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

Teign Estuary

September 2013

Food Standards Agency

Cover photo: Arch Brook.

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

http://www.cefas.defra.gov.uk/our-science/animal-health-and-food-safety/food-safety/sanitary-surveys/england-and-wales.aspx

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
Local Delivery Division
Food Standards Agency
Aviation House
125 Kingsway
London
WC2B 6NH

☎ 0207 276 8970
✉ shellfishharvesting@foodstandards.gsi.gov.uk

Statement of use

This report provides a sanitary survey relevant to bivalve mollusc beds within the Teign Estuary, 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).

Revision history

Version	Details	Approved by	Approval date
1	Internal draft	Simon Kershaw	05/09/2013
2	Draft for client/consultee comment	Simon Kershaw	09/09/2013
3	Final	Simon Kershaw	21/11/2013

Consultation

Consultee	Date of consultation	Date of response
Teignbridge DC	10/09/2013	None
Environment Agency	10/09/2013	None
South West Water	10/09/2013	None
Devon and Severn IFCA	10/09/2013	None
Shellfish Association of Great Britain	10/09/2013	None

Dissemination

Food Standards Agency, Teignbridge DC. The report is available publicly via the CEFAS website.

Recommended Bibliographic Reference

Cefas, 2013. 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.

Contents

1. Introduction

1.1. Legislative Requirement

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

When consumed raw or lightly cooked, bivalves contaminated with pathogenic microorganisms may cause infectious diseases (e.g. Norovirus-associated gastroenteritis, Hepatitis A and Salmonellosis) in humans. Infectious disease outbreaks are more likely to occur in coastal areas, where bivalve mollusc production areas (BMPAs) are impacted by sources of microbiological contamination of human and/or animal origin.

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

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

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

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

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

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

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

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

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

In addition to better targeting the location of RMPs and frequency of sampling for microbiological monitoring, it is 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 a sanitary survey undertaken for mussels and Pacific oysters within the Teign estuary. The area was prioritised for survey in 2013-14 by a shellfish hygiene risk ranking exercise of existing classified areas.

1.2. Area description

The Teign Estuary is situated on the south west coast of England to the west of the Exe estuary (Figure 1.1). A narrow mouth in the east connects it to the English Channel. The estuary covers an area of approximately 37 km², of which 60% is intertidal (Futurecoast, 2002).

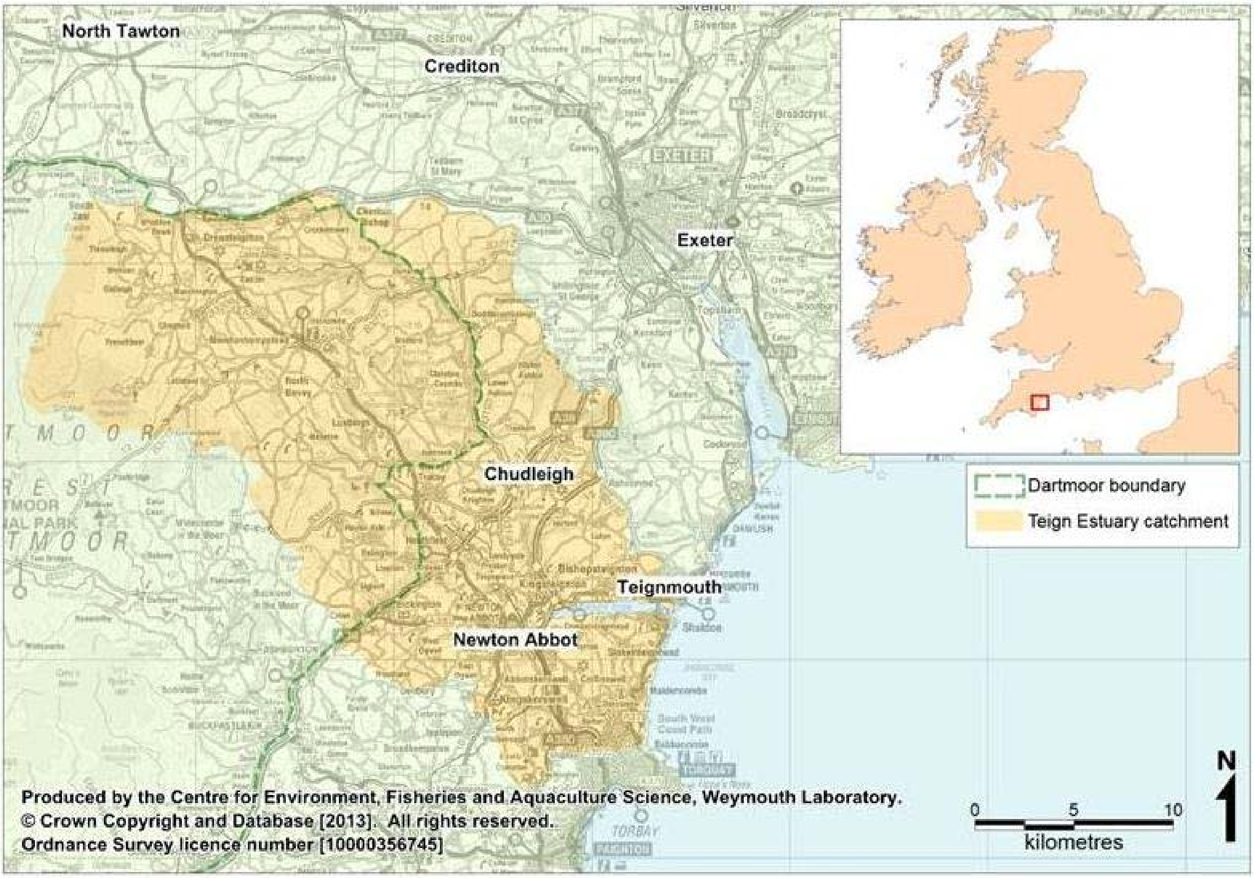


Figure 1.1: Location of the Teign Estuary

The estuary comprises of large areas of intertidal flats with some saltmarsh, which attracts significant populations of internationally and nationally important birds and an abundance of other wildlife. Sections of the estuary have been designated as a National Nature Reserve (NNR), Local Nature Reserve (LNR), County Wildlife Site (CWS), and it forms part of the South Devon Natural Area.

The estuary is popular for recreational boating including yachting, dinghy sailing, kayaking and windsurfing. It hosts a commercial port which predominantly deals with the exportation of dry bulks, and a small commercial fishing fleet. The harvesting of shellfish within the Teign dates back centuries (Teign Estuary Partnership, 2004). Currently, the shellfishery is divided up into plots by the Teign Musselmen's Society Ltd., and these are then managed by individual harvesters.

1.3. Catchment

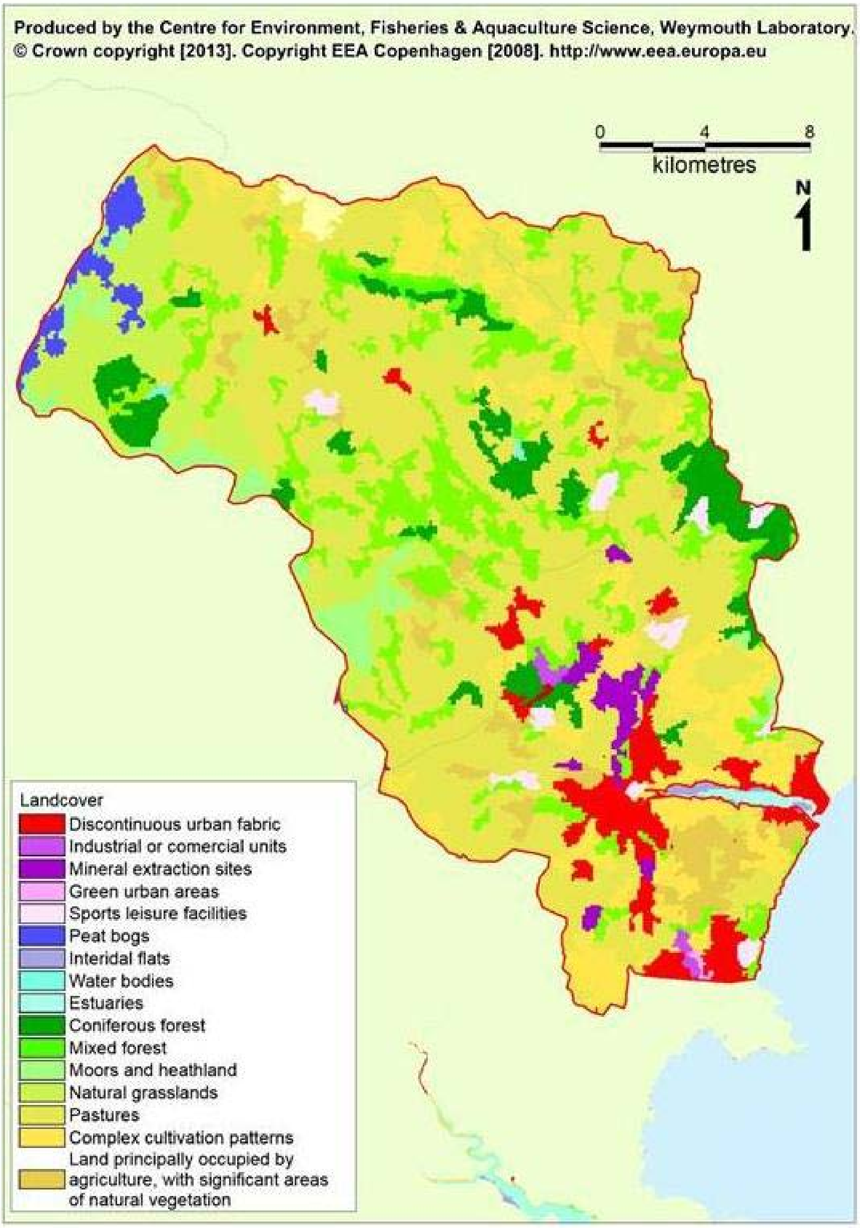


Figure 1.2 Land cover in the Teign Estuary catchment area

Figure 1.2 shows land cover within the Teign estuary catchment, which covers an area of approximately 530 km². It is predominantly rural with urbanised areas concentrated in the lower catchment adjacent to the shore. The urbanised areas represent the towns of Teignmouth, Newton Abbot and Chudleigh. The upper catchment falls within Dartmoor National Park and contains areas of peat bogs, heath land, pasture and woodland.

Different land cover types will generate differing levels of microbiological 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 bacterial contributions from all land cover types would be expected to increase significantly after marked rainfall events, particularly for improved grassland, the contributions from which can increase up to 100 fold under such conditions.

There is a marked difference in the geology between the upper catchment and the lower catchment, and this is likely to result in differing hydrological regimes. Dartmoor in the upper reaches is underlain with impermeable granite, whereas the lower reaches are underlain with Devonian and Carboniferous deposits, which are much more permeable, so there will be significant flows of groundwater in this area (Environment Agency, 2009).

2. Recommendations

2.1. Mussels

As mussels are widespread and not confined to the main beds, the sampling plan covers the entire fishery order area. It is proposed that it should be divided into the following four zones:

Gas Works

This zone contains one of the two main mussel beds (Gas Works). It is likely, as for the whole of the estuary, that the main contaminating influence to this bed is catchment sources delivered by the rivers to the upper reaches of the estuary. However, there is a small stream and an unmonitored CSO discharging almost directly to the eastern end of the bed, where at times a hotspot of contamination may occur. Additionally, the Bitton Brook and several CSOs discharge to the north shore just east of Shaldon Bridge. It is therefore recommended that the RMP be located at the inshore eastern end of this mussel bed.

Devon Valley

This zone contains the other main mussel bed (Devon Valley). Again, the majority of contamination found in mussels here is likely to originate from up-estuary sources. Locally, there are minor streams discharging to either side of the bed. The eastern stream receives two CSOs, although these both discharge for less than 1% of the time. There are also two further monitored CSOs (spilling <1% of the time) and one unmonitored CSO towards the eastern end of this zone, away from the main mussel bed. On balance, it is recommended that the RMP be located at the western end of the main Devon Valley bed to capture contamination from up-estuary sources, and to be best representative of conditions on the main aggregation of mussels within this zone.

Teign Central

This zone contains some mussel beds/lays along the north edge of the central sandbank. There are also mussels in the north channels which are sometimes dredged. Again, the majority of contamination found in mussels here is likely to originate from up-estuary sources, particularly for any stocks on the central sandbank. Local sources are limited to a few small streams, and a CSO at Flow Point which discharges for less than 1% of the time. It is therefore recommended that the RMP be located on the western tip of the central sandbank as this will best capture contamination from up-estuary sources.

Teign Upper

Currently there are not thought to be any active mussel beds in this zone, which will be the most heavily influenced of all by catchment sources discharging to the upper estuary. Arch Brook is likely to be of some influence, which will be most acute in the drainage channel it cuts across the intertidal. Maintaining a sample bag of mussels at the eastern inshore corner of the Arch Brook trestles should adequately capture the influence of these sources. It is however recognised that there are difficulties accessing the trestles due to the muddy substrate here, and the LEA intends to investigate options for the deployment of a secure but accessible sampling installation in the immediate vicinity of the Arch Brook drainage channel.

Sampling requirements

It is recognised that the RMP locations given in Table 3.1 may require some slight adjustments due to the uncertainties over the exact extent of mussel coverage, to ensure they coincide with stocks and follow the principles identified in these recommendations. Any adjustments should be communicated by the LEA to the classification team at Cefas.

Sampling should be on a monthly basis to maintain a full year round classification. Samples should be of mussels of a harvestable size. RMP tolerances, once locations are agreed, should be 10m. If bagged mussels are used they should be allowed to equilibrate *in situ* for at least two weeks prior to sampling.

2.2. Pacific oysters

There are two trestle sites within the fishery order area where Pacific oysters are cultured. There are also occasional naturally occurring specimens, which may possibly be used as a source of seed. Continued classification is only really required for the trestle sites. Therefore, the following two zones are proposed:

Central Bank Trestles

This zone includes the block of trestles on the eastern end of the central sandbank. There are no sources of contamination discharging directly to it, and it will be mainly influenced by catchment sources discharging to the head of the estuary. It is therefore recommended that the RMP be located at the north eastern corner of the trestles.

Arch Brook

Within this zone there is a block of trestles on the lower foreshore just to the east of Arch Brook. Again, a major influence from catchment sources discharging to the head of the estuary is anticipated. Arch Brook is likely to be of some influence, which will be most acute in the drainage channel it cuts across the intertidal. Maintaining a sample bag at the eastern inshore corner of the Arch Brook trestles should adequately capture the influence of these sources. As for Pacific oysters, it is recognised that access here is problematic and the LEA are investigating options for the deployment of a secure but accessible sampling installation in the immediate vicinity of the Arch Brook drainage channel.

Sampling requirements

It is recognised that the RMP locations given in Table 3.1 may require some slight adjustments due to the uncertainties over and changes to the exact extent of the trestles, to ensure they coincide with stocks and follow the principles identified in these recommendations. Any adjustments should be communicated by the LEA to the classification team at Cefas.

Sampling should be on a monthly basis to maintain a full year round classification. Samples should be of Pacific oysters of a harvestable size. RMP tolerances, once locations are agreed, should be 10m. Stocks should be allowed to equilibrate *in situ* for at least two weeks prior to sampling.

3. Sampling Plan

3.1. General Information

Location Reference

Production Area	Teign
Cefas Main Site Reference	M027
Ordnance survey 1:25,000 map	OS Explorer 110
Admiralty Chart	5602.8

Shellfishery

Species/culture	Mussels Pacific oysters	Cultured/wild Cultured
Seasonality of harvest	Year round (both species)	

Local Enforcement Authority

Name and address	Teignbridge District Council Forde House Newton Abbot TQ12 4XX
Environmental Health Officer	Gavin Fearby
Telephone number ☎	01626 215 321
Fax number 🖷	
E-mail	gavin.fearby@teignbridge.gov.uk

3.2. Requirement for Review

The Guide to Good Practice for the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2010) indicates that sanitary assessments should be fully reviewed every 6 years, so this assessment is due a formal review in 2019. The assessment may require review in the interim should any significant changes in sources of contamination come to light, such as the upgrading or relocation of any major discharges.

Table 3.1 Number and location of representative monitoring points (RMPs) and frequency of sampling for classification zones within the Teign estuary

Classification zone	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Gas Works	TBA*	Gas Works East	SX 9282 7284	50º 32.73'N 03º 30.84'W	Mussels	Bed culture	Hand/Dredge	Hand	10m	Monthly	Moves current Gas Works RMP to eastern inshore end of bed
Devon Valley	TBA*	Devon Valley West	SX 9210 7237	50º 32.47'N 03º 31.44'W	Mussels	Bed culture	Hand/Dredge	Hand	10m	Monthly	Moves current Devon Valley RMP to western inshore end of bed
Teign Central	TBA*	Central Bank Upper	SX 9130 7269	50º 32.63'N 03º 32.13'W	Mussels	Bed culture	Hand/Dredge	Hand	10m	Monthly	Moves Gappa Bank RMP to western tip of central sandbank
Teign Upper	TBA*	Arch Brook trestles	SX 9096 7235	50º 32.44'N 03º 32.41'W	Mussels	Wild/bed culture	Hand/Dredge	Hand (deployment bag)	10m	Monthly	New RMP: not thought to be a zone which is currently active for mussels. Only to be sampled and classified if required. A bag of mussels could be maintained on the trestles if required. May potentially be sampling officer access issues due to mud.

Central Bank Trestles	TBA*	Central Bank East	SX 9217 7280	50º 32.70'N 03º 31.39'W	Pacific oysters	Trestle culture	Hand	Hand	10m	Monthly	Moves existing RMP to upstream end of trestle site
Arch Brook	TBA*	Arch Brook trestles	SX 9096 7235	50º 32.44'N 03º 32.41'W	Pacific oysters	Trestle culture	Hand	Hand	10m	Monthly	Moves existing Arch Brook RMP to upstream inshore end of trestle site. May potentially be sampling officer access issues due to mud.

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

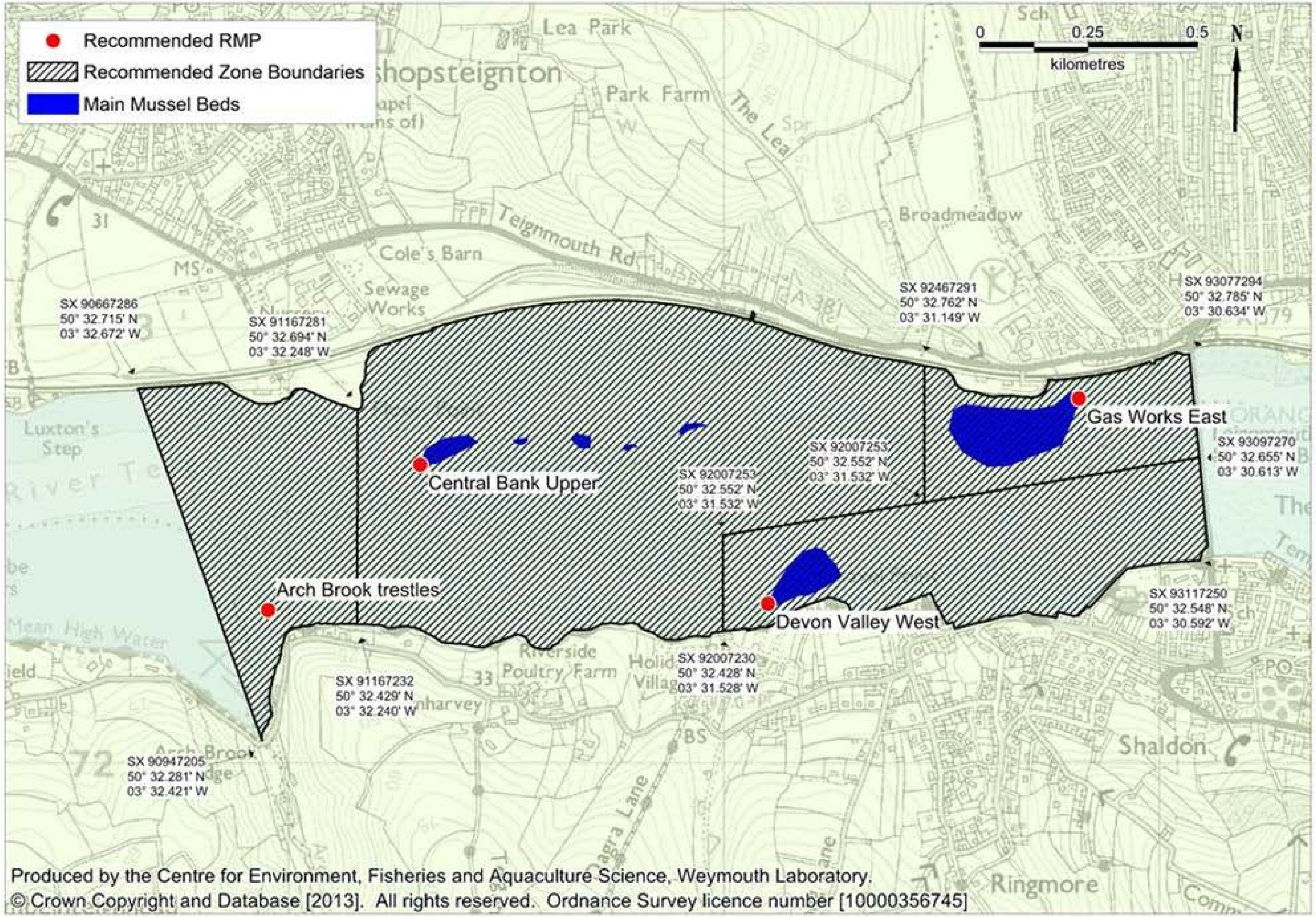


Figure 3.1: Recommended zoning and monitoring arrangements (Mussels)

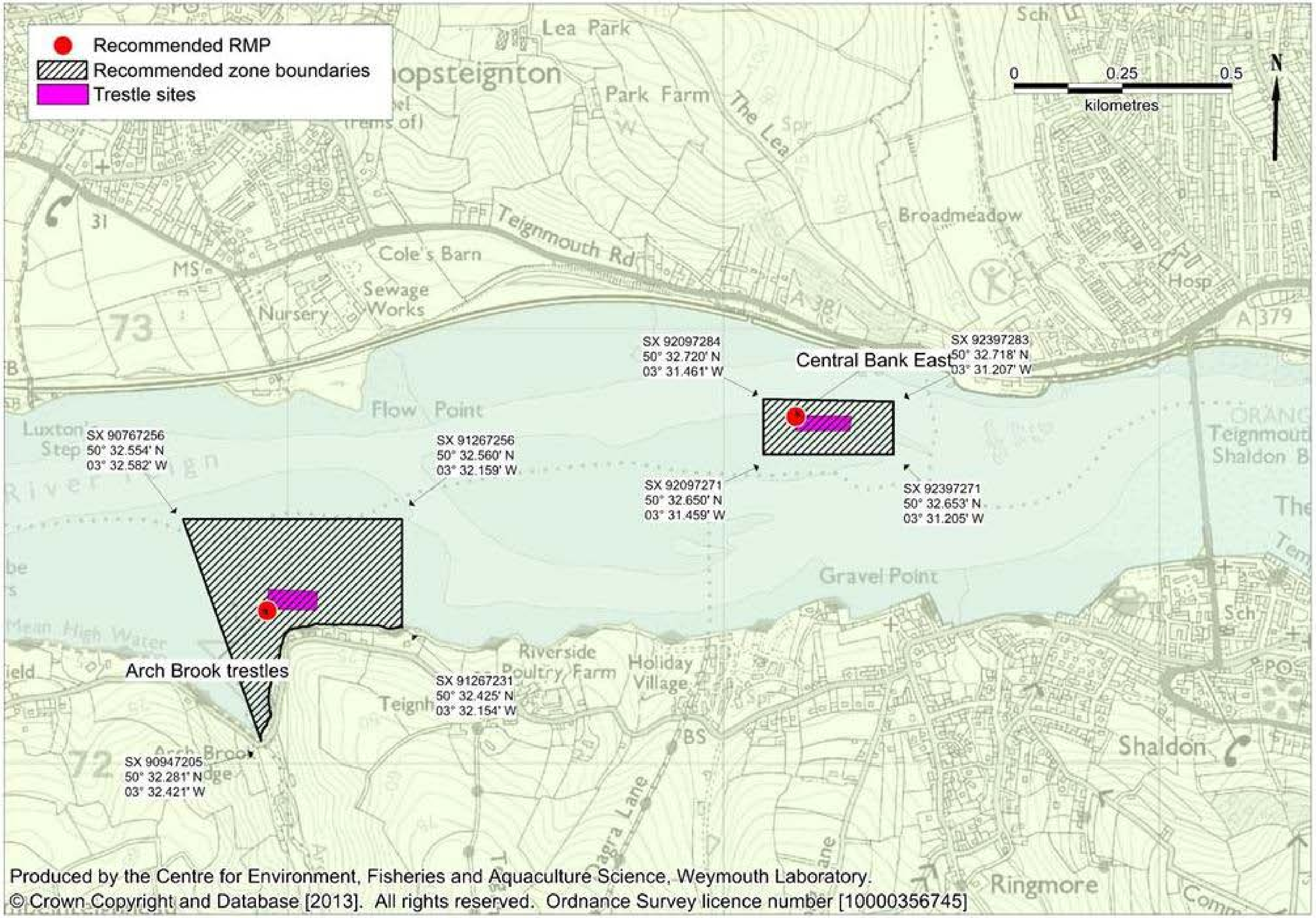


Figure 3.2: Recommended zoning and monitoring arrangements (Pacific oysters)

4. Shellfisheries

4.1. Species, location and extent

The Teign estuary supports naturally occurring and bottom cultured mussels, as well as several Pacific oyster culture sites. These all fall within the River Teign Mussel Fishery Order 1996, which conveys the fishing rights for mussels and oysters to the Teign Musselmen's Society Ltd. This co-operative consists of several harvesters, who work their own allocated plots within the fishery order area. Outside of the fishery order area, downstream of the Shaldon Bridge, there are seed mussel beds, which are sometimes used to restock the mussel lays. Seed mussels do not need to be taken from classified areas, but must be ongrown in a classified area for at least six months before harvest. There are also some cockles in the outer estuary around the Shaldon Bridge, but they are not thought to be present in commercial quantities, and have never been classified. Figure 4.1 shows the extent of the fishery order and the locations of the Pacific oyster trestle sites, and the main mussel beds/lays.

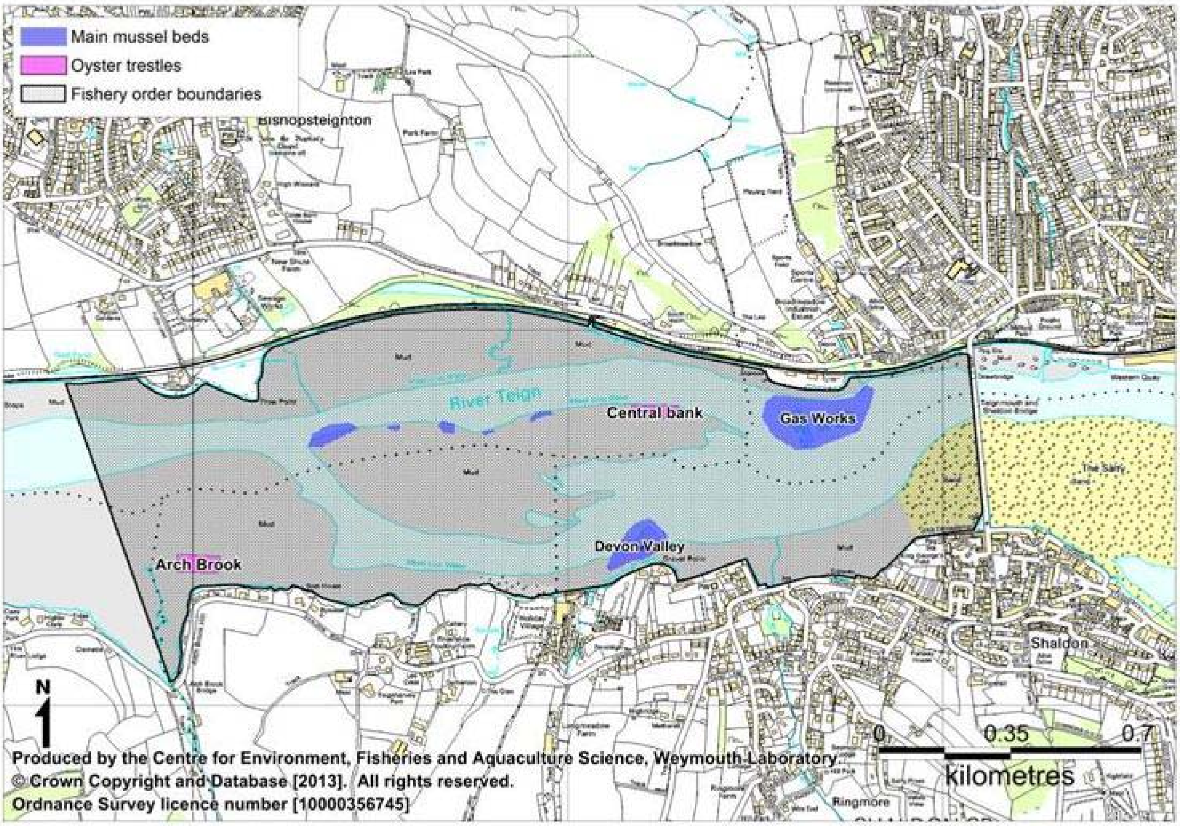


Figure 4.1: Map of Teign Shellfisheries

Naturally occurring mussels are quite widespread throughout the fishery order area outside of the main beds/lays, although they are not generally of a commercial quality and size. Some natural settlement of Pacific oysters also occurs within the fishery order, but these stocks are much sparser than the mussels. There is currently no firm information available on the distribution and density of cockle stocks. Historically, cockle stocks in The Teign have been described as present ‘in small numbers’ and ‘insufficient to support a regular fishery’ (Edwards, 1987). The IFCA have recently undertaken a brief survey of these stocks, but the results of this were not available in a usable form at the time of writing (Devon & Severn IFCA, pers comm.).

