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EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Tenby

September 2014

Food Standards Agency

Cover photo: Caldey Island from the cliffs west of Giltar Point

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Statement of use

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

Report prepared by

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Revision history

Version	Details	Approved by	Approval date
1	Draft for internal consultation	Fiona Vogt	19/08/2014
2	Draft for client/consultee comment	Simon Kershaw	08/09/2014
3	Final	Simon Kershaw	18/12/2014

Consultation

Consultee	Date of consultation	Date of response
Milford Haven Port Health Authority	16/09/2014	02/10/2014
Natural Resources Wales/Cyfoeth Naturiol Cymru	16/09/2014	13/10/2014
Welsh Government Fisheries	16/09/2014	27/10/2014
Welsh Water/Dwr Cymru	16/09/2014	06/10/2014
Shellfish Association of Great Britain	16/09/2014	-

Dissemination

Food Standards Agency, Milford Haven Port Health Authority. The report is available publicly via the Cefas website.

Recommended Bibliographic Reference

Cefas, 2014. Sanitary survey of Tenby. Cefas report on behalf of the Food Standards Agency, to demonstrate compliance with the requirements for classification of bivalve mollusc production areas in England and Wales under EC regulation No. 854/2004.

Contents

1. Introduction

1.1. Legislative Requirement

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

When consumed raw or lightly cooked, bivalves contaminated with pathogenic microorganisms may cause infectious diseases (e.g. Norovirus-associated gastroenteritis, Hepatitis A and Salmonellosis) in humans. In England and Wales, fish and shellfish constitute the fourth most reported food item causing infectious disease outbreaks in humans after poultry, red meat and desserts (Hughes *et al.*, 2007).

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

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

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

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

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

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

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

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

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

This report documents the information relevant to undertake a sanitary survey for mussels (*Mytilus* spp.) and razors (*Ensis* spp.) at Tenby. The area was prioritised for survey in 2014-15 by a shellfish hygiene risk ranking exercise of existing classified areas.

1.2. Area description

The survey area is situated on the south west coast of Wales on the Pembrokeshire coast (Figure I. 1).

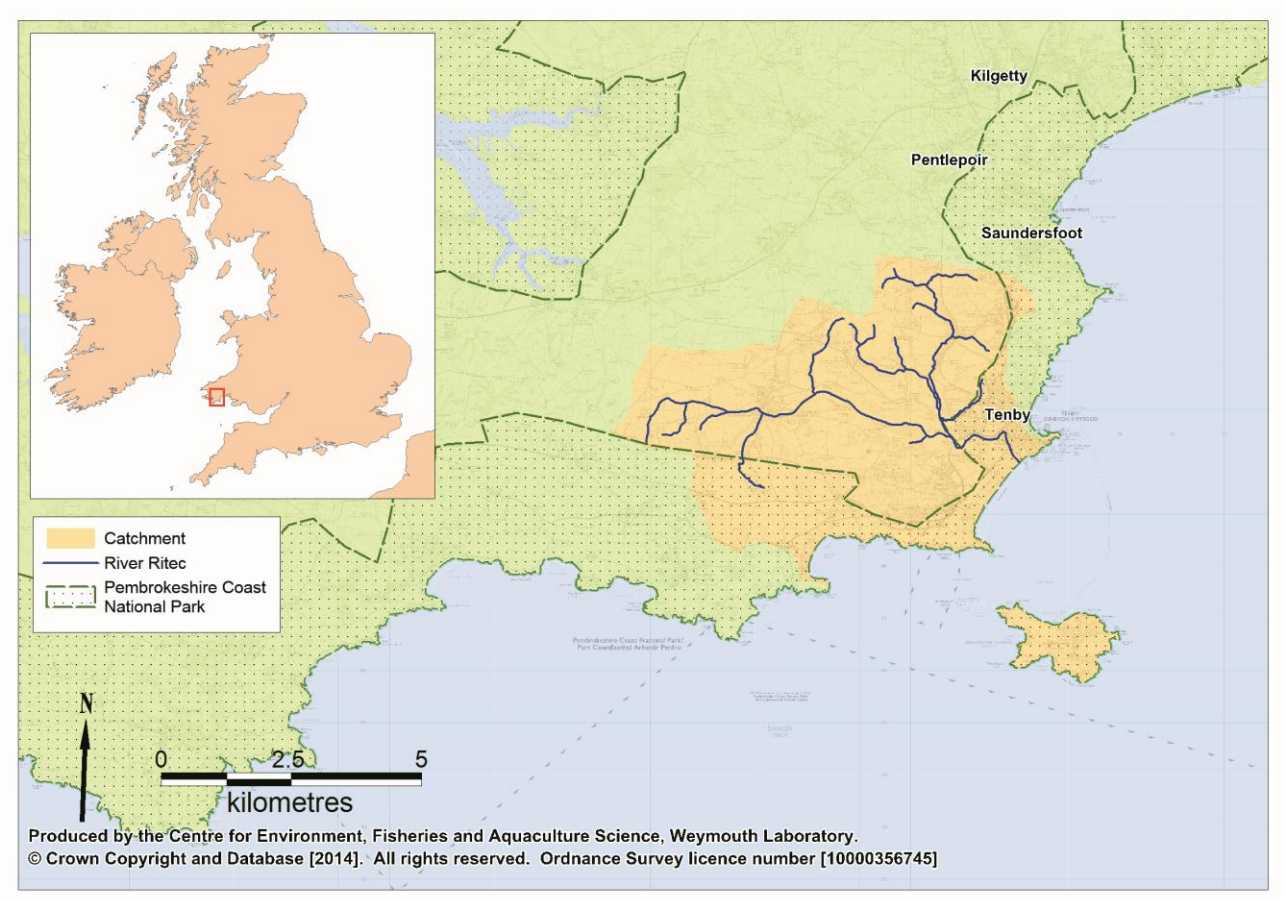

Figure I. 1: Location of the Tenby survey area

The area encompasses a range of marine habitats including rocky cliffs, sand dunes and sandy bays which falls under several national and international conservation statuses, including: the Pembrokeshire Coast National Park, Marine Special Area of Conservation (SAC) and Special Site of Scientific Interest (SSSI). A minor river, the Ritec, drains the catchment and discharges to the shore at Tenby. Population densities within the catchment are generally quite low; however during the summer months there is usually an influx of tourists to the area which increases Tenby's population considerably.

Within the survey area there is a managed mussel fishery under development at Lydstep Bay and a naturally occurring razor clam fishery north of Caldey Island. Both of these fisheries lie in sub-tidal areas.

1.3. Catchment

Figure I. 2 illustrates land cover within the hydrological catchment which covers an area of approximately 34 km². It is predominantly rural comprising of pasture and arable land with smaller areas of woodland and grassland. There are a couple of smaller areas of urbanised land situated close to the coast and these represent the towns of Tenby and Penally.

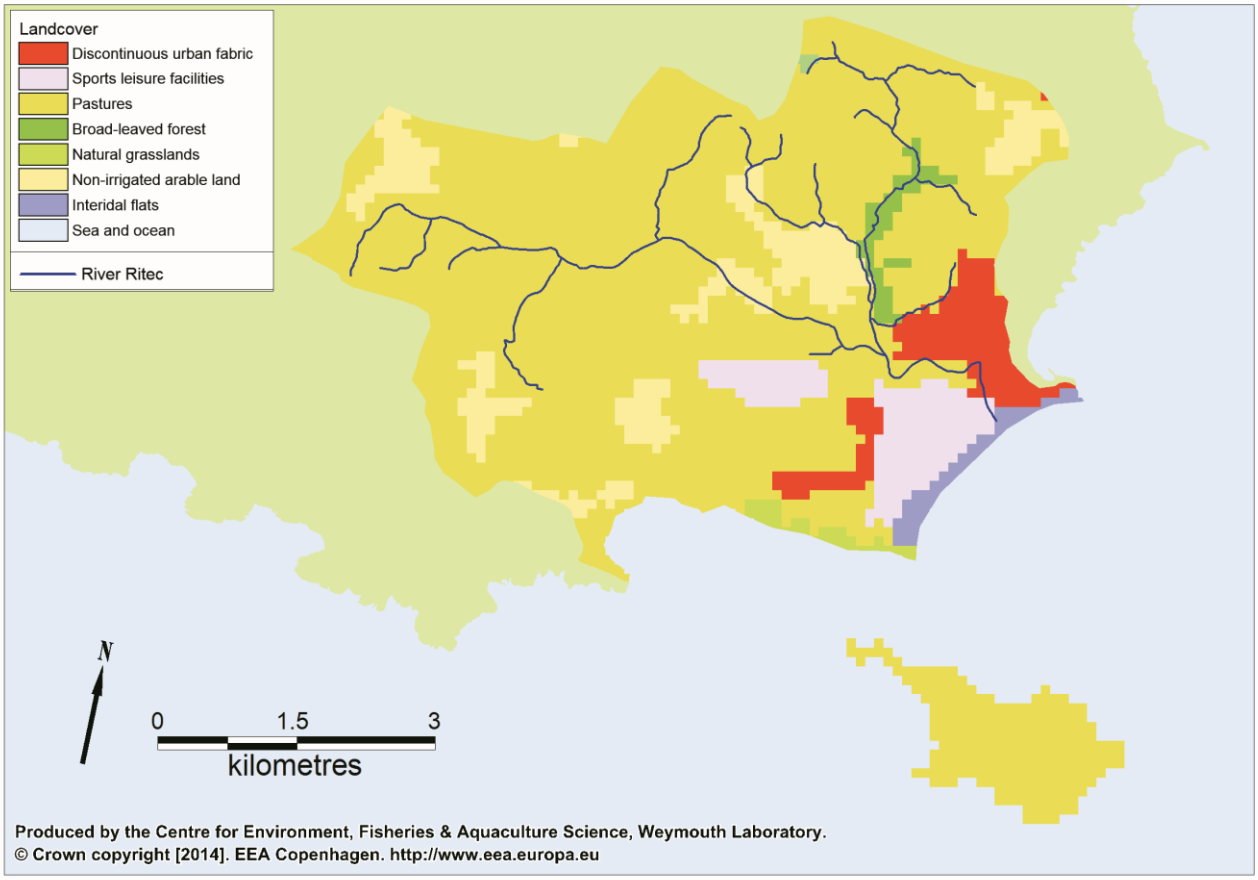

Figure I. 2: Landcover in the Tenby catchment

Different land cover types will generate differing levels of contamination in surface runoff. Highest faecal coliform contribution arises from developed areas, with intermediate contributions from the improved pastures and lower contributions from the other land types (Kay *et al*. 2008a). The contributions from all land cover types would be expected to increase significantly after marked rainfall events, particularly for improved grassland which increase up to 100 fold. The underlying catchment is comprised of a mixture of low and medium permeability bedrock, consequently surface waters flows are likely to dominate in the survey catchment (NERC, 2012).

2. Recommendations

For both species a preferred sampling plan, where the monitoring points are located within the actual fisheries is proposed. Additionally, in recognition of the difficulties faced by the local authority in accessing subtidal stocks, a second, less representative sampling plan is provided where RMPs that can be accessed from the shore is provided. It is recommended for both species that some parallel monitoring of the intertidal and subtidal RMPs is undertaken to assess how representative the intertidal RMPs are of conditions in the subtidal fisheries. This is considered to be more critical in the case of the razor fishery, for reasons outlined below. The number of parallel samples required is uncertain, and will largely depend on the results, which should be evaluated as they arise.

Mussels

No significant sources of contamination direct to the fishery order area or to the adjacent shore have been identified, and so little spatial variation in levels of contamination across this fishery is anticipated. The land behind the cliffs between Giltar Point and Lydstep Haven slopes down to the north so there is no land runoff from this stretch. There may be some minor amounts of runoff from the holiday park area onto the beach at Lydstep Haven at times, but there are no actual watercourses there. There may be some diffuse inputs to this beach from birds and dogs, although the latter are banned during the summer. The southern end of Lydstep Haven is sometimes used as an anchorage for pleasure craft. The bird colonies on Caldey and St Margaret's Islands may represent a diffuse source of contamination to the east of the fishery order. Tidal streams are stronger, and depths are greater at the western end of the fishery order, providing more scope for the dispersion and dilution of contamination.

Overall, it is recommended the preferred RMP be located at the western tip of the fishery to best capture any impacts associated with the anchorage and birds and dogs on the beach at Lydstep. If an RMP accessible from the shore is required, the sample bag should be located just north of Lydstep Point where it is anticipated that results would be very similar.

Stock should be of a harvestable size (45 mm). A provisional classification may be issued after 10 samples have been taken not less than a week apart. Following this, sampling should be monthly and year round. If a dredge is used then a tolerance of 100 m applies. If a sample bag is used then a tolerance of 10 m applies, and stock should be allowed to equilibrate *in situ* for at least two weeks before sampling.

Razors

The Tenby sewage treatment works (STW) may be a significant contaminating influence to the area requiring classification, particularly at times when the UV treatment is not working as effectively as it usually does. It is anticipated that the plume from this outfall will reach the north eastern corner of the fishery first, so highest impacts are generally expected to arise there. There is however significant scope for dilution, the plume is likely to be buoyant, and this outfall is not permitted to make overflow (storm/emergency) discharges of untreated sewage (the storm tanks from Tenby STW discharge to the Ritec rather than via the long sea outfall). The bird and seal colonies at Caldey Island represent a diffuse source of contamination to the intertidal zone along the north shore of this island. There are also several sources of contamination to the mainland shore between Tenby and Giltar Point. These include the River Ritec, the Penally Burrows drainage outfall, and a few intermittent discharges mainly in the Tenby area. It is anticipated that tidal streams would not usually carry contamination from these sources towards the razor fishery.

The preferred classification zone for razors encompasses only the subtidal area for which classification has been requested, thereby largely excluding the influence of mainland sources between Tenby and Giltar Point. The preferred RMP should be located on the north east corner of the zone to best capture any impacts from the Tenby STW outfall, which is the source with the greatest potential for contaminating the fishery. A tolerance of 100 m applies to allow repeated sampling, and samples here should be hand salted by diver.

Should a shore based RMP be required, the classification zone will have to be extended to ensure it lies within the classified zone. This need not extend to Tenby and the River Ritec outfall. The RMP should be located in the lower intertidal, by any drainage channel originating from the Burrows drainage outfall which is the only known fixed input direct to the zone. Such a strategy presents an obvious risk in that it provides no information on the extent to which the Tenby STW is an influence on shellfish hygiene within the actual fishery. For this reason it is strongly recommended that parallel sampling of the intertidal and subtidal RMPs is undertaken to assess how representative the intertidal RMP is of conditions within the actual fishery. A tolerance of 100 m applies to allow repeated sampling as stocks are likely to be sparser here, and samples should be collected by salting the burrows.

For both RMPs, sampling should be monthly and year round, and sampled stock should be of a harvestable size (minimum 100 mm, preferably over 150 mm).

3. Sampling Plan

3.1. General Information

Location Reference

Production Area	Tenby
Cefas Main Site Reference	M080
Ordnance survey 1:25,000 map	Explorer OL36
Admiralty Chart	1482

Shellfishery

Species/culture	Mussels	Cultured/managed wild stocks
	Razor clams	Wild
Seasonality of harvest	Potentially year round for both, although mussels will generally be harvested from September to March inclusive.	

Local Enforcement Authority

Name	Milford Port Health Authority Pembrokeshire County Council County Hall Haverfordwest Pembrokeshire SA61 1TP
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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, such as the upgrading or relocation of any major discharges. Water company data may become available to allow an assessment of spills from intermittent discharges at the time of the next review.

Table 3.1: Details of recommended RMPs

Classification zone	RMP*	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Lydstep	B088O	Lydstep Fishery Order West	SS 0960 9792	51° 38.865' N 04° 45.209' W	Mussels	Wild/ managed natural stocks	Dredge	Dredge	100 m	Monthly	Preferred RMP.
Lydstep	B080N	Lydstep Mussels	SS 0924 9783	51° 38.809' N 04° 45.518' W	Mussels	Wild/ managed natural stocks	Dredge	Hand (deployment bag)	10 m	Monthly	Shore access RMP (use subject to approval following validation monitoring against preferred RMP).
Caldey Roads	B080L	Caldey Roads NE	SS 1504 9830	51° 39.179' N 04° 40.509' W	Razors (*Ensis* spp.)	Wild	Hand salting by diver	Hand salting by diver	100 m	Monthly	Preferred RMP.
Caldey Roads & Giltar Point	B080P	Burrows Outfall	SS 1248 9852	51° 39.247' N 04° 42.733' W	Razors (*Ensis* spp.)	Wild	Hand salting by diver	Hand salting	100 m	Monthly	Shore access RMP (use subject to approval following validation monitoring against preferred RMP). Will not capture any impacts from Tenby STW.

