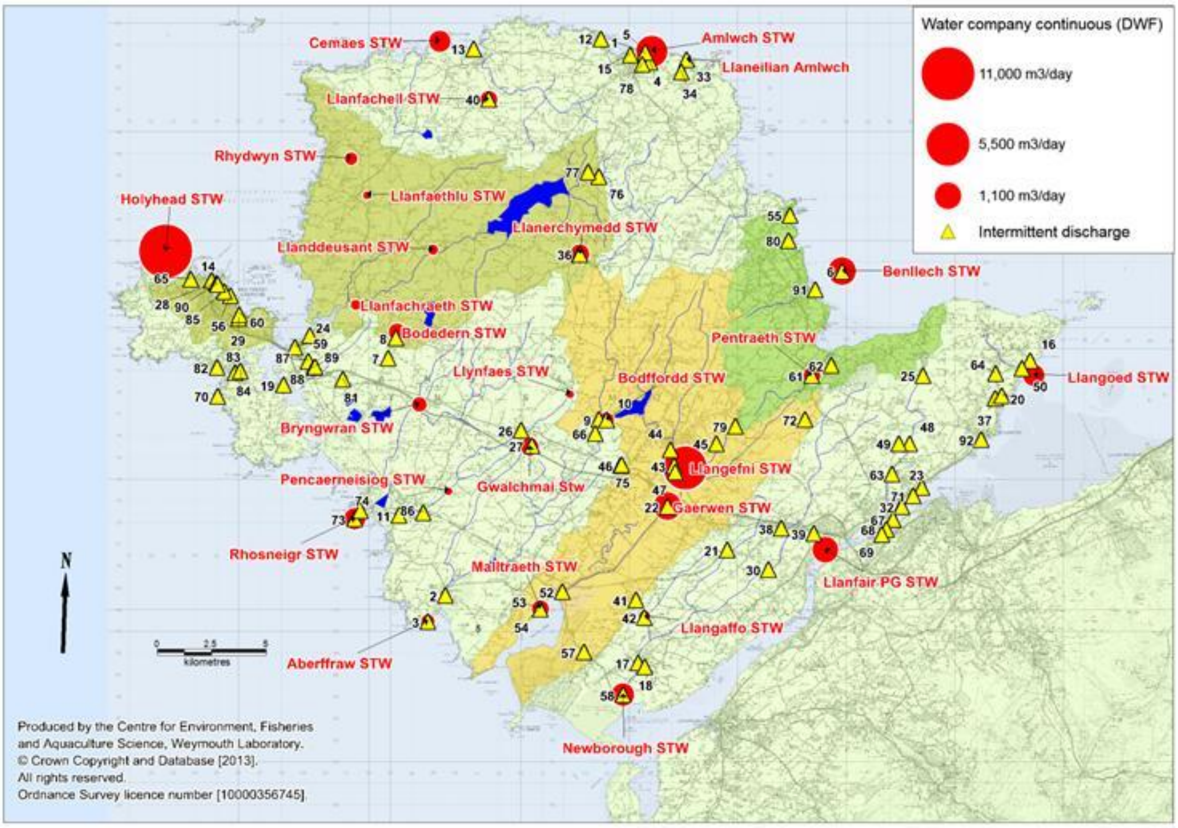


Figure II.1: Water company sewage discharges in Anglesey
Data from the Environment Agency

There are 28 continuous water company discharges on Anglesey, details of which are presented in Table II.1. Those discharges impacting on each of the three production areas are discussed below. Water company intermittent discharges on Anglesey are listed in Table II.3.

Table II.1: Details of continuous water company sewage works on Anglesey

Name	NGR	Treatment	DWF (m^3/day)	Estimated bacterial loading (cfu/day)*	Receiving environment
Aberffraw STW	SH3471067510	Biological Filtration	98	3.23×10^{11}	Aberffraw Bay
Amlwch STW	SH4501793771	Biological Filtration	1946	6.42×10^{12}	Coastal Waters
Benllech STW	SH5379083630	Biological Filtration	1230	4.06×10^{12}	Coastal Waters
Bodedern STW	SH3328080810	Biological Filtration	234	7.72×10^{11}	Un-Named Trib. Of Alaw
Bodffordd STW	SH4292076760	Biological Filtration	170.4	5.62×10^{11}	Un-Named Trib. Of Cefni
Bryngwran STW	SH3431077490	Biological Filtration	139.2	4.59×10^{11}	Crugyll
Cemaes STW	SH3526094200	UV Disinfection	544	1.52×10^{9}	Coastal Waters
Gaerwen STW	SH4574372790	Biological Filtration	1188.78	3.92×10^{12}	Afon Cefni
Gwalchmai Stw	SH3941075550	Biological Filtration	302	9.97×10^{11}	Nant Cwyrtai
Holyhead STW	SH2263084550	Biological Filtration	10879	3.60×10^{13}	Coastal Waters
Llanddeusant STW	SH3494084620	Biological Filtration	48	1.58×10^{11}	Alaw
Llaneilian Amlwch	SH4661893378	Screening	Unspecified		Coastal Waters
Llanerchymedd STW	SH4172384406	Biological Filtration	318	1.05×10^{12}	Afon Goch Dulas
Llanfachell STW	SH3751091540	UV Disinfection	217.6	6.09×10^{8}	Meddanen
Llanfachraeth STW	SH3138082070	Biological Filtration	48	1.58×10^{11}	Alaw Estuary
Llanfaethlu STW	SH3190087130	Biological Filtration	21.8	7.19×10^{10}	Un-Named Trib. Of Afon Alaw
Llanfair PG STW	SH5302470802	Biological Filtration	957.8	3.16×10^{12}	Menai Strait
Llangaffo STW	SH4469067710	Biological Filtration	64	2.11×10^{11}	Trib Of River Braint
Llangefni STW	SH4654874584	Biological Filtration	5741	1.90×10^{13}	Afon Cefni
Llangoed STW	SH6262078820	Biological Filtration	475.3	1.57×10^{12}	Menai Strait
Llynfaes Stw	SH4126077980	Unspecified	16	5.30×10^{10}	Nant Ddrydwy
Malltraeth STW	SH3988168071	Biological Filtration	216.4	7.14×10^{11}	Cefni Estuary
Newborough STW	SH4370064140	Biological Filtration	570	1.88×10^{12}	Estuary Of Afon Braint
Pencaerneisiog STW	SH3565073510	Biological Filtration	23	7.60×10^{10}	Ddrydwy
Pentraeth STW	SH5239078800	Biological	237	7.82×10^{11}	Nant Nodwydd

Name	NGR	Treatment	DWF (m^3/day)	Estimated bacterial loading (cfu/day)*	Receiving environment
		Filtration			
Rhosneigr STW	SH3133072220	UV Disinfection	539	$1.51x10^9$	Coastal Waters Irish Sea
Rhydwyn STW	SH3116088830	Biological Filtration	82	$2.71x10^{11}$	Un-Named Stream

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

None of the UV treated sewage works are located where they will have any impacts on any of the shellfisheries considered in this report. The results of bacteriological testing of their final effluents are therefore not examined. No bacteriological testing of final effluents is undertaken at the sewage works without any disinfection step. For the estimation of the bacterial loadings from each works reference values from the literature were used (Table II.2).

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.

In addition to the continuous sewage discharges, there are several intermittent water company discharges associated with the sewerage networks also shown on Figure II.1. Details of these are shown in Table II.3, where discharges highlighted in yellow have spill event monitoring.

Table II.3: Intermittent discharges on Anglesey

No.	Name	Grid reference	Receiving water	Type
1	A Sewage Pumping Station Craig Y	SH4471793607	Afon Goch	Pumping Station / Sewer Storm Overflow
2	Aberffraw SPS Glan Y Mor Aberffraw	SH3552368721	Afon Ffraw	Emergency Discharge
3	Aberffraw STW	SH3471067510	Abberffraw Bay	STW Storm Overflow/Storm Tank
4	Amlwch Port PS	SH4494093250	Coastal Waters - Amlwch Harbou	Pumping Station
5	Amlwch U/S Octel (Bot) – SSO	SH4472093710	Unnamed Stream	Sewer Storm Overflow
6	Benllech STW LSO Benllech	SH5379083630	Coastal Waters	STW Storm Overflow/Storm Tank
7	Bodedern PS	SH3288079630	Un-Named Ditch	Sewer Storm Overflow

No.	Name	Grid reference	Receiving water	Type
	(Emergency)			
8	Bodedern SPS	SH3322780549	Alaw Tributary	Emergency Discharge
9	Bodffordd Opp Capel Sardis	SH4260076800	Cefni	Sewer Storm Overflow
10	Bodffordd STW (Emergency)	SH4295076780	Cefni Reservoir By-Pass Channe	Sewer Storm Overflow / Storm Tank
11	Bryn Du SPS	SH3337972400	Llyn Maelog	Emergency Discharge
12	Bull Bay PS	SH4269094340	Coastal Waters - Bull Bay	Pumping Station
13	Cemaes PS/Balancing Tank Cemaes Bay	SH3683093870	Coastal Waters Of Irish Sea	Emergency Discharge / Overflow
14	Coastguard CSO	SH2472983228	New Harbour, Holyhead	Sewer Storm Overflow
15	Craig Ddu Estate Amlwch ,	SH4403093590	Unnamed Watercourse	Sewer Storm Overflow
16	Cynlai PS Llangoed Anglesey	SH6246079520	Coastal Waters	Pumping Station
17	Dwyran By School - SSO	SH4440065600	Braint	Sewer Storm Overflow
18	Dwyran Rhydwyn - SSO	SH4470065400	Braint	Sewer Storm Overflow
19	Four Mile Bridge PS	SH2806078400	Estuary - Holy Island Straits	Emergency Discharge
20	Fryars Bay PS	SH6115077910	Unnamed Ditch	Pumping Station
21	Gaerwen Station SPS	SH4850070800	Trib Braint	Pumping Station
22	Gaerwen STW Storm	SH4574372791	Cefni	STW Storm Overflow/Storm Tank
23	Glyn Garth PS Llandegfan	SH5747073680	Estuary - Menai Strait	Pumping Station
24	Gorad PS Gorad Nr Valley Angle	SH2928080679	Estuary - Afon Alaw	Emergency Discharge
25	Gorsllwyd Sewage Pumping Station	SH5752978828	The Afon Cadnant	Emergency Discharge
26	Gwalchmai Isaf PS	SH3900076300	Stream	Pumping Station
27	Gwalchmai STW	SH3950075590	Nant Cwyrtai	STW Storm Overflow/Storm Tank
28	Hibernia Row PS	SH2497583069	New Harbour, Holyhead	Pumping Station
29	Holyhead STW Final Effluent PS	SH2600481455	Un-Named Watercourse	Sewer Storm Overflow
30	Llanddaniel Pont Y Crug SPS	SH5040069900	Afon Briant	Sewer Storm Overflow
31	Llandegfan (Menai) PS	SH5652072800	Menai Strait	Pumping Station
32	Llandegfan PS (Emergency)	SH5655072790	Menai Strait	Sewer Storm Overflow
33	Llaneilian Amlwch	SH4661893378	Coastal Waters	Pumping Station / Storm Overflow
34	Llanelian SPS	SH4640092800	Sea Outfall	Pumping Station
35	Llanerchymedd STW	SH4170084410	Afon Goch Dulas	Sewer Storm Overflow / Tank
36	Llanerchymedd STW	SH4172384406	Afon Goch Dulas	STW Storm Overflow/Storm Tank
37	Llanfaes PS (Emergency)	SH6085077780	Unnamed Watercourse	Sewer Storm Overflow
38	Llanfair PG SPS	SH5100071800	Braint	Pumping Station

No.	Name	Grid reference	Receiving water	Type
39	Llanfairpwll SSO No. 2	SH5250071570	Trib. Of Braint	Sewer Storm Overflow
40	Llanfechell PS	SH3751891549	The Afon Meddanen	Pumping Station
41	Llangaffo Cae Berllan SPS	SH4430068500	Unnamed Ditch	Pumping Station
42	Llangaffo STW SSO	SH4469067690	Braint	STW Storm Overflow/Storm Tank
43	Llangefni Main PS	SH4604774671	Cefni	Emergency Discharges
44	Llangefni Mh Front Ynys Mon Of	SH4590075400	Cefni	Sewer Storm Overflow
45	Llangefni Mh Rear Of Burgess	SH4800075700	Clai	Sewer Storm Overflow
46	Llangefni Rhostrehwfa	SH4360074700	Adj Ditch	Sewer Storm Overflow
47	Llangefni STW Storm Overflow	SH4609774394	Afon Cefni	STW Storm Overflow/Storm Tank
48	Llansadwrn PS	SH5690075700	Cadnant	Pumping Station
49	Llansadwrn PS	SH5640075700	Trib.Of Cadnant	Pumping Station
50	Lleiniog PS	SH6209079150	Menai Strait	Pumping Station
51	Malltraeth Village CSO	SH4090368870	Cefni	Sewer Storm Overflow
52	Malltraeth Village PS	SH4090468871	Estuary - Afon Cefni	Pumping Station
53	Malltraeth STW - Storm	SH3988168071	Cefni Estuary	STW Storm Overflow/Storm Tank
54	Malltraeth STW Terminal	SH3988168071	Cefni Estuary	Emergency Discharges
55	Moelfre PS Moelfre	SH5139086220	Coastal Waters	Pumping Station
56	Morawelon SPS	SH2561782513	Coastal Waters	Pumping Station
57	Newborough Millbank SPS	SH4190066100	Unnamed Ditch	Pumping Station
58	Newborough STW	SH4370064140	Afon Braint (Estuary)	STW Storm Overflow/Storm Tank
59	Newlands Beach PS Valley Angle	SH2859080120	Estuary - Afon Alaw	Pumping Station
60	Penrhos Beach PS	SH2602681631	Beddmanarch Bay	Pumping Station
61	Pentraeth STW	SH5239078820	Afon Nodwydd	STW Storm Overflow/Storm Tank
62	Pentraeth Tan Y Graig SPS	SH5330079300	Nodwydd	Pumping Station
63	Pont Llandegfan SPS	SH5609874287	Cadnant	Pumping Station
64	Pont Y Brenin PS	SH6088078930	Y Brenin	Pumping Station
65	Porth Y Felin PS	SH2379783270	New Harbour, Holyhead	Pumping Station
66	Proposed Capel Gad SPS	SH4243076170	Un-Named Watercourse	Sewer Storm Overflow
67	PS No 1 (Faelog Causeway) (Emergency)	SH5616072210	Menai Strait	Pumping Station / Storm Overflow
68	PS No 2 (Porth Wrach) (Emergency)	SH5584071760	Menai Strait	Pumping Station / Storm Overlow
69	PS No 3 (Suspension Bridge) (Emergency)	SH5563071520	Menai Strait	Pumping Station / Storm Overflow
70	Ravens Point Trearddur Bay	SH2503077880	Coastal Waters	STW Storm Overflow/Storm Tank
71	Rhianfa PS Llandegfan	SH5708073300	Estuary - Menai Strait	Pumping Station
72	Rhoscefnhir SPS	SH5210076800	Unnamed Ditch	Pumping Station
73	Rhosneigr SPS	SH3133072221	Irish Sea	Sewer Storm Overflow

No.	Name	Grid reference	Receiving water	Type
	Rhosneigr			
74	Rhosneigr STW	SH3160072600	Coastal Waters	STW Storm Overflow/Storm Tank
75	Rhostrehwfa PS	SH4363074720	Un-Named Trib Afon Gwna	Pumping Station
76	Rhosybol Gorslwyd PS	SH4260088000	Alaw Catchment	Pumping Station
77	Rhosybol Plas Y Ffrwd SPS	SH4210088200	Alan Catchment	Pumping Station
78	Storm Tank Army Cadet Centre Glan	SH4457793172	Afon Goch	Pumping Station / Storm Overflow
79	Talwrn SPS	SH4887576494	Unnamed Ditch	Pumping Station
80	Traeth Bychan PS Traeth Bychan Ang	SH5133085040	Unnamed Watercourse	Sewer Storm Overflow
81	Tre Ifan Pumping Station	SH3078378668	Un-Named Watercourse	Sewer Storm Overflow
82	Trearddur Bay Haul A Mor SPS	SH2500079200	Adj Ditch	Pumping Station
83	Trearddur Bay PS (Gravity)	SH2583278977	Un-Named Watercourse	Emergency Discharge
84	Trearddur Bay PS (Pumped Discharge)	SH2607679036	Esturial Waters Of Inland Sea	Pumping Station
85	Turkey Shore PS Holyhead Anglesey	SH2533582698	Coastal Waters Of Irish Sea	Pumping Station
86	Ty Croes SPS	SH3450072500	Unnamed Watercourse	Pumping Station
87	Valley Dyffryn And Pendyffryn	SH2920079500	Unnamed Stream	Pumping Station
88	Valley Storm PS (Gravity Discharge)	SH2946379205	Un-Named Watercourse	Emergency Discharges
89	Valley Storm PS	SH2949979224	Un-Named Watercourse	Emergency Discharges
90	Waterside Pumping Station	SH2501283039	New Harbour, Holyhead	Pumping Station
91	Wendon Car Park PS Benllech	SH5256082800	Coastal Waters	Pumping Station / Storm Overflow
92	West End PS Beaumaris Anglesey	SH6022075880	Estuary - Menai Strait	Pumping Station

Data from the Environment Agency

For those without event monitoring it is difficult to assess their potential impacts aside from noting their location and potential to spill untreated sewage. Event monitoring data for Llanfaes PS were not examined as this pumping station is located in the Beaumaris area. Event monitoring data are summarised in Table II.4 for the two monitored outlets from Malltreath STW, for the period April 2005 to March 2013. The two outlets have the same grid reference on both the spill records and the permit database, but they are named differently so it is not possible to be certain which is which.

Welsh Water are nearing completion of a project to install telemetry to record spills on all their assets that discharge near designated shellfish and EC bathing waters. Once completed this will provide a significant improvement in the amount of information available

Table II.4: Summary of spill records, January 2008 to March 2012.

	Malltraeth SPS (Presumably 54)			Malltraeth STW (presumably 53)		
Season	**No. events**	**Total duration (hrs)**	**% time active**	**No. events**	**Total duration (hrs)**	**% time active**
Spring	5	2.9	<0.1%	49	1945.5	11.0%
Summer	18	20.4	0.1%	17	178.3	1.0%
Autumn	17	124.5	0.7%	107	3420.0	19.6%
Winter	4	3.0	<0.1%	151	3853.4	22.2%
Total	44	150.8	0.2%	324	9397.2	13.4%

Data from the Environment Agency

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 are presented in Table II.5 and mapped in Figure II.2.

Table II.5: Details of private sewage discharges on Anglesey >4 m^3/day within the hydrological catchments of either Inland Sea, Red Wharf Bay or Malltraeth

Ref.	Property served	Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
1	1-7 Council Houses At Llanynghenedl	SH3136481101	Package Treatment Plant	4.9	Trib Of Afon Alaw
2	Anglesey Sea Zoo Brynsiencyn Angl	SH4783065420	Unspecified	20	Un-Named Ditch To Menai Strait
3	Bodwina Bellaf	SH4090176705	Package Treatment Plant	4.32	Unnamed W/Ourse Via Ptl S/Away
4	Borthwen	SH2982987699	Package Treatment Plant	4.05	Un-Named Watercourse
5	Capel Parc Llandyfrydog ,	SH4485087220	Biodisc	7	Unnamed Watercourse
6	Conway Centre Llanfairpwll ,	SH5226069900	Septic Tank	60	Menai Strait
7	Ffrwd Win County Primary School	SH3081485786	Package Treatment Plant	20	Unnamed Trib Of Holyhead Bay
8	Garnedd Ddu (Holiday Cottages) Star	SH5044072010	Biodisc	5	Unnamed Watercourse
9	Glan Llyn Farm Pentrafelin	SH4389091790	Package Treatment Plant	4.5	Afon Coch
10	Glan Yr Afon Bodwrog Near Llynfaes	SH3976079170	Package Treatment Plant	5	Unnamed Trib Of Afon Caradog
11	Indefatigable School Llanfair Pg	SH5337071020	Biological Filtration	36	Menai Strait
12	Kingsbridge Caravan Park	SH6056178734	Package Treatment Plant	9.4	Afon Y Brenin
13	Llanfairpwll Plas Newydd	SH5216069470	Package Treatment Plant	30	Estuary - Menai Strait
14	Llidiart-Twrcelyn	SH4587081771	Package Treatment Plant	4.5	Unnamed Watercourse
15	Llyn Y Gors	SH5766874947	Package Treatment Plant	12	Un-Named Watercourse

Ref.	Property served	Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
16	Lon Llydan Park	SH5001380031	Package Treatment Plant	12	Trib Of The Afon Ceint
17	Nos 1-5 Kensington Close	SH4289292155	Package Treatment Plant	4	Un Named Watercourse
18	Old Passenger Lounge Salt Island	SH2510083300	Unspecified	13.5	Coastal Waters
19	Parc Cefni	SH4337176851	Package Treatment Plant	19.3	Cefni Reservoir Bypass Channel
20	Pentre Coed Country Park	SH5413473649	Package Treatment Plant	4.7	Afon Rhyd Eilian
21	Plas Coch Caravan Park	SH5191767711	UV Disinfection	194.2	Menai Strait
22	Ptp Serving Visitor Centre At	SH5217169746	Package Treatment Plant	9	Menai Strait
23	Quality Care Nursing Home Glan Rhos	SH4744067120	Package Treatment Plant	15	Partial Soakaway
24	RAF Station	SH3099076140	Package Treatment Plant	17	Surface Drain Via Soakaway
25	RAF Station Valley Holyhead	SH3171377091	Biological Filtration	1782	Llyn Penrhyn
26	RAF Station Valley Outfall J	SH3134075810	Biological Filtration	6	Sewer Via Partial Soakaway
27	RAF Station Valley Discharge K	SH3100075761	Package Treatment Plant	6	Coastal Waters Via Sw Sewer
28	Rhosgoch Tank Farm Amlwch ,	SH4125090950	Unspecified	5	Afon Wygyr
29	The Gazelle Hotel Glyngarth	SH5799074003	Package Treatment Plant	13.8	Menai Straits
30	Treetops Country Club Bwlch Lane B	SH5075082100	Unspecified	4.7	Marchogion
31	Tre-Ysgawen Hall Hotel	SH4528881094	Package Treatment Plant	26	Stream Via Partial Soakaway
32	Tros Yr Afon Holiday Homes Penmon	SH6159079170	Unspecified	5	Afon Lleiniog
33	Wavecrest Cafe Church Bay Rhydwyn A	SH3006089140	Unspecified	5	Unnamed Watercourse
34	Wern Y Wylan	SH5617479725	Package Treatment Plant	4.86	Wern Y Wylan Stream
35	5 Tai Betws	SH5066781084	Package Treatment Plant	4	Groundwater Via A Soakaway
36	Bodafon	SH5150083660	Septic Tank	12.3	Land
37	Bodwina Bellaf	SH4090176704	Package Treatment Plant	4.32	Unnamed W/Ourse Via Ptl S/Away
38	Borthwen	SH2978787544	Package Treatment Plant	4.05	Un-Named Watercourse
39	Carmel Bungalows	SH3867582431	Septic Tank	10	Land
40	Clynnog	SH4356465595	Package Treatment Plant	5	Into Land
41	Ffordd Yr Ysgol Housing Act Works	SH5119080440	Biological Filtration	7.4	Land
42	Fron Caravan And	SH4696966993	Septic Tank	20	Groundwaters Via

Ref.	Property served	Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
	Camping Park				Soakaway
43	Gadlys Country House Hotel	SH3778093850	Septic Tank	16	Soakaway
44	Henllys Farmhouse Apartments	SH5999577727	Package Treatment Plant	16	Groundwater Via Soakaway
45	Home Farm Caravan Park	SH4978584845	Septic Tank	15	Ground - Soakaway
46	Home Farm Caravan Park Marianglas	SH4959084900	Septic Tank	12	To Land
47	Kingsbridge Caravan Park	SH6042178493	Package Treatment Plant	15	To Ground
48	Kingsbridge Caravan Park	SH6067078854	Septic Tank	7.5	To Ground
49	Maes Gwynedd Housing Act Works	SH4581182450	Biological Filtration	7.02	Land
50	Nant Newydd Caravan Park	SH4844081590	Septic Tank	19	Ground
51	Nant Newydd Caravan Park	SH4840081490	Septic Tank	18	Ground
52	Outdoor Alternative	SH2778075315	Septic Tank	12	Groundwater Via A Soakaway
53	Penrhyn Bay Caravan Park Site	SH2837684802	Septic Tank	20	Groundwater Via Soakway Rd Bed
54	Penrhyn Point Caravan Park	SH5162084320	Septic Tank	19	Land
55	Pensieri Caravan Park Rhosneigr	SH3275072220	Biological Filtration	16.2	Land
56	Pigeon House Caravan Park	SH5003183977	Septic Tank	61.2	Groundwater
57	Pigeon House Caravan Park	SH5007784225	Septic Tank	28.35	Groundwater
58	Pigeon House Caravan Park	SH4994884165	Septic Tank	27	Groundwater
59	Plas Caravan Pk (North) Llanfaelog	SH3314073940	Septic Tank	9	Land
60	Plas Caravan Pk (South) Llanfaelog	SH3310073900	Septic Tank	11.5	Land
61	Plas Uchaf Camping Park (Static)	SH5047083420	Septic Tank	18.65	Land
62	Plas Uchaf Camping Park (Static)	SH5080083550	Septic Tank	18.65	Land
63	Plas Uchaf Caravan Park	SH5088683265	Septic Tank	20	Groundwater Via Soakaway
64	Porthdafarch South Caravan Park	SH2381880392	Septic Tank	25.45	Groundwater
65	Pwll Preban	SH2724676333	Septic Tank	5	Groundwaters Via Soakaway
66	RAF Facility	SH3147575650	Package Treatment Plant	8.8	Groundwaters Via A Soakaway
67	RAF Station Valley Discharge K	SH3130975670	Package Treatment Plant	16	Surface Water Drain
68	RAF Station Valley Discharge K	SH3018075200	Biological Filtration	4.6	Groundwater
69	RAF Station Valley	SH2998175396	Package	18	To Ground

Ref.	Property served	Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
	Discharge L		Treatment Plant		
70	Red Wharf Bay Sailing Clubhouse	SH5134985011	Septic Tank	5	Ground Waters Via Infiltration
71	Rhos Caravan Park (2)	SH5180579258	Septic Tank	14.9	Groundwater Via Soakaway
72	Rhos Caravan Park Site	SH5159779162	Septic Tank	30.6	Groundwater Via Soakaway
73	Shoreside Caravan Pk (N) Rhosneigr	SH3218074020	Septic Tank	8.7	Ground
74	Shoreside Caravan Pk (S) Rhosneigr	SH3222073960	Septic Tank	8.7	Ground
75	Springholme Residential Home	SH5214080430	Package Treatment Plant	8.4	Ground
76	Storws Wen Golf Club	SH4970382435	Package Treatment Plant	20	Ground
77	Stp @ The Oyster Catcher	SH3244972503	Package Treatment Plant	10	Land
78	Tre-Ysgawen Hall Hotel	SH4512981125	Package Treatment Plant	26	Stream Via Partial Soakaway
79	Troed Y Garn Housing Act Works	SH3220091030	Biological Filtration	4.5	Land
80	Ty'n Rhos Caravan Site	SH4936286592	Septic Tank	19	To Ground
81	Tynewydd Caravan Park	SH5078081100	Septic Tank	20	Into Land
82	Valley Of The Rocks Caravan Park	SH2308780115	Septic Tank	19.35	Groundwater

Data from the Environment Agency.

