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EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Brixham

January 2015

Food Standards Agency

Cover photo: Fishcombe

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Statement of use

This report provides a sanitary survey relevant to the bivalve mollusc farm at Brixham, 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 review	Fiona Vogt	19/01/2015
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Final	Final report post consultation	Simon Kershaw	16/04/2015

Consultation

Consultee	Date of consultation	Date of response
Torbay Council	04/02/2015	25/02/2015
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Natural England	04/02/2015	-

Dissemination

Food Standards Agency, Torbay Council. The report is available publicly via the Cefas website.

Recommended Bibliographic Reference

Cefas, 2015. Sanitary survey of Brixham. 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 in humans (e.g. Norovirus-associated gastroenteritis, Hepatitis A and Salmonellosis). 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 Bivalve Mollusc Production Areas (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 anticipated that the sanitary survey may serve to help to target future water quality improvements and improve analysis of their effects on shellfish hygiene. Improved monitoring should lead to improved detection of pollution events and identification of the likely sources of pollution. Remedial action may then be possible either through funding of improvements in point sources of contamination or as a result of changes in land management practices.

This report documents the information relevant to undertake a sanitary survey for mussels (*Mytilus* spp.) at Brixham. The area was prioritised for survey in 2014-15 via a risk ranking exercise.

1.2. Area description

Brixham is a fishing town situated on the southern shore of Tor Bay in Devon. The rope mussel farm which is the subject of this survey lies in the southern part of Tor Bay, just to the west of Brixham.

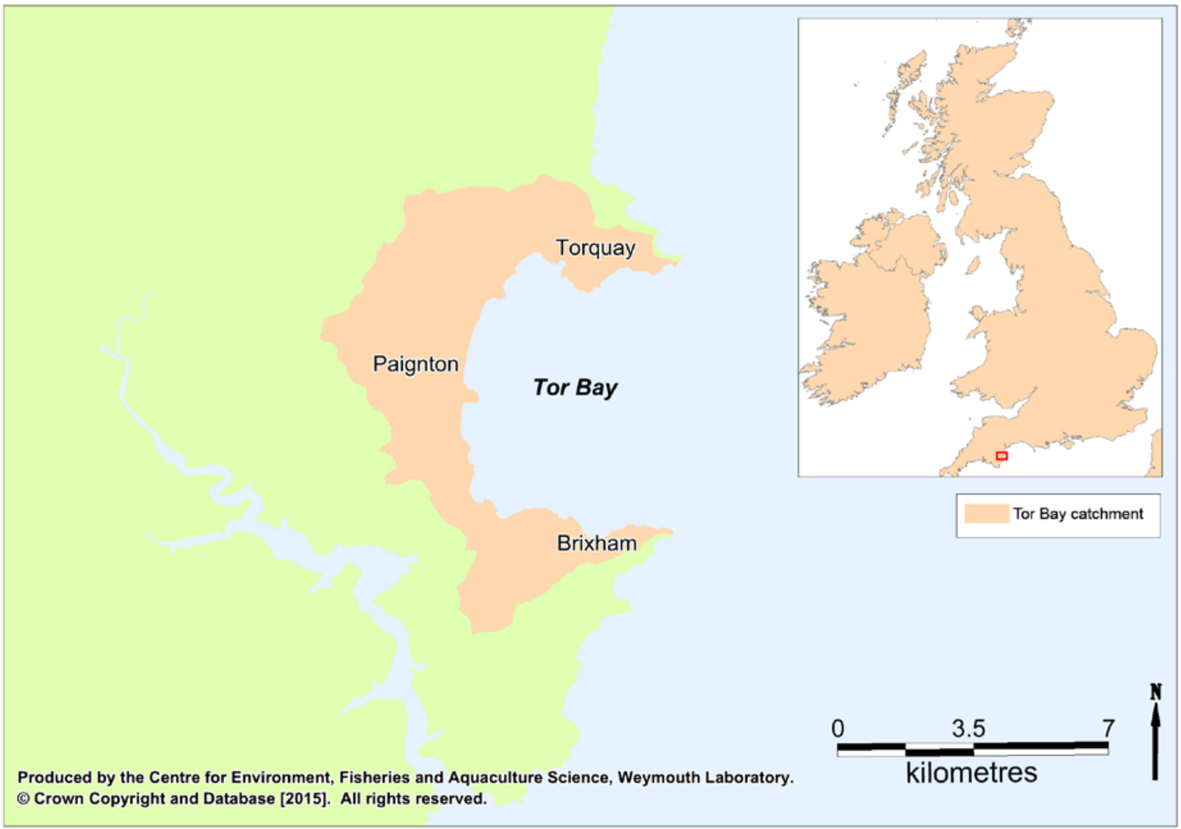

Figure 1.1: Location of Brixham

Fishing forms a major part of the economy within the region, with Brixham Harbour being home to the largest fishing fleet in England Tourism is also important to the local economy within the survey area particularly the seaside towns of Paignton and Torquay.

1.3. Catchment

The hydrological catchment of Tor Bay is relatively small, covering an area of only 38 km^2.

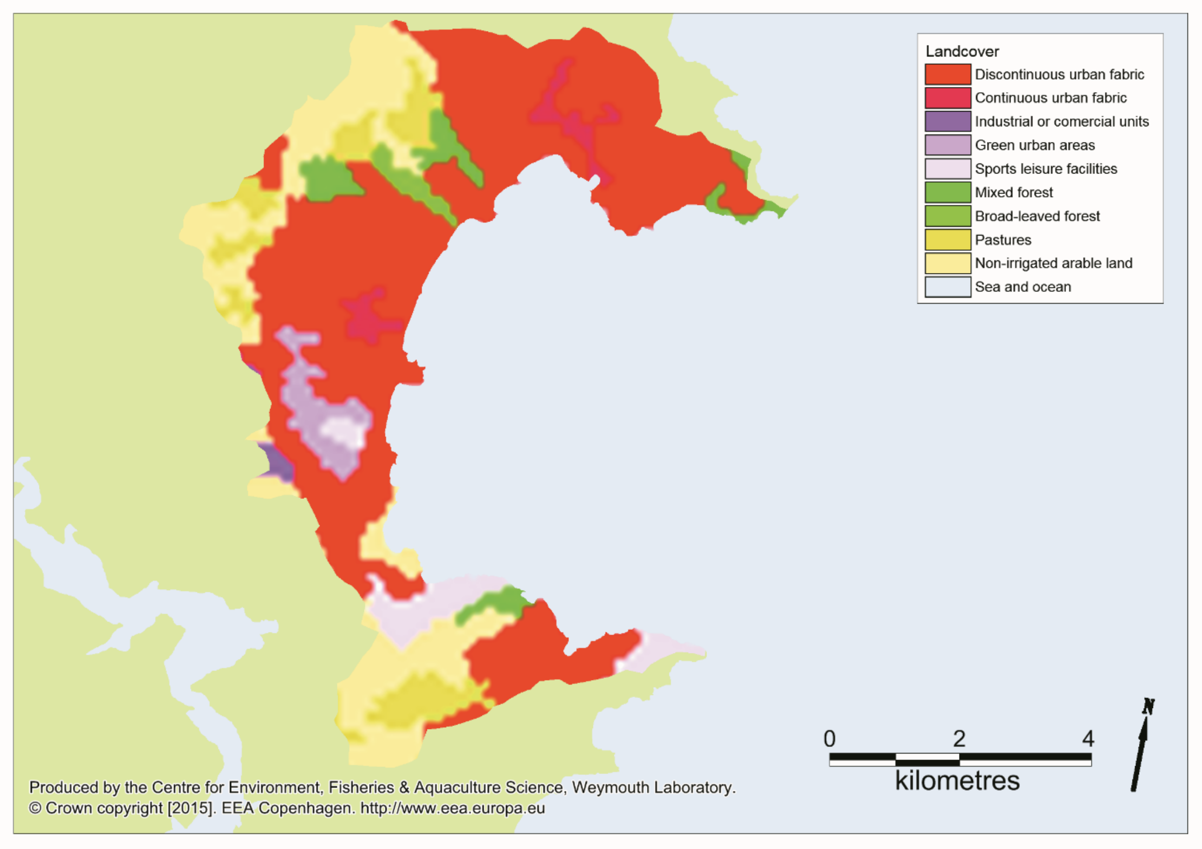

Figure 1.2: Land cover in the Brixham catchment

Land cover in the catchment is predominantly urban, including the seaside towns of Brixham, Paignton and Torquay. There are some smaller rural areas inland of Paignton and Torquay, and between Paignton and Brixham, where land cover is a mix of arable farmland, pasture, woodland and a golf course. The area is drained by a series of small watercourses which drain to the shore at intervals.

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, the contribution from which increases up to 100 fold.

The landscape is quite hilly, rising to around 190 m in the most westerly section of the catchment. The underlying hydrogeology is reported to be of low to moderate permeability throughout (NERC, 2012). Watercourses draining the area will therefore respond rapidly to rainfall.

2. Recommendations

Within the survey area there is a large rope mussel farm which requires continued classification. The same area may also require classification for the harvest of king scallops in a few years' time depending on how a recently started pilot trial progresses, and possibly native oysters further in the future.

Tidal streams in the vicinity of the mussel farm flow from west to east for most of the tidal cycle due to the formation of eddy currents within the bay, so shoreline sources to the west will be of greatest impact. Although significant vertical differences in salinity are not generally anticipated, it is possible that levels of contamination are slightly higher towards the top of the water column at times of high freshwater input. There are no major sources of contamination in the immediate vicinity of the mussel farm. There are a number of minor watercourses which drain to the shore of the bay at intervals. There are clusters of intermittent discharges in the Brixham and Paignton areas. There is a large amount of boat traffic in the bay, with the main centres of activity located at Brixham, Torquay and Paignton. Birds resting on the mussel floats may also represent a local (but diffuse) source of contamination. A bacteriological survey was undertaken in relatively dry conditions in January 2015. It showed little spatial variation (range 68 to 490 *E. coli* MPN/100 g) with slightly higher results at the western end of the site and towards the bottom of the mussel lines.

It is recommended that the classification zone boundaries be revised immediately so that the entire farm and lease area is included. The RMP should be located at the inshore western corner of the site. Whilst it is considered more likely that on average, *E. coli* concentrations may be higher towards the top of the water column, this was not apparent during the bacteriological survey. It is therefore recommended that samples are taken from both the top and the bottom of the lines (at 2 and 6 m depth) for the first five sampling occasions. If there is a consistent difference, then the RMP should be located at the depth showing the highest average result. If there is no consistent difference, then the RMP should be located at the top of the lines (2 m depth). The species sampled should be mussels and animals should be of a harvestable size. A tolerance of 10 m applies. Should the site expand, then the RMP should be moved to the new inshore western corner of the site. If the classification of other species is required, these should also be monitored using the same RMP specifications as for mussels. The requirement for additional species to be sampled alongside mussels may be reviewed after a year of parallel monitoring.

3. Sampling Plan

3.1. General Information

Location Reference

Production Area	Brixham
Cefas Main Site Reference	M082
Ordnance survey 1:25,000 map	Explorer OL 20
Admiralty Chart	26

Shellfishery

Species/culture	Mussel	Rope culture
Seasonality of harvest	Year round	

Local Enforcement Authority

Name & Address	Food & Safety Team Community Safety c/o Torquay Town Hall Castle Circus Torquay TQ1 3DR
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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 2021. The assessment may require review in the interim should any significant changes in sources of contamination come to light, such as the upgrading or relocation of any major discharges.

Table 3.1: Number and location of representative monitoring points (RMPs) and frequency of sampling

Classification zone	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Brixham	B082B	Fishcombe SW corner	SX 9096 5741	50° 24.385' N 03° 32.148' W	Mussels	Rope culture	Winch/ hand	Winch/ hand	10m	Monthly	Sample from both the top and bottom of the lines for the first five sampling occasions. If a consistent difference is observed, the sample depth should be at whichever depth returns the highest result. If no difference is observed then sampling depth should be at the top of the lines (2 m). Should other species require classification in the future they should be sampled from this location.

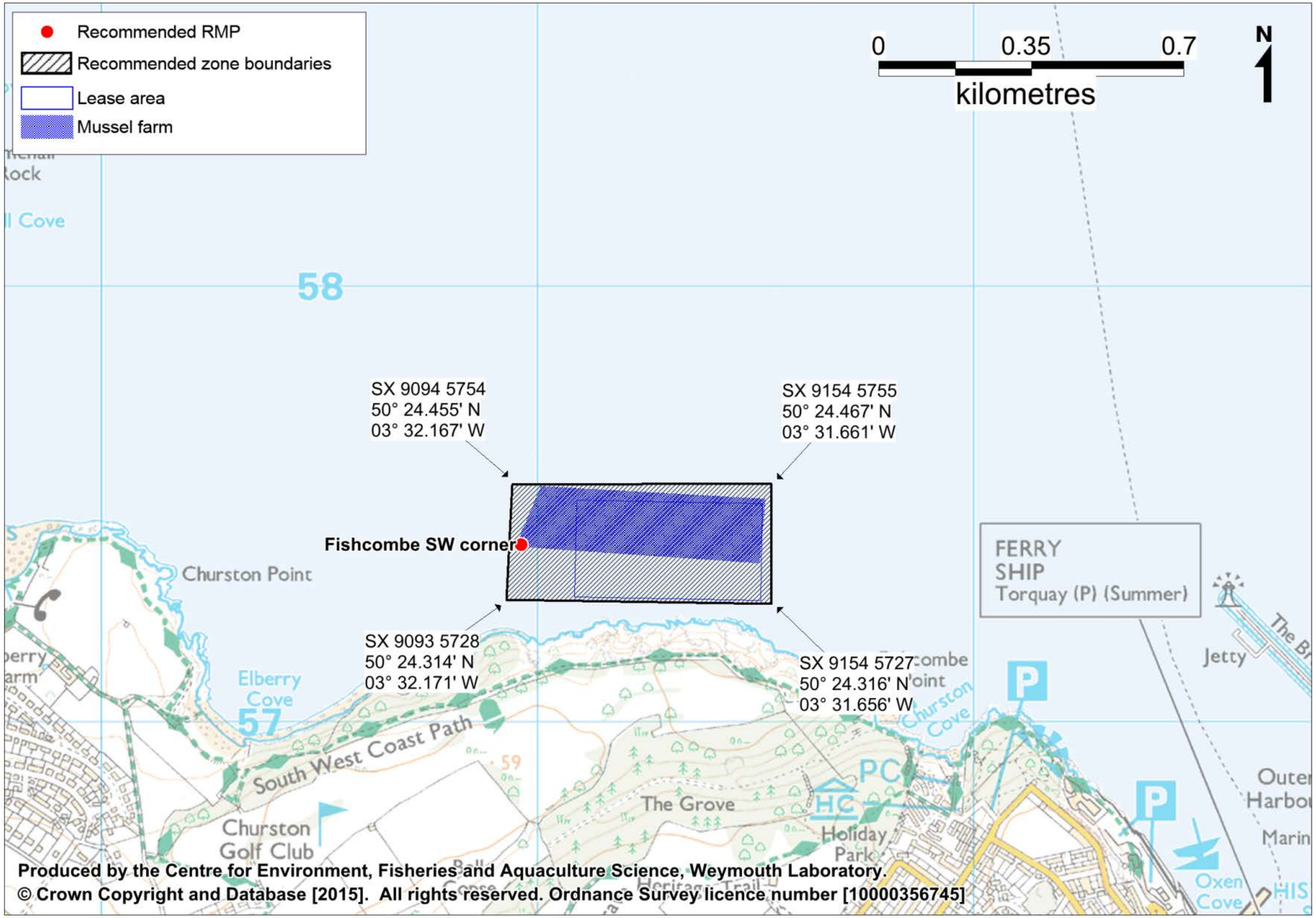

Figure 3.1: Recommended zoning and monitoring arrangements (mussels)

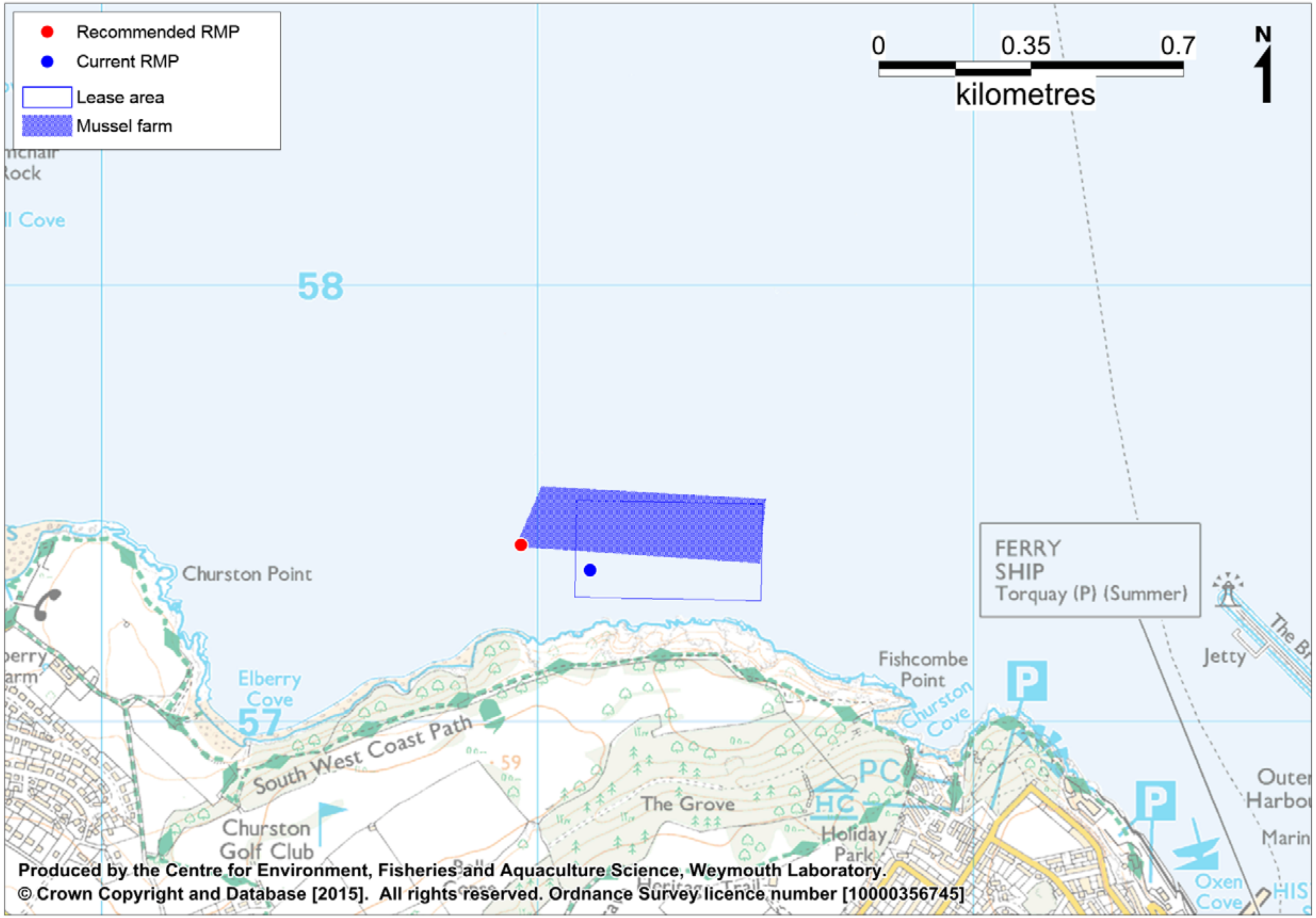

Figure 3.2: Locations of current and recommended RMPs

4. Shellfisheries

4.1. Description of fishery

The fishery which is the subject of this survey is a well established rope mussel farm. It consists of multiple mussel lines. The headlines are suspended at 2 m depth from a series of tubular floats. The dropper loops upon which the mussels are attached extend a further 4 m down from the headlines. Each line is anchored at either end. This arrangement ensures the dropper lines are suitably damped against wave action so that mussels are not shaken off during storms. Figure 4.1 shows its location and extent, although the date on which the aerial photograph of the mussel farm was taken is uncertain, and may not accurately represent its current extent.