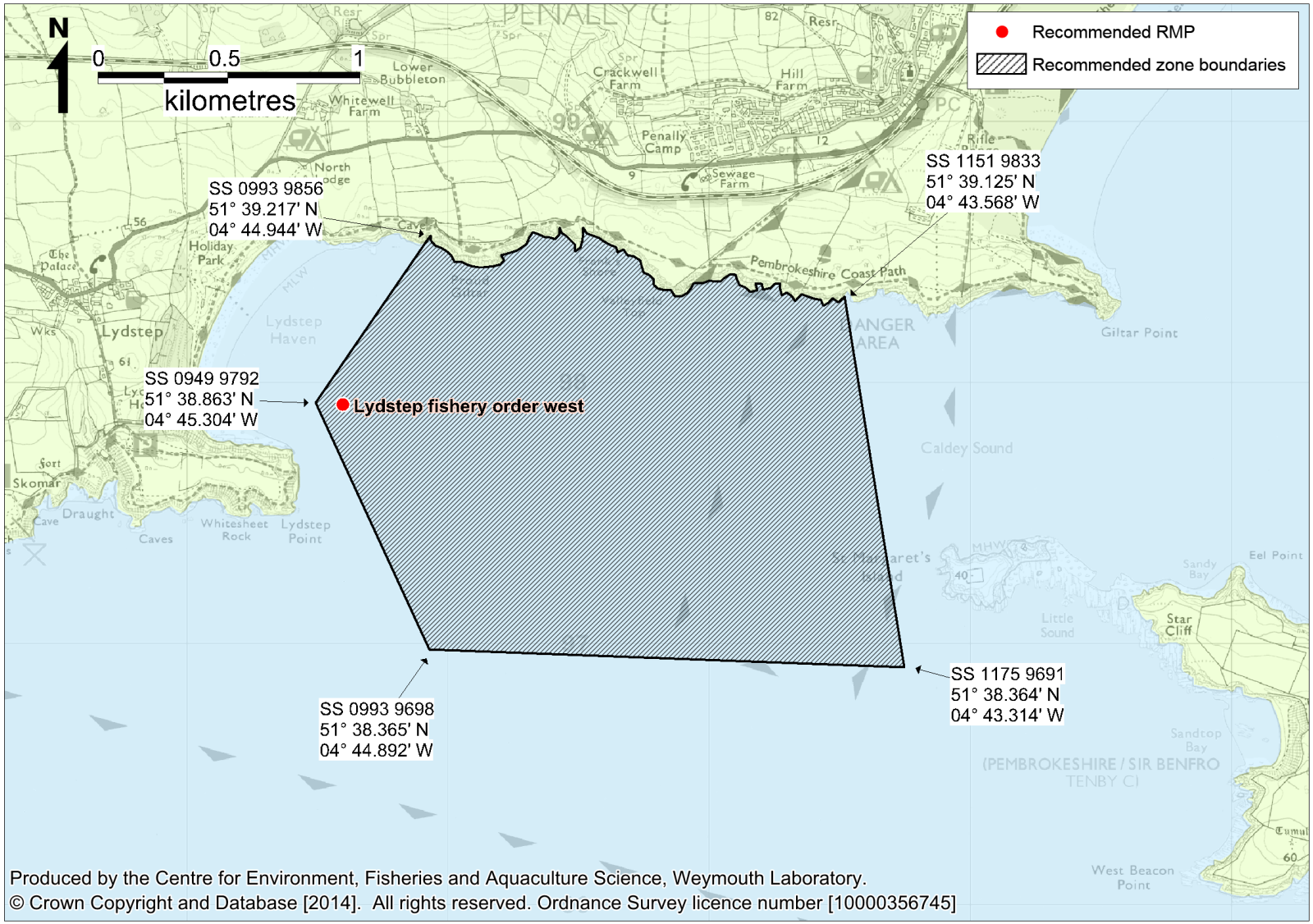

Figure 3.1: Recommended zoning and monitoring arrangements (mussels)

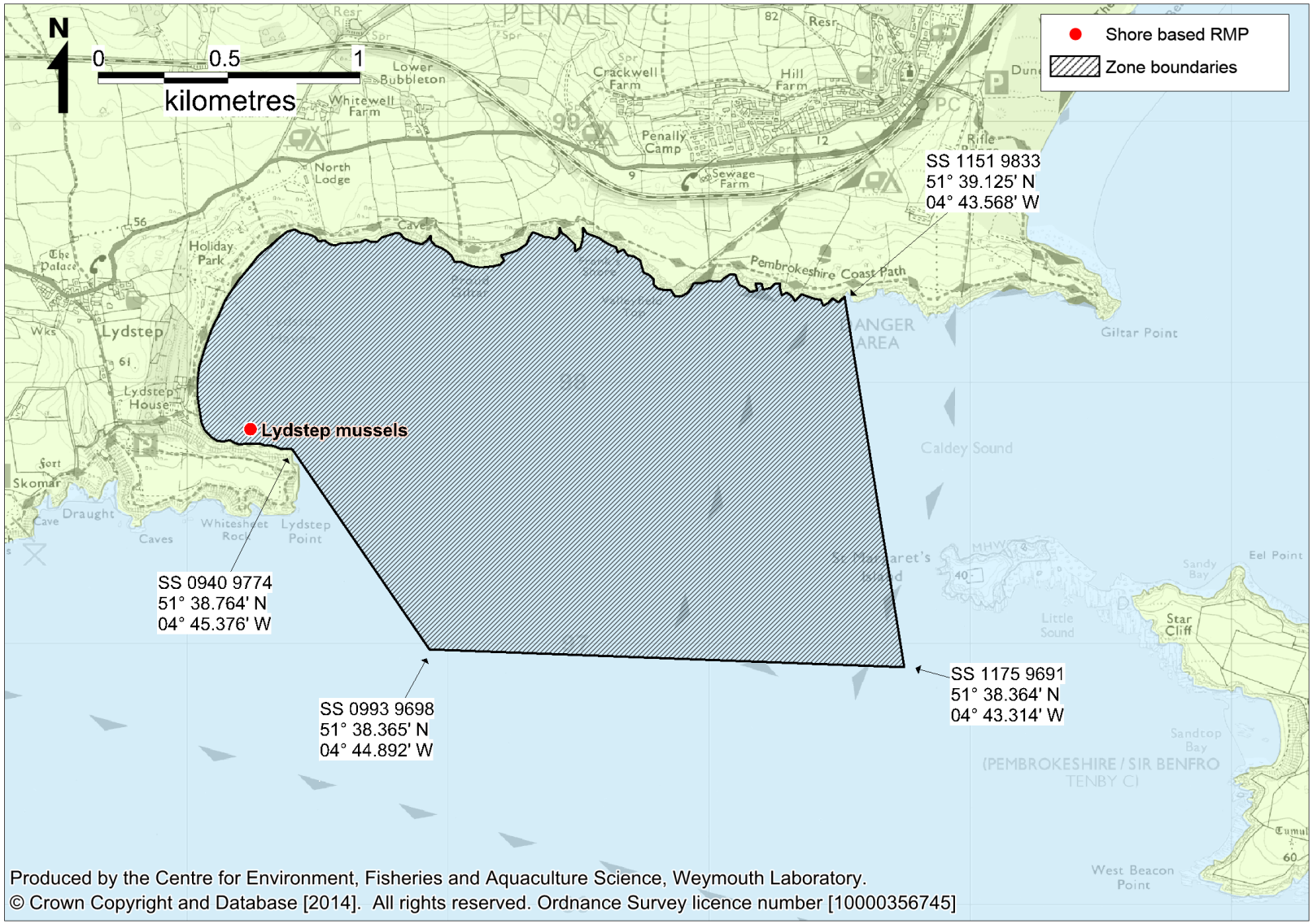

Figure 3.2: Shore based zoning and monitoring arrangements (mussels)

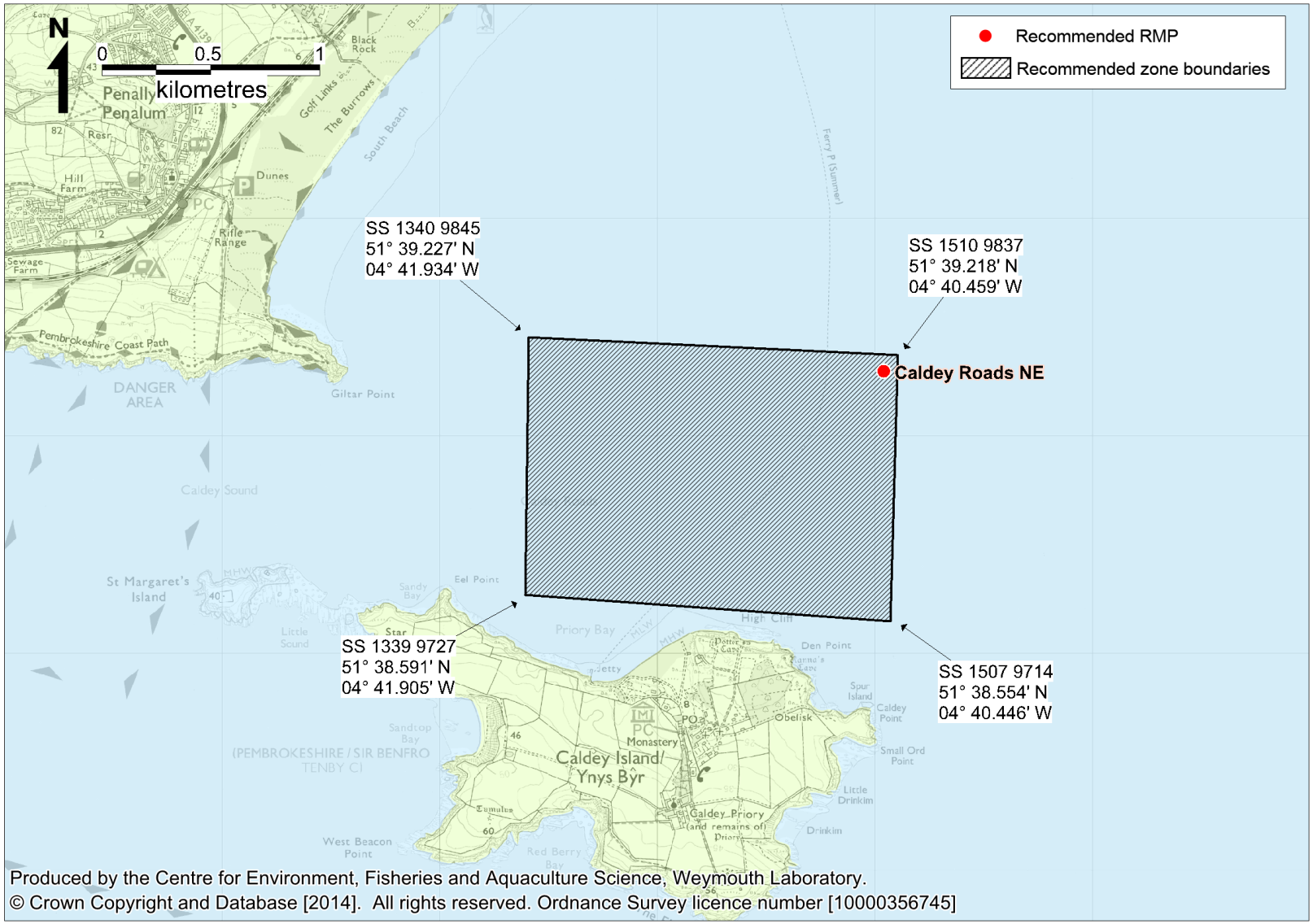

Figure 3.3: Recommended zoning and monitoring arrangements (razors)

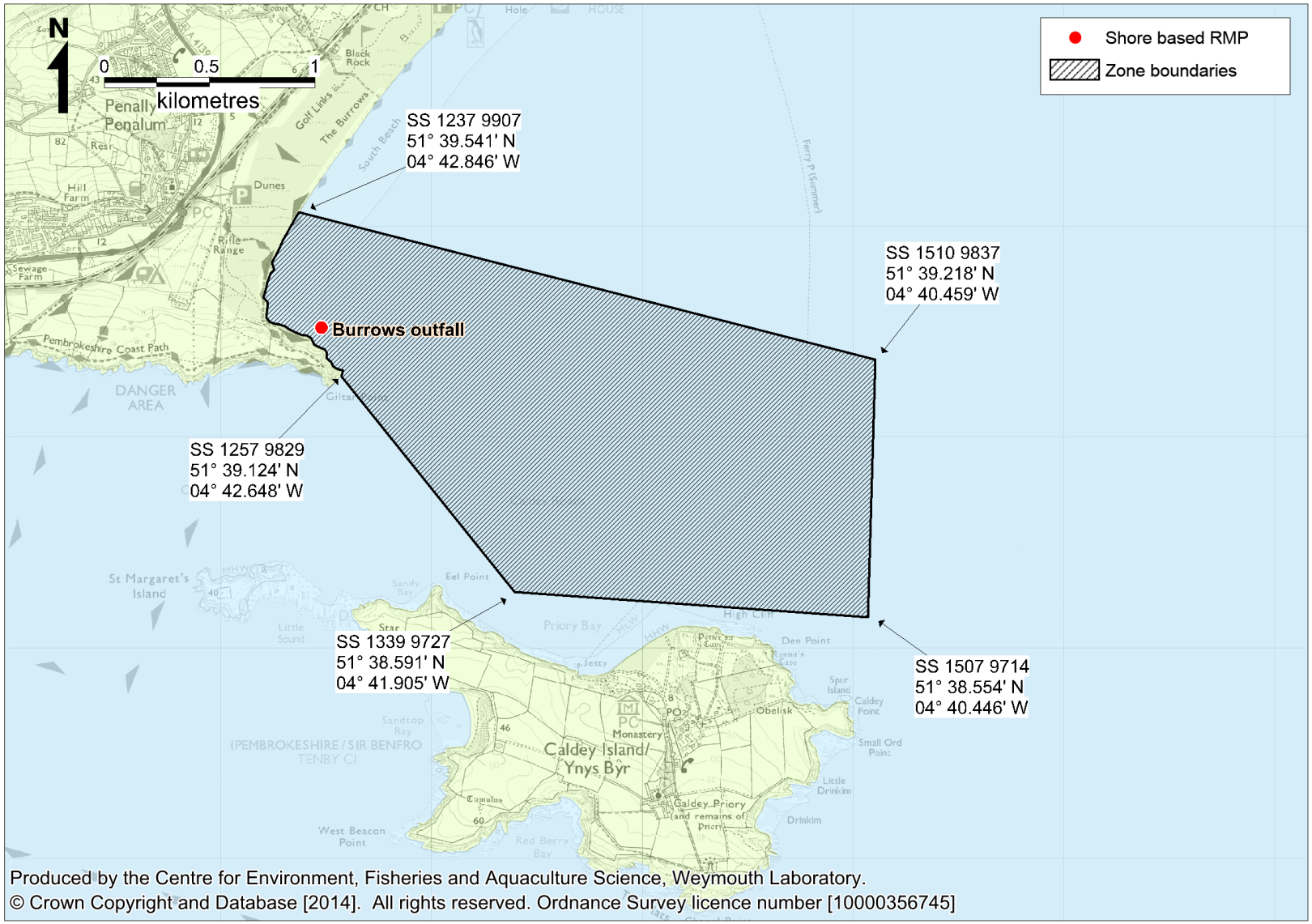

Figure 3.4: Shore based zoning and monitoring arrangements (razors)

4. Shellfisheries

Commercial bivalve fisheries within the survey area comprise of a recently awarded several order area at Lydstep, and an extensive bed of naturally occurring razor clams off Caldey Island. Both of these fisheries are in subtidal areas.

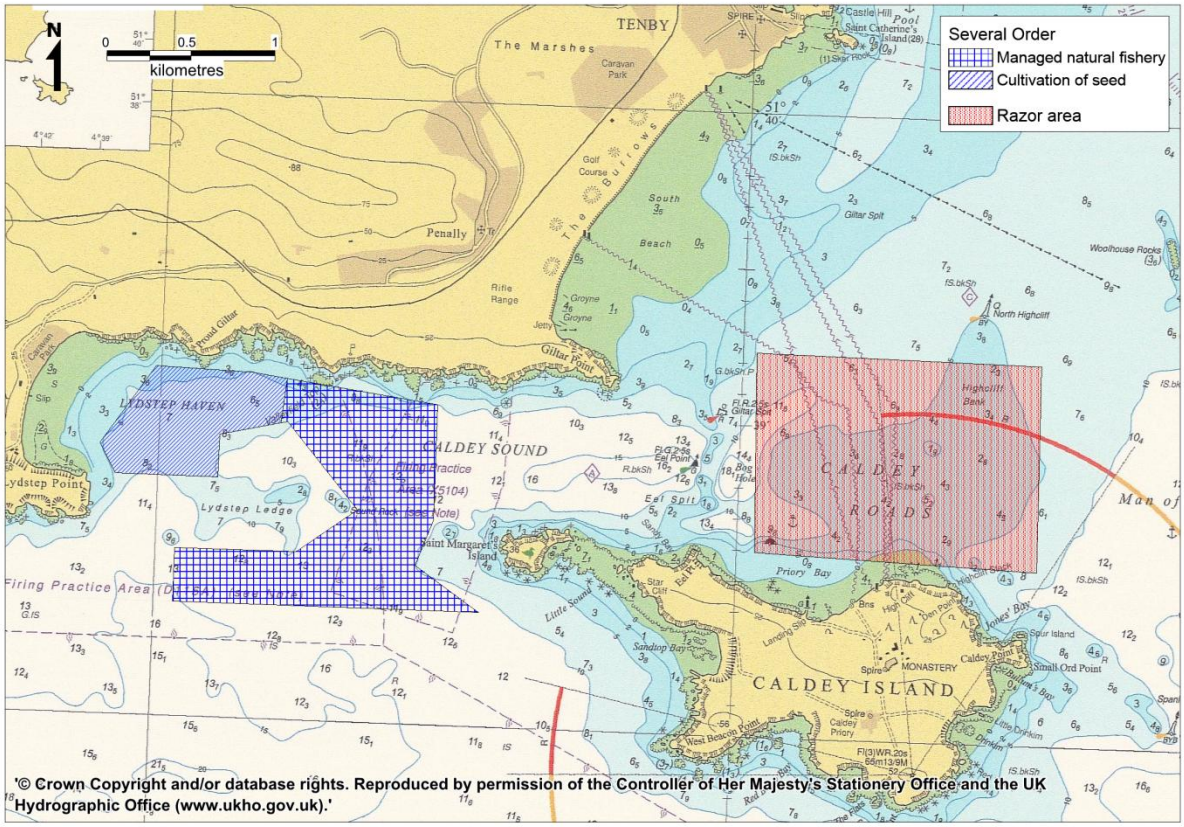

Figure 4.1: Shellfish interests within the survey area

The fishery order was granted for a period of 15 years in December 2013, and covers an area about 1.7 km^2. Of this, around 0.5 km^2 will be used for bottom culture of seed stocks. The remaining 1.1 km^2 supports natural stocks and these will be managed to maximise their survival to market size.

Little information is available on the status of the razor stocks, which have not been subject to a survey. The extent of the 2 km^2 area they are to be fished from represents the area that the harvester requested be classified. It is likely that stocks are not just limited to this area.

4.1. Growing Methods and Harvesting Techniques

The existing mussel beds within the fishery order area are believed to be subject to heavy predation by starfish (*Asterias rubens*) during the summer, which results in their break-up. This then renders them susceptible to being washed away by winter

storms. It is planned to remove starfish when they are present in high densities using a towed starfish 'mop'. This would help maintain the integrity of the bed, thus rendering it more resilient to damage from winter storms. Further management measures such as manipulation of stock densities will be explored as the fishery develops. As well as the managed natural beds, seed from nearby ephemeral seed mussel beds will be ongrown in the shallower, more sheltered area at the western end of the site. Seed will only be deposited on the parts where there is a relatively flat seabed of sediment and not in the more rocky areas. Stocking densities will be relatively low (2.5 kg/m^2). It is estimated that seed will take around 12-18 month to attain a marketable size. Harvest will be by a mussel dredge equipped with a bar to minimise disturbance of the substrate.

The razor stocks are entirely naturally occurring, and will be harvested by hand by a diver using small quantities of saturated salt solution injected into the burrows from a squeezable bottle to draw them out. .

4.2. Seasonality of Harvest, Conservation Controls and Development Potential

Harvesting of the mussel fishery will mainly take place from September to March. Permission is required from Welsh Government for each seed collection. No minimum landing size or closed season would apply within the fishery order, but harvest will be of market sized mussels (45 mm). The harvester indicates a projected production of around 1,000 tonnes per year, although the success of the fishery cannot be guaranteed at this early stage.

There is no closed season for the razor fishery. A statutory minimum landing size of 100 mm applies, although in practice larger animals (150 mm) are more marketable.

4.3. Hygiene Classification

Currently, there are no hygiene classifications within the survey area. The most recent classifications were for cockles at Perrys Point (2001, 2002 and 2004) and Tenby North Beach (2004). Mussels at Caldey Island were also classified from 1995 to 1997. All these classifications were B.

