EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT
Taw/Torridge

2013

Cover photo: Trestles at Zeta Berth on the Torridge.

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
DT43 8UB

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

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

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

☎ +44 (0) 20 7276 8000
shellfishharvesting@foodstandards.gsi.gov

STATEMENT OF USE: This report provides a sanitary survey relevant to bivalve mollusc beds in the Taw/Torridge 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).

CONSULTATION:

Consultee	Date of consultation	Date of response
Environment Agency	01/02/2013	None
Local Enforcement Authority	01/02/2013	None
IFCA	01/02/2013	None
Water company	01/02/2013	None

DISSEMINATION: Food Standards Agency, North Devon District Council, Torridge District Council, Devon and Severn IFCA, Environment Agency.

RECOMMENDED BIBLIOGRAPHIC REFERENCE: Cefas, 2013. Sanitary survey of the Taw Torridge 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 of EC Regulation No. 854/2004.

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

This report documents the information relevant to undertake a sanitary survey for mussels (*Mytilus* spp.) and Pacific oyster (*Crassostrea gigas*) within the Taw Torridge estuary. The area was prioritised for survey in 2012-13 by a shellfish hygiene risk ranking exercise of existing classified areas.

1.2 AREA DESCRIPTION

SITE DESCRIPTION

The Taw Torridge is a macro tidal estuary situated in North Devon, in the south west of England Figure 1.1. It forms a twin estuarine system of the River Taw and The River Torridge, which flows into Bideford Bay near the mouth of the Bristol Channel

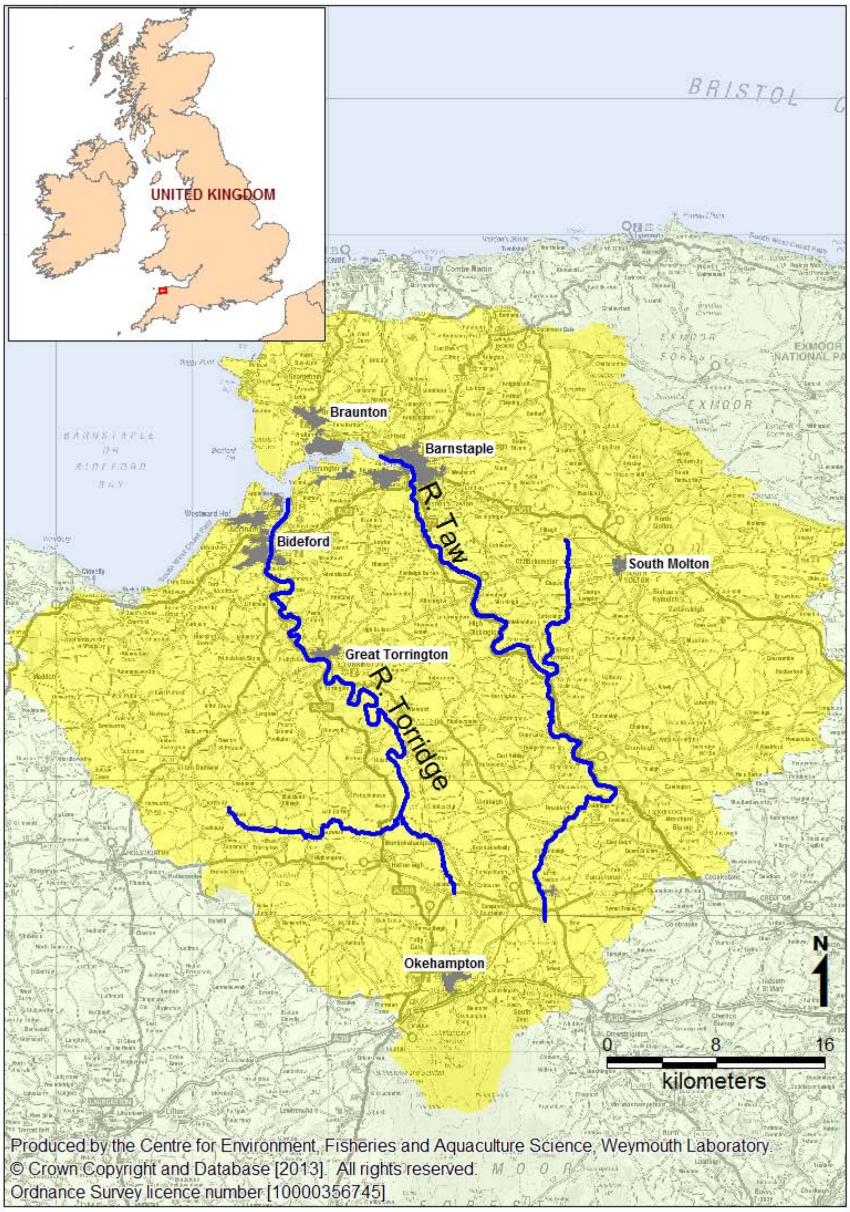
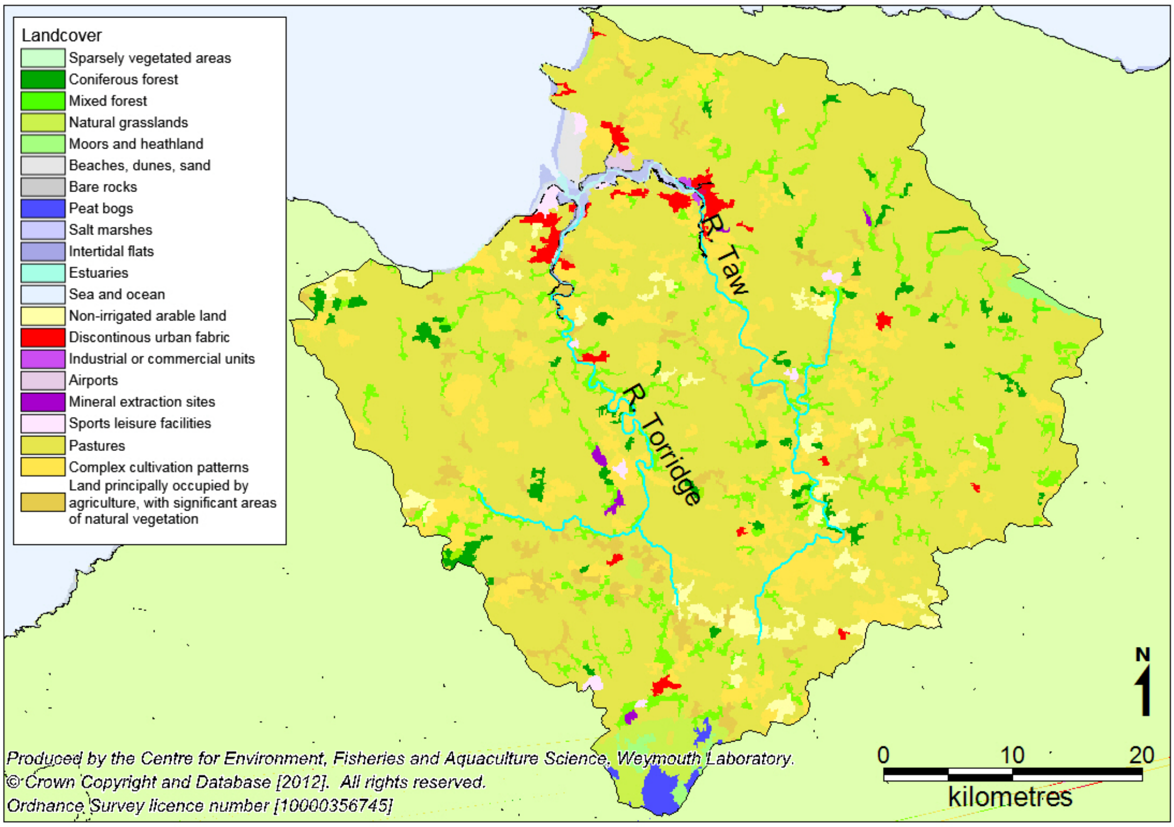


Figure 1.1 Location of the Taw Torridge Estuary

The Taw Torridge estuary encompasses a rich variety of estuarine and coastal habitats with a complete sand dune sequence at Braunton Burrows, rare salt marshes, reed beds grassland and intertidal mudflats. The estuary falls within North Devon's UNESCO Biosphere Reserve and is designated as an SSSI an AONB and an SAC owing to its complete sand dune sequence, geological features, rare species and vulnerable species such as the important overwintering and migratory bird populations that frequent the saltmarsh and mudflats. The intertidal mudflats also sustain a large variety of bivalves and marine invertebrates; a source of food for the birds that frequent the mudflats and supporting a bivalve fishery. The harvesting of mussels from the Taw Torridge has taken place since the 14th Century (Northern Devon Fisheries Local Action group, 2011).

The Taw Torridge is a popular tourist location and for boating activities with many recreational activities taking place such as yachting, dinghy sailing, windsurfing and canoeing. A number of commercial fishermen and charter fishing boats operate out of Appledore. The estuary is also used for commercial shipping associated with the ball clay trade and there is a ship building yard at Appledore.

CATCHMENT



(Data Copyright EEA Copenhagen [2008]. http://www.eea.europa.eu)

Figure 1.2 Land Cover in the Taw Torridge

Figure 1.2 shows the land cover within the hydrological catchment draining to the Taw Torridge. The Taw Torridge catchment covers an approximate area of 2090 km². The principal land cover is agricultural (75%), which it is predominantly used for cattle and sheep grazing (Maier et al., 2009). Other land uses include woodland and forest, covering 12% of the total catchment and rough grasslands, covering 9% (Maier et al., 2009). Urbanised areas are largely concentrated to land adjacent to the upper estuaries, representing the towns of Bideford, Barnstaple and Braunton. Peat bogs are present in the south of the catchment within Dartmoor National Park.

The underlying bedrock consisting of Upper Carboniferous rocks, sandstones and mudstones (Pethick, 2007). It is largely impermeable or has low permeability and as a result, most of the catchment responds quickly to rainfall (Environment Agency, 2008).

Highest faecal coliform contributions arise from developed areas, with intermediate contributions from the improved pastures and lower contributions from the other land cover types (Kay *et al*. 2008a). The contributions from all land cover types would be expected to increase significantly after marked rainfall events, particularly for improved grassland which may increase up to 100 fold.

2. RECOMMENDATIONS

2.1 PACIFIC OYSTERS

2.1.1 Zeta Berth. This area is located on the east shore of the Torridge estuary. Land runoff from the wider catchment is likely to be the main contaminating source. Locally, there are a few small streams discharging to the foreshore to both the north and south of the oyster racks, and an unmonitored intermittent discharge about 3-400m to the south. Sources on the opposite bank are unlikely to be of significance given the hydrography of the area.

Only a small area requires continuing classification for this species at present. Classification zone boundaries should be restricted to reflect this. There is little scope for noticeable and consistent spatial variation in levels of contamination across this site given its small footprint. The existing arrangement of classification monitoring based on sampling mussels provided by the harvester from the oyster racks (SS 4678 2928) should therefore be adequately protective of public health. Such a strategy would also allow this site to be classified for the harvest of mussels as well.

The recorded location of this RMP should be updated on the Cefas Shellfish Hygiene System (SHS) database to the more accurate one provided in this sampling plan. A tolerance of 10m should be used. The mussels used should be allowed to equilibrate *in situ* for at least two weeks before sampling, so the sampling officer should ensure that they meet this requirement, perhaps via a labelling or tagging system. They should also be of a market size (50mm). Monthly sampling should be continued to maintain the year round classification.

Should the site expand significantly, the default approach of relocating the RMP to the up-estuary (southern) end of the fishery should apply. This arrangement would also best capture any contamination potentially arising from the Westleigh PS overflow, which is the only known sewage discharge in the vicinity.

2.1.2 River Taw Mussel Fishery Order Should Pacific oyster culture become established within this area, then the mussel zoning and monitoring arrangements detailed below for Chivenor (2.2.1) may also be used to classify Pacific oysters.

2.2 MUSSELS

The following four zones are proposed:

2.2.1 Chivenor. This zone includes the Taw Mussel Fishery Order bed and two much smaller beds, neither of which were surveyed by the IFCA in 2011. The main contaminating influence within this area is likely to be runoff and other sources from the wider catchment so an underlying increase in contamination towards the up-estuary end of this zone is anticipated. Other potential impacting sources are a few small watercourses and the Chivenor RMB sewage discharge. For the small bed just to the west of the Caen estuary mouth sources discharging to the Caen estuary may be of significance, but would have been subject to significant dilution before arriving there. On balance, it is proposed that the RMP be located by the RMB

Chivenor sewage outfall (SS 4981 3373) which represents the most concentrated source of contamination. This point should also be effective in capturing contamination from up-estuary and catchment sources as it lies about 600m down from the up-estuary boundary. The use of bagged mussels would be appropriate here as access is via RMB Chivenor which is not open to the general public. A tolerance of 10m should be used. The mussels used should be allowed to equilibrate *in situ* for at least two weeks before sampling. They should also be of a market size (50mm). Monthly sampling should be continued if full classification is to be maintained. Otherwise, the LEA may wish to consider temporarily declassifying the area, which is not believed to be in active production, by reducing sampling frequency to quarterly. This should be on a 'rolling month' basis (i.e. different months each year) for a maximum of two years, thereafter declassification may be required by the FSA.

2.2.2 Coolstone and Power Station. This zone includes the mussel beds at Coolstone and at the Power Station. Again, the principle contaminating influences are likely to be up-estuary and catchment sources so an underlying increase in contamination towards the up-estuary end of this zone is anticipated. Sources within this zone are limited to a few minor watercourses and the Yelland PS intermittent outfall. This discharge is monitored and only discharged for about 0.3% of the time in recent years, so whilst it may be of occasional significance its effects are unlikely to be captured via monthly sampling. A slight increase in mean *E. coli* levels was observed towards the up-estuary end of these beds during previous classification monitoring. It is therefore recommended that the RMP be located at the up-estuary end of this zone, under the power station jetty (SS 4804 3268) where there is sufficient naturally occurring stock to support repeated sampling. A tolerance of 50m is recommended for sampling wild stocks. Animals should be of a market size (50mm) and sampled by hand. Monthly sampling should be continued if full classification is to be maintained.

2.2.3 Outer estuary (main beds). This zone includes the main mid channel beds (Spratt Ridge and Pulley Ridge) as well as Neck Gut, which has not been subject to commercial harvest for some years. There are no significant sources of contamination discharging directly to this zone, and again the principle contaminating sources are likely to be up-estuary and catchment sources. Historic classification monitoring data indicates that samples taken from Spratt Ridge showed higher average levels of contamination than Pulley Ridge. Neck gut showed lower average levels of contamination than either but has not been sampled nearly so often, and the lack of activity here suggests separate monitoring and classification is not merited for this bed. It is recommended that the RMP be located at the eastern end of the Spratt Ridge bed (SS 4657 3142) where there is sufficient naturally occurring stock to support repeated sampling. A tolerance of 50m is recommended for sampling wild stocks. Animals should be of a market size (50mm) and sampled by hand or rake. Monthly sampling should be continued if full classification is to be maintained.

2.2.4 Appledore Lifeboat. This is a relatively small zone encompassing the Lifeboat slip mussel bed only. It has seen some recent commercial harvesting and historic classification monitoring results indicate it is slightly less contaminated than the adjacent mid estuary beds, so separate monitoring is justified on this basis. There are no major contaminating sources direct to this zone, and again up-estuary sources are likely to be the main influence, especially those discharging to the Appledore seafront. These include the Appledore PS (although this only spilled for 0.1% of the time in recent years), a private discharge from the shipyard and numerous boat moorings, as well as the wider up-estuary and catchment sources. Sources discharging to the Skern may also be of some influence as contamination from these may be carried towards the mussel beds on the early flood tide. These include a small watercourse draining pastures, and the Skern PS intermittent discharge, although this only spilled for 0.9% of the time in recent years. On balance it is recommended that the RMP be located at the eastern end of the mussel bed (SS 4618 3107). A tolerance of 50m is recommended for sampling wild stocks. Animals should be of a market size (50mm) and sampled by hand or rake. Monthly sampling should be continued if full classification is to be maintained.

2.3 Razor Clams

If a razor fishery emerges off Northam Burrows/Westward Ho then the RMP should be located towards the northern end of the area requiring classification to reflect the influence of the local hydrography which advects potentially contaminated estuarine water over this area during the ebb tide.

3. SAMPLING PLAN

GENERAL INFORMATION

Location Reference

Production Area	Taw/Torridge
Cefas Main Site Reference	M036
Ordnance survey 1:25,000 map	Explorer 139
Admiralty Chart	1160

Shellfishery

Species/culture	Mussels (*Mytilus* spp.) Pacific oysters (*Crassostrea gigas*)	Wild Cultured
Seasonality of harvest	Year round	

Local Enforcement Authorities

Name	Food, Health and Safety Environmental Health and Housing North Devon District Council The Ilfracombe Centre 44 High Street Ilfracombe EX34 8AL
Environmental Health Officer	Dean Davies (Senior Food Safety Officer)
Telephone number ☎	01271 855309
Fax number	01271 388328
E-mail	Dean.Davies@northdevon.gov.uk
Name	Commercial Services Torridge District Council Town Hall Bideford EX39 2HS
Environmental Health Officer	Mike Sealey
Telephone number ☎	01237 428823
Fax number	01237 474407
E-mail	Mike.Sealey@torridge.gov.uk

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 Taw Torridge

Classification zone (Species)	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species Sampled	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Chivenor (Mussels)	B036Z	Chivenor Outfall	SS 4981 3373	51° 4.99'N 4° 8.74'W	Mussels	Wild	Hand or rake	Hand (bagged)	10m	Monthly	Covers Several Order, Allens Rock and Caen Mouth beds. The mussels samples may be used to classify Pacific oysters also if required. LEA may wish to consider temporary declassification (quarterly (rolling month) sampling) if the zone remains inactive.
Coolstone and Power Station (Mussels)	B36AA	Under Power Station Jetty	SS 4804 3268	51° 4.40'N 4° 10.23'W	Mussels	Wild	Hand or rake	Hand or rake	50m	Monthly	Covers Coolstone and Power Station beds
Outer estuary (main beds) (Mussels)	B36AB	Spratt Ridge East	SS 4657 3142	51° 3.69'N 4° 11.45 'W	Mussels	Wild	Hand or rake	Hand or rake	50m	Monthly	Covers Spratt Ridge, Pulleys Ridge and Neck Gut
Lifeboat Slip (Mussels)	B36AC	Appledore	SS 4618 3107	51° 3.50'N 4° 11.78'W	Mussels	Wild	Hand or rake	Hand or rake	50m	Monthly	Covers Lifeboat slip beds only.
Zeta Berth (Mussels and Pacific oysters)	B036Y	Zeta Berth	SS 4678 2928	51° 2.54'N 4° 11.22'W	Mussels	Rack culture	Hand (bagged)	Hand (bagged)	10m	Monthly	Covers Pacific oyster site at Zeta Berth. If mussels continue to be sampled then both species can be classified if required. RMP coordinates require updating on SHS.

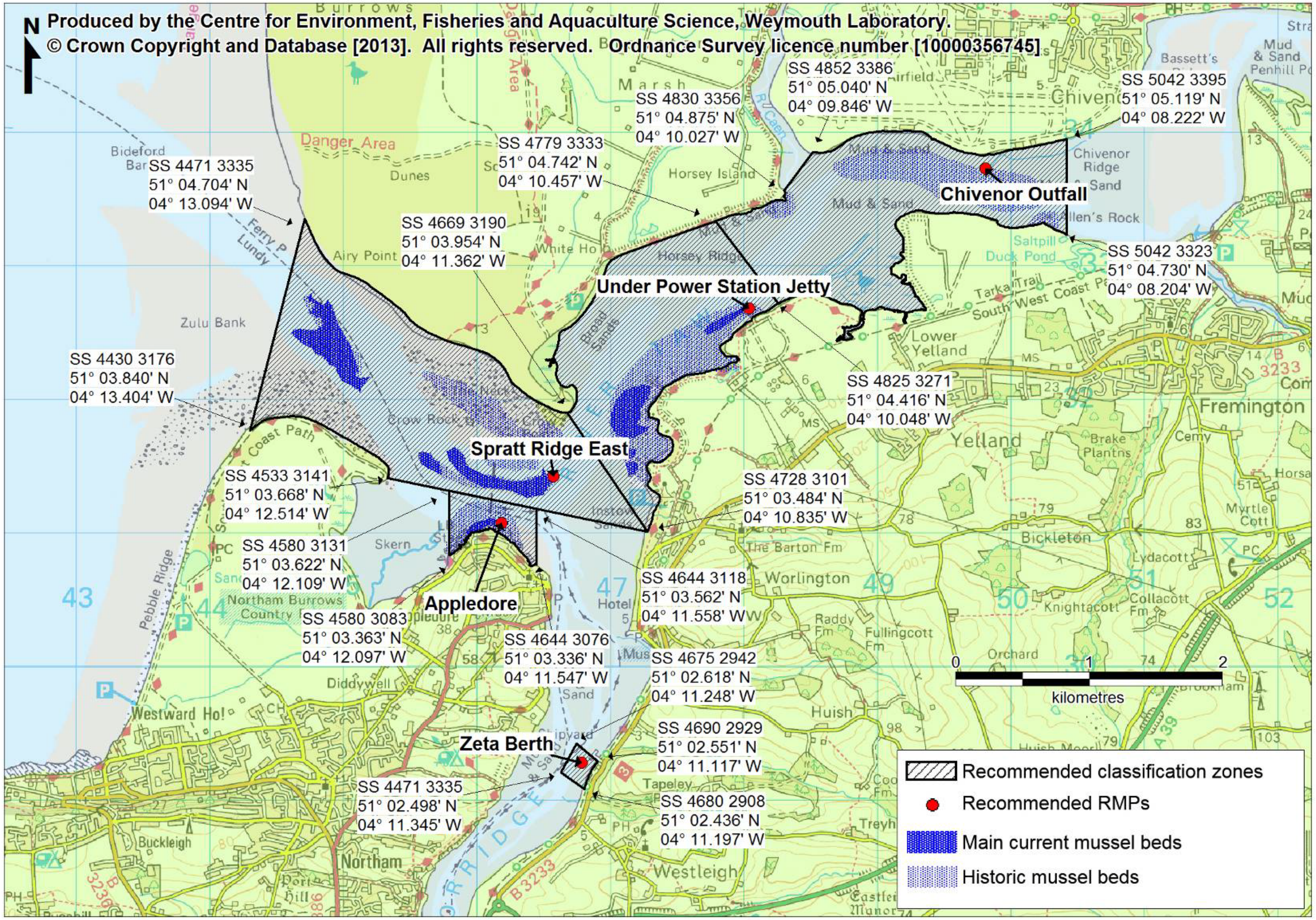
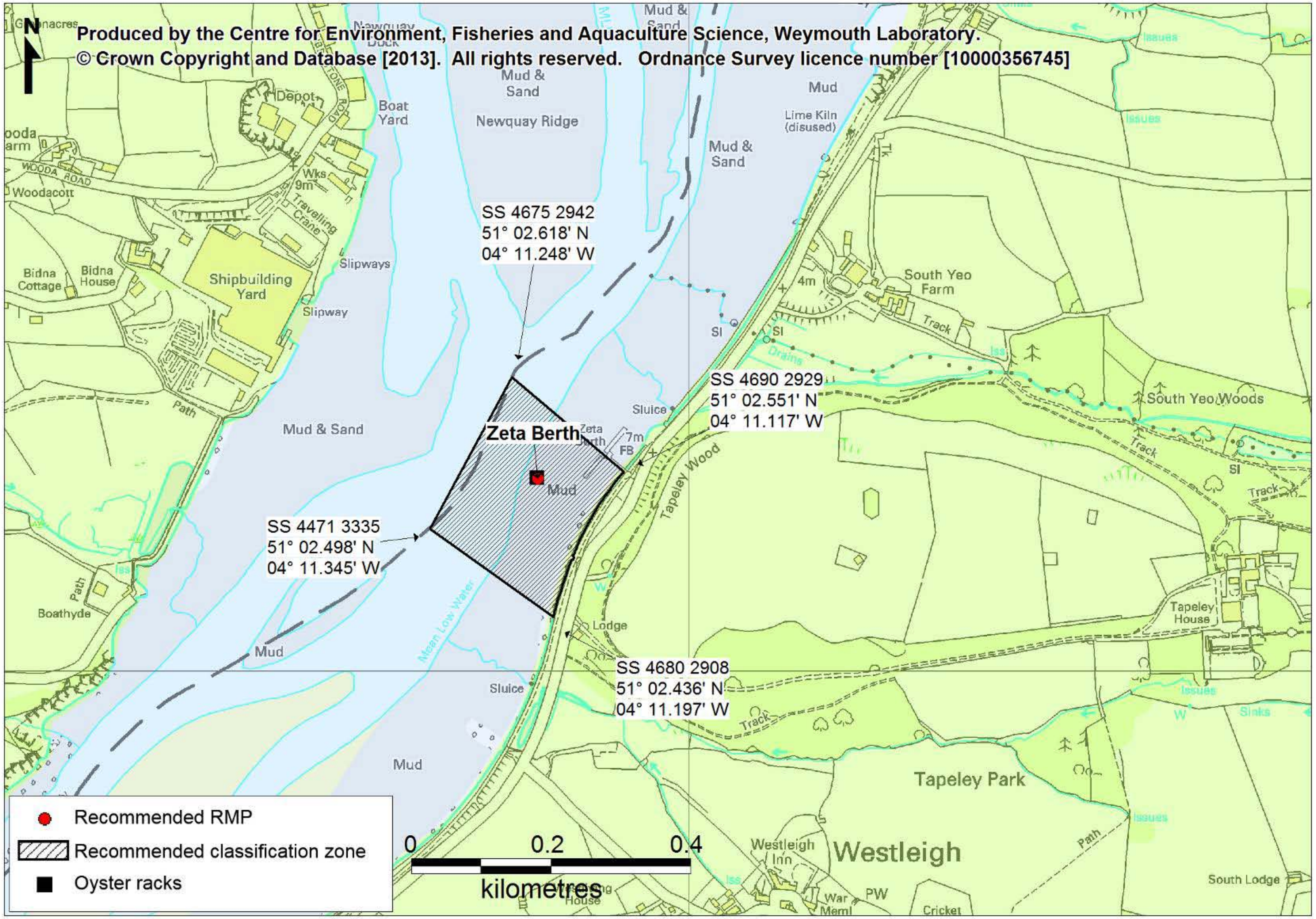


Figure 3.1 Recommended classification zone boundaries and RMP locations for mussels


Produced by the Centre for Environment, Fisheries and Aquaculture Science, Weymouth Laboratory.
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N
SS 4675 2942
51° 02.618' N
04° 11.248' W
SS 4690 2929
51° 02.551' N
04° 11.117' W
SS 4471 3335
51° 02.498' N
04° 11.345' W
SS 4680 2908
51° 02.436' N
04° 11.197' W
Zeta Berth
Recommended RMP
Recommended classification zone
Oyster racks
0
0.2
0.4
kilometres
Mud & Sand
Newquay Ridge
Shipbuilding Yard
Boat Yard
Slipways
Slipway
South Yeo Farm
South Yeo Woods
Tapeley Wood
Tapeley House
Tapeley Park
Westleigh
Boathyde
Bidna Cottage
Bidna House
Woodacott
Lodge
Sluice
Mud
South Lodge

Figure 3.2 Recommended classification zone boundaries and RMP locations for Pacific oysters

4. SHELLFISHERIES

4.1 SPECIES, LOCATION AND EXTENT

The Taw/Torridge estuary supports naturally occurring stocks of mussels, as well as a Pacific oyster culture site and other species potentially of commercial interest (cockles and razors). Part of the Taw estuary at Chivenor is covered by the River Taw Mussel Fishery Order 1962. These fishing rights, which apply to the mussel stocks only, are currently held by South West Water. The rest of the mussel beds are a public fishery, which the Devon and Severn IFCA has recently taken over the management of from the Environment Agency.

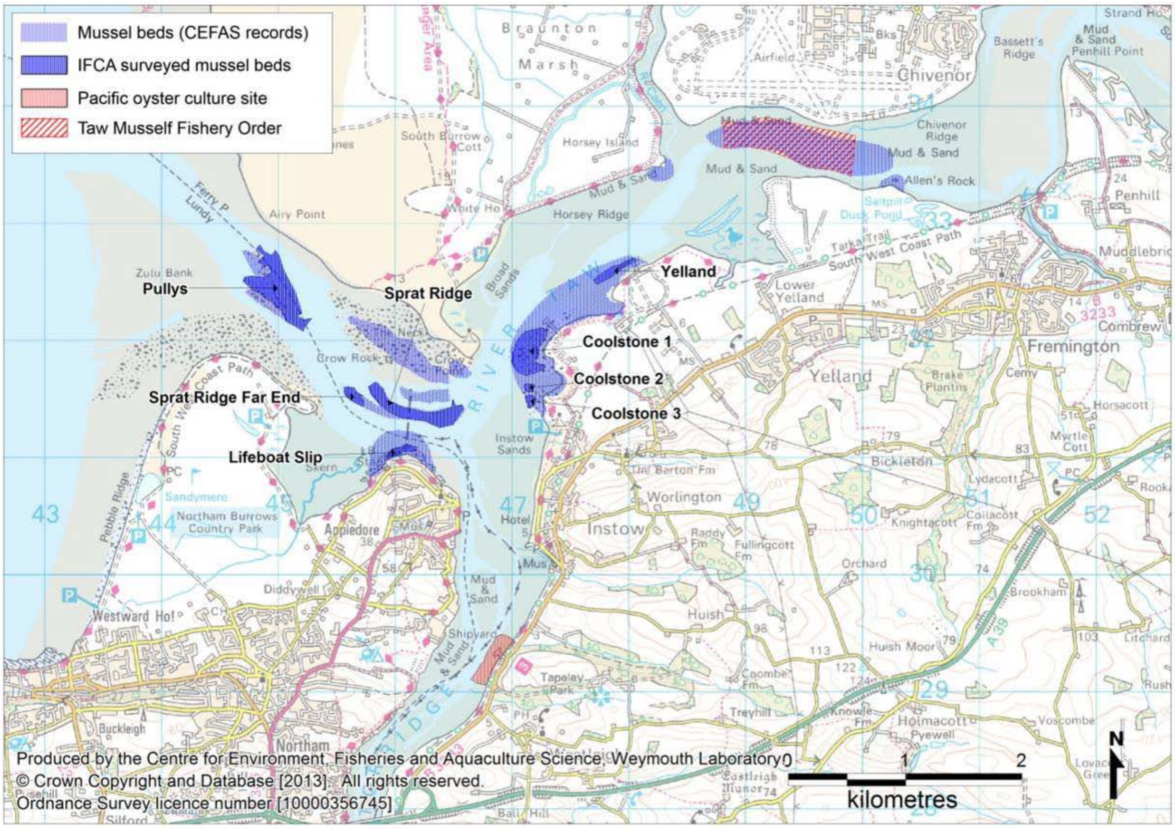


Figure 4.1. Overview of shellfisheries within the Taw/Torridge

Figure 4.1 shows the locations of mussel beds from both historic CEFAS records and also from a more recent survey of the main intertidal beds undertaken by the Devon and Severn IFCA in 2011. This survey estimated that the total stock biomass across these eight beds was 2347 tonnes, of which 601 tonnes were of a marketable size so there are considerable resources present (Gray, 2012). The locations of the main beds are fairly stable from year to year, although there are likely to be some fluctuations in stock levels and the proportion of animals which are a harvestable size. The historic CEFAS records also show some other mussel beds which were not surveyed in 2011. The beds to the north of Neck Gut are of little interest to commercial fishermen and have not been harvested in about 8 years (Dean Davies, North Devon District Council, pers comm.). The status of the small patch just to the west of the Caen estuary mouth and at Allens Rock are uncertain. Pulleys Ridge and Appledore Lifeboat Slipway are within the Torridge DC boundary, and all other mussel beds are within the North Devon DC boundary.

The public mussel beds are subject to a hand gathering fishery which supports 2-3 commercial fishermen (North Devon Fisheries Local Action Group, 2011), although North Devon District Council advises that at present there is little if any activity. The several order area is not currently managed or harvested, although South West Water are keen to lease the site on to a harvester.

Pacific oysters are cultured by the Zeta Berth on the east shore of the Torridge estuary. Currently this site is on a relatively small scale only covering an area of about 20m x 20m. The harvester has recently established depuration facilities in Appledore. This site is within the North Devon DC boundary.

Cockles and razors are also present in the area and local fishermen have expressed an interest in both these species (Sarah Clark, Devon and Severn IFCA, pers comm.). The Environment Agency fishery officer however has only seen very occasional casual gathering of cockles for personal consumption and was not aware of any commercial interest in these stocks (Paul Carter, pers comm.). The locations of any commercial concentrations of cockles are unknown at this stage, although dead cockle shell was commonly observed within the estuary during the course of the shoreline survey. Razors are thought to be present around and below the low water mark from the estuary mouth down towards Westward Ho, in the more sheltered southern half of Bideford Bay. They may also be present in some parts of the outer estuary. In the absence of any more formal expression of interest in these species, and with no firm knowledge of their distribution it will not be possible to identify RMPs and a zoning plan for these.

4.2 GROWING METHODS AND HARVESTING TECHNIQUES

All stocks of mussels are wild, although some areas have been managed to some extent to maximise productivity. Harvesting is via hand picking or hand raking. At present there is little activity in this fishery. Pacific oysters at Zeta Berth are grown from seed in suspended triangular net bags. Harvesting is via hand. Other stocks of potential interest (cockles, razors) are naturally occurring, not managed in any way, and whilst they may be subject to occasional casual gathering have never been harvested on a commercial basis.

