Centre for Environment Fisheries & Aquaculture Science

www.cefas.defra.gov.uk

EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Lyme Bay

January 2015

Food
Standards
Agency

Cover photo: Mussel floats, Lyme Bay

This document/publication is also available on our website at:

https://www.cefas.co.uk/publications-data/food-safety/sanitary-surveys/england-and-wales/

Contacts

For enquires relating to this report or further information on the implementation of sanitary surveys in England and Wales:

Simon Kershaw
Food Safety Group
Cefas Weymouth Laboratory
Barrack Road
The Nothe
Weymouth
Dorset
DT4 8UB

☎ +44 (0) 1305 206600
✉ fsq@cefas.co.uk

For enquires relating to policy matters on the implementation of sanitary surveys in England:

Karen Pratt
Hygiene Delivery Branch
Enforcement and Delivery Division
Food Standards Agency
Aviation House
125 Kingsway
London
WC2B 6NH

☎ +44 (0) 020 7276 8970
✉ shellfishharvesting@foodstandards.gsi.gov.uk

Statement of use

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

Report prepared by

Alastair Cook, David Walker, Rachel Parks and Fiona Vogt

Revision history

Version	Details	Approved by	Approval date
1	Draft for internal review	Fiona Vogt	15/01/2015
2	Draft for external review	Andrew Younger	26/01/2015
Final	Final report post consultation	Simon Kershaw	29/05/2015
Revision	Final report revised	Simon Kershaw	18/06/2015

Consultation

Consultee	Date of consultation	Date of response
Torbay Council	12/03/2015	None received
Devon & Severn IFCA	12/03/2015	None received
Environment Agency	12/03/2015	None received
South West Water	12/03/2015	None received
Shellfish Association of Great Britain	12/03/2015	None received
Natural England	12/03/2015	None received
Defra	12/03/2015	None received
Offshore Shellfish Ltd	12/03/2015	12/04/2015

Dissemination

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

Recommended Bibliographic Reference

Cefas, 2015. Sanitary survey of Lyme Bay. Cefas report on behalf of the Food Standards Agency, to demonstrate compliance with the requirements for classification of bivalve mollusc production areas in England and Wales under EC regulation No. 854/2004.

Contents

1. Introduction

1.1. Legislative Requirement

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

When consumed raw or lightly cooked, bivalves contaminated with pathogenic microorganisms may cause infectious diseases 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.) within Lyme Bay. The area was prioritised for survey in 2014-15 as a new area requiring classification.

1.2. Area description

Lyme Bay is a large, open embayment on the south coast of England which straddles the Devon / Dorset border. It stretches 65 kilometres from Start Point Lighthouse, near Torcross in the west eastwards towards Portland Bill Lighthouse on Portland. The subject of this survey is a mussel farm which lies across three sites between 3 and 10 km offshore of Sidmouth and Seaton.

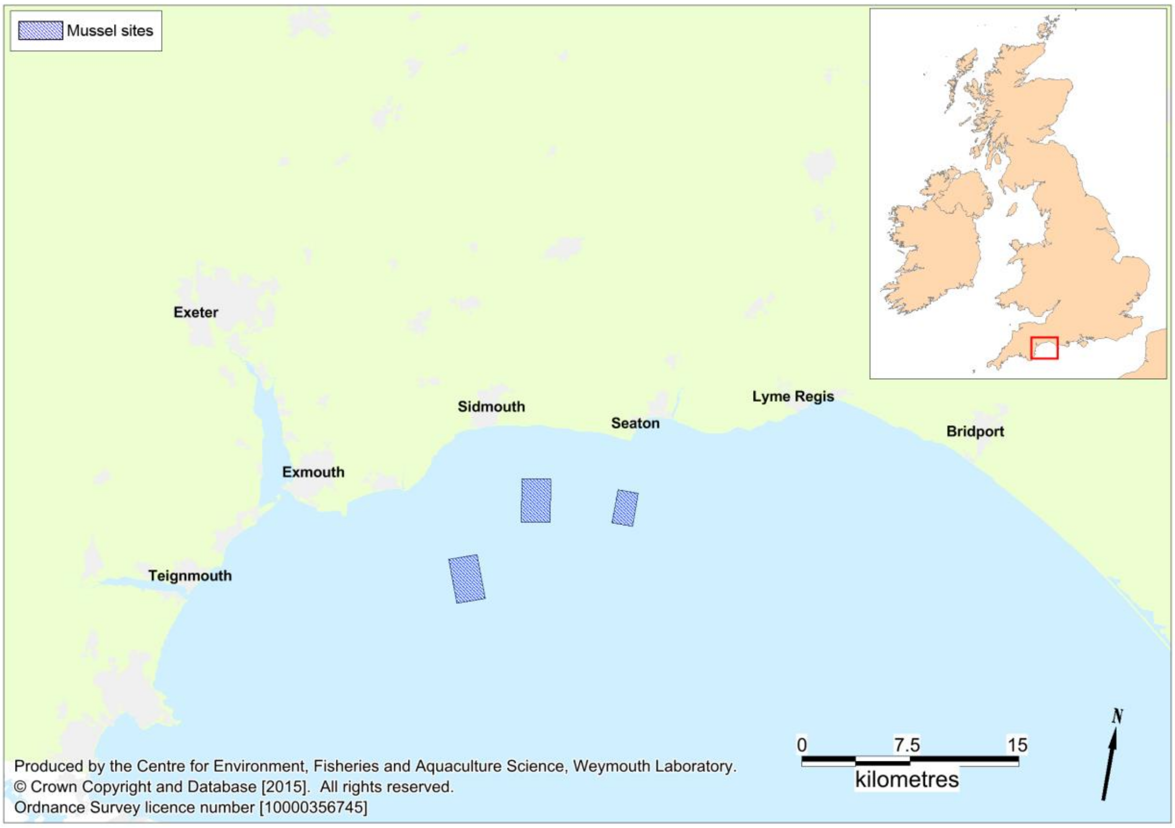

Figure 1.1: Location of Lyme Bay

The shore is largely backed by cliffs. There are a series of coastal villages and towns, generally located where watercourses discharge to the shore and where there are no cliffs. The Exe and Teign estuaries drain to the western end of the Bay. Tourism is important to the local economy. There is significant boat traffic in the area, including yachts and fishing vessels. The bathymetry of the Bay is uncomplicated, with the seabed gently sloping away from the coast to a depth of about 25 m in the vicinity of the mussel sites.

1.3. Catchment

The hydrological catchment considered in detail in this survey extends east of Straight Point, Exmouth to Charton Bay, Seaton. It covers an area of approximately 733 km^2, as estimated from topographical maps. Whilst the Exe and possibly the Teign catchments are also likely to be an influence on the mussel farm in Lyme Bay, these have been covered in detail in previous surveys (Cefas 2013 a & b).

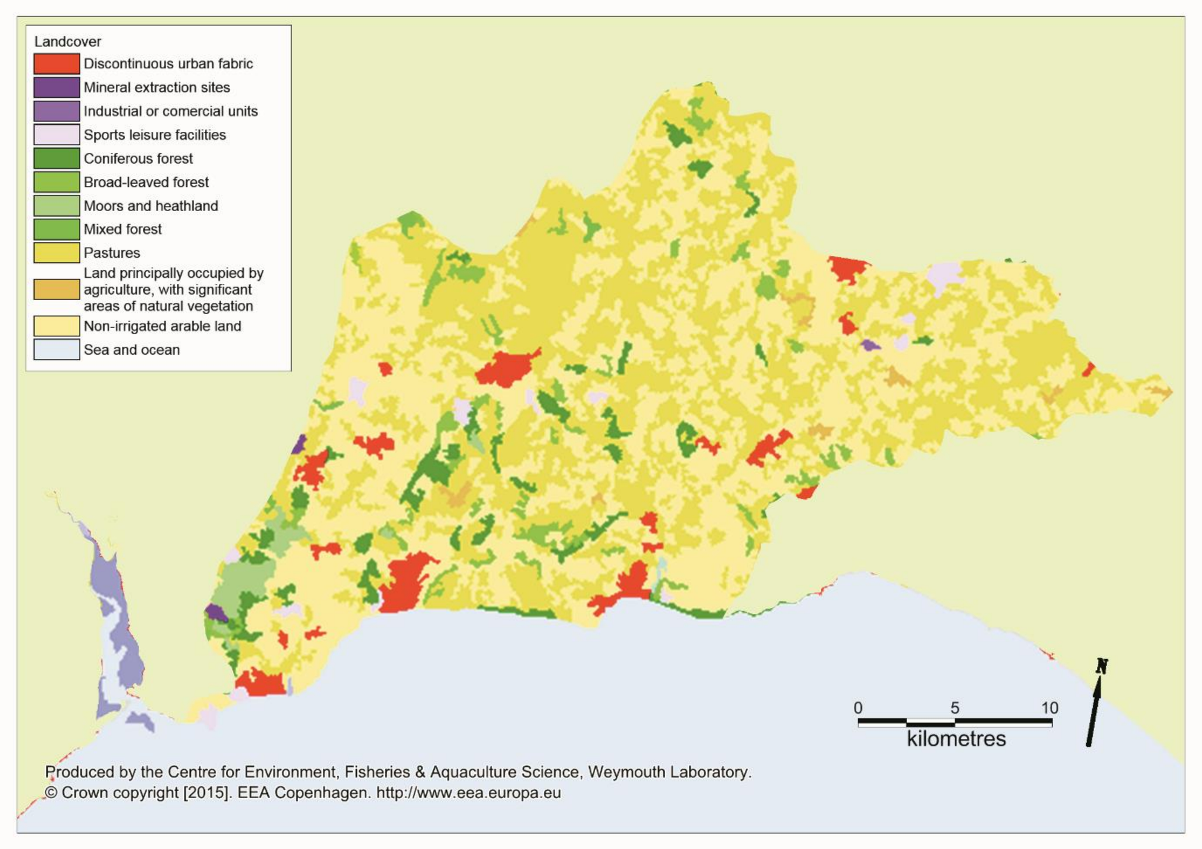

Figure 1.2 Land cover in the Lyme Bay catchment

Land cover in the catchment is a mixture of arable farmland, pasture, woodland and a small area of heathland in the south west of the catchment. There are pockets of urbanised land throughout the catchment; around half of which is located on the coast, including the towns of Exmouth, Sidmouth and Seaton. The catchment is drained by two principal watercourses (River Otter and River Axe).

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.

Elevations rise to around 315 m in inland areas. The underlying hydrogeology of the catchment varies considerably. The Otter catchment is underlain by high permeability bedrock in its lower reaches and moderate/mixed permeability bedrock in its upper reaches. The Axe catchment is largely a mix of moderate and low permeability bedrock, although there are some areas of high permeability in its upper reaches (NERC, 2012). There will therefore be some damping of river response to rainfall through the discharge and recharge of ground waters.

2. Recommendations

The following three zones are recommended for mussels:

Site 1

Within this zone there are currently two pilot lines in the south eastern corner, which will be harvested sometime in 2015. Ultimately lines will fill the entire zone, but it is likely that development will be a gradual process. Potential local sources of contamination to the zone include boats, birds and marine mammals, inputs from all of which may be considered as diffuse and unpredictable spatially. There may be a tendency for birds to rest on the larger marker buoys at either end of the lines in preference to the tubular floats from which the lines are suspended. The main shoreline sources lie to the north and west (Exe and Otter estuaries, various sewage discharges). Contamination from these will not be carried directly towards this site by tidal streams, but northerly winds will promote the advection of any plumes towards the fishery. The inshore edge of the site will be most vulnerable. There is some evidence of slightly increasing freshwater influence towards the west in this area at times, and of a slight decrease in salinity towards the surface. It is therefore recommended that for initial monitoring of the pilot lines, the RMP should be located at the western end of the lines. When the site is fully developed the RMP should be moved to the north west corner of the lease area. If the site is partially developed, the RMP should be located as close to the shore as possible, then as far west as possible. Bagged mussels may be used if there are lines present to suspend them from but the mussels present are not sufficiently large to sample. 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 3 and 10m 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 (3 m depth).

Site 2

Within this zone there is currently one pilot line in the north western corner, which will be harvested sometime in 2015. Ultimately lines will fill the entire zone, but it is likely that development will be a gradual process. Potential local sources of contamination to the zone include boats, birds and marine mammals, inputs from all of which may be considered as diffuse and unpredictable spatially. There may be a tendency for birds to rest on the larger marker buoys at either end of the lines in preference to the tubular floats from which the lines are suspended. The main shoreline sources lie to the north and west (Exe, Otter and Axe estuaries, various sewage discharges). Contamination from these will not be carried directly towards this site by tidal streams, but northerly winds will promote the advection of any plumes towards the fishery. The inshore side of the site will be most vulnerable. There is some evidence of slightly increasing freshwater influence towards the west in this area at times, and of a slight decrease in salinity towards the surface. It is therefore recommended that for initial monitoring of the pilot lines, the RMP should be located at the western end of the lines. When the site is fully developed the RMP should be moved to the north west corner of the lease area. If the site is partially developed, the RMP should be located as close to the shore as possible, then as far west as possible. Bagged mussels may be used if there are lines present to suspend them from but the mussels present are not sufficiently large to sample. 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 3 and 10 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 (3 m depth).

Site 3

There has been no tackle deployed within this lease area as yet, so this will not require monitoring or classification at present. Ultimately lines will fill the entire zone, but it is likely that development will be a gradual process. Potential local sources of contamination to the zone include boats, birds and marine mammals, inputs from all of which may be considered as diffuse and unpredictable spatially. There may be a tendency for seabirds to rest on the larger marker buoys which will be placed to mark the corners in preference to the tubular floats from which the lines are suspended. The main shoreline sources lie to the north and west (Axe and Otter estuaries, various sewage discharges). Contamination from these will not be carried directly towards this site by tidal streams, but northerly winds will promote the advection of any plumes towards the fishery. The inshore edge of the site will be most vulnerable. It is therefore recommended that when the site is fully developed the RMP should be located at the north west corner of the lease area. If the site is partially developed, the RMP should be located as close to the shore as possible, then as far west as possible. Bagged mussel may be used if there are lines present to suspend them from but the mussels there are not sufficiently large to sample. 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 3 and 10m 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 (3m depth).

General requirements

The sampling frequency should be monthly. It may be possible to reduce this to bi-monthly at some point in the future, given that the lease areas are remote from any point sources of contamination. However this will depend on the monitoring results, and the initial (high) results from the bacteriological survey suggest that this would not be appropriate. Should a more rapid initial classification be required, this may be awarded on the basis of 10 samples taken not less than one week apart. Samples should be of animals of a market size. Bagged mussels may be used where lines have been deployed but they do not hold mature stock. A horizontal tolerance of 100 m applies.

3. Sampling Plan

3.1. General Information

Location Reference

Production Area	Lyme Bay
Cefas Main Site Reference	TBA
Ordnance survey 1:25,000 map	Explorer 115 and 116
Admiralty Chart	3315

Shellfishery

Species/culture	Mussel	Rope culture
Seasonality of harvest	No closed season	

Local Enforcement Authority

Name & Address	Food & Safety Team Community Safety Torbay Council c/o Torquay Town Hall Castle Circus Torquay TQ1 3DR
Environmental Health Officer	Lars Barker
Telephone number	01803 208084
Fax number	01803 208854
E-mail	Lars.Barker@torbay.gov.uk

3.2. Requirement for Review

The Guide to Good Practice for the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2014) indicates that sanitary assessments should be fully reviewed every 6 years, so this assessment is due a formal review in 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: Pilot sites: 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
Site 1	B090M	Site 1 Pilot West (Top)	SY 1368 7543	50° 34.333'N 03° 13.220'W	Mussels	Rope	Hand or mechanical	Hand/bagged*	100 m	Monthly
Site 1	B090N	Site 1 Pilot West (Bottom)	SY 1368 7543	50° 34.333'N 03° 13.220'W	Mussels	Rope	Hand or mechanical	Hand/bagged*	100 m	Monthly
Site 2	B090O	Site 2 Pilot West (Top)	SY 1615 8413	50° 39.048'N 03° 11.246'W	Mussels	Rope	Hand or mechanical	Hand/bagged*	100 m	Monthly
Site 2	B090P	Site 2 Pilot West (Bottom)	SY 1615 8413	50° 39.048'N 03° 11.246'W	Mussels	Rope	Hand or mechanical	Hand/bagged*	100 m	Monthly

†Interim RMPs for pilot lines. 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 for ongoing monitoring 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 (3 m).

**Bagged, marketable sized, mussels may be used if there are lines present to suspend them from and where mussels present are not sufficiently large to sample.*

Table 3.2: 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	Depth**	Frequency
Site 1	TBA*	Site 1 North West	SY 1159 7770	50° 35.539'N 03° 15.023'W	Mussels	Rope	Hand or mechanical	Hand/bagged†	100 m	TBA	Monthly
Site 2	TBA*	Site 2 North West	SY 1568 8402	50° 38.984'N 03° 11.643'W	Mussels	Rope	Hand or mechanical	Hand/bagged†	100 m	TBA	Monthly
Site 3	TBA*	Site 3 North West	SY 2245 8431	50° 39.197'N 03° 05.902'W	Mussels	Rope	Hand or mechanical	Hand/bagged†	100 m	TBA	Monthly

** Monitoring not possible at these RMPs locations at present. RMP codes to be generated once site becomes established and sampling stock available at these RMP locations. Interim RMPs for pilot lines should be located as far inshore as possible, then as far west as possible.*

*** Sample from both the top and bottom of the pilot 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 (3 m).*

† Bagged, marketable sized, mussels may be used if there are lines present to suspend them from and where mussels present are not sufficiently large to sample.

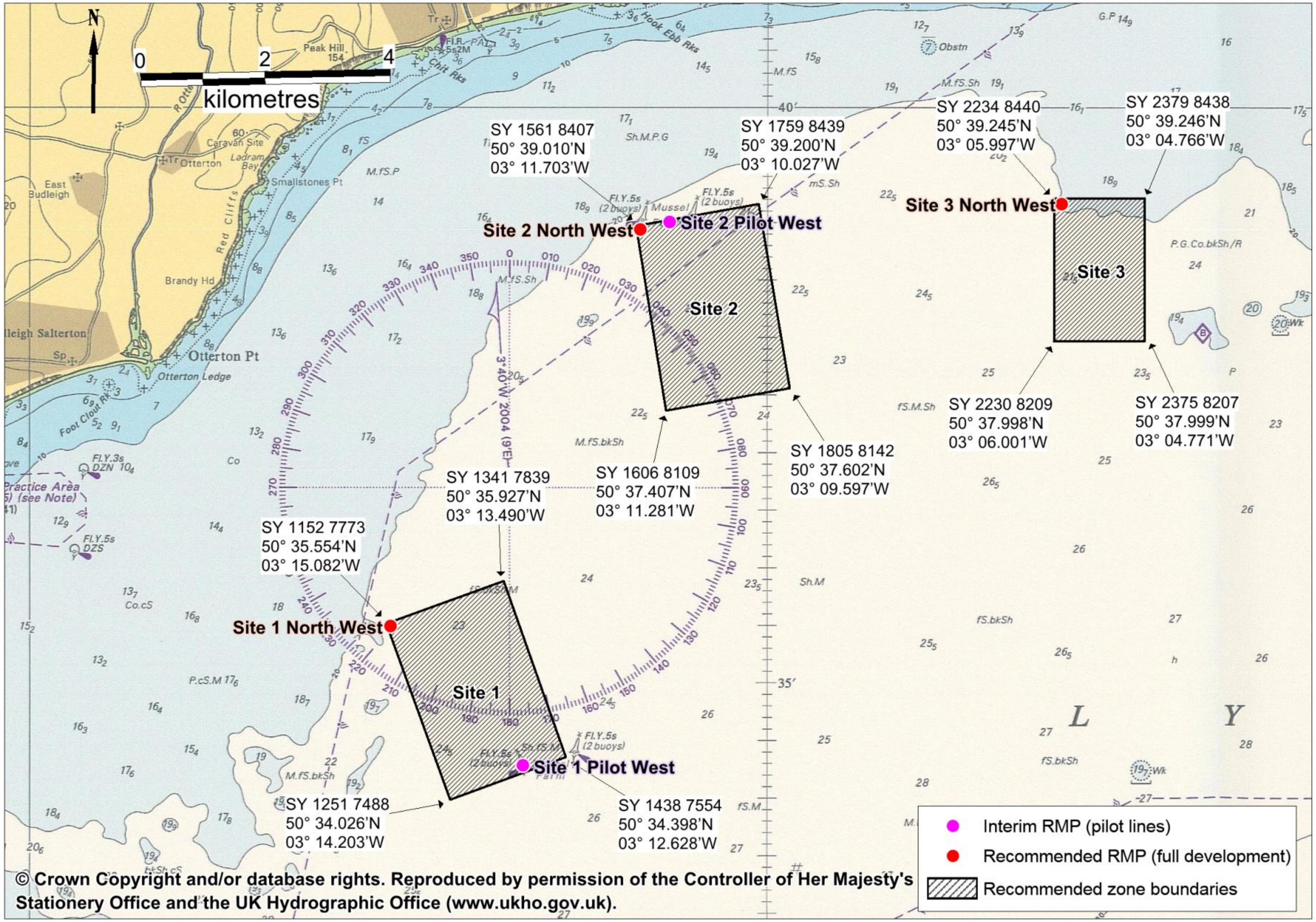

Figure 3.1: Recommended zoning and monitoring arrangements (mussels)

4. Shellfisheries

4.1. Description of fishery

The fishery which is the subject of this survey is a rope mussel farm that is in the early stages of development. It is unique in England and Wales in that it is located in an exposed area between about 3 and 10 km offshore. Figure 4.1 shows its location and extent.

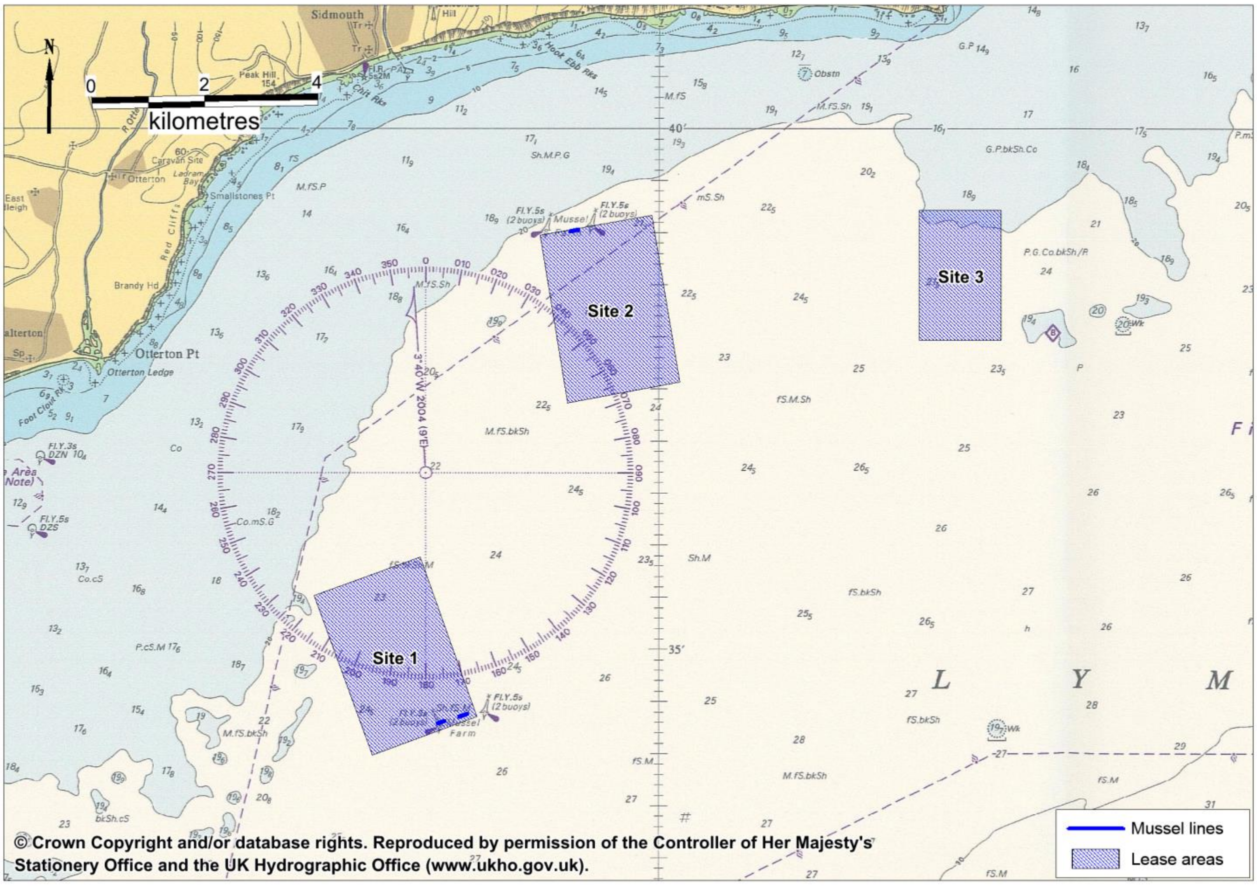

Figure 4.1: Location of mussel farm

Crown Estates leases have been granted for three discrete areas, which between them cover an area of about 15 km^2. Three pilot mussel lines between 120 and 150 m in length have been established, two of which lie in Site 1 and one of which lies in Site 2. These lines were seeded with spat in May 2014, which was approaching a marketable size by November 2014. The headlines are suspended 3 m below the surface from a series of tubular floats. From the headline a series of dropper loops extend a further 10 m down, upon which the mussels are attached. This arrangement ensures the dropper lines are suitably damped against wave action. It is anticipated that these three lines will provide a harvest of around 30 tonnes between them in 2015. Ultimately, when the three areas are fully developed, an annual production of somewhere between 5,000 and 10,000 tonnes is anticipated. This will be landed at Brixham and exported to continental Europe.

