EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Fowey Estuary (Cornwall)

2010

Cover photo: oyster trestles at Pont Pill - Relay.

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STATEMENT OF USE: This report provides information from a desk study evaluation of the information available relevant to perform a sanitary survey of bivalve mollusc production areas in the Fowey Estuary, Cornwall. Its primary purpose is to demonstrate compliance with the requirements for classification of bivalve mollusc production areas in EC Regulation 854/2004, laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption. The Centre for Environment, Fisheries and Aquaculture Science (Cefas) undertook this work on behalf of the Food Standards Agency (FSA).

DISSEMINATION: Food Standards Agency, Fowey Port Health Authority, Environment Agency.

CONTENTS

1 INTRODUCTION

1.1 LEGISLATIVE REQUIREMENT

Filter feeding, bivalve molluscan shellfish (e.g. oysters, mussels) retain and accumulate a variety of microorganisms from their natural environments. Since filter feeding promotes retention and accumulation of microorganisms, the microbiological safety of bivalve molluscs for human consumption depends heavily on the quality of the waters from which they are taken (Bell, 2006).

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 human and or animal microbiological contamination.

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 shellfish with pathogens is assessed through the microbiological monitoring of shellfish. 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[1], laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption, competent authorities are required to undertake a number of activities collectively known (in England and Wales) as “sanitary surveys”.

The Centre for Environment Fisheries and Aquaculture Science (Cefas) is performing sanitary surveys for new BMPAs in England and Wales, on behalf of the Food Standards Agency (FSA). The purpose of these sanitary surveys is 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 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

[1] See Section 6, Annex II of the Regulation.

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 and is therefore indicative of contamination of faecal origin.

In addition to better targeting the location of RMPs and frequency of monitoring, it is believed that sanitary surveys may serve to help to target future water quality improvements and better analyse their effects on BMPAs. 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 quantitative assessment made of the levels of microbiological contamination in bivalves from the Fowey Estuary, Cornwall and presents the recommended sampling plan as a result of a sanitary survey undertaken by Cefas on behalf of the Food Standards Agency (FSA).

1.2 SITE DESCRIPTION

FOWEY ESTUARY

The Fowey Estuary is situated in south Cornwall, southwest coast of England (Figure 1.1). It is a flooded river valley ria (drowned river valley) formed by post glacial sea level rise infiltrating river valleys during the last ice age. The estuary is approximately 11km in length covering approximately 4km^2 at high tide. Table 1.1 summarises the main morphological characteristics of the estuary. The outline is branching and the entrance to the estuary is relatively narrow with bedrock shores leading to sedimentary shorelines further into the estuary between Mixtow (Figure 1.2) and Golant and in small tributaries such as Pont Pill creek (Figure 1.3).

Table 1.1 Main characteristics of the Fowey Estuary.

Geomorphological type	Ria
Shoreline length (km)	39.2
Core area (ha)	304.8
Intertidal area (ha)	146

Data from the Estuary Guide (ABPmer and Wallingford, 2009).
Intertidal refers to the area between MHWS and MLWN tidal levels.

Figure 1.1 Aerial view of the Fowey Estuary showing its main localities and tributaries.
Reproduced under licence Google Earth™ mapping service.

Figure 1.2 Aerial view of the Fowey Estuary at Mixtow.
Reproduced under licence Google Earth™ mapping service.

Figure 1.3 Aerial view of the Fowey Estuary at Pont Pill.
Reproduced under licence Google Earth™ mapping service.

From Golant, there is a shallow gradient through open moorland with low intensity “hill” farming leading into steep sided wooded valley where it continues to flow through wooden valleys bounded by agricultural land use. The upper reaches of the estuary have largely silted up leaving extensive mudflats (Figure 1.4) and sandflats.

Figure 1.4 Middle reaches of Pont Pill at low tide.
Photo courtesy of Philip Halling.

The Fowey Estuary is biologically rich, both in terms of biodiversity and habitats. These are recognised by a number of nature conservation designations: Lantic Bay is a Special Area of Conservation (SAC), and there are various Special Sites of Scientific Interest (SSSI). The upper reaches of the River Fowey flow through an Area of Outstanding Natural Beauty (AONB) and a Special Area of Great Landscape Value. The estuary itself is also within the boundary of an AONB.

The main commercial uses of the estuary include shipping, coastal fisheries and tourism, in particular water-based activities (e.g. rowing, canoeing, sub-aqua). Fowey is also a busy commercial China Clay port (Figure 1.5).

The estuary contains several designated areas for salmon, sea trout, eels and bass fisheries. Bait harvesting also takes place in estuary.

Figure 1.5 IMERYS Port terminal in Fowey.

CATCHMENT

For the purposes of this assessment, the bivalve mollusc production area (BMPA) is under the influence of pollution sources from two river catchments: Fowey and Fowey (tidal) (Figure 1.6) (total area = 27,590 hectares). The catchment drains the area of southeast Cornwall from the southern slopes of Bodmin Moor to the south coast.

Land uses in these catchments include natural and improved grassland (over 60% of the total catchment area) and a significant proportion of woodland along river valleys (less than 18% of the catchment area). The percentage of built-up areas does not exceed 3% of the catchment.

There is no heavy industry within the catchment though historically there have been quite extensive areas of mineral extraction, particularly copper, tin, lead and zinc and China clay.

Tourism and recreation are vital sectors of the local economy.