Table 4.1: 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 two fisheries within the survey area for which sampling plans are required. The first is a managed mussel fishery within a fishery order, which was granted for a period of 15 years in December 2013, and covers around 1.6 km^2 of the subtidal area in Lydstep Haven and Caldey Sound. This fishery is in an early stage of its development. The shallower, more sheltered western part is to be used for benthic culture of re-laid seed mussels sourced from outside the area. It is estimated that the seed will take around 12-18 months to attain a marketable size here. The deeper, more exposed eastern part already supports natural mussel beds. Management of the naturally occurring mussels will involve the use of starfish mops to control these predators, which heavily infest the beds during the warmer months. With reduced predation the beds will remain more intact, helping them to resist breaking up during winter storms. Further management measures such as manipulation of stock densities will be explored as the fishery develops. Harvest will be by a mussel dredge equipped with a bar to minimise disturbance of the substrate, and will mainly take place from September to March, but may potentially occur at any time of the year as no closed season applies. No minimum landing size applies within the fishery order, but harvest will be of market sized mussels (45 mm). Projected production is around 1,000 tonnes per year, but the success of the fishery cannot be guaranteed at this early stage. This fishery has yet to be sampled towards classification, although a sample bag has been deployed on the intertidal area on the southern shore of Lydstep Haven.

The other fishery is a wild razor clam fishery located in the shallow subtidal area just to the north of Caldey Island (Caldey Roads). Here it is intended that razor clams will be hand gathered by a diver using concentrated salt solution to induce them out of their burrows. Little information is available on the status of the razor stocks as they have not been subject to a survey. The area for which classification has been requested is about 2 km^2 in size, but it is quite likely that the razors are much more

widespread. There is no closed season for this fishery, and a minimum landing size of 100 mm applies, although in practice larger animals (>150 mm) are more marketable. Sampling towards classification has started, but these samples are taken from the low water mark just north of Giltar Point, a location that actually falls outside of the area for which classification has been requested.

Milford Port Health Authority do not have the capability or resources (i.e. a boat, mussel dredge and suitably qualified diver) to sample stocks from the subtidal area here themselves. Without the assistance of the harvesters, they will therefore be limited to a shore based sampling plan. Whether the harvesters will be able to assist is uncertain, and the razor fishery in particular creates problems with health and safety certification as it has to be sampled by a diver. As such, a shore based sampling plan will be required in addition to the preferred sampling plan involving direct sampling of the actual fisheries. Should a shore based plan need to be adopted, some parallel sampling of the subtidal fisheries and the shore based sampling points is recommended to evaluate how representative the intertidal locations are of the actual fisheries.

5.3. Pollution Sources

Freshwater Inputs

The hydrological catchment draining directly to this stretch of coast is small (33 km^2). The main freshwater input is the River Ritec, which is a minor river that discharges via a piped outfall to the subtidal area at the northern end of Tenby South Beach. There is one further but much smaller freshwater input that drains a small area of low lying land just north of Giltar Point via another piped outfall. There are no freshwater inputs from Giltar Point through to Lydstep Point as the coastal areas here are of a higher elevation than the land to the north, so runoff drains northwards towards the River Ritec or the Burrows drainage outfall. The hydrogeology of the catchment area is described as being a mixture of low and moderate permeability, and the Ritec is surface water dominated, so will respond rapidly to rainfall, a high proportion of which will run off.

There is one flow gauging station on the Ritec, which is located at St Florence, in the upper reaches, representing roughly 40% of the total area this watercourse drains. The mean flow recorded here (2005-2014) was 0.127 m^3/sec, with lowest average flows from April to September, and highest flows on average from November to February. High flow events (exceeding 0.5 m^3/sec) only tended to occur in the November to February period, and the highest individual flow events occurred in November and December. A study undertaken during May to September 2003 estimated the mean discharge from the Ritec at its tidal limit at about 0.15 m^3/sec. The geometric mean *E. coli* concentration from multiple samples taken from this

watercourse was 4500 cfu/100ml. This indicates that a typical (summer) bacterial loading delivered by this watercourse is in the order of $6x10^{11}$ *E. coli*/day, although this will vary greatly with conditions.

Due to the unusual configuration of its outfall, the River Ritec was not sampled or measured during the shoreline survey. The Burrows drainage outfall was sampled and measured during the shoreline survey in June 2014 and on a previous visit in September 2011. Bacterial loadings were estimated at $3.5x10^{8}$ and $1.4x10^{10}$ on these two occasions respectively. It is therefore concluded that the Ritec is the more significant of the two by some margin, and that bacterial loading delivered by both is likely to be very variable and possibly of potential significance to the shellfisheries at times.

Human Population

Total resident population within census areas contained within or partially within the catchment area was approximately 13,000 at the time of the last census in 2011. The largest settlement in the area is Tenby, which has a population of about 5,000. Tenby is a popular seaside resort and there are several static caravan holiday parks at Penally and Lydstep. It can therefore be expected that the population of the catchment will vary significantly throughout the year, peaking during the summer holiday period, with volumes of sewage received by treatment plants fluctuating accordingly.

Sewage Discharges

There are two water company sewage works within the survey area. The largest of these is Tenby STW, which is consented to discharge a dry weather flow of 8,220 m^3 of UV treated effluent per day via a long sea outfall, which lies in 5-10 m of water 2.7 km off Tenby beach. The outfall location offers a high dilution potential, but lies only about 700 m from the razor area at Caldey Roads. Its spatial pattern of impacts will be determined by water circulation patterns in the area. Bacteriological testing results for the final effluent from Tenby STW indicates that disinfection is effective, and the estimated (average) bacterial loading it generates is therefore minor (4.3×10^{10} faecal coliforms/day). The maximum concentration of faecal coliforms recorded was over two orders of magnitude higher than the average however so the loading will occasionally be significantly higher. There was little in the way of seasonality in the bacteriological content of the final effluent, although results were less variable in the autumn.

The other water company sewage works (St. Florence STW) discharges to the River Ritec, and is consented to discharge a dry weather flow of 134 m^3/day of secondary treated effluent. The lower level of treatment is likely to result in a higher concentration of faecal indicator bacteria in the effluent. Although no bacteriological

testing results were available for this works, it is estimated that it generates a bacterial loading of 4.42×10^{11} based on the published results of effluents from other similar works. Whilst there will be some bacterial die off during transit to coastal waters, this works will make a significant contribution to the bacterial loading delivered via the River Ritec.

As well as the continuous discharges, there are six intermittent overflow discharges associated with the sewer networks within the survey area. Three of these discharge to the Ritec and tributaries thereof, two discharge to the shore at Tenby, and one discharges to the unnamed watercourse that in turn discharges to the drainage outfall at Penally Burrows. The Tenby long sea outfall is not permitted to make storm or emergency discharges. No spill records were available for any of these discharges, so it is difficult to assess their impacts aside from noting their locations and their potential to spill storm sewage.

Although the majority of properties within the survey area are served by water company sewerage infrastructure, there are also a number of permitted private discharges. Where specified, these are generally treated by small treatment works such as package plants, and the majority of these are small, serving one or two properties. Most of the private sewage discharges are to soakaway so should have no impacts on coastal waters, assuming they are functioning correctly. This includes the sewage discharge serving Caldey Island. There are four discharging to the Ritec and tributaries thereof, which will make some contribution to the bacterial loading delivered by this watercourse. There is also a small septic tank discharge from the lighthouse on the south shore of Caldey Island direct to the sea, but this is sufficiently distant from the shellfisheries to be of negligible significance.

Agriculture

Pastures are widespread throughout the catchment covering about 50% of its area, as are small pockets of arable land which cover about 7% of its area. The 2012 agricultural census indicates that there were 2,784 cattle and 1,061 sheep within the catchment at the time. There were also very small numbers of poultry (388), pigs (8), goats (2) and horses (55). During the shoreline survey around 190 sheep were observed on the cliff-top fields between Giltar Point and Lydstep, and three horses were seen on Caldey Island.

Livestock manures will either be deposited directly on pastures by grazing animals, or collected from operations such as cattle sheds and poultry houses and spread on both arable land and pasture. This in turn may be washed into watercourses which will carry it to coastal waters. Watercourses which animals can access will be more vulnerable than those that are fenced off. Given the ubiquity of farmland throughout the survey area, both of the watercourses may potentially be affected at times. The geographical pattern of agricultural impacts is likely to mirror those of land runoff,

with the majority delivered to coastal waters via the River Ritec. As the primary mechanism for mobilisation of faecal matter deposited on pastures into watercourses is via land runoff, fluxes of agricultural contamination into coastal waters will be highly rainfall dependent. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the 'first flush').

There is likely to be seasonality in levels of contamination originating from livestock. 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 access watercourses more frequently to drink and cool off. 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. Other manures and sewage sludge may be spread at any time of the year. Therefore peak levels of contamination from grazing livestock 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 occur at any time of the year.

Boats

The discharge of sewage from boats is a potential source of bacterial contamination of shellfisheries within the survey area. There is a small harbour at Tenby where 11 fishing vessels are based. Wildlife and fishing tours operate from here during the summer months, as does a small ferry to Caldey Island. Tenby harbour is also used by recreational craft (yachts and cabin cruisers) and there are moorings and anchorages just offshore from it. Lydstep Haven is also used as an anchorage for pleasure craft. Some of these vessels will have on-board toilets and so will make overboard discharges from time to time. Other watersports including kayaking, windsurfing, dinghy sailing and jet skiing are also popular within the survey area, but these are unlikely make overboard discharges so are not considered further.

There is considerable uncertainty about the extent to which overboard discharges occur and whether they will impact significantly on shellfish hygiene. Those in occupation on moorings, or those in transit through the area may be most likely to discharge, whereas the crew of vessels in Tenby Harbour have access to on-shore facilities. As such the mooring/anchorage areas off Tenby and within Lydstep Haven may be most vulnerable. Vessels on passage may discharge almost anywhere within the survey area. Volumes of small boat traffic will peak during the summer, as will levels of overnight occupancy, so any impacts would be greatest at these times.

Wildlife

The main wildlife aggregation of relevance to shellfish hygiene in the area is a seabird (gulls, terns, etc) breeding colony of around 6,000 individuals on Caldey Island. Although these birds will forage over large areas, their impacts will be most concentrated in the vicinity of their nest sites so the southern edge of the razor fishery and to a lesser extent the eastern edge of the mussel fishery will be most vulnerable. Whilst most of these birds will remain in the area throughout the year it is likely that they are more dispersed outside of their breeding season (late spring/early summer).

Across the whole of Carmarthen Bay the average total count of overwintering waterbirds was only 49,874 over the five winters up until 2012/2013. The survey area forms only a small fraction of the area to which the counts apply so this does not represent a particularly dense aggregation. These birds may therefore be a diffuse source of contamination to intertidal areas and coastal grasslands during the winter moths, but will have not material bearing on the sampling plan.

The Pembrokeshire coast supports around 5,000 grey seals, of which up to 60 use Caldey Island as a haulout site. Their exact preferred haulout locations on the island are uncertain. They will forage over large areas and impacts outside of their haulout areas will be diffuse and spatially unpredictable. The southern edge of the razor area and the eastern edge of the mussel fishery will be most vulnerable to contamination originating from seals. They tend to spend less time hauled out during the late spring and early summer months, so their impacts will be more dispersed at these times. No other wildlife species which may influence shellfish hygiene within the survey area 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. The intensity of dog walking is likely to be higher closer to the more accessible paths and along the beaches. Dogs are not allowed on Lydstep, North Beach and Tenby Beach between 1st May and 30th September but they are allowed year round on Castle Beach and South Beach. As a diffuse source, this will have little influence on the location of RMPs.

Summary of Pollution Sources

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

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

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

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

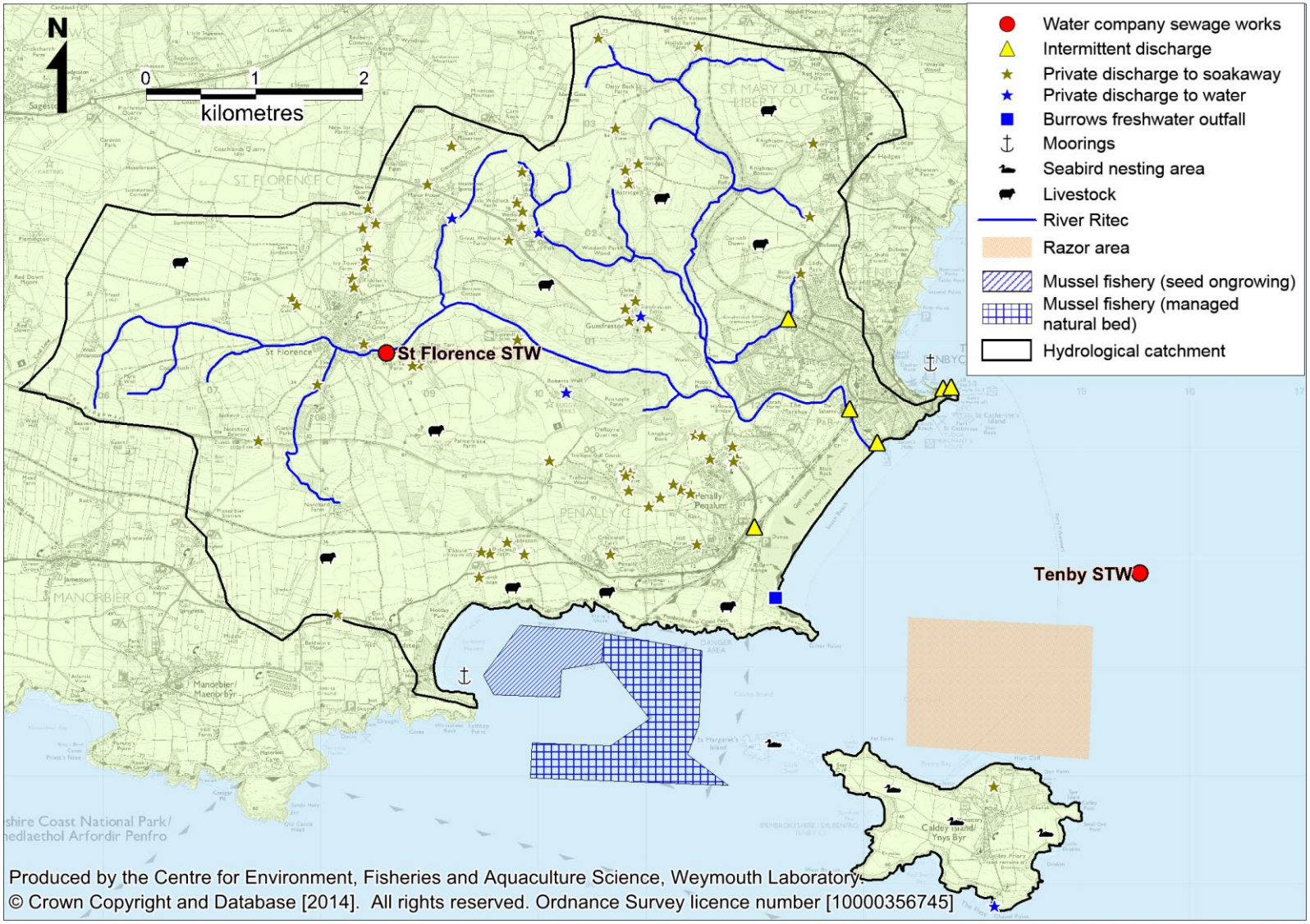

Figure 5.1: Summary of main contaminating influences

5.4. Hydrography

The survey area lies in an open coast location in the very outer reaches of the Bristol Channel. Such situations offer high potential for dilution and water exchange. Between Tenby and Giltar Point the bathymetry is uncomplicated, sloping gently away through the intertidal and into the subtidal areas. It deepens to nearly 20 m in Caldey Sound where tides are funnelled between Caldey Island and Giltar Point. There is a raised bar at the eastern end of Caldey Sound over which tides are likely to accelerate and turbulent mixing of the water column may occur. Caldey Roads, where the razor stocks are located, is relatively shallow and may represent an area of slacker tidal streams where they split around Caldey Island. There are headlands at Tenby and Lydstep Point, around which tidal streams may accelerate slightly. Lydstep Haven forms a shallow, gently sloping embayment to the north of Lydstep Point within which tidal streams are likely to be slacker, and where eddies may form.

The tidal range at Tenby is relatively large, at 7.5 m on spring tides and 3.3 m on neap tides, and this drives extensive water movements through the area. Tidal streams are bidirectional, travelling up the Bristol Channel roughly parallel to the coast on the flood, and back out on the ebb. They accelerate significantly through Caldey Sound, where they reach velocities of 1.3 m/s on spring tides. A nearby tidal diamond suggests the plume from the Tenby STW would be carried towards the north eastern corner of the razor area at Caldey Roads. However, as the tidal stream will split around Caldey Island to the south, and the outfall lies further offshore than the tidal diamond, it is possible that the plume largely remains to the east of the razor beds, then passes to the east of Caldey Island rather than through Caldey Sound. Tidal streams are likely to be slower over shallower and intertidal areas due to the effects of friction. The Lydstep Haven embayment is likely to represent a slacker area, and it is possible that eddies may form here at certain states of the tide. There will therefore be stronger currents towards the eastern end of the mussel several order area than at its western end. Rough estimates of tidal excursions in the more offshore areas where tidal diamonds are located range from 3 km on neap tides to 22 km on spring tides, although the latter figure is based on a diamond where tides accelerate in Caldey Sound. For diamonds outside of Caldey Sound estimates of tidal excursion are around half of this.

Freshwater inputs are minimal, and the survey area is in an open coastal location, so it is unlikely that freshwater related stratification of the water column will occur. This is confirmed by salinity measurements taken at the bathing water monitoring points where no salinities of less than 30 ppt were recorded. It is therefore concluded that density effects will not result in significant modification to water circulation patterns. A density related effect of relevance to this assessment is the buoyant nature of sewage plumes. The plume from the Tenby STW long sea outfall will have a tendency to rise in the water column due to its lower density compared to the surrounding seawater, and this will reduce its impact on benthic shellfish stocks to some extent.

Strong winds will modify surface currents within the survey area. These currents will create return currents, either lower down the water column or along sheltered margins. The prevailing south westerly winds would tend to advect the (buoyant) plume from Tenby STW away from the razor beds. 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. 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. The two fishery areas are largely sheltered from the prevailing south westerly winds, although the eastern end of the mussel several order area is more exposed. Winds from the south east will cause significant wave action along Tenby South Beach, and to a lesser extent within Lydstep Haven.

5.5. Summary of Existing Microbiological Data

The survey has been subject to considerable microbiological monitoring over recent years, consisting of Bathing and Shellfish Waters monitoring programmes and shellfish flesh monitoring for hygiene classification purposes. Figure 5.2 shows the locations of the monitoring points referred to in this assessment. Results from 2003 onwards are considered in the analyses.