Whilst there are some conditions attached to the development, such as the provision of appropriate marker buoys, monitoring of impacts and a requirement to return the site to its original state after use, none are of direct relevance to the sampling plan. No minimum landing size or closed season applies.

4.2. Hygiene Classification

None of the three lease areas has ever been classified.

Table 4.1: Criteria for classification of bivalve mollusc production areas.

Class	**Microbiological standard[1]**	**Post-harvest treatment required**
A[2]	Live bivalve molluscs from these areas must not exceed 230 Most Probable Number (MPN) of *E. coli* 100 g^{-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* 100 g^{-1} FIL in more than 10% of samples. No sample may exceed an upper limit of 46,000 *E. coli* 100 g^{-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* 100 g^{-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* 100 g^{-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 offshore mussel farm in Lyme Bay. The area considered in detail is the hydrological catchment extending about 7 km to the west and east either side of the mussel farms, which approximately equates to the tidal excursion off this stretch of coast. However, it is likely that the ebb plume from the Exe estuary and possibly the Teign estuary are potential influences on water quality within the lease areas, so are also considered in this assessment where appropriate.

5.2. Shellfisheries

The shellfishery considered in this report is an extensive offshore rope mussel farm in an early stage of development. Permissions have been granted for the farm to cover an area of 15 km^2 over three sites located between 3 and 10 km offshore. At present the operation is still in the pilot stages. A total of three mussel lines of between 120 and 150 m in length have been established across two of the sites. The mussels are grown on rope droppers of 10m in length suspended from a headline 3 m below the surface, so the sampling plan should indicate the depth as well as the coordinates from which samples should be taken. The droppers were seeded with mussel spat in May 2014 which was approaching a marketable size by November 2014. It is anticipated that these three lines will provide a harvest of around 30 tonnes between them in 2015. Ultimately, when all three areas are fully developed, an annual production of somewhere between 5,000 and 10,000 tonnes is anticipated. This will be landed at Brixham and exported to continental Europe. The fishery is not subject to a minimum landing size and harvest may occur at any time of the year.

The mussel farm has been deemed to be 'offshore' by the competent authority as the central point of all three sites lie at least 5 km from the shore. The term 'offshore' is assumed to be analogous to the term 'remote area' as defined in the Good Practice Guide (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2014). However, the results of the bacteriological survey suggest that it does not meet the criteria for a 'remote area', as the variable and sometimes high levels of contamination recorded were not consistent with an area upon which no sources of contamination impact. This survey has also identified potential local sources of contamination such as boats, birds and marine mammals. Good Practice Guide recommendations for monitoring remote areas, such as reduced sampling frequency, will therefore not apply.

5.3. Pollution Sources

Freshwater Inputs

The main freshwater inputs to the shore in the vicinity of the mussel sites are the Rivers Axe and Otter. The smaller River Sid drains to the shore between them. Further to the west are the estuaries of two larger rivers (the Exe and the Teign).

The Axe has a catchment area of about 400 km^2, and land cover is principally a mix of pasture and arable farmland. Its hydrogeology is largely a mix of moderate and low permeability bedrock, although there are some areas of high permeability in the upper reaches. Its gradient is steep in the upper reaches and tributaries, but is more gentle near the coast where there are significant floodplains. It is slower to respond to rainfall than the Otter and the Sid. Flow gauging records from a gauging station on the lower reaches (capturing about 75% of the entire catchment) indicate a mean discharge rate of 5.9 m^3/sec. As well as significant day to day variation in response to rainfall, flows were higher on average during the colder months (November through to February). High flow events were recorded in most if not all months of the year, but there tended to be a greater number of higher magnitude events during the autumn and winter. Repeated bacteriological testing of the Axe at its tidal limit (2006-2011) showed geometric mean and maximum faecal coliform concentrations of 1,674 and 100,000 cfu/100 ml. An estimate of the average bacterial loading it delivers is in the order of 10^{13} faecal coliforms/day, although this will vary significantly. It discharges to coastal waters via a small enclosed estuary, the plume from which will only drain into Lyme Bay whilst the tide is ebbing.

The Sid has a catchment area of about 40 km^2, and again drains mainly mixed usage farmland. It has a high gradient throughout, and is underlain by moderate/mixed permeability geology. It has a calculated mean daily discharge of 0.574 m^3/sec. There will be significant day to day variations in flow, and it is likely that it displays a similar seasonal pattern in discharge to the Otter and Axe. Repeated bacteriological testing near its tidal limit (2001-2007) showed geometric mean and maximum faecal coliform concentrations of 2,683 and >100,000 cfu/100 ml. An estimate of the average bacterial loading it delivers is in the order of 10^{12} faecal coliforms/day, although this will vary significantly. It drains directly across the beach at Sidmouth and does not have an enclosed estuary, so will drain to coastal waters throughout the tidal cycle.

The Otter has a catchment area of about 250 km^2, mainly a mix of arable farmland and pasture with some woodland. Its hydrogeology is of mixed/moderate permeability in the upper reaches, and of high permeability in the lower reaches. Its gradient is steep in the upper reaches and tributaries, but becomes gentler near the coast where there are significant floodplains. Flow gauging records from a gauging station on the lower reaches (capturing about 80% of the entire catchment) indicate a mean discharge rate of 3.4 m^3/sec. As well as significant day to day variation response to rainfall, flows were higher on average during the colder months (November through to February). High flow events were recorded in most if not all months of the year, but there tended to be a greater number of higher magnitude events during the autumn and winter. No bacteriological testing results were available for this watercourse, but its microbiological content is likely to be broadly similar to that of the Axe and Sid, given the comparable nature of their catchments. The bacterial loading it delivers is therefore likely to be slightly lower than that of the Axe, but significantly larger than that of the Sid. It discharges to coastal waters via a small enclosed estuary, the plume from which will only drain into Lyme Bay whilst the tide is ebbing.

Although the Exe and Teign estuaries are more remote from the mussel sites (11 and 18 km distant) the ebb plumes from their estuaries may be an influence. Information on these two rivers is taken from recent sanitary surveys (Cefas 2013 a&b). The Exe estuary has a hydrological catchment of about 1,500 km^2. Land cover is mainly pasture, and the hydrogeology is generally impermeable. Mean discharge for the River Exe is 25 m^3/sec, and fluctuates significantly in response to rainfall, displaying a similar seasonal pattern in average flows to that of the Otter and Axe. It drains via a large estuary which offers high potential for dilution of runoff with cleaner seawater before draining from the estuary on the ebb tide. The Teign estuary has a catchment area of 530 km^2 within which land cover is mainly a mix of pasture and arable farmland. Its hydrogeology is impermeable in the upper reaches, but more permeable in the lower reaches. The mean discharge of the River Teign is 9.1 m^3/sec, and displays similar day to day and seasonal variation as the other rivers considered in this assessment. It also has a large enclosed estuary so runoff will be diluted with cleaner seawater before draining to Lyme Bay on the ebb tide.

It is therefore concluded that the four main rivers (Axe, Otter, Exe and Teign) will generate significant ebb plumes containing a mixture of land runoff and cleaner seawater in varying proportions. The fluxes of indicator bacteria to Lyme Bay from these watercourses will be large, particularly for the Exe, and the estuary plumes will generally carry significantly higher concentrations of *E. coli* than the fully saline waters of Lyme Bay. Fluxes of indicator bacteria from the River Sid to the bay will be smaller, and will continue throughout the tidal cycle. The spatial extents of impacts in Lyme Bay will depend on local water circulation patterns.

Human Population

Total resident population within the adjacent (Axe/Otter/Sid) catchment was approximately 135,200 at the time of the last census in 2011. A significant proportion of the population resides in the coastal towns of Budleigh Salterton, Sidmouth and Seaton. The Exe and Teign catchments have populations of about 377,000 and 172,000, again much of which resides in coastal areas (Cefas 2013 a&b). The south Devon/Dorset coast is a popular tourist destination during the summer months due to its beaches, attractive countryside, and seaside towns. Significant influxes of holidaymakers are therefore anticipated at these times, and so some sewage works serving the area (particularly the coastal towns) will receive effluent from larger populations during the summer.

Sewage Discharges

There are seven water company owned sewage works discharging directly to the coastal waters of Lyme Bay in the general vicinity of the mussel sites, although none are in close proximity to the sites. From west to east, these are:

- Newton Abbot STW. This is a large secondary works that discharges via long sea outfall about 2 km off from the Teign estuary about 17 km west of Site 1. It has a consented dry weather flow of 21,818 m^3/day and generates an estimated bacterial loading of around $7x10^{13}$ faecal coliforms/day, the largest of any works considered in this report.
- Dawlish STW. This works provides UV disinfection for a consented dry weather flow of 4,856 m^3/day. The disinfection is reasonably effective, and an estimate of the average bacterial loading it delivers is only $3x10^{10}$ faecal coliforms/day. There was statistically significant seasonality in final effluent faecal coliform concentrations, which were higher on average in the summer than all other seasons. It discharges 900 m off Dawlish, about 14 km to the west of Site 1.
- Exmouth STW. This works provides UV disinfection for a consented dry weather flow of 11,825 m^3/day. The disinfection is less effective than at most other UV works, but nevertheless the average bacterial loading it delivers is not particularly large ($2x10^{11}$ faecal coliforms/day). It discharges 300 m off Straight Point, about 8 km to the west of Site 1.
- Otterton STW. This is a smaller works (dry weather flow of 1,643 m^3/day) which provides very effective UV disinfection. The estimated average bacterial loading it generates is about $1x10^9$ faecal coliforms/day. It discharges to the intertidal about 6 km north of Site 1 and 6 km west of Site 2.
- Sidmouth STW. This works provides UV disinfection for a consented dry weather flow of 6,331 m^3/day. The disinfection is effective and the average bacterial loading it delivers is only about $3x10^9$ faecal coliforms/day. There was statistically significant seasonality in final effluent faecal coliform concentrations, which were higher on average in the summer than in autumn and winter. It discharges 400 m off Sidmouth, about 4 km north of Site 2.
- Lyme Regis STW. This works has a consented dry weather flow of 3,022 m^3/day, and provides secondary treatment, with additional UV disinfection during the bathing season (May to September). The estimated bacterial loading it generates is about $3x10^9$ during the bathing season, and about $1x10^{13}$ at other times. It discharges about 600 m off Lyme Regis, about 12 km north east of Site 3.
- Charmouth STW. This is a relatively small secondary works (dry weather flow of 1,270 m^3/day) which generates an estimated bacterial loading of about $4x10^{12}$ faecal coliforms/day. It discharges about 1.3 km off Charmouth, and about 15 km north east of Site 3.

The other water company sewage works considered in this report all discharge to inland watercourses, with the exception of Northleigh Street and Dotton STWs, which discharge to soakaway. The Axe catchment receives a further 5,146 m^3/day of generally secondary treated effluent on top of that from Seaton STW, and not including those works for which no dry weather flow was specified. The Otter catchment receives 6,081 m^3/day of mainly secondary treated effluent, not including those works for which no dry weather flow was specified. The Branscombe stream received 310 m^3 of secondary treated effluent per day from Branscombe STW, and an unnamed watercourse just west of Sidmouth receives effluent from Salcombe Regis STW (volume and treatment type unspecified). These sewage works will contribute to the bacterial loading delivered to coastal waters by the watercourses to which they discharge, although some bacterial die-off is likely to occur in transit, particularly for those located further inland. The Exe and Teign estuaries also receive significant volumes of sewage effluent from both inland sewage works and works discharging directly to them (Cefas, 2013 a&b).

There are also a large number of water company intermittent discharges associated with the various sewer networks. They are widely distributed throughout the survey catchment and the main clusters are associated with the more extensive built up areas. There are coastal clusters around the main seaside towns (Budleigh Salterton, Sidmouth and Seaton). Spill records were only available for one of these discharges (the Exmouth STW overflow) and these indicate that it was active for 6.8% of the time for a period of about 11 months spanning 2010 and 2011. These limited records may not be an accurate indication of its average performance over a more extended timescale. For the other intermittent discharges it is difficult to assess their significance aside from noting their locations and their potential to spill untreated sewage.

There are just over 800 private discharges within the catchment considered in detail in this report. Most are small, serving one or a small number of properties, and provide treatment via package plant or septic tank. About half of them discharge to soakaway so should be of no impact on coastal waters assuming they are functioning correctly. The rest discharge to water, mainly to watercourses in the Axe and Otter catchments, although the Sid and other minor watercourses also receive a small number. They will make a contribution to the bacterial loading delivered to Lyme Bay by the watercourses to which they discharge. None discharges directly to Lyme Bay.

It is therefore concluded that there will be sewage inputs via the main watercourses draining to Lyme Bay, principally the Otter, Axe, Exe and Teign. As well as this there are a series of sewage works discharging to Lyme Bay at roughly 5-10 km intervals along the shore. Those nearest to the mussel sites provide UV disinfection so their impacts on water quality will generally be minor. The largest in terms of bacterial loading is Newton Abbot STW, but this lies about 17 km from the nearest lease area. Intermittent discharges are widespread throughout the area, but tend to be clustered around the more extensive built up areas, including the seaside towns of Budleigh Salterton, Sidmouth and Seaton. There are numerous small private discharges to various watercourses draining to this part of Lyme Bay, which will contribute to the bacterial loading they deliver to the bay. None of these sewage inputs are in close proximity to the lease areas, and whether any actually impact on the mussel sites will depend on water circulation patterns in the area.

Agriculture

The majority of land within the catchment considered in detail in this report is used for agriculture. It comprises a mix of arable farmland and pasture in roughly equal proportions. Agricultural census data indicates that there were about 89,000 cattle and 82,000 sheep held within the Axe/Otter/Sid catchments in 2013. They were quite evenly distributed, with a tendency for slightly higher densities in the more inland areas. The census also recorded about 25,000 pigs and 540,000 poultry. Pig densities were highest in the upper reaches of the Otter catchment, and poultry densities were highest in the upper Axe and Otter catchments. Large numbers of livestock of various types, including grazers, are also present in the Teign and Exe catchments. All significant watercourses draining to Lyme Bay are therefore likely to be impacted by diffuse contamination of agricultural origin.

Faecal matter from grazing livestock is either deposited directly on pastures, or collected from livestock sheds if animals are housed indoors, then applied to agricultural lands as a fertilizer. Manure from pigs and poultry operations is typically stored and applied tactically to nearby farmland. Sewage sludge may also be applied. The primary mechanism for mobilisation of faecal matter from agricultural land is via land runoff, so fluxes of livestock related contamination into the estuary will be highly rainfall dependent. Peak fluxes of contamination from grazing livestock are likely to arise following high rainfall events, 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.

There is likely to be some seasonality in fluxes of agricultural contamination to coastal waters. Rainfall and river flows are generally higher during the winter months, although high rainfall events may occur at any time of the year. Numbers of sheep and cattle will increase significantly in the spring, with the birth of lambs and calves, and decrease in the autumn when animals are sent to market. During the warmer months, livestock are likely to access watercourses more frequently to drink and cool off. Cattle may be housed indoors during the winter, so slurry collected from such operations is likely to be spread in the late winter and spring, depending on the storage capacities of each farm. The seasonal pattern of application of other organic fertilizers (e.g. poultry manure or sewage sludge) is uncertain.

It is therefore concluded that the plumes from the main estuaries are likely to carry the main fluxes of agricultural contamination into Lyme Bay. Smaller watercourses such as the Sid are also likely to be impacted. The magnitude of these fluxes will vary significantly on a day to day basis in response to rainfall. There may be some seasonal variation relating to seasonal patterns of pasture occupation (highest numbers of grazing animals in summer) and any seasonal patterns of application of organic fertilizers, which are uncertain.

Boats

A variety of vessels use Lyme Bay, and as they are able to make overboard sewage discharges in very close proximity to the mussel farm, they are potentially one of the most significant sources of contamination to it. Boat traffic in the area consists mainly of recreational craft (e.g. yachts), commercial fishing vessels and fishing/diving charters. Larger vessels such as tankers and container ships also pass through Lyme Bay.

The nearest commercial ports are at Portland and Plymouth, both of which are a considerable distance away. The main English Channel shipping routes pass through the central reaches of the channel, a large distance to the south of the mussel sites. Merchant shipping is frequently observed in Lyme Bay, but is unlikely to pass near to the mussel farm on a regular basis, particularly given the full extent of the mussel farm will be marked on nautical charts and lit and buoyed as appropriate. Such vessels are not permitted to make discharges overboard discharges within 5.5 km of land, but this will only convey protection to the more inshore parts of the lease areas.

The two main centres locally for recreational vessels are Exmouth and Lyme Regis. There are marinas at both, which have 200 and 220 berths respectively. Sewage pump out facilities are available at Lyme Regis. There is a smaller, 100 berth marina at Axmouth. There are also yacht moorings at Exmouth, Axmouth and Lyme Regis, and an anchorage off Beer. Twenty fishing vessels are listed as having their home port at Beer, Sidmouth or Axmouth, and significant fleets operate out of other ports in Lyme Bay (e.g. Brixham, Exmouth). Recreational craft will generally avoid coming in close proximity to the mussel lines as they are/will be well marked and represent a hazard to navigation. It is however likely that such vessels will make overboard discharges in fairly close proximity to the mussel lines from time to time. Peak recreational activity will occur during the summer months. Fishing vessels are likely to work in the areas adjacent to the mussel farm, and vessels using static gear may well operate within the lease boundaries. Fishing vessels may therefore make overboard discharges in close proximity to the mussel lines from time to time, and their presence is likely to be more evenly distributed throughout the year. A further consideration is the possibility that the mussel farm may attract aggregations of certain species of fish. If this proves to be the case, the area in which the mussel farm is located may well be attractive to fishing vessels and angling/diving charter boats.

It is therefore concluded that boat traffic in the survey area is generally limited to pleasure craft and fishing vessels and that these will make overboard discharges in close proximity to the mussel lines. The chances of an overboard discharge being made in the vicinity of the farm are likely to increase in the summer when more recreational craft are at sea. It is possible that larger overboard discharges may occasionally be made in the area by merchant shipping, although traffic volumes are low and they are less likely to closely approach the mussel farms. The plumes from overboard discharges will be highly localised and transient, particularly near the point of discharge where they will be most concentrated. There is considerable uncertainty about the locations and frequencies of such discharges, so whilst they offer the potential for significant localised increases of faecal indicator bacteria in the water column, it will not be possible to specifically target their impacts through the sampling plan.

Wildlife

As with boats, marine wildlife populations are a potential source of contamination directly within the lease areas. Species which may introduce faecal contamination within such offshore areas are seabirds and marine mammals.

A survey in the early summer of 1999 along the coastline between Straight Point, Exmouth and Charton Bay, Seaton, recorded 578 pairs of breeding seabirds. An average total count of 2,895 gulls and terns were recorded in the Axe estuary over the five years up until 2012/2013. 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 or roost sites. These are on land so are remote from the mussel farm. It is possible that seabirds will forage around the mussel farm and rest on the floats and buoys, although no birds or bird droppings were observed during a site visit undertaken in early November 2014. Should birds use floats or buoys for resting on, it may be more likely that the larger navigational buoys located on the edges/corners of the farm represent a more stable platform than the tubular floats from which the headlines are suspended. RMPs located by the navigational buoys may therefore be best positioned to capture contamination from seabirds.

There are no major seal colonies in Lyme Bay, with the closest significant colony in the Solent. Whilst they may forage in the vicinity of the mussel farm from time to time, they are unlikely to be a significant source of contamination to the shellfishery. Also, their presence will be unpredictable spatially and temporally, so whilst they may potentially be an influence it will not be possible to define an RMP location which will reliably capture their impacts.

Some cetaceans are known to frequent Lyme Bay. Whilst larger species such as Minke Whales are occasionally sighted here, harbour porpoises and several dolphin species are a regular presence. The dolphins generally tend to frequent the more offshore areas in central Lyme Bay, but porpoises are more frequently observed closer to the shore. As with seals, their presence will be unpredictable spatially and temporally, so whilst they may potentially be an influence it will not be possible to define an RMP location which will reliably capture their impacts.

The estuaries draining to the shore of Lyme Bay attract significant aggregations of overwintering waterbirds (wildfowl and waders). Average total counts of 3,006 (Axe) and 28,569 (Exe) were recorded over the five winters up until 2012/2013. These birds are likely to contribute to the loadings of faecal indicator organisms delivered to coastal waters by the ebb plumes from these estuaries, but will not represent a local source in the immediate vicinity of the lease areas. No other wildlife species which may influence the sampling plan have been identified.

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
Land runoff												
Continuous sewage discharges												
Intermittent sewage discharges												
Birds												
Boats												
Seals/dolphins												

Red - high risk; orange - moderate risk; yellow - low risk.

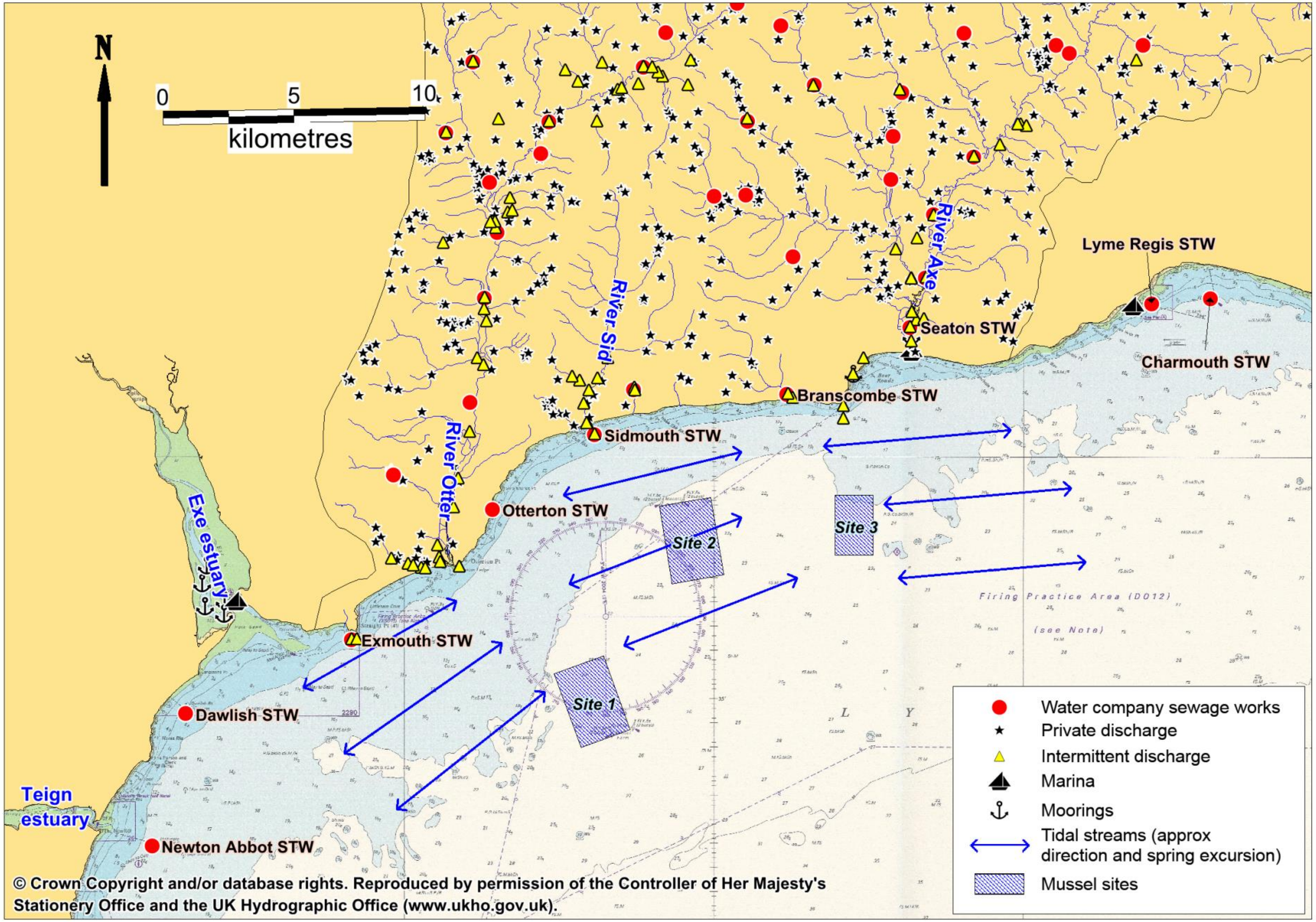

Figure 5.1: Summary of main (non-mobile) contaminating influences

Hydrography

Lyme Bay is a large, open, south facing embayment in the western English Channel. It lies between the headlands of Portland Bill and Start Point, which are 65 km apart. Its bathymetry is relatively uncomplicated, sloping gently away from the intertidal zone to a depth of about 50 m in the central outer reaches. The shore of the eastern part of the bay is backed by Chesil Beach, a shingle bar. The rest of Lyme Bay is mainly backed by cliffs, apart from where the various watercourses drain to it. Portland Bill and Start Point are headlands around which tidal streams are likely to accelerate. There are also some smaller, much less protrusive headlands such as Beer Head and Straight Point in the western part of the bay. The mussel lease areas are located in the western half of the Bay, and lie between 3 and 10 km offshore in depths of between 20 and 25 m relative to chart datum.