4.3 SEASONALITY OF HARVEST, CONSERVATION CONTROLS AND DEVELOPMENT POTENTIAL

Mussels may be fished at any time of the year. The only management measure which applies is a minimum landing size of 50mm. There may be some potential to increase landings from the public beds through more active management and increased effort. South West Water are actively seeking to lease the Several Order area to a harvester to manage and harvest, as would be required to ensure its long term future. Despite some expressions of interest, the possibility of a downgrade from the current long term B classification should high results occur has made the lease a less attractive prospect. South West Water would also consider leasing the site for use as an oyster farm, and intend to investigate this possibility with the local industry (Paul McNie, South West Water, pers comm.).

The Pacific oyster culture fishery is not subject to any fishery management controls, and has significant potential for expansion above its current level of production. The footprint of the site may potentially expand along the low water line. Harvest may occur at any time of the year.

For cockles a minimum size of ¾" applies in the district, and the statutory minimum size of 100mm applies to razors, although in practice only animals of more than 15cm are likely to be marketable. No closed season applies to either. Any future fishery for these species would be monitored and managed by IFCA, and so may be subject to further conservation controls. Given the lack of information on these stocks the development potential for these fisheries is unknown.

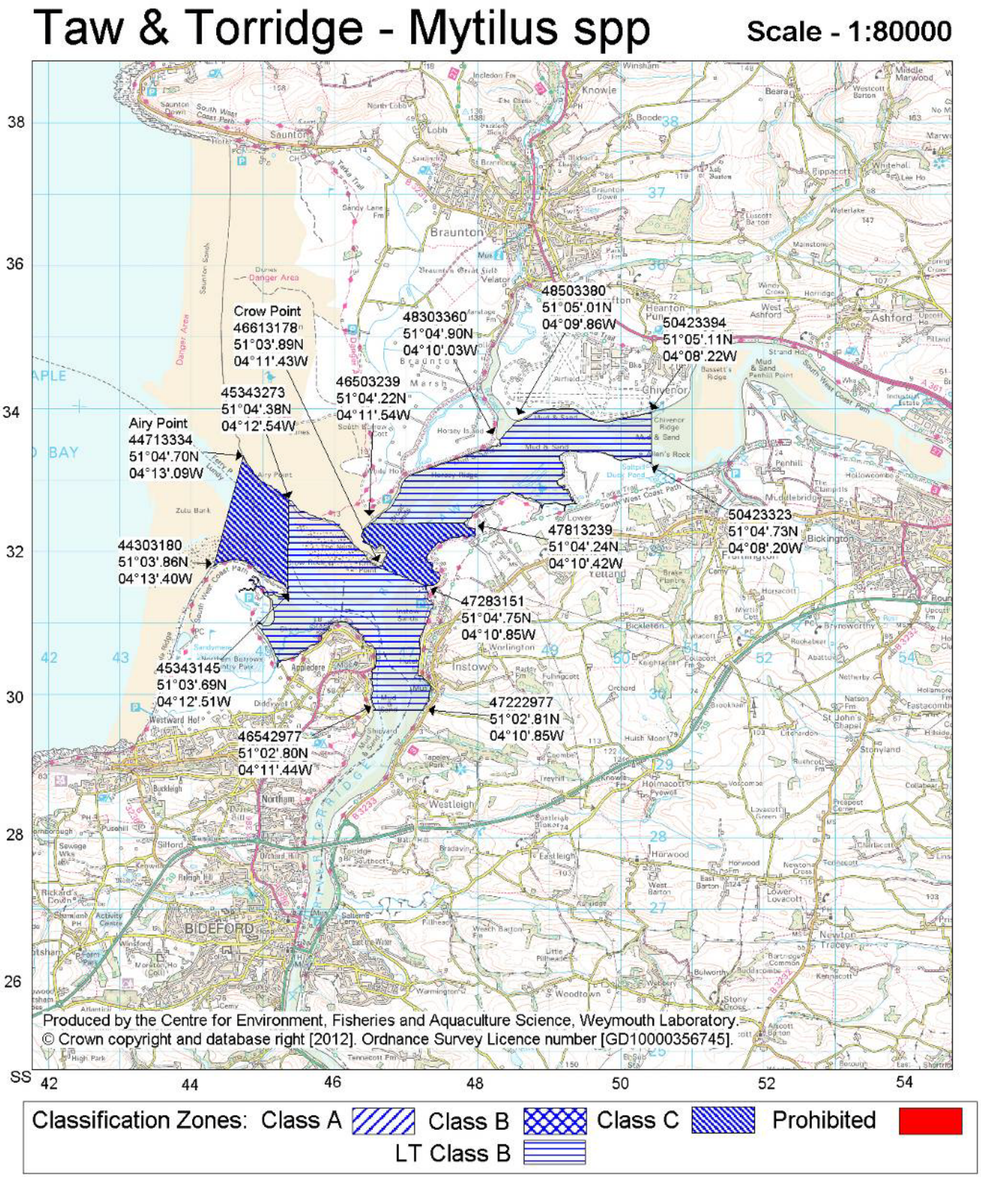
4.5 HYGIENE CLASSIFICATION

Table 4.1 lists all classifications within the Taw/Torridge estuary from 2003 onwards. Most parts are classified as B in recent years, but the area around Coolstone is has held a C classification since 2009 and the Pulley Ridge was classified a C in 2010 and 2011, upgraded to B in September 2012, but downgraded to C again in December 2012. In 2003 some areas were prohibited, but by 2005 all areas were class B suggesting a significant improvement in water quality around this time.

Table 4.1 Classification history for the Taw/Torridge, 2003 onwards

Area	Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Lifeboat Slipway	Mussels	B	B	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Spratt Ridge	Mussels	B	B	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Pulley Ridge	Mussels	B	B	B	B	B	B	B	C	C	C
Coolstone - Instow	Mussels	P	C	B	B	B	B	C	C	C	C
Power Station - Yelland	Mussels	P	C	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Zeta Berth	C. gigas	B	B	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Neck Gut	Mussels	B	B	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Blackstone Rock	Mussels	-	B	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
All other beds except Coolstone and Power Station	Mussels	C	-	-	-	-	-	-	-	-	-

LT denotes long term classification



Classification of Bivalve Mollusc Production Areas: Effective from 20 December 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)

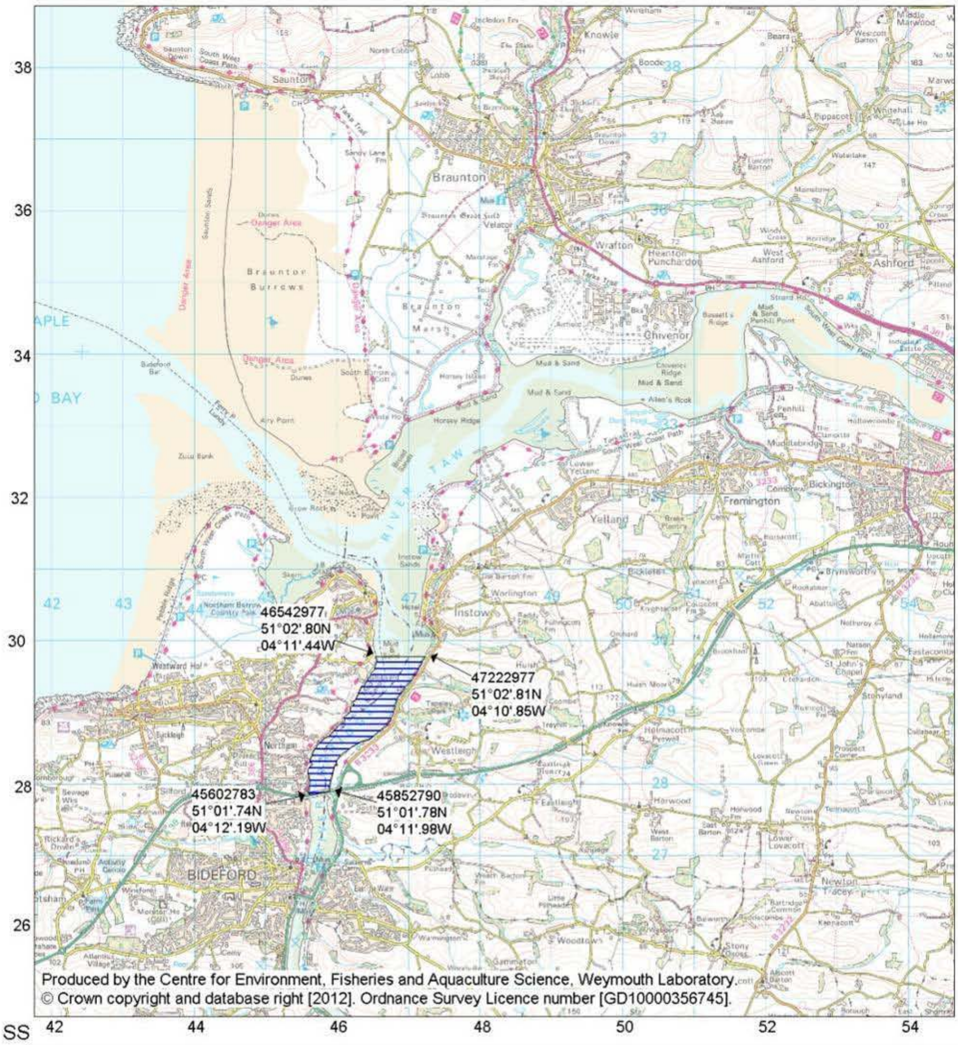
N.B. Lat/Longs quoted are WGS84
Separate map available for C. gigas at Taw & Torridge

Food Authorities: North Devon District Council (Taw) Torridge District Council (Torridge)

Figure 4.3 Current mussel classifications

Taw & Torridge - C. gigas

Scale - 1:80000



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

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 Taw & Torridge

Food Authorities: North Devon District Council (Taw) Torridge District Council (Torridge)

Figure 4.4 Current Pacific oyster classifications

Table 4.2 Criteria for classification of bivalve mollusc production areas.

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

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

5. OVERALL ASSESSMENT

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.

SHELLFISHERIES

The Taw/Torridge estuary supports significant mussel stocks, which occur naturally in certain places in the outer Taw estuary and the combined estuary mouth. The locations of these are relatively stable from year to year. The mussel bed to the south of RMB Chivenor falls within a Several Order held by South West Water, and the rest of the beds are public fisheries. The Several Order bed has not been managed or harvested in recent years, but South West Water are actively seeking to lease this on to a harvester so the LEA may wish to consider temporarily declassifying this until it becomes active again. This may be achieved by reducing sampling frequency to quarterly, and when the fishery becomes active again it can be reclassified once monthly sampling restarts. South West Water have also indicated that Pacific oyster farming here may be an option for the future, although plans are very tentative at this stage.

The public mussel fishery has been worked by a few harvesters in recent years but at present there is little activity. Depending on how the situation develops, the LEA may also wish to consider (in consultation with local fishermen) temporarily declassifying some or all areas until the fishery becomes active again. Mussel harvesting within both the Several Order and public fishery may occur at any time of the year so any classifications should be year round. Mussels are subject to a minimum landing size of 50mm, so any classification samples should also consist only of animals of over 50mm. Mussels are harvested by hand or by rake, so either of these sampling methods will be acceptable.

There is also a small Pacific oyster culture site by the Zeta Berth on the east shore of the Torridge estuary. It only currently occupies a small area of around 20mx20m, although significant expansion may occur in the future. It requires continued year round classification. Currently, it is classified based on samples of mussels, which are provided by the harvester and held in bags alongside the oysters. It is possible that some of these mussels are destined for human consumption but the volumes present were very small. Mussels are considered a suitable surrogate for Pacific oysters (Younger & Reese, 2010) so it is acceptable for this arrangement to continue. Such an arrangement would also permit mussels to be harvested commercially there. The mussels used should be allowed to equilibrate *in situ* for at least two weeks before sampling, so the sampling officer should ensure that the mussels sampled meet this requirement, perhaps via a labelling system.

There are other shellfish resources within the estuary and in Bideford Bay. Dead cockle shell was frequently sighted during the shoreline survey. Occasional casual gathering of cockles has been reported within the estuary, and it is thought that razors occur near Westward Ho and perhaps in the outer estuary. Some fishermen have informally expressed an interest in harvesting these species to the Devon and Severn IFCA. It would be desirable for this report to include a sampling plan for these species in case these fisheries are developed commercially. However, at the time of writing there is virtually no information on the distributions and stock levels for these species. As the areas potentially requiring classification, and locations from which samples can be taken are not known it is not possible to produce a suitably informed zoning and monitoring plan for either of these species. However, the assessment provided in this report should provide a useful basis for producing a plan in the event a formal application is made identifying the location and extent of stocks requiring classification.

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 Taw/Torridge estuary drains a catchment area of 2090 km^2 within which the primary land use is grazing pastures. The Taw catchment is slightly larger than the Torridge but both are similar in size and character. Both receive sewage from a series of discharges generally serving small rural settlements. These rivers and their major tributaries enter at the heads of their respective estuaries upstream of the fisheries. They are likely to account for a large proportion of the fluxes of indicator bacteria into the estuary. Therefore 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 there may be more localised 'hotspots' associated with smaller freshwater inputs discharging in close proximity to the shellfish beds which should also be considered in the sampling plan.

Most potentially significant freshwater inputs in the vicinity of the fisheries were sampled and the discharge measured during the shoreline survey. This identified that the Caen/Knowle Water is a significant source of indicator bacteria carrying a combined *E. coli* loading of 1.71×10^{12}. Such a loading is likely to result in a hotspot around the mouth of the Caen estuary. The watercourse discharging at Allens Rock carried a loading of 1.53×10^{11} *E. coli*/day and so may be of some more localised significance. All other inputs were relatively minor, carrying $<10^{11}$ *E. coli* cfu/day. At the oyster farm, the watercourses draining to the north of the trestles were carrying higher loadings (1.07×10^{10} and 3.90×10^{10} *E. coli*/day) than the one draining to the south (1.05×10^{9} *E. coli*/day) suggesting that the RMP should be located at the down estuary end of the site, although all were relatively minor. Fremlington Pill/Creek may also be of some local significance to the more up estuary mussels beds on the south shore of the Taw estuary.

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'). Both the Taw and Torridge are spate rivers, which respond rapidly to rainfall so the bacterial loadings they deliver to the estuary are likely to fluctuate greatly in response to rainfall.

HUMAN POPULATION

Total resident population within the Taw and Torridge estuary catchment was 318,923 at the time of last census for which suitable data was available (2001). The two principle population centres are at Bideford (at the head of the Torridge estuary) and Barnstaple (at the head of the Taw estuary). There are also a series of smaller towns and villages on the shores of the estuary including Braunton, Fremlington, Yelland, Instow and Appledore. The wider catchment is predominantly rural and more sparsely populated.

The North Devon Coast is a popular tourist destination in the summer months due to its beaches, attractive countryside and seaside towns (Devon County Council, 2007). Significant influxes of holidaymakers are therefore anticipated at these times, especially at resorts such as Westward Ho, Appledore and Instow. 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 is one major sewage works discharging direct to the estuary complex (Barnstaple Ashford STW) which serves a population of 47,450 and discharges to the north bank of the Taw estuary almost 3km upstream of the nearest mussel bed. This discharge receives UV treatment, and the average concentration of faecal coliforms in the effluent has been 213 faecal coliforms/100ml in recent years indicating that this treatment is generally effective. Based on the geometric mean concentration of faecal coliforms and the permitted dry weather flow (15,231 m^3/day) the estimated bacterial loading generated by this works is only 3.24×10^{10} faecal coliforms/day. Occasionally higher concentration of faecal coliforms up to 170,000 cfu/100ml have been recorded however, so the loading generated by this works may sporadically increase by several orders of magnitude.

There is one other water company owned discharge direct to the estuary (Clevelands Park STW) at Northam, which provides secondary treatment for a population of only 25. Sewage generated by most of the area surrounding the Torridge estuary (Bideford, Appledore etc) is treated by the Cornborough STW, which serves a population of 66,981 and discharges via long sea outfall to Bideford Bay over 5km from the estuary mouth. It also provides UV treatment and final effluent testing data shows an average concentration of 378 faecal coliforms cfu/100ml so given this and its location it should have no impact on the shellfisheries within the estuary.

There are also three relatively large private discharges to the Taw estuary which may have some impact on the shellfish beds. RMB Chivenor is consented to discharge 370m^3/day of UV treated effluent immediately adjacent to the Several Order. This was sampled during the shoreline survey and carried a concentration of 19,000 *E. coli* cfu/100ml. This would translate to a loading of 7.03x10^{10} *E. coli*/day, but this should be treated with caution as it is only derived from one sample result. The effluent was clear at the time so the UV treatment should have been working reasonably effectively. There is also a package plant discharge from an Inn just to the east of RMB Chivenor consented to discharge up to 21.4m^3/day and a secondary treated discharge from the Appledore shipyard consented to discharge up to 70 m^3/day to the west bank of the Torridge estuary via a short watercourse.

The wider inland catchment is served by a large number of generally small sewage works, most of which discharge to watercourses draining to the estuary via the rivers Taw and Torridge. Watercourses draining the Taw catchment receive treated effluent from a population of just over 23,000 and watercourses draining the Torridge catchment receive effluent from a population of almost 27,000. Most of these works provide secondary treatment, although some provide additional nutrient removal and some of the very small ones only provide primary treatment. It is likely that there is significant bacterial die-off during transit through the watercourses to the estuary, particularly for the more distant sewage works. On the basis of their geographical distribution, their impacts will be greatest towards the heads of the estuary. Also of potential significance are four small sewage works draining to the Caen/Knowle Water catchment serving a combined population of just over 1100.

In addition to the continuous sewage discharges, there are a large number of intermittent water company discharges associated with the sewerage networks. The main clusters of these are at Barnstaple and at Bideford, as well as some at Braunton, Fremlington, Instow and Appledore. There is also one at Westleigh, about 400m south of the Zeta Berth. A large number of these have spill event recording. The intermittent outfall at Westleigh is not one of these. Of the monitored outfalls, the Pottington PS at Barnstaple spilled the most overall, although it has not spilled so much in more recent years. Fremington Pill PS and Instow A PS were the next most regular spillers, although they were only active for 1.8% and 1.4% of the period respectively. All of the other monitored outfalls were active for less than 1% of the time, and some hardly spilled at all. It is therefore concluded that all intermittent discharges, excepting the Pottington PS, and possibly the Fremington Pill PS and Instow PS are generally of little significance and the effects of spills are unlikely to be captured via a monthly sampling programme. The Yelland PS outfall is in close proximity to mussel beds at Yelland and Coolstone, and there are two intermittent outfalls (Skern and Appledore PS) within 1km of the mussel beds at Lifeboat Slip. None of these outfalls spilled for more than 1% of the time. The unmonitored Westleigh outfall is of possible significance to the site at Zeta Berth.

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

AGRICULTURE

The majority of land within the Taw/Torridge catchment is used for agriculture. Most are pastures, although there are many smaller pockets where crops are cultivated. A total of 205,680 cattle and 563,118 sheep were recorded within the catchment area in the 2010 agricultural census, so significant and widespread impacts from grazing animals are anticipated. Environment Agency bathing waters investigations using a DNA tracing technique indicate the majority of faecal indicator bacteria are of agricultural origin at the Instow bathing waters site (Environment Agency, 2012). This will probably apply to most of the estuary outside of any hotspots associated with sewage discharges. 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. Significant numbers of poultry and some pigs are also farmed in the catchment. 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 on this basis. 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.

On the south shore of the Taw estuary there is an area of saltmarsh by Bickington which is used for grazing sheep on a year round basis. Livestock may access the intertidal areas in other places, such as around the Caen estuary and on the Northam Burrows. Contamination deposited in the intertidal areas will be carried into the estuary via tidal inundation which is a particularly direct and predictable mechanism, the risk of which is greater during spring tides.

In summary, the upper reaches of the estuary will be most impacted by contamination of livestock origin, but there may be a hotspot by the mouth of the Caen estuary and in the vicinity of other significant freshwater inputs. It is likely that the saltmarsh grazing at Bickington, on the south bank of the Taw about 3km up-estuary from the shellfish beds, makes a significant contribution at times. Therefore RMPs situated towards the up-estuary ends of the shellfish beds and by the drainage channels crossing intertidal areas are likely to capture peak levels of livestock related contamination. Livestock numbers are highest during summer and autumn so some seasonality in impacts may be anticipated. Whilst the flux of contamination from pastures will be highly rainfall dependent, peak fluxes from grazing marsh may be anticipated on spring tides.

Boats

The Taw Torridge estuary is used by a variety of craft, including commercial shipping, fishing vessels, recreational craft of various sizes, houseboats and military vessels. The majority of boating activity takes place on the River Torridge and around the mouth of the estuary. Commercial ship traffic is centred around the port at Bideford. Military craft use the Zeta Berth and undertake exercises within the estuary. Most moorings for yachts, cabin cruisers and fishing vessels are located on the edge of the deep water channels in the Torridge estuary, although there are some within the Caen estuary. Houseboats were observed in the upper reaches of the Caen estuary and on the north bank of the Taw just to the east of RMB Chivenor.

Commercial shipping is not permitted to discharge to inshore waters so should be of no impact. It is uncertain whether this also applies to military craft. 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. Occupied houseboats are also likely to make regular overboard discharges. On this basis, the outer Torridge estuary, the Caen estuary and the north bank of the Taw to the east of RMB Chivenor are likely to be most at risk. There may be the possibility that overboard discharges are made by military craft at the Zeta Berth. 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 Taw Torridge Estuary contains a diversity of habitats including sand dunes, saltmarsh, grazing marsh, mudflats and sand spits, which support a significant population of overwintering waterbirds (waders and wildfowl). The most recent count recorded peak winter numbers of 13,856 waterbirds. Some species of waders feed on intertidal invertebrates so will forage (and defecate) directly on the shellfish beds across a wide area. They may tend to aggregate in certain areas holding the highest densities of their preferred size and species of prey, but this may vary from year to year. They will therefore represent a diffuse input and whilst they may be a significant contaminating influence at times, they will not influence the positioning of any RMPs. Other overwintering waterbirds such as grazing ducks, plovers and lapwings will mainly frequent the saltmarsh, where their faeces will be carried into coastal waters via runoff into tidal creeks or through tidal inundation. RMPs positioned in or by creeks and channels draining from such areas would be best positioned to capture contamination from these.

Although the majority of waterbirds migrate elsewhere to breed, other species such as gulls and terns are present during the summer months. Relatively small numbers of such birds use the Taw/Torridge estuary due to the lack of suitably undisturbed nesting places such as islands. They are likely to forage around the estuary so represent a minor source of diffuse contamination, but this will not influence the sampling plan.

The closest colony of seals to the Taw Torridge Estuary is located at Lundy Island, about 20km to the west, where about 60 grey seals haul out in the summer and about 120 in winter. They are likely to forage widely so seals will enter the Taw Torridge Estuary from time to time but only in small numbers and their presence will be unpredictable both spatially and temporally. Due to their low numbers and high mobility the presence of seals will not influence the sampling plan.

Otters are present within the Taw Torridge Estuary in both the Taw and Torridge near Barnstaple and Bideford. Exact numbers are not known but are likely to be relatively small. They tend to favour the more secluded areas with access to watercourses. However, given their likely wide distribution and small numbers otters have no material bearing on the sampling plan. No other wildlife species which have a potentially significant influence on levels of contamination within shellfish within the survey area have been identified.

Domestic animals

Dog walking takes place along coastal path that runs adjacent to the shoreline of the estuary this could represent a potential source of diffuse contamination to the near shore zone. Large numbers of dog walkers were seen on the beach at Instow, and several were seen on the Northam Burrows. As a diffuse source, this will have little influence on the location of RMPs.

Summary of Pollution Sources

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

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

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

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

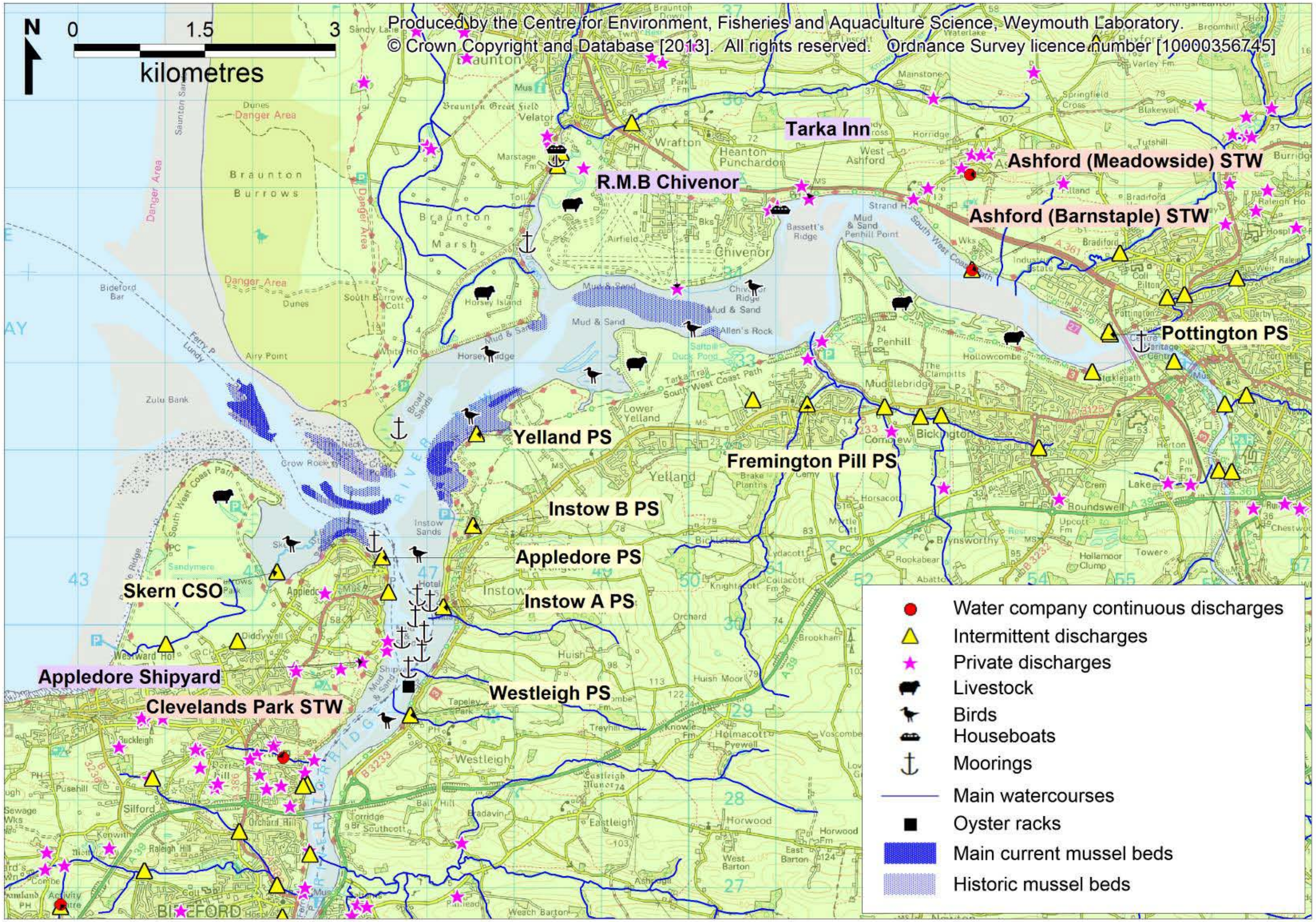


Figure 5.1 Significant sources of microbiological pollution to the Taw/Torridge estuary.

HYDROGRAPHY

The Taw Torridge is a west facing double spit enclosed estuary, which flows into Bideford Bay in the outer Bristol Channel. Most of it is intertidal, with sand and gravel beds in the outer estuary and finer sediments further up-estuary. Its shallow intertidal nature will promote tidal exchange, but will reduce dilution potential. Meandering river channels bisect the intertidal areas. The Taw estuary has two small side arms (the Caen and Fremington Pill) where minor rivers join it. The two main river channels join in the very outer reaches of the estuary between Appledore and Crow Point. The Torridge estuary lies within a steeper valley that the Taw and as a consequence is narrower with smaller intertidal areas. Saltmarsh is present in the upper reaches of both the Taw and the Torridge which are inundated on the larger tides.

Tidal amplitude is large, at 7.3m on spring tides and 3.6m on neap tides at Appledore. This drives extensive water movements through the estuary complex. The flood tide conveys relatively clean Atlantic water into the estuary which follows the main channels up the estuary at lower water levels but is more spread out towards high water. The reverse occurs on the ebb. Therefore, contamination from shoreline sources will tend to drain into the main channels via channels across the intertidal, and travel parallel to the shore when it reaches tidal waters. As a consequence these sources will primarily impact either side of their locations on the same shore to which they discharge, and in the vicinity of any drainage channels they follow across the intertidal. RMPs should therefore be located to reflect this. Sources discharging to the Caen estuary and Fremington Pill will tend to primarily impact to the west of their mouth as the tide ebbs from them, but will be subject to significant dilution before leaving these creeks.

Peak current speeds of up to 1.5m/s arise on spring tides in the estuary mouth, and about half of this on neap tides. Measured current speeds within the estuary were slower, but still sufficient to ensure contamination from shoreline sources will be carried several km during the course of a flood or an ebb tide.

Where the main Taw and Torridge channels merge, areas to the south of the outer (combined) channel will be more influenced by sources to discharging to the Torridge, and areas to the north of the channel will be more influenced by sources to the Taw. The plume emanating from the estuary during the ebb tide travels in a SSW direction parallel to the shore once it joins the main tidal stream in Bideford Bay. If a razor fishery emerges off Northam Burrows/Westward Ho then the RMP should be located towards the northern end of the area requiring classification to reflect this.

Freshwater inputs may modify the circulation of water around estuaries via density effects. Freshwater inputs to the estuary are significant and may result in some stratification particularly at higher river flows and in the upper estuary. Any stratification will result in a shear in currents down the water column, with a net seaward flow in the upper layers and a net landward flow at depth. Stratification will tend to entrain freshwater borne contamination in the surface layers meaning stocks at lower elevations may be more separated from such contamination, at higher states of the tide at least.

Multiple measurements indicate salinities were mostly approaching that of full strength seawater at the estuary mouth, although occasional lower salinities were recorded. Salinity becomes lower on average towards the upper reaches of both the Taw and Torridge estuaries, and varies from approaching full strength seawater to almost completely fresh water at all stations sampled above the confluence. Strong negative correlations were found between levels of indicator bacteria and salinity at these sites so increasingly variable and higher average levels of contamination are anticipated towards the head of the estuaries. Zoning and monitoring arrangements should reflect this overall principle.

Water circulation may also be modified by the effects of wind, although exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so will be highly dynamic and difficult to predict. Such effects will not therefore influence the sampling plan. Winds drive surface currents, which in turn will create return currents at depth or along sheltered margins. The prevailing wind direction is from the south west, which will tend to push surface water up the Taw estuary. The Torridge, which is in a steeper valley and has a north south orientation will be more affected by winds from the north and south. As well as driving surface currents, onshore winds will create wave action, which may re-suspend any contamination held within sediments. Significant wave action is anticipated in Bideford Bay and at the estuary mouth at times, and within the estuary strong onshore winds may create waves large enough to disturb the finer sediments present here.

SUMMARY OF EXISTING MICROBIOLOGICAL DATA

The Taw/Torridge 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. Only the results of samples since 2003 were considered as major upgrades to the local sewerage systems were ongoing until 2002.