Figure 5.2: Microbiological sampling sites

Bathing waters

Five sites were sampled under the Bathing Waters monitoring programme, where around 20 water samples were taken each bathing season (May-September) and enumerated for faecal coliforms. Data covering the period 2004 to 2011 was considered in the analyses. The geometric mean result at all of the sites was less than 10 faecal coliforms/100ml, and they were ranked in the following order; Penally>Castle Beach>South Beach>North Beach>Lydstep. Statistically significant differences in average result were detected, which was significantly lower at Lydstep than all other locations, and significantly lower at North Beach than at Penally. Paired (same day) sample results from all site pairings tested showed significant correlations, indicating that they share similar contamination sources or are affected in a similar manner by environmental factors such as weather conditions. Although the majority of sites could be compared with one another there were insufficient paired results to compare Lydstep with any of the other sites apart from Penally.

Faecal coliform levels have remained fairly stable at most sites except Penally since 2004. At Penally there appeared to be a slight decline in faecal coliform levels between 2004 and 2007. Significant correlations between faecal coliform results and tidal state on both the high/low and spring neap tidal cycles were detected at North Beach, Penally and Lydstep, but not at the two other sites. Across the high/low tidal cycle, higher results tended to occur at lower states of the tide at North Beach. At Penally, results were higher on average during the ebb tide. There was no obvious pattern apparent when the data from Lydstep was plotted. Across the spring/neap tidal cycle faecal coliform concentrations tended to be higher during spring tides at Penally; there were fewer low results just after spring tides at Lydstep, and no obvious patterns at North Beach. Significant positive correlations between faecal coliform results and antecedent rainfall were detected at all sites, and this influence was greatest two days after a rainfall event. The influence was weaker at Lydstep than at the other four sites, presumably as it is more distant from freshwater inputs. Salinity was recorded on most sampling occasions at North Beach, Castle Beach and Lydstep. A significant (but weak) correlation between salinity and faecal coliforms was detected at Lydstep only, but as the range of salinities at which samples was taken was small and the number of samples taken at lower salinities was low this result should be treated with caution.

Shellfish hygiene

The only shellfish flesh testing results since 2005 are from one location in the lower intertidal just north of Giltar Point, where razor clams were sampled on nine occasions since April 2013. Results ranged from <20 to 940 *E. coli* MPN/100g and the geometric mean was 76 *E. coli* MPN/100g. Due to the low sample numbers further analyses of these results were not undertaken.

Bacteriological survey

As there is little microbiological monitoring data available a bacteriological survey would have been useful for this survey area. However, both fisheries are located in the subtidal, necessitating the use of a boat and specialist equipment to access them (dredge or diver). As such it was not possible to undertake a bacteriological survey with the given resources and within the contractual timescales for reporting this sanitary survey.

Appendices

Appendix I. Human Population

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

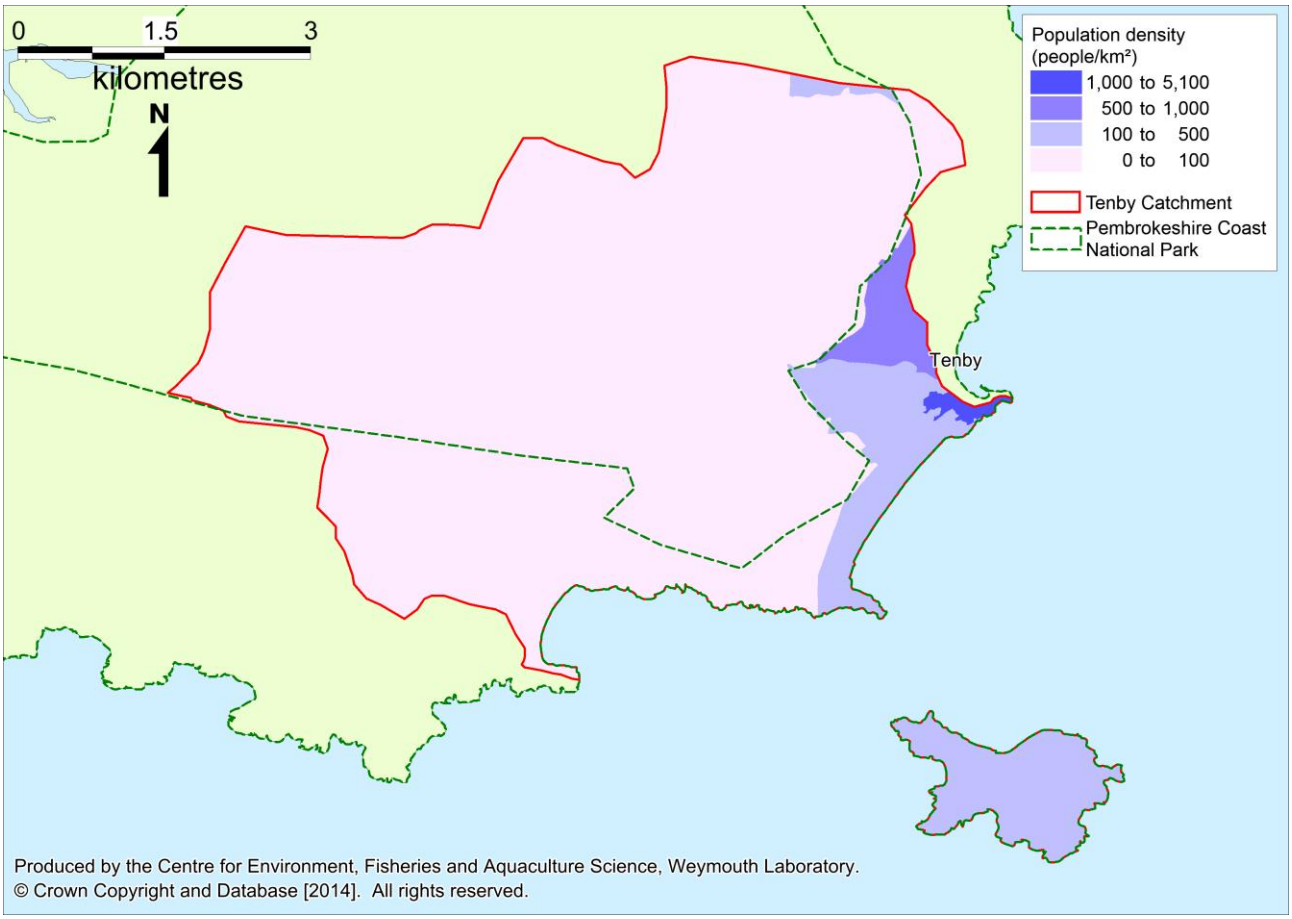

Figure I.1: Human population density in census areas in the survey catchment.

Total resident population within census areas contained within or partially within the catchment area was approximately 13,000 at the time of the last census. The largest settlement in the area is Tenby, which has a population of about 5,000. The majority of the catchment has a population of less than 100 people/km², and the higher population densities are towards the east.

Pembrokeshire is a popular tourist destination, largely for outdoor attractions and activities. It received around 4.2 million visitors in 2011 (GTS 2011), compared with a resident population of approximately 120,000 for the whole county. According to the Pembrokeshire County Council, Tenby is the most popular resort in the county and accounts for approximately 10% of annual visits (Pembrokeshire County Council, Pers Comm). There are several static caravan holiday parks in the area, at Tenby, Penally and Lydstep.

It can therefore be expected that the population of the catchment will fluctuate greatly throughout the year, peaking during the summer holiday period, with volumes of sewage received by treatment plants fluctuating accordingly.

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

Details of all consented sewage discharges within the survey area were taken from the most recent update of the Environment Agency/Natural Resources Wales national permit database (March 2014). Additionally, Natural Resources Wales also provided the locations of private discharges which have recently been registered with them and are not yet on the EA national permit database. These are mapped in Figure II.1.

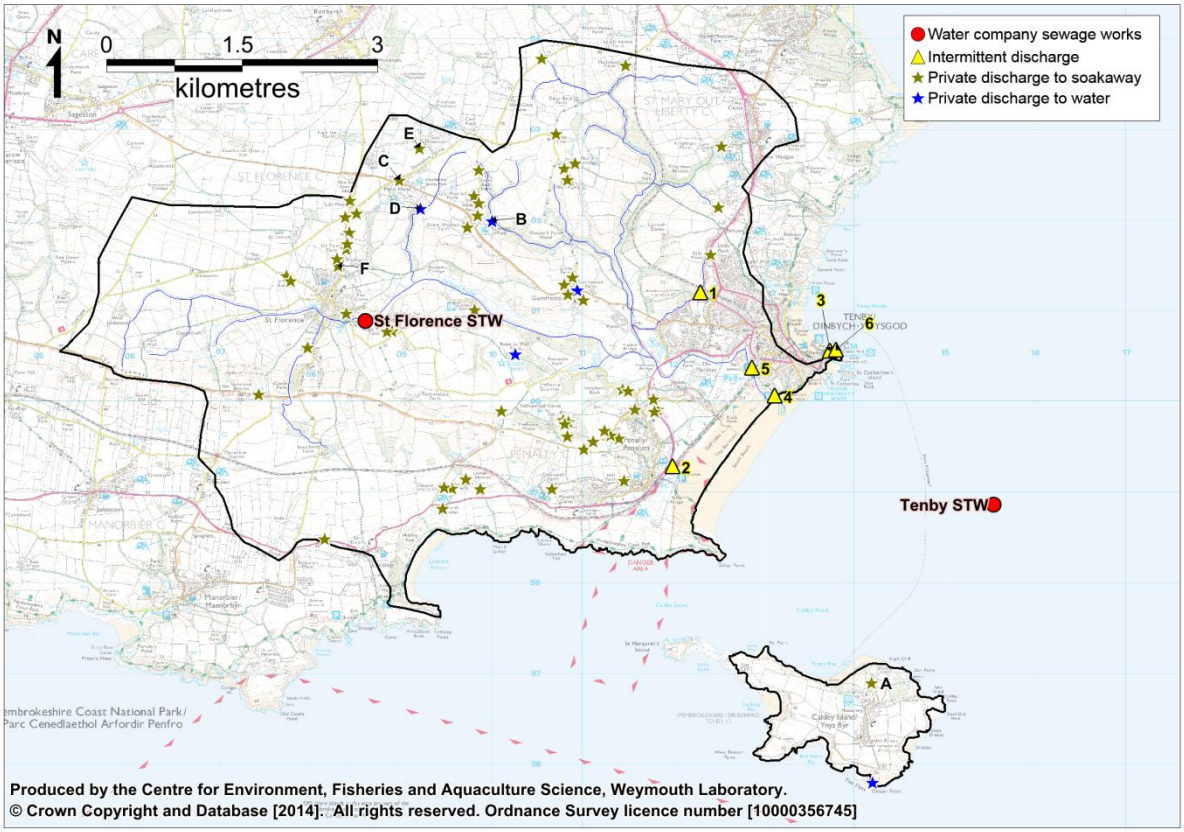

Figure II.1: Permitted sewage discharges to the survey area
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There are two continuous water company sewage works discharging within the survey area, details of which are presented in Table II.1

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

Name	NGR	Treatment	DWF (m^3/day)	Estimated bacterial loading (cfu/day)	Receiving environment
St. Florence STW	SN0860000900	Biological filtration	134	4.42×10^{11}*	River Ritec
Tenby STW	SS1554098870	UV disinfection	8,220	4.28×10^{10}**	Carmarthen Bay

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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	$7.2x10^6$
Primary (12)	127	$1.0x10^7$	14	$4.6x10^6$
Secondary (67)	864	$3.3x10^5$	184	$5.0x10^5$
Tertiary (UV) (8)	108	$2.8x10^2$	6	$3.6x10^2$

Data from Kay et al. (2008b).
n - number of samples.
Figures in brackets indicate the number of STWs sampled.

The Tenby STW provides UV disinfection, the efficacy of which is monitored. Table II.3 and Figure II.2 summarises the results of bacteriological testing of the final effluent from this works.

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

Sewage works	No.	Geometric mean result (cfu/100ml)	Minimum	Maximum
Tenby STW	60	521	<10	210,000

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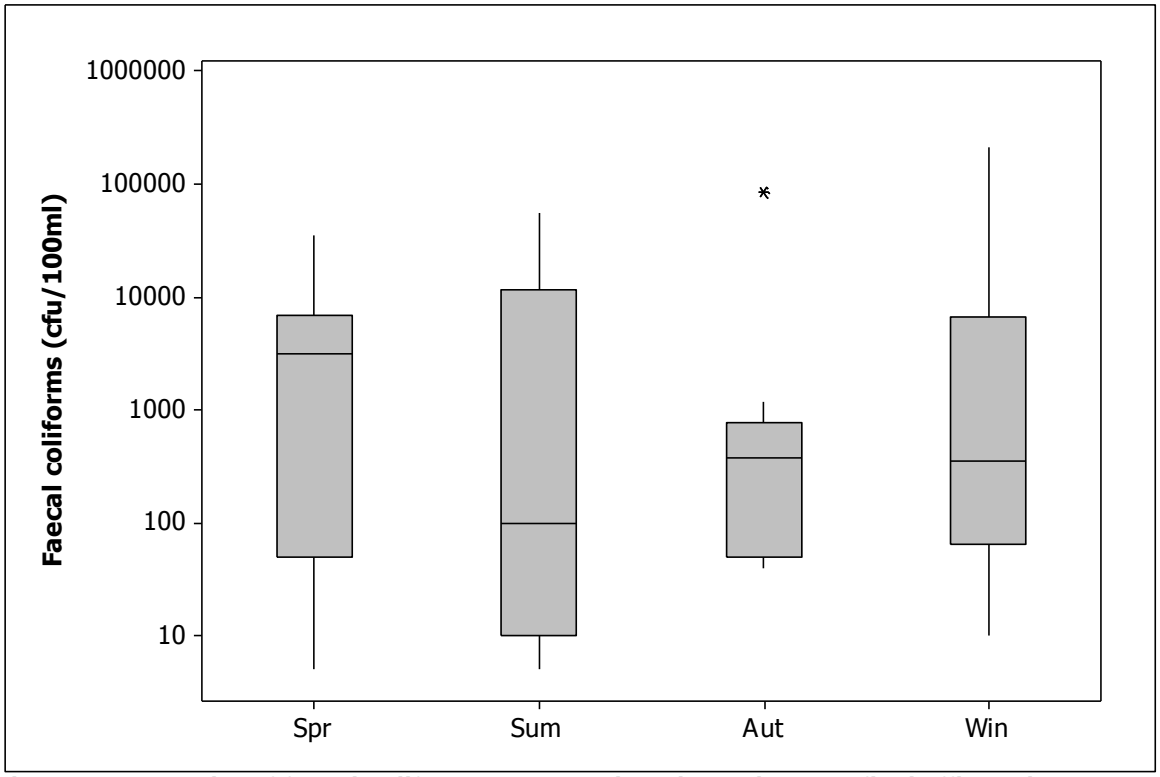

Figure II.2: Boxplot of faecal coliform concentrations in Tenby STW final effluent by season.
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Bacteriological testing results for the final effluent from Tenby STW indicates that disinfection is effective, and the estimated (average) bacterial loading it generates is therefore minor. The maximum concentration of faecal coliforms recorded was over two orders of magnitude higher than the average however. There is little in the way of

seasonality in the bacteriological content of the final effluent, although results were less variable in the autumn. It must be noted that UV disinfection is less effective at eliminating viruses than bacteria (e.g. Tree et al, 1997).

The Tenby STW discharges via a long sea outfall which lies in 5-10 m of water 2.7 km off Tenby beach. This location offers a high dilution potential, but lies only about 700 m from the razor area at Caldey Roads. The other water company sewage works (St. Florence STW) discharges to the River Ritec, which drains to the shore at Tenby. It only provides secondary treatment so is likely to make a significant contribution to the bacterial loading carried into coastal waters by this watercourse.

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 survey area

No.	Name	Grid reference	Receiving water
1	Lamack Vale PS	SN1230001200	Knightson Brook
2	Penally PS	SS1199399281	Unnamed stream
3	Tenby East PS	SN1373000560	Sea
4	Tenby Headworks Storm Tanks	SN1312000060	River Ritec
5	Tenby Headworks Storm Tanks	SN1287000370	River Ritec
6	Tenby Lifeboat CSO	SN1380000570	Sea

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No spill records were available for any of these discharges, so it is difficult to assess their impacts aside from noting their locations and their potential to spill storm sewage. Five of the six are located within the town of Tenby, and the sixth (Penally PS) discharges to a watercourse which drains to the southern end of Tenby South Beach. The Tenby STW long sea outfall is not permitted to make overflow discharges.

Although the majority of properties within the survey area are served by water company sewerage infrastructure, there are also a number of permitted private discharges. Where specified, these are generally treated by small treatment works such as package plants, and the majority of these are small, serving one or two properties. All permitted and registered 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. It is possible that there are further private discharges that Natural Resources Wales are not yet aware of.

Table II.5: Details of permitted private sewage discharges (> 5m^3/day) to the survey area

Ref.	Property served	Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
A	Caldey Abbey Septic Tank	SS1419096900	Septic Tank	16	Soakaway
B	Dinosaur & Country Park	SN1000002000	Unspecified	5.3	Ritec trib.
C	Heatherton Country Park	SN0897602448	Package plant	25	Soakaway
D	Heatherton Country Sports Park	SN0920602132	Package plant	13.5	Ritec trib.
E	New Minerton Leisure	SN0920002800	Unspecified	21	Soakaway

Ref.	Property served	Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
	Park				
F	Plough Penny Field Nursery	SN0830001500	Unspecified	5	Soakaway

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Most of the private sewage discharges are to soakaway so should have no impacts on coastal waters, assuming they are functioning correctly. There are four discharging to the Ritec and tributaries, including two of the larger ones (B and E). These will make a relatively minor contribution to the bacterial loading delivered to coastal waters by this watercourse. Additionally, there is a small septic tank discharge from the lighthouse on the south shore of Caldey Island direct to the sea, but this is sufficiently distant from the shellfisheries to be of negligible significance.

Appendix III. Sources and Variation of Microbiological Pollution: Agriculture

Agricultural census data from 2012 indicates that about 50% of the land within the survey catchment is pasture, and about 7% is used for growing crops (Welsh Government, pers. comm.). The land cover map (Figure 1.2) shows that pastures are widespread throughout the catchment, as are small pockets of arable land.

Table III.1 presents livestock numbers and densities for the catchment deriving from the 2012 agricultural census. Geographic assignment of animal counts in this dataset is based on the allocation of a single point to each farm, whereas in reality an individual farm may span the catchment boundary. Nevertheless, Table III.1 should give a reasonable indication of the numbers and types of livestock within the catchment.

Table III.1: Summary statistics from 2012 livestock census for the Tenby catchment

	Total numbers	Density (no/km^2)
Cattle	2,784	85.2
Sheep	1,061	32.5
Poultry	388	11.9
Pigs	8	0.2
Goats	2	0.1
Horses	55	1.7

Data from Welsh Government

The concentration of faecal coliforms excreted in the faeces of animals and humans 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.

Animal	Faecal coliforms (No./g wet weight)	Excretion rate (g/day wet weight)	Faecal coliform load (No./day)
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).

Table III.1 indicates that there are significant numbers of cattle and sheep within the catchment, but little other livestock. During the shoreline survey around 190 sheep were observed on the cliff-top fields between Giltar Point and Lydstep, and three horses were seen on Caldey Island.