Employment is provided directly through the boatyards and related industry as well as indirectly through a wide range of businesses reliant on tourist and leisure spending to maintain their livelihoods.

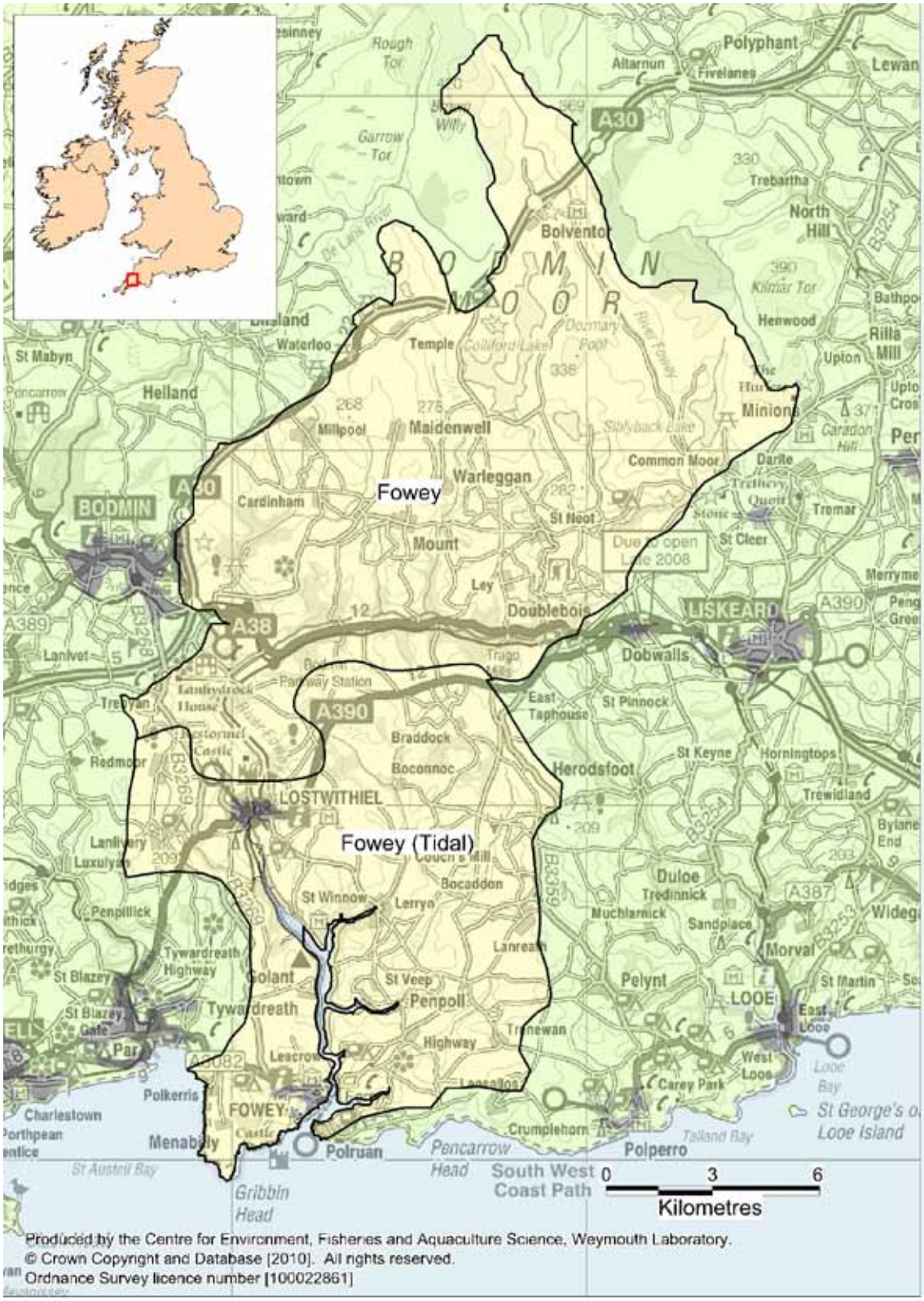


Figure 1.6 Location of river catchments draining to the Fowey Estuary.

2. SHELLFISHERIES

2.1 SPECIES, LOCATION AND EXTENT

The harvesting of bivalve molluscs for human consumption is an activity with some tradition in the Fowey Estuary. In the past, commercial operations for native oysters (*O. edulis*) (Laing *et al*., 2005) and Manila clams (*Tapes philippinarum*) were established in the estuary. Native oysters were classified in 1992, whereas clams were classified between 1996 and 2004. Subsequently, the commercial interest for this species was lost, partially due to persistent water quality problems.

More recently, commercial operations for mussels (*Mytilus* spp.) and Pacific oysters (*Crassostrea gigas*) have been established at Pont Pill and Wiseman's.

Historical classifications for these species in the Fowey Estuary for the period 1996–2009 are summarised in Table 2.1. Provisional classifications for all mussel beds in the estuary were given in 1992, following the implementation of statutory controls on the commercial production of bivalve molluscs in England and Wales. Microbiological monitoring was suspended for some time because beds were not being commercially harvested. In 1998, a separate classification was attributed for mussels and Pacific oysters at Pont Pill when further cultivation operations for this species were re-established. Initial classifications for Pacific oysters at Pont Pill were given in 1996. Both species obtained classifications at Wiseman's in 1999 (Table 2.2).