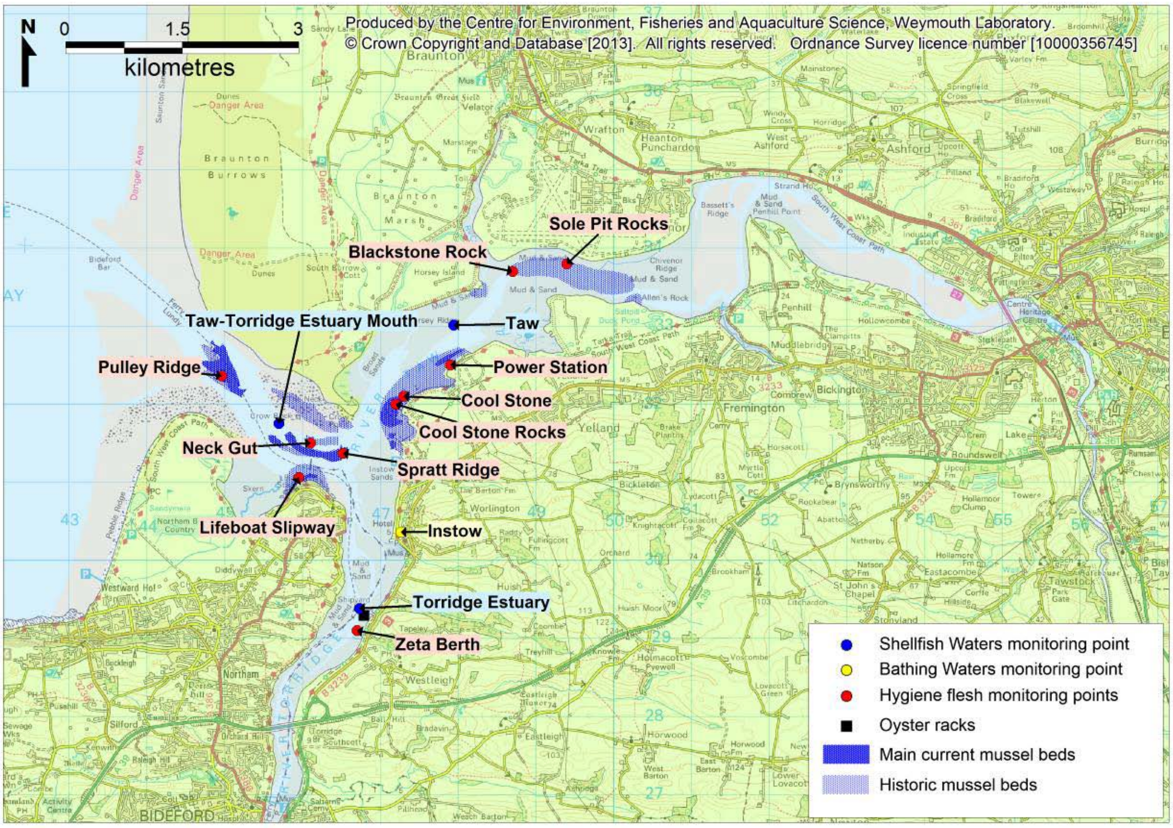


Figure 5.2. Location of shellfish and seawater sampling locations

Only one site at Instow was sampled under the Bathing Waters monitoring programme, where around 20 samples were taken each bathing season (May-September). Results here ranged from <2 to 39,600, with a geometric mean of 57.1 and 13.3% of samples returned a result of over 1000 faecal coliforms/100ml. This indicates considerable variability with some very high results occurring on occasion. Significant influences of both the high/low and spring neap tidal cycles were found here. Results were higher on average around low water suggesting up estuary influences are of importance. They were also slightly lower at the neap tides suggesting more distant sources may be an influence. A significant and consistent influence of rainfall up to 7 days before sampling indicating that rainfall dependent sources (presumably land runoff) are a major influence.

Water samples were taken on a quarterly basis and tested for faecal coliforms from three locations under the Shellfish Waters monitoring programme (Taw, Torridge and estuary mouth). Results were similar at the Taw and Torridge sites, with geometric mean results of 98 and 110 faecal coliforms/100ml and 27 and 26% of results exceeding 1000 faecal coliforms/100ml respectively. At the estuary mouth site, results were significantly lower, with a geometric mean result of 20 faecal coliforms/100ml and only 2% of samples exceeding 1000 faecal coliforms/100ml. This is indicative of a much higher influence of cleaner oceanic water in the very outer reaches of the estuary. A very marked seasonality was found at all three sites, with lowest results in the spring and highest results in the winter. Very strong negative correlations between levels of faecal coliforms and salinity were found at all three sites indicating that land runoff is a major influence. This conclusion is reinforced by the strong correlations observed between levels of faecal coliforms and rainfall recorded in the 7 days prior to sampling. An influence of the high/low tidal cycle was found at Taw and Torridge, but not the estuary mouth. At both sites results were higher around low water suggesting up estuary influences are of significance. An influence of the spring/neap tidal cycle was only detected at Torridge, where results were lower on average as tide size decreased towards neap tides. The reasons for this are unclear.

A total of 10 locations have been sampled under the shellfish classification monitoring programme since 2003. All were sampled for mussels, and one was also sampled for Pacific oysters (Zeta Berth). One of these locations was only sampled once (Sole Pit Rocks) so will not be considered further in this assessment. The *E. coli* results at all 9 main mussel RMPs were highly variable, ranging from class A through to class C or prohibited levels. The proportion of samples exceeding 4,600 MPN/100g was greater than 10% at all sites except Neck Gut and Lifeboat Slipway. At Blackstone Rock, Cool Stone and Pulley Ridge, *E. coli* levels exceeded 46,000 MPN/100g on at least one occasion. Comparisons of *E. coli* levels revealed that there were significant differences between sites, with levels of *E. coli* found in mussels generally decreasing slightly towards the estuary mouth.

Across the PowerStation/Coolstone area a decrease in geometric mean result was observed across the three RMPs here from east to west. The geometric mean result at Blackstone Rock, slightly further up estuary and on the opposite bank, was marginally higher than at these three RMPs. The geometric mean result was slightly higher at Spratt Ridge than at Pulley Ridge, the two most heavily sampled RMPs in the outer estuary. The RMP at Neck Gut had a lower geometric mean result than either, but was sampled on much fewer occasions. The geometric mean result from Lifeboat Slip was also lower than that from Spratt Ridge and Pulley Ridge. The geometric mean result for mussels from Zeta Berth was highest of all. When paired (same-day) sample results were compared, strong correlations in levels of *E. coli* were found between all sites tested except Blackstone vs. Neck Gut. The lack of correlation between *E. coli* levels at these two RMPs was probably due largely to the low numbers of paired samples taken in relation to the other site pairings. The significant correlations between the other sites suggest that they are influenced in a similar way by environmental variables.

The geographical analysis of mussel sampling results would suggest the following:

- Zeta Berth requires continued monitoring separate from other areas.
- Blackstone Rock and beds further up the Taw estuary will require monitoring separate from the outer estuary.
- The Power Station/Coolstone area should be monitored separately from other areas but one RMP may suffice here.
- Only one RMP is necessary to cover Spratt Ridge and Pulley Ridge.
- For the PowerStation/Coolstone and Spratt Ridge/Pulley Ridge areas the RMP should be located at the up-estuary end of the beds. This general principle should be applied to any other zones where there is no evidence to suggest otherwise.
- Lifeboat Slipway may merit separate monitoring as it is generally cleaner than Spratt Ridge and Pulley Ridge.

- The same may apply to Neck Gut, although there have perhaps been insufficient samples taken here to draw any firm conclusions.

The single RMP for Pacific oysters at Zeta Berth did not exceed 4,600 MPN/100g despite being sampled on 19 occasions. This suggests that sampling of Pacific oysters here rather than mussels may potentially yield a better classification. However, it was never sampled for both species on the same day so a proper paired comparison of the relative levels to which *E. coli* is accumulated in these two species at Zeta Berth is not possible.

For all sites sampled throughout the period 2003-present, with the exception of Zeta Berth, levels of *E. coli* in mussels have increased gradually and to a statistically significant extent. Results for mussels at Zeta Berth have also increased slightly on average in recent years. The reasons for this are unclear, but it would appear that the whole estuary is affected. There was a general tendency for higher results during the summer and autumn month at most mussel RMPs. Seasonal variation was statistically significant only at Blackstone Rock, Power Station and Spratt Ridge. Pacific oysters at Zeta Berth showed a similar patter to mussels of slightly higher results on average during the summer.

Rainfall has a large effect on *E. coli* levels found in mussel flesh in the Taw and Torridge area, reinforcing the conclusion that land runoff is the primary contaminating influence. At most sites, this effect is strongest between 2 days and 4 days after rainfall. While there was an effect of rainfall at Zeta Berth in mussels, the same effect was not observed in Pacific oysters. This may be due to the relatively low number of samples of Pacific oysters or possibly differing effects of decreased salinity on the feeding physiology of these two species.

APPENDICES

APPENDIX I
HUMAN POPULATION

Figure I.1 shows population densities in census output areas within or partially within the Taw Torridge catchment, derived from data collected at the time of last census (2001). Equivalent data was from the 2011 census was not available at the time of writing.

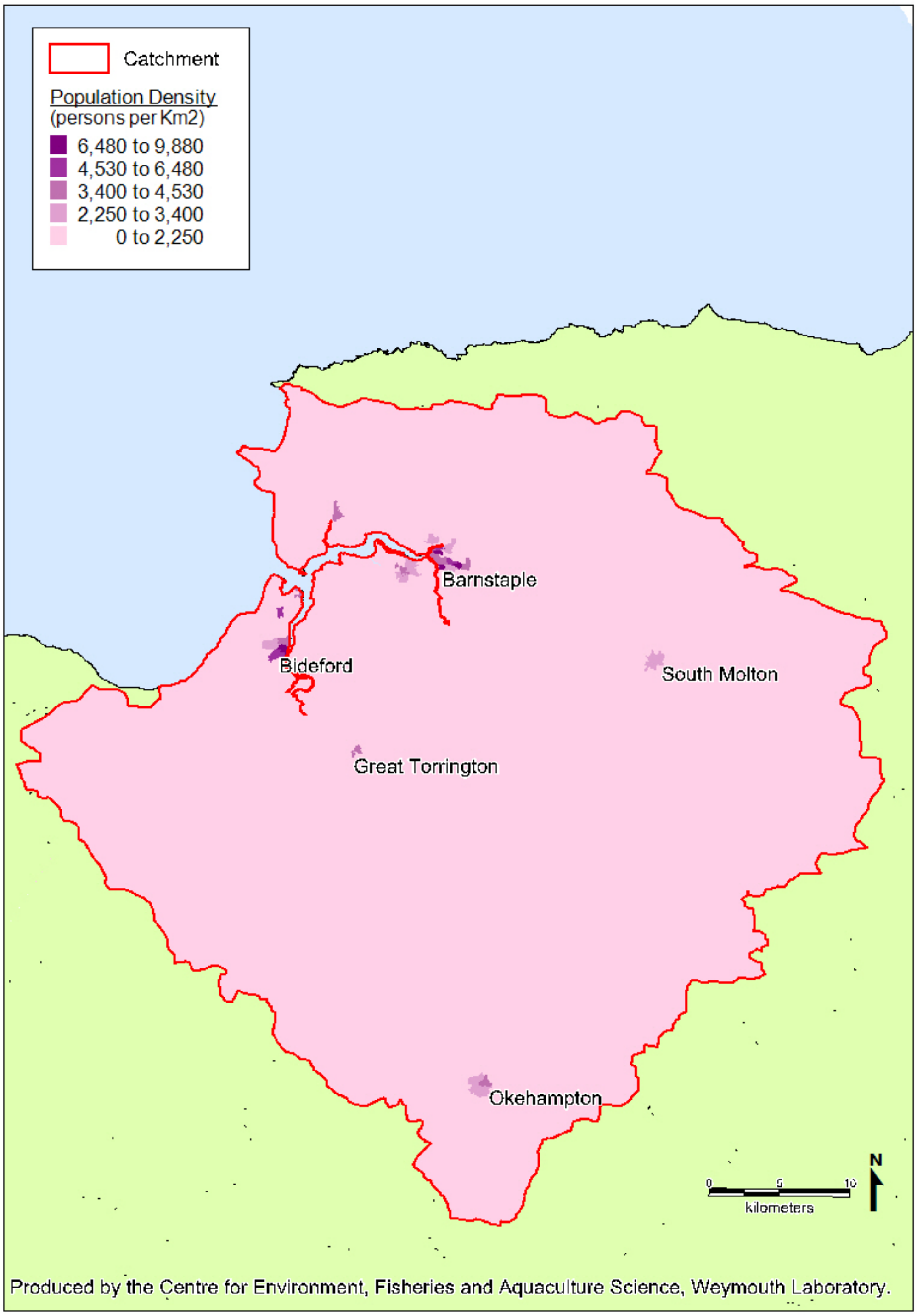


Figure I.1 Human population density in the Taw Torridge Estuary Catchment
Source: ONS, Super Output Area Boundaries (Lower layer). Crown copyright 2004. Crown copyright material is reproduced with the permission of the Controller of HMSO.

Total resident population within the Taw and Torridge estuary catchment was 318,923 at the time of last census. Figure I.1 indicates that the highest density within the Taw Torridge catchment is in the towns of Bideford on the river Torridge and Barnstaple on the river Taw with a range of 6,480 to 9,880 per km^2. There are three other areas that have raised population densities in comparison to the majority of the catchment these signify the smaller towns of Great Torrington, South Moulton and Okehampton. The catchment is predominantly rural and moorland with a few small hamlets and villages scattered throughout, this is reflected in the low population densities of between 0 and 2,250 population density per km^2. Therefore the areas that are most highly urbanised are Barnstaple and Bideford and consequently urban runoff will be most prominent here, potentially increasing microbiological input into the river Taw and Torridge at these proximities. Impacts from sewage will depend on the nature and locations of discharges associated with these settlements, which are discussed in detail in Appendix VII.

The North Devon Coast is a popular tourist destination in the summer months owing to its beautiful sandy beaches, good surfing conditions, seaside resorts and bird watching. Woolacombe a small seaside resort located on the north western edge of the catchment is popular for its award winning sandy beaches, excellent surfing conditions and family ambience. A study in 2007 detailed that Woolacombe had the tourist capacity of 12,030 tourists per night. Croyde is a surfer's beach situated on the western coast below Woolacombe that hosts an annual surfing and music festival which will bring in several thousand tourists to the area. Westward Ho! located on the coast south of Bideford holds a tourist capacity of 2,905 people per night in 2007. Barnstaple and Bideford appear to attract smaller numbers of tourists, with Barnstaple offering a tourist capacity of 770 tourists per night. They form part of the Tarka trail which may attract more day tourists, whom may be passing through and the ferry to Lundy Island a designated marine conservation zone off the coast of North Devon run from Bideford which may attract day or overnight tourists to the area. Exact numbers of tourists to the area are not available but it is likely that there is seasonal variation in visitor numbers. With higher number of tourists in the summer this could increase the amount of sewage discharged and bacterial loadings from sewage treatment works serving the area will fluctuate accordingly.

APPENDIX II
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: SEWAGE DISCHARGES

Details of all Water company owned sewage treatment works within the Taw/Torridge estuary hydrological catchment and nearby coastal waters were provided by South West Water. The locations of the water company owned sewage treatment works are shown in Figure II.1. Further details of these treatment works are presented in Table II.1. The treatment type categories shown in Table II.1 are defined as follows:

- **Primary:** Include works whose treatment methods are restricted to primary treatment (screening, comminution, maceration, grit and detritus removal, pre-aeration and grease removal, storm tanks, plus primary sedimentation, including where assisted by the addition of chemicals e.g. Clariflow).
- **Secondary activated sludge:** As primary, plus works whose treatment methods include activated sludge (including diffused air aeration, coarse bubble aeration, mechanical aeration, oxygen injection, submerged filters) and other equivalent techniques including deep shaft process, extended aeration (single, double and triple ditches) and biological aerated filters as secondary treatment.
- **Secondary biological:** As primary, plus works whose treatment methods include rotating biological contactors and biological filtration (including conventional filtration, high rate filtration, alternating double filtration and double filtration), root zone treatment (where used as a secondary treatment stage).
- **Tertiary A1:** Works with a secondary activated sludge process whose treatment methods also include prolonged settlement in conventional lagoons or raft lagoons, irrigation over grassland, constructed wetlands, root zone treatment (where used as a tertiary stage), drum filters, microstrainers, slow sand filters, tertiary nitrifying filters, wedge wire clarifiers or Clariflow installed in humus tanks, where used as a tertiary treatment stage.
- **Tertiary A2:** Works with a secondary activated sludge process whose treatment methods also include rapid-gravity sand filters, moving bed filters, pressure filters, nutrient control using physico-chemical and biological methods, disinfection, hard COD and colour removal, where used as a tertiary treatment stage.
- **Tertiary B1:** Works with a secondary stage biological process whose treatment methods also include prolonged settlement in conventional lagoons or raft lagoons, irrigation over grassland, constructed wetlands, root zone treatment (where used as a tertiary stage), drum filters, microstrainers, slow sand filters, tertiary nitrifying filters, wedge wire clarifiers or Clariflow installed in humus tanks, where used as a tertiary treatment stage.
- **Tertiary B2:** Works with a secondary biological process whose treatment methods also include rapid gravity sand filters, moving bed filters, pressure filters, nutrient control using physico-chemical and biological methods, disinfection, hard COD and colour removal, where used as a tertiary treatment stage.

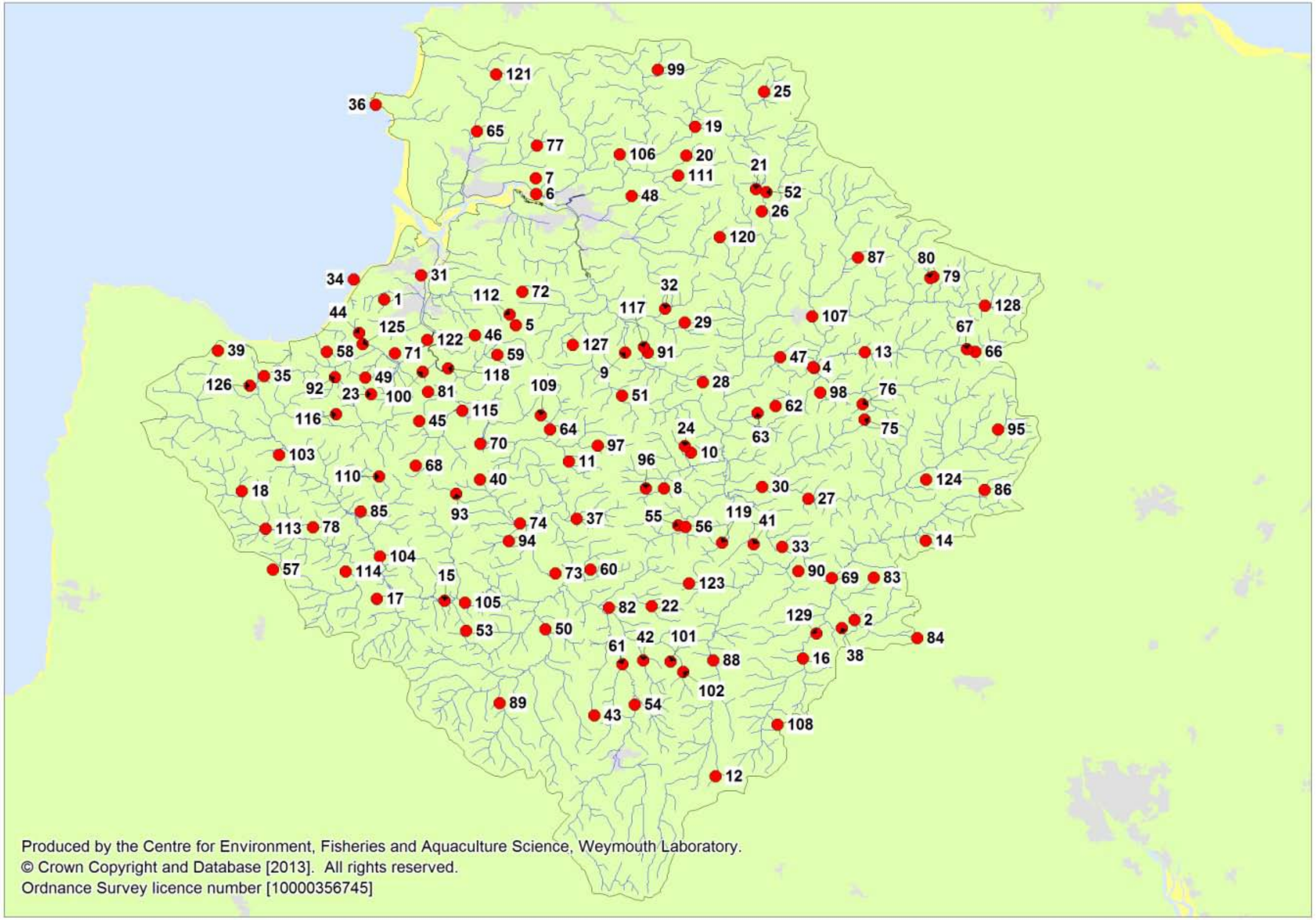


Figure II.1 Water company sewage treatment works discharging within the Taw/Torridge catchment and to nearby coastal waters

Table II.1 Details of the continuous water company sewage discharge to the area

No.	Short name	NGR	Permitted DWF (m^3/day)	Actual DWF (2011)	Population	Treatment Category	Receiving environment
1	Abbotsham STW	SS 4280 2680	55	37.611	234	Tertiary (B1)	Torridge estuary
2	Allington Terrace STW	SS 7517 0473	5		18	Secondary (B)	Knathorne Brook
3	Alswear No1 STW	SS 7240 2210			19	Secondary (B)	Little Silver Stream
4	Alswear No2 STW	SS 7232 2215			4	Primary	River Mole
5	Alverdiscott ST	SS 5185 2504	1.1		14	Primary	River Taw
6	Ashford (Barnstaple) STW	SS 5325 3406	15231	8824.5	47450	Tertiary (A2)	Taw estuary
7	Ashford (Meadowside) STW	SS 5323 3515			77	Secondary (B)	Knowl Water
8	Ashreigney STW	SS 6207 1381			172	Secondary (B)	Mully Brook
9	Atherington STW	SS 5938 2315			162	Secondary (B)	Taw
10	Balls Corner STW	SS 6390 1625			63	Secondary (B)	Mully Brook
11	Beaford STW	SS 5552 1564	81	51.931	334	Secondary (B)	Beaford Brook
12	Belston & South Tawton STW	SX 6562 9399	404	176.923	1300	Secondary (A)	Taw
13	Bishops Nympton STW	SS 7588 2317	162	25.29	361	Secondary (B)	Crooked Oak
14	Black Dog STW	SS 8007 1019	32		93	Secondary (B)	Dalch
15	Black Torrington STW	SS 4697 0607	72	32.755	292	Secondary (B)	Torridge
16	Bow STW	SS 7161 0210	272	140.09	1046	Secondary (B)	Ash Brook
17	Bradford STW	SS 4230 0620	4.3		28	Secondary (B)	Torridge
18	Bradworthy STW	SS 3300 1360	112	77.4	729	Secondary (B)	Waldon
19	Bratton Fleming ST STW	SS 6420 3869			15	Secondary (B)	Rye Stream
20	Bratton Fleming STW	SS 6360 3670	243	73.379	824	Secondary (A)	Chelfham Stream
21	Brayford STW	SS 6840 3440			137	Secondary (B)	Bray
22	Broadwoodkelly STW	SS 6121 0568			66	Tertiary (B1)	Hole Brook
23	Buckland Brewer STW	SS 4190 2030	131	65.96	502	Tertiary (B1)	River Duntz
24	Burrington STW	SS 6350 1670			200	Secondary (A)	Mully Brook
25	Chalcombe ST STW	SS 6894 4111	2.2		15	Primary	Bray
26	Charles ST STW	SS 6878 3286	1.8		3	Primary	Bray
27	Chawleigh STW	SS 7199 1307	103	36.328	389	Secondary (B)	Little Dart River
28	Chittlehampton (Chittlehamholt) STW	SS 6474 2110	39		108	Tertiary (B1)	Taw
29	Chittlehampton (Chittlehampton) STW	SS 6350 2521	110	55.558	444	Tertiary (B1)	Hawkridge Brook
30	Chumleigh STW	SS 6880 1390	341	178.3	1198	Secondary (B)	Little Dart River
31	Clevelands Park STW	SS 4535 2848			25	Secondary (B)	Torridge estuary
32	Cobbaton STW	SS 6214 2616	12		78	Secondary (A)	Hawkridge Brook
33	Coldridge STW	SS 7020 0978			129	Tertiary (B1)	Taw

No.	Short name	NGR	Permitted DWF (m^3/day)	Actual DWF (2011)	Population	Treatment Category	Receiving environment
34	Cornborough STW	SS 4070 2817	10717		66981	Tertiary (B2)	Bideford Bay
35	Cranford ST STW	SS 3453 2152				Primary	Dipple Water
36	Croyde STW	SS 4223 4021	1457		9106	Tertiary (B2)	Croyde Bay
37	Dolton STW	SS 5604 1171	165	98.79	652	Tertiary (B1)	Dolton Stream
38	Down St Mary STW	SS 7429 0418	10.3		29	Secondary (B)	Knathorne Brook
39	Dyke Green STW	SS 3135 2328	3.2		64	Secondary (B)	Dipple Water
40	East Yarde STW	SS 4939 1441	12		44	Secondary (A)	Little Mere River
41	Eggesford Fourways STW	SS 6822 0997			37	Secondary (B)	Taw
42	Exbourne STW	SS 6064 0197	60	30.175	242	Secondary (B)	Hole Brook
43	Folly Gate STW	SX 5725 9818			169	Tertiary (B1)	Okement
44	Ford & Fairy Cross STW	SS 4109 2451	47		174	Tertiary (B1)	Duntz
45	Frithelstockstone STW	SS 4522 1844	11		99	Secondary (B)	Langtree Lake
46	Gammaton ST STW	SS 4905 2434			5	Primary	Huntshaw water
47	George Nympton STW	SS 7006 2284			110	Secondary (B)	Mole
48	Goodleigh STW	SS 5982 3394	61	21.7	234	Tertiary (B1)	Taw Estuary
49	Halsbury ST STW	SS 4150 2143			2	Primary	Duntz
50	Hatherleigh STW	SS 5390 0410	278	226	1486	Tertiary (B1)	Lew
51	High Bickington STW	SS 5916 2017	151	91.41	643	Secondary (B)	Langham Lake
52	High Bray ST STW	SS 6910 3420	7		37	Secondary (B)	Bray
53	Highampton ST STW	SS 4845 0399	15		32	Secondary (A)	Pulworthy Brook
54	Hill Barton STW	SX 6004 9892	2246	1351.3	10068	Secondary (A)	Okement
55	Hollocombe (Barton Close) STW	SS 6304 1126	4		11	Secondary (B)	Hollocombe Water
56	Hollocombe STW	SS 6355 1115			75	Tertiary (B1)	Hollocombe Water
57	Holsworthy Beacon STW	SS 3515 0821			34	Tertiary (B1)	Waldon
58	Horns Cross STW	SS 3885 2320	24.3		110	Tertiary (A1)	Duntz
59	Huntshaw ST STW	SS 5060 2300			11	Primary	Huntshaw water
60	Iddlesleigh STW	SS 5700 0820			61	Tertiary (A1)	Iddlesleigh Stream
61	Jacobstowe STW	SS 5920 0170			75	Secondary (B)	Okement
62	Kings Nympton (North) STW	SS 6973 1946	19		104	Secondary (B)	Mole
63	Kings Nympton (South) STW	SS 6849 1898			148	Secondary (B)	Mole
64	Kingscott STW	SS 5422 1785	29		83	Secondary (B)	Kingscott Stream
65	Knowle STW	SS 4919 3838	53	34.534	253	Tertiary (B2)	Caen
66	Knowstone (East) STW	SS 8350 2320			33	Secondary (B)	Crooked Oak
67	Knowstone (Village) ST STW	SS 8291 2339	5.6		23	Secondary (B)	Crooked Oak

No.	Short name	NGR	Permitted DWF (m^3/day)	Actual DWF (2011)	Population	Treatment Category	Receiving environment
68	Langtree STW	SS 4497 1535			145	Secondary (B)	Langtree Lake
69	Lapford STW	SS 7362 0762	176.2	97.241	933	Secondary (B)	Dalch
70	Little Torrington STW	SS 4943 1687			91	Secondary (B)	Torridge
71	Littleham STW	SS 4353 2310	39.6		267	Tertiary (B1)	Duntz
72	Lovacott STW	SS 5230 2733			71	Secondary (B)	Taw
73	Meeth STW	SS 5458 0795	28		97	Tertiary (B1)	Little Mere River
74	Merton STW	SS 5216 1139			224	Secondary (B)	Little Mere River
75	Meshaw Moor STW	SS 7586 1853	5		5	Secondary (B)	Huntacott Water
76	Meshaw STW	SS 7573 1961			71	Secondary (B)	Little Silver Stream
77	Middle Marwood STW	SS 5332 3739	283	142.96	484	Secondary (B)	Knowl Water
78	Milton Damarel STW	SS 3791 1112	7		20	Secondary (A)	Waldon
79	Molland (East) STW	SS 8060 2838			15	Secondary (B)	Yeo (Molland)
80	Molland (West) STW	SS 8040 2830			28	Secondary (B)	Yeo (Molland)
81	Monkleigh STW	SS 4582 2046	40		165	Secondary (B)	Torridge
82	Monkokehampton STW	SS 5826 0559			65	Secondary (B)	Hole Brook
83	Morchard Bishop STW	SS 7649 0766	144	94.19	697	Tertiary (B2)	Knathorne Brook
84	New Buildings STW	SS 7950 0350			28	Secondary (B)	Knathorne Brook
85	Newton St Petrock ST STW	SS 4118 1222	2.2		10	Primary	Torridge
86	Nomansland STW	SS 8412 1370			108	Secondary (B)	Dalch
87	North Molton STW	SS 7540 2970	132	69.5	782	Tertiary (B1)	Mole
88	North Tawton STW	SS 6546 0196	417	306.19	1769	Secondary (B)	Taw
89	Northlew STW	SX 5075 9901	70	34.28	320	Secondary (B)	Northlew Stream
90	Nymet Rowland STW	SS 7130 0810			28	Secondary (B)	Taw
91	Parkgate ST STW	SS 6094 2315			27	Secondary (B)	Taw
92	Parkham STW	SS 3940 2146	88	56.676	291	Tertiary (B1)	Duntz
93	Peters Marland STW	SS 4775 1342			5	Primary	Little Mere River
94	Petrockstowe STW	SS 5139 1016	70	27.824	265	Secondary (B)	Little Mere River
95	Rackenford STW	SS 8504 1786			179	Secondary (B)	Little Dart River
96	Riddlecombe ST STW	SS 6082 1379	9		35	Tertiary (B1)	Mully Brook
97	Roborouch STW	SS 5751 1675	28		125	Secondary (B)	Beaford Brook
98	Romansleigh STW	SS 7280 2040	6.1		26	Secondary (B)	Little Silver Stream
99	Ruxfield ST STW	SS 6164 4263	2.2		14	Primary	Yeo (Barnstaple)
100	Saltrens STW	SS 4546 2182			65	Secondary (B)	Torridge
101	Sampford Chapple STW	SS 6250 0189			28	Secondary (B)	Hole Brook

No.	Short name	NGR	Permitted DWF (m^3/day)	Actual DWF (2011)	Population	Treatment Category	Receiving environment
102	Sampford Courtenhay STW	SS 6337 0115	95	14.921	222	Tertiary (B1)	Hole Brook
103	Sessacott ST STW	SS 3558 1610				Primary	Torridge
104	Shebbear STW	SS 4250 0910	106.8	93.174	403	Secondary (B)	Torridge
105	Sheepwash STW	SS 4835 0594			247	Secondary (B)	Torridge
106	Shirwell STW	SS 5900 3680	6.4		31	Secondary (B)	Yeo (Barnstaple)
107	South Moulton STW	SS 7225 2563	1300	1016.3	5211	Tertiary (B2)	Mole
108	Spreyton STW	SX 6987 9753	34		173	Secondary (B)	Ash Brook
109	St Giles in the Wood STW	SS 5359 1882	49.3		188	Tertiary (B1)	Kingscott Stream
110	Stebb Cross STW	SS 4246 1462			238	Secondary (B)	Combe Lake
111	Stoke Rivers STW	SS 6303 3533			89	Secondary (B)	Chelfham Stream
112	Stoney Cross STW	SS 5143 2577			62	Secondary (B)	Taw
113	Sutcombe Mill STW	SS 3464 1103			207	Secondary (B)	Waldon
114	Thornbury STW	SS 4015 0808			12	Secondary (B)	Cookbury Stream
115	Torrington STW	SS 4819 1916	1885	854	6333	Tertiary (A1)	Torridge
116	Twitchen Hill ST STW	SS 3950 1890				Primary	Duntz
117	Umberleigh ST STW	SS 6069 2352	2.7		15	Primary	Taw
118	Weare Giffard STW	SS 4720 2206			239	Secondary (A)	Torridge
119	Wembworthy New STW	SS 6605 1006	45		138	Secondary (A)	Taw
120	West Buckland STW	SS 6590 3110	40		251	Tertiary (B1)	Bray
121	Westdown STW	SS 5050 4230	88	30.17	314	Tertiary (B1)	Caen
122	Whitehall Landcross STW	SS 4576 2402	7		11	Secondary (A)	Yeo (Bideford)
123	Winkleigh STW	SS 6378 0726	247	173.24	1184	Tertiary (A1)	Bullow Brook
124	Witheridge STW	SS 8010 1440	245	202.9	1200	Secondary (A)	Little Dart River
125	Woodtown STW	SS 4131 2372			66	Secondary (B)	Duntz
126	Woolsery STW	SS 3355 2087	250	95.22	709	Tertiary (B1)	Dipple Water
127	Yarnscombe STW	SS 5578 2367	34		155	Secondary (B)	Langham Lake
128	Yeo Mill ST STW	SS 8416 2639	16		49	Secondary (B)	Yeo (Molland)
129	Zeal Monachorum STW	SS 7256 0380	63	33.784	351	Secondary (B)	Ash Brook

Data from South West Water

Due to its rural nature, the Taw Torridge catchment is served by a large number of generally small sewage works, most of which discharge to watercourses draining to the estuary via the rivers Taw and Torridge. Watercourses draining the Taw catchment receive treated effluent from a population of just over 23,000 and watercourses draining the Torridge catchment receive effluent from a population of almost 27,000. Most of these works provide secondary treatment, although some of the very small ones only provide primary treatment (septic tank), some of the larger ones provide tertiary treatment such as additional nutrient removal steps. On the basis of their geographical distribution, their impacts will be greatest towards the heads of the estuary, although some watercourses draining to the lower estuary such as the Caen do receive potentially significant sewage inputs. Table II.2 summarises the typical levels of faecal indicator bacteria found in sewage effluents of various types. It is likely that there is significant bacterial die-off during transit through the watercourses to the estuary, particularly for the more distant sewage works.