4.2. Growing Methods and Harvesting Techniques

Although there is some natural settlement on the mussel lays, most mussels are produced by ongrowing seed stocks sourced from the outer estuary and elsewhere. Seed stocks may originate from unclassified areas. They are grown on the seabed and harvesting is via hand picking or raking. Mussels are also dredged from some areas.

Pacific oysters are cultured from hatchery seed, either on the sea bed or in bags held on trestles or suspended from racks. They take around three years to reach market size. Harvesting is by hand.

Cockles are subject to some casual gathering, but there is not thought to be any organised commercial harvesting of these stocks.

4.3. Seasonality of Harvest, Conservation Controls and Development Potential

Mussels may be fished at any time of the year, although they are in poorer (post-spawning) condition in the late spring and early summer so most harvesting activity takes place from September to March. The only management measure which applies is a minimum landing size of 2” (50.8mm). Mussels cultured here are quite slow growing and of high quality because of high tidal exposure and periods of extreme low salinity. An estimate of potential mussel production within the Teign is in the order of 1000 tonnes per year (MacAlister Eliot, 1999). The area east of the Shaldon Bridge is also considered suitable for mussel production, but is occupied by moorings. Possible expansion into the upper reaches of the estuary may be constrained by water quality and low salinities. The fluctuating availability of seed stocks may be a limiting factor at times.

The Pacific oyster culture fishery is not subject to any fishery management controls, and operates on a year round basis. It is possible that during July and August the quality of the oysters is lower post spawning, as has been observed in the nearby Dart (Cefas, 2011). There is considerable potential for expansion of Pacific oyster culture within the fishery order area.

The hygiene classification is critical to the viability of the fishery for both species. A B classification allows the shellfish to be marketed live following purification, whereas a C classification precludes the marketing of live animals on which the fishery depends. A downgrade in 1998 resulted in an immediate cessation of shellfish harvesting. The possibility of a downgrade from B to C at relatively short notice is likely to constrain investment in the fishery to some extent.

The only conservation control applying to cockles is a minimum size of ¾" (19.1mm). There are no limits to the amount of cockles which can be taken for personal consumption within the district, at present, although it is likely that the IFCA may impose bag limits on non-commercial gathering at some point to help prevent overexploitation.

4.4. Hygiene Classification

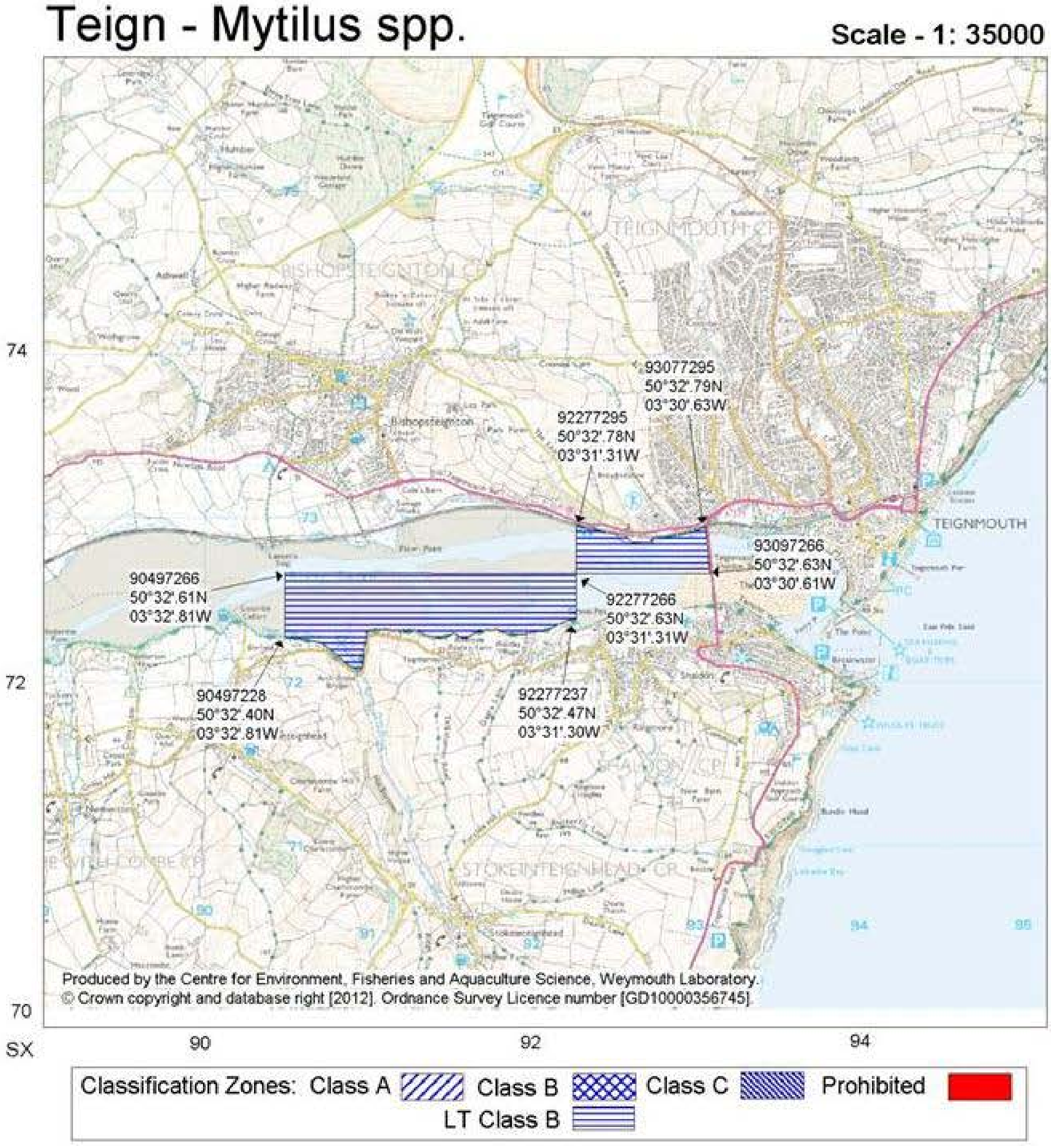
Table 4.1 lists all classifications within the Teign estuary from 2004 onwards.

Table 4.1: Classification history for the Teign, 2003 onwards

Area	Species	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Arch brook	P. oysters	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Gappa Bank	Mussels	C	C	C	B	B	B	B	B	-	-
Gas Works Bank	Mussels	B	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Gas Works Bank	P. oysters	B	B-LT	B	B	B	B	B	B	B	B
Devon Valley	Mussels	B	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
The Ponds	P. oysters	-	B	B	B	B	-	-	-	-	

LT denotes long term classification

All areas have been classified B since 2007. Prior to 2006, Mussels at Gappa Bank were classified C. The Ponds was declassified in 2009 and has not been classified since. Currently, only the north east and south west quarters of the fishery order area are classified. The western half of the trestle site on the central bank, and the mussel sites along the northern edge of this bank to the west of the trestle site are unclassified. The south west quarter extends slightly up-estuary from the upper boundary of the fishery order.



Classification of Bivalve Mollusc Production Areas: Effective from 1 September 2012

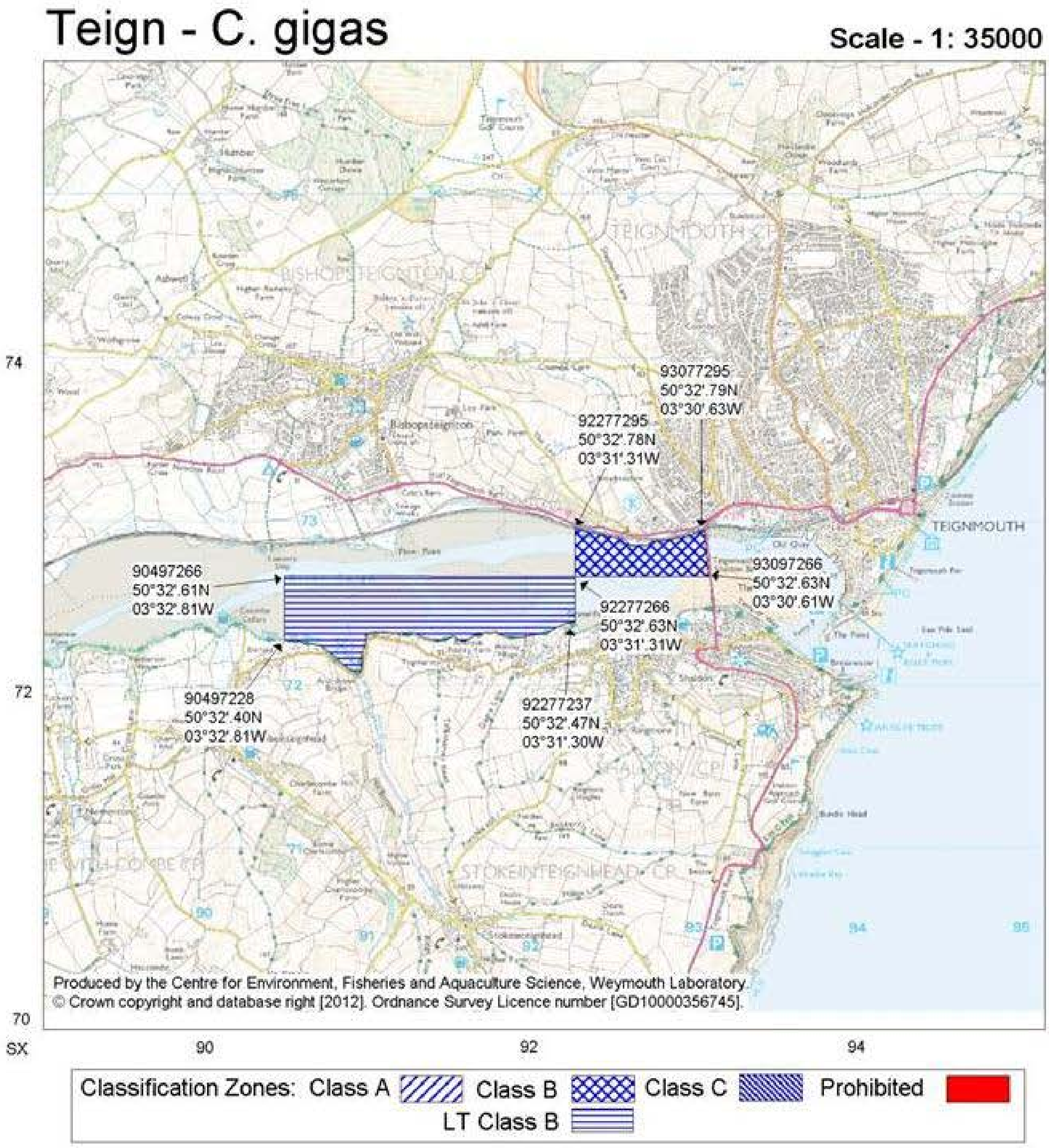
The areas delineated above are those classified as bivalve mollusc production areas under EU Regulation 854/2004.

Further details on the classified species and the areas may be obtained from the responsible Food Authority. Enquiries regarding the maps should be directed to: Shellfish Microbiology, CEFAS Weymouth Laboratory, Barrack Road, The Nothe, Weymouth, Dorset DT4 8UB.
(Tel: 01305 206600 Fax: 01305 206601)

N.B. Lat/Longs quoted are WGS84
Separate map available for C. gigas at Teign

Food Authority: Teignbridge District Council

Figure 4.2: Current mussel classifications



Classification of Bivalve Mollusc Production Areas: Effective from 1 September 2012

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

Further details on the classified species and the areas may be obtained from the responsible Food Authority. Enquiries regarding the maps should be directed to: Shellfish Microbiology, CEFAS Weymouth Laboratory, Barrack Road, The Nothe, Weymouth, Dorset DT4 8UB.
(Tel: 01305 206600 Fax: 01305 206601)

N.B. Lat/Longs quoted are WGS84
Separate map available for Mytilus spp. at Teign

Food Authority: Teignbridge District Council

Figure 4.4: Current Pacific oyster classifications

5. Overall Assessment

5.1. Aim

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

5.2. Shellfisheries

The Teign supports a mussel and Pacific oyster culture fishery, the rights to which are held by the Teign Musselmen's Society Ltd, who are grantees of the River Teign Mussel Fishery Order 1996. Within the fishery order boundaries, there are two Pacific oyster sites, where they are cultured from seed stocks on trestles. There are two main mussel beds/lays, and some further smaller areas where mussels have are ongrown from seed, or occur naturally in commercial beds. There are also widespread but sparser and less commercially desirable settlements of mussels on parts of the intertidal area, and some very limited natural settlement of Pacific oysters. The sampling plan will therefore need to cover the entire fishery order area for mussels, but only the culture sites for Pacific oysters. As both these fisheries may operate on a year round basis, regular monthly sampling will be required.

In some areas in England and Wales, it has been considered acceptable to classify one species on the basis of monitoring results from another. This approach will reduce laboratory costs, but must be suitably protective of public health whilst not resulting in an unfairly poor classification. Younger & Reese (2011) identified that mussels may be a suitable surrogate species for Pacific oysters, although they can accumulate *E. coli* to about twice the level of that found in oysters. Mussels are more tolerant of lower salinities (Laing and Spencer, 2006), and so are likely to feed and hence accumulate *E. coli* at lower salinities. Salinity is highly variable within the estuary, and class B compliance is sometimes borderline. Therefore, the use of mussels as a surrogate for Pacific oysters may result in an unfairly poor classification in Pacific oysters and so is not appropriate here.

No sampling plan is provided for cockles, as they are not subject to a commercial fishery, their classification has never been requested, and although there is no firm information available on their distribution or status the stocks are not though sufficient to support a regular commercial fishery.

5.3. Pollution Sources

Freshwater Inputs

All rivers and streams carry some contamination from land runoff and so will require consideration in this assessment. Their impacts will be greatest where they enter the estuary, and within or immediately adjacent to any drainage channels they follow across the intertidal area.

The Teign estuary drains a catchment area of 530 km² within which the primary land use is agriculture. There are significant urban areas around the head and the mouth of the estuary, and the upper reaches of the catchment fall within Dartmoor. The vast majority of the catchment is drained by the River Teign and other watercourses draining to the head of the estuary. A tentative estimate of the average bacterial loading carried by the Teign, based on the average gauged flow and the geometric mean of 15 bacteriological samples is around $4x10^{13}$ faecal coliforms/day. There will be additional significant contributions from other watercourses draining to the head of the estuary (River Lemon, Aller Brook). Together, these are likely to account for a large proportion of the fluxes of indicator bacteria into the estuary. The influence of freshwater borne contamination is likely to be highest towards the up-estuary ends of the shellfish beds, so a general principle of locating RMPs at the up-estuary end of classification zones should be applied.

Superimposed on this underlying geographical pattern there may be more localised 'hotspots' associated with smaller freshwater inputs discharging in close proximity to the shellfish beds. These should also be considered in the sampling plan. Spot flow measurements and bacteriological sampling of streams discharging to or in close proximity to the fishery was undertaken during the shoreline survey. All of these were carrying moderate to high levels of *E. coli*, so although none was particularly large in terms of discharge volume, some carried bacterial loadings likely to be of local significance. The Broad Stream drains immediately adjacent to the mussel bed at Gas Works. Arch Brook drains close to an oyster trestle site, where it is likely to be an influence. There are also small watercourses draining to either side of the Devon Valley mussel bed of potential local significance.

There will be considerable variation in the bacterial loadings delivered to the estuary by rivers and streams, both on a day to day and seasonal basis. Flow gauging records from the River Teign show that volumes of runoff are generally higher in the late autumn and winter, although high flow events may occur at any time of the year. Increased levels of runoff are likely to result in an increased bacterial loading carried into coastal waters, particularly as river levels rise when heavy rain occurs following a dry period (the 'first flush').

Human Population

Total resident population within the Teign Estuary catchment was approximately 172,000 at the time of the last census. The main settlements are located around the head of the estuary (Newton Abbot) and around the mouth of the estuary (Teignmouth and Shaldon). The upper half of the catchment falls within Dartmoor where population densities are very low. The impacts of the human population on shellfish hygiene will largely depend on the nature of the sewerage infrastructure serving the area.

Both the coastal seaside resorts (Teignmouth and Shaldon) and Dartmoor are holiday destinations. Significant population increases are therefore anticipated during the summer months. Increased population numbers will result in increased volumes of sewage treated by the sewage works so there may be some seasonality in the bacteriological loadings generated by these.

Sewage Discharges

There are no continuous water company sewage discharges direct to the Teign estuary. The towns adjacent to the estuary are served by Buckland STW, which provides secondary treatment for a consented dry weather flow of 21,218 m^3/day and discharges effluent via an outfall in Lyme Bay, about 2km offshore from Teignmouth. This outfall will be of negligible significance to the estuary.

The more rural, inland parts of the catchment are served by a series of small to medium sized treatment works which discharge to watercourses. Their combined consented discharge volume is about 7,500 m^3/day (dry weather flow). Most provide secondary treatment, but the largest (Heathfield STW, consented for a dry weather flow of 3,563 m^3/day) was upgraded to provide UV treatment in 2010. Final effluent testing data indicates the UV treatment here is suitably effective. Almost all of these sewage works discharge to watercourses draining to the head of the estuary, and their spatial pattern of impacts will align with that of the watercourses to which they discharge. The exception is a very small works at Bishopsteignton (a septic tank with a consented dry weather flow of 9.09 m^3/day) which discharges to a short watercourse draining to the north shore of the estuary about 1km upstream of the fishery order area. This will make a minor contribution to the levels of indicator bacteria carried by the watercourse to which it discharges.

There are numerous intermittent sewage discharges directly to or in close proximity of the estuary. The main clusters of these are associated with the urban areas around the head and the mouth of the estuary. Just over half of these are monitored, and the spill records for these covering the period January 2006 to March 2012 were examined. Of the monitored outfalls, the most active were Keyberry Road No. 18 CSO, and Opp 65 Highweek Road CSO, both of which spilled for just over 5% of the period considered. Both are located within Newton Abbot, at the head of the estuary. A further seven discharges spilled for between 1 and 5% of the period considered. Four of these are located in Newton Abbot, two at Teignmouth and one at Bishopsteignton. Of the two at Teignmouth (Bitton Park Rugby Club CSO and Gales Hill PS) the former is likely to be of most significance as it spilled for more of the time and is located closer to the fishery. The one located at Bishopsteignton (Horns Close CSO) discharges to a culverted stream which in turn discharges to the north shore of the estuary just up-estuary from the Shaldon Bridge. The rest of the monitored outfalls spilled for less than 1% of the time, with some of these hardly spilling at all. It is not possible to assess the importance of the unmonitored discharges, aside from noting their location and their potential to discharge storm sewage.

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

Although the vast majority of properties within the Teign catchment are served by the water company sewerage networks, there are also a small number of private sewage discharges. Some of these may be of some significance to the fishery. There is a small cluster of private discharges to water at Coombe Cellars, the largest of which is a septic tank or package plant serving the Coombe Cellars Inn. This is consented to discharge up to 30m^3/day to a short watercourse draining to the estuary about 1km upstream of the Arch Brook trestles. The Wear Farm Caravan Park may also be of some significance, as it is relatively large (up to 50m^3/day) and discharges to a short watercourse which feeds into the estuary about 1.5km upstream of the fishery order boundary.

Agriculture

Around 60% of land within the Teign catchment is used for agriculture, with more pastures in the upper catchment and more arable farming in the lower catchment. There are some areas of pasture in the valley within which the estuary lies. Totals of 30,681 cattle, 2,018 sheep, 77,339 pigs and 112,282 poultry were recorded within the catchment during the 2010 agricultural census. Highest numbers and densities of grazing animals and pigs were recorded in the upper reaches of the catchment, although there were 3,671 cattle and 8,342 pigs within the sub-catchment bordering the estuary. Highest numbers and densities of poultry were recorded in the middle reaches of the catchment.

Faecal matter from grazing livestock is either deposited directly on pastures, or collected from livestock sheds if animals are housed indoors during the colder months and then applied to agricultural lands as a fertilizer. Manure from pigs and poultry is typically stored and applied tactically to nearby farmland.

A large proportion of the agricultural land lies within parts of the catchment drained by watercourses discharging to the estuary upstream of the fishery so higher impacts towards the up-estuary ends of the shellfisheries are generally anticipated. Almost all significant watercourses will be affected to some extent. Therefore, in general RMPs should be situated at the up-estuary ends of shellfish beds, or at points where significant watercourses enter the estuary.

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. Rainfall and river flows are generally higher during the winter months, although high rainfall events may occur at any time of the year. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the ‘first flush’). Numbers of sheep and cattle will increase significantly in the spring, with the birth of lambs and calves, and decrease in the autumn when animals are sent to market. The seasonal pattern in application of manures and slurries to agricultural land is uncertain. Cattle may be housed indoors during the winter, so applications of slurry collected from such operations is likely to be spread in the late winter and spring, depending on the storage capacities of each farm.

Boats

The discharge of sewage from boats is potentially a significant source of bacterial contamination of shellfisheries within the Teign estuary. There is significant boat traffic within the outer reaches of the Teign estuary, which hosts a commercial port at Teignmouth, a small fishing fleet, and is heavily used by pleasure vessels such as yachts and cabin cruisers. There are around 700 moorings within the Teign, which are mainly used by small yachts, cabin cruisers and open dinghy type vessels. The majority of these are downstream from the Shaldon Bridge, although they do extend upstream along the south shore just past the Devon Valley mussel bed.

Commercial shipping is not permitted to discharge to inshore waters so should be of no impact. It is likely that the larger of the private vessels (yachts, cabin cruisers, fishing vessels) which have onboard toilets make overboard discharges from time to time. This may occur whilst boats are on passage, and it is quite likely that any boats in overnight occupation on the moorings will make a discharge at some point during their stay. On this basis, the outer estuary, and to a lesser extent the south channel up to Ringmore are most at risk. Peak pleasure craft activity will occur in the summer, so highest impacts are anticipated at this time. However, it is difficult to be more specific without any firm information about the locations, timings and volumes of such discharges, and as such boating will have little material bearing on the sampling plan.

Wildlife

The Teign estuary encompasses a variety of habitats including, intertidal mudflats, saltmarsh, and saline lagoons. These features attract significant populations of birds and other wildlife. The most significant wildlife aggregation in terms of shellfish hygiene is likely to be overwintering waterbirds (waders and wildfowl). There are no formal published counts of overwintering waterbirds for the Teign estuary. The neighbouring Exe estuary attracts in the region of 19,000 waterbirds each winter so it is therefore likely that the Teign, a similar but smaller estuary, attracts several thousand overwintering waterbirds each year.

Geese and ducks will mainly frequent the saltmarsh in the upper estuary, where their faeces will be carried into coastal waters via runoff into tidal creeks or through tidal inundation. Any contamination from such birds will therefore mainly arrive at the estuary upstream of the fisheries. Waders, such as dunlin and oystercatchers forage upon shellfish and so will forage (and defecate) directly on any shellfish beds on the intertidal. Contamination from these, whilst a potentially significant influence on hygiene sampling results at times, may be considered diffuse and will therefore not influence the location of RMPs.

Whilst a small proportion of these waterbirds may remain in the area during the summer, most will migrate away to breed. Gulls also breed in the area during the summer months (222 pairs in 2001) most of which were recorded nesting in the Teignmouth area. Again, their impacts are considered diffuse away from their nesting sites, and so will not influence the sampling plans.

A few otters are present, but these are confined to the upper estuary and are present at very low densities. Also, it is possible that the occasional seal enters the estuary, although there are no major seal colonies in the vicinity. Neither of these mammals will be an influence on the sampling plan due to their low numbers and wide ranging habits. No other wildlife species which may have a bearing on the sampling plan have been identified.

Domestic animals

Dog walking takes place on beaches and paths adjacent to the southern shoreline of the survey area and could represent a potential source of diffuse contamination to the near shore zone. The intensity of dog walking is likely to be higher closer to the urban areas at Teignmouth and Shaldon. The north shore adjacent to the fishery is relatively inaccessible and so is less vulnerable. As a diffuse source, this will have little influence on the location of RMPs however.

Summary of Pollution Sources

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

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

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

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

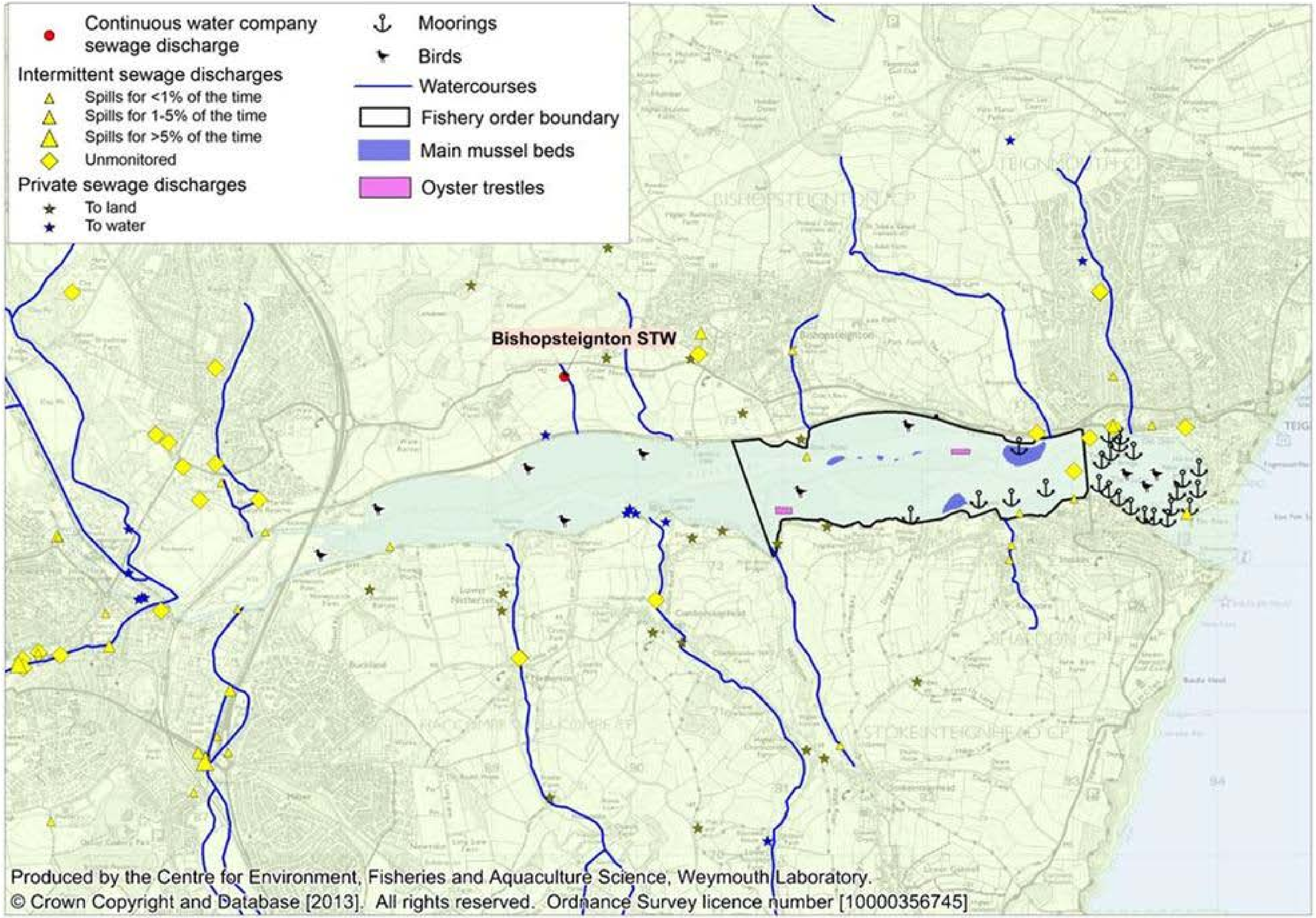


Figure 5.1: Summary of main contaminating influences

5.4. Hydrography

The Teign estuary is relatively narrow (up to 800 m wide), approximately 6-7 km long, and is quite uniform in width and orientation throughout. It is largely a natural water body which lies in a valley, with the surrounding hills rising to well over 100m. It covers an area of about 3.7 km^2, of which 60% is intertidal. A significant river drains to its head. It is characterised by a meandering river channel flanked by sand and mudflats. The mouth is constrained by a sandbar protruding from the north shore and a rocky headland on the south shore. The main river channel is approximately 100 m wide with a maximum depth of 5.8 m at its mouth. It runs east for approximately 2 km and then splits around a sandbank where many of the shellfish plots lie. The main channel becomes progressively shallower as it meanders through the middle and upper reaches. Where watercourses drain to the lower and middle reaches of the estuary, they have cut drainage channels across the intertidal area, which generally run perpendicular to the shore.