Table 2.1 Historical classifications of bivalve molluscs in the Fowey Estuary.

Bed name	Pont Pill	Pont Pill	Pont Pill - Relay	Wiseman's	Wiseman's
Bed ID	B070P	B070Q	B070M	B070K	B070S
Species	*C. gigas*	*Mytilus* spp.	*Mytilus* spp.	*C. gigas*	*Mytilus* spp.
1996	C	-	-	-	-
1997	B	-	-	-	-
1998	B	B	-	-	-
1999	B	B	-	B	B
2000	B	B	-	B	B
2001	B	B	B	B	B
2002	B	B	B	B	B
2003	B	B	B	B	B
2004	B	B	B[1]	B	B
2005	B-LT	B	B-LT	B	B[1]
2006	B-LT[1]	B-LT[1]	B-LT	B	B
2007	B-LT[1]	B-LT[1]	B-LT	B	B[1]
2008	B-LT	B-LT[1]	B-LT[1]	B[1]	C
2009	B-LT	B-LT[1&2]	-	B[2]	B

[1] *Area classified at higher level, due to results close to the tolerance limit.*
[2] *Results close to the tolerance limit. A downgrade may be possible if further failures are returned.*
LT - Long-Term classification system applies. NB. Long-Term (LT) classification system was introduced in England and Wales alongside the annual classification system, and applies to class B areas only. New class B areas will initially be given annual classification until they meet criteria for a long-term classification.

Table 2.2 summarises the post-harvest treatment required before bivalve molluscs can be sold for human consumption.

Table 2.2 Criteria for classification of bivalve mollusc production areas.

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

[1] *The reference method is given as ISO 16649-3.*
[2] *By cross-reference from EC Regulation 854/2004, via EC Regulation 853/2004, to EC Regulation 2073/2005.*
[3] *From EC Regulation 1021/2008.*
[4] *From EC Regulation 854/2004.*
[5] *This level is not specifically given in the Regulation but does not comply with classes A, B or C. The competent authority has the power to prohibit any production and harvesting of bivalve molluscs in areas considered unsuitable for health reasons.*

Figure 2.1 shows locations of classified beds for Pacific oysters and mussels and current representative monitoring points (RMPs). Classification zone boundaries and classification status for these species are shown in Figures 2.2–2.3.