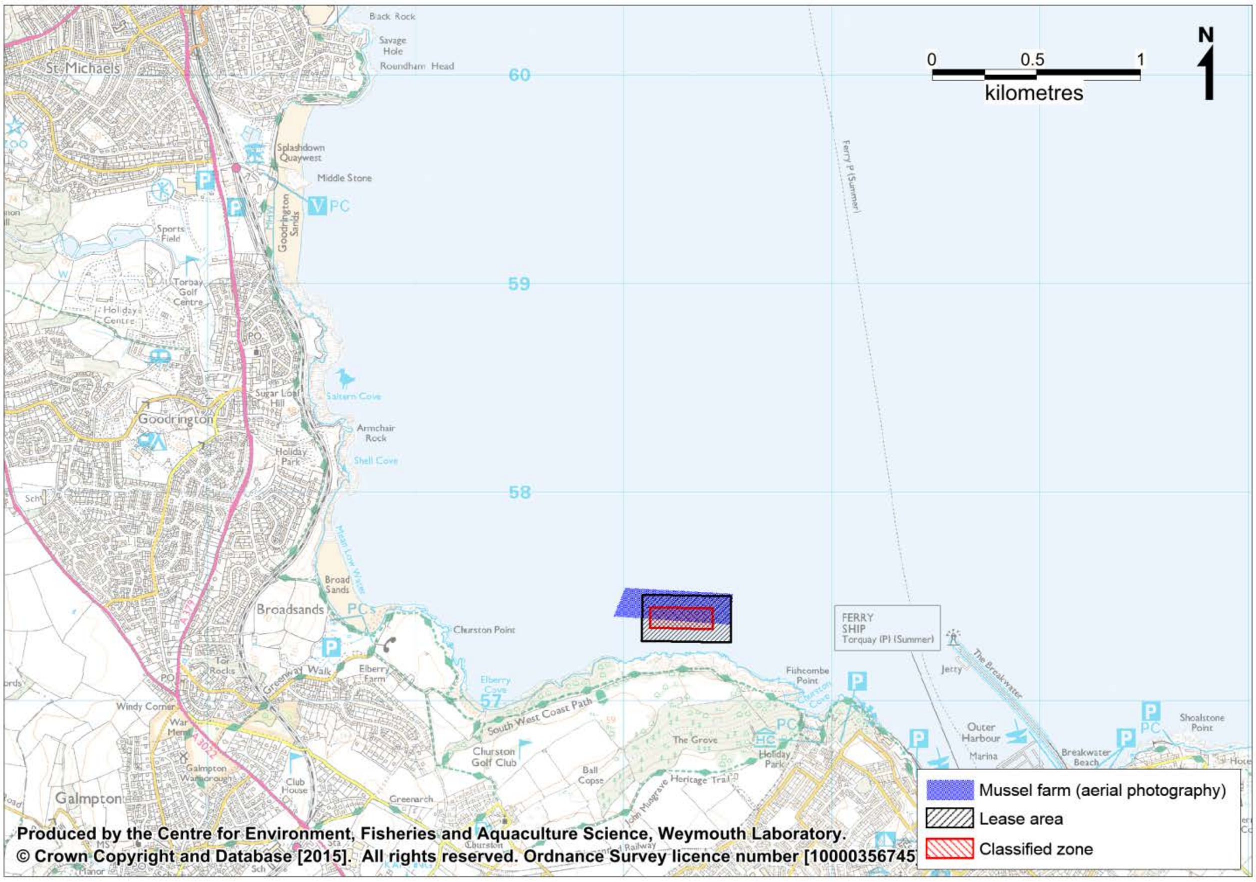

Figure 4.1: Location of mussel farm

Fibrous collector lines are deployed at the farm in the spring, onto which seed subsequently settles. The seed is then stripped from the collector lines in late summer and deployed onto the dropper ropes in cotton socking at the appropriate density (~600 per metre). These are then left to grow to a market size (50-60 mm), a process which can take as little as 14 months. To harvest, the lines are lifted mechanically, stripped by hand and the mussels are graded at sea. Meat yields are high relative to mussels grown on the seabed, and the speed of growth means that harvest occurs before they become encrusted with barnacles. The annual harvest is currently about 150 tonnes per year and there are no immediate plans for further expansion, although there is the potential for significant increases in production levels at this site. The harvesters have their own depuration facilities, and mussels are sold to a variety of markets. No conservation controls such as closed seasons or minimum landing size apply to this fishery.

King scallop culture is being piloted at the site in suspended cages, where hatchery produced seed stock was introduced in late summer 2014. Initial survival and growth appears good, although animals are unlikely to reach market size for at least 2-3 years. Trials of native oyster culture may also be attempted at some point in the future, but the timescales for this are uncertain.

4.2. Hygiene Classification

Table 4.1: Historical hygiene classifications, 2005 to present

Bed name	Species	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Fishcombe Cove	Mussels	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT

The site has held a long term B classification for the last decade. The classified area does not fully encompass the mussel farm or the lease area (Figure 4.1) so will require expansion.

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

Class	Microbiological standard[1]	Post-harvest treatment required
A[2]	Live bivalve molluscs from these areas must not exceed 230 Most Probable Number (MPN) of *E. coli* $100g^{-1}$ Fluid and Intravalvular Liquid (FIL)	None
B[3]	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution MPN test of 4,600 *E. coli* $100g^{-1}$ FIL in more than 10% of samples. No sample may exceed an upper limit of 46,000 *E. coli* $100g^{-1}$ FIL	Purification, relaying or cooking by an approved method
C[4]	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution Most Probable Number (MPN) test of 46,000 *E. coli* $100g^{-1}$ FIL	Relaying for, at least, two months in an approved relaying area or cooking by an approved method
Prohibited[6]	>46,000 *E. coli* $100g^{-1}$ FIL[5]	Harvesting not permitted

[1] The reference method is given as ISO 16649-3.
[2] By cross-reference from EC Regulation 854/2004, via EC Regulation 853/2004, to EC Regulation 2073/2005.
[3] From EC Regulation 1021/2008.
[4] From EC Regulation 854/2004.
[5] This level is not specifically given in the Regulation but does not comply with classes A, B or C. The competent authority has the power to prohibit any production and harvesting of bivalve molluscs in areas considered unsuitable for health reasons.
[6] Areas which are not classified and therefore commercial harvesting of LBMs cannot take place. This also includes areas which are unfit for commercial harvesting for health reasons e.g. areas consistently returning prohibited level results in routine monitoring and these are included in the FSA list of designated prohibited beds

5. Overall Assessment

5.1. Aim

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

5.2. Shellfisheries

The area requiring continued classification is a rope mussel farm located about 150 m off the southern shore of Tor Bay. The area currently classified does not cover the entire extent of the leased area so will require expansion. Mussels are grown from locally collected spat on dropper loops suspended from a headline held up by a series of tubular floats. The headline is about 2 m below the surface, and the droppers extend a further 4 m down, so the mussels are grown between 2 and 6 m sub surface. From settlement on the lines to harvest can take as little as 14 months. Annual production is in the order of 150 tonnes, and could potentially be increased significantly, although there are no plans to do so at present. The fishery is not subject to a minimum landing size, and harvesting may occur at any time of the year.

Pilot trials of king scallop culture in suspended cages have been started recently, and although initial results are encouraging the outcome will not be known for another 2-3 years. Similar trials using native oysters may also be attempted in the future. The harvester will need to give sufficient notice (preferably a year) if either of these species require classification. After an appropriate period of parallel sampling (one year) the requirement to sample all species may be reviewed.

5.3. Pollution Sources

Freshwater Inputs

Tor Bay has a small hydrological catchment of 38 km^2, which is drained by a series of small streams which discharge to the shore at intervals. Most of the catchment is urbanised, although there are some pockets of farmland and woodland. The topography is quite hilly reaching a maximum elevation of 190 m at Beacon Hill, west of Paignton. The hydrogeology comprises a mixture of low to moderate permeability, and the urbanised nature of the catchment will reduce its permeability. Watercourses will therefore respond rapidly to rainfall, a high proportion of which will run off, and the generally urban nature of the catchment suggests that they may carry quite high concentrations of faecal indicator organisms. Fluxes of faecal indicator organisms into coastal waters will be highly rainfall dependent.

There are no flow gauging stations on any of the watercourses within the catchment. Rainfall in the area tends to be higher from October to January, and during the colder months there will be less transpiration and evaporation. Discharge from freshwater inputs is therefore likely to be higher on average during the colder months of the year, although whether this translates to increased fluxes of faecal indicator organisms is uncertain.

The two watercourses closest to the mussel farm were sampled and measured during the shoreline survey (December 2014). The small freshwater outfall at Broadsands Beach was delivering a bacterial loading of $5.2x10^{10}$ *E. coli*/day, and the culverted stream discharging to Brixham Inner Harbour was delivering a bacterial loading of $2.5x10^{12}$ *E. coli*/day. The latter was carrying a very high concentration of *E. coli* (52,000 cfu/100 ml) but neither was close enough to the mussel lines to result in one end of the farm being significantly more contaminated than the other.

It is therefore concluded that freshwater inputs to the bay are minor although they may carry quite high concentrations of faecal indicator bacteria. Whilst they will contribute to background levels of contamination in the water column, any acute impacts will be localised and are unlikely to extend as far as the mussel farm. In addition to seasonal fluctuations, the bacterial loadings they deliver will fluctuate significantly on a day to day in response to antecedent rainfall.

Human Population

Although the survey catchment is small, it is densely populated, with a total resident population of approximately 117,500 at the time of the last census in 2011. The population is concentrated within the towns of Brixham, Paignton and Torquay, all of which are directly adjacent to the coast. The Tor Bay area is known as the English Riviera due to its attractive setting and climate, and as a result the population increases by about 50% during the peak summer holiday season. The volumes of effluent received by sewage works serving the area will fluctuate accordingly.

Sewage Discharges

Sewage from Torquay, Paignton and Brixham is treated at the Torquay (Brokenbury) STW and the effluent is discharged to St. Marys Bay. This is a large works, with a consented dry weather flow of 42,396 m^3/day. It provides UV treatment and final effluent testing data indicates that this is effective, with an average faecal coliform concentration of 576 cfu/100ml for the period 2007-2013. The estimated (average) bacterial loading it generates is relatively small ($2.4x10^{11}$ faecal coliforms/day) although this may be significantly higher at times as the peak faecal coliform concentration in the effluent was almost two orders of magnitude higher than the average. No seasonal variations in effluent quality were apparent. As it is located about 2.3 km south of Berry Head its impacts at the mussel farm will be minor at most.

There are 28 intermittent discharges associated with the water company sewer networks either discharging direct to Tor Bay or within its hydrological catchment. They are distributed fairly evenly throughout the urbanised areas. Those in closest proximity to the mussel farm discharge to the Brixham Harbour area. Spill records were only available for two of the 28 intermittent discharges, both of which are in the Brixham area. The Berry Head CSO only spilled for 75 minutes during the two year period considered (April 2012 to March 2014) so should not be of significance to the mussel farm. The Oxen Cove overflow is located just to the west of the Brixham fish market, and spilled more frequently (3.2% of the period considered). Spill events were of a much longer average duration during the winter months, during which time the overflow was active for 9.9% of the time. For those with no event monitoring it is difficult to assess their importance aside from noting their location and potential to spill untreated sewage.

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

As well as the water company owned sewage infrastructure, there are 25 privately owned discharges within the survey area, 19 of which discharge to soakaway, and 6 of which discharge to water. Those discharging to soakaway should be of no impact on coastal waters assuming they are functioning correctly. Of those discharging to water, three are to watercourses and three are to coastal waters. The largest private discharge is from a zoo and aquarium at Torquay. Its location, together with its treatment level (UV disinfection) would suggest that it is of negligible significance to the fishery. There are two discharges at Brixham. The larger is of waste water from fish processing, and is only screened. The significance in terms of the faecal indicator bacteria content of this waste water is unclear. The AstraZeneca discharge is from aquarium facilities just to the west of the fish market, and is also subject to UV treatment so should have a negligible *E. coli* content. The three others discharging to watercourses are in the Paignton area and are all consented to discharge less than 5 m^3/day. They will make a minor contribution to the bacterial loading delivered by the watercourses to which they discharge.

Agriculture

There is very little agricultural land within the survey catchment. It consists of a mix of arable farmland and pasture and is located inland of Paignton and Torquay, and between Paignton and Brixham. Agricultural census data for 2013 indicated that there were 1190 cattle and 1126 sheep held within the catchment. However, this may be inaccurate, particularly in the case of such a small catchment, as the location of these animals is based on the allocation of a single point to each farm whereas in reality these farms are likely to span the catchment boundaries. Numbers of pigs and poultry could not be disclosed for confidentiality reasons due to the small number of farms which rear them. Given the small numbers of livestock and small areas of agricultural land, the impacts of agriculture on bacteriological water quality within Torbay are likely to be minor.

Diffuse inputs associated with grazing livestock will occur through direct deposition on pastures and subsequent wash off into watercourses. Slurry, manures or sewage sludge may also be applied to fields as fertilizer, but no information on local practices was available at the time of writing. The primary mechanism for mobilisation of faecal matter deposited or spread on farmland to coastal waters is via land runoff, so fluxes of livestock related contamination into the bay 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’). It is likely that any streams draining farmland will be impacted to some extent by agriculture.

As well as day to day variations due to rainfall, there is likely to be some 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 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 organic fertilizers may potentially be spread at any time of the year. Peak levels of contamination from sheep and cattle may therefore arise following high rainfall events in the summer, or on a more localised basis if wet weather follows a slurry application which may be more likely in winter or spring.

Boats

Boat traffic in Tor Bay mainly consists of fishing vessels and recreational craft such as yachts. There are two marinas and numerous moorings situated at Brixham and Torquay. Brixham marina has around 500 berths for recreational craft and Torquay Marina holds around 440 recreational berths. A further 120 moorings are situated in Paignton Harbour. The nearest sewage pump out facilities are at Lyme Regis, about 50 km away so boats in Tor Bay will not have access to such facilities and will have to discharge overboard from time to time.

Brixham is one of the most important fishing ports in England and Wales. There are currently 119 fishing vessels listed as having their home port at Brixham, just over half of which are over 10 metres in length. Four fishing vessels under 10 metres in length were registered as having Paignton and Torquay as their home port. It is likely that the majority of the larger vessels will fish outside of the survey area, but some of the smaller boats will work within Tor Bay.

The closest commercial port is located over 45 km west of the survey area at Plymouth, and merchant shipping has no reason to enter Tor Bay although the occasional smaller commercial vessel may visit Brixham. There is a deep water anchorage about 4 km off Hopes Nose which is used by merchant shipping such as tankers and container ships either sheltering or awaiting direction. As these vessels are not permitted to discharge their tanks within 5.5 km of land they should be of no impact on the mussel farm.

Watersports such as jet skiing, kayaking, dinghy sailing and windsurfing are popular in Tor Bay, but these small craft will obviously not have on board toilets, so such activities should be of no impact on shellfish hygiene.

It is therefore concluded that boat traffic within Tor Bay is relatively heavy and consists mainly of recreational craft such as yachts and cabin cruisers as well as fishing vessels. These are likely to make overboard discharges from time to time. This may either occur when the boats are berthed 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 marinas and mooring areas at Brixham, Torquay and Paignton are most at risk. Vessels are likely to pass in close proximity to the mussel farm on a regular basis, and should one make an overboard discharge in such a location it is likely to result in a temporary, localised, but significant elevation in levels of *E. coli* in shellfish. Peak pleasure craft activity is anticipated during the summer, so associated impacts are likely to follow this seasonal pattern. It is difficult to be more specific about the potential impacts from boats and how they may affect the sampling plan without any firm information about the locations, timings and volumes of such discharges.

Wildlife

Within the survey area the most significant wildlife population of relevance to shellfish hygiene is likely to be seabirds such as gulls and terns, which are widespread throughout the area all year round. A survey in the early summer of 1999 recorded 2,440 breeding seabirds. The main nesting colonies, where their impacts will be most concentrated, were in the vicinity of Berry Head and Hopes Nose. These are remote from the mussel farm so will have no bearing on RMP location. It is likely that seabirds will rest on the floats and buoys at the mussel farm. This may occur anywhere within the farm so although it may be a significant contaminating influence it will not influence the positioning of RMPs.

The area does not attract major populations of overwintering waterbirds (waders and wildfowl) in the same way that nearby estuaries such as the Dart do. As such it is not subject to regular waterbird counts. Whilst there is likely to be a small influx of such birds during the winter months, it is concluded that they are likely to represent a minor source of diffuse contamination to the intertidal areas during the winter months. As such they will have no influence on RMP location.

Although the nearest major seal colony is in the Solent area, they do frequent the area in small numbers. A seal was observed within Brixham Harbour, by the fish market, during the shoreline survey for example. Several species of dolphin and porpoise are regularly sighted in Lyme Bay so are likely to enter Tor Bay from time to time. Impacts, if any, from both seals and dolphins will be minor and unpredictable spatially and temporally so will have no influence on the sampling plan. No other wildlife species of potential significant to shellfish hygiene in the area have been identified.

Domestic animals

Dog walking takes place on coastal paths and beaches around Tor Bay and is therefore likely to represent a potential source of diffuse contamination to the near shore zone. 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.

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

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

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

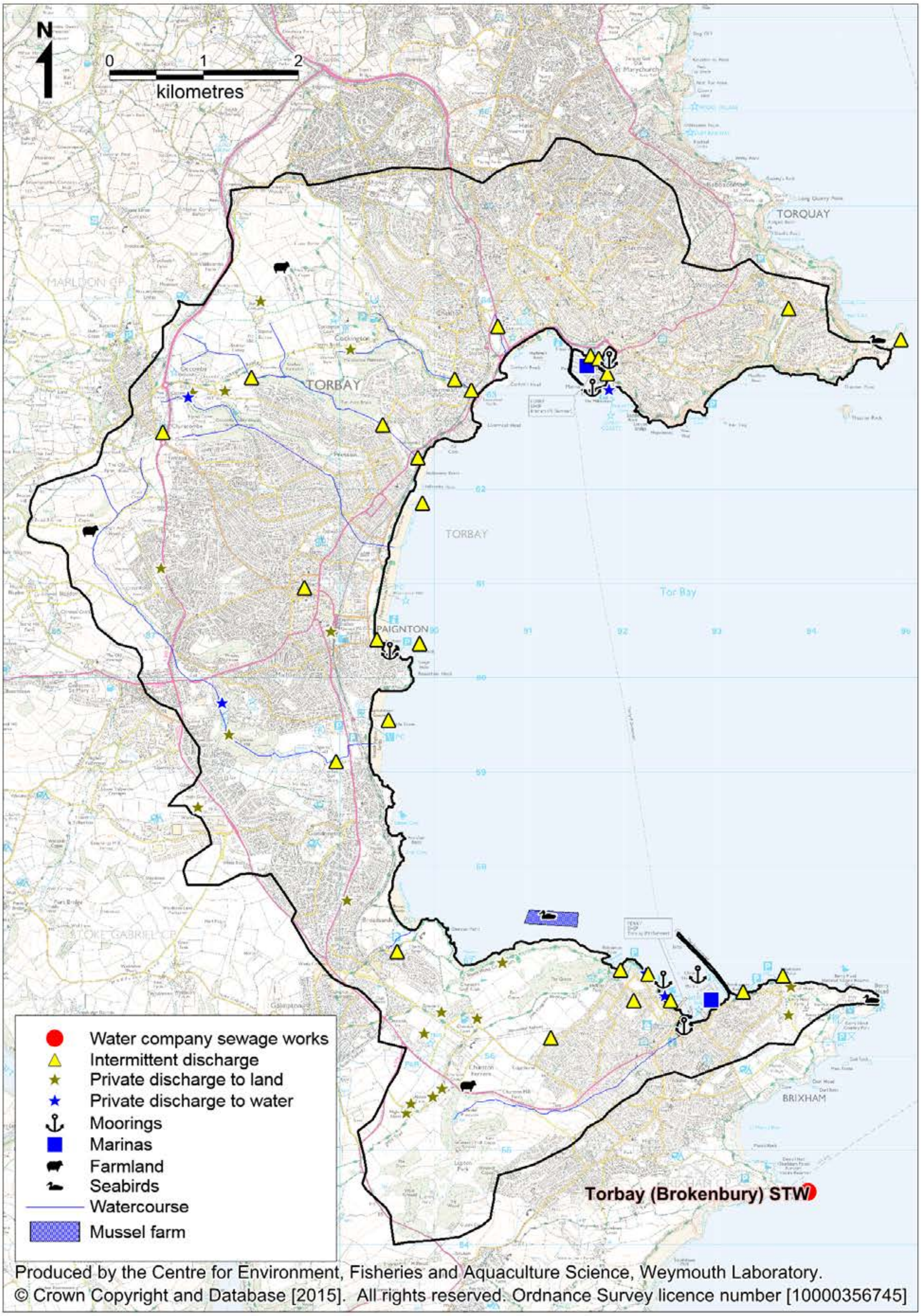

Figure 5.1: Summary of main contaminating influences

Hydrography

Tor Bay is a shallow, east facing embayment located at the western end of Lyme Bay in the English Channel. It lies between the headlands of Hopes Nose and Berry Head, which are about 7 km apart, and indents the coastline by about 5 km. The bathymetry is relatively uncomplicated, with subtidal areas sloping gently away to a depth of just over 10 m relative to chart datum in the outer bay. The gradient of the slope is shallower in the southern half of the bay. The west shore of the Bay consists of a series of small headlands in between which lie sandy beaches. The north and south shores have smaller intertidal areas. A manmade breakwater extends from the south shore, just to the east of Brixham Harbour. Off Berry Head, the seabed slopes away rapidly to over 30 m relative to chart datum, whereas off Hopes Nose the slope is less steep and there are some small rocky islands. The mussel farm is located about 150 m off the southern shore of the bay, in depths of about 7 m relative to chart datum.