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

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

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

The two largest sewage works in the area are Cornborough STW and Ashford (Barnstaple) STW, which discharge direct to coastal waters and both have UV disinfection. The populations they serve are 66,981 and 47,450 respectively. The former discharges to Bideford Bay over 5km from the estuary mouth, so will have no impact on shellfish hygiene within the estuary. The latter discharges to the upper reaches of the Taw estuary. Based on the geometric mean concentration of faecal coliforms and the permitted dry weather flow, the estimated bacterial loading generated by this works is only 3.24×10^{10} faecal coliforms/day. Croyde STW, which serves a population of 9,106 also receives UV disinfection. It discharges to Croyde Bay about 6km from the estuary mouth so should have no impacts on any shellfisheries within the estuary. Final effluent bacteriological testing results were available for these three sewage works. These are presented in Figure II.2 and Table II.3.

Table II.3. Summary statistics for final effluent testing data (faecal coliform cfu/100ml) January 2003 to March 2011.

Site name	No.	Geomean	Minimum	Maximum
Barnstaple (Ashford) STW	172	213	0	170,000
Cornborough STW	172	378	6	240,000
Croyde STW	158	19	0	26,000

Data from the Environment Agency

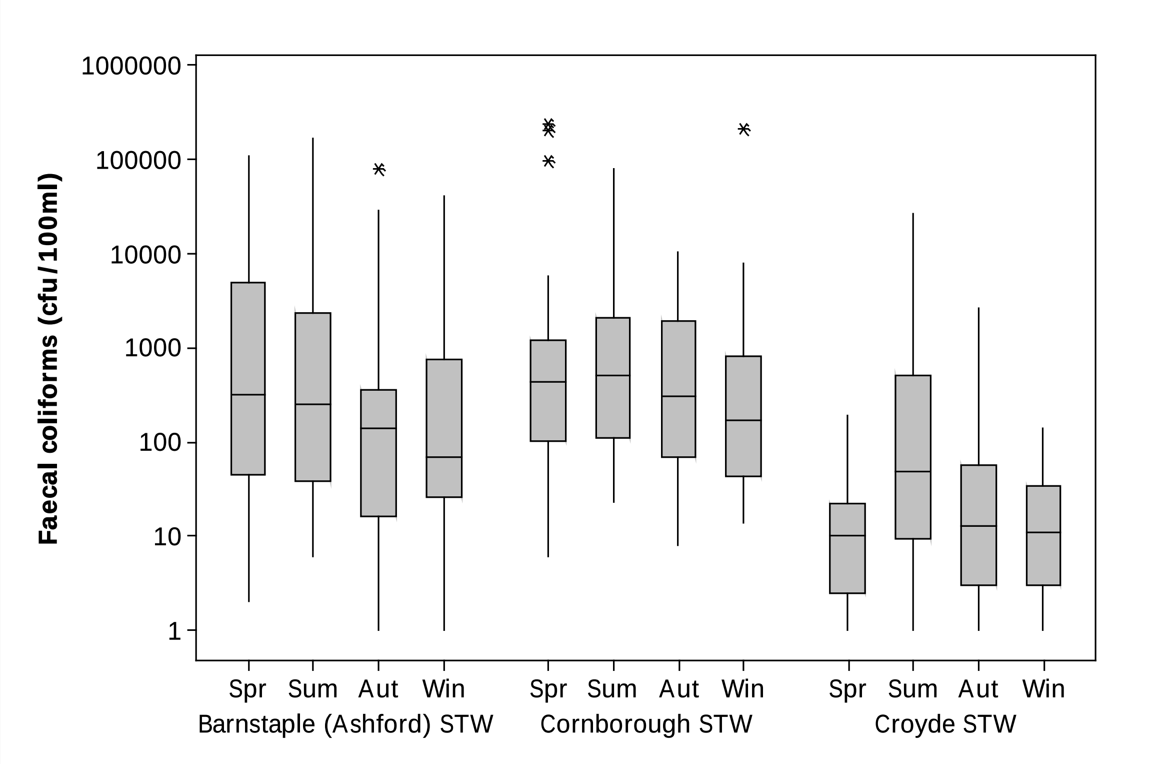


Figure II.2. Boxplots of final effluent bacteriological testing results be sewage works and season. *Data from the Environment Agency.*

The geometric mean levels of faecal coliforms in these effluents suggest that all three of these works, particularly Croyde STW, are performing effectively, although faecal coliform levels are slightly higher during the summer months. Levels of faecal coliforms in the effluent from Barnstaple (Ashford) STW were lower on average during the autumn and winter, although higher concentrations (>10,000 cfu/100ml) were occasionally found throughout the year.

In addition to the continuous sewage discharges, there are a large number of intermittent water company discharges associated with the sewerage networks. Figure II.3 shows the locations of these as well as private discharges directly to or within close proximity of the estuary. Table II.4 presents details of the intermittent discharges, although it is not possible to tell from the permitting database from which this information was extracted whether they are permitted to discharge under storm or emergency conditions. Details of the larger private discharges (>5m^3/day maximum permitted flow) are presented in Table II.6. In addition there are many other intermittent outfalls and private discharges distributed around the more inland areas of the catchment which are not shown in Figure II.3.

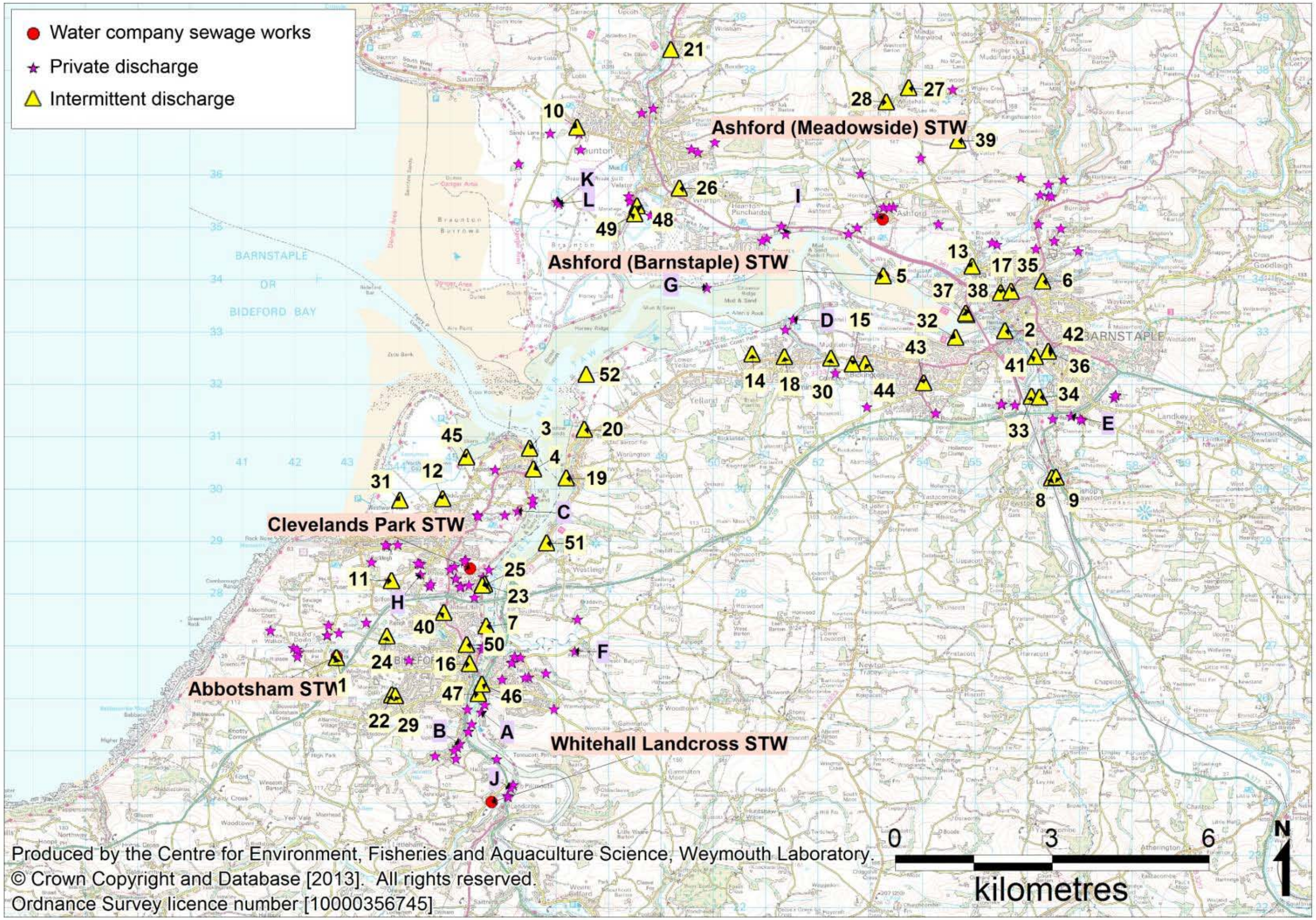


Figure II.3 Intermittent and private discharges in close proximity to the Taw Torridge estuary

Table II.4. Details of nearby intermittent discharges

No.	Name	NGR
1	Abbotsham STW	SS4280026770
2	Anchorwood PS	SS5557033010
3	Appledore PS	SS4649030770
4	Appledore CSO	SS4656030370
5	Barnstaple (Ashford) STW	SS5325034060
6	Barnstaple St Georges Road PS	SS5629033960
7	Bideford Fine Screening	SS4566027370
8	Bishops Tawton PS (1)	SS5647030200
9	Bishops Tawton PS (2)	SS5655030220
10	Braunton - Saunton Rd PS	SS4739036900
11	Buckleigh PS	SS4385028240
12	Causeway Close CSO	SS4482629807
13	Chaddiford Lane PS	SS5495034250
14	Childpark PS	SS5074032570
15	Combrew Lane CSO	SS5266032380
16	Ethelwynne Brown Close PS	SS4534026650
17	Fairview Car Park CSO	SS5549033740
18	Fremington Pill PS	SS5136032520
19	Instow A PS	SS4719030200
20	Instow B PS	SS4753031130
21	Knowle STW	SS4919038390
22	Laurel Avenue CSO	SS4385626056
23	Limers Lane PS	SS4563028170
24	Londonderry Farm PS	SS4376027180
25	Lower Cleave PS	SS4558228150
26	Lower Park Road PS	SS4935035740
27	Middle Marchwood STW (3)	SS5373037660
28	Middle Marchwood STW (1&2)	SS5331037390
29	Moreton Park Road CSO	SS4392026040
30	Muddlebridge CSO	SS5225032490
31	Northam Waste Water PS	SS4400829773
32	Oakland Park CSO	SS5463032890
33	Pill PS (1)	SS5608031760
34	Pill PS (2)	SS5623031750
35	Pilton Quay CSO	SS5569033770
36	Portmarsh CSO	SS5640032620
37	Pottington PS (1)	SS5484033320
38	Pottington PS (2)	SS5482033350
39	Prixford PS	SS5467336652
40	Raleigh Hill CSO	SS4485027630
41	Rock Park CSO (1)	SS5615032520
42	Rock Park CSO (2)	SS5640032620
43	Roundswell PS	SS5402032020
44	Shieling Road CSO	SS5290032390
45	Skern CSO	SS4528030600
46	Torridge Mount CSO	SS4558026260
47	Torrington Street PS	SS4551026080
48	Velator PS	SS4854035400
49	Velator Bridge PS	SS4850035250
50	Westcombe Lane CSO	SS4528027020
51	Westleigh PS	SS4681028960
52	Yelland PS	SS4757032180

Discharges highlighted in yellow have spill recording. Data from the Environment Agency.

The main clusters of intermittent discharges at Barnstaple, on the upper Taw estuary, and at Bideford, on the west shore of the Torridge estuary. A large number of the intermittent discharges have spill event recording. Figure II.4 presents a boxplot of spill records, and summary data is presented in Table II.5.

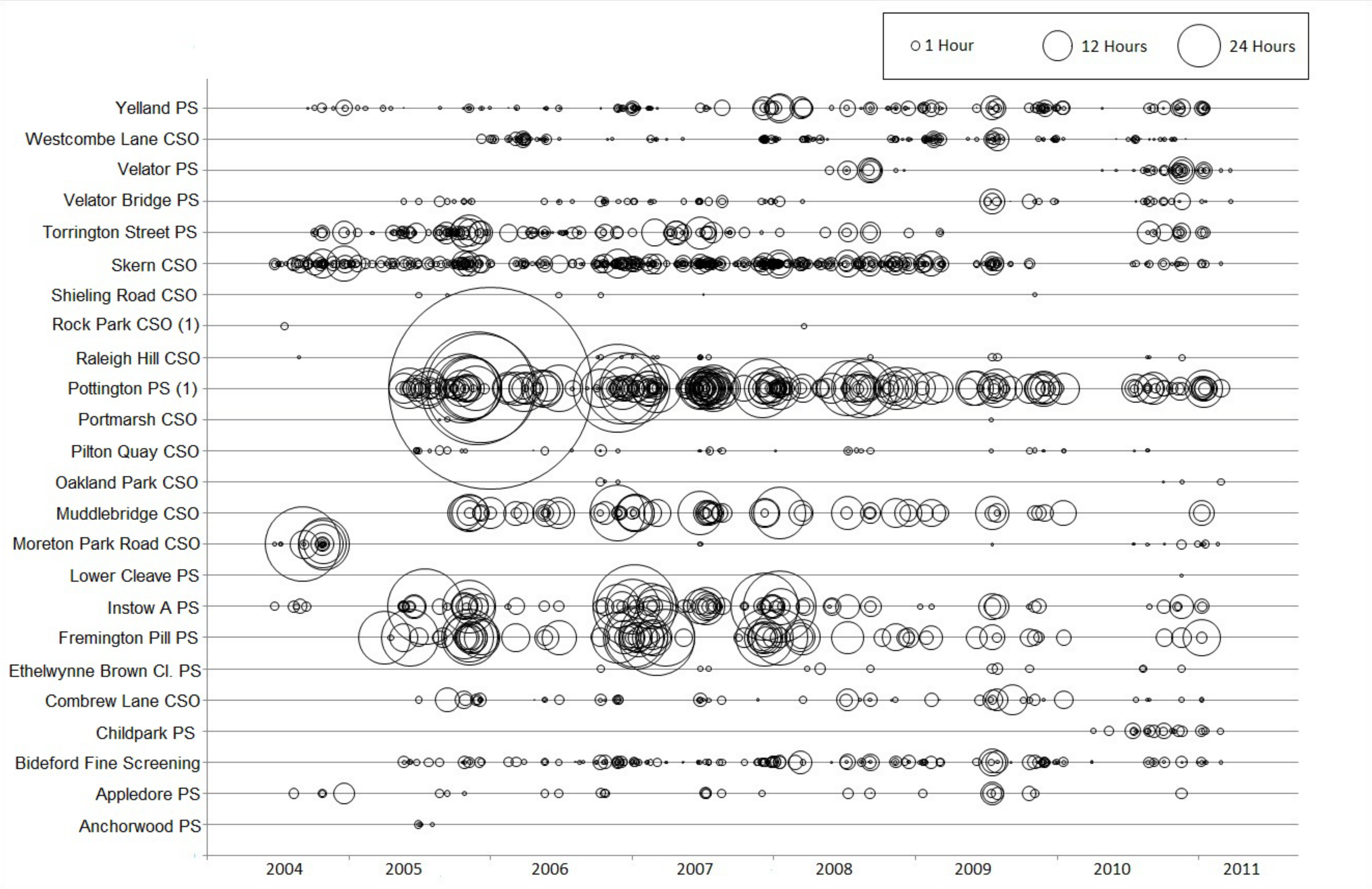


Figure II.4 Bubble plot of spill records from all monitored outfalls, June 2004 to March 2011
Data from the Environment Agency

Table II.5. Summary of spill data from monitored outfalls indicating number of individual events (n), total events duration (hrs) and overall percentage of the time the outfall was active. Period covered is June 2004 to March 2011.

	2004		2005		2006		2007		2008		2009		2010		2011		All years		
	n	hrs	n	hrs	n	hrs	n	hrs	n	hrs	n	hrs	n	hrs	n	hrs	n	hrs	% time
Anchorwood PS	0		4	1.5	0		0	0.0	0		0		0		0		4	2	<0.05%
Appledore PS	5	9.6	3	1.7	5	4.7	5	5.6	3	2.9	7	19.6	1	1.7	0		29	46	0.1%
Bideford Fine Screening	0		16	11.8	30	19.8	36	21.8	25	37.9	32	43.4	14	8.1	5	2.0	158	145	0.2%
Childpark PS	0		0		0		0	0.0	0		0		16	19.3	4	3.5	20	23	<0.05%
Combrew Lane CSO	0		10	20.4	12	7.1	8	4.8	8	12.9	12	32.4	5	5.7	2	0.4	57	84	0.1%
Ethelwynne Brown Close PS	0		0		1	0.7	2	0.7	3	2.7	3	3.8	3	1.9	0		12	10	<0.05%
Fremington Pill PS	0		19	317.5	9	105.1	25	475.8	11	122.7	8	35.5	3	12.1	2	20.2	77	1089	1.8%
Instow A PS	5	7.2	20	206.4	11	97.1	34	362.4	13	126.0	8	27.2	5	12.3	2	4.1	98	843	1.4%
Lower Cleave PS	0		0		0		0	0.0	0		0		1	0.2	0		1	0	<0.05%
Moreton Park Road CSO	22	195.4	0		0		2	0.6	0		1	0.1	7	2.1	5	1.4	37	200	0.3%
Muddlebridge CSO	0		9	84.1	19	115.7	25	180.8	11	100.2	10	50.5	1	8.9	2	12.9	77	553	0.9%
Oakland Park CSO	0		0		3	1.3	0	0.0	0		0		2	0.3	1	0.6	6	2	<0.05%
Pilton Quay CSO	0		10	4.4	7	3.2	6	2.0	6	2.4	5	1.4	5	0.8	0		39	14	<0.05%
Portmarsh CSO	0		2	0.5	0		0	0.0	0		1	0.2	0		0		3	1	<0.05%
Pottington PS (1)	0		43	1397.5	37	491.0	75	776.3	46	425.0	28	229.0	19	89.7	9	65.0	257	3473	5.8%
Raleigh Hill CSO	1	0.1	0		3	0.6	8	1.6	1	0.4	3	2.5	3	0.8	0		19	6	<0.05%
Rock Park CSO (1)	1	0.7	0		0		0	0.0	1	0.4	0		0		0		2	1	<0.05%
Shieling Road CSO	0		2	0.5	2	0.8	1	0.1	0		1	0.3	0		0		6	2	<0.05%
Skern CSO	44	78.4	65	88.1	57	70.4	149	129.1	94	133.2	38	54.9	14	7.8	4	2.5	465	564	0.9%
Torrington Street PS	9	15.8	57	112.4	36	30.2	23	67.5	7	18.0	2	1.1	10	21.6	3	4.4	147	271	0.5%
Velator Bridge PS	0		9	4.6	11	5.0	18	9.9	3	2.2	11	18.7	11	9.3	3	0.7	66	50	0.1%
Velator PS	0		0		0		0	0.0	12	29.3	0		27	34.0	7	7.1	46	71	0.1%
Westcombe Lane CSO	0		2	1.9	36	21.9	29	8.9	34	9.9	53	37.4	21	4.1	0		175	84	0.1%
Yelland PS	8	5.8	16	3.6	18	7.3	26	30.5	25	52.0	36	44.5	16	19.5	7	8.8	152	172	0.3%

Data from the Environment Agency

Of the monitored outfalls, the Pottington PS at Barnstaple spilled the most overall, although has not spilled so much in more recent years. Fremington Pill PS and Instow A PS were the next most regular spillers, although they were only active for 1.8% and 1.4% of the period respectively. All of the other monitored outfalls were active for less than 1% of the time, and some hardly spilled at all. The Yelland PS which discharges in close proximity to the Yelland and Coolstone mussel beds only discharged for 0.3% of the time. The Appledore and Yelland PS outfalls are within 1km of the Lifeboat Slip mussel beds but these only spilled for 0.1% and 0.9% of the time respectively. It is therefore concluded that all intermittent discharges, excepting the Pottington PS and possibly the Fremington Pill PS and Instow PS are of little influence, but neither of these are particularly close to any of the mussel beds. There is an unmonitored outfall at Westleigh, about 400m up-estuary from the oyster site at Zeta Berth which may be of influence here on occasion.

In addition to the water company owned discharges, there are a number of private discharges in the vicinity of the estuary. 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. About half of those shown on Figure II.3 discharge to soakaway, and half discharge to watercourses or the estuary. The details of those with maximum consented flows of over $5m^3$/day are presented in Table VII.6.

Table VII.6 Details of nearby private sewage discharges with consented flow of over $5m^3$/day.

Ref	Name	NGR	Max Flow	Treatment type	Discharges to
A	1-5 Nuttaberry Rise	SS4556025740	7	Package Plant	Torridge estuary
B	2-11 Forest Hill	SS4515225138	8.5	Septic Tank	Soakaway
C	Appledore Shipyard	SS4626029580	70	Biological Filtration	Unnamed watercourse
D	Fremington Quay	SS5153033250	6	Package Plant	Soakaway
E	North Devon Hospice	SS5684031390	9.01	Package Plant	Unnamed watercourse
F	Pillhead Farm	SS4735026900	5	Package Plant	Lake
G	RMB Chivenor	SS4987033850	370*	UV disinfection	Taw estuary
H	Stables & Coach House	SS4440028370	5	Unspecified	Unnamed watercourse
I	Tarka Inn	SS5138034880	21.4	Package Plant	Taw estuary
J	The Former Landcross Methodist	SS4612024290	5	Biological Filtration	River Yeo
K	Willowfield Lake	SS4700335490	15.5	Package Plant	St Arthurs Pill
L	Willowfield Lake Holiday Cottages	SS4705035450	15	Unspecified	Soakaway

**Flow rate for RMB Chivenor is permitted dry weather flow rather than maximum permitted flow.*
Data from the Environment Agency.

The largest of these is the RMB Chivenor discharge, with a dry weather flow of $370m^3$/day. It receives UV treatment so should not generate a large bacterial loading, but discharges in very close proximity to a mussel bed. None of the other discharges listed in Table VII.6 are in close proximity to any of the shellfish beds, although effluent from the Appledore Shipyard discharge will be carried directly towards the Lifeboat slipway bed on an ebbing tide.

APPENDIX III
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: AGRICULTURE

The majority of land within the Taw/Torridge catchment is used for agriculture. Most are pastures, although there are many smaller pockets where crops are cultivated (Figure 1.2). Table VIII.1 and Figure VIII.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 good indication of the numbers of livestock within the catchment.

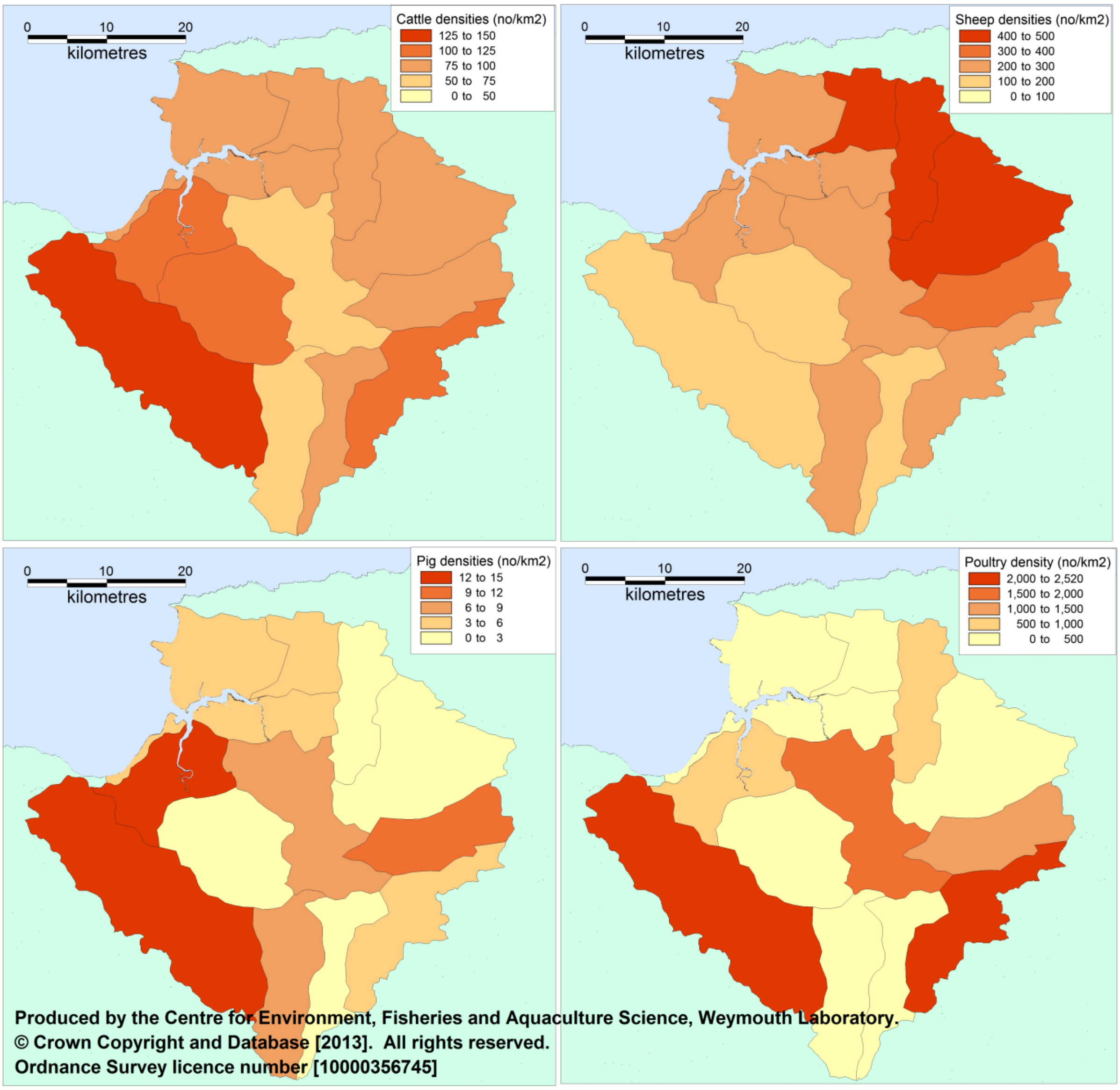


Figure VIII.1. Livestock densities within the Taw/Torridge catchment.

Table VIII.1 Summary statistics from 2010 livestock census for Taw Torridge catchment

	Numbers				Density (animals/km^2)			
Catchment name	Cattle	Sheep	Pigs	Poultry	Cattle	Sheep	Pigs	Poultry
Barnstaple Yeo	7,724	34,845	238	13,232	97	439	3	167
Bray	8,499	44,868	**	86,404	77	405	0	780
Little Dart	11,381	38,435	1,193	159,243	90	303	9	1,255
Mole	18,904	117,122	377	118,692	78	481	2	488
Okement	10,072	30,047	1,163	14,702	69	206	8	101
Taw (Middle)	15,318	54,219	1,624	345,061	74	260	8	1,656
Taw (Upper)	8,994	19,025	188	19,819	91	191	2	199
Taw Estuary	22,517	66,829	777	13,257	92	273	3	54
Torridge (Middle)	21,281	35,246	188	37,363	116	192	1	203
Torridge (Tidal)	15,427	25,565	1,818	69,386	121	200	14	543
Torridge (Upper)	48,742	57,896	5,031	940,690	130	155	13	2,513
Yeo and Dalch	16,821	39,021	500	324,324	118	273	4	2,271
TOTAL	205,680	563,118	13,097	2,142,173	99	270	6	1,026

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

The concentration of faecal coliforms excreted in the faeces of animal and human and corresponding loads per day are summarised in Table VIII.1.

Table VIII.1 Levels of faecal coliforms and corresponding loads excreted in the faeces of warm-blooded animals.

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

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

There are large numbers of grazing animals within the catchment with over 200,000 cattle and over 500,000 sheep. Significant 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. Large numbers of poultry and relatively small numbers of pigs are also raised within the catchment. 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'). Given the ubiquity of pastures throughout the catchment most, if not all watercourse 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.

On the south shore of the Taw estuary there is an area of saltmarsh of about 0.6km^2 by Bickington which is used for grazing sheep on a year round basis. Contamination from these may be carried into the estuary via tidal inundation as well as runoff. The latter is a particularly direct and predictable mechanism which may result in large amounts of faecal matter being washed into the southern half of the estuary during spring tides. An Environment Agency study conducted in the Ribble estuary found a significant increase in levels of faecal coliforms within saltmarsh creeks in grazed areas as the tide started to ebb following tidal inundation (Dunhill, 2003) so this is a recognised phenomenon.

During the shorelines survey, sheep were observed on the Northam Burrows where they had access to the shoreline. Significant concentrations of livestock were also recorded on pastures around the Caen estuary (where they are reported to escape onto shoreline from time to time), and on the south bank of the Taw between Fremington and Yelland. Watercourse draining these areas will be subject to some contamination of livestock origin.

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. Highest sheep counts on the grazing marshes on the south shore of the estuary are reported to occur from April to October. 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 AND MICROBIOLOGICAL POLLUTION: BOATS

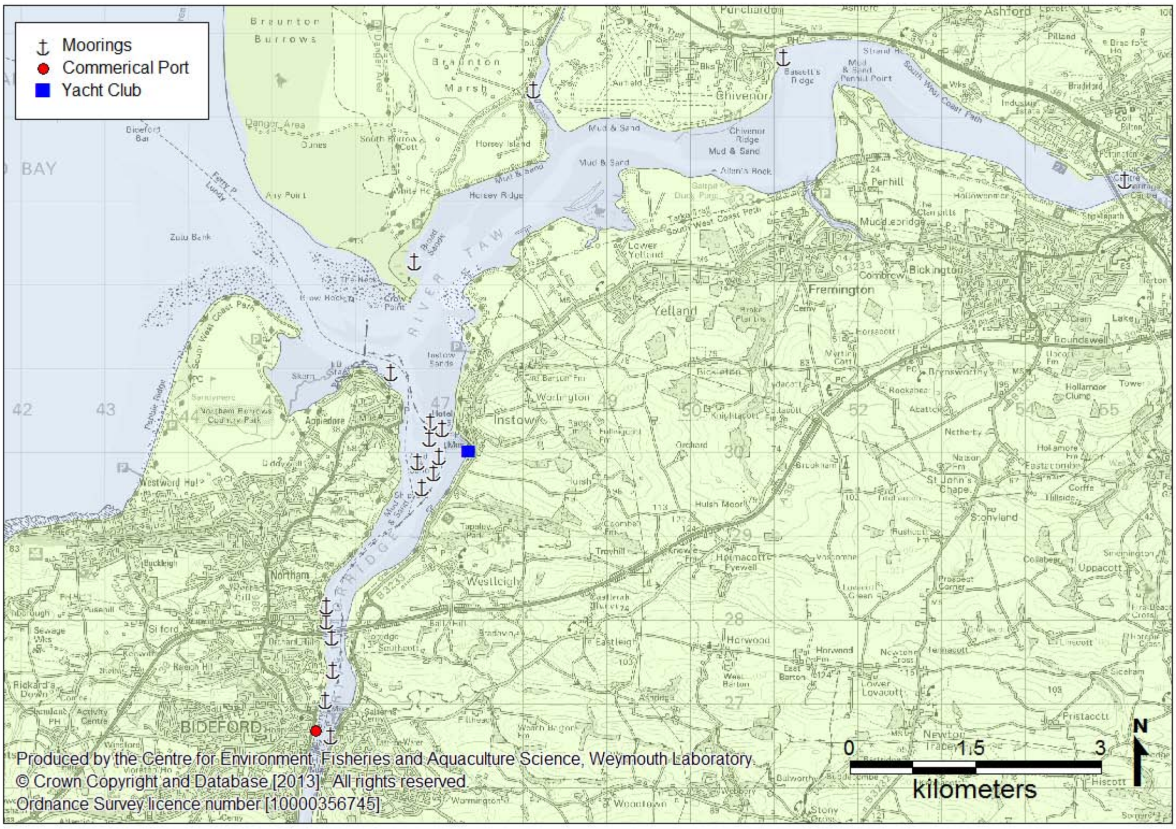


Figure IX.1 Locations of moorings, marinas and commercial ports in the Taw Torridge Estuary.

Boating activities in the Taw Torridge Estuary are represented in Figure IX.1 derived from the shoreline survey, satellite images and various internet sources. The discharge of sewage from boats is potentially a significant source of bacterial contamination of shellfisheries within the Taw Torridge estuary. The majority of boating activity takes place on the River Torridge and at the mouth of the estuary. A number of small fishing boats, small cabin cruisers and yachts operate from here as well as the Lundy Island Ferry and large commercial ships. Military exercises involving amphibious craft were also seen during the shoreline survey in the outer Taw estuary, and the Zeta Berth where the oyster trestles are located is in military use.

Recreational boating within the estuary includes the following: yachting, motor boats, sailing dinghies, kayaking and kite surfing. Devon Yacht Club situated on the River Torridge close to the convergence of the River Taw and Torridge offers dinghy sailing and a variety of RYA motor and sailing courses and hosts racing for a small fleet of cruising yachts.

Most moorings within the Taw Torridge are situated on the edge of the deep water channels in the Torridge estuary the majority dry out at low tide. Moorings are mainly occupied by locals although there are a few dry moorings on the River Taw that are available for visitors, a small number available at the yacht club and a few short term alongside berths in Barnstaple.