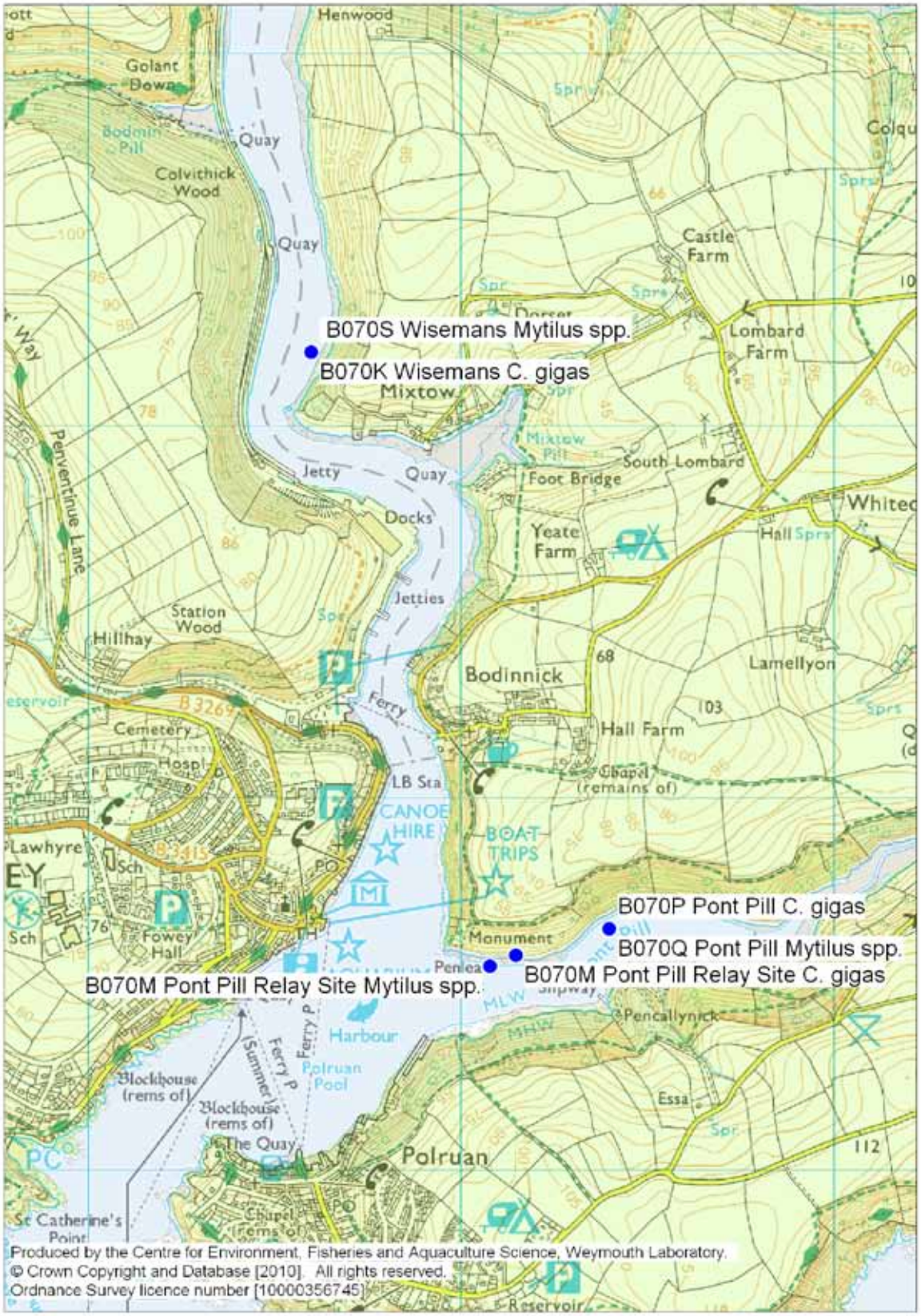
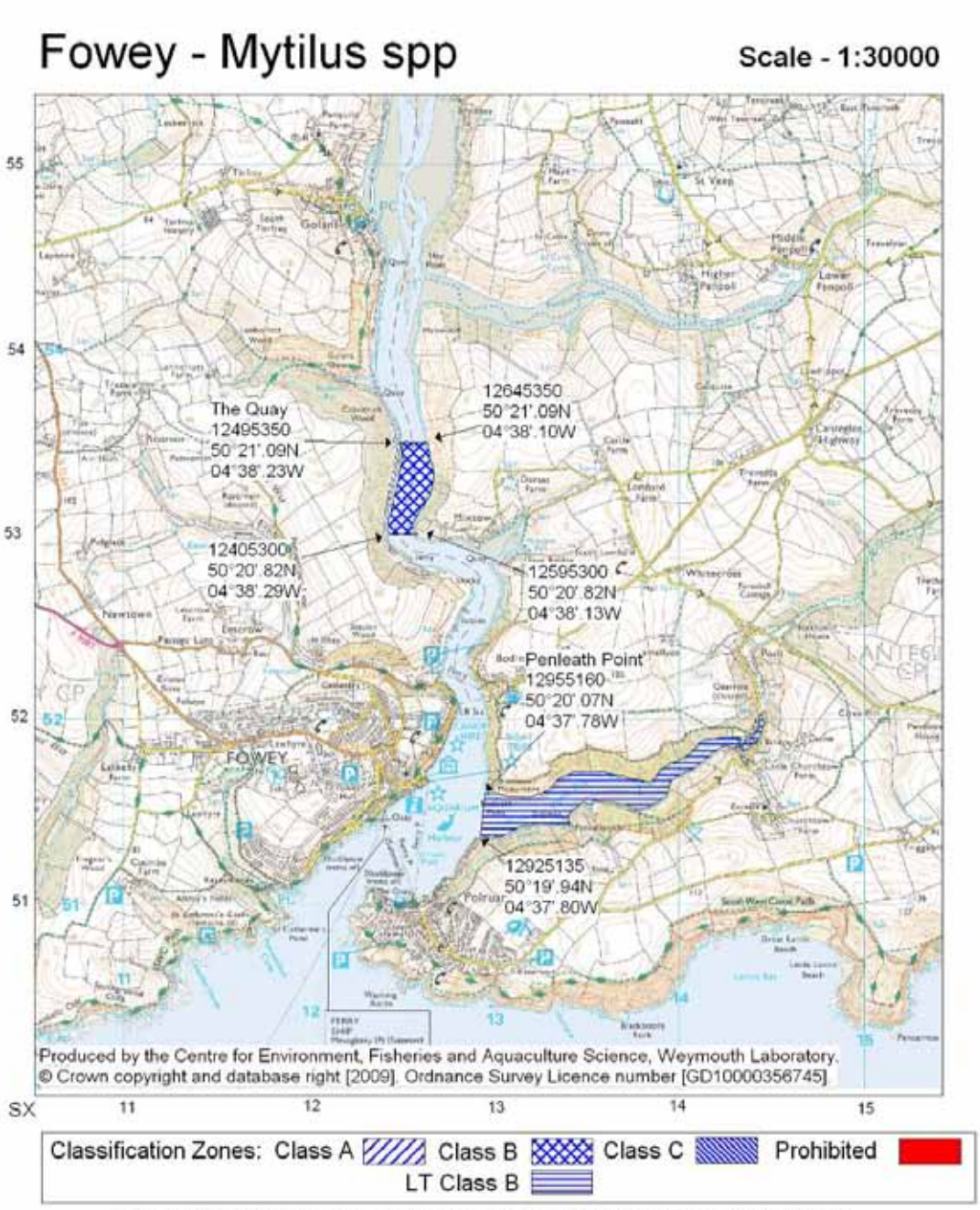


***Figure 2.1 Location of representative monitoring points (current) in the Fowey Estuary. Mussels - Mytilus* spp.; Pacific oysters - *Crassostrea gigas*.**



Classification of Bivalve Mollusc Production Areas: Effective from 1 September 2009

