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EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Colwyn Bay

November 2014

Food Standards Agency

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Statement of use

This report provides a sanitary survey relevant to bivalve mollusc fisheries at Colwyn Bay, 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	04/11/2014
2	Draft for client/consultee comment	Simon Kershaw	12/11/2014
3	Final	Simon Kershaw	13/04/2015

Consultation

Consultee	Date of consultation	Date of response
Conwy County BC	24/11/2014	26/02/2015
Natural Resources Wales	24/11/2014	24/12/2014
Welsh Government Fisheries	24/11/2014	-
Welsh Water/Dwr Cymru	24/11/2014	-
Shellfish Association of Great Britain	24/11/2014	-

Dissemination

Food Standards Agency, Conwy County Borough Council. The report is available publicly via the Cefas website.

Recommended Bibliographic Reference

Cefas, 2014. Sanitary survey of Colwyn Bay. 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 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.) at Colwyn Bay. The area was prioritised for survey in 2014-15 by a risk ranking exercise.

1.2. Area description

The survey area is located on the north coast of Wales immediately to the east of Great Ormes Head (Figure 1.1).

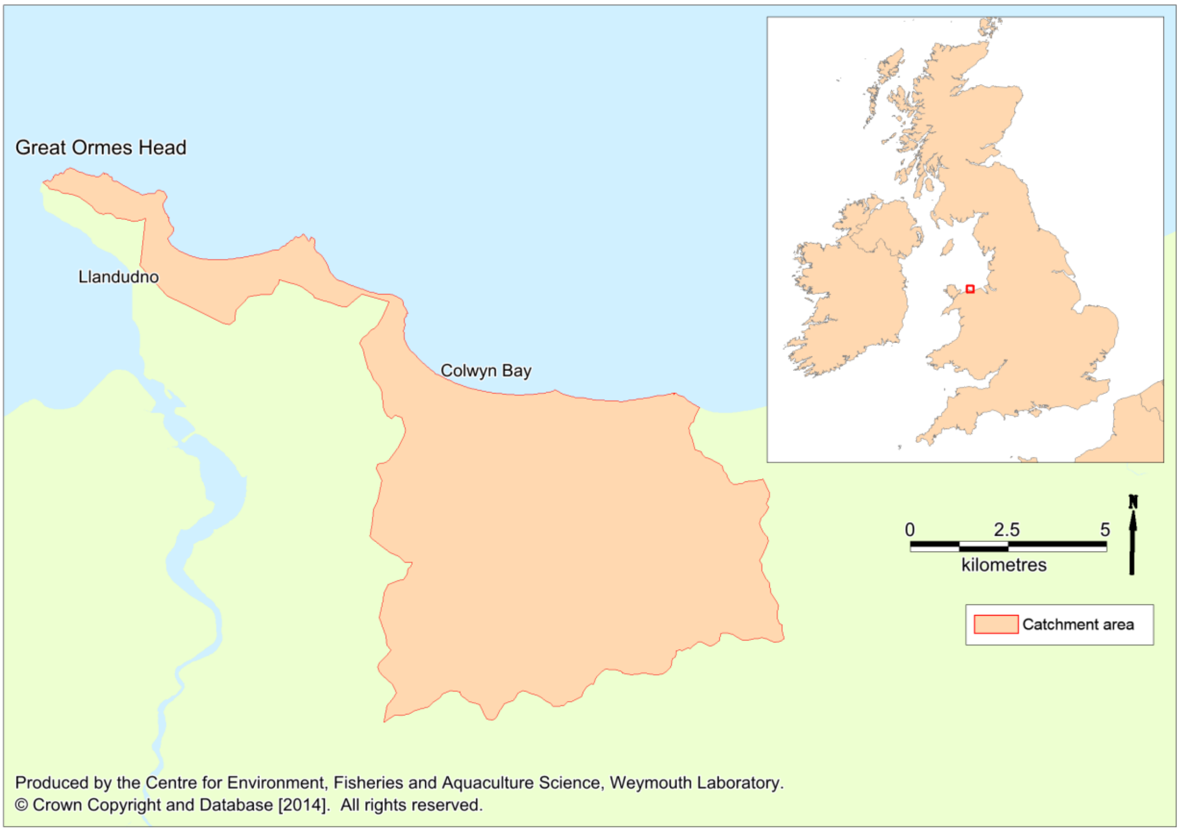


Figure 1.1: Location of the survey area

It is an open, north facing coastline which consists of a series of sandy bays (Llandudno, Penrhyn and Colwyn Bay) separated by rocky headlands. The area supports a significant tourism industry, some limited industry and fishing. Agriculture is also important to the local economy. There are several areas where mussels occur in the intertidal zone, and these have been the subject of a minor fishery in the past.

1.3. Catchment

The Colwyn Bay survey area has a relatively small hydrological catchment of about 79 km^2.

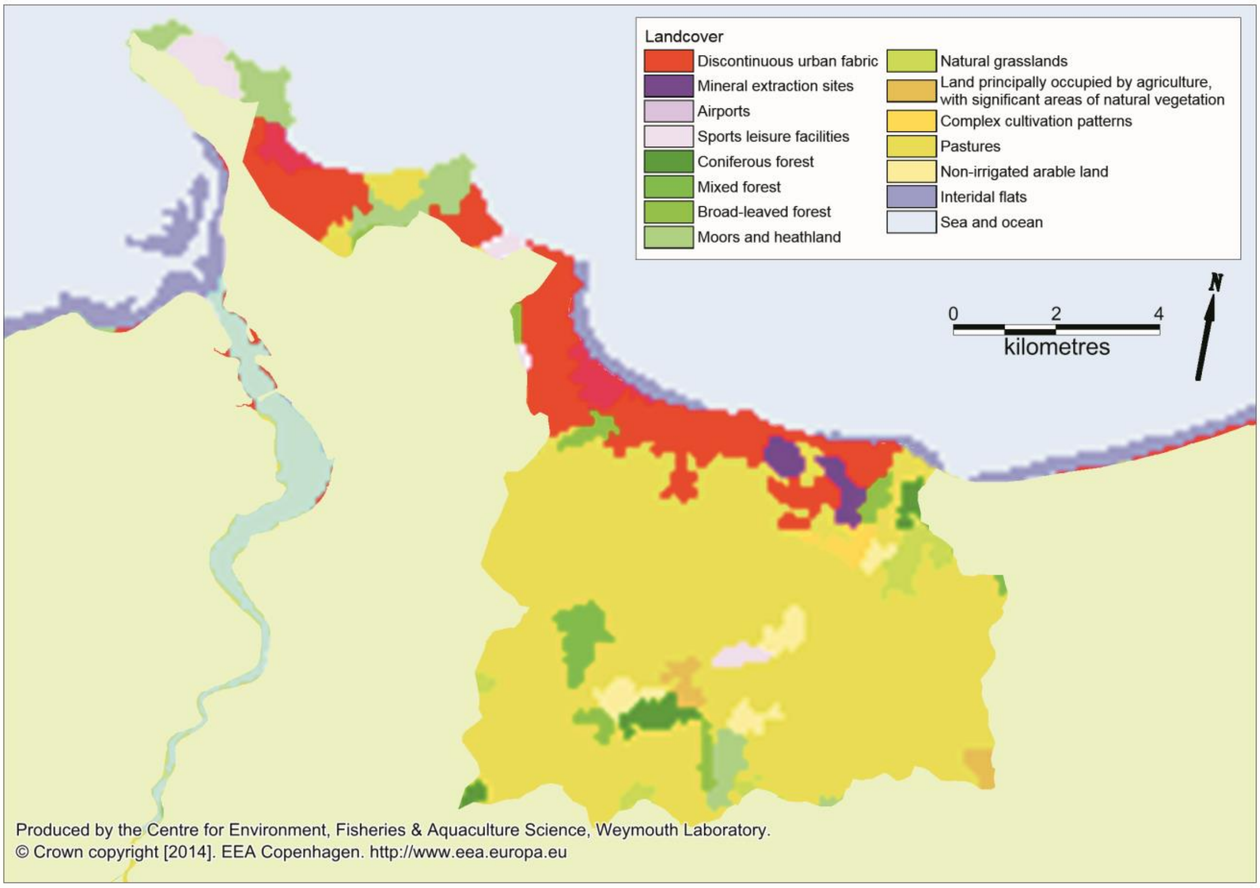


Figure 1.2: Landcover in the survey area catchment

The western part of the catchment consists of a narrow coastal strip, whereas the eastern part extends several kilometres inland. The coastal strip is mainly urban throughout, although there are some small areas of grassland/pasture. Where it extends inland, pasture is the main land cover type.

Different land cover types will generate differing levels of contamination in surface runoff. Highest faecal coliform contribution arises from developed areas, with intermediate contributions from the improved pastures and lower contributions from the other land types (Kay *et al*. 2008a). The contributions from all land cover types would be expected to increase significantly after marked rainfall events, particularly for improved grassland which increase up to 100 fold.

Hydrogeology maps indicate that the coastal strip is underlain by a mixture of low and moderate permeability geology, and the more inland area is of low permeability (NERC, 2012). The topography is quite hilly, with elevations of up to 351 m in inland areas. This suggests that watercourses will respond rapidly to rainfall, a high proportion of which will run off, particularly for the more inland areas.

2. Recommendations

The following three mussel classification zones are proposed. One RMP is identified for each, and these are located to best capture peak levels of contamination within the zone. The presence of mussels in the exact recommended RMP locations could not be confirmed at the time of writing, so it is possible that some slight adjustments may be required both on the first sampling run and as distributions shift in future seasons. Any revision of RMP locations should be based on the principles identified within these recommendations, and should be communicated to the FSA and the classification team at Cefas.

Llandudno

At Llandudno the mussel bed lies in the intertidal region either side of the pier. This bed is currently closed for harvesting by Welsh Government Fisheries. To the north-west of the pier is the Great Orme, which hosts a seabird colony and a herd of feral goats. To the south and south-west of the pier lies the town of Llandudno, from which there will be a number of points where urban runoff drains intermittently, the main one being over 1 km to the west. There are no permitted sewage discharges to water at Llandudno, either continuous or intermittent. However there a surface water outfall onto the beach reported to have sewage misconnections into it from individual houses. The microbiological monitoring results from two RMPs either side of the pier indicate that levels of contamination are higher to the south of the pier, although both RMPs demonstrate robust compliance with the class B requirement. It is therefore recommended that the existing RMP to the south of the pier (Llandudno Pier West) is retained and used to classify the entire zone. It would be more accurate to rename this RMP as Llandudno Pier South.

Rhos Point

Within this zone there is an intertidal mussel bed at Rhos Point. This bed is currently closed for harvesting by Welsh Government Fisheries. To the west there are three intermittent sewage discharges to the foreshore of Penrhyn Bay, including one which is only about 125 m to the west of the mussel bed. No spill records were available for these discharges. Immediately to the south-east, there is an area of small boat moorings, and about 1 km away there is an intermittent sewage discharge. The Ganol STW outfall is about 1.6 km offshore from Rhos-On-Sea. Tidal circulation patterns suggest the plume from it will travel parallel to the coast, although it may be pushed towards the shore by northerly winds. The results of some limited microbiological monitoring suggest there may be a localised hotspot of contamination just to the west of the mussel bed. It is therefore recommended that the RMP is relocated to the western end of the mussel bed.

Llanddulas

There is a mussel bed just to the west of where the river Dulas drains to the foreshore. Although it has been classified in the past, it is currently an ephemeral seed mussel bed which is unlikely to be of commercial interest in the immediate future. It is currently closed by Welsh Government Fisheries. As such it will not require classification until specifically requested. The main contaminating influence to this bed is the Dulas, which drains to the foreshore of the Llanddulas production area at its western end. It is therefore recommended that the RMP is located as close as possible to the drainage channel this watercourse follows across the intertidal.

Sampling requirements

Mussels should be sampled by hand. A tolerance of 50 m applies. Sampled stock should be of a harvestable size (45 mm). The sampling frequency is monthly. For the two beds that are currently classified (Llandudno Pier and Rhos-On-Sea) the Conwy County Borough Council may wish to consider temporarily declassifying by reducing to quarterly sampling, if the current lack of activity continues.

3. Sampling Plan

3.1. General Information

Location Reference

Production Area	Conwy (Llandudno Pier only) and Colwyn Bay
Cefas Main Site Reference	B044 and B069
Ordnance survey 1:25,000 map	Explorer 264 and OL 17
Admiralty Chart	1978

Shellfishery

Species/culture	Mussels	Wild
Seasonality of harvest	Year round	

Local Enforcement Authority

Authority	Environmental Health Department Conwy County Borough Council Civic Centre Colwyn Bay LL29 8AR
Environmental Health Officer	Mark Hughes
Telephone number ☎	01492 575130
Fax number	01492 575204
E-mail	mark.d.hughes@conwy.gov.uk

3.2. Requirement for Review

The Guide to Good Practice for the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2014) 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 or any changes to the shellfishery occur other than those currently planned.

Table 3.1: Location of representative monitoring point (RMP) and frequency of sampling

Classification zone	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Llandudno	B044J	Llandudno Pier South (Formerly Llandudno Pier West)	SH 7840 8280	53° 19.686' N 03° 49.639' W	Mussels	Wild	Hand	Hand	50 m	Monthly	No harvesting activity in this zone at present.
Rhos Point	B069F	Rhos West	SH 8389 8140	53° 19.005' N 03° 44.664' W	Mussels	Wild	Hand	Hand	50 m	Monthly	No harvesting activity in this zone at present.
Llandullas	B069G	Dulas Channel	SH 9122 7878	53° 17.687' N 03° 38.011' W	Mussels	Wild	Hand	Hand	50 m	Monthly	Not currently classified. Unlikely to require classification in the foreseeable future.

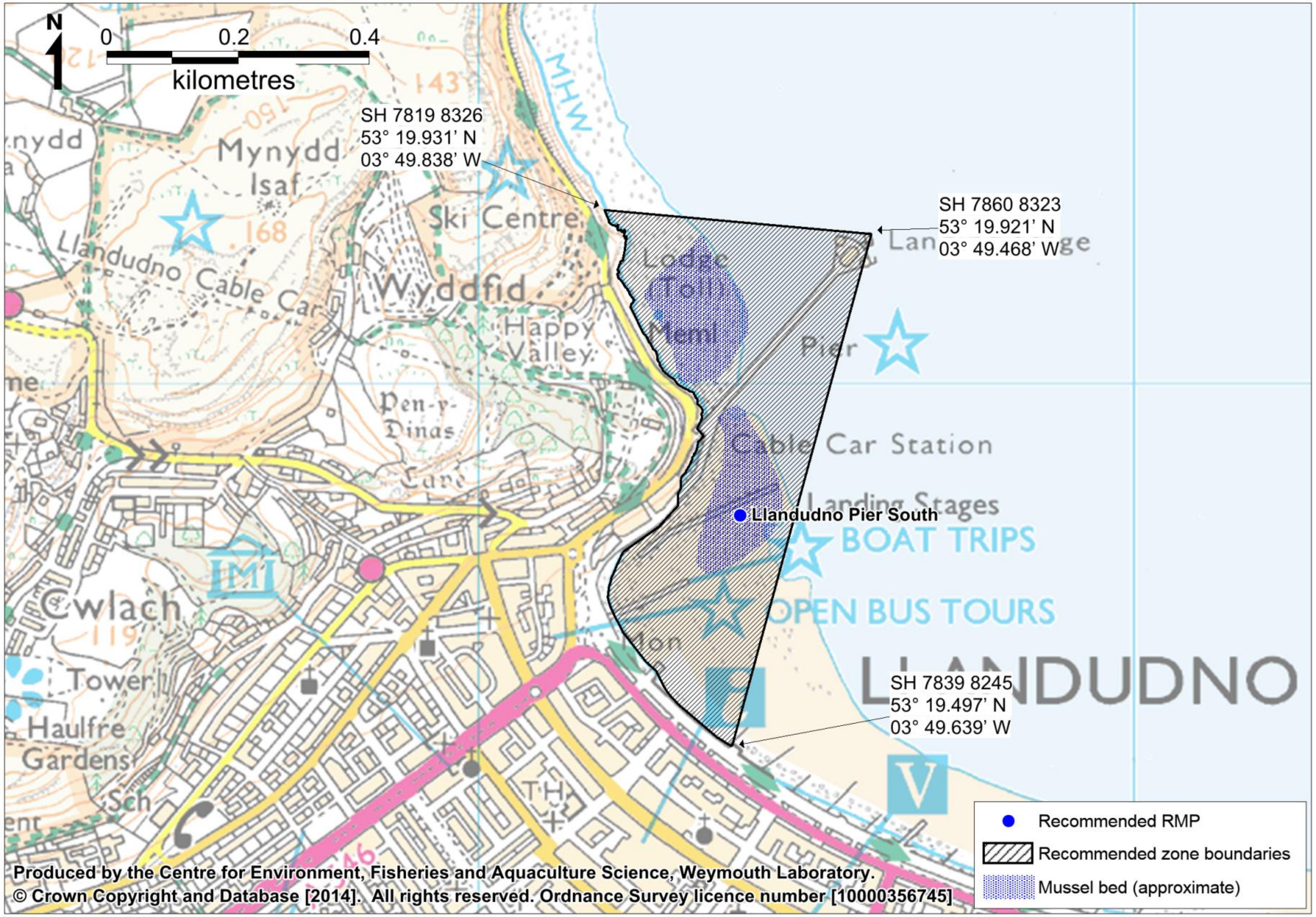


Figure 3.1: Recommended zoning and monitoring arrangements (Llandudno)

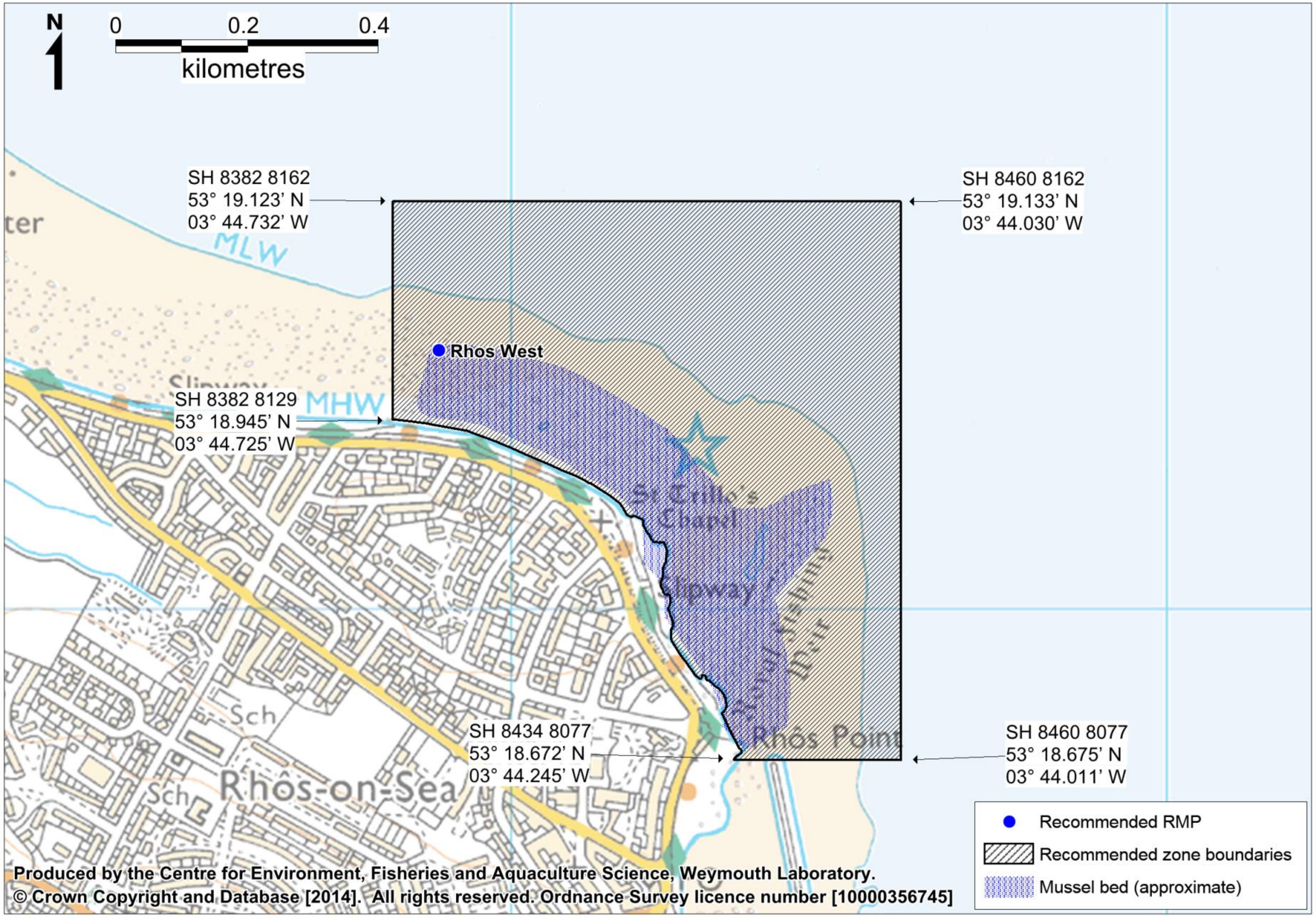


Figure 3.2: Recommended zoning and monitoring arrangements (Rhos Point)

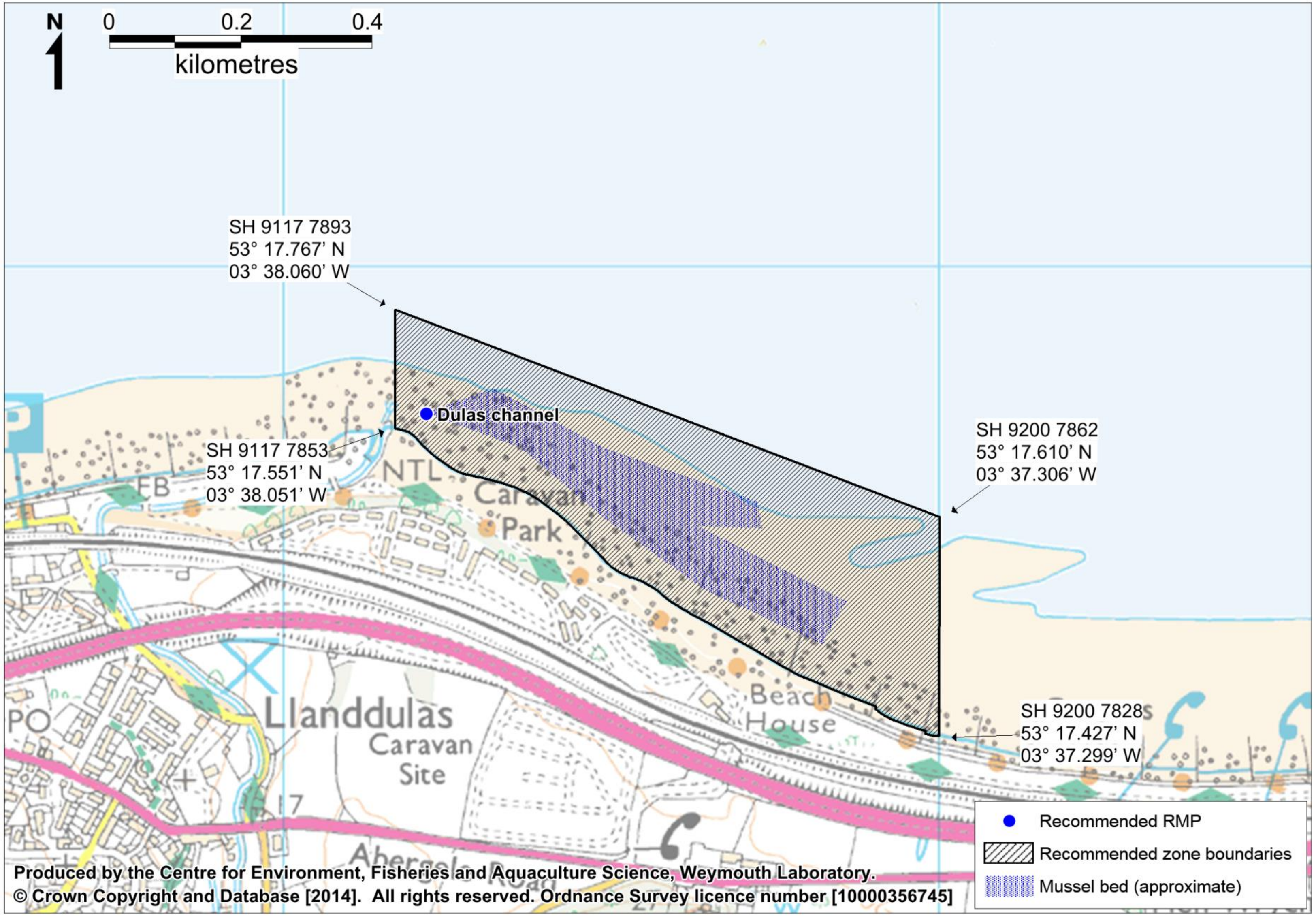


Figure 3.3: Recommended zoning and monitoring arrangements (Llanddulas)