The average tidal range at Teignmouth is 3.8m on spring tides and 1.6m on neap tides. The tidal curve is asymmetrical, with a shorter duration and faster moving ebb tide. The relatively large tidal range drives extensive water movements within the estuary. The strongest tidal currents of up to 5 m/s arise in the estuary mouth. No information on current velocities within the fishery order were available, so it was not possible to make an estimate of tidal excursion for this part of the estuary.

Tidal streams flood up the estuary in a westerly direction, following the main channels, and spreading out across intertidal areas, where current velocities will be considerably lower, with the reverse occurring on the ebb. Shoreline sources of contamination will therefore primarily impact up and downtide of their locations along the bank to which they discharge. Their impacts will decrease with distance travelled, as the plume becomes progressively more diluted. At lower states of the tide contamination from some shoreline sources such as watercourses will be carried through any intertidal drainage channels where the dilution potential is low. Relatively high concentrations of indicator bacteria may arise in these channels at such times. The shellfish plots on the central sandbank will mainly be exposed to contamination originating from upstream and downstream and carried along the main channel. Those on the intertidal area adjacent to the north and south shores will also be influenced by shoreline sources discharging to the shore where they are located.

The majority of land runoff enters the estuary at its head. The average and maximum flow ratios (freshwater input:tidal exchange) are 0.034 and 0.515 respectively, so density effects may modify circulation at times, particularly in the upper estuary and during times of high freshwater input. Neap tides may also accentuate density effects as both tidal current velocities (and hence the extent of turbulent mixing) and the volume of tidal exchange will be lower. When such effects occur, they will result in a shear between surface and bottom currents, with less dense freshwater moving in a net seaward direction at the surface, and a net movement of more saline water up-estuary lower in the water column.

The degree of freshwater influence increases greatly towards the head of the estuary, as indicated by near surface salinity measurements taken under the Shellfish Waters monitoring programme. Around the upstream boundary of the fishery order salinity averaged 14.2ppt, with measurements as low as 0.2ppt recorded. Near the downstream boundary by Shaldon Bridge, salinity averaged 27.9ppt with a minimum of 14.0ppt recorded. Decreased salinity was strongly correlated with higher levels of faecal coliforms at both these locations. Due to density effects, this may be more acute in the upper layer of the water column than on the estuary bed, where the shellfish are located, although intertidal shellfish plots will be exposed to lower salinity water towards low tide. It is therefore concluded that there is likely to be a quite pronounced gradient of runoff borne contamination across the fishery, and RMPs set at the upstream end of the shellfishery will be most effective at capturing contamination from this source.

Strong winds can modify surface currents. The relatively steep sides of the estuary will result in winds tending to be funnelled up or down it. The prevailing south westerly winds will tend to push surface water down the estuary, which will in turn create return currents at depth or along any sheltered margins. Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great number of scenarios may arise. Where strong winds blow across a sufficient distance of water they may create wave action, and where these waves break contamination held in intertidal sediments may be resuspended, although given the enclosed nature of the Teign estuary strong wave action is not anticipated.

5.5. Summary of Existing Microbiological Data

The Teign estuary has been subject to considerable microbiological monitoring over recent years, deriving from Bathing Waters and Shellfish Waters monitoring programmes as well as shellfish flesh monitoring for hygiene classification purposes. Figure 5.2 shows the locations of the monitoring points referred to in this assessment. Despite the provision of UV at the Heathfield STW in 2010, data from 2003 until the present time is considered in this assessment as the upgrade did not appear to have a major effect on shellfish hygiene in the estuary.

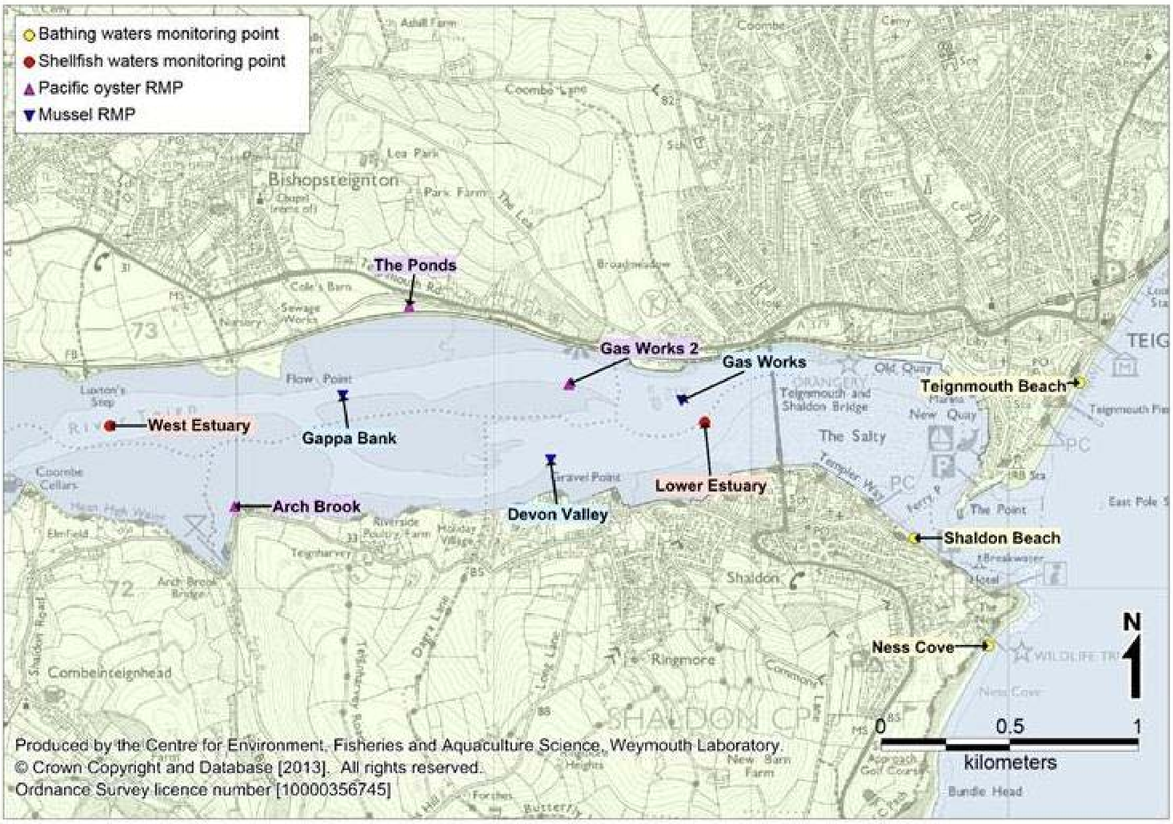


Figure 5.2: Microbiological sampling sites

Three sites were sampled under the Bathing Waters monitoring programme, where around 20 water samples were taken each bathing season (May-September) and enumerated for faecal coliforms. All three sites were downstream of the fishery, and two were just outside the estuary, so the results are of limited relevance to the fishery. The geometric mean concentration of faecal coliforms at Ness Cove (5.0 cfu/100ml) was significantly lower on average than that at Shaldon Beach and Teignmouth Beach (23.5 and 25.3 cfu/100ml respectively). A comparison of paired (same day) samples revealed that results at all sites were strongly correlated on a sample by sample basis, suggesting they are all under similar influences. Since 2003, levels of faecal coliforms have been relatively stable, with the exception of Shaldon Beach. Results improved significantly here since 2010, although whether this was a direct result of improvements at Heathfield STW is uncertain.

A significant influence of the high/low tidal cycle was detected at Ness Cove and Shaldon Beach. At both sites, faecal coliform concentrations were generally higher during the ebb tide, which implies up-estuary sources are of some significance. A significant influence of the spring/neap tidal cycle was detected at Shaldon Beach only, where there was a tendency for higher results during the larger spring tides. This suggests that more distant sources may be of importance. Faecal coliform levels at all three sites were rapidly influenced by rainfall and this influence continues for several days after a rainfall event, indicating that the influence of rainfall dependent sources (rivers, CSOs) extends outside of the estuary.

Under the shellfish waters monitoring programme two sites (Teign Estuary (West) and Teign Estuary (East)) were sampled for faecal coliforms in water on a quarterly basis. The locations of these two sites roughly align with the up and downstream ends of the shellfishery. Results were significantly higher at Teign Estuary (West) than at Teign Estuary (East), with geometric means of 968 and 133 faecal coliforms/100ml respectively. This supports the previous assertion of a significant gradient of increasing runoff related contamination towards the upstream end of the fishery. A comparison of paired (same day) sample results revealed that the two sites were strongly correlated on a sample by sample basis, suggesting they are both under similar influences.

Since 2003, the levels of faecal coliforms at both sites increased to a peak in 2005 and have been declining in general since. This may be due in part to improvements to intermittent discharges that took place between 2004 and 2006. Comparisons of faecal coliform levels before and after UV treatment was fitted to the Heathfield STW showed no significant improvements at either site. A strong seasonal pattern was observed at both sites, with significantly higher faecal coliform levels during the autumn than during the spring and summer at both sites.

A significant influence of the high/low tidal cycle was detected at both sites, with a tendency for higher results around low water. This implies that up-estuary sources may be of significance. No significant variation associated with the spring/neap tidal cycle was detected at either location. Faecal coliform levels at both sites were strongly influenced by rainfall and the influence continued for several days after a rainfall event. The influence was marginally stronger and more rapid to take effect at Teign Estuary (West), the more upstream site. Strong negative correlations were observed between salinity and faecal coliform concentrations at both sites, further reinforcing the conclusion that land runoff is a significant contaminating influence and is felt more acutely further up the estuary.

Under the shellfish hygiene classification monitoring programme there have been three Pacific oyster and three mussel RMPs active since 2003. One of the Pacific oyster RMPs (The Ponds) lies within a small tidal lagoon connected to the main body of the estuary via a narrow channel. All other RMPs lie within the main body of the estuary.

Over 10% of results exceeded 4600 *E. coli* MPN/100g at all three mussel sites, suggesting B classifications are borderline throughout. The Gas Works RMP had significantly lower *E. coli* levels than both Gappa Bank and Devon Valley, but there were no significant differences between Gappa Bank and Devon Valley. Across the three RMPs, both the average and peak levels of *E. coli* suggest a slight gradient of increasing levels of contamination towards the head of the estuary. This was not nearly as marked as that observed in the shellfish waters water sampling results, which may be a consequence of reduced feeding at lower salinities and/or density effects. A comparison of paired (same day) samples revealed that results at all site pairings were strongly correlated on a sample by sample basis, suggesting they are all under similar contaminating influences.

Of the three Pacific oyster sites, only Gas Works 2 had more than 10% of results exceeding 4600 *E. coli* MPN/100g. The Ponds RMP had significantly lower average *E. coli* levels than both Arch Brook and Gas Works 2; there was no significant difference between Arch Brook and Gas Works 2. Again, all site pairings were correlated on a sample by sample basis, but the correlations between The Ponds and the other two RMPs were much weaker. This suggests that whilst the two Pacific oyster RMPs in the main body of the estuary are influenced by similar sources, The Ponds is under slightly different influences. This may be a consequence of bacterial dieoff within the lagoon, which has limited water exchange, and an absence of sources discharging directly to it.

The level of *E. coli* in both mussels and Pacific oysters has remained fairly steady at all RMPs since 2003, aside from a slight decline in *E. coli* levels at mussels from Gappa bank from 2009 onwards. This slight improvement was not statistically significant. Significant seasonal variation was found at two of the three mussel RMPs (Gappa Bank and Devon Valley). *E. coli* levels were significantly higher in summer and autumn than spring and winter at Gappa Bank, and at Devon Valley they were higher in autumn than the spring and winter. No significant differences between seasons was found at any of the three Pacific oyster RMPs, although a pattern of higher results on average during the summer/autumn can be seen to varying extents when the data was plotted.

Some influence of tide across the high/low and spring neap cycles was detected at some RMPs, but sampling was strongly targeted towards low water on increasing sized tides so it was not possible to draw any meaningful conclusions from these analyses. Levels of *E. coli* at all RMPs were positively correlated with antecedent rainfall within 2 days of a rainfall event. Levels of *E. coli* in mussels were more sensitive to rainfall than Pacific oysters. This is perhaps due to mussels' higher tolerance to changing environmental conditions, allowing them to continue feeding when salinities fall after a rainfall event. Unsurprisingly, Pacific oysters at The Ponds were least affected.

Appendices

Appendix I. Human Population

Figure 5.3 shows population densities in census output areas within or partially within the Teign Estuary catchment area, derived from data collected from the 2011 census.

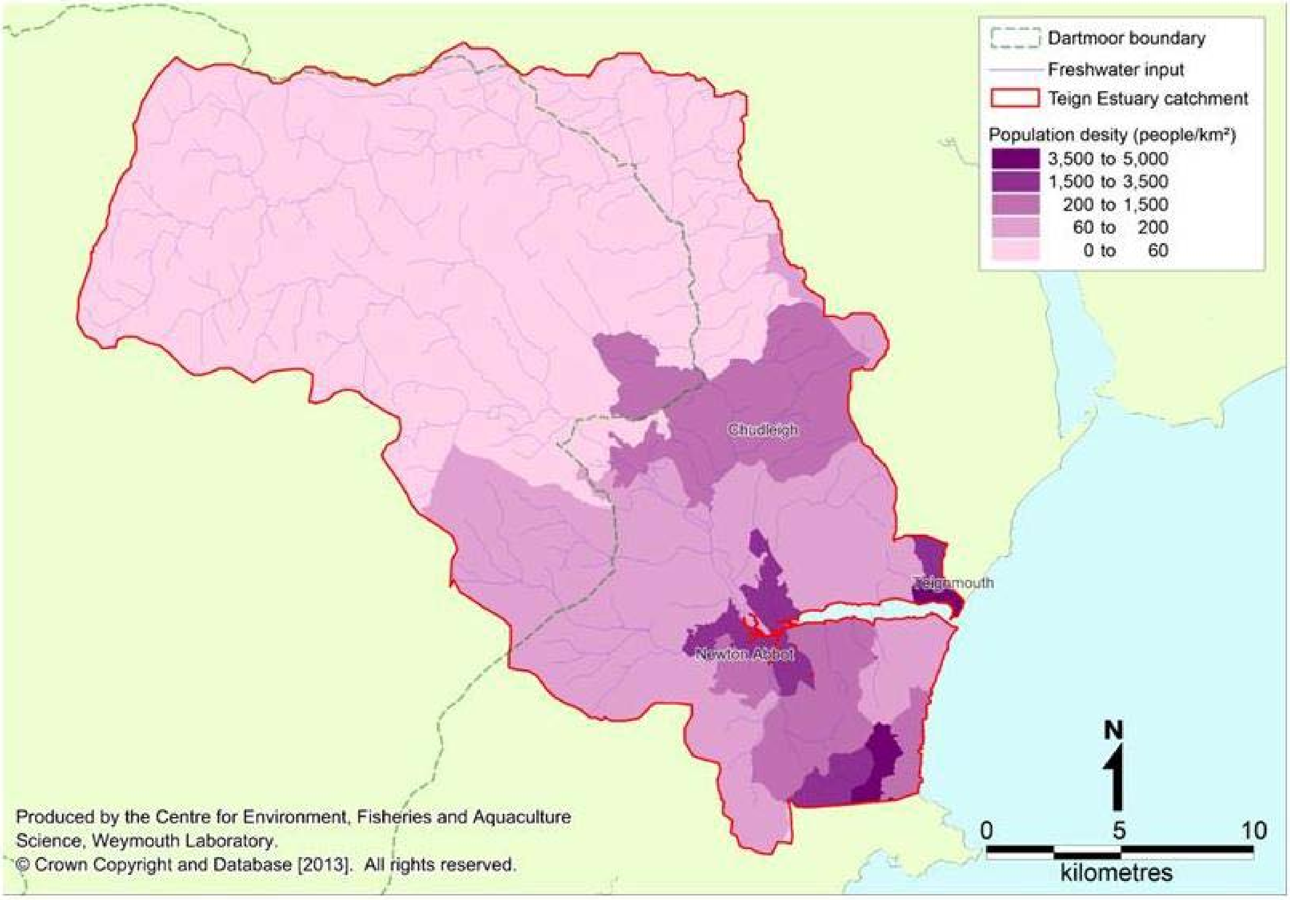


Figure 5.3: Human population density in census areas in the Teign Estuary catchment.

Total resident population within the Teign Estuary catchment was approximately 172,000 at the time of the last census (2011). Figure 5.3 indicates that population densities are highest at the western end of the estuary around Newton Abbot, and on the north side of the estuary mouth around Teignmouth where maximum population density is 4900 people/km^2. There is also higher population density to the south, but not directly adjacent to the estuary. These areas are therefore at the most risk from contaminated urban runoff. Impacts from sewage will depend on the nature and locations of discharges associated with these settlements and are discussed in detail in Appendix II. Approximately 46% of the catchment lies within by the Dartmoor National Park, where population densities are low (<60 persons per km^2) relative to the coastal areas.

Both the coastal seaside resorts and Dartmoor are holiday destinations. In 2001, approximately 3.4 million tourist nights were spent in the Teignbridge district, illustrating that the area receives significant influxes of tourists (Teignbridge DC, 2013). Therefore a significant seasonal variation in population levels in the catchment is anticipated, and the volumes of sewage received by treatment works serving the area is expected to fluctuate accordingly.

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

Details of all consented sewage discharges in the Teign Hydrological catchment were taken from the most recent update of the Environment Agency national permit database (December 2012). Figure II.1: Water company owned sewage works within the Teign catchment shows the locations of the water company owned sewage works within this area.

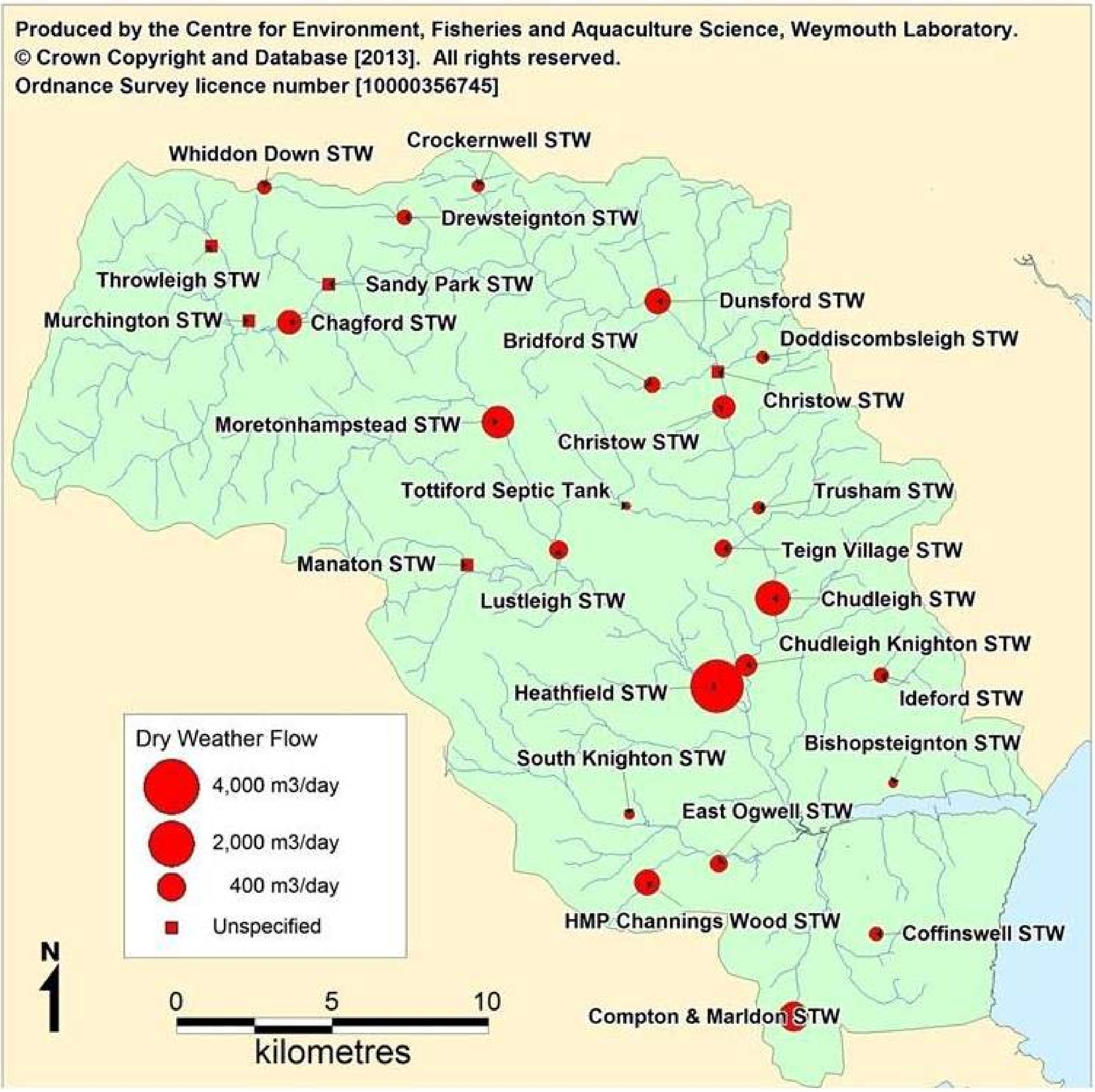


Figure II.1: Water company owned sewage works within the Teign catchment

There are 28 continuous water company owned discharges to the area, details of which are presented in Table II.1.

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

Name	NGR	Treatment	Dry weather flow (m^3/day)	Estimated bacterial loading (cfu/day)	Receiving environment
Bishopsteignton STW	SX8950073300	Septic tank	9.09	$3.0x10^{10}$*	Unnamed watercourse
Bridford STW	SX8176086100	Biological filtration	68	$2.2x10^{11}$*	Rookery Brook
Chagford STW	SX7010088100	Biological filtration	273	$9.0x10^{11}$*	River Teign
Christow STW	SX8387086510	Biological filtration	Unspecified	-	River Teign
Christow STW	SX8406085380	Activated sludge	209	$6.9x10^{11}$*	River Teign
Chudleigh Knighton STW	SX8477077080	Biological filtration	190	$6.3x10^{11}$*	River Teign
Chudleigh STW	SX8562079240	Biological filtration	812	$2.7x10^{12}$*	River Teign
Coffinswell STW	SX8895068450	Septic tank	45.76***	$4.6x10^{11}$*	Coffinswell Stream
Compton & Marldon STW	SX8630065800	Biological filtration	515	$1.7x10^{12}$*	River Teign
Crockernwell STW	SX7617092490	Biological filtration	28.5	$9.4x10^{10}$*	Scotley Brook
Doddiscombsleigh STW	SX8530086970	Biological filtration	26	$8.6x10^{10}$*	Doddiscombleigh Stream
Drewsteignton STW	SX7379091480	Biological filtration	49	$1.6x10^{11}$*	Fingle Brook
Dunsford STW	SX8193088780	Unspecified	280	$9.2x10^{11}$*	River Teign
East Ogwell STW	SX8390070700	Biological filtration	90.91	$3.0x10^{11}$*	River Lemon
Heathfield STW	SX8384076400	UV disinfection	3563	$2.8x10^{10}$**	River Bovey
Ideford STW	SX8911676761	Biological filtration	54	$1.8x10^{11}$*	Colley Brook
Lustleigh STW	SX7875080790	Biological filtration	100	$3.3x10^{11}$*	Wray Brook
Manaton STW	SX7580080300	Biodisc	Unspecified	-	Hayne Brook
HMP Channings Wood STW	SX8160070100	Biological filtration	299	$9.9x10^{11}$*	Barhams Brook
Moretonhampstead STW	SX7680084900	Biological filtration	700	$2.3x10^{12}$*	Wray Brook
Murchington STW	SX6880088150	Septic tank	Unspecified	-	Soakaway
Sandy Park STW	SX7136089320	Unspecified	Unspecified	-	River Teign
South Knighton STW	SX8102072300	Biological filtration	17	$5.6x10^{10}$*	South Knighton Stream
Teign Village STW	SX8405080840	Biological filtration	83.9	$2.8x10^{11}$*	River Teign
Throwleigh STW	SX6760090550	Biological filtration	Unspecified	-	Throwleigh Stream
Tottiford Septic Tank	SX8093082190	Septic tank	6.2	$6.2x10^{10}$*	Beadon Brook
Trusham STW	SX8518082140	Biological filtration	34	$1.1x10^{11}$*	Trusham Stream
Whiddon Down STW	SX6929092440	Biological filtration	41	$1.4x10^{11}$*	Fingle Brook

*Faecal coliforms (cfu/day) based on geometric base flow averages from a range of UK STWs providing secondary treatment (Table II.2).
** Faecal coliforms (cfu/day) based on geometric mean concentrations in final effluent from this works (Table II.3).
*** DWF estimated on basis of consented population equivalent, assuming a water usage of 160l/head/day.
Data from the Environment Agency

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

Treatment Level	Flow			
	Base-flow		High-flow	
	n	Geometric mean	n	Geometric mean
Storm overflow (53)	-	-	200	$7.2x10^6$
Primary (12)	127	$1.0x10^7$	14	$4.6x10^6$
Secondary (67)	864	$3.3x10^5$	184	$5.0x10^5$
Tertiary (UV) (8)	108	$2.8x10^2$	6	$3.6x10^2$

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

Table II.3: Summary statistics for final effluent testing data from Heathfield STW

Date of first sample	Date of last sample	No.	Geometric mean result (cfu/100ml)	Minimum	Maximum
19/04/2010	22/03/2011	21	774	19	30000

Data from the Environment Agency

The towns adjacent to the estuary (Newton Abbot, Shaldon, Teignmouth, Bishopsteignton, Kingsteignton, Stoketeignhead, Combeinteignhead, Kingskerswell) are served by Buckland STW. This provides secondary treatment and has a consented dry weather flow of 21,818m^3/day and discharges via long sea outfall to Lyme Bay, about 2km offshore from Teignmouth. Given its location, this will be of negligible significance to the Teign estuary. The more rural inland areas of the catchment are served by a series of relatively small sewage works which, with the exception of Murchington Septic Tank, discharge to watercourses. The total volume discharged is about 7,500 m^3/day. Most works provide secondary treatment, although some of the smaller ones are septic tanks. The largest of the inland works (Heathfield STW) provides UV treatment, which final effluent data indicates is effective. The estimated bacterial loading generated by this works is therefore minor. Of the 27 works discharging to watercourses 26 are to watercourses which drain to the head of the estuary. On this basis higher levels of contamination are anticipated towards the head of the estuary. Many of these are a significant distance from the tidal limit however, so some bacterial dieoff during transit is anticipated. Bishopsteignton STW discharges to a small watercourse which enters the middle reaches of the estuary from the north shore, but is minor in terms of volumes discharged.

In addition to the continuous sewage discharges, there are numerous intermittent water company discharges associated with the sewerage networks. Locations of those within 2km of the Teign estuary are shown in Figure II.2, and details are shown in Table II.4. These details include summary spill information for monitored discharges for the period January 2006 to March 2012, where records were available.

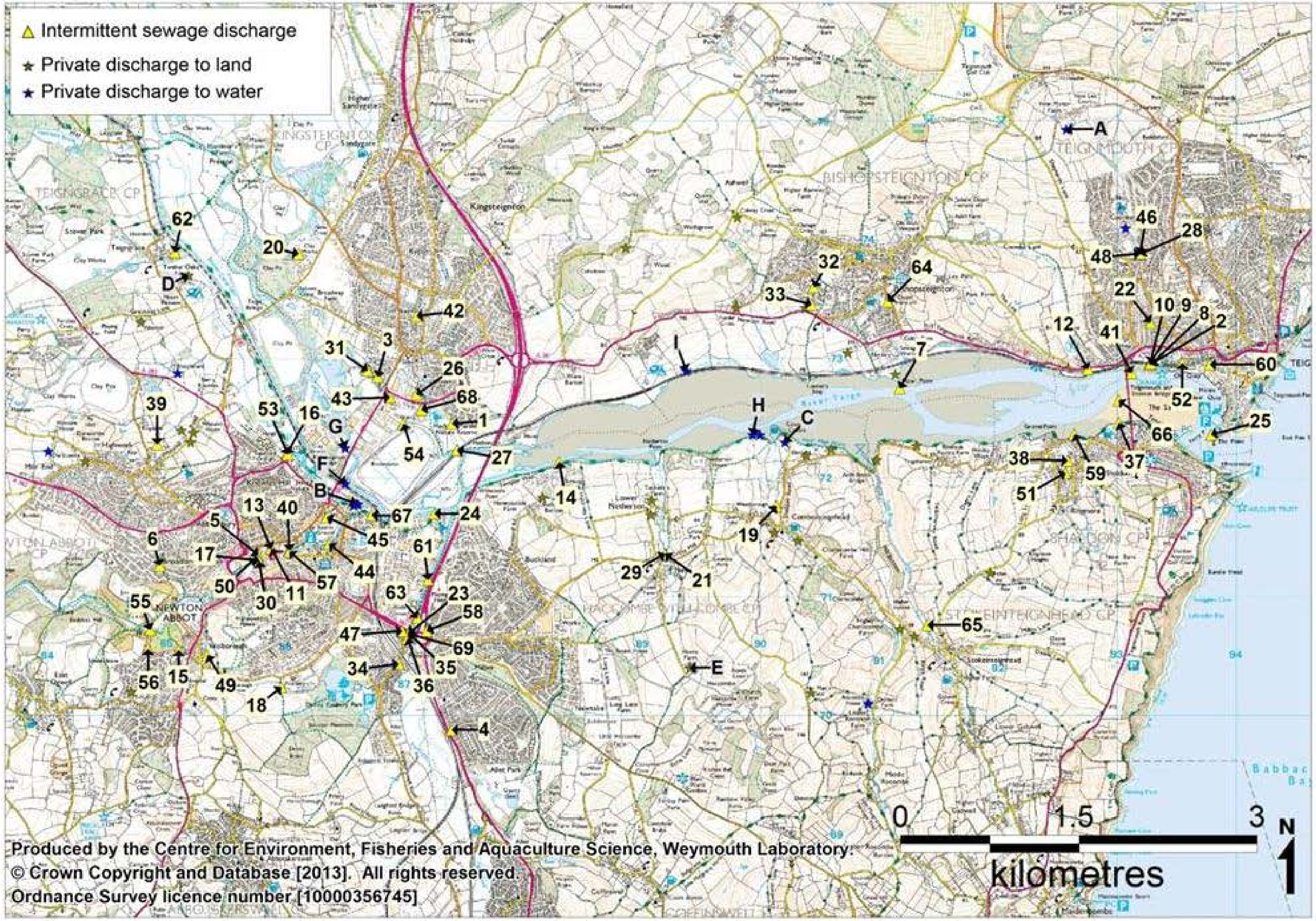


Figure II.2: Intermittent and private discharges within 2km of the Teign estuary.