During the shoreline survey, about 10 houseboats were observed on the north bank of the Taw just to the east of RMB Chivenor, and about 20 were observed in the upper reaches of the Caen estuary. Some appeared to be in occupation at the time.

Fishing activity with the Taw Torridge takes place on both a recreational and commercial scale. Salmon, sea trout, bass and other sea fish are caught commercially within the Taw Torridge, eight boats operate out of the historic fishing village of Appledore, situated where the two rivers meet (Northern Devon Fisheries Local Action group, 2011). The seasonal pattern of fishing activity is uncertain, but is likely to be on a more year round basis although poor weather is more likely to curtail activity during the autumn and winter months.

Bideford Quay, the only commercial port within the estuary, is located in the town of Bideford on the River Torridge, dry moorings are available for large commercial ships and can hold boats up to 90m in length. These ships carry ball clay from Bideford to Finland, Spain, France and Holland (Ports and Harbours of the UK, 2012). A passenger ferry to Lundy Island also runs from Bideford quay once a day and two to three times a week in the peak summer months carrying up to 267 people (Direct Links, 2012).

Merchant shipping vessels are not permitted to make overboard discharges within three nautical miles of land so vessels associated with the commercial port should produce little or no impact. Any impacts from military craft are uncertain. Private vessels such as yachts, pleasure craft and fishing vessels are not covered by the specific sewage disposal regulations for commercial shipping, and so those with onboard toilets are likely to make overboard discharges. This may occur whilst boats are on passage, but it is quite likely that boats in overnight occupation on the anchorages will make a discharge at some point during their stay. Houseboats in occupation are also likely to make regular overboard discharges. Dinghies and smaller motor boats are not large enough to contain onboard toilet facilities and are unlikely to make any discharges overboard.

The areas that are at highest risk from microbiological pollution are the main navigation routes in the deeper waters of the River Torridge which see the largest through fare of commercial and pleasure boats, it is quite likely that some overboard discharges are made by boats on this passage. The boats most likely to make overboard discharges are yachts and houseboats in overnight occupation at the moorings. The numbers of overnight yacht stays here are low, and limited to the summer months, so anticipated impacts are relatively minor, seasonal, and localised. The houseboats by the Caen estuary and east of RMB Chivenor are likely to make regular contributions. 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 Taw Torridge Estuary contains a diversity of habitats including sand dunes, saltmarsh, grazing marsh, mudflats and sand spits. The Taw Torridge estuary and its surrounding areas have been designated as conservation areas protecting its wildlife and habitats. The estuary falls within North Devon's UNESCO Biosphere Reserve and has been designated as an SSSI for the important overwintering and migratory bird populations. Three areas around the estuary have also been designated as SSSI's; Braunton Burrows, Northam Burrows and Fremington Quay Cliffs for their, dune sequences, unique geological features, coastal habitats, rare and or vulnerable species. Braunton Burrows has also been designated as a SAC for its complete sand dune sequence.

The Taw Torridge Estuary supports a significant population of overwintering waterbirds (waders and wildfowl). The most recent count coordinated by the British Trust for Ornithology recorded a peak winter count of 13,856 waterbirds (Holt *et al*, 2011) Species sighted in the estuary include the bar-tailed godwit, cormorant, oystercatcher, curlew, golden plover, dunlin, common sandpiper knot, redshank, lapwing, shelduck, teal, and wigeon. Some species, such as Oystercatchers feed on intertidal invertebrates so will forage (and defecate) directly on the shellfish beds across a wide area. They may tend to aggregate in certain areas holding the highest densities of their preferred size and species of prey, but this will probably vary from year to year. Studies in the UK have found significant concentrations of microbiological contaminants (thermophilic campylobacters, salmonellae, faecal coliforms and faecal streptococci) from intertidal sediment samples supporting large communities of birds (Obiri-Danso and Jones, 2000). Contamination via direct deposition may be quite patchy, with some shellfish containing quite high levels of *E. coli* with others a short distance away unaffected. 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 albeit diffuse influence during the winter months.

Other overwintering waterbirds such as grazing ducks, plovers and lapwings will mainly frequent the saltmarsh, 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.

The majority of waterbirds migrate elsewhere to breed, but other species such as gulls and terns are present during the summer months. At high water most of the Taw and Torridge Estuary is covered by water consequently there are very few undisturbed places such as islands for gulls and terns to breed and nest. This is evident in the relatively small numbers of seabirds breeding within the estuary. A small number of Herring gulls have been recorded (10 pairs) outside the main estuarine area in the vicinity of Rock Nose, located south west of Westward Ho! (Mitchell *et al*, 2004). Therefore during the summer months there are likely to be considerably lower impacts hygiene status of the fisheries from birds.

The closest colony of seals to the Taw Torridge Estuary is located at Lundy Island, about 20km to the west. Lundy Island has been distinguished as a haul out site by around 60 grey seals and in the summer months this number doubles (www.lundy.org.uk). They are likely to forage widely so seals will enter the Taw Torridge Estuary from time to time but only in small numbers and their presence will be unpredictable both spatially and temporally. Due to their low numbers and high mobility the presence of seals will not influence the sampling plan.

Otters are present within the Taw Torridge Estuary, an internationally important population (Environment Agency, 2010). The Fifth Otter Survey undertaken by the Environment Agency confirms that otters are present upstream in both the rivers Taw and Torridge near Barnstaple and Bideford. Exact numbers are not known but otters have reached their carrying capacity in the Taw and Torridge. Otters generally tend to favour the more secluded areas with access to watercourses. However, given their likely wide distribution and small numbers otters have no material bearing on the sampling plan.

No other wildlife species which have a potentially significant influence on levels of contamination within shellfish within the survey area have been identified. Dog walking takes place along beaches and coastal paths that run adjacent to the shoreline of the estuary such as the Tarka trail which follows the river Taw from Bideford across to the river Torridge to Barnstable this could represent a potential source of diffuse contamination to the near shore zone.

APPENDIX VI
METEOROLOGICAL DATA: RAINFALL

The Chivenor weather station which is located close to the Taw and Torridge estuaries received approximately 667 mm of rain per year on average between 2003 and 2012. Figure II.1 presents a boxplot of daily rainfall records by month at Chivenor.

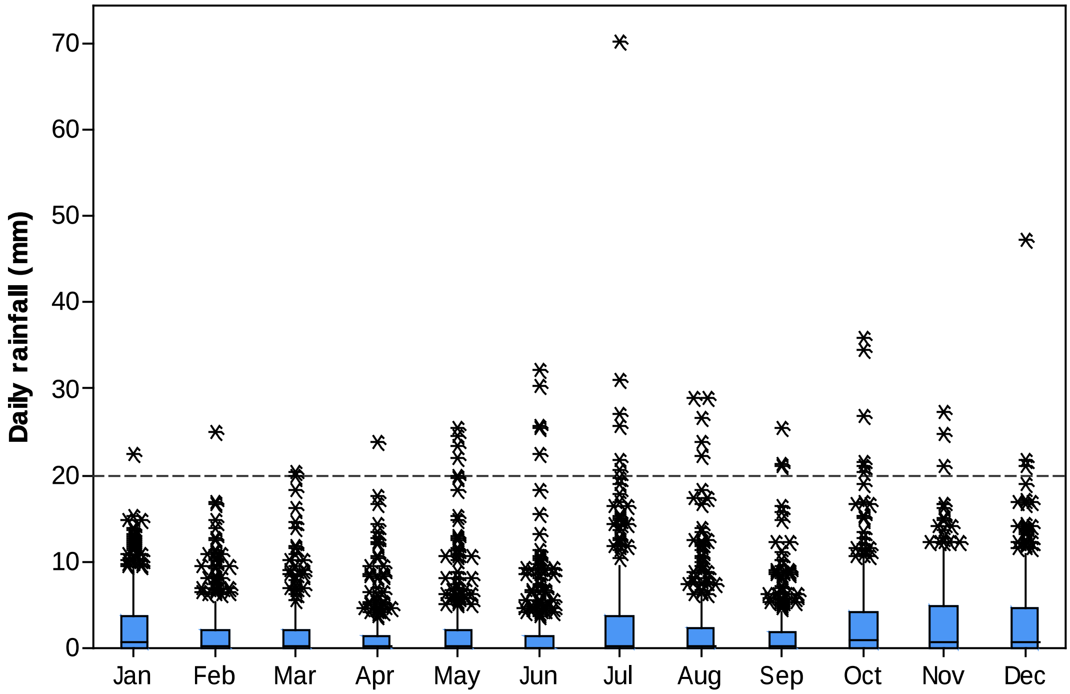


Figure II.1 Boxplot of daily rainfall totals at Chivenor, January 2003 to May 2012.
Data from the Environment Agency

Rainfall records from Chivenor, which is representative of conditions in the vicinity of the shellfish beds indicate some seasonal variation in average rainfall, with a tendency for higher rainfall to occur in the autumn and winter. A secondary peak can be seen in July, although this is not apparent in the long term averages. Rainfall was lowest on average in April and highest on average in October, although high rainfall events (>20mm) occurred in all months of the year. Daily totals of over 20mm were recorded on 1.1% of days and 40.2% of days were dry.

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 XI and XII.

APPENDIX VII
METEOROLOGICAL DATA: WIND

South-west England is one of the more exposed areas of the UK (Met Office, 2012). The strongest winds are associated with the passage of deep areas of low pressure close to or across the UK. The frequency and strength of these depressions is greatest in the winter half of the year, especially from November to March and this is when mean speeds and gusts are strongest, during December and January gusts can reach over 80 knots (Met Office, 2012).

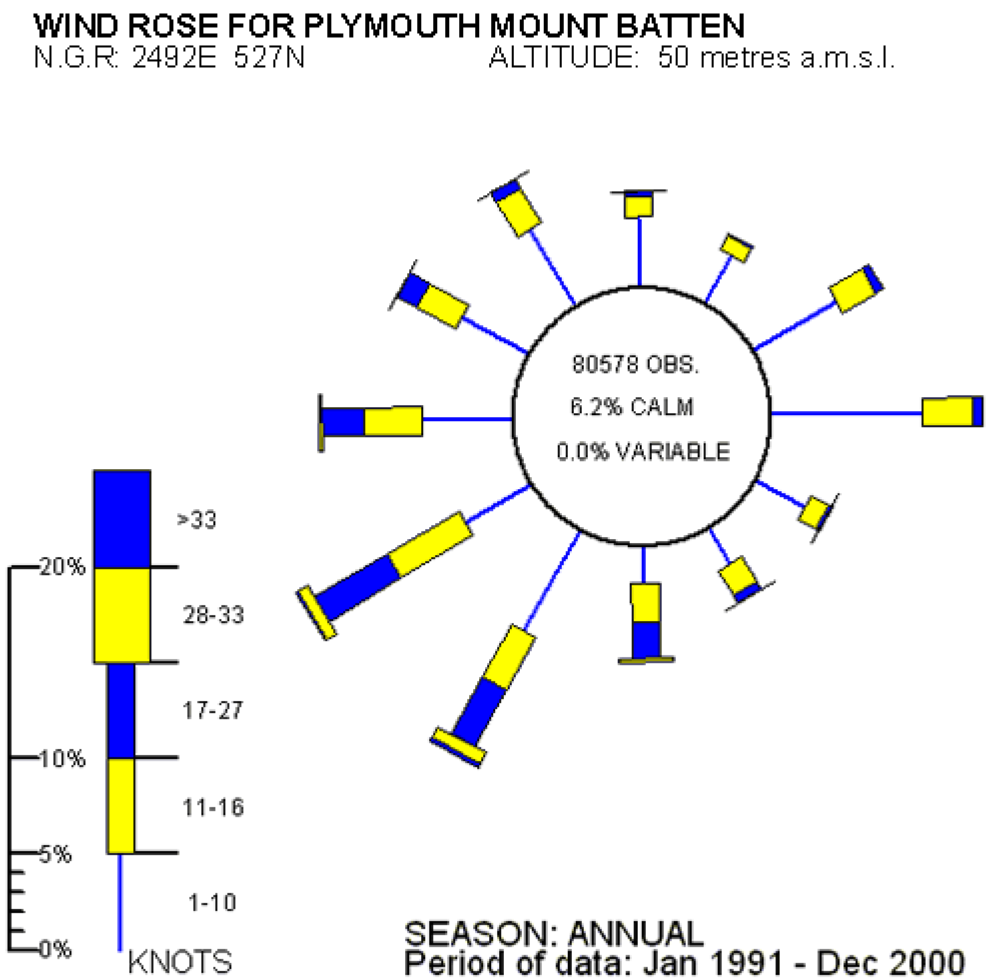


Figure VII.1 Wind rose for Plymouth Mount Batten.
Produced by the Meteorological Office. Contains public sector information licensed under the Open Government Licence v1.0

The wind rose for Plymouth is typical of a coastal location in the south west. The predominant wind direction is from the south west and the strongest winds usually blow from this direction (Met Office, 2012). The Taw Torridge estuary opens out to the west; consequently it is quite exposed to westerly winds, the entrance to the estuary is surrounded by low lying land which offers little protection but it has a narrow entrance which subsequently reduces exposure to the inner shores. The Taw is likely to be more exposed than the Torridge to the prevailing winds because of its east to west orientation which will funnel the prevailing wind upstream. In comparison, the Torridge's north to south orientation and higher land in the south, will keep it more protected. The lower reaches of the River Torridge are also reasonably protected by hills at Appledore.

Hartland Point offers the southern half of Bideford bay slightly more protection from the prevailing south westerly wind and swells than the northern half, so may represent a better environment for razors and other burrowing bivalves.

APPENDIX VIII
HYDROMETRIC DATA: FRESHWATER INPUTS

The Taw/Torridge estuary drains a catchment area of 2090 km² (Figure VIII.1) within which the primary land use is grazing pastures. Approximately 40% of this area drains to the Torridge estuary, and 60% drains to the Taw estuary. For both the Taw and the Torridge most of the land drains to the head of the estuaries (about 90% and 95% respectively). A series of smaller watercourses also drain into the estuary at various locations. A very small fraction (<2%) of this area is a coastal strip drained by small streams flowing direct into Bideford Bay. The majority of land runoff therefore enters the estuaries upstream of the fisheries, so an underlying a gradient of decreasing runoff related levels of indicator bacteria is anticipated from the heads of both estuaries down to the mouth. The smaller watercourses entering the estuary in the vicinity of the fisheries range from small surface water outfalls to minor rivers and will be of more localised significance but may cause hotspots of contamination where they enter the estuary.

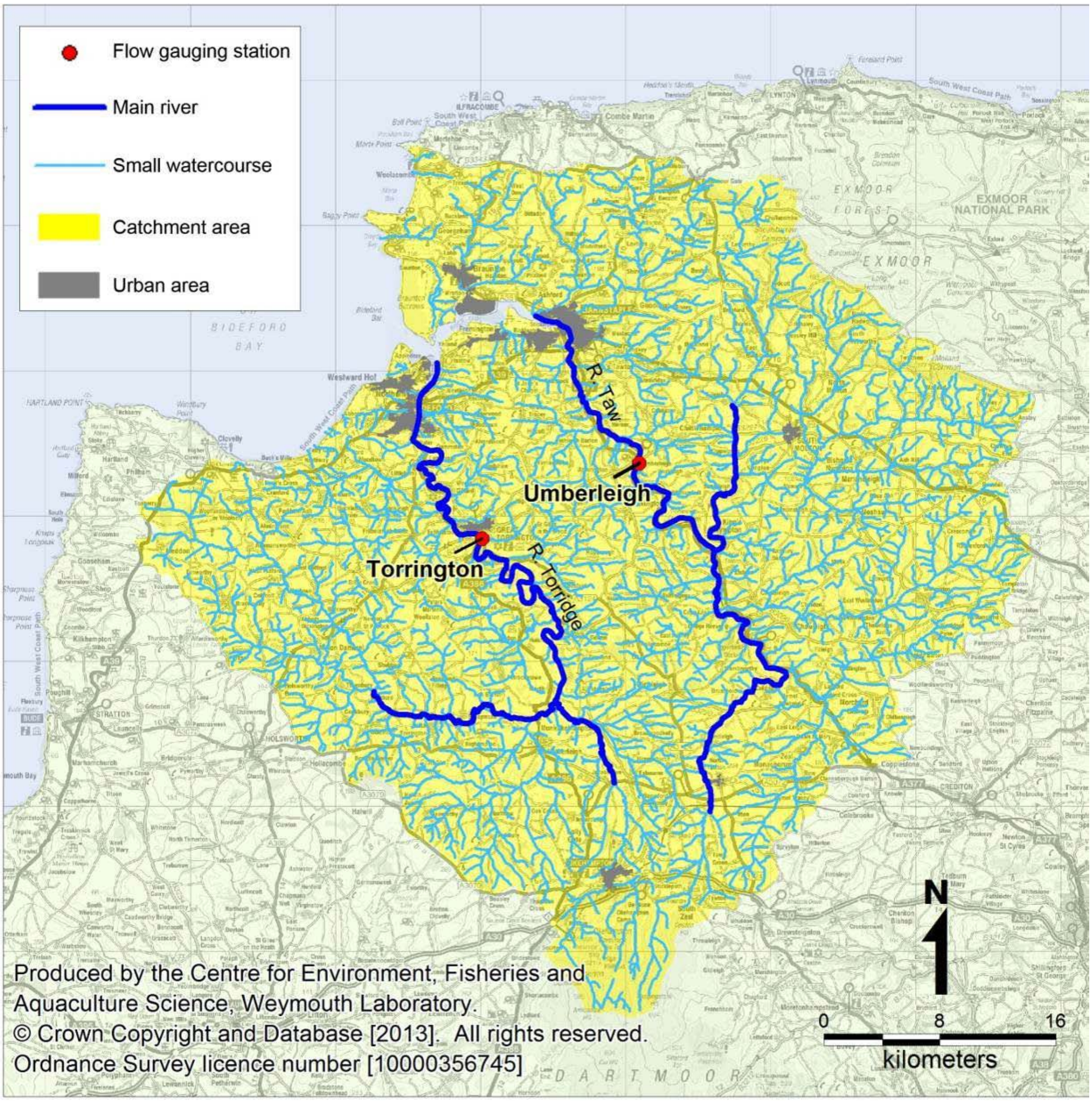


Figure VIII.1: Watercourses within the survey catchment area

These rivers will receive microbiological pollution from several point and diffuse sources such as STW discharges and urban and agricultural runoff. They are therefore potentially a major source of microbiological contamination for the shellfisheries in the estuary. The underlying bedrock is largely impermeable or low permeability, and as a result most of the catchment responds quickly to rainfall (EA 2008). Summary statistics for two of the flow gauges on these rivers are presented in Table VIII.1.

Table VIII.1: Summary flow statistics for flow gauge stations on the Taw and Torridge

Watercourse	Station name	Catchment area (km^2)	Mean annual rainfall 1961-1990 (mm)	Mean flow (m^3s^{-1})	Q95[1] (m^3s^{-1})	Q10[2] (m^3s^{-1})
Taw	Umberleigh	826.2	1155	18.1	1.22	47.39
Torridge	Torrington	663	1186	15.5	0.85	39.48

[1]Q95 is the flow that is exceeded 95% of the time (i.e. low flow). [2]Q10 is the flow that is exceeded 10% of the time (i.e. high flow). *Data from NERC, 2012.*

Boxplots of mean daily flow records by month at the Umberleigh and Torrington gauging stations are presented in Figures VIII.2 and VIII.3. Flows were highest in the colder months at both gauging stations, although major high flow events were recorded in most months of the year. 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.

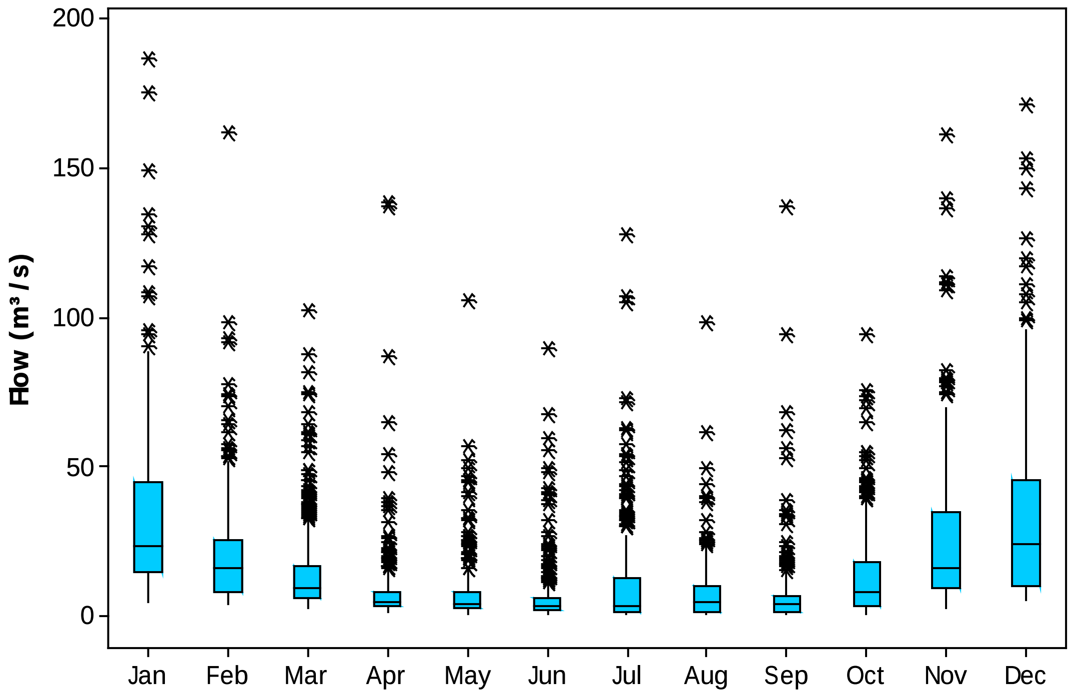


Figure VIII.2: Boxplots of mean daily flow records from the Umberleigh gauging station on the River Taw from 2003-2012. *Data from the Environment Agency*

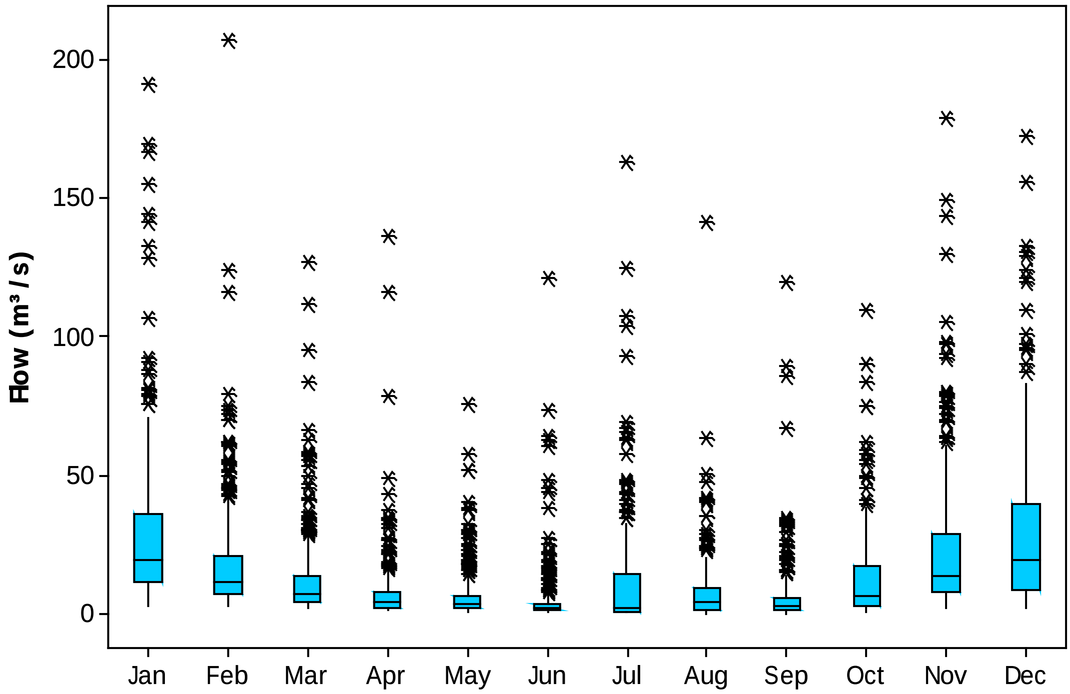


Figure VIII.3: Boxplots of mean daily flow records from the Torrington gauging station on the River Torridge from 2003-2012. *Data from the Environment Agency.*

From the period March 1990 to February 1991, the National Rivers Authority (now the Environment Agency) carried out a detailed investigation into the contribution of various sources to the bacterial loads entering the estuary. Whilst the bacteriological data is not entirely relevant to the current situation given the improvements to sewerage systems and the possible changes to agricultural practices, the flows recorded within various watercourses should still reflect the current situation. Figure VIII.4 and Table VIII.2 shows the averages for the discharges recorded from the watercourses considered during this study (NRA South West Region, 1993).

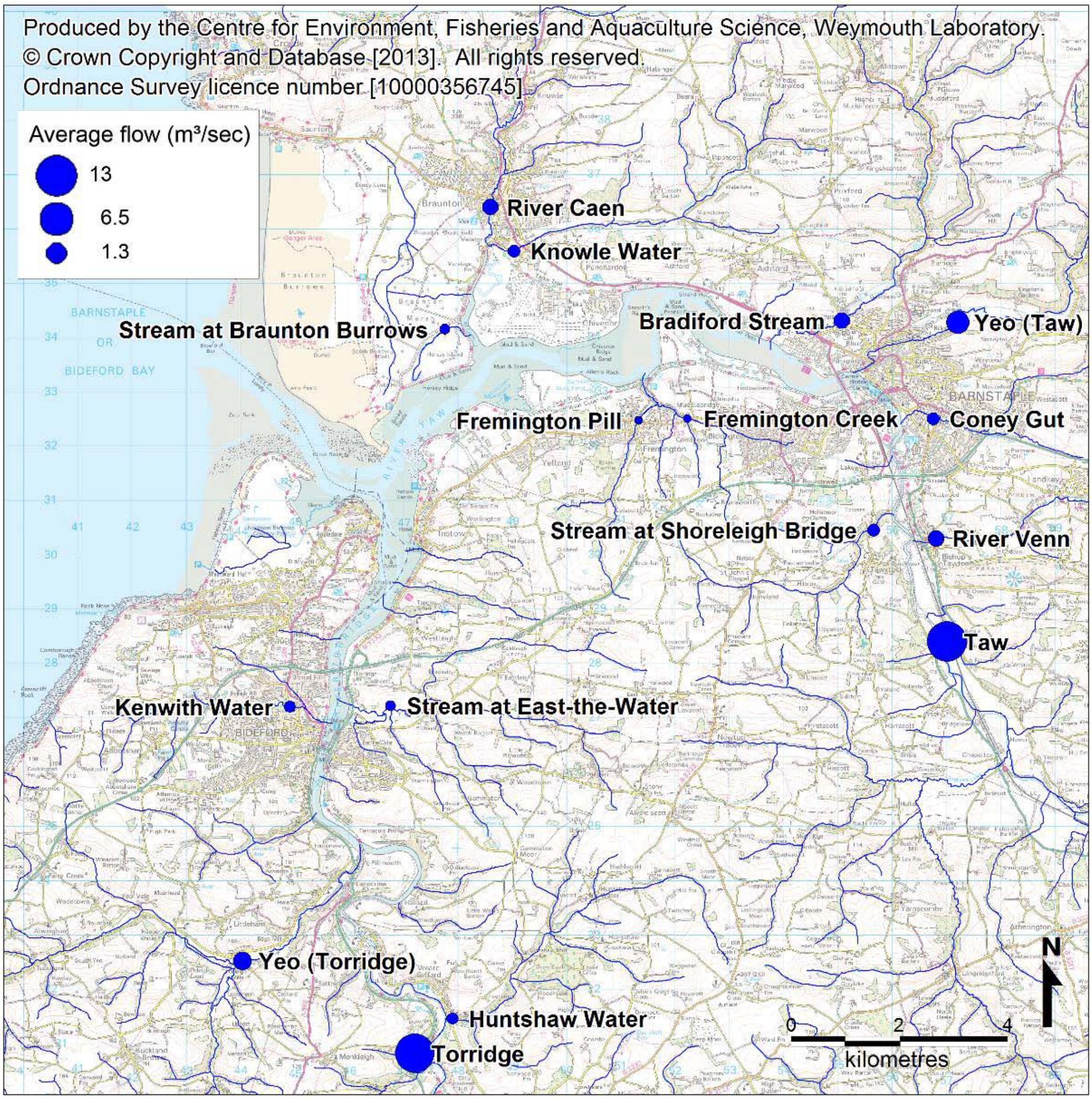


Figure VIII.3. Average flows recorded between March 1990 and February 1991 at various watercourses *Data from the Environment Agency*

Table VIII.2. Average flows recorded between March 1990 and February 1991 at various watercourses *Data from the Environment Agency*

Watercourse name	NGR	Mean discharge (m^3/sec)
Torridge	SS 4720 2082	10.83
Huntshaw Water	SS 4789 2146	0.193
Yeo (Torridge)	SS 4402 2252	0.876
Stream at East-the-Water	SS 4675 2722	0.121
Kenwith Water	SS 4490 2720	0.172
Stream at Braunton Burrows	SS 4775 3415	0.152
River Caen	SS 4859 3640	0.560
Knowle Water	SS 4903 3559	0.253
Bradiford Stream	SS 5506 3431	0.575
Yeo (Taw)	SS 5720 3428	1.696
Coney Gut	SS 5675 3250	0.219
River Venn	SS 5680 3030	0.503
Taw	SS 5700 2840	12.089
Stream at Shoreleigh Bridge	SS 5565 3045	0.248
Fremington Creek	SS 5222 3251	0.054
Fremington Pill	SS 5132 3247	0.063

These measurements further reinforce the conclusion that the vast majority of runoff enters the estuary upstream of the fisheries. The combined inputs to the River Caen estuary, which discharges to the north bank of the outer Taw estuary are also significant in terms of volume with a combined average flow of 0.965m^3/sec. The combined flows from Fremington Creek and Fremington Pill are much lower than this (0.117 m^3/sec). These flow measurements do not provide direct information on the significance of these watercourses to the fishery as it does not consider the concentrations of *E. coli* carried by them, which may vary significantly from watercourse to watercourse.

During the shoreline survey, all significant surface water inputs to shorelines adjacent to any shellfisheries were sampled and measured apart from two where access was not possible. This allowed a 'snapshot' estimate of the *E. coli* loading carried by these to be made. Figure XII.2 and Table XII.2 (Appendix XII, Shoreline survey report) presents these measurements and results.

Of these, the most River Caen and Knowle water were most significant, carrying a combined *E. coli* loading of $1.71x10^{12}$. The watercourse discharging at Allens Rock carried a loading of $1.53x10^{11}$ *E. coli*/day and so may be of some more localised significance. All other inputs were relatively minor, carrying $<10^{11}$ *E. coli* cfu/day. At the oyster farm, the watercourses draining to the north of the trestles were carrying higher loadings ($1.07x10^{10}$ and $3.90x10^{10}$ *E. coli*/day) than the one draining to the south ($1.05x10^{9}$ *E. coli*/day) although all were relatively minor.

APPENDIX IX
HYDROGRAPHY

BATHYMETRY

Source data for part of the admiralty chart presented in Figure IX.1 were mainly gathered in the 1970's therefore the bathymetry may be slightly different now. However important features discussed below are unlikely to have significantly changed.

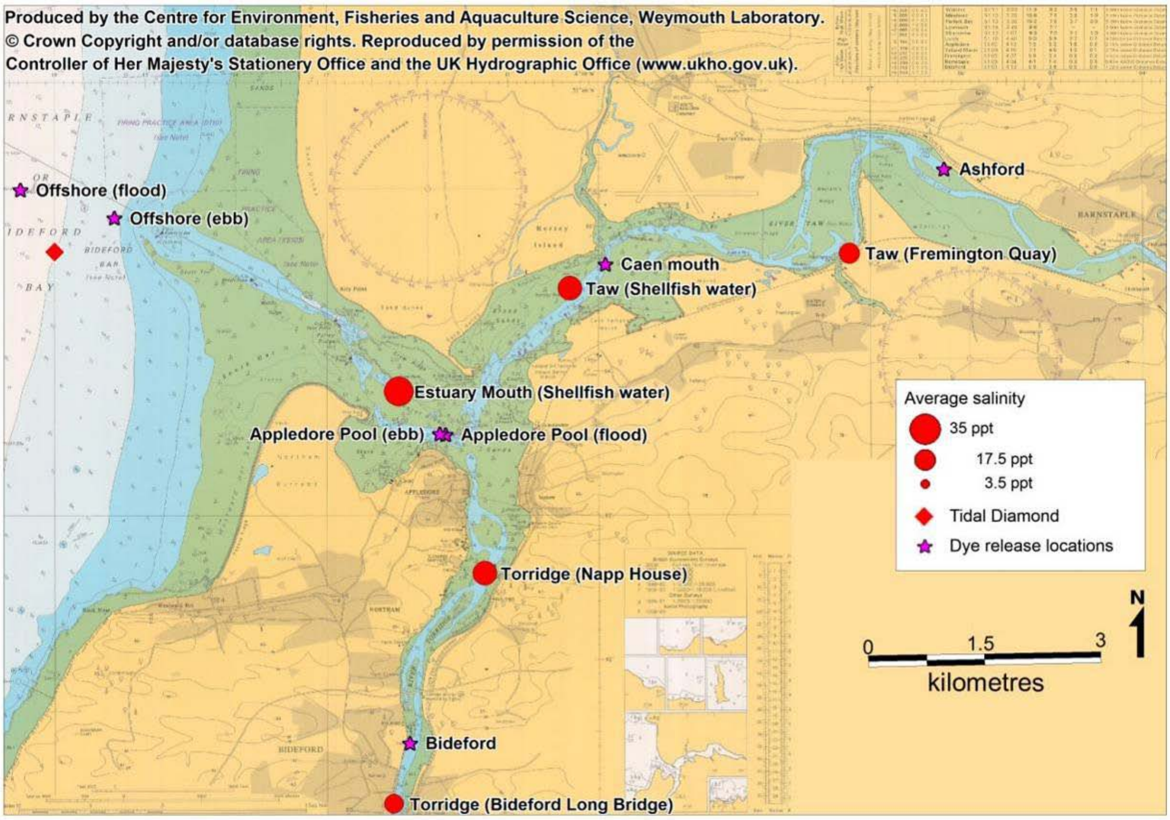


Figure IX.1 Bathymetry chart of the Taw Torridge Estuary

The Taw Torridge is a west facing double spit enclosed estuary, which flows into the outer Bristol Channel (Futurecoast, 2002). The estuary is predominantly intertidal, with extensive sand and gravel beds at the mouth and mud flats in the upper reaches (Maier et al. 2009). 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. Saltmarsh is present in the upper reaches of both the Taw (landwards of Penhill Point) and the Torridge (above the Torridge bridge) where the sediments become finer. These saltmarsh areas are inundated on the larger tides. However, as a result of the rock valley slopes in the Torridge, saltmarsh development is limited (Pethick, 2007).