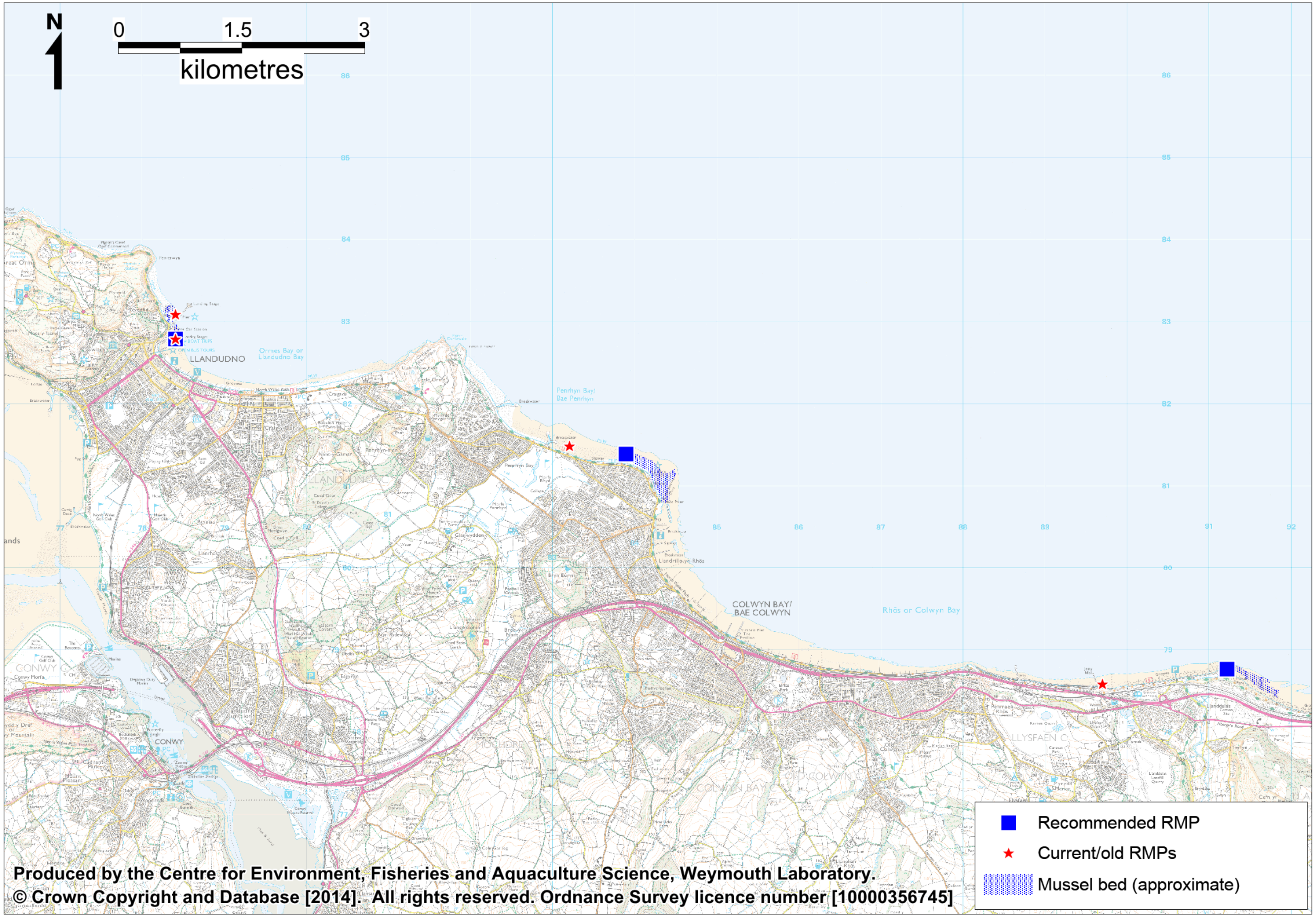


Figure 3.4: Comparison of current/old against recommended RMPs

4. Shellfisheries

4.1. Description of fisheries

Shellfish resources considered in this survey are three intertidal mussel beds. One of these is an ephemeral seed mussel bed at Llanddulas which has only been used as a source of seed in recent years. The other two (Rhos-on-Sea and Llandudno Pier) do sometimes contain marketable sized stocks but are generally only exploited for seed, for which a classification is not required.

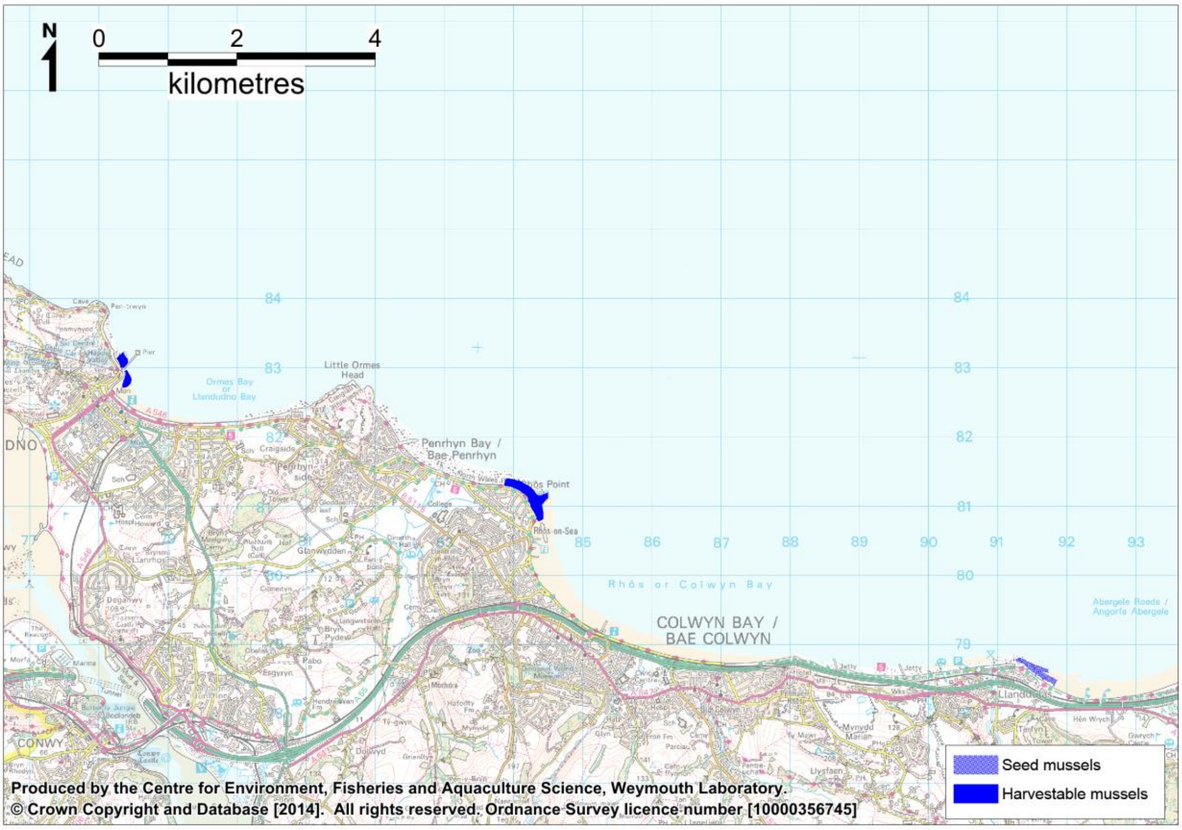


Figure 4.1: Approximate mussel bed locations

Although there is no commercial harvesting on any of these mussel beds at present some gathering for personal consumption does occur from time to time from Rhos-on-sea and Llandudno. All are currently closed by Welsh Government Fisheries. It is considered unlikely that there will be any interest in harvesting mussels from Llandudno in the future (Conwy County Borough Council, pers. comm.). It is possible that from time to time the other two beds may be opened for the harvest of market size mussels.

All mussel harvesting within the area is currently regulated under the Cockles and Mussels (Specified Area) (Wales) Order 2011, under which only permit holders are allowed to take more than 5 kg of cockles or mussels per day. No closed season applies to mussels, which have a minimum landing size of 45 mm in the district. Welsh Government Fisheries may close shellfish beds at any time for reasons of stock preservation.

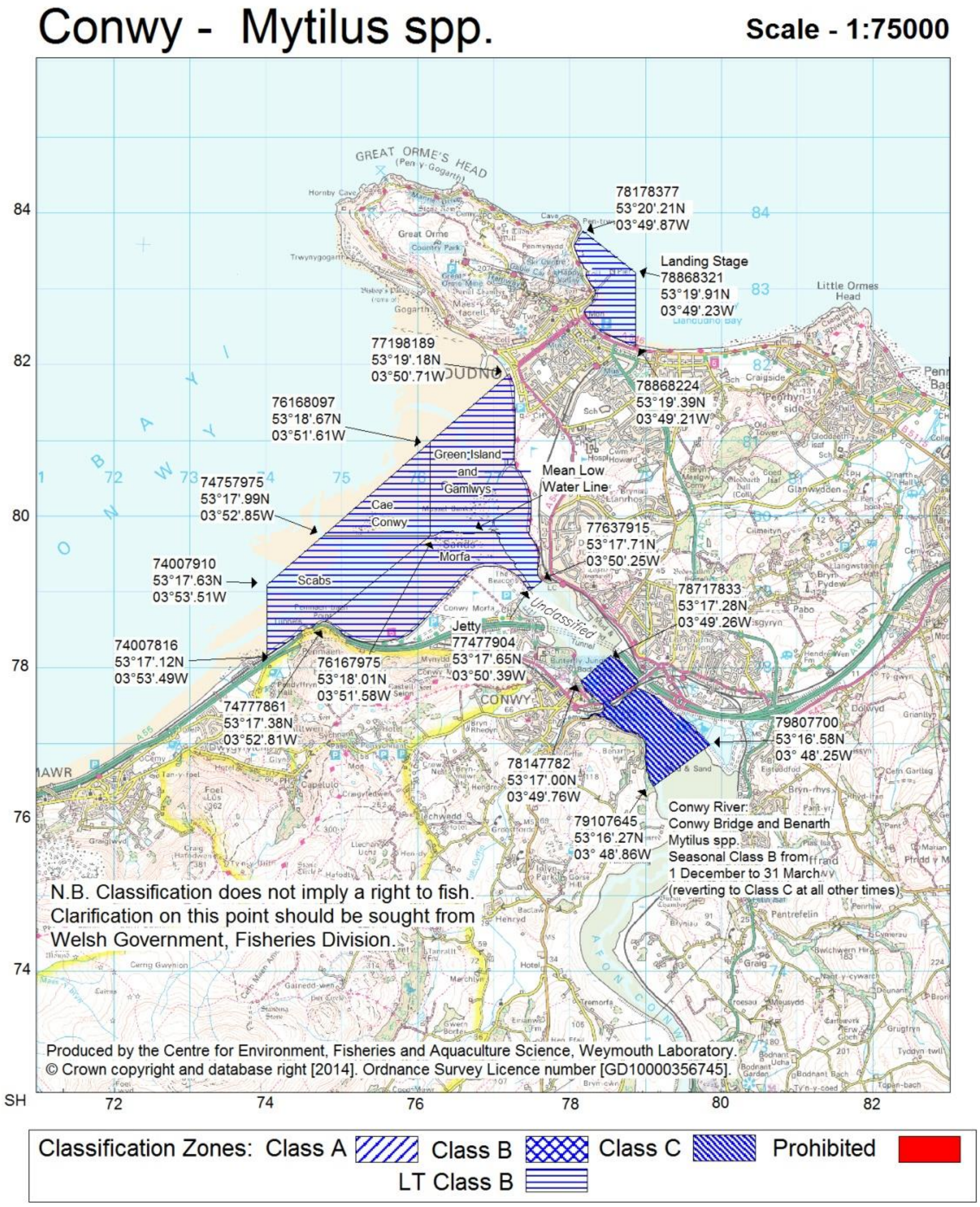
4.2. Hygiene Classification

Table 4.1 lists all classifications within the survey area since 2005.

Table 4.1: Classification history for Conwy, 2004 onwards

Area	Species	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Llandudno Pier (East and West)	Mussels	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Rhos-on-sea	Mussels	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Llanddulas	Mussels	B	-	-	-	-	-	-	-	-	-	-

LT denotes long term classification



Classification of Bivalve Mollusc Production Areas: Effective from 1 September 2014

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)

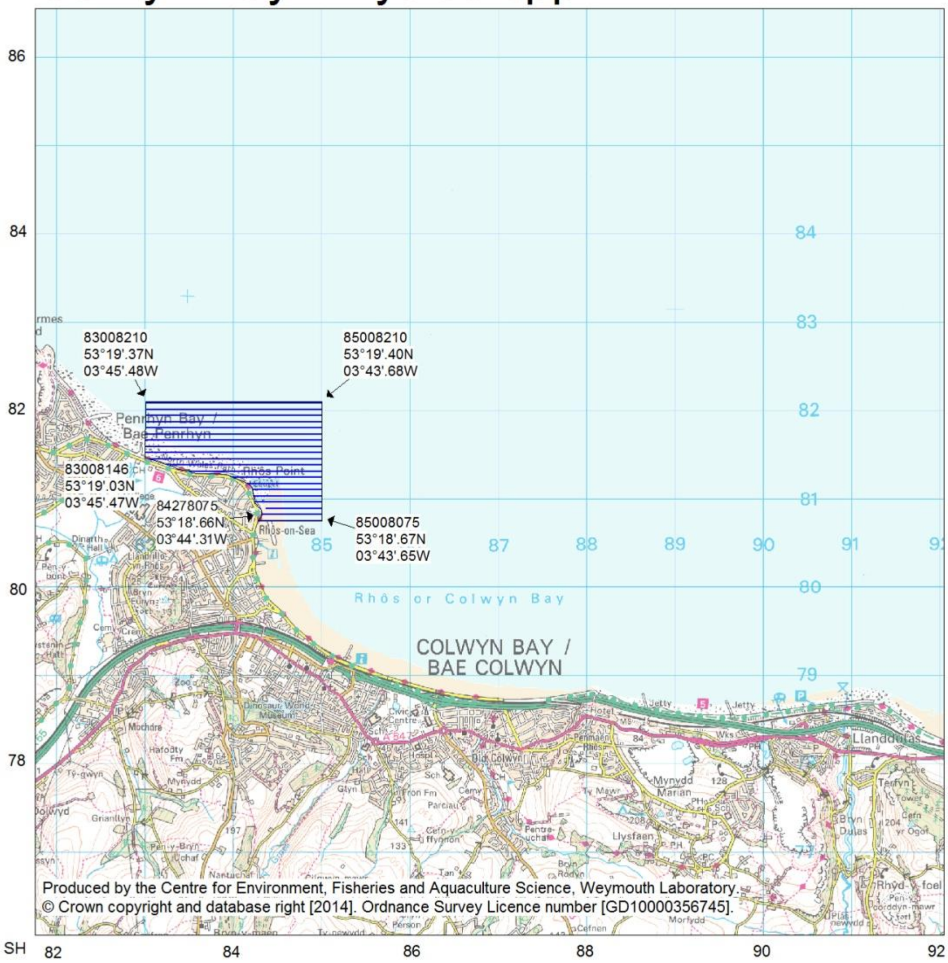
N.B. Lat/Longs quoted are WGS84

Food Authority: Conwy County Borough Council

Figure 4.2: Current mussel classifications (Llanddudno)

Colwyn Bay - Mytilus spp.

Scale - 1:65000



Classification Zones: Class A, Class B, Class C, Prohibited, LT Class B

Classification of Bivalve Mollusc Production Areas: Effective from 1 September 2014

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N.B. Lat/Longs quoted are WGS84

Food Authority: Conwy County Borough Council

Figure 4.3: Current mussel classifications (Rhos-on-Sea)

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

There are three intertidal mussel beds within the survey area. All are currently closed for commercial exploitation. Two of these (Llandudno Pier and Rhos-On-Sea) can contain market size stocks, and are currently classified, although most commercial activity involves the collection of seed only. The third, which is located at Llanddulas, is an ephemeral seed mussel bed which has not held a hygiene classification since 2004. A sampling plan is nevertheless provided for all three. The LEA may wish to consider temporarily declassifying Llandudno Pier and Rhos-On-Sea by reducing the sampling frequency to quarterly. When temporarily declassified, a classification may be rapidly reinstated following the resumption of monthly sampling. There is no formal closed season so the beds may open at any time of the year. A minimum landing size of 45 mm applies in the district.

5.3. Pollution Sources

Freshwater Inputs

All rivers and streams carry some contamination from land runoff and so will require consideration in this assessment. The hydrological catchment draining to the shore of the survey area is relatively small at 79 km^2. The western half consists of a narrow coastal strip generally less than 1 km wide, and the eastern end extends up to 8 km inland. Most of the coastal strip is urbanised. Behind this the eastern inland areas are largely pasture. As the topography is hilly and the hydrogeology is mainly of low permeability, watercourses will respond rapidly to rainfall and a high proportion of rainfall will run off.

There are no significant streams draining to the western end, although there will be a number of points (e.g. road drains) where small amounts of urban runoff will be intermittently discharged to the foreshore. The main surface water outfall in the

Llandudno area is the Washington Outfall, located opposite the Washington Hotel, which is thought to receive misconnected sewage inputs. There are a number of streams and minor rivers draining to the shore to the east of Rhos Point. The largest of these is the river Dulas, which drains just under half of the catchment area. The combined mean discharge estimate for the river Dulas and a Dulas tributary, which between them represent about 75% of the catchment, is 0.157 m^3/sec. The average faecal coliform result at the furthest downstream sampling site on this watercourse (Dulas at Pant Glan Yr Afon) was just over 1,000 faecal coliforms/100 ml. Using this limited information, an approximate estimate of the average bacterial loading it generates is in the order of $2x10^{12}$ faecal coliforms/day. The Dulas discharges just to the west of the seed mussel bed at Llanddulas so is likely to be a significant contaminating influence here at times. The second largest watercourse is the Nant y Ffynnon, which discharges about 4 km west of the Dulas. It was sampled and measured during the shoreline survey and was delivering an estimated bacterial loading of $1.9x10^{10}$ *E. coli*/day. There are a further three smaller watercourses between Nant y Ffynnon and Rhos-On-Sea, but no information is available on their discharge rates or bacterial content.

As well as significant day to day variation in discharge and faecal indicator bacteria concentrations in response to rainfall, some seasonality in average discharge rates is anticipated. Rainfall is higher on average during the autumn and early winter, and during the colder months of the year there is less evaporation and transpiration, and soils will tend to be more waterlogged. As such, discharge rates are likely to be higher on average during the colder months of the year. Whether this variation is associated with a corresponding variation in the loadings of faecal indicator bacteria delivered to coastal waters is uncertain.

Human Population

Total resident population within census areas contained within or partially within the catchment area was approximately 62,000 at the time of the last census in 2011. Most of the population resides in a series of towns located along the coast. The more inland areas are rural and sparsely populated. The seaside towns such as Llandudno and Colwyn Bay are popular holiday resorts, so will experience significant increases in population during the summer. Sewage works serving these towns will therefore receive effluent from a larger population at these times.

Sewage Discharges

There are three water company sewage works discharging within the survey area. Two are located inland and discharge to watercourses. The Betws Yn Rhos STW is consented to discharge a dry weather flow of 135 m^3/day of secondary treated effluent to the Dulas. An estimate of the bacterial loading it generates at the point of discharge is $4.5x10^{11}$ faecal coliforms/day, although some bacterial die-off will occur during transit to coastal waters. The other inland sewage works (Llaneilian Yn Rhos STW) is much smaller. It is consented to discharge a dry weather flow of 11 m^3/day of secondary treated effluent to the Nant y Ffynnon, and generates an estimated bacterial loading of $3.6x10^{10}$ faecal coliforms/day. The third sewage works (Ganol STW) is much larger, and discharges UV treated effluent off Penrhyn Bay, about 1.3 km out from the mean low water line in a depth of about 10 m. The plume from the outfall will therefore travel parallel to the coast with tidal streams, and not generally impact on shellfish beds in the intertidal. An onshore wind would however advect it towards the shore. It is consented to discharge a dry weather flow of 21,686 m^3/day. Bacteriological testing results indicate the effluent contained a geometric mean of 19,000 faecal coliforms/100ml through the period January 2011 to March 2013, which suggests that disinfection is not as effective as is typical for such plants. It must also be noted that UV disinfection is less effective at eliminating viruses than bacteria. An estimate of the average bacterial loading the works generates is $4.1x10^{12}$ faecal coliforms/day. Given that the maximum result was 2,300,000 faecal coliforms/100ml in the effluent, the loading it generates may be two orders of magnitude higher than the average on occasion. Statistically significant seasonal variation was observed, with significantly higher faecal coliform concentrations in the summer than all other seasons.

Welsh Water/Dwr Cymru intend to remove the UV disinfection from this plant at some point in the future (Conwy CBC, pers. comm.). This would result in a significant increase in the bacterial loading associated with this discharge. Without information on the bacteriological quality of the effluent prior to disinfection it is difficult to estimate the magnitude of this increase. Assuming the secondary treated effluent contains the average concentration for this type of treatment as reported by Kay *et al* (2008b) an estimate of the bacterial loading is in the order of $7x10^{13}$ faecal coliforms/day, an increase of over an order of magnitude. This would result in more acute and widespread impacts.

In addition to the continuous sewage discharges, there are 16 intermittent water company discharges within the survey area. Most discharge from the urbanised coastal strip either direct to the sea or to the lower reaches of watercourses. There are a small number further inland, most of which discharge to the Dulas. None is located to the west of Little Orme Head so the mussel beds at Llandudno Pier will not be acutely affected by spills. Four are to Penrhyn Bay, including one to the foreshore about 125 m to the west of the Rhos-on-sea mussel bed. Also of relevance to the sampling plan, one discharges to the foreshore about 500 m west of the seed mussel bed at Llanddulas, and two to the lowest reaches of the Dulas. No spill records were available for any of these discharges, so it is difficult to assess their impacts aside from noting their locations and potential to spill untreated sewage. Welsh Water/Dwr Cymru are currently installing telemetry on all intermittent discharges likely to impact on bathing or shellfish waters, so spill records will be available at some point in the future.

Although most properties within the catchment are served by water company sewerage infrastructure, there are also 398 private discharges. These are mainly treated by small package treatment works such as package plants, and most are small, serving one or two properties. The majority discharge to soakaway so should be of no impact on coastal waters. Most of those discharging to water are to the Dulas, so will make a contribution to the bacterial loading it delivers to the coast.

Agriculture

The majority of land within the survey catchment, outside of the urbanised coastal strip, is used for agriculture. Most are pastures, although there are a few very small pockets where crops are cultivated. A total of 45,167 sheep and 4,943 cattle were recorded within the catchment area in the 2012 agricultural census, so significant impacts from grazing animals are anticipated. 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 small numbers of pigs and poultry farmed in the area. Manure from these is typically stored and applied tactically to nearby farmland. Sewage sludge is occasionally applied to some fields in the middle and upper reaches of the 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 watercourses draining the west of the catchment are likely to be affected to some extent. RMPs should be located as close as possible to the drainage channels they follow across the intertidal to best capture the impacts of agricultural runoff. 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 slurry collected from such operations is likely to be spread in the late winter and spring, depending on the storage capacities of each farm.

Boats

The discharge of sewage from boats is potentially a source of bacterial contamination of shellfisheries within Colwyn Bay. Boat traffic in the area is mainly limited to small numbers of recreational craft (e.g. yachts) and the occasional fishing vessel. There are approximately 35 moorings located at Rhos-On-Sea Harbour, and visiting recreational craft may also anchor off Llandudno, Penrhyn and Colwyn Bays if sea conditions permit. There is a commercial jetty to the west of Llandulas which is used for the transportation of locally mined limestone. However, merchant shipping is not allowed to discharge to inshore waters so vessels accessing this jetty should be of no impact. Smaller pleasure craft such as kayaks and sailing dinghies will not have onboard toilets and so are unlikely to make overboard discharges.

It is therefore concluded any impacts from boats are likely to be minor at most. 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. Therefore, whilst overboard discharges may be made anywhere within the survey area, it may be most likely to occur in the vicinity of Rhos-On-Sea, and possibly at the anchorages if they are used. 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.

Wildlife

The survey area includes sandy embayments with significant intertidal areas, separated by rocky headlands and sea cliffs. The main wildlife aggregation of potential significance to shellfish hygiene is a seabird breeding colony of around 5,000 individuals at Great Orme and Little Orme. Seabirds (gulls, auks etc) 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. The mussel bed at Llandudno Pier is therefore likely to be impacted most heavily, particularly towards its western end. At the other mussel beds, which are relatively remote from the colony, impacts will be diffuse and so have no bearing on the sampling plan. Flocks of gulls were observed on intertidal areas in the vicinity of the Rhos-On-Sea mussel beds during the shoreline survey suggesting the mussel beds may represent favoured foraging areas. Most seabird species are likely to be present all year round, although they may be more dispersed outside of their breeding season.