Table II.4: Intermittent discharges within 2km of the Teign Estuary, with summary of spill records for monitored discharges

No.	Name (Permit database)	Permit number	NGR	Period monitored	No. individual events	Total duration (hrs)	% of period active
1	11 Maple Close PSEO	201584	SX8739872452	Not monitored			
2	155 Bitton Park Rd CSO	203205	SX9327872951	2006-2012	183	437.3	0.80%
3	4 Homers Lane CSO	201765	SX8677572848	Not monitored			
4	Aller Brake Road CSO	203093	SX8739769879	2006-2012	63	27.6	0.05%
5	Bank Street (Market entrance) CSO	201958	SX8576971349	Not monitored			
6	Barton Drive CSO	203381	SX8494071260	2006-2012	47	99.4	0.18%
7	Bishopsteignton CSO	NRA-SW-2866	SX9117072750	2011-2012	3	11.5	0.11%
8	Bitton Court CSO	201704	SX9327972950	Not monitored			
9	Bitton Park Rd CSO	203345	SX9327072950	2006-2012	20	46.8	0.09%
10	Bitton Park Rugby Club CSO	203346	SX9328072960	2006-2012	319	2291.3	4.18%
11	Bradley Court CSO	202224	SX8588071400	Not monitored			
12	Broadmeadow PS	203087	SX9275472911	Not monitored			
13	Brunswick House CSO	203099	SX8587671400	2006-2012	30	85.3	0.16%
14	Buckand PS STW	NRA-SW-2863	SX8830072130	2011-2012	8	15	0.14%
15	Canada Farm PS B	NRA-SW-5530	SX8510070550	Not monitored			
16	Churchill PS	203334	SX8601072200	2006-2012	71	1025.1	1.87%
17	Clocktower CSO	203335	SX8578071300	2006-2012	11	5.2	0.01%
18	Coach Road CSO	203095	SX8596470236	2006-2012	20	4	0.01%
19	Combeteignhead SPS	002659/PC/01	SX9013071760	Not monitored			
20	Elm Road CSO	201682	SX8611073880	Not monitored			
21	Field near war memorial CSO	201770	SX8919371361	Not monitored			
22	Fire Station CSO	203088	SX9327973303	2006-2012	33	20.2	0.04%
23	Forde Park/Torquay Road CSO	203098	SX8703070692	2006-2012	138	79.2	0.14%
24	Forde Road PSCSO/EO	203336	SX8725071700	2006-2012	147	429.9	0.78%
25	Gales Hill PS	203347	SX9379072360	2006-2012	72	713.4	1.30%

No.	Name (Permit database)	Permit number	NGR	Period monitored	No. individual events	Total duration (hrs)	% of period active
26	Greenhill Way	SWWA 2379	SX8710072700	Not monitored			
27	Hackney PS	203337	SX8744072230	2006-2012	37	215.9	0.39%
28	Headway Cross Road CSO	201702	SX9319073880	Not monitored			
29	Higher Netherton SPS	002660/PC/01	SX8919071360	Not monitored			
30	Highweek Road CSO	202230	SX8577671294	Not monitored			
31	Homers Lane PSEO	200747	SX8669072900	Not monitored			
32	Horns Close CSO	203090	SX9044273602	2006-2012	393	969.3	1.77%
33	Horns Park PSEO	201509	SX9042573453	Not monitored			
34	Keyberry Rd No. 5 CSO	203101	SX8695070434	2006-2012	108	362.4	0.66%
35	Keyberry Rd No. 2	203199	SX8703170691	2006-2012	30	83.6	0.15%
36	Keyberry Rd No. 18 CSO	203200	SX8702670648	2006-2012	557	2873.5	5.25%
37	King George's Field CSO	203348	SX9301072460	2006-2012	32	64.3	0.12%
38	Laurel Lane CSO	203084	SX9258272139	2006-2012	2	0.5	<0.01%
39	Loweicke House PS	203102	SX8491872279	2006-2012	9	9.6	0.02%
40	Market Walk CSO	203339	SX8603071390	2006-2012	47	23.3	0.04%
41	Millford Park PSCSO/EO	201656	SX9312072880	Not monitored			
42	New Park Road CSO	202238	SX8709873358	Not monitored			
43	Newton Road CSO	201762	SX8687672677	Not monitored			
44	No. 15 Lemon Rd CSO	203138	SX8636571445	2006-2012	402	1804.7	3.30%
45	O/S 11 Kingsteignton Rd CSO	203092	SX8634371667	2006-2012	4	2	<0.01%
46	O/S 12 Dunnings Walk CSO	201684	SX9319073880	Not monitored			
47	O/S 4 Keyberry Rd CSO	203100	SX8697970711	2006-2012	69	848.2	1.55%
48	O/S 45 Higher Combe Dr CSO	201701	SX9319173884	Not monitored			
49	Old Totnes Rd CSO	201737	SX8534070507	Not monitored			
50	Opp 65 Highweek Rd CSO	203338	SX8574071320	2006-2012	148	2958.2	5.40%
51	Orchard Close CSO	203085	SX9256472041	2006-2012	119	58.1	0.11%

No.	Name (Permit database)	Permit number	NGR	Period monitored	No. individual events	Total duration (hrs)	% of period active
52	Park Hill CSO	203089	SX9354672963	2006-2012	15	13.9	0.03%
53	Pitt Hill Rd CSO	203096	SX8601872195	2006-2012	3	0.7	<0.01%
54	Pottery Rd (UBM) PSEO	201601	SX8699072450	Not monitored			
55	PS A Canada Farm (outlet 1)	200007/PE/01	SX8486070720	Not monitored			
56	PS B Canada Farm (outlet 1)	200007/PE/01	SX8484070560	Not monitored			
57	Queen St CSO	203573	SX8603071380	Not monitored			
58	Queensway PS	203103	SX8718770711	2006-2012	30	126.3	0.23%
59	Ringmore Rd CSO	203086	SX9263772362	2006-2012	90	70.6	0.13%
60	Rugby Club CSO	201697	SX9377872950	Not monitored			
61	Sandrigham Park CSO	203340	SX8720071140	2006-2012	209	1064	1.94%
62	School Rd PSEO	201594	SX8506773892	Not monitored			
63	St Marychurch Rd CSO	203342	SX8711070820	2006-2012	108	514.7	0.94%
64	Stockmeadow House CSO	203350	SX9107073480	2006-2012	199	269.2	0.49%
65	Stoketeignhead PS	203091	SX9140170758	2006-2012	1	0.2	<0.01%
66	Teignhaven PSEO	2898/16	SX9301072650	Not monitored			
67	Templers Rd CSO	202245	SX8672171687	Not monitored			
68	The Butts PS	203343	SX8714072570	2006-2012	57	328.5	0.60%
69	Torquay Rd CSO	203344	SX8703070690	2006-2012	174	226.2	0.41%

Data from the Environment Agency

The main clusters of intermittent discharges are around the head and around the mouth of the estuary. Of the monitored outfalls, the most active were Keyberry Road No. 18 CSO, and Opp 65 Highweek Road CSO, both of which spilled for just over 5% of the period considered. Both are located within Newton Abbot, at the head of the estuary. A further seven discharges spilled for between 1 and 5% of the period considered. Four of these are located in Newton Abbot, two at Teignmouth and one at Bishopsteignton. Of the two at Teignmouth (Bitton Park Rugby Club CSO and Gales Hill PS) the former is likely to be of most significance as it spilled for more of the time and is located closer to the fishery. The one located at Bishopsteignton (Horns Close CSO) discharges to a stream which in turn discharges to the north shore of the estuary around the upper limit of the classified area. The rest of the monitored outfalls spilled for less than 1% of the time, with some of these hardly spilling at all.

Although the vast majority of properties located within 2km of the Teign estuary are connected to mains sewerage, a small number are served by private discharges. Where specified, these are generally treated by either septic tank or small treatment works such as package plants. The majority of these are small, serving one or a small number of properties and discharging less than 1m^3/day. Of the 42 permitted private sewage discharges within 2km of the estuary, 27 discharge to soakaway and 15 discharge either to watercourses or direct to the estuary. Those which go to soakaway are unlikely to be of any significance to the fishery assuming they are functioning properly. Seven of the private discharges are consented to discharge over 3m^3 per day, and details of these are shown in Table II.5.

Table II.5: Details of private sewage discharges of over 3m^3/day

Ref.	Property served	Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
A	1 - 11 Venn Farm Barns	SX9257074930	Package plant	5	Bicton Brook
B	Bear Feet Play Centre	SX8659271782	Package plant	9	Whitelake (Tidal)
C	Coombe Cellars Inn	SX9020072300	Unspecified	30	Unnamed watercourse
D	Farmhouse, Flat & cottages	SX8518073700	Unspecified	4	Soakaway
E	Home Farm Barns	SX8940070400	Unspecified	4.7	Soakaway
F	Industrial Site & Nightclub	SX8650071950	Unspecified	11	Teign Estuary
G	Newton Abbot Clays Quarry	SX8650072250	Unspecified	5.46	River Teign
H	Restawhile	SX8993072360	Unspecified	4	Teign Estuary
I	Wear Farm Caravan Park	SX8937072900	Biodisc	50	Unnamed watercourse

Data from the Environment Agency.

There is a small cluster of private discharges to the estuary at Coombe Cellars. This includes the Coombe Cellars Inn and Restawhile. The Wear Farm Caravan Park may also be of some significance, as it is relatively large and discharges to a short watercourse which feeds into the estuary just upstream of the fishery.

Appendix III. Sources and Variation of Microbiological Pollution: Agriculture

Around 60% of land within the Teign catchment is used for agriculture (Cycleau Project, 2004). Of this, a large proportion is pasture, although arable farming is more prevalent in the lower catchment (Figure 1.2). Table III.1 and Figure III.1 present livestock numbers and densities for the catchments draining to the estuary. This data was provided by Defra and is based on the 2010 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 the distribution and numbers of livestock within the catchment.

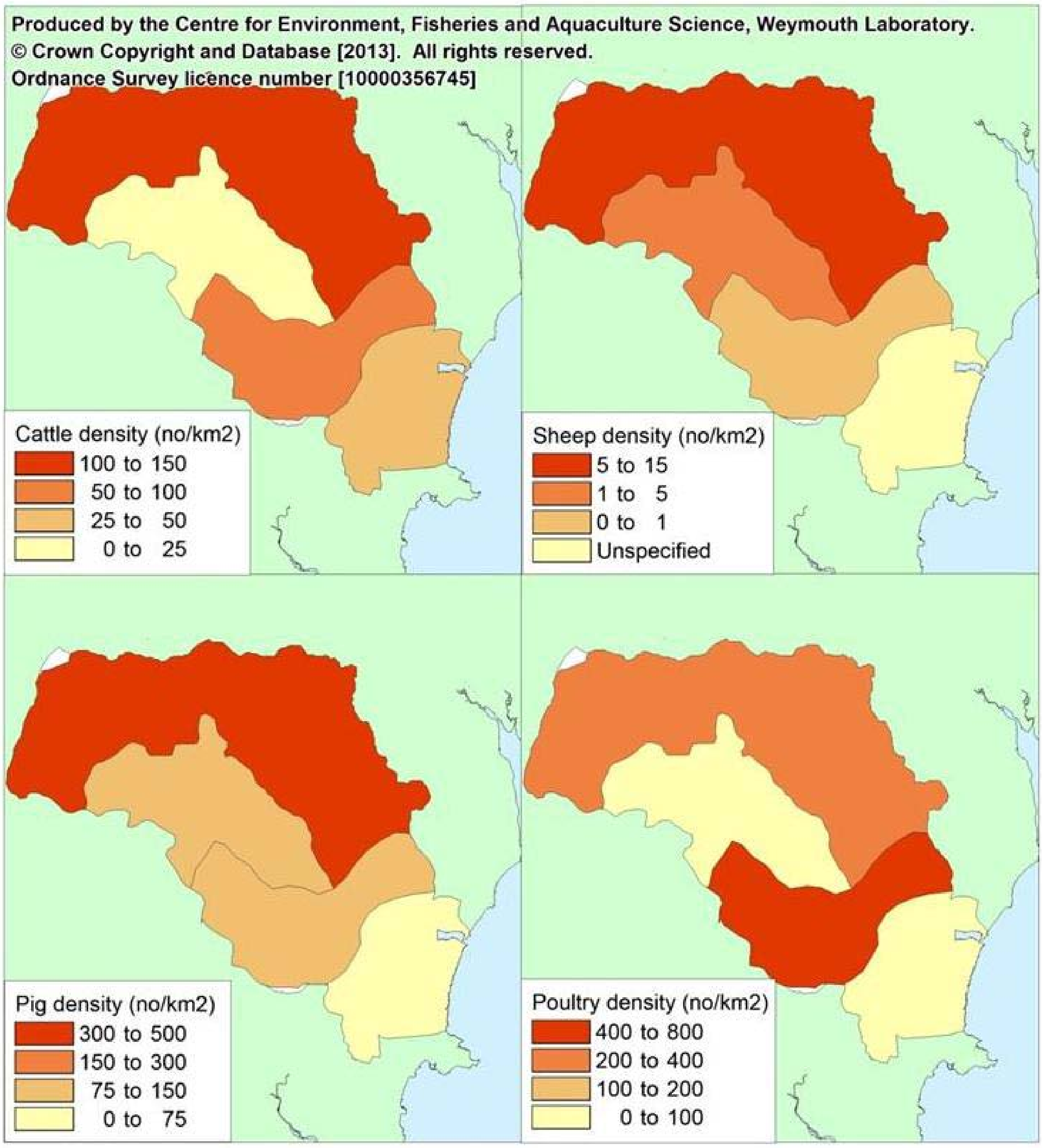


Figure III.1: Livestock densities within the Teign catchment.

Table III.1: Summary statistics from 2010 livestock census for Teign catchment

	Numbers				Density (animals/km^2)			
Catchment name	**Cattle**	**Sheep**	**Pigs**	**Poultry**	**Cattle**	**Sheep**	**Pigs**	**Poultry**
Teign (Tidal) and Torbay	3,671	**	8,342	2,172	28.3	**	64.4	16.8
Teign and Lemon (Lower)	6,718	71	9,559	63,992	67.5	0.7	96.1	643.1
Teign (Upper)	14,669	1,246	39,383	40,614	141.3	12.0	379.4	391.3
Bovey	5,803	701	20,056	5,505	23.4	2.8	80.9	22.2
Total	30,861	2,018	77,339	112,282	53.1	3.5	133.1	193.3

**Data suppressed to prevent disclosure of information about individual holdings

The concentration of faecal coliforms excreted in the faeces of animal and humans and corresponding loads per day are summarised in Table III.2.

Table III.2: Levels of faecal coliforms and corresponding loads excreted in the faeces of warm-blooded animals.

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

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

The numbers of grazing animals within the catchment area are of potential significance, but the overall densities are not particularly high outside of the upper reaches. Some 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 present at higher overall densities than grazing animals. Manure from pig and poultry operations is typically collected, stored and spread on nearby farm land (Defra, 2009). Sewage sludge may also be used as fertilizer, but no information on local practices was available at the time of writing.

The primary mechanism for mobilisation of faecal matter deposited or spread on farmland to coastal waters is via land runoff, so fluxes of livestock related contamination into the 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. Runoff from the majority of the catchment area enters the estuary upstream of the fisheries. Higher impacts may therefore be anticipated towards the up-estuary ends of the shellfish beds on this basis, although there are some significant tributaries feeding into the lower estuary which will also carry some agricultural contamination. No livestock were recorded on pastures adjacent to the estuary during the shoreline survey.

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

Appendix IV. Sources and Variation of Microbiological Pollution: Boats

The discharge of sewage from boats is potentially a significant source of bacterial contamination of shellfisheries within the Teign River. There is significant boat traffic within the Teign estuary, which hosts a commercial port and small fishing fleet, and is heavily used by pleasure vessels such as yachts and cabin cruisers. Figure IV.1 presents an overview of boating activity derived from the shoreline survey, satellite images and various internet sources.

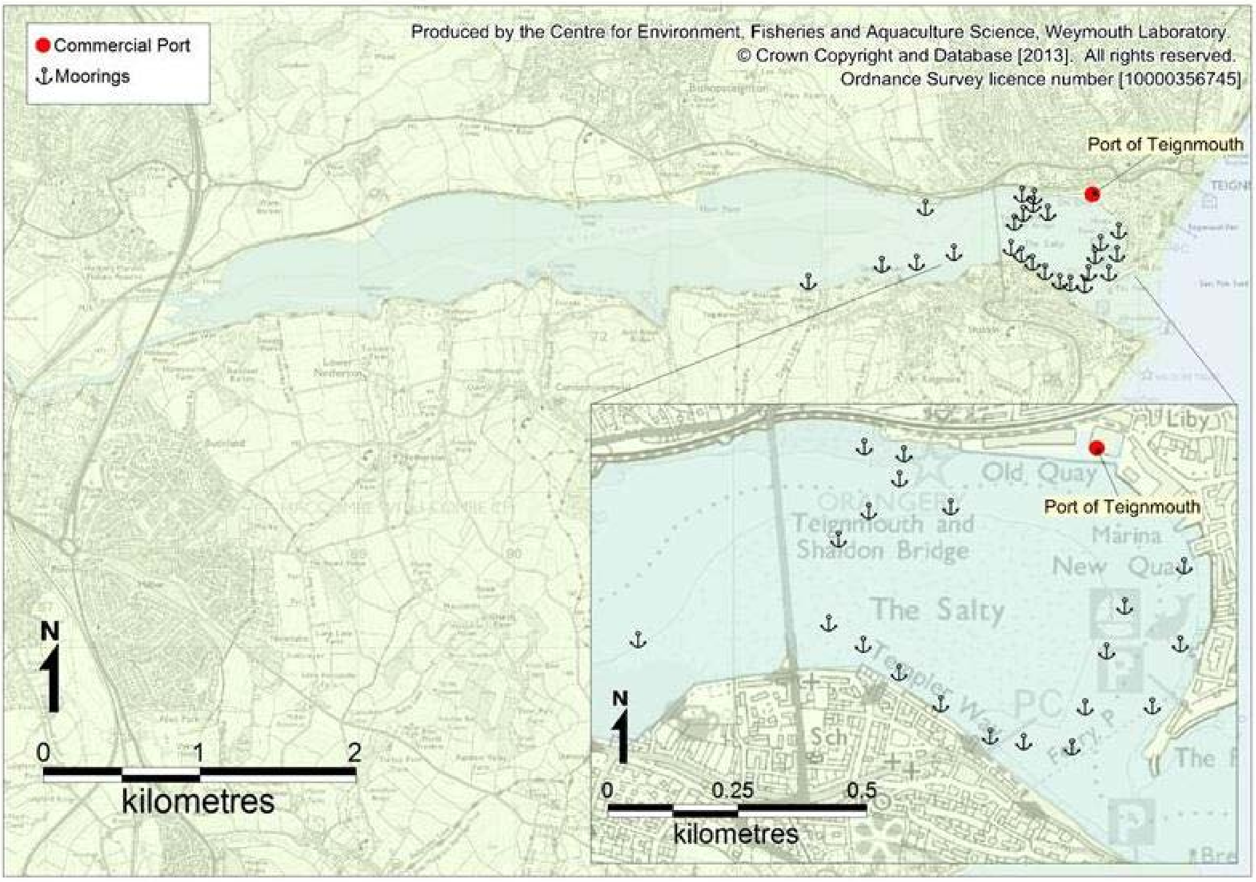


Figure IV.1: Boating Activity within the Teign Estuary

The commercial port exports around 400,000 tonnes of dry bulks each year predominantly ball clay but also other dry bulks including animal feed, grain, salt, stone chippings (ABP, 2013). This equates to over 800 shipping movements each year (Ports and Harbour, 2013). Merchant shipping vessels are not permitted to make overboard discharges within 3 nautical miles of land[1] so vessels associated

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

with the commercial port should be of no impact. A small passenger ferry runs between Teignmouth and Shaldon, however it is not large enough to contain onboard toilet facilities and therefore poses little to no risk of microbiological contamination to the shellfish beds.

There are no marinas at Teignmouth, the closest is located in Torquay approximately 7 km away. The Teignmouth Harbour commission manages 100 deepwater moorings and 600 drying moorings (Teignmouth Harbour Commission, 2013). Most of these are downstream from the Shaldon Bridge, although they do extend into the classified area, mainly along the south shore.

One sailing club operates out of the Teign Estuary (Teign Corinthian Yacht Club) which offers a variety of racing and courses for dinghies and the larger yachts and motor cruisers. A range of other watersports also takes place in the Teign including canoeing, kayaking, waterskiing and windsurfing. However, the smaller recreational boats are not large enough to contain onboard toilet facilities and therefore are unlikely to make overboard discharges.

Private vessels such as yachts, cabin cruisers and fishing vessels of a sufficient size are likely to make overboard discharges from time to time. This may either occur when the boats are moored or at anchor, particularly if they are in overnight occupation, or while they are navigating through the relative calm of the estuary. The areas that are at highest risk from microbiological pollution therefore include the mooring areas for larger private vessels and the main navigation routes into the estuary. Therefore, the lower reaches of the estuary downstream of the Shaldon Bridge will receive the majority of any overboard discharges. Peak pleasure craft activity is anticipated during the summer, so associated impacts are likely to follow this seasonal pattern. It is difficult to be more specific about the potential impacts from boats and how they may affect the sampling plan without any firm information about the locations, timings and volumes of such discharges.

Appendix V. Sources and Variation of Microbiological Pollution: Wildlife

The Teign estuary encompasses a variety of habitats including intertidal mudflats, saltmarsh and saline lagoons. These features attract significant populations of birds and other wildlife. Parts of the Teign and surrounding areas have been designated as a National Nature Reserve (NNR), a Local Nature Reserve (LNR), a County Wildlife Site (CWS), and part of the South Devon Natural Area.

The most significant wildlife aggregation in terms of shellfish hygiene is likely to be overwintering waterbirds (waders and wildfowl). Studies in the UK have found significant concentrations of microbiological contaminants (thermophilic Campylobacter, salmonellae, faecal coliforms and faecal streptococci) from intertidal sediment samples supporting large communities of birds (Obiri-Danso and Jones, 2000). The Teign estuary supports internationally and nationally important species of wildfowl including Dunlin, redshank, curlew and Bar-tailed Godwit (Teign Estuary Partnership, 2004). The British Trust for Ornithology co-ordinates regular counts of overwintering waterbirds (waders and wildfowl) at many coastal sites around the UK, but there are no published counts for the Teign estuary. The neighbouring Exe estuary attracts in the region of 19,000 waterbirds each winter (Holt *et al*., 2012). It is therefore likely that the Teign, a similar but smaller estuary, attracts several thousand overwintering waterbirds each year.

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

Birds such as gulls and terns and relatively small numbers of waders remain in the area to breed in the summer, but the majority migrate elsewhere outside of the winter months. Bird numbers and potential impacts on the hygiene status of the fisheries are therefore much lower during the summer. The JNCC Seabird 2000 census recorded 222 breeding pairs of herring gulls around the estuary, the majority of which (173 pairs) were at Teignmouth (Mitchell *et al*, 2004). These seabirds are likely to forage widely throughout the area so inputs could be considered as diffuse, but are likely to be most concentrated in the immediate vicinity of the nest sites. Their faeces will be carried into coastal waters via runoff from their nesting sites or via direct deposition to the adjacent intertidal.

Otters are present within the Teign estuary at Newton Abbot. In 2011 between 1 and 20 otters were recorded per 5 km^2 (Devon Mammal Group, 2012) so population densities are very low. Otters generally tend to favour the more secluded areas with access to watercourses. However, given their likely wide distribution and small numbers they have no material bearing on the sampling plan.

There are no major seal colonies in the vicinity of the Teign estuary (SCOS, 2012), so whilst there may be occasional seal sightings as these animals forage widely, they will not be a significant source of contamination to the shellfishery. No other wildlife species which may have a bearing on the sampling plan have been identified.

Appendix VI. Meteorological Data: Rainfall

The Teignmouth weather station, received an average of 807 mm of rainfall per year between 2003 and 2012. Figure VI.1 presents a boxplot of daily rainfall records by month at Teignmouth.

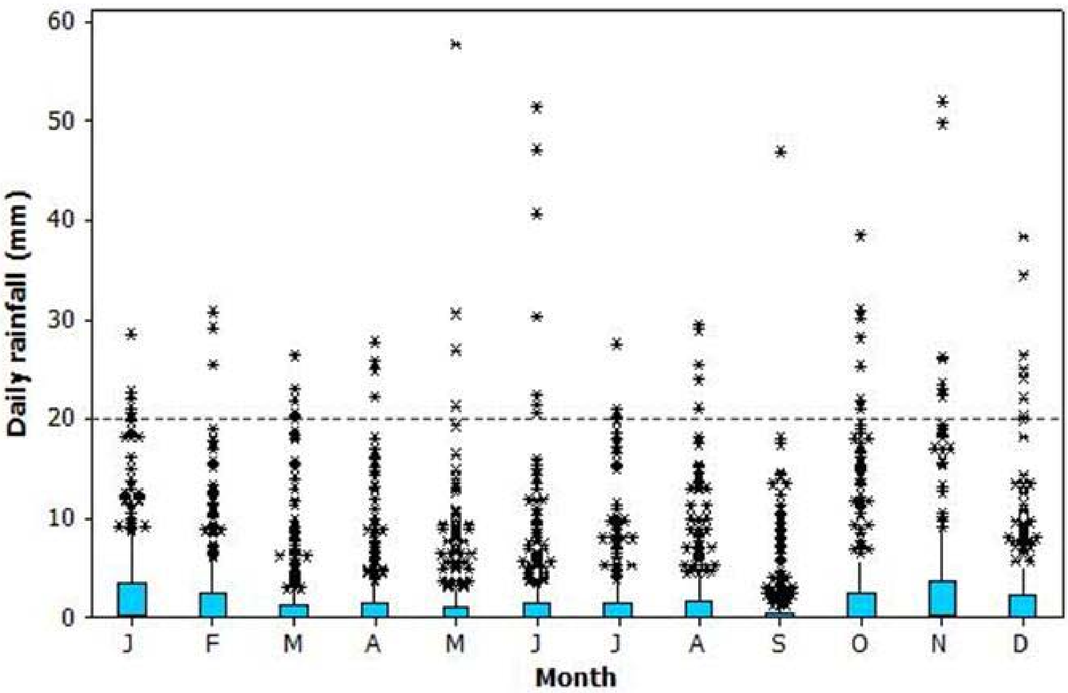


Figure VI.1: Boxplot of daily rainfall totals at Teignmouth, January 2003 to December 2012.
Data from the Environment Agency

Rainfall records from Teignmouth, which is representative of conditions in the vicinity of the shellfish beds, indicate relatively low seasonal variation in average rainfall. Rainfall was lowest on average in September and highest on average in November. Daily totals of over 20mm were recorded on 1.6% of days and 53% of days were dry. High rainfall events occurred in all months.

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

Appendix VII. Meteorological Data: Wind

South-west England is one of the more exposed areas of the UK, with wind speeds on average only greater in western Scotland. The strongest winds are associated with the passage of deep depressions close to or across the British Isles. The frequency and strength of depressions is greatest in the winter half of the year and this is when mean speeds and gusts are strongest. (Met Office, 2012).