Two large estuaries (Exe and Teign) drain to the western part of the bay about 11 and 18 km, respectively, from the westernmost mussel site. The smaller Otter and Axe estuaries drain to the shore directly to the north of the mussel sites. The ebb plumes from these estuaries are likely to represent hotspots of contamination within the bay, and may be an influence at the mussel sites if they are advected towards them. The plume from the Exe and Teign will be large in volume, but due to the large size of the estuaries land runoff will be heavily diluted with cleaner seawater. The plumes from the Axe and Otter will be much smaller in volume, but their smaller estuaries offer less scope for dilution of land runoff with seawater, so they are likely to carry higher concentrations of faecal indicator organisms. Whilst contamination from these estuaries will only drain into the bay during the ebb tide, runoff delivered by the River Sid and smaller coastal streams will drain to the bay throughout the tidal cycle as they do not have enclosed estuaries.

Currents in coastal waters are predominantly driven by a combination of tides, which are regular and predictable, as well as wind and density effects, which are more dynamic. Tidal amplitude ranges from 4.4 m on springs and 1.9 m on neaps at Start Point, to 3.4 m on springs and 1.4 m on neaps at Chesil Cove. Tidal streams are likely to dominate patterns of water circulation in the bay under most conditions.

Tidal streams throughout most of the bay are bidirectional, with east and westward going streams that travel roughly parallel to the coast. The tidal diamonds indicate that the eastwards tidal stream starts to run between two and three hours before high water at Exmouth. This continues until between three and four hours after high water at Exmouth, at which point it reverts to a westwards flow. The main exception to this bidirectional pattern arises to the west of Portland Bill, where a clockwise eddy forms for much of the time when the tide is heading westwards throughout the rest of the bay. No other large scale eddies form within Lyme Bay. Peak tidal current velocities in the vicinity of the mussel farm are 0.51 m/s on a west going tide and 0.36 m/s on an east going tide. An estimate of tidal excursion here is about 7 km on a spring tide and roughly half that on a neap tide. Near bed flows and flows in shallower near shore areas are likely to be slower than surface flows due to the effects of friction.

Contamination from sources discharging to the shoreline will travel parallel to the coast becoming progressively diluted with time and distance, and will therefore impact along the near shore zone to either side of their location. Whilst the tide is ebbing, and the Exe and other estuaries are draining, the tide will carry their plumes of more contaminated water eastwards for the first 2-3 hours, then westwards until low water. Contamination from shoreline sources will remain inshore of the lease areas in the first instance, but may eventually arrive at the sites several tidal cycles after release and not before significant dilution and bacterial die off. It is therefore concluded that shoreline and nearshore sources are unlikely to be a major contaminating influence at the mussel farm, nor are they likely to cause marked spatial variation in levels of contamination across the sites under tidal influences alone. RMPs located at the most inshore points of the lease areas would best capture contamination from shoreline sources.

Superimposed on tidally driven currents are the effects of density and winds. Density effects may arise through vertical and horizontal differences in either salinity or temperature. Given the relatively weak tidal currents and the uniform nature of the bathymetry, significant turbulent mixing of the water column in the vicinity of the mussel farm is unlikely to occur through tidal action alone. It is however possible that the mussel lines will induce some turbulence as tidal streams pass through them. The plumes of low salinity water emanating from the mouths of the various estuaries will be less dense than the more saline seawater and so will have a tendency to spread out and to float on the surface. Vertical differences in salinity may be accompanied by corresponding vertical differences in faecal indicator organism concentrations, depending on how much bacterial die-off has occurred. Vertical density gradients may also result in some vertical shear in current speed and direction. An observational study noted some slight vertical differences in temperature and salinity. This was less marked during late summer than in early spring, when differences of up to 0.3 ppt were recorded down the water column, with the halocline lying about 10 m below the surface. This may suggest that RMPs should be located towards the top of the mussel lines to best capture the remnants of any land runoff derived contamination. A horizontal salinity gradient was also observed during the early spring surveys, with a decrease in salinity of about 0.2 ppt between Site 2 and Site 1. This suggests that the influence of land runoff may increase to the west, in the vicinity of these two lease areas at least. Salinity measurements made during bathing water monitoring at various intertidal sites along the shore to the north of the lease areas showed low average salinities at the mouths of the Axe and Otter estuaries, but the influence did not usually extend far along the shore. Occasionally lower salinities were recorded away from the estuary mouths at times of high river flow.

Winds may have a significant effect on water circulation within the bay. Winds typically drive surface water which then drive return currents which may travel lower in the water column or along sheltered margins. The area in which the mussel sites are located is offered some shelter from northerly and to a lesser extent westerly winds by the surrounding land, and is most exposed to winds from the south. Northerly winds would tend to push contamination from shoreline sources towards the mussel sites, so periods of strong northerly winds are likely to represent the highest risk of significant impacts from land based sources. 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. Strong winds will also induce wave action, which will lead to increased mixing of the water column in offshore areas, and the re-suspension of sediment entrained contamination in intertidal areas. Southerly winds and swells are likely to be most effective in generating energetic wave action in the vicinity of the mussel sites.

5.4. Summary of Microbiological Data

The only bacteriological sampling data of direct relevance to the lease areas derives from mussel flesh and water testing undertaken as a bacteriological survey on one day during November 2014 and one day in March 2015 . There are also several bathing waters located in intertidal areas at intervals along the coast between Budleigh Salterton and Seaton, the results from which were also analysed although they are not likely to be representative of conditions further offshore.

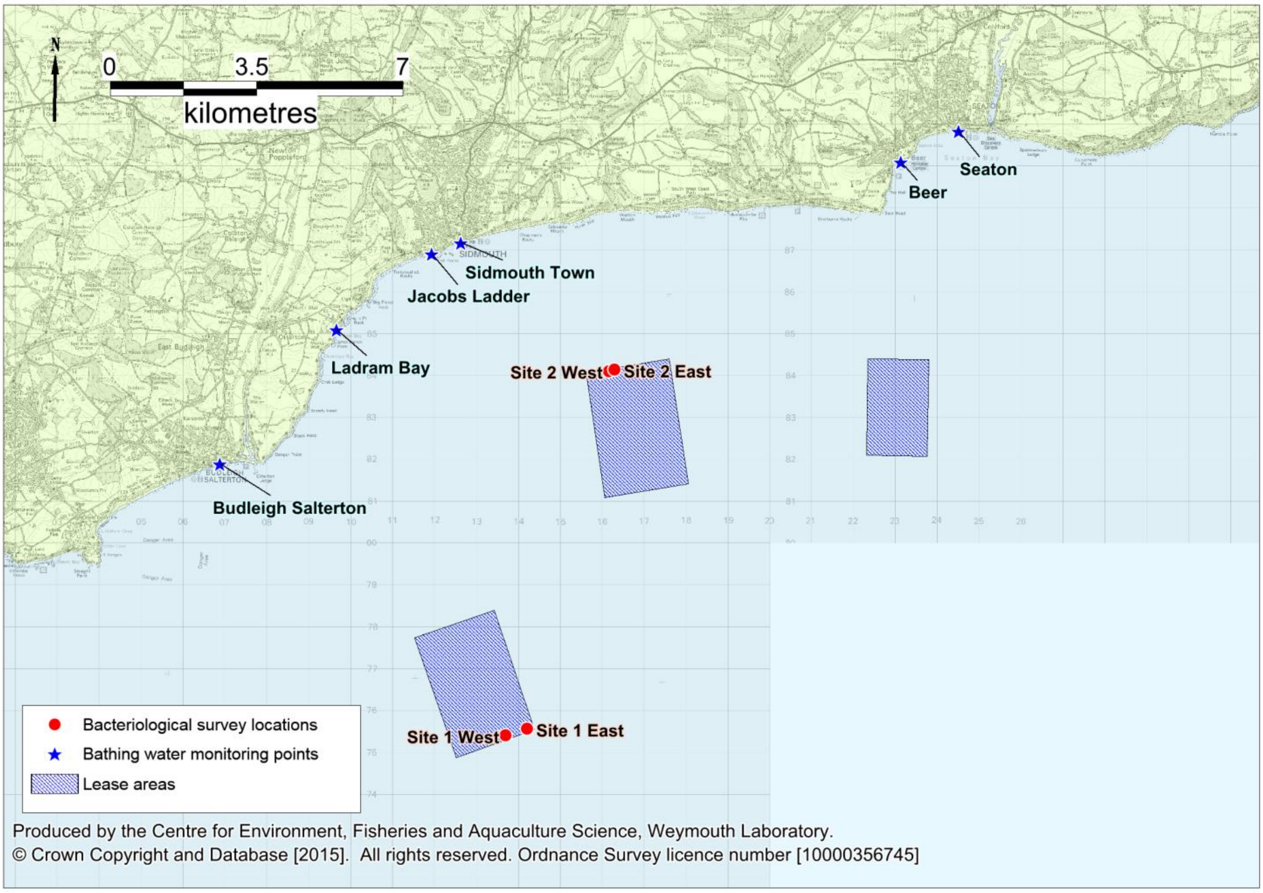

Figure 5.2: Location of microbiological sampling sites.

Bathing Waters

There are six bathing waters along the shoreline of Lyme Bay to the north of the lease areas. Around 20 water samples are taken from each of these during the bathing season (May to September) and enumerated for faecal coliforms until the end of the 2011 season, after which they were enumerated for *E. coli*. These two parameters are not directly comparable, so statistical analyses were undertaken using the smaller *E. coli* dataset as it is more recent, more directly relevant to shellfish hygiene standards, and there were sufficient samples for robust analyses.

Geometric mean *E. coli* concentrations ranged from 11.5 cfu/100 ml at Jacobs Ladder to 37.4 cfu/100 ml at Budleigh Salterton. There were statistically significant differences between average results. *E. coli* concentrations were significantly higher at Budleigh Salterton than at Jacobs Ladder and Beer, and *E. coli* concentrations at Ladram Bay were significantly higher than at Jacobs Ladder. These variations are likely to reflect the magnitude and proximity of the various contaminating sources to the monitoring points. Budleigh Salterton for example lies in close proximity to the Otter estuary. Whilst there were significant differences in average results between some sites, comparisons of paired (same day) samples from all site pairings showed statistically significant correlations. This indicates that all these sites are subject to sources which respond in a similar way to environmental conditions.

E. coli concentrations have remained fairly stable at the bathing waters since 2012, although fewer high results were recorded in 2014. Seasonal variation could not be investigated as sampling was restricted to the bathing season. Significant correlations between *E. coli* results and tidal state across the high/low tidal cycle were found at Budleigh Salterton and Ladram Bay. At both sites higher *E. coli* concentrations tended to occur at lower states of the tide, possibly relating to the lower dilution potential at such times. Significant correlations between *E. coli* results and tidal state across the spring/neap tidal cycle were found at Budleigh Salterton, Ladram Bay and Beer. *E. coli* results tended to be lower during the decreasing tide sizes at Budleigh Salterton and Beer, and during spring tides at Ladram Bay. The reasons for this are unclear. Significant correlations between *E. coli* concentrations and antecedent rainfall were found for all bathing waters, suggesting that land runoff is a significant influence along this stretch of coast. However, significant correlations between salinity and *E. coli* levels were only observed at Ladram Bay, Jacobs Ladder and Sidmouth Town.

Bacteriological survey

A bacteriological survey was undertaken on the 5th November 2014. Mussel samples (average length less than marketable size) were taken from the top and bottom of the dropper ropes at each end of the pilot lines installed in Sites 1 and 2 and enumerated for *E. coli*. Water samples were also taken from these points at the surface and 10 m depth. *E. coli* was not detected in the water samples at three of the four locations, but at Site 1 West counts of 6 and 7 *E. coli* per 100 ml were recorded at the surface and at 10 m depth. It is possible that these higher results may represent the remnants of a plume from sources to the west, possibly the Exe estuary, although if this was the case, the absence of *E. coli* at Site 1 East (only 500 m away) is perhaps unexpected.

Counts of *E. coli* in shellfish flesh ranged from 45 MPN/100 g at the bottom of the lines at Site 2 East to 16,000 MPN/100 g at the bottom of the lines at Site 2 West, which only lie about 100 m apart. Five of the nine samples taken exceeded 230 *E. coli* MPN/100 g and the geometric mean of all sample results was 551 *E. coli* MPN/100 g. There was no obvious spatial pattern, either vertically or horizontally. These results were unexpectedly high and variable considering the samples were taken from a homogeneous water body over 3 km offshore and remote from any point sources of contamination. No possible sources (e.g. yachts, bird aggregations) were observed in the vicinity of the farm by the surveyors. The north easterly winds may have promoted the advection of contamination from shoreline sources towards the fishery, although they were not particularly strong (Beaufort force 2-4).

A second set of mussel samples (of marketable size) were collected from Lyme Bay on the 16th March 2015 under dry conditions with moderate easterly winds (Beaufort force 3-4). Samples were taken on a flooding tide, between 2 ½ and 3 ½ hours before high water at Brixham, which is roughly the time when tidal streams turn from westward flowing to eastward flowing. Mussel samples were taken from the top (3 m depth) and bottom (10 m depth) at the eastern and western ends of sites 1 and 2. The shell lengths of 10 mussels were measured from each of the eight samples. Surface water samples were also taken at each of the four locations from which the mussel samples were taken.

All mussel sample results were under 230 *E. coli* MPN/100 g. All samples from site 1 were below the limit of quantification for the test (18 *E. coli* MPN/100 g). At site 2 low levels of *E. coli* were present. Results were marginally higher for samples taken from 3 m depth, and were marginally higher towards the western end of the site. All mussels which were measured were in excess of 45 mm so they are now of a marketable size. Three of the four water samples contained *E. coli* levels of less than the limit of detection of the test (1 cfu/100 ml). The sample taken from Site 2 east contained 1 *E. coli* cfu/100 ml.

Appendices

Appendix I. Human Population

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

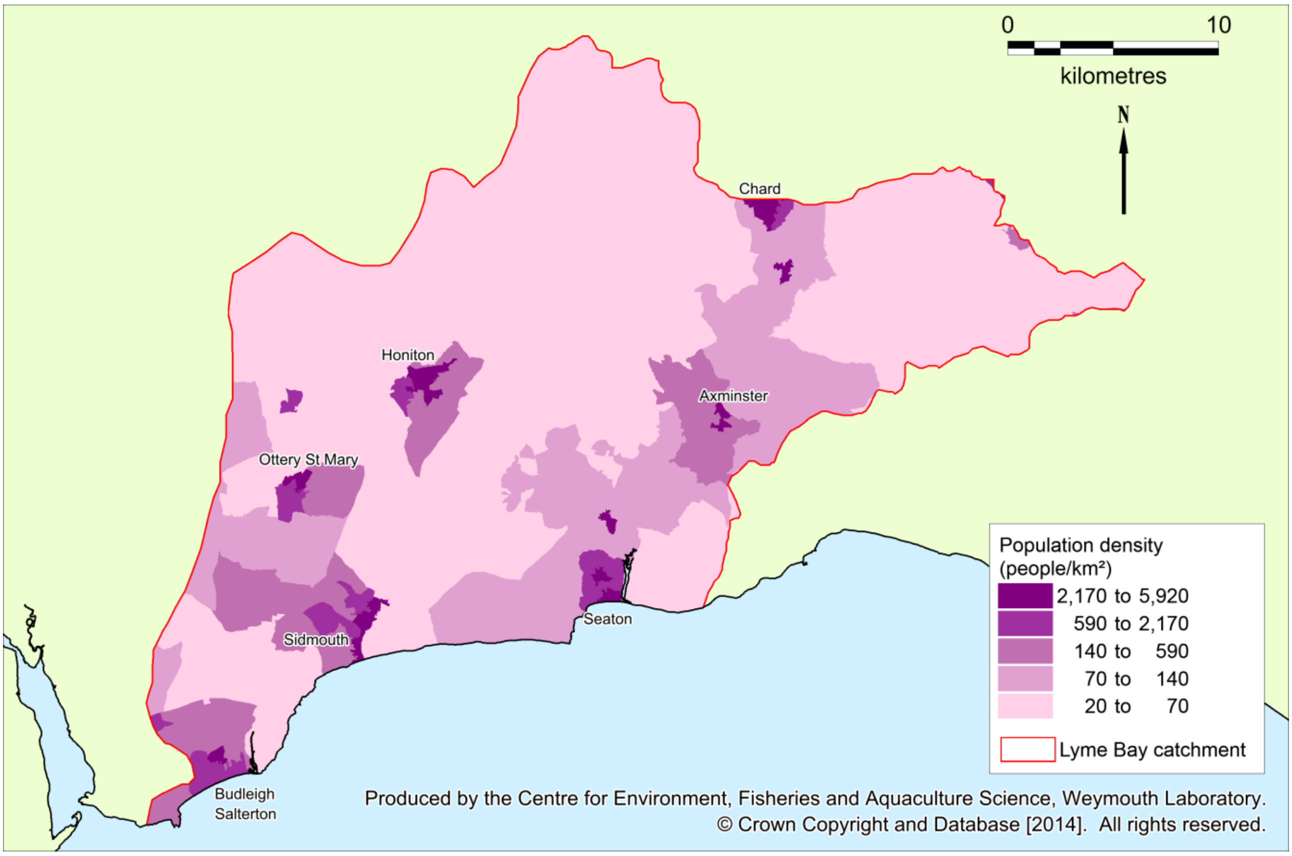

Figure I.1: Human population density in census areas in the Lyme Bay catchment.

Total resident population within census areas contained within or partially within the catchment area was approximately 135,200 at the time of the last census. The population is concentrated in seven towns across the catchment. The three towns of Budleigh Salterton, Sidmouth and Seaton are directly adjacent to the coast.

Much of the coastline forms part of the Dorset and East Devon UNESCO world heritage site and attracts many tourists. Sidmouth and Seaton are both popular tourist destinations. While no tourism statistics were available for the area, it can be assumed that the population in Sidmouth and Seaton will increase significantly during the summer.

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

Details of all consented sewage discharges within the Lyme Bay hydrological catchment and more remote large coastal discharges which may potentially impact on the shellfishery were taken from the most recent update of the Environment Agency national permit database (July 2014). Their locations are shown in Figure II.1 (water company discharges) and Figure II.3 (private discharges) and selected permit details are presented in (Table II.1, Table II.4 and Table II.6).

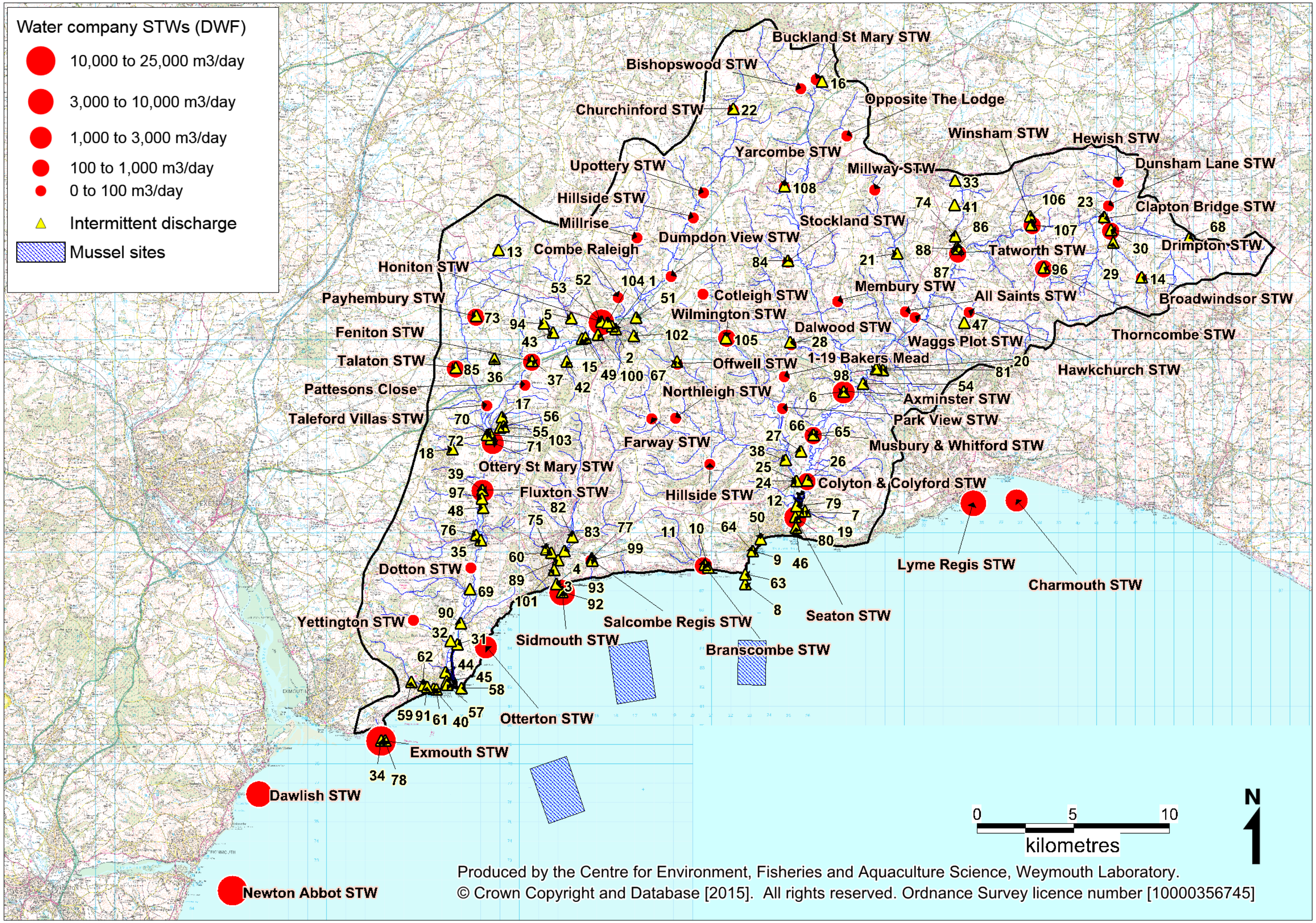

Figure II.1: Water company continuous and intermittent permitted sewage discharges to the Lyme Bay catchment

Contains Environment Agency information © Environment Agency and database right

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

Name	NGR	Treatment	DWF (m^3/day)	Estimated bacterial loading (cfu/day)**	Discharges to
1-19 Bakers Mead	SY2473398128	Biological Filtration	11*	$3.63x10^{10}$	Freshwater (Axe catchment)
All Saints STW	ST3101001510	Biological Filtration	5*	$1.65x10^{10}$	Freshwater (Axe catchment)
Axminster STW	SY2780097300	Chemical - Phosphate Stripping	2,229	$7.36x10^{12}$	Freshwater (Axe catchment)
Bishopswood STW	ST2558013080	Biological Filtration	10	$3.3x10^{10}$	Freshwater (Axe catchment)
Branscombe STW	SY2055088320	Biological Filtration	310	$1.02x10^{12}$	Freshwater (Branscombe Stream)
Broadwindsor STW	ST4328003250	Reedbed	97	$3.2x10^{11****}$	Freshwater (Axe catchment)
Buckland St Mary STW	ST2640013570	Biological Filtration	32	$1.1x10^{11}$	Freshwater (Axe catchment)
Charmouth STW	SY3678091710	Biological Filtration	1,270	$4.19x10^{12}$	Lyme Bay
Churchinford STW	ST2208012010	Biological Filtration	96	$3.17x10^{11}$	Freshwater (Otter catchment)
Clapton Bridge STW	ST4132006280	Biological Filtration	46	$1.52x10^{11}$	Freshwater (Axe catchment)
Colyton & Colyford STW	SY2590092700	Biological Filtration	783	$2.58x10^{12}$	Freshwater (Axe catchment)
Combe Raleigh	ST1610002250	Unknown	Unknown	-	Freshwater (Otter catchment)
Cotleigh STW	ST2050102433	Biological Filtration	10*	$3.33x10^{10}$	Freshwater (Axe catchment)
Dalwood STW	SY2510099800	Biological Filtration	Unknown	-	Freshwater (Axe catchment)
Dawlish STW	SX9742076470	UV Disinfection	4,856	$3.37x10^{10***}$	Lyme Bay
Dotton STW	SY0844088220	Septic Tank	2	$2.0x10^{11}$	Soakaway
Drimpton STW	ST4170005700	Biological Filtration	102	$3.37x10^{10}$	Freshwater (Axe catchment)
Dumpdon View STW	ST1884003330	Biological Filtration	18	$5.94x10^{10}$	Freshwater (Otter catchment)
Dunsham Lane (Wayford) STW	ST4157007010	Biological Filtration	4	$1.32x10^{10}$	Freshwater (Axe catchment)
Exmouth STW	SY0379079190	UV Disinfection	11,825	$1.57x10^{11***}$	Lyme Bay
Farway STW	SY1786095960	Biological Filtration	7	$2.31x10^{10}$	Freshwater (Axe catchment)
Feniton STW	SY1160098900	Activated Sludge	400	$1.32x10^{12}$	Freshwater (Otter catchment)
Fluxton STW	SY0904092190	Biological Filtration	1,100	$3.63x10^{12}$	Freshwater (Otter catchment)
Hawkchurch STW	ST3434001470	Biological Filtration	65	$2.15x10^{11}$	Freshwater (Axe catchment)