The area is meso-tidal, with a tidal range at Torquay of 4.1 m on spring tides and 1.7 m on neap tides. This drives extensive water movements through the area via the twice daily tidal cycle. Outside of Tor Bay, tidal streams are bidirectional and run parallel to the coast. Any contamination released in the offshore anchorage is therefore unlikely to be carried into the bay by tidal streams. Offshore tidal currents reach a velocity of about 0.6 m/s on spring tides and 0.3 m/s on neap tides. They are likely to accelerate around Hopes Nose and Berry Head, and be slacker within Tor Bay. The area inside of the Brixham Breakwater is likely to be quiescent. Due to the formation of eddies, the patterns of tidal circulation within Tor Bay are difficult to predict, and no observational or modelling studies were found during the literature search. The harvester advised that for about 90% of the time the tidal stream at the mussel farm runs eastwards along the shore due to the formation of an eddy at certain states of the tide. This will increase the importance of sources of contamination to the west and north, whilst reducing the impacts of sources in the Brixham area. This also suggests that, in the absence of contamination sources in the immediate vicinity of the mussel farm, the RMP should be located towards its western end. It is not possible to be more specific about the patterns of tidal circulation within the bay without any firm information.

Superimposed on tidally driven currents are the effects of freshwater inputs and wind. There is little in the way of freshwater inputs along the coast in Tor Bay so density effects are unlikely to modify water circulation here. A lack of salinity stratification also suggests that there are unlikely to be major and consistent vertical differences in levels of contamination within the mussel farm. The minimal freshwater influence is confirmed by salinity readings taken at the 10 bathing waters sites within the bay, where average salinity ranged from 33.8 to 34.8 ppt. Salinities of less than 30 ppt were however recorded occasionally at some sites, presumably due to the localised influence of various minor freshwater inputs.

Strong winds will modify surface currents within Tor Bay by driving surface currents, which in turn drive return currents either along sheltered margins or at depth. Under conditions of strong winds, wind driven currents are likely to be of a similar magnitude to tidal streams, if not faster. Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great number of scenarios may arise. Tor

Bay is sheltered from the prevailing south westerly winds by the adjacent land, whereas it is exposed to the east, so winds from the latter direction are likely to have a greater effect, pushing surface water in a westerly direction thereby potentially advecting contamination from the harbour area towards the mussel lines. Strong easterly winds will also result in significant wave action within the bay, and this may mobilise sediment entrained faecal indicator bacteria into the water column.

5.4. Summary of Microbiological Data

The survey area has been subject to extensive microbiological monitoring over recent years, deriving from the Bathing Water 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 2004 onwards are considered in these analyses.

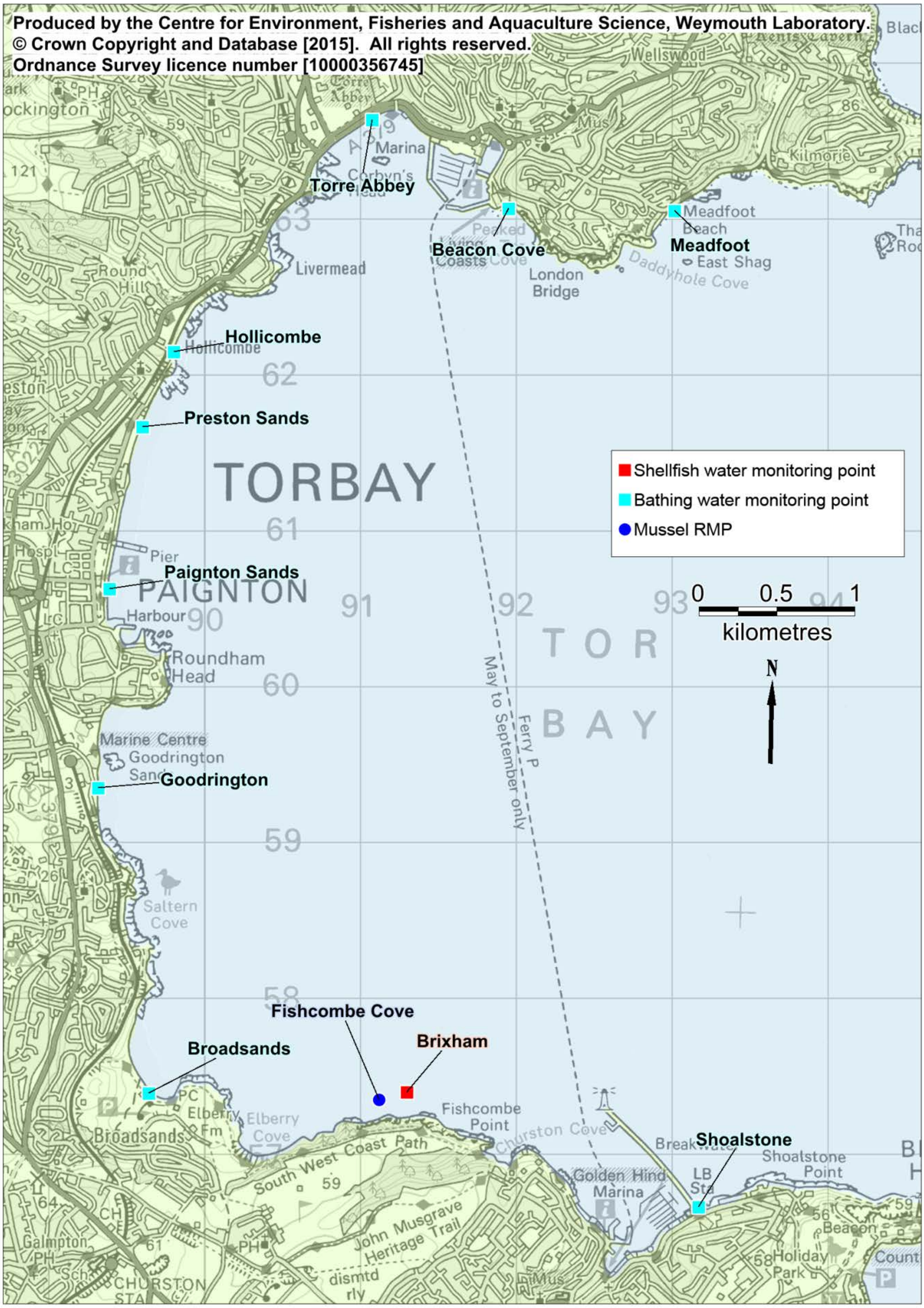

Figure 5.2: Location of microbiological sampling sites.

Bathing Waters

There are 10 bathing waters monitoring points, where water samples were taken about 20 times at weekly intervals throughout the bathing season (May to September). These were enumerated for faecal coliforms up to the end of 2011, after which they were enumerated for *E. coli*. The larger faecal coliforms dataset is considered in the following analyses.

The geometric mean faecal coliform result ranged from 1.6 cfu/100ml to 21.8 cfu/100ml, and most sites recorded values of over 1,000 cfu/100ml occasionally. The two cleanest sites were the two outermost sites (Meadfoot and Shoalstone) where results were significantly lower than most other sites. There was a general pattern of increasing results towards the central part of the bay around Paignton. Comparisons of paired (same day) samples showed significant correlations on a sample by sample basis, indicating that the whole of the bay is subject to contamination from sources that respond in a similar way to environmental variables. Shoalstone, which lies outside of the Brixham Harbour breakwater did not correlate significantly with Torre Abbey, Hollicombe or Preston Sands.

Results were relatively stable on average at all sites, with a slight improvement at some from 2008. A correlation between faecal coliform concentration and tidal state across the high/low cycle was found only at Torre Abbey, where higher results tended to occur during the flood tide. Given the uncertainty in exact patterns of tidal circulation in the bay, the reasons for this are unclear. Correlations between faecal coliform concentration and tidal state across the spring/neap tidal cycle were detected at Torre Abbey, Paignton Sands and Broadsands. Plots of the data suggested that results were higher on average during smaller tides at Torre Abbey, suggesting that nearby sources were of importance. No patterns were apparent in plots of the data for the other two sites. Significant positive correlations between faecal coliform concentrations and antecedent rainfall were found at all sites apart from Meadfoot and Hollicombe. The correlations were found 1-2 days after a rainfall event, which is consistent with the small and relatively rapidly responding watercourses. Results at Torre Abbey and Preston Sands were influenced most strongly. Faecal coliform concentrations at Torre Abbey, Goodrington and Broadsands all correlated negatively with salinity indicating that the freshwater inputs are an influence. Beacon Cove correlated positively with salinity, in contradiction with the significant (positive) correlations with rainfall observed at this location.

Shellfish Waters

There is one shellfish water monitoring point at the mussel farm, where water samples are taken on a quarterly basis and enumerated for faecal coliforms. The average result here was only 2.9 faecal coliforms/100ml, with 77% of results being below the limit of quantification of the test used. The highest recorded result was 101 cfu/100 ml. Results have been quite stable on average since 2004. Faecal coliform concentrations were highest on average during the winter, although the seasonal variation was not statistically significant. A statistically significant correlation between faecal coliform concentrations and tidal state on the high/low tidal cycle was found, with higher results tending to occur at lower states of the tide. No significant influence of antecedent rainfall was found. Faecal coliform levels did however correlate weakly with salinity. This may indicate that land runoff may be an important source of contamination at this site despite the lack of correlation with rainfall. Alternatively, there may be interactions between other factors, for example slightly lower average salinities occurring during the winter months when survival times of faecal indicator organisms in the water column are higher.

Shellfish Hygiene monitoring

There is only one RMP in the Brixham production area (Fishcombe Cove) where mussels have been sampled 121 times on a monthly basis from 2005 to 2014. The depth at which samples were taken from is not specified on the results database. The geometric mean result was 120 *E. coli* MPN/100g, and only 32% of samples exceeded 230 *E. coli* MPN/100g. Occasional high results were recorded, with 6% of samples exceeding 4,600 *E. coli* MPN/100 g, and one result (from a sample taken in June 2011) exceeded 46,000 *E. coli* MPN/100 g. *E. coli* results have remained fairly stable since 2005, although there appears to have been a slight increase in average result in recent years. Several high results were recorded during the summer of 2011. Seasonal variation was not statistically significant, but some patterns were apparent in plots of the data. Peak results tended to occur in the summer, and fewer very low results were recorded in the autumn and winter. The high results recorded in the summer may possibly be associated with peak yachting activity within the bay, although there are a number of other possible causes and contributing factors, such as unmonitored CSOs or easterly winds advecting contamination from the harbour area towards the fishery. There were no significant correlations between *E. coli* results and tidal state across either the high/low or spring/neap tidal cycles. Rainfall had a significant influence on *E. coli* levels in mussels between 2 and 5 days after a rainfall event. However, some of the highest results including the only prohibited level result arose during relatively dry periods, suggesting that rainfall independent sources (e.g. birds, boats) cause occasional contamination events.

Bacteriological survey

Additional sampling was undertaken on the 6th January 2015 to ascertain information on spatial variation in levels of contamination across the farm, both on the horizontal and vertical planes. The survey was undertaken in relatively dry conditions. Samples were taken from the top and bottom of the mussel lines at the south east and south west corners of the farm. A sample was also taken from the regular RMP. The spatial variation across the site was low, with results ranging from 68 to 490 *E. coli* MPN/100g. At both corners, the result was slightly higher at the bottom of the line. Results were also marginally higher at the south west corner of the site than at the south east corner.

Appendices

Appendix I. Human Population

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

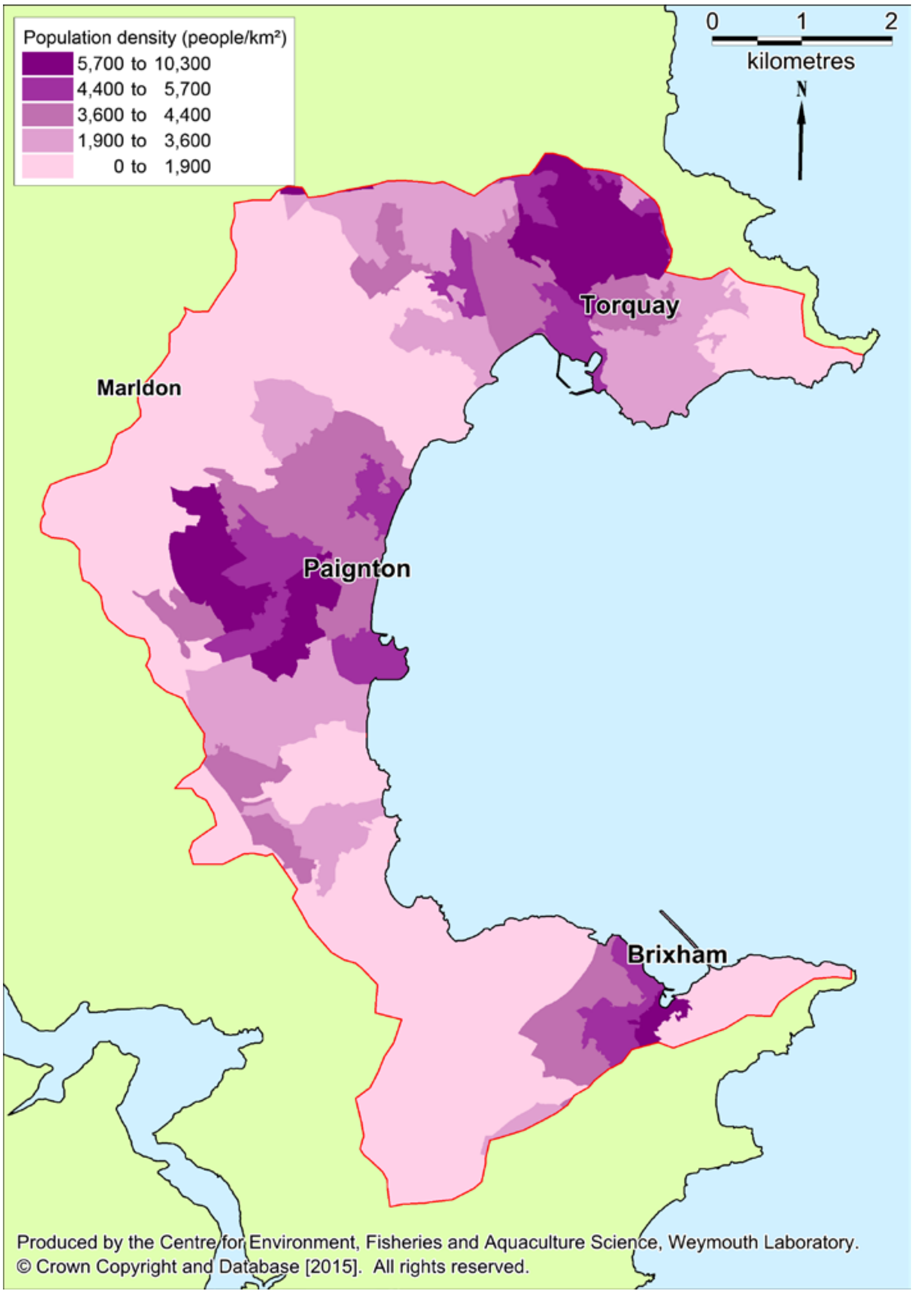

Figure I.1: Human population density in census areas in the Brixham catchment.

Total resident population within census areas contained within or partially within the catchment area was approximately 117,500 at the time of the last census. The population is concentrated around the three towns of Brixham, Paignton and Torquay, all of which are directly adjacent to the coast.

The area around Tor Bay, also known as the English Riviera is Devon's most popular tourist destination, with approximately 1.2 million staying visitors and 2.5 million day visitors in 2009 (The South West Research Company, 2011). The population of Tor Bay is reported to increase by 50% at the peak of the holiday season (Torbay Council, 2004). Visitors are attracted to the areas many beaches and other outdoor activities (Torbay Development Agency, 2007). This means that during the summer holidays the entire catchment is likely to have a significantly larger population than at other times of the year.

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

All permitted sewage discharges within the hydrological catchment are mapped in Figure II.1. The source of this information was the Environment Agency permit database (July 2014 update).

Figure II.1: All permitted sewage discharges to Tor Bay and catchment
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There are no water company owned sewage treatment works discharging to Tor Bay or its hydrological catchment. Sewage from Torquay, Paignton and Brixham is treated at the Torquay (Brokenbury) STW and the effluent is discharged to St. Marys Bay.

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

Name	NGR	Treatment	Dry Weather Flow (m^3/day)	Estimated bacterial loading*	Receiving environment
Torbay (Brokenbury) STW	SX9396054570	UV disinfection	42,396	2.4×10^{11}	English Channel

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*faecal coliforms (cfu/day) based on dry weather flow and average faecal coliform concentrations in the effluent from this works, 2007-2013 (Table II.3).

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

Treatment Level	Flow			
	Base-flow		High-flow	
	n	Geometric mean	n	Geometric mean
Storm overflow (53)	-	-	200	7.2×10^6
Primary (12)	127	1.0×10^7	14	4.6×10^6
Secondary (67)	864	3.3×10^5	184	5.0×10^5
Tertiary (UV) (8)	108	2.8×10^2	6	3.6×10^2

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

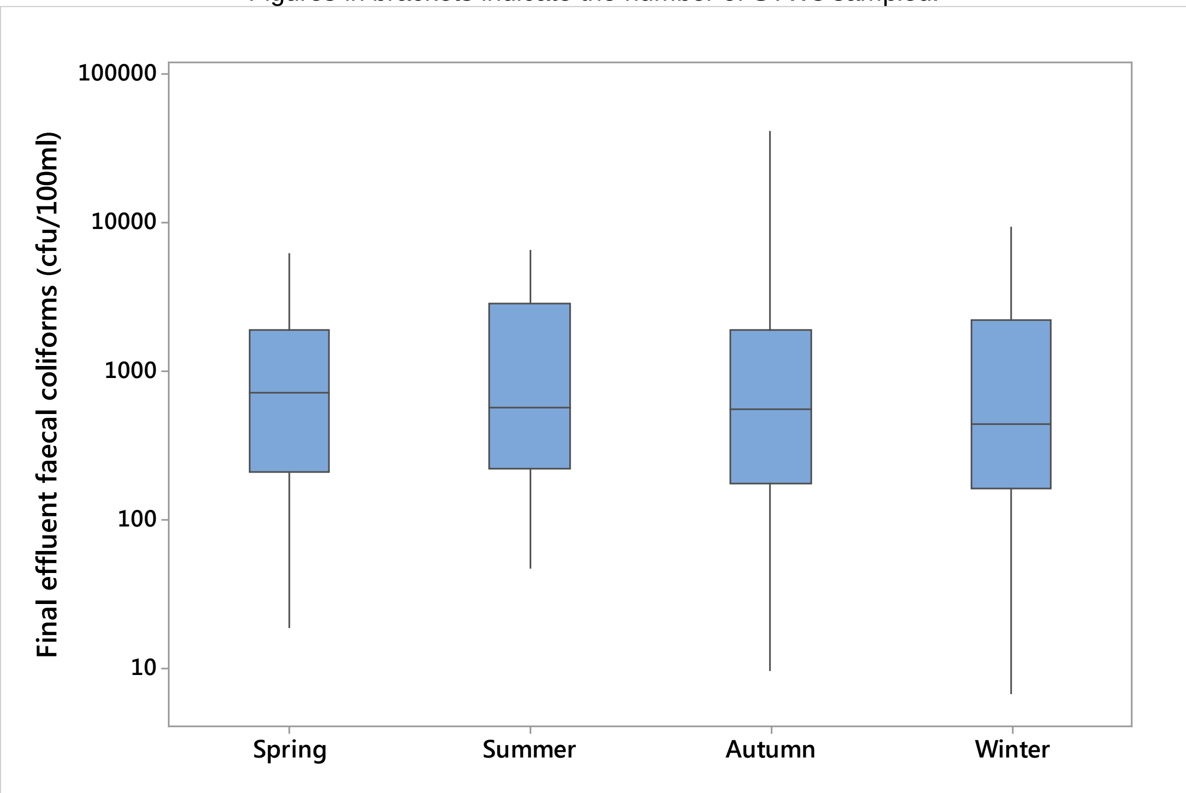

Figure II.2: Boxplot of faecal coliform concentrations Torbay (Brokenbury) STW final effluent by season (2007-2013)
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Table II.3: Summary statistics for faecal coliform concentrations in Torbay (Brokenbury) STW final effluent (2007-2013)

Works	No.	Faecal coliforms (cfu/100ml)		
		Geometric mean	Minimum	Maximum
Torbay (Brokenbury) STW	102	576	7	41,000

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Despite being a large works, the bacterial loading generated by the Torbay STW is small. Effluent testing indicates that the UV treatment is generally effective, although the maximum recorded concentration was about two orders of magnitude higher than the average. No seasonal variations in effluent quality are apparent. As it is located about 2.3 km south of Berry Head its impacts at the mussel farm will be negligible.