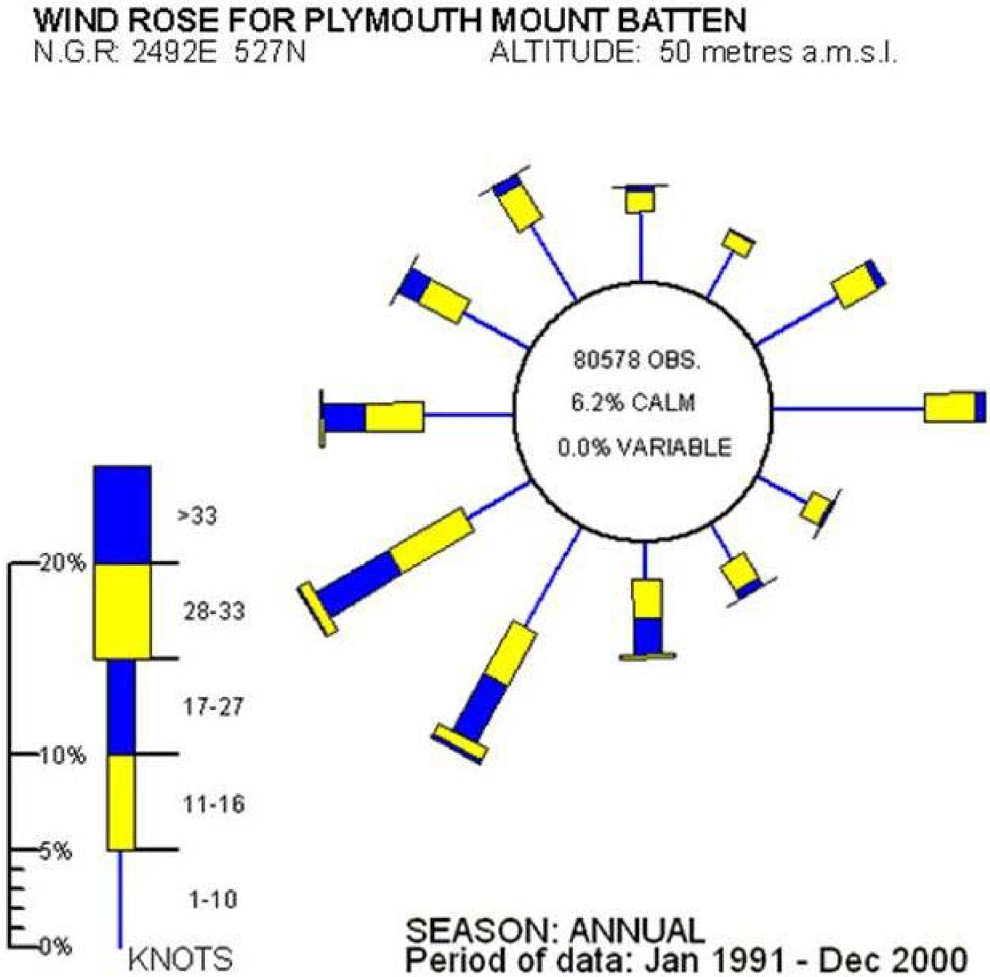


Figure VII.1: Wind Rose for Plymouth, Mount Batten.
Produced by the Meteorological Office. Contains public sector information licensed under the Open Government Licence v1.0

The wind rose in illustrates the typical frequency of speed and direction throughout a year and confirms a prevailing South Westerly wind. The Teign is a single spit enclosed estuary, with a narrow mouth that faces east which is constricted by a spit and a flood delta. The land surrounding the Teign is hilly and is particularly steep around its mouth. Consequently, it is relatively well protected from the prevailing winds. However it is exposed to winds from the north east quadrant, which will be funnelled up-estuary.

Appendix VIII. Hydrometric Data: Freshwater Inputs

The Teign has a catchment area of about 530 km² in total. The main freshwater input is the river Teign, which discharges to the head of the estuary. The River Teign flows from its source near Cranmere Pool on Dartmoor for approximately 48 km before discharging into the English Channel at Teignmouth. Three rivers the Lemon, Bovey and Aller Rivers converge with the river Teign at Newton Abbot, where the river becomes tidal. There are numerous other small streams discharging at various points within the estuary.

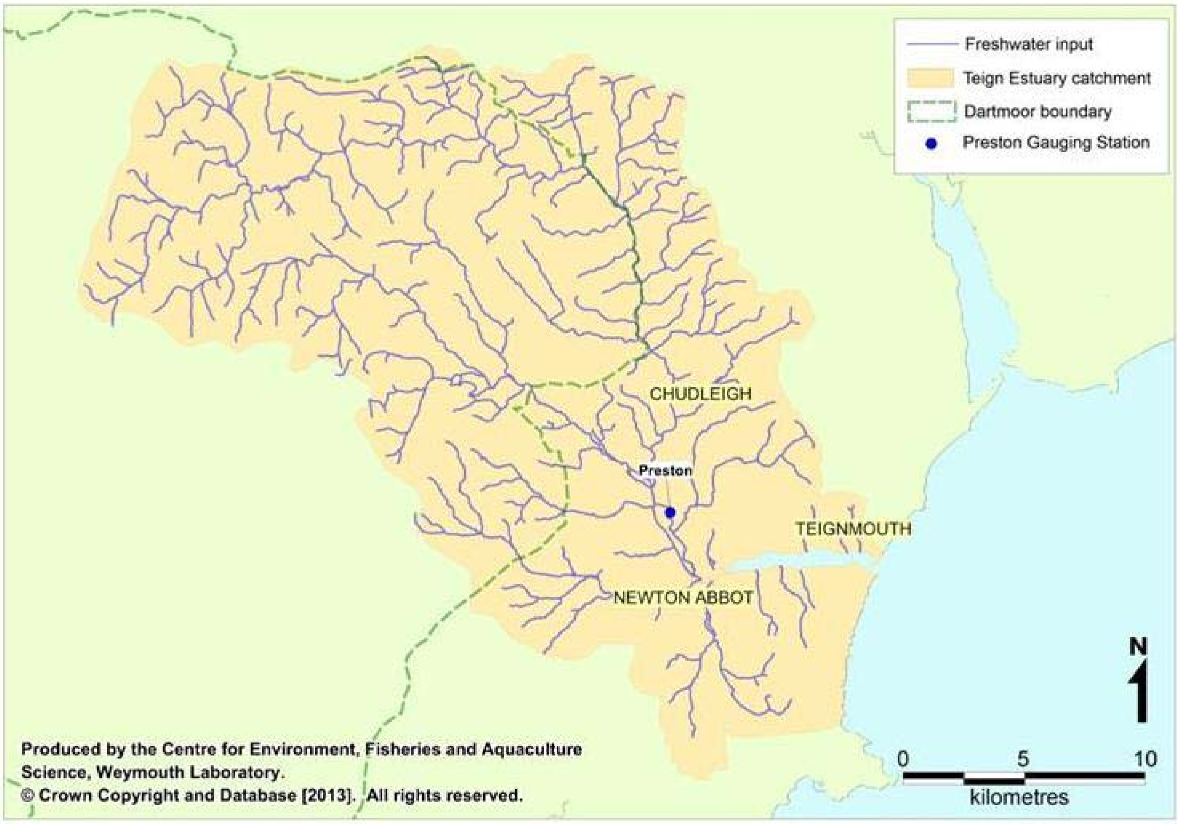


Figure VIII.1: Freshwater inputs into the Teign estuary

The majority of the catchment is rural, with moorland and pasture in its upper reaches and small areas of urbanised land concentrated close to the shore. The upper catchment falls within Dartmoor National Park and is characterised by steep slopes of moorland underlain with impermeable granite. As a result the river here rises rapidly in response to rainfall. In comparison the lower catchment has a gentler gradient with wide valleys and is underlain with more a permeable bedrock; Devonian and Carboniferous deposits (Environment Agency, 2009). A proportion of rainwater which falls in the lower catchment will infiltrate the bedrock and will be transported to the watercourses via groundwater.

Given that the vast majority of freshwater enters the upper reaches of the estuary, upstream of the shellfisheries, a gradient of decreasing levels of contamination towards the seaward ends of the shellfish beds is anticipated. The River Teign will receive microbiological pollution from point and diffuse sources such as STW discharges and urban and agricultural runoff. It is therefore likely to be a significant source of microbiological contamination to the shellfisheries in the estuary.

There is one flow river gauging station (Preston), summary statistics for which are presented in Table VIII.1 for the period January 1997 – May 2007.

Table VIII.1: Summary flow statistics for the Preston gauge station draining into the Teign estuary

Station Name	Catchment (km^2)	Mean Flow (m^3s^{-1})	Q95[1] (m^3s^{-1})	Q10[2] (m^3s^{-1})
Preston	381	9.116	1.070	22.400

Data from the Environment Agency

The mean flow rate at Preston Gauging Station is 9.116 m^3/s, with a base flow of just over 1 m^3/sec. Boxplots of mean daily flow records by month are presented in Figure VIII.2.

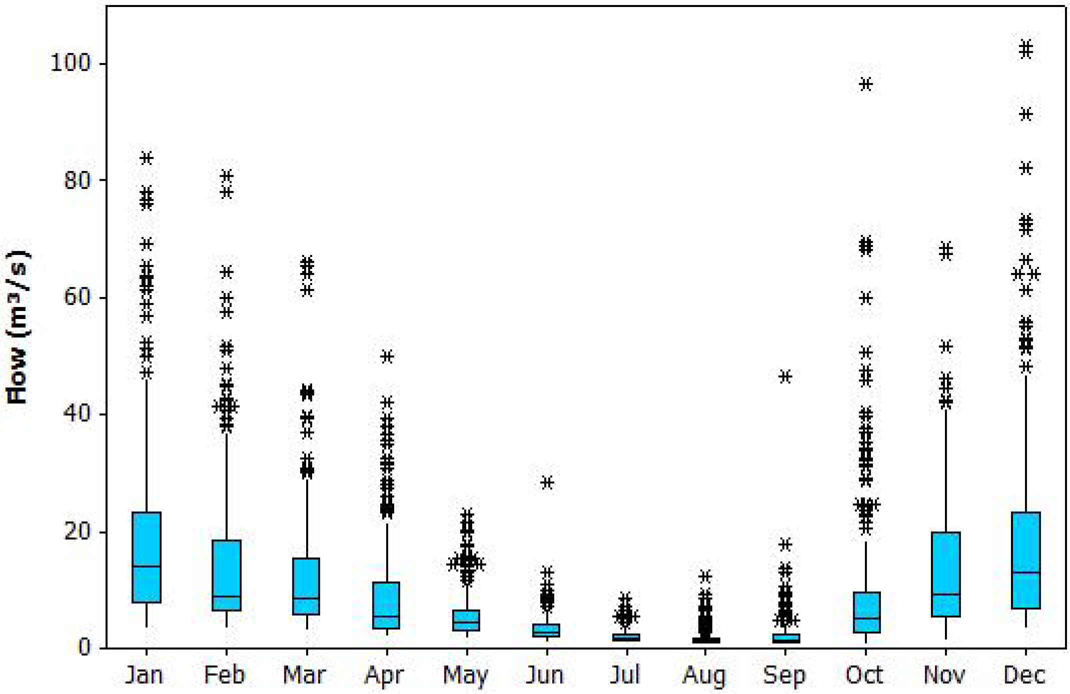


Figure VIII.2: Boxplots of mean daily flow records from Preston gauging station on the River Teign from 1997 – 2007.
Data from the Environment Agency

Flows were much higher on average during the colder months, with the highest flow rate (103 m^3/s) recorded in December 1999. High flow events of over 20m^3/sec are very rare from May to September. 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. 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.

Some bacteriological sampling of selected watercourses was undertaken under the Cycleau project from June 2005 to September 2006 (Cycleau Project, 2006). Additionally, some Environment Agency spot flow gauging records were available for some of the smaller watercourses discharging to the estuary, taken between 1971 and 2006. Locations of bacteriological sampling points and spot flow gauging sites are illustrated in Figure VIII.3.

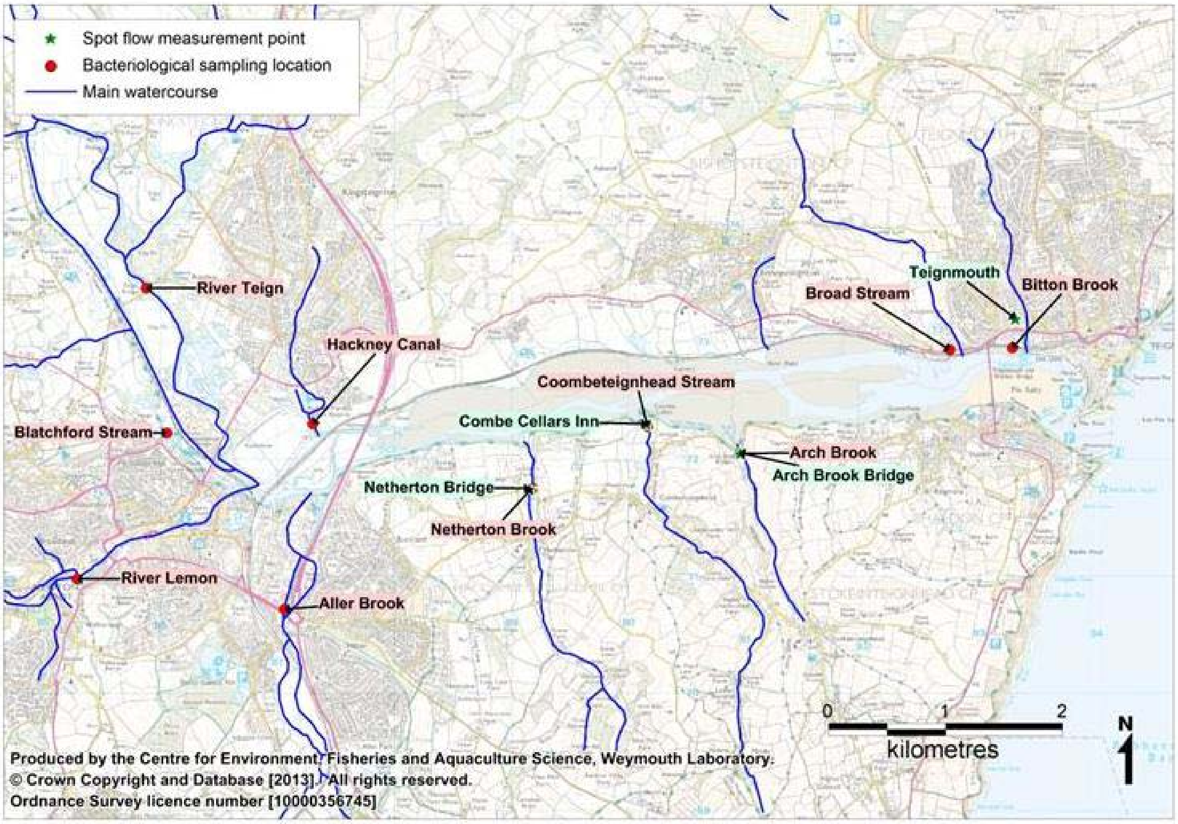


Figure VIII.3: Locations of bacteriological sampling points and spot flow gauging sites

Summary statistics for the spot flow gauging records are presented in
Table VIII.2, and summary statistics for the bacteriological sampling are presented in Table VIII.3. As the sampling and spot flow gauging were undertaken at different times, estimates of the bacterial loadings carried by these watercourses were not made.

Table VIII.2: Mean flow for spot gauging stations on watercourses draining into the Teign Estuary (1971-2006)

Site name	Watercourse name	Mean flow (m^3/s)	Max flow (m^3/s)	No of measurements
Coombe Cellars Inn	Combeteignhead Stream	0.034	0.051	8
Arch Brook Bridge	Arch Brook	0.023	0.036	7
Netherton Bridge	Netherton Brook	0.016	0.025	10
Teignmouth	Bitton Brook	0.009	0.017	4

Data from the Environment Agency

As may be expected, the mean discharge rates are very low relative to the main river Teign. The data available may not represent the full range of conditions as the sampling is sporadic and the number of measurements taken is low.

Table VIII.3: Summary of bacteriological sampling results from watercourses (June 2005-September 2006)

	Faecal coliforms (presumptive) cfu/100ml			
Site name	**No.**	**Geomean**	**Min.**	**Max.**
Aller Brook	15	5,700	455	100,000
Arch Brook	16	1,648	180	33,000
Bitton Brook	15	17,903	4,100	100,000
Blatchford Stream	15	1,701	99	29,000
Broad Stream	16	3,363	126	77,000
Combeteignhead Stream	15	4,871	270	51,000
Hackney Canal	14	5,072	780	34,000
Netherton Brook	15	2,054	153	44,000
River Lemon	15	4,596	901	69,000
River Teign	15	7,319	1,545	40,000

Data collected by the Cycleau Project, and provided by Teignbridge DC

Of these watercourses, Bitton Brook had the highest average concentrations of faecal coliforms, which is perhaps unsurprising as it drains an urban area. The main River Teign also carried quite high average concentrations of faecal coliforms. Two of these watercourses discharge direct to the fishery order area (Arch Brook and Broad Stream) and carried average concentrations of 1648 and 3363 faecal coliforms/100ml respectively. The small stream discharging at Bishopsteignton was not sampled.

During the shoreline survey, which was conducted under dry conditions, watercourses discharging directly to or near to the fishery area were sampled for *E. coli* and spot flow measurements were made. The results are presented in Table VIII.4 and Figure VIII.4. One small watercourse at Bishopsteignton was not sampled due to a surveyor error. It should be noted that the bacteriological results from the shoreline survey are not directly comparable with those obtained under the Cycleau investigation. Shoreline survey results provide *E. coli* (confirmed) results whereas samples from Cycleau report faecal coliforms (presumptive).

Table VIII.4: Shoreline survey water sample results (*E. coli*), measured discharge rate and calculated *E. coli* loadings

No.	Position	Name	*E. coli* (cfu/100ml)	Discharge (m^3/day)	E. coli loading (cfu/day)
1	SX 92545 72318	Unnamed	4100	742	$3.04x10^{10}$
2	SX 92062 72315	Unnamed	7500	549	$4.12x10^{10}$
3	SX 91856 72309	Unnamed	3000	4	$1.24x10^{8}$
4	SX 90942 72062	Arch Brook	720	3345	$2.41x10^{10}$
5	SX 90123 72314	Combeteignhead stream	3500	5884	$2.06x10^{11}$
6	SX 90240 72866	Unnamed	2400	432	$1.04x10^{10}$
7	SX 92774 72882	Broad Stream	7000	1776	$1.24x10^{11}$
8	SX 93282 72957	Bitton Brook	8700	5314	$4.62x10^{11}$

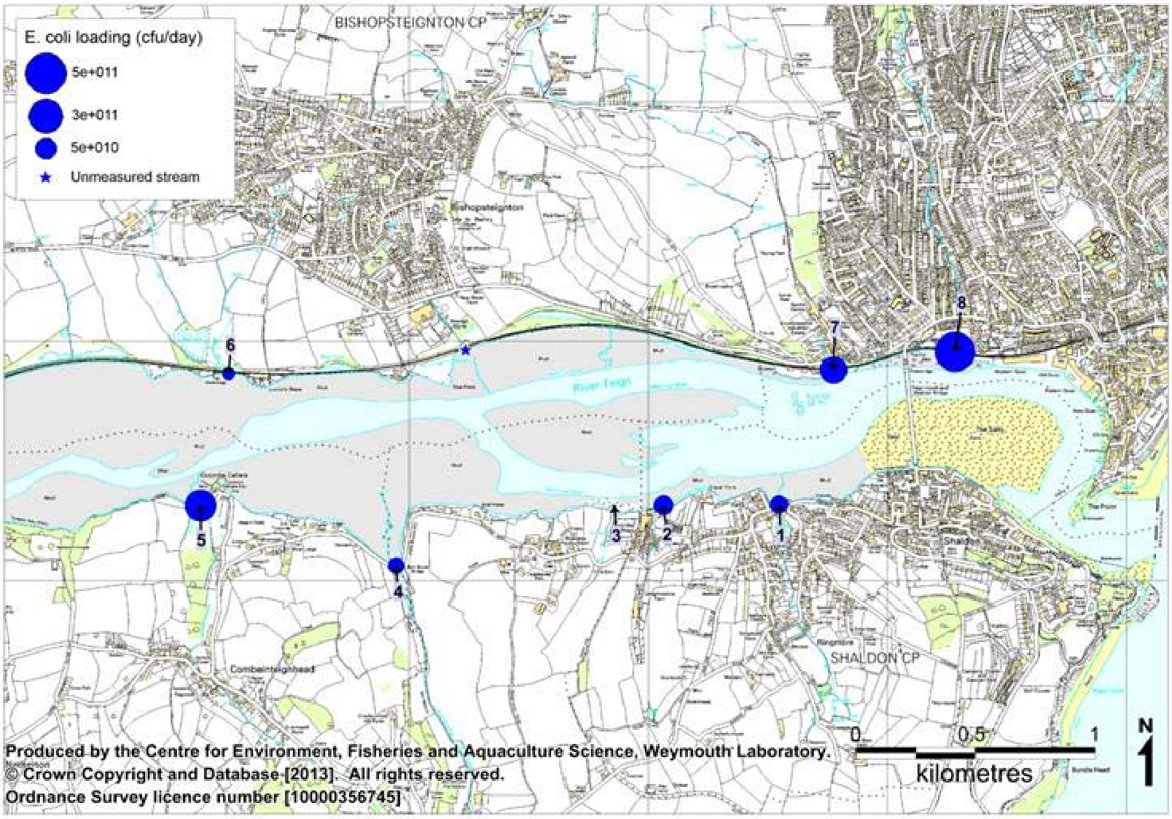


Figure VIII.4: Measured stream *E. coli* loadings from shoreline survey

All watercourses were carrying moderate to high levels of *E. coli*, so although none was particularly large in terms of discharge volume, some carried bacterial loadings likely to be of local significance. Three streams carried bacterial loadings exceeding 10^{11} *E. coli/*day, two of these were located on the north shore either side of Shaldon Bridge.

Appendix IX. Hydrography

IX.1. Bathymetry

The Teign is an east facing single spit enclosed estuary, which flows into Lyme Bay in the English Channel. It covers an area of about 3.7 km², of which 60% is intertidal (Futurecoast, 2002). Consequently a large proportion of water will be exchanged on each tide, but the dilution potential will be quite low away from the main channels, particularly in the upper estuary. Figure IX.1 shows aerial photography of the Teign, reproduced from Google Earth. Admiralty charts are not presented due to a lack of detail outside of the very lower reaches of the estuary. A Google Earth photograph taken in 2006, and accessed in 2008 was used as more recent versions were taken while the tide was at a higher level.

Figure IX.1: Ariel photograph of the Teign Estuary
Google Earth, 2006

The Teign is relatively narrow (up to 800m wide), approximately 6-7km long (Bernades *et al*, 2006), and is quite uniform in width and orientation throughout. Its mouth is constrained by a sandy spit to the north and a rocky steep headland to the south. There are extensive gravel and sand deltas at its mouth, both seawards and landwards. The main river channel is approximately 100m wide with a maximum depth of 5.8m at its mouth. It runs east for approximately 2km and then splits into two channels around a sandbank where many of the shellfish plots lie. These two channels then rejoin upstream of the sandbank. The main channel become progressively shallower as it meanders through the middle and upper reaches. Where watercourses drain to the lower and middle reaches of the estuary, they have cut drainage channels across the intertidal area, which generally run perpendicular to the shore. The surrounding land is quite steeply sloping, especially around the outer reaches of the estuary. It is largely a natural water body with little reclaimed land. Some maintenance dredging is undertaken in the approach channel (Futurecoast, 2002).

IX.2. Tides and Currents

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. The average tidal range at Teignmouth (New Quay) is 3.8m on spring tides and 1.6m on neap tides. Tides are asymmetrical, with a shorter duration and faster moving ebb tide (Futurecoast, 2002).

Table IX.1:Tide Levels and ranges within the Teign

	Height above chart datum (m)				Range (m)	
Port	MHWS	MHWN	MLWN	MLWS	Spring	Neap
Teignmouth (New Quay)	4.7	3.6	2.0	0.9	3.8	1.6
Teignmouth (Approaches)	4.6	3.6	2.0	0.7	3.9	1.6

Data from Admiralty Total Tide

Advection of pollutants by tidal currents is likely to be the main mode of contaminant transport in the Teign estuary. Tidal streams flood up the estuary in a westerly direction, following the main channels, and spreading out across intertidal areas, where current velocities will be considerably lower. The reverse will occur on the ebb. Shoreline sources of contamination will therefore primarily impact up and downtide of their locations along the bank to which they discharge. Their impacts will decrease with distance travelled, as the plume becomes progressively more diluted. At lower states of the tide contamination from some shoreline sources such as watercourses will be carried through any intertidal drainage channels where the dilution potential is low. Relatively high concentrations of indicator bacteria may arise in these channels at such times. The shellfish plots on the central sandbank will mainly be exposed to contamination originating from upstream and downstream and carried along the main channel. Those on the intertidal area adjacent to the north and south shores will also be influenced by shoreline sources discharging to the shore where they are located.

The strongest tidal flows are likely to be experienced in the narrow mouth, which can exceed 5 m/s at times (Pritchard and Huntley, 2002). Although a large number of hydrographic studies on the Teignmouth area have been published (e.g. Whitehouse, 2004) no tidal stream modelling or current velocity measurements were available for the estuary upstream of the Shaldon Bridge, where the fishery is located. It is therefore not possible to make any estimates of tidal excursion through the fishery area. The general decrease in sediment particle size towards the head of the estuary (Futurecoast, 2002) is indicative of a reduction in flow velocity, with coarser sediments present in the outer estuary where tidal streams are the strongest.

Superimposed on tidal currents are the effects of freshwater inputs and wind. The main freshwater input, the River Teign discharges to the head of the estuary. The average and maximum flow ratios (freshwater input:tidal exchange) are 0.034 and 0.515 respectively, and the estuary is described as partially mixed at lower river discharges (Futurecoast, 2002). This suggests that some density effects are likely to arise, particularly in the upper estuary and at higher river discharge rates. Neap tides may also accentuate density effects as both tidal current velocities (and hence the extent of turbulent mixing) and the volume of tidal exchange will be lower. When such effects occur, they will result in a shear between surface and bottom currents, with less dense freshwater moving in a net seaward direction at the surface, and a net movement of more saline water up-estuary lower in the water column.

Repeated salinity measurements were taken between 2003 and 2013 by the Environment Agency at two points within the Teign alongside shellfish water bacteriological sampling. Their locations, which coincide approximately with the upper and lower boundaries of the shellfishery, are shown in Figure IX.2. It is presumed that the salinity measurements were taken from the surface layer.

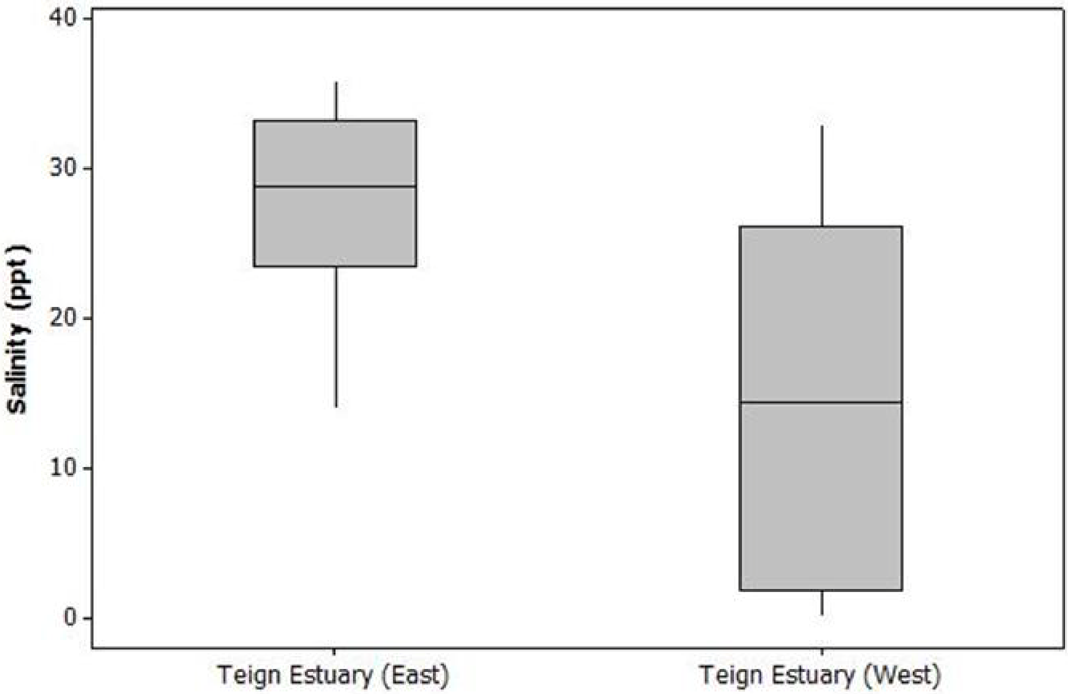


Figure IX.2: Boxplot of salinity readings taken in the Teign estuary, 2003-2013
Data from the Environment Agency

Salinity was quite variable at both sites, indicating a significant but variable freshwater influence throughout the fishery area. At Teign Estuary (East) the average and minimum salinities were 27.9 and 14.0ppt respectively. At Teign Estuary (West), salinity was much lower on average (14.2ppt) and considerably more variable, often consistent with almost pure river water (minimum of 0.2ppt). These salinity measurements highlight two important points. Firstly, they suggest that there are likely to be some stratification and density driven effects on circulation in the vicinity of the fishery. Secondly, they indicate that there is a strong salinity gradient across the fishery. Salinity may be considered a proxy for levels of runoff borne contamination, and was strongly negatively correlated with levels of faecal coliforms at both sites (Figure X.11). Therefore it is concluded that the influence of contamination carried into the estuary by land runoff will increase significantly towards the up-estuary end of the fishery. Due to density effects, this may be more acute in the upper layer of the water column than on the estuary bed, where the shellfish are located, although intertidal shellfish plots will be exposed to lower salinity water towards low tide.