Hewish STW	ST4207008230	Biological Filtration	5	$1.65x10^{10}$	Freshwater (Axe catchment)
Hillside STW	ST1999006370	Biological Filtration	5	$1.65x10^{10}$	Freshwater (Otter catchment)
Hillside STW	SY2085093580	Biological Filtration	5*	$1.65x10^{10}$	Freshwater (Axe catchment)
Honiton STW	ST1522000940	Sand Filtration	3,115	$1.03x10^{13}$****	Freshwater (Otter catchment)
Lyme Regis STW	SY3454091560	UV Disinfection (bathing season) Secondary (other times)	3022	$2.57x10^{9}$*** $9.97x10^{12}$	Lyme Bay
Membury STW	ST2750002030	Unknown	Unknown	-	Freshwater (Axe catchment)
Millrise	ST1708005360	Biological Filtration	8	$2.64x10^{10}$	Freshwater (Otter catchment)
Millway STW	ST2944007820	Biological Filtration	5*	$1.65x10^{10}$	Freshwater (Axe catchment)
Musbury & Whitford STW	SY2625095100	Biological Filtration	285	$9.41x10^{11}$	Freshwater (Axe catchment)
Newton Abbot STW	SX9606071430	Biological Filtration	21,818	$7.20x10^{13}$	Lyme Bay
Northleigh St STW	SY1908095980	Biological Filtration	5*	$1.65x10^{10}$	Soakaway
Offwell STW	SY1919098790	Biological Filtration	80	$2.64x10^{11}$	Freshwater (Axe catchment)
Opposite The Lodge	ST2798010630	Package Treatment Plant	5	$1.65x10^{10}$	Freshwater (Axe catchment)
Otterton STW	SY0923084090	UV Disinfection	1,643	$1.12x10^{9}$***	Lyme Bay
Ottery St Mary (Town) STW	SY0956394687	Biological Filtration	1,063	$3.51x10^{12}$	Freshwater (Otter catchment)
Park View STW	SY2464096490	Biological Filtration	6*	$1.98x10^{10}$	Freshwater (Axe catchment)
Pattesons Close	SY1127097690	Unknown	Unknown	-	Freshwater (Otter catchment)
Payhembury STW	ST0872001240	Biological Filtration	132	$4.36x10^{11}$	Freshwater (Otter catchment)
Salcombe Regis STW	SY1470088600	Unknown	Unknown	-	Freshwater (unnamed stream)
Seaton STW	SY2529090810	UV Disinfection	2,493	$2.49x10^{8}$***	Freshwater (Axe catchment)
Sidmouth STW	SY1317086900	UV Disinfection	6,331	$3.29x10^{9}$***	Lyme Bay
Stockland STW	ST2490004080	Unknown	Unknown	-	Freshwater (Axe catchment)
Talaton STW	SY0765098550	Biological Filtration	132	$4.36x10^{11}$	Freshwater (Otter catchment)
Taleford Villas STW	SY0929096620	Biological Filtration	5	$1.65x10^{10}$	Freshwater (Otter catchment)
Tatworth STW	ST3373004530	Lagoon Settlement	937	$3.1x10^{12}$	Freshwater (Axe catchment)
Thorncombe STW	ST3820003760	Activated Sludge	110	$3.63x10^{11}$	Freshwater (Axe catchment)
Upottery STW	ST2053007670	Unknown	Unknown	-	Freshwater (Otter catchment)

Waggs Plot STW	ST3152201201	Package Treatment Plant	17	$5.61x10^{10}$	Freshwater (Axe catchment)
Wilmington STW	ST2175000140	Biological Filtration	101	$3.33x10^{11}$	Freshwater (Axe catchment)
Winsham STW	ST3760006000	Biological Filtration	141	$4.65x10^{11}$	Freshwater (Axe catchment)
Yarcombe STW	ST2472007990	Biological Filtration	48	$1.58x10^{11}$	Freshwater (Axe catchment)
Yettington STW	SY0548085490	Biological Filtration	7	$2.31x10^{10}$	Freshwater (Otter catchment)

*Maximum flows per day (DWF not available)

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

*** Faecal coliforms (cfu/day) based on geometric mean concentrations in final effluent from this works (Table II.3)

**** Faecal coliforms (cfu/day) calculated assuming microbial reduction equates to secondary treatment as in Table II.2

Table II.2: Summary of reference faecal coliform levels (cfu/100 ml) 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.

Six of the larger sewage works provide UV disinfection, so microbiological testing results were available for their final effluents. Five of these discharge directly to Lyme Bay, and Seaton STW discharges to freshwater in the very lowest reaches of the Axe catchment. UV disinfection is only used during the bathing season at Lyme Regis STW, whereas all other works provide year round disinfection. Summary statistics for their final effluent testing results are given in Table II.3.

Table II.3: Summary statistics for final effluent monitoring data for UV disinfected effluents

Name	Date of first sample	Date of last sample	No.	Geometric mean result (cfu/100 ml)	Minimum	Maximum
Dawlish STW	09/01/07	16/03/11	94	694	7	76,000
Exmouth STW	14/01/09	01/03/14	78	1327	10	82,000
Lyme Regis STW	10/05/07	15/09/10	22	85	7	3,700
Otterton STW	14/01/09	20/03/14	77	68	<1	150,000
Seaton (Main) STW	14/01/09	04/03/14	77	10	<1	6,600
Sidmouth STW	14/01/09	04/03/14	77	52	<1	26,000

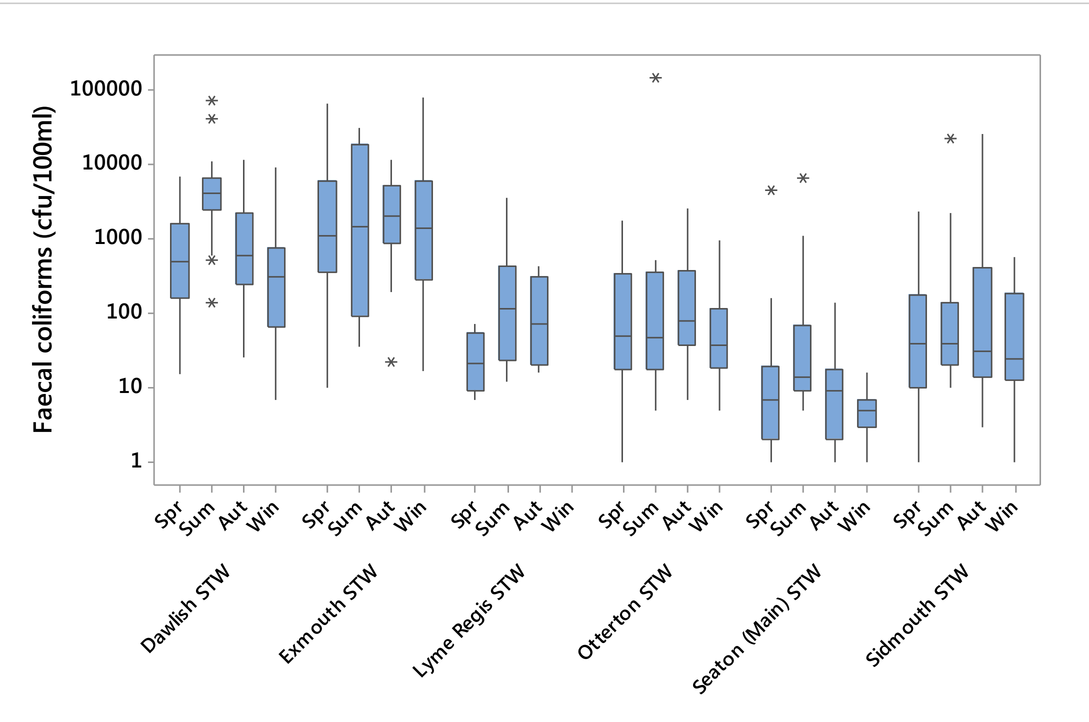

Figure II.2: Boxplot of faecal coliform concentrations in final effluent by season for UV treated works

The summary statistics in Table II.3 and the boxplots in Figure II.2 show that the effluent from Exmouth and Dawlish STWs have a much higher concentration of faecal coliforms than the effluents from the other works, where disinfection is generally very effective. The maximum recorded results were about 2-3 orders of magnitude higher than the average, indicating that they will occasionally generate much higher bacterial loadings. There was statistically significant seasonal variation in results at Seaton STW (One way ANOVA, p=0.002) and Dawlish STW (One way ANOVA, p=0.000). Results were significantly higher on average in the summer than in autumn and winter at Seaton STW, and significantly higher in the summer than all other seasons at Dawlish STW. This may be due to increased volumes of effluent received during the summer holiday season. Seasonality was not investigated at Lyme Regis, as UV disinfection is only applied in the summer. The bacterial loading generated by this works is likely to increase by around three orders of magnitude when the disinfection is not in use. It must be noted that UV disinfection is less effective at eliminating viruses than bacteria (e.g. Tree et al, 1997).

There are two further sewage works discharging direct to Lyme Bay which may be of some significance to the mussel farm. Both provide secondary treatment. The largest is Newton Abbot STW, which generates the largest estimated bacterial loading of all works, but lies about 17 km west of the nearest mussel site. Charmouth STW is much smaller, and lies about 15 km east of the nearest mussel site. Their remoteness from the mussel sites will greatly limit their impacts.

The other water company sewage works considered in this report all discharge to inland watercourses, with the exception of Northleigh St and Dotton STWs, which discharge to soakaway. The Axe catchment receives a further 5,146 m^3/day of generally secondary treated effluent on top of that from Seaton STW, and not including those works for which no dry weather flow was specified. The Otter catchment receives 6,081 m^3/day of mainly secondary treated effluent, not including those works for which no dry weather flow was specified. The Branscombe stream received 310 m^3 of secondary treated effluent per day from Branscombe STW, and an unnamed watercourse just west of Sidmouth receives effluent from Salcombe Regis STW (volume and treatment type unspecified). These sewage works will contribute to the bacterial loading delivered to coastal waters by the watercourses to which they discharge, although some bacterial die-off is likely to occur in transit, particularly for those located further inland.

In addition to the continuous sewage discharges, there are a large number of intermittent water company discharges associated with the sewerage networks, details of which are shown in Table II.4. Spill data was only available for one of these discharges, which is highlighted in yellow.

Table II.4: Intermittent discharges to the survey catchment

No.	Name	Grid reference	Receiving water
1	191 High Street CSO	ST1595200548	The Gissage
2	27 Oaklea CSO	ST1576700698	The Gissage
3	Alma Bridge No.1 CSO	SY1288987325	River Sid
4	Alma Bridge No.2 CSO	SY1288987324	River Sid
5	Awliscombe PSCSO/EO	ST1365001120	River Wolf

No.	Name	Grid reference	Receiving water
6	Axminster STW	SY2780097300	Trib of River Axe
7	Axmouth PSCSO/EO	SY2553091070	River Axe
8	Beer Car Park PS	SY2268087330	Lyme Bay
9	Beer Car Park PS	SY2307089040	Lyme Bay
10	Branscombe PSCSO/EO	SY2076088170	Branscombe
11	Branscombe STW	SY2059088320	Branscombe Stream
12	Bridge House CSO	SY2536092663	River Coly
13	Broadhembury PSCSO/EO	ST0987304677	River Tale
14	Broadwindsor STW	ST4328003250	Trib of Drimpton Stream
15	Buckerell PSCSO/EO	ST1422200059	R.Otter
16	Buckland St Mary STW	ST2669013400	Trib of River Yarty
17	Butt's Hill PS	SY1005095990	Soakaway
18	Castle Copse PS	SY0748094320	Trib of River Otter
19	Chapel Stepps Lane CSO	SY2580891099	Stream
20	Chard Road SSO	SY2960098500	Watercourse
21	Chardstock PS	ST3058004490	River Kit
22	Churchinford STW	ST2208012010	River Otter
23	Clapton PS	ST4133006380	Clapton Stream
24	Colyford PSCSO/EO	SY2535492665	River Coly
25	Colyford PSEO	SY2535492675	R Coly
26	Colyford/Colyton ST	SY2591792700	River Axe
27	Colyton SSO	SY2560094200	River Coly
28	Dalwood PS	SY2501499885	The Corry Brook
29	Drimpton PSCSO/EO	ST4182005040	Temple Brook
30	Drimpton STW – EO	ST4169005690	Watercourse
31	East Budleigh PSCSO/EO	SY0773984189	Trib of River Otter
32	East Budleigh PSCSO/EO	SY0738784379	Trib of River Otter
33	Edwards PS	ST3359008270	Trib Of River Axe
34	Exmouth STW	SY0379079190	Lyme Bay
35	Factory Lane CSO	SY0895589608	Trib River Otter
36	Feniton	SY0966199021	Stream
37	Feniton STW	SY1160098900	River Otter
38	Fire Station CSO	SY2478193781	River Coly
39	Fluxton STW	SY0904092190	River Otter
40	Fore Street CSO	SY0649081880	Knowle Stream
41	Forton SPS (Blackland Lane)	ST3355007000	Watercourse
42	Gittisham PS	SY1342098870	Trib Of River Otter
43	Glebe Farmhouse PSCSO/EO	ST1272000400	Trib River Otter
44	Granary Lane (North) CSO	SY0711082740	Kersbrook Channel
45	Granary Lane CSO	SY0718082270	Trib River Otter
46	Harbour Road SPS	SY2532090240	River Axe Estuary
47	Hawkchurch STW	ST3406000880	Blackwater River/Stream
48	Hayne Barton PSEO	SY0908491289	River Otter
49	Heathpark Industrial Estate	ST1439000130	River Otter
50	Hole PSEO	SY2349489649	Coastal Stream
51	Honiton (Monkton Rd) SPS	ST1703001150	Trib Of River Otter
52	Honiton STW	ST1522000940	River Otter
53	Honiton STW	ST1522000940	River Otter
54	Horslears PS	SY2880097720	River Axe
55	Junc Batt's Lane/Brook St CSO	SY0996095450	Brook Street Stream
56	Junc Chapel Lane/Brook St CSO	SY1015095510	Brook Street Stream

No.	Name	Grid reference	Receiving water
57	Lime Kiln PSEO	SY0722082100	Kersbrook Channel
58	Lime Kiln Tank CSO	SY0794081920	English Channel
59	Little Knowle CSO	SY0535082260	Knowle Stream
60	Manstone Lane CSO	SY1262288955	Woolbrook
61	Marine Parade CSO	SY0664081860	Knowle Stream
62	Meadow Road Tank CSO	SY0597082060	Knowle Stream
63	Memorial Gardens PS	SY2268087830	Lyme Bay And Seaton Bay
64	Memorial Gardens PS	SY2307089040	Lyme Bay And Seaton Bay
65	Musbury & Whitford PSEO	SY2625095060	River Axe
66	Musbury & Whitford STW	SY2624095070	River Axe
67	Offwell STW	SY1916098890	Trib of Offwell Brook
68	Orchard Way PSCSO/EO	ST4574605266	River Axe
69	Otter Farm CSO	SY0840487056	Trib of River Otter
70	Otter Mill Car Park CSO	SY0939095090	River Otter
71	Ottery St Mary (Town Works) PS	SY0950094850	Leat of River Otter
72	Ottery St Mary (Town) STW	SY0946595101	Tributary of River Otter
73	Payhembury STW	ST0872001240	Payhembury Stream
74	Perry Street CSO	ST3360605371	Stream
75	R/O 68 Woolbrook Road CSO	SY1235189127	Woolbrook
76	Recreation Ground CSO	SY0873289871	Back Brook
77	Salcombe Regis STW	SY1472088650	Salcombe Regis Stream
78	Sandy Bay Holiday Park PSEO	SY0398079190	Straight Point
79	Seaton North PSEO	SY2535091380	Seaton Bay
80	Seaton STW	SY2529090810	River Axe Estuary
81	Shand Park CSO	SY2983098430	River Axe
82	Sidford Tennis Courts CSO	SY1372289790	River Sid
83	Sidmouth Fortescue CSO	SY1331089030	The River Sid
84	Stockland STW	ST2491004110	Watercourse
85	Talaton STW	SY0765098550	Trib of River Tale
86	Tatworth STW	ST3371004790	Forton Brook
87	Tatworth STW	ST3368004810	Forton Brook
88	Tatworth STW PSEO	ST3374004720	Forton Brook
89	Temple Street CSO	SY1296588576	River Sid
90	The Green CSO	SY0793485291	River Otter
91	The Green Tank CSO	SY0617081990	Knowle Stream
92	The Ham PS Tank & CSO	SY1317086900	River Sid and Lyme Bay
93	The Ham PS Tank & CSO	SY1288087320	River Sid and Lyme Bay
94	The Oaks PSCSO/EO	ST1223000851	Stream
95	Thorncombe STW	ST3820003760	River Synderford
96	Thorncombe STW PSEO	ST3820003750	River Synderford
97	Tipton St John PSCSO/EO	SY0900291747	River Otter
98	Town Railway Station SSO	SY2950098500	River Axe
99	Track CSO	SY1473788542	Stream
100	Ventura CSO	ST1502800273	Ditch
101	Vicarage Road CSO	SY1277588067	River Sid
102	Waterleat Park PSCSO/EO	ST1691600199	Trib of River Otter
103	West Bank PS	SY0929095080	Trib of River Otter
104	Willowdale PSCSO/EO	ST1555600898	Trib of River Otter
105	Wilmington STW	ST2170000100	Umborne Brook
106	Winsham STW	ST3750006400	Watercourse
107	Winsham STW PSCSO/EO	ST3754005980	River Axe

No.	Name	Grid reference	Receiving water
108	Yarcombe STW	ST2472007990	Trib River Yarty

Contains Environment Agency information © Environment Agency and database right

Table II.5: Summary of spill records for the monitored intermittent discharge (2010-2011)

Discharge name	Location	Period of data available	No spill events	Total duration (hrs)	% time active
Exmouth STW	SY0379079190	31/3/2010-22/2/2011	40	534.18	6.8

Contains Environment Agency information © Environment Agency and database right

The Exmouth STW overflow was active for 6.8% of the period for which records were available. As this was just under 11 months in total it is difficult to make a robust assessment of its performance. For the rest of the intermittent discharges, it is difficult to assess their significance aside from noting their location and their potential to spill untreated sewage. They are widely distributed throughout the survey catchment and are generally associated with the more extensive built up areas. There are coastal clusters around the main seaside towns (Budleigh Salterton, Sidmouth and Seaton).

Although the majority of properties within the survey area are served by water company sewerage infrastructure, there are also 808 permitted private discharges. Figure II.3 and

Table II.6 present details of those consented to discharge 10 m^3/day or more to water.

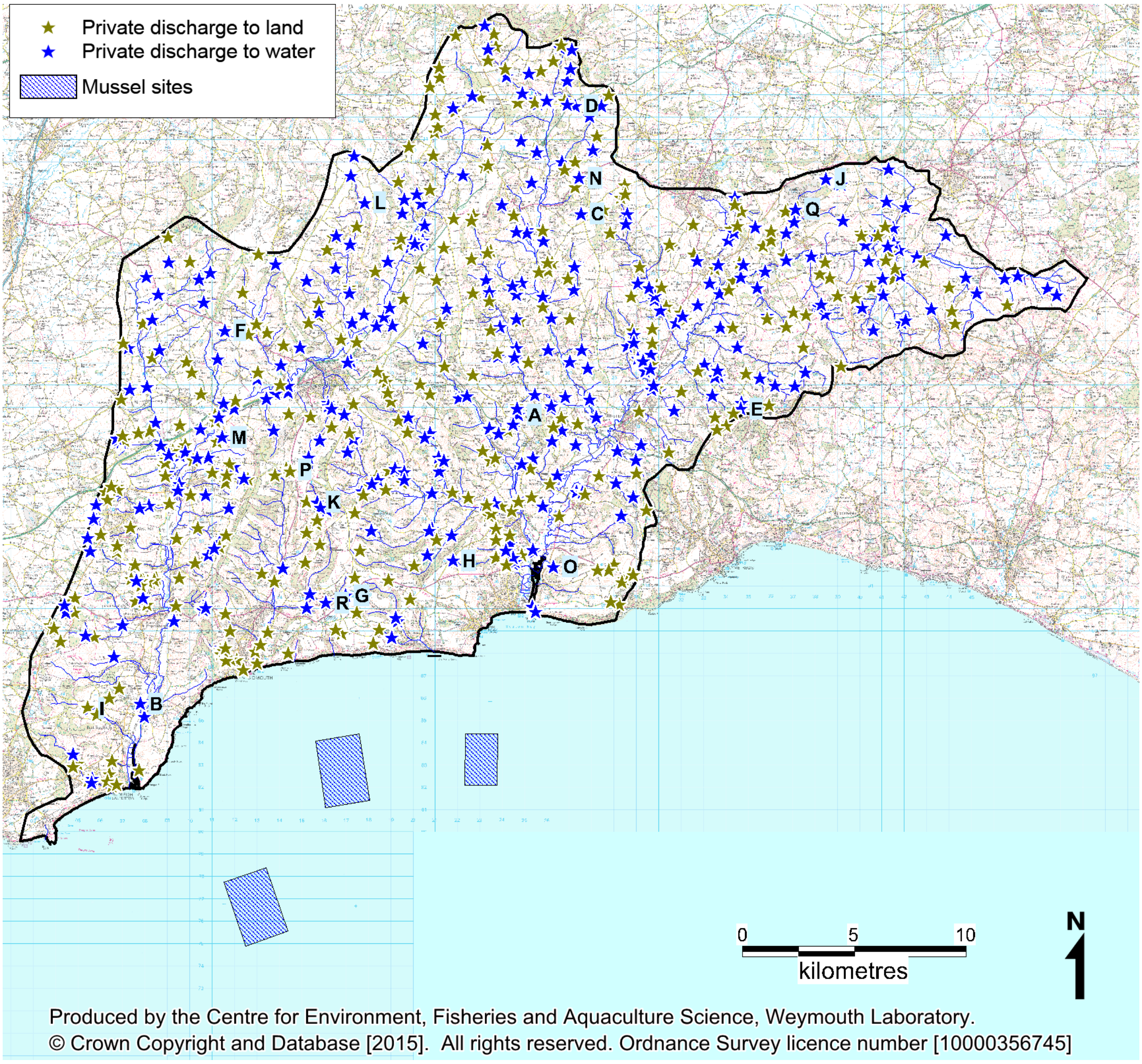

Figure II.3: Private permitted sewage discharges in the Lyme Bay catchment

Contains Environment Agency information © Environment Agency and database right

Table II.6: Details of private sewage discharges to water >10 m^3/day to the Lyme Bay catchment

Ref.		Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
A	Andrewshayes Farm	SY2470098700	Unspecified	20.5	Trib Of Corry Brook
B	Bicton Farm	SY0776085770	Reedbed	18	A Tributary Of The River Otter
C	Fern Animal Sanctuary	ST2750007700	Package Plant	12.6	Tributary To The River Yarty
D	Five Acres Caravan Site	ST2725012550	Unspecified	17.85	A Local Watercourse
E	Hawkwell Caravan Park	SY3466098971	UV Disinfection	10.8	Trib Of Fairwater Stream
F	Hembury Fort House And Cottage	ST1155002480	Biological Filtration	10.33	Tributary Of Vine Water

Ref.		Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
G	Kings Down Tail Caravan Park	SY1695090610	Reedbed	18.27	Constructed Wetland
H	Leacroft Touring Park	SY2176092180	Unspecified	30	Trib Of Holyford Brook
I	Lemprice Farmhouse	SY0550085550	Biological Filtration	12	Budleigh Brook
J	London Lodge	ST3846909251	Package Plant	11.5	Ditch Trib Of Purtington Brook
K	Lower Knapp Farm	SY1570094790	Package Plant	11.6	Roncombe Stream
L	Otter Brewery	ST1781208189	Package Plant	30	Tributary Of The River Love
M	Site Adjoining Alfington Farm	SY1143097700	Package Plant	10.8	The Alfington Brook
N	South Somerset Caravan Park	ST2740809305	Package Plant	20	Un-Named Trib Of R.Yarty
O	Stedcombe Vale	SY2627091900	Unspecified	10	Trib Of River Axe
P	Stp @ The Hare And Hounds	SY1447196236	Package Plant	20	Ditch Tributary Of The R. Sid
Q	The Cricket St Thomas Estate	ST3710007900	Biological Filtration	172.8	Pertington Brook
R	The Donkey Sanctuary	SY1608090280	Package Plant	23.6	Trib Of The Snod Brook

Contains Environment Agency information © Environment Agency and database right

The majority of private discharges are small, serving one or two properties. Where specified, these are generally treated by small septic tanks or package plants. Of the 808 private discharges, 406 discharge to soakaway so should be of no impact on Lyme Bay assuming they are functioning correctly. Of the 402 discharging to water, 18 have a maximum consented flow of >10m^3/day as listed in Table II.6.

The vast majority of private discharges to water are within the Axe and Otter catchments. They will make a contribution to the bacterial loading delivered to Lyme Bay via their receiving waters. A degree of bacterial die off will take place during transit, particularly for those discharges located further up catchment. None of the larger private discharges are direct to coastal waters.

Appendix III. Sources and Variation of Microbiological Pollution: Agriculture

The majority of land within the catchment is used for agriculture. Agricultural land is a mosaic of pasture and arable land in roughly equal proportions (Figure 1.2). Table III.1 and Figure III.1 present livestock numbers and densities for the sub-catchments 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. Nevertheless, the data should give a reasonable indication of numbers of livestock within the catchment.