There are 28 intermittent discharges associated with the water company sewer network serving the area. Details of these are shown in Table II.4. Those with spill records are highlighted in yellow.

Table II.4: Intermittent discharges in the Torbay catchment

Label	Name	Grid reference	Receiving water
1	Adj The Close PSEO	SX9211056580	Groundwater
2	Beacon Hill CSO	SX9183063220	New Harbour Torquay
3	Berry Head Road CSO	SX9327056670	Torbay
4	Breakwater Quarry PS	SX9327056670	Shoalstone ECBW
5	Clennon Valley PS	SX8951059550	Goodrington Sands
6	Fishcombe Public Toilets PS*	SX9197056900	Soakaway
7	Fleet Walk No.1 CSO	SX9165063410	Torquay Harbour
8	Fleet Walk No.2 CSO	SX9174063380	Torquay Harbour
9	Freshwater Quarry PS	SX9226056860	English Channel
10	Hollicombe Gardens PS	SX8982062330	Hollicombe Lake
11	Ilsham Road CSO	SX9375063910	Ilsham Valley Stream
12	Ilsham Valley PS	SX9494063580	English Channel
13	Kings Drive CSO	SX9067063720	Kings Drive Stream
14	Littlegate Road CSO	SX8862060950	Victoria Park Watercourse
15	Marldon (Churscombe Cross) PS	SX8712262595	Unnamed Stream
16	O/S 2 Sycamore Close PSEO	SX8960557095	Groundwater
17	Old Mill Road CSO	SX9021063160	Cockington Stream
18	Old Paignton Road PS	SX8945062680	Hollicombe Lake
19	Oxen Cove Attenuation Tank CSO	SX9250056580	Brixham Harbour
20	Paignton (Cockington Lane) PS	SX9039063040	Cockington Stream
21	Paignton (Templar Road)	SX8806063180	Hollicombe Lake
22	Paignton Green Tank PSCSO/EO	SX8984060360	Paignton Sands
23	Preston Green Attenuation Tank	SX8987061850	Preston Sands
24	R/O North Boundary Road PSEO	SX9123056180	Groundwater
25	Roundham Road Storm & Emergency	SX8939060400	Paignton Sands
26	Roundham Road Storm & Emergency	SX8984060360	Paignton Sands
27	Shoalstone Pumping Station	SX9369056840	English Channel
28	Torbay (Brokenbury) STW Inlet PS	SX8895559112	Clennon Valley Stream

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*Council owned

Table II.5: Summary of spill records from the two monitored intermittent discharges, April 2012 to March 2014

	Spring			Summer			Autumn			Winter			Total		
	No. events	Total duration (hrs)	% time active	No. events	Total duration (hrs)	% time active	No. events	Total duration (hrs)	% time active	No. events	Total duration (hrs)	% time active	No. events	Total duration (hrs)	% time active
Berry Head CSO	10	37.3	0.8%	14	35.4	0.8%	19	56.5	1.3%	18	428	9.9%	61	557	3.2%
Oxen Cove Attenuation Tank CSO	0	0	0.0%	0	0	0.0%	4	1.25	<0.1%	0	0	0.0%	4	1.25	<0.01%

Intermittent discharges are widely spread throughout the catchment. Four discharge to soakaway so should not be an influence, including the nearby O/S 2 Sycamore Close PSEO. The remainder either discharge to Tor Bay or to short watercourses draining to it. There is a cluster of intermittent discharges in the Brixham area, relatively local to the mussel farm, and a smaller cluster at Paignton. For those with no event monitoring it is difficult to assess their importance aside from noting their location and potential to spill untreated sewage. Both monitored discharges are located at Brixham. The Berry Head CSO only spilled for 75 minutes during the two year period considered, so should not be of significance to the mussel farm. The Oxen Cove overflow is closer to the farm and spilled more frequently. Spill events were of a much longer average duration during the winter months.

Whilst the majority of the survey area is served by water company sewerage infrastructure, there are also a number of private discharges in the catchment. Of the 25 permitted private discharges, 19 are to soakaway and 6 are to water. Where specified, they are generally treated by small works such as package plants or septic tanks. Table II.6 details private discharges >5 m^3/day (max daily flow).

Table II.6: Details of private discharges over 5 m^3/day in the survey catchment

Ref	Property served	Grid reference	Treatment type	Max. daily flow (m^3/day)	Receiving environment
A	Living Coasts	SX9185063060	UV Disinfection	100	Beacon Cove
B	Brixham Harbour	SX9244056640	Screening	80	Brixham Harbour
C	AstraZeneca Ltd.	SX9224056880	UV Disinfection	50	English Channel
D	Higher Alston Farm	SX8970055400	Unspecified	5	Soakaway

Those discharging to soakaway should be of no impact on coastal waters assuming they are functioning correctly. Of those discharging to water, three are to watercourses and three are to coastal waters. The largest private discharge is from a zoo and aquarium at Torquay. Its location, together with its treatment level would suggest that it is of negligible significance to the fishery. There are two discharges at Brixham. The larger is of waste water from fish processing, and is only screened. It is presumed that the faecal indicator bacteria content of the waste water is minimal. The AstraZeneca discharge is from aquarium facilities, and is subject to UV treatment so should have a negligible *E. coli* content. The three others discharging to watercourses are all consented to discharge less than 5 m^3/day and will make a minor contribution to the bacterial loading delivered by the receiving water.

Appendix III. Sources and Variation of Microbiological Pollution: Agriculture

There is very little agricultural land within the survey catchment (Figure 1.2). It is located inland of Paignton and Torquay, and between Paignton and Brixham, and is a mix of arable farmland and pasture. Table III.1 presents livestock numbers and densities within the survey area. This data was provided by Defra and is based on the 2013 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. In this case, given the small amount of agricultural land within the catchment it may not accurately reflect the true numbers of animals held within the catchment.

Table III.1: Livestock census data for the Tor Bay Catchment

Cattle		Sheep		Pigs		Poultry	
No.	**Density (no/km^2)**	**No.**	**Density (no/km^2)**	**No.**	**Density (no/km^2)**	**No.**	**Density (no/km^2)**
1,190	31.5	1,126	29.8	*	*	*	*

Data from Defra

*Data suppressed for confidentiality reasons

The concentration of faecal coliforms excreted in the faeces of animal 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.

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

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

There are a relatively small number of grazing animals within the catchment area, so major impacts from agriculture are not anticipated. Diffuse inputs associated with grazing livestock may occur through direct deposition on pastures and subsequent wash off into watercourses. Slurry may also collected from livestock sheds when cattle are housed indoors and subsequently applied to fields as fertilizer. Manure from pig and poultry operations is typically collected, stored and spread on nearby farm land (Defra, 2009). Sewage sludge may also be used as fertilizer, but no information on local practices was available at the time of writing.

The primary mechanism for mobilisation of faecal matter deposited or spread on farmland to coastal waters is via land runoff, so fluxes of livestock related contamination into the bay 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'). It is likely that any streams draining farmland will be impacted to some extent by agriculture. No livestock were observed during the shoreline survey

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

Appendix IV. Sources and Variation of Microbiological Pollution: Boats

The discharge of sewage from boats is a potential source of bacterial contamination of shellfisheries within the Brixham survey area. Boat traffic in Tor Bay is relatively heavy and mainly comprises of fishing vessels and recreational craft such as yachts. Figure IV.1 presents an overview of boating activity derived from the shoreline survey, satellite images and various internet sources.

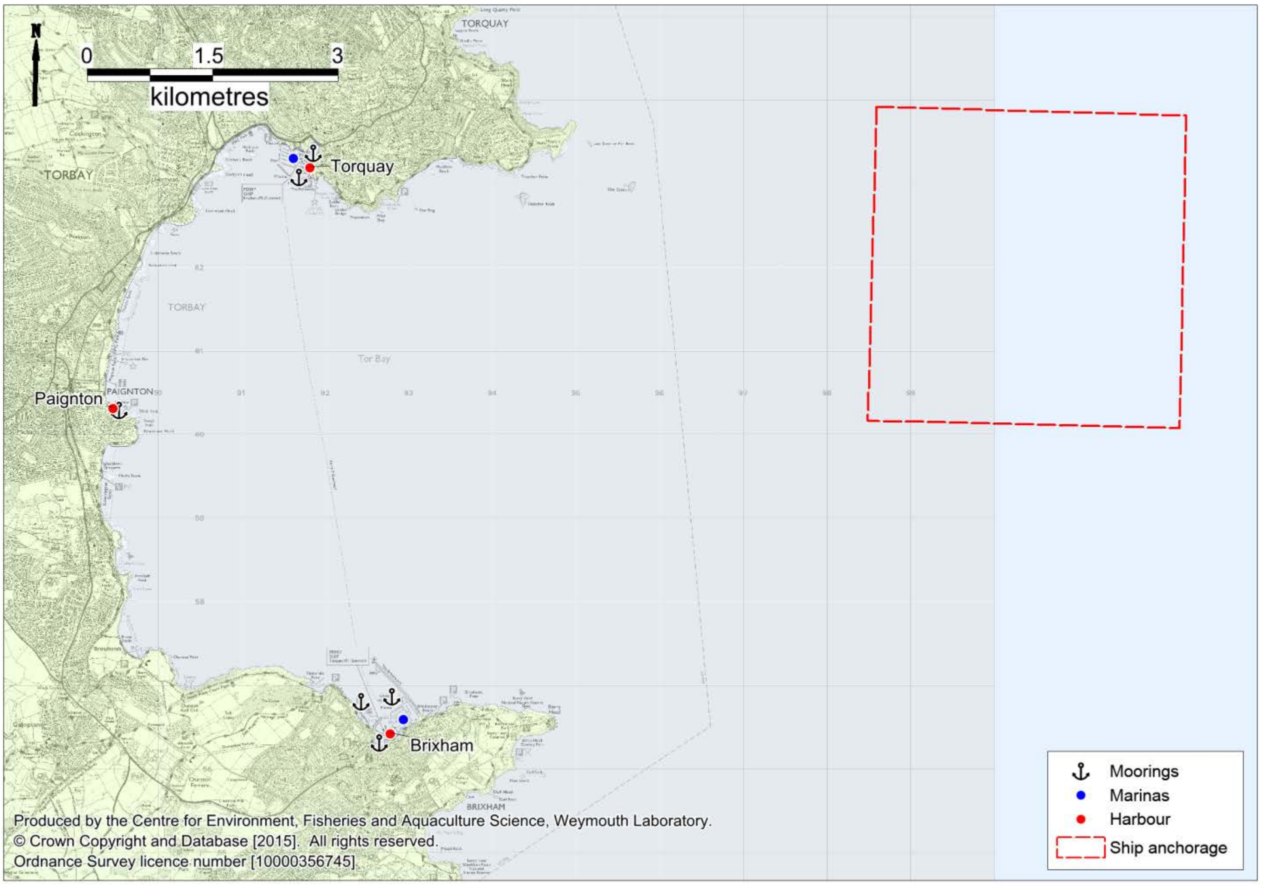

Figure IV.1 Boating activity in the Brixham survey area

There are two marinas and numerous moorings situated at Brixham and Torquay. Brixham marina has around 500 berths for recreational craft and Torquay Marina holds around 440 recreational berths and 15 commercial moorings. Additional moorings are situated in Paignton Harbour (approximately 120 moorings). Lyme Regis Harbour situated east of the survey area has the closest sewage pump out facilities (The Green Blue, 2010).

Brixham is one of the most important fishing ports in England and Wales. As of November 2014, 119 fishing vessels were listed as having their home port at Brixham and 57% of these are over 10 metres in length. Small numbers of vessels under 10 metres in length were registered as having Paignton (4) and Torquay (4) as their home port (MMO, 2014). It is likely that the majority of the larger vessels will fish outside of the survey area. Some of the smaller boats will work within Tor Bay and can be observed regularly off Berry Head, Fishcombe and Hopes Nose (Tor Bay Harbour, 2014).

There are no commercial ports within the survey area. The closest is located over 45 km west of the survey area at Plymouth. There is however a deep water anchorage about 4 km offshore from Hopes Nose which is regularly used by merchant shipping such as tankers and containerships seeking shelter or awaiting orders. These anchorages are over 7 km north east of the mussel fishery and merchant shipping vessels are not permitted to make overboard discharges within 3 nautical miles (5.5 km) of land[1] so commercial shipping should be of little or no impact.

Watersports are also popular within Tor Bay with numerous clubs and hire/charter businesses operating along the shore, such as Torbay Sea School and Paignton Sailing Club and Brixham Sea School. Watersports include sailing, windsurfing, kitesurfing and kayaking. However, these smaller recreational boats are not large enough to contain onboard toilet facilities and therefore are unlikely to make overboard discharges.

It is therefore concluded that boat traffic in the survey area is quite heavy, and mainly consists of yachts and fishing vessels. 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 berthed 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 areas at Brixham, Torquay and Paignton are most at risk. Vessels are likely to pass in close proximity to the mussel farm on a regular basis, and should one make an overboard discharge in such a location it is likely to result in a temporary, localised, but significant elevation in levels of *E. coli* in shellfish. Peak pleasure craft activity is anticipated during the summer, so associated impacts are likely to follow this seasonal pattern. It is difficult to be more specific about the potential impacts from boats and how they may affect the sampling plan without any firm information about the locations, timings and volumes of such discharges.

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

Appendix V. Sources and Variation of Microbiological Pollution: Wildlife

Tor Bay encompasses a variety of habitats including sea cliffs, sea caves, rocky reefs, honeycomb worm reefs, sandy beaches, and sea grass beds. These features attract populations of birds and other wildlife. Consequently Tor Bay falls under several national conservation statuses including, Area of Outstanding Natural Beauty (AONB), Special Area of Conservation (SAC), National Nature Reserve (NNR), Marine Conservation Zone (MCZ), Local Nature Reserve (LNR) and Special Site of Scientific Interest (SSSI).

Within the survey area the most significant wildlife population of relevance to shellfish hygiene is likely to be seabirds such as gulls and terns, which are widespread throughout the area and present all year round. A survey in the early summer of 1999 recorded 2,440 breeding seabirds in the Tor Bay area, including European Herring Gull, Lesser Black-backed Gull, Northern Fulmar, Black-legged kittiwake, Great black-backed Gull, European shag, Great Cormorant and Common guillemot (Mitchell et al, 2004). Highest numbers were recorded on and surrounding both headlands on either side of Tor Bay, Berry Head and Hope's Nose. Seabirds are likely to forage widely throughout the area so inputs could be considered as diffuse, but are likely to be most concentrated in the immediate vicinity of the nest sites. Their faeces will be carried into coastal waters via runoff from their nesting sites or via direct deposition to the adjacent intertidal. The nesting sites are remote from the mussel farm so will have no bearing on RMP location. It is possible that seabirds will forage around the mussel farm and rest on the floats and buoys. This may occur anywhere within the farm so although it may be a significant contaminating influence it will not influence the positioning of RMPs.

There are no sites within the survey area where the British Trust for Ornithology undertakes counts of overwintering waterbirds (waders and wildfowl) (Austin *et al*, 2014). However, intertidal areas are likely to provide a source of food for a low number of overwintering waterbirds. It is concluded that whilst there is likely to be a small influx during the winter months, the survey area does not attract these birds in significant numbers. They are therefore likely to represent a minor source of diffuse contamination to the intertidal areas during the winter months.

No major seal colonies exist in the vicinity of the survey area, with the closest significant colony in the Solent (SCOS, 2013). They will forage in the bay from time to time in small numbers. A seal was observed at Brixham fish market during the shoreline survey for example. Several species of dolphin and porpoise are regularly sighted in Lyme Bay (Brereton et al, 2010) so are likely to enter Tor Bay from time to time. Impacts, if any, from both seals and dolphins will be minor and unpredictable spatially and temporally so will have no influence on the sampling plan.

Appendix VI. Meteorological Data: Rainfall

Rainfall records from the Torre Abbey weather station for the period 2005 to 2014 are presented in Figure VI.1. This gauging station lies on the coast just west of the Torquay Marina.

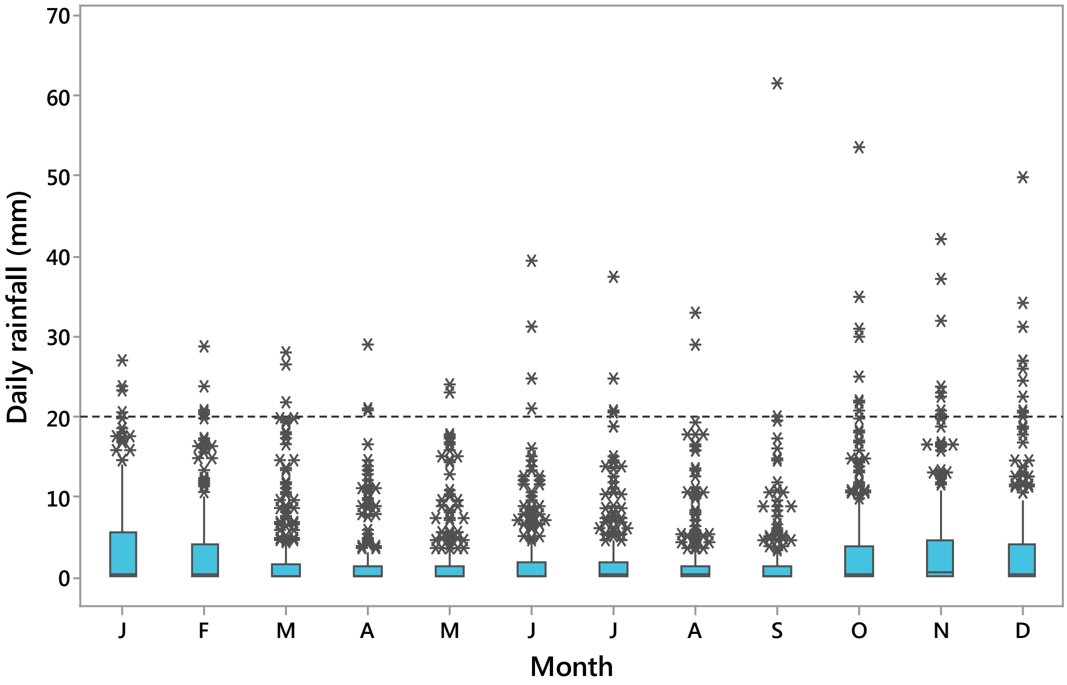

Figure VI.1: Boxplot of daily rainfall totals at Torre Abbey, January 2005 to April 2014.
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The Torre Abbey weather stations received an average of 1,362 mm per year through the period considered. April had the lowest average rainfall and November had the highest. Daily totals of over 20 mm were recorded on 1.8%, and 48% of days were dry. High rainfall events were recorded in all months, but were more frequent and of a greater magnitude during the latter part 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

The southwest is one of the more exposed areas of the UK. The strongest winds are associated with the passage of deep depressions and the frequency and strength of depressions is greatest in the winter so mean wind and maximum gust speeds are strongest at this time of year. As Atlantic depressions pass the UK, the wind typically starts to blow from the south or southwest, but later comes from the west or northwest as the depression moves away (Met Office, 2012). Another seasonal pattern noted was the increased prevalence of winds from the north east during spring. The annual wind rose for Plymouth Mount Batten is presented in Figure VII.1.