Whilst the adjacent Conwy Bay and estuary, and Lavan Sands further to the west are known to support large numbers of overwintering waterbirds (wildfowl, waders etc) no formal counts are undertaken within the area considered in this survey. It is concluded that whilst there may be a small influx in the Colwyn Bay area during the winter months, it does not attract these birds in large concentrations. They are likely to represent a minor source of diffuse contamination to the intertidal areas and any coastal grasslands.

Seals occasionally frequent the survey area, and have been observed hauled out at Little Ormes Head. Seals will forage widely, but numbers are small and away from their haul-out sites their impacts may be considered as diffuse and unpredictable, so their presence will have no bearing on the sampling plan. No other wildlife species which may have an influence on the sampling plan have been identified.

Domestic animals

Dog walking takes place on paths adjacent to the shoreline of the survey area and could represent a potential source of diffuse contamination to the near shore zone throughout the survey area. As a diffuse source, this will have little influence on the location of RMPs.

Summary of Pollution Sources

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

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

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

Red - high risk; orange - moderate risk; yellow - lower risk; white – little or no risk

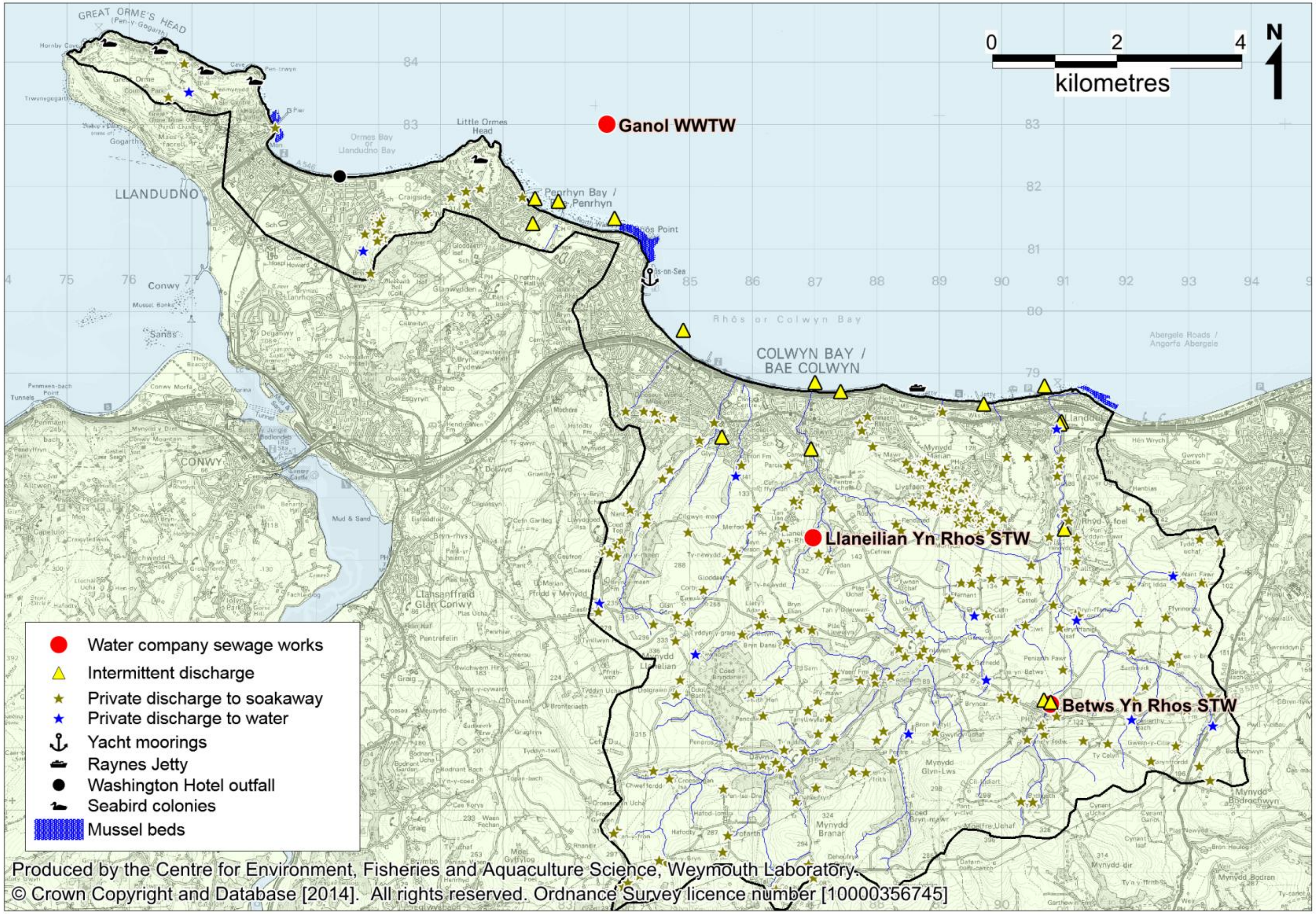

Figure 5.1: Summary of main contaminating influences

5.4. Hydrography

The survey area is an open coastal location at the south western extremity of Liverpool Bay. It is exposed to the Irish Sea, with a fetch to the north of over 100 km. It consists of a series of headlands (Great Ormes Head, Little Ormes Head, and Rhos Point) between which lie slightly indented sandy bays. There is a gently sloping intertidal area of up to about 500 m in width, which continues to slope gently in subtidal areas. The gradient of the subtidal drop off becomes shallower to the east of Rhos Point. The depth drops off more rapidly and there is little or no intertidal at Great Ormes Head and, to a lesser extent, at Little Orme. Offshore subtidal sandbanks are oriented roughly parallel to the coastline, suggesting that tidal streams run parallel to the coast. Given its open coastal location there is high potential for dilution and dispersion of contamination from shoreline sources, although this is likely to decrease slightly towards the shallower eastern end of the survey area.

The tidal range is large, at 7.1 m on spring tides and 3.6 m on neap tides. This drives extensive water movements through the area across the twice daily high/low tidal cycle. Tidal streams are bidirectional, flooding along the coast in an easterly direction and ebbing in a westerly direction. Contamination from shoreline sources will therefore travel parallel to the coast, impact either side of their locations, and the magnitude of their impacts will decrease with distance as the plume spreads and becomes more diluted. The situation may be slightly more complicated at the western end of Llandudno Bay, as eddies may form in the lee of the Great Orme. The plume from the Ganol STW outfall will travel parallel to the coast, and will not generally impact on the intertidal mussel beds.

Modelling studies indicate peak current velocities range from just under 0.5 m/s in Colwyn Bay to around 0.8 m/s to the north of Great Ormes Head. Predicted tidal excursions ranged from about 5 km in Colwyn Bay to about 8 km off Great Ormes Head. In the nearshore and intertidal areas the rates of travel are likely to be slower due to friction. It is therefore concluded that contamination from shoreline sources is unlikely to be carried more than 5 km along the coast before the tide reverses. As such, the plume from the Dulas will only impact significantly at the Llanddulas mussel bed.

Superimposed on tidally driven currents are the effects of freshwater inputs and wind. There is little in the way of freshwater inputs to this coast, and the coastal waters here are unenclosed so density effects are unlikely to modify water circulation here. A series of salinity measurements made under the bathing and shellfish waters monitoring programmes confirm that there is little freshwater influence, with salinity approaching that of full strength seawater at all locations sampled. There was a very slight decrease in average salinity from west to east, as may be expected given the locations of the freshwater inputs. A density related effect of potential relevance to the fishery is that the plume from the Ganol STW outfall will tend to rise to the surface, rendering it susceptible to advection by wind driven currents.

Strong winds will drive surface water currents, which in turn will create return currents, either lower down the water column or along sheltered margins. The survey area is most exposed to winds from the north. Exact effects are dependent on the wind speed and direction and the state of the tide at the time and so a great range of scenarios may arise. The prevailing south westerly wind direction will tend to advect contamination in the upper part of the water column away from the shore and out towards the Irish Sea, although the adjacent land provides shelter from such winds. Northerly winds will tend to advect any buoyant plume from Ganol STW towards the shore. As well as driving surface currents, onshore winds will create wave action. This may resuspend any contamination held within the sediments of the intertidal zone, temporarily increasing levels of contamination within the water column until it is carried away by the tides.

5.5. Summary of Existing Microbiological Data

The survey area has a comprehensive microbiological monitoring history, deriving from the bathing waters and shellfish waters monitoring programmes, as well as hygiene classification monitoring. Figure 5.2 shows the locations of the monitoring points referred to in this assessment. Results of samples taken from 2004 onwards are considered in these analyses.

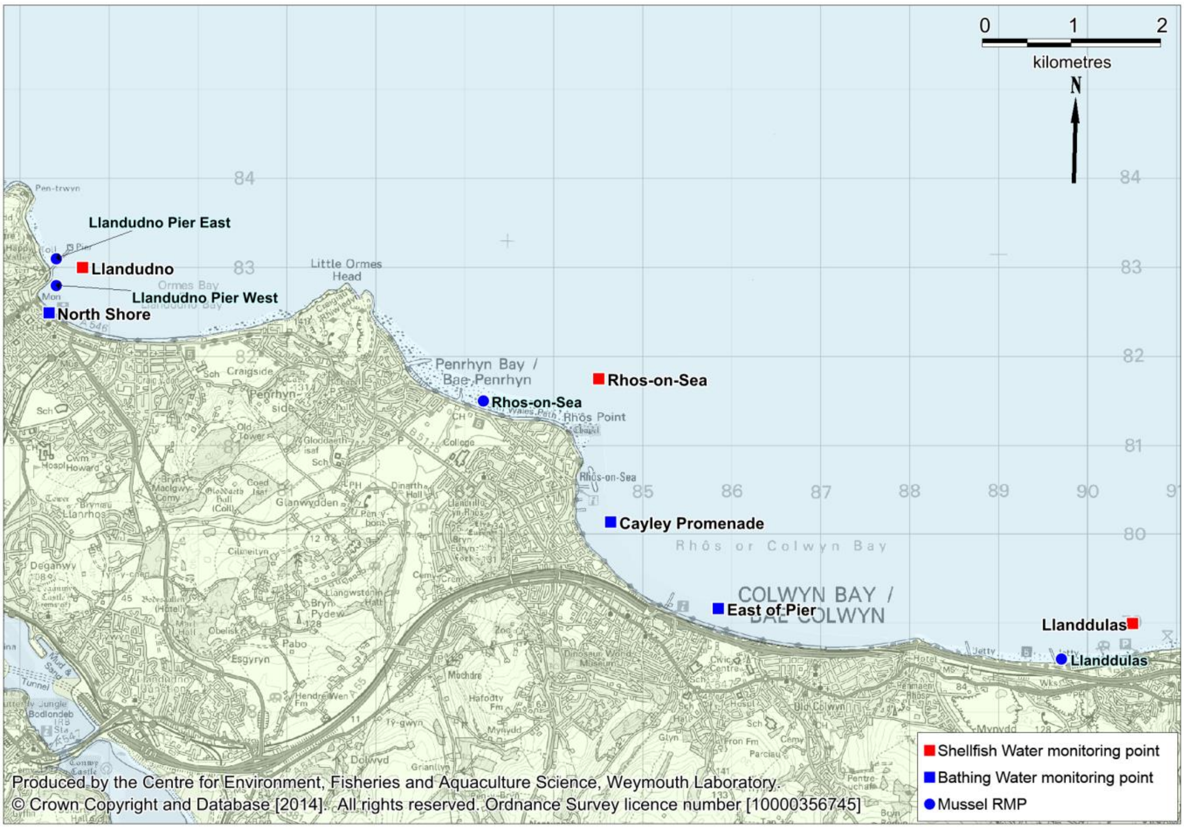

Figure 5.2: Microbiological sampling locations

Shellfish Waters monitoring

There are three shellfish water monitoring points, the locations of which coincide with the three mussel beds that are the subject of this survey. At each of these points, water samples were taken on a quarterly basis and enumerated for faecal coliforms. Results were lower on average at Llandudno (geometric mean of 5.8 faecal coliforms/100 ml) compared to Rhos-on-Sea and Llanddulas (geometric means of 9.4 and 9.7 respectively. A comparison of paired (same day) sample results revealed significant correlations between all site pairings suggesting they share similar sources of contamination.

No overall increase or decrease in average result was observed at any of the three sites since 2004. A similar seasonal pattern of highest average results in the winter was observed at all three, but this was only statistically significant at Llandudno and Rhos-On-Sea. A statistically significant influence of tide across the high/low cycle was detected at Rhos-On-Sea and Llanddulas. Higher results tended to occur in samples collected during the flood tide at Rhos-On-Sea suggesting a source to the west (possibly Ganol STW) is of significance. At Llanddulas, higher results tended to occur around low water, possibly suggesting a local source such as the Dulas is of significance. A significant correlation between faecal coliform results and the spring/neap tidal cycle was detected at Llanddulas only. Higher results tended to occur during the smaller tides, again suggesting that a local source such as the Dulas is of significance. Statistically significant positive correlations between antecedent rainfall and faecal coliform concentrations were found at all three sites. The influence was weakest at Llandudno, which is unsurprising at it is more remote from any significant freshwater inputs than the other two sites. The response was quite rapid (1-3 days) at all sites, which is consistent with the relatively small hydrological catchment draining to this stretch of coast. Conversely, there were no significant effects of salinity on faecal coliform concentrations at any of the sites, suggesting that land runoff is not a major influence.

Bathing water monitoring

There are three bathing water sites within the survey area, where samples are taken and enumerated for faecal indicator organisms on a weekly basis throughout the bathing season (May-September). Results up to 2011 were for faecal coliforms, but in 2012 the analysis method changed and from then on *E. coli* was enumerated. Statistical analyses were carried out using the larger faecal coliform dataset. Of the three bathing water sites, North Shore was sampled throughout the period 2004-present, East of Pier was sampled 2004-10, and Cayley Promenade was sampled from 2010 to present.

The East of Pier sampling site had the highest geometric mean and maximum faecal coliform concentrations, while Cayley Promenade, had the lowest geometric mean and maximum faecal coliform concentrations. Statistical analyses indicated that Cayley Promenade had significantly lower concentrations than both other sites and East of Pier had significantly higher concentrations than both other sites. A significant correlation was found between the results of paired (same day) samples taken from North Shore and East of Pier, but not between any other site combinations. This would indicate that these two sites are subject to similar sources of contamination. Whether this lack of correlation between the other sites is due to the lower number of paired samples between Cayley Promenade and the other two sites is uncertain.

Faecal coliform levels have remained fairly stable on average since 2004. A statistically significant influence of high/low tidal cycle was found at North Shore and East of Pier. At both sites there appeared to be a weak trend of slightly lower results around low water. A significant correlation between faecal coliform results and tidal state on the spring/neap cycle was observed at North Shore only. Results here were higher on average on the larger tides, possibly suggesting that distant sources are of some significance. Statistically significant positive correlations between antecedent rainfall and faecal coliform concentrations were found at all three sites. The influence was weakest at Cayley Promenade, possibly as a consequence of the lower numbers of samples from here. As for the shellfish waters, the effect was found from one to three days following a rainfall event. However, Cayley Promenade was the only site where faecal coliform concentrations correlated significantly with salinity. It is possible that these apparent anomalies are due to the differing sample numbers and periods of monitoring.

Shellfish Hygiene classification monitoring

There are four RMPs within the survey area that have been sampled between 2004 and 2014, all of which are for mussels. One of these (Llanddulas) was only sampled on 8 occasions in 2004, so was not considered in the statistical analyses. It recorded the lowest geometric mean result (128.4 *E. coli* MPN/100g) and none of the 8 samples exceeded 4,600 *E. coli* MPN/100g. The other three RMPs were sampled on a more or less monthly basis throughout the period considered. All showed solid class B compliance, with the proportion of results exceeding 4,600 ranging from 0% at Llandudno Pier West to 3.3% at Rhos-On-Sea. There was a statistically significant difference in average result, whereby *E. coli* levels were significantly higher at Llandudno Pier East and Rhos-On-Sea than at Llandudno Pier West. Paired (same day) sample results were strongly correlated between Llandudno Pier East and West, and between Llandudno Pier West and Rhos-On-Sea, suggesting all sites share similar sources of contamination.

E. coli levels have remained stable at all three RMPs since 2004. Seasonality in results was inconsistent across the three RMPs. No statistically significant seasonal variation was observed at Llandudno Pier West. At Llandudno Pier East, levels of *E. coli* were significantly higher in spring than in autumn, and at Rhos-On-Sea they were significantly higher in winter than in autumn. Sampling was targeted towards low water, and whilst a statistically significant association between tidal state across the high/low cycle was detected at Llandudno Pier East, no patterns were apparent when the data was plotted. Statistically significant correlations between E. coli results and tidal state across the spring/neap cycle were detected at Llandudno Pier West and Rhos-On-Sea. In both cases there appeared to be a tendency for higher results on the larger tides, perhaps suggesting that more remote sources are of some influence. A relatively weak influence of antecedent rainfall two days after an event was detected at Rhos-On-Sea, but no influence of rainfall was detected at either of the Llandudno Pier sites

Bacteriological survey

Due to the extensive microbiological monitoring history of the survey area, it was considered unnecessary to undertake a bacteriological survey.

A small number of seawater samples were taken by Natural Resources Wales from various intertidal locations in the summer and autumn of 2011 to investigate spatial variation in levels of contamination in the area. These limited results suggest that there is a significant localised hotspot of contamination at one location on the intertidal, about 300 m to the west of the Rhos-On-Sea mussel bed. The closest identified point source of contamination is an intermittent sewage discharge from the Church Road PS.

Appendices

Appendix I. Human Population

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

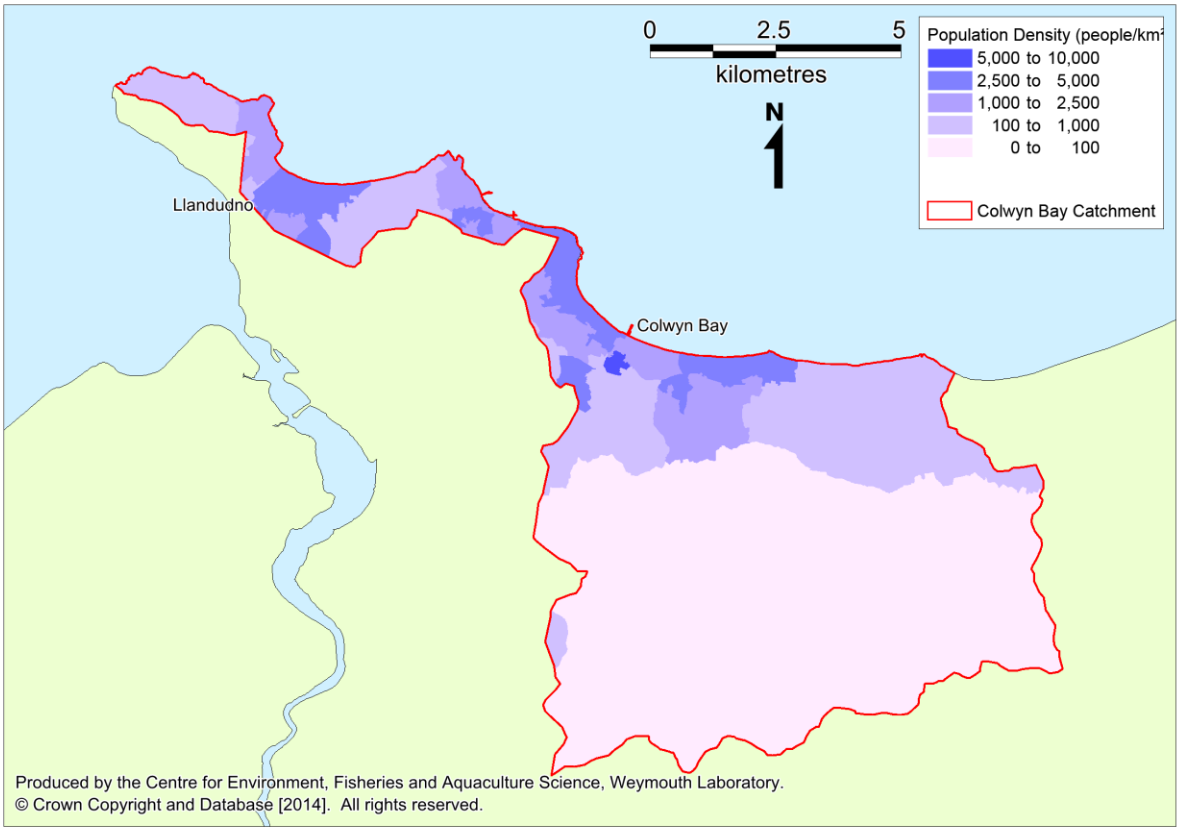

Figure I.1: Human population density in census areas in the Colwyn Bay catchment.

Total resident population within census areas contained within or partially within the catchment area was approximately 62,000 at the time of the last census. The largest settlements in the area are Llandudno and Colwyn Bay, which had populations of about 20,700 and 11,000 respectively in the 2011 census. Most of the population is concentrated towards the coast, with inland population densities generally below 100 people/km².

Llandudno and Colwyn Bay are popular tourist destinations. Additionally, with its proximity to Snowdonia many visitors will use the region as a base for trips to the national park. The population of the catchment is therefore likely to fluctuate significantly throughout the year, peaking during summer holidays due to tourism.

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

Details of all consented sewage discharges within the Colwyn Bay hydrological catchment were taken from the most recent update of the Environment Agency national permit database (March 2014). These are mapped in Figure II.1.

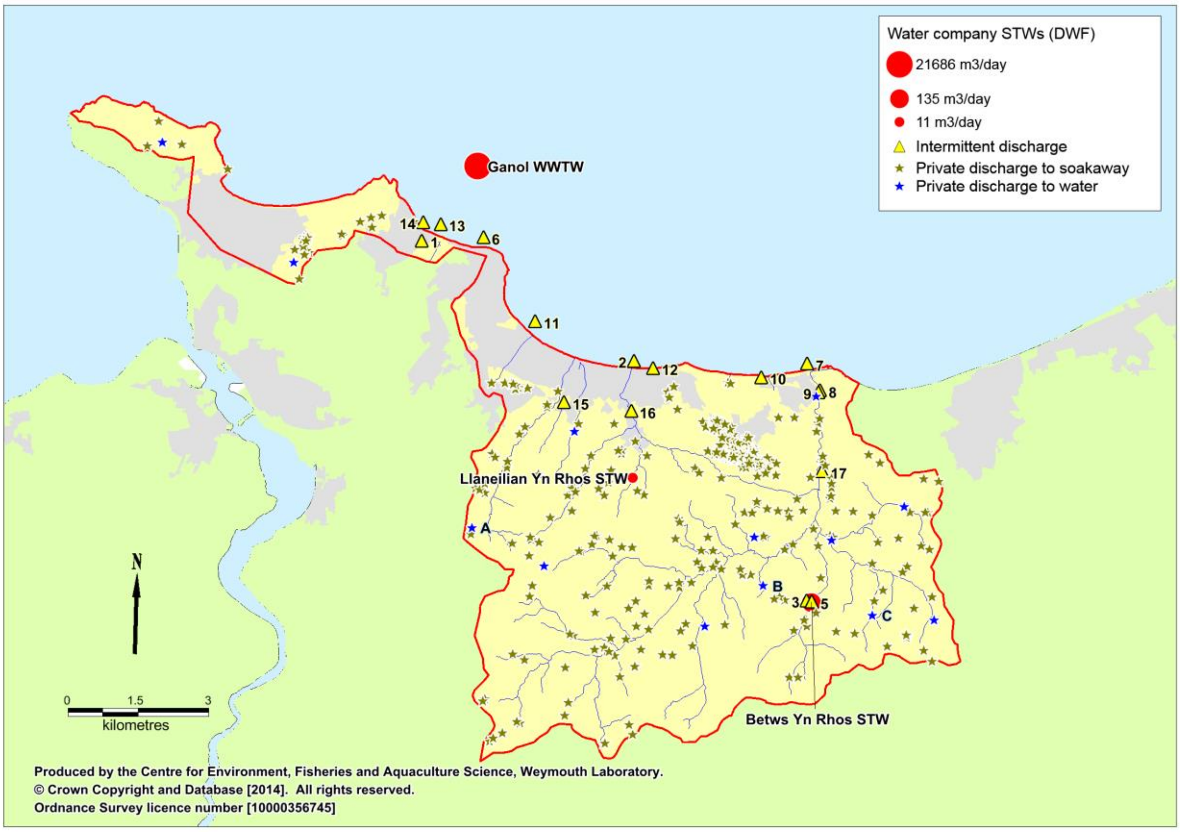

Figure II.1: All permitted sewage discharges to the Colwyn Bay catchment
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There are three continuous water company sewage works discharging within the survey area, details of which are presented in

Table II.1.