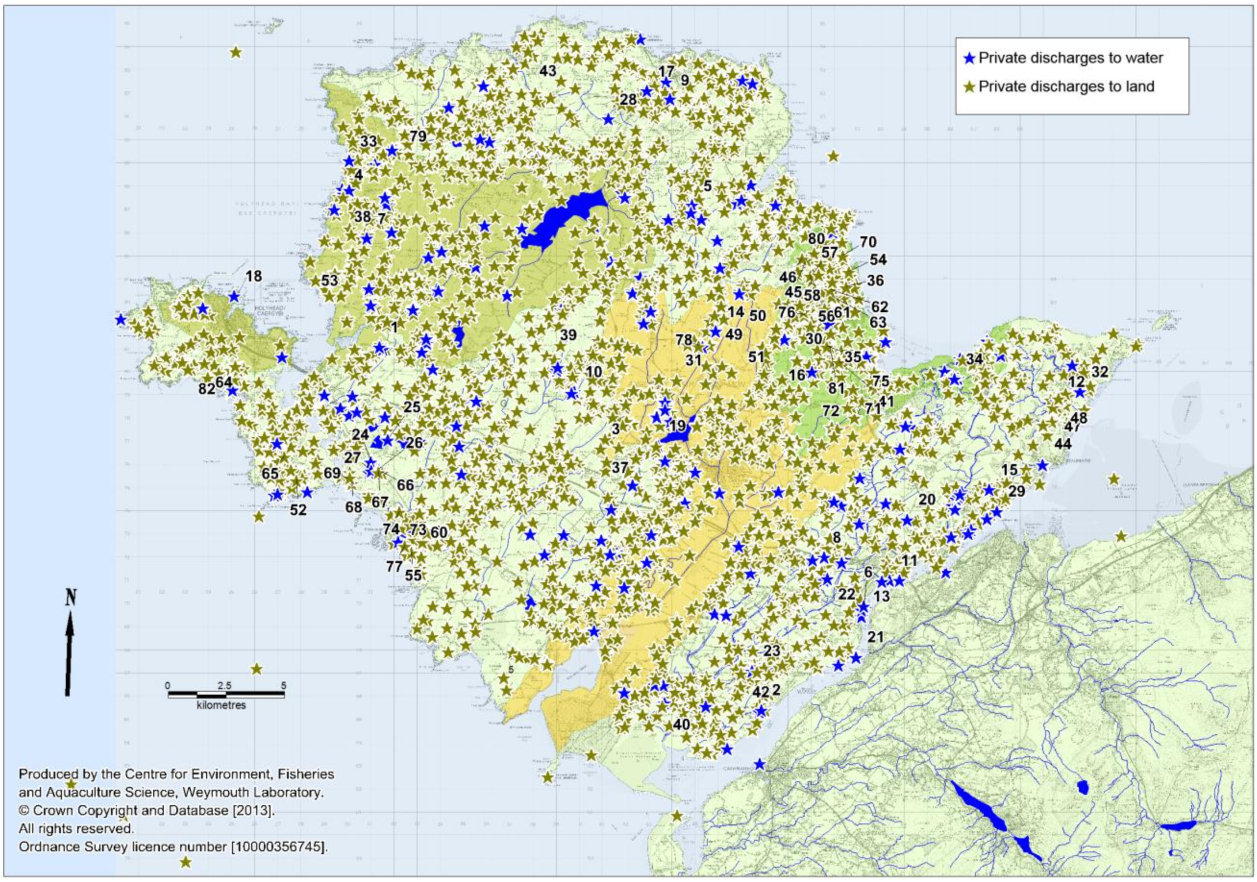


Figure II.2: Private discharges in Anglesey
Data from the Natural Resources Wales and Environment Agency

II.2. Inland Sea

Holyhead STW is the largest continuous discharge on Anglesey and is located at the northernmost point of Holy Island. It has a consented dry weather flow (DWF) of 10,879 m^3/day and the effluent undergoes secondary treatment. It discharges to between 15 and 20 m of water about 3 km to the west of the end of the Holyhead Breakwater. Whether it impacts on the shellfisheries in the Inland Sea will depend on water circulation patterns. The River Alaw and tributaries receive effluent from three sewage works, and the Alaw estuary receives effluent from a fifth sewage discharge in its very upper reaches. All of these provide secondary treatment and their consented dry weather flows total 351.8 m^3/day. These will contribute to the bacterial loading delivered by the Alaw to the Inland Sea area. The Llanerchymedd STW lies within the Alaw catchment but has been re-routed to protect the water supply reservoir, so other than in an emergency, it now discharges to the Afon Goch Dulas which drains to the east coast of Angelesey.

There are various water company intermittent discharges on Holy Island and Anglesey that may impact on the shellfisheries in the Inland Sea from time to time. The main cluster of these is along the Holyhead seafront, and there are two discharging to the foreshore at Valley. There are also a small number feeding to the enclosed area between the Stanley

Embankment and the Four Mile Bridge. No spill data were available for any of these so it is difficult to make an assessment of their potential impacts on the shellfisheries.

Although the majority of properties in the survey catchment are served by the water company sewerage network, there are a small number of private sewage discharges. Most are small, serving one or a small number of properties, and providing treatment via package plant or septic tank. Whilst they may contribute to levels of faecal indicator bacteria in watercourses such as the Alaw, none appear to be of particular significance to the fisheries or the sampling plan.

II.3. Red Wharf Bay

The largest sewage discharge impacting on Red Wharf Bay is the Benllech STW, which provides secondary treatment for a dry weather flow of 1230 m^3/day and discharges 1.6 km off Benllech in about 6 m of water. The extent of its impacts on the cockle or mussel beds here will depend on water circulation patterns. There is also another, smaller sewage works at Pentraeth, which provides secondary treatment for a consented dry weather flow of 237 m^3/day and discharges to the River Nodwydd just over 1 km upstream of its tidal limit. Issues relating to operation of this works are documented Environment Agency Wales now Natural Resources Wales, (EA Wales, [No date]). This is likely to make a highly significant contribution to the bacterial loading delivered by this watercourse, the drainage channel of which cuts through part of the cockle bed at Red Wharf Bay.

There are only five intermittent discharges to the survey area. Two of these discharge to the Nodwydd, one discharges to the Benllech seafront, one discharges via the Benllech STW long sea outfall, and one discharges to the seafront at Moelfre. No spill information was available for any of these so it is difficult to assess their likely impacts on the shellfisheries.

There are 28 consented private discharges to soakaway and six private discharges to water within the survey catchment area. Most are small, serving one or a small number of properties, and providing treatment via package plant or septic tank. Those discharging to ground should not affect water quality in coastal waters, provided systems are working correctly. Those discharging to watercourses will make a minor contribution to the bacterial loading carried into the survey area by the receiving water.

II.4. Malltraeth

There is one sewage discharge direct to the survey area (Malltraeth STW) which provides secondary treatment for a consented dry weather flow of 216.4 m^3/day, and discharges to the main estuary channel by Malltraeth village. The consent conditions only permit discharge for three hours during each tidal cycle, from half an hour after high water until 3.5 hours after high water (Natural Resources Wales, pers. comm.*)* although on one occasion a discharge was observed at low water in breach of the consent (EA Wales, [No date]). As well as this there are three further sewage works discharging to the River Cefni and tributaries, all of which provide secondary treatment. Two of these discharge to the lower reaches of the river, a short distance upstream of the canalised tidal section (Llangefni and Gaerwen STWs). Between them they are consented to discharge a dry weather flow of 6929.8 m^3/day and so will make a highly significant contribution to the bacterial loading carried by this watercourse. The third is a small sewage works (Bodffordd, consented for a dry weather flow of 170.4 m^3/day) that discharges to the Cefni reservoir bypass channel, in the upper reaches of the catchment.

There are 14 intermittent discharges associated with the water company sewerage network within the survey catchment. Of these, 12 discharge to the Cefni and tributaries, none of which have spill records. It is therefore concluded that these 12 discharges may contribute to the bacterial loading carried by the Cefni at times, although it is not possible to assess how often this may occur. The other two intermittent discharges are from the Malltraeth STW and discharge in the same place. An examination of spill records (Table II.4) indicated that one of these discharges very infrequently (0.2% of the time since 2008) whereas the other spilled for 13.4% of the time in recent years. As such their combined impacts will probably be captured during the course of a year or two of monthly monitoring. The main spiller was much more active in the autumn and winter compared to the summer, presumably as a result of rainfall patterns.

Although the majority of properties in the survey catchment are served by the water company sewerage network, there are 28 consented private sewage discharges within the survey catchment, of which 10 discharge to land and 18 discharge to watercourses. Most are small, serving one or a small number of properties, and providing treatment via package plant or septic tank. Those discharging to ground should not affect water quality in coastal waters, provided systems are working correctly. All but one of those discharging to water are to the Cefni and tributaries, so they will make a minor contribution to the bacterial loading carried by this watercourse.

Appendix III. Sources and Variation of Microbiological Pollution: Agriculture

Most of the land on Anglesey 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.

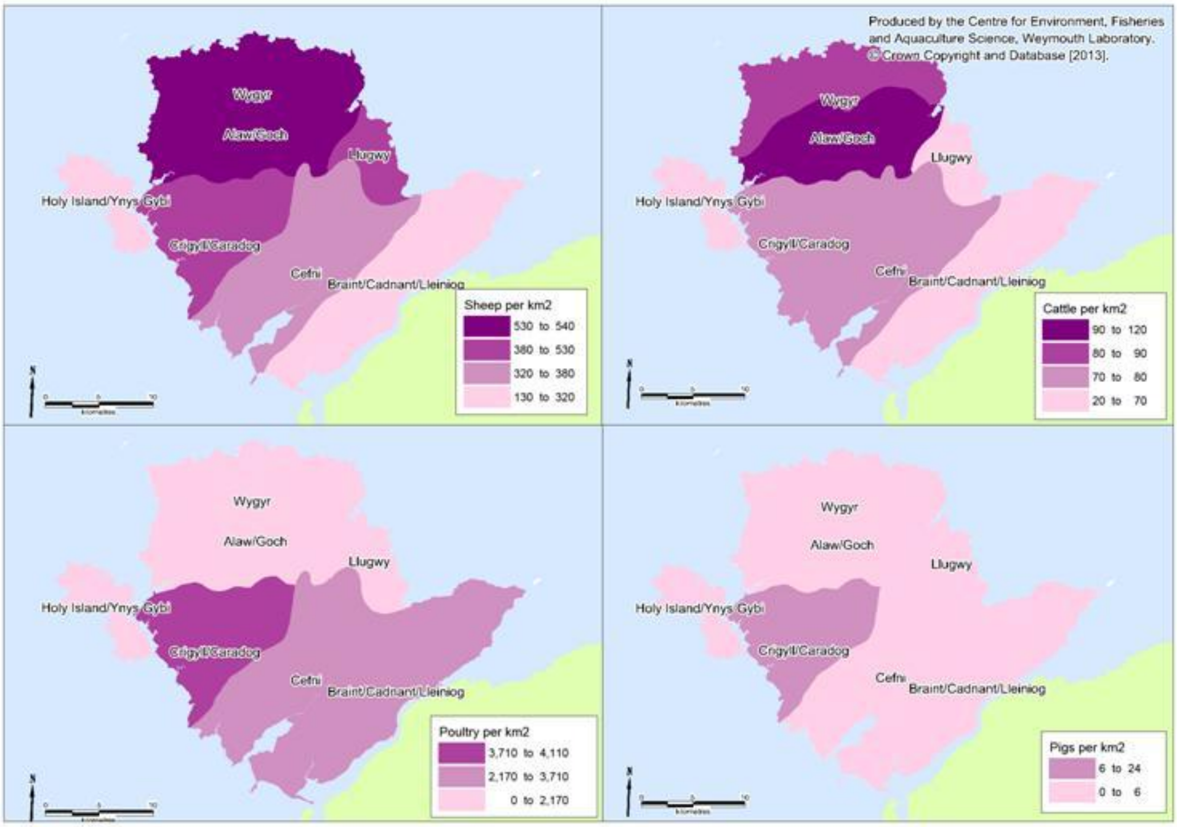


Figure III.1: Livestock densities in 2012 for Anglesey subcatchments
Data from Welsh Government.

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

		Cattle	Sheep	Poultry	Pigs
Alaw/Goch	No.	13,480	64,677	147,749	38
	No/km^2	*111.3*	*534.1*	*1,220.1*	*0.3*
Braint/Cadnant/Lleiniog	No.	10,046	45,509	313,171	127
	No/km^2	*69.7*	*315.6*	*2,171.8*	*0.9*
Cefni	No.	13,222	54,466	622,091	956
	No/km^2	*78.7*	*324.4*	*3,705.1*	*5.7*
Crigyll/Caradog	No.	8,073	41,231	442,315	2,583
	No/km^2	*75.0*	*383.2*	*4,110.7*	*24.0*
Holy Island	No.	844	4,822	202	8
	No/km^2	*24.3*	*138.8*	*5.8*	*0.2*
Llugwy	No.	2,326	14,532	435	22
	No/km^2	*66.9*	*417.7*	*12.5*	*0.6*
Wygyr	No.	8,670	53,878	16,505	18
	No/km^2	*85.3*	*530.3*	*162.5*	*0.2*
Total	**No.**	**56,661**	**279,115**	**1,542,468**	**3,752**
	No/km^2	***79.6***	***392.1***	***2,166.6***	***5.3***

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 275,000 animals at similar relatively high densities throughout all sub-catchments apart from Holy Island, although there are significant numbers there also. There are also almost 57,000 cattle, which are also widespread but again with lowest densities on Holy Island. Potentially significant numbers of poultry are farmed in the area in intensive units, although there are few in the Holy Island, Llugwy and Wygyr sub catchments. Only small numbers of pigs are reared on Anglesey.

During the shoreline survey only two horses and two cows were recorded at Red Wharf Bay. In the Inland Sea survey area, 100 sheep were seen in a field fenced off from the shoreline on Holy Island, and 10 cows were seen two fields back from the shoreline on Anglesey between the Stanley Embankment and Four Mile Bridge. Around Malltraeth, two horses were observed at Malltreath village and about 70 cattle were seen in a field at the tops of cliffs on the western shore. At the north eastern end of the bay around 500 sheep were observed in fields stretching from a freshwater pool to the forest edge. No areas of grazed saltmarsh were observed.

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).

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

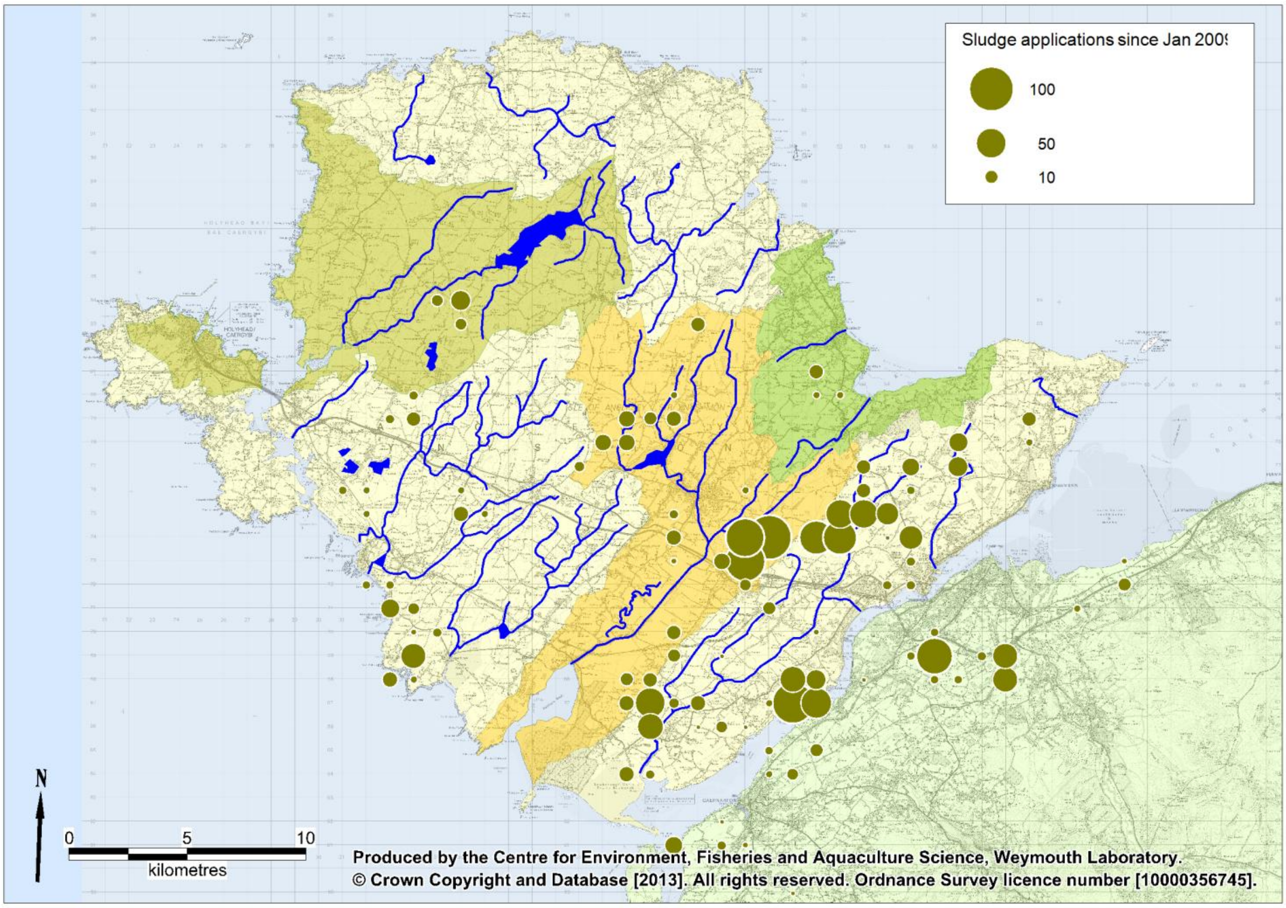


Figure III.2: Number of weeks (Jan 2009 to May 2013) during which sewage sludge was applied to fields within each square km within Anglesey and Menai Strait catchments.
Data from Natural Resources Wales.

Whilst Figure III.2 provides no firm indication of the volumes or types of sludge applied, it shows that the practice occurs frequently on certain parts of Anglesey. The areas where most spreading occurs tend to align with the locations of arable land (Figure 1.2), with the Malltraeth catchment much more heavily affected than either the Inland Sea or Red Wharf Bay catchments. Numbers of applications were similar across the four seasons. Natural Resources Wales advise that sludge deriving from a creamery, an abbatoir and chicken processing plants is also spread on land within the Malltraeth catchment.

The primary mechanism for mobilisation of faecal matter or organic fertilisers deposited or spread on farmland to coastal waters is via land runoff, so fluxes of livestock related contamination into the harvesting areas 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 occurrence of fluxes of indicator bacteria into coastal waters are anticipated to arise where animals have access to watercourses, particularly if this is in close proximity to the coast.

As well as significant day to day variation driven by rainfall there is likely to be some seasonal differences in the fluxes of faecal indicator bacteria of agricultural origin into the survey area. Number of sheep and cattle will increase in the spring with the birth of lambs and calves, and then decrease in the autumn as they are sent to market. In warmer weather, grazing animals are more likely to access watercourses to cool off and drink. It is likely that sheep are moved from the higher pastures to more sheltered areas during the colder months. During winter cattle may be transferred from pastures to indoor sheds, and at these times slurry will be collected and stored for later application to fields. Timing of these applications is uncertain, although farms without large storage capacities are likely to spread during the winter and spring. Poultry/pig manure and sewage sludge may be spread at any time of the year. Therefore peak levels of contamination from sheep and cattle may arise following high rainfall events in the summer, particularly if these have been preceded by a dry period which would allow a build up of faecal material on pastures, or on a more localised basis if wet weather follows a slurry application which is more likely in winter or spring.

Appendix IV. Sources and Variation of Microbiological Pollution: Boats

The discharge of sewage from boats is potentially a significant source of bacterial contamination of shellfisheries in coastal waters. Holyhead is the main boating hub with one commercial ferry port, one marina and a considerable fishing fleet. Figure IV.1 presents an overview of boating activity derived from the shoreline survey, satellite images and various internet sources.

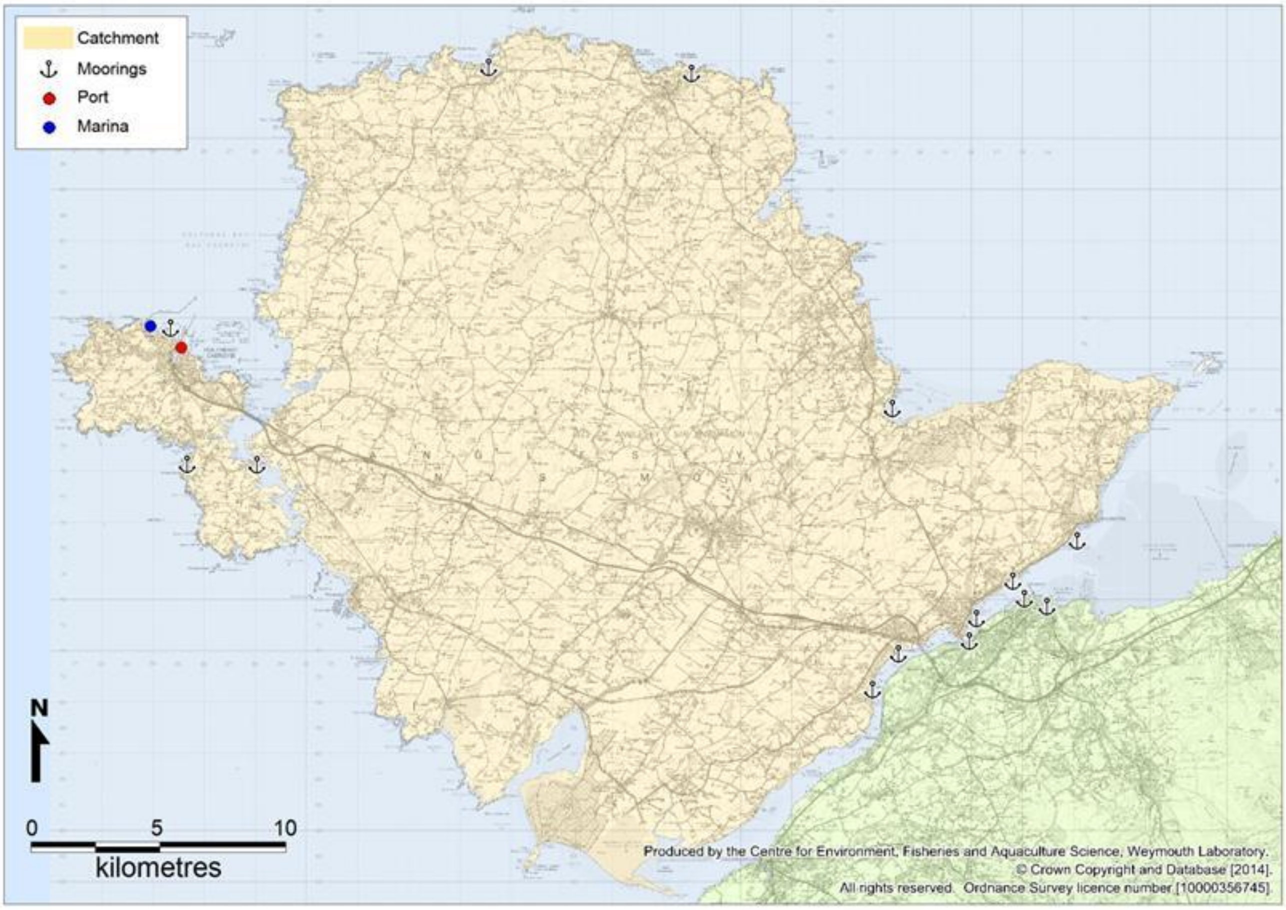


Figure IV.1 Boating activity in Anglesey survey areas

Holyhead Port is one of the busiest ferry ports in the UK forming a major transport link with North Wales and Northern England to Ireland with 8,500 ferry and freight movements per year (Makintosh, 2013). It is unlikely that any commercial vessels will enter either the shallow waters of Red Wharf Bay or Malltraeth, although they are reported to shelter off the east coast of Angelsey during poor weather (Natural Resources Wales, pers. comm.). Merchant shipping are not permitted to make overboard discharges within 3 nautical miles of land[1] so such vessels transiting the area have no impact.

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

Holyhead has a large fishing fleet, with 26 under 10 m fishing boats and seven over 10 m listed as having their home port as Holyhead in December 2013 (MMO, 2013). Three angling charter boats also operate from here on a part time basis (Charter Boats UK, 2013).

There is significant recreational boat traffic to the 500 berth marina at Holyhead (Reeds Almanac, 2012). There are also numerous moorings available adjacent to the marina and in several bays around the Anglesey coastline see Figure IV.1. There are approximately 30 moorings in Red Wharf Bay indicating that there is some recreational boating within the bay and there are no moorings at Malltraeth. Sewage pump out facilities are not available at Holyhead Marina, the closest are located at Caernarfan Victoria Dock in the West Menai (The Green Blue, 2010). The recreational routes around Anglesey are reported to receive 'moderate recreational use' (RYA, 2004).

Racing and cruising for yachts and dinghies are available through the Holyhead Sailing Club and racing for dinghies at Red Wharf Bay Sailing & Water Sports Club. Watersports are popular in North Wales particularly in the Menai Strait and kayaking in the Inland Sea (the semi enclosed body of water south of the Inland Sea survey area). However, the smaller recreational boats are not large enough to contain onboard toilet facilities and therefore are therefore unlikely to make overboard discharges.

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. Sewage from boats will be a consideration at Inland Sea and to a lesser extent at Red Wharf Bay. At Malltraeth, sewage from boats is unlikely to be a contaminating influence.

Appendix V. Sources and Variation of Microbiological Pollution: Wildlife

Anglesey encompasses a wide range of marine habitats including intertidal flats sandbanks, saltmarsh, large shallow bays, sea caves and limestone cliffs which attract a variety of wildlife (Anglesey Heritage website, 2013). Consequently the survey areas are protected by several international and national environmental legislations. The majority of the coast is designated as an Area of Outstanding Natural Beauty (AONB) and there are over 60 Sites of Special Scientific Interest (SSSI) across Anglesey. The Fens Wetland Site adjacent to Red Wharf Bay is designated as a Special Area of Conservation (SAC) (JNCC, 2013), a National Nature Reserve and part of it is protected as a Ramsar site, for its importance to wetland birds. The South Stack Nature Reserve on Holy Island is protected due to the large numbers of seabirds that inhabit it. Newborough Forest situated east of Malltreath Bay forms part of a National Nature Reserve and Newborough Warren is designated as a National Nature Reserve.

Studies in the UK have found significant concentrations of microbiological contaminants (thermophilic campylobacters, salmonellae, faecal coliforms and faecal streptococci) from intertidal sediment samples supporting large communities of birds (Obiri-Danso and Jones, 2000). Large numbers of nationally and internationally important species of overwintering birds are observed in three survey areas although these are not routinely counted by the Wetland Bird Survey co-ordinated by the British Trust for Ornithology. The sand and intertidal flats at all three locations Bay provide an important food source (shellfish and lugworms) at low tide for large numbers of waders; species include oystercatchers, snipe, redshank, curlews, bar tailed godwits, mute swans, dunlin, great crested grebes, and Brent Geese (Visit Anglesey website, 2013). On the shoreline survey flocks of birds were regularly observed, 100 birds were observed in the upper reaches of Malltraeth Bay. At Inland Sea survey area 450 birds were observed on the mudflats north of the A55/A5 causeway and at Red Wharf Bay 170 birds were observed along the southern shore in three locations.

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

In addition to overwintering and wildfowl flocks, seabirds such as gulls and terns are also widespread throughout Anglesey all year round. They predominantly use the limestone cliffs as nest sites, and were subject to a survey during the nesting season in the early summer of 2000 (Mitchell *et. al,* 2004). A total of 522 seabird pairs were recorded in the vicinity of Red Wharf Bay. This included 228 pairs which were using Moelfre Island and the adjacent cliffs. The other main aggregation was along the cliffs just to the east of Red Wharf Bay, where 211 pairs were recorded. Puffin Island located 6 km south east of Red Wharf Bay is a major nesting colony (4,687 pairs recorded) with species including guillemots, razorbills, cormorants, kittiwakes, puffins and various gulls. Puffins, guillemots and razorbills are present in the summer months when they inhabit the sea cliffs to breed, during the winter months they usually head offshore (RSPB, 2013). The total count on Holy Island was 6,559 individual seabirds at the time of this survey, of which the majority were in the vicinity of South Stack, at the north east tip of the island. Natural Resources Wales indicate that about 11,000 individuals now use the island as a breeding site. Finally, 224 pairs (mainly cormorants and shags) were recorded on rocks, islands and cliffs both to the north and south of the mouth of the Cefni estuary. The colony to the south of the estuary mouth (Ynys Adar) consisted of 35 pairs of shags at the time of the seabird survey, but Natural Resources Wales indicate that they stopped using this site a few years ago.

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 such, the mussel beds at Moelfre are most at risk from contamination associated with seabird nesting colonies.

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 hauled out along the rocky shores of Anglesey. Sites of particular importance regarding their close vicinity to the survey areas are North Stack on Holy Island and Puffin Island to the South East of Red Wharf Bay (Westcott & Stringell, 2004). Other sites include the Skerries, Carmel Head, and Yns Llanddwvn around Inland Sea survey area and Ynys Dulas north of Red Wharf Bay. A survey undertaken in 2002 and 2003 revealed numbers of up to 37 at North Stack with highest numbers recorded in the spring and summer months during the breeding and haul out season. At Puffin Island numbers ranged from between 11 and 130, with highest numbers being recorded in the winter months (Westcott & Stringell, 2004). There are also significant seal colonies further south in North West Pembrokeshire, Cardigan Bay and Skomer Island. Seals may create a localised ‘hotspot’ of contamination where they haul out on sandbanks and islands, but none of their known haulout sites coincides with any shellfish resources considered here. 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.