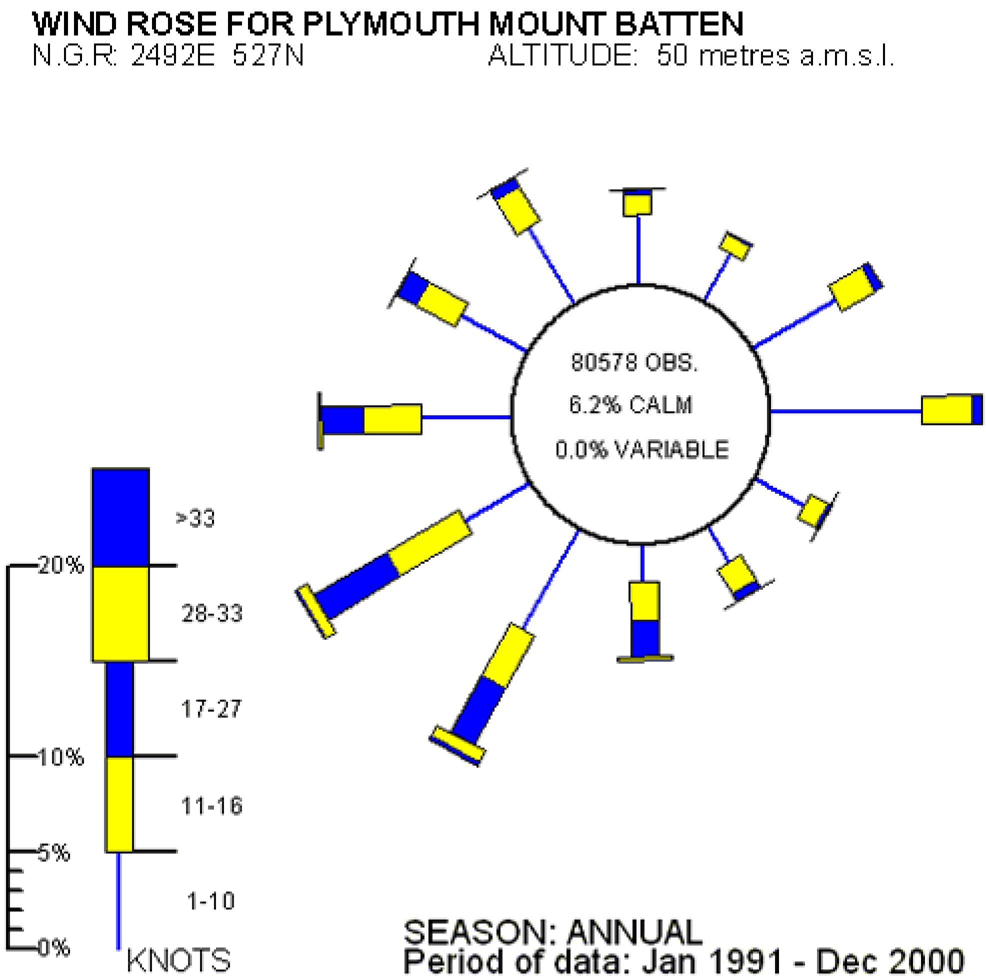

Figure VII.1 Windrose for Plymouth Mount Batten

Figure VII.1 indicates that the prevailing wind direction at Mount Batten is from the south west. Torbay is east facing and forms part of the larger Lyme Bay embayment. Due to its orientation it will be quite exposed to winds from the east but will be relatively sheltered from the prevailing winds. Strong winds may modify water circulation and generate some wave action in the vicinity of the shellfish beds.

Appendix VIII. Hydrometric Data: Freshwater Inputs

Tor Bay has a hydrological catchment of 38 km², as estimated from topography maps. It is drained by a series of small streams which discharge to the shore at intervals. Figure VIII.1 shows the main watercourses draining the survey area catchment.

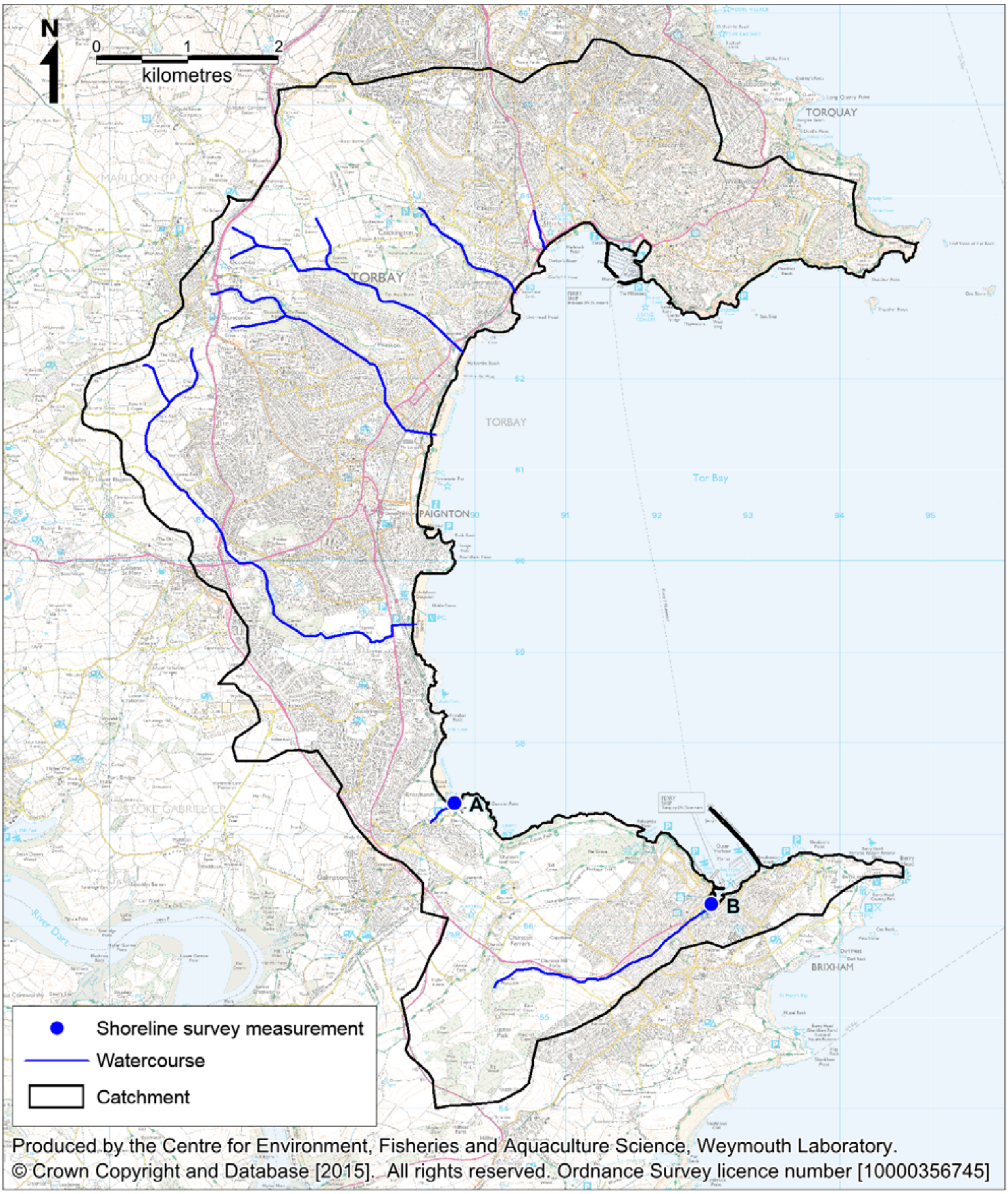

Figure VIII.1: Freshwater inputs flowing into Brixham survey area

Most of the catchment is urbanised, although there are some pockets of farmland and woodland. The topography is quite hilly reaching a maximum elevation of 190 m at Beacon Hill west of Paignton. The hydrogeology is comprised of a mixture of low to moderate permeability. Watercourses will therefore respond rapidly to rainfall, a high proportion of which will run off. There are no flow gauging stations on any of the watercourses within the catchment.

Seasonal variation of rainfall is relatively limited but highest rainfall on average was during October to January at Torre Abbey Weather Station (see Appendix VI). Flow rates generally tend to be higher during and after heavy rainfall events and therefore there will be a corresponding seasonal variation in river discharge. This will be accentuated by the reduced rates of evaporation and transpiration during the colder months of the year. Increased levels of runoff are likely to result in an increase in the flux of faecal indicator bacteria into coastal waters. Additionally, higher runoff will decrease residence time in rivers, allowing contamination from more distant sources to have an increased impact during high flow events.

During the shoreline survey, which was conducted under dry conditions, all watercourses encountered were sampled for *E. coli* and spot flow measurements were taken. The results and locations are presented in Table VIII.1 and Figure VIII.1.

Table VIII.1: Details of freshwater inputs observed on the shoreline survey

Ref	Description	*E*. coli (cfu/100 ml)	Flow (m^3/sec)	*E*. coli loading (cfu/day)
A	Freshwater outfall	1,700	0.0354	5.2×10^{10}
B	Culverted stream	52,000	0.0056	2.5×10^{11}

Both watercourses were low in terms of the volumes discharged, although watercourse B, which discharges to Brixham Inner Harbour, was carrying a very high concentration of *E. coli* at the time. It is therefore concluded that the watercourses draining to Tor Bay are small, so will only discharge small volumes of runoff, but may carry relatively high concentrations of faecal indicator bacteria as they generally drain urban areas. Nevertheless, their small size and the relatively unenclosed nature of Tor Bay will result in their impacts generally being minor and localised, although the bacterial loadings they deliver are likely to increase significantly following rainfall events.

Appendix IX. Hydrography

IX.1. Bathymetry

Torbay is a small, shallow embayment situated on the south coast of England in Devon. It stretches 7 km from Hope's Nose Headland to Berry Head and faces east out into Lyme Bay. Figure IX.1 shows the bathymetry of Torbay, taken from Admiralty Chart 1613 and an insert of the Brixham shellfish farm from Admiralty Chart 26.

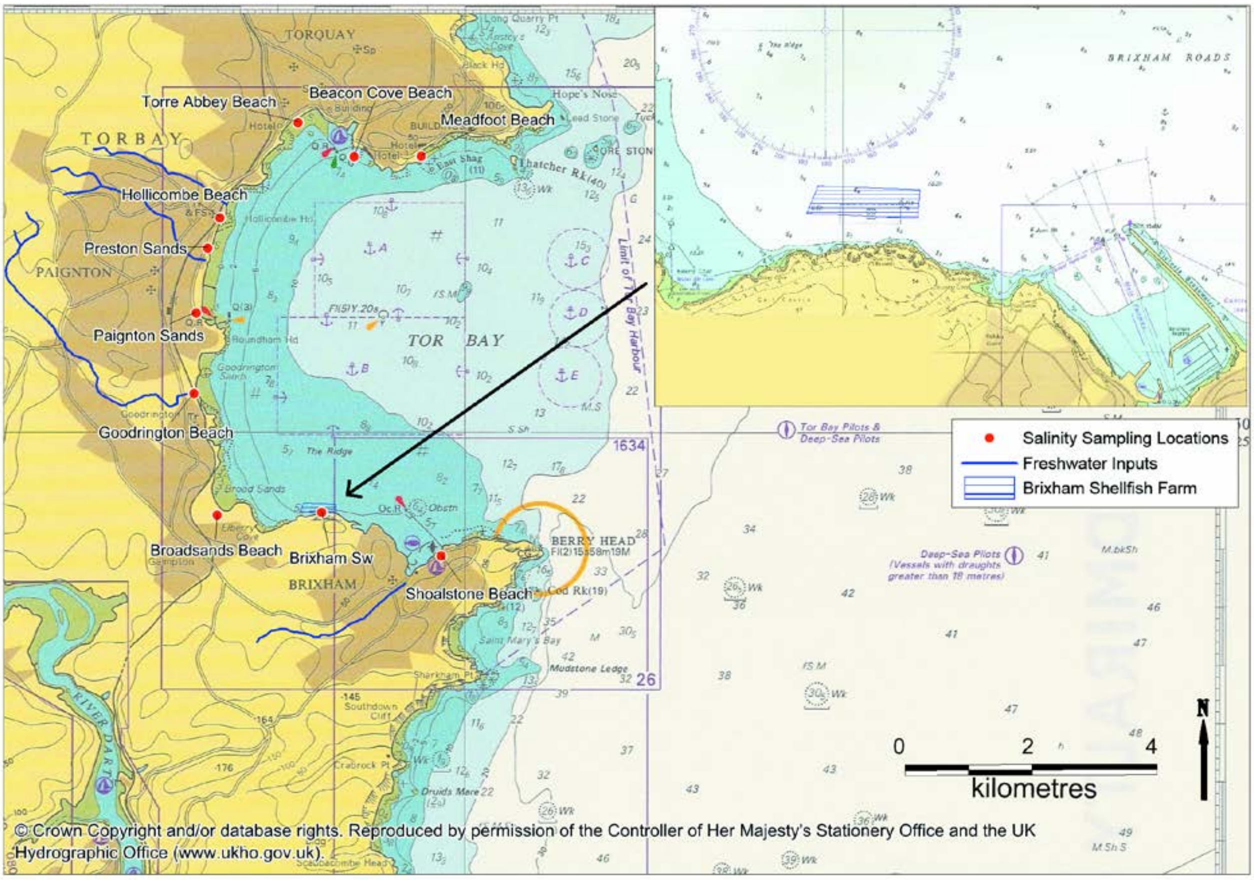

Figure IX.1: Bathymetry chart of Tor Bay area and salinity sampling locations

The west shore of the Bay consists of a series of small headlands in between which lie sandy beaches. The north and south shores have smaller intertidal areas. The bathymetry is relatively uncomplicated, with subtidal areas sloping gently away to a depth of just over 10 m relative to chart datum in the central outer bay. The gradient of the slope is slightly shallower in the southern half of the bay. A manmade breakwater extends from the south shore, just to the east of Brixham Harbour. Outside of the bay, east from Berry Head, the seabed slopes away rapidly to over 30 m relative to chart datum, whereas off Hope's Nose the slope is more gentle and there are some small rocky islands. Tidal streams are likely to be faster around these headlands. The mussel farm is located about 150 m off the southern shore of the bay, in depths of about 7 m relative to chart datum.

IX.2. Tides and Currents

Currents in coastal waters are predominantly driven by a combination of tide, wind and density effects. Tidal amplitude is moderate, and tidal streams are likely to dominate patterns of water circulation in the area under most conditions.

Table IX.1: Tide levels and ranges Torquay

	Height (m) above Chart Datum				Range (m)	
Port	MHWS	MHWN	MLWN	MLWS	Springs	Neaps
Torquay	5.0	3.9	2.2	0.9	4.1	1.7

Data from Admiralty TotalTide©

Outside of the bay, tidal streams are bidirectional and run parallel to the coast, flooding in a southerly direction and ebbing in a northerly direction. A tidal diamond located 7.5 km to the east of Hope's Nose indicated a maximum current velocity of about 0.6 m/s on spring tides and 0.3 m/s on neap tides. There are no tidal diamonds within Tor Bay, and no published studies describing tidal streams within the bay were found during the literature search. Current velocities are likely to be fastest off Hope's Nose and Berry Head, and considerably slower within the bay. The area inside of the Brixham Breakwater is likely to be quiescent. Tidal streams at the mussel farm are reported to flow in an easterly direction for about 90% of the tidal cycle (Brixham Sea Farms, pers comm.) due to the formation of an anticlockwise eddy when the tide offshore is running northwards. This will increase the importance of sources of contamination from the west and north, whilst reducing the impacts of sources in the Brixham area. It is difficult to be more specific about the patterns of tidal circulation within the bay without any firm information.

Superimposed on tidally driven currents are the effects of freshwater inputs and wind. There is little in the way of freshwater inputs along the coast in Tor Bay so density effects are unlikely to modify water circulation here. A lack of salinity stratification also suggests that there is unlikely to be major and consistent vertical differences in levels of contamination within the mussel farm which would occur if a layer of more contaminated, less saline water floats on the surface. The minimal freshwater influence is confirmed by salinity readings taken at bathing waters sites (Figure IX.2).

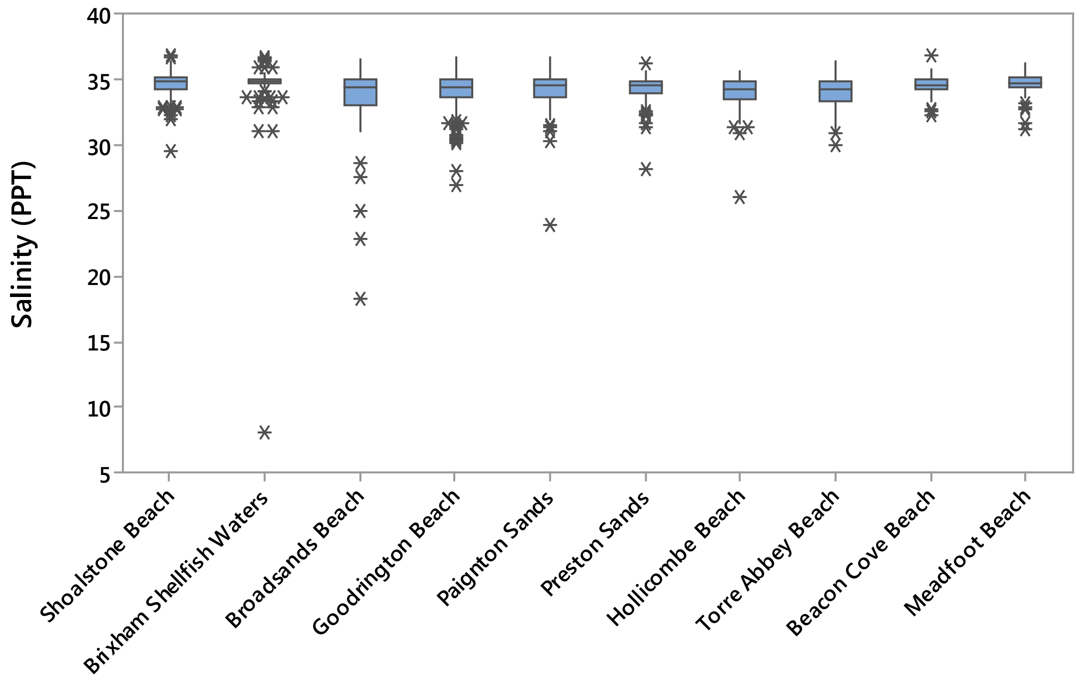

Figure IX.2: Box-and-whisker plots of levels of salinity readings (for the period 2004 - 2014)
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Salinity levels averaged between 33.8 and 34.8 ppt at all locations indicating little freshwater influence throughout Tor Bay. Salinities of less than 30 ppt were recorded occasionally at some sites, presumably due to the localised influence of various minor freshwater inputs.

Strong winds will modify surface currents within Tor Bay. Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2m/s) would drive a surface water current of about 1 knot or 0.5 m/s. Therefore, under conditions of moderate to strong winds, wind driven currents are likely to be of a similar magnitude to tidal streams, if not faster. These surface currents in turn drive return currents, which may flow at depth or along sheltered margins. Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great number of scenarios may arise. Easterly winds would tend to advect contamination from the harbour area towards the mussel farm for example. Where strong winds blow across a sufficient distance of water they may create wave action. Where these waves break contamination held in intertidal sediments may be re-suspended. Tor Bay is sheltered from the prevailing south westerly winds by the adjacent land. It is open to the east, so winds from this direction will be of greatest influence both on water circulation and via wave action mobilising sediment entrained faecal indicator bacteria.

Appendix X. Microbiological Data: Seawater

X.1. Bathing Waters

There are nine bathing waters relevant to the Brixham production area designated under the Directive 76/160/EEC (Council of the European Communities, 1975), the locations of which are shown in Figure X.1.

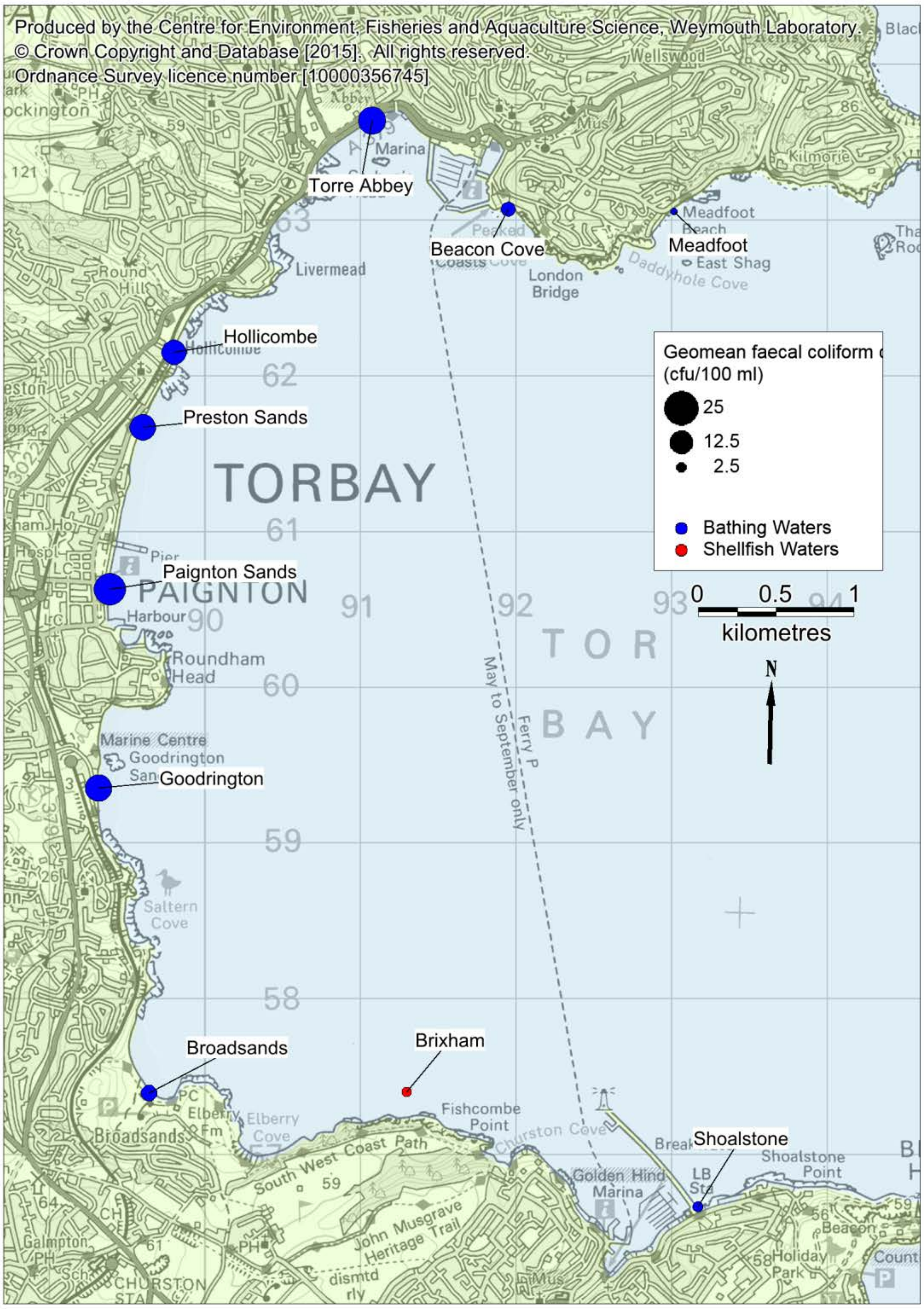

Figure X.1: Location of designated bathing and shellfish waters monitoring points relevant to the Brixham production area

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Due to changes in the analyses of bathing water quality by Environment Agency from 2012, faecal coliform data from 2004 to 2011 are presented separately from post-2012 *E. coli* data as these results are not directly comparable. Summaries of the faecal coliform and *E. coli* data are presented in Table X.1 and Table X.2 respectively. Due to the relatively restricted number of results available post 2012, only the extended 2004-2011 data were used in the further analyses.