Table II.1: Details of continuous water company sewage works to the Colwyn Bay catchment

Name	NGR	Treatment	DWF (m^3/day)	Estimated bacterial loading (cfu/day)	Receiving environment
Betws Yn Rhos STW	SH9077573719	Biological Filtration	135	4.5×10^{11}*	Dulas trib.
Ganol WWTW	SH8366083020	UV Disinfection	21,686	4.1×10^{12}**	Coastal waters
Llaneilian Yn Rhos STW	SH8697076390	Biological Filtration	11	3.6×10^{10}*	Nant y Ffynnon

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

**Faecal coliforms (cfu/day) based on geometric mean final effluent testing data (Table II.3)

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	7.2×10^6
Primary (12)	127	1.0×10^7	14	4.6×10^6
Secondary (67)	864	3.3×10^5	184	5.0×10^5
Tertiary (UV) (8)	108	2.8×10^2	6	3.6×10^2

Data from Kay et al. (2008b).

n - number of samples.

Figures in brackets indicate the number of STWs sampled.

Table II.3: Summary statistics for final effluent testing data (faecal coliform cfu/100ml) from Ganol STW, January 2011 to March 2013

Sewage works	No.	Geometric mean result (cfu/100ml)	Minimum	Maximum
Ganol STW	131	18,906	20	2,300,000

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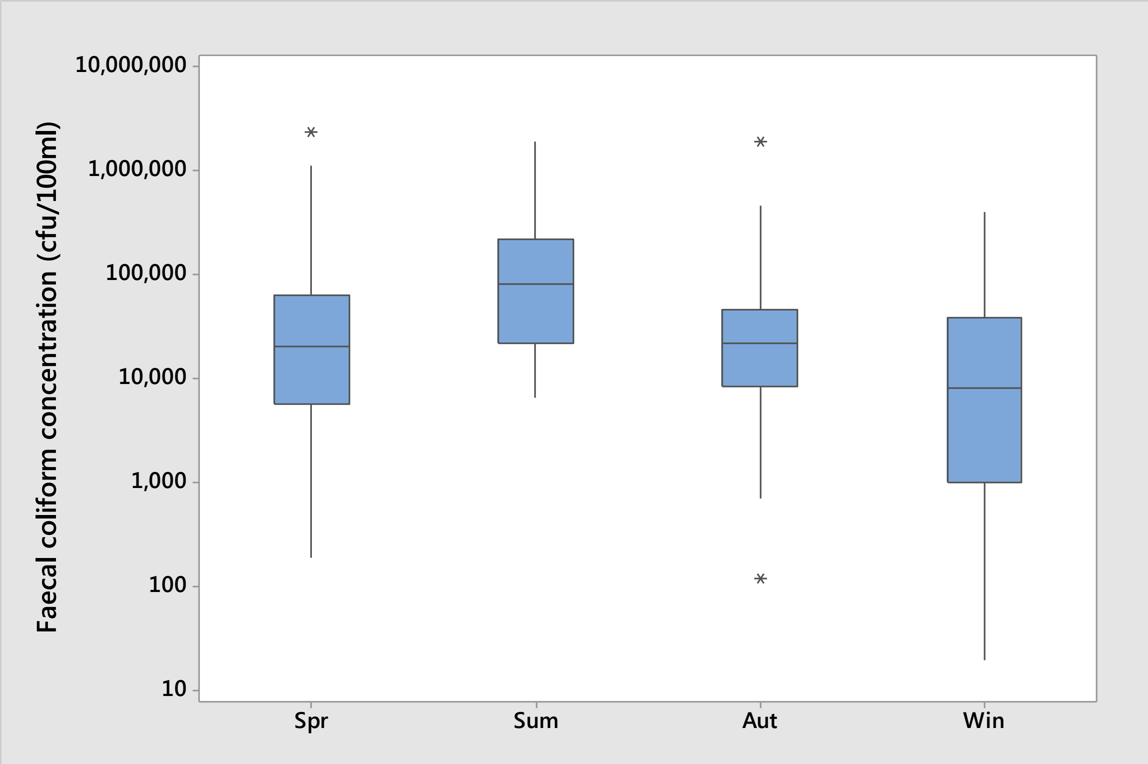

Figure II.2: Boxplot of faecal coliform concentrations in Ganol STW final effluent by season.
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The largest continuous water company discharge by a considerable margin is Ganol STW, which has a consented Dry Weather Flow (DWF) of 21,686 m^3/day. It discharges UV treated effluent to the coastal waters of Colwyn Bay, about 1.3 km out from the mean low water line in a depth of about 10 m. The average concentration of faecal coliforms in the effluent was over an order of magnitude higher than the average value reported in the literature (Table II.2). The maximum concentration at Ganol STW was a further two orders of magnitude higher than the average. It is therefore concluded that the disinfection of effluent is not as effective as is typical for such sewage works. It must also be noted that UV disinfection is less effective at eliminating viruses than bacteria (e.g. Tree et al, 1997). The seasonal variation in faecal coliform concentrations was statistically significant (One way ANOVA, $p<0.001$). Post ANOVA testing (Tukeys) indicated that concentrations were significantly higher in the summer than all other seasons, and significantly lower in the winter than in the autumn.

Welsh Water/Dwr Cymru intend to remove the UV disinfection from this plant at some point in the future (Conwy CBC, pers. comm.). This would result in a significant increase in the bacterial loading associated with this discharge. Without information on the bacteriological quality of the effluent prior to disinfection it is difficult to estimate the magnitude of this increase. Assuming the secondary treated effluent contains the average concentration for this type of treatment (Table II.2) an estimate of the bacterial loading is in the order of $7x10^{13}$ faecal coliforms/day, an increase of over an order of magnitude. This would result in more acute and widespread impacts.

The two other water company owned sewage works are located inland and discharge to watercourses. Both of these are relatively small and undergo biological filtration, but they will contribute to the bacterial loadings carried by the watercourses to which they discharge. Some natural die-off of micro-organisms is likely to occur between the point of discharge and coastal waters, depending on river transit times.

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.4.

Table II.4: Intermittent discharges to the Colwyn Bay catchment

No.	Name	Grid reference	Receiving water
1	92 Penrhyn Isaf CSO	SH8246781405	Unnamed watercourse
2	Beach Road CSO Colwyn Bay	SH8699078850	Coastal waters
3	Betws Yn Rhos Sports Ground	SH9067073750	Dulas trib.
4	Betws Yn Rhos Storm Sewage	SH9077673719	Dulas trib.
5	Betws Yn Rhos Sewage PS EO	SH9077573718	Dulas trib.
6	Church Rd PS	SH8378081480	Coastal waters
7	Llanddulas PS	SH9068078790	Coastal waters
8	Llanddulas Beach Rd	SH9095078220	Dulas
9	Llanddulas Mill St CSO	SH9092078180	Dulas
10	Llysfaen	SH8970078500	Coastal waters
11	Marine Rd CSO	SH8488079690	Coastal waters
12	Old Colwyn Queens Road SSO	SH8740078700	Coastal waters
13	Penrhyn Bay PS	SH8287081760	Coastal waters
14	Penrhyn Hill	SH8250081800	Coastal waters
15	PS At Glyn Farm Res Dev Glyn Av	SH8550077970	Nant Y Groes
16	PS Off Llanelion Road	SH8693077780	Nant Y Ffynnon
17	Rhyd Y Foel	SH9100076500	Dulas

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There are 17 intermittent discharges in the area, the majority of which discharge from the urbanised coastal strip either direct to the sea or to the lower reaches of watercourses. There are a small number further inland, most of which discharge to the Dulas. None is located to the west of Little Orme Head so the mussel beds at Llandudno Pier will not be acutely affected by spills. Four are to Penrhyn Bay, including one to the foreshore about 125 m to the west of the Rhos-on-Sea mussel bed (Church Road PS). There is one to the foreshore about 500 m west of the seed mussel bed at Llanddulas (Llanddulas PS Llanddulas), and two to the lowest reaches of the Dulas. No spill records were available for any of these discharges, so it is difficult to assess their impacts aside from noting their locations and potential to spill untreated sewage. Welsh Water/Dwr Cymru are currently installing event monitoring on all intermittent discharges thought to impact on shellfish and bathing waters so a more robust assessment of their impacts will be possible at some point in the future.

Although the vast majority of properties within the survey area are served by water company sewerage infrastructure, there are also a number of private sewage discharges. These are generally treated by small package treatment works such as package plants, and the majority of these are small, serving one or two properties. All permitted private sewage discharges are mapped in Figure II.1, and Table II.5 presents details of those consented to discharge more than 5 m^3/day to water.

Table II.5: Details of private sewage discharges >5 m^3/day to the Colwyn Bay catchment

Ref.	Property served	Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
A	Llwydgoed Primary School	SH8354075330	Unspecified	5	Nant Y Groes trib.
B	Peniarth Bach	SH9207773465	Package Plant	18.5	Dulas trib.
C	STW Serving a Caravan Site	SH8975074095	Package Plant	8	Dulas trib.

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There are 398 private discharges within the Colwyn Bay catchment, including those which have recently been registered through a Natural Resources Wales initiative. Most are located away from the urbanised coastal strip and the vast majority (382) are to soakaway so should be of no impact on coastal water quality. Of the 16 discharges to water, three have a maximum consented flow of > 5 m^3/day. These three private discharges are located a considerable distance inland, so whilst they will contribute to bacterial concentrations in their receiving watercourses, they are unlikely to be of significance to any of the shellfisheries.

Appendix III. Sources and Variation of Microbiological Pollution: Agriculture

The majority of agricultural land within the catchment is pasture, with a few very limited pockets where crops are cultivated (Figure 1.2). Numbers and overall densities of livestock within the catchment, as recorded in the 2012 agricultural census are presented in Table III.1. This data attributes each farm to a single point, whereas in reality farms may span the catchment boundary. It should nevertheless give a reasonable indication of numbers and types of livestock in the survey area.

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

Cattle		Sheep		Pigs		Poultry	
No.	Density (no/km^2)	No.	Density (no/km^2)	No.	Density (no/km^2)	No.	Density (no/km^2)
4,943	62.3	45,167	569.4	135	1.7	1,210	15.3

Data from Welsh Government.

Sheep farming is widespread, with around 45,000 animals at high average stocking densities. There are also significant numbers of cattle, but few poultry and pigs farmed within the catchment. Additionally, a herd of around 125 feral Kashmiri goats reside on the Great Orme (BBC News, April 2014). 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).

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 or manure will be collected and stored for use as a fertilizer. Manure from pig and poultry operations is typically collected, stored and spread tactically on nearby farm land (Defra, 2009). Sewage sludge is also occasionally applied as a fertilizer within the middle and upper reaches of the catchment, with 26 applications recorded by Natural Resources Wales from January 2009 to May 2013. There may therefore be some impacts arising from the periodic application of organic fertilizers to pastures and crops as well as from animals grazing on pasture.

The primary mechanism for mobilisation of faecal matter deposited or spread on farmland to coastal waters is via land runoff, so fluxes of livestock related contamination into the survey will be highly variable and depend on rainfall. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the 'first flush'). Most, if not all significant watercourses will be impacted to some extent by agriculture. The largest and most consistent fluxes of indicator bacteria into coastal waters are anticipated to arise 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. Numbers 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 and pig manure and sewage sludge may be spread at any time of the year. Therefore peak levels of contamination from sheep and cattle may arise following high rainfall events in the summer, particularly if these have been preceded by a dry period which would allow a build up of faecal material on pastures, or on a more localised basis if wet weather follows a slurry application which may be more likely in winter or spring.

Appendix IV. Sources and variation of microbiological pollution: Boats

The discharge of sewage from boats is a potential source of bacterial contamination of shellfisheries within Colwyn Bay. Boat traffic in inshore waters here is largely limited to recreational craft such as small motor boats. Figure IV.1 presents an overview of boating activity derived from the shoreline survey, satellite images and various internet sources.

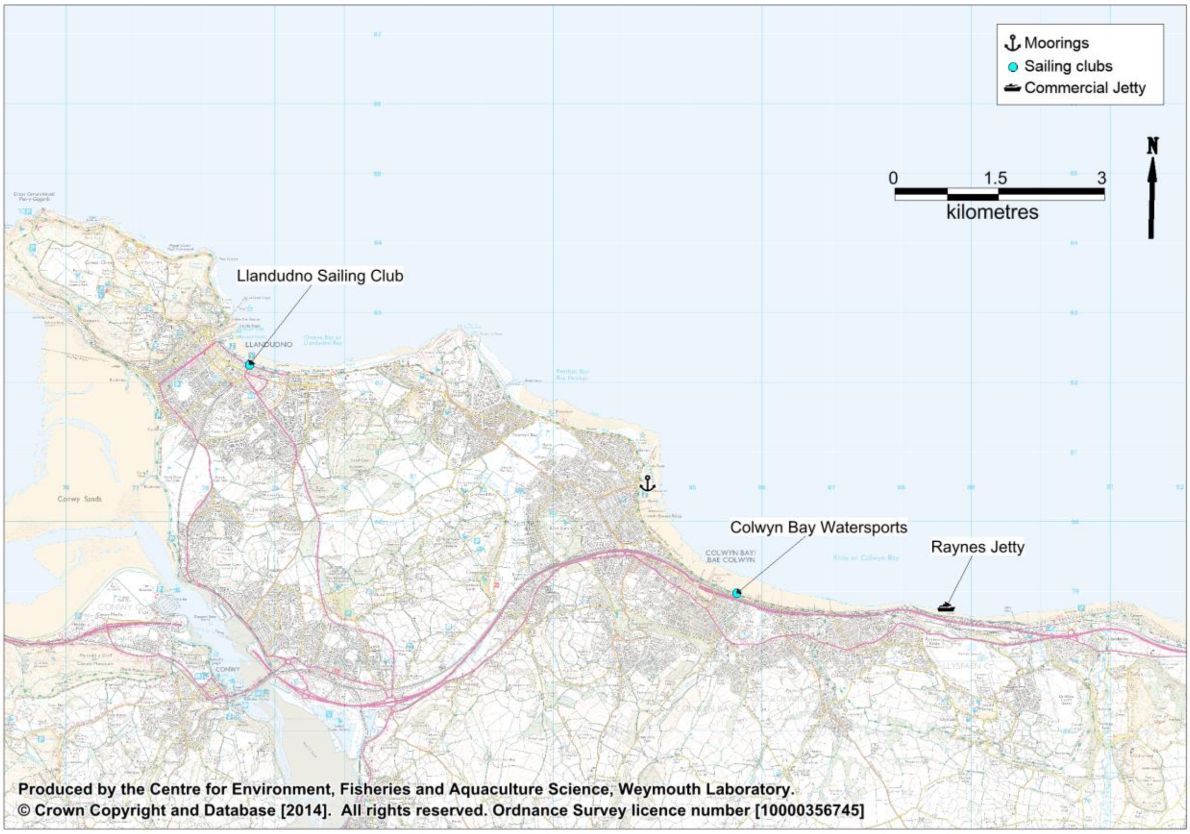

Figure IV.1: Boating activity in the Colwyn Bay survey area

There are no marinas within the survey area. The closest one is located in the Conwy estuary, more than 13 km away. There are approximately 35 privately owned half tide moorings located at Rhos-on-Sea Harbour. Visiting recreational craft may also anchor off Llandudno, Penrhyn and Colwyn Bays if sea conditions permit. Watersports are popular within the area, with a sailing club at Llandudno and a watersports centre in Colwyn Bay which collectively offer dinghy sailing, yacht sailing, kayaking, windsurfing and jet skiing.

One fishing vessel was registered as having its home port as Rhos-on-Sea (MMO, 2014) although it is probable that vessels from other ports operate in the area at times. There is a commercial jetty (Raynes Jetty), to the west of Llanddulas, where small numbers of merchant vessels are used for the transportation of limestone from a nearby quarry. Aside from this, the nearest commercial port is Liverpool, and the main shipping routes to Liverpool lie more than 10 km to the north. Merchant shipping vessels are not permitted to make overboard discharges within 3 nautical miles of land[1], so this commercial traffic should be of no impact.

It is therefore concluded that boat traffic in the area is mainly limited to a small number of pleasure craft and the occasional merchant ship and fishing vessel, so any impacts are likely to be minor at most. 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. Therefore, whilst overboard discharges may be made anywhere within the survey area, this is most likely to occur whilst boats are at anchor. Smaller pleasure craft such as kayaks and sailing dinghies will not have onboard toilets and so are unlikely to make overboard discharges. Peak pleasure craft activity is anticipated during the summer, so associated impacts are likely to follow this seasonal pattern. It is difficult to be more specific about the potential impacts from boats and how they may affect the sampling plan without any firm information about the locations, timings and volumes of such discharges.

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

Appendix V. Sources and Variation of Microbiological Pollution: Wildlife

Colwyn Bay survey area comprises of three sandy embayments separated by rocky headlands and sea cliffs. At low tide the survey area uncovers large expanses of intertidal sand flats. The survey area coincides with several international and national conservation designations including a Special Area of Conservation (SAC), Sites of Special Scientific Interest (SSSI), and several Local Nature Reserves.

In the survey area the most significant wildlife aggregation of relevance to shellfish hygiene is likely to be seabirds such as gulls and terns, which are widespread throughout the area. 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). A survey in the early summer of 2000 recorded 5,347 individuals within a 1.5 km radius of the shoreline including Black-legged kittiwake, Guillemot, Great cormorant, Razorbill and European herring gull (Mitchell *et al*, 2004). The principal nesting site is on Great Orme and Little Orme where around 93% of these seabirds nest. 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 on the adjacent shores. The mussel bed at Llandudno Pier is likely to be most vulnerable, particularly at the western end. Most species are likely to be present all year round, although they may be more dispersed outside of their breeding season.

The survey area is not subject to regular organised counts of overwintering waterbirds (wildfowl and waders). In the neighbouring Conwy Bay and estuary, an average total count of 3,722 was recorded over the winter of 2011/2012 (Austin *et. al*, 2014). Further to the west, Lavan Sands routinely attracts over 15,000 of these birds. It is concluded that whilst there may be a small influx in the Colwyn Bay area during the winter months, it does not attract these birds in large concentrations. These are likely to represent a minor source of diffuse contamination to the intertidal areas and any coastal grasslands.

It has been estimated that there are around 365 grey seals in North Wales (Westcott & Stringell, 2004). Seals do frequent the survey area, and have been observed hauled out at Little Ormes Head (Conwy CBC, pers comm.). Their numbers are small, and they will forage widely but away from their haul-out sites their impacts may be considered as diffuse and unpredictable, so their presence will have no bearing on the sampling plan. No other wildlife species which may have an influence on the sampling plan have been identified.

Appendix VI. Meteorological Data: Rainfall

The monthly rainfall data for the Colwyn Bay weather station are shown in Figure VI.1.

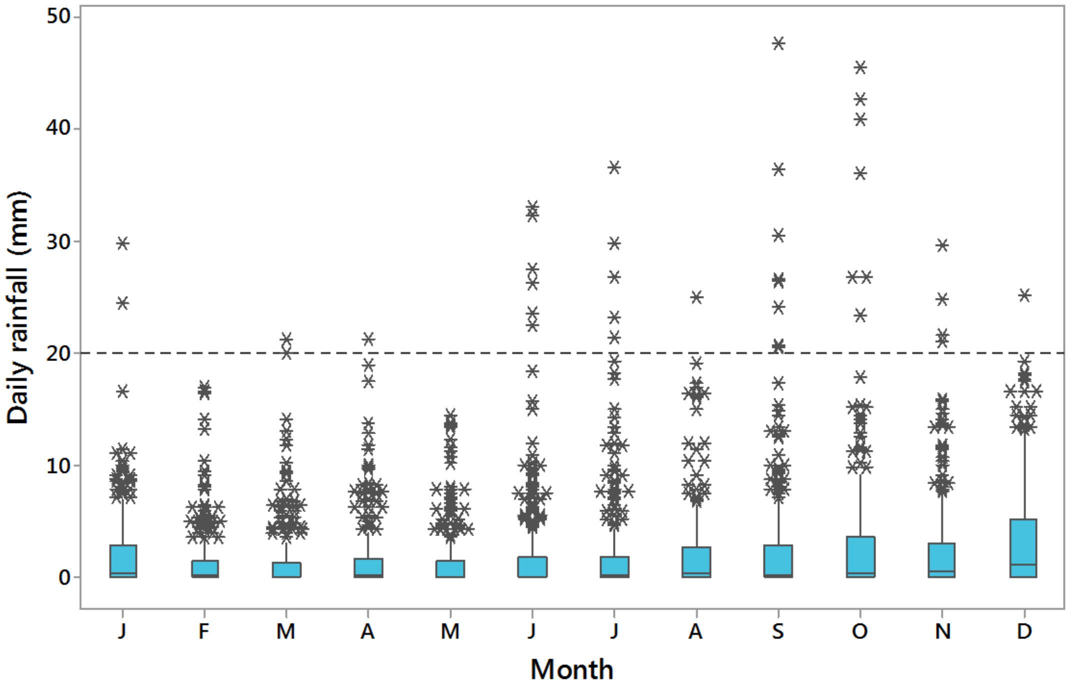

Figure VI.1: Boxplot of daily rainfall totals at Colwyn Bay, January 2004 to December 2013.
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The Colwyn Bay weather station received an average of 751 mm per year between 2004 and 2014. The annual rainfall in the more inland areas is roughly double this (NERC, 2012). The autumn and early winter months (September to December inclusive) had the highest average rainfall, while February had the lowest average rainfall. Daily totals of over 20 mm were recorded on 1% of days and no rainfall was recorded on 44% of days between 2004 and 2014. The wettest days tended to occur in summer and autumn.

Rainfall may lead to the discharge of raw or partially treated sewage from combined sewer overflows (CSOs) 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. 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).

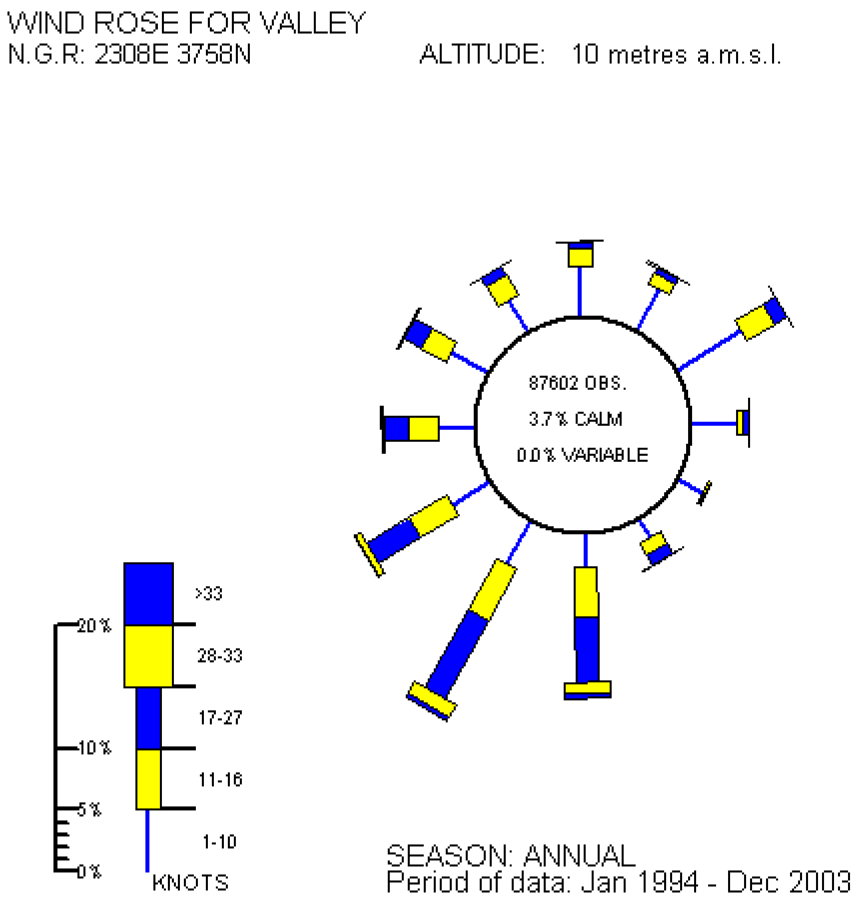

Figure VII.1: Windrose for Valley

Produced by the Meteorological Office. Contains public sector information licensed under the Open Government Licence v1.0

The annual wind rose for Valley is typical of coastal locations in Wales. The prevailing wind is from the south west throughout the year, but there is also a high frequency of winds from the north east in the spring. The Colwyn Bay survey area is relatively sheltered to the prevailing winds as it faces north and is sheltered by hills to the south and Great Ormes Head to the west. However, as it consists of a series of open embayments it will be fully exposed to winds and waves from the north.

Appendix VIII. Hydrometric Data: Freshwater Inputs

The hydrological catchment draining to the survey area is relatively small at 79 km^2. The western end consists of a narrow coastal strip of between 100 m and 1.3 km in width, whereas the eastern end extends up to 8 km inland.