The mouth is a relatively narrow channel, bordered by steep bedrock cliff to the north and gentle sloping, sand-scoured boulders and cobbles to the south (Moore & Little, 1994). The main channel splits, just north of Appledore into the Taw estuary which meanders towards the sea in an east to west orientation and the shorter and narrower Torridge estuary which has a south to north orientation. The deepest part is in the mouth, 9m below CD, and this is likely to be as a result of the scouring effect. Extensive dune systems at the mouth of the Taw Torridge mark the coastal limit, Saunton Sands to the north and Westward Ho! Sands to the south. The outer estuary is characterised by several rock outcrops including, Pulley Ridge situated in the mouth, Crow ridge situated south east of Airy Point and Cool Stone, adjacent to Instow Sands. A shore-attached sand bar, Instow Sands is also present, possibly representing the flood-tidal delta of the estuary system (Pethick, 2007).

The Taw consists mainly of a sandy substrate and its tidal limit stretches 18km inland. A small tributary, the Caen, joins the main channel of the Taw estuary east of Braunton Burrows. At low tide the main channels are obstructed by numerous sand banks, consequently the channels are diverted often splitting the channel in two around the bank and converging once the sand bank has subsided. Extensive areas on the northern side of the Taw have been reclaimed such as Horsey Island (Pethick, 2007). Dredging and aggregate extraction occurs within the channels of the outer estuary and the Torridge which sees the highest through fare of shipping traffic.

HYDROGRAPHY

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. Tidal amplitude is large (Table V.1) and this drives extensive water movements within the estuary complex.

Table IX.1 Tide levels and ranges within the Taw Torridge

Port	**Height (m) above Chart Datum**				**Range (m)**		**Lag time to HW relative to Appledore**
	MHWS	MHWN	MLWN	MLWS	Springs	Neaps	
Appledore	7.5	5.2	1.6	0.2	7.3	3.6	-
Yelland Marsh	7.1	4.8	1.3	0.1	7.0	3.5	10 mins
Fremington	5.9	3.4	0.3	0.2	5.7	3.1	10 mins
Barnstaple	4.1	1.4	0.3	0.3	3.8	1.1	19 mins
Bideford	5.9	3.6	0.0	0.0	5.9	3.6	0 mins

Data from the Proudman Oceanographic Laboratory

Tidal amplitude decreases in the Taw estuary with distance from the estuary mouth, and there is a lag of about 20 minutes between high water at Appledore and high water at Barnstaple. The spring tidal range also decreases between Appledore and Bideford, although there is no lag. The tidal regime is probably ebb dominant according to the Futurecoast study (Futurecoast, 2002).

The flood tide will convey relatively clean water originating from the open Atlantic Ocean into the estuary, whereas the ebb tide will carry contamination from shoreline sources out through the estuary. There is only one tidal diamond on the nautical chart for the area which lies just to the west of the estuary mouth (Figure IX.1). Tidal stream information from this diamond is shown in Table IX.2.

Table IX.2. Tidal stream information for 51 05'N 04 16'W relative to high water at Avonmouth (Appledore +~1h10min).

	Direction (°)	Spring rate (m/s)	Neap rate (m/s)
HW-6	359	0.3	0.2
HW-5	38	0.2	0.0
HW-4	60	0.4	0.2
HW-3	60	0.5	0.3
HW-2	65	0.4	0.2
HW-1	83	0.2	0.1
HW	184	0.4	0.2
HW+1	198	0.5	0.2
HW+2	212	0.5	0.2
HW+3	225	0.4	0.2
HW+4	290	0.3	0.2
HW+5	313	0.4	0.2
HW+6	340	0.4	0.2

Currents are relatively weak here and the tide here floods in an ENE direction (towards the estuary mouth) and ebbs in the opposite direction. Further tidal stream information was presented on the nautical chart for the main estuary channel between Crow Point to Pulley Ridge for two hours either side of high water. This indicates that tidal currents in the outer estuary follow the main channels, travelling at up to 1.5m/s 2hrs before high water on spring tides in the channel off Airy Point. They decrease to about half this where the channel divides to the Taw and Torridge. Current velocities are about half that on neap tides compared to spring tides. The information presented was not sufficient to make an estimate of tidal excursion within the estuary, but it can be concluded that contamination from shoreline sources will be carried several km during the course of a flood or an ebb tide.

The general pattern of tidal circulation within the estuary as a whole is bi-directional, with water moving up the estuary on the flood and back out on the ebb with the main flows aligning with the main channels. Outside of the estuary, tides flood up the Bristol Channel parallel to the coast, with ebb tides travelling in the opposite direction. On this basis any plume of contamination ebbing from the estuary mouth may be expected to travel towards Westward Ho.

A dye tracing survey was carried out on behalf of South West Water in 1988 (Wimpol, 1989). Dye was released from several locations and the plume tracked at various intervals post release by a survey vessel towing a fluorometer. The findings of this study are summarised in Table IX.3.

Table XI.3. Summary of dye release study

Release location	Tidal conditions	Current speed and direction at release site for continuous releases or plume speed and direction for batch releases	Observations on plume behaviour
Ashford (continuous release, 2 tracing runs)	Neap ebb	0.56m/s, NW (HW+1) 0.44m/s, NW (HW+3)	Plume followed channel along north shore.
Caen Mouth (continuous release, 3 tracing runs)	Neap ebb	0.34m/s, WSW (HW+1) 0.51m/s, WSW (HW+2) 0.63m/s, WSW (HW+3)	Plume followed channel towards Crow Point.
Bideford (continuous release, 3 tracing runs)	Neap ebb	0.23m/s, N (HW+1:30) 0.36m/s, N (HW+2:30) 0.36m/s, N (HW+3:30)	Plume followed channel towards Instow.
Appledore Pool (continuous release, 3 tracing runs)	Spring flood	1.03m/s, ESE (HW-3:45) 1.50m/s, ESE (HW-2:45) 0.95m/s, E(HW-1:15)	Plume moved east into shallower water by east shore north of Instow, where it underwent some turbulent mixing and then moved south towards Instow.
Appledore Pool (continuous release, 3 tracing runs)	Spring ebb	0.57m/s, WNW (HW+1) 0.74m/s, WNW (HW+2) 1.17m/s, WNW (HW+3)	Plume followed channel past Grey Sand Hill
Off estuary mouth (batch release at , 3 tracing runs)	Intermediate flood	0.11m/s, NNE (HW-4:09) 0.15m/s, NNE (HW-3:47 0.16m/s, NE, (HW-2:49)	Plume moved in a northerly direction parallel to shore. Moderate to strong NNW wind.
Off estuary mouth (batch release, 4 tracing runs)	Intermediate ebb	0.11m/s, SW, (HW+1:18) 0.28m/s, SSW (HW+2:19) 0.42m/s, SSW (HW+3:30) 0.36m/s, SW (HW+4:33)	Plume moved in a SSW direction parallel to shore. Light NW wind.

Summarised from Wimpol (1989).

For the estuarine releases, the plume tended to follow the main estuary channels, dispersing and becoming more patchy as it progressed. The flood release from Appledore Pool however travelled east over the main Torridge channel into the shallower water over Instow Sands before being carried up the Torridge estuary. The offshore releases moved parallel to the coast at slower speeds than the estuarine releases spreading as they travelled.

Freshwater inputs may significantly modify the circulation of water around estuaries via density effects. The Futurecoast study (Futurecoast, 2002) indicated a mean flow ratio of 0.014 and a maximum flow ratio of 0.211. This indicates that the freshwater inputs are significant and may result in some stratification particularly at higher river flows and in the upper estuary. Any stratification will result in a shear in currents down the water column, with a net seaward flow in the upper layers and a net landward flow at depth. Perhaps more important in terms of contamination of shellfish, stratification will tend to entrain freshwater borne contamination in the surface layers meaning stocks at lower elevations may be more separated from such contamination.

Since 2003, between 48 and 149 salinity measurements were taken from five locations within the estuary complex (Figure IX.1). Figure IX.2 presents a boxplot of these.

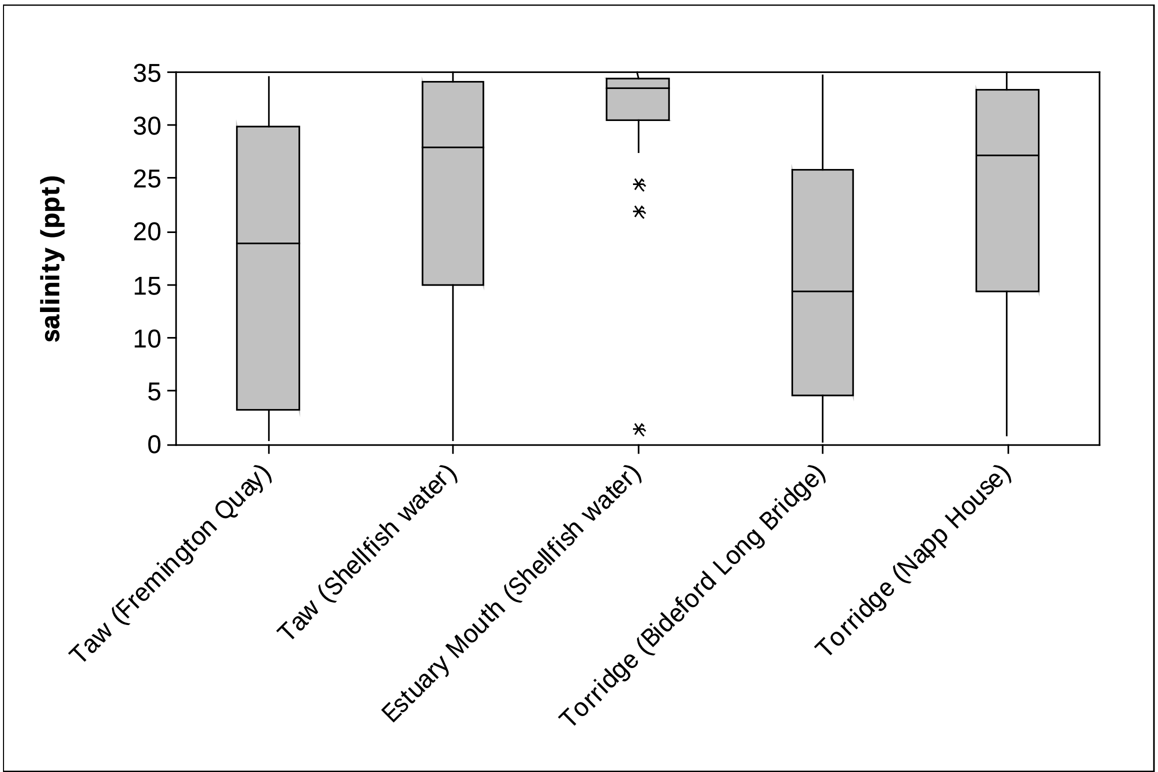


Figure IX.2 Boxplot of salinity readings take from the estuary
Data from the Environment Agency

Figure IX.2 shows a clear gradient of decreasing average salinity towards the head of the estuary. At the estuary mouth, salinities were mostly approaching that of full strength seawater although occasional lower salinities were recorded. Salinity becomes lower on average towards the upper reaches of both the Taw and Torridge estuaries, and varies from approaching full strength seawater to almost completely fresh water at all stations sampled above the confluence. Strong negative correlations were found between levels of indicator bacteria and salinity at these sites (Appendix X). On this basis increasingly variable and higher average levels of contamination are anticipated towards the head of the estuaries.

Tidally driven currents may also be modified by the effects of wind. Strong winds will typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m s^{-1}) would drive a surface water current of about 1 knot or 0.5 m s^{-1}. The prevailing wind direction is from the south west. Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great range of scenarios may arise. Winds from a westerly direction will tend to push surface water up the Taw estuary. The Torridge, which is in a steeper valley and has a north south orientation will be more affected by winds from the north and south. As well as driving surface currents, onshore winds will create wave action. Waves may resuspend any contamination held within the sediments of the intertidal zone, temporarily increasing levels of contamination within the water column until it is carried away by the tides. There is a long fetch across the open Atlantic to the west, so energetic wave action will occur in Bideford Bay and at the estuary mouth at times. The finer sediments within the estuary will be more easily disturbed than the coarser sediments found in the more energetic areas so the gentler waves that will be found in the estuary may also remobilise contamination at certain times and places.

APPENDIX X
MICROBIOLOGICAL DATA: SEAWATER

BATHING WATERS

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. There is 1 bathing water site within the survey area designated under the Directive 76/160/EEC (Council of the European Communities, 1975).

Figure X.1 Location of designated bathing water monitoring points at Taw and Torridge.

Twenty water samples were taken from the bathing waters site during each bathing season, which runs from the 15th May to the 30th September. Faecal coliforms (confirmed) were enumerated in all these samples. Summary statistics of all results from 2003 to 2011 are presented in Table X.1. Figure X.2 presents box plots of all results from the Instow bathing water site by year from 2003 to 2011.

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

N	Geo-mean	Min.	Max.	% exceeding 100 cfu/100ml	% exceeding 1000 cfu/100ml
180	57.1	<2	39,600	37.8	13.3

Data from the Environment Agency

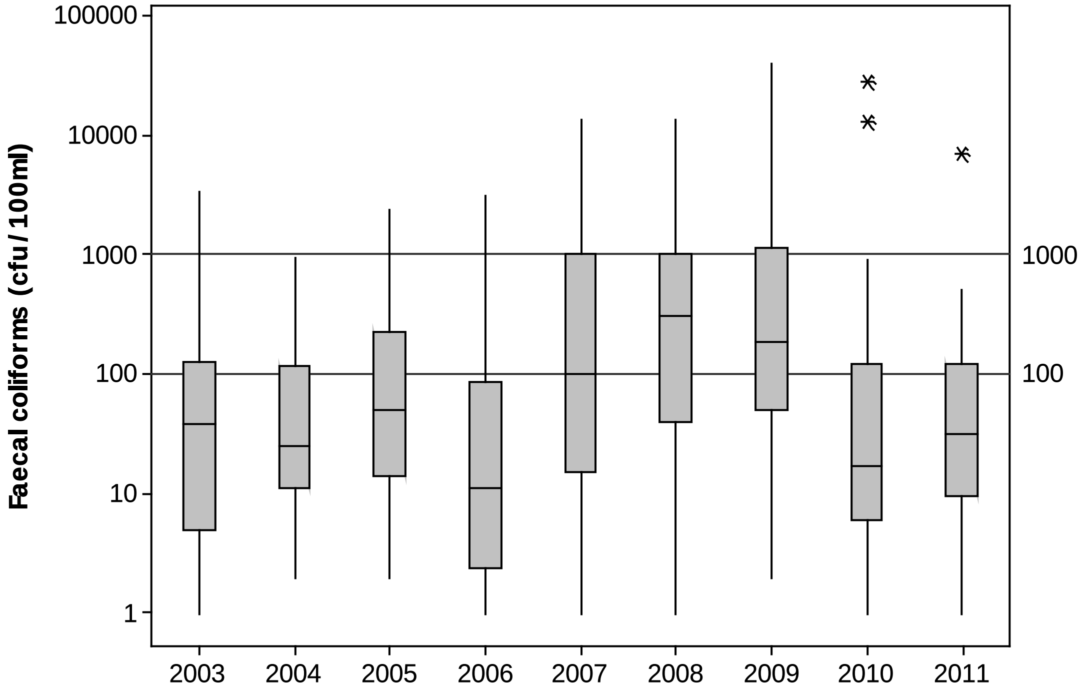


Figure X.2 Box-and-whisker plots of all faecal coliforms results by year
Data from the Environment Agency

Levels of faecal coliforms appeared to be higher from 2007 to 2009, when the average cfu/100ml were greater than 100. Comparisons of the results found a significant difference by year (1-way ANOVA, p=0.011). Posthoc ANOVA testing (Tukey's comparison) indicated that only the results for 2006 and 2009 were significantly different.

To investigate the effects of tidal state on faecal coliform results, circular-linear correlations were carried out against both the high/low and spring/neap tidal cycles. Correlation coefficients are presented in Table X.2.

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

	high/low		spring/neap	
n	**r**	**p**	**r**	**p**
180	0.276	<0.001	0.327	<0.001

Data from the Environment Agency

Figure X.3 present 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 the Taw and Torridge estuaries 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.

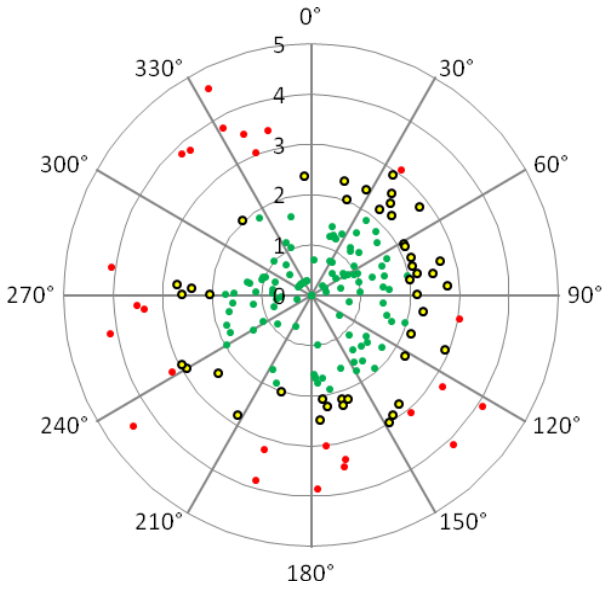


Figure X.3. Polar plots of $\log_{10}$ faecal coliforms against tidal state on the high/low tidal cycle for Instow bathing waters monitoring point *Data from the Environment Agency*

The levels of faecal coliforms found at the Instow bathing site were higher on average around low water suggesting up estuary influences are of importance. Figure X.4 presents polar plots of faecal coliform results against the lunar spring/neap cycle. 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.

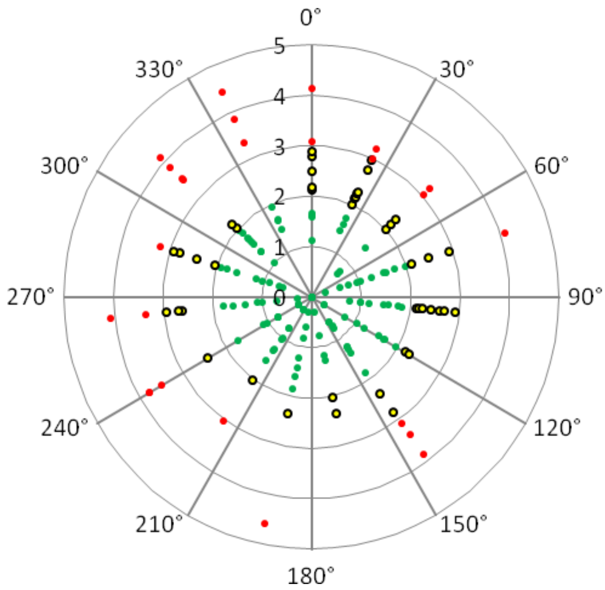


Figure X.4. Polar plots of $\log_{10}$ faecal coliforms against tidal state on the spring/neap tidal cycle for Instow bathing water monitoring point *Data from the Environment Agency*

The numbers of faecal coliforms at the Instow bathing waters monitoring point are slightly lower at the neap tides. The results are otherwise similar throughout the rest of the lunar cycle.

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 Chivenor weather station (Appendix VI for details) over various periods running up to sample collection and faecal coliforms results. These are presented in Table X.4.

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

	n	180
24 hour periods prior to sampling	1 day	0.200
	2 days	0.347
	3 days	0.348
	4 days	0.316
	5 days	0.172
	6 days	0.206
	7 days	0.284
Total prior to sampling over	2 days	0.390
	3 days	0.459
	4 days	0.487
	5 days	0.488
	6 days	0.501
	7 days	0.524

Data from the Environment Agency

Significant (p <0.05) correlations between rainfall and faecal coliform numbers at the Instow bathing waters site were found for all comparisons. This indicates that at Instow, the waters are very sensitive to rainfall events which is likely to be due to its location within the estuary of a major river.

SHELLFISH WATERS

Figure X.5 shows the location of the Taw-Torridge estuary shellfish water monitoring points, designated under Directive 2006/113/EC (European Communities, 2006). Table X.5 presents summary statistics for bacteriological monitoring results from these points. Only water sampling results are presented as flesh results from the shellfish hygiene monitoring programme (Appendix XII) are used to assess compliance with bacteriological standards in shellfish flesh.

Figure X.5 Map showing the locations of the shellfish waters in the Taw-Torridge estuary

Table X.5 Summary statistics for shellfish waters faecal coliforms results (cfu/100ml), 2003-2012.

Site	No.	Geometric mean	Minimum	Maximum	% exceeding 100 cfu/100ml	% exceeding 1000 cfu/100ml
Taw	48	98.0	<2	13000	50.0	27.1
Torridge	47	110.1	<2	6300	53.2	25.5
Taw-Torridge Mouth	48	20.1	<2	2560	27.1	2.1

Data from the Environment Agency

Comparisons between monitoring sites (1-way ANOVA) show that there are significant differences in faecal coliform levels between sites (p = 0.001). Post ANOVA comparisons (Tukey) show that the Taw and the Torridge sites did not differ significantly from each other, but both had significantly greater faecal coliform levels than the Taw-Torridge mouth.

Figure X.6 indicates that there is strong seasonality in levels of contamination in the Taw-Torridge Estuary, with highest results in the winter and autumn. Statistically significant difference were found between seasons at all three site (One-way ANOVA, p=0.001 - 0.030). Post ANOVA tests (Tukey) showed that at the Taw and Taw-Torridge Mouth sites, winter levels of faecal coliforms were significantly greater than in the spring. While at the Torridge site, autumn and winter had higher faecal coliform levels than both spring and summer.

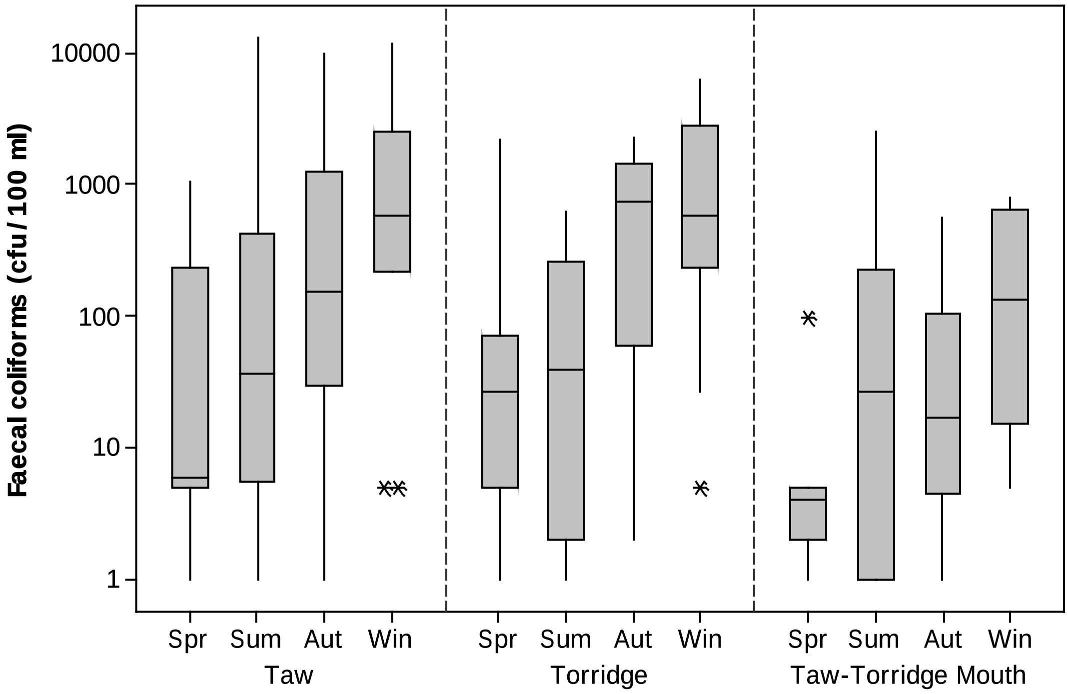


Figure X.6 Boxplot of shellfish growing waters faecal coliforms results by season
Data from the Environment Agency

Figure X.7 shows the relationships between salinity and faecal coliform levels in the Taw-Torridge Estuary. A negative correlation between salinity and faecal coliform levels was found across all sites (r = -0.645, p < 0.001). Analysis of salinity and faecal coliforms at individual sites showed a correlation coefficient of -0.733 (p <0.001) at the Taw, -0.552 (p <0.001) at the Torridge and -0.481 (p = 0.001) at the Taw-Torridge Mouth.

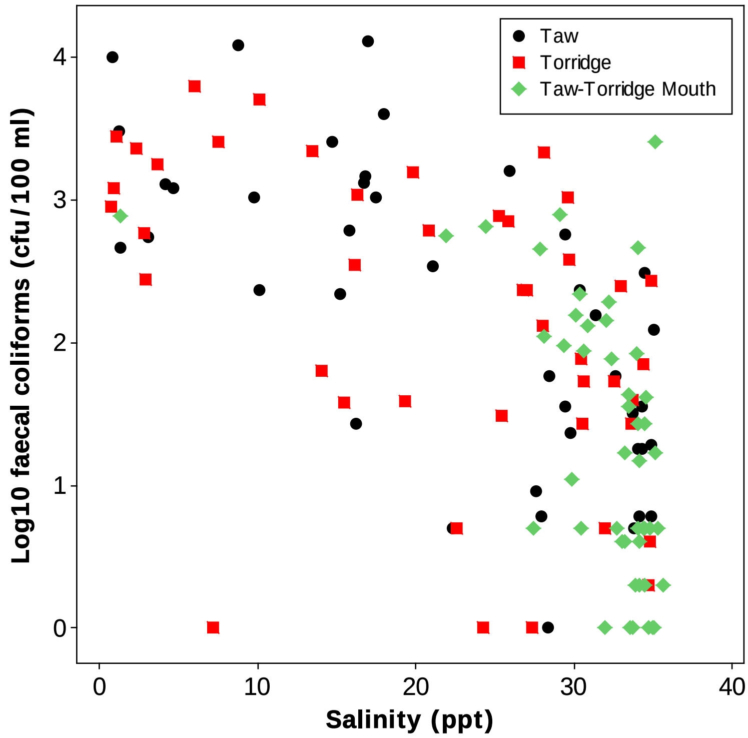


Figure X.7 Graph showing the relationship between salinity and log$_{10}$ faecal coliform levels in the Taw-Torridge Estuary. *Data from the Environment Agency*

Significant correlations were found between faecal coliforms results and the high/low tidal cycle at both the Taw ($r = 0.417$, $p < 0.001$) and the Torridge sites ($r=0.427$, $p < 0.001$) but not at the Taw-Torridge Mouth. Figure X.8 presents a polar plot of log$_{10}$ faecal coliforms results against tidal state on the high/low cycle. High water at Appledore 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.

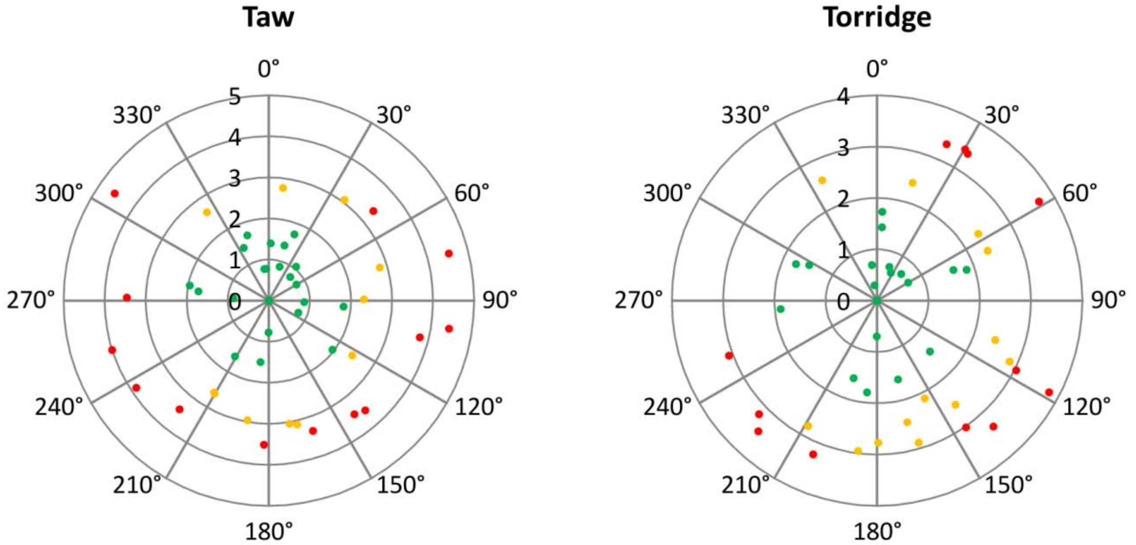


Figure X.8 Polar plots of log$_{10}$ faecal coliforms against tidal state on the high/low tidal cycle *Data from the Environment Agency*

Significant correlations were found between faecal coliforms results and the spring/neap tidal cycle at the Torridge site (r=0.308, p = 0.015) but not at the Taw or the Taw-Torridge Mouth. Figure X.9 presents polar plots of faecal coliform results against the lunar spring/neap cycle for Torridge. 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.

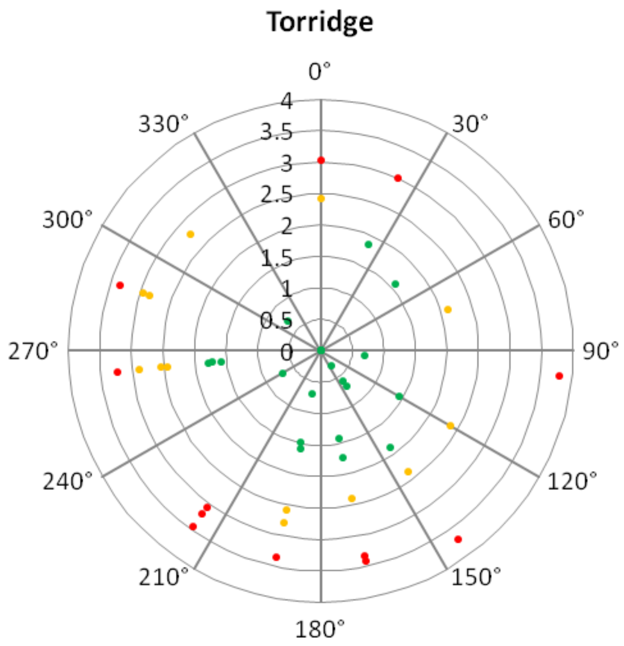


Figure X.9 Polar plots of log_{10} faecal coliforms against tidal state on the spring/neap tidal cycle *Data from the Environment Agency*

Results were lower on average as tide size decreased towards neap tides. 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 Chivenor weather station over various periods running up to sample collection and faecal coliforms 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 coliform results against recent rainfall

		Taw	Torridge	Taw-Torridge Mouth
	No.	48	47	48
24 hour periods prior to sampling	1 day	0.343	0.310	0.200
	2 days	0.141	0.130	0.078
	3 days	0.551	0.418	0.442
	4 days	0.474	0.265	0.183
	5 days	0.451	0.374	0.405
	6 days	0.506	0.484	0.480
	7 days	0.348	0.273	0.367
Total prior to sampling over	2 days	0.306	0.229	0.214
	3 days	0.456	0.410	0.379
	4 days	0.507	0.398	0.361
	5 days	0.566	0.476	0.438
	6 days	0.585	0.494	0.493
	7 days	0.604	0.523	0.519

Data from the Environment Agency

Faecal coliform levels are affected by rainfall at all of the shellfish waters in the Taw-Torridge Estuary. At both the Taw and the Torridge shellfish water sites, rainfall has a significant impact after just 24 hours, whereas at the Taw-Torridge Mouth site, it takes 3 days for rainfall to have significant effect on faecal coliform levels.