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

Sampling Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1,000
Meadfoot	161	04/05/2004	20/09/2011	1.6	<2	202	0.6	0.0
Beacon Cove	161	04/05/2004	20/09/2011	5.2	<2	2,124	4.3	0.6
Torre Abbey	169	11/05/2004	21/09/2011	17.1	<2	8,000	18.9	4.7
Hollicombe	170	22/03/2004	21/09/2011	14.5	<2	2,000	14.7	1.8
Preston Sands	169	22/03/2004	21/09/2011	14.9	<2	2,280	14.8	2.4
Paignton Sands	172	22/03/2004	21/09/2011	21.8	<2	2,040	18.6	1.2
Goodrington	166	22/03/2004	21/09/2011	15.6	<2	2,585	13.9	1.8
Broadsands	163	22/03/2004	21/09/2011	6.9	<2	736	8.0	0.0
Shoalstone	160	11/05/2004	21/09/2011	3.1	<2	1,600	3.1	0.6

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Table X.2: Summary statistics for bathing waters *E. coli* results, 2012-2013 (cfu/100ml).

Sampling Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1,000
Meadfoot	41	09/05/2012	25/09/2013	6.1	<10	430	2.4	0.0
Beacon Cove	41	09/05/2012	25/09/2013	9.6	<10	720	7.3	0.0
Torre Abbey	80	04/05/2012	18/10/2013	18.2	<10	1,500	17.5	2.5
Hollicombe	41	04/05/2012	16/09/2013	10.8	<10	1,600	2.4	2.4
Preston Sands	42	04/05/2012	16/09/2013	12.9	<10	1,200	7.1	2.4
Paignton Sands	42	04/05/2012	16/09/2013	20.1	<10	680	14.3	0.0
Goodrington	136	07/05/2009	16/09/2013	13.1	<2	210	8.8	0.0
Broadsands	41	04/05/2012	16/09/2013	12.8	<10	136	2.4	0.0
Shoalstone	41	04/05/2012	16/09/2013	6.7	<10	73	0.0	0.0

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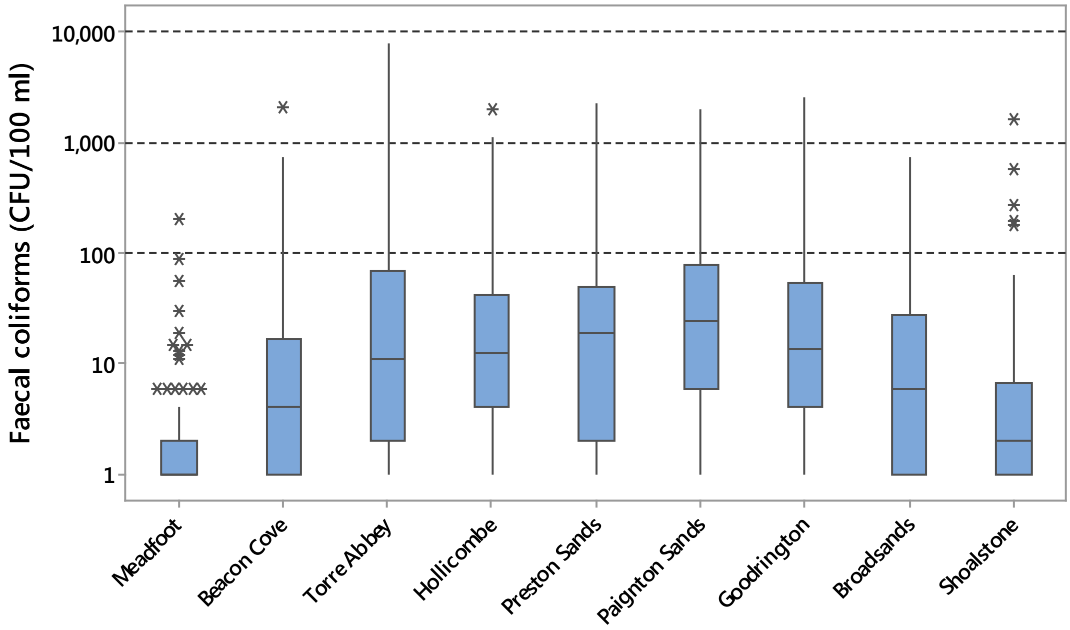

Figure X.2: Box-and-whisker plots of all faecal coliforms results by site
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The Paignton Sands sampling site had the highest geometric mean and Torre Abbey had the highest maximum faecal coliform concentrations, while Meadfoot had the lowest geometric mean faecal coliform concentration. There appeared to be a general trend of increased faecal coliform concentrations toward the middle of Tor Bay, around Paignton. A one-way ANOVA test showed that there were significant differences in faecal coliform concentrations between sites ($p<0.001$). Post-ANOVA Tukey tests showed that Meadfoot and Beacon Cove had significantly lower faecal coliform concentrations than most sites. The exceptions were that Beacon Cove did not differ significantly from Broadsands or Shoalstone. Additionally, Broadsands and Shoalstone had significantly lower faecal coliform concentrations than all sites except Meadfoot and Beacon Cove.

Correlations (Pearson's) were run between samples at the sites that shared sampling dates, and therefore environmental conditions, on at least 20 occasions. Meadfoot and Beacon Cove could only be compared with each other, and it was found that these sites correlated significantly ($r=0.185$, $p=0.019$). Nearly all other comparisons showed significant correlations ($p=<0.001-0.39$). The exception to this was that Shoalstone did not correlate significantly with Torre Abbey, Hollicombe or Preston Sands. The overall significantly correlations between sites indicates that most of the sites probably share similar contamination sources.

Overall temporal pattern in results

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

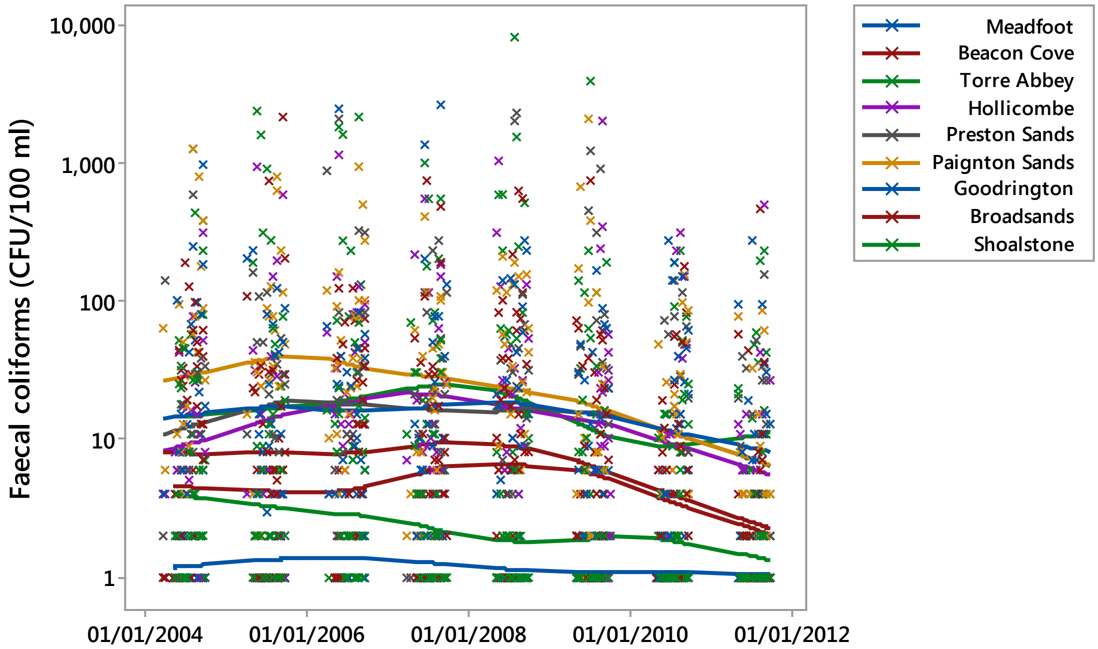

Figure X.3: Scatterplot of faecal coliform results for bathing waters in Tor Bay overlaid with loess lines.

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Faecal coliform levels have remained fairly stable since 2004, with a slight improvement at some from 2008.

Influence of tides

To investigate the effects of tidal state on faecal coliform results, circular-linear correlations were carried out against both the high/low and spring/neap tidal cycles for each of the bathing waters sampling points. Correlation coefficients are presented in Table X.3, with statistically significant correlations highlighted in yellow.

Table X.3: Circular linear correlation coefficients (r) and associated p values for faecal coliform results against the high low and spring/neap tidal cycles

	High/low tides		Spring/neap tides	
Site Name	**r**	**p**	**r**	**p**
Meadfoot	0.028	0.886	0.103	0.190
Beacon Cove	0.089	0.286	0.029	0.874
Torre Abbey	0.216	<0.001	0.167	0.010
Hollicombe	0.128	0.066	0.073	0.413
Preston Sands	0.063	0.516	0.094	0.229
Paignton Sands	0.096	0.209	0.195	0.002
Goodrington	0.052	0.641	0.044	0.729
Broadsands	0.034	0.830	0.177	0.007
Shoalstone	0.120	0.106	0.040	0.782

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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 correlation indicating a statistically significant effect. High water at Torquay 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.

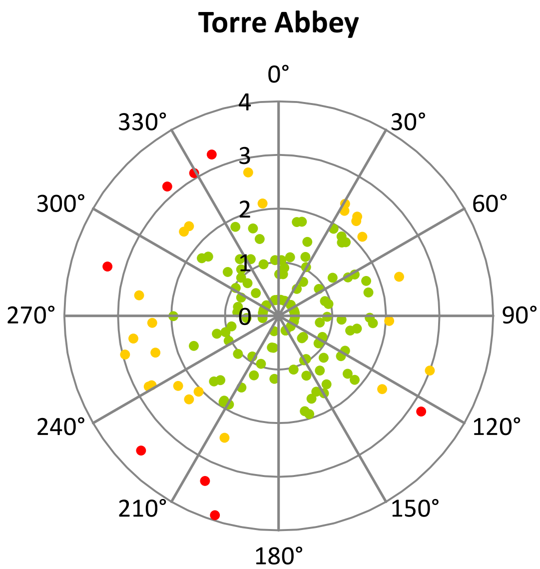

Figure X.4: Polar plots of log_{10} faecal coliform results (cfu/100 ml) against high/low tidal state.
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At Torre Abbey higher results tended to occur on the flood tide.

Figure X.5 presents polar plots of log_{10} faecal coliform results against the spring neap tidal cycle for those locations where correlations indicate a statistically significant effect. 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.

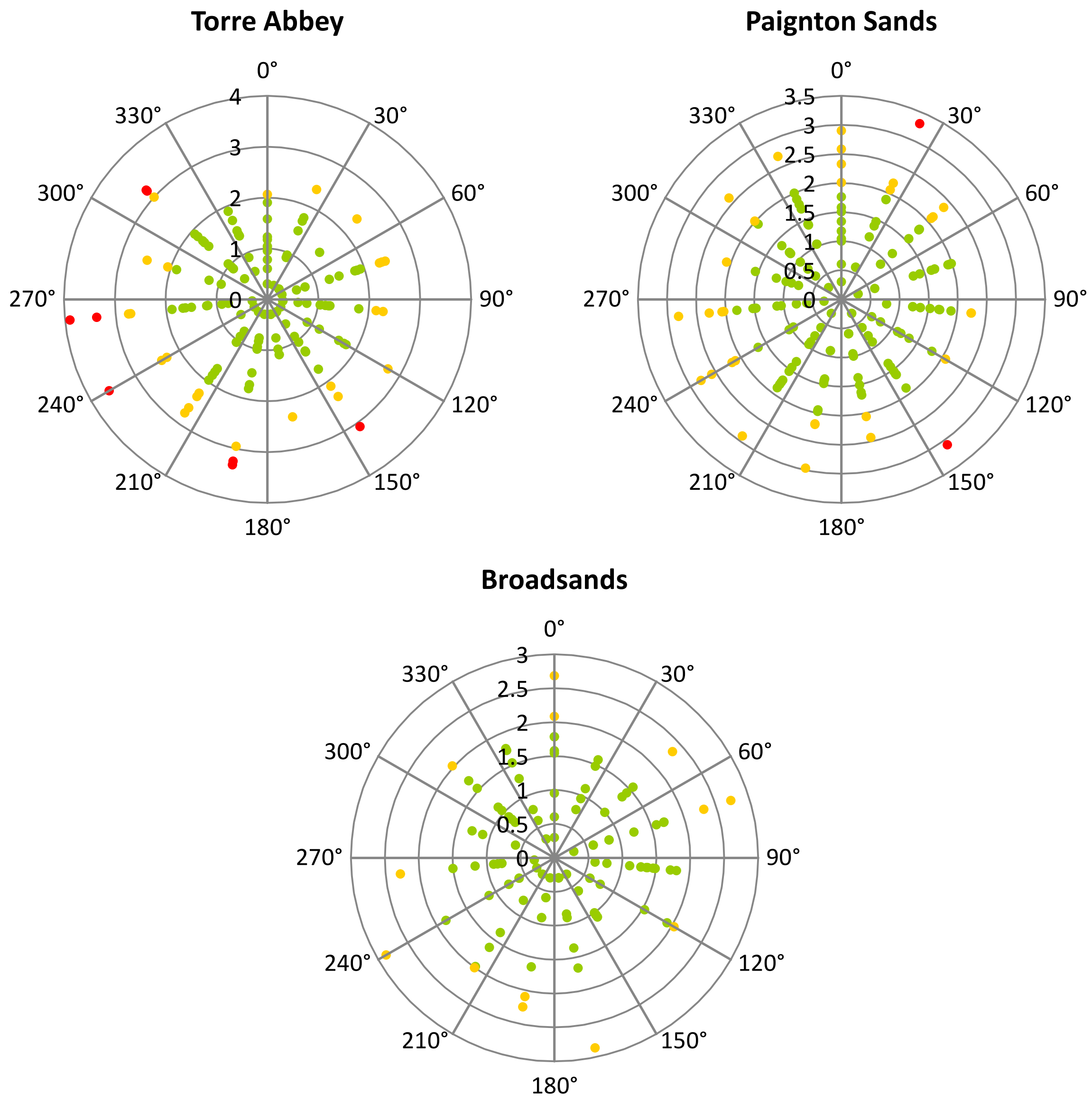

Figure X.5: Polar plots of log_{10} faecal coliform results (cfu/100 ml) against spring/neap tidal state.

At Torre Abbey, most of the higher results tended to occur closer on smaller tides, while no obvious patterns are apparent at Paignton Sands or Broadsands.

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 Torre Abbey weather station (Appendix II for details) over various periods running up to sample collection and faecal coliforms results. These are presented in Table X.4 and statistically significant positive correlations ($p<0.05$) are highlighted in yellow.

Table X.4: Spearman's Rank correlation coefficients for faecal coliforms results against recent rainfall

	Site	Meadfoot	Beacon Cove	Torre Abbey	Hollicombe	Preston Sands	Paignton Sands	Goodrington	Broadsands	Shoalstone
	n	120	120	128	126	126	129	122	120	120
24 hour periods prior to sampling	1 day	-0.022	0.167	0.361	0.149	0.333	0.084	0.267	0.129	0.107
	2 days	0.069	0.182	0.372	0.088	0.287	0.240	0.282	0.211	0.244
	3 days	0.070	0.067	0.142	0.073	0.103	0.045	0.085	0.002	-0.009
	4 days	0.081	0.116	0.034	-0.097	0.067	-0.074	-0.007	-0.012	0.061
	5 days	-0.056	0.171	0.004	-0.081	-0.065	-0.085	-0.016	-0.215	0.008
	6 days	-0.171	0.122	0.054	0.024	-0.020	-0.048	-0.018	-0.032	-0.104
	7 days	-0.118	0.052	0.065	0.029	-0.080	-0.032	-0.089	0.005	-0.126
Total prior to sampling over	2 days	0.032	0.205	0.422	0.120	0.324	0.154	0.285	0.191	0.187
	3 days	0.063	0.174	0.392	0.134	0.284	0.133	0.25	0.155	0.129
	4 days	0.081	0.124	0.351	0.052	0.265	0.095	0.224	0.116	0.176
	5 days	0.061	0.175	0.308	0.067	0.234	0.101	0.211	0.044	0.157
	6 days	0.018	0.188	0.327	0.078	0.229	0.064	0.165	0.004	0.092
	7 days	0.034	0.174	0.331	0.098	0.215	0.058	0.152	0.031	0.086

Faecal coliform concentrations at Torre Abbey, Preston Sands and Goodrington were most affected by rainfall. No influence was detected at Meadfoot and Hollicombe. Where an influence was detected, it did not persist for longer than 2 days after a rainfall event.

Salinity

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

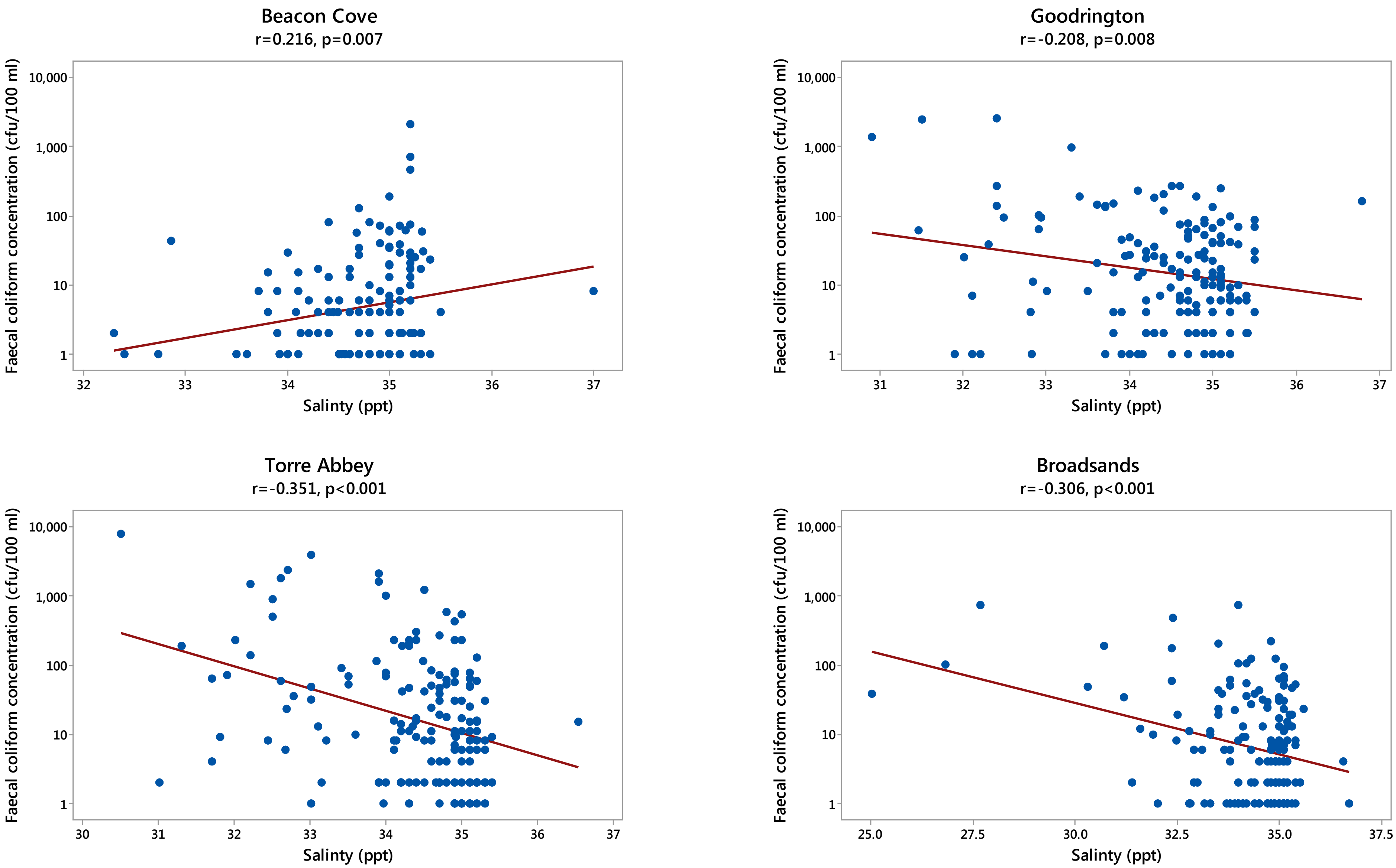

Figure X.6: Scatter-plots of salinity against faecal coliform concentration.
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Faecal coliform concentrations at Torre Abbey, Goodrington and Broadsands all correlated negatively with salinity indicating that the freshwater affecting these sites contains a source of faecal coliforms. Beacon Cove correlated positively with salinity, which is somewhat contradictory with the significant (positive) correlations with rainfall observed at this location.