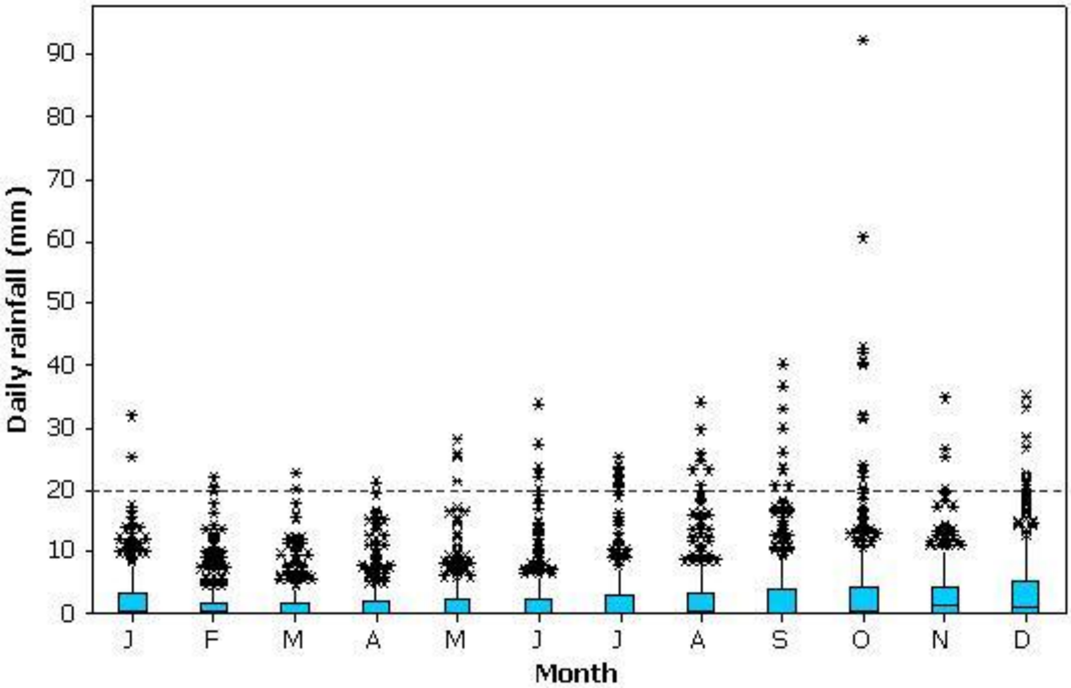


Figure VI.1: Boxplot of daily rainfall totals at Parc Menai, January 2003 to December 2012.
Data from the Environment Agency

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 more 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.

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).

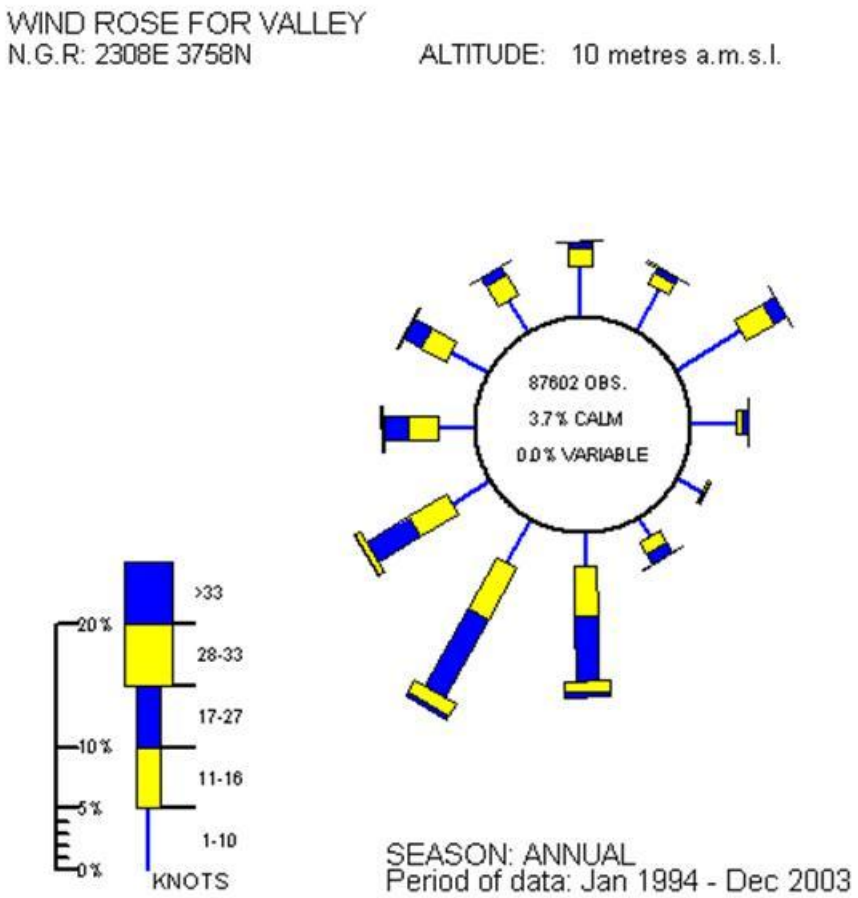


Figure VII.1: Wind rose for Valley.
Produced by the Meteorological Office. Contains public sector information licensed under the Open Government Licence v1.0

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.

Malltraeth Bay faces south west and is surrounded by low lying land so is therefore quite exposed to the prevailing winds. Inland Sea is relatively sheltered from the prevailing winds as it faces north and is surrounded by a more hilly topography. Holyhead Breakwater offers protection from north westerly winds and waves. Red Wharf Bay faces east and so is sheltered from the prevailing winds, but its open aspect means it is exposed to winds from the north and east.

Appendix VIII. Hydrometric Data: Freshwater Inputs

VIII.1. Overview

Anglesey covers an area of 716 km² (Environment Agency Wales, 2007), of which the Inland Sea hydrological catchment occupies approximately 117 km^2, the Red Wharf Bay catchment only 42 km^2, and the Malltraeth catchment 123 km^2. Figure VIII.1 shows the main watercourses draining Anglesey.

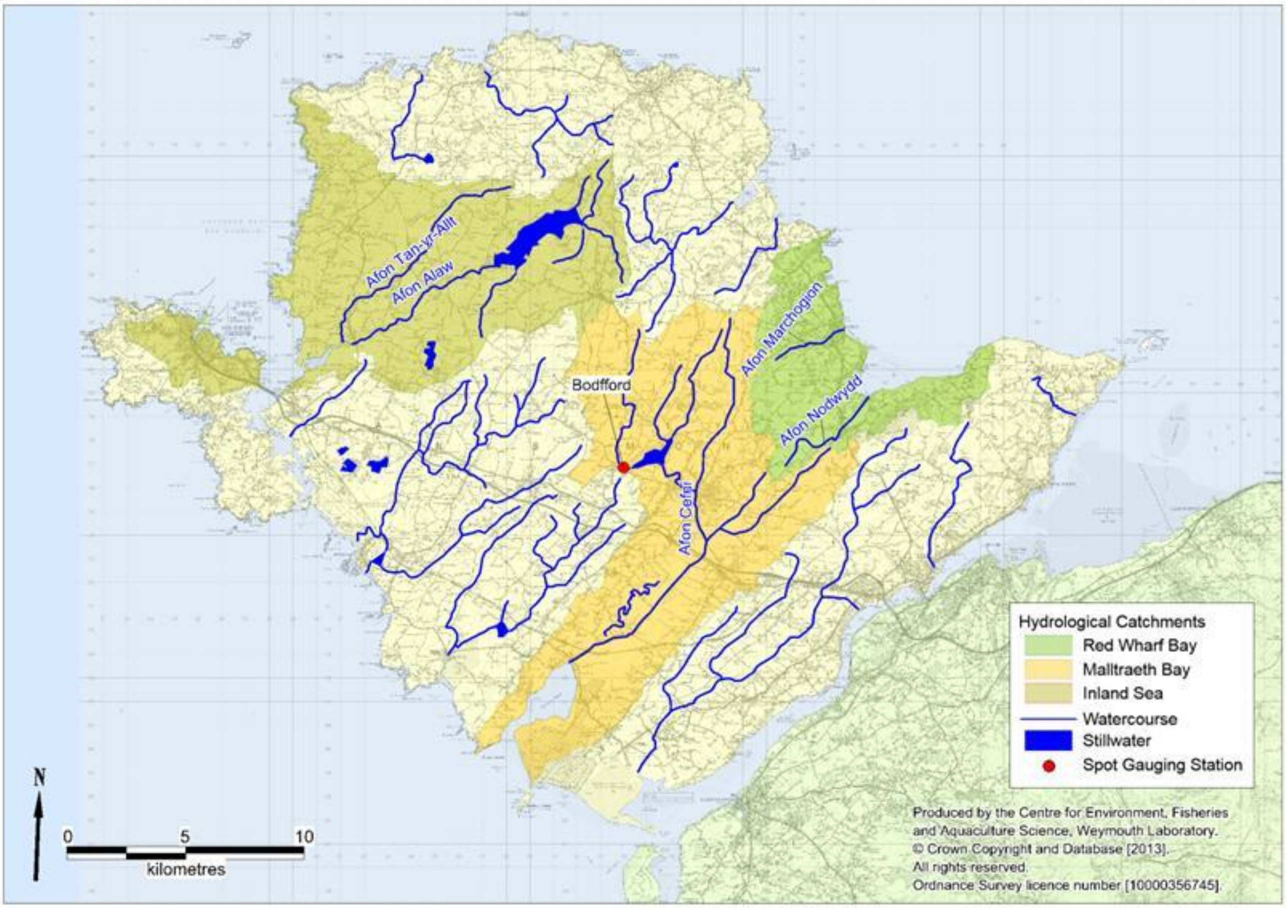


Figure VIII.1: Main watercourses on Anglesey

The three hydrological catchments considered in this survey all have broadly similar patterns of land use, with pasture dominating, some natural areas, and a few urbanised pockets. All watercourses will therefore carry some faecal indicator bacteria, originating from agricultural sources and in some cases urban runoff and sewage discharges so will therefore require consideration in relation to the sampling plan. The underlying geology is generally impermeable so land drainage is via surface watercourses and a high proportion of rainfall will run off (Wrighton *et. al*, 2012). The lower reaches of the Cefni, and the Nodwydd in its entirety are underlain with limestone bedrock, so flows in these two watercourses may be damped to some extent through groundwater discharge and recharge. There is only one flow gauging station within these three catchments, which is located on the upper reaches of the Cefni, immediately upstream of where it feeds into a reservoir. Due to its location, it will not be fully representative of discharge volumes from this watercourse, but the flow gauging records should be broadly representative of the seasonal variation in flows experienced in natural watercourses on Anglesey. Summary statistics for this station are presented in Table VIII.1, where data for mean flow, Q95 and Q10 cover the period from 2003 - 2013.

Table VIII.1 Summary flow statistics for one gauging stations draining into Malltraeth Bay(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})
Cefni	Bodffordd	21.7	1056	0.44	0.03	1.00

[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 the Environment Agency.

Base flows (Q95) are less than 10% of mean flows, the Q10 is just over double the mean flow. Boxplots showing mean daily flow records for Bodffordd gauging station by month are presented in Figure VIII.2.

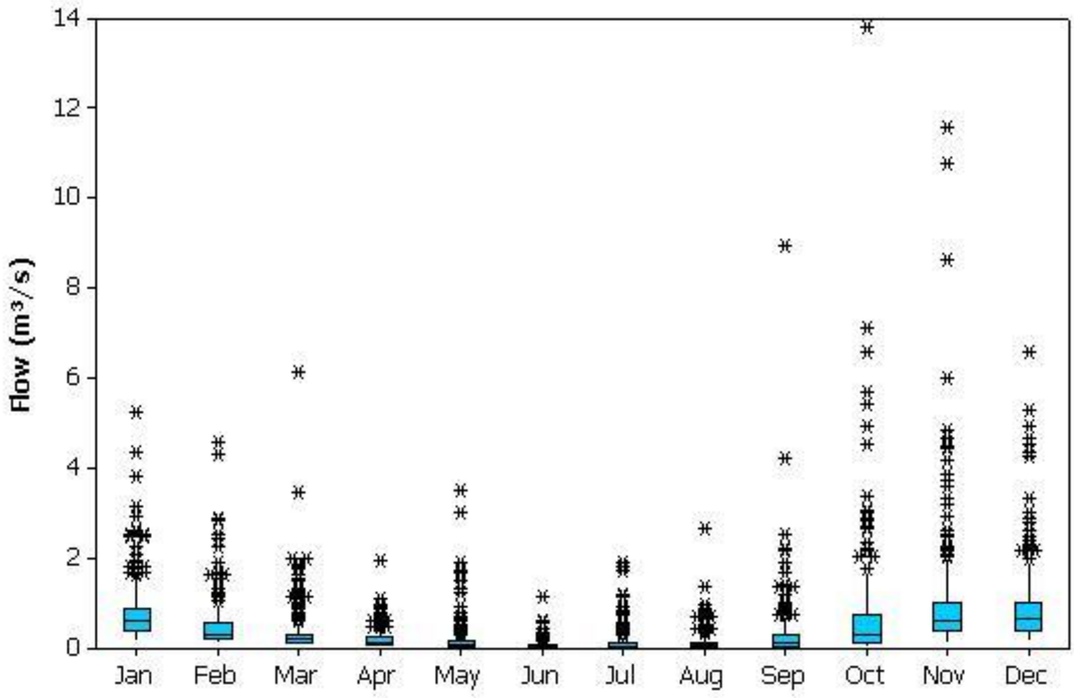


Figure VIII.2 Boxplots of mean daily flow records from the Bodffordd gauging station on the Cefni watercourse (2003-2013)

Considerable seasonal variation in flow is apparent at this gauging station. Flows are highest on average from October to December, and the peak flow events (>5 m^3/sec) tend to occur during this period. Flows in the summer months tend to be much lower, and high flow events rarely exceed 2 m^3/sec. The seasonal pattern of flows is not entirely dependent on rainfall as during the colder months there is less evaporation and transpiration. 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.

VIII.2. Inland Sea

The Inland Sea catchment area has two main watercourses (the Alaw and the Tan-yr-Allt) both of which drain to the head of a small enclosed estuary. The drainage channel from this estuary then follows the mainland shore southwards and joins the main subtidal channel running through the straits immediately north of the Stanley Embankment. The Alaw has a reservoir in its upper reaches which is likely to buffer flows in this watercourse to some extent. A water sample taken from just downstream of the Alaw/Tan-yr-Allt confluence during the shoreline survey contained 1,200 *E. coli* cfu/100ml. The channel was too large to safely obtain a spot flow measurement during this survey, but the relatively large size of this freshwater input combined with the observed level of faecal indicator bacteria would suggest it is a highly significant contaminating influence to the area. Aside from this, only a few very minor freshwater inputs were observed during the shoreline survey, details of which are presented in Table VIII.2.

Figure VIII.3: Locations of shoreline survey stream observations, Inland Sea

Table VIII.2: Water 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)
R	Pipe	5	0.002	$7.8x10^6$
S	Pipe	340	$3.6x10^{-5}$	$1.0x10^7$
T	Pipe	280,000	$2.8x10^{-5}$	$6.7x10^9$
U	Gorad Road Pumping Station pipe	310	Flow to low to measure	
V	Alaw channel	1200	Too deep to measure	

Aside from the Alaw/ Tan-yr-Allt, the four observed freshwater inputs directly to the Inland Sea survey area were all very minor piped surface water outfalls. Three of these discharge from the foreshore at Valley to the Alaw channel, and one was located on Holy Island just north of the Stanley Embankment. One of these pipes (T) was carrying a very high concentration of *E. coli*, suggesting it had a sewage content. Nevertheless, the *E. coli* loading it was carrying was less than 10^{10} *E. coli* cfu/day, so the Alaw is likely to be much more significant.

VIII.3. Red Wharf Bay

Red Wharf Bay receives land runoff from its relatively small catchment area via two main watercourses (the Marchogion and the Nodwydd) both of which flow directly across the intertidal. Neither are particularly large, and there are numerous other small streams draining to the foreshore. Those discharging to Red Wharf Bay and in the Bellench area were all sampled and measured during the shoreline survey (Table VIII.3). The area around the mussel bed at Moelfre Island was not surveyed. Maps of this area indicate that there is a stream about 750 m south of the mussel bed, whilst the nearest significant watercourse to the north discharges to Lligwy Bay, about 2.5k m to the north.

Figure VIII.4: Locations of shoreline survey stream observations, Red Wharf Bay

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

Ref.	Watercourse	*E. coli* concentration (CFU/100 ml)	Flow (m^3/s)	*E. coli* loading (CFU/day)
G	Stream	60	0.074	3.8x10^{9}
H	Stream	50	0.011	4.9x10^{8}
I	Stream	150	0.479	6.2x10^{10}
J	Stream	5	0.045	1.9x10^{8}
K	Stream	30	0.015	3.8x10^{8}
L	Nodwydd	2,300	0.834	1.7x10^{12}
M	Stream	40	0.082	2.8x10^{9}
N	Stream	3,900	0.073	2.5x10^{11}
O	Stream	140	0.016	2.0x10^{9}
P	Marchogion (1st measurement)	600	0.252	1.3x10^{11}
Q	Marchogion (2nd measurement)	460	0.216	8.6x10^{10}

The Nodwydd was the most significant watercourse both in terms of discharge volume and the bacterial loading it was carrying. It follows a drainage channel through the cockle bed where its contaminating influence is likely to be the strongest. This channel also receives two other smaller watercourses (M and N) the latter of which was carrying a relatively high concentration of *E. coli*, and the second highest bacterial loading. The Marchogian was sampled and measured twice and on both occasions gave the third highest bacterial loading in the area, but does not discharge in close proximity to the cockle bed so will be of little influence there. Stream I may also be of local significance, but discharges to the east of the cockle bed. All other watercourses were carrying less than 10^{10} *E. coli*/day at the time of survey so were of less significance. It is therefore concluded that the confluence of the drainage channels from the Nodwydd and streams M and N will represent the point most heavily impacted by freshwater inputs.

VIII.4. Malltraeth

Malltraeth is an enclosed estuary that receives one main watercourse, the Cefni, which is the largest river on Anglesey. The Cefni has a reservoir in the upper reaches of its catchment which may buffer flows to a limited extent. It has been canalised and embanked in its tidal reaches to allow adjacent coastal marshes to be reclaimed, and discharges to the estuary together with two adjacent marsh drainage channels through a set of sluice gates at Malltreath village. It subsequently follows a drainage channel which lies to the west of the cockle bed on Malltraeth Sands. A water sample taken from the Cefni at the sluice during the shoreline survey contained high levels of *E. coli* (8,200 cfu/100ml). The channel was too large to safely obtain a spot flow measurement during this survey, but the relatively large size of this freshwater input combined with the high concentration of faecal indicator bacteria would suggest it is a major contaminating influence to the area. Aside from this, only a few very minor freshwater inputs were observed during the shoreline survey, details of which are presented in Table VIII.4.

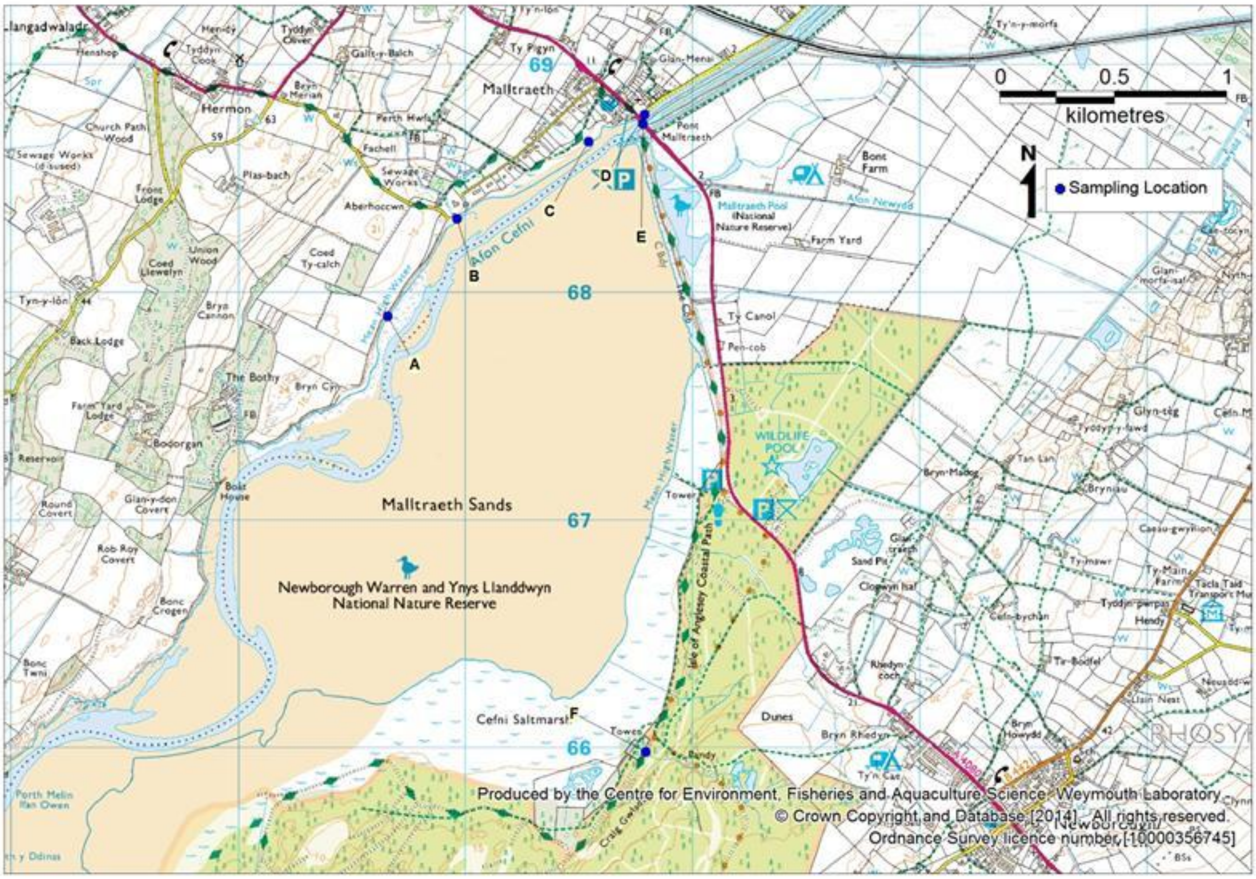


Figure VIII.5: Locations of shoreline survey stream observations, Malltreath Bay

Table VIII.4: *E. coli* sample results, measured discharge and calculated *E. coli* loadings

Ref.	Survey Area	Watercourse	*E. coli* concentration (CFU/100 ml)	Flow (m³/s)	*E. coli* loading (CFU/day)
A	Malltraeth	Stream	730	0.013	$8.0x10^{9}$
B	Malltraeth	Stream	860	0.047	$3.5x10^{10}$
C	Malltraeth	Stream	190	0.002	$2.7x10^{8}$
D	Malltraeth	Pipe	730	Not accessible	
E	Malltraeth	River - Afon Cefni	8,200	Not accessible	
F	Malltraeth	Ground water	80	Not flowing	

Three minor watercourses were observed on the west shore of the estuary near Malltraeth, only one of which was carrying a bacterial loading exceeding 10^{10} *E. coli*/day. Their drainage channels across the intertidal do not run directly through the cockle bed before meeting the main channel. It is therefore concluded that the points where the main Cefni drainage channel comes in closest proximity to the cockle bed are likely to represent the parts of the bed most impacted by land runoff.

Appendix IX. Hydrography

IX.1. Bathymetry

Inland Sea

Inland Sea is a 10 km strait located between Anglesey and Holy Island. The shellfishery is located in the northern part of the strait, where it connects to Holyhead Bay (Figure IX.1).

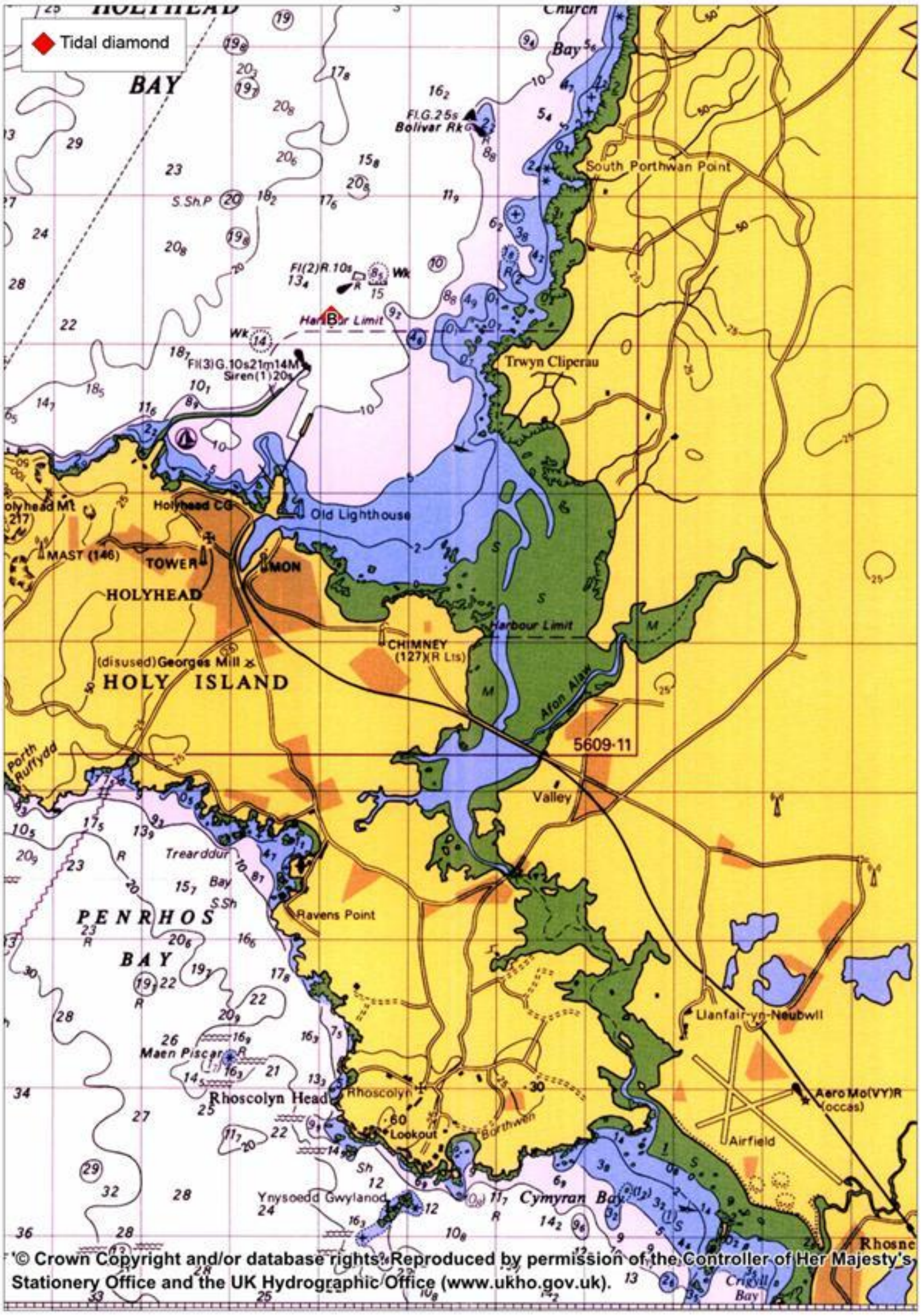


Figure IX.1: ~Bathymetry of Inland Sea (Admiralty Chart 5609.11)

There are two man-made causeways (Stanley Embankment and Four Mile Bridge), both of which lie to the south of the classified area. These are solid structures with narrow culverts (~10 m in the case of the Stanley Embankment) that impede the passage of tidal streams to the extent that water level differences across them result in the formation of standing waves (Figure XII.29). They effectively divide the strait into three hydrographically distinct zones, and turbulent mixing of the water column will occur as the tide passes through them. The northern zone in which the fishery is located consists of a subtidal channel flanked by extensive intertidal areas. The intertidal areas then gently slope away into the subtidal and the straits open out into Holyhead Bay. A 2.4 km breakwater extends across the bay from Holyhead in an easterly direction, which will provide some shelter from north westerly winds and swells. There is a small enclosed estuary on the eastern shore which receives the Alaw, the main freshwater input to the area. Its mouth is narrow and flanked by a pair of sand spits. The main drainage channel extending from the mouth of the Alaw estuary runs in a southerly direction adjacent to the Anglesey coast before joining the main channel through the strait just north of the Stanley Embankment. There is also a secondary drainage channel visible on aerial photography which emanates from the mouth of the estuary in a north westerly direction and feeds into the main subtidal channel near the northern extremity of the mussel lay.

Red Wharf Bay

The survey area includes the cockle bed at Red Wharf Bay, an open embayment that faces north east into the Northern Irish Sea and a rocky outcrop around Moelfre Island where mussels are present (Figure IX.2).