Strong winds will modify surface currents. 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 surface water currents which may travel lower in the water column or along sheltered margins. The relatively steep sides of the estuary will tend to funnel winds up or down it. The prevailing south westerly winds will therefore tend to push surface water down the estuary. 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. Where strong winds blow across a sufficient distance of water they may create wave action, and where these waves break, contamination held in intertidal sediments may be resuspended, although given the enclosed nature of the Teign estuary strong wave action is not anticipated.

Appendix X. Microbiological Data: Seawater

X.1. Bathing Waters

There are 3 bathing waters relevant to the Teign Estuary designated under the Directive 76/160/EEC (Council of the European Communities, 1975), shown in Figure X.1. Due to changes in the analyses of bathing water quality by the Environment Agency from 2012, only data produced up to the end of 2011 was used in these analyses.

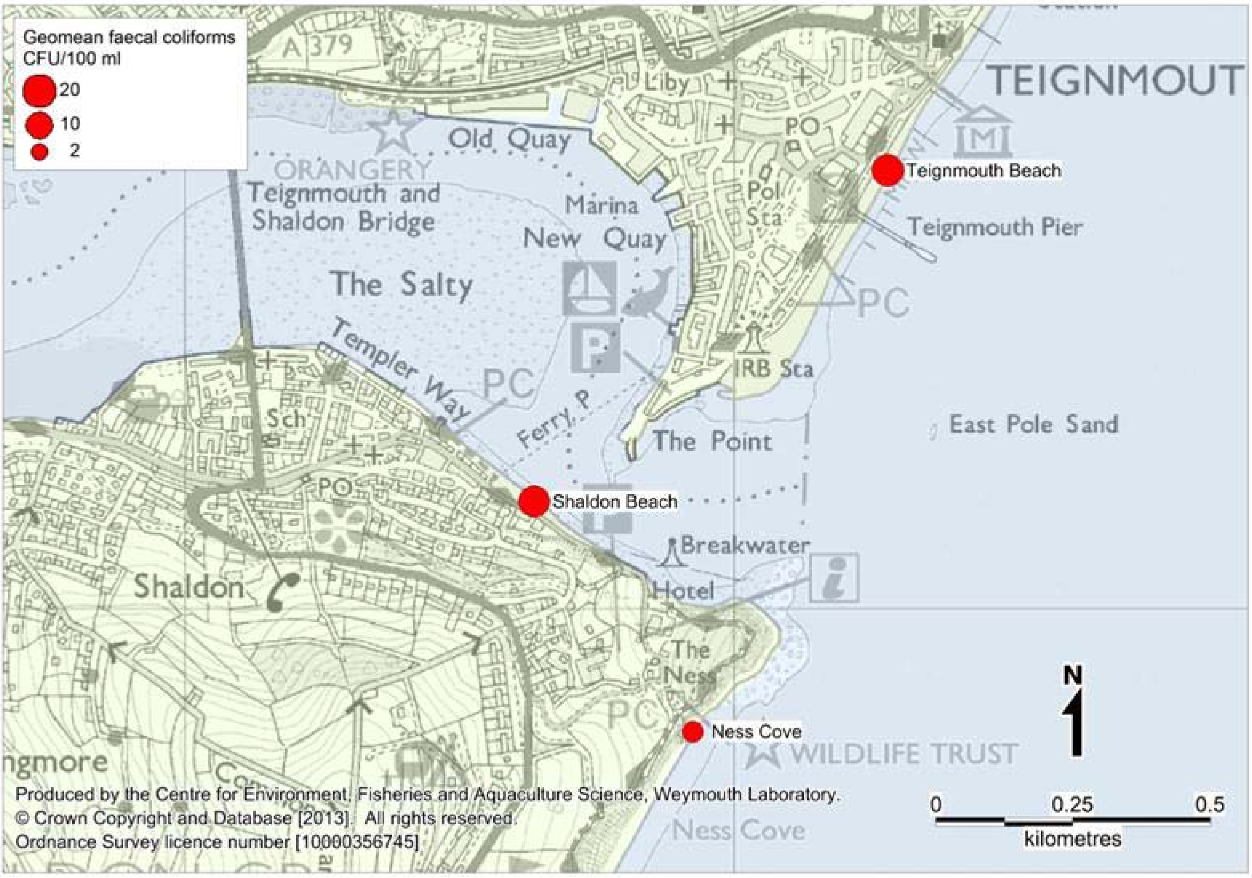


Figure X.1: Location of designated bathing waters monitoring points in the Teign Estuary and associated geomean of faecal coliform results (cfu/100ml)

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

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

Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1000
Shaldon Beach	194	01/05/2003	20/09/2011	23.5	<2	8,000	18.6	3.1
Ness Cove	184	01/05/2003	20/09/2011	5.0	<2	50,000	3.8	0.5
Teignmouth Beach	227	08/04/2003	20/09/2011	25.3	<2	620,000	21.1	0.9

Data from the Environment Agency

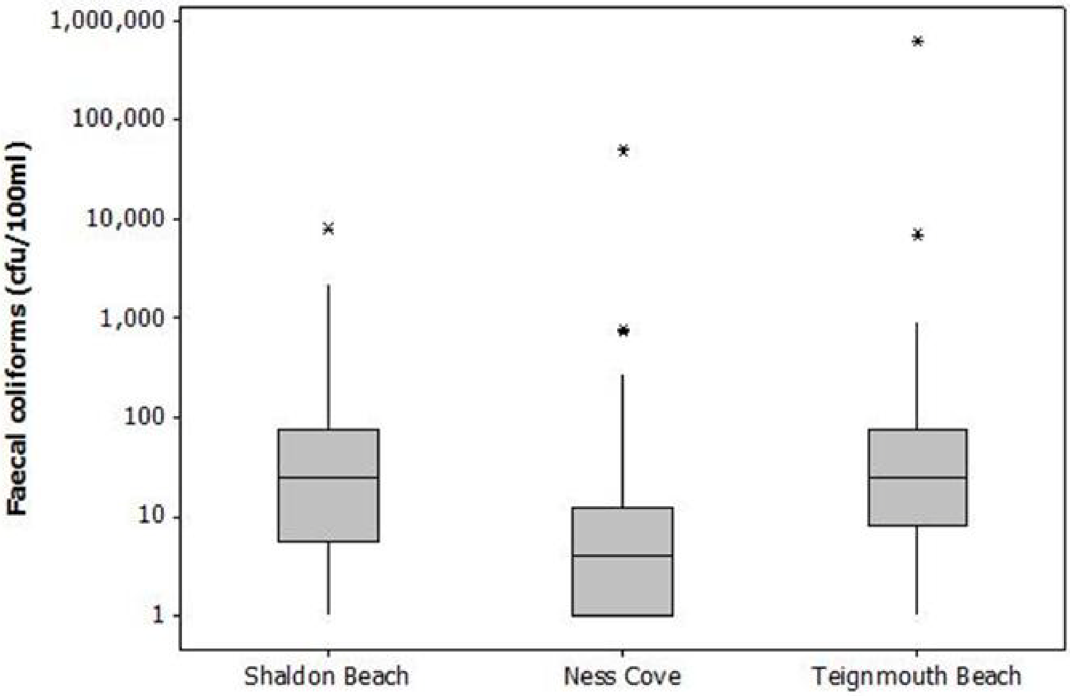


Figure X.2: Box-and-whisker plots of all faecal coliforms results by site
Data from the Environment Agency

All sites had results exceeding 100 faecal coliforms/100 ml, but Ness Cove had much fewer than the other sites, and also had the lowest geometric mean faecal coliform levels. One-way ANOVA testing showed there to be a significant difference in faecal coliform levels between sites. Post ANOVA tests (Tukey) revealed that Ness Cove had significantly lower levels of faecal coliforms than both of the other sites, but there were no significant differences between Shaldon Beach and Teignmouth Beach.

More robust comparisons of sites were carried out on a pair-wise basis by undertaking correlations (Pearson's) between sites that shared sampling dates, and therefore environmental conditions, on at least 20 occasions. There were highly significant correlations ($p < 0.001$) between all sites, suggesting that they are influenced by similar sources.

Overall temporal pattern in results

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

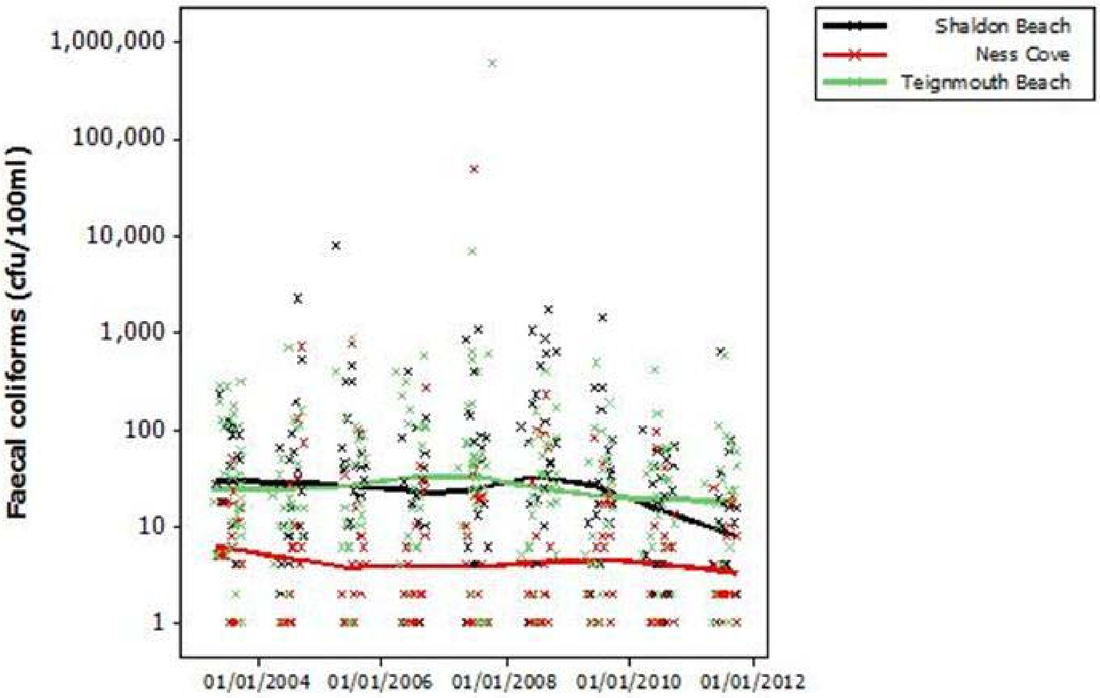


Figure X.3: Scatterplot of *E. coli* results for bathing waters in the Teign Estuary overlaid with loess lines.
Data from the Environment Agency

The level of faecal coliforms remained steady except for a slight decline at Shaldon Beach. This decline may possibly be explained by the implementation of UV treatment at Heathfields STW in March 2010. Comparisons of bathing water results for equal time periods before and after the improvements revealed that there was a significant reduction in the mean faecal coliform levels at Shaldon Beach (T-test, p=0.003) from approximately 15 cfu/100 ml to 10 cfu/100 ml.

Influence of tides

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

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

Site	High/low tides		Spring/neap tides	
	r	p	r	p
Shaldon Beach	0.476	<0.001	0.412	<0.001
Ness Cove	0.160	0.01	0.094	0.201
Teignmouth Beach	0.054	0.522	0.103	0.094

Data from the Environment Agency

Figure X.4 presents polar plots of log_{10} faecal coliform results against tidal states on the high/low cycle for the correlations indicating a statistically significant effect. High water at Teignmouth (New Quay) is at 0° and low water is at 180°. Results of 100 faecal coliforms/100ml or less are plotted in green, those from 101 to 1000 are plotted in yellow, and those exceeding 1000 are plotted in red.

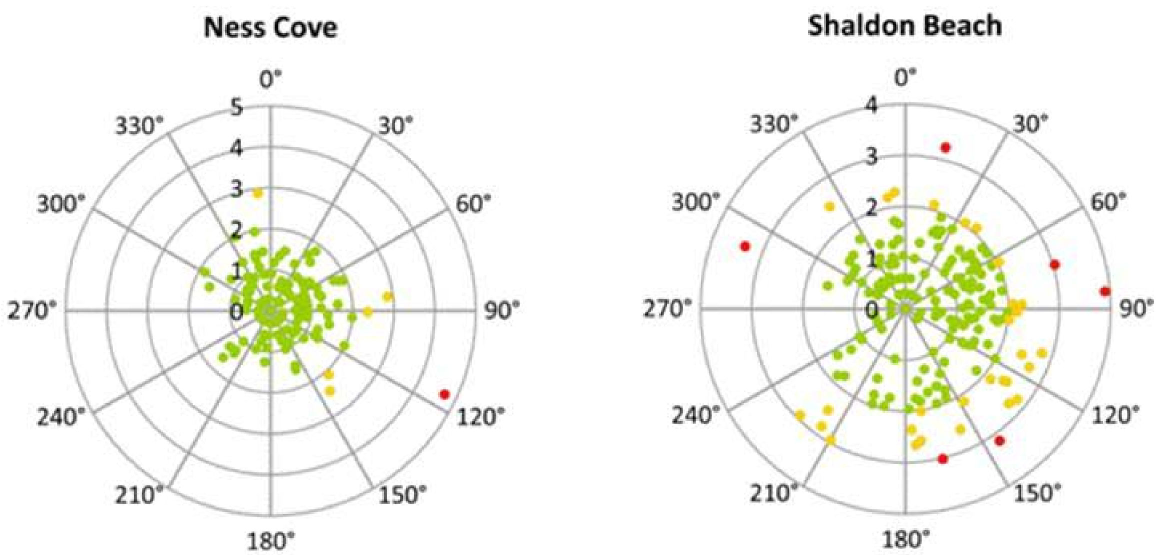


Figure X.4: Polar plots of log_{10} faecal coliforms against tidal state on the high/low tidal cycle for bathing waters monitoring points with significant correlations
Data from the Environment Agency

At Ness Cove there appears to have been a slight increase in faecal coliform levels during the ebb tide, however, the correlation is weak. Shaldon Beach shows a much stronger correlation, with much fewer low results occurring just before the low tide. Both these patterns are consistent with up-estuary sources of contamination being of influence.

Figure X.5 presents a polar plot of log_{10} faecal coliform results against the lunar spring/neap cycle for Shaldon Beach, where a statistically significant correlation was found. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 100 faecal coliforms/100ml or less are plotted in green, those from 101 to 1000 are plotted in yellow, and those exceeding 1000 are plotted in red.

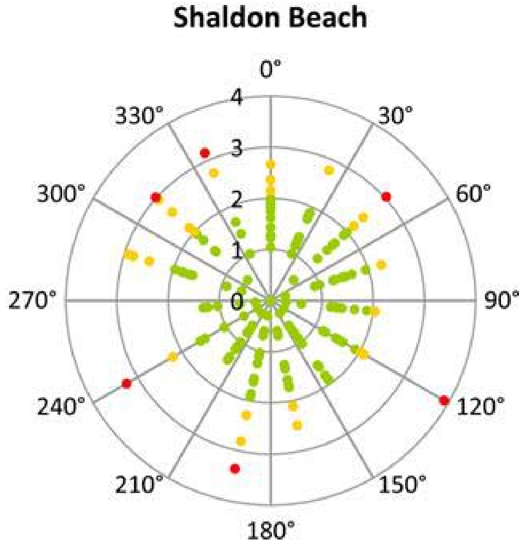


Figure X.5: Polar plots of $\log_{10}$ faecal coliforms against tidal state on the spring/neap tidal cycle for bathing waters monitoring points with significant correlations
Data from the Environment Agency

At Shaldon Beach, faecal coliform levels were lower on average during neap tides, possibly suggesting that sources of contamination influencing this site are located some distance away.

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 Southgate weather station (Appendix II for details) over various periods running up to sample collection and faecal coliforms results. These are presented in Table X.3 and statistically significant correlations ($p<0.05$) are highlighted in yellow.

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

Site		Shaldon Beach	Ness Cove	Teignmouth Beach
n		191	184	203
24 hour periods prior to sampling	1 Day	0.144	0.196	0.255
	2 days	0.239	0.212	0.293
	3 days	0.109	0.142	0.217
	4 days	0.188	0.152	0.227
	5 days	0.087	0.066	0.067
	6 days	0.137	0.112	0.135
	7 days	0.059	0.095	0.064
Total prior to sampling over	2 days	0.249	0.243	0.331
	3 days	0.259	0.273	0.348
	4 days	0.287	0.279	0.329
	5 days	0.272	0.249	0.300
	6 days	0.276	0.243	0.298
	7 days	0.255	0.239	0.264

Data from the Environment Agency

Faecal coliform levels within all the Teign bathing water sites are rapidly influenced by rainfall and this influence continues for several days after a rainfall event.

X.2. Shellfish waters

Figure X.6 shows the location of the Teign Estuary shellfish waters (water) monitoring points, designated under Directive 2006/113/EC (European Communities, 2006). Table X.4 presents summary statistics for bacteriological results for samples taken from these monitoring points. Only water sampling results are presented here, as flesh results from the shellfish hygiene monitoring programme (Appendix XII) are used to assess compliance with bacteriological standards in shellfish flesh under this legislation.

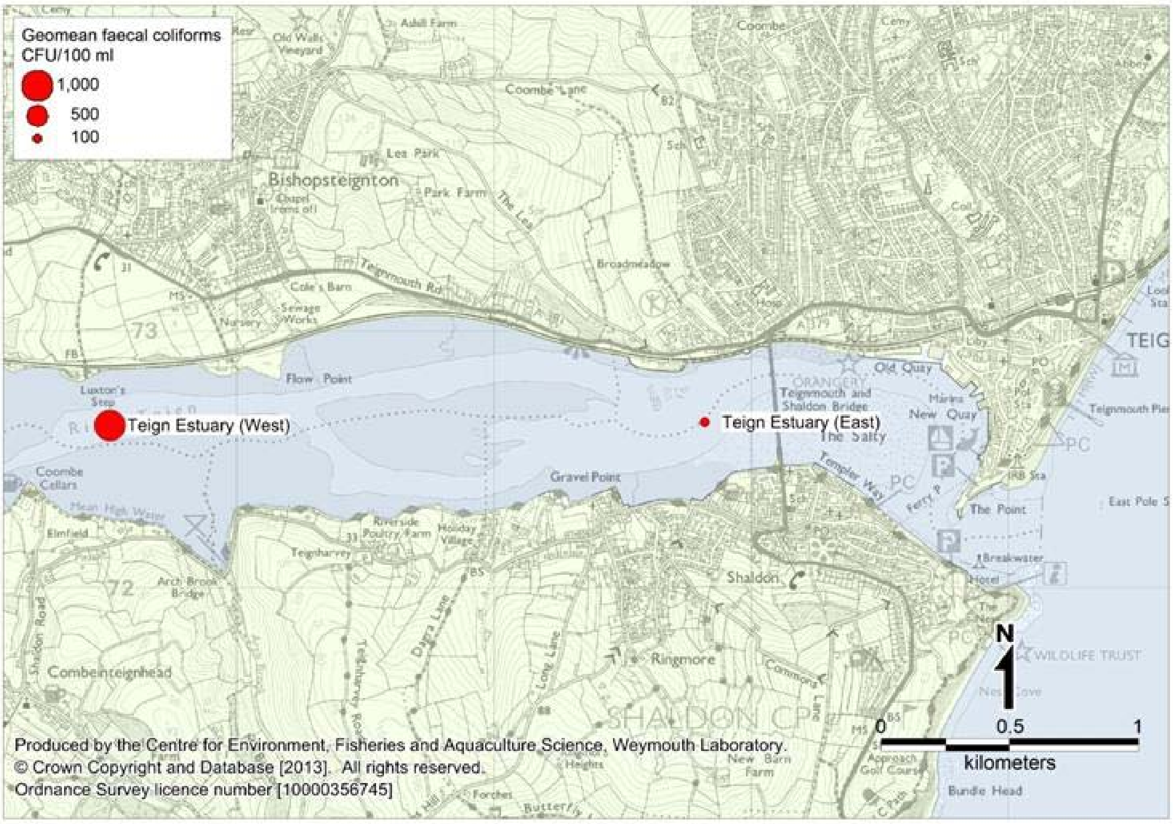


Figure X.6: Location of designated shellfish waters monitoring points in the Teign Estuary and associated geomean of faecal coliform results (cfu/100ml)

Data from the Environment Agency

Table X.4: Summary statistics for shellfish waters faecal coliforms results, 2003-2011 (cfu/100ml).

Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1,000	% over 10,000
Teign Estuary (West)	49	16/04/2003	17/01/2013	976.5	<10	60,300	83.7	63.3	10.2
Teign Estuary (East)	49	16/04/2003	17/01/2013	132.7	<2	11,700	63.3	18.4	2.0

Data from the Environment Agency

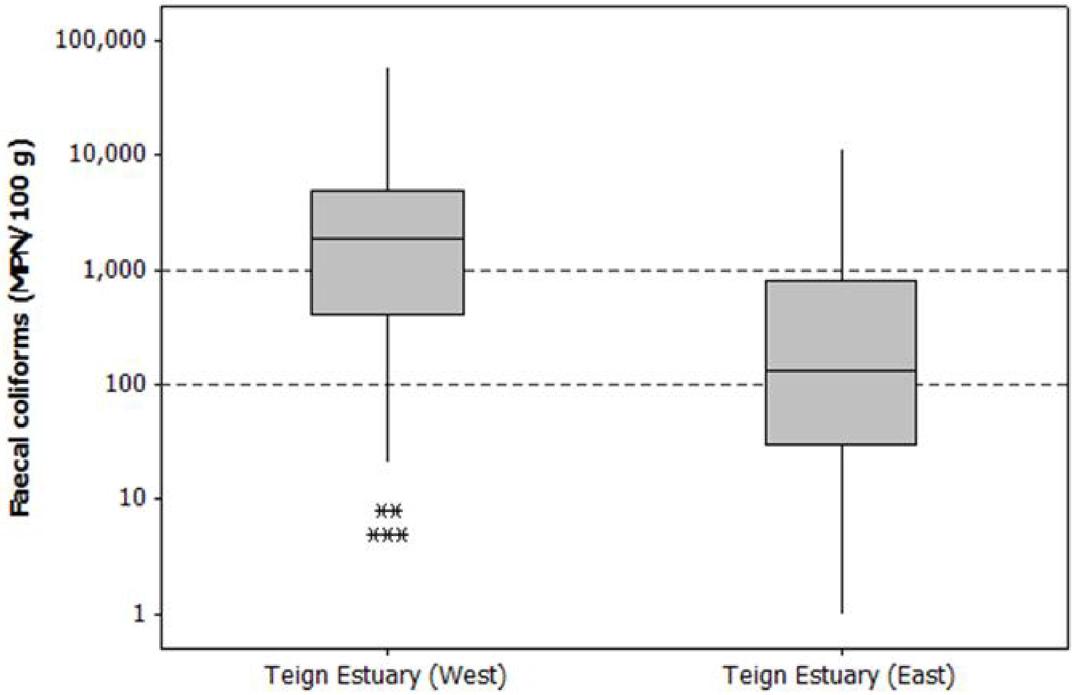


Figure X.7: Box-and-whisker plots of all faecal coliforms results by site
Data from the Environment Agency

Both sites had results exceeding 10,000 faecal coliforms/100 ml, but Teign Estuary (West) had much more than Teign Estuary (East), and also had the highest geographical mean faecal coliform levels. There was a significant difference in faecal coliform levels between sites (T-test, p<0.001). Although only two points were sampled, this difference is consistent with a gradient of increasing contamination towards the head of the estuary. Comparisons of paired (same day) sample results between the two sites showed a very strong correlation (Pearson's correlation, p<0.001). This suggests that the two sites are under the influence of the same or similar sources of contamination.

Overall temporal pattern in results

The overall variation in faecal coliform levels found in shellfish waters in the Teign Estuary since 2003 is shown in Figure X.8.

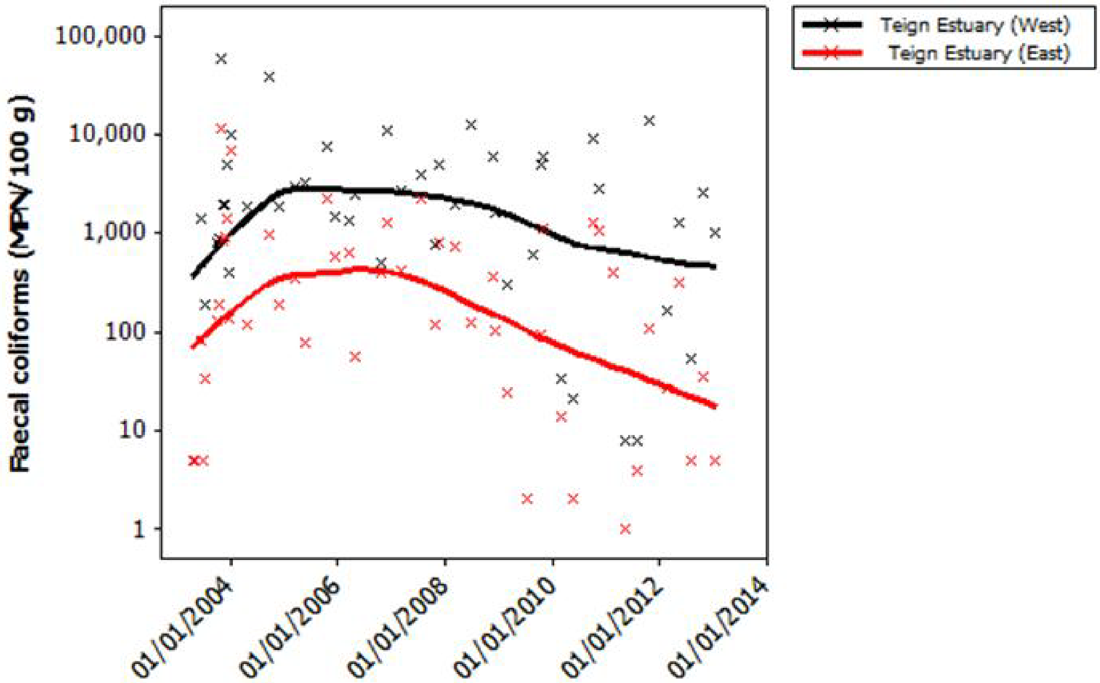


Figure X.8: Scatterplot of faecal coliforms results for shellfish waters in the Teign Estuary overlaid with loess lines
Data from the Environment Agency

The level of faecal coliforms at both sites increased to a peak in 2005 and has been declining since. This may be due in part to improvements to intermittent discharges that took place between 2004 and 2006. Comparisons of faecal coliform levels before and after UV treatment was fitted to Heathfield STW showed no significant improvements at either site (T-test, p=0.100 and 0.158 at Teign Estuary (West) and Teign Estuary (East) respectively).

Seasonal patterns of results

Figure X.9 shows the seasonal variation in faecal coliforms levels found at the shellfish waters in the Teign Estuary.

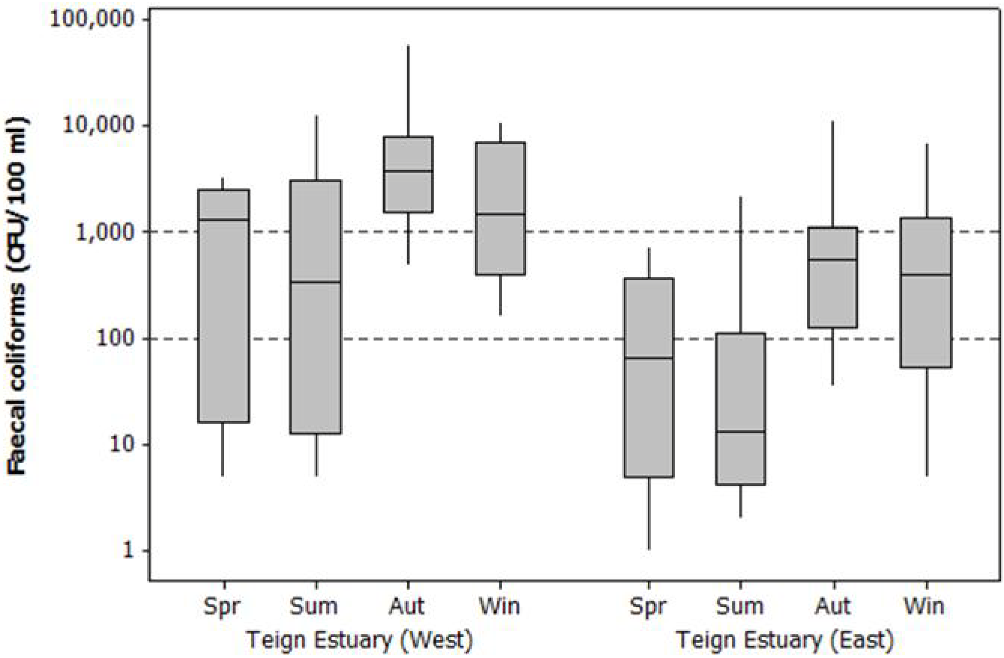


Figure X.9: Boxplot of faecal coliforms results in shellfish waters by site and season
Data from the Environment Agency

One-way ANOVA tests revealed that there were significant differences in faecal coliforms levels between seasons at both sites (p = 0.003 and 0.002 at Teign Estuary (West) and Teign Estuary (East) respectively). Post ANOVA Tukey tests showed that there were significantly higher faecal coliform levels during the autumn than during the spring and summer at both sites.