X.2. Shellfish Waters

Summary statistics and geographical variation

There is one shellfish waters monitoring site designated under Directive 2006/113/EC (European Communities, 2006) relevant to the Brixham production area. Water samples are taken from here on a quarterly basis and tested for faecal coliforms. Figure X.1 shows the location of this site. Table X.5 presents summary statistics for bacteriological monitoring results and Figure X.7 presents a boxplot of faecal coliform levels from the monitoring point.

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

Sampling Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1,000
Brixham	36	10/02/2004	26/06/2013	2.9	<2	101	2.8	0.0

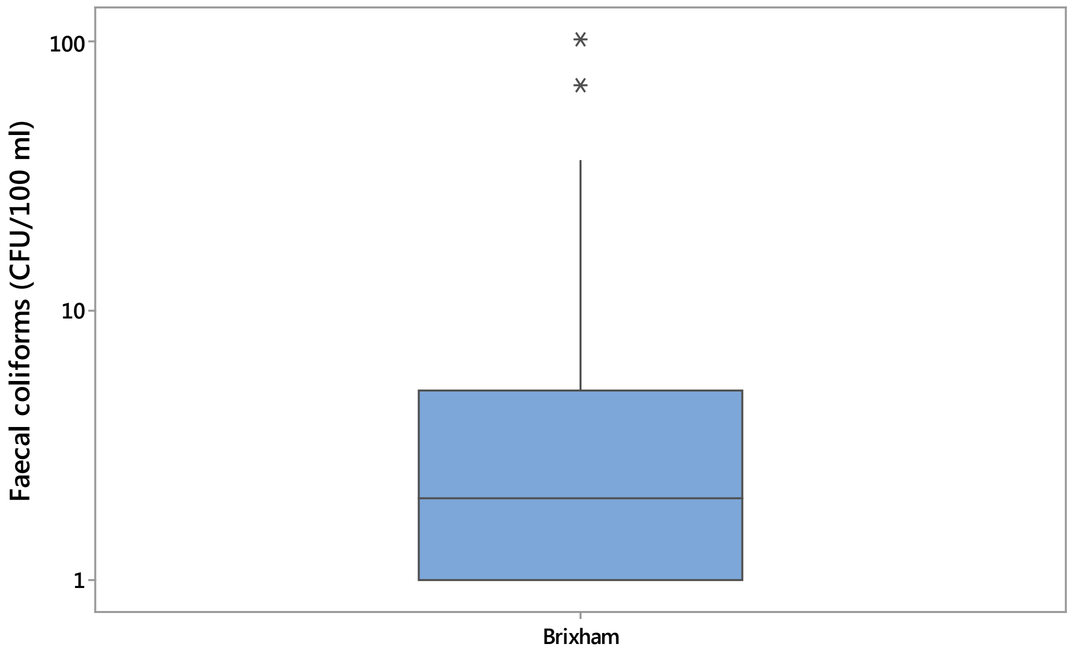

Figure X.7: Box-and-whisker plot of all faecal coliforms results

The average result here was very low, with 77% of results being below the limit of quantification for the test used. Only one sample had a faecal coliform concentration of more than 100 cfu/100 ml.

Overall temporal pattern in results

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

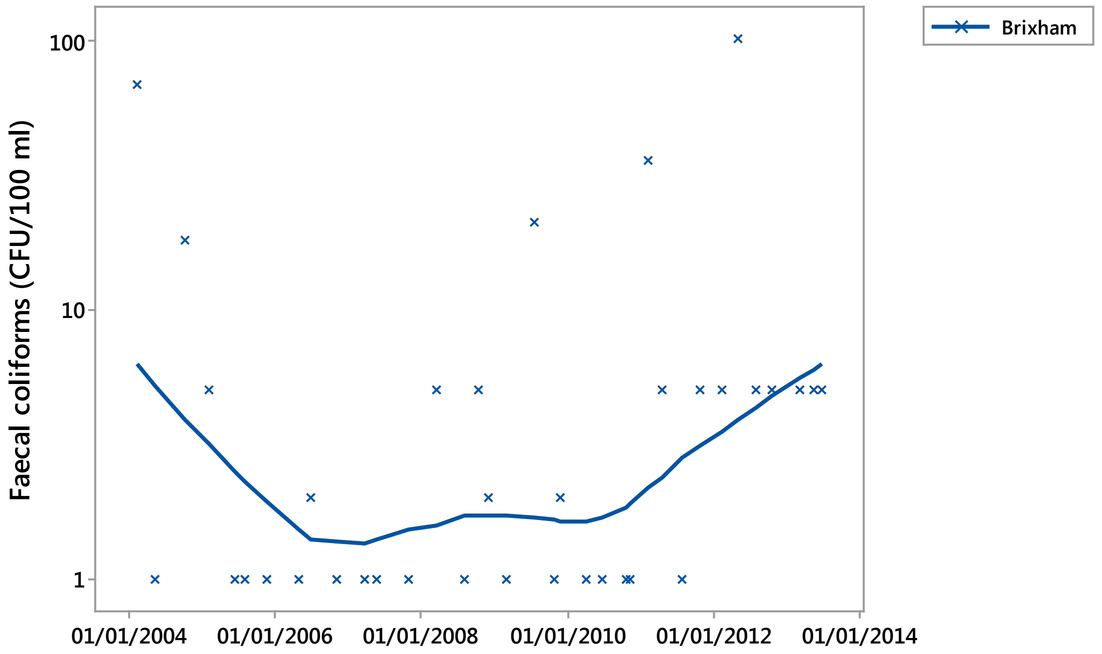

Figure X.8: Scatterplot of faecal coliform results by date, overlaid with loess lines
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Despite the appearance of the loess line, faecal coliform levels have remained fairly constant at Brixham, with occasional relatively high results. The apparent increase since 2010 is due to an increase in the limit of quantification from 2 to 10 cfu/100ml.

Seasonal patterns of results

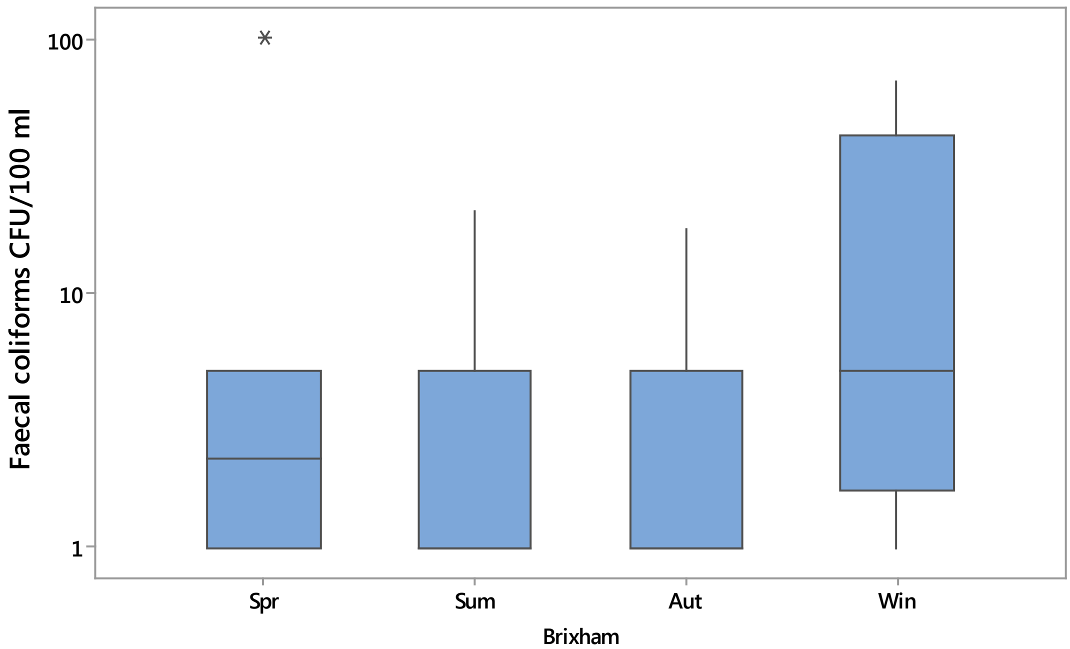

Figure X.9: Boxplot of faecal coliform results by site and season
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While there were higher average faecal coliform concentrations in the winter (Figure X.9), one-way ANOVA tests revealed there to be no significant differences between seasons (p=0.286).

Influence of tide

To investigate the effects of tidal state on faecal coliform results, circular-linear correlations were carried out against both the high/low and spring/neap tidal cycles. Correlation coefficients are presented in Table X.6, with statistically significant correlations highlighted in yellow.

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

Site Name	High/low tides r	High/low tides p	Spring/neap tides r	Spring/neap tides p
Brixham	0.326	0.030	0.165	0.406

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

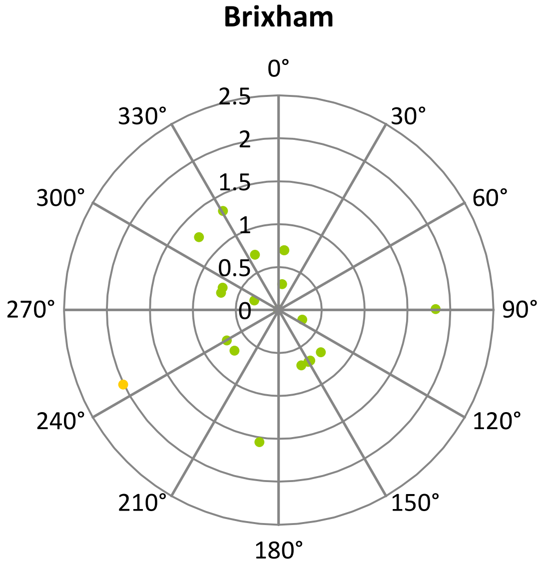

Figure X.10: Polar plots of log10 faecal coliforms against tidal state on the high/low tidal cycle for shellfish waters monitoring points with significant correlations
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Samples with high faecal coliform concentrations tended to be collected at the lower tidal states. However, not enough samples have been taken throughout the tidal cycle to show any true patterns.

Influence of rainfall

To investigate the effects of rainfall on levels of contamination at the water quality monitoring sites Spearman's rank correlations were carried out between rainfall recorded at the Torre Abbey weather station (Appendix VI for details) over various periods running up to sample collection and faecal coliform results. These are presented in Table X.7 and statistically significant correlations ($p<0.05$) are highlighted in yellow.

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

	Site	Brixham
	n	29
24 hour periods prior to sampling	1 day	-0.026
	2 days	0.201
	3 days	0.236
	4 days	0.177
	5 days	0.162
	6 days	0.207
	7 days	0.000
Total prior to sampling over	2 days	0.086
	3 days	0.190
	4 days	0.232
	5 days	0.319
	6 days	0.322
	7 days	0.278

Rainfall had no significant impact on faecal coliform levels at Brixham.

Salinity

Salinity was recorded on most sampling occasions. Figure X.11 shows scatter-plots between faecal coliforms and salinity. Pearson's correlations were run to determine the effect of salinity on faecal coliforms at the bathing waters site.

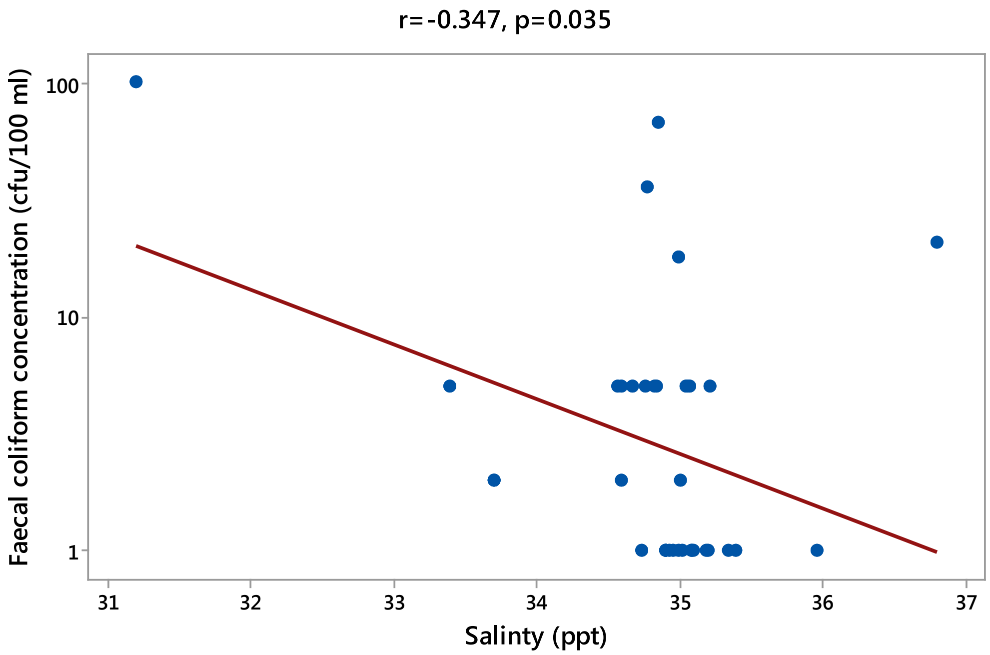

Figure X.11: Scatter-plots of salinity against faecal coliform concentration.

Faecal coliform levels at Brixham correlated relatively weakly with salinity. This may indicate that land runoff may be an important source of contamination at this site despite the lack of correlation with rainfall. Alternatively, there may be interactions between other factors (e.g. seasonal variation in salinity and survival times of faecal indicator bacteria).

Appendix XI. Microbiological Data: Shellfish Flesh

There is only one RMP in the Brixham production area that has been sampled on a more or less monthly basis from 2005 to 2014. Its location is shown in Figure XI.1, summary statistics are presented in Table XI.1 and a boxplot of results is shown in Figure XI.2.

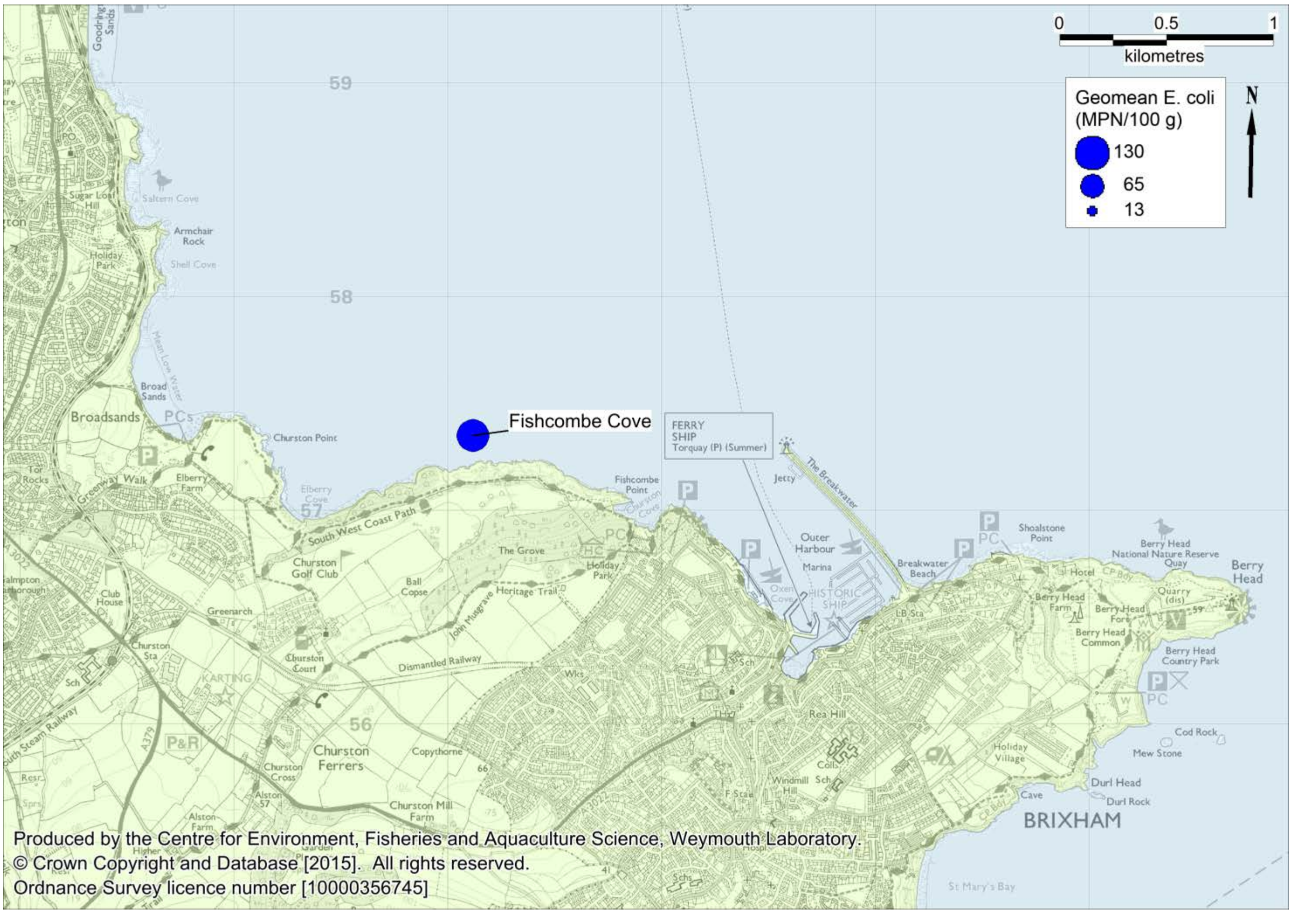

Figure XI.1: Mussel RMP active since 2005.

Table XI.1: Summary statistics of *E. coli* results (MPN/100 g) from RMPs sampled from 2005 onwards.

Site	Species	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 230	% over 4,600	% over 46,000
Fishcombe Cove	Mussel	121	08/02/2005	15/07/2014	120.1	<20	160,000	32.2	5.8	0.8

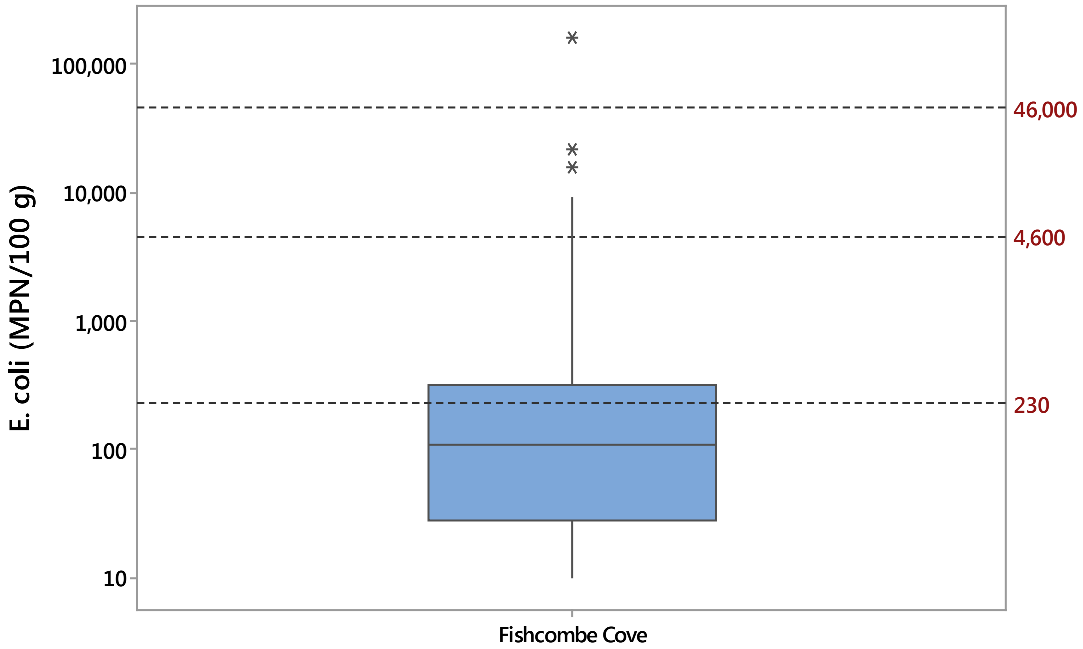

Figure XI.2: Boxplot of *E. coli* results from the Fishcombe Cove mussel RMP from 2005 onwards.