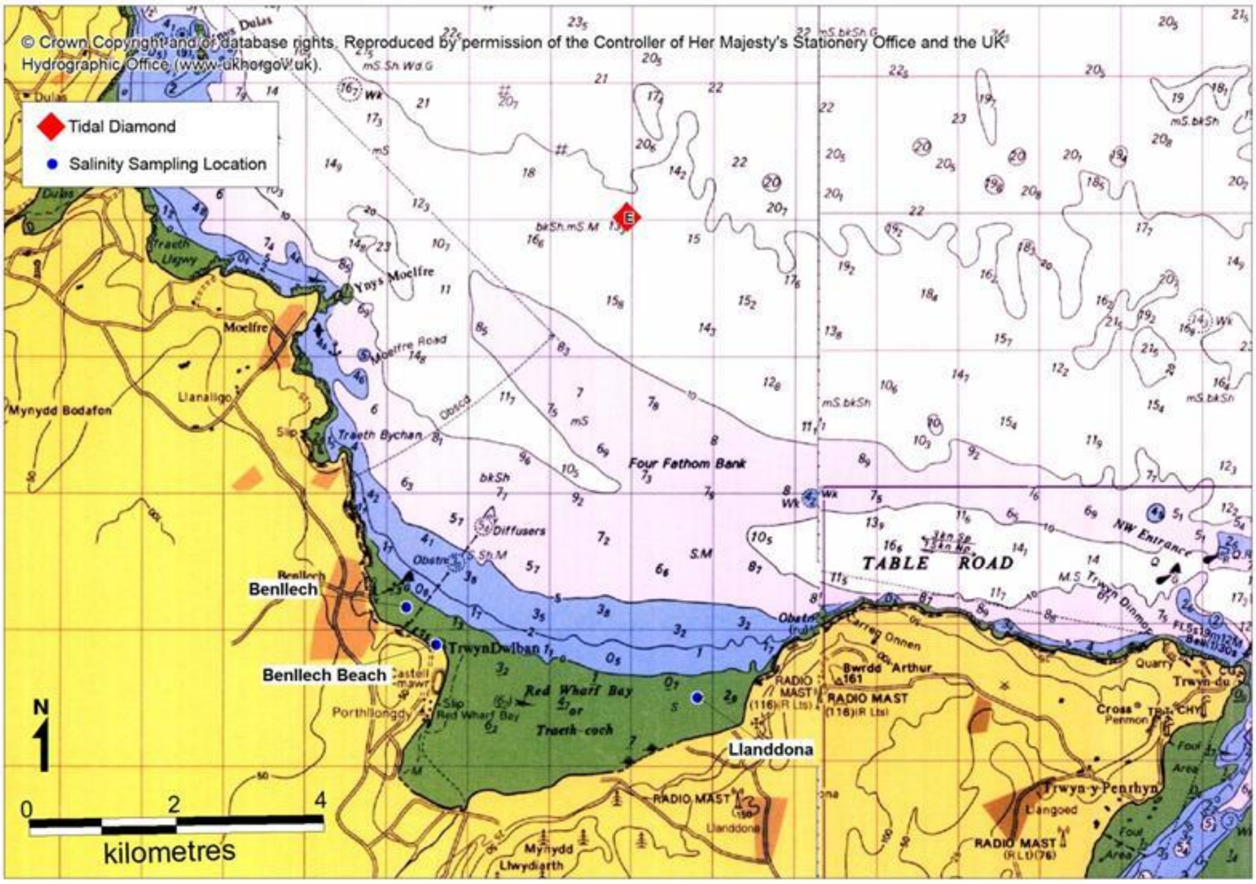


Figure IX.2: Bathymetry of Red Wharf Bay (Admiralty Charts 5609.10 & 5609.13)

The bathymetry of Red Wharf Bay is relatively uncomplicated. It is comprised of a large area (approximately 7 km²) of intertidal sand flats which gently slope away into the subtidal. There are several drainage channels cutting across the intertidal area which carry freshwater inputs where relatively high concentrations of faecal indicator bacteria are likely to arise at lower states of the tide. Either side of the bay the foreshore becomes steeper and depths increase more rapidly in the subtidal. At Moelfre, the mussel beds are located on a rocky intertidal reef protruding from the Moelfre Headland which has a small island at its tip. The depth drops away rapidly to over 10 m off the island. It is likely that there is some acceleration of tidal flows around the headland.

Malltraeth

The survey area at Malltraeth consists of the enclosed estuary of the Cefni, which is characterised by a large area of intertidal sand flats bisected by a meandering river channel (Figure IX.3).

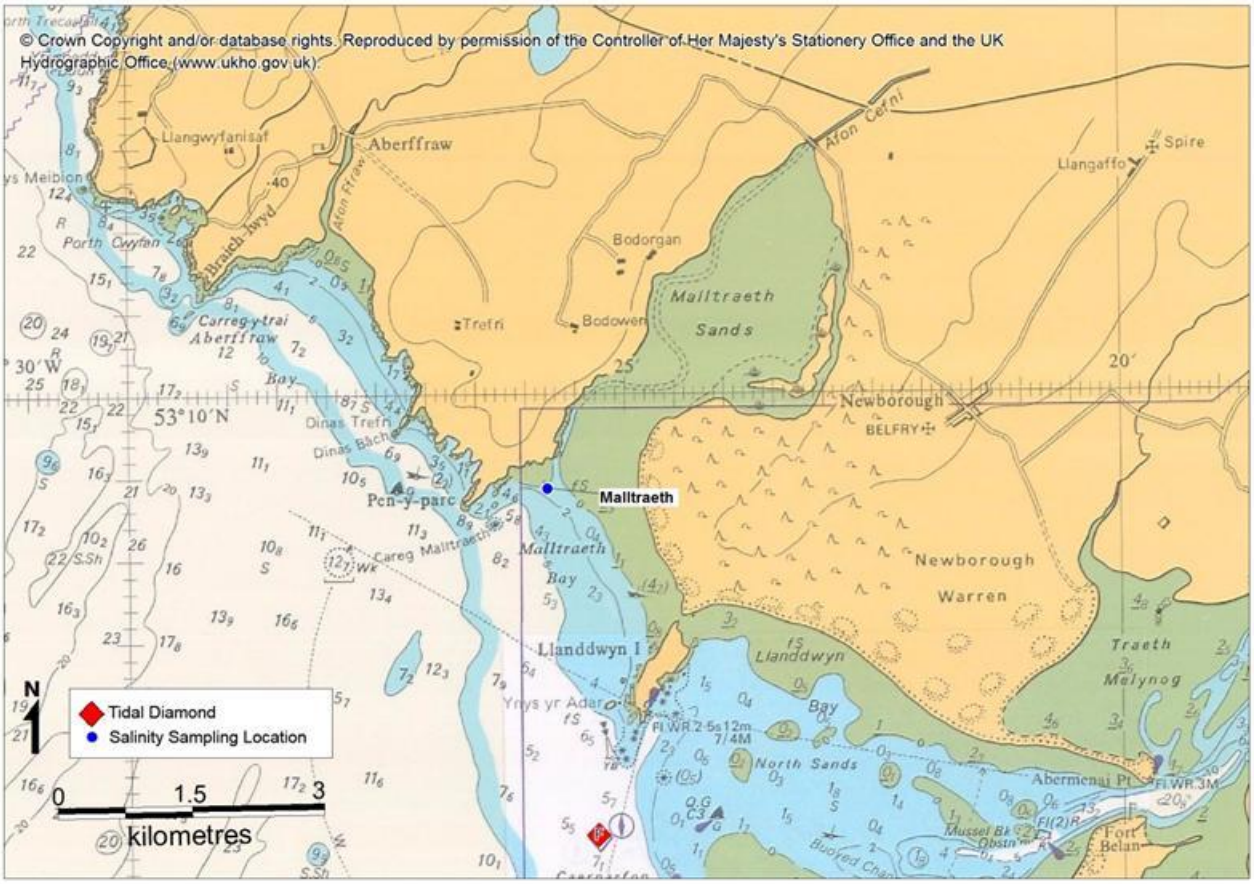


Figure IX.3: Bathymetry of Malltraeth (Admiralty Chart 1970)

About 83% of the estuary is intertidal (ABPmer, 2010) so a large proportion of water will be exchanged each tide but the dilution potential will be relatively low. The estuary mouth faces south west and is flanked on either side by rocky outcrops. Sand dunes have accreted on the eastern side resulting in a narrowing of the estuary just inside the mouth. The river channel generally follows the western shore, and there is some saltmarsh inside of the dunes on the eastern shore. There are several drainage channels from these saltmarsh areas that cut across the intertidal before joining the main river channel. The estuary underwent significant land reclaim during the early 19th century, when the upper reaches were embanked and canalised to reclaim the Malltraeth Marshes. The canalised section discharges to the main body of the estuary via sluice gates.

IX.2. Tides and Currents

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. Tidal amplitude is relatively large (Table IX.1) and this drives extensive water movements around Anglesey. The tidal range increases significantly from the west to the east of the Island.

Table IX.1: Tide levels and ranges within Malltraeth, Inland Sea and Red Wharf Bay

		Height above chart datum (m)				Range (m)	
Survey Area	Port	MHWS	MHWN	MLWN	MLWS	Spring	Neap
Inland Sea	Holyhead	5.6	4.4	2.0	0.7	4.9	2.4
Red Wharf	Moelfre	7.5	5.8	2.5	0.9	6.6	3.3
Malltraeth	Llanddwyn Island	4.9	3.9	1.9	0.7	4.2	2.0

Data from Admiralty TotalTide©

Offshore tidal streams flood around Anglesey from the southwest, running roughly parallel to the coast, then head in an easterly direction past the north coast and then on into Liverpool Bay. They also move down the east coast of the island into Conwy Bay and the eastern Menai Strait. The reverse occurs on the ebb. Tidal streams are strongest around the headlands of the north-west coast of Anglesey (Holy Island and Carmel Head) where they may exceed 2 m/s, but are generally much weaker in near shore areas, particularly where the coastline is indented (Robins et al, 2012). Table IX.2 presents information from tidal diamonds on the direction and rate of tidal streams on spring and neap tides and at hourly intervals before and after high water at the closest diamonds to each survey area.

Table IX.2: Direction and rate of tidal streams at three location close to Inland Sea, Malltraeth and Red Wharf Bay on spring and neap tides and at hourly intervals before and after high water.

Time before /after High Water	**Station B** Approach to Holyhead			**Station F** offshore from Malltraeth			**Station E** offshore from Red Wharf Bay		
	Direction	Rate (m/s) Spring	Neap	Direction	Rate (m/s) Spring	Neap	Direction	Rate (m/s) Spring	Neap
HW-6	90	0.36	0.15	110	0.10	0.05	108	0.10	0.05
HW-5	81	0.72	0.36	40	0.26	0.15	122	0.36	0.21
HW-4	89	0.72	0.36	10	0.46	0.21	126	0.62	0.31
HW-3	102	0.36	0.15	1	0.46	0.26	129	0.67	0.36
HW-2	121	0.15	0.05	357	0.46	0.26	140	0.36	0.21
HW-1	244	0.31	0.15	353	0.36	0.15	167	0.15	0.10
HW	243	0.57	0.26	307	0.10	0.05	284	0.15	0.10
HW+1	258	0.62	0.31	196	0.26	0.15	308	0.36	0.21
HW+2	262	0.51	0.26	190	0.41	0.21	315	0.57	0.31
HW+3	277	0.26	0.15	189	0.46	0.26	320	0.62	0.31
HW+4	350	0.05	0.05	185	0.41	0.21	316	0.36	0.21
HW+5	52	0.10	0.05	182	0.36	0.21	315	0.15	0.10
HW+6	81	0.26	0.10	140	0.15	0.05	74	0.05	0.05
Excursion (flood)		9.3	4.4		4.6	2.4		8.3	4.6
Excursion (ebb)		8.3	4.3		10.2	5.4		8.0	4.4

Data from Admiralty Charts 5609.11 & 5609.10

The diamonds lie offshore rather than within the survey areas so are of limited relevance, although they do align with the offshore patterns of tidal streams described above. Estimates of tidal excursion made from these diamonds are in the order of 8-9 km on spring tides and 4-5 km on neap tides. The exception is the tidal diamond off Malltraeth, which is highly asymmetrical most likely due to its location where the tidal stream splits to move along the west coast of Anglesey and up the Menai Strait.

Strong winds drive surface water currents at about 3% of the wind speed (Brown, 1991) so gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 0.5 m/s, which will create return currents lower in the water column or along sheltered margins. Effects of wind upon tide are highly dynamic and variable making firm predictions difficult. Freshwater inputs can modify water circulation patterns via density effects, and spatial and temporal variation in salinity in coastal waters is usually associated with a corresponding variation in the concentration of faecal indicator bacteria deriving from land runoff. Plumes from long sea sewage outfalls (e.g. Holyhead and Benllech STWs) are less dense than seawater and will tend to float to the surface. This will result in a degree of separation from benthic shellfish stocks in their vicinity, but render the shape of the plumes they form susceptible to significant modification by wind driven currents. Assessments of the local tidal circulation patterns within the three survey areas and the potential effects of winds and freshwater inputs upon these are made in the following subsections.

Inland Sea

Flood tide streams arrive first at the southern entrance to the Holy Island Strait, and progress up the strait in a northerly direction, then start to flood through the constriction at Four Mile Bridge. They then arrive through the northern entrance, progress in a southerly direction then flood through the Stanley Embankment, arriving there about half an hour after they arrive at Four Mile Bridge. After high water the tide starts ebbing through both the Stanley Embankment and Four Mile Bridge simultaneously (Krawiecki & Biggs, 2006). The tidal range in the central section is greatly reduced, and water exchange between the three sections of the strait is limited due to the presence of these constrictions. The reduced flushing of the central section may result in higher concentrations of faecal indicator bacteria here, thereby generating an ebb plume of more contaminated water, although this will depend on inputs to the area.

The tidal diamond off Holyhead Breakwater indicates that tides here align with the east west axis. Off the tip of Holyhead Breakwater the tidal stream will split, and progress both up the coast of Anglesey and into the Holy Island Strait. Within the survey area in the northern section of the Holy Island Strait currents will tend to align with the north south orientation of the straits. The plume from the Holyhead STW may be carried into the survey area, in part at least, during the flood tide. Estimates of tidal excursion in the area suggest it may not reach the shellfisheries on the smaller tides, particularly given that maximum modelled tidal stream velocities decrease to less that 0.25 m/s within the northern part of the strait (Robins et al, 2012).

Shoreline sources within the survey area will therefore impact on the same shore to which they discharge, either side of their location, with the impacts becoming progressively less acute with distance as the plume becomes more diluted. It is possible that eddy currents may form either side of the Holyhead Breakwater, and in other places where there are indentations and headlands. There is also some uncertainty concerning the path that any ebb plume of more contaminated water emanating from the Alaw estuary will follow. The main subtidal channel from the mouth of this estuary follows the shore in a southerly direction and joins with the main subtidal channel through the strait just north of the Stanley Embankment. There is also a second shallower channel emanating from the mouth in a north westerly direction. It is therefore likely that the plume is carried in a northerly direction out into Holyhead Bay during the earlier stages of the ebb, but that towards low water it follows the channels described above. Its impacts are likely to be mainly felt to the east of the main subtidal channel through the strait.

Tidal exchange is large in relation to freshwater input so the system is likely to be well mixed with salinities usually approaching that of full strength seawater (Futurecoast, 2002) outside of the enclosed Alaw estuary at least. There is likely to be an area of decreased salinity associated with the mouth of the Alaw estuary, particularly at times of high river flow. This and corresponding increases in levels of faecal indicator bacteria is likely to be most acute in its drainage channel around low water. No salinity measurements were available to confirm these hypotheses.

The area is sheltered from winds from all directions apart from the north. These will tend to push surface water in a southerly direction, and so may advect any buoyant plume from the Holyhead STW into the strait. Given its relatively sheltered aspect strong wave action which may resuspend contamination in the sediment is not generally anticipated although swells may enter the area from the north at times.

Red Wharf Bay

Tidal streams flood along the Red Wharf Bay area parallel to the coast in a south westerly direction, with the reverse occurring on the ebb. Shoreline sources within the survey area will therefore impact either side of their location, with the impacts becoming progressively less acute with distance as the plume becomes more diluted. It is however quite possible that eddy currents may form either side of the Moelfre headland and in Red Wharf Bay, although no firm information to substantiate this could be found. The Benllech STW outfall is likely to be sufficiently far offshore to be carried by the offshore tidal streams rather than being caught in any eddies that may form in indentations to the coast. As such it may be more likely to impact on the mussel bed at Moelfre than in Red Wharf Bay itself, in the absence of wind effects at least.

The offshore tidal diamond indicates a maximum current velocity of 0.67 m/s on spring tides. A modelling study indicates that closer to the shore indicates that maximum current velocities at Moelfre Island are about 0.5 m/s, whereas in the intertidal areas of Red Wharf Bay where the cockles are located the maximum current velocities are <0.25 m/s (Robins et al, 2012). As such, very local sources will be of most significance at Red Wharf Bay, whereas the mussels at Moelfre may be subject to contamination from more distant shoreline sources. The estimate of offshore tidal excursion (~5 km on neaps and ~8 km on springs) indicates that the plume from the Benllech STW will be carried as far as Moelfre.

The survey area is an open coastal location with little in the way of freshwater inputs, so density driven circulation is unlikely to be of significance and salinities are likely to be that of full strength seawater throughout. Repeated salinity measurements taken at three locations within the survey area appear to confirm this (Figure IX.4).

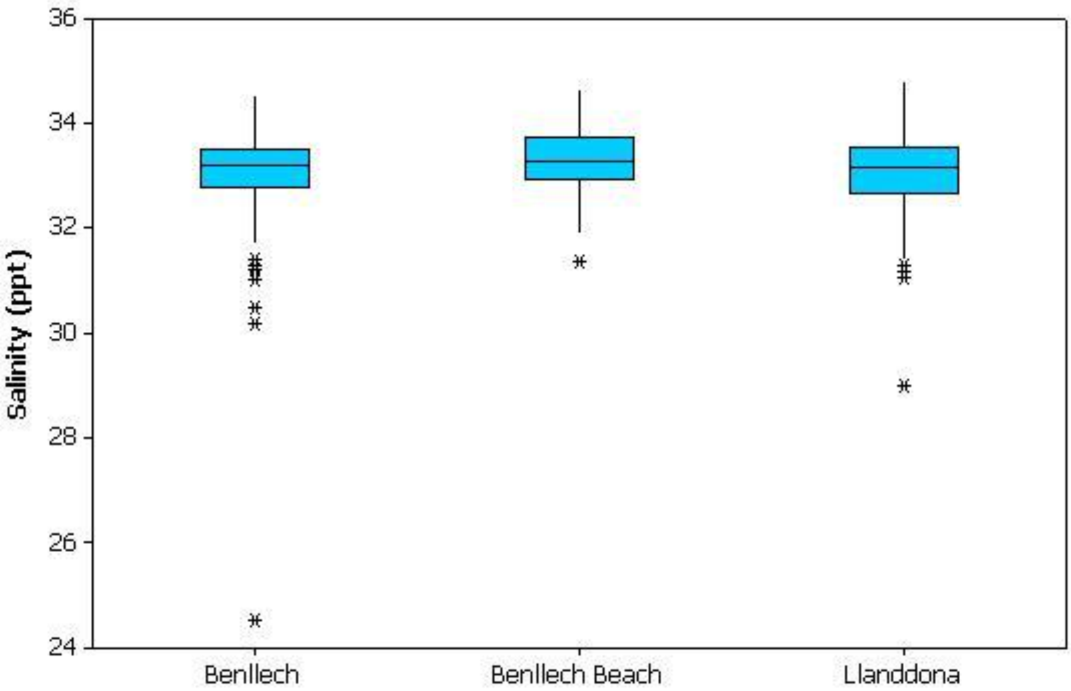


Figure IX.4: Boxplot of salinity readings taken from three Locations in Red Wharf Bay (Benllech, 2003 – 2013; Benllech Beach, 2005 -2011; Llanddona, 2003 -2011)
Data from the Environment Agency

There may be localised areas of decreased salinity in near shore areas associated with freshwater inputs, the magnitude of which will vary with discharge rates. The most acute influences of land runoff will be felt in the immediate vicinity of drainage channels which carry freshwater inputs across the intertidal, where relatively high concentrations of faecal indicator bacteria may arise at lower states of the tide. Very little freshwater influence is anticipated at Moelfre as freshwater inputs to this stretch of coast are very minor and the dilution potential is very high.

The survey area is most exposed to winds blowing from the north and east. Strong winds will modify tidal circulation patterns, particularly where they are weakest in the inner reaches of Red Wharf Bay. Winds from the north east quadrant will tend to advect any buoyant plume from the Benllech STW towards the shore and under such conditions it is likely to have a greater contaminating influence on shellfish at both Red Wharf Bay and Moelfre. Such winds are also likely to generate energetic wave action, which may resuspend any contamination entrained in intertidal sediments.

Malltraeth

Tides will flood up this estuary, firstly up the main channel then spreading out over the intertidal as water levels rise. After high water the estuary will drain in the opposite manner. Currents are likely to be weaker away from the main river channel, but no information on current velocities within the estuary could be found. Contamination from shoreline sources will therefore tend to impact on either side of its location at higher tidal states, whilst at lower states of the tide it will follow drainage channels across the intertidal and into the main estuary channel. The highest concentrations of faecal indicator bacteria are therefore likely to arise in the drainage channels and the main river channel around low water.

The ratio of average river flow to tidal exchange is low, suggesting that salinity will generally be approaching that of full strength seawater, and that stratification and density driven circulation is unlikely to be of significance apart from at high river flows. Repeated salinity measurements taken from the estuary mouth appear to confirm this (Figure IX.5).

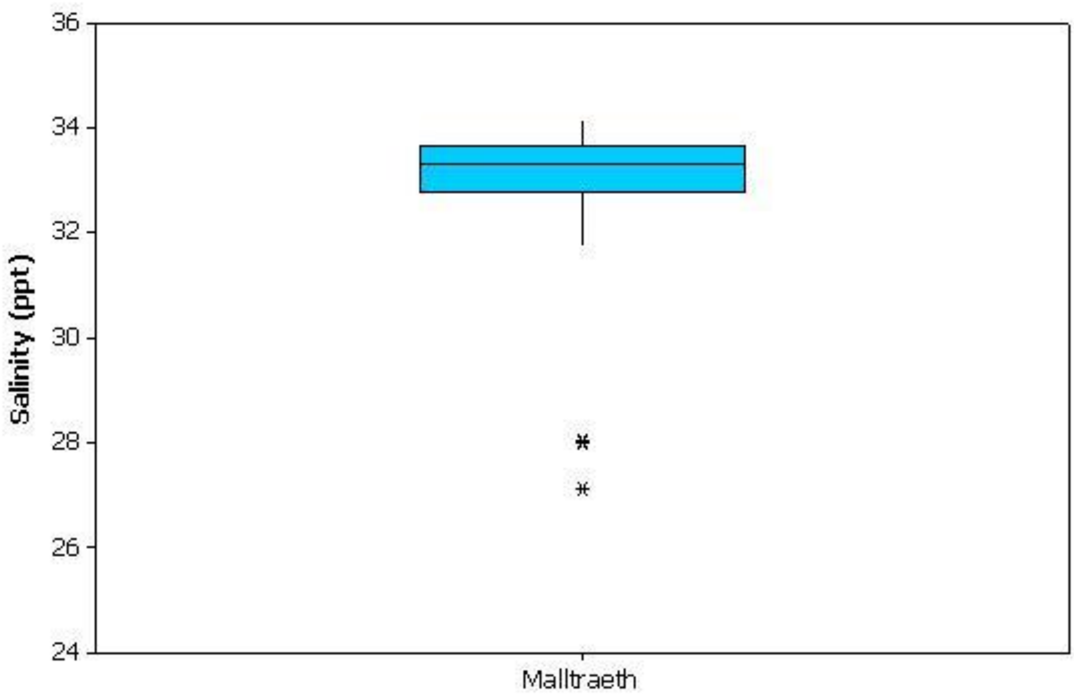


Figure IX.5 Boxplot of salinity readings taken from one location in Malltraeth Bay (2003 - 2013)
Data from the Environment Agency

It is likely that there is a gradient of decreasing average salinity towards the head of the estuary, and this will be associated with a corresponding gradient of increasing levels of runoff borne contamination. RMPs located towards the up estuary ends of any shellfish beds would best capture this, although the cockle bed comes in closest proximity to the main river channel towards its downstream end.

The estuary faces south west into the prevailing winds, which will tend to push surface water up the estuary. The dunes just inside the mouth will largely prevent waves from entering the estuary, which could otherwise potentially resuspend contamination within sediments.

Appendix X. Microbiological Data: Seawater

X.1. Bathing Waters

There are three bathing waters relevant to the survey area, designated under the Directive 76/160/EEC (Council of the European Communities, 1975) all of which are within the Red Wharf Bay survey area. Due to changes in the testing method used by the Environment Agency from 2012 onwards, only data produced up to the end of 2011 were used in these analyses.

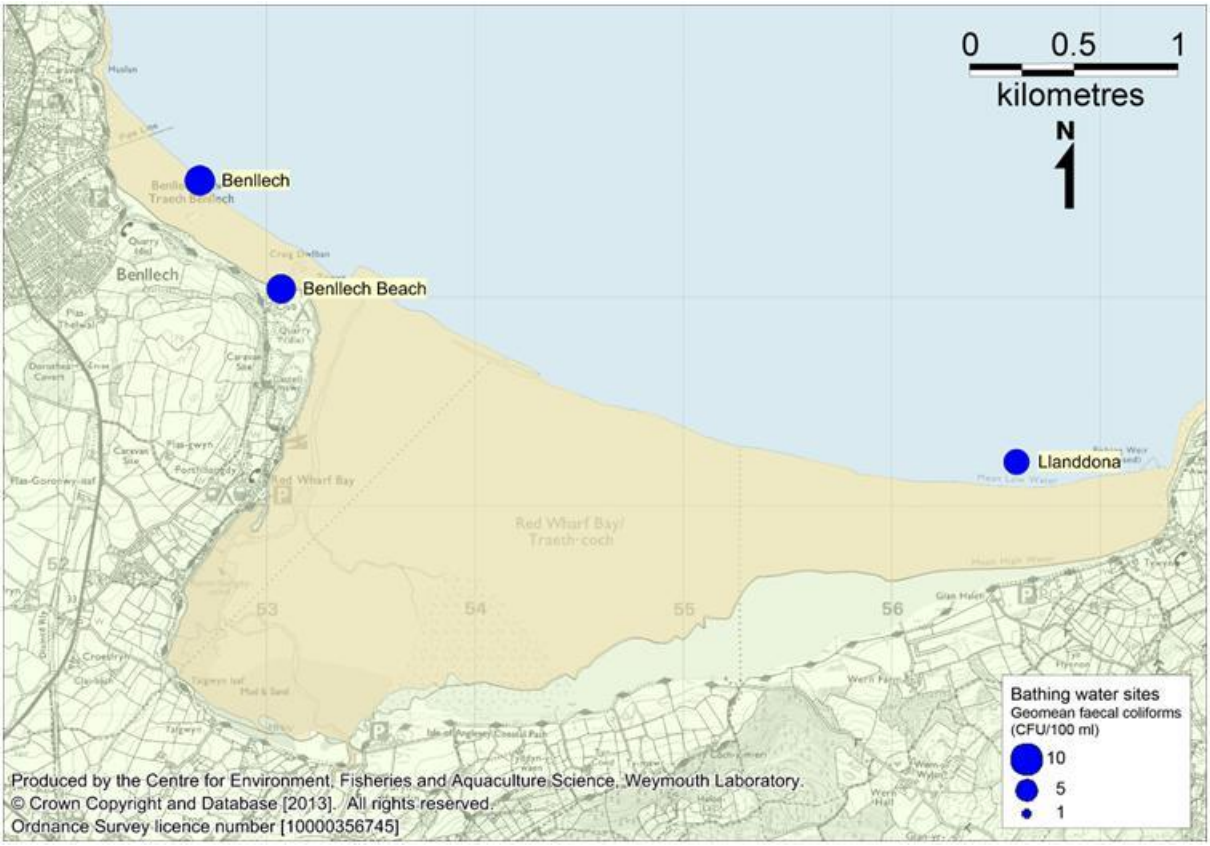


Figure X.1: Location of designated bathing waters and shellfish waters monitoring points.
Data from the Environment Agency

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

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

Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1,000
Benllech	180	08/05/2003	21/09/2011	8.9	2	623	5.6	0.0
Benllech Beach	180	07/05/2003	21/09/2011	8.4	2	1320	6.1	0.6
Llanddona	180	08/05/2003	21/09/2011	7.1	2	3692	3.3	0.6

Data from the Environment Agency

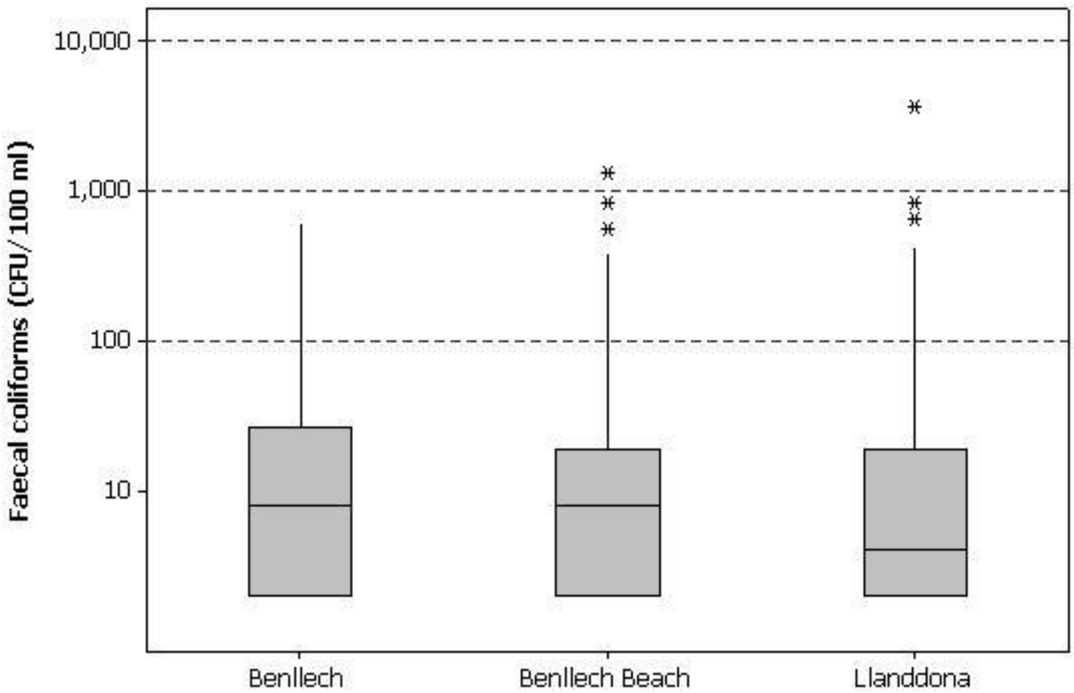


Figure X.2: Box-and-whisker plots of all faecal coliforms results by site
Data from the Environment Agency

Results were very similar across all three sites, and levels of faecal coliforms were generally low. All sites had results exceeding 100 faecal coliforms/100 ml. While Benllech had the highest geometric mean of faecal coliforms cfu/100 ml, Llanddona had the highest individual result of 3,692 cfu/100 ml. One-way ANOVAs showed that there were no significant differences between faecal coliform levels between sites ($p = 0.288$).