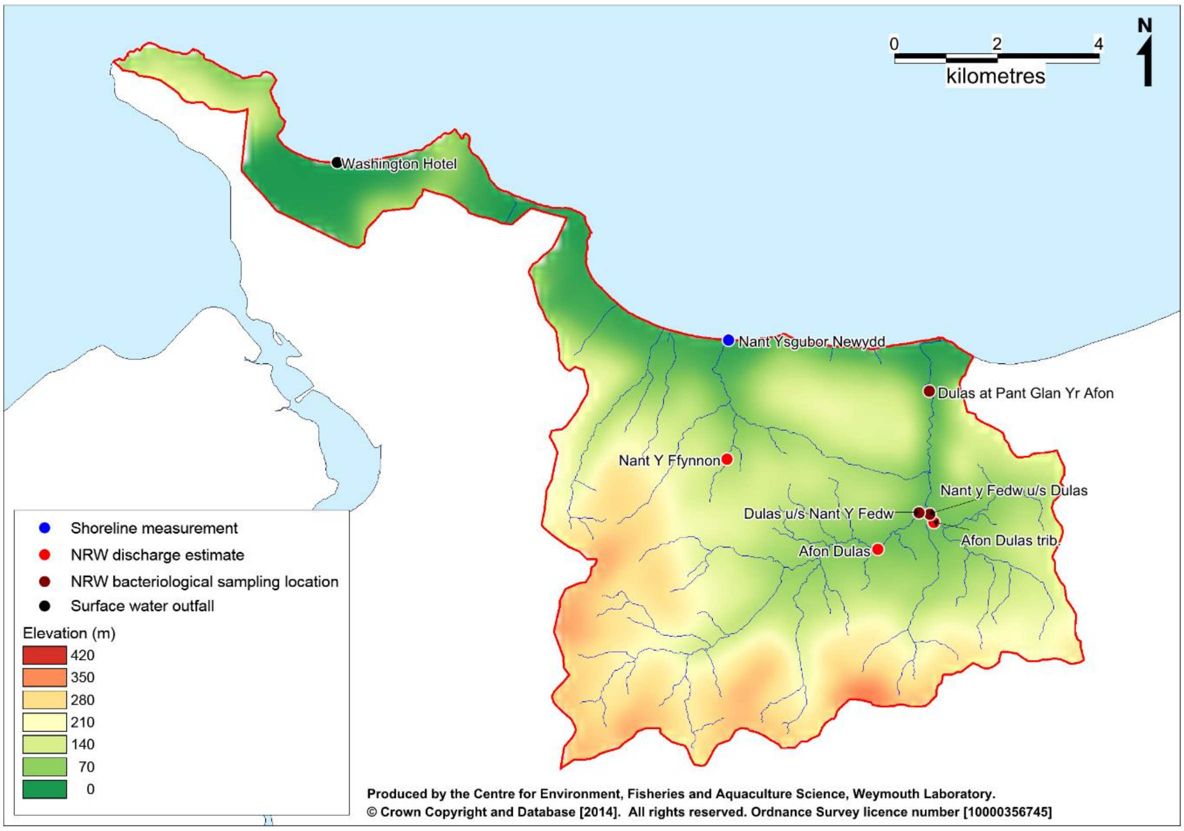

Figure VIII.1: Freshwater inputs to Colwyn Bay

The western end therefore only receives limited runoff, mostly from urban areas. The larger eastern half of the catchment is drained by a series of streams and small rivers. These drain a hilly catchment which is primarily used for sheep grazing in the upper reaches, with an urbanised strip along most of the coast. Hydrogeology maps indicate that the coastal strip is underlain by a mixture of low and moderate permeability geology, and the more inland area is of low permeability (NERC, 2012). This suggests that watercourses will generally respond rapidly to rainfall, a high proportion of which will run off, particularly for the more inland areas where rainfall is higher due to the topography.

There are no fixed flow gauging stations on any of the watercourses within the catchment. Natural Resources Wales provided estimates of discharge at two points on the Dulas catchment and one point on the very upper reaches of the Nant y Ffynnon, as well as some limited bacteriological testing results at three locations on the Dulas river system. During the shoreline survey the Nant y Ffynnon was sampled and a spot discharge measurement made, but only the areas in the immediate vicinity of the Llanddudno Pier and Rhos-on-Sea mussel beds were surveyed. This information is summarised in Table VIII.1 to Table VIII.3.

Table VIII.1: Shoreline survey measurements

Watercourse	Flow (m^3/s)	*E. coli* concentration (cfu/100 ml)	*E. coli* loading (cfu/day)
Nant y Ffynnon	0.019	1,200	1.93×10^{10}

Table VIII.2: Summary of watercourse bacteriological sampling results

Site	No.	Date of 1st sample	Date of last sample	Faecal coliforms (cfu/100ml)		
				Geomean	Min.	Max.
Dulas at Pant Glan Yr Afon	6	14/09/2011	22/12/2011	1,011.6	240	2,400
Dulas u/s Nant Y Fedw	2	14/09/2011	14/10/2011	715.8	610	840
Nant y Fedw u/s Dulas	6	14/09/2011	22/12/2011	3,069.0	440	56,000

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Table VIII.3: Estimates of discharge on watercourses draining to Colwyn Bay

Site	Mean daily flow (m^3/sec)	Q_{95} (m^3/sec)
Nant y Ffynnon	0.028	0.003
Afon Dulas trib.	0.111	0.011
Afon Dulas	0.046	0.005

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The largest watercourse in the area is the Dulas, which drains just under half of the catchment area, including the upper reaches where rainfall is higher. The combined mean discharge estimate for Afon Dulas and Afon Dulas trib., which between them represent about 75% of the catchment, is 0.157 m^3/sec. The average faecal coliform result at the furthest downstream sampling site on this watercourse (Dulas at Pant Glan Yr Afon) was just over 1,000 faecal coliforms/100 ml. Using this limited information, an approximate estimate of the average bacterial loading it generates is in the order of 2×10^{12} faecal coliforms/day. The second largest watercourse is the Nant y Ffynnon. The discharge estimate for this watercourse was made at a location in its very upper reaches, so is of little relevance. It was sampled and measured during the shoreline survey and was delivering an estimated bacterial loading of 1.9×10^{10} *E. coli*/day. At the time, the measured discharge was less than the mean discharge estimate for the station in its upper reaches. A further three small watercourses drain to Colwyn Bay west of Rhos-on-Sea. At the time of writing no information on their discharge rates or bacterial content was available. As well as these watercourses, there are likely to be several points where small amounts of surface runoff are discharged intermittently to the foreshore, from road drainage for example. The main surface water outfall in the Llandudno area is the Washington Outfall, located opposite the Washington Hotel, which is thought to receive misconnected sewage inputs (NRW, pers. comm.).

As well as significant day to day variation in discharge of land runoff in response to rainfall, some seasonality in average discharge rates is anticipated. Rainfall is higher on average during the autumn and early winter, and during the colder months of the year there is less evaporation and transpiration, and soils will tend to be more waterlogged. As such, discharge rates are likely to be higher on average during the colder months of the year. Whether this variation is associated with a corresponding variation in the loadings of faecal indicator bacteria delivered to coastal waters is uncertain.

Appendix IX. Hydrography

IX.1. Bathymetry

The survey area is a north facing, open coastal location at the south western extremity of Liverpool Bay. It is exposed to the open Irish Sea, with a fetch to the north of over 100 km, though relatively sheltered from the prevailing south west wind. It consists of a series of headlands (Great Ormes Head, Little Ormes Head, and Rhos Point, between which lie slightly indented sandy bays. The bathymetry is uncomplicated, with a gently sloping intertidal area of up to about 500 m in width, which continues to slope gently in subtidal areas. The gradient of the subtidal seabed becomes shallower to the east of Rhos Point. The depth increases more rapidly and there is little or no intertidal at Great Ormes Head and, to a lesser extent, at Little Orme. Tidal streams are likely to accelerate around these headlands. Given its open coastal location there is high potential for dilution and dispersion of contamination from shoreline sources, although this is likely to decrease slightly towards the eastern end of the survey area. The offshore sandbanks are oriented roughly parallel to the coastline, suggesting that tidal streams run parallel to the coast.

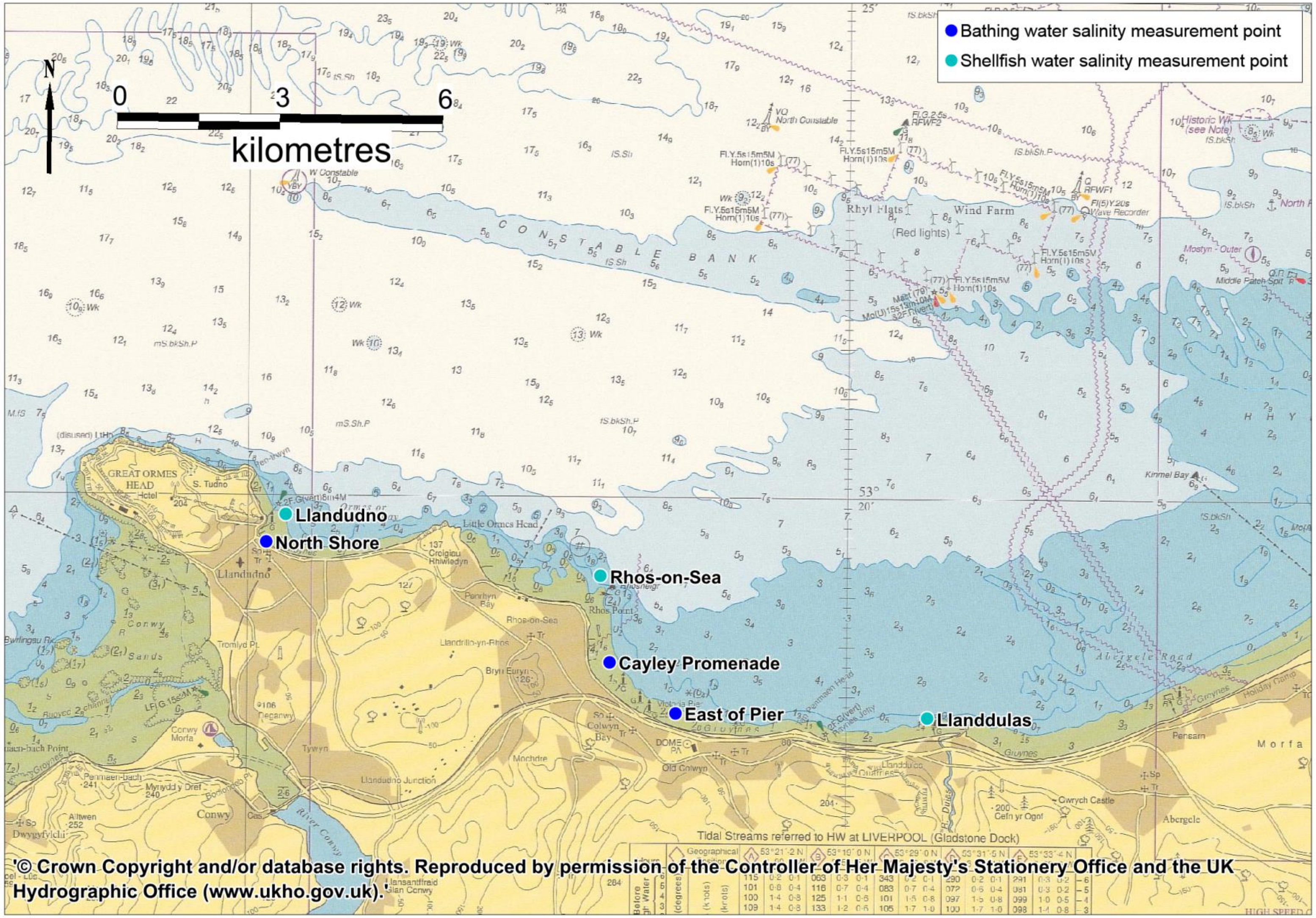

Figure IX.1: Bathymetry of the survey area

IX.2. Tides and Currents

Water circulation patterns within estuaries and coastal waters are driven by tides, which are regular and predictable, with more dynamic and variable effects from freshwater inputs, barometric pressure and winds superimposed on this.

Table IX.1: Tidal levels and ranges at Colwyn Bay

	Height above chart datum (m)				Range (m)	
Port	**MHWS**	**MHWN**	**MLWN**	**MLWS**	**Spring**	**Neap**
Llanddudno	7.62	5.88	2.24	0.5	7.12	3.64
Colwyn Bay	7.8	6.10	-	-	-	-

Data from Admiralty TotalTide©

The tidal range is large, and this will drive extensive water movements through the area across the twice daily high/low tidal cycle. As the range on spring tides is roughly twice that of neap tides, current velocities will be significantly higher on spring tides, increasing the distance over which sources of contamination may impact, but also providing increased dilution.

Tidal streams are bidirectional, flooding along the coast in an easterly direction and ebbing in a westerly direction. Contamination from shoreline sources will therefore travel parallel to the coast, impact either side of their locations, and the magnitude of their impacts will decrease with distance as the plume spreads and becomes more diluted. The situation may be slightly more complicated at the western end of Llandudno Bay, as eddies may form in the lee of Great Ormes Head.

There are no tidal diamonds in Figure IX.1. Modelling studies indicate peak current velocities range from just under 0.5 m/s in Colwyn Bay to around 0.8 m/s to the north of Great Ormes Head. Predicted tidal excursions ranged from about 5 km in Colwyn Bay to about 8 km off Great Ormes Head (Centrica, 2014). This gives an approximate indication of the distance over which sources of contamination are likely to impact over. In the nearshore and intertidal areas the rates of travel are likely to be slower due to friction.

Superimposed on tidally driven currents are the effects of freshwater inputs and wind. There is little in the way of freshwater inputs to this coast, and the coastal waters here are unenclosed so density effects will not modify water circulation. A series of salinity measurements made under the bathing and shellfish waters monitoring programmes confirm that there is little freshwater influence (Figure IX.2).

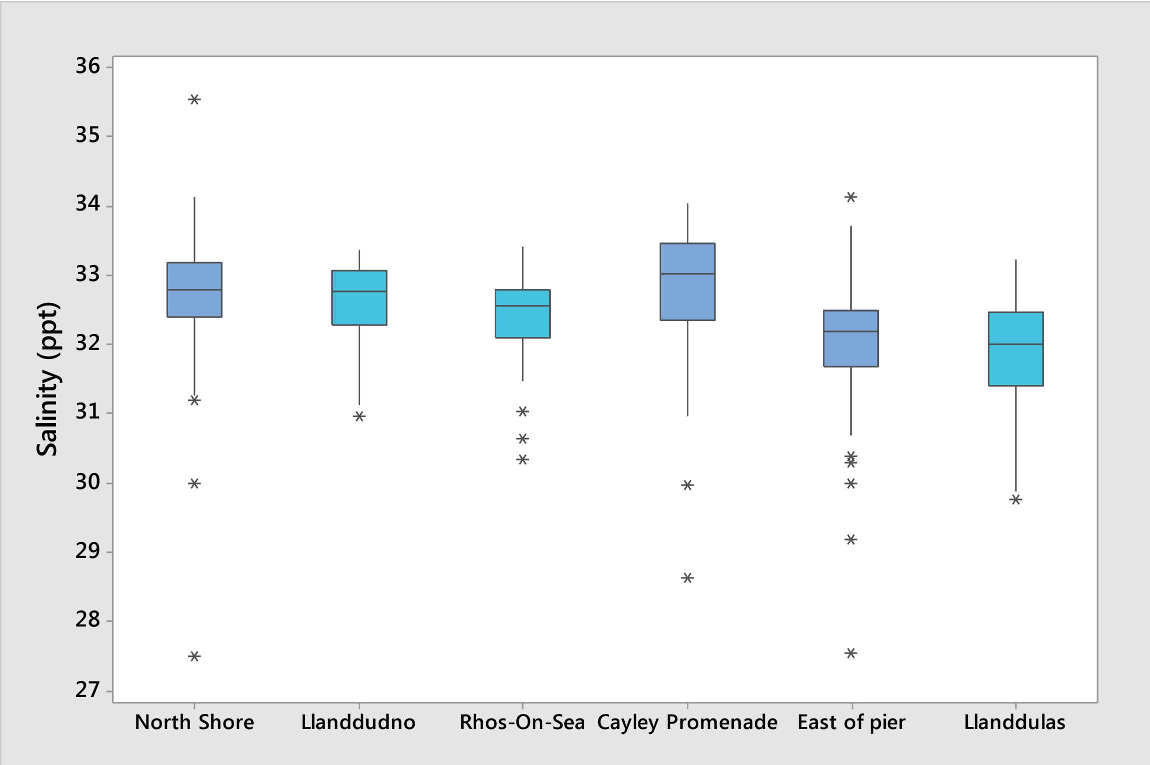

Figure IX.2: Boxplot of salinities from bathing waters (darker blue) and shellfish waters (lighter blue) monitoring points at Colwyn Bay

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Average salinities approaching that of full strength seawater were recorded at all locations. A very slight decrease in average salinity from west to east is apparent, as may be expected given the locations of the larger freshwater inputs. A density related effect of potential relevance to the fishery is that sewage discharged from the Ganol STW outfall, being less dense than the receiving seawater, will tend to rise to the surface.

Strong winds will modify surface currents. Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s. These currents will create return currents, either lower down the water column or along sheltered margins. The survey area is most exposed to winds from the north. Exact effects are dependent on the wind speed and direction and the state of the tide at the time and so a great range of scenarios may arise. The prevailing south westerly wind direction will tend to advect contamination in the upper part of the water column away from the shore and out towards the Irish Sea, although the adjacent land provides shelter from such winds. Northerly winds will tend to advect any buoyant plume from Ganol STW towards the shore. As well as driving surface currents, onshore winds will create wave action. This may resuspend any contamination held within the sediments of the intertidal zone, temporarily increasing levels of contamination within the water column until it is carried away by the tides.

Appendix X. Microbiological data: Water

X.1. Bathing Waters

There are two bathing waters around Colwyn Bay, originally designated under the Directive 76/160/EEC (Council of the European Communities, 1975). There are also three shellfish waters originally designated under Directive 2006/113/EC (European Communities, 2006) which has since been replaced by the Water Framework Directive. The locations of associated monitoring points are shown in Figure X.1. The bathing water monitoring point at Colwyn Bay was moved from East of Pier to Cayley Promenade in 2011 due to a change in location used by bathers.

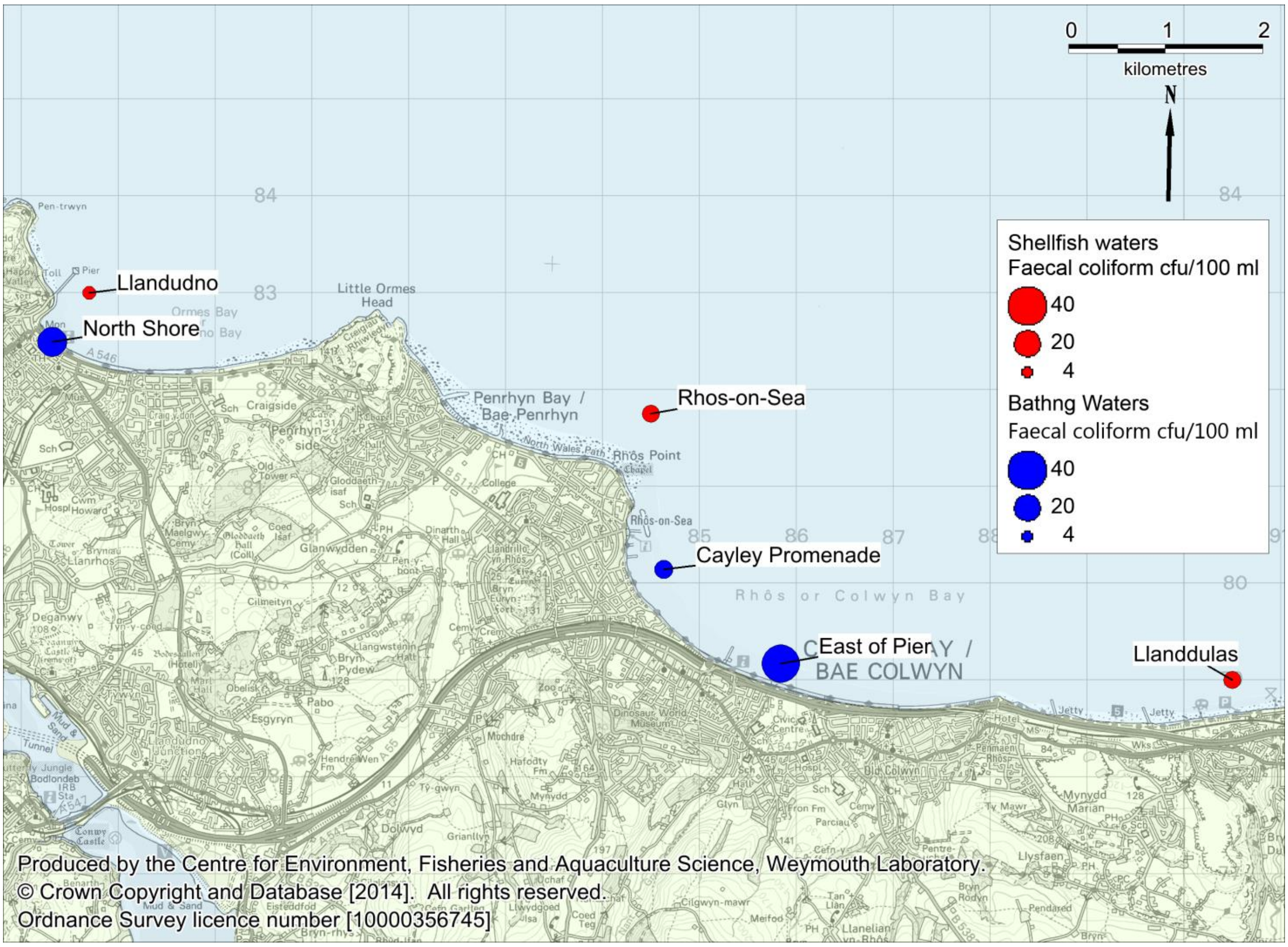

Figure X.1: Location of designated bathing and shellfish waters monitoring points in the around Colwyn Bay

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Due to changes in the analyses of bathing water quality by Natural Resources Wales from 2012, faecal coliform data from 2004 to 2011 are presented separately from post-2012 *E. coli* data. Summaries of the faecal coliform and *E. coli* data are presented in Table X.1 and Table X.2 respectively. Given the relatively restricted number of results available post 2012, only the extended 2004-2011 data were used in the further analyses.

Table X.1: Summary statistics for bathing waters faecal coliforms results, 2004-2011 (cfu/100ml).

Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1,000
North Shore	162	07/05/2004	18/09/2011	24.4	<2	1,120	15.4	1.2
Cayley Promenade	40	04/05/2010	18/09/2011	10.8	<2	423	5.0	0.0
East of Pier	142	07/05/2004	21/09/2010	38.0	<2	4,000	22.5	2.1

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Table X.2: Summary statistics for bathing waters *E. coli* results, 2012 (cfu/100ml).

Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1,000
North Shore	46	08/05/2012	12/06/2014	18.7	<10	1,064	8.7	2.2
Cayley Promenade	46	08/05/2012	12/06/2014	17.5	<10	770	10.9	0.0

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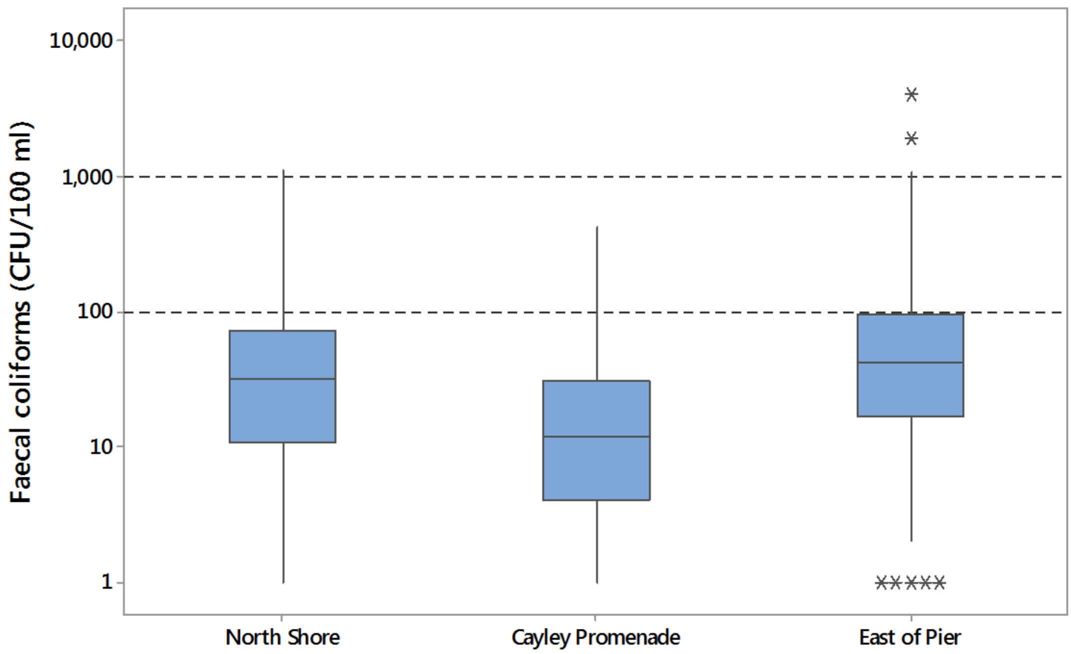

Figure X.2: Box-and-whisker plots of all faecal coliforms results by site
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The East of Pier sampling site had the highest geometric mean and maximum faecal coliform concentrations, while Cayley Promenade, had the lowest geometric mean and maximum faecal coliform concentrations. A one-way ANOVA test showed that there was a significant difference in faecal coliform concentrations between sites (p<0.001), and post-ANOVA Tukey tests showed that Cayley Promenade had significantly lower concentrations than both other sites and East of Pier had significantly higher concentrations than both other sites.