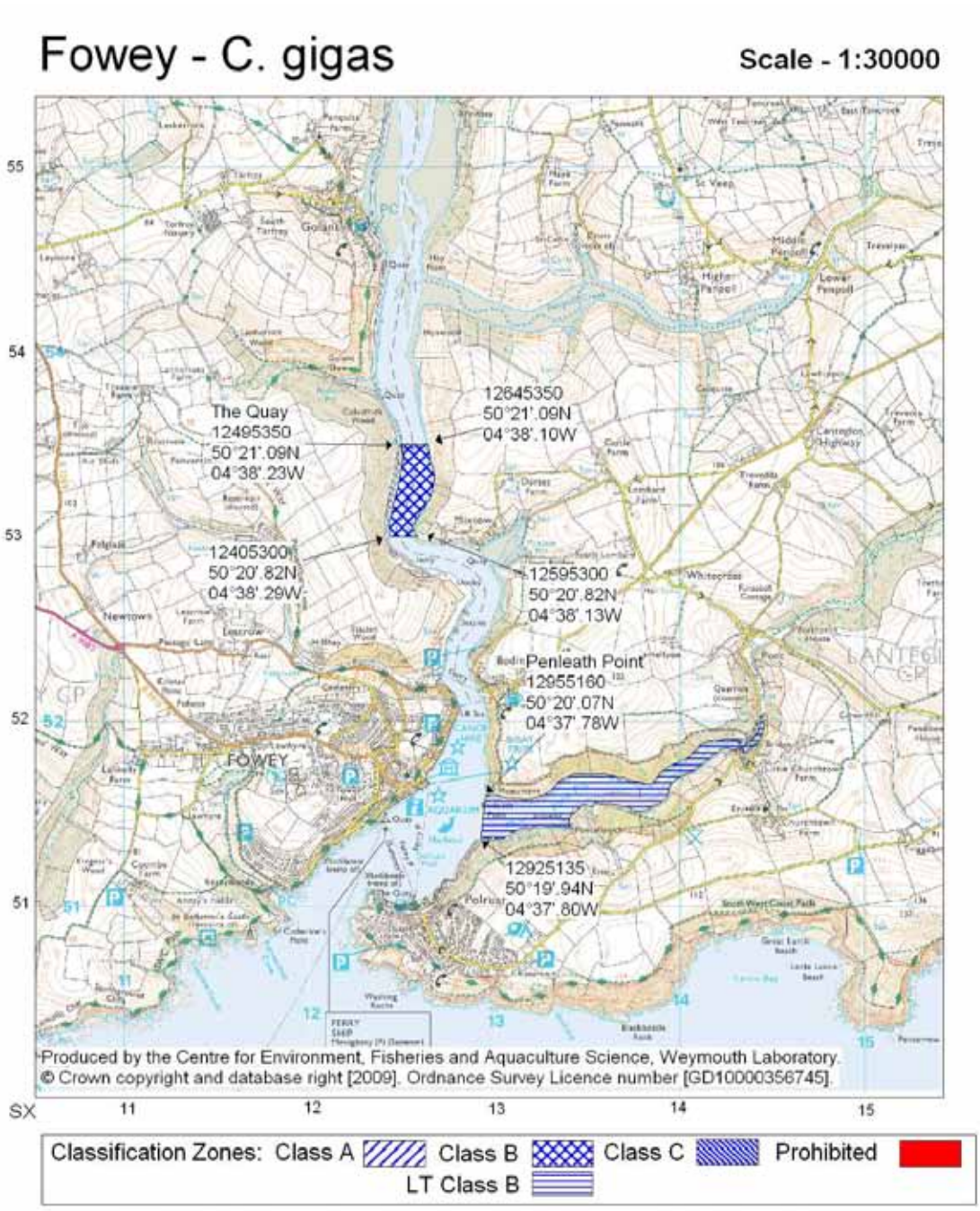
The areas delineated above are those classified as bivalve mollusc production areas under EU Regulation 854/2004.

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 Fowey

Food Authority: Fowey Port Health Authority

Figure 2.2 Existing production area and current classification status of mussels in the Fowey Estuary.



Classification of Bivalve Mollusc Production Areas: Effective from 15 September 2009

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 Fowey

Food Authority: Fowey Port Health Authority

Figure 2.3 Existing production area and current classification status of Pacific oysters in the Fowey Estuary.

Both *Mytilus galloprovincialis* and *Mytilus edulis* have been recorded in the coasts of southwest England (National Biodiversity Network Gateway, 2009). However, literature indicates that both species present large morphological, physiological and behavioural similarities and are therefore difficult to differentiate for commercial purposes due to adaptations to environmental conditions (see Wijsman and Smaal, 2006 and references therein). Data from molecular analyses have highlighted high levels of hybridisation[2] and gene introgression[3] between these species in the southwest of England. Therefore, in the context of the present sanitary survey, the taxonomy of mussels is referred at genus level.

Mussels are often found in sheltered coasts and estuaries, just below the low water, where a food supply of suspended organic detritus and phytoplankton is available (Tebble, 1976).

The Pacific oyster is a non-native species in the UK (Spencer *et al*., 1994) that shows enhanced growth and survival compared with the native oyster. On the other hand, disease free progeny of imported adult stock in the past has helped commercial hatcheries to sustain large scale production (Spencer, 2002).

Commercial operations of Pacific oysters in the Fowey depend on the regular supply of seed from the Camel Estuary. The supply of mussel stock to commercial operations in the Fowey Estuary is provided by classified beds in Falmouth, Camel Estuary and St. Austell Bay (Ropehaven).

2.2 GROWING METHODS AND HARVESTING TECHNIQUES

Mussels and oysters at Wiseman's and Pont Pill are grown in bags supported above the riverbed on trestles. Both species are harvested by hand during periods of low water over the tidal cycle.