Comparisons of sites were carried out on a pair-wise basis by running correlations (Pearson's) between sites that shared sampling dates, and therefore environmental conditions. There were very strong correlations ($p < 0.001$ in all cases) between all site pairings, suggesting that they are all influenced by similar sources.

Overall temporal pattern in results

The overall variation in faecal coliform levels across the period 2003 to 2010 is shown in Figure X.3.

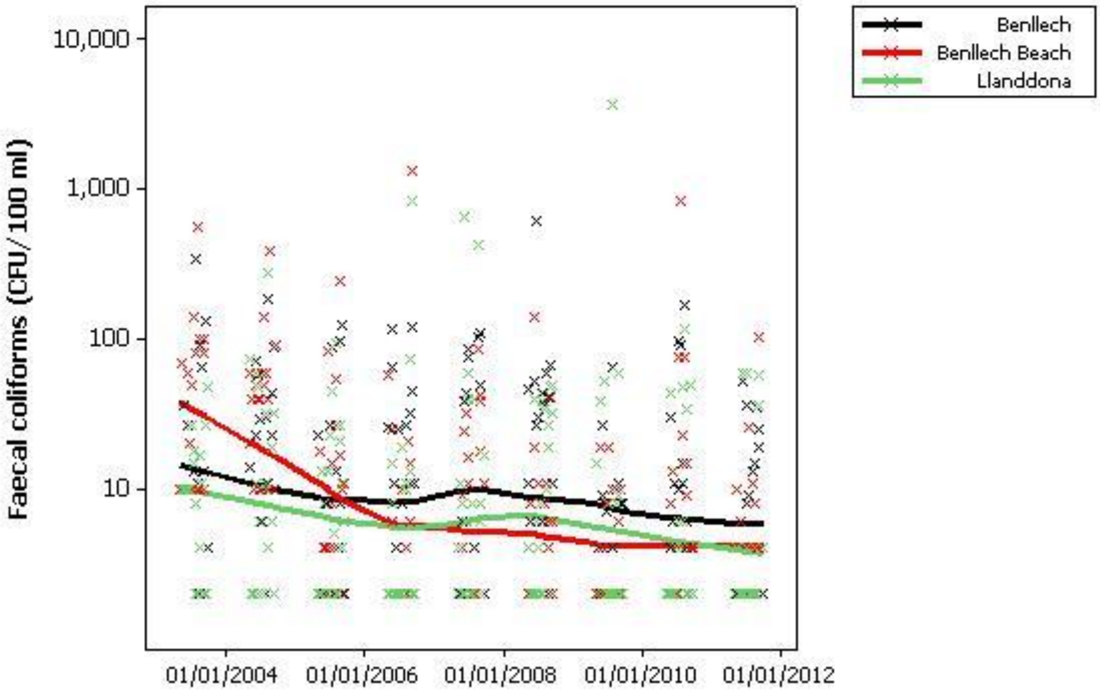


Figure X.3: Scatterplot of faecal coliform results for bathing waters overlaid with loess lines.
Data from the Environment Agency

There was a slight decline in faecal coliform levels at Benllech Beach from 2003 to 2006, otherwise faecal coliform levels have remained stable at all bathing waters sites.

Influence of tides

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

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

	High/low tides		Spring/neap tides	
Site Name	r	p	r	p
Benllech	0.372	<0.001	0.313	<0.001
Benllech Beach	0.078	0.343	0.265	<0.001
Llanddona	0.182	0.003	0.341	<0.001

Data from the Environment Agency

Figure X.4 presents polar plots of $\log_{10}$ faecal coliform results against tidal states on the high/low cycle for the sites where a significant correlation was found. High water is at 0° and low water is at 180°. Results of 100 faecal coliforms/100ml or less are plotted in green, those from 101 to 1000 are plotted in yellow, and those exceeding 1000 are plotted in red.

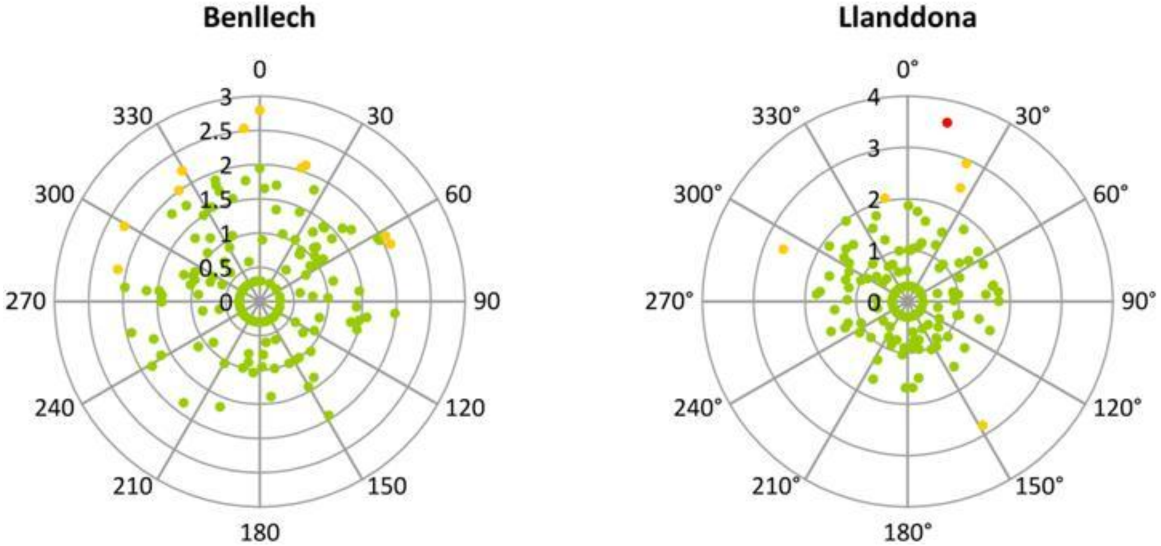


Figure X.4: Polar plots of $\log_{10}$ faecal coliforms against tidal state on the high/low tidal cycle for bathing waters monitoring points with significant correlations
Data from the Environment Agency

At both Benllech and Llandona, the higher results tended to arise during the higher states of the tide.

Figure X.5 presents polar plots of faecal coliform results against the lunar spring/neap cycle. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 100 faecal coliforms/100ml or less are plotted in green, those from 101 to 1000 are plotted in yellow, and those exceeding 1000 are plotted in red.

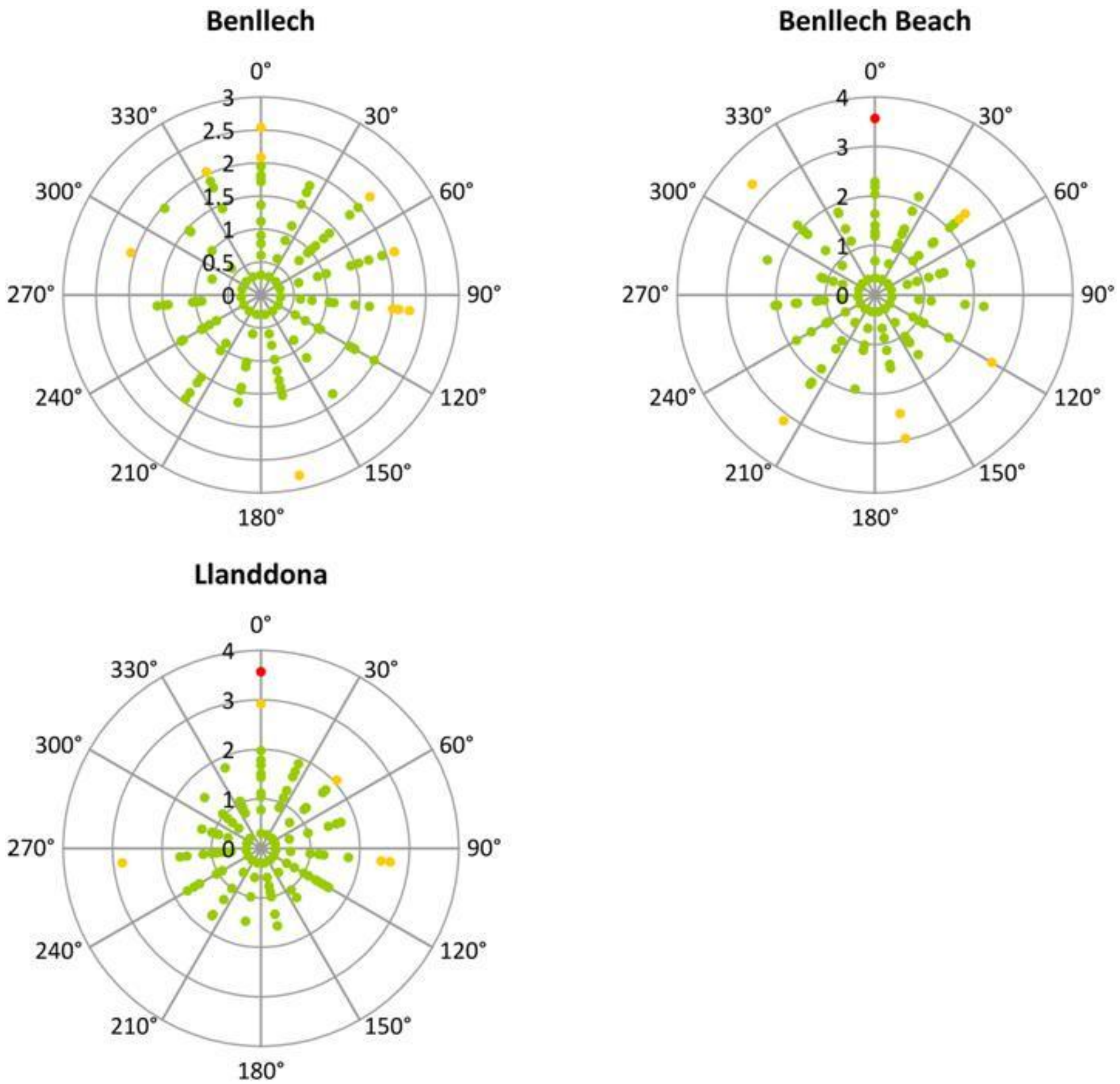


Figure X.5: Polar plots of log_{10} faecal coliforms against tidal state on the spring/neap tidal cycle for bathing waters monitoring points with significant correlations

Data from the Environment Agency

An examination of the data indicated that results were higher on average during spring tides and lower on average during neap tides at all three sites, although the high number of very low results obscures this pattern on the polar plots.

Influence of Rainfall

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

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

Site	Benllech	Benllech Beach	Llanddona
n	180	180	180

24 hour periods prior to sampling	1 day	0.086	-0.030	0.189
	2 days	0.105	0.093	0.237
	3 days	0.078	0.047	0.100
	4 days	0.005	0.026	0.100
	5 days	0.067	0.129	0.105
	6 days	0.014	0.167	0.168
	7 days	0.179	0.253	0.283
Total prior to sampling over	2 days	0.117	0.040	0.231
	3 days	0.134	0.080	0.224
	4 days	0.107	0.074	0.209
	5 days	0.144	0.089	0.218
	6 days	0.125	0.109	0.231
	7 days	0.159	0.148	0.285

Data from the Environment Agency

Rainfall affected faecal coliform levels at all three sites to some extent. The influence was greatest and most consistent at Llanddona. There was a delay of several days before faecal coliform levels rose at Benllech and to a lesser extent at Benllech Beach.

X.2. Shellfish Waters

Summary statistics and geographical variation

There are three shellfish waters monitoring sites designated under Directive 2006/113/EC (European Communities, 2006) around the Isle of Anglesey in addition to those in the Menai Strait. These coincide with the individual areas considered in this survey. Here, water samples are taken on a quarterly basis and enumerated for faecal coliforms. The shellfish water at Inland Sea was only designated in 2011, so the very limited data generated here was not considered in this report. Figure X.6 shows the location of the monitoring points at Red Wharf Bay and Malltraeth Sands. Table X.4 presents summary statistics for bacteriological monitoring results and Figure X.7 presents a boxplot of faecal coliforms levels from the monitoring points.

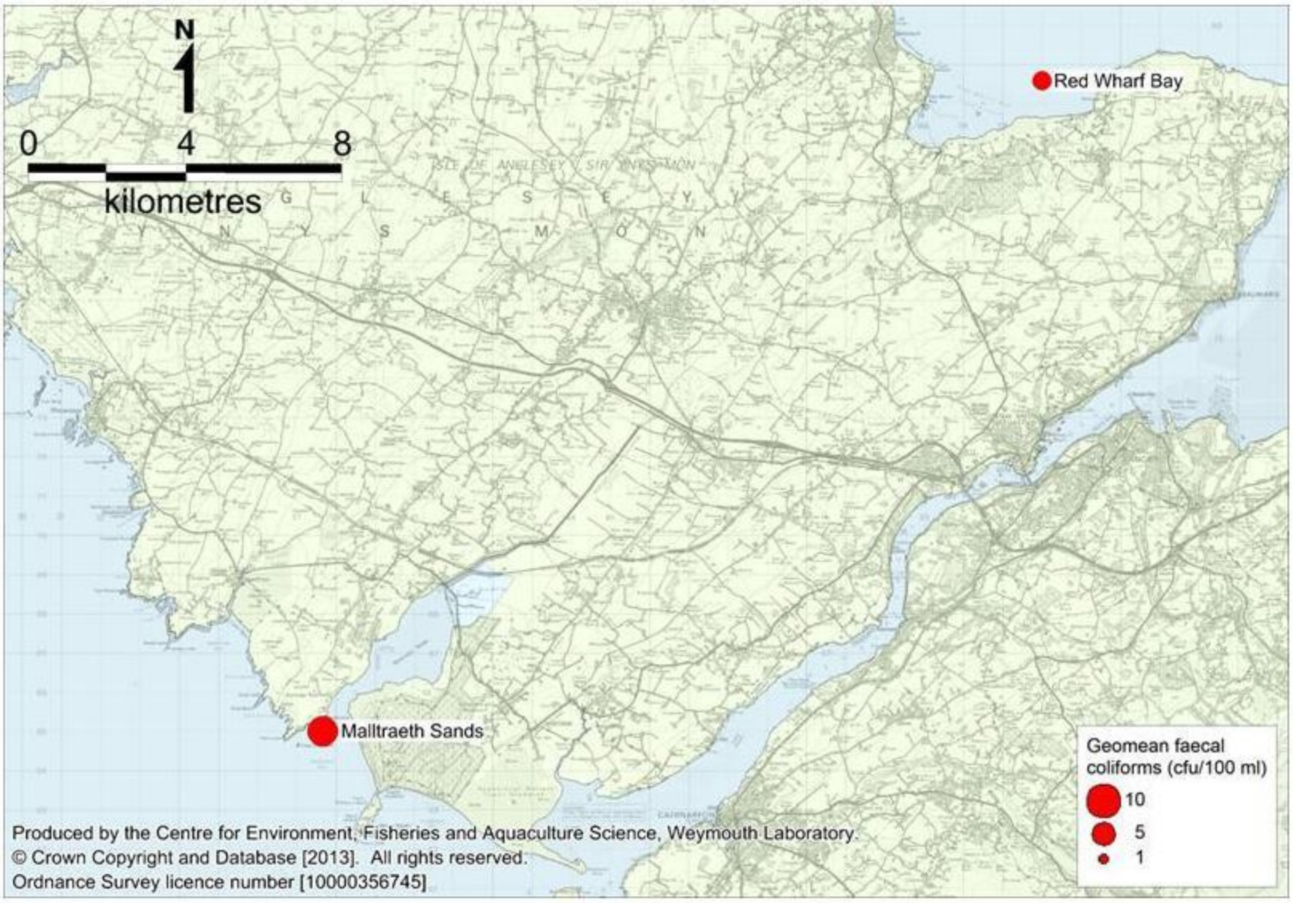


Figure X.6: Location of shellfish waters monitoring points
Data from the Environment Agency

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

Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100
Red Wharf Bay	46	20/01/2003	15/10/2013	3.5	<2	38	0.0
Malltraeth Sands	46	07/01/2003	04/03/2013	8.3	2	636	4.3

Data from the Environment Agency

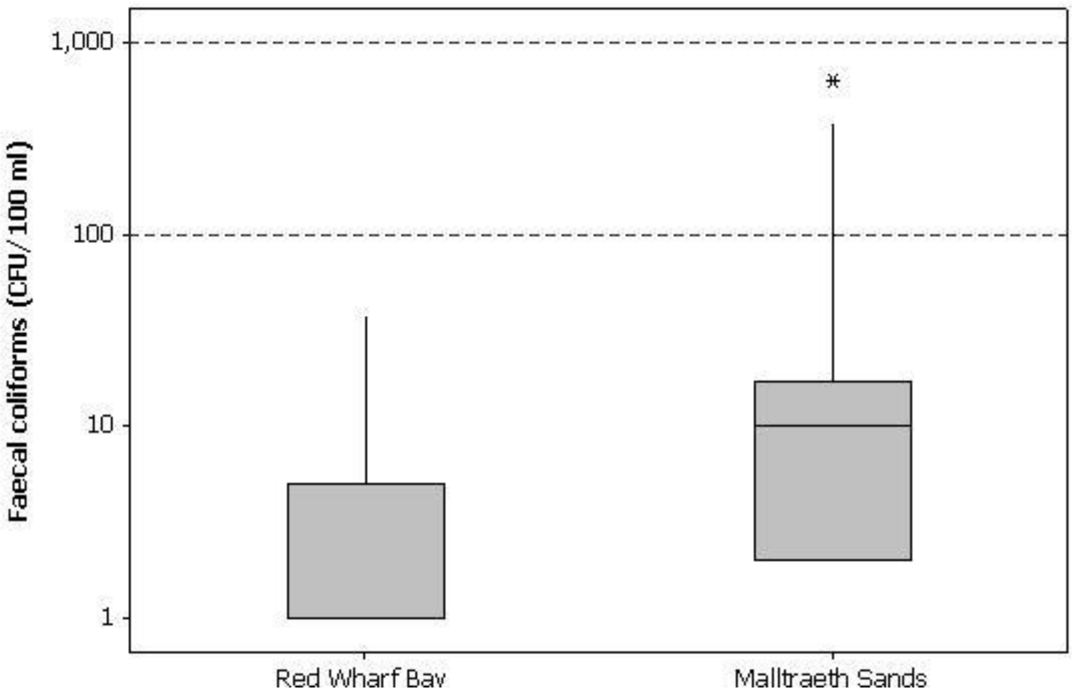


Figure X.7: Box-and-whisker plots of all faecal coliforms results
Data from the Environment Agency

Results were generally low at both sites. At Red Wharf Bay 100% of samples had faecal coliform levels below 100 cfu/100 ml, while at Malltraeth 95.7% of samples had faecal coliform levels below 100 cfu/100 ml with none above 1,000 cfu/100 ml. Two-sample t-tests showed that Malltraeth had significantly higher faecal coliform levels than Red wharf Bay ($p<0.001$).

Overall temporal pattern in results

The overall variation in faecal coliform levels found at the shellfish waters sites is shown in Figure X.8.

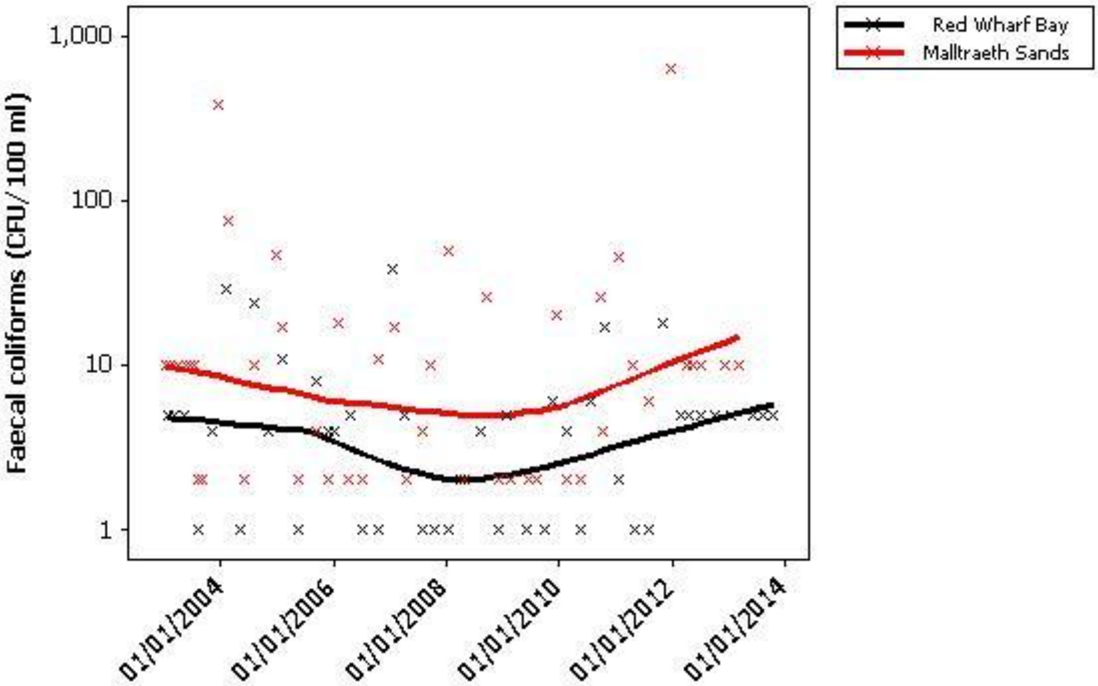


Figure X.8: Scatterplot of faecal coliform results by date, overlaid with loess lines
Data from the Environment Agency

Faecal coliform levels have remained stable at both sites since 2003.

Seasonal patterns of results

Figure X.9 shows the variation in faecal coliform levels at the shellfish waters monitoring points between seasons.

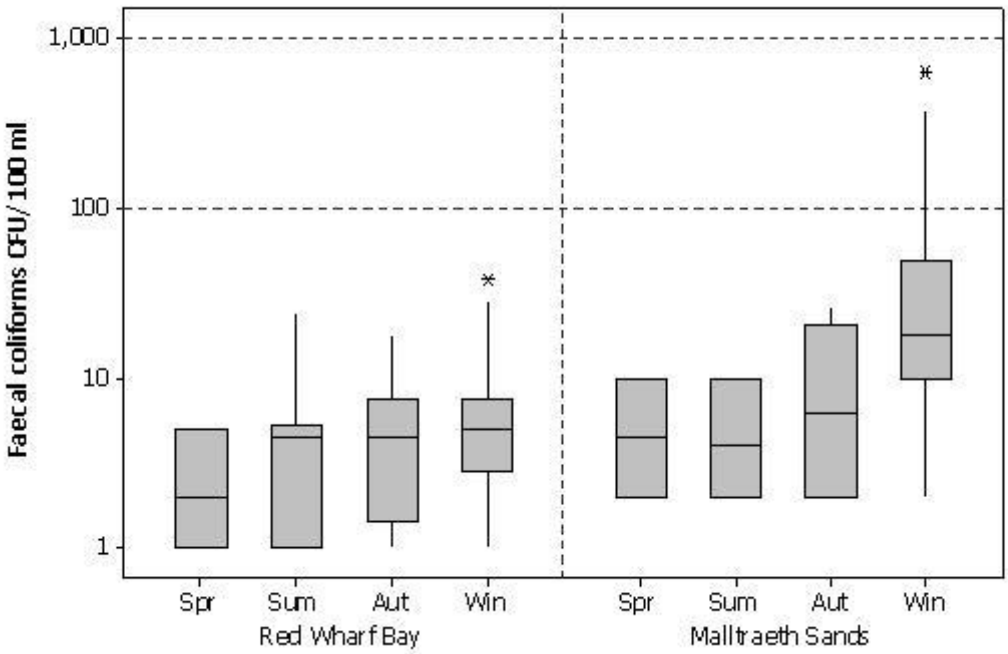


Figure X.9: Boxplot of faecal coliform results by site and season
Data from the Environment Agency

There were no significant differences in faecal coliform levels between seasons at Red Wharf Bay (p=0.231). However, there were significant differences between seasons at Malltraeth Bay (p=0.001). Post ANOVA Tukey tests revealed that there were significantly higher levels of faecal coliforms in winter than any other season.

Influence of tide

To investigate the effects of tidal state on faecal coliform results, circular-linear correlations were carried out against both the high/low and spring/neap tidal cycles. Correlation coefficients are presented in Table X.5, with statistically significant correlations highlighted in yellow.

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

		High/low tides		Spring/neap tides	
Site Name	**Tidal station**	**r**	**p**	**r**	**p**
Red Wharf Bay	Moelfre	0.149	0.387	0.139	0.437
Malltraeth Sands	Llanddwyn Island	0.225	0.112	0.386	0.002

Data from the Environment Agency

No influence of the high low tidal cycle was detected, but a significant correlation with the spring/neap tidal cycle was found at Malltraeth Sands. Figure X.10 presents a polar plot of faecal coliform results against the lunar spring/neap cycle. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 100 faecal coliforms/100ml or less are plotted in green, those from 101 to 1000 are plotted in yellow, and those exceeding 1000 are plotted in red.

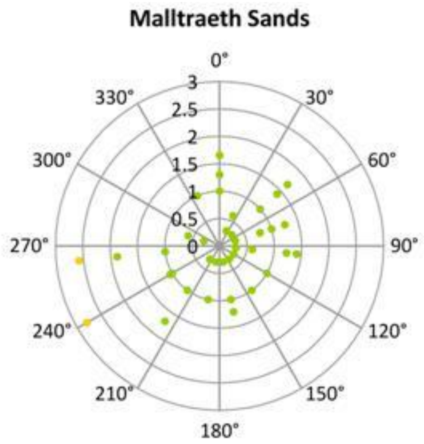


Figure X.10 Polar plots of log_{10} faecal coliforms against tidal state on the spring/neap tidal cycle for bathing waters monitoring points with significant correlations
Data from the Environment Agency

At Malltraeth the low results tended to occur as the tide size decreased from springs to neaps.

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 VI for details) over various periods running up to sample collection and faecal coliform results. These are presented in Table X.6 and statistically significant correlations ($p<0.05$) are highlighted in yellow.

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

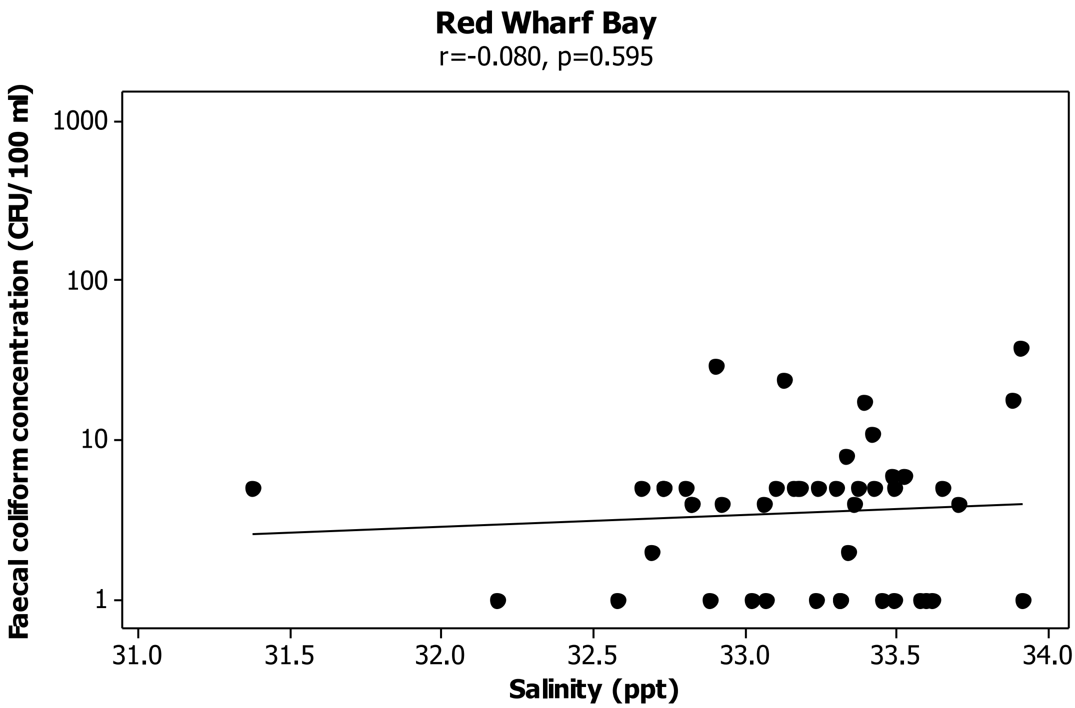
	Site	Red Wharf Bay	Malltraeth Sands
	n	42	45
24 hour periods prior to sampling	1 day	0.199	0.245
	2 days	0.212	0.372
	3 days	0.008	0.155
	4 days	0.130	0.037
	5 days	0.281	0.369
	6 days	0.099	0.122
	7 days	0.206	0.156
Total prior to sampling over	2 days	0.218	0.367
	3 days	0.178	0.309
	4 days	0.103	0.268
	5 days	0.147	0.330
	6 days	0.169	0.316
	7 days	0.168	0.308

Data from the Environment Agency

At Malltraeth sands significant influences of recent rainfall were detected at various intervals following a rainfall event. There was very little affect of rainfall on faecal coliform levels at Red Wharf Bay.