Correlations (Pearson's) were run between samples at the sites that shared sampling dates, and therefore environmental conditions, on at least 20 occasions. There was a significant correlation between North Shore and East of Pier (r=0.186, p=0.029) but not between Cayley Promenade and either of the other sites. Given the geographical separation between North Shore and East of Pier and the lack of a significant correlation between Cayley

Promenade and East of Pier, which are located in relatively close proximity to each other it is likely that these sites are subject to contamination from different sources.

Overall temporal pattern in results

The overall variation in faecal coliform levels found at bathing water sites over time is shown in Figure X.3.

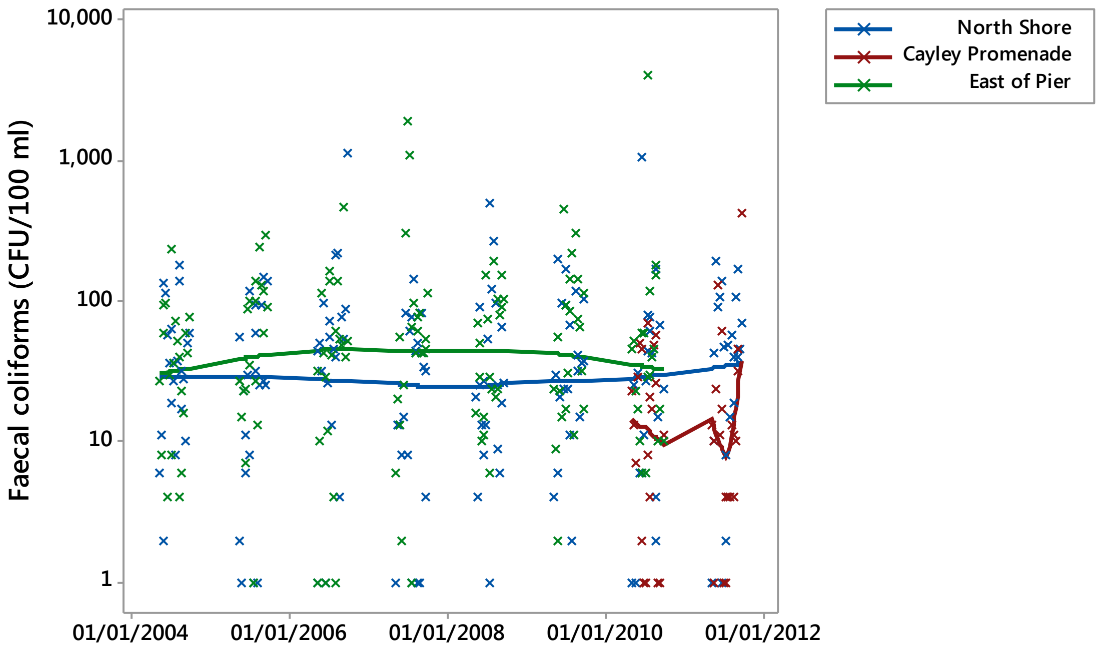

Figure X.3: Scatterplot of faecal coliform results for bathing waters in Colwyn Bay overlaid with loess lines.

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Faecal coliform levels have remained fairly stable on average since 2004.

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 the bathing waters sampling points. Correlation coefficients are presented in Table X.3 with significant correlations highlighted in yellow.

Table X.3: 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**
North Shore	0.360	<0.001	0.229	<0.001
Cayley Promenade	0.107	0.656	0.114	0.620
East of Pier	0.321	<0.001	0.038	0.814

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Figure X.4 presents polar plots of $\log_{10}$ faecal coliform results against tidal states on the high/low cycle for the correlations indicating a statistically significant effect. High water at Colwyn Bay is at 0° and low water is at 180°. Results of 100 faecal coliform cfu/100 ml or less are plotted in green, those from 101 to 1,000 are plotted in yellow, and those exceeding 1,000 are plotted in red.

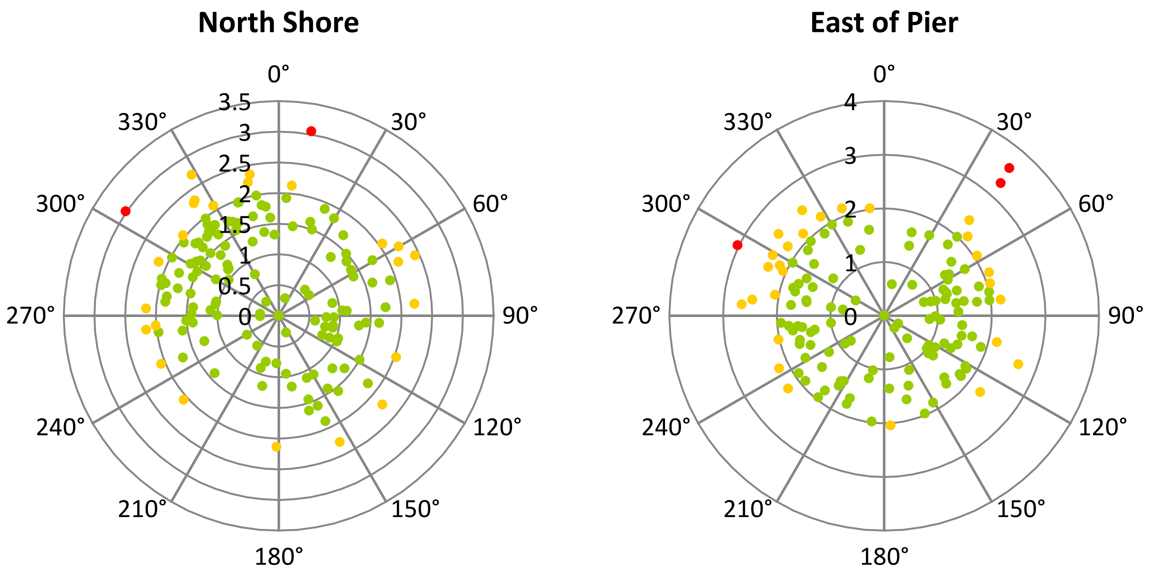

Figure X.4: Polar plots of log10 faecal coliform results (cfu/100 ml) against high/low tidal state.
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At both sites there appeared to be a tendency for lower results around low water.

Figure X.5 presents polar plots of $\log_{10}$ faecal coliform results against the spring/ neap tidal cycle for each RMP. Full/new moons occur at 0º, and half moons occur at 180º, and the largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 100 faecal coliform cfu/100 ml or less are plotted in green, those from 101 to 1,000 are plotted in yellow, and those exceeding 1,000 are plotted in red.

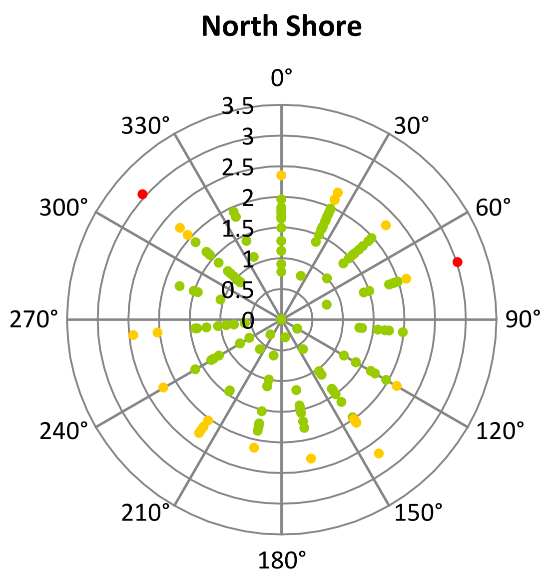

Figure X.5: Polar plots of log10 faecal coliform results (cfu/100 ml) against spring/neap tidal state.
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Results were higher on average on increasing and larger tides.

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 Colwyn Bay weather station (Appendix VI for details) over various periods running up to sample collection and faecal coliform results. These are presented in Table X.4 and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table X.4: Spearmans Rank correlation coefficients for faecal coliforms results against recent rainfall

	Site	North Shore	Cayley Promenade	East of Pier
	n	162	40	142
24 hour periods prior to sampling	1 day	0.166	0.640	0.344
	2 days	0.200	0.110	0.367
	3 days	0.155	-0.228	0.036
	4 days	0.061	-0.048	0.124
	5 days	0.082	-0.049	0.101
	6 days	0.034	0.019	0.068
	7 days	0.107	-0.080	0.153
Total prior to sampling over	2 days	0.226	0.458	0.414
	3 days	0.228	0.184	0.305
	4 days	0.197	0.182	0.307
	5 days	0.215	0.148	0.324
	6 days	0.205	0.134	0.304
	7 days	0.226	-0.031	0.299

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Faecal coliform concentrations at both North Shore and East of Pier were affected to similar degrees by rainfall. At both sites rainfall affected faecal coliform concentrations within 24 hours and these effects were no longer apparent after two or three days. The influence of a rainfall event was more short lived at Cayley Promenade, where it persisted for one day.

Salinity

Salinity was recorded on most sampling occasions. Figure X.6 shows scatter-plots between faecal coliforms and salinity. Pearson's correlations were run to determine the effect of salinity on faecal coliforms at the bathing water sites.

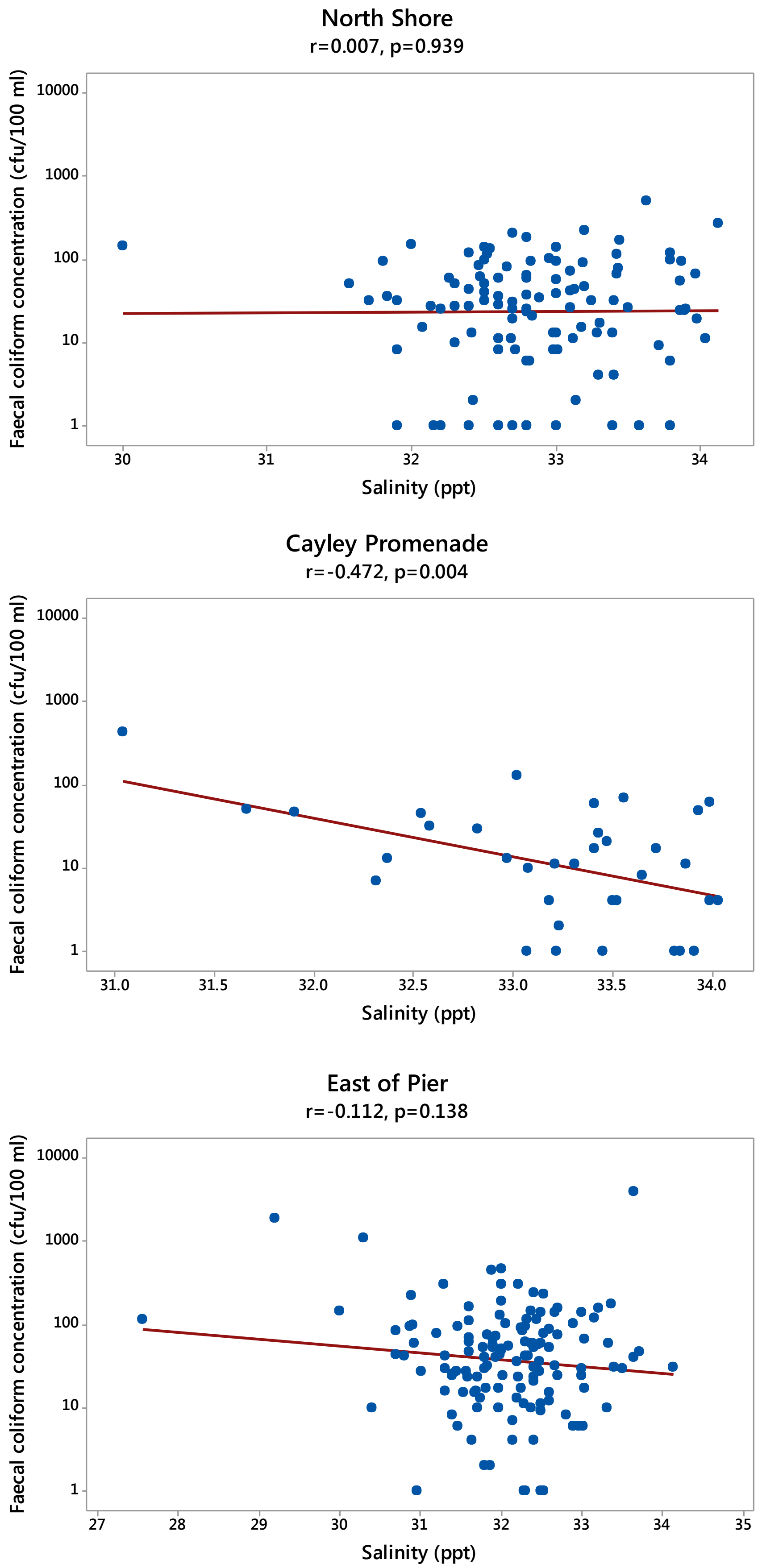

Figure X.6: Scatter-plots of salinity against faecal coliform concentration.
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Faecal coliform levels at Cayley Promenade correlated significantly with salinity. This suggests that land runoff is a significant influence at this site only.

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) relevant to the Colwyn Bay production area. Figure X.1 shows the location of these sites. Table X.5 presents summary statistics for bacteriological monitoring results and Figure X.7 presents a boxplot of faecal coliform levels from the monitoring point.

Table X.5: Summary statistics for shellfish waters faecal coliform results, 2004 to 2013 (cfu/100ml).

Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1,000
Llandudno	39	04/02/2004	13/11/2013	5.8	<2	84	0.0	0.0
Rhos-on-Sea	40	04/02/2004	13/11/2013	9.4	<2	900	15.0	0.0
Llanddulas	45	04/02/2004	10/07/2013	9.7	<2	310	13.3	0.0

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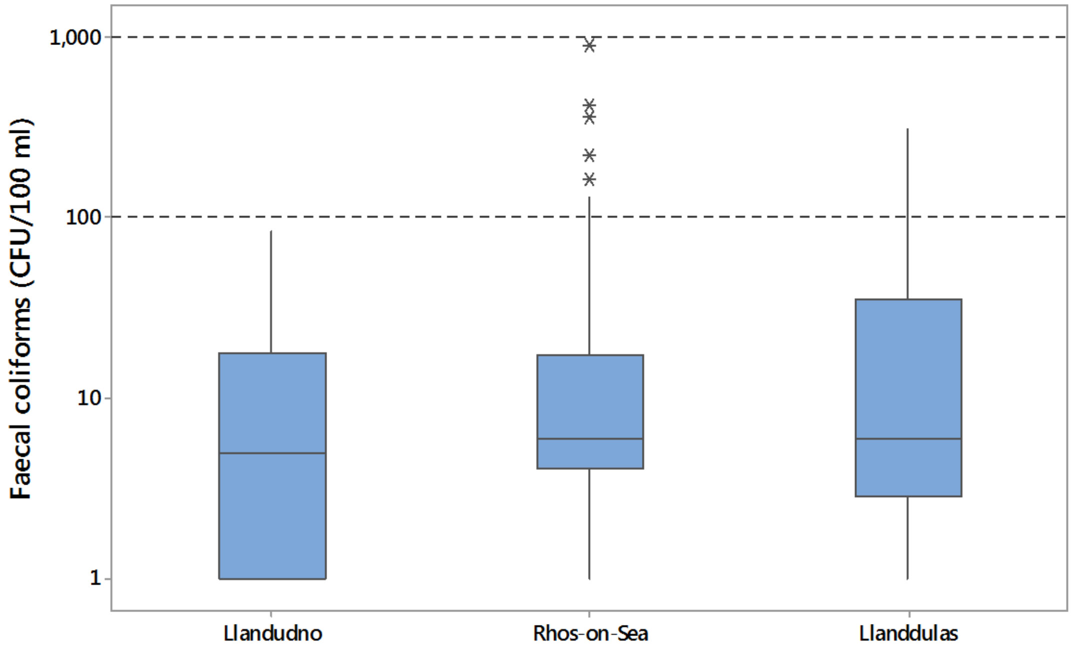

Figure X.7: Box-and-whisker plots of all faecal coliforms results
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None of the sites had any samples exceeding 1,000 faecal coliforms cfu/100 ml. While Llandudno had the lowest geometric mean, a one-way ANOVA test showed that there were no significant differences between sites (p=0.291).

Correlations (Pearson's) were run between samples at the sites that shared sampling dates, and therefore environmental conditions, on at least 20 occasions. All sites correlated significantly ($p<0.05$) indicating that they share similar contamination sources.

Overall temporal pattern in results

The overall variation in faecal coliform levels found at shellfish water sites over time is shown in Figure X.8.

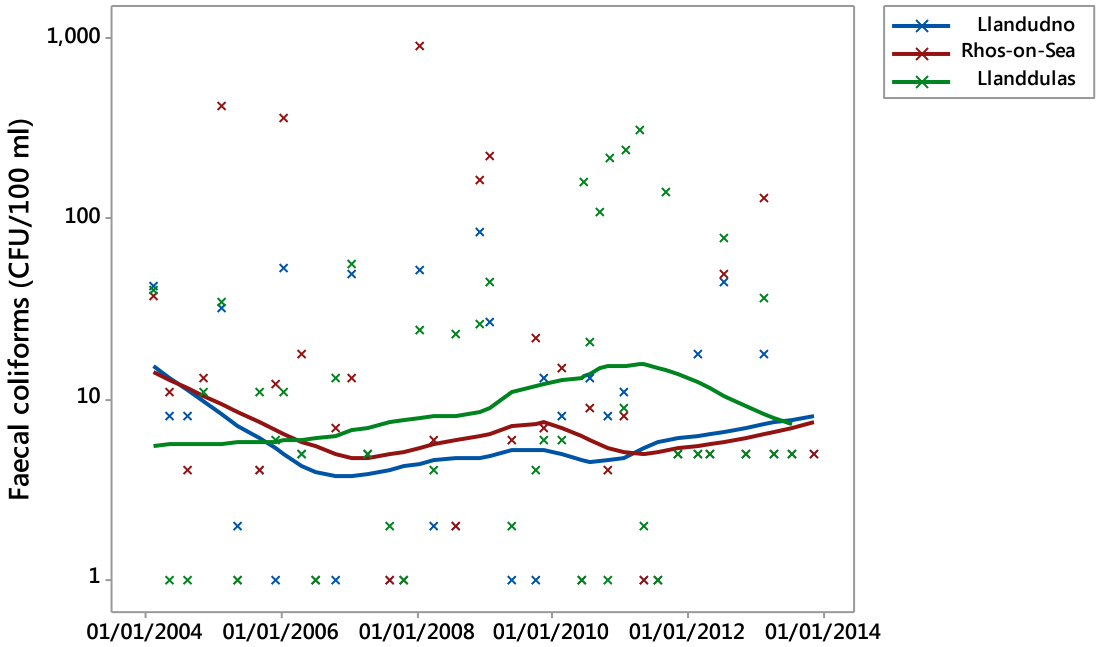

Figure X.8: Scatterplot of faecal coliform results for shellfish waters by date, overlaid with loess lines
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Faecal coliform concentrations have remained fairly stable since 2004.

Seasonal patterns of results

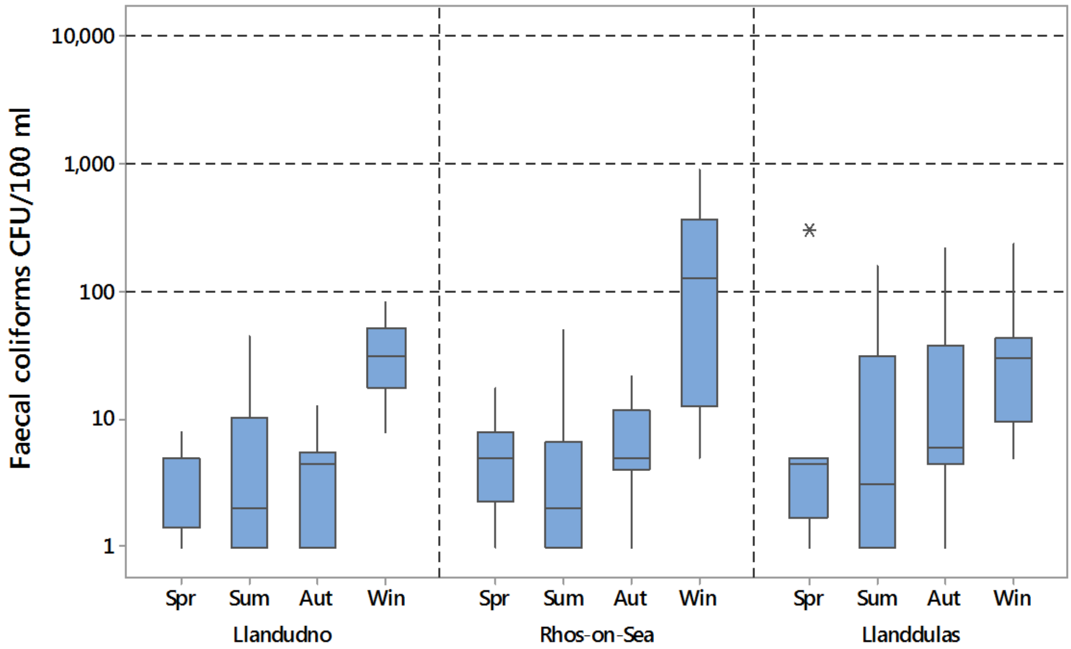

Figure X.9: Boxplot of faecal coliform results by site and season
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One-way ANOVA tests showed that there were significant variations in faecal coliform concentrations between seasons at Llandudno and Rhos-on-Sea ($p<0.001$ in both cases) but not at Llanddulas ($p=0.078$). Post-hoc Tukey tests showed that faecal coliform levels were significantly higher in winter than in any other season at both Llandudno and Rhos-on-Sea.

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 for each of these shellfish waters sampling points. Correlation coefficients are presented in Table X.6, with statistically significant correlations highlighted in yellow.

Table X.6: Circular linear correlation coefficients (r) and associated p values for faecal coliform results against the high low and spring/neap tidal cycles

Site Name	High/low tides		Spring/neap tides	
	r	p	r	p
Llandudno	0.190	0.272	0.177	0.325
Rhos-on-Sea	0.298	0.037	0.270	0.067
Llanddulas	0.318	0.014	0.409	0.001

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Figure X.10 presents polar plots of $\log_{10}$ faecal coliform results for those sites with significant correlations against tidal states on the high/low cycle. High water at Colwyn Bay 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.

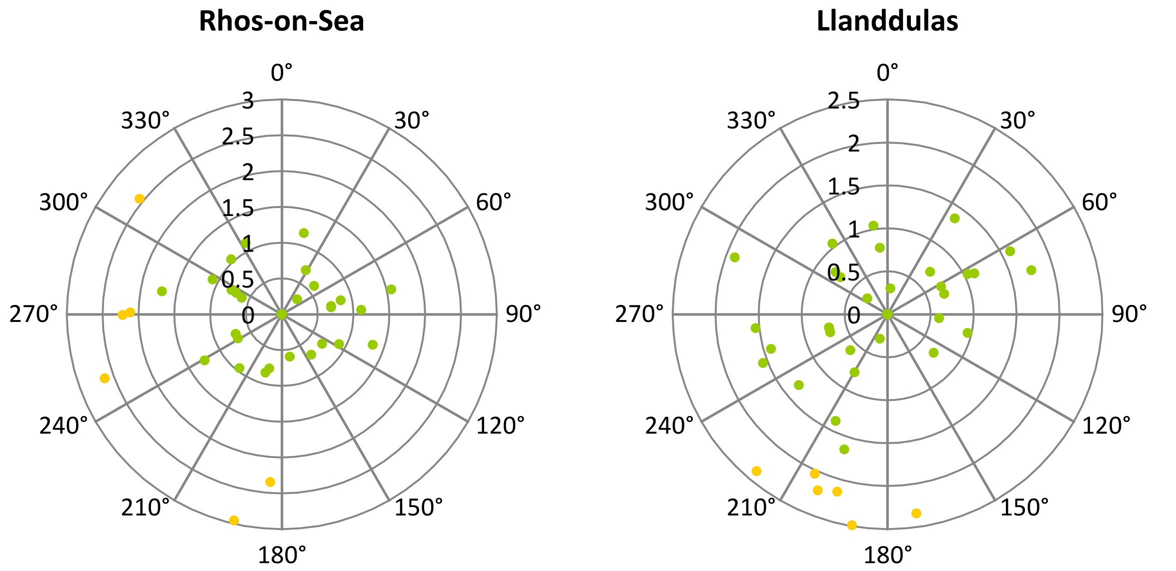

Figure X.10: Polar plots of log_{10} faecal coliforms against tidal state on the high/low tidal cycle for shellfish waters monitoring points with significant correlations

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Higher results tended to occur in samples collected during the flood tide at Rhos-on-Sea suggesting that there is likely to be a significant contamination source to the west. At Llanddulas, higher results tended to be obtained around low water indicating that there may be a contamination source that is nearby that is not subject to a large degree of dilution at these times.