Table III.1: Livestock census data for sub-catchments within the survey area

Sub-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)
Axe (Lower)	2,882	57	4,508	90	*	*	9,736	194
Axe (Middle)	13,670	124	10,894	98	454	4	2,354	21
Axe (Upper)	24,187	131	21,702	118	535	3	209,397	1,137
Yarty	17,205	191	9,958	111	4,250	47	11,277	125
Sid	2,036	54	5,064	134	*	*	8,312	220
Otter	24,943	111	29,983	133	19,056	85	300,060	1,335
Otter (Lower)	4,105	117	*	*	*	*	*	*
Total / Average	89,028	122	82,109	112	24,295	33	541,136	739

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 x 10^8
Pig	3,300,000	2,700	8.9 x 10^8
Human	13,000,000	150	1.9 x 10^9
Cow	230,000	23,600	5.4 x 10^9
Sheep	16,000,000	1,130	1.8 x 10^{10}

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

There are significant numbers of grazing animals within the catchment area. Diffuse inputs associated with grazing livestock are therefore anticipated via direct deposition on pastures. Slurry is also collected from livestock sheds when cattle are housed indoors and subsequently applied to fields as fertilizer. Pigs and poultry are also present in significant numbers. 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.

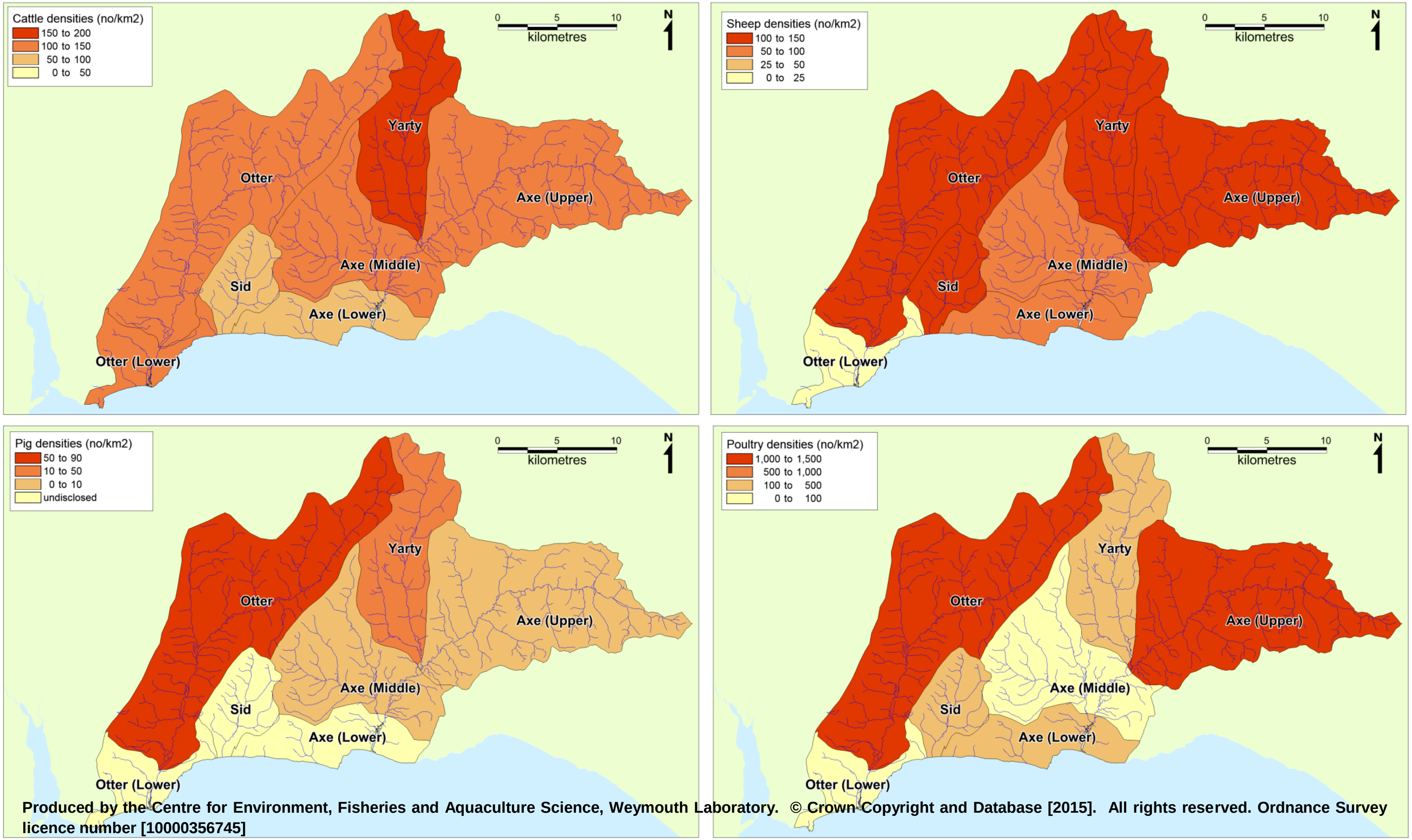

Figure III.1: Livestock densities by sub-catchment

Data from Defra

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 estuary 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 most, if not all, of the main watercourses will be impacted to some extent by agriculture.

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 to the mussel farm. Boat traffic in Lyme Bay mainly consists of recreational craft such as yachts as well as fishing vessels. Figure IV.1 presents an overview of boating activity derived from the shoreline survey, satellite images and various internet sources.

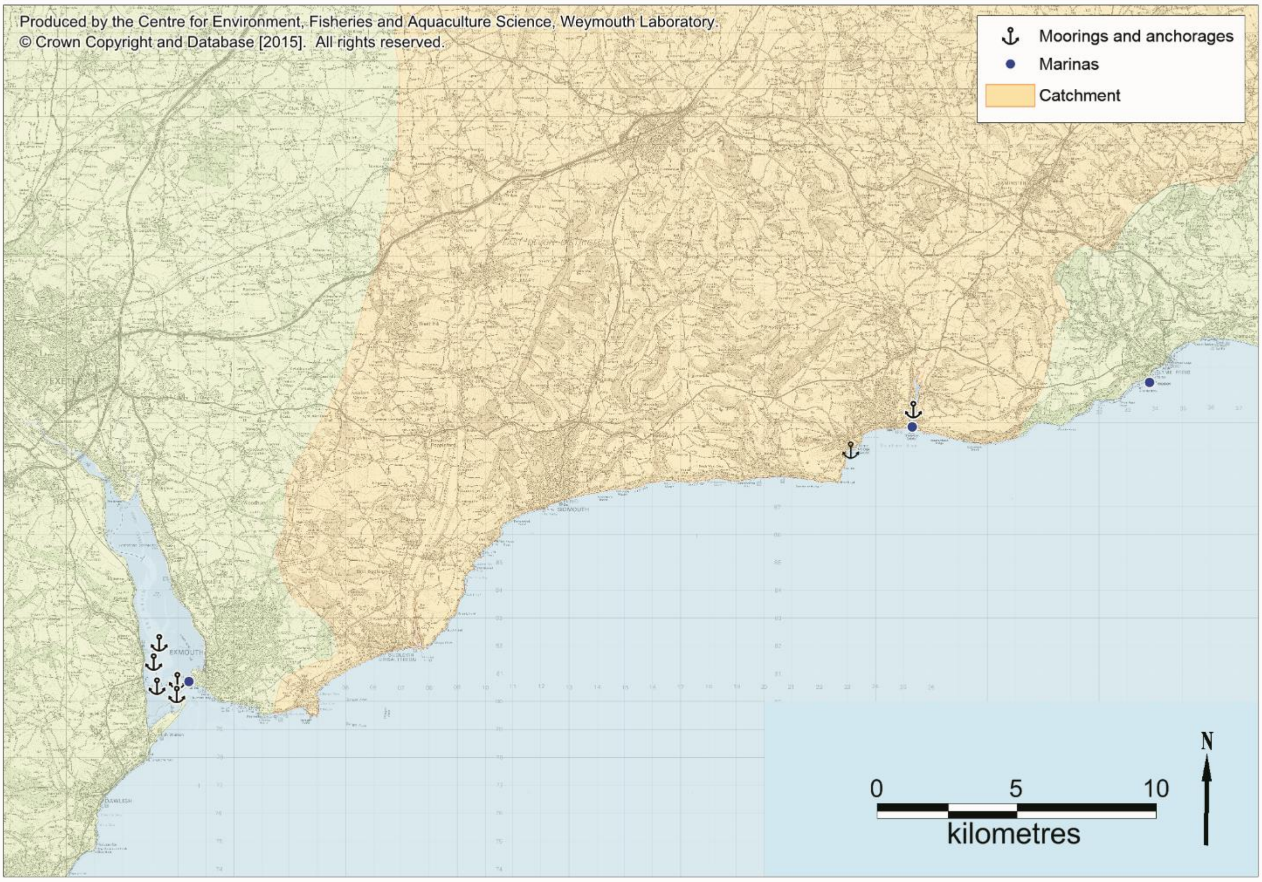

Figure IV.1: Boating activity in the Lyme Bay survey area

There are no commercial ports within the survey area or the wider Lyme Bay area. The closest commercial port is located approximately 45 km east of the mussel farm at Portland Harbour. The main shipping routes pass through the central English Channel, a significant distance to the south of the mussel farm (MMO, 2014a). Merchant shipping is frequently observed in Lyme Bay, but is unlikely to pass near to the mussel farm on a regular basis, particularly given the full extent of the mussel farm will be marked on nautical charts and lit and buoyed as appropriate. Commercial shipping is not permitted to make overboard discharges within 3 nautical miles (or 5.5 km) of land[1], but this only conveys protection to the more inshore parts of the mussel farm. It is therefore concluded that there is the potential

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

for significant overboard discharges to be made by commercial shipping in the vicinity of the more offshore parts of the mussel farm, but the likelihood of such an event occurring is low.

There is significant recreational boat traffic in Lyme Bay (yachts, cabin cruisers, angling/diving charters etc). The two main local centres for such activity are at Exmouth and Lyme Regis. Exmouth marina has around 200 berths for recreational craft and Lyme Regis harbour holds around 220 recreational berths and 15 commercial moorings. Additional moorings are situated at both Exmouth and Lyme Regis. Lyme Regis Harbour has the closest sewage pump out facilities (The Green Blue, 2010). There is also a smaller marina at Axmouth which holds 100 berths for recreational craft. Moorings are also available within the lower Axe estuary and anchorages are accessible offshore of Beer. Recreational craft will generally avoid coming in close proximity to the mussel lines as they are/will be well marked and represent a hazard to navigation. It is quite likely that such vessels will make overboard discharges in fairly close proximity to the mussel lines from time to time. Peak recreational activity will occur during the summer months.

There is a small fishing fleet which operates in the area. Nineteen fishing vessels under 10 metres in length are listed as having their home port at Beer, Sidmouth or Axmouth and one fishing vessel over 10 metres is listed as having Beer as its home port (MMO, 2014b). Fishing vessels are therefore likely to work in the areas adjacent to the mussel farm, and smaller vessels using static gear may well operate within the lease boundaries. Fishing vessels may therefore make overboard discharges in close proximity to the mussel lines from time to time, and their presence is likely to be more evenly distributed throughout the year. A further consideration is the possibility that the mussel farm, which provides underwater structure and a potential food source, may attract aggregations of certain species of fish. If this proves to be the case, the mussel farm may well prove attractive to fishing vessels and angling/diving charter boats.

It is therefore concluded that boat traffic in the survey area is generally limited to pleasure craft and fishing vessels, and that these will not generally navigate in close proximity to the mussel farm. There are likely to be some impacts from such vessels from time to time. The plumes from overboard discharges will be highly localised and transient, particularly near the point of discharge where they will be most concentrated so are unlikely to be captured during routine monitoring. The chances of an overboard discharge bring made in the vicinity of the farm are likely to increase in the summer when more recreational craft are at sea. It is possible that larger overboard discharges may occasionally be made in the area by merchant shipping, although traffic volumes are low and they are unlikely to closely approach the mussel farms. It is difficult to be more specific about the potential impacts from boats and how they may affect the sampling plan without any firm information about the locations, timings and volumes of such discharges.

Appendix V. Sources and Variation of Microbiological Pollution: Wildlife

Lyme Bay encompasses a variety of habitats including sea cliffs, offshore reefs, shingle beaches, and several estuaries of varying sizes. These features attract significant populations of birds and other wildlife. Consequently Lyme Bay falls under several national and international conservation statuses, including: the largest Marine Protected Area (MPA) in the UK, Special Area of Conservation (SAC), National Nature Reserve (NNR) and Special Site of Scientific Interest (SSSI). In addition to this a large proportion of the Lyme Bay coastline has been designated as a World Heritage Site for both its ecology and geology. The offshore location of the mussel farm will largely limit the list of wildlife species that may impact upon it to those which typically frequent offshore areas, such as seabirds and marine mammals.

A survey in the early summer of 1999 along the coastline between Straight Point, Exmouth and Charton Bay, Seaton, recorded 578 pairs of breeding seabirds including European Herring Gull, Lesser Black-backed Gull, Northern Fulmar, Black-legged kittiwake, Great Black-backed Gull, European shag and Great Cormorant (Mitchell *et al*, 2004). An average total count of 2,895 gulls and terns were recorded in the Axe estuary over the five years up until 2012/2013 (Austin *et. al*, 2014). 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 or roost sites. These are on land so are remote from the mussel farm. It is possible that seabirds will forage around the mussel farm and rest on the floats and buoys, although no birds or bird droppings were observed during a site visit undertaken in early November 2014. Should birds use floats or buoys for resting on, it may be more likely that the larger navigational buoys located on the edges/corners of the farm represent a more stable platform than the tubular floats from which the headlines are suspended. RMPs located by the navigational buoys may therefore be best positioned to capture contamination from seabirds.

There are no major seal colonies in Lyme Bay, with the closest significant colony in the Solent (SCOS, 2013). Whilst they may forage in the vicinity of the mussel farm from time to time, they are unlikely to be a significant source of contamination to the shellfishery. Also, their presence will be unpredictable spatially and temporally, so whilst they may potentially be an influence it will not be possible to define an RMP location which will reliably capture their impacts. Some cetaceans are known to frequent Lyme Bay. Whilst larger species such as Minke Whales are occasionally sighted here, harbour porpoises and several dolphin species are a regular presence (Brereton *et al*, 2013). The dolphins generally tend to frequent the more offshore areas in central Lyme Bay, but porpoises are more frequently observed closer to the shore. As with seals, their presence will be unpredictable spatially and temporally, so whilst they may potentially be an influence it will not be possible to define an RMP location which will reliably capture their impacts.

Counts of overwintering waterbirds (wildfowl and waders) are undertaken in the Axe estuary and the Exe estuary. An average total count of 3,006 (Axe) and 28,569 (Exe) was recorded over the five winters up until 2012/2013 (Austin *et al*, 2014). These birds are likely to contribute to the loadings of faecal indicator organisms delivered to coastal waters by the ebb plumes from these estuaries. No other wildlife species which may influence the sampling plan have been identified.

Appendix VI. Meteorological Data: Rainfall

The monthly rainfall data for the Kersbrook Lodge weather station is shown in Figure VI.1. It is located on the coast towards the western end of the survey area, near Budleigh Salterton.

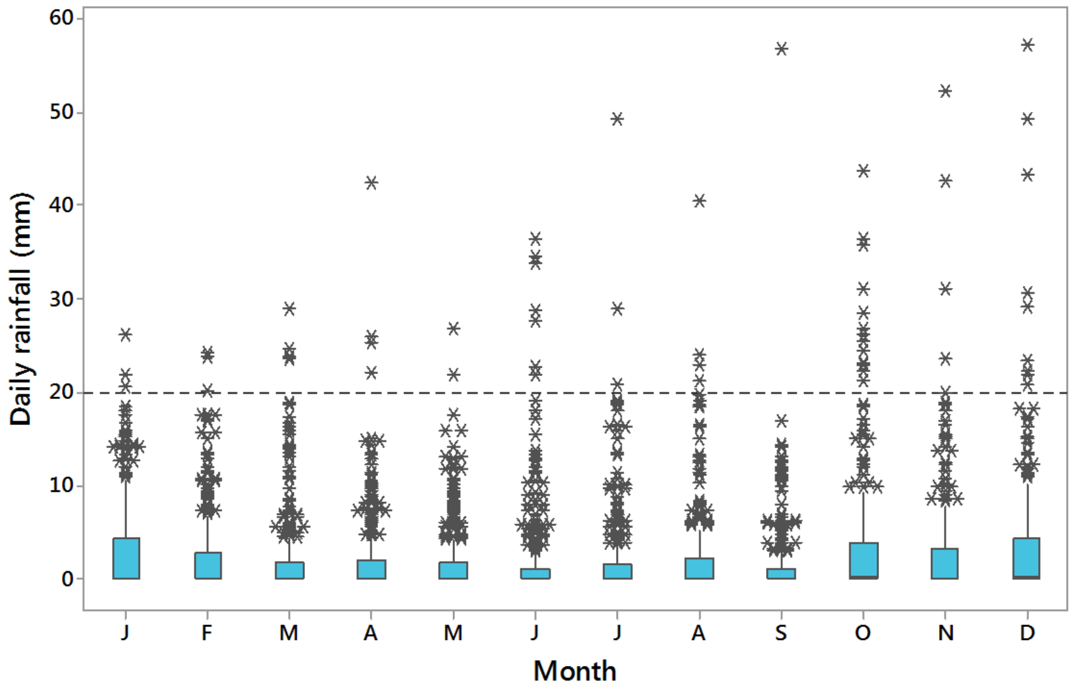

Figure VI.1: Boxplot of daily rainfall totals at Kersbrook Lodge, January 2004 to December 2013.
Contains Environment Agency information © Environment Agency and database right

The Kersbrook Lodge weather station received an average of 751 mm rainfall per year between 2004 and 2014. Autumn and early winter (September to December inclusive) had the highest average rainfall, while February to May (inclusive) had the lowest rainfall. Daily totals of over 20 mm were recorded on 1% of days and no rainfall was recorded on 44% of days between 2004 and 2014. High rainfall events occurred throughout the year, but then highest magnitude events tended to occur in the second half of the year.

Rainfall may lead to the discharge of raw or partially treated sewage from combined sewer overflows (CSOs) and other intermittent discharges as well as runoff from faecally contaminated land (Younger *et al*., 2003). Representative monitoring points located in parts of shellfish beds closest to rainfall dependent discharges and freshwater inputs will reflect the combined effect of rainfall on the contribution of individual pollution sources. Relationships between levels of *E. coli* and faecal coliforms in shellfish and water samples and recent rainfall are investigated in detail in Appendices XI and XII.

Appendix VII. Meteorological Data: Wind

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, 2013). 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.

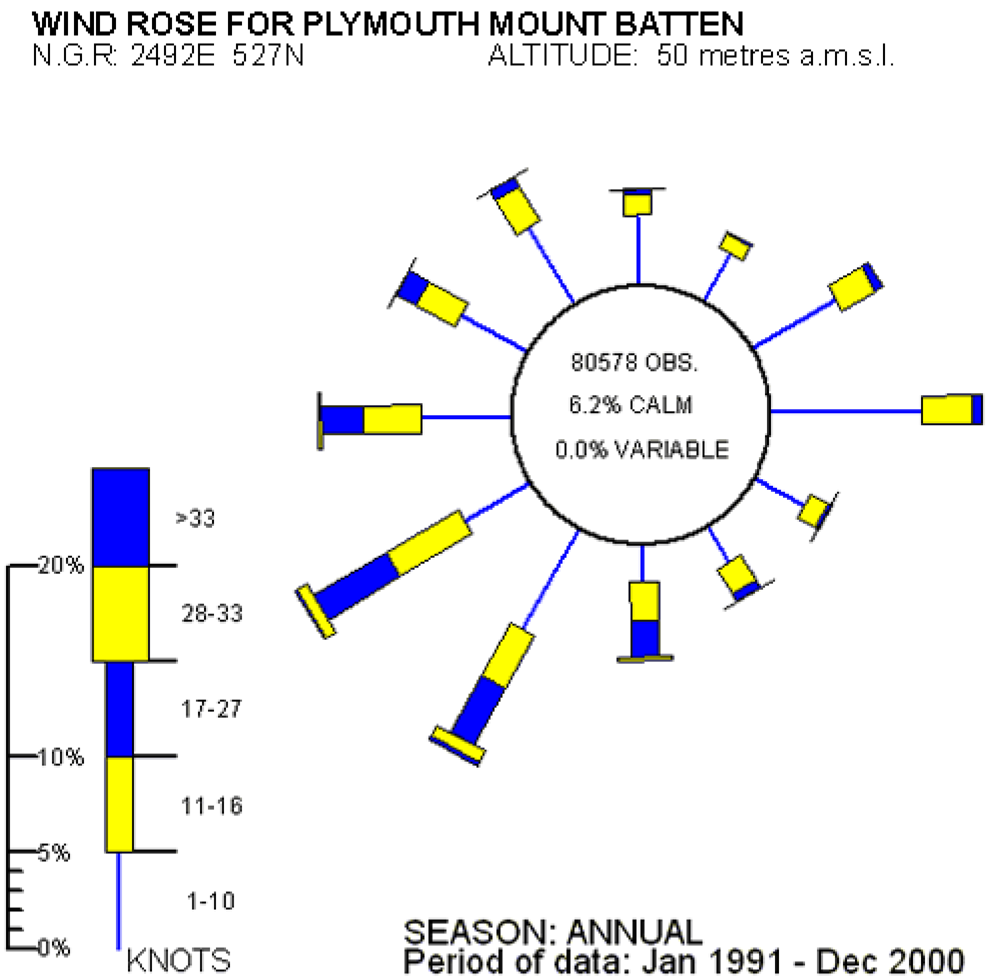

Figure VII.1: Windrose for Plymouth Mount Batten
Produced by the Meteorological Office. Contains public sector information licensed under the Open Government Licence v1.0

Figure VII.1 indicates that the prevailing wind direction at Mount Batten is from the south west. The survey area, situated between Exmouth and Lyme Regis is south facing and forms part of the larger Lyme Bay embayment. Due to its open location it will be quite exposed to the prevailing winds. Strong winds are likely to modify water circulation and generate significant wave action in the vicinity of the mussel farm.

Appendix VIII. Hydrometric Data: Freshwater Inputs

The survey area has a hydrological catchment of 733 km², as estimated from topographical maps. There are two main rivers which drain this catchment, the Otter and the Axe. There are also several small streams and a minor river (the Sid) which drain to the shore of the survey area.

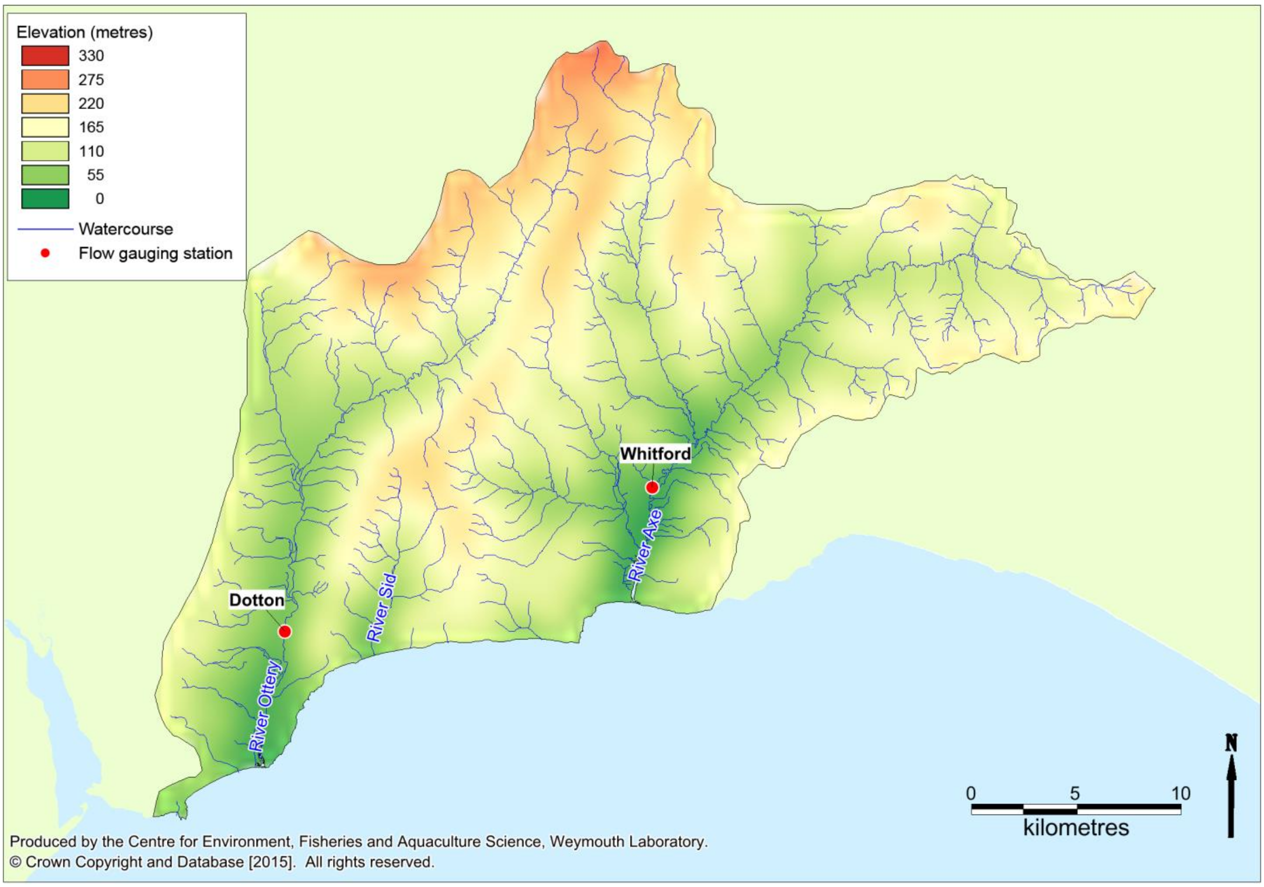

Figure VIII.1: Freshwater inputs flowing into the Lyme Bay survey area

The dominant land cover is predominately rural, consisting of a mixture of pasture and arable land, with some natural areas (woodland and heathland). There are several built up areas, about half of which are situated on the coast. The hydrogeology varies considerably throughout the catchment. A band of high permeability bedrock extends through the lower reaches of the Otter catchment, whereas the rest of the catchment is underlain with mixed permeability bedrocks. The Axe catchment is largely a mix of moderate and low permeability bedrock, although there are some areas of high permeability in its upper reaches (NERC, 2012). The gradients of the Otter and Axe are quite steep in their upper reaches and tributaries, becoming gentler towards the coast, with significant floodplains in their lower reaches. The Sid has a high gradient throughout. All three rivers are responsive to rainfall, although the Axe is slower to respond (Environment Agency, 2005).