Influence of Tides

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

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

	High/low tides		Spring/neap tides	
Site Name	**r**	**p**	**r**	**p**
Teign Estuary (West)	0.404	<0.001	0.229	0.09
Teign Estuary (East)	0.452	<0.001	0.129	0.463

Data from the Environment Agency

Figure X.10 presents polar plots of $\log_{10}$ faecal coliform results against tidal states on the high/low cycle for the correlations indicating a statistically significant effect. High water at Teignmouth (New Quay) is at 0° and low water is at 180°. Results of 100 faecal coliforms/100ml or less are plotted in green, those from 101 to 1000 are plotted in yellow, and those exceeding 1000 are plotted in red.

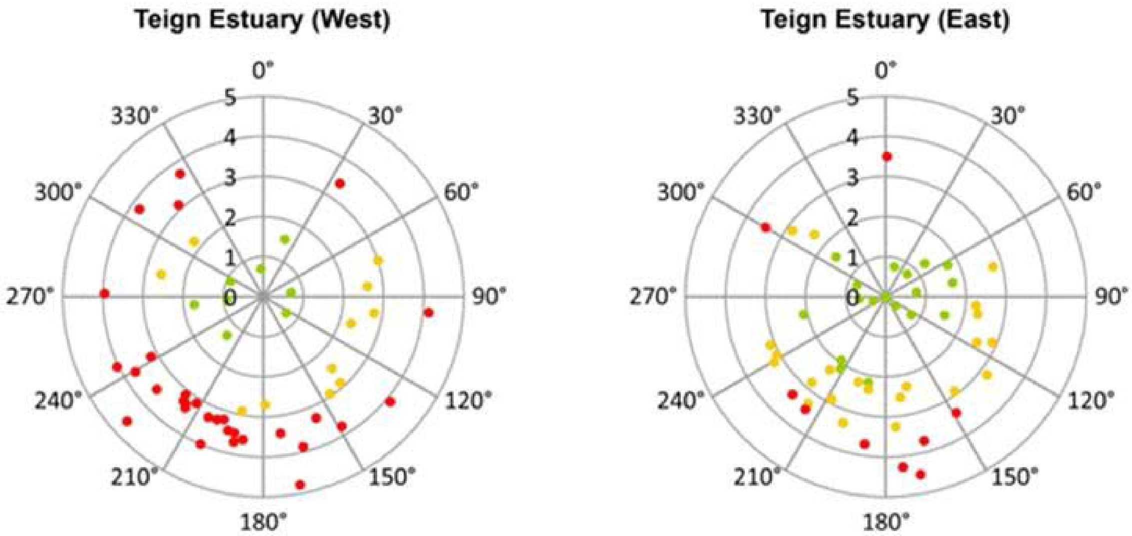


Figure X.10: Polar plots of $\log_{10}$ faecal coliforms against tidal state on the high/low tidal cycle for bathing waters monitoring points with significant correlations
Data from the Environment Agency

At both sites an increase in faecal coliform levels around the low tide is apparent implying upstream sources may be of some significance.

Influence of Rainfall

To investigate the effects of rainfall on levels of contamination at the shellfish waters sites Spearman's rank correlations were carried out between rainfall recorded at the Southgate weather station over various periods running up to sample collection and faecal coliform results. These are presented in Table X.6 and statistically significant correlations ($p<0.05$) are highlighted in yellow.

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

Site		Teign Estuary (West)	Teign Estuary (East)
n		49	49
24 hour periods prior to sampling	1 day	0.312	0.225
	2 days	0.667	0.579
	3 days	0.512	0.562
	4 days	0.416	0.373
	5 days	0.520	0.365
	6 days	0.042	0.277
	7 days	-0.023	0.085
Total prior to sampling over	2 days	0.585	0.469
	3 days	0.582	0.547
	4 days	0.580	0.566
	5 days	0.626	0.583
	6 days	0.634	0.616
	7 days	0.629	0.633

Data from the Environment Agency

Faecal coliform levels at both sites are strongly influenced by rainfall and this influence continues for several days after a rainfall event. The influence was marginally stronger and more rapid to take effect at Teign Estuary (West), the more upstream site.

Influence of salinity

Salinity was recorded on all sampling occasions. Figure X.11 shows scatterplots of faecal coliforms against salinity and the results of Pearson's correlations between the two.

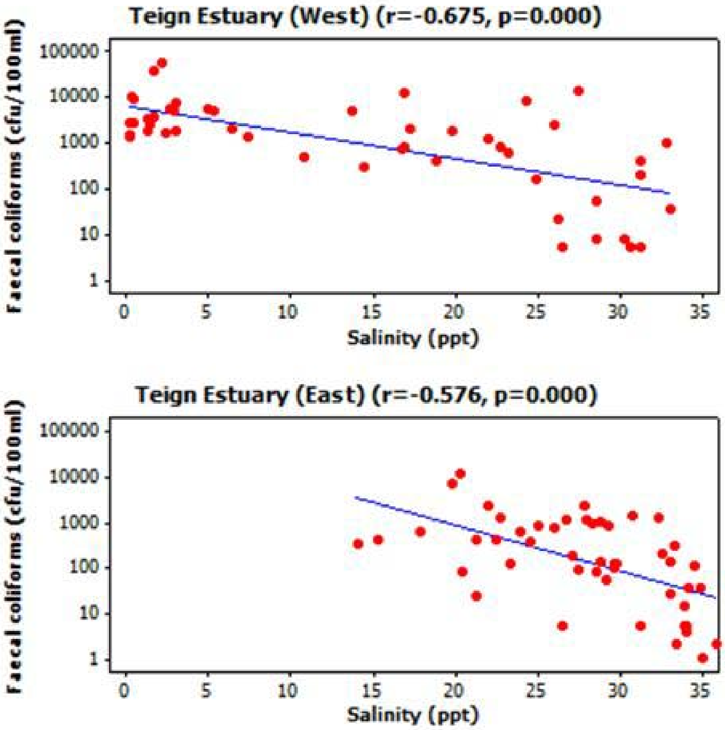


Figure X.11: Scatterplots of salinity against faecal coliforms results
Data from the Environment Agency

Strong negative correlations were observed at both sites. Taken together with the rages of salinities observed, this suggests that land runoff is a significant contaminating influence, which is felt more acutely higher up the estuary.

Appendix XI. Microbiological Data: Shellfish Flesh

XI.1. Summary statistics and geographical variation

There are a total of 6 RMPs in the Teign Estuary that have been sampled between 2003 and 2013. Three of these RMPs are for monitoring mussels, and the other three are for Pacific oysters. One of the Pacific oyster RMPs (The Ponds) lies within a tidal lagoon connected to the main body of the estuary via a narrow channel. The geometric mean results of shellfish flesh monitoring from all RMPs sampled from 2003 onwards are presented in Figure XI.1. Summary statistics are presented in Table XI.1 and boxplots for sites are show in Figure XI.2 and Figure XI.3.

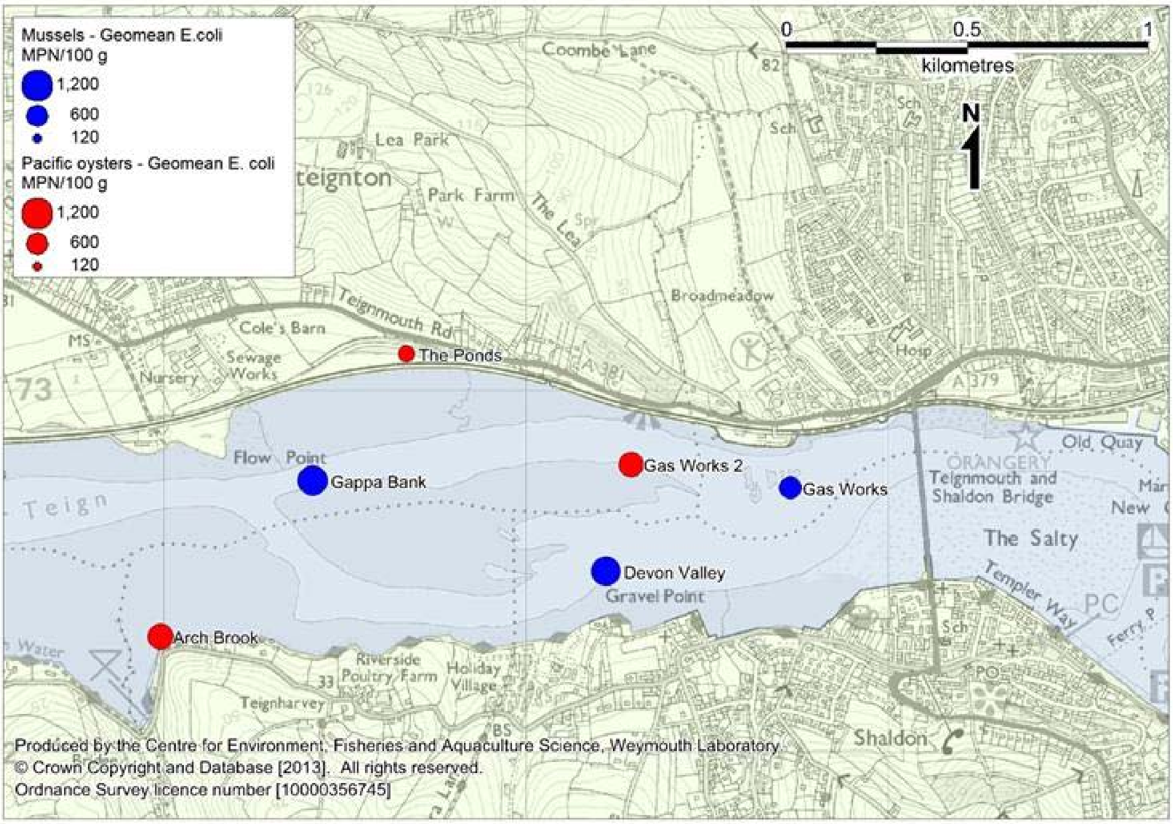


Figure XI.1: Bivalve RMPs active since 2003 and associated geomean of *E. coli* results (MPN/100g)

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

RMP	Species	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 230	% over 4600
Gappa Bank	Mussel	104	16/01/2003	08/04/2013	1138.5	40	24000	91.3	13.5
Devon Valley	Mussel	124	16/01/2003	07/05/2013	1084.4	<20	16000	90.3	12.1
Gas Works	Mussel	124	16/01/2003	07/05/2013	674.4	<20	16000	79.8	10.5
Arch Brook	Pacific oyster	110	16/01/2003	07/05/2013	875.6	<20	35000	88.2	6.4
The Ponds	Pacific oyster	55	21/09/2004	20/07/2009	396.4	<20	9200	67.3	3.6
Gas Works 2	Pacific oyster	127	16/01/2003	07/05/2013	828.7	<20	35000	85.8	13.4

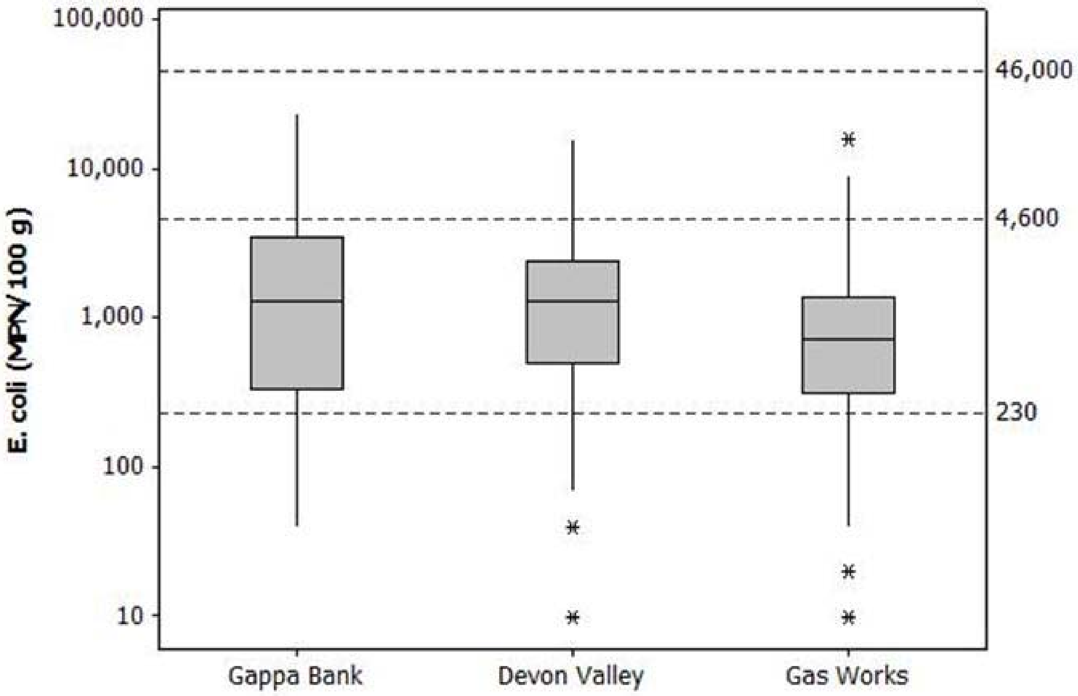


Figure XI.2: Boxplots of *E. coli* results from mussel RMPs from 2003 onwards.

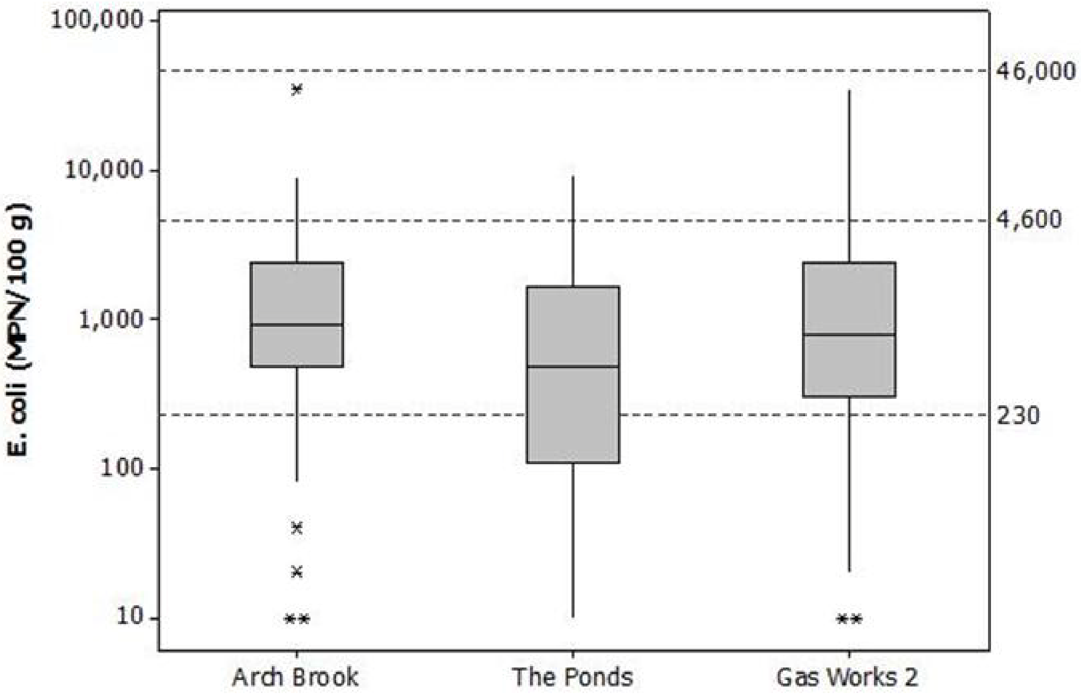


Figure XI.3: Boxplots of *E. coli* results from Pacific oyster RMPs from 2003 onwards.

E. coli levels in mussels exceeded 4,600 MPN/100 g in more than 10% of samples for all RMPs, but never exceeded 46,000 MPN/100 g. Comparisons of the sites (1-way ANOVA) showed that there were significant differences in the *E. coli* levels (p=0.003). Post ANOVA (Tukey) tests which compared *E. coli* levels at each site on a pair-wise basis revealed that the Gas Works RMP had significantly lower *E. coli* levels than both Gappa Bank and Devon Valley, but there were no significant differences between Gappa Bank and Devon

Valley. Across the three RMPs, both the average and peak levels of *E. coli* suggest a slight gradient of increasing levels of contamination towards the head of the estuary.

Only one of the Pacific oyster RMPs (Gas Works 2) exceeded 4,600 *E. coli* MPN/100 g in more than 10% of samples. ANOVA tests showed that there were significant differences between the RMPs (p = 0.003). Tukey tests revealed that the Ponds RMP had significantly lower *E. coli* levels than Arch Brook and Gas Works 2; there was no difference between Arch Brook and Gas Works 2.

Comparisons of RMPs were carried out on a pair-wise basis between sites that shared sampling dates, and therefore environmental conditions, on at least 20 occasions. There were significant correlations between all RMPs for both mussels and Pacific oysters, suggesting that the sites are all influenced by similar sources. The correlations were strongest between the three mussels RMPs (p<0.001 in all site pairings) and between Gas Works 2 and Arch Brook Pacific oyster RMPs (p<0.001). Correlations between The Ponds and the other two Pacific oyster sites were considerably weaker (p=0.020 and 0.026 for Arch Brook and Gas Works 2 respectively. This suggests that The Ponds may receive a significant influence from a different, possibly more local source than the other three Pacific oyster sites.

XI.2. Overall temporal pattern in results

The overall variation in *E. coli* levels found in bivalves is shown in Figure XI.4 and Figure XI.5.

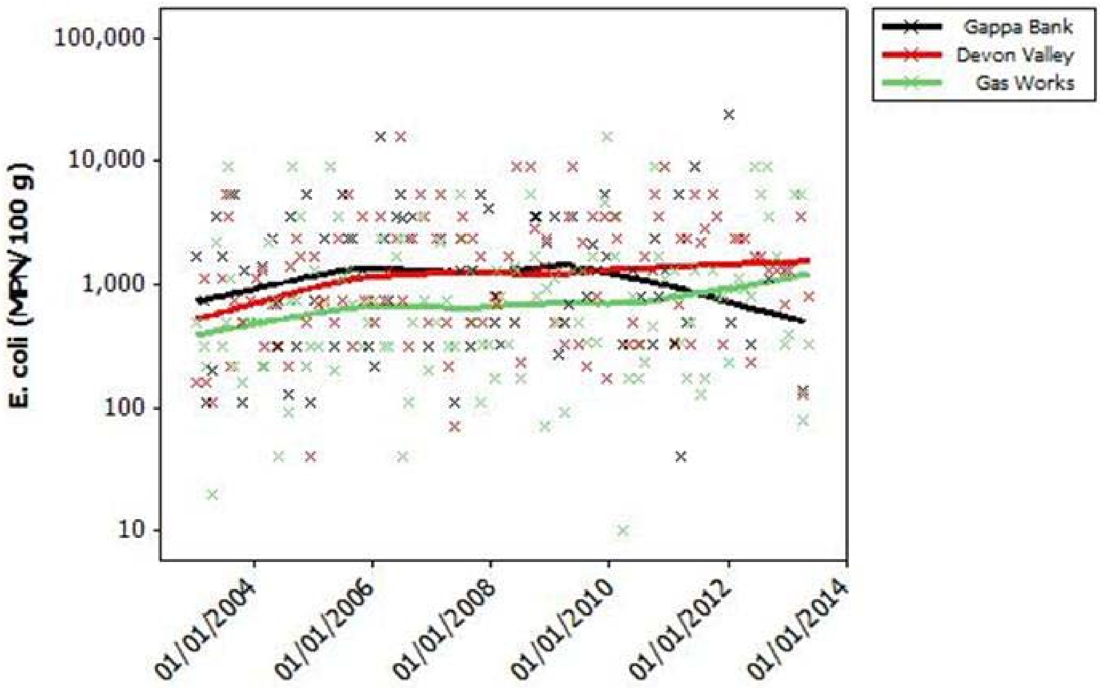


Figure XI.4: Scatterplot of E. coli results for mussels in the Teign Estuary overlaid with loess lines.

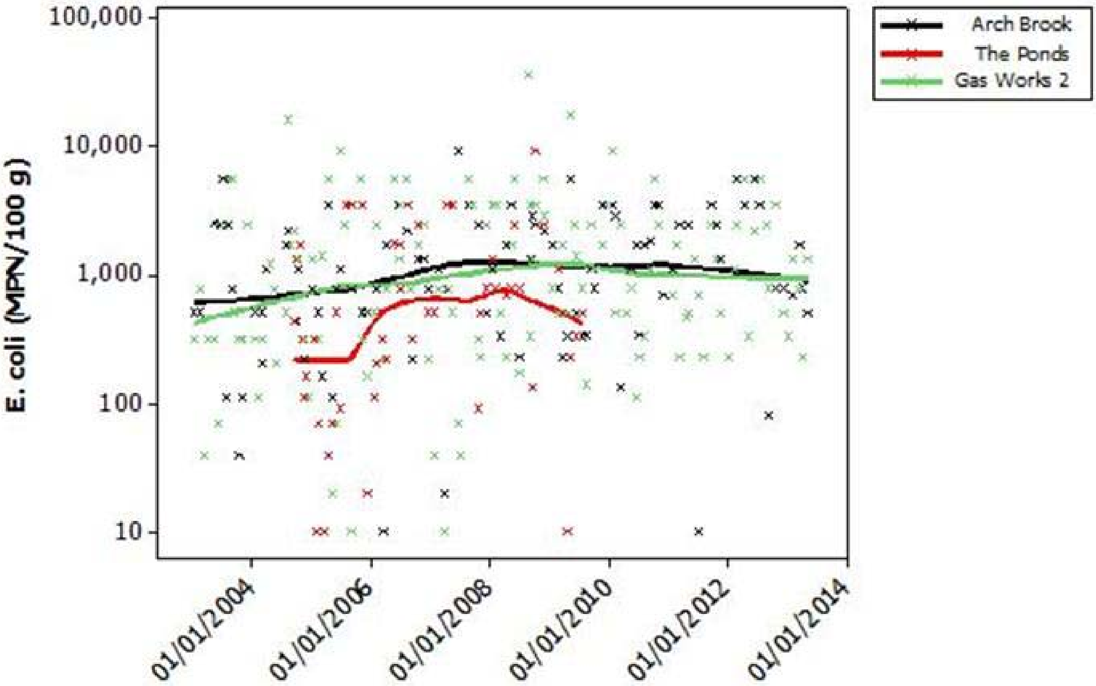


Figure XI.5: Scatterplot of E. coli results for Pacific oysters in the Teign Estuary overlaid with loess lines.

The level of *E. coli* in both mussels and Pacific oysters has remained fairly steady at all sites since 2003. However there appears to have been a slight decline in *E. coli* levels at mussels from Gappa Bank from 2009 onwards. To determine whether this decline was related to improvements to the treatment of effluent from the Heathfield STW in 2010, two sample t-tests were run comparing samples taken before and after the improvements. No significant differences between before and after treatment samples were found at any site for either species (p=0.308 to 0.643).

XI.3. Seasonal patterns of results

Boxplots of *E. coli* results by season are shown in Figure XI.6 and Figure XI.7.

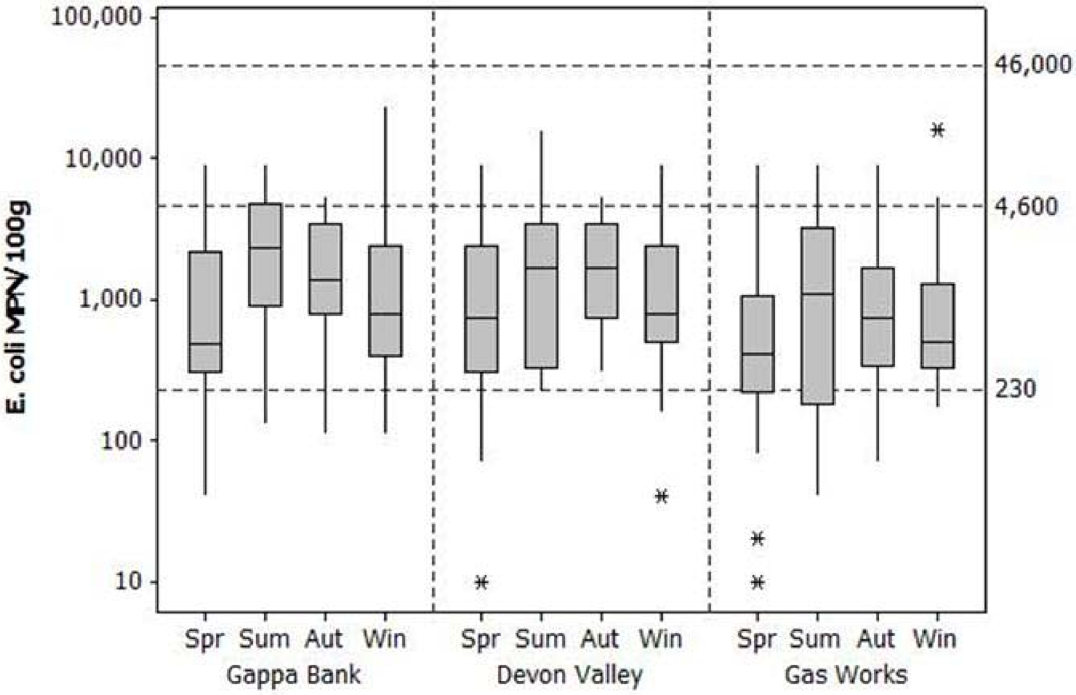


Figure XI.6: Boxplot of *E. coli* results in mussels by RMP and season

Comparisons of *E. coli* levels for individual mussel RMPs showed that there were significant seasonal differences in *E. coli* levels at both Gappa Bank (p=0.009) and Devon Valley (One way ANOVA, p=0.031), but not at Gas Works (p=0.276). Post ANOVA testing (Tukeys comparison) showed that *E. coli* levels were greater in summer and autumn at Gappa Bank than spring and winter, and at Devon Valley *E. coli* levels were higher in autumn than the spring and winter.

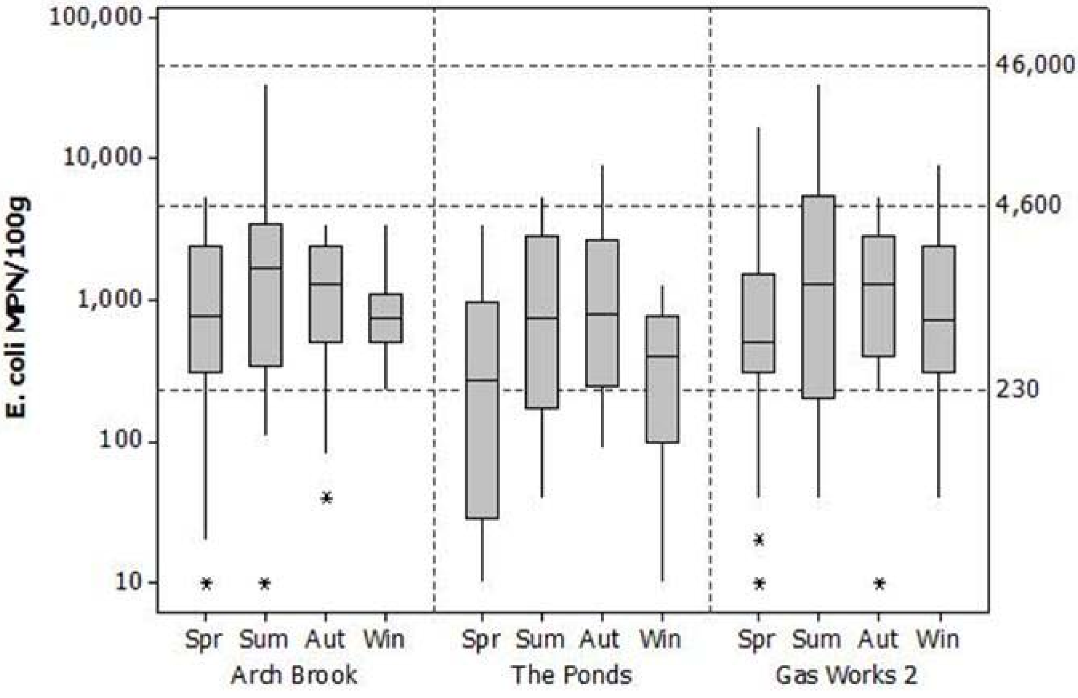


Figure XI.7: Boxplot of *E. coli* results in Pacific oysters by RMP and season

A boxplot of *E. coli* results in Pacific oysters by RMP and season is shown in Figure XI.7. No significant differences between seasons were found at any of the three Pacific oyster RMPs (One way ANOVA, p=0.093 to 0.529), although a pattern of higher results on average during the summer/autumn can be seen to varying extents.