Livestock manures will either be deposited directly on pastures by grazing animals, or collected from operations such as cattle sheds and poultry houses and spread on both arable land and pasture. This in turn may be washed into watercourses which will carry it

to coastal waters. Watercourses which animals can access will be more vulnerable than those that are fenced off. Given the ubiquity of farmland throughout the survey area, all watercourses may potentially be affected at times.

The geographical pattern of agricultural impacts is likely to mirror those of land runoff, with the majority delivered to coastal waters via the River Ritec. As the primary mechanism for mobilisation of faecal matter deposited on pastures into watercourses is via land runoff, fluxes of agricultural contamination into coastal waters will be highly rainfall dependent. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the 'first flush').

There is likely to be seasonality in levels of contamination originating from livestock. 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 access watercourses more frequently to drink and cool off. 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. Other manures and sewage sludge may be spread at any time of the year. Therefore peak levels of contamination from grazing livestock 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 occur at any time of the year.

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 the survey area. Boat traffic in the area is mainly limited to recreational craft (yachts and cabin cruisers) and fishing vessels. Figure IV.1 presents an overview of boating activity derived from the shoreline survey, satellite images and various internet sources.

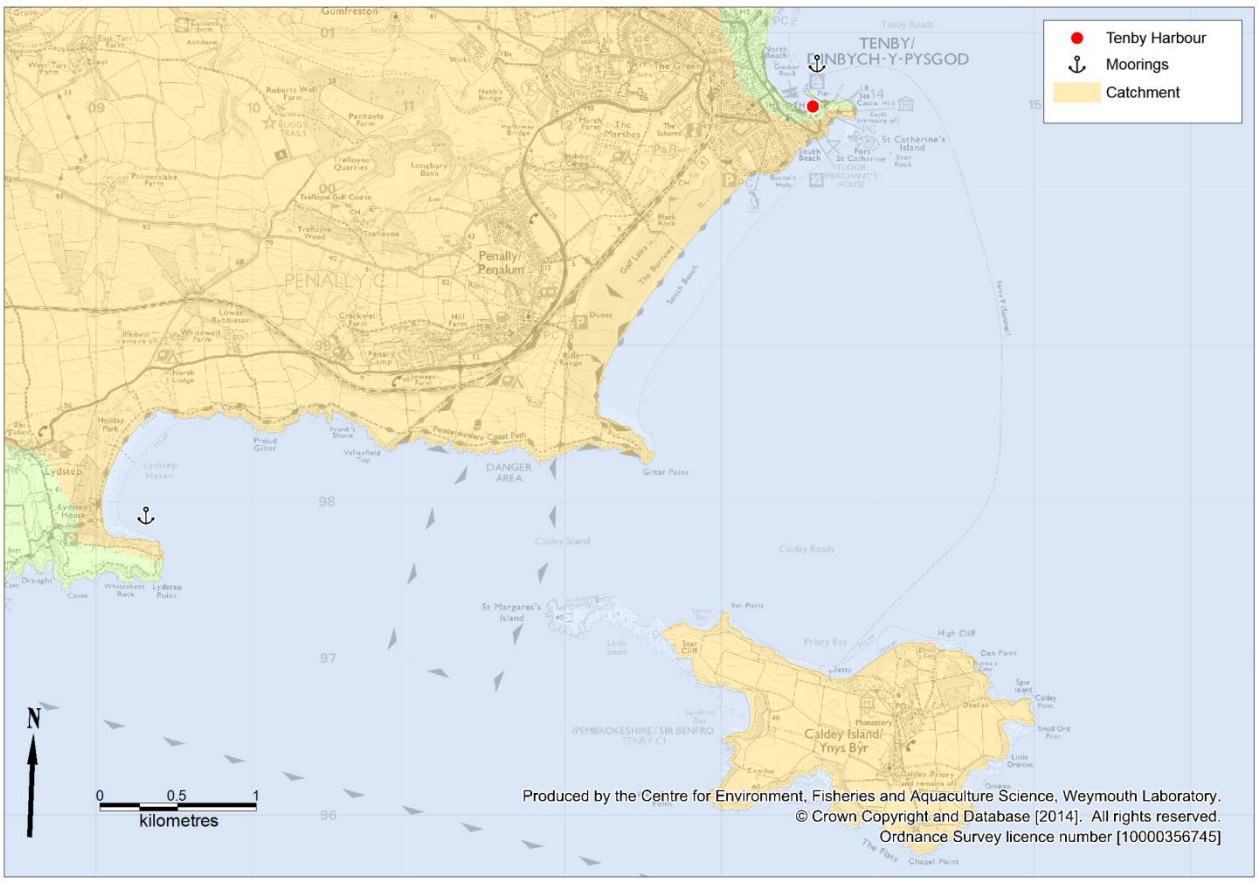

Figure IV.1: Boating activity in the Tenby survey area

There are no commercial ports, marinas or facilities within the area, however there are a few moorings available for fishing vessels and pleasure boats in Tenby Harbour, and the sheltered bays such as Lydstep Haven also offer a place to anchor for visiting pleasure craft. The closest sewage pump out facilities are situated in Swansea around 60 km south east (The Green Blue, 2010). Tenby Sailing Club located in Tenby Harbour north of the survey area offers a variety of cruising and racing for yachts and the smaller dinghies. Other watersports including kayaking, windsurfing, dinghy sailing and jet skiing are also popular within the survey area (Pembrokeshire Coast National Park, 2013).

Tenby was once a thriving fishing port, but today it supports a reduced fishing fleet of 9 fishing vessels under 10 metres and 1 vessel over 10 metres that are listed as having

Tenby as their home port (MMO, 2014). Their fishing patterns are uncertain but are unlikely to cause significant microbiological pollution given their small numbers. Boat trips are run from Tenby Harbour for fishing trips and wildlife tours, and there is a small ferry which runs to Caldey Island. These only operate during the summer months.

It is therefore concluded that boat traffic in the area is limited to small numbers of pleasure craft, fishing vessels, and tour boats so the impacts from boat traffic are likely to be minor. 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 is likely that the moorings and the main navigation routes through the area are most at risk of contamination from this source. 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.

Appendix V. Sources and Variation of Microbiological Pollution: Wildlife

The survey area, which includes Caldey Island, encompasses rocky cliffs, sandy bays and sand dunes which attract significant populations of birds and other wildlife. Consequently the area falls under several national and international conservation statuses, including forming part of the Pembrokeshire Coast National Park and is partly within Carmarthen Bay and Estuaries Special Area of Conservation (SAC). The cliffs of Tenby and St. Catherine's Island qualify as a Special Site of Scientific Interest (SSSI) because of their habitats and geology.

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). 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. A survey in the early summer of 2000 recorded 6,741 individuals including lesser black-backed gulls, European herring gulls, northern fulmars, razorbills and European shags. (Mitchell *et al*, 2004). The principal nesting site is Caldey Island, where around 90% of these seabirds nest. Their presence in large numbers here was confirmed on the shoreline survey. 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. Nesting colonies on Caldey Island are in close proximity to the razor clam shellfishery and so may be a significant source of microbiological pollution to the shellfisheries. Most species are likely to be present all year round, although they may be more dispersed outside of their breeding season.

Counts of overwintering waterbirds (wildfowl and waders) are undertaken in Carmarthen Bay, of which the survey area forms a small part at its western extremity. An average total count of 49,874 was recorded over the five winters up until 2012/2013 (Austin *et. al*, 2014). It is concluded that whilst there is likely to be an influx during the winter months, the survey area does not attract these birds in large concentrations. These are likely to represent a minor source of diffuse contamination to the intertidal areas and coastal grasslands.

The Pembrokeshire coast hosts a large colony of grey seals of around 5,000 individuals (Pembrokeshire Marine SAC website, 2014). A small proportion of this colony, around 28 to 60 seals are known to haul out on Caldey Island (Kiely et. al, 2000). The moulting and pupping season for grey seals is between December to April and August to December respectively and in these months they will spend more time at their haul out sites and less time in the water. Given their small numbers and the large area they are likely to forage over their impacts are likely to be minor, and unpredictable in spatial terms. No other wildlife populations of potential relevance to this survey have been identified.

Appendix VI. Meteorological Data: Rainfall

The monthly rainfall data for the Tenby Sewage Treatment Works (STW) weather station are shown in Figure VI.1.

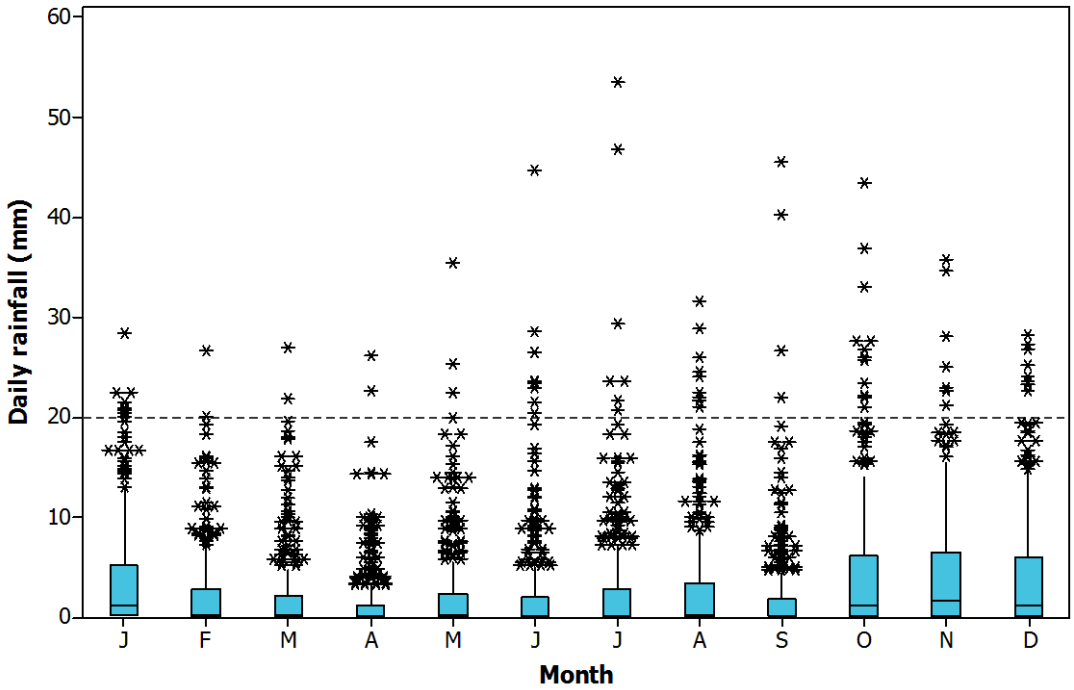

Figure VI.1: Boxplot of daily rainfall totals at Tenby STW, January 2004 to December 2013.
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The Tenby STW weather station received an average of 1,059 mm per year between 2004 and 2014. The winter and autumn months (October to January inclusive) had the highest average rainfall, while April had the lowest average rainfall. Daily totals of over 20 mm were recorded on 2% of days and no rainfall was recorded on 42% of days between 2004 and 2014. High rainfall events (> 20 mm/day) were recorded in all months of the year but were more frequent in the second half of the year.

Rainfall may lead to the discharge of raw or partially treated sewage from combined sewer overflows (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 (Met Office, 2012). The strongest winds are associated with the passage of deep areas of low pressure close to or across the UK. The frequency and strength of these depressions is greatest in the winter half of the year, especially from November to February, and this is when mean speeds and gusts are strongest (Met Office, 2012).

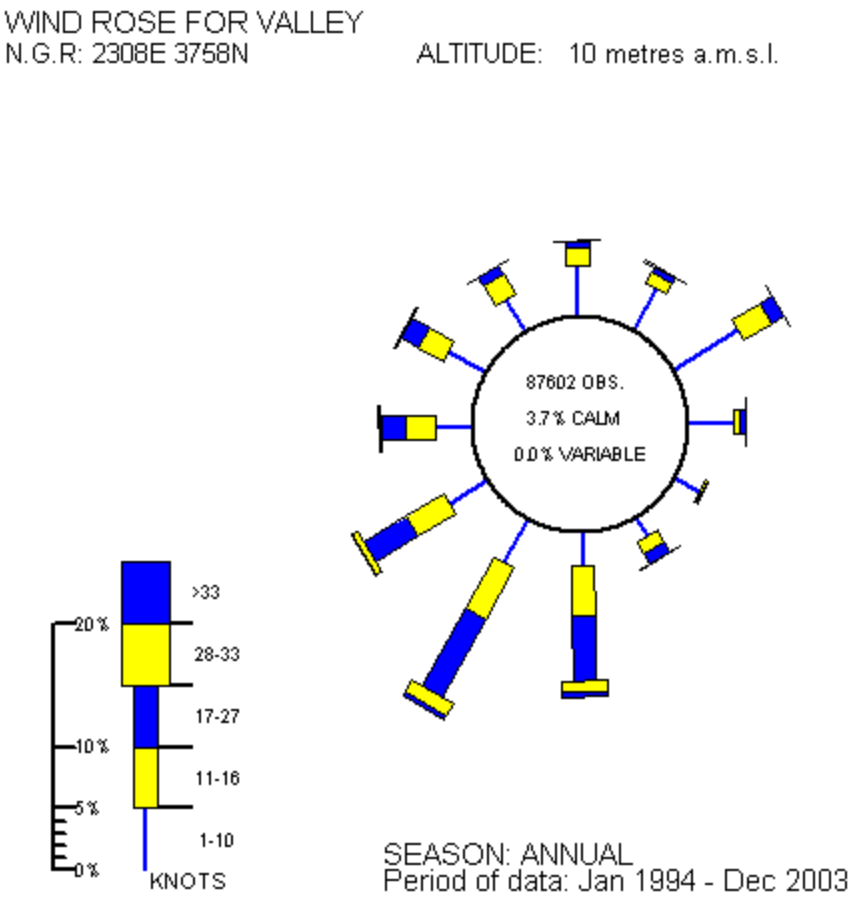

Figure VII.1: ***Wind rose for Valley.***
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The wind rose for Valley (Anglesey) is typical of coastal locations in Wales. The prevailing wind direction is from the south west and the strongest winds usually blow from this direction. A higher frequency of north easterly winds occurs during spring. The adjacent land provides shelter from winds from the north and the west, whilst Caldey Island provides more limited shelter from winds from the south and east. The eastern end of the mussel site is most exposed to the prevailing south westerly winds and swells.

Appendix VIII. Hydrometric Data: Freshwater Inputs

A small hydrological catchment of only 33 km^2 drains to the shore of the survey area. The main freshwater input is the River Ritec, which is a minor river that discharges via a piped outfall to the subtidal area at the northern end of Tenby South Beach. There is one further but much smaller freshwater input that drains a small area of low lying land just north of Giltar Point via another piped outfall, the Penally Burrows drainage outfall. There are no freshwater inputs from Giltar Point through to Lydstep Point as the coastal areas here are of a higher elevation than the land to the north, so runoff drains northwards towards the River Ritec or the Burrows outfall.

Figure VIII.1: Freshwater inputs into the Tenby survey area

The hydrogeology of the catchment area is described as being a mixture of low and moderate permeability (NERC, 2012). The Ritec is surface water dominated, so will respond rapidly to rainfall, a high proportion of which will run off (Natural Resources Wales, 2014). The maximum elevation in the catchment is just over 100 m, so the Ritec is not a particularly high gradient river.

There is one flow gauging station on the Ritec, which is located at St Florence, in the upper reaches, representing roughly 40% of the total area this watercourse drains. Summary statistics for this flow data are presented in Table VIII.1. Data considered covers the period from October 2005 to February 2014.

Table VIII.1: Summary flow statistics for the St Florence Bridge gauging station, 2005-2014

Station Name	Water course	Mean Flow (m^3s-1)	Q95[1] (m^3s^{-1})	Q10[2] (m^3s^{-1})
St Florence Bridge	Ritec	0.127	0.029	0.260

[1]Q95 is the flow that is exceeded 95% of the time (i.e. low flow). [2]Q10 is the flow that is exceeded 10% of the time (i.e. high flow).

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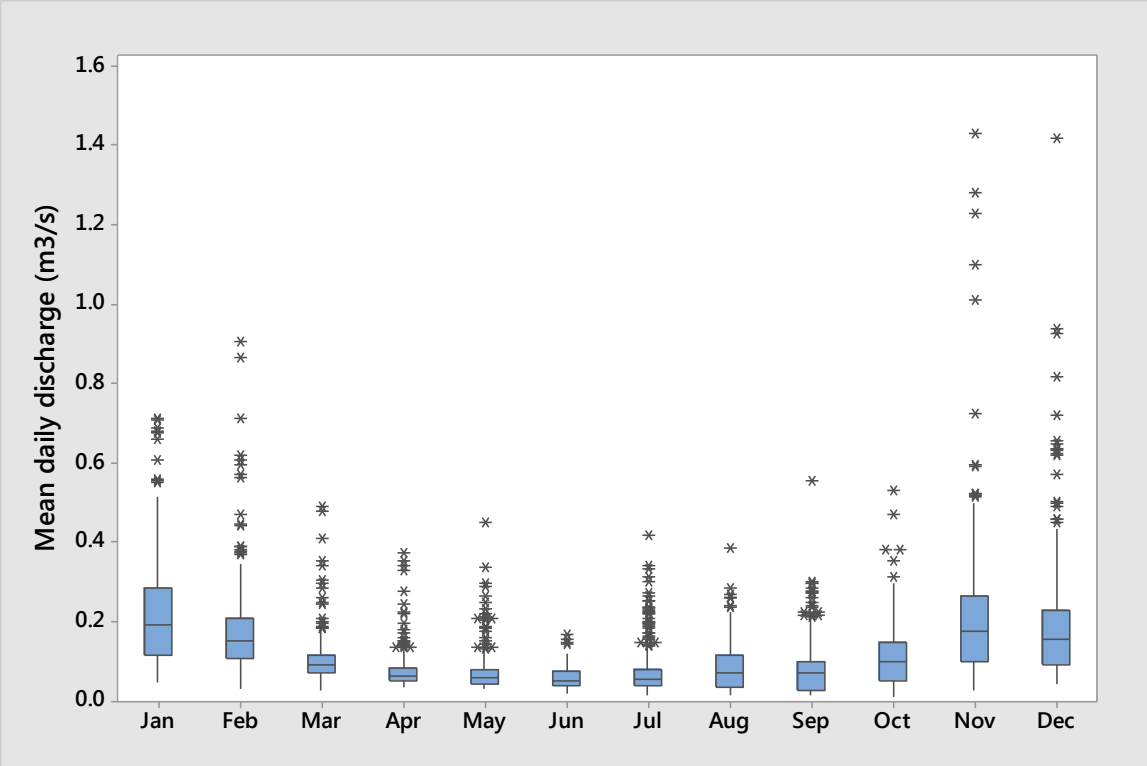

Figure VIII.2: Boxplots of mean daily flow records from St Florence Bridge gauging station, 2005-2014

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Strong seasonal variation is apparent in Figure VIII.2, with lowest average flows from April to September, and highest flows on average from November to February. Although flow does vary from day to day, relatively high flow events (exceeding 0.5 m^3/sec) only tended to occur in the November to February period, and the highest individual flow events occurred in November and December. The highest flow recorded in June was only 0.169 m^3/sec. A study undertaken during May to September 2003 (Wyer *et al*, 2003) estimated the mean discharge from the Ritec at its tidal limit is about 0.15 m^3/sec. The geometric mean *E. coli* concentration from multiple samples taken from this watercourse during this study was 4,500 cfu/100ml. This indicates that a typical (summer) bacterial loading delivered by this watercourse is in the order of $6x10^{11}$ *E. coli*/day, although this will vary greatly with conditions.