Pont Pill has been used both as a production and relaying area for mussels. Cefas has been informed by Fowey Harbour Authority that this area was used when classification at Wiseman's was downgraded to class C. There is interest from the shellfish industry to maintain this bed as a back up reserve area for this purpose (John Pegg, pers. comm.).

2.3 SEASONALITY OF HARVEST, CONSERVATION CONTROLS AND DEVELOPMENT POTENTIAL

All bivalves in the Fowey Estuary are harvested on a weekly basis during the year.

In 2008, mussel production was approximately 203 tonnes. Oyster production in the same year exceeded 100,000 oysters.

[2] The formation of a hybrid organism, e.g. by a cross between genetically dissimilar organisms.
[3] The incorporation of the genes of one species into the gene pool of another species.

The riverbed is owned by Fowey Harbour Authority. Shellfish industry members pay a rent in order to use the riverbed for commercial production of bivalve molluscs.

The commercial production of bivalves in the Fowey Estuary is not managed by Several, Regulating or Hybrid Order.

It has been considered that some commercial uses of the estuary (e.g. yachting, china clay terminal) may reduce the potential for further aquaculture development (MacAlister, Elliot & Partners Ltd., 1999).

3. OVERALL ASSESSMENT

AIM

This section presents an assessment of pollution sources impacting on the microbiological contamination of the bivalve mollusc production area (BMPA) in the Fowey Estuary (Cornwall), as a result of a sanitary survey undertaken by Cefas on behalf of the Food Standards Agency. Its main purpose is to inform the sampling plan for the microbiological monitoring and classification of mussels (*Mytilus* spp.) and Pacific oysters (*Crassostrea gigas*) in this estuary.

SHELLFISHERIES

The currently classified beds for farmed mussels and Pacific oysters occur in intertidal sandflats and mudflats on the East side of the main river channel at Mixtow (Wiseman's Reach) and at Pont Pill creek at the confluence with the main estuary[4]. Pont Pill has been designated as both a production and relaying area for mussels.

Relaying areas are sea, estuarine or lagoon areas clearly marked and indicated by buoys, posts or any other fixed means used exclusively for the natural purification of live bivalve molluscs. These areas have the same sanitary survey requirements as production areas as determined by European Union legislation[5]. Furthermore, they must operate on a batch basis, i.e. "all in all out" system. Batches should not be mixed at any time.

Mussels and Pacific oysters are grown in bags supported above the river bed on trestles established along the foreshore[6]. Bivalves growing in intertidal drying areas are not covered by water during periods of low water and therefore cannot accumulate microbial contaminants during these periods. The location of these beds was updated during a shoreline performed in the estuary on 23–24 February 2009.

These bivalve mollusc beds are under the jurisdiction of Fowey Port Health Authority (Local Enforcement Authority).

POLLUTION SOURCES

The River Fowey (mean flow = 4.82m^3 s^{-1} at Restormel)[7] drains microbiological contamination from a catchment with approximately 27,590hectares, from its headwaters on Bodmin moor to the sea along a distance of approximately 40km[8]. The estuary receives freshwater inputs from the River Lerryn (a tributary of the Fowey) and other minor tributaries. These constitute the most significant routes of contamination of faecal origin from the wider catchment to the estuary.

[4] 2. Shellfisheries.
[5] Annex II, Chapter II A.6 of Regulation (EC) No 854/2004.
[6] Figure XIII.6–XIII.8.
[7] Appendix III.
[8] Figure 1.3.

Water levels in watercourses across the Fowey catchment are significantly controlled by impermeable geological formations across the catchment, the effect of Colliford and Sibblyback reservoirs at the headwaters and the high slope gradient across the catchment.

The average runoff coefficients at River Fowey increase substantially between July (28mm) and December (141mm). Monthly total rainfall increases between June (87mm) and December (181mm)[9]. Rainfall accounts for a significant proportion of runoff in the river during the period June–September and this is considered to be the period of higher risk of runoff contamination from the wider catchment.
Water levels in the River Fowey are characterised by rapid rises and falls in response to rainfall. This "flashy" response may give rise to peaks of contamination delivered during periods of high river flow discharge.

The catchment is predominantly rural and mostly (nearly 70%) used for agricultural purposes[10]. Livestock production on natural and improved grassland is one of the main activities in the catchment. Livestock production areas will represent high risk of faecal contamination to the estuary when animals have direct access to watercourses or when there are hydrological connections between grazing areas and the tidal waters. Microbial deterioration of the water quality in the estuary will be also expected when manure/slurries (biosolids) are spread shortly before/during rainfall, as a result of inadequate storage or when biosolids are spread near a watercourse. Farmers were intensively spreading slurry immediately prior the shoreline survey and this is said to be common practice.

Freshwater samples collected during the shoreline survey[11] 2009 indicated the following gradient in *E. coli* loadings of faecal contamination (*E. coli* day^{-1}):

- River Lerryn: 4.1×10^{11};
- Stream below Lerryn STW: 4.8×10^{10};
- River Fowey: 6.3×10^{9};
- Milltown stream 3.9×10^{9}; and
- Stream at Golant: 3.2×10^{9}.

Microbial loads from all the above watercourses will impact on bivalve molluscs at Wiseman's. Concentrations of the microbiological indicator in shellfish samples from Wiseman's bed were, at the time of the survey, within the range for class B (MPN of *E. coli* $100g^{-1}$ fluid and intravalvular liquid≤4,600).