Influence of salinity

Salinity was recorded on most sampling occasions at Red wharf Bay and Malltraeth Sands. Pearson's correlations were run to determine the effect of salinity on faecal coliforms at shellfish waters sites. Figure X.11 shows a scatter-plot of faecal coliforms against salinity.



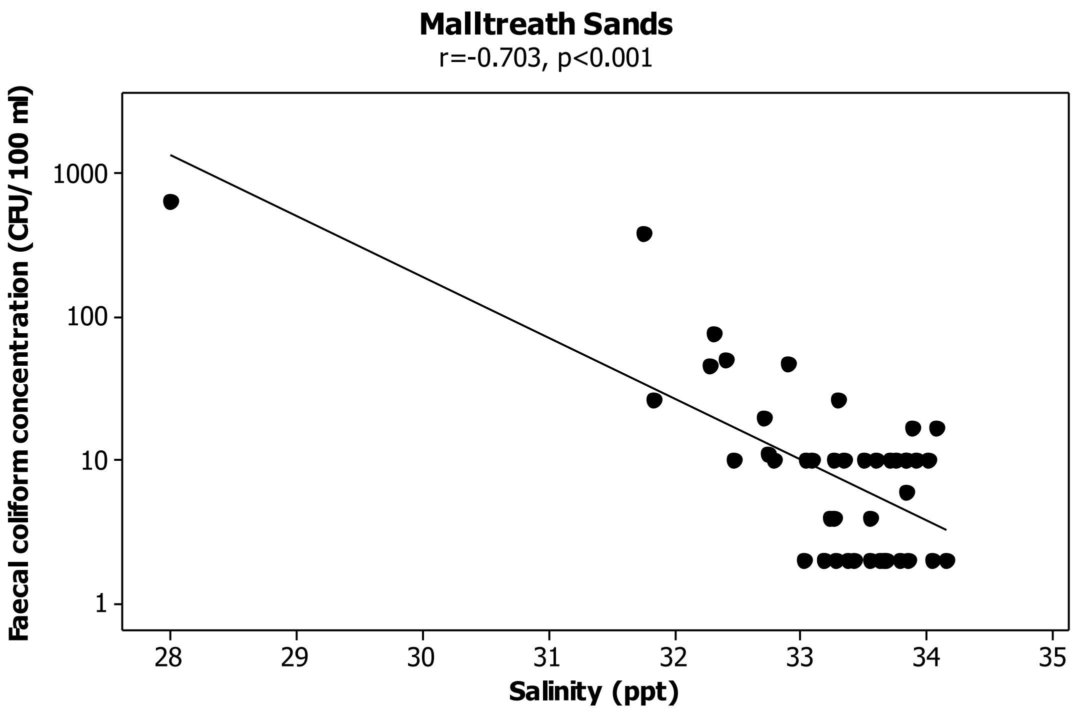


Figure X.11: Scatter-plots of salinity against faecal coliforms.
Data from the Environment Agency

There was no correlation between salinity and faecal coliform concentration at Red wharf Bay. Although there was little variation in salinity, a very strong negative correlation between salinity and faecal coliform levels was found at Malltraeth Sands. This suggests that runoff borne contamination is an influence at this site.

Appendix XI. Microbiological Data: Shellfish Flesh Hygiene

XI.1. Inland Sea

Summary statistics and geographical variation

There is one mussel RMP in the Inland Sea production area. The geometric mean results of shellfish flesh monitoring from 2004 to 2013 at this RMP are presented in Figure XI.1. Summary statistics are presented in Table XI.1 and boxplots are shown in Figure XI.2.

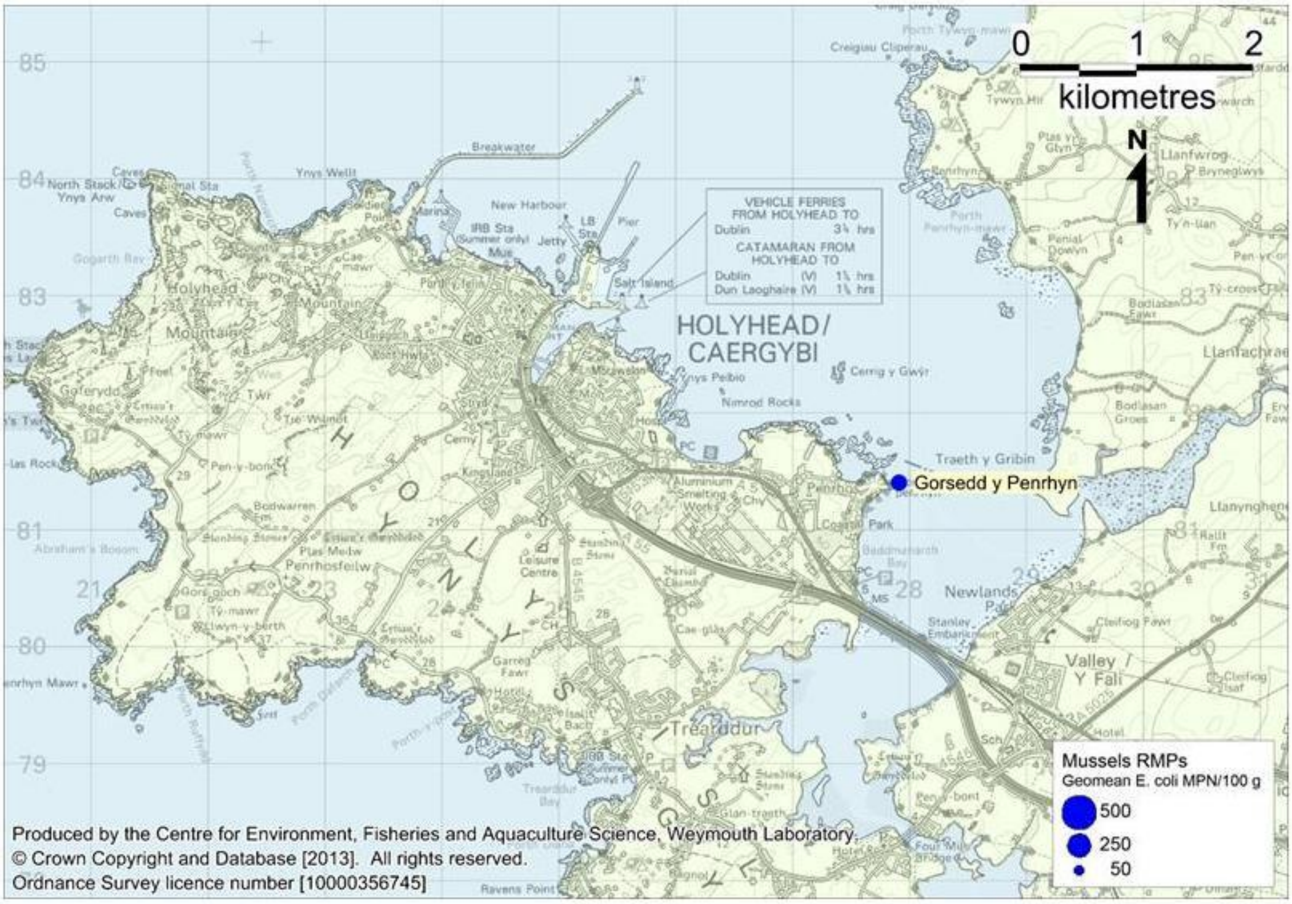


Figure XI.1: Bivalve RMPs active at Inland Sea since 2003

Table XI.1: Summary statistics of *E. coli* results (MPN/100 g) sampled from 2004 onwards

Site	Gorsedd y Penrhyn
Species	Mussel
No.	117
Date of first sample	15/03/2004
Date of last sample	14/10/2013
Geometric mean	137.3
Min.	<20
Max.	5400
% over 230	41.0
% over 4,600	1.7

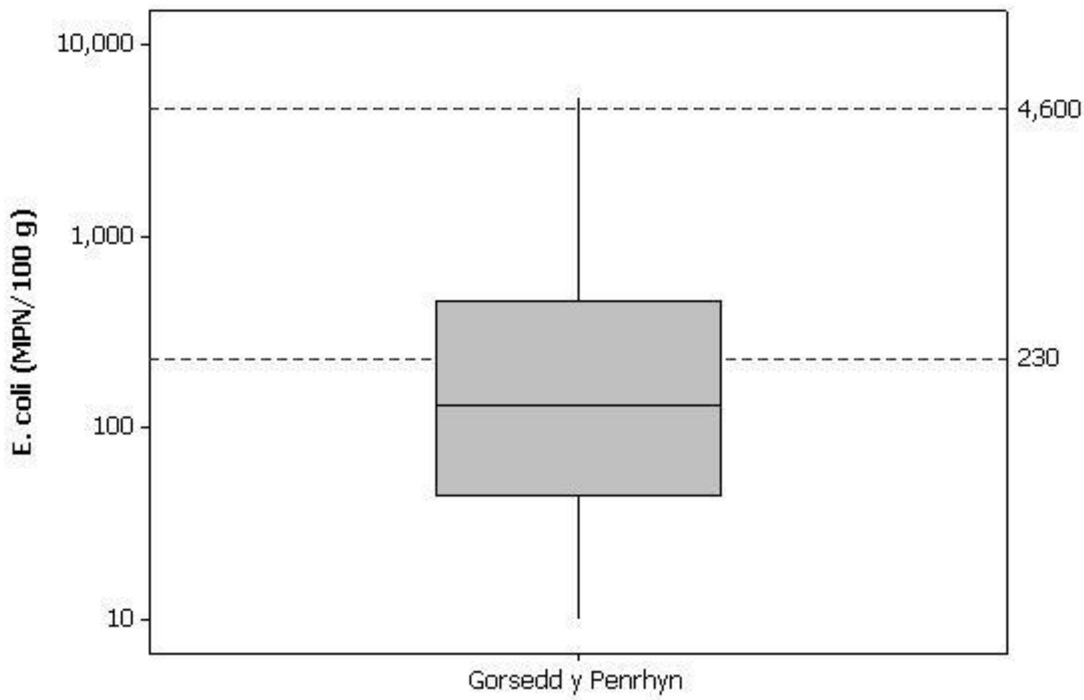


Figure XI.2: Boxplots of *E. coli* results from 2004 onwards.

E. coli levels exceeded 230 MPN/100 g in 41% of samples at all sites, but only exceeded 4,600 MPN/100 g in more than 1.7% of samples.

Overall temporal pattern in results

The overall variation in *E. coli* levels found in mussels is shown in Figure XI.3.

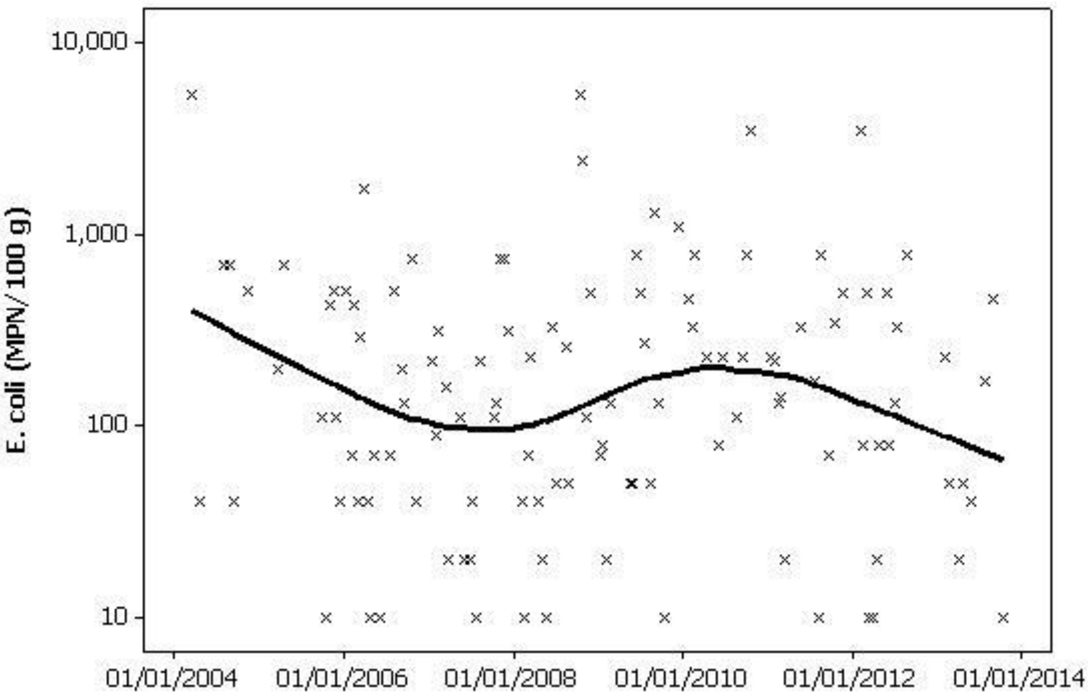


Figure XI.3: Scatterplot of *E. coli* results by date, overlaid with loess line

The loess line suggests the levels of *E. coli* found in mussels have varied considerable between 2004 and 2013, with a general pattern of decline over the years.

Seasonal patterns of results

Figure XI.4 shows the variation in *E. coli* levels between seasons at the Gorsedd y Penrhyn mussel RMP.

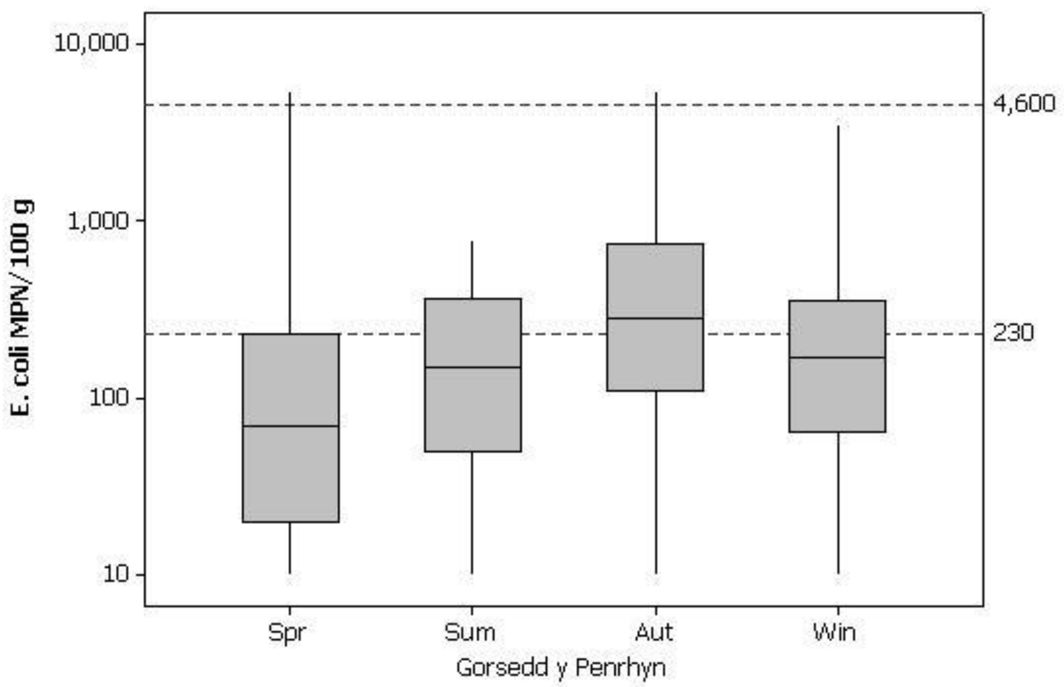


Figure XI.4: Boxplot of *E. coli* results by season

One-way ANOVA tests showed that there was significant variation between seasons (p=0.049). Post ANOVA Tukey tests showed that there were significantly higher levels of *E. coli* in autumn than in spring.

Influence of tide

To investigate the effects of tidal state on *E. coli* results, circular-linear correlations were carried out against the high/low cycles at Holyhead 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.

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

		High/low tides		Spring/neap tides	
Site Name	**Species**	**r**	**p**	**r**	**p**
Gorsedd y Penrhyn	Mussel	0.123	0.179	0.161	0.053

Neither of the tidal cycles had a statistically significant influence on *E. coli* levels.

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	Gorsedd y Penrhyn
	Species	Mussel
	n	109
24 hour periods prior to sampling	1 day	0.213
	2 days	0.350
	3 days	0.108
	4 days	0.023
	5 days	0.051
	6 days	0.047
	7 days	0.090
Total prior to sampling over	2 days	0.318
	3 days	0.272
	4 days	0.257
	5 days	0.217
	6 days	0.197
	7 days	0.205

E. coli levels increased rapidly in response to rainfall events at this RMP but the effects are generally short lived.

XI.2. Malltraeth

Summary statistics and geographical variation

There are two RMPs in the Malltraeth production area. One is for cockles and one is for mussels. The geometric mean results of shellfish flesh monitoring from 2003 to 2013 at these RMPs are presented in Figure XI.5. Summary statistics are presented in Table XI.4 and boxplots are shown in Figure XI.6. Only six samples were taken at the Llanddwyn Bay mussel RMP, and so this site will not be considered in the more detailed analyses.

Figure XI.5: Bivalve RMPs active at Malltraeth since 2003

Table XI.4: Summary statistics of *E. coli* results (MPN/100 g) sampled from 2003 onwards

Site	Cefni Estuary	Llanddwyn Bay
Species	Cockle	Mussel
No.	94	6
Date of first sample	28/01/2003	24/03/2010
Date of last sample	22/04/2013	12/04/2011
Geometric mean	440.4	82.6
Min.	<20	40
Max.	16000	310
% over 230	68.1	16.7
% over 4,600	6.4	0.0

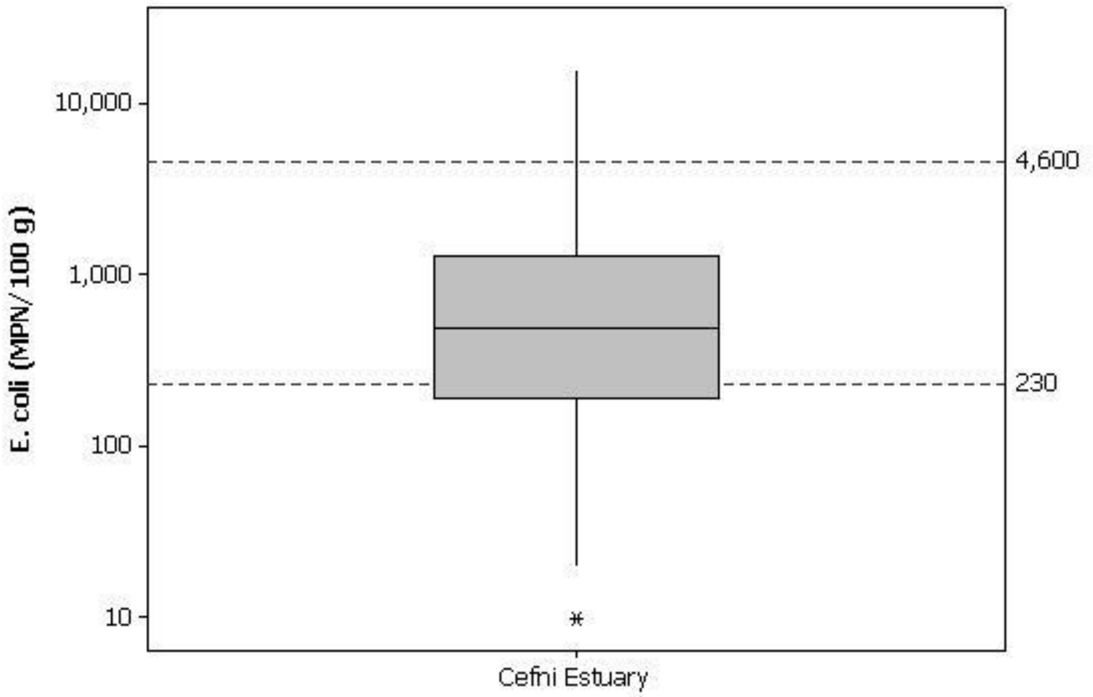


Figure XI.6: Boxplots of *E. coli* results from 2003 onwards.

E. coli levels exceeded 230 MPN/100 g in 68% of samples at Cefni Estuary, and exceeded 4,600 MPN/100 g in more than 6.4% of samples. A peak result of 16,000 MPN/100g was recorded.

Overall temporal pattern in results

The overall variation in *E. coli* levels found in cockles is shown in Figure XI.7.

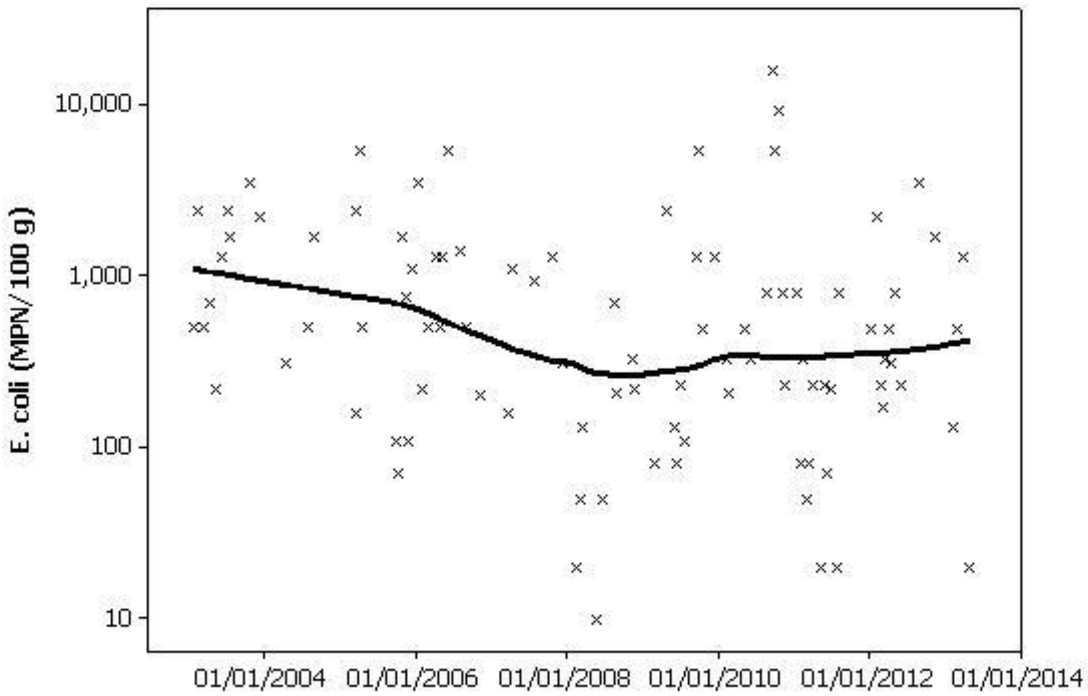


Figure XI.7: Scatterplot of *E. coli* results by date, overlaid with loess lines

The levels of *E. coli* found at in cockles at Cefni Estuary have remained fairly stable since 2003. However there was a slight decline in *E. coli* numbers from 2003 to 2008.

Seasonal patterns of results

Figure XI.8 shows the variation in *E. coli* levels between seasons at the Cefni Estuary cockle RMP.

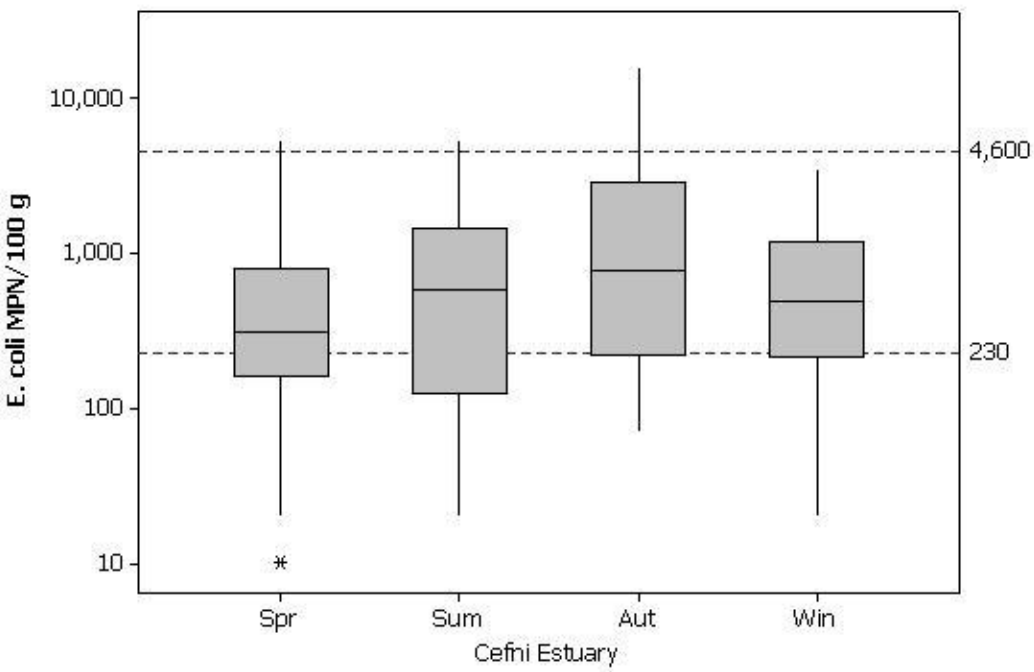


Figure XI.8: Boxplot of *E. coli* results by season

Results were highest on average during the autumn, and lowest on average during the spring. However, one-way ANOVA tests showed that there was no significant variation in *E. coli* numbers in cockles between seasons (p=0.111).

Influence of tide

To investigate the effects of tidal state on *E. coli* results, circular-linear correlations were carried out against the high/low cycles at Llanddwyn Island 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.5, and significant results are highlighted in yellow.

Table XI.5: Circular linear correlation coefficients (r) and associated p values for *E. coli* results from RMPs against the high/low and spring/neap tidal cycles.

		High/low tides		Spring/neap tides	
Site Name	**Species**	**r**	**p**	**r**	**p**
Cefni Estuary	Cockle	0.095	0.444	0.205	0.022

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

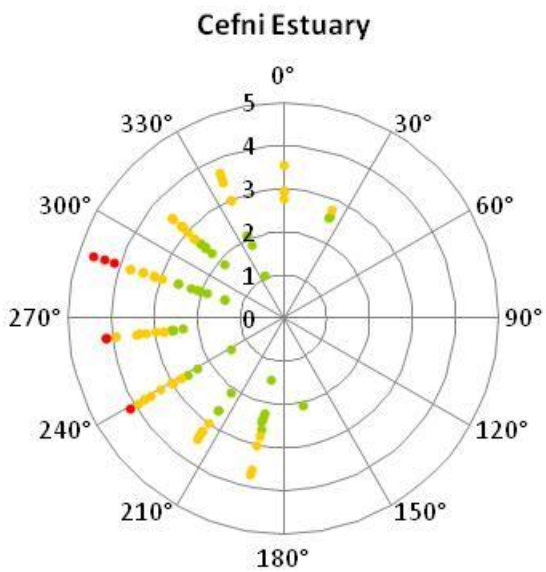


Figure XI.9: Polar plot of log10 E. coli results (MPN/100g) against spring/neap tidal state

The majority of sampling was conducted while tide sizes increased from the neap tides to the spring tides, so the full tidal cycle in not represented. The highest results tended to occur just after neap tides.

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 VI for details) over various periods running up to sample collection. These are presented in Table XI.6, and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table XI.6: Spearman's Rank correlations between rainfall recorded at Parc Menai and shellfish hygiene results

	Site	Cefni Estuary
	Species	Cockle
	n	90
24 hour periods prior to sampling	1 day	0.005
	2 days	0.223
	3 days	0.017
	4 days	-0.085
	5 days	-0.003
	6 days	0.047
	7 days	0.026
Total prior to sampling over	2 days	0.080
	3 days	0.042
	4 days	0.014
	5 days	0.030
	6 days	0.041
	7 days	0.073

A significant influence of rainfall was detected two days after a rainfall event, but not before or after this.

XI.3. Red Wharf Bay

Summary statistics and geographical variation

There are two RMPs in the Red Wharf Bay production area that have been sampled between 2003 and 2013. One is for mussels and one is for cockles. The geometric mean results of shellfish flesh monitoring from 2003 to 2013 at these RMPs are presented in Figure XI.10. Summary statistics are presented in Table XI.7 and boxplots are shown in Figure XI.11 and Figure XI.12.