Figure X.11 presents polar plots of faecal coliform results against the lunar spring/neap cycle, where a statistically significant correlation was found. 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.

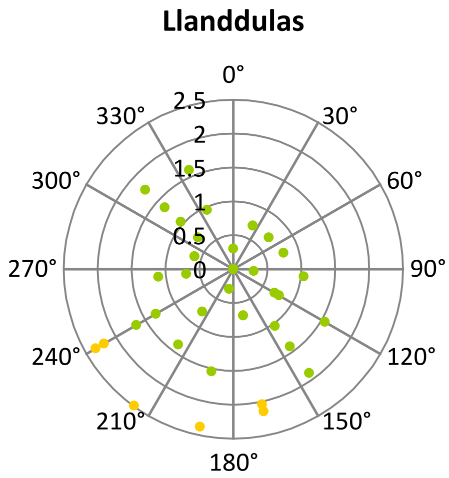

Figure X.11: Polar plots of log10 faecal coliforms against tidal state on the spring/neap tidal cycle for shellfish waters monitoring points with significant correlations

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Higher results tended to occur during the smaller tides indicating that the contamination sources are fairly close to the sampling point. During the larger tides it is likely that there is a larger degree of mixing and dilution, leading to lower results.

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 Colwyn Bay weather station (Appendix VI for details) over various periods running up to sample collection and faecal coliform results. These are presented in Table X.7 and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table X.7: Spearman's Rank correlation coefficients for faecal coliform results against recent rainfall

	Site	Llandudno	Rhos-on-Sea	Llanddulas
	n	39	40	45
24 hour periods prior to sampling	1 day	0.303	0.313	0.274
	2 days	0.258	0.316	0.320
	3 days	0.268	0.411	0.297
	4 days	0.008	-0.059	-0.095
	5 days	0.094	-0.139	-0.147
	6 days	0.230	0.237	0.263
	7 days	0.032	-0.078	-0.061
Total prior to sampling over	2 days	0.249	0.259	0.303
	3 days	0.324	0.435	0.347
	4 days	0.222	0.272	0.218
	5 days	0.23	0.202	0.113
	6 days	0.228	0.192	0.133
	7 days	0.236	0.187	0.116

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Rainfall had very little influence on faecal coliform concentrations at Llandudno. At Rhos-on-Sea, there was a significant effect on faecal coliform concentrations 24 hours after rainfall. At Llanddulas, there was a significant effect on faecal coliform concentrations 48 hours after rainfall at Rhos-on-Sea there was a significant effect after 24 hours. At both these locations the effects were no longer apparent after 3 days.

Influence of salinity

Salinity was recorded on most sampling occasions. Figure X.12 shows scatter-plots between faecal coliforms and salinity. Pearson's correlations were run to determine the effect of salinity on faecal coliforms at the shellfish water sites.

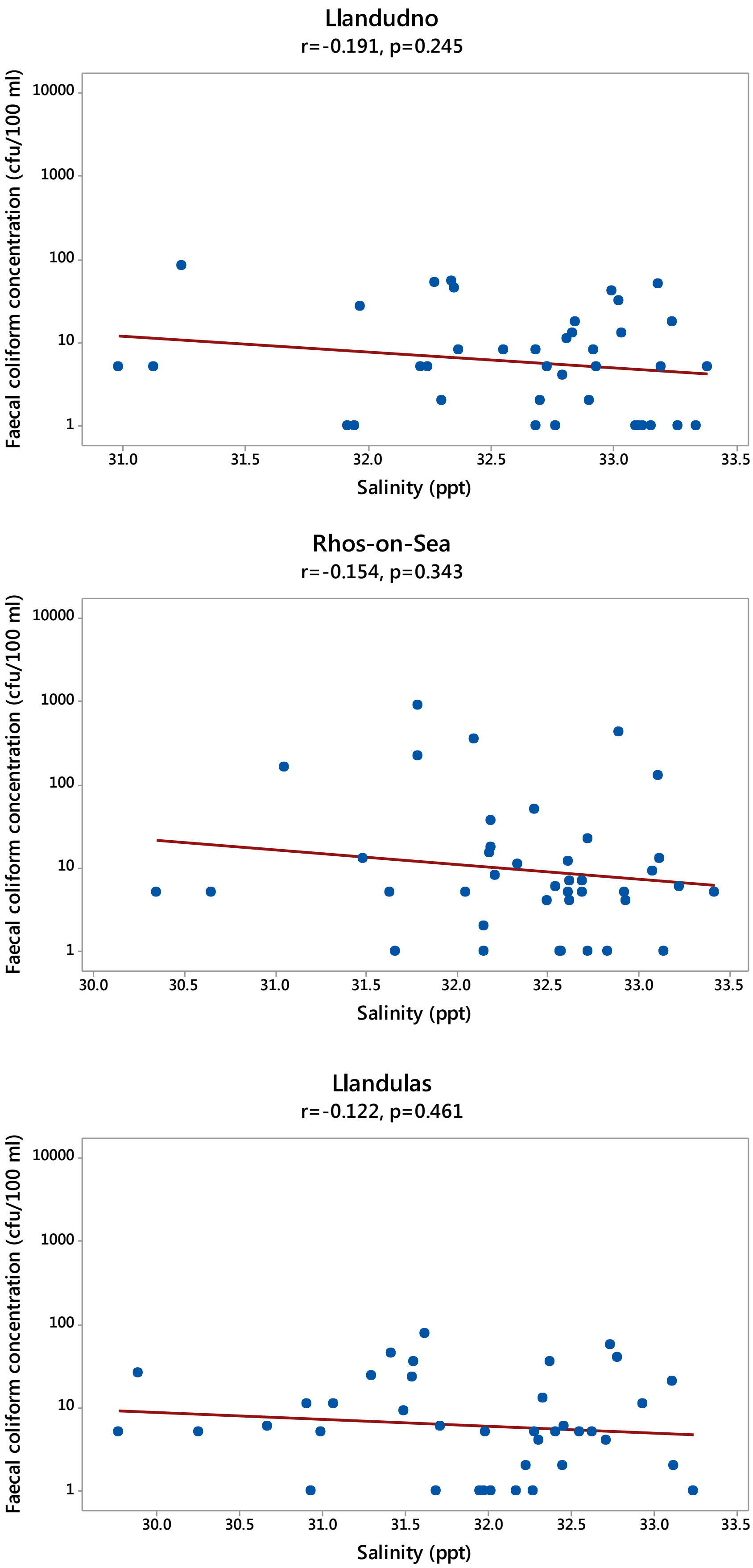

Figure X.12: Scatter-plots of salinity against faecal coliform concentration.
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There were no significant effects of salinity on faecal coliform concentrations at any of the sites, suggesting that land runoff is not a major influence.

X.3. Natural Resources Wales Investigations

A small number of seawater samples were taken from various intertidal locations in the summer and autumn of 2011 to investigate spatial variation in levels of contamination in the area. Locations sampled are shown in Figure X.13 and results are summarised in Table X.8.

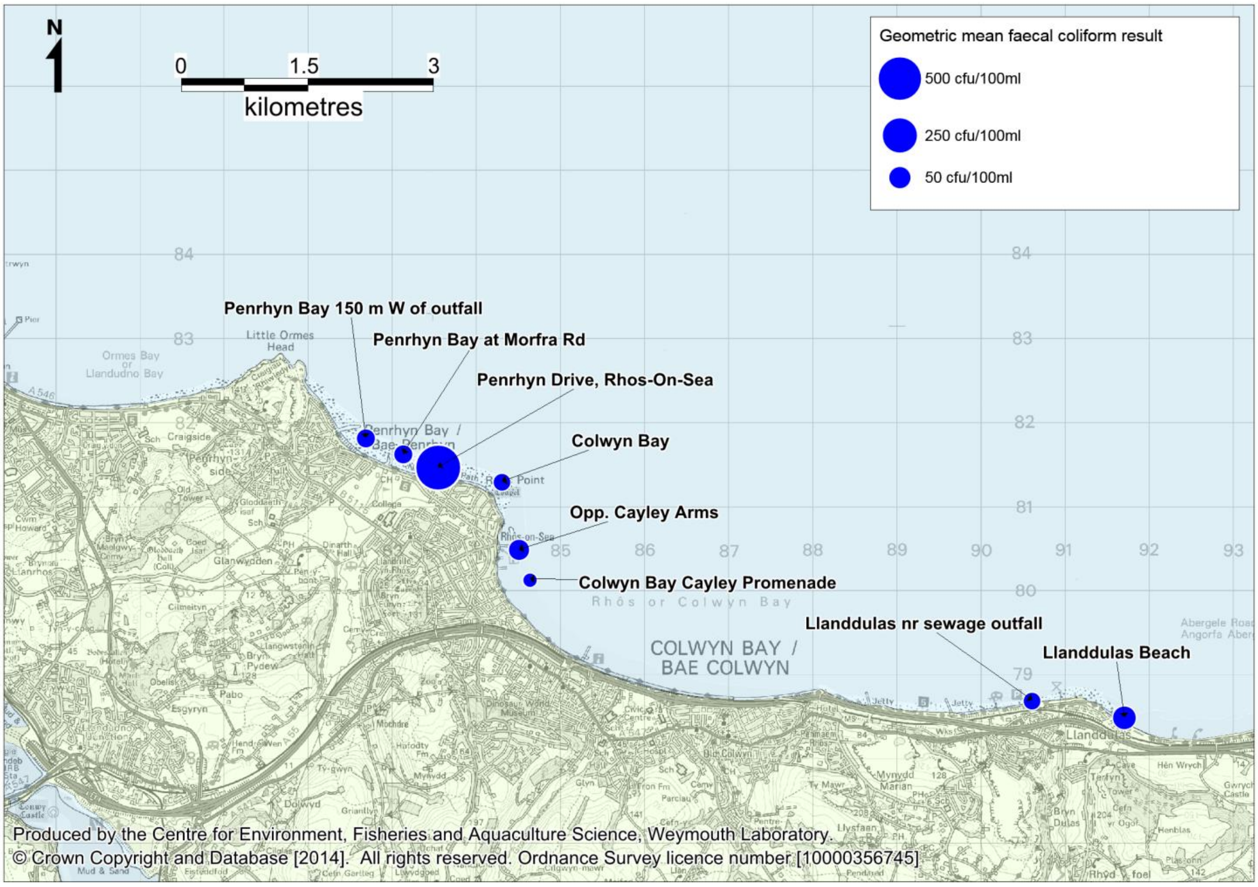

Figure X.13: Sampling locations and geometric mean faecal coliform results
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Table X.8: Summary statistics for bacteriological investigation sampling results, 2011

Name	No.	Date of 1st sample	Date of last sample	Faecal coliforms (cfu/100ml)		
				Geomean	Min.	Max.
Colwyn Bay	4	15/07/2011	14/10/2011	21.0	2	63
Colwyn Bay Cayley Promenade	20	03/05/2011	18/09/2011	11.2	<2	423
Llanddulas Beach	2	14/09/2011	14/10/2011	56.0	54	58
Llanddulas nr sewage outfall	2	14/09/2011	14/10/2011	21.6	13	36
Opp. Cayley Arms	4	15/07/2011	14/10/2011	39.7	36	42
Penrhyn Bay 150 m W of outfall	3	02/09/2011	14/10/2011	26.6	18	42
Penrhyn Bay at Morfra Rd	24	04/05/2011	14/10/2011	26.7	<2	462
Penrhyn Drive, Rhos-On-Sea	4	15/07/2011	14/10/2011	524.8	70	4,400

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These limited results suggest that there is a significant localised hotspot of contamination at the Penrhyn Drive site, about 300 m to the west of the Rhos-On-Sea mussel bed.

Appendix XI. Microbiological Data: Shellfish Flesh

XI.1. Summary statistics and geographical variation

There are four shellfish hygiene RMPs within the survey area that have been sampled between 2004 and 2014, all of which are for mussels. The geometric mean results of shellfish flesh monitoring from all RMPs sampled from 2004 onwards are presented in Figure XI.1. Summary statistics are presented in Table XI.1 and boxplots for sites are show in Figure XI.2. Llanddulas was sampled on fewer than 10 occasions and so will not be considered further.

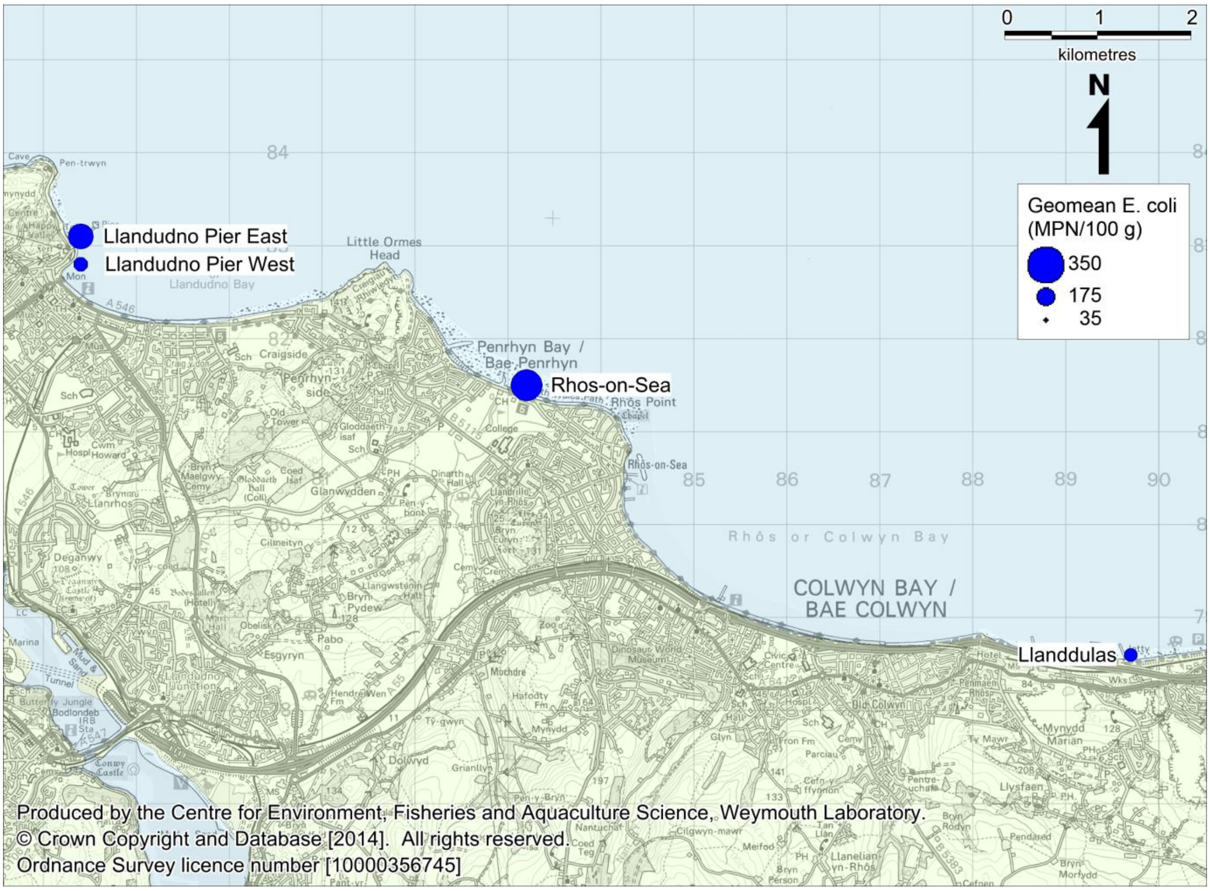

Figure XI.1: Mussel RMPs active since 2004.

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

Site	Species	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 230	% over 4,600
Llandudno Pier East	Mussels	122	29/01/2004	16/04/2014	244.6	<20	5,400	56.6	0.8
Llandudno Pier West	Mussels	122	29/01/2004	16/04/2014	138.5	<20	3,500	39.3	0.0
Rhos-on-Sea	Mussels	122	29/01/2004	16/04/2014	301.7	<20	9,100	54.9	3.3
Llanddulas	Mussels	8	29/01/2004	11/08/2004	128.4	20	750	37.5	0.0

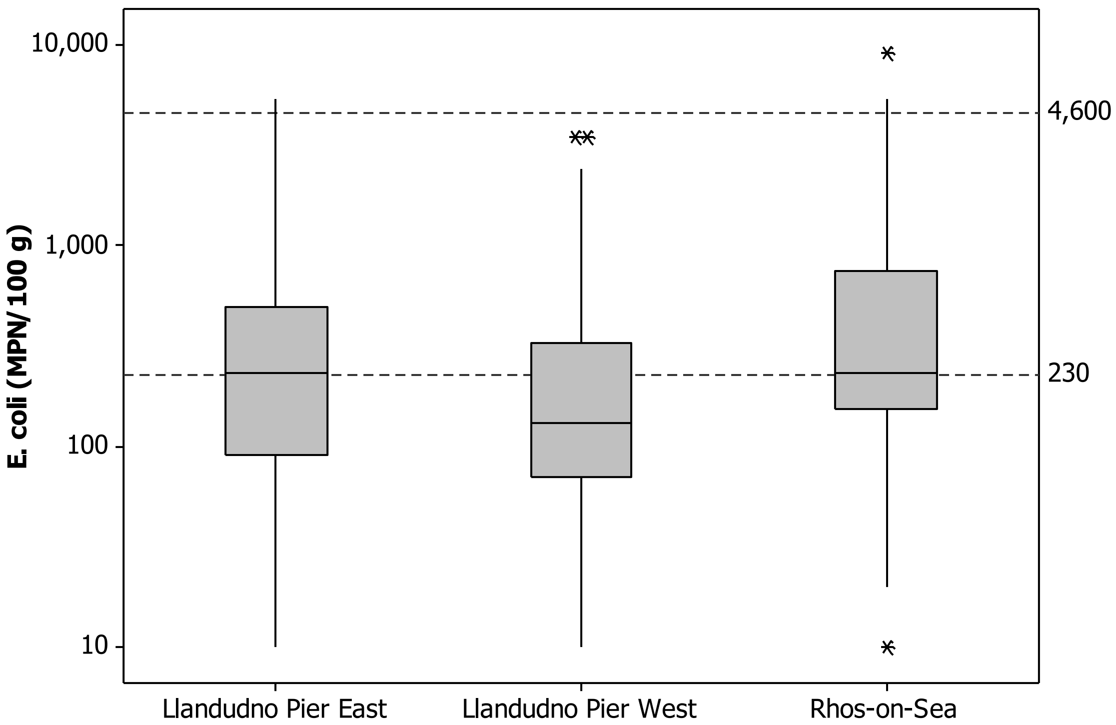

Figure XI.2: Boxplots of *E. coli* results from mussel RMPs from 2004 onwards.

E. coli levels exceeded 230 MPN/100 g at all sites. *E. coli* levels did not exceed 4,600 MPN/100 g in 10% or more samples or 46,000 MPN/100 g in any samples at any of the RMPs. A one-way ANOVA test showed that there were significant differences in *E. coli* levels between sites (p<0.001). A post ANOVA Tukey test showed that *E. coli* levels were significantly higher at Llandudno Pier East and Rhos-on-Sea than at Llandudno Pier West.

Comparisons of RMPs were carried out on a pair-wise basis by running correlations (Pearson's) between sites that shared sampling dates, and therefore environmental conditions. There were significant correlations in *E. coli* levels between Llandudno Pier East and West (r=0.468, p<0.001), and between Llandudno Pier West and Rhos-on-Sea (r=0.287, p=0.001). This suggests that these sites share similar sources of contamination.

XI.2. Overall temporal pattern in results

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

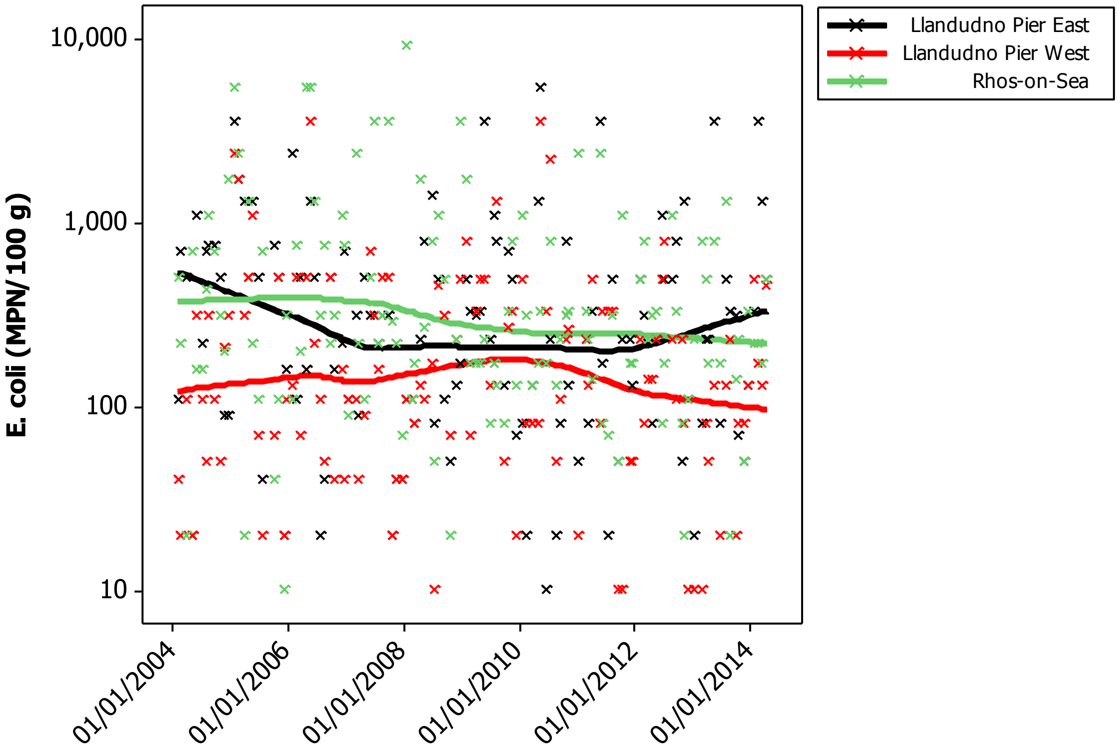

Figure XI.3: Scatterplot of *E. coli* results for mussels overlaid with loess line.

E. coli levels have remained stable at all sites since 2004.

XI.3. Seasonal patterns of results

The seasonal patterns of results from 2004 to 2014 were investigated by species and RMP. Figure XI.4 shows the variation in *E. coli* levels between seasons at different RMPs.

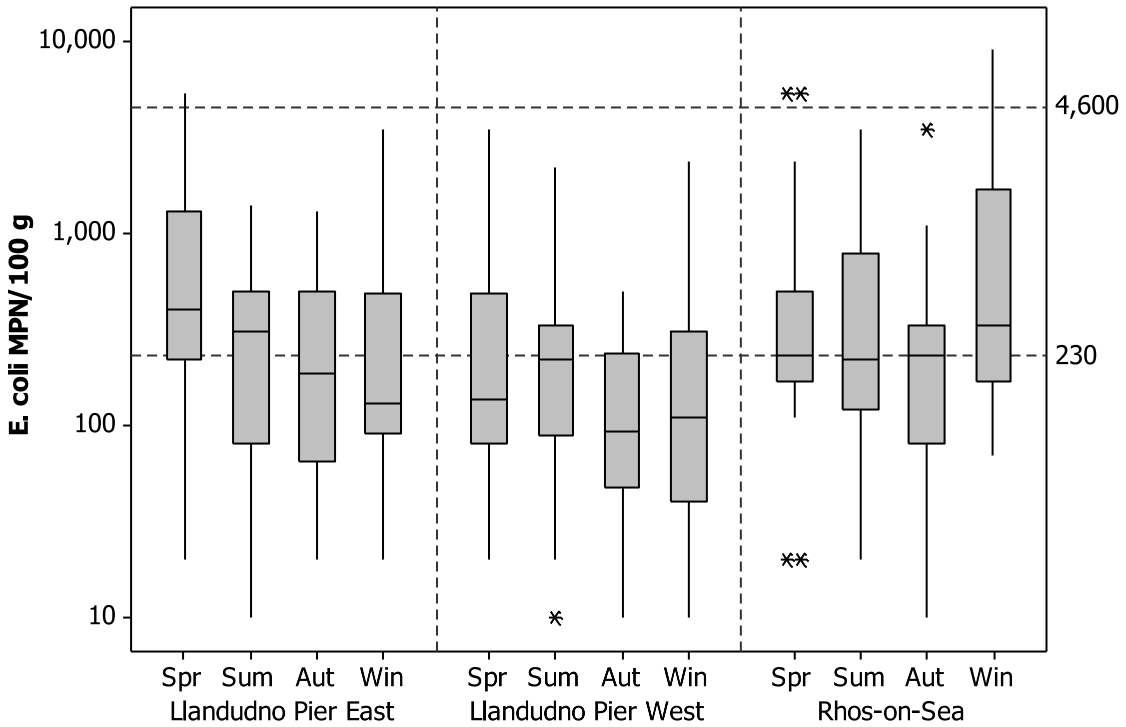

Figure XI.4: Boxplot of *E. coli* results for mussels by RMP and season

At Llandudno Pier East and Rhos-on-Sea, there were significant differences in *E. coli* levels between seasons (One-way ANOVA, p=0.035 and 0.032 respectively). Post ANOVA Tukey tests showed that there were significantly higher levels of *E. coli* in spring than in autumn at Llandudno Pier East, and there were significantly higher *E. coli* levels in winter than in autumn at Rhos-on-Sea.