Loadings of *E. coli* in one stream discharging to Pont Pill Creek (4.5×10^{10} *E. coli* day^{-1}) were of the same order of magnitude of those in Penpoll Creek (3.1×10^{10} *E. coli* day^{-1}) suggesting that both watercourses contribute significantly to the overall microbial load to the estuary. However, three shellfish samples from Pont Pill returned concentrations of *E. coli* within the range for class A (MPN of

[9] Appendix III.
[10] Appendix VIII.
[11] Appendix XIII.

E. coli 100g^{-1} fluid and intravalvular liquid≤230) indicating that this bed might not be heavily impacted by pollution sources further upstream.

The total human population in the Fowey catchment is approximately 10,400[12]. This compares with a significantly higher number of farmed animals [(mostly sheep (c. 51,470 animals) and cattle (c. 33,980 animals[13]]. Furthermore, the average human population density across most of the Fowey river catchment is less than 0.16 people per ha, whereas that across most of the Fowey tidal river catchment is less than 0.27 people per ha[14]. This compares with a significantly higher average density for England and Wales (3.4 people per ha). This suggests that pollution sources of animal origin may significantly contribute to microbiological loads to the estuary.

A number of continuous and intermittent sewage discharges representing a significant or potentially significant impact on the microbial quality of the estuary occur within 10km of the estuary or its tidal limit[15]. The most significant water company continuous discharges are: Lanteglos Highway Sewage Treatment Works (STW) (primary), Bodinnick STW (DWF = 52.8 m^3 day^{-1}; approximately 1.4km south of Wiseman's Reach bed), Lerryn STW (DWF = 79.5 m^3 day^{-1}; approx. 4.2km from Wiseman's bed), Golant STW (DWF = 66 m^3 day^{-1}; approx. 1.2km from Wiseman's bed) and Lostwithiel STW (DWF = 6.78 litres sec^{-1}; approx. 6km from Wiseman's bed). Another fifteen intermittent discharges (emergency and storm overflows) discharge to the River Fowey or directly to the estuary. The locations of Lostwithiel STW, Lanteglos STW, Lerryn STW and two other significant intermittent discharges (Coulston Park PS and Lanteglos PS) were observed during the shoreline survey. Effluents from Fowey STW (tertiary; DWF = 1,185 m^3 day^{-1}) receive tertiary treatment (UV disinfection) and overall this discharge is considered to represent less impact to bivalve molluscs. There have been occasional periods of deteriorated microbial quality of effluent discharges from these STW. Furthermore, levels of faecal coliforms in these effluents have been significantly (Kruskal-Wallis test: H = 18.21; p = 0.000) higher in the summer than those in the winter. However, average levels are well above the reference values referred in the literature for this level of treatment.

The Fowey Estuary provides habitats for a significant number of species of waterbirds[16]. These birds tend to feed and roost in areas of saltmarsh and mudflats in the upper and middle reaches of the estuary. This was observed during the shoreline survey[17]. The most abundant species are Curlew, Mallard and Shellduck. Low densities of Cormorant, Mute Swan and Grey Heron occur in the lower reaches of the estuary[18].

Previous studies have found significant concentrations of microbial contaminants in intertidal sediment samples in UK coastal areas and that

[12] Appendix I.
[13] Appendix VIII.
[14] Appendix I.
[15] Appendix VII.
[16] Appendix IX.
[17] Appendix XIII.
[18] Appendix IX.

approximately 10% of faecal matter could be deposited under a roost. Birds are thought to contribute to background levels of contamination in the Fowey Estuary. Beds at Wiseman's Reach are likely to be more vulnerable to faecal matter from birds than those situated at Pont Pill.

The Port of Fowey is of regional importance for commercial shipping and sailing[19]. The estuary receives over 7,200 craft each year. Two main sailing clubs operate from Fowey. There are approximately 1,500 permanent moorings within Fowey Harbour limits and four floating pontoons for visitor craft.

It has long been established that sewage discharged from boats could represent a significant public health risk for bivalve mollusc beds. However, the contribution from this source is difficult to estimate due to the intermittent nature of these discharges. Sewage pump out facilities are available at Berril's Yard pontoon and this could minimise the risk of a pollution incident associated with these discharges. However, the discharge of ballast water to the estuary is permitted under some circumstances, as determined by Harbour Byelaw. The discharge of ballast water is cause for concern from the hygiene point of view since there is growing evidence that this is an important mechanism of introduction of microbial pathogens in harbours. The main risk would correspond to the main period of use (May–September).

Dogs are allowed on two beaches (Readymoney Cove and Whitehouse) of the inner estuary between 1 October and Easter. Dog faeces deposited onto sandy beaches may constitute significant sources of contamination to bivalve mollusc beds during this period.

A schematic representation of the most significant pollution sources likely to impact the microbial status of BMPAs in the Fowey Estuary is shown in Figure 3.1.

[19] Appendix X.