There are flow gauging stations on the Otter and Axe. Table VIII.1 presents summary statistics, and Figure VIII.2 and Figure VIII.3 present boxplots of mean daily flows by month for the gauging stations located closest to the coast on these watercourses. There is no flow gauging station on the river but the Environment Agency have calculated a theoretical mean daily flow of 0.574 m^3/sec and a Q95 of 0.134 m^3/sec (Environment Agency, 1999). During spates the flow may be much greater (>10 m^3/sec).

Table VIII.1: Summary of flow statistics for gauging stations on the Otter and Axe

Watercourse	Station Name	Catchment Area (Km^2)	Mean Annual Rainfall 1961-1990 (mm)	Mean Flow (m^3s-1)	Q95[1] (m^3s-1)	Q10[2] (m^3s-1)
Otter	Dotton	202.5	976	3.36	0.98	7.05
Axe	Whitford	288.5	994	5.90	1.34	12.70

[1]Q95 is the flow that is exceeded 95% of the time (i.e. low flow). [2]Q10 is the flow that is exceeded 10% of the time (i.e. high flow). Data from NERC, 2012 and contains Environment Agency information © Environment Agency and database right

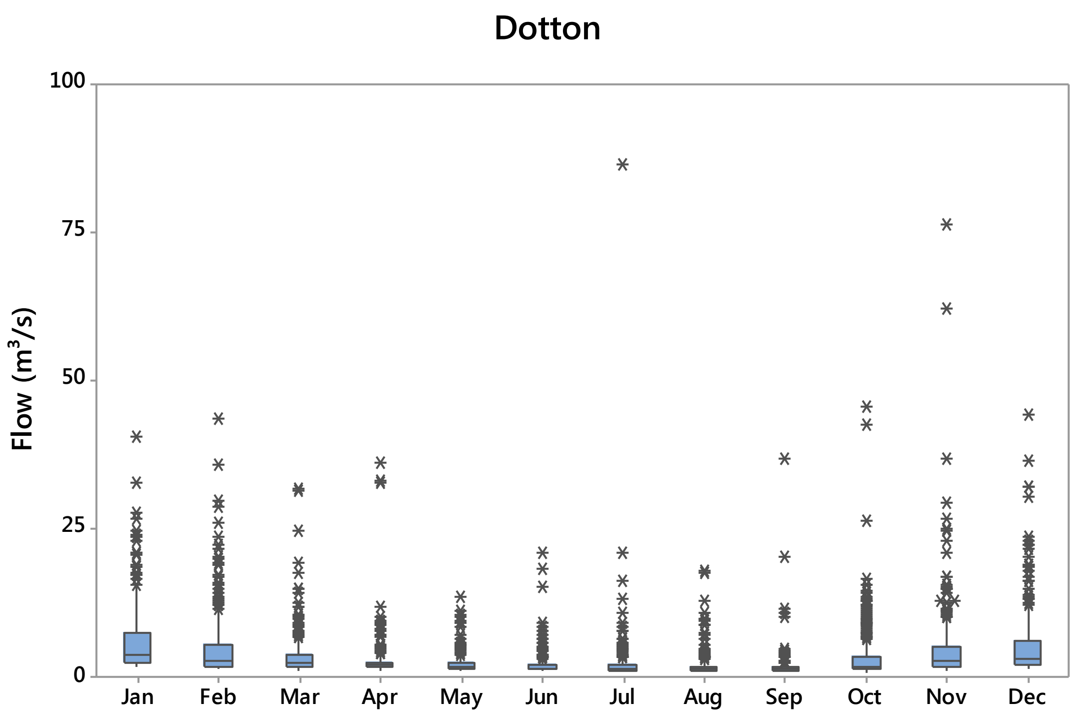

Figure VIII.2: Boxplots of mean daily flow records from the Dotton gauging station on the Otter watercourse (2004 – 2014)

Contains Environment Agency information © Environment Agency and database right

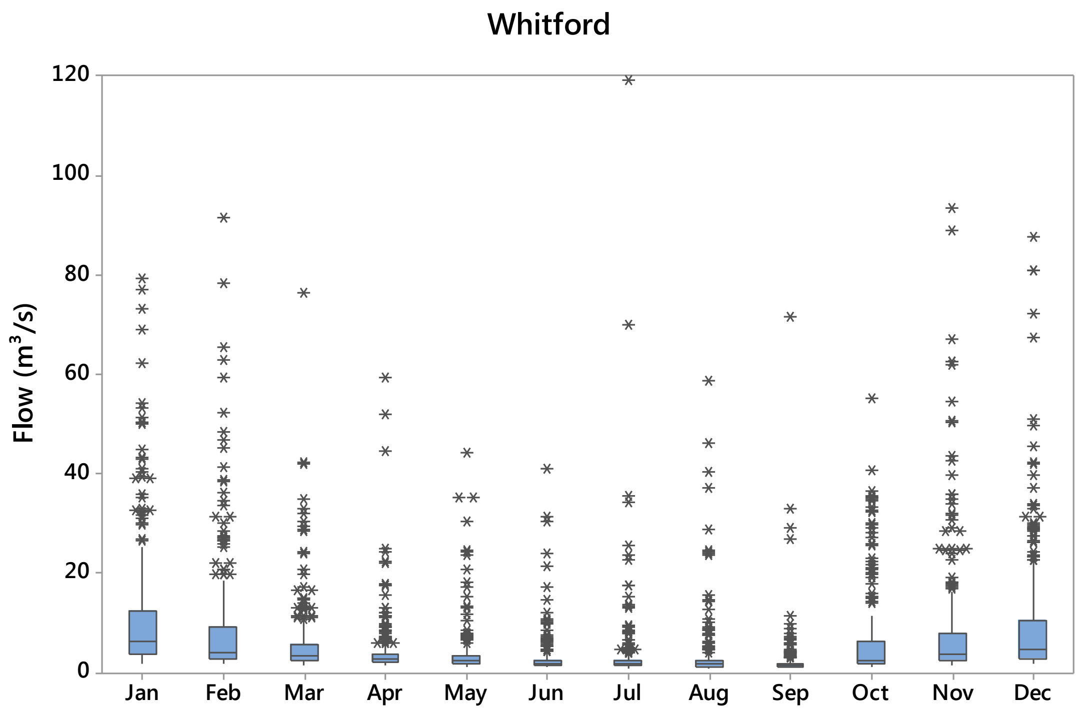

Figure VIII.3: Boxplots of mean daily flow records from the Whitford gauging station on the Axe watercourse (2004-2014)

Flows were higher on average during the colder months (November through to February) on both watercourses. High flow events were recorded in most if not all months of the year, but there tended to be a greater number of higher magnitude events during the autumn and winter. The seasonal pattern of flows is not entirely dependent on rainfall as during the colder months there is less evaporation and transpiration, leading to a higher water table. This in turn leads to a greater level of runoff immediately after rainfall. Increased levels of runoff are likely to result in an increase in the amount of microorganisms carried into coastal waters. Additionally, higher runoff will decrease residence time in rivers, allowing contamination from more distant sources to have an increased impact during high flow events.

Bacteriological testing data was available for the Axe and the Sid just above their tidal limits. Results are summarised in Figure VIII.4 and Table VIII.2.

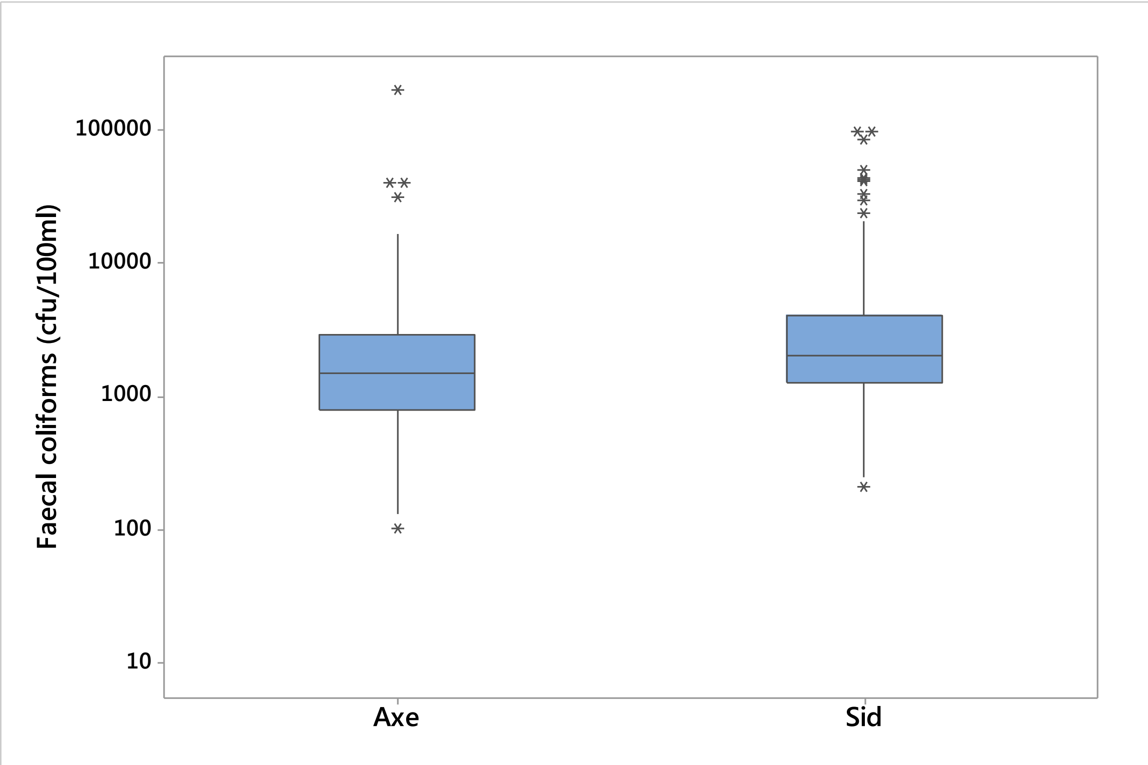

Figure VIII.4: Boxplot of faecal coliform concentrations in the Axe and Sid just above their tidal limits
Contains Environment Agency information © Environment Agency and database right

Table VIII.2: Summary statistics for faecal coliforms in the Axe and Sid

River	No.	Date of first sample	Date of last sample	Faecal coliforms presumptive (cfu/100 ml)		
				Geometric mean	Minimum	Maximum
Axe	96	19/06/2006	19/09/2011	1,674	104	100,000
Sid	145	08/05/2001	21/09/2007	2,683	210	>100,000

Contains Environment Agency information © Environment Agency and database right

The average and peak bacterial concentrations indicate that these watercourses are potentially significant contaminating influences, in the vicinity of their outfalls at least. Estimates of the average bacterial loading they deliver are approximately $1x10^{12}$ and $9x10^{12}$ faecal coliforms/day for the Axe and Sid respectively. The variation in faecal coliform concentrations span four orders of magnitude, so together with the large range in discharge rates the bacterial loading delivered by these watercourses can vary enormously.

The size and shape of their estuaries is of importance in determining the spatial pattern of impacts of the various watercourses discharging to Lyme Bay. Watercourses with no estuary will generate a plume of runoff in the bay throughout both the flood and ebb tide. For those with a significant estuary plume formation outside of the estuary mouth will be limited to the ebb tide only. Both the Otter and Axe have estuaries which extend a significant distance inland, whereas the Sid and minor streams do not.

.

Appendix IX. Hydrography

IX.1. Bathymetry

Lyme Bay is a large, open, south facing embayment on the western English Channel. It stretches 65 kilometres from Start Point to Portland Bill. The mussel farm which is the subject of this survey lies towards the western end of the bay, between Straight Point and Charton Bay, between 3 and 10 km offshore. Figure IX.1 shows the bathymetry of the survey area, taken from Admiralty Chart 3315.

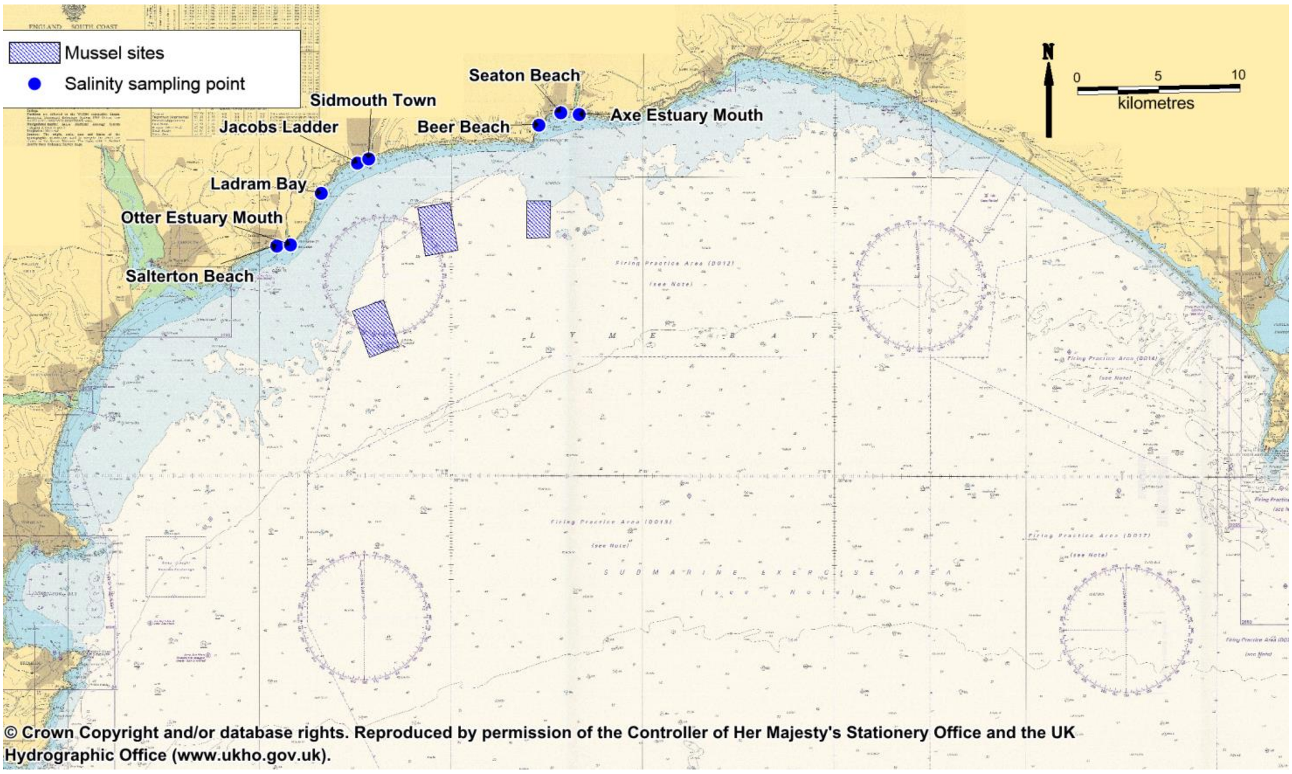

Figure IX.1: Bathymetry chart of Lyme Bay Survey area and salinity sampling locations

The bathymetry of Lyme Bay is relatively uncomplicated, sloping gently away from the coast to a depth of between 20 and 25 m relative to chart datum where the mussel sites are located, then continuing to a depth of about 50 m in the central outer reaches of the Bay. Portland Bill and Start Point are headlands around which tidal streams are likely to accelerate. There are also some smaller headlands such as Beer Head and Straight Point in the western part of the bay. The shore of the eastern part of the bay is backed by Chesil Beach, a shingle bar. The rest of Lyme Bay is mainly backed by cliffs, apart from where the various watercourses drain to it. Two large estuaries (Exe and Teign) drain to the western part of the bay about 11 and 18 km from the westernmost mussel site. The smaller Otter and Axe estuaries drain to the shore directly to the north of the mussel sites. The ebb plumes from these estuaries are likely to represent hotspots of contamination within the bay, and may be an influence at the mussel sites if they are advected towards them. The characteristics of these estuaries are summarised in Table IX.1

Table IX.1: Selected characteristics of the four main estuaries in the vicinity of the mussel sites

Estuary	Area (m^2)	Volume (m^3)	Percentage intertidal	River input (m^3/sec)		Flow ratio *	
				Mean	Max	Mean	Max
Axe	$7.90x10^5$	$2.61x10^6$	79%	5.03	107.9	0.087	1.861
Otter	$3.60x10^5$	$1.13x10^6$	53%	2.84	60.4	0.113	2.411
Exe	$1.81x10^7$	$2.25x10^7$	58%	23.34	370.6	0.047	0.741
Teign	$3.70x10^6$	$1.24x10^7$	59%	9.31	141.6	0.034	0.515

Data from Futurecoast, 2002

* Ratio of river input / tidal exchange.

The Exe is the largest of these estuaries in terms of freshwater inputs. The mean flow ratio is low indicating that the plume will be well mixed and usually of a high salinity, although at high river flows it will contain a much higher proportion of land runoff. The Teign is smaller, and has similar mean and maximum flow ratios. The Otter and Axe estuaries are much smaller, and have higher flow ratios. This indicates that land runoff in their ebb plumes will be less diluted with seawater, and will therefore be less saline and generally carry higher concentrations of faecal indicator bacteria. The volumes draining from the latter two estuaries will however be much lower than for the Exe and Teign.

IX.2. Tides and Currents

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. Tidal amplitude is moderate to large, and tidal streams are likely to dominate patterns of water circulation in the bay under most conditions. Table IX.2 shows the tidal ranges at four ports within Lyme Bay, with Exmouth being the closest port to the shellfish beds.

Table IX.2: Tide levels and ranges at four ports in Lyme Bay

	Height (m) above Chart Datum				Range (m)	
Port	MHWS	MHWN	MLWN	MLWS	Springs	Neaps
Start Point	5.4	4.2	2.3	1.0	4.4	1.9
Exmouth (Approaches)	4.6	3.4	1.7	0.5	4.1	1.7
Lyme Regis	4.3	3.1	1.7	0.6	3.7	1.4
Chesil Cove	4.0	2.8	1.7	0.6	3.4	1.4

Data from Admiralty TotalTide©

Table IX.3 presents the direction and rate of tidal streams at six locations within Lyme Bay at hourly intervals before and after high water at Plymouth (Devonport), which arrives about 45 minutes earlier than at Exmouth. Figure IX.2 presents peak flood and ebb vectors.

Table IX.3: Tidal stream predictions for Lyme Bay summarised from Admiralty Chart 3315

Time before /after High Water	Station A		
	Direction (°)	Rate (m/s) Spring	Neap
HW-6	218	0.41	0.21
HW-5	226	0.46	0.26
HW-4	214	0.57	0.31
HW-3	211	0.31	0.15
HW-2	290	0.10	0.05
HW-1	11	0.21	0.10
HW	25	0.36	0.21
HW+1	36	0.36	0.21
HW+2	43	0.36	0.21
HW+3	60	0.26	0.15
HW+4	100	0.10	0.05
HW+5	125	0.10	0.05
HW+6	210	0.31	0.15
Excursion (west)		7.8 km	4.1 km
Excursion (east)		6.3 km	3.5 km

Time before /after High Water	Station B		
	Direction (°)	Rate (m/s) Spring	Neap
HW-6	250	0.31	0.15
HW-5	254	0.51	0.26
HW-4	254	0.51	0.26
HW-3	261	0.31	0.15
HW-2	330	0.05	0.05
HW-1	56	0.21	0.10
HW	67	0.31	0.15
HW+1	69	0.41	0.21
HW+2	75	0.36	0.21
HW+3	83	0.31	0.15
HW+4	94	0.21	0.10
HW+5	219	0.15	0.10
HW+6	242	0.26	0.10
Excursion (west)		7.6 km	3.9 km
Excursion (east)		6.5 km	3.3 km

Time before /after High Water	Station C		
	Direction (°)	Rate (m/s) Spring	Neap
HW-6	252	0.36	0.21
HW-5	265	0.67	0.31
HW-4	271	0.67	0.31
HW-3	281	0.46	0.26
HW-2	306	0.21	0.10
HW-1	29	0.21	0.10
HW	59	0.36	0.15
HW+1	67	0.46	0.26
HW+2	74	0.57	0.26
HW+3	81	0.57	0.26
HW+4	93	0.36	0.21
HW+5	136	0.15	0.10
HW+6	229	0.21	0.10
Excursion (west)		9.3 km	4.6 km
Excursion (east)		9.6 km	4.8 km

Time before /after High Water	Station D		
	Direction (°)	Rate (m/s) Spring	Neap
HW-6	276	0.26	0.15
HW-5	289	0.51	0.26
HW-4	297	0.57	0.31
HW-3	302	0.46	0.21
HW-2	297	0.15	0.10
HW-1	41	0.15	0.05
HW	102	0.26	0.10
HW+1	111	0.31	0.15
HW+2	117	0.41	0.21
HW+3	120	0.41	0.21
HW+4	122	0.31	0.15
HW+5	118	0.10	0.05
HW+6	265	0.21	0.10
Excursion (west)		7.8 km	4.1 km
Excursion (east)		7.0 km	3.3 km

Time before /after High Water	Station E		
	Direction (°)	Rate (m/s) Spring	Neap
HW-6	312	0.51	0.26
HW-5	303	0.93	0.46
HW-4	318	0.87	0.41
HW-3	337	0.57	0.31
HW-2	12	0.57	0.26
HW-1	57	0.46	0.26
HW	89	0.62	0.31
HW+1	108	0.82	0.41
HW+2	115	0.82	0.41
HW+3	124	0.87	0.41
HW+4	133	0.67	0.31
HW+5	162	0.26	0.10
HW+6	304	0.31	0.15
Excursion (west)		11.5 km	5.7 km
Excursion (east)		18.3 km	8.9 km

Time before /after High Water	Station F		
	Direction (°)	Rate (m/s) Spring	Neap
HW-6	286	0.82	0.41
HW-5	290	1.44	0.72
HW-4	302	1.64	0.82
HW-3	318	1.49	0.77
HW-2	323	0.87	0.46
HW-1	0	0.51	0.26
HW	80	0.67	0.31
HW+1	100	1.23	0.62
HW+2	111	1.29	0.67
HW+3	124	1.34	0.67
HW+4	126	0.98	0.51
HW+5	148	0.26	0.10
HW+6	283	0.57	0.26
Excursion (west)		26.5 km	13.3 km
Excursion (east)		20.7 km	10.4 km

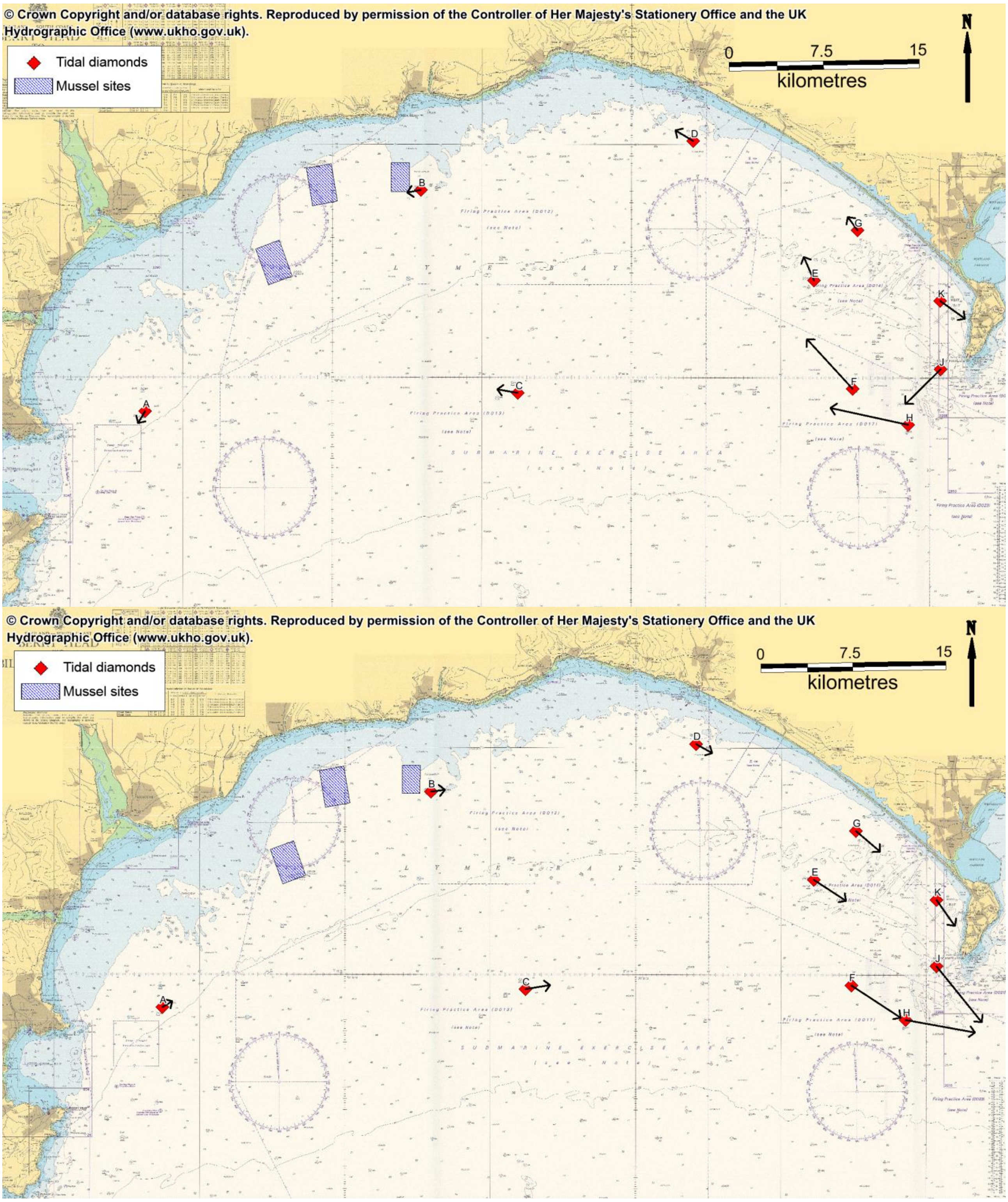

Figure IX.2: Location of tidal diamonds, and direction and relative strength of tidal streams during peak westwards flows (top) and peak eastward flows (bottom) during spring tides. The length of the arrows indicate the distance a particle would travel in an hour, assuming it carried on at the speed and direction indicated by the diamond.