XI.4. Influence of tide

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

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

	High/low tides		Spring/neap tides	
Site Name	**r**	**p**	**r**	**p**
Llandudno Pier East	0.201	0.008	0.090	0.381
Llandudno Pier West	0.114	0.212	0.280	0.000
Rhos-on-Sea	0.058	0.674	0.191	0.013

Figure XI.5 presents polar plots of $\log_{10}$ *E. coli* results against tidal states on the high/low cycle for the correlations indicating a statistically significant effect. High water at Colwyn Bay is at 0° and low water is at 180°. Results of 230 *E. coli* MPN/100 g or less are plotted in green, those from 231 to 4,600 are plotted in yellow, and those exceeding 4,600 are plotted in red.

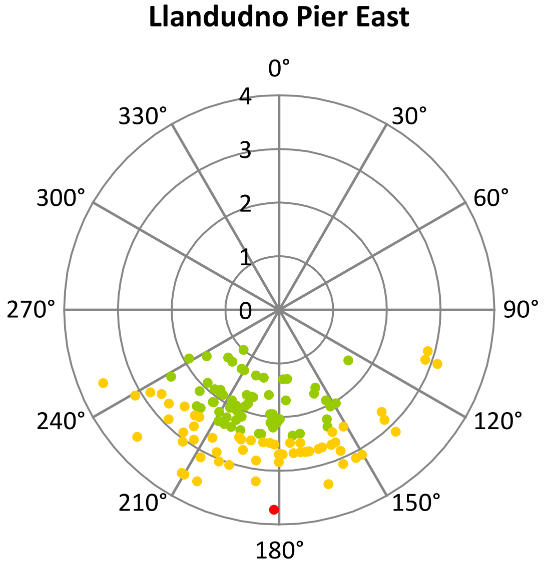

Figure XI.5: Polar plot of log_{10} *E. coli* results (MPN/100 g) at mussel RMPs against high/low tidal state

While a significant correlation of the high/low tidal cycle was detected, sampling was strongly targeted towards low water and no patterns are apparent in the polar plots.

Figure XI.6 presents polar plots of log_{10} *E. coli* results against the spring/ neap tidal cycle for each RMP for which a correlation was detected. Full/new moons occur at 0º, and half moons occur at 180º, and the largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 230 *E. coli* MPN/100 g or less are plotted in green, those from 231 to 4,600 are plotted in yellow, and those exceeding 4,600 are plotted in red.

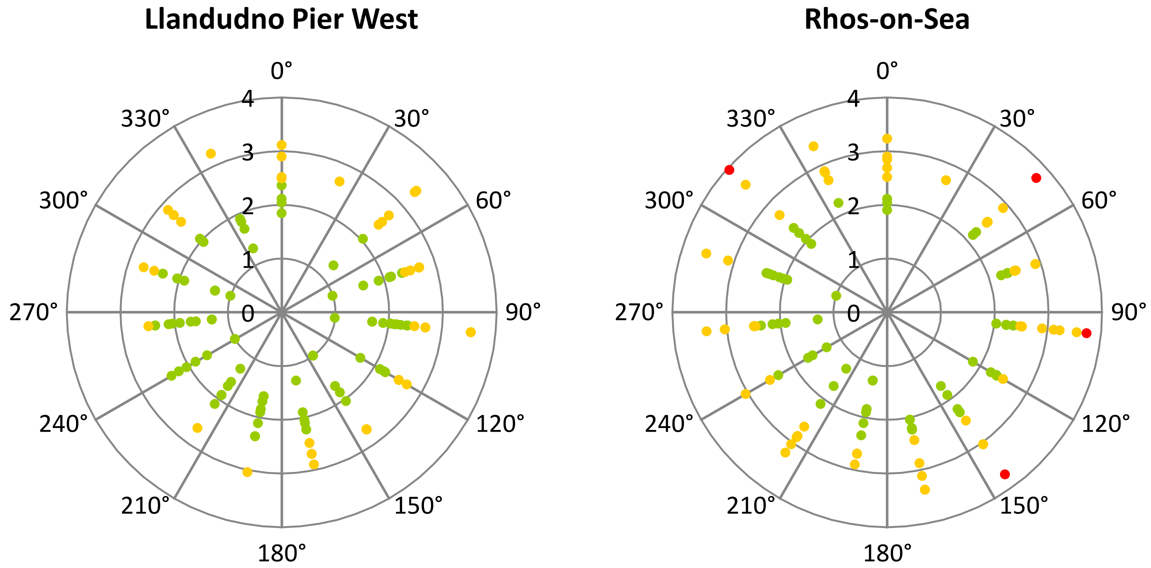

Figure XI.6: Polar plot of log10 *E. coli* results (MPN/100 g) at mussel RMPs against spring/neap tidal state

At both Llandudno Pier West and Rhos-on-Sea, there appeared to be fewer low results around spring tides.

XI.5. Influence of rainfall

To investigate the effects of rainfall on levels of contamination within shellfish samples Spearman's rank correlations were carried out between *E. coli* results and rainfall recorded at the Colwyn Bay 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 Colwyn Bay and shellfish hygiene results

	Site	Llandudno Pier East	Llandudno Pier West	Rhos-on-Sea
	Species	Mussel	Mussel	Mussel
	n	118	118	118
24 hour periods prior to sampling	1 day	0.027	0.069	0.082
	2 days	0.083	0.040	0.231
	3 days	0.086	0.001	0.141
	4 days	0.001	0.102	0.139
	5 days	0.085	0.144	0.176
	6 days	0.024	0.071	0.205
	7 days	0.001	0.127	0.016
Total prior to sampling over	2 days	0.009	0.077	0.219
	3 days	0.034	0.078	0.226
	4 days	0.031	0.090	0.246
	5 days	0.013	0.096	0.237
	6 days	<0.001	0.107	0.255
	7 days	0.011	0.136	0.229

E. coli levels at both Llandudno Pier sites were not affected significantly by rainfall at Colwyn Bay, while *E. coli* results at Rhos-on-Sea were.

Appendix XII. Shoreline Survey Report

Date (time):
18/08/2014, 09:00 – 12:30
19/08/2014, 08:30 – 15:00
20/08/2014, 08:30 – 15:00

Cefas Officers:
David Walker
Rachel Parks

Survey Partners:
Mark Hughes, Conwy Council (18/08/2014 only)

Area surveyed:
Llandudno Bay (pier to base of Little Ormes Head), Penrhyn Bay to Rhos-on-Sea. Additional spot samples towards the west on Colwyn Bay.

Weather:
18/08/2014 – Partial cloud, 17°C, wind bearing 315° at 14 km/h.
19/08/2014 – Partial cloud, 17°C, wind bearing 315° at 12 km/h.
20/08/2014 – Partial cloud, 17°C, wind bearing 307° at 9 km/h.

Tides:
Admiralty TotalTide© predictions for Conwy 53°17'N 3°50'W. All times in this report are BST.

18/08/2014		
High	05:16	6.8 m
Low	12:10	2.3 m
High	17:57	6.5 m

19/08/2014		
Low	00:48	2.5 m
High	06:33	6.4 m
Low	13:22	2.6 m
High	19:20	6.4 m

20/08/2014		
Low	02:09	2.6 m
High	08:00	6.3 m
Low	14:41	2.7 m
High	20:38	6.5 m

Objectives:

The shoreline survey aims to obtain samples of freshwater inputs to the area for bacteriological testing; to confirm the location of previously identified sources of potential contamination; to locate other potential sources of contamination that were previously unknown and to 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.

XII.1. Fishery

It was not possible to meet with the harvesters on this survey. No additional shellfishery information was obtained.

XII.2. Sources of contamination

Sewage discharges

Two intermittent water company discharges were observed during this survey. The Beach Road CSO (observation 3) was below the tide and could not be sampled. The Penrhyn Bay pumping station outfall (observation 6) had an *E. coli* concentration of 170,000 cfu/100 ml, but a very low flow. The pipe for this outfall was split, so that it was spilling further inland than the intended discharge point.

There were additional pipes (not recorded) along the length of Colwyn Bay none of which were flowing.

Freshwater inputs

A culverted stream was seen at observation 2. This stream had an *E. coli* concentration of 1,200 cfu/100 ml and an *E. coli* loading of 1.93×10^{10} cfu/day.

Livestock

No livestock was observed during this survey.

Wildlife

Very little wildlife was observed during this survey except for some flocks of gulls in the vicinity of the mussel bed at Rhos-on-Sea (observations 7 and 8).

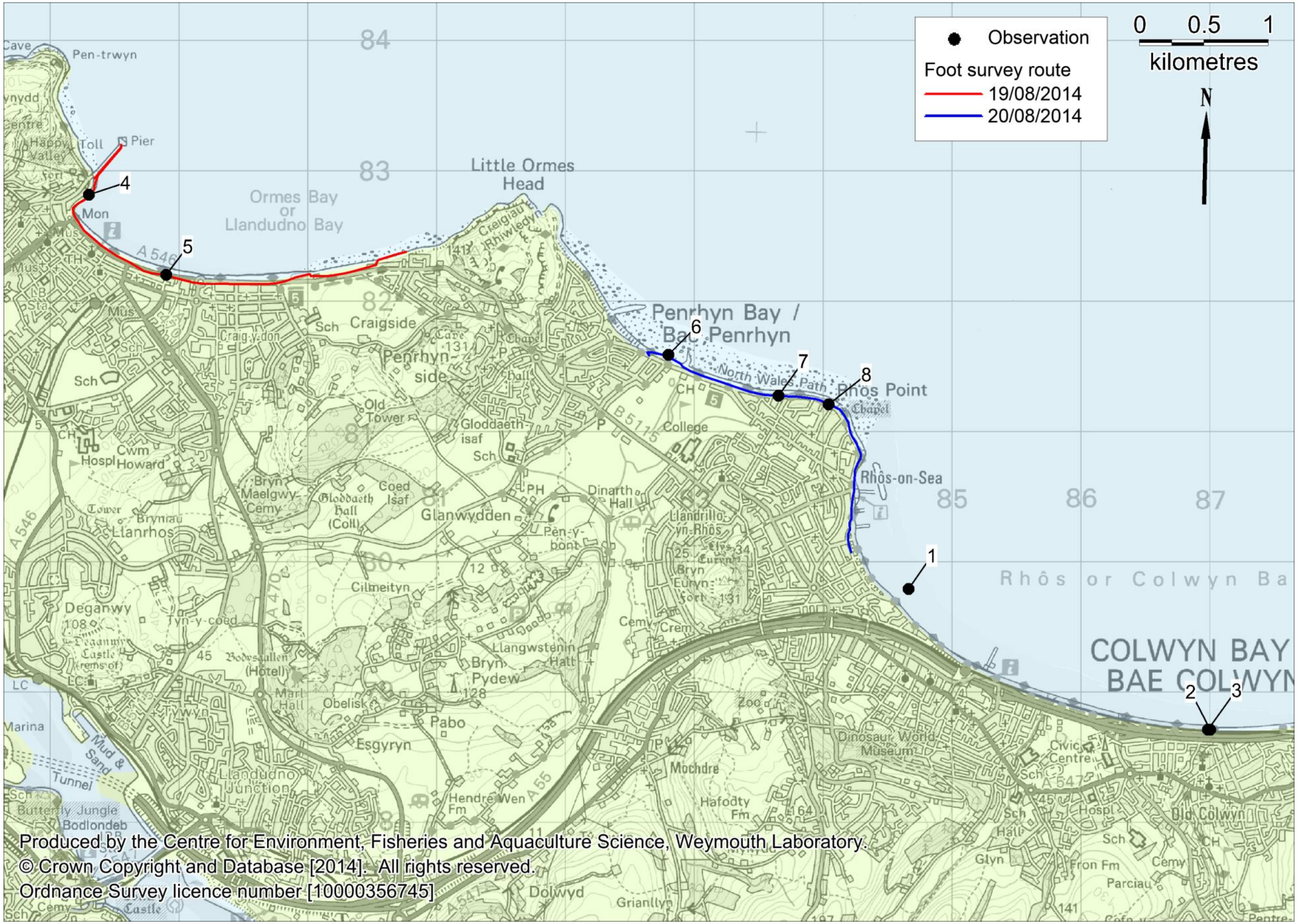

Figure XII.1: Locations of shoreline observations (Table XII.1 for details).

Table XII.1: Details of Shoreline Observations

Observation no.	NGR	Date & time	Description	Photo
1	SH8466579789	18/08/2014 11:52	Concrete grated pipe, 0.6 m diameter. Not flowing.	Figure XII.4
2	SH8700678708	18/08/2014 12:18	Culverted stream (0.2 m x 0.07 m x 1.328 m/s) (Sample LL07).	Figure XII.5
3	SH8698878709	18/08/2014 12:18	Start of Beach Road CSO. End below tide.	Figure XII.6
4	SH7830482814	19/08/2014 13:42	Mussels.	
5	SH7890282200	19/08/2014 16:18	Pipe on beach repeated every 20 m for around 100 m.	Figure XII.7
6	SH8280081585	20/08/2014 13:05	Penrhyn Bay PS. Iron pipe (0.7 m diameter). Leaking 2.5 m from end (no flow from end, only from leak). 3.5s to fill pot (Sample LL16)	Figure XII.8& Figure XII.9
7	SH8365581272	20/08/2014 13:22	150 gulls.	
8	SH8404381205	20/08/2014 13:28	150 gulls.	

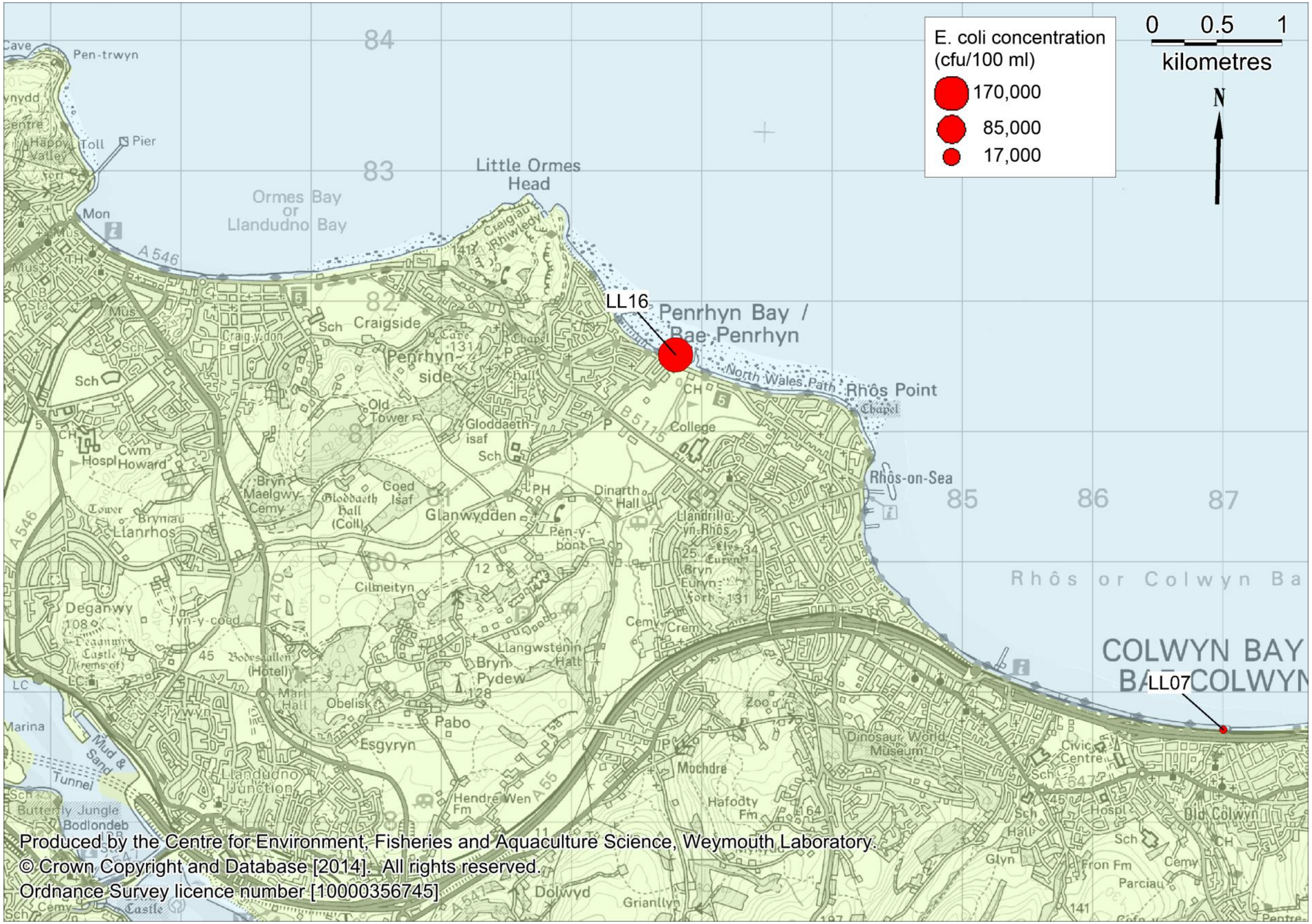

Figure XII.2: Water sample results (Table XII.2 for details).

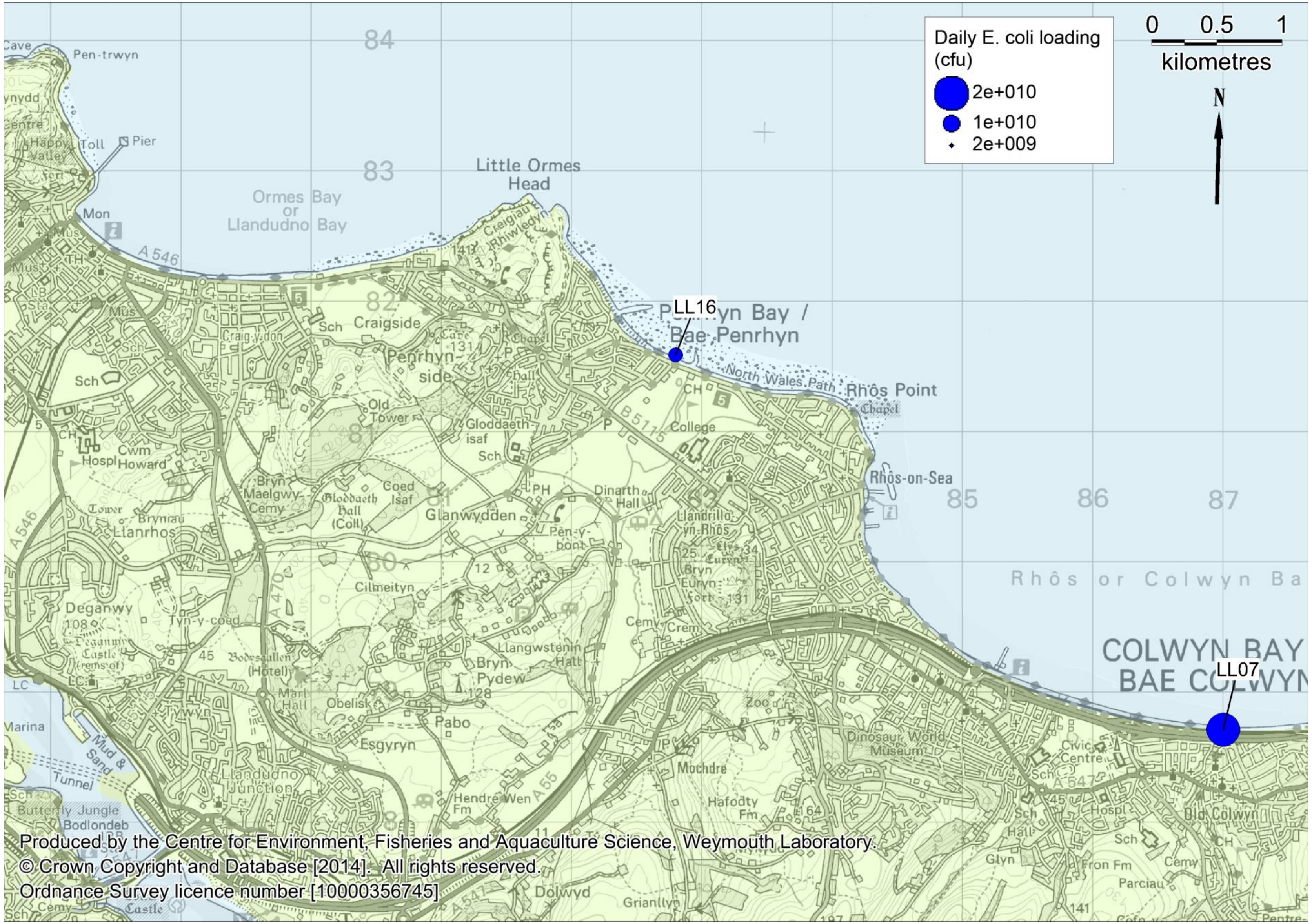

Figure XII.3: ***E. coli*** **stream loadings (Table XII.2 for details).**

Table XII.2: Water sample *E. coli* results, spot flow gauging results and estimated loadings.

Sample ID	Observation number	Date and time	Description	Flow (m^3/s)	*E. coli* concentration (cfu/100 ml)	*E. coli* loading (cfu/day)	NGR
LL07	2	18/08/2014 12:18	Stream	0.019	1,200	1.93×10^{10}	SH8700678708
LL16	6	20/08/2014 13:05	Pipe	<0.001	170,000	8.39×10^{9}	SH8280081585


Figure XII.4


Figure XII.5

Figure XII.6

Figure XII.7

Figure XII.8

Figure XII.9

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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
ppt	parts per thousand
PS	Pumping Station
RMP	Representative Monitoring Point
SAC	Special Area of Conservation
SHS	Cefas Shellfish Hygiene System, integrated database and mapping application
SSSI	Site of Special Scientific Interest
STW	Sewage Treatment Works
UV	Ultraviolet
WGS84	World Geodetic System 1984

Glossary

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

Flow ratio	Ratio of the volume of freshwater entering into an estuary during the tidal cycle to the volume of water flowing up the estuary through a given cross section during the flood tide.
Geometric mean	The geometric mean of a series of N numbers is the Nth root of the product of those numbers. It is more usually calculated by obtaining the mean of the logarithms of the numbers and then taking the anti-log of that mean. It is often used to describe the typical values of skewed data such as those following a log-normal distribution.
Hydrodynamics	Scientific discipline concerned with the mechanical properties of liquids.
Hydrography	The study, surveying, and mapping of the oceans, seas, and rivers.
Loess	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 LOESS fit is complete after regression function values have been computed for each of the n data points. LOESS fit enhances the visual information on a scatterplot.
Telemetry	A means of collecting information by unmanned monitoring stations (often rainfall or river flows) using a computer that is connected to the public telephone system.
Secondary Treatment	Treatment to applied to breakdown and reduce the amount of solids by helping bacteria and other microorganisms consume the organic material in the sewage or further treatment of settled sewage, generally by biological oxidation.
Sewage	Sewage can be defined as liquid, of whatever quality that is or has been in a sewer. It consists of waterborne waste from domestic, trade and industrial sources together with rainfall from subsoil and surface water.
Sewage Treatment Works (STW)	Facility for treating the waste water from predominantly domestic and trade premises.
Sewer	A pipe for the transport of sewage.
Sewerage	A system of connected sewers, often incorporating inter-stage pumping stations and overflows.
Storm Water	Rainfall which runs off roofs, roads, gulleys, etc. In some areas, storm water is collected and discharged to separate sewers, whilst in combined sewers it forms a diluted sewage.
Waste water	Any waste water but see also “sewage”.

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