Figure XI.10: Bivalve RMPs active at Red Wharf Bay since 2003

Table XI.7: Summary statistics of *E. coli* results (MPN/100 g) sampled from 2003 onwards

Site	Traeth Coch	Y Swnt
Species	Cockle	Mussel
No.	116	129
Date of first sample	28/01/2003	28/01/2003
Date of last sample	14/10/2013	04/06/2013
Geometric mean	369.9	42.1
Min.	<20	<20
Max.	16000	2400
% over 230	64.7	15.5
% over 4,600	4.3	0.0

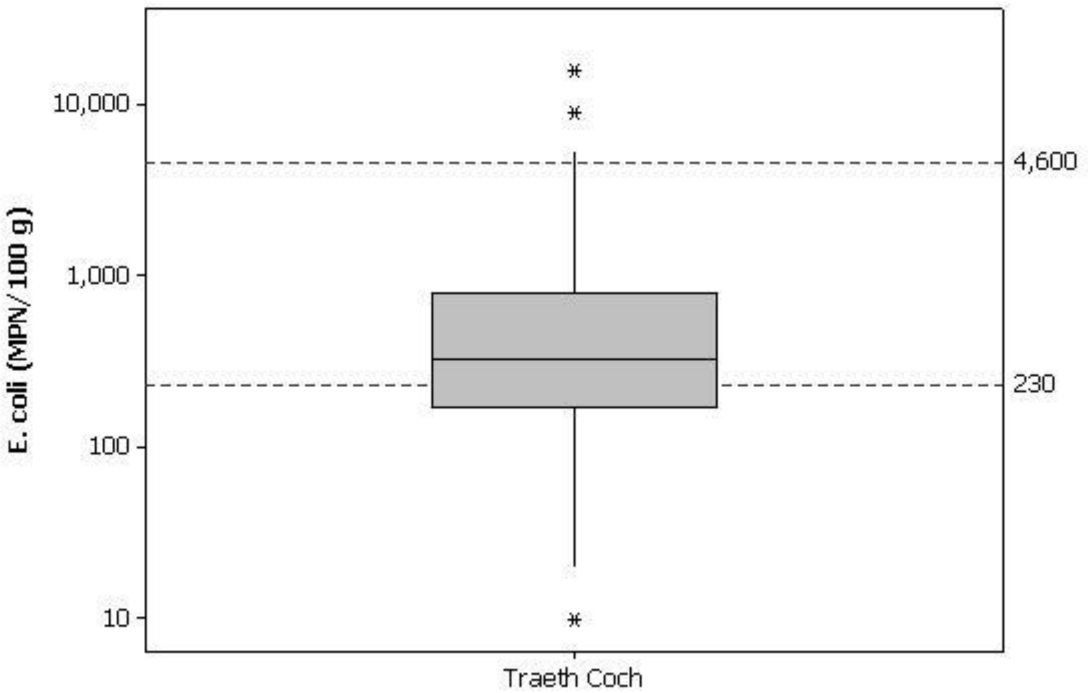


Figure XI.11: Boxplots of *E. coli* results from cockles from 2003 onwards.

At the Traeth Coch cockle RMP *E. coli* results exceeded 230 MPN/100 g in 64.7% of samples and exceeded 4,600 MPN/100 g in 4.3% of samples.

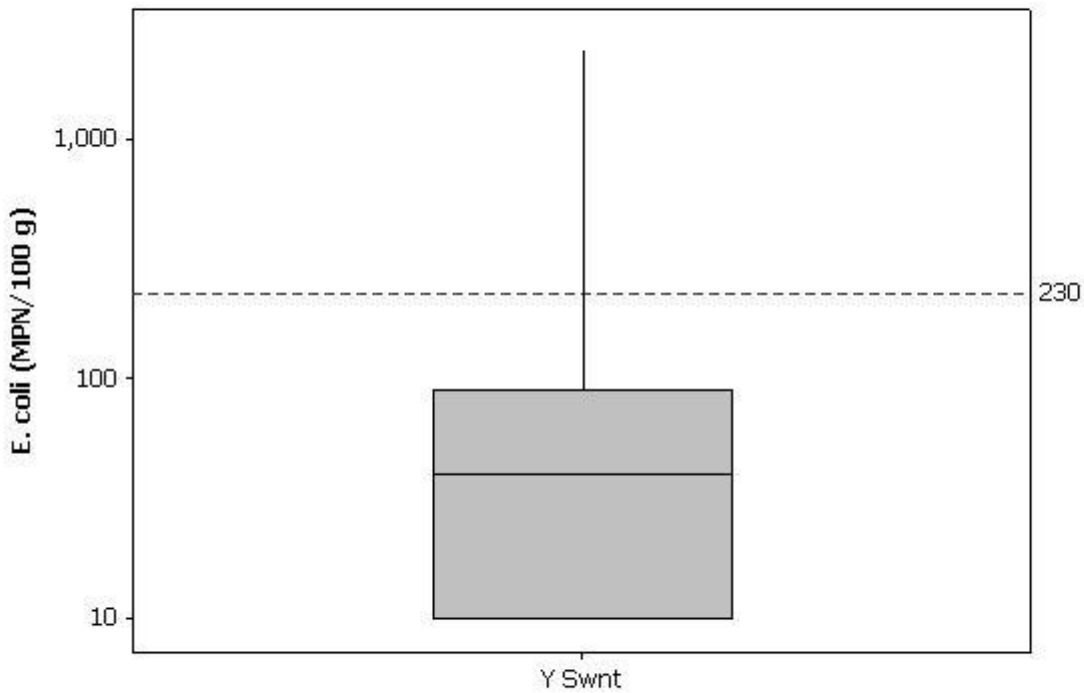


Figure XI.12: Boxplots of *E. coli* results from mussels from 2003 onwards.

At the Y Swnt mussel RMP *E. coli* results were approaching that of a class A area, exceeding 230 MPN/100 g in only 15.5% of samples and not exceeding 4,600 MPN/100 g in any sample.

Overall temporal pattern in results

The overall variation in *E. coli* levels found in bivalves is shown in Figure XI.13 and Figure XI.14.

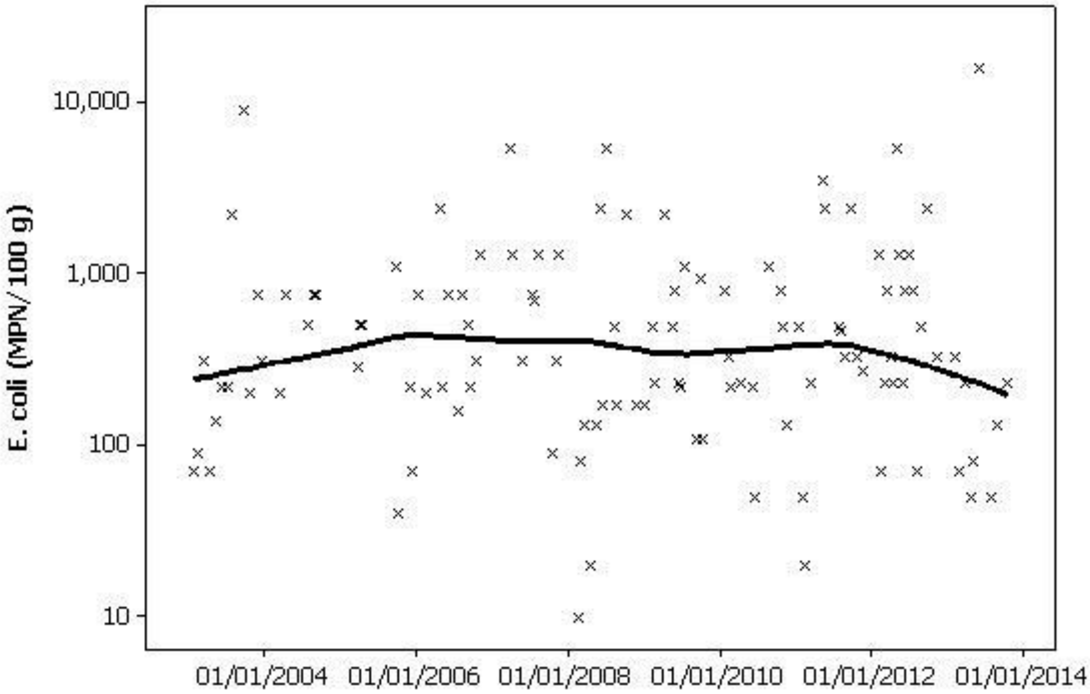


Figure XI.13: Scatterplot of *E. coli* results from cockles by date, overlaid with loess lines

E. coli levels have remained stable at Traeth Coch since 2003.

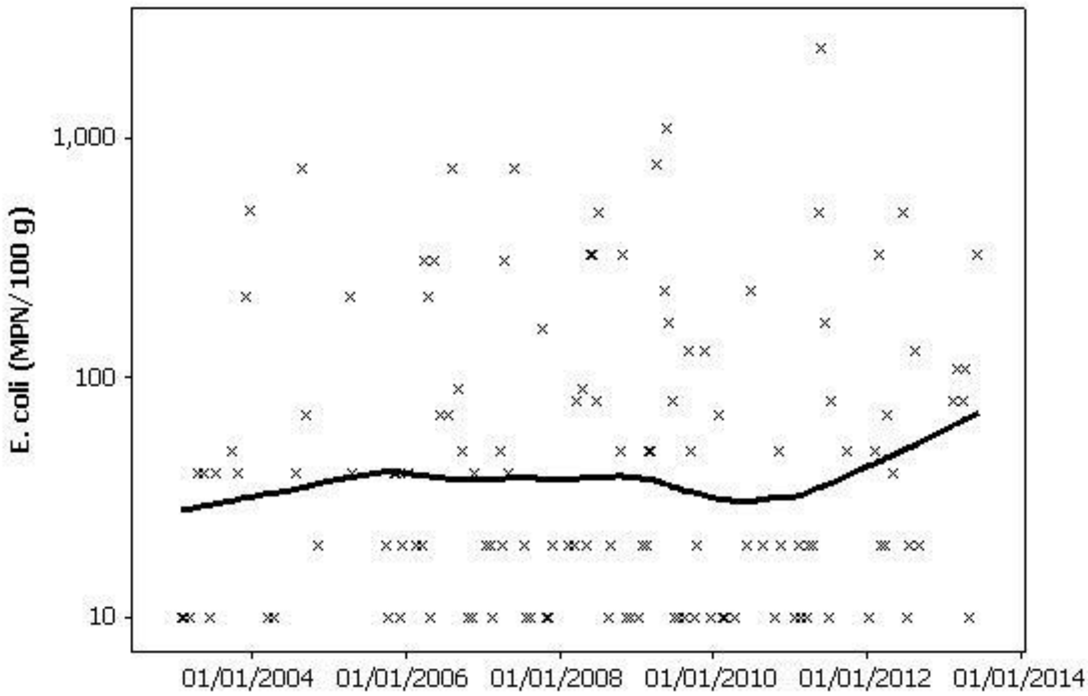


Figure XI.14: Scatterplot of *E. coli* results from mussels by date, overlaid with loess lines

E. coli levels have remained stable at Y Swnt since 2003, although the loess line does suggest a recent run of higher than average results.

Seasonal patterns of results

Figure XI.15 and Figure XI.16 show the variation in *E. coli* levels between seasons at the cockle and mussel RMPs respectively.

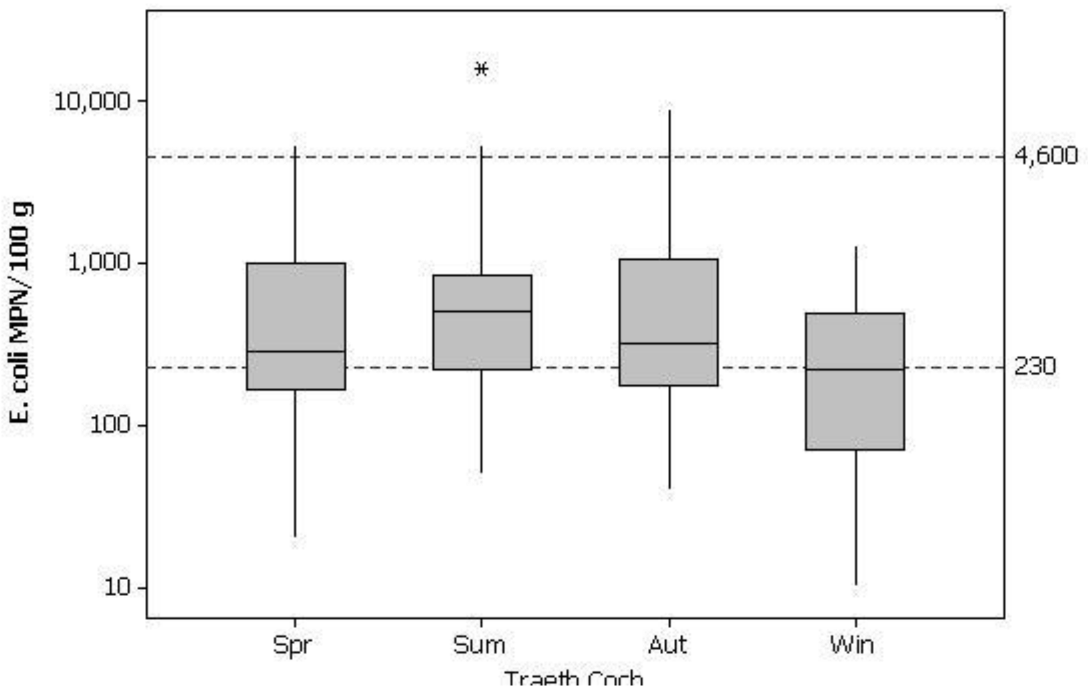


Figure XI.15: Boxplot of *E. coli* results from cockles by season

One-way ANOVA tests showed that there was significant variation between seasons at Traeth Coch (p=0.025). Post ANOVA Tukey tests showed that there were significantly higher levels of *E. coli* in summer than in winter.

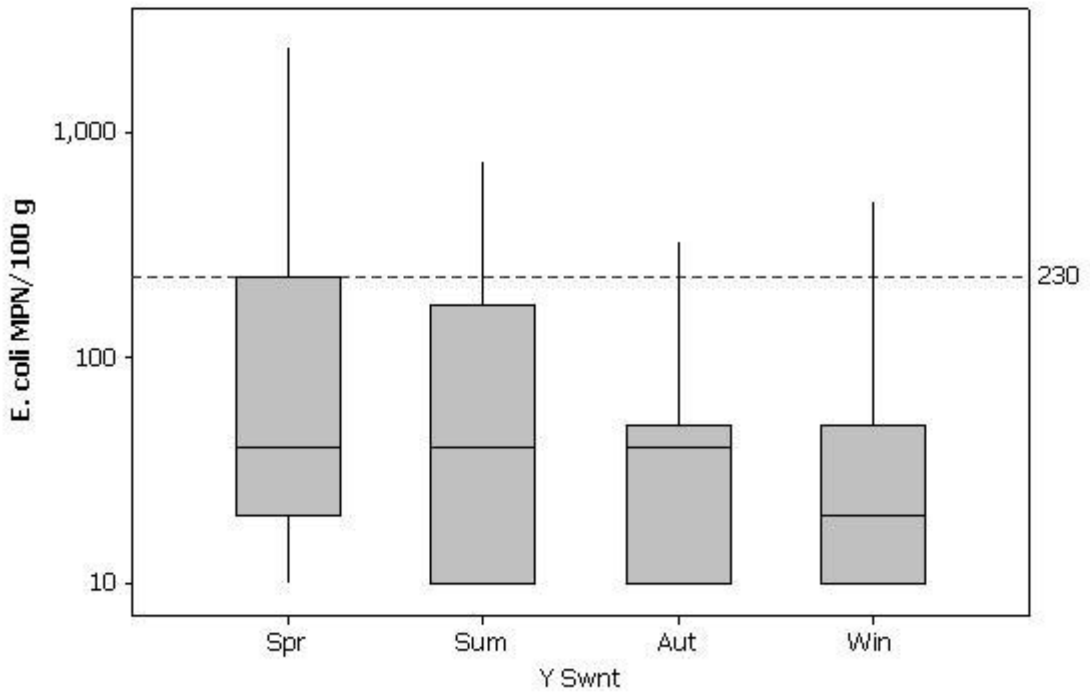


Figure XI.16: Boxplot of *E. coli* results from mussels by season

Results were higher on average and more variable during spring and summer. One-way ANOVA tests showed that there was significant variation between seasons at Y Swnt (p=0.030). However post ANOVA Tukey tests did not reveal the source of these differences.

Influence of tide

To investigate the effects of tidal state on *E. coli* results, circular-linear correlations were carried out against the high/low cycles at Moelfre 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.8 and significant results are highlighted in yellow.

Table XI.8: Circular linear correlation coefficients (r) and associated p values for *E. coli* results from RMPs against the high/low and spring/neap tidal cycles.

		High/low tides		Spring/neap tides	
Site Name	**Species**	**r**	**p**	**r**	**p**
Traeth Coch	Cockle	0.154	0.068	0.212	0.006
Y Swnt	Mussel	0.035	0.856	0.108	0.231

Figure XI.17 presents a polar plot of $\log_{10}$ *E. coli* results against the spring neap tidal cycle for Traeth Coch. 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.

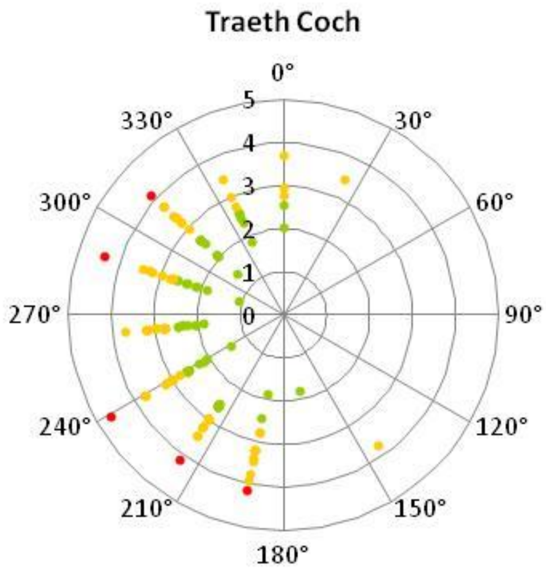


Figure XI.17: Polar plot of log10 E. coli results (MPN/100g) at Traeth Coch against spring/neap tidal state

The majority of sampling was conducted while tide sizes increased from the neap tides to the spring tides, so the full tidal cycle in not represented. The lower results tended to occur just before spring tides.

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 VI for details) over various periods running up to sample collection. These are presented in Table XI.9, and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table XI.9: Spearman's Rank correlations between rainfall recorded at Parc Menai and shellfish hygiene results

	Site	Traeth Coch	Y Swnt
	Species	Cockle	Mussel
	n	106	123
24 hour periods prior to sampling	1 day	0.031	0.049
	2 days	0.107	-0.045
	3 days	0.070	0.056
	4 days	0.104	-0.035
	5 days	0.243	0.002
	6 days	0.191	-0.007
	7 days	0.136	0.075
Total prior to sampling over	2 days	0.067	0.053
	3 days	0.142	0.118
	4 days	0.104	0.068
	5 days	0.167	0.055
	6 days	0.215	0.097
	7 days	0.231	0.098

Rainfall affected *E. coli* levels at the Traeth Coch cockle RMP but this influence was only detected 5-6 days after a rainfall event. No influence of antecedent rainfall was found at the Y Swnt mussel RMP.

Appendix XII. Shoreline Survey Report

Date (time):

29th October 2013 (09:10-13:30)
30th October 2013 (09:00-14:30)
31st October 2013 (09:00-14:30)

Cefas Officers:

Owen Morgan & Jessica Larkham (29/10/2013)
Louise Rae & Jessica Larkham (30/10/2013)
David Walker, Owen Morgan & Jessica Larkham (31/10/2013)

Area surveyed:

Red Wharf Bay (29/10/2013). Penrhos Beach (Holy Island) to mouth of Afon Alaw (Valley), A55/A5 causeway to Four Mile Bridge (30/10/2013). Malltraeth Bay (31/10/2013).

Weather:

29th October 12:00, dry, partially cloudy, 12°C, wind bearing 315° at 3 km/h
30th October 12:00, dry, partially cloudy, 13°C, wind bearing 200° at 24 km/h
31st October 12:00, dry, partially cloudy, 13°C, wind bearing 230° at 38 km/h

Tides:

Admiralty TotalTide© predictions for Moelfre (53°20'N 4°14'W), Holyhead (53°19'N 4°37'W) and Llanddwyn Island (53°08'N 4°25'W). All times in this report are GMT.

29/10/2013 Moelfre			30/10/2013 Holyhead			31/10/2013 Llanddwyn Island		
High	06:21	5.8 m	High	07:20	6.2 m	High	06:53	4.4 m
High	18:38	6.1 m	High	19:43	6.5 m	High	19:04	4.6 m
Low	00:26	2.5 m	Low	01:27	2.4 m	Low	01:11	1.5 m
Low	12:46	2.7 m	Low	13:44	2.6 m	Low	13:25	1.7 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 to Figure XII.3.

XII.1. Fishery

No additional information was gathered on the various fisheries in the survey areas as Ynys Mons Council staff were unable to attend.

XII.2. Sources of contamination

Sewage discharges

The locations of three intermittent discharges were confirmed, all in the Inland Sea survey area. The Penrhos Beach PS and Four Mile Bridge PS (observations 23 and 45) were not flowing. The Gorad Road PS discharge was sampled and found to have an *E. coli* concentration of only 310 *E. coli* cfu/100 ml and there was insufficient flow to obtain a measurement.

Observation 39, which does not appear to relate to any of the discharges in the EA consented discharges to controlled waters database, had an *E. coli* concentration of 280,000 cfu/100 ml which indicates that it has sewage contamination. This pipe had a calculated daily *E. coli* loading of 6.7×10^{9} cfu/day.

Freshwater inputs

In the Red wharf Bay survey area, one river, Afon Nodwydd, was sampled and measured. It was found to have a relatively high *E. coli* concentration of 2,300 cfu/100 ml and an *E. coli* loading of 1.7×10^{12} cfu/day. The presence of the Pentraeth STW discharges approximately 1.5 km upstream of the sampling point is likely to have contributed to this result.

In addition to the Afon Nodwydd, nine un-named watercourses were observed and measured in the Red wharf Bay survey area (observations 1, 4, 5, 7, 8, 12, 13, 16, 17 and 20). These streams had a combined calculated *E. coli* loading of 6.2×10^{11} cfu/day. The streams at observation 13 and 17 had *E. coli* loadings of 2.5×10^{11} and 1.3×10^{11} cfu/day respectively and so contributed most of the *E. coli* in the combined loading. Observation 13 had an *E. coli* concentration of 3,900 cfu/100 ml. According to the EA consented discharges to controlled waters database, there is a private package treatment plant approximately 400 m upstream of this sampling point, which appears to be the only feasible source of contamination for this sample.

In the Inland Sea survey area only one watercourse, Afon Alaw, was observed and measured (observation 46). This river was too deep to obtain flow and depth measurements, but it was found to have an *E. coli* concentration of 1,200 cfu/100 ml. The Llanfachraeth STW which is approximately 400 m upstream of this sampling point is likely to contribute to the *E. coli* levels in this sample.

Across the Malltraeth survey area, one river, Afon Cefni, was observed and measured (observation 56). The river was not accessible for depth or flow measurements, but a water sample had an *E. coli* concentration of 8,200 cfu/100 ml. The Malltraeth CSO located approximately 200 m upstream of this sampling point may have contributed to the *E. coli* in this sample, but the CSO discharge was not observed and so it is not possible to say if it was active.

Additionally 3 un-named streams (observations 48, 51 and 53) were observed and measured. All of these streams were located on the western shore of the bay and had a combined *E. coli* loading of 4.3×10^{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

In the Red Wharf Bay survey area, two horse (observation 3) and two cows were seen (observation 6).

In the inland Sea survey are, 100 sheep were seen in a field fenced off from the shoreline (observation 24), and 10 cows were seen two field back from the shoreline (observation 44).

Around Malltraeth Bay, two horses were observed in a field (observation 55), and approximately 70 cattle were seen in a field at the tops of cliffs on the western shore (observation 60). At the north eastern end of the bay around 500 sheep were observed in fields stretching from a freshwater pool to the forest edge (observation 57)

Wildlife

Wild birds were seen throughout all of the survey areas (observations 2, 10, 11, 14, 26, 28, 52 and 57).

Figure XII.1: Locations of shoreline observations at Red Wharf Bay (Table XII.1 for details)

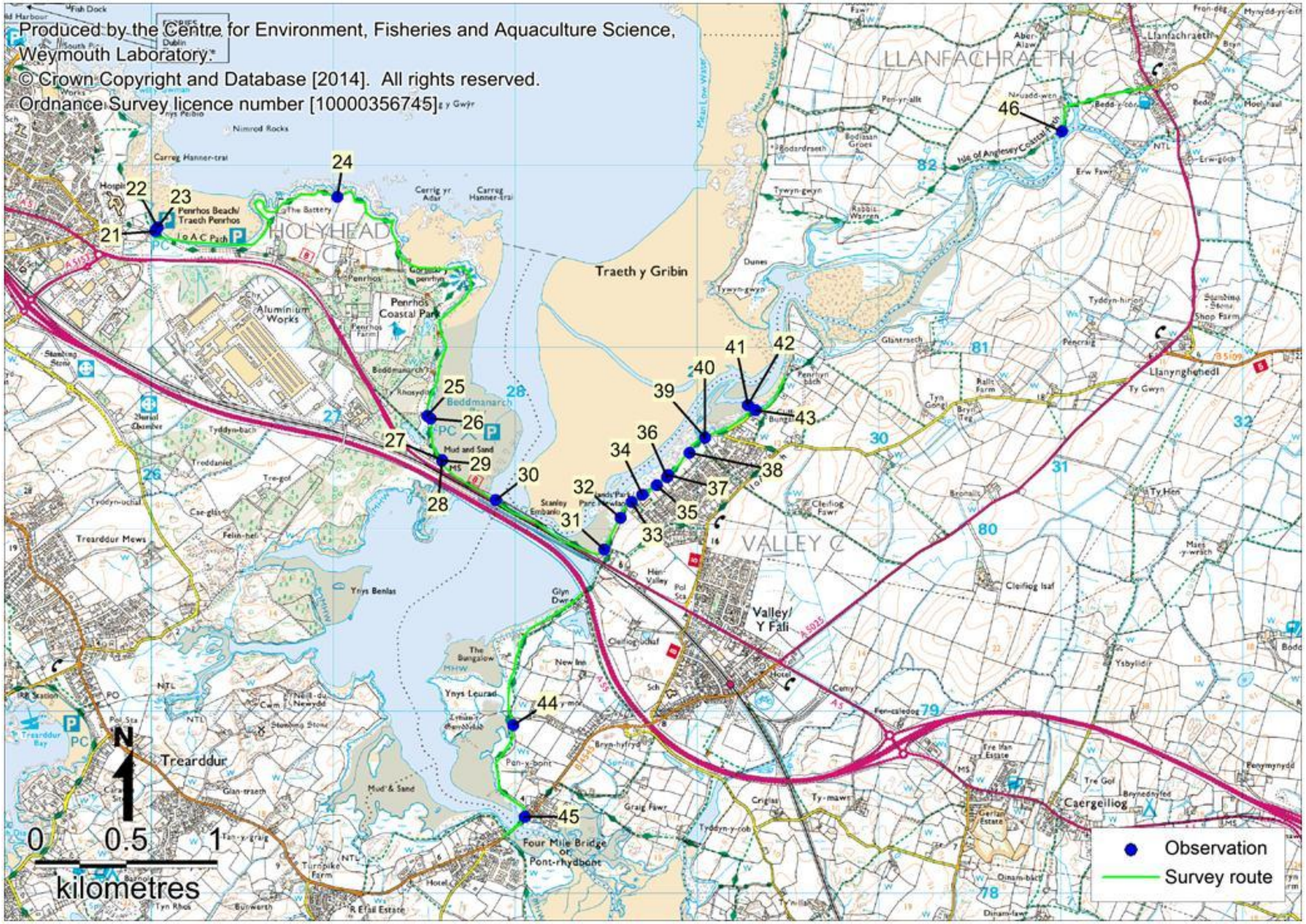


Figure XII.2: Locations of shoreline observations at Inland Sea (Table XII.1 for details)