Tides throughout most of the bay are bidirectional, with east and westward going streams that travel roughly parallel to the coast. The tidal diamonds indicate that the eastwards tidal stream starts to run between one and two hours before high water at Plymouth, or between two and three hours before high water at Exmouth. This continues until between four and five hours after high water at Plymouth, or between three and four hours after high water at

Exmouth, at which point it reverts to an eastwards flow. The main exception to this bidirectional pattern arises to the west of Portland Bill, where a clockwise eddy forms for much of time when the tide is heading westwards throughout the rest of the bay. No other large scale eddies are apparent either on Figure IX.2 or the more detailed tidal stream atlas for Lyme Bay (UK Hydrographic Office, 2003).

Tidal diamond B is located approximately 1 km east of the easternmost mussel site and is likely to best represent the tidal streams at the farm. The maximum tidal flows here are 0.51 m/s on a west-going tide and 0.36 m/s on an east-going tide. An estimate of tidal excursion based on this diamond is roughly 7 km on spring tides and half of that on neap tides. Peak current velocities are similar at surrounding diamonds (A, C & D) ranging from 0.57 m/s to 0.67 m/s, suggesting relatively homogeneous tidal streams throughout the mussel farm areas. Towards Portland tidal streams become much stronger where they are forced around Portland Bill. Near bed flows and flows in shallower near shore areas are likely to be slower than surface flows due to the effects of friction.

Contamination from sources discharging to the shoreline will travel parallel to the coast becoming progressively diluted with time and distance, and will therefore impact along the near shore zone to either side of their location. Whilst the tide is ebbing, and the Exe and other estuaries are draining, the tide will carry their plumes of more contaminated and less saline water eastwards for the first 2-3 hours, then westwards until low water. They will be filling for the rest of the tidal cycle so will not emit a plume at these times. Contamination will not be carried directly towards the mussel farm by tidal streams. It will remain inshore of them in the first instance, but may eventually arrive there several tidal cycles after release and not before significant dilution and bacterial die off. It is therefore concluded that shoreline and nearshore sources are unlikely to be a major contaminating influence at the mussel farm, nor are they likely to cause marked spatial variation in levels of contamination across the sites.

Superimposed on tidally driven currents are the effects of density and winds. Density effects may arise through vertical and horizontal differences in either salinity or temperature. Given the relatively weak tidal currents and the uniform nature of the bathymetry, significant turbulent mixing of the water column in the vicinity of the mussel farm is unlikely to occur through tidal action alone. It is however possible that the mussel lines will induce some turbulence as tidal streams pass through them, particularly when the farm is fully developed. The plumes of low salinity water emanating from the mouths of the various estuaries will be less dense than the more saline seawater and so will have a tendency to spread out and to float on the surface. Vertical differences in salinity may be accompanied by corresponding vertical differences in faecal indicator organism concentrations, depending on how much bacterial die-off has occurred. Vertical density gradients may also result in some vertical shear in current speed and direction.

Observations of current speed and direction, salinity and temperature were repeatedly made along a transect running from the centre of Site 1 through to the centre of Site 2 during spring and neap tides in August 2013 and March 2014 (Offshore Shellfish Ltd, pers. comm.). Current speeds and directions were similar to that predicted by the tidal diamonds. During the summer surveys, salinities were between 34.4 and 34.5 ppt throughout the water column and no significant horizontal variation was observed. During the March surveys, vertical differences in salinity of up to 0.3 ppt were observed across the water column, with minimum values of 34.15 ppt. The pycnocline was at a depth of about 10 m. A horizontal gradient in salinity was also observed in some of these transects, whereby surface salinity at the southwestern end of the transect (Site 1) was up to 0.2 ppt lower than at the other end (Site 2). Lowest salinities were recorded whilst the tide was running eastwards, possibly suggesting that the Exe estuary may be the main source of freshwater in the area. It is unlikely that these relatively small variations in salinity translate to consistent and noticeable variation in levels of contamination across the mussel sites, either vertically or horizontally, but they do suggest that the north western corner of Site 1 may be most exposed to the remnants of any plumes originating from the Exe estuary.

A series of salinity measurements were made at the bathing waters sampling points, alongside the bacteriological testing. They all lie in the intertidal areas to the north of the mussel sites, and two lie in the mouths of estuaries (Otter Estuary and Axe Estuary).

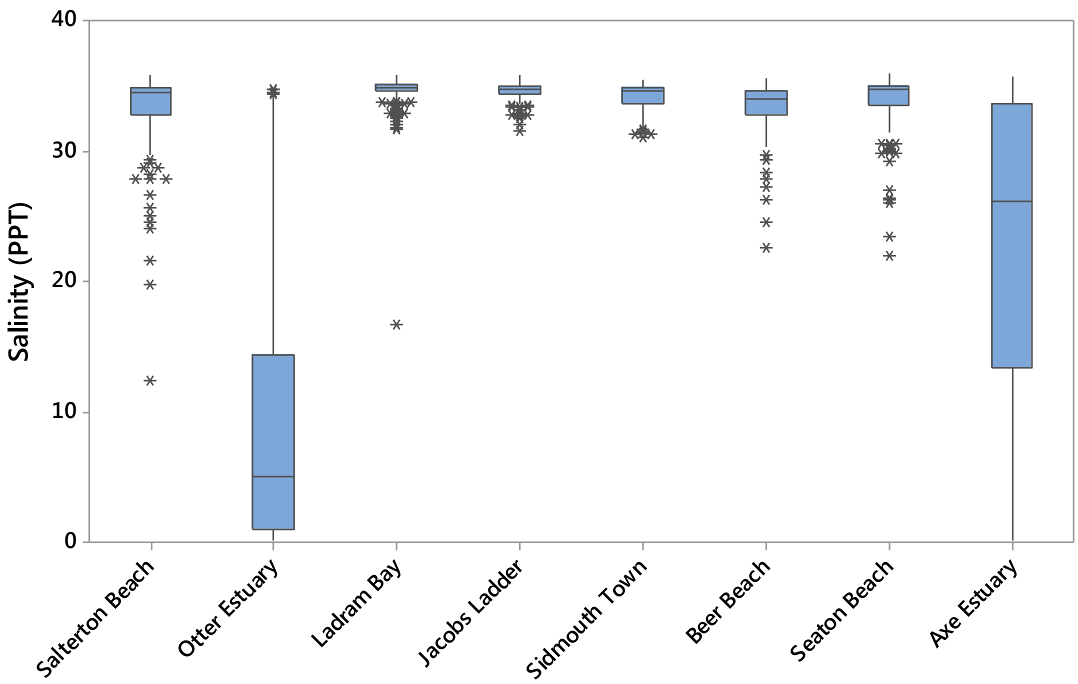

Figure IX.3: Box-and-whisker plots of levels of salinity readings taken between March and December (for the period 2004 - 2014).

Contains Environment Agency information © Environment Agency and database right

Salinity at the mouths of the Axe and Otter estuaries ranged from that of full strength seawater through to that of pure fresh water. It was lower on average at the Otter estuary mouth, which is consistent with its smaller volume in relation to its freshwater inputs. Salinities at the beaches were typically approaching that of full strength seawater, although at most locations salinities of less than 30 ppt were occasionally recorded. This indicates that strong freshwater influence within the bay is generally limited to the immediate vicinity of the estuary mouths, although at times of high freshwater inputs their region of influence along the shore may be extended.

Winds may have a significant effect on water circulation within the bay. Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so gale force wind (34 knots or 17.2 m/s) would drive a current of about 0.5 m/s. These surface currents drive return currents which may travel lower in the water column or along sheltered margins. The area in which the mussel sites are located is offered some shelter from northerly and to a lesser extent westerly winds by the surrounding land, and is most exposed to winds from the south. Northerly winds would tend to push contamination from shoreline sources towards the mussel sites, so periods of strong northerly winds are likely to represent the highest risk of significant impacts from land based sources. 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. Strong winds will also induce wave action, which will lead to increased mixing of the water column in offshore areas, and the re-suspension of sediment entrained contamination in intertidal areas. Southerly winds and swells are likely to be most effective in generating energetic wave action in the vicinity of the mussel sites.

Appendix X. Microbiological data: Seawater

There are six bathing waters along the stretch of coast considered in this survey, designated under the Directive 76/160/EEC (Council of the European Communities, 1975). All are located in intertidal areas (Figure X.1).

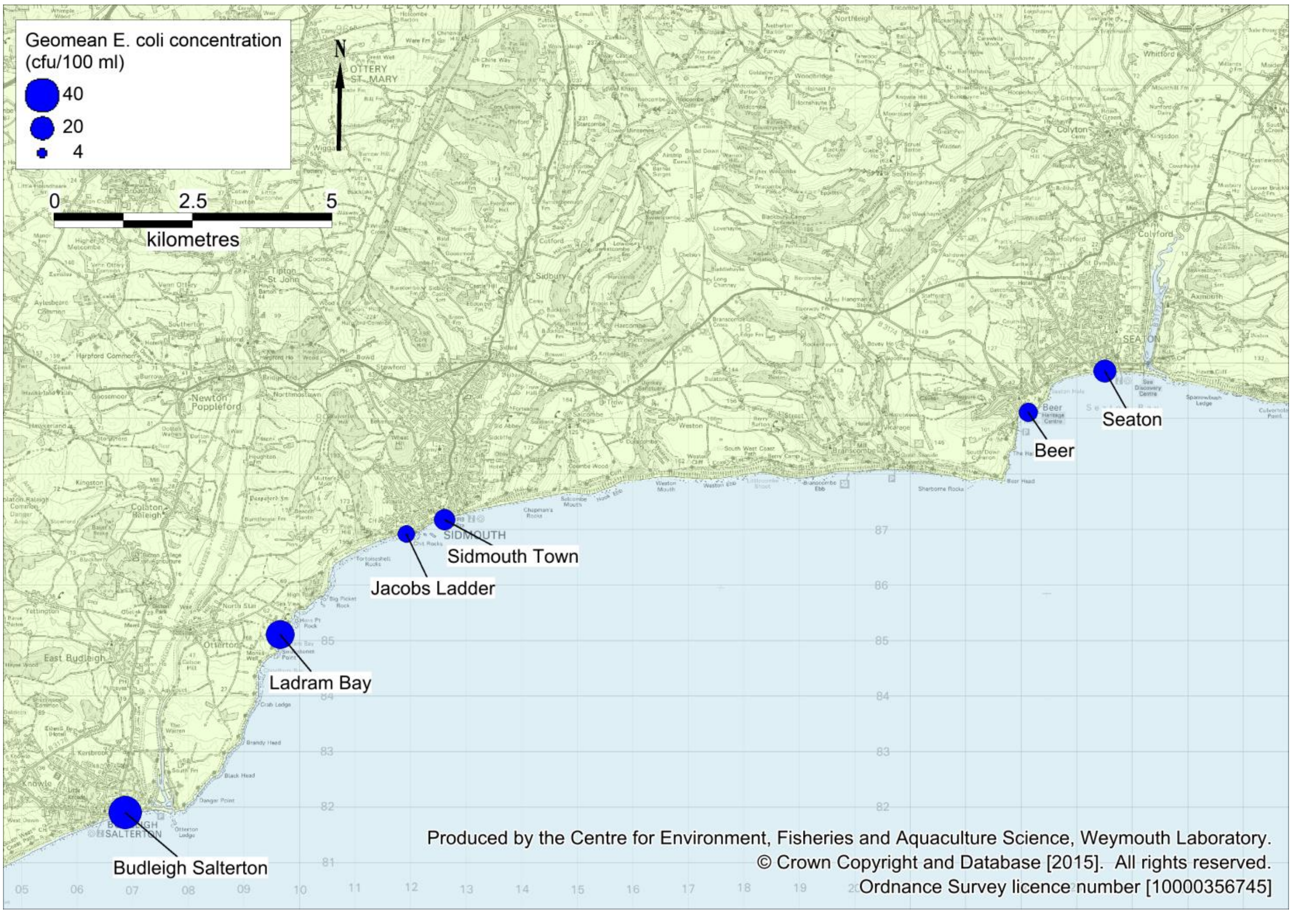

Figure X.1: Location of designated bathing waters monitoring points in Lyme Bay
Contains Environment Agency information © Environment Agency and database right

Due to changes in the analyses of bathing water quality by the Environment Agency, only *E. coli* data from 2012 were available for analysis. Summaries of the *E. coli* results are presented in Table X.1.

Table X.1: Summary statistics for bathing waters *E. coli* results, 2012-2014 (cfu/100 ml).

Sampling Site	N.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1,000	% over 10,000
Budleigh Salterton	97	02/05/2012	22/07/2014	37.4	<10	8,600	33.0	6.2	0.0
Ladram Bay	54	02/05/2012	22/07/2014	29.0	<10	791	22.2	0.0	0.0
Jacobs Ladder	52	02/05/2012	22/07/2014	11.5	<10	240	9.6	0.0	0.0
Sidmouth Town	54	02/05/2012	22/07/2014	17.0	<10	1,800	11.1	3.7	0.0
Beer	52	02/05/2012	22/07/2014	14.6	<10	4,000	11.5	1.9	0.0
Seaton	52	02/05/2012	22/07/2014	20.0	<10	1,700	15.4	1.9	0.0

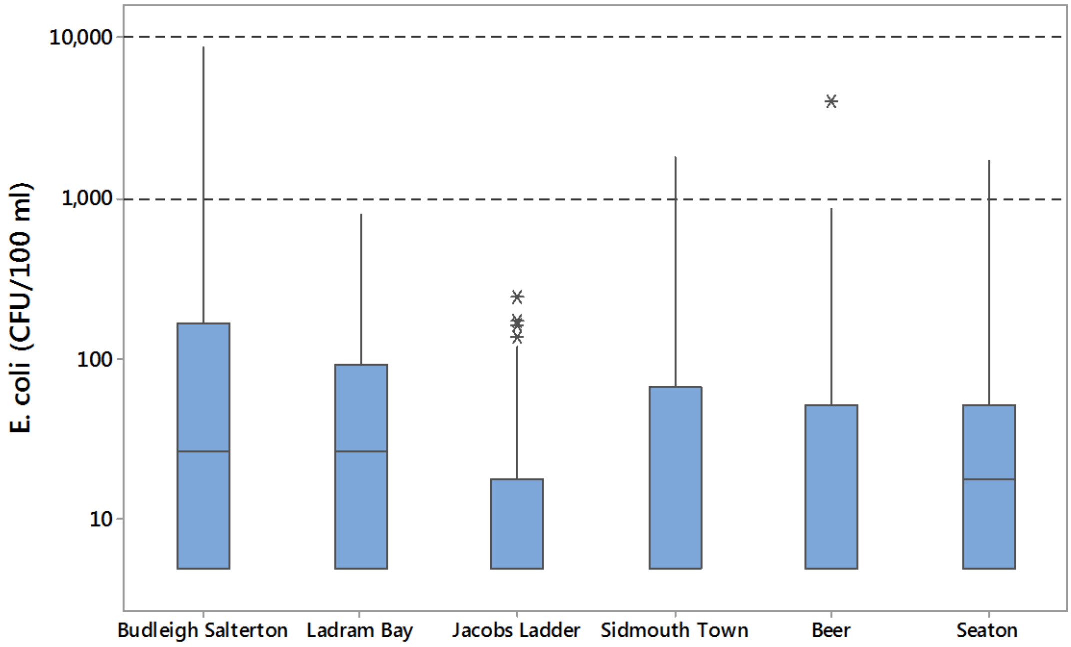

Figure X.2: Box-and-whisker plots of all *E. coli* results by site

Budleigh Salterton sampling site had the highest geometric mean and maximum *E. coli* concentrations, while Jacobs Ladder, had the lowest geometric mean and maximum *E. coli* concentrations. A one-way ANOVA test showed that there were significant differences in *E. coli* concentrations between sites (p<0.001). Post ANOVA Tukey tests showed that *E. coli* concentrations at Jacobs Ladder were significantly lower than at Budleigh Salterton and Ladram Bay. *E. coli* concentrations were also significantly lower at Beer than at Budleigh Salterton.

Correlations (Pearson's) were run between samples at the sites that shared sampling dates, and therefore environmental conditions, on at least 20 occasions. All sites correlated significantly with all other sites (p=0.018 or less) indicating that these sites are likely to be affected by contamination sources which respond in a similar way to environmental conditions.

Overall temporal pattern in results

The overall variation in *E. coli* levels found at bathing water sites is shown in Figure X.3. However, no sites were sampled consistently for long enough to show any trends.

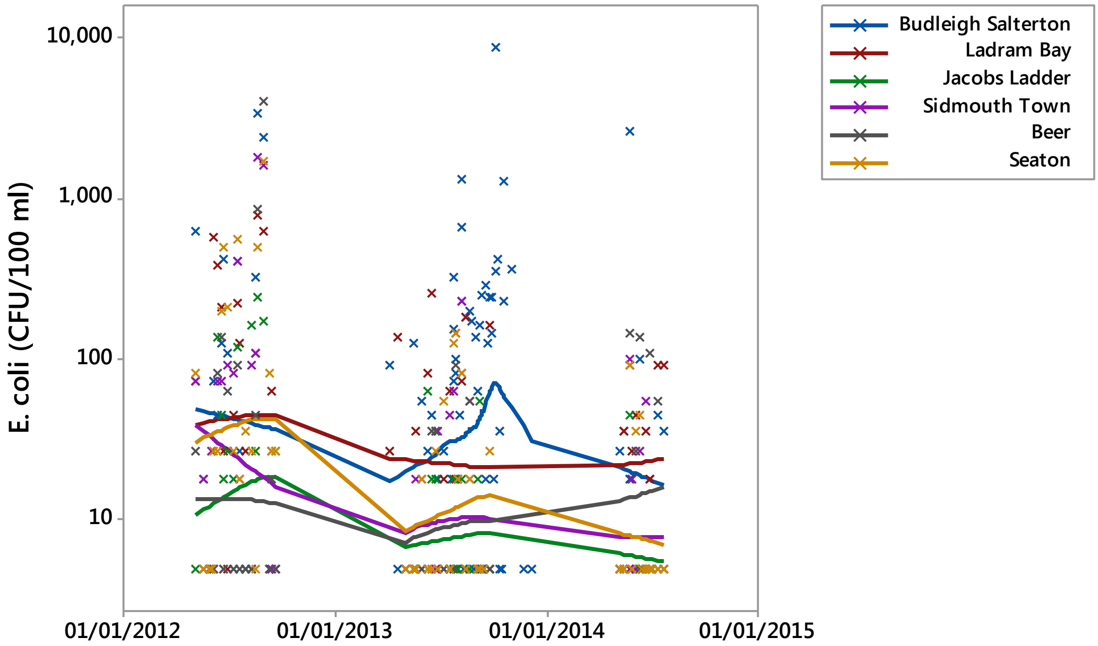

Figure X.3: Scatterplot of *E. coli* results for bathing waters in the Lyme Bay overlaid with loess lines.
Contains Environment Agency information © Environment Agency and database right

E. coli concentrations have remained fairly stable across Lyme Bay since 2012, although fewer high results were recorded in 2014.

Influence of tides

To investigate the effects of tidal state on *E. coli* 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.2 and statistically significant correlations are highlighted in yellow.

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

	High/low tides		Spring/neap tides	
Site Name	**r**	**p**	**r**	**p**
Budleigh Salterton	0.434	<0.001	0.426	<0.001
Ladram Bay	0.343	0.002	0.314	0.007
Jacobs Ladder	0.097	0.632	0.212	0.110
Sidmouth Town	0.121	0.476	0.106	0.563
Beer	0.165	0.264	0.335	0.004
Seaton	0.008	0.997	0.239	0.061

Contains Environment Agency information © Environment Agency and database right

Figure X.4 presents polar plots of $\log_{10}$ *E. coli* results against tidal states on the high/low cycle for the correlations indicating a statistically significant effect. High water at Lyme Regis is at 0° and low water is at 180°. Results of 100 *E. coli* 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.

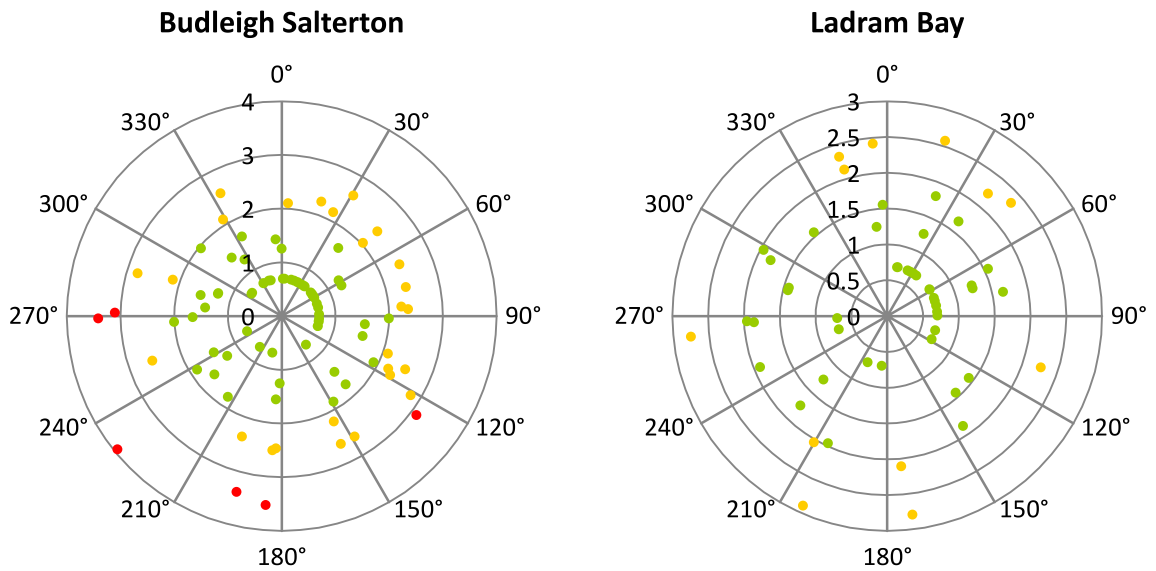

Figure X.4: Polar plots of $\log_{10}$ *E. coli* results (cfu/100 ml) against high/low tidal state.
Contains Environment Agency information © Environment Agency and database right

At both Budleigh Salterton and Ladram Bay, higher *E. coli* concentrations tended to occur at lower states of the tide, possibly relating to the lower dilution potential at such times.