XI.4. Influence of tide

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

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

		High/low tides		Spring/neap tides	
Site	**Species**	**r**	**p**	**r**	**p**
Gappa Bank	Mussel	0.223	0.007	0.116	0.255
Devon Valley	Mussel	0.06	0.642	0.112	0.217
Gas Works	Mussel	0.11	0.231	0.199	0.008
Arch Brook	Pacific oyster	0.245	0.002	0.028	0.918
The Ponds	Pacific oyster	0.239	0.051	0.049	0.882
Gas Works 2	Pacific oyster	0.31	<0.001	0.139	0.091

Data from the Environment Agency

Figure XI.8 and Figure XI.9 present 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 Teignmouth (New Quay) is at 0° and low water is at 180°. Results of 230 *E. coli* MPN/100g or less are plotted in green, those from 231 to 4600 are plotted in yellow, and those exceeding 4600 are plotted in red.

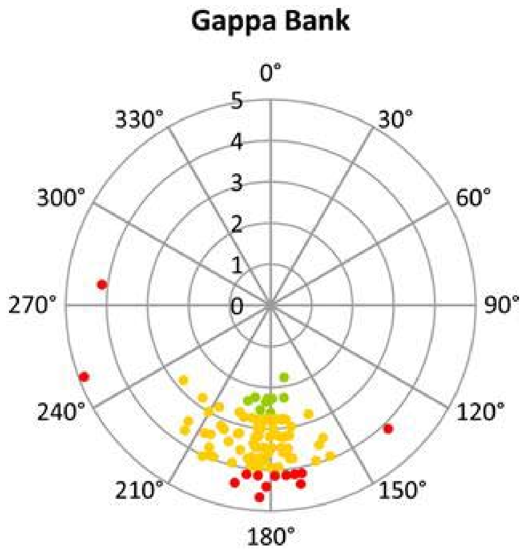


Figure XI.8: Polar plot of $\log_{10}$ *E. coli* results (MPN/100g) against high/low tidal state for mussel RMPs

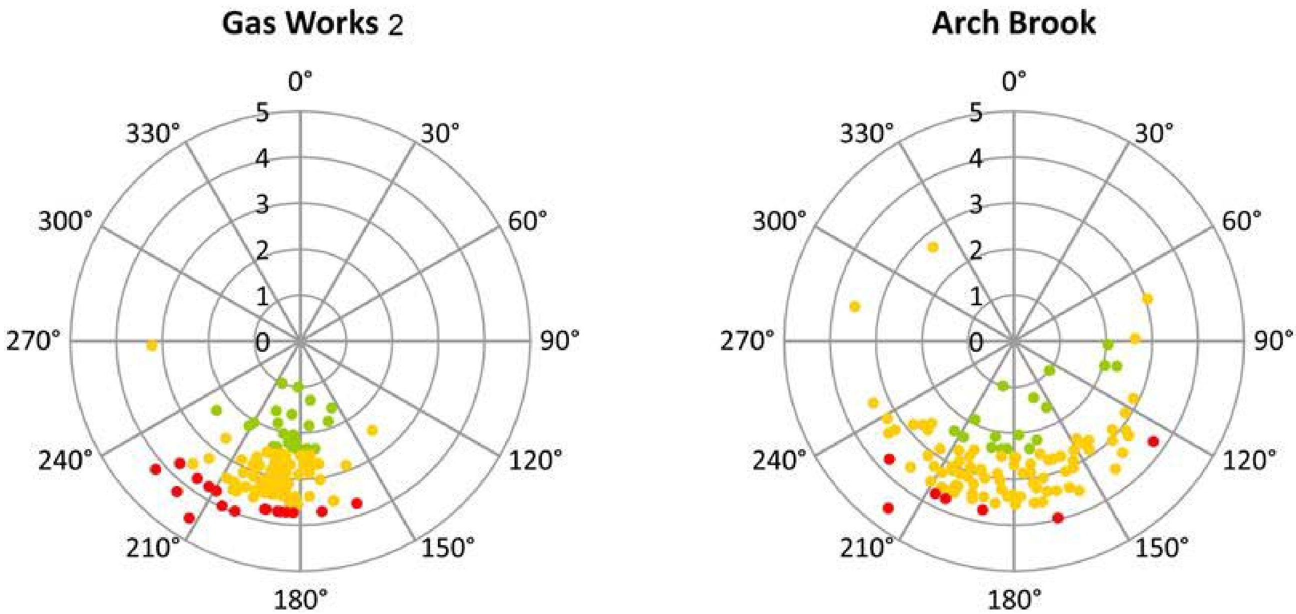


Figure XI.9: Polar plots of $\log_{10}$ *E. coli* results (MPN/100g) against high/low tidal state for Pacific oyster RMPs

Sampling was strongly targeted towards low water, and no strong patterns are apparent in Figure XI.8 and Figure XI.9.

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

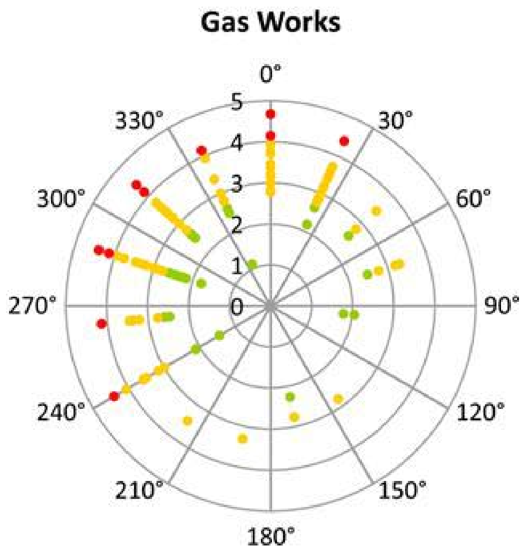


Figure XI.10: Polar plot of $\log_{10}$ *E. coli* results (MPN/100g) against spring/neap tidal state for mussel RMPs

The higher *E. coli* levels tended to occur in the period from the spring tide to the neap tide, when the tidal range was decreasing. However, there was also a higher sampling effort during this time, and so the true level of *E. coli* during the rest of the tidal cycle may not be properly represented by these data.

XI.5. Influence of rainfall

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

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

Site		Gappa Bank	Devon Valley	Gas Works	Arch Brook	The Ponds	Gas Works 2
Species		Mussel	Mussel	Mussel	Pacific oyster	Pacific oyster	Pacific oyster
n		103	122	122	108	55	125
24 hour periods prior to sampling	1 day	-0.016	0.114	0.153	-0.042	-0.056	-0.059
	2 days	0.235	0.206	0.316	0.168	0.341	0.207
	3 days	0.205	0.333	0.299	0.252	0.050	0.149
	4 days	0.286	0.313	0.292	0.121	-0.008	0.179
	5 days	0.104	0.193	0.308	0.173	0.196	0.185
	6 days	0.220	0.219	0.232	0.191	0.061	0.231
	7 days	0.240	0.217	0.284	0.116	0.109	0.184
Total prior to sampling over	2 days	0.162	0.187	0.272	0.095	0.214	0.085
	3 days	0.217	0.299	0.284	0.145	0.182	0.120
	4 days	0.275	0.351	0.349	0.179	0.160	0.150
	5 days	0.240	0.367	0.392	0.215	0.241	0.185
	6 days	0.308	0.426	0.435	0.262	0.260	0.232
	7 days	0.334	0.432	0.465	0.259	0.220	0.247

Levels of *E. coli* at all RMPs for both mussels and Pacific oysters are affected by rainfall after 2 days. The overall pattern is a positive correlation between rainfall and levels of *E. coli* in bivalve flesh. Levels of *E. coli* in mussels were more sensitive to rainfall than Pacific oysters. This is perhaps due to mussels' higher tolerance to changing environmental conditions, allowing them to continue feeding when salinities fall after a rainfall event. Pacific oysters at The Ponds were least affected.

Appendix XII. Shoreline Survey Report

Date (time): 06/08/2013 (09:00 – 15:00)

Cefas Officer: Alastair Cook, Louise Rae

Local Enforcement Authority Officer: Gavin Fearby (Teignbridge DC)

Area surveyed: North and south shore of outer Teign estuary (Figure XII.1)

Weather: Dry, sunny, 15°C, wind W, force 1. Some significant rainfall had occurred in the days leading up to the survey, before which there was a prolonged dry spell.

Tides:

Admiralty TotalTide tidal predictions for Teignmouth New Quay (50°33'N 3°30'W). All times in this report are BST.

06/08/2013

	Time	Height
High	07:06	4.2 m
	19:22	4.5 m
Low	00:48	1.3 m
	13:04	1.2 m

XII.1. Objectives

The shoreline survey aims to obtain samples of freshwater inputs to the area for bacteriological testing, confirm the location of previously identified sources of potential contamination; locate other potential sources of contamination that were previously unknown and find out more information about the fishery. A full list of recorded observations is presented in Table XII.1 and the locations of these observations are mapped in Figure XII.1. Photographs are presented in Figure XII.3 to Figure XII.11.

XII.2. Description of Fishery

The Teign estuary supports a fishery for Pacific oysters and mussels in its outer reaches, and fishing rights for these species are held by the Teign Musselmen's Society. Currently, there are two harvesters working the area on a more or less full time basis. Pacific oysters are cultured from seed on trestles at two sites. Some naturally occurring specimens of various sizes were observed, but not in great numbers. Mussels are cultured on managed lays in several locations within the estuary. The main beds/lays are at Gas Works and Devon Valley, but there are also other patches at various locations around the estuary. A number of smaller mussel beds/lays were observed on the northern margins of the central sandbank at low water. They are also dredged up from the estuary channel to the north of the central sandbank. They are relatively slow growing and of a high quality. Some casual gathering of cockles occurs in the outer estuary around the Shaldon Bridge.

Naturally occurring mussels are much more common and widespread than Pacific oysters, so are likely to represent a more flexible and reliable sampling option. Sample bags containing Pacific oysters left in accessible locations are often stolen. The trestles at Arch Brook are difficult for sampling officers to access due to the soft substrate here. Access to the trestle site on the mid estuary bank is via boat, and the substrate here is relatively firm sand.

XII.3. Sources of contamination

Sewage discharges

The locations of several CSO outfalls pipes were confirmed (observations 6, 21 and 27). Storm tanks and a pumping station were observed just west of Shaldon Bridge on the south shore (observations 2 and 3) but their outlets were not visible and no obvious marker posts were seen.

There were a few private discharges recorded (observations 9, 11, 15, 16, 18). Not all appeared to be in recent use.

Freshwater inputs

All flowing freshwater inputs were sampled and measured thus providing a ‘snapshot’ estimate of the bacterial loadings they were carrying at the time (Figure XII.2). The exception to this was a small watercourse discharging to the south of Bishopsteignton, which was mistaken for the outlet of a tidal pond by the surveyor and not sampled. This un-sampled stream was located between observations 21 and 22 on the north shore, and was small, flowing clear, and carried no odour.

Livestock

No livestock were recorded in fields immediately adjacent to the estuary.

Boats and shipping

The outer Teign estuary has a considerable number of moorings, generally used by craft such as dinghies and small cabin cruisers and yachts. Most of these are downstream of the bridge, but moorings do extend further up the estuary along the south channel. There is a small commercial port at Teignmouth.

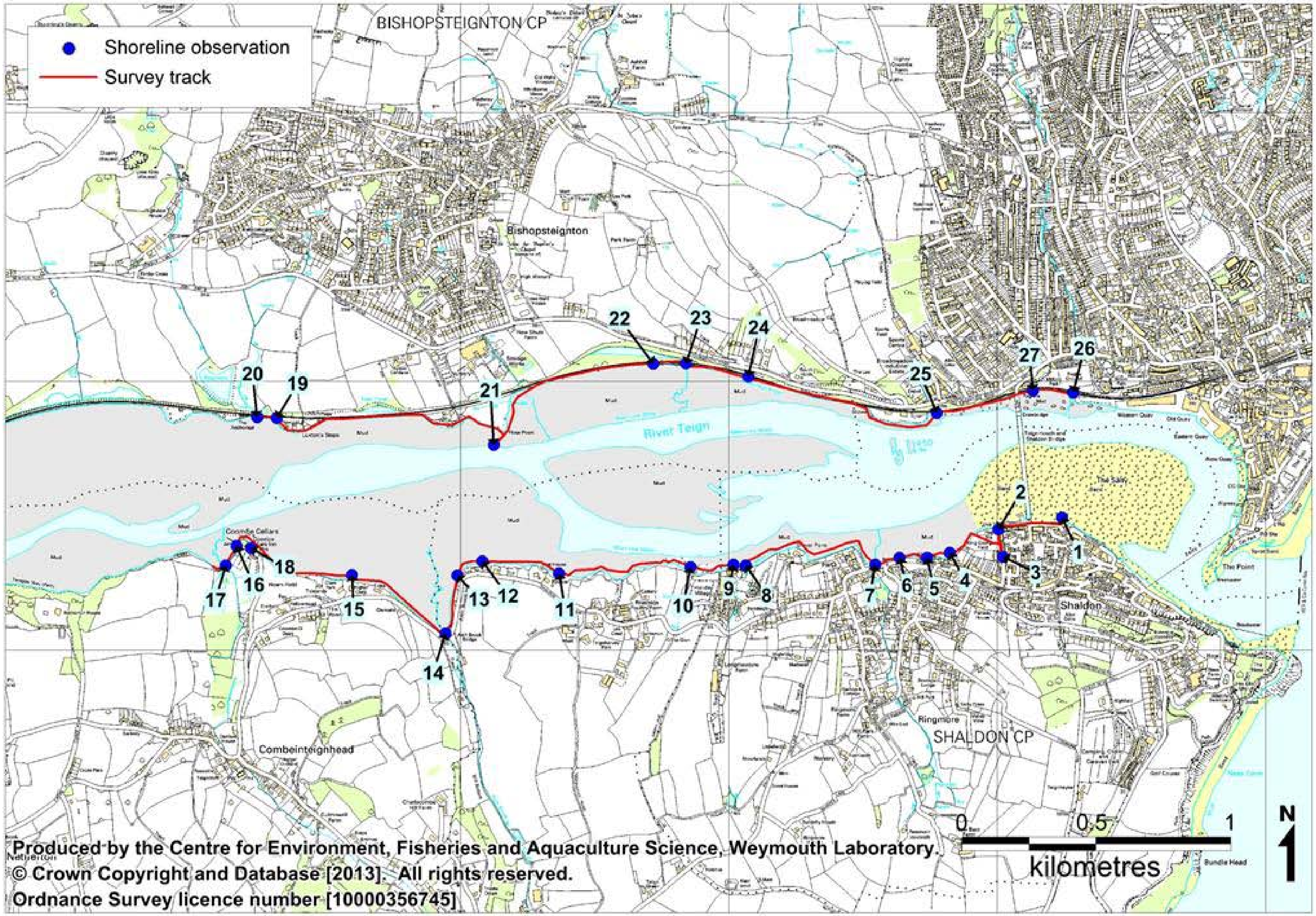


Figure XII.1: Locations of shoreline observations

Table XII.1: Details of shoreline observations

No.	NGR	Time	Description	Photo
1	SX 93241 72493	06/08/2013 09:52	Several hundred seagulls on mid estuary sandbank. Many boat moorings.	Figure XII.3
2	SX 93004 72449	06/08/2013 09:59	Inspection covers suggesting sewage tanks under paving. No outfall visible.	Figure XII.4
3	SX 93020 72346	06/08/2013 10:03	Shaldon PS (inland, no outfall visible on adjacent shore).	Figure XII.5
4	SX 92822 72361	06/08/2013 10:09	Seawater sample 1	
5	SX 92738 72343	06/08/2013 10:12	Flap valve outfall, dripping slowly, presumed surface water only	
6	SX 92634 72343	06/08/2013 10:15	Red marker post offshore, likely to mark the Ringmore Road CSO outfall	Figure XII.6
7	SX 92545 72318	06/08/2013 10:22	Inspection cover on beach. Culverted stream 61cmx3cmx0.469m/s. Water sample 2	Figure XII.7
8	SX 92062 72315	06/08/2013 10:34	Surface water outfall. 28cmx7cmx0.324m/s. Water sample 3	
9	SX 92016 72318	06/08/2013 10:40	Cast iron pipe, 15cm diameter, runs from hotel down beach to below the tide. Possible private discharge from hotel	Figure XII.8
10	SX 91856 72309	06/08/2013 10:44	Surface water outfall, 15cmx2cmx0.16m/s. Water sample 4.	
11	SX 91366 72284	06/08/2013 10:57	110mm orange sewer pipe and slightly smaller ribbed black pipe run down cliff from gardens to foreshore. Likely to be a private discharge, but no signs of recent use.	Figure XII.9
12	SX 91079 72330	06/08/2013 11:04	Marker sticks planted in estuary just offshore.	
13	SX 90987 72278	06/08/2013 11:08	Oyster samples are secreted here by harvester a day or two before collection by the sampling officer.	
14	SX 90942 72062	06/08/2013 11:13	Arch Brook, 200cmx11cmx0.176m/s. Water sample 5.	
15	SX 90594 72279	06/08/2013 11:22	Broken orange sewer pipe probably redundant.	
16	SX 90164 72387	06/08/2013 11:31	Broken orange sewer pipe probably redundant.	
17	SX 90123 72314	06/08/2013 11:33	Stream 100cmx10cmx0.681m/s. Water sample 6.	
18	SX 90217 72379	06/08/2013 11:41	Possible sewage tank and pump in pub garden.	Figure XII.10
19	SX 90313 72863	06/08/2013 12:47	2 pipes from holiday home to foreshore. Probably just roof/patio drainage.	
20	SX 90240 72866	06/08/2013 12:51	Stream 100cmx10cmx0.05m/s. Water sample 7.	
21	SX 91122 72763	06/08/2013 13:11	CSO outfall pipe with green marker post. Must be Bishopsteignton CSO.	
22	SX 91717 73065	06/08/2013 13:23	Concrete enclosure with inspection covers and vent. No outfall. Likely to be sewer pipeline inspection chamber.	
23	SX 91839 73066	06/08/2013 13:27	Outfall from seawater lagoon. Mistaken for a freshwater stream so sampled and measured. 160cmx3cmx0.315m/s. Water sample 8.	

24	SX 92071 73017	06/08/2013 13:33	Possible pumping station on other side of railway tracks	
25	SX 92774 72882	06/08/2013 13:47	Culverted stream, 85cmx39cmx0.062m/s. Water sample 9. Has occasionally carried orange silt recently, possibly relating to construction of a new supermarket on an old landfill site.	
26	SX 93282 72957	06/08/2013 14:01	Stream 75cmx10cmx0.820m/s. Water sample 10.	
27	SX 93132 72965	06/08/2013 14:08	CSO outfall with green marker post at end. Must be Milford Park PCSO/EO.	Figure XII.11

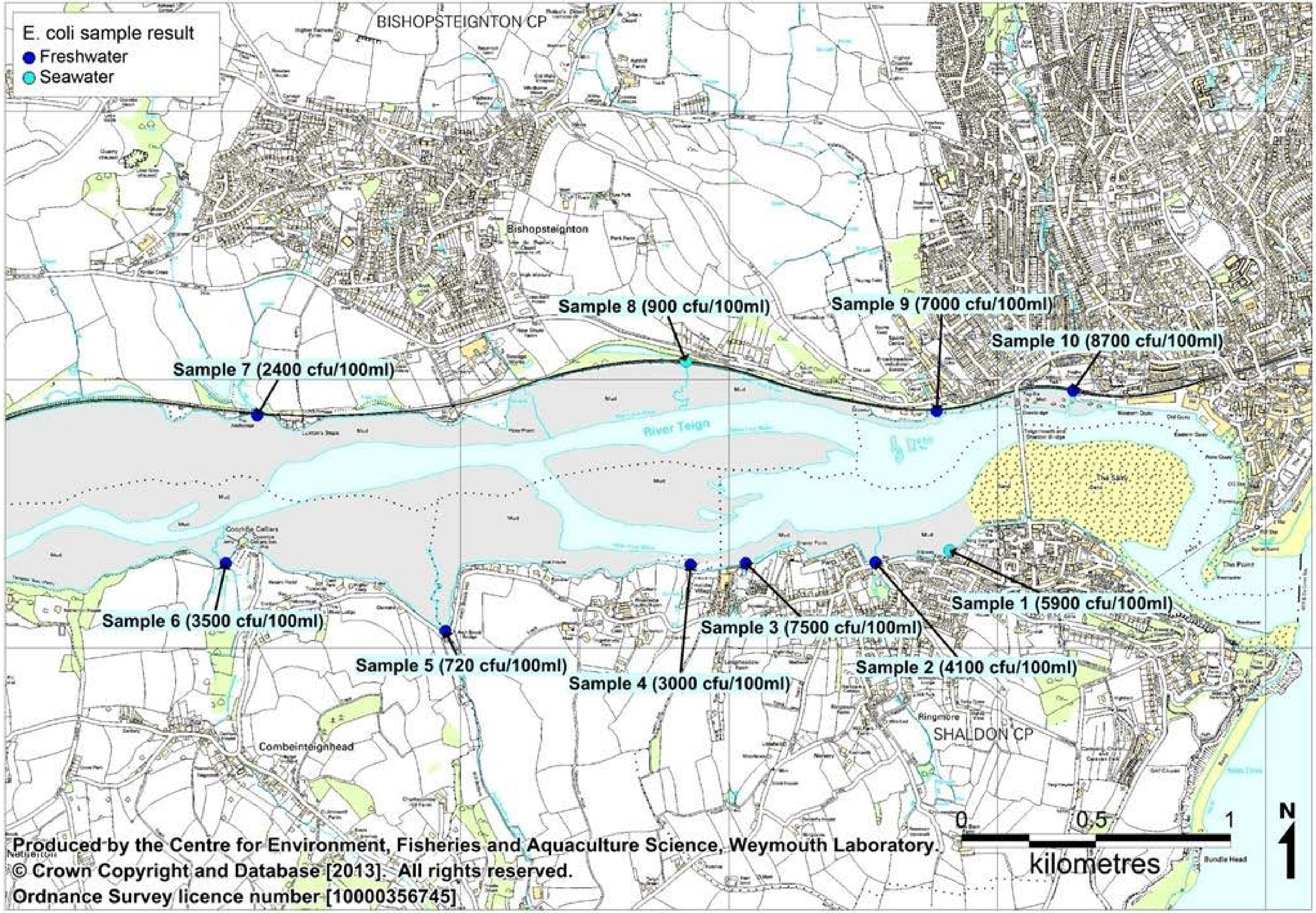


Figure XII.2: Water sample results

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

Sample No.	Type	*E. coli* concentration (CFU/100 ml)	Discharge (m^3/day)	*E. coli* loading (CFU/day)
1	Seawater	5900		
2	Freshwater	4100	742	3.04×10^{10}
3	Freshwater	7500	549	4.12×10^{10}
4	Freshwater	3000	4	1.24×10^{8}
5	Freshwater	720	3345	2.41×10^{10}
6	Freshwater	3500	5884	2.06×10^{11}
7	Freshwater	2400	432	1.04×10^{10}
8	Seawater	900		
9	Freshwater	7000	1776	1.24×10^{11}
10	Freshwater	8700	5314	4.62×10^{11}

The seawater sample taken at Shaldon (sample 1) contained a high concentration of *E. coli*. The seawater sample taken from the saline lagoon outfall (sample 8) contained a lower but nonetheless relatively high *E. coli* concentration for coastal waters. The sampled watercourses all carried moderate to high concentrations of *E. coli*, but none were particularly large in terms of discharge volume.

Figure XII.3


Figure XII.4


Figure XII.5

Figure XII.6

Figure XII.7

Figure XII.8

Figure XII.9

Figure XII.10

Figure XII.11

References

ABP, 2013. Teignmouth. Available at: http://www.abports.co.uk/Our_Locations/Short_Sea_Ports/Teignmouth/. Accessed June 2013.

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

Bernardes, M.E.C.; Davidson, M.A.; Dyer, K.R.; George, K.J., 2006. Towards medium-term (order of months) morphodynamic modelling of the Teign estuary, UK. Ocean Dynamics. 56, 16-197

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, 2011. Sanitary Survey of Dart Estuary (Devon). 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 Regulation (EC) 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.

Cycleau Project, 2004. A Profile of the River Teign Catchment 2004. Sarah Clark, Teign Estuary Partnership.

Cycleau Project, 2006. Developing an Innovative Bacteriological Approach to Teign Catchment Water Quality Monitoring. Teign Estuary Partnership.

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.

Devon Mammal Group, 2012. Available at: http://www.devonmammalgroup.org/devons-mammals/otter/ Accessed June 2013

Edwards, E., 1987. Estuary profile for mollusc cultivation: Teign estuary Devon. Internal report number 1282. Shellfish Association of Great Britain, August 1987.

Environment Agency, 2009. South Devon Catchment Flood Management Plan.

EU Working Group on the Microbiological Monitoring of Bivalve Harvest Areas (2010). Microbiological Monitoring of Bivalve Harvest Areas. Guide to Good Practice: Technical Application. Issue 4, August 2010.

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.

Futurecoast, 2002. Department of Environment, Food and Rural Affairs (Defra), Halcrow Group Ltd 3 CD set.

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.

Holt, C., Austin, G., Calbrade, N., Mellan, H., Hearn, R., Stroud, D., Wotton, S., Musgrove, A., 2012. Waterbirds in the UK 2010/11. The Wetland Bird Survey.

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, 442-454.

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.

Laing, I., and Spencer, B.E., 2006. Bivalve cultivation: criteria for selecting a site. Cefas science series technical report no.136. ISSN 0308-5589.

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

MacAlister, Eliot and Partners, 1999. The Potential of Estuarine and Coastal Areas in the South West for the Development of Aquaculture. Report No. 920/R/02C.

Met Office, 2012. Regional Climates. Available at: http://www.metoffice.gov.uk/climate/regional/ Accessed October 2012.

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.

Obiri-Danso, K., Jones, K., 2000. Intertidal sediments as reservoirs for hippurate negative campylobacters, salmonellae, and faecal indicators in three EU recognised bathing waters in North-West England. Water Research 34(2): 519−527.

Ports and Harbours, 2013. Teignmouth. Available at: http://www.ports.org.uk/port.asp?id=164. Accessed June 2013.

Pritchard, M.; Huntley, D. A., 2002. Instability and Mixing in a Small Estuarine Plume Front. Estuarine, Coastal and Shelf Science. 55, 275-285

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

SCOS, 2012. Special Committee on Seals. Scientific Advice on Matters Related to the Management of Seal Populations: 2012. http://www.smru.st-andrews.ac.uk/pageset.aspx?psr=411. Accessed July 2013.

Teign Estuary Partnership, 2004. Fisheries. Available at: http://www.teignbridge.gov.uk/CHttpHandler.ashx?id=17540&p=0 Accessed June 2013.

Teign Estuary Partnership, 2004. Nature. Available at: http://www.teignbridge.gov.uk/CHttpHandler.ashx?id=15842&p=0 Accessed June 2013

Teignbridge DC, 2013. "A Tourism Strategy for Teignbridge", available from: http://www.teignbridge.gov.uk/CHttpHandler.ashx?id=1174&p=0. Accessed on 17/06/2013.

Teignmouth Harbour Commission, 2013. Moorings information page from website. Available at: http://www.teignmouthharbour.com/moorings. Accessed August 2013.

Whitehouse, R.J.S., 2004. Editorial, Teignmouth special edition. Continental Shelf Research 24, 1165–1169.

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.

Younger, A.D., Reese, R.A.R., 2011. *E. coli* accumulation compared between mollusc species across harvesting sites in England and Wales. Cefas/FSA internal report.

List of Abbreviations

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

Glossary

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

	the ebb tide.
Flow ratio	Ratio of the volume of freshwater entering into an estuary during the tidal cycle to the volume of water flowing up the estuary through a given cross section during the flood tide.
Geometric mean	The geometric mean of a series of N numbers is the Nth root of the product of those numbers. It is more usually calculated by obtaining the mean of the logarithms of the numbers and then taking the anti-log of that mean. It is often used to describe the typical values of skewed data such as those following a log-normal distribution.
Hydrodynamics	Scientific discipline concerned with the mechanical properties of liquids.
Hydrography	The study, surveying, and mapping of the oceans, seas, and rivers.
Lowess	Locally Weighted Scatterplot Smoothing, more descriptively known as locally weighted polynomial regression. At each point of a given dataset, a low-degree polynomial is fitted to a subset of the data, with explanatory variable values near the point whose response is being estimated. The polynomial is fitted using weighted least squares, giving more weight to points near the point whose response is being estimated and less weight to points further away. The value of the regression function for the point is then obtained by evaluating the local polynomial using the explanatory variable values for that data point. The LOWESS fit is complete after regression function values have been computed for each of the n data points. LOWESS fit enhances the visual information on a scatterplot.
Telemetry	A means of collecting information by unmanned monitoring stations (often rainfall or river flows) using a computer that is connected to the public telephone system.
Secondary Treatment	Treatment applied to breakdown and reduce the amount of solids in sewage 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

Gavin Fearby (Teignbridge DC)