Due to the unusual configuration of its outfall, the River Ritec was not sampled or measured during the shoreline survey. The Burrows drainage outfall was accessible and a water sample was taken for bacteriological testing and a spot flow gauging was made. The same was done on a previous visit to the area in 2011.

Table VIII.2: Spot flow gauging and *E. coli* sample results from the Burrows outfall

Date and time	Position	*E. coli* (cfu/100ml)	Discharge m^3/day	Bacterial loading (*E. coli*/day)
03/06/2014 08:16	SS 12183 98637	120	320	$3.5x10^8$
13/09/2011 10:28	SS 12247 98613	1,800	778	$1.4x10^{10}$

The limited data suggests that this watercourse is of less potential significance than the Ritec, and highlights the variable nature of bacterial loadings delivered by such watercourses.

Appendix IX. Hydrography

IX.1. Bathymetry

The survey area lies in an open coast location in the very outer reaches of the Bristol Channel. Figure IX.1 shows a bathymetric chart of the area.

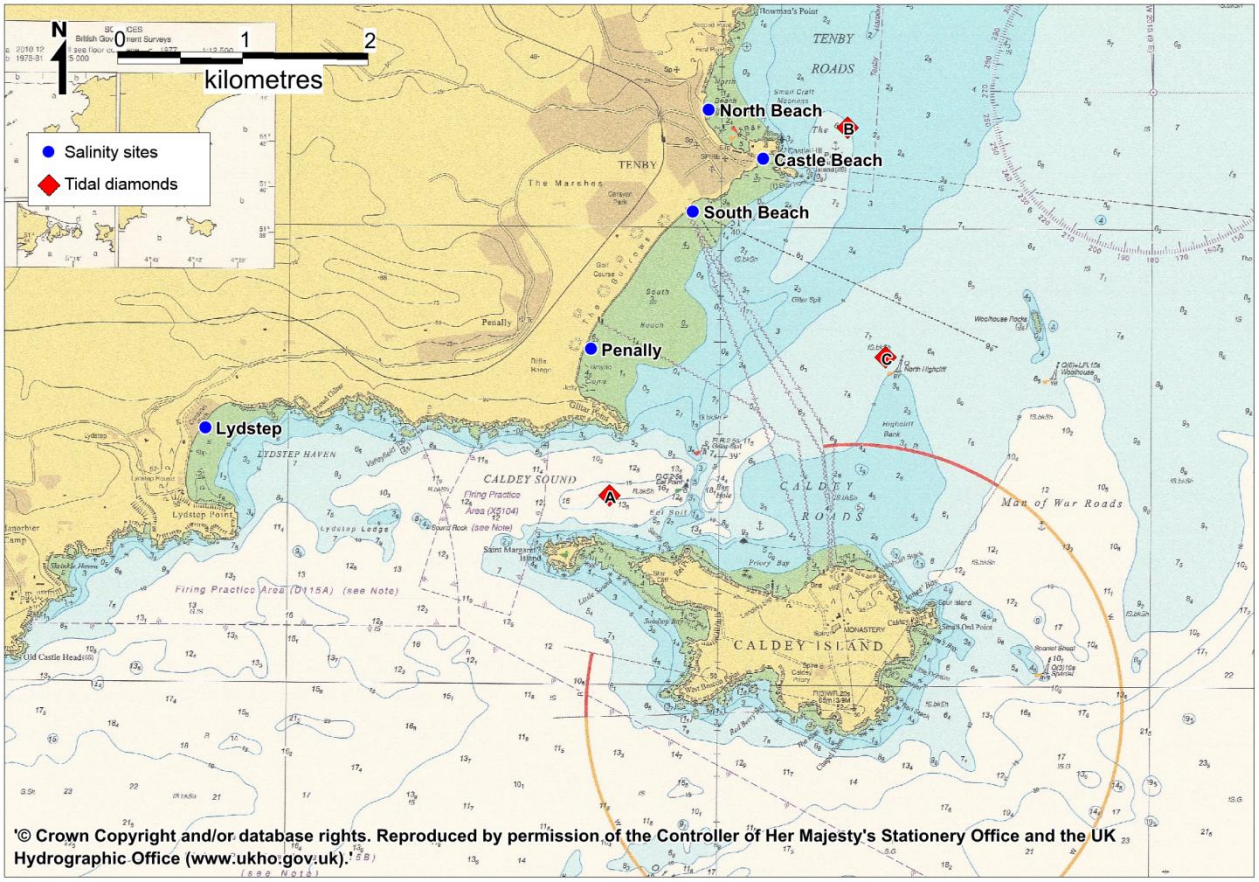

Figure IX.1: Bathymetry of the survey area

Between Tenby and Giltar Point the bathymetry is uncomplicated, sloping gently away through the intertidal and into the subtidal areas. It deepens to nearly 20 m in Caldey Sound where tides are funnelled between Caldey Island and Giltar Point. There is a raised bar at the eastern end of Caldey Sound (Eel Spit) over which tides are likely to accelerate and turbulent mixing of the water column may occur. Caldey Roads, where the razor stocks are located, is relatively shallow and may represent an area of slacker tidal streams where they split around Caldey Island. There are headlands at Tenby, Giltar Point and Lydstep point, around which there are also likely to be increases in current speed. The depression in the seabed off Tenby for example is likely to be a result of the scouring action of increased tidal currents. Lydstep Haven forms a shallow, gently sloping embayment to the north of Lydstep Point within which tidal streams are likely to be slacker, and within which eddies may form. The open coastal location will offer high potential for dilution and water exchange.

IX.2. Tides and Currents

Currents in coastal waters are largely driven by a combination of tides, winds and density effects. The tidal range in the area is large (7.5 m on spring tides) and this will drive extensive water movements.

Table IX.1: Tide levels and ranges at Tenby

	Height above chart datum (m)				Range (m)	
Port	MHWS	MHWN	MLWN	MLWS	Spring	Neap
Tenby	8.4	6.3	3.0	0.9	7.5	3.3

Data from Admiralty Totaltide

There are three tidal diamonds within the survey area (Figure IX.1). Tidal stream information from these is presented in Table IX.2. This includes estimates of flood and ebb tidal excursions, which are the distances a drifting particle would be carried during the course of a tide. These are based on a fixed point so they should be treated with caution as tidal stream strength and direction will vary with location. Nonetheless they will give an indication of the distance over which sources of contamination such as the Tenby STW will impact over.

Table IX.2: Tidal stream information (relative to high water at Avonmouth, which is about 1 hour after high water at Tenby)

Hours before / after high water	Diamond A			Diamond B			Diamond C		
	Direction (°)	Spring rate (m/s)	Neap rate (m/s)	Direction (°)	Spring rate (m/s)	Neap rate (m/s)	Direction (°)	Spring rate (m/s)	Neap rate (m/s)
HW-6	76	1.1	0.5	7	0.5	0.2	31	0.7	0.3
HW-5	76	1.3	0.6	7	0.4	0.2	58	0.6	0.3
HW-4	75	1.2	0.6	357	0.3	0.1	41	0.4	0.2
HW-3	78	0.7	0.4	2	0.2	0.1	21	0.6	0.3
HW-2	250	0.3	0.1	142	0.1	0.1	310	0.4	0.2
HW-1	256	1.0	0.5	177	0.4	0.2	217	0.6	0.3
HW	253	1.1	0.5	184	0.5	0.2	220	0.7	0.3
HW+1	257	1.1	0.5	182	0.5	0.2	216	0.6	0.3
HW+2	258	1.0	0.5	188	0.2	0.2	212	0.6	0.3
HW+3	259	0.5	0.2	195	0.2	0.1	214	0.4	0.2
HW+4	67	0.1	0.1	356	0.2	0.1	68	0.1	0.1
HW+5	77	0.6	0.3	3	0.5	0.2	48	0.5	0.2
HW+6	76	0.9	0.4	6	0.5	0.2	40	0.6	0.3
Flood direction/ excursion	ENE	22 km	10 km	N	9 km	4 km	NE	12 km	6 km
Flood direction/ excursion	WSW	18 km	8 km	S	6 km	3 km	SW	12 km	5 km

Data from the UK Hydrographic office (Admiralty Chart 1482)

The tidal diamonds indicate a bidirectional pattern of tidal streams, which move roughly parallel to the coast, travelling up the Bristol Channel on the flood, and back out on the

ebb. As anticipated, they accelerate significantly through Caldey Sound, where they reach velocities of 1.3 m/s on spring tides. Diamond C suggests that the plume from the Tenby STW would be carried towards the north eastern corner of the razor area at Caldey Roads. However, as the tidal stream will split around Caldey Island to the south, and the outfall lies further offshore than the tidal diamond, it is possible that the plume largely remains to the east of the razor beds, then passes to the east of Caldey Island rather than through Caldey Sound. Tidal streams are likely to be slower over shallower and intertidal areas due to the effects of friction. The Lydstep Haven embayment is likely to represent a slacker area, and it is possible that eddies may form here at certain states of the tide. There will therefore be stronger currents towards the eastern end of the mussel several order area than at its western end.

Superimposed on tidally driven currents are the effects of freshwater inputs and wind. Freshwater inputs are minimal, and the survey area is in an open coastal location, so it is unlikely that freshwater related stratification of the water column will occur. This is confirmed by salinity measurements taken at the bathing water monitoring points (Figure IX.2).

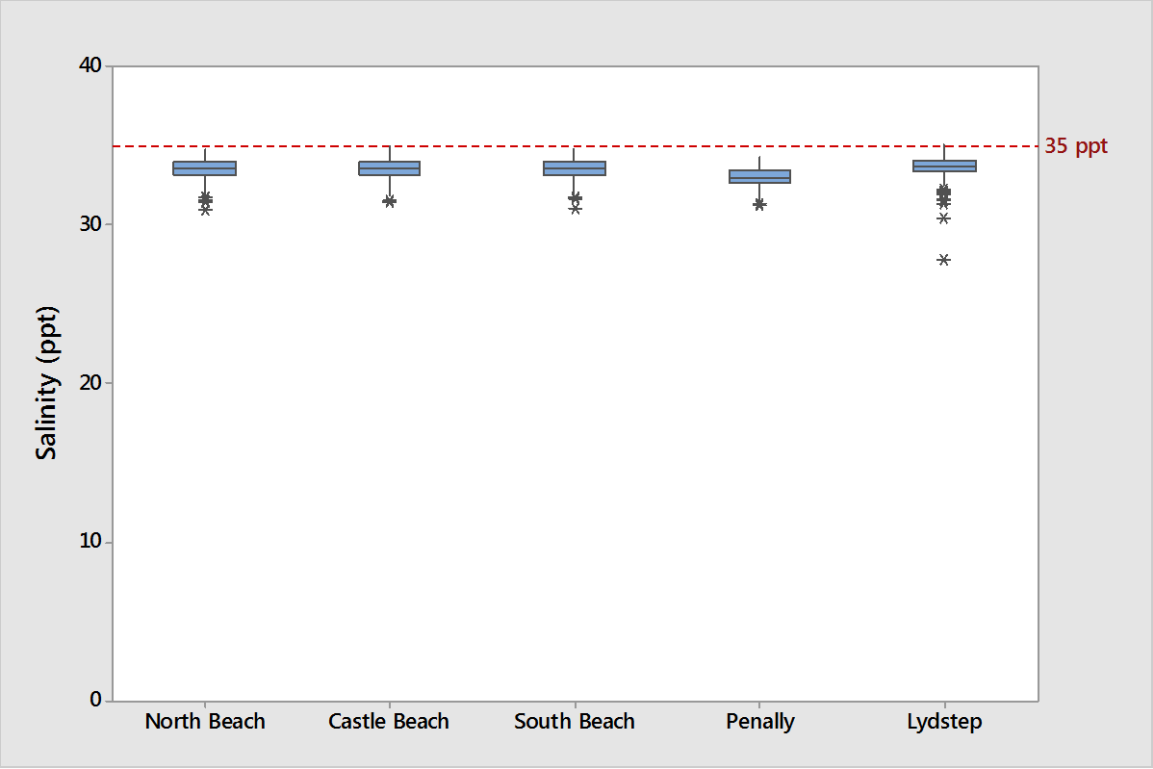

Figure IX.2: Boxplot of salinities recorded at the bathing water monitoring points
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Salinities recorded at the bathing water monitoring points were consistently that of full strength seawater. Although these measurements were all made during the warmer months of the year, it can nevertheless be concluded that freshwater influence here is minimal. Even at South Beach, near where the River Ritec drains, the salinity never dropped below 30 ppt. A density related effect of potential relevance to the fishery is that sewage discharged from long sea outfalls, being less dense than the receiving seawater,

will tend to rise to the surface and this will limit their impacts on any benthic shellfish beds in their vicinity to some extent.

Strong winds will modify surface currents within the survey area. 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^{-1}) would drive a surface water current of about 1 knot or 0.5 m s^{-1}. These currents will create return currents, either lower down the water column or along sheltered margins. South westerly winds would tend to advect the (buoyant) plume from Tenby STW away from the razor beds. 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.

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. The two fishery areas are largely sheltered from the prevailing south westerly winds, although the eastern end of the mussel several order area is more exposed. Winds from the south east will cause significant wave action along Tenby South Beach, and to a lesser extent within Lydstep Haven.

Appendix X. Microbiological Data: Seawater

There are five bathing waters around Tenby designated under the Directive 76/160/EEC (Council of the European Communities, 1975), the locations of which are shown in Figure X.1.

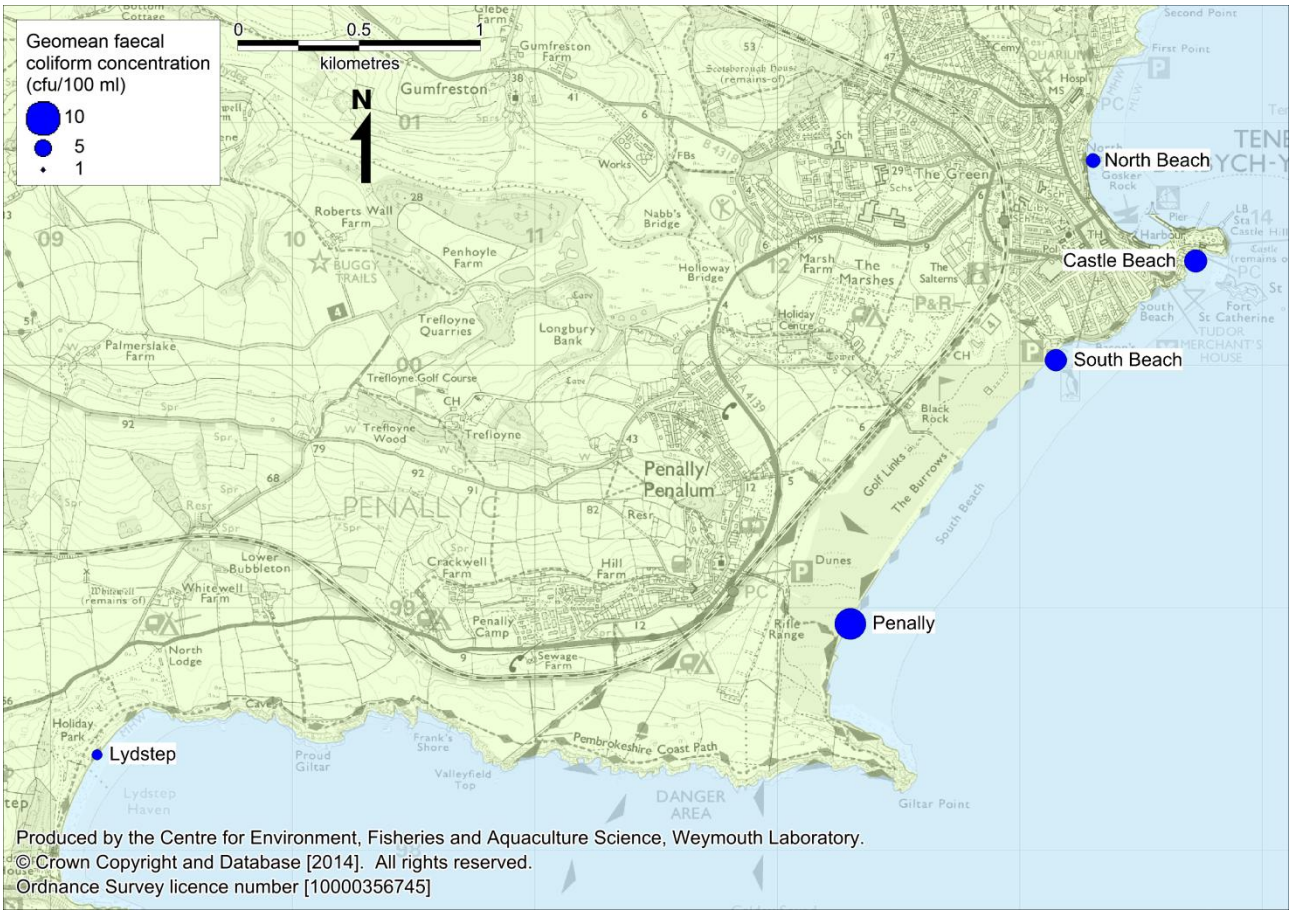

Figure X.1: Location of designated bathing waters monitoring points around Tenby.
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Around twenty water samples were taken from each of the bathing waters sites during each bathing season, which runs from the 15th May to the 30th September. Due to changes in the analyses of bathing water quality by Natural Resources Wales from 2012, summary statistics of results by bathing water before and after 2012 are presented separately in Table X.1: Summary statistics for bathing waters *E. coli* results, 2012-2013 (cfu/100 ml).

Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1,000
North Beach	40	09/05/2012	16/09/2013	8.9	<10	1,800	5.0	2.5
Castle Beach	40	09/05/2012	16/09/2013	12.4	<10	280	10.0	0.0
South Beach	40	09/05/2012	16/09/2013	11.0	<10	560	7.5	0.0
Penally	40	09/05/2012	18/09/2013	10.3	<10	82	0.0	0.0
Lydstep	40	09/05/2012	18/09/2013	6.8	<10	136	2.5	0.0

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Table X. and Table X.2 below.

Table X.1: Summary statistics for bathing waters *E. coli* results, 2012-2013 (cfu/100 ml).

Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1,000
North Beach	40	09/05/2012	16/09/2013	8.9	<10	1,800	5.0	2.5
Castle Beach	40	09/05/2012	16/09/2013	12.4	<10	280	10.0	0.0
South Beach	40	09/05/2012	16/09/2013	11.0	<10	560	7.5	0.0
Penally	40	09/05/2012	18/09/2013	10.3	<10	82	0.0	0.0
Lydstep	40	09/05/2012	18/09/2013	6.8	<10	136	2.5	0.0

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Table X.2: Summary statistics for bathing waters faecal coliforms results, 2004-2011 (cfu/100 ml).

Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1,000
North Beach	163	06/05/2004	22/09/2011	4.3	<2	1,400	2.5	0.6
Castle Beach	164	06/05/2004	22/09/2011	6.6	<2	554	4.3	0.0
South Beach	162	06/05/2004	22/09/2011	6.3	<2	1,188	4.3	0.6
Penally	121	04/05/2004	13/09/2011	9.2	<2	840	9.9	0.0
Lydstep	162	07/05/2004	21/09/2011	3.0	<2	308	0.6	0.0

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Owing to the relatively restricted number of results available post 2012 and the similar range in levels of results post 2012, only the extended 2004-2011 data set are used in the further analyses below. Figure X.2 presents box plots of these data.

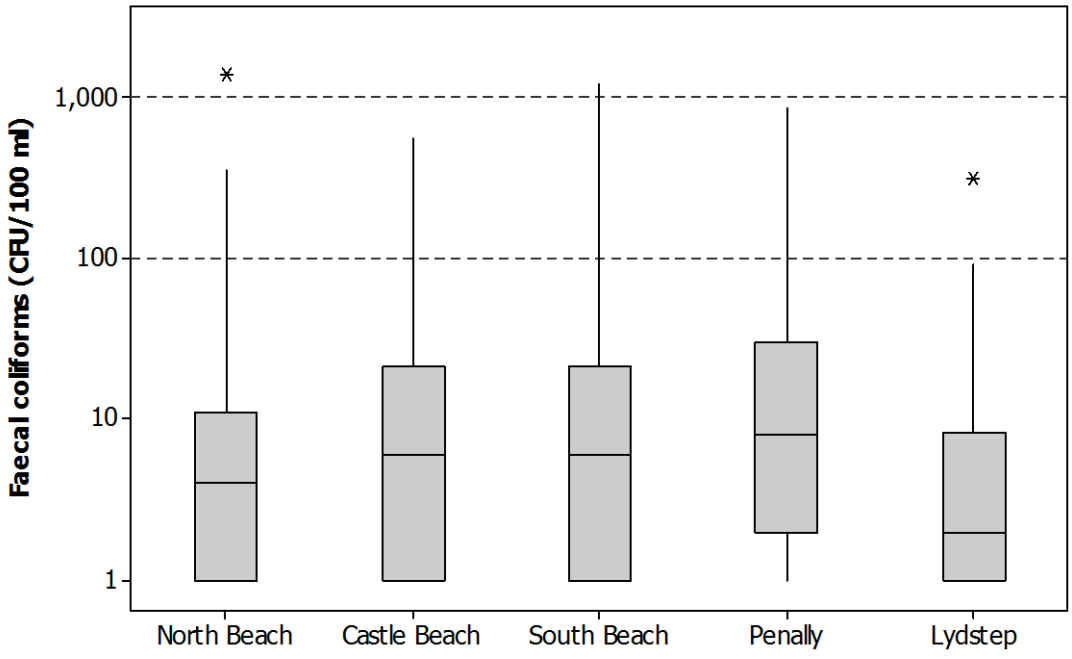

Figure X.2: Box-and-whisker plots of all faecal coliforms results by site

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North Beach and South Beach had results exceeding 1,000 faecal coliform cfu/100 ml, but no sites had any samples exceeding 10,000 faecal coliforms/100 ml. A one-way ANOVA

test showed that there were significant differences in faecal coliform concentrations between sites (p<0.001). Tukey post-hoc tests showed that Lydstep had significantly lower faecal coliform concentrations than all other sites except North Beach. Additionally, North Beach had significantly lower faecal coliform concentrations than Penally.

Correlations (Pearson's) were run between samples at the sites that shared sampling dates, and therefore environmental conditions, on at least 20 occasions. Lydstep was sampled on the same day as all other sites except Penally on fewer than 20 occasions. There was a significant correlation between Lydstep and Penally (r=0.500, p=0.012). All other sites correlated significantly (r=0.374-0.487, p= <0.001-0.049). The correlations between sites indicate that they share similar contamination sources or are affected in a similar manner by environmental factors such as weather conditions.

Overall temporal pattern in results

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

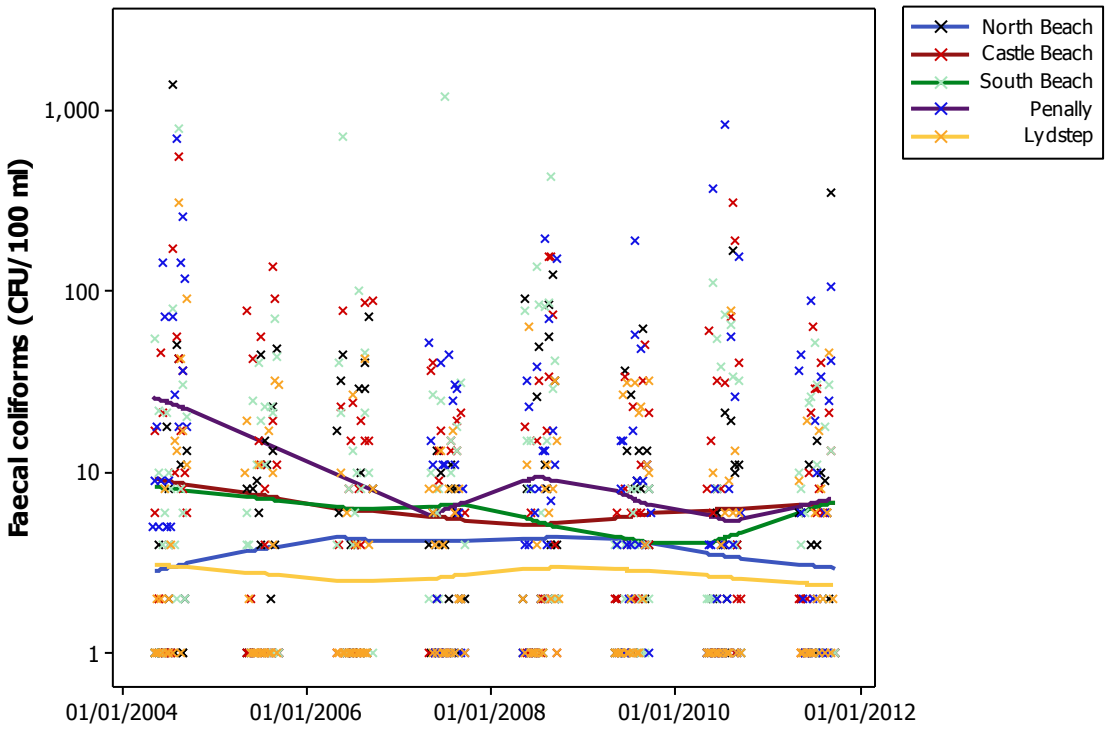

Figure X.3: Scatterplot of faecal coliform results for bathing waters around Tenby overlaid with loess lines.

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Faecal coliform levels have remained fairly stable at most sites except Penally since 2004. At Penally there appeared to be a slight decline in faecal coliform levels between 2004 and 2007.

Influence of tides

To investigate the effects of tidal state on faecal coliform results, circular-linear correlations were carried out against both the high/low and spring/neap tidal cycles for each of these bathing waters sampling points. Correlation coefficients are presented in Table X.1 statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table X.1: 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 Beach	0.250	0.000	0.260	<0.001
Castle Beach	0.076	0.395	0.095	0.231
South Beach	0.082	0.345	0.125	0.084
Penally	0.267	0.000	0.359	<0.001
Lydstep	0.220	0.000	0.196	0.002

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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 Tenby 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.

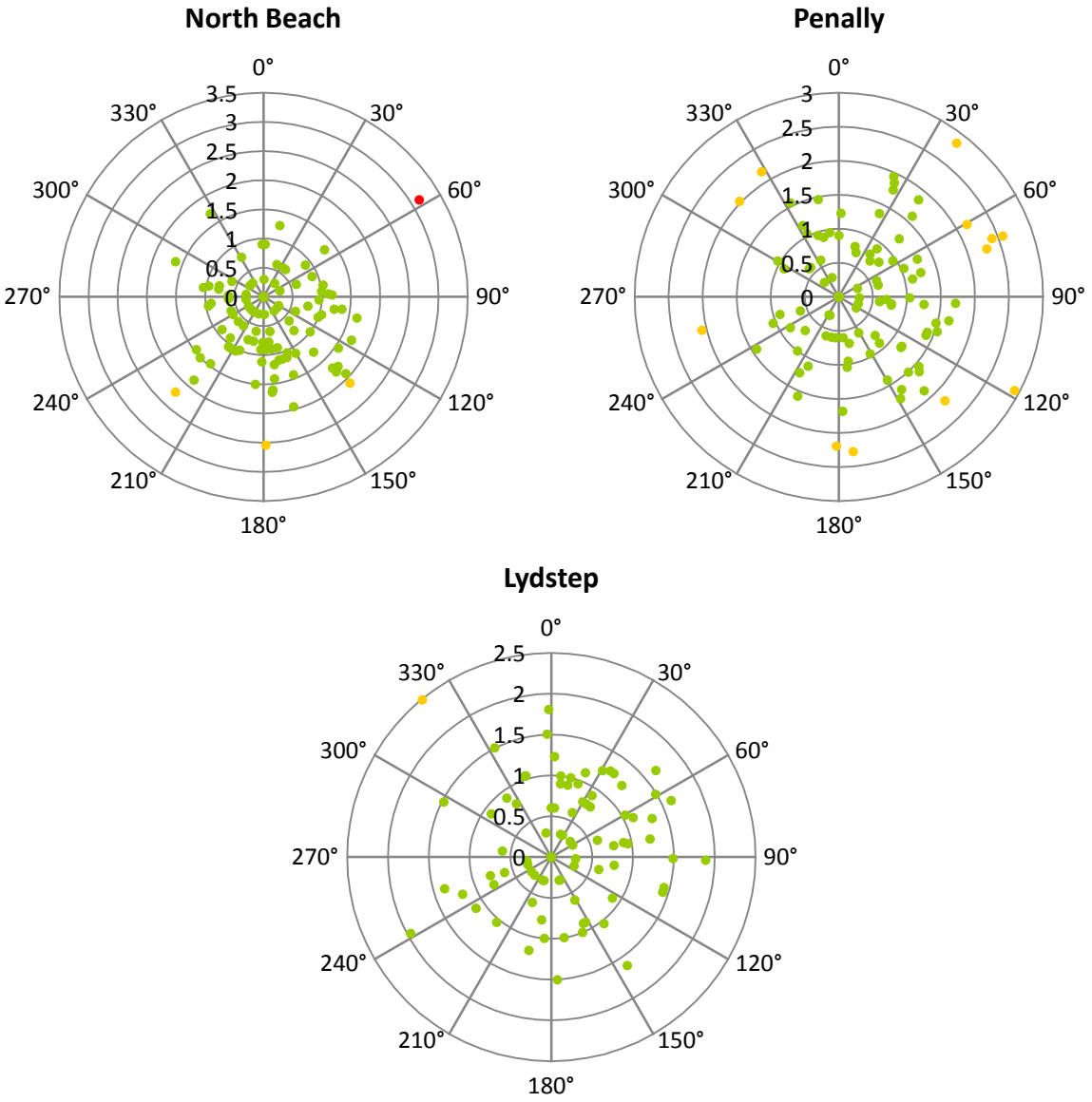

Figure X.4: Polar plots of log_{10} faecal coliform results (cfu/100 ml) against high/low tidal state.
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At North Beach higher results tended to occur at lower states of the tide. At Penally, results were higher on average during the ebb tide. There is no obvious pattern apparent in the polar plot for Lydstep.

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.

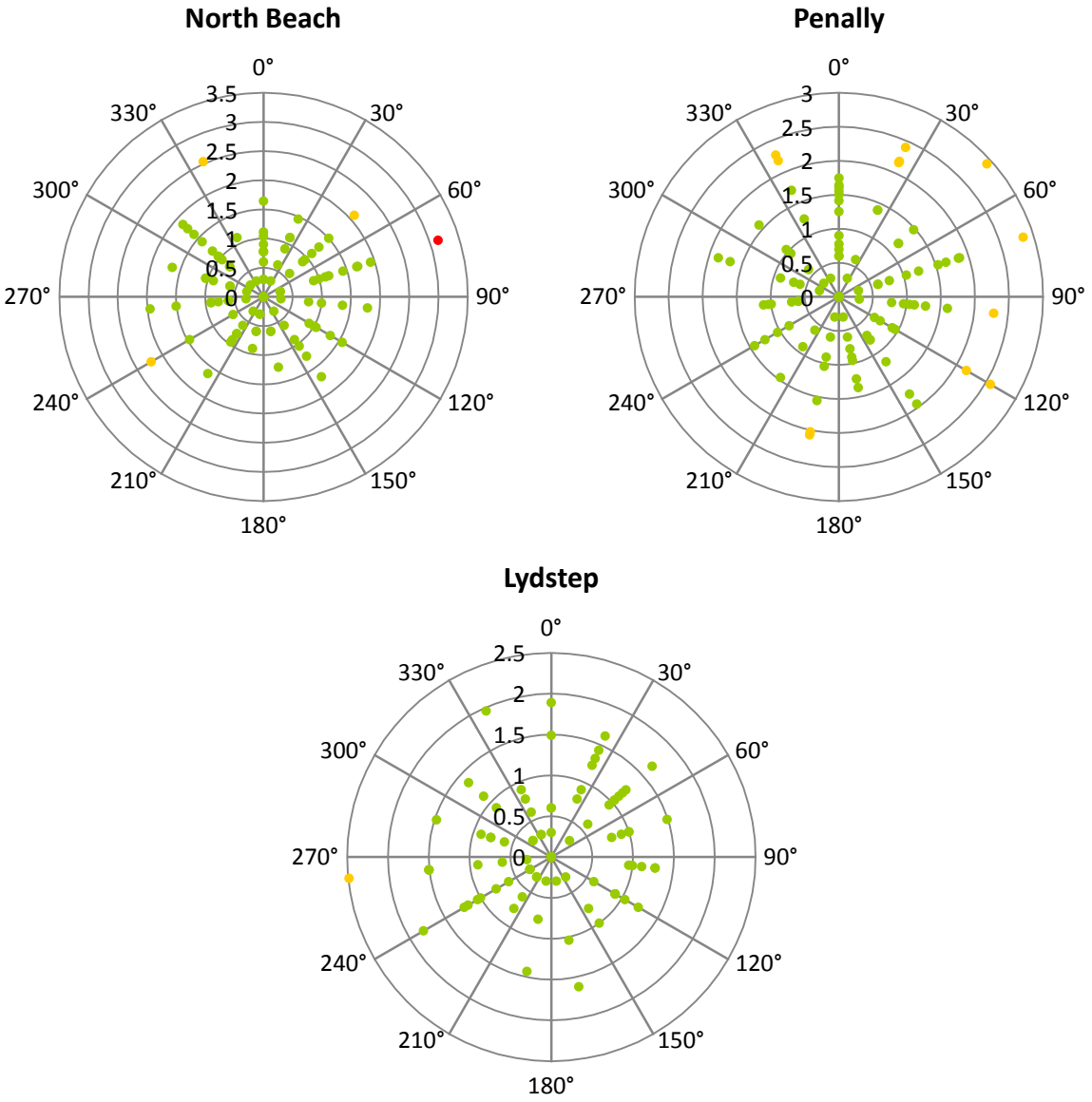

Figure X.5: Polar plots of log_{10} faecal coliform results (cfu/100 ml) against spring/neap tidal state.
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While correlations showed there to be significant changes in faecal coliforms concentrations with spring/neap tidal state at North Beach, no strong pattern was evident from the polar plot. At Penally, faecal coliform concentrations tended to be higher during spring tides. At Lydstep, there were fewer low results just after spring 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 Tenby STW weather station (Appendix VI for details) over various periods running up to sample collection and faecal coliforms results. These are presented in Table X.2 where statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table X.2: Spearmans Rank correlation coefficients for faecal coliforms results against recent rainfall

	Site	North Beach	Castle Beach	South Beach	Penally	Lydstep
	n	163	164	162	121	162
24 hour periods prior to sampling	1 day	0.219	0.098	0.089	0.170	0.129
	2 days	0.286	0.351	0.209	0.281	0.165
	3 days	0.167	0.280	0.041	0.096	0.039
	4 days	0.100	0.113	0.117	0.002	0.040
	5 days	0.190	0.022	0.081	0.150	0.073
	6 days	0.118	0.076	0.021	0.229	0.047
	7 days	0.047	0.081	0.120	0.057	0.132
Total prior to sampling over	2 days	0.302	0.254	0.165	0.266	0.170
	3 days	0.338	0.338	0.183	0.246	0.123
	4 days	0.302	0.288	0.183	0.242	0.074
	5 days	0.296	0.279	0.223	0.244	0.073
	6 days	0.321	0.263	0.220	0.303	0.087
	7 days	0.289	0.183	0.165	0.285	0.081

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North Beach had increased faecal coliform concentrations one day after rainfall and all sites had increased faecal coliform concentrations two days after a rainfall event. North Beach and Castle Beach continued to have increased faecal coliform concentrations 3 days after rainfall. The influence of rainfall was weakest overall at Lydstep.

Salinity

Salinity was recorded on most sampling occasions at North Beach, Castle Beach and Lydstep. Pearson's correlations were run to determine the effect of salinity on faecal coliforms at the bathing waters site. There was no significant correlation between salinity and faecal coliform concentration at North Beach or Castle Beach (p=0.934 and 0.617 respectively). There was a significant correlation between faecal coliform concentration and salinity at Lydstep (r=-0.174, p=0.028). Figure X.6 shows a scatter-plot of faecal coliforms against salinity at Lydstep.