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

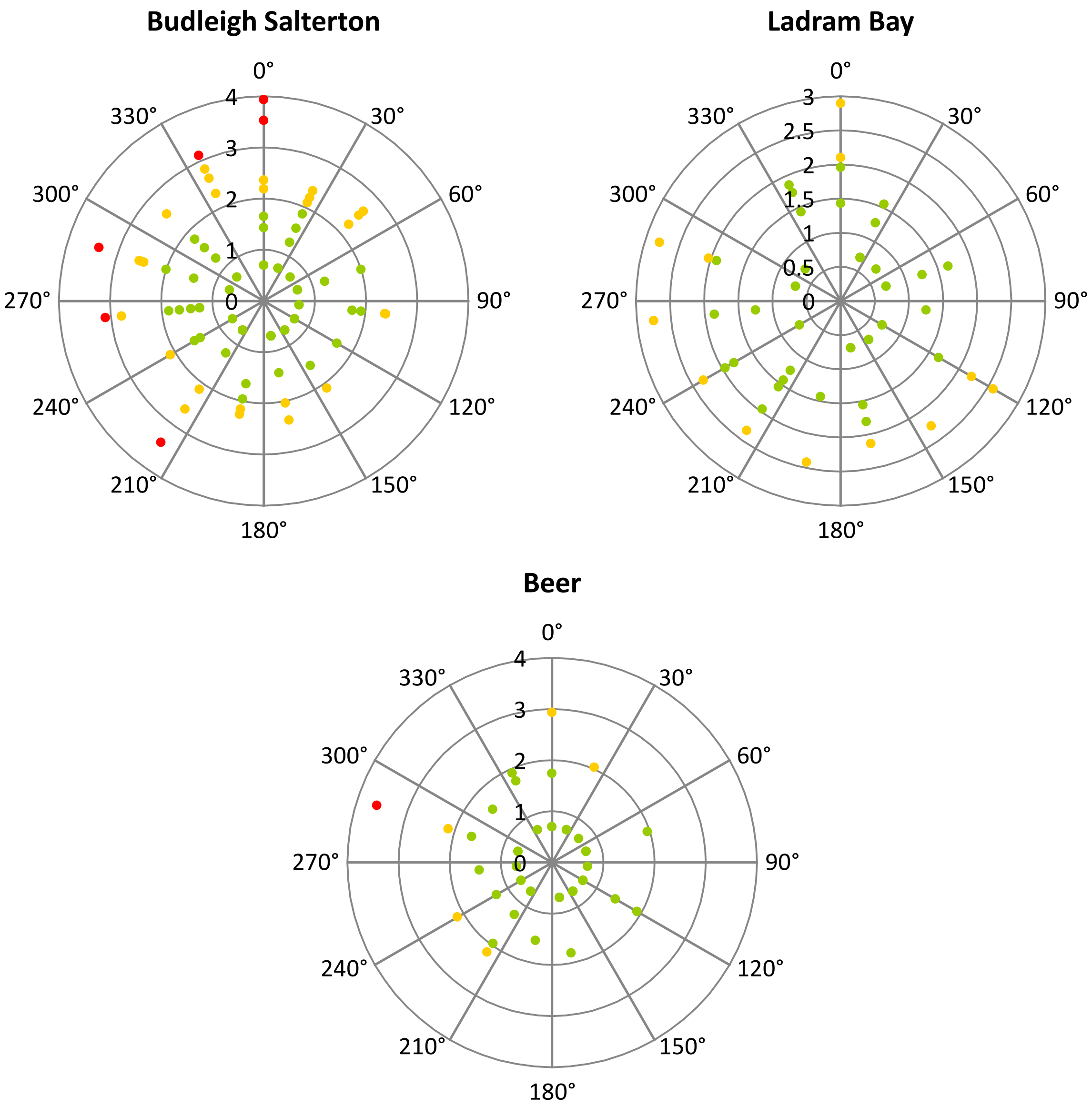

Figure X.5: Polar plots of $\log_{10}$ *E. coli* results (cfu/100 ml) against spring/neap tidal state.
Contains Environment Agency information © Environment Agency and database right

E. coli results tended to be lower during the decreasing tide sizes at Budleigh Salterton and Beer, and during spring tides at Ladram Bay.

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 Kersbrook Lodge weather station (Appendix VI for details) over various periods running up to sample collection and *E. coli* results. These are presented in Table X.3 and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table X.3: Spearmans Rank correlation coefficients for *E. coli* results against recent rainfall

	Site	Budleigh Salterton	Ladram Bay	Jacobs Ladder	Sidmouth Town	Beer	Seaton
	n	80	42	40	40	40	40
24 hour periods prior to sampling	1 day	0.278	0.275	0.295	0.156	0.340	0.187
	2 days	0.042	0.288	0.179	0.351	0.379	0.155
	3 days	0.200	0.360	0.354	0.247	0.137	0.283
	4 days	0.137	0.077	0.072	0.235	0.124	0.109
	5 days	0.033	0.171	0.246	0.266	0.180	0.271
	6 days	-0.011	0.132	0.173	0.258	0.261	0.270
	7 days	0.095	0.062	0.141	0.227	0.183	0.186
Total prior to sampling over	2 days	0.221	0.335	0.283	0.286	0.441	0.207
	3 days	0.287	0.373	0.433	0.281	0.393	0.323
	4 days	0.345	0.336	0.357	0.328	0.403	0.370
	5 days	0.303	0.294	0.345	0.375	0.408	0.329
	6 days	0.231	0.279	0.333	0.393	0.417	0.356
	7 days	0.217	0.264	0.334	0.391	0.43	0.339

E. coli concentrations at all sites were higher following a rainfall event.

Salinity

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

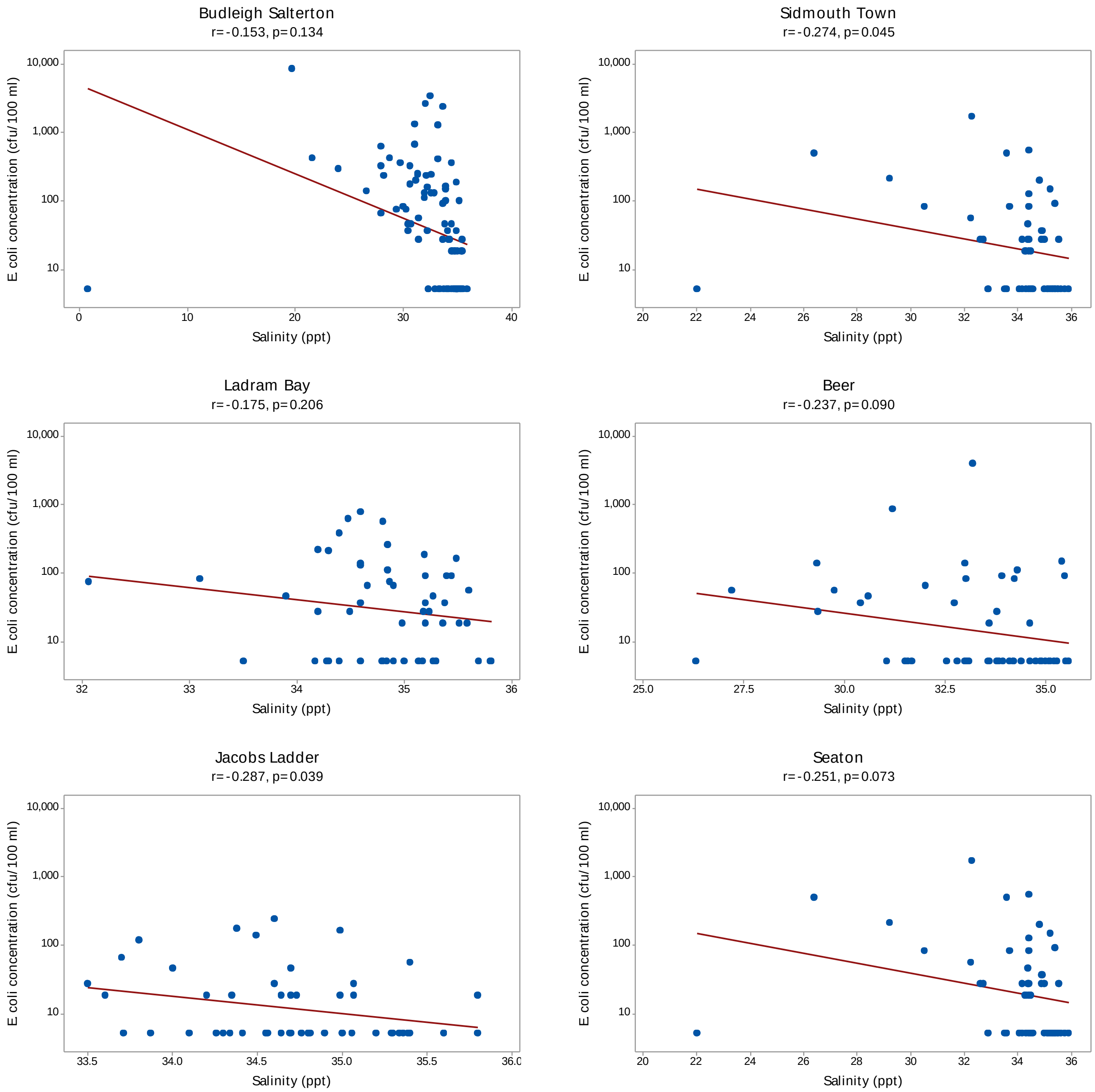

Figure X.6: Scatter-plots of salinity against *E. coli* concentration.

Contains Environment Agency information © Environment Agency and database right

E. coli levels correlated significantly with salinity at Ladram Bay, Jacobs Ladder and Sidmouth Town. This indicates that freshwater inputs have a significant effect on contamination levels at these three sites.

Appendix XI. Microbiological Data: Shellfish Flesh

The only shellfish flesh monitoring results available derive from a bacteriological surveys undertaken on in November 2014 and March 2015.

Lyme Bay bacteriological survey (November 5th 2014)

The survey was undertaken in dry conditions, with a light to moderate north easterly wind (Beaufort force 2-4). Mussel samples were taken from the top and bottom of the dropper ropes at each end of sites 1 and 2 and enumerated for *E. coli*. Water samples were also taken from these points at the surface and 10 m depth.

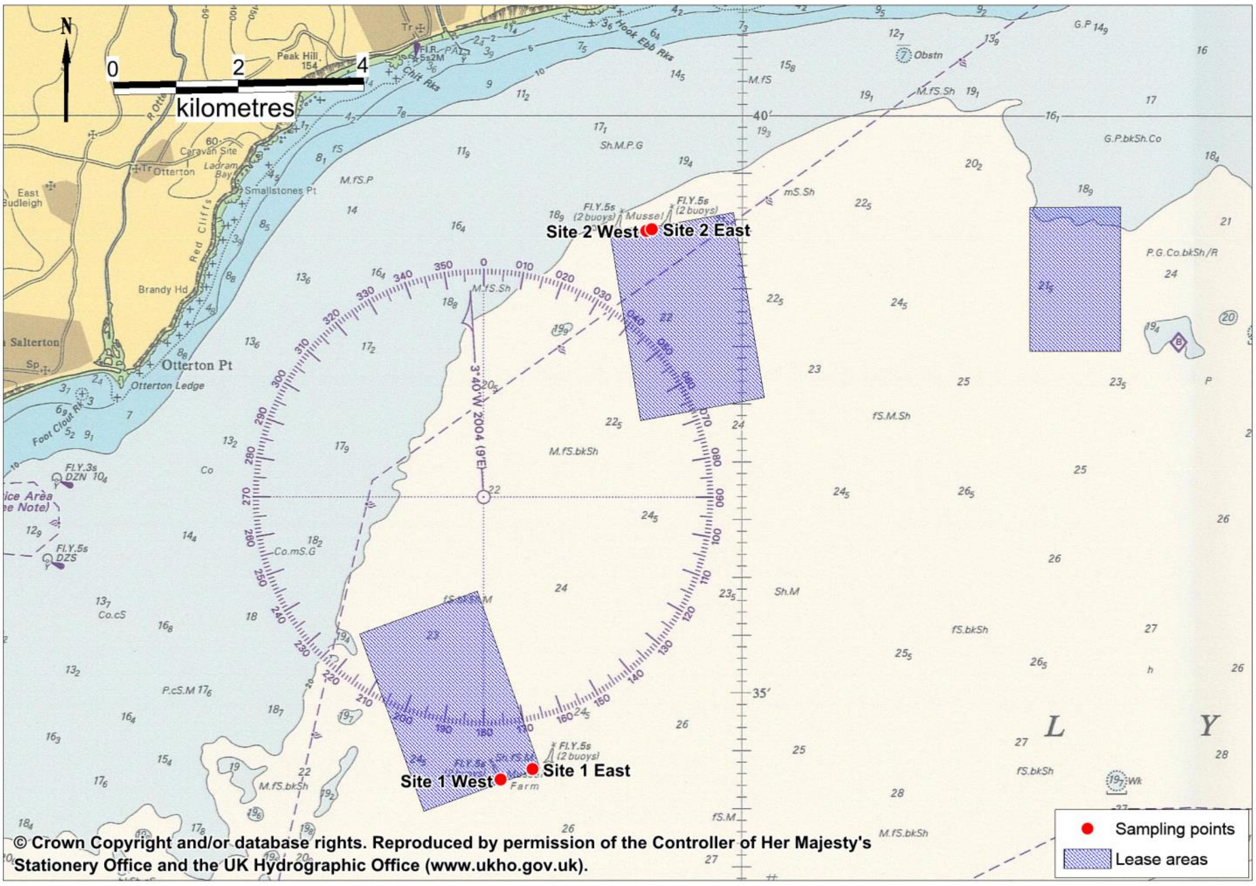

Figure XI.1: Mussel flesh and water sampling locations

Table XI.1: Mussel sample results

Location	Depth	*E. coli* (MPN/100 g)	Mean shell length (mm)
Site 1 West	3 m	1,700	47.2
Site 1 West	5 m	2,400	41.3
Site 1 West	12 m	78	40.2
Site 1 East	3 m	490	36.3
Site 1 East	12 m	230	37.2
Site 2 West	3 m	230	37.0
Site 2 West	12 m	16,000	34.1
Site 2 East	3 m	790	34.8
Site 2 East	12 m	45	42.5

Table XI.2: Water sample results

Location	Depth	*E. coli* (MPN/100 ml)	Salinity (ppt)
Site 1 West	Surface	7	34.9
Site 1 West	10 m	6	34.8
Site 1 East	Surface	<1	34.8
Site 1 East	10 m	<1	34.7
Site 2 West	Surface	<1	34.8
Site 2 West	10 m	<1	34.8
Site 2 East	Surface	<1	34.4
Site 2 East	10 m	<1	34.7

The results obtained for mussels were unexpectedly high and variable considering the samples were taken from a homogeneous water body over 3 km offshore and remote from any point sources of contamination. The highest and lowest individual results were taken from either end of site 2 from the bottom of the lines for example (16,000 and 45 *E. coli* MPN/100 g) at locations only about 100 m apart. The explanation that this was a result of a significant local source of contamination does not appear likely, and no possible sources (e.g. yachts, bird aggregations) were observed in the vicinity of the farm by the surveyors. *E. coli* concentrations in the water column were below the limit of detection at three of the four locations, but at Site 1 West counts of 6 and 7 per 100 ml were recorded. Salinities were that of full strength seawater at all sampling points, with negligible vertical variation indicating that the water body is well mixed and fully marine.

<u>Lyme Bay bacteriological survey (March 2015)</u>

A second set of mussel and water samples were collected from Lyme Bay on the 16th March 2015 under dry conditions with moderate easterly winds (force 3-4). Samples were taken on a flooding tide, between 2 ½ and 3 ½ hours before high water at Brixham, which is roughly the time when tidal streams turn from westward flowing to eastward flowing. Mussel samples were taken from the top (3 m depth) and bottom (10 m depth) at the eastern and western ends of sites 1 and 2. The shell lengths of 10 mussels were measured from each of the eight samples. Surface water samples were also taken at each of the four locations from which the mussel samples were taken.

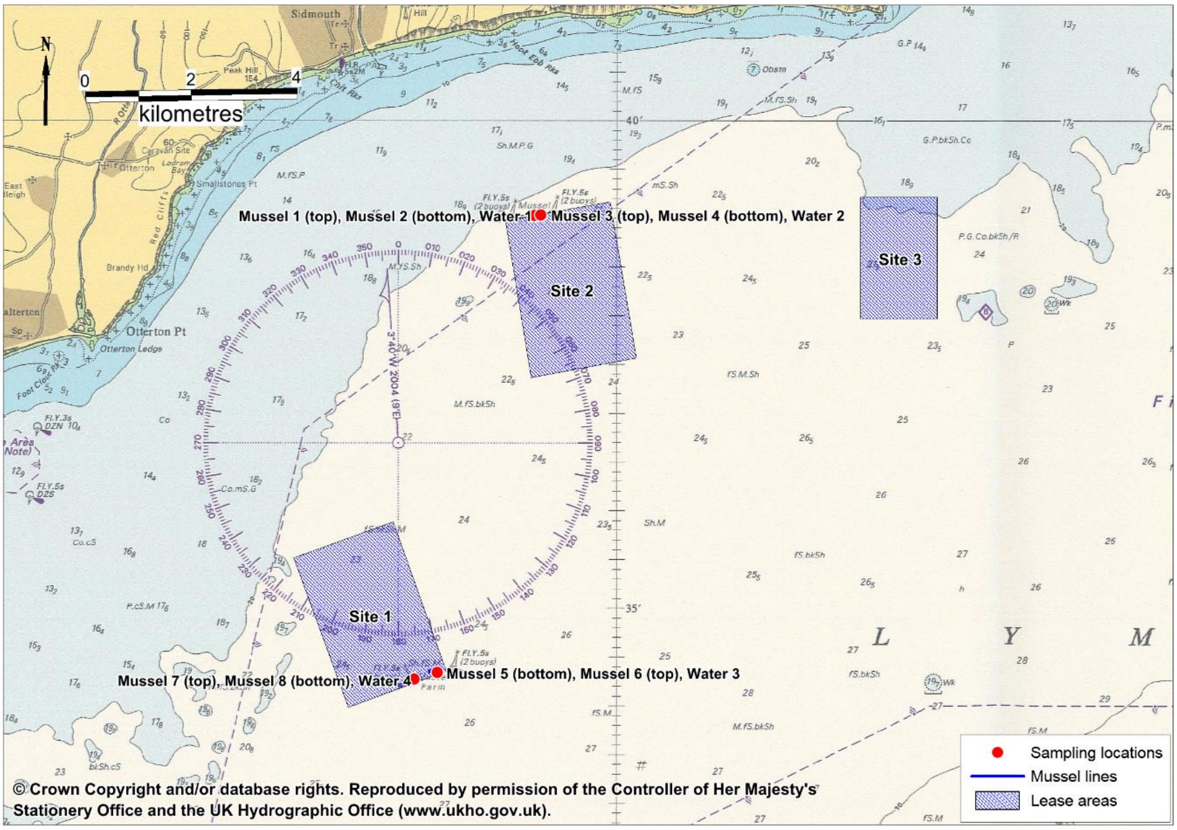

Figure XI.2: Sampling locations

Table XI.3: Mussel sample results

Location	Depth	*E. coli* (MPN/100g)	Mean shell length (mm)
Site 2 West	3 m	170	54.1
Site 2 West	10 m	130	53.5
Site 2 East	3 m	78	52.4
Site 2 East	10 m	68	49.8
Site 1 East	10 m	<18	57.1
Site 1 East	3 m	<18	55.5
Site 1 West	3 m	<18	53.6
Site 1 West	10 m	<18	54.2

Table XI.4: Water sample results

Location	Depth	*E. coli* (cfu/100ml)	Salinity (ppt)
Site 2 West	Surface	<1	*
Site 2 East	Surface	1	*
Site 1 East	Surface	<1	*
Site 1 West	Surface	<1	*

* *Instrument failure*

All mussel sample results were under 230 *E. coli* MPN/100 g. All samples from site 1 were below the limit of quantification for the test (18 *E. coli* MPN/100 g). At site 2 low levels of *E. coli* were present. Results were marginally higher for samples taken from 3 m depth, and were marginally higher towards the western end of the site. All mussels which were measured were in excess of 45 mm so they are now of a marketable size. Three of the four water samples contained *E. coli* levels of less than the limit of detection of the test (1 cfu/100 ml). The sample taken from Site 2 east contained 1 *E. coli* cfu/100 ml.

Appendix XII. Shoreline Survey

The competent authority (FSA) considered the mussel farm to be offshore and remote from sources of contamination so advised that a shoreline survey was not required. During the bacteriological survey (November 2015) no birds were observed on the floats or buoys, and no vessels were observed in the vicinity of the two lease areas visited. Information on the shellfishery was obtained from the harvester, which is presented in Section 4.

References

Ashbolt, J. N., Grabow, O. K., Snozzi, M., 2001. Indicators of microbial water quality. In Water quality: guidelines, standards and health. Fewtrell, L. and Bartram, J. (Eds). IWA Publishing, London. pp. 289−315.

Austin, G.E., Read, W.J., Calbrade, N.A., Mellan, H.J., Musgrove, A.J., Skellorn, W., Hearn, R.D., Stroud, D.A., Wotton, S.R., and Holt, C.A., 2014. Waterbirds in the UK 2011/12: The Wetland Bird Survey. BTO/RSPB/JNCC. Thetford.

Brereton, T., Lewis, K., MacLeod, C., 2013. Lyme Bay: A recently discovered hotspot for white-beaked dolphins in the English Channel. Proceedings of the ECS / ASCOBANS / WDC Workshop Towards a Conservation Strategy for White-beaked Dolphins in the Northeast Atlantic. Warsaw, Poland, 27-29 August 2013.

Brown J., 1991. The final voyage of the Rapaiti. A measure of surface drift velocity in relation to the surface wind. Marine Pollution Bulletin 22: 37-40.

Cefas, 2013a. Sanitary survey of the Exe estuary. 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.

Cefas 2013b. Sanitary survey of the Teign estuary. 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.

Council of the European Communities, 1975. Council Directive 76/160/EEC of 8 December 1975 concerning the quality of bathing water. Official Journal L031: 0001-0007.

Defra, 2009. Pigs and Poultry Farm Practices Survey 2009 – England. http://www.defra.gov.uk/evidence/statistics/foodfarm/enviro/farmpractice/documents/FPS2009-pigspoultry.pdf. Accessed October 2012.

Environment Agency (1999). Sid & Otter Local Environment Agency Plan. Consultation Draft. November 1999.

Environment Agency (2005). East Devon Catchment Flood Management Plan. Scoping Report. November 2005

EU Working Group on the Microbiological Monitoring of Bivalve Harvest Areas, 2014. Microbiological Monitoring of Bivalve Harvest Areas. Guide to Good Practice: Technical Application. Issue 5, June 2014.

European Communities, 2000. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, Official Journal the European Communities 22.12.2000 L327:1-72.

European Communities, 2004. EC Regulation No 854/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules on products of animal origin intended for human consumption. Official Journal of the European Communities L226: 83-127.

European Communities, 2006. Directive 2006/113/EC of the European parliament and of the Council of 12 December 2006 on the quality required of shellfish waters (codified version). Official Journal of the European Communities L376: 14-20.

Geldreich, E.E., 1978. Bacterial and indicator concepts in feces, sewage, stormwater and solid wastes. In Berg, G. (ed.). Indicators of Viruses in Water and Food. MI: Ann Arbor.

Hughes, C., Gillespie, I.A., O'Brien, S.J., 2007. Foodborne transmission of infectious intestinal disease in England and Wales 1992-2003. Food Control 18: 766−772.

Kay, D, Crowther, J., Stapleton, C.M., Wyler, M.D., Fewtrell, L., Anthony, S.G., Bradford, M., Edwards, A., Francis, C.A., Hopkins, M. Kay, C., McDonald, A.T., Watkins, J., Wilkinson, J., 2008a. Faecal indicator organism concentrations and catchment export coefficients in the UK. Water Research 42: 2649–2661.

Kay, D., Crowther, J., Stapleton, C.M., Wyer, M.D., Fewtrell, L., Edwards, A., Francis, C.A., McDonald, A.T., Watkins, J., Wilkinson, J., 2008b. Faecal indicator organism concentrations in sewage and treated effluents. Water Research 42: 442-454.

Lee, R.J., Younger, A.D., 2002. Developing microbiological risk assessment for shellfish purification. International Biodeterioration and Biodegradation 50: 177−183.

Lees, D.N., 2000 Viruses in bivalve shellfish. Int. J. Food. Microbiol. 59: 81-116.

Met Office, 2013. UK Regional Climates. Available at: http://www.metoffice.gov.uk/climate/uk/regional-climates Accessed November 2014

Mitchell, P. Ian, S. F. Newton, N. Ratcliffe & T. E. Dunn, 2004. Seabird Populations of Britain and Ireland, Results of the Seabird 2000 Census (1998-2002). T&AD Poyser, London.

MMO, 2014a. Mapping UK Shipping Density and Routes from AIS. A report produced for the Marine Management Organisation, pp 35. MMO Project No: 1066. ISBN: 978-1-909452-26-8.

MMO, 2014b. UK Vessel Lists November 2014. Available at: https://www.gov.uk/government/collections/uk-vessel-lists. Accessed November 2014

NERC, 2012. UK gauging station network. Available at: http://www.ceh.ac.uk/data/nrfa/uk_gauging_station_network.html

Reeds Nautical Almanac, 2012. (Eds. Du Port, A. and Butress, R.) Aldard Coles Nautical, MS Publications, Colchester.

SCOS, 2013. Scientific Advice on Matters Related to the Management of Seal Populations: 2013. Available at: http://www.smru.st-andrews.ac.uk/documents/1199.pdf Accessed November 2014.

The Green Blue, 2010. Pump Out Directory. Available at: http://www.thegreenblue.org.uk/pump_out_directory.aspx. Accessed November 2014

Tree, J.A., Adams, M.R., Lees, D.N., 1997. Virus inactivation during disinfection of wastewater by chlorination and UV irradiation and the efficacy of F+ bacteriophage as a 'viral indicator'. Water Science and Technology, Volume 35 (11–12), 227-232.

UK Hydrographic Office, 2003. NP 263. Lyme Bay Tidal Stream Atlas.

Younger, A.D., Lee, R.J., Lees, D.N. 2003. Microbiological monitoring of bivalve mollusc harvesting areas in England and Wales: rationale and approach. In: Villalba, A., Reguera, B., Romalde, J. L., Beiras, R. (eds). Molluscan Shellfish Safety. Consellería de Pesca e Asuntos Marítimos de Xunta de Galicia and Intergovernmental Oceanographic Commission of UNESCO, Santiago de Compostela, Spain. pp. 265−277.

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”.

Acknowledgements

Mr Holmyard (Offshore Shellfish Ltd.).