APPENDIX XI
MICROBIOLOGICAL DATA: SHELLFISH FLESH

SUMMARY STATISTICS AND GEOGRAPHICAL VARIATION

The geometric mean results of shellfish flesh monitoring from all RMPs sampled from 2003 onwards are presented in Figure XI.11 and Figure XI.2. Summary statistics are presented in Table XI.1 and boxplots for sites sampled on 10 or more occasions are shown in Figure XI.3.

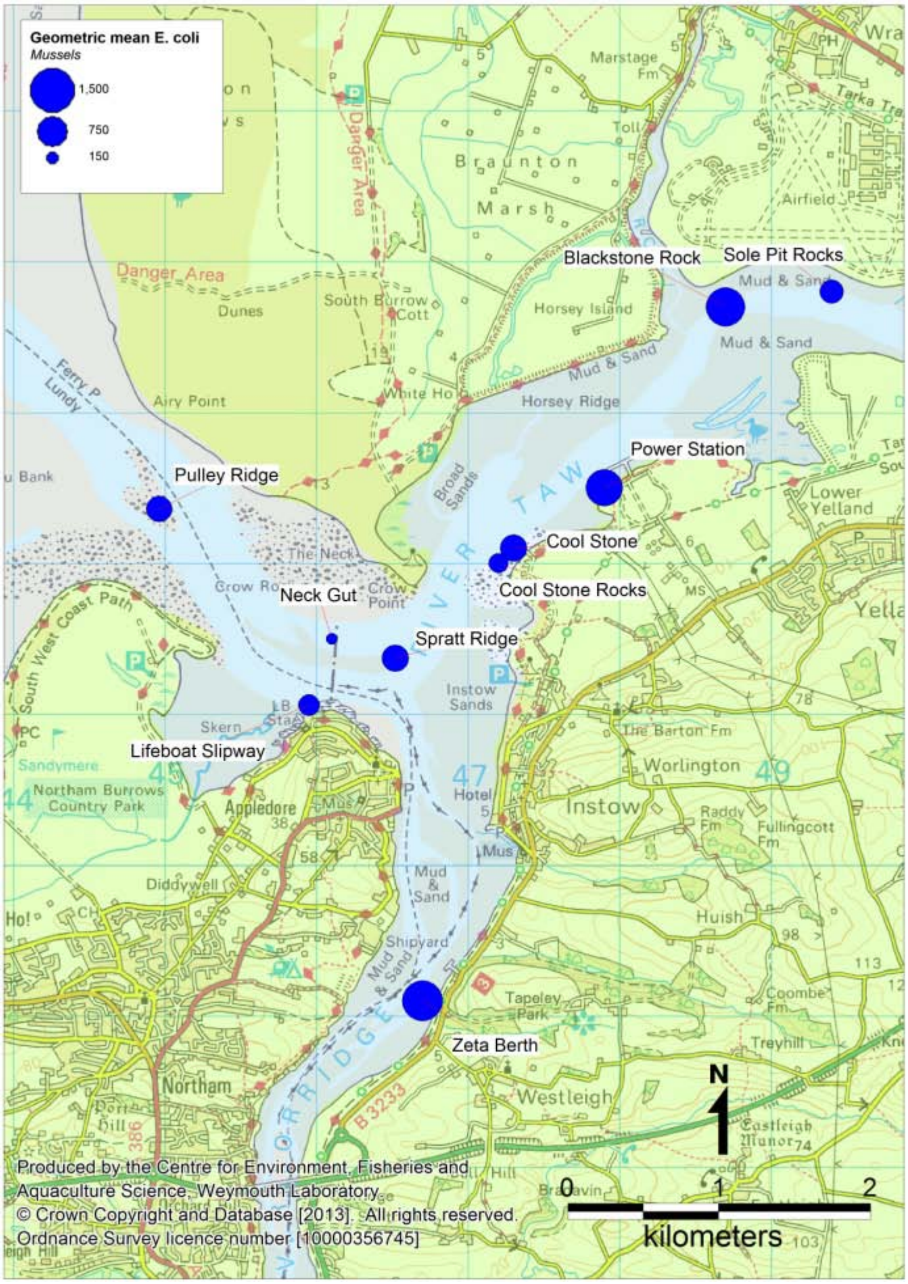


Figure XI.1: Mussel RMPs active since 2003

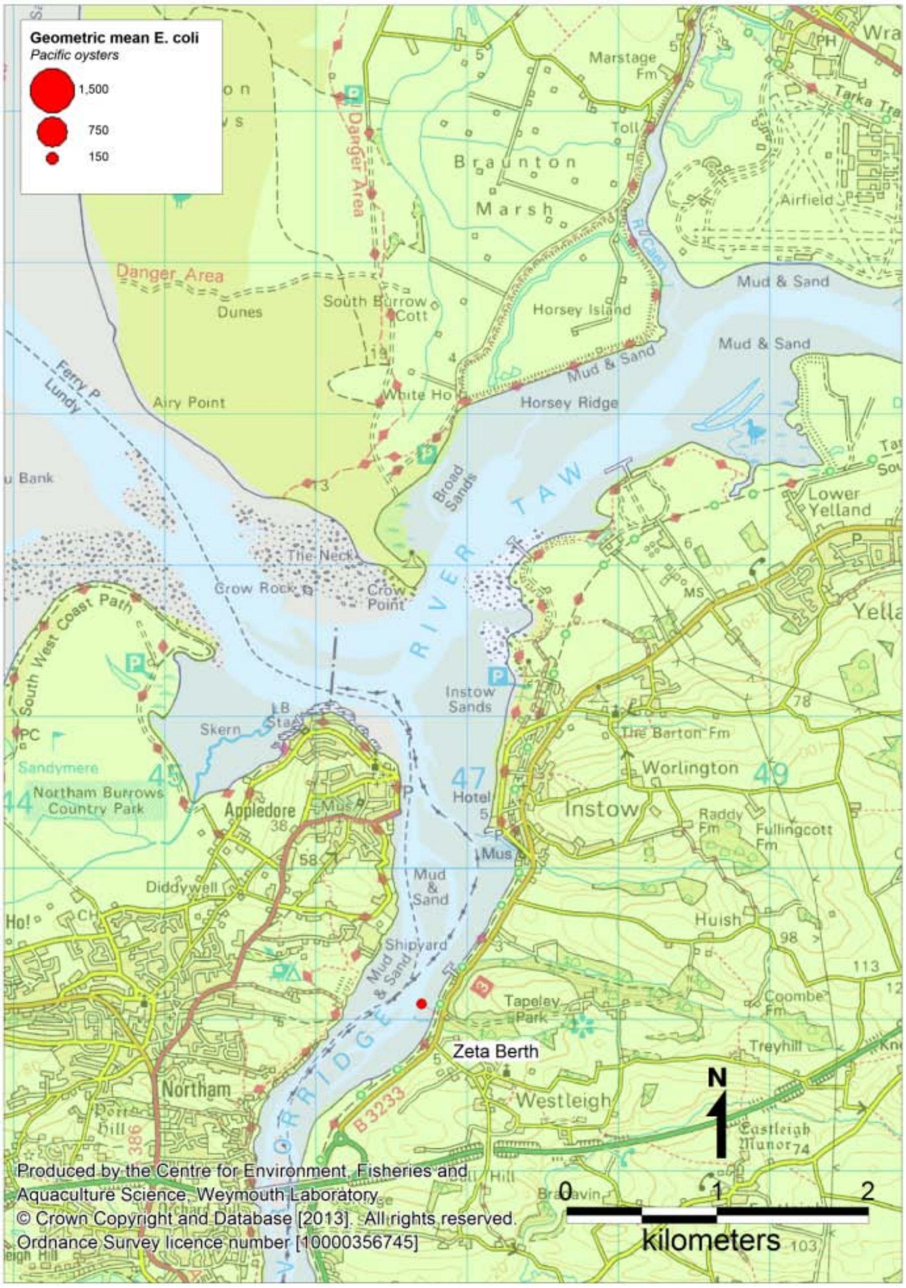


Figure XI.2: Pacific oyster RMPs active since 2003

Table XI.1: Summary statistics of E. coli results (MPN/100g) 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	% over 46000
Sole Pit Rocks	Mussel	1	10/04/2003	10/04/2003	500.0	500	500	100.0	0.0	0.0
Zeta Berth	Mussel	92	22/10/2003	15/10/2012	1267.6	<20	22000	88.0	17.4	0.0
Blackstone Rock	Mussel	111	20/01/2003	15/10/2012	1197.2	20	54000	81.1	20.7	0.9
Power Station	Mussel	115	21/01/2003	15/10/2012	1082.5	<20	35000	81.7	19.1	0.0
Cool Stone	Mussel	106	21/01/2003	15/10/2012	610.4	<20	54000	65.1	13.2	0.9
Cool Stone Rocks	Mussel	10	14/05/2003	19/04/2004	357.2	20	17000	60.0	10.0	0.0
Spratt Ridge	Mussel	120	15/01/2003	15/10/2012	606.7	<20	36000	67.5	15.8	0.0
Lifeboat Slipway	Mussel	119	15/01/2003	15/10/2012	415.3	<20	17000	58.8	9.2	0.0
Neck Gut	Mussel	22	20/01/2003	26/04/2005	124.4	<20	16000	27.3	9.1	0.0
Pulley Ridge	Mussel	119	15/01/2003	15/10/2012	575.8	20	54000	64.7	14.3	0.8
Zeta Berth	P. oyster	19	21/01/2003	19/03/2007	112.6	<20	1700	31.6	0.0	0.0

Only one RMP was sampled on less than 10 occasions so will not be considered in detail in the following more detailed analyses (Sole Pit Rocks).

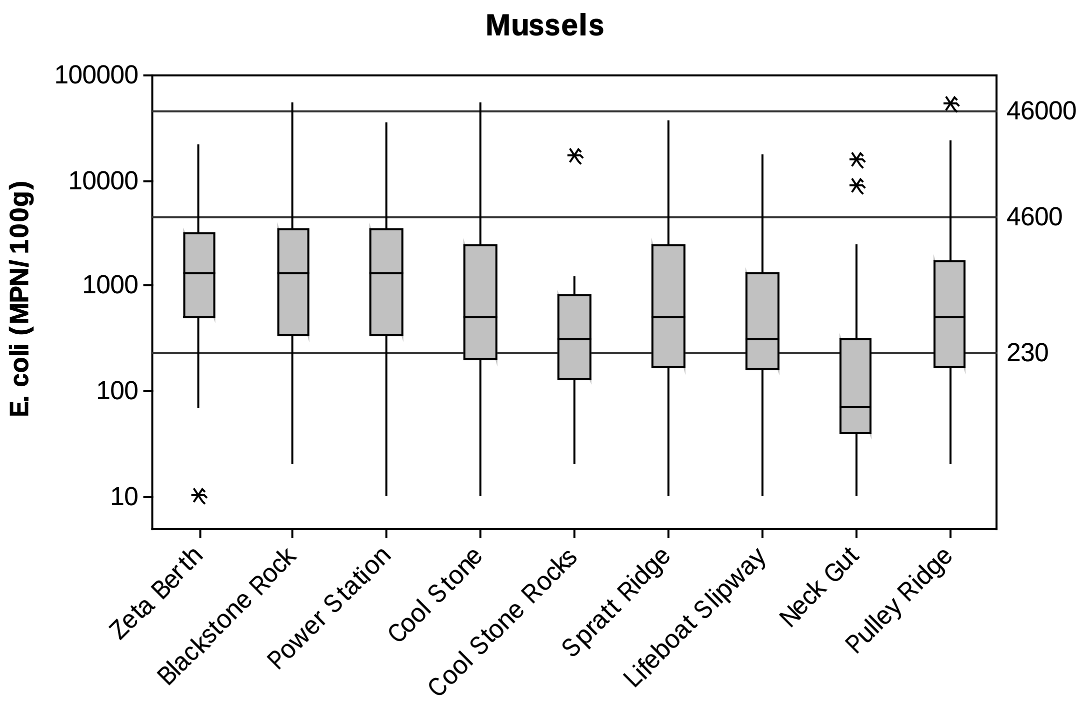


Figure XI.3: Boxplots of E. coli results from mussel RMPs sampled on 10 or more occasions from 2003 onwards.

At the nine mussel RMPs, the level of *E. coli* exceeded 4,600 MPN/100g at all sites sampled more than 10 times. The frequency of samples above 4,600 MPN/100g exceeded 10% at all sites except Neck Gut and Lifeboat Slipway. At Blackstone Rock, Cool Stone and Pulley Ridge, *E. coli* levels exceeded 46,000 MPN/100g on at least one occasion. The single RMP for Pacific oysters at Zeta Berth did not exceed 4,600 MPN/100g.

Comparisons of *E. coli* levels revealed that there were significant differences between sites (one-way ANOVA, p<0.001). Post ANOVA tests (Tukey, Table XI.2) suggested that the level of *E. coli* found in mussels generally decreased towards the mouth of the estuary.

Table XI.2. Results of Post ANOVA testing (Tukeys comparison) of* E. coli *levels recorded at the main eight mussel RMPs.

Bed Name	N	Mean	Grouping*
Zeta Berth	92	1268	A
Blackstone Rock	111	1197	A B
Power Station	115	1082	A B C
Cool Stone	106	610	A B C D
Spratt Ridge	120	607	B C D
Pulley Ridge	119	576	C D
Lifeboat Slipway	119	415	D E
Neck Gut	22	124	E

*Sites that do not share a letter are significantly different.

Comparisons of RMPs were carried out on a pair-wise basis by running correlations (Pearson's) between sites that shared sampling dates, and therefore environmental conditions, on at least 20 occasions. Table XI.3 shows the results of these correlations.

Table XI.3: Correlations between RMPs that shared sampling dates on at least 20 occasions. Significant results are shaded in grey.

Comparison	n	r	p
Zeta Berth vs. Blackstone Rock	88	0.676	<0.001
Zeta Berth vs. Power Station	91	0.727	<0.001
Zeta Berth vs. Cool Stone	87	0.582	<0.001
Zeta Berth vs. Spratt Ridge	44	0.796	<0.001
Zeta Berth vs. Lifeboat Slipway	44	0.501	0.001
Zeta Berth vs. Pulley Ridge	44	0.524	<0.001
Blackstone Rock vs. Power Station	104	0.759	<0.001
Blackstone Rock vs. Cool Stone	95	0.688	<0.001
Blackstone Rock vs. Spratt Ridge	50	0.798	<0.001
Blackstone Rock vs. Lifeboat Slipway	50	0.556	<0.001
Blackstone Rock vs. Neck Gut	21	0.347	0.123
Blackstone Rock vs. Pulley Ridge	50	0.748	<0.001
Power Station vs. Cool Stone	101	0.743	<0.001
Power Station vs. Spratt Ridge	51	0.801	<0.001
Power Station vs. Lifeboat Slipway	51	0.592	<0.001
Power Station vs. Pulley Ridge	51	0.556	<0.001
Cool Stone vs. Spratt Ridge	50	0.730	<0.001
Cool Stone vs. Lifeboat Slipway	50	0.669	<0.001
Cool Stone vs. Pulley Ridge	50	0.700	<0.001
Spratt Ridge vs. Lifeboat Slipway	119	0.617	<0.001
Spratt Ridge vs. Pulley Ridge	118	0.746	<0.001
Lifeboat Slipway vs. Pulley Ridge	118	0.545	<0.001

A significant correlation was found between all sites tested except Blackstone vs. Neck Gut. Numbers of paired samples for this site pairing were lower than the others, perhaps explaining to some extent the lack of correlation. The significant correlations between sites suggest that the sites compared are influenced in a similar way by environmental variables.

OVERALL TEMPORAL PATTERN IN RESULTS

The overall variation in levels of *E. coli* found in bivalves is shown in Figures XI.4 and XI.5. Only RMPs with data for more than two years were included.

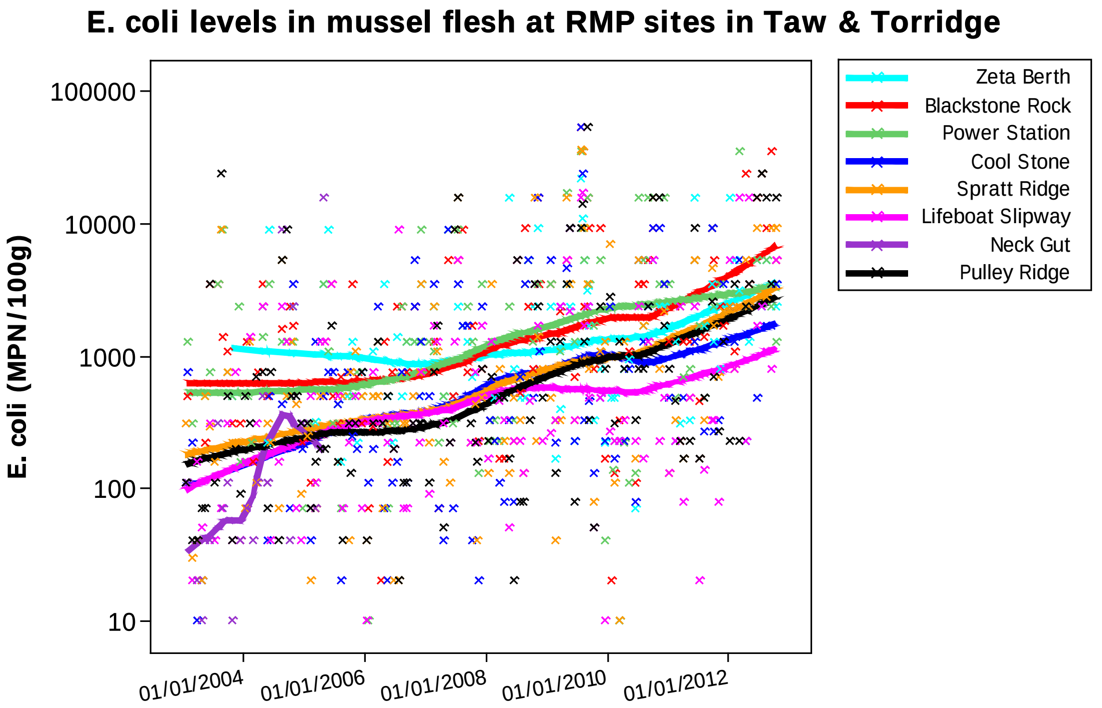


Figure XI.4 Scatterplot of* E. coli *results for mussels overlaid with loess lines.

Figure 4 shows that the levels of *E. coli* in mussels has been increasing at most sites across the Taw Torridge estuary since 2003. *E. coli* levels at Zeta Berth, which is the most upstream RMP on the River Torridge, remained fairly consistent between 2004 and 2010 but appear to be increasing since 2011. This was confirmed with linear regressions which showed a significant trend ($p<0.001$ to 0.007) at all sites except Zeta Berth ($p=0.061$)

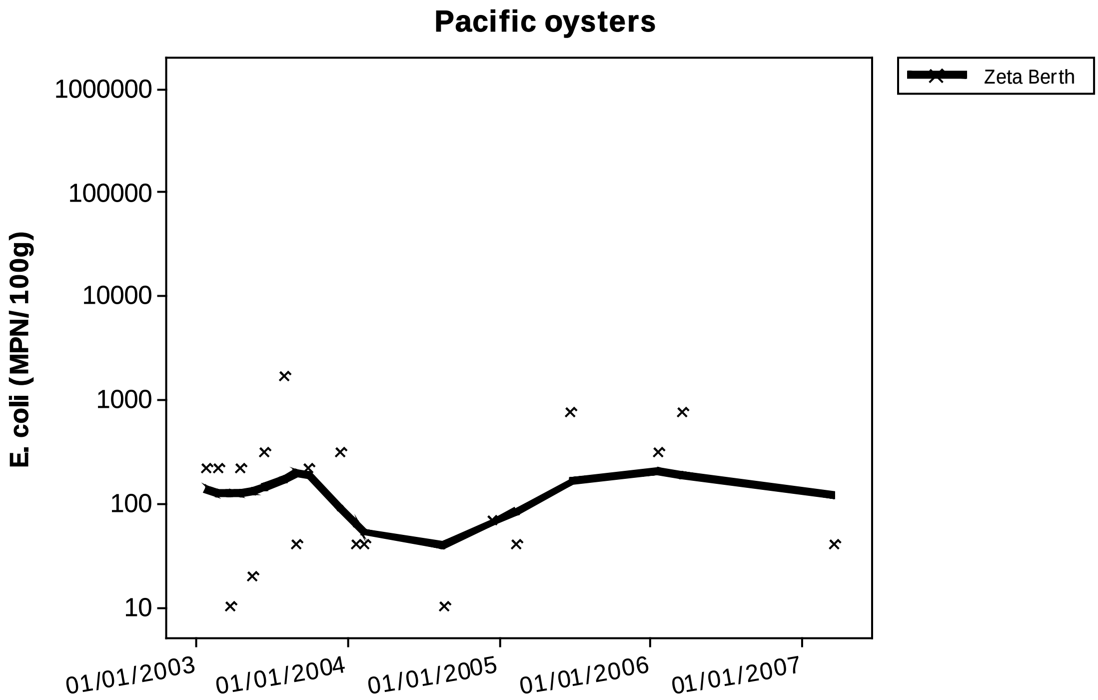


Figure XI.5 Scatterplot of* E. coli *results for Pacific oysters overlaid with loess lines.

Figure 5 shows that *E. coli* levels in Pacific oysters have remained fairly consistent at Zeta Berth between 2003 and 2007.

SEASONAL PATTERNS OF RESULTS

The seasonal patterns of results from 2003 onwards were investigated by RMP for all RMPs where at least 30 samples had been taken.

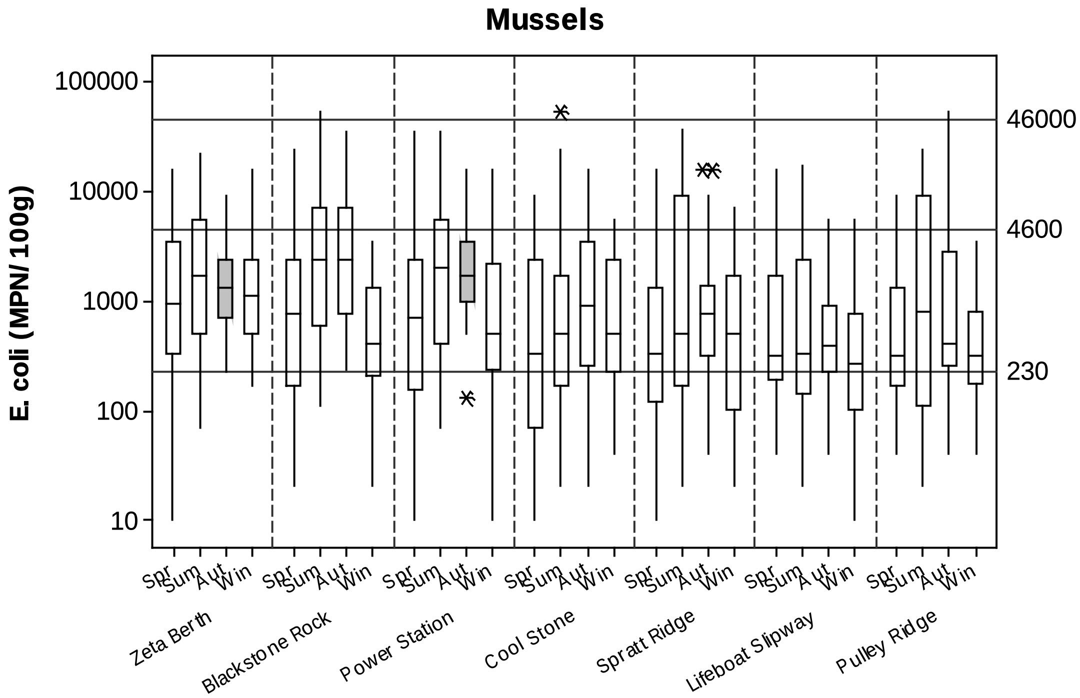


Figure XI.6: Boxplot of mussel* E. coli *results by RMP and season

There was significant seasonal variation at Blackstone Rock, Power Station and Spratt Ridge (one-way ANOVA, p<0.001, 0.003 & 0.044 respectively). Post ANOVA tests (Tukey) showed that at Blackstone Rock summer and autumn had significantly higher levels of *E. coli* than spring and winter. At Power Station, there were significantly higher *E. coli* levels during the autumn compared with winter and spring, and significantly higher levels in summer compared with winter. No pair-wise differences were found between seasons at Spratt Ridge.

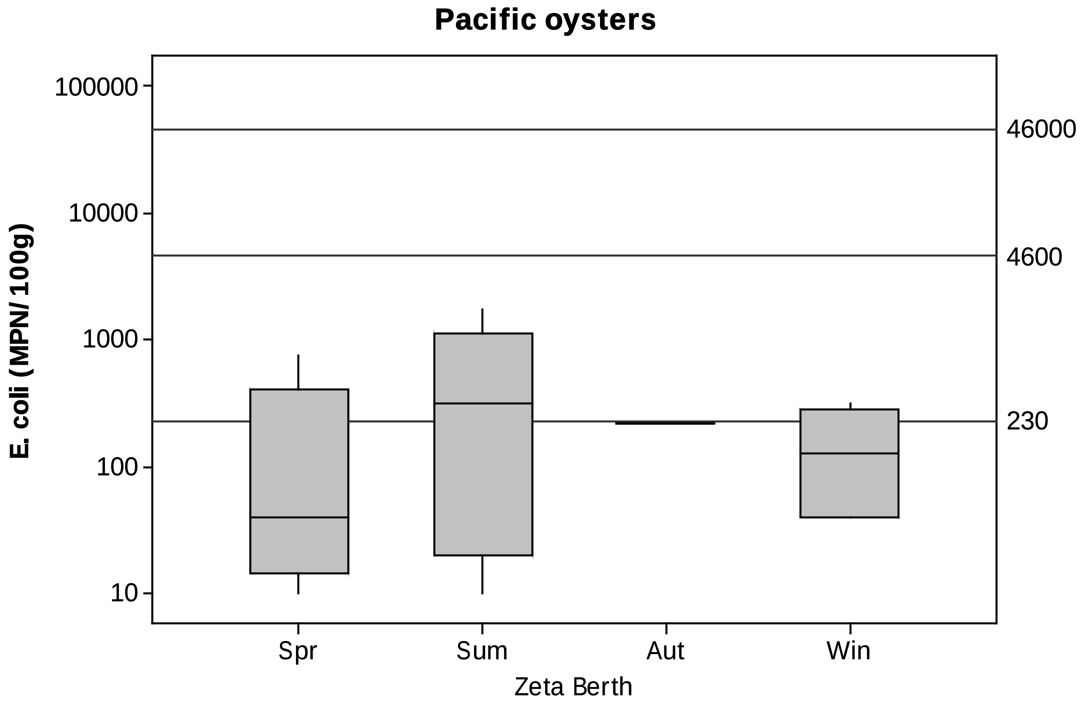


Figure XI.7: Boxplot of Pacific oyster* E. coli *results by RMP and season

No significant variation was found between season in Pacific oysters (one-way ANOVA, p=0.773). However, very few samples have been taken during the autumn, and so it is possible that these data are not powerful enough to detect seasonality.

INFLUENCE OF TIDE

To investigate the effects of tidal state on *E. coli* results, circular-linear correlations were carried out against the spring/neap tidal cycle for each RMP where at least 30 samples had been taken since 2003. Results of these correlations are summarised in Table XI.55, and significant results are highlighted in yellow.

Table XI.5: Circular linear correlation coefficients (r) and associated p values for* E. coli *results against the high/low and spring/neap tidal cycles

			High low		Spring neap	
Site	**Species**	**n**	**r**	**p**	**r**	**p**
Zeta Berth	Mussels	92				
Blackstone Rock	Mussels	111				
Power Station	Mussels	115				
Cool Stone	Mussels	106			0.113	0.269
Spratt Ridge	Mussels	120	0.129	0.144	0.108	0.255
Lifeboat Slipway	Mussels	119	0.048	0.767	0.096	0.34
Pulley Ridge	Mussels	119	0.209	0.006	0.114	0.223

Data from the Environment Agency

Figure XI.8 presents polar plots of log10 *E. coli* results against tidal states on the high/low cycle for the correlations indicating a statistically significant effect. High water at Appledore 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.

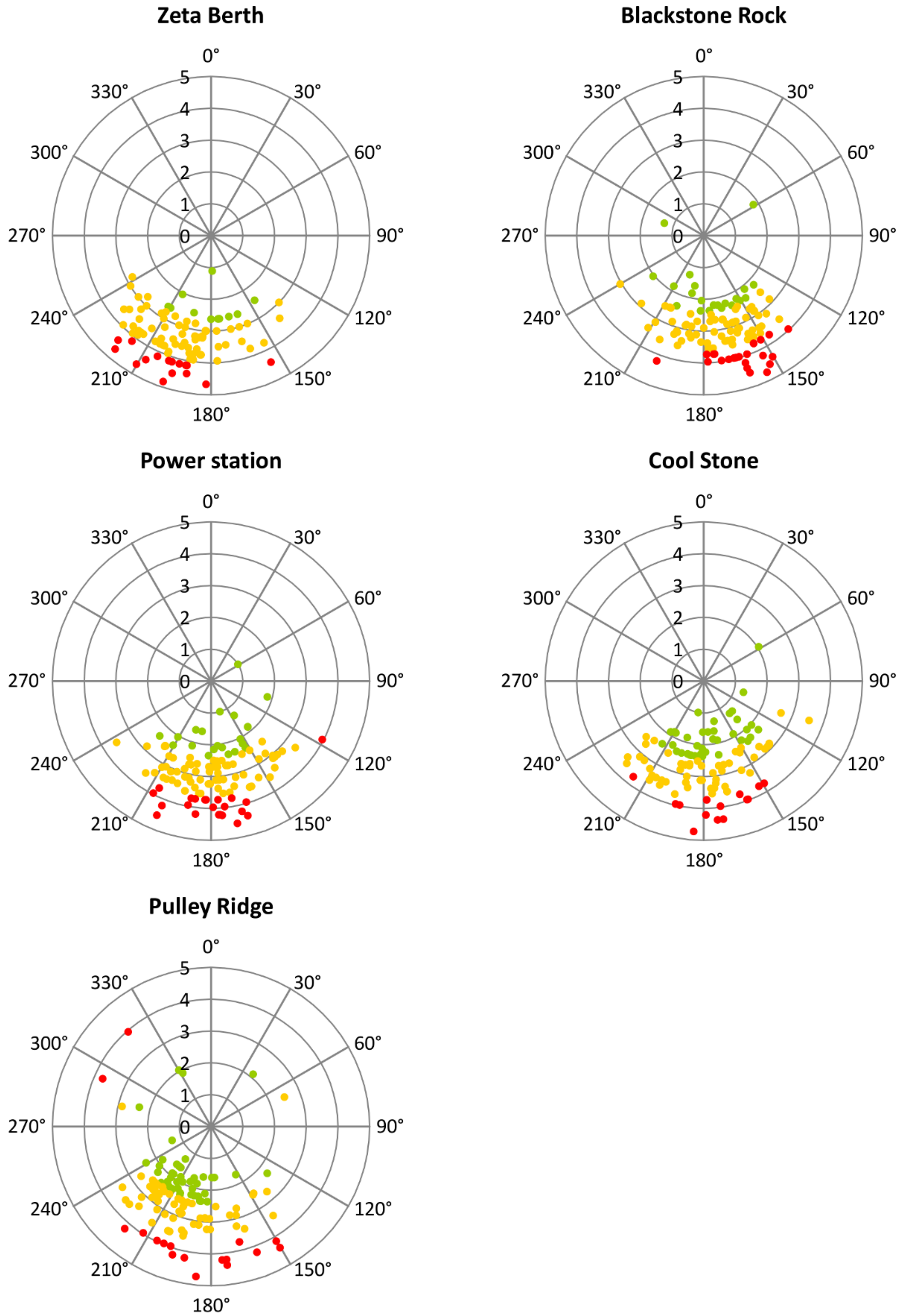


Figure XI.8: Polar plots of log10* E. coli *results (MPN/100g) in against high/low tidal state

Figure XI.9 presents polar plots of log10 *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.