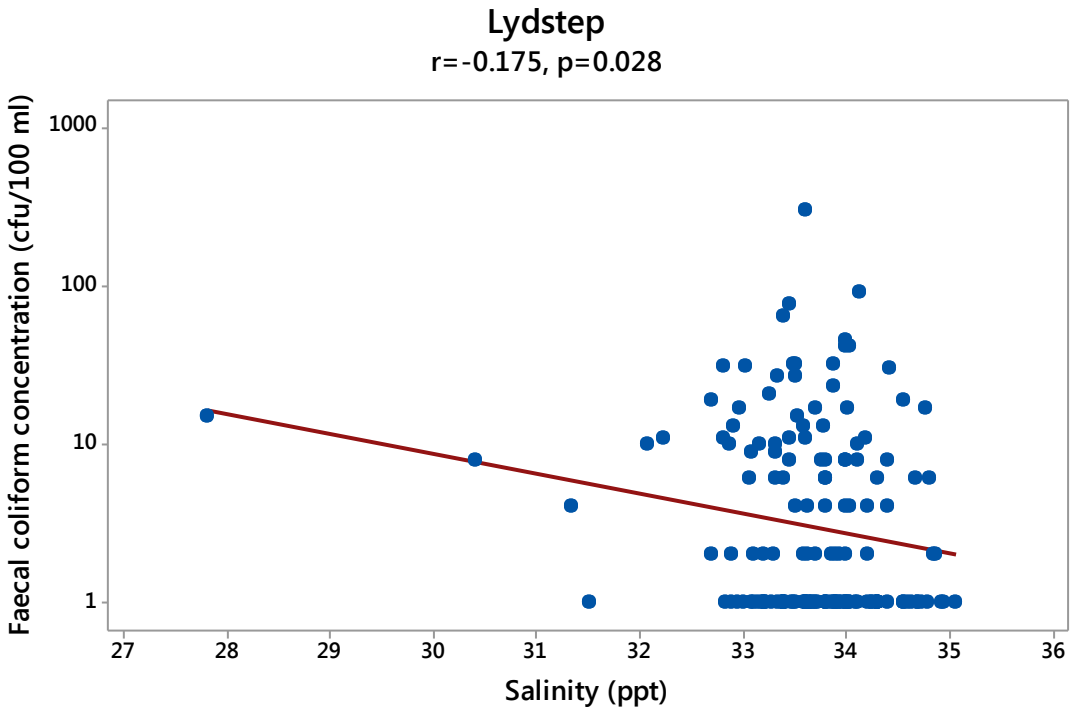

Figure X.6: Scatter-plots of salinity against faecal coliform concentration.
Contains Natural Resources Wales information © Natural Resources Wales and database right

While a significant (but relatively weak) correlation was found between salinity and faecal coliform concentrations at Lydstep, the range of salinities at which samples was taken was low and the number of samples taken at lower salinities was also low. Therefore no conclusion can be drawn as to the relationship between salinity and faecal coliform concentration at this site.

Appendix XI. Microbiological Data: Shellfish Flesh

One RMP (razor clams) has been sampled in the Tenby production area between 2005 and 2014. The location sampled is shown in Figure XI.1 and summary statistics are presented in Table XI.1.

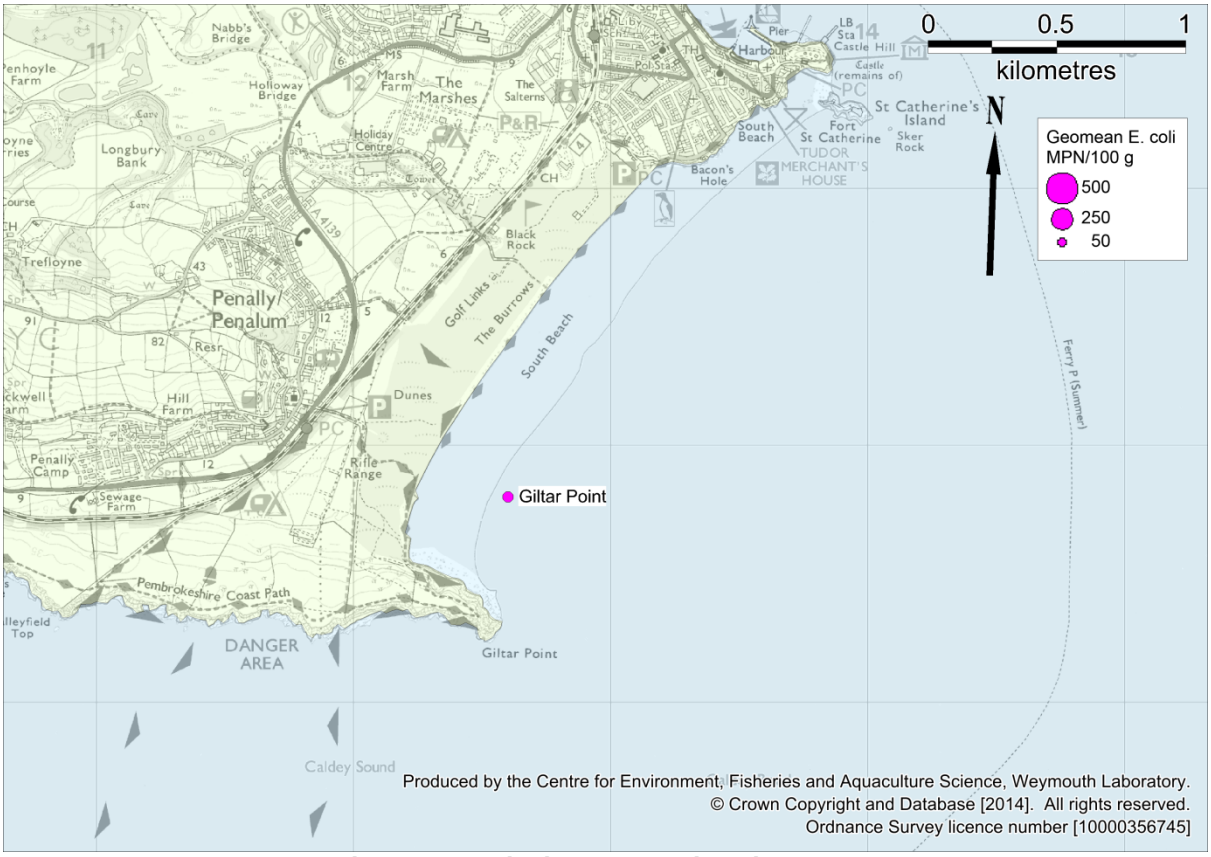

Figure XI.1: Bivalve RMP active since 2005

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

Site	Species	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 230	% over 4,600
Giltar Point	Razor clam	9	26/04/2013	15/06/2014	75.9	<20	940	44.4	0.0

Only nine samples have been taken from the Giltar Point razor clam RMP and so it is not yet classified. Of the nine samples, none have exceeded 4,600 *E. coli* MPN/100 g, while 44.4% have exceeded 230 *E. coli* MPN/100 g. The final sample required for initial classification is due to be taken later in 2014.

Appendix XII. Shoreline Survey Report

Date (time):
3rd June 2014 (08:30-13:30)

Cefas Officers:
David Walker

Local Enforcement Authority Officers:
Carwyn Thomas, Pembrokeshire County Council
Gary Tawn, Pembrokeshire County Council

Area surveyed:
Tenby Castle Sands to Lydstep Haven. Caldey Island, north shore beach and inland.

Weather:
Partial cloud, 17°C, wind bearing 246° at 6 km/h

Tides:
Admiralty TotalTide predictions for Tenby (51°40'N 4°42'W). All times in this report are BST.

03/06/2014		
High	10:13	7.1 m
High	22:29	7.2 m
Low	04:04	2.1 m
Low	16:13	2.3 m

XII.1. Objectives

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

It was not possible to access all of the north shore of Caldey Island due to private land extending along most of the coast except for the beach. An attempt to view the land adjacent to the shore was made by walking inland and uphill. However, there were too many obstructions to be able to see the coastline.

XII.2. Description of Fishery

It was not possible to meet with any of the harvesters during the trip to Tenby. Razor clam, cockle and Tapes clam dead shells were observed commonly along South Beach and native oysters were seen occasionally.

XII.3. Sources of contamination

Sewage discharges

No sewage discharges were observed during the survey.

Freshwater inputs

One fresh water input was seen at observation 2, which was probably drainage from the marshland that lies slightly inshore from South Beach. This input had an *E. coli* loading of only $3.84x10^{8}$ cfu/day.

Livestock

Sheep were seen at observations 4 and 6. At observation 6, there were around 150 sheep in one field which extended to the cliff edge. Three horses were seen inland on Caldey Island at observation 15.

Wildlife

Large number of gulls were seen roosting on the rocky north shore of Caldey Island (observation 11). There were also around 20 gulls seen on the north shore beach on Caldey Island (observation 12).

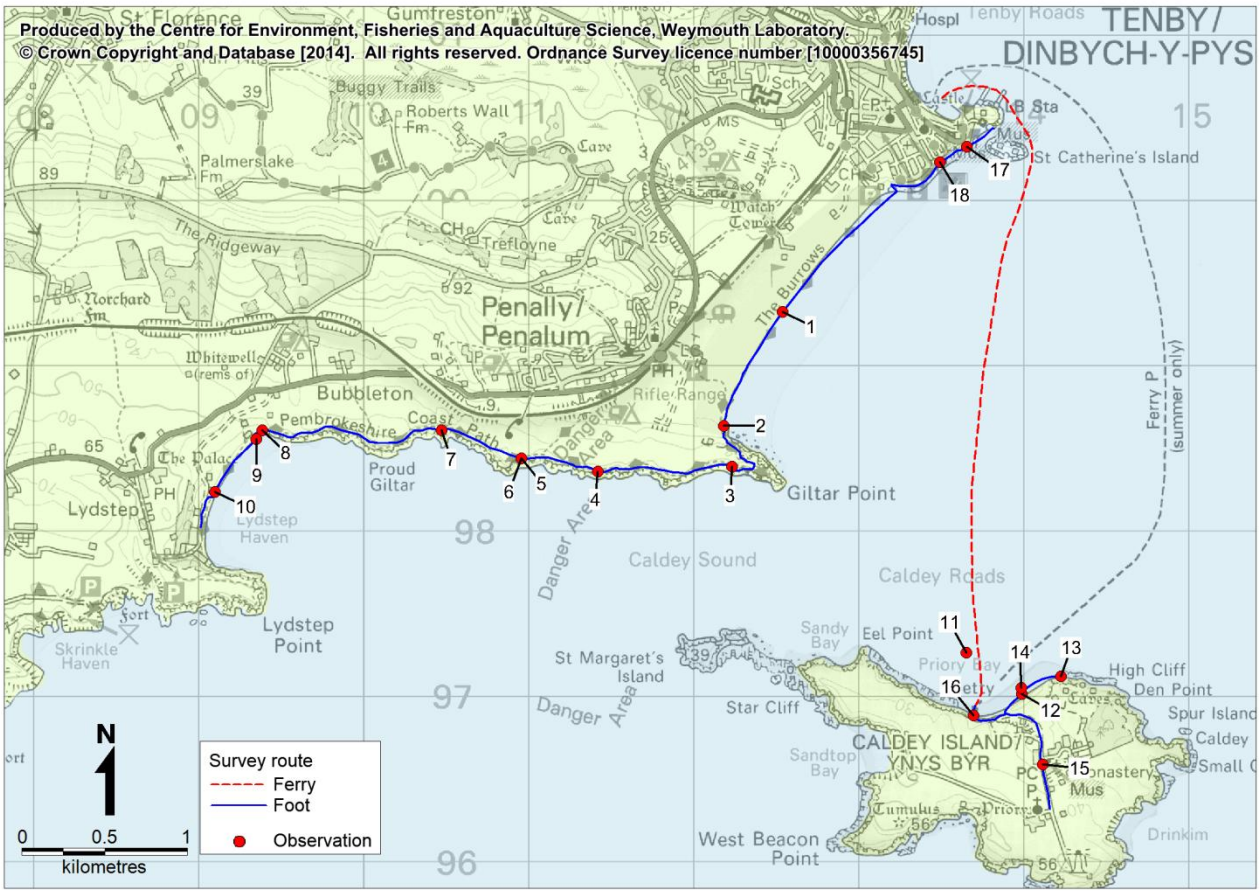

Figure XII.1: Locations of Shoreline Observations (Table XII.1 for details)

Table XII.1: Details of Shoreline Observations

Observation no.	NGR	Date	Time	Description	Photo
1	SS1253899327	03/06/2014	08:05	Razor clam (frequent), cockle (frequent), *Tapes* clam (frequent) and native oyster (rare) deadshell along entire beach	
2	SS1218398637	03/06/2014	08:16	Iron valved pipe. Probable marsh drainage (0.85 m diameter, 0.3 m flow width, 0.672 m/s, sample T01)	Figure XII.3
3	SS1223298390	03/06/2014	08:30	Start of firing range	
4	SS1141998361	03/06/2014	08:42	Around 40 sheep in field	
5	SS1095698440	03/06/2014	08:49	End of firing range	
6	SS1095698440	03/06/2014	08:49	Around 150 sheep grazing between cliff top and road	
7	SS1047298609	03/06/2014	08:56	End of sheep grazing, start of arable land	
8	SS0938498610	03/06/2014	09:17	Start of caravan park	
9	SS0934898557	03/06/2014	09:20	Seawater sample (T02)	
10	SS0910098238	03/06/2014	09:30	Seawater sample (T03)	
11	SS1365397264	03/06/2014	10:45	Gulls roosting along entire rocky shore	Figure XII.4
12	SS1398997013	03/06/2014	10:56	Around 20 gulls	
13	SS1422697119	03/06/2014	11:02	Seawater sample (T04)	
14	SS1398797050	03/06/2014	11:08	Seawater sample (T045)	
15	SS1411696586	03/06/2014	11:26	Three horses in field bearing 210°, 300 m	
16	SS1369796884	03/06/2014	12:14	Seawater sample (T06)	
17	SN1365700327	03/06/2014	12:49	Ground water drainage in walls	Figure XII.5
18	SN1349300232	03/06/2014	12:54	Two pipes under road at top of cliff	Figure XII.6

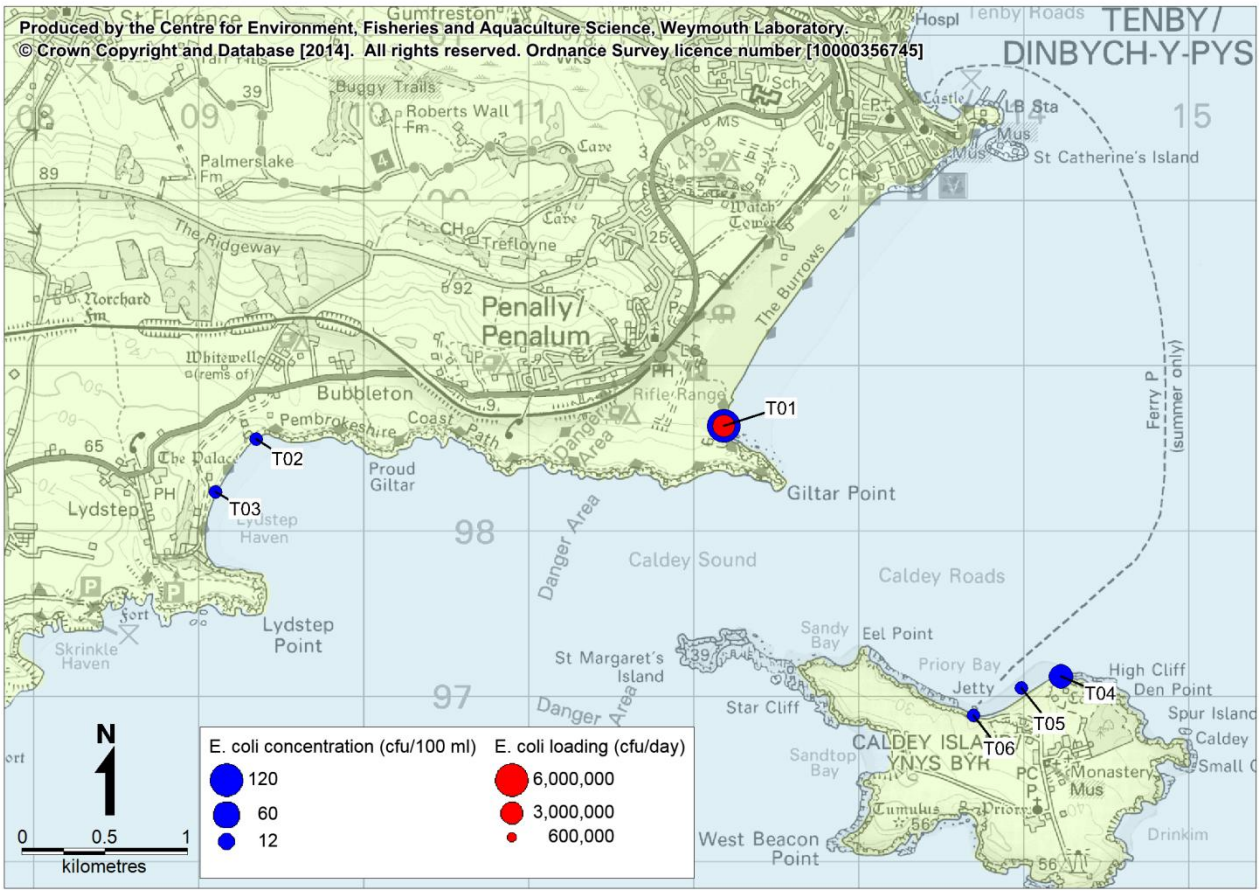

Figure XII.2: Water sample results (Table XII.2 for details)

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
T01	2	03/06/2014 08:16	Marsh drainage	0.0037	120	$3.84x10^8$	SS1218398637
T02	9	03/06/2014 09:20	Seawater sample		<10		SS0934898557
T03	10	03/06/2014 09:30	Seawater sample		<10		SS0910098238
T04	13	03/06/2014 11:02	Seawater sample		40		SS1422697119
T05	14	03/06/2014 11:08	Seawater sample		<10		SS1398797050
T06	16	03/06/2014 12:14	Seawater sample		<10		SS1369796884

Figure XII.3

Figure XII.4

Figure XII.5

Figure XII.6

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List of Abbreviations

AONB	Area of Outstanding Natural Beauty
BMPA	Bivalve Mollusc Production Area
CD	Chart Datum
Cefas	Centre for Environment Fisheries & Aquaculture Science
CFU	Colony Forming Units
CSO	Combined Sewer Overflow
CZ	Classification Zone
Defra	Department for Environment, Food and Rural Affairs
DWF	Dry Weather Flow
EA	Environment Agency
E. coli	Escherichia coli
EC	European Community
EEC	European Economic Community
EO	Emergency Overflow
FIL	Fluid and Intravalvular Liquid
FSA	Food Standards Agency
GM	Geometric Mean
IFCA	Inshore Fisheries and Conservation Authority
ISO	International Organization for Standardization
km	Kilometre
LEA (LFA)	Local Enforcement Authority formerly Local Food Authority
M	Million
m	Metres
ml	Millilitres
mm	Millimetres
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MPN	Most Probable Number
NM	Nautical Miles
NRA	National Rivers Authority
NWSFC	North Western Sea Fisheries Committee
OSGB36	Ordnance Survey Great Britain 1936
mtDNA	Mitochondrial DNA
PS	Pumping Station
RMP	Representative Monitoring Point
SAC	Special Area of Conservation
SHS	Cefas Shellfish Hygiene System, integrated database and mapping application
SSSI	Site of Special Scientific Interest
STW	Sewage Treatment Works
UV	Ultraviolet
WGS84	World Geodetic System 1984

Glossary

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

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

Acknowledgements

Carwyn Thomas and Gary Tawn (Milford Port Health Authority), Andy Woolmer (Salicia Marine).