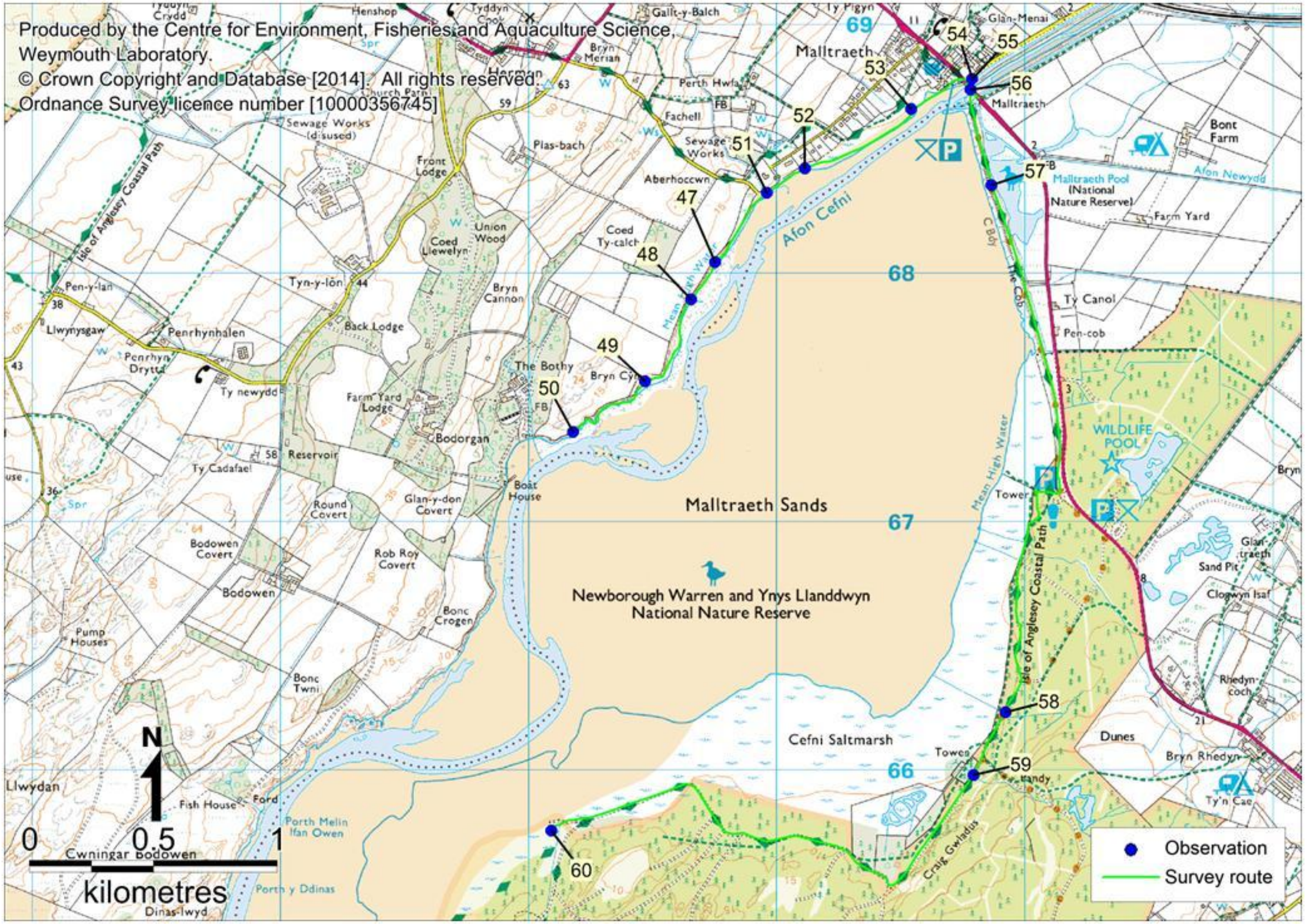


Figure XII.3: Locations of shoreline observations at Malltraeth (Table XII.1 for details)

Table XII.1: Details of Shoreline Observations

Obs. no.	Survey Area	NGR	Date	Time	Description	Photo
1	Red Wharf Bay	SH 57319 80850	29/10/2013	09:48	Stream (0.14 x 2.5 m) (sample RW01)	Figure XII.10
2	Red Wharf Bay	SH 57319 80850	29/10/2013	09:48	40 gulls	
3	Red Wharf Bay	SH 57239 80839	29/10/2013	09:57	Land drainage, 1 horse on beach, 1 horse on road, dogs	
4	Red Wharf Bay	SH 56361 80613	29/10/2013	10:11	Stream (0.1 x 0.5 m) (sample RW02)	Figure XII.11
5	Red Wharf Bay	SH 55733 80517	29/10/2013	10:32	Stream (0.45 x 8 m) (sample RW03)	Figure XII.12
6	Red Wharf Bay	SH 55748 80294	29/10/2013	11:10	2 cows in field	
7	Red Wharf Bay	SH 54753 80096	29/10/2013	11:26	Stream (0.1 x 0.9 m) (sample RW04)	Figure XII.13
8	Red Wharf Bay	SH 54413 79967	29/10/2013	11:37	Stream (0.08 x 0.5 m) (sample RW05)	Figure XII.14
9	Red Wharf Bay	SH 53401 79860	29/10/2013	12:00	River - Afon Nodwydd (0.15 x 5 m) (sample RW06)	Figure XII.15
10	Red Wharf Bay	SH 53401 79860	29/10/2013	12:00	30 geese	
11	Red Wharf Bay	SH 52632 80142	29/10/2013	12:42	100 sea birds	
12	Red Wharf Bay	SH 52545 80177	29/10/2013	12:47	Stream (0.3 x 1.5 m) (sample RW07)	Figure XII.16
13	Red Wharf Bay	SH 52558 80390	29/10/2013	12:58	Stream (0.2 x 1 m) (sample RW08)	Figure XII.17
14	Red Wharf Bay	SH 52558 80390	29/10/2013	12:58	13 boats, around 200 gulls	
15	Red Wharf Bay	SH 52672 80700	29/10/2013	13:09	Non return valve from house	Figure XII.18
16	Red Wharf Bay	SH 53102 82029	29/10/2013	13:45	Stream from country club/holiday park (0.1 x 0.35 m) (sample RW09)	Figure XII.19
17	Red Wharf Bay	SH 52287 82696	29/10/2013	14:09	Convergence of two water courses (average 0.105 x 3 m) (sample RW10)	Figure XII.20
18	Red Wharf Bay	SH 52242 82634	29/10/2013	14:17	Two outfall pipes, one with flow, one with green algae (not flowing)	Figure XII.21 & Figure XII.22
19	Red Wharf Bay	SH 52231 82657	29/10/2013	14:19	Large culvert under road with flow and algae surrounding (sampled at observation 17)	Figure XII.23
20	Red Wharf Bay	SH 52210 82701	29/10/2013	14:25	Resample of large stream (sample RW11)	
21	Inland Sea	SH 26020 81639	30/10/2013	09:29	Old public toilets	Figure XII.24
22	Inland Sea	SH 26034 81659	30/10/2013	09:31	Intermittent discharge below toilets, not flowing (sewage smell)	
23	Inland Sea	SH 26034 81659	30/10/2013	09:31	Valved pipe, not flowing.	Figure XII.25
24	Inland Sea	SH 27021 81828	30/10/2013	09:52	100 sheep in fenced field behind shoreline	
25	Inland Sea	SH 27517 80624	30/10/2013	10:32	Public toilets (no discharge)	Figure XII.26
26	Inland Sea	SH 27536 80608	30/10/2013	10:34	120 seabirds, 30 pigeons	

27	Inland Sea	SH 27597 80381	30/10/2013	10:40	Flowing discharge pipe (sample HH01)	Figure XII.27
28	Inland Sea	SH 27597 80381	30/10/2013	10:40	200 birds	
29	Inland Sea	SH 27597 80379	30/10/2013	10:42	Culvert/pipe in sea wall - not flowing	Figure XII.28
30	Inland Sea	SH 27893 80160	30/10/2013	10:54	Main seawater culvert under bridge. No access to sample (SAMPLED NEXT DAY) (sample HW01)	Figure XII.29
31	Inland Sea	SH 28491 79889	30/10/2013	11:04	Brown seaweed sludge	Figure XII.30
32	Inland Sea	SH 28581 80061	30/10/2013	11:08	Two rowing boats moored, 100 seabirds	
33	Inland Sea	SH 28640 80149	30/10/2013	11:11	Land drainage near CSO consent	
34	Inland Sea	SH 28699 80190	30/10/2013	11:14	Small orange pipe, dripping	Figure XII.31
35	Inland Sea	SH 28779 80241	30/10/2013	11:18	25cm diameter pipe surrounded by concrete structure (sample HH02)	Figure XII.32
36	Inland Sea	SH 28835 80286	30/10/2013	11:23	Two ground water drainage pipe	Figure XII.33
37	Inland Sea	SH 28842 80298	30/10/2013	11:24	Ground water drainage pipe	Figure XII.34
38	Inland Sea	SH 28960 80420	30/10/2013	11:27	Ground water drainage pipe	Figure XII.35
39	Inland Sea	SH 29044 80504	30/10/2013	11:31	Pipe surrounded by concrete (sample HH03)	Figure XII.36
40	Inland Sea	SH 29044 80504	30/10/2013	11:32	Black drainage pipe coming from shoreline	Figure XII.37
41	Inland Sea	SH 29281 80682	30/10/2013	11:40	Outfall pipe 32cm diameter (sample HH04)	Figure XII.38
42	Inland Sea	SH 29280 80681	30/10/2013	11:40	Closed outfall pipe 17 cm diameter	
43	Inland Sea	SH 29323 80654	30/10/2013	11:55	inspection covers for outfall pipe	
44	Inland Sea	SH 27990 78923	30/10/2013	13:15	10 cows in fenced off field, two fields back from shoreline	
45	Inland Sea	SH 28052 78417	30/10/2013	13:50	Drainage pipe - not flowing	
46	Inland Sea	SH 31008 82188	30/10/2013	14:15	River - Afon Alaw (too deep to measure) (sample HH05)	Figure XII.39
47	Malltraeth	SH 39753 68046	31/10/2013	09:37	Dead shell along this stretch of shoreline. Cockles & mussels	
48	Malltraeth	SH 39656 67895	31/10/2013	09:41	Stream (0.09 x 0.4 m) (sample M01)	Figure XII.40
49	Malltraeth	SH 39471 67566	31/10/2013	09:51	Basket (possibly used for cockling)	
50	Malltraeth	SH 39180 67362	31/10/2013	10:00	No access beyond this point due to tide. No visible contamination sources further on	
51	Malltraeth	SH 39961 68325	31/10/2013	10:22	Stream (0.08 x 1.05 m) (sample M02)	Figure XII.41
52	Malltraeth	SH 40114 68423	31/10/2013	10:28	50 birds on sand bank (150m bearing 140°)	
53	Malltraeth	SH 40542 68663	31/10/2013	10:36	Stream through marsh (0.03 x 0.15 m) (sample M03)	Figure XII.42
54	Malltraeth	SH 40789 68783	31/10/2013	10:54	Pipe from wall just behind sluice. Not accessible for flow reading (sample M04)	Figure XII.43
55	Malltraeth	SH 40789 68783	31/10/2013	10:54	Two horses in field	

56	Malltraeth	SH 40782 68740	31/10/2013	11:07	River – Afon Cefni. Flow from river under bridge. No flow reading (too far and fast) (sample M05)	Figure XII.44
57	Malltraeth	SH 40867 68355	31/10/2013	11:16	Pasture on other side of pool from river to forest ~500 sheep, 50 birds in pool	
58	Malltraeth	SH 40923 66232	31/10/2013	11:58	Drainage channel (0.1 x 0.35 m) (sample leaked in transport to lab) (sample M06)	
59	Malltraeth	SH 40794 65979	31/10/2013	12:03	Ground water (sample M07)	
60	Malltraeth	SH 39093 65755	31/10/2013	12:39	70 cows on opposite shore (bearing 319°-340°)	

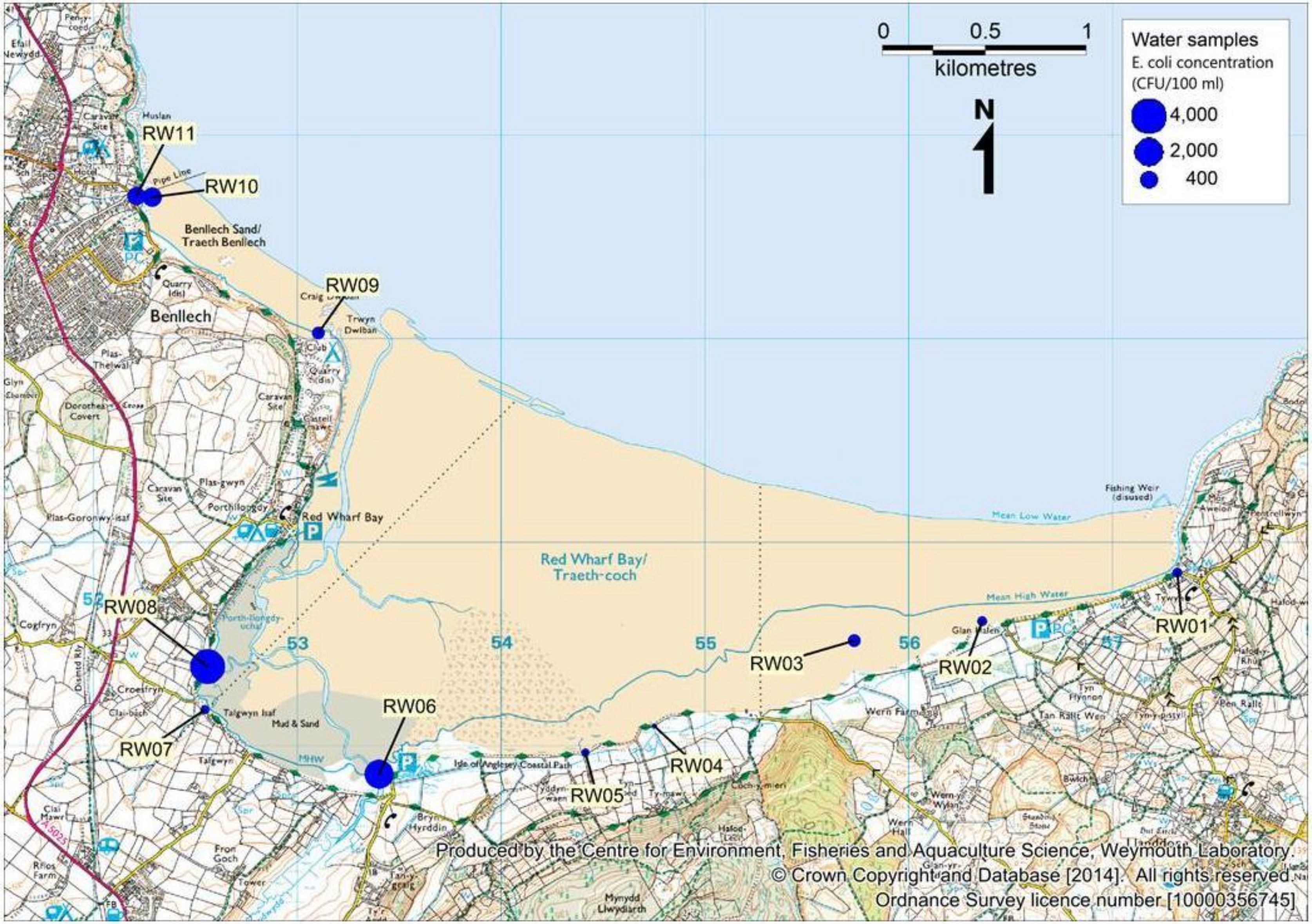


Figure XII.4: Water sample results for Red Wharf Bay (Table XII.2 for details)

Figure XII.5: Water sample results for Inland Sea (Table XII.2 for details)

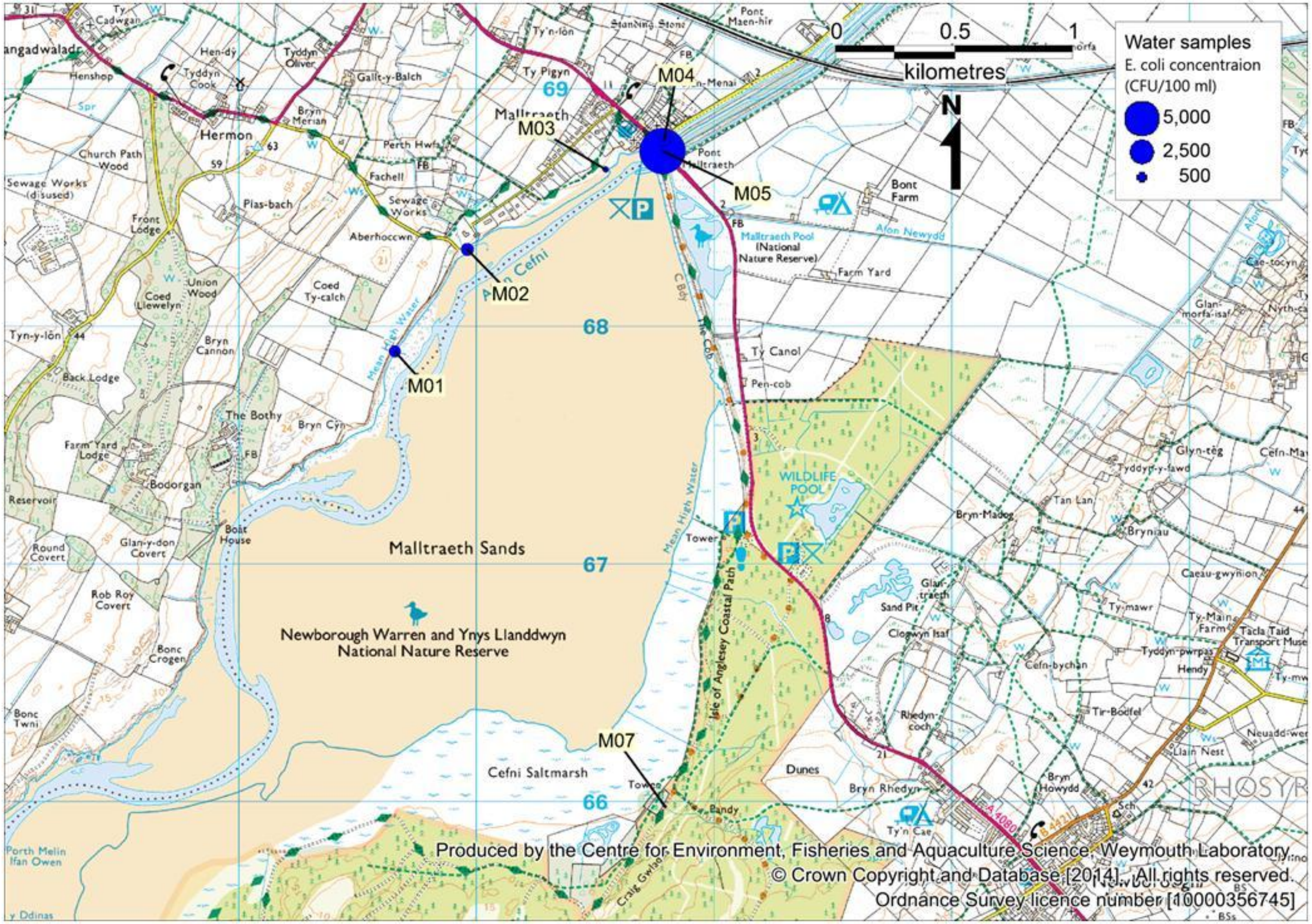


Figure XII.6: Water sample results for Malltraeth (Table XII.2 for details)

Figure XII.7: ***E. coli*** **stream loadings for Red Wharf Bay (Table XII.2 for details).**

Figure XII.8: ***E. coli*** **stream loadings for Inland Sea (Table XII.2 for details).**

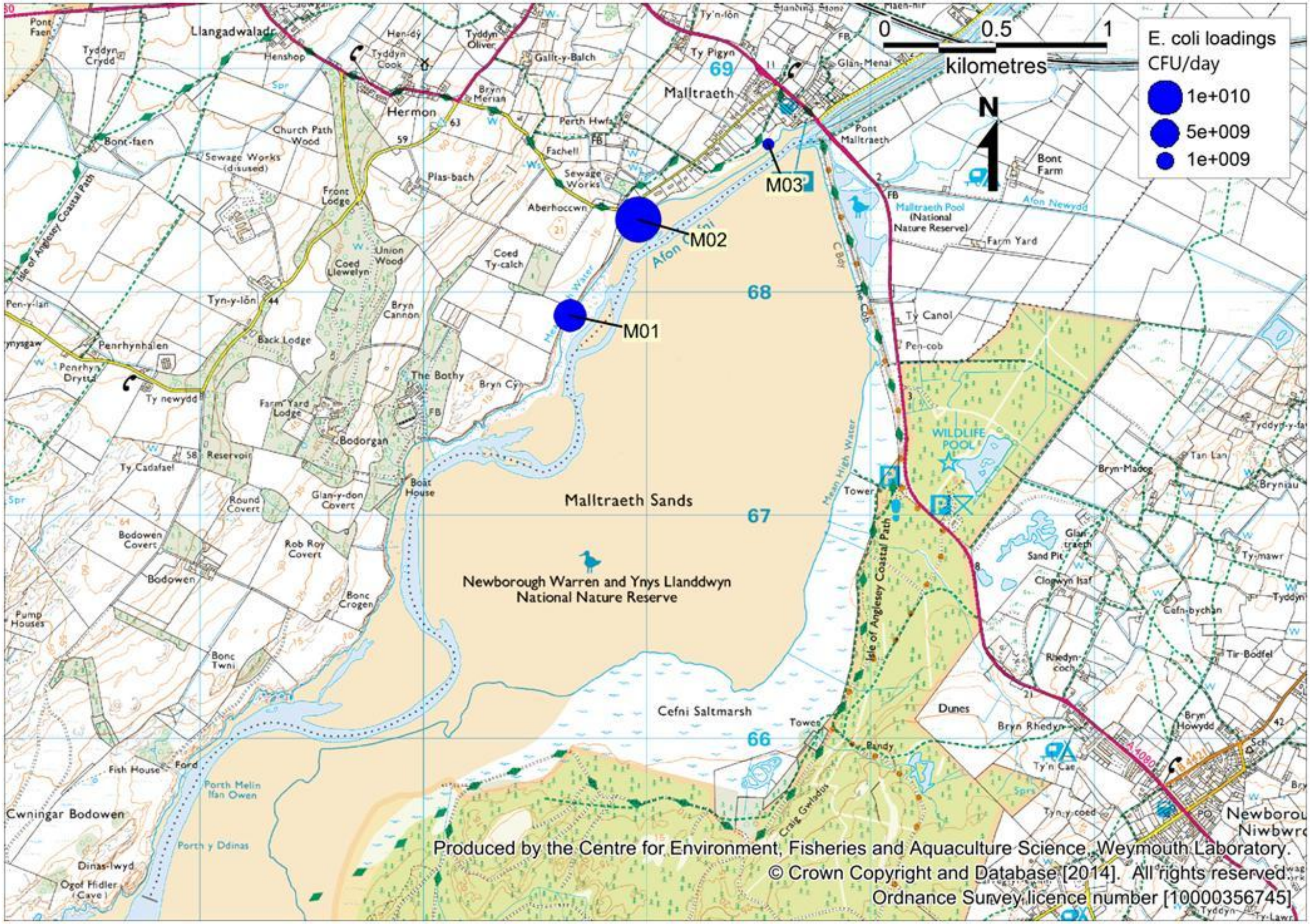


Figure XII.9: *E. coli* stream loadings for Malltraeth (Table XII.2 for details).

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

Sample ID	Observation number	Date and time	Water type	Description	Flow (m^3/s)	*E. coli* concentration (CFU/100 ml)	*E. coli* loading (CFU/day)	NGR
RW01	1	29/10/2013 09:48	Fresh	Stream	0.074	60	$3.8x10^{9}$	SH 57319 80850
RW02	4	29/10/2013 10:11	Fresh	Stream	0.011	50	$4.9x10^{8}$	SH 56361 80613
RW03	5	29/10/2013 10:32	Fresh	Stream	0.479	150	$6.2x10^{10}$	SH 55733 80517
RW04	7	29/10/2013 11:26	Fresh	Stream	0.045	5	$1.9x10^{8}$	SH 54753 80096
RW05	8	29/10/2013 11:37	Fresh	Stream	0.015	30	$3.8x10^{8}$	SH 54413 79967
RW06	9	29/10/2013 12:00	Fresh	River - Afon Nodwydd	0.834	2,300	$1.7x10^{12}$	SH 53401 79860
RW07	12	29/10/2013 12:47	Fresh	Stream	0.082	40	$2.8x10^{9}$	SH 52545 80177
RW08	13	29/10/2013 12:58	Fresh	Stream	0.073	3,900	$2.5x10^{11}$	SH 52558 80390
RW09	16	29/10/2013 13:45	Fresh	Stream	0.016	140	$2.0x10^{9}$	SH 53102 82029
RW10	17	29/10/2013 14:09	Fresh	Stream	0.252	600	$1.3x10^{11}$	SH 52287 82696
RW11	20	29/10/2013 14:25	Fresh	Stream	0.216	460	$8.6x10^{10}$	SH 52210 82701
HH01	27	30/10/2013 10:40	Fresh	Pipe	0.002	5	$7.8x10^{6}$	SH 27597 80381
HW01	30	30/10/2013 10:54	Salt	Seawater culvert		30		SH 27893 80160
HH02	35	30/10/2013 11:18	Fresh	Pipe	$3.6x10^{-5}$	340	$1.0x10^{7}$	SH 28779 80241
HH03	39	30/10/2013 11:31	Fresh	Pipe	$2.8x10^{-5}$	280,000	$6.7x10^{9}$	SH 29044 80504
HH04	41	30/10/2013 11:40	Fresh	Pipe		310		SH 29281 80682
HH05	46	30/10/2013 14:15	Fresh	River - Afon Alaw		1200		SH 31008 82188
M01	48	31/10/2013 09:41	Fresh	Stream	0.013	730	$8.0x10^{9}$	SH 39656 67895
M02	51	31/10/2013 10:22	Fresh	Stream	0.047	860	$3.5x10^{10}$	SH 39961 68325
M03	53	31/10/2013 10:36	Fresh	Stream	0.002	190	$2.7x10^{8}$	SH 40542 68663
M04	54	31/10/2013 10:54	Fresh	Pipe		730		SH 40789 68783
M05	56	31/10/2013 11:07	Fresh	River - Afon Cefni		8,200		SH 40782 68740
M07	59	31/10/2013 12:03	Fresh	Ground water		80		SH 40794 65979

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

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Figure XII.28

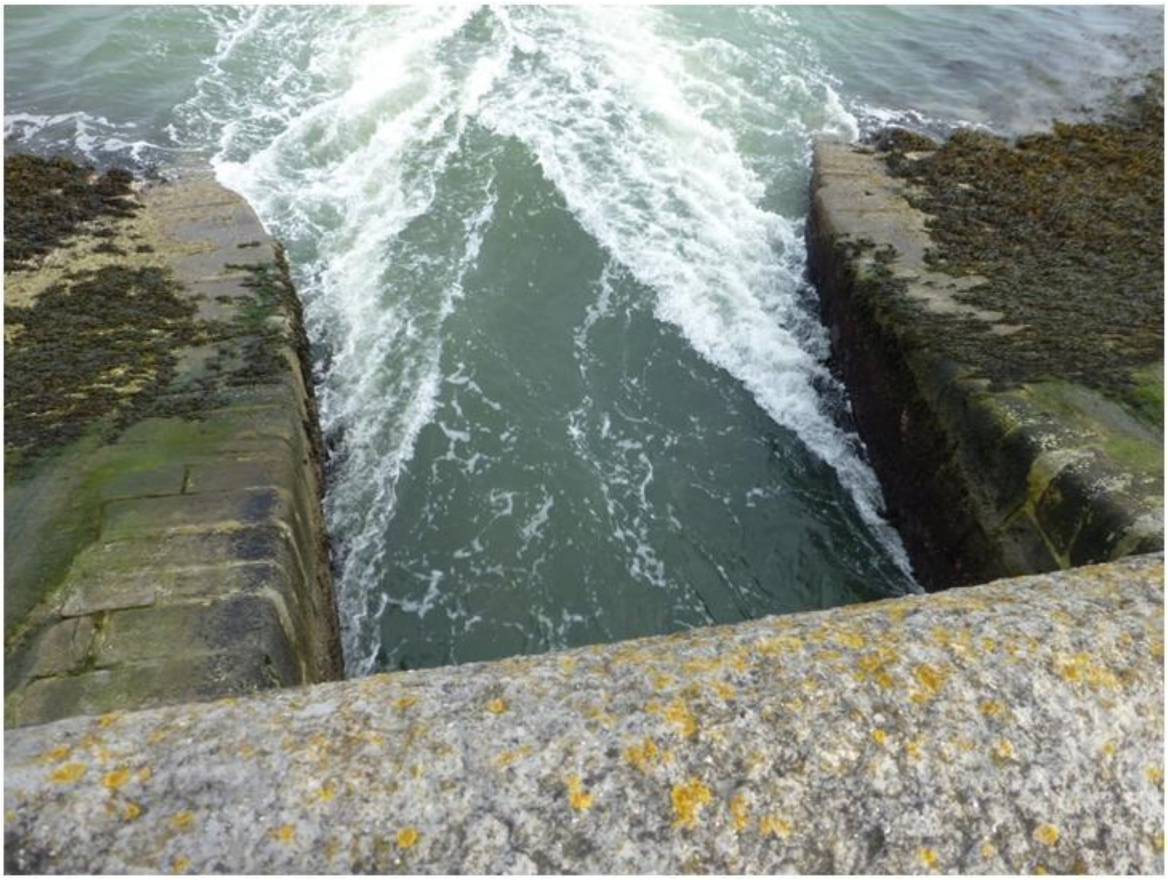
Figure XII.29


Figure XII.30


Figure XII.31

Figure XII.32

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Figure XII.41

Figure XII.42

Figure XII.43

Figure XII.44

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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.
Equilibrate	To bring to or be in equilibrium/balance. In the context used in this report: a time period which allows sufficient time for the species of filter feeding bivalve mollusc being sampled to reach an equilibrium between the amount of faecal indicator bacteria in the overlying water and the amount ingested/accumulated by the shellfish. This necessarily assumes consistent level of bacteria in the water whereas in practise the level will vary.
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”.

Acknowledgements

Virginia Prieto, Greta Hughes and Bill Somerfield (Welsh Government Fisheries), James Wilson (Deepdock Ltd).