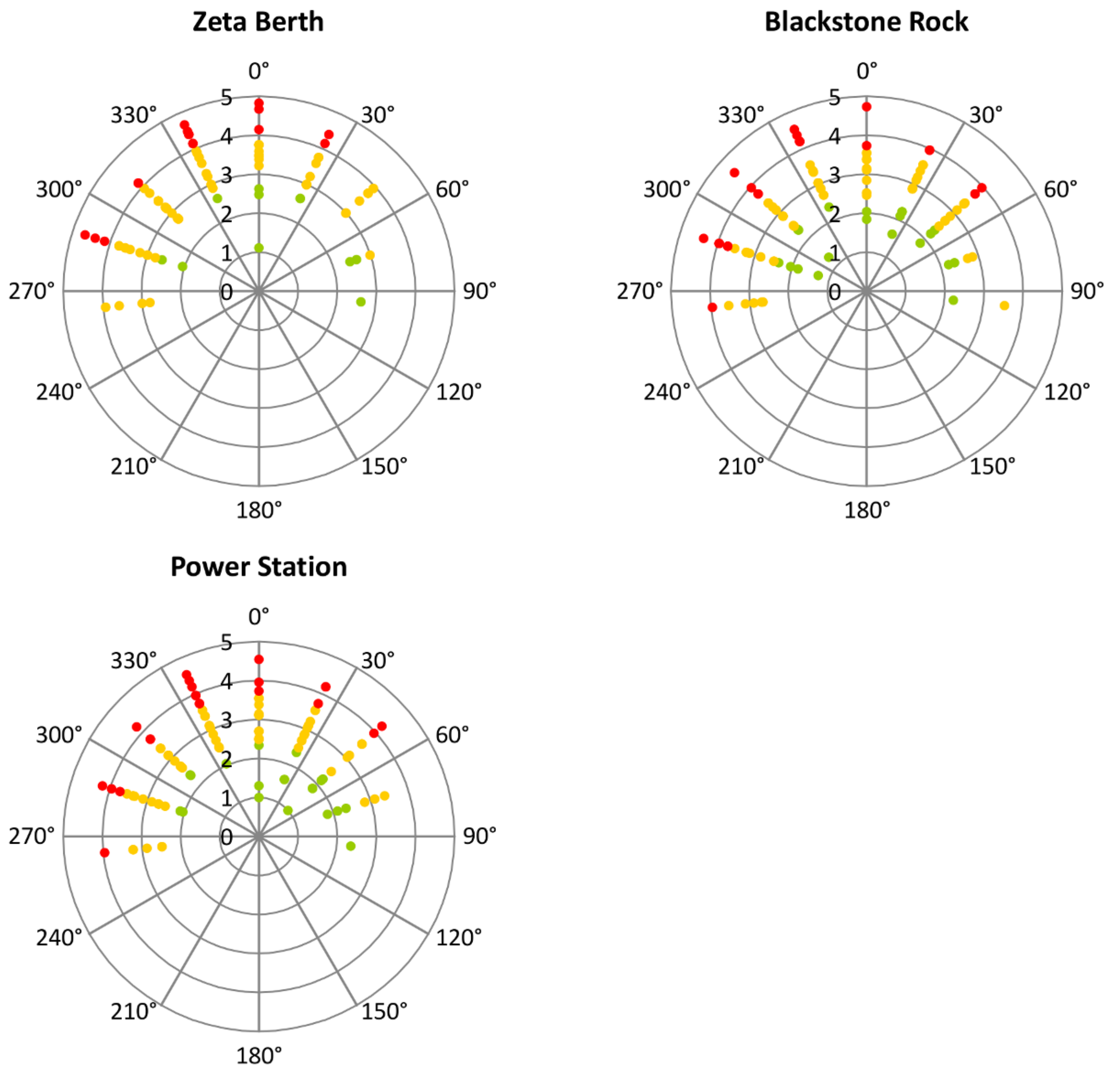


Figure XI.9: Polar plot of log10* E. coli *results (MPN/100g) against spring/neap tidal state

Most of the mussel samples were collected around low water as tide size increased towards springs.. While correlations were found between the tidal state and *E. coli* levels at some mussel RMPs, no clear patterns are evident on the polar plots.

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 Chivenor weather station (Appendix VI for details) over various periods running up to sample collection. These are presented in Table XI.6, and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table XI.6 Spearman's Rank correlations between rainfall recorded at Chivenor and shellfish hygiene results

	Site	Zeta Berth	Blackstone Rock	Power Station	Cool Stone	Spratt Ridge	Lifeboat Slipway	Neck Gut	Pulley Ridge	Zeta Berth
	Species	Mussel								Pacific oyster
	n	92	111	115	106	120	119	113	119	19
24 hour periods prior to sampling	1 day	0.024	0.085	0.163	0.140	0.173	0.201	0.126	0.185	-0.004
	2 days	0.229	0.280	0.247	0.292	0.203	0.250	0.275	0.284	0.289
	3 days	0.388	0.373	0.340	0.419	0.331	0.283	0.333	0.379	-0.017
	4 days	0.275	0.197	0.212	0.349	0.290	0.322	0.151	0.341	0.225
	5 days	0.143	0.179	0.177	0.247	0.160	0.160	0.101	0.186	0.039
	6 days	0.172	0.207	0.206	0.255	0.099	0.170	0.218	0.060	-0.040
	7 days	0.097	0.148	0.141	0.223	0.236	0.115	0.163	0.265	0.191
Total prior to sampling over	2 days	0.182	0.267	0.295	0.29	0.206	0.264	0.247	0.276	0.218
	3 days	0.344	0.355	0.385	0.423	0.303	0.317	0.348	0.377	0.227
	4 days	0.409	0.365	0.408	0.457	0.366	0.380	0.396	0.427	0.278
	5 days	0.393	0.357	0.382	0.440	0.359	0.355	0.361	0.409	0.163
	6 days	0.401	0.367	0.394	0.450	0.343	0.353	0.380	0.372	0.145
	7 days	0.398	0.373	0.390	0.469	0.367	0.348	0.390	0.383	0.204

Rainfall has a large effect on *E. coli* levels found in mussel flesh in the Taw and Torridge area. At most sites, this effect is strongest between 2 days and 4 days after rainfall. At Cool Stone rocks, the effects of rainfall continue for at least 7 days after rainfall. While there was an effect of rainfall at Zeta Berth in mussels, the same effect was not observed in Pacific oysters. This may be due to the low number of samples of Pacific oysters which have been taken not providing sufficient data to detect an effect or differing effects of decreased salinity on the feeding physiology of these two species.

APPENDIX XII
SHORELINE SURVEY

Date (time): 14 January 2013 (08:30-15:30)
15 January 2013 (08:30-14:30)

Cefas Officer: Alastair Cook

Local Enforcement Authority Officers:
Dean Davies (North Devon District Council)

Area surveyed: Outer reaches of Taw / Torridge estuary complex

Weather: 14 January 2013 - Wind NW force 3, 5°C, overcast
15 January 2013 - Wind NE force 3, 3°C, overcast

Tidal predictions for Appledore (Admiralty TotalTide):

Appledore, 51°03' N 04°12' W. Times are GMT. Predicted heights are in metres above chart datum.

15/1/2013			16/1/2013		
Low	01:45	0.4 m	Low	02:30	0.6 m
High	07:00	7.3 m	High	07:45	7.1 m
Low	14:15	0.3 m	Low	14:55	0.6 m
High	19:30	6.8 m	High	20:10	6.5 m

Objectives:

The shoreline survey aims to obtain samples of freshwater inputs to the area for bacteriological testing; confirm the location of previously identified sources of potential contamination; locate other potential sources of contamination that were previously unknown; find out more information about the fishery. A full list of recorded observations is presented in Table and the locations of these observations are mapped in Figure . Photographs referenced in Table are presented in Figure XII.2 - Figure XII.25.

Description of Fishery

A full shellfish stock survey was beyond the scope of the shoreline survey, and this report only presents observations made during the survey. The main mussel beds in the outer Taw estuary and the estuary mouth were visible from the shore at low tide. Those further upstream around Chivenor were not uncovered at the time this area was surveyed. There is little, if any harvesting activity on the mussel beds at present. Cockle shells were seen in numerous locations around the shore suggesting there may be substantial concentrations of this species in places. Clam shells were also observed in large numbers, but these were not from species which are currently harvested commercially in England & Wales. Razors are reported to occur in Bideford Bay between the estuary mouth and Westward Ho. The LEA has never been approached by any parties expressing an interest in classifying cockles, razors or clams.

The Pacific oyster trestle site by Zeta Berth was observed towards low water. This consists of an area of no more than about 20mx20m where Pacific oysters are cultured in suspended triangular net bags (Observation 45) at about the spring tide low water line. There was also a separate row of bags slightly higher up the shore where mussels are held for hygiene sampling purposes. It was not possible to walk around the trestles with the GPS as the tide had not receded fully. The harvester has recently established depuration facilities in Appledore.

Sources of contamination

Sewage discharges

The following continuous discharges to the estuary were observed:

- RMB Chivenor private sewage works (discharge sampled, water clear, 19,000 *E. coli* cfu/100ml).
- Braunton Inn (formerly Tarka Inn) package plant observed but outfall covered by tide.

The locations of several of the intermittent discharges to the estuary were tentatively confirmed:

- Yelland PS (observation 27)
- Appledore PS (observation 33)
- Skern CSO (observation 38)

It is presumed that any others which were not seen although the surveyors passed by their locations feed into the various surface water outfalls which were observed.

Additionally, a possible unregistered sewage discharge was seen at the Skern (observation 32).

Freshwater inputs

All significant surface water inputs to shorelines adjacent to any shellfisheries were sampled and measured (Table XII.2) apart from those where access was not possible (observation 25 and a marsh outfall to the Caen estuary).

Livestock

Livestock were recorded in numerous locations. These include around the Caen estuary, on the south bank of the Taw between Fremington and Yelland, and on the golf course at Northam Burrows. At Northam Burrows livestock have access to the shoreline so may deposit faeces on the intertidal. On the east bank of the Caen estuary, livestock sometimes escape and graze on the intertidal saltmarsh. Their presence in these areas is year round. Also of potential significance is an area of saltmarsh which is used for grazing sheep on a year round basis on the south bank of the Taw estuary between Penhill Point and Sticklepath, although this area was not visited during the shoreline survey.

Wildlife

Wading birds and some seagulls and their droppings were frequently sighted on the intertidal throughout the survey but no major aggregations were recorded. Flocks of geese were recorded on pastures by Yelland (observation 19) and on salt grass at Northam Burrows (observation 29).

Large numbers of dog walkers were seen on the beach at Instow and a few were seen on the Northam Burrows.

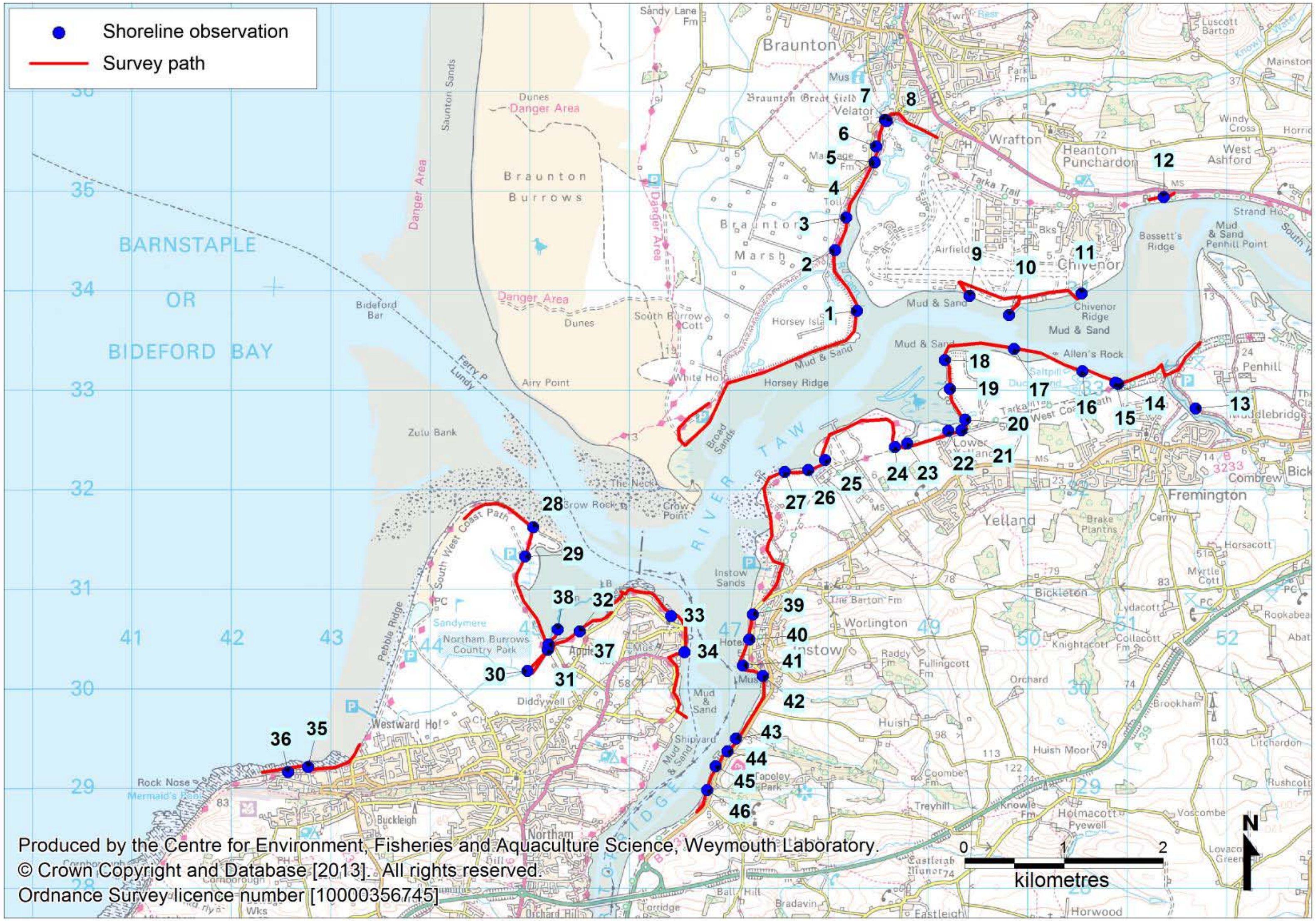


Figure XII.1: Locations of shoreline observations for the Taw Torridge estuary (see Table XII.1 for details)

Table XII.1: Details of shoreline observations

No.	Date and time	NGR	Photograph	Observation
1	15-JAN-13 9:41:23AM	SS 48287 33799		Cattle sometimes escape onto saltmarsh on opposite bank
2	15-JAN-13 9:52:08AM	SS 48068 34406	Figure XII.3	About 15 boats on moorings/bank. Sheep sometimes on salt grass here
3	15-JAN-13 9:59:32AM	SS 48180 34736	Figure XII.4	Possible houseboat. Cotton but in tideline
4	15-JAN-13 10:12:09AM	SS 48464 35288		About 70 sheep on field on opposite bank. Sometimes up to 150 sheep or 30 cattle.
5	15-JAN-13 10:12:40AM	SS 48466 35289	Figure XII.5	Outfall pipe by brick shed (ex factory discharge?)
6	15-JAN-13 10:18:29AM	SS 48479 35450	Figure XII.6	About 20 houseboats and 20 yachts. Smoke from some houseboat chimneys.
7	15-JAN-13 10:26:17AM	SS 48569 35716		Stream 10.5m wide, 30cm deep & 0.353m/s at point 1, 40cm deep and 0.287m/s at point 2. Water sample 1.
8	15-JAN-13 10:33:14AM	SS 48587 35705	Figure XII.7	Stream, 4.7m wide, 22cm deep, 0.731m/s, water sample 2. 2 flap valves on concrete structure.
9	15-JAN-13 11:10:30AM	SS 49418 33949	Figure XII.8	Surface water outfall, 140cmx5cmx0.273m/s. Water sample 3.
10	15-JAN-13 11:22:43AM	SS 49816 33756	Figure XII.9	RMB Chivenor STW outfall. Water sample 4.
11	15-JAN-13 11:37:21AM	SS 50543 33973	Figure XII.10	Stream 1mx9cmx0.214m/s. Water sample 5.
12	15-JAN-13 11:50:58AM	SS 51369 34938	Figure XII.11	Package plant serving Braunton Inn, about 10 houseboats in corner just downstream.
13	15-JAN-13 12:44:09PM	SS 51691 32816		Pumping station outfall on opposite bank?
14	15-JAN-13 1:03:45PM	SS 50909 33065		Stream 65cmx4cmx0.210m/s. Water sample 6
15	15-JAN-13 1:05:56PM	SS 50884 33075	Figure XII.12	15cm cast iron pipe to intertidal. Not flowing. Field drain?
16	15-JAN-13 1:14:46PM	SS 50553 33190	Figure XII.13	Stream 115cmx15cmx0.542m/s. Water sample 7.
17	15-JAN-13 1:38:29PM	SS 49866 33415		Fresh sanitary debris (rag)
18	15-JAN-13 1:51:26PM	SS 49171 33303		Field of 22 sheep
19	15-JAN-13 1:55:59PM	SS 49220 33013		~50 sheep, ~50 geese.
20	15-JAN-13 2:01:23PM	SS 49374 32705	Figure XII.14	~50 sheep in field. Stream 44cmx8cmx0.301m/s. Water sample 8.
21	15-JAN-13 2:08:42PM	SS 49337 32597		3 horses
22	15-JAN-13 2:13:36PM	SS 49206 32594	Figure XII.15	Stream 90cmx11cmx0.169m/s. Water sample 9.
23	15-JAN-13 2:24:23PM	SS 48791 32466		Stream 80cmx15cmx0.069m/s. Water sample 10.
24	15-JAN-13 2:30:55PM	SS 48670 32432		Outfall, tricking, too small to sample/measure.
25	15-JAN-13 2:49:17PM	SS 47966 32301	Figure XII.16	Small stream seeping from bottom of concrete structure, not possible to access.
26	15-JAN-13 2:55:46PM	SS 47796 32200	Figure XII.17	Stream 155cmx12cmx0.324m/s. Water sample 11.
27	15-JAN-13 3:02:21PM	SS 47562 32181	Figure XII.18	Yelland PS outfall, not flowing
28	16-JAN-13 9:18:41AM	SS 45033 31625		~50 sheep, have access to intertidal all around this area.
29	16-JAN-13 9:48:10AM	SS 44953 31330		~100 geese on small patch of salt grass. A few dog walkers in the area.
30	16-JAN-13 10:01:59AM	SS 44977 30182		Stream 130cmx40cmx0.404m/s. Water sample 12.
31	16-JAN-13 10:10:21AM	SS 45181 30393		4 horses.
32	16-JAN-13 10:21:19AM	SS 45502 30580	Figure XII.19	12cm orange plastic sewer pipe to intertidal. Variable flow, but measured at

				100ml/sec. Water sample 13.
33	16-JAN-13 10:53:23AM	SS 46420 30735	Figure XII.20	Appledore pumping station. Tanks under car park. Outfall covered by tide.
34	16-JAN-13 11:02:38AM	SS 46554 30372		Moorings/pontoons between here and WP34.
35	16-JAN-13 11:30:08AM	SS 42773 29216	Figure XII.21	Possible CSO off sewer pipe which runs all along this shore. Trickling but probably just tide draining from rockpools. Water sample 14.
36	16-JAN-13 11:40:32AM	SS 42573 29166	Figure XII.22	Pipe outfall 10cmx2cmx0.582m/s. Water sample 15.
37	16-JAN-13 12:21:02PM	SS 45189 30449	Figure XII.23	Pipe flowing ~500ml/sec. Water sample 16.
38	16-JAN-13 12:32:50PM	SS 45282 30600	Figure XII.24	Outfall, 60cmx20cmx1.864m/s. Water sample 17. This might be the same water as WP31, although uncertain how it arrives at this outfall.
39	16-JAN-13 1:02:09PM	SS 47239 30748	Figure XII.25	Stream 35cmx2cmx0.251m/s. Water sample 18. Many dog walkers on beach.
40	16-JAN-13 1:09:33PM	SS 47208 30498	Figure XII.26	Road drain 8cmx1cmx0.570m/s. Water sample 19.
41	16-JAN-13 1:19:16PM	SS 47142 30236		Stream 110cmx13cmx0.372m/s. Water sample 20.
42	16-JAN-13 1:23:29PM	SS 47341 30132	Figure XII.27	Double culvert from which WP43 stream originates. One flowing, one just trickling. Smaller one may be Instow A PS outfall.
43	16-JAN-13 1:39:40PM	SS 47072 29504		Stream 70cmx2cmx0.491m/s. Water sample 21.
44	16-JAN-13 1:48:02PM	SS 46986 29377		Stream 120cmx12cmx0.174m/s. Originates from same ditch as WP45 so water not resampled.
45	16-JAN-13 1:52:37PM	SS 46867 29223	Figure XII.28	Small area of trestles about 15mx15m due west of here. About 25m further off than the pier head. Not sufficiently uncovered to walk around recording corners.
46	16-JAN-13 2:05:37PM	SS 46780 28987	Figure XII.29	Stream 110cmx10cmx0.110m/s. Water sample 22.

Sample results

Freshwater inputs were sampled and spot discharge measurements taken, to give spot estimates of their *E. coli* loadings (Table and Figure). Due to the extensive microbiological monitoring history of the Taw/Torridge estuary no seawater or shellfish sampling was considered necessary.

Table XII.2: Water sample* E. coli *results and estimated stream loadings

Sample No.	Date and Time	Position	Description	*E. coli* (cfu/100ml)	Flow (m³/day)	*E. coli* (cfu/day)*
1	15/01/2013 10:26	SS 48569 35716	River Caen	1200	101606	$1.22x10^{12}$
2	15/01/2013 10:33	SS 48587 35705	Knowle Water	750	65306	$4.90x10^{11}$
3	15/01/2013 11:10	SS 49418 33949	Unnamed watercourse	100	1651	$1.65x10^{9}$
4	15/01/2013 11:22	SS 49816 33756	RMB Chivenor STW	19000	370**	$7.03x10^{10}$
5	15/01/2013 11:37	SS 50543 33973	Unnamed watercourse	170	1664	$2.83x10^{9}$
6	15/01/2013 13:03	SS 50909 33065	Unnamed watercourse	100	472	$4.72x10^{8}$
7	15/01/2013 13:14	SS 50553 33190	Unnamed watercourse	1900	8078	$1.53x10^{11}$
8	15/01/2013 14:01	SS 49374 32705	Unnamed watercourse	100	915	$9.15x10^{8}$
9	15/01/2013 14:13	SS 49206 32594	Unnamed watercourse	2100	1446	$3.04x10^{10}$
10	15/01/2013 14:24	SS 48791 32466	Unnamed watercourse	1300	715	$9.30x10^{9}$
11	15/01/2013 14:55	SS 47796 32200	Unnamed watercourse	260	5207	$1.35x10^{10}$
12	16/01/2013 10:01	SS 44977 30182	Unnamed watercourse	200	18151	$3.63x10^{10}$
13	16/01/2013 10:21	SS 45502 30580	Orange plastic sewer pipe	<100	9***	$4.32x10^{6}$
14	16/01/2013 11:30	SS 42773 29216	Surface water outfall	<100	Trickle	Negligible
15	16/01/2013 11:40	SS 42573 29166	Outfall pipe	700	101	$7.04x10^{8}$
16	16/01/2013 12:21	SS 45189 30449	Outfall pipe	<100	43	$2.16x10^{7}$
17	16/01/2013 12:32	SS 45282 30600	Outfall for Skern CSO	200	19326	$3.87x10^{10}$
18	16/01/2013 13:02	SS 47239 30748	Road drain	100	152	$1.52x10^{8}$
19	16/01/2013 13:09	SS 47208 30498	Road drain	1200	39	$4.73x10^{8}$
20	16/01/2013 13:19	SS 47142 30236	Unnamed watercourse	800	3954	$3.16x10^{10}$
21a	16/01/2013 13:39	SS 47072 29504	Unnamed watercourse	1800	594	$1.07x10^{10}$
21b	16/01/2013 13:48	SS 46986 29377	Unnamed watercourse	1800	2165	$3.90x10^{10}$
22	16/01/2013 14:05	SS 46780 28987	Unnamed watercourse	100	1045	$1.05x10^{9}$

*Numbers of *E. coli* per day introduced to coastal waters from each input, calculated from spot gauging of discharges and corresponding water sample *E. coli* results.
**Consented Dry weather flow rather than actual measurement
***Flow noticeably variable at time of survey

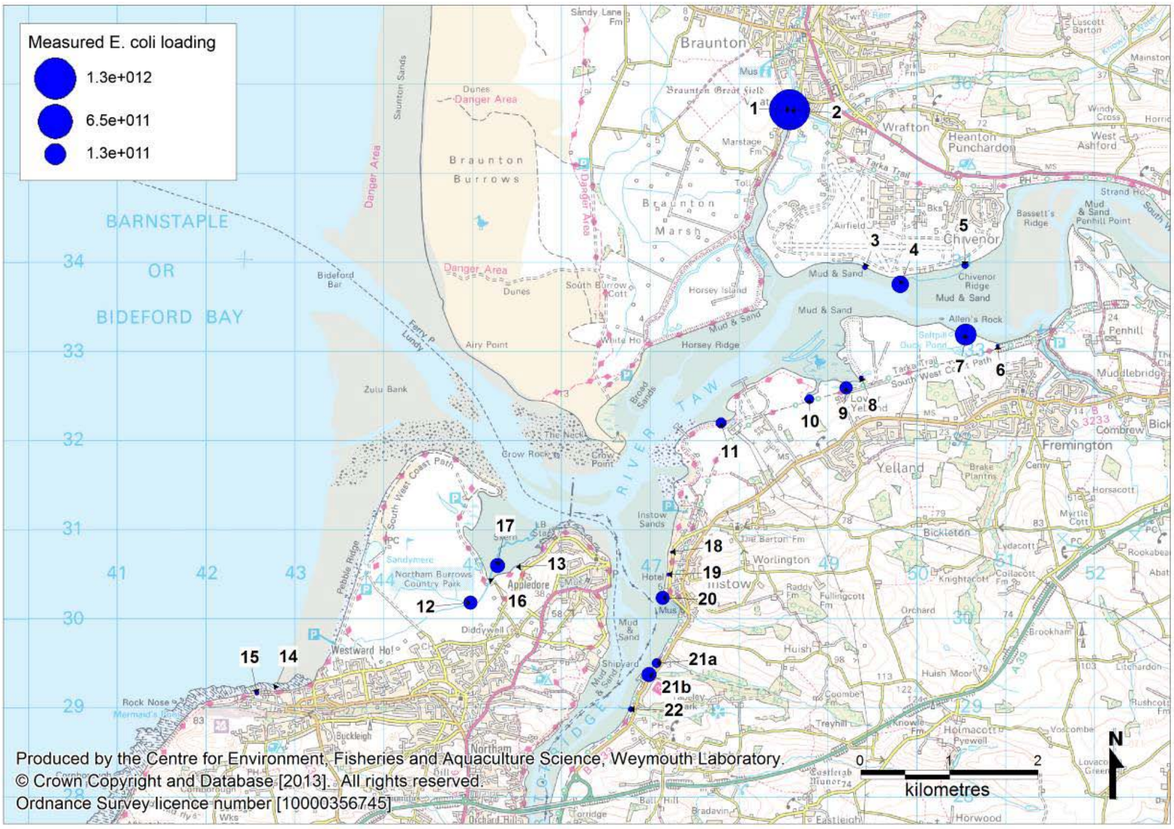


Figure XII.2: Thematic map of measured* E. coli *loadings

The most significant freshwater inputs are the River Caen and Knowle water, with a combined *E. coli* loading of 1.71×10^{12}. The watercourse discharging at Allens Rock (7) carried a loading of 1.53×10^{11} *E. coli*/day. All other inputs were relatively minor ($<10^{11}$) and only likely to be of localised significance. Samples 12 and 17 are likely to be repeat measurements of the same watercourse, which was measured on the Northam Burrows at High water, had somehow infiltrated into the pipe outfall when the area was passed again once the tide had receded. The possible sewer pipe outfall (13) contained <100 *E. coli* cfu/100ml so was not carrying any foul water at the time. At the oyster farm, the watercourses draining to the north of the trestles were carrying higher loadings than the one draining to the south although all were relatively minor.

Figure XII.3

Figure XII.2

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

Figure XII.12

Figure XII.13

Figure XII.14

Figure XII.15

Figure XII.16

Figure XII.17

Figure XII.18

Figure XII.19

Figure XII.20

Figure XII.21

Figure XII.22

Figure XII.23

Figure XII.24

Figure XII.25

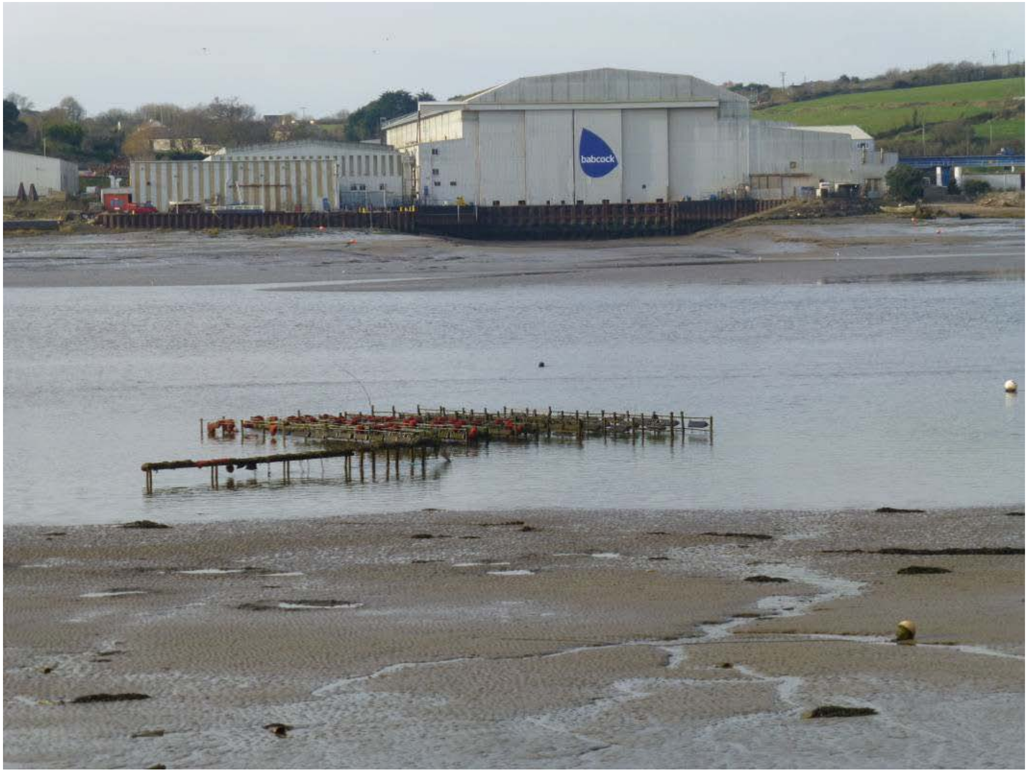


Figure XII.28

Figure XII.29

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List of Abbreviations

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

Glossary

Bathing Water	Element of surface water used for bathing by a large number of people. Bathing waters may be classed as either EC designated or non-designated OR those waters specified in section 104 of the Water Resources Act, 1991.
Bivalve mollusc	Any marine or freshwater mollusc of the class Pelecypoda (formerly Bivalvia or Lamellibranchia), having a laterally compressed body, a shell consisting of two hinged valves, and gills for respiration. The group includes clams, cockles, oysters and mussels.
Classification of bivalve mollusc production or relaying areas	Official monitoring programme to determine the microbiological contamination in classified production and relaying areas according to the requirements of Annex II, Chapter II of EC Regulation 854/2004.
Coliform	Gram negative, facultatively anaerobic rod-shaped bacteria which ferment lactose to produce acid and gas at 37°C. Members of this group normally inhabit the intestine of warm-blooded animals but may also be found in the environment (e.g. on plant material and soil).
Combined Sewer Overflow	A system for allowing the discharge of sewage (usually dilute crude) from a sewer system following heavy rainfall. This diverts high flows away from the sewers or treatment works further down the sewerage system.
Discharge	Flow of effluent into the environment.
Dry Weather Flow (DWF)	The average daily flow to the treatment works during seven consecutive days without rain following seven days during which rainfall did not exceed 0.25 mm on any one day (excludes public or local holidays). With a significant industrial input the dry weather flow is based on the flows during five working days if production is limited to that period.
Ebb tide	The falling tide, immediately following the period of high water and preceding the flood tide. Ebb-dominant estuaries have asymmetric tidal currents with a shorter ebb phase with higher speeds and a longer flood phase with lower speeds. In general, ebb-dominant estuaries have an amplitude of tidal range to mean depth ratio of less than 0.2.
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 N^{th} root of the product of those numbers. It is more usually calculated by obtaining the mean of the logarithms of the numbers and then taking the anti-log of that mean. It is often used to describe the typical values of skewed data such as those following a log-normal distribution.
Hydrodynamics	Scientific discipline concerned with the mechanical properties of liquids.
Hydrography	The study, surveying, and mapping of the oceans, seas, and rivers.
Lowess	LOcally WEighted Scatterplot Smoothing, more descriptively known as locally weighted polynomial regression. At each point of a given dataset, a low-degree polynomial is fitted to a subset of the data, with explanatory variable values near the point whose response is being estimated. The polynomial is fitted using weighted least squares, giving more weight to points near the point whose response is being estimated and less weight to points further away. The value of the regression function for the point is then obtained by evaluating the local polynomial using the explanatory variable values for that data point. The LOWESS fit is complete after regression function values have been computed for each of the *n* data points. LOWESS fit enhances the visual information on a scatterplot.
Telemetry	A means of collecting information by unmanned monitoring stations (often rainfall or river flows) using a computer that is connected to the public telephone system.
Secondary Treatment	Treatment to applied to breakdown and reduce the amount of solids by helping bacteria and other microorganisms consume the organic material in the sewage or further treatment of settled sewage, generally by biological oxidation.
Sewage	Sewage can be defined as liquid, of whatever quality that is or has been in a sewer. It consists of waterborne waste from domestic, trade and industrial sources together with rainfall from subsoil and surface water.
Sewage Treatment Works (STW)	Facility for treating the waste water from predominantly domestic and trade premises.
Sewer	A pipe for the transport of sewage.
Sewerage	A system of connected sewers, often incorporating inter-stage pumping stations and overflows.
Storm Water	Rainfall which runs off roofs, roads, gulleys, etc. In some areas, storm water is collected and discharged to separate sewers, whilst in combined sewers it forms a diluted sewage.
Waste water	Any waste water but see also “sewage”.

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