At Fishcombe Cove, the majority of *E. coli* results were 230 MPN/100 g or less (67.8%). A small proportion (5.8%) exceeded 4,600 *E. coli* MPN/100 g, and a single result exceeded 46,000 *E. coli* MPN/100 g.

XI.1. Overall temporal pattern in results

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

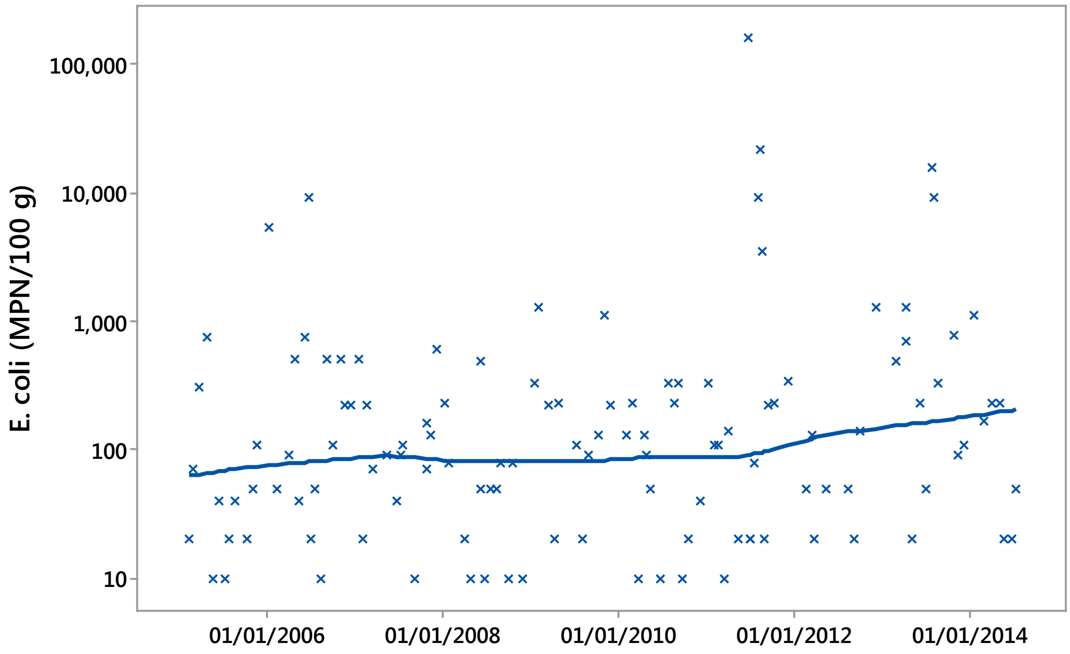

Figure XI.3: Scatterplot of *E. coli* results for mussels overlaid with loess line.

E. coli results have remained fairly stable since 2005, although there appears to have been a slight increase in average result in recent years.

XI.2. Seasonal patterns of results

The seasonal patterns of results from 2005 to 2014 were investigated. Figure XI.4 shows boxplots of *E. coli* levels by season.

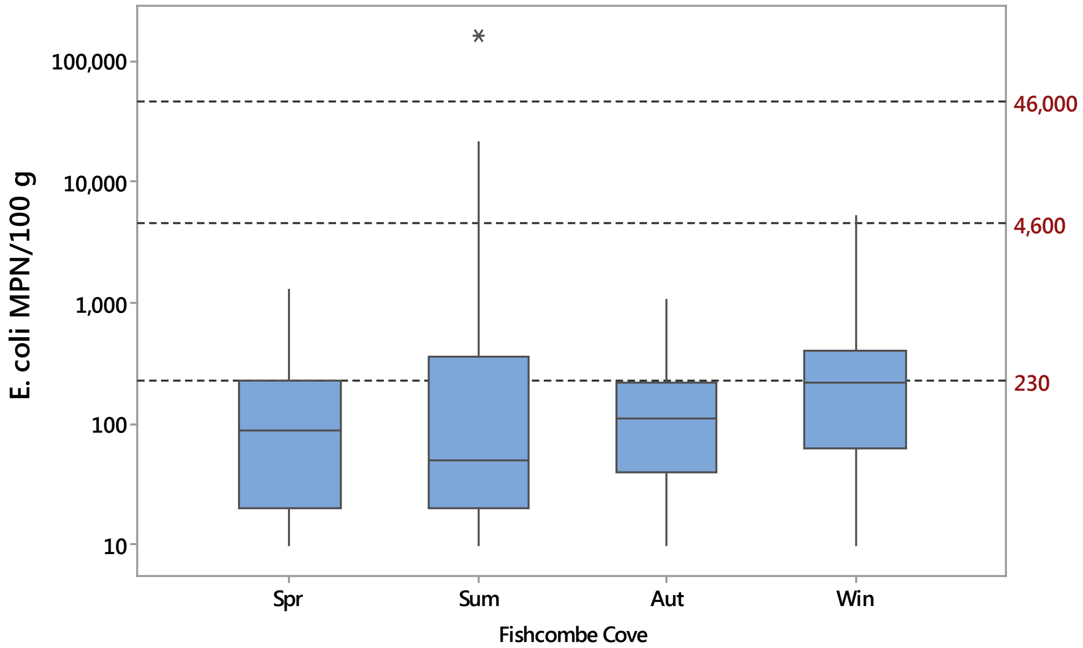

Figure XI.4: Boxplot of *E. coli* results by season

One-way ANOVAs showed that there were no significant differences in *E. coli* levels in between seasons (p=0.337). Peak results tended to occur in the summer, and fewer very low results were recorded in the autumn and winter.

XI.3. Influence of tide

To investigate the effects of tidal state on *E. coli* results, circular-linear correlations were carried out against the high/low tides at Torquay and spring/neap tidal cycles. Results of these correlations are summarised in Table XI.2.

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

		High/low tides		Spring/neap tides	
Site Name	**Species**	**r**	**p**	**r**	**p**
Fishcombe Cove	Mussel	0.033	0.876	0.096	0.339

There were no significant correlations between *E. coli* results and tidal state.

XI.4. Influence of rainfall

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

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

	Site	Fishcombe Cove
	n	104
24 hour periods prior to sampling	1 day	0.091
	2 days	0.214
	3 days	0.398
	4 days	0.050
	5 days	0.245
	6 days	0.189
	7 days	0.137
Total prior to sampling over	2 days	0.214
	3 days	0.325
	4 days	0.280
	5 days	0.277
	6 days	0.275
	7 days	0.283

Rainfall had a significant influence on *E. coli* levels in mussels between 2 and 5 days after a rainfall event. However, several of the highest results, including the only prohibited level result occurred during relatively dry periods (Figure XI.5).

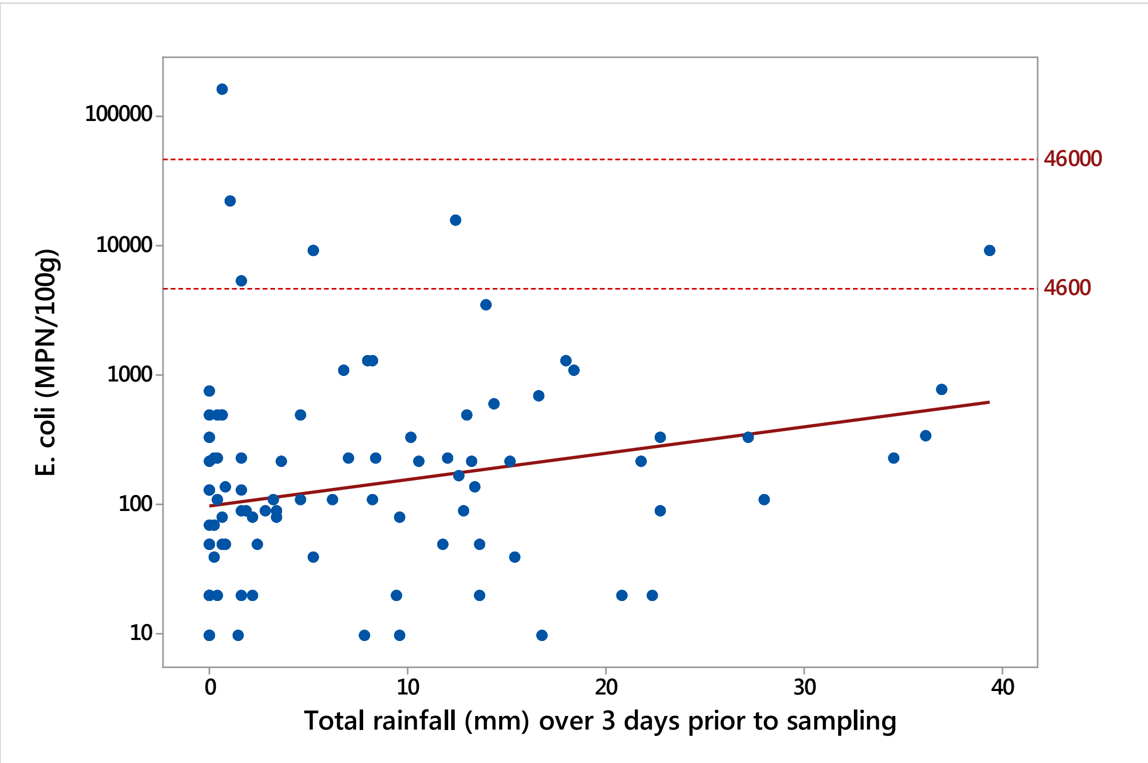

Figure XI.5: Scatterplot of *E. coli* results against rainfall totals over 3 days prior to sampling

XI.5. Bacteriological survey

Only one location within the mussel farm has been sampled historically so additional sampling was undertaken on the 6th January 2015 to ascertain information on spatial variation in levels of contamination across the farm, both on the horizontal and vertical planes. The survey was undertaken in relatively dry conditions. Samples were taken from the top and bottom of the mussel lines at the south east and south west corners of the farm. A sample was also taken from the regular RMP.

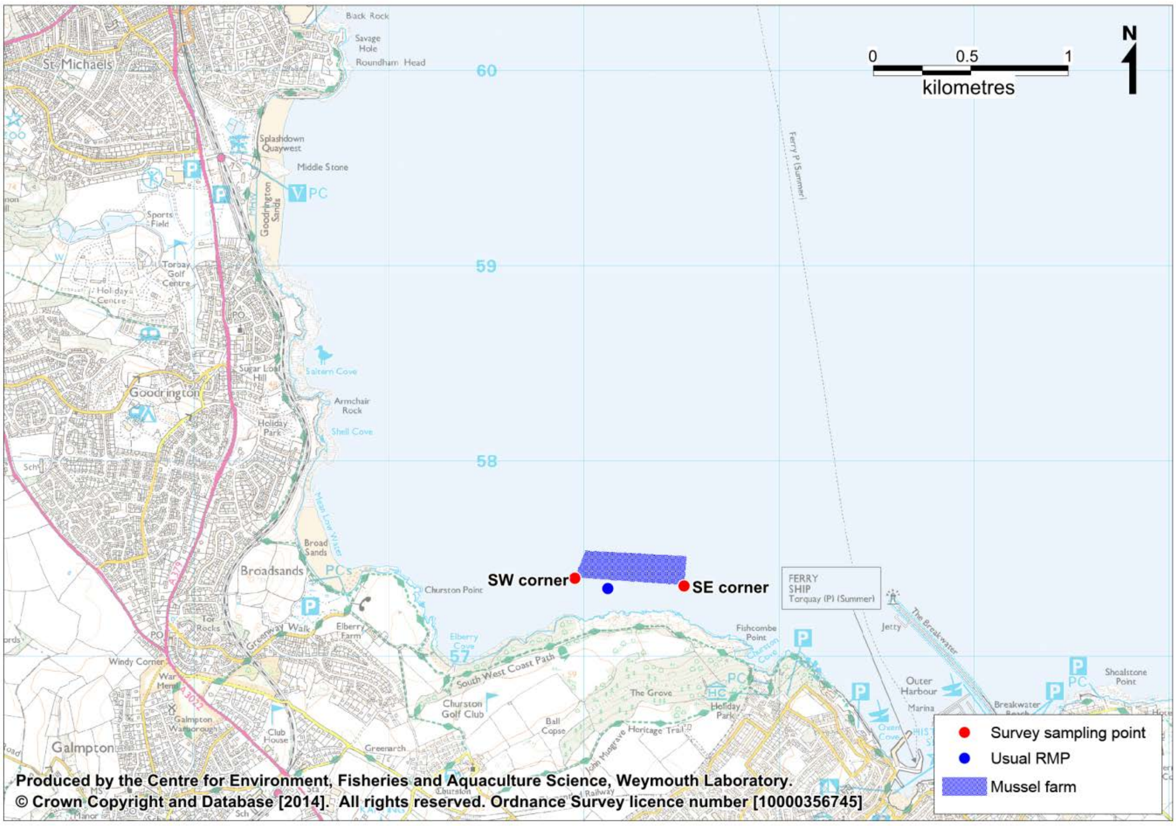

Figure XI.6: Sampling locations

Table XI.4: Sample results

Location	Depth	*E. coli* (MPN/100g)
South east corner (top of lines)	2 m	68
South east corner (bottom of lines)	6 m	330
South west corner (top of lines)	2 m	230
South west corner (bottom of lines)	6 m	490
Usual RMP	2 m	330

The spatial variation across the site was low, with results ranging from 68 to 490 *E. coli* MPN/100g. At both corners, the result was slightly higher at the bottom of the line. Results were also marginally higher at the south west corner of the sites.

Appendix XII. Shoreline Survey Report

Date (time): 08/12/2014 (09:00 – 14:00)

Cefas Officer: Alastair Cook

Local Enforcement Authority Officer: Lars Barker (Torbay Council).

Area surveyed: Goodrington to Brixham (Figure XII.1).

Weather: Dry, overcast, 10°C, wind W force 3.

Tides:

Admiralty Totaltide predictions for Torquay. All times in this report are GMT.

08/12/2014	
High 07:04	5.1 m
High 19:24	4.8 m
Low 00:34	1.0 m
Low 12:57	1.1 m

Objectives:

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

XII.1. Fishery

The fishery is a large mussel rope farm, which lies in the relatively exposed waters of Tor Bay. A meeting was held with the harvester and details of the culture processes were obtained (presented in Section 4.1). In addition to the mussels, pilot trials of king scallop culture in suspended cages are underway, and it is possible that similar trials using native oysters will also be undertaken in the future.

XII.2. Sources of contamination

Sewage discharges

The Oxen Cove intermittent discharge and the Astra Zeneca Laboratory intake/outlet were both observed (observations 4 and 6) but the actual outfall pipes were not seen as they were underwater.

Freshwater inputs

Two freshwater outfalls were sampled and measured (observations 2 and 7). The latter was carrying a high concentration of *E. coli*, but flows were small from both. A further small surface water outfall was seen at the bottom of a concrete sea wall, (observation 5) but this could not be accessed.

Boats and Shipping

Brixham is an active fishing port and also has a sizeable marina where many large yachts were present.

Livestock

No livestock were observed during the course of the survey. Dog walkers were frequently encountered, particularly at Broadsands Beach.

Wildlife

No major aggregations of wildlife were observed.

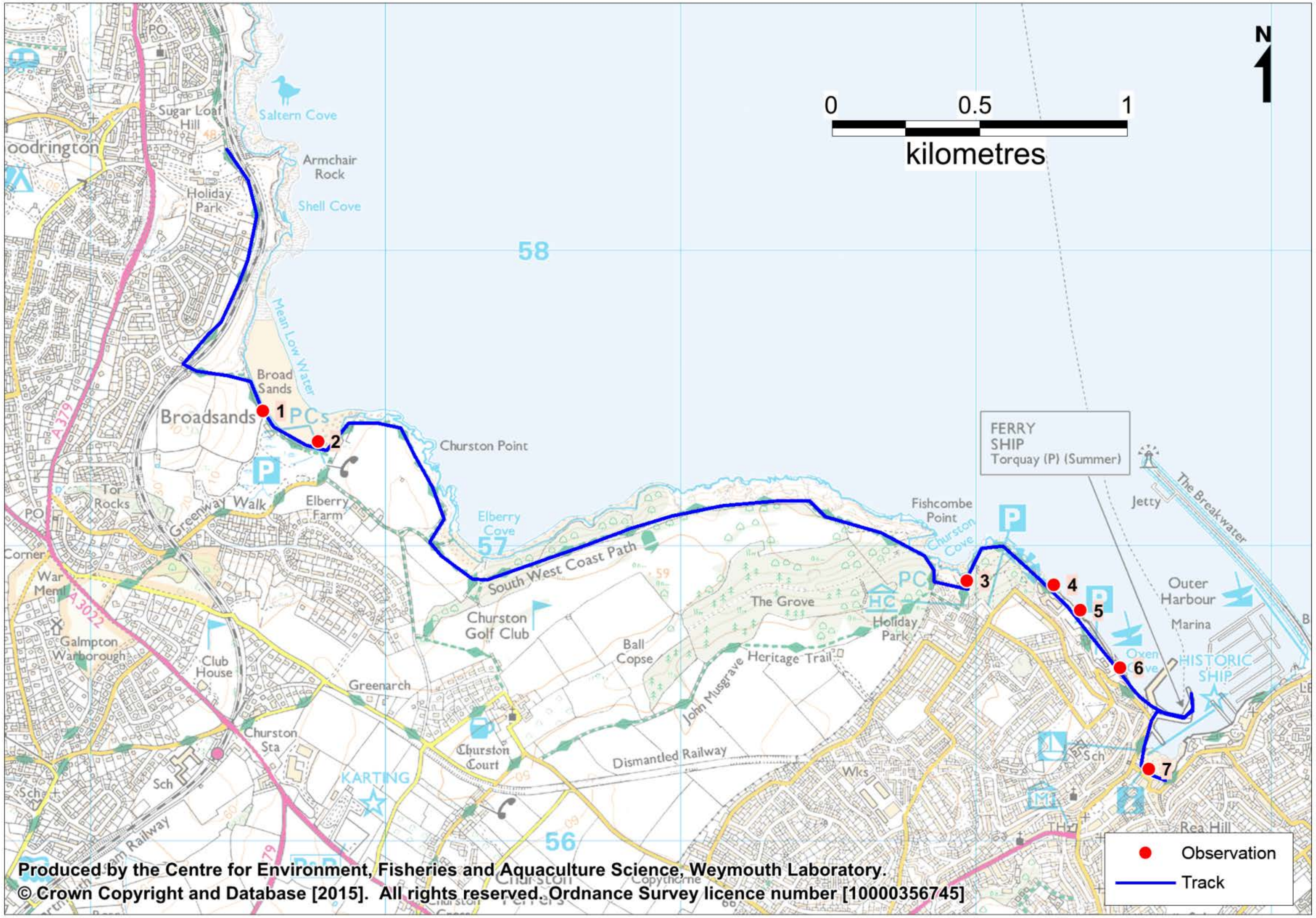

Figure XII.1: Locations of shoreline observations (see Table XII.1 for details)

Table XII.1: Details of Shoreline Observations

No	Time and Date	NGR	Photograph	Observation
1	SX 89584 57459	08/12/2014 10:19		5 dogs on beach
2	SX 89770 57356	08/12/2014 10:23		Freshwater outfall (75 cm x11 cm x 0.419 m/s). Water sample 1
3	SX 91968 56883	08/12/2014 11:21		Toilet block and shed, no outfall visible
4	SX 92264 56869	08/12/2014 11:34		Intake/discharge from laboratory.
5	SX 92353 56783	08/12/2014 11:39	Figure XII.2	Small surface water outfall on sea wall. Flowing. Inaccessible.
6	SX 92488 56589	08/12/2014 11:45	Figure XII.3	Oxen Cove intermittent discharge
7	SX 92585 56245	08/12/2014 12:02	Figure XII.4	Culverted stream (200 cm x 2 cm x 0.139m/s). Water sample 2

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

No.	Date and time	NGR	Description	*E. coli* (cfu/100ml)	Discharge (m^3/sec)	Bacterial loading (*E. coli*/day)
2	08/12/2014 10:23	SX 89770 57356	Freshwater outfall	1,700	0.0354	$5.2x10^{10}$
7	08/12/2014 12:02	SX 92585 56245	Culverted stream	52,000	0.0056	$2.5x10^{11}$

Figure XII.2

Figure XII.3

Figure XII.4

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

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