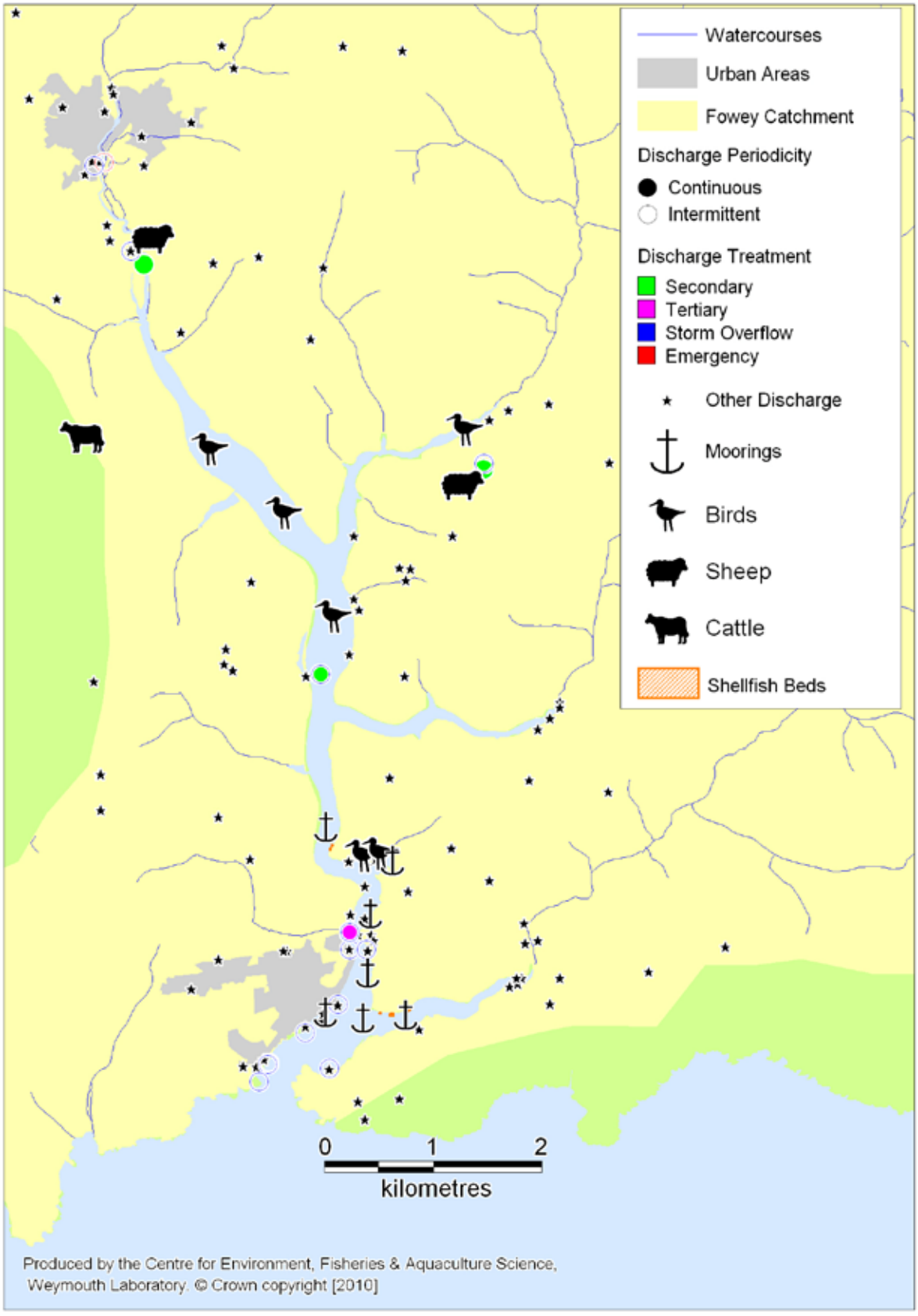


Figure 3.1 Significant pollution sources impacting on the microbial status of bivalve mollusc production areas in the Fowey Estuary.

HYDRODYNAMICS

The Fowey is a shallow[20], macro-tidal (mean spring tidal range = 4.8m) estuary, with a tidal length of approximately 11km and an estimated residence time of three days[21]. Extensive areas in the upper reaches of the estuary dry on low water springs. This was noted at the time of the shoreline survey. This will markedly reduce the time over which contamination will impact on bivalve molluscs.

The maximum averaged suspended particulate matter concentration[22] in the Fowey is lower than that in other estuaries in the southwest United Kingdom (e.g. Dart, Helford, Salcombe, Fal). This fact combined with the low residence time suggests that the estuary mouth is well mixed.

Tidal currents of 0.71m s^{-1} have been recorded in the lower estuary. High tidal currents, the macro-tidal regime relative to the overall bathymetric profile across the lower reaches of the estuary will promote dilution of microbiological contamination in bivalve mollusc beds at the mouth of Pont Pill.

The bathymetric profile of the Fowey Estuary suggests that water flows may follow a rectilinear (back and forth) pattern along the main river channel. Bivalve mollusc beds will be impacted by microbial contamination from pollution sources situated at the mouth of the estuary during the flood tide. Conversely, the river plume will be the primary mechanism of transport of contamination from the wider catchment.

Bivalve mollusc beds will be impacted by contamination from this channel and Penpoll and Pont Pill creeks. Consideration is given in the sampling plan for recommending a representative monitoring point (RMP) in the north edge of Wiseman's bed since this area will be more vulnerable to multiple sources of contamination from the wider catchment.

SUMMARY OF HISTORICAL MICROBIOLOGICAL DATA

Levels of faecal coliforms in surface waters at Readymoney designated bathing water have shown periods of deteriorated water quality in recent years[23]. The high geometric mean of the microbiological indicator in 2008 (112) is consistent with the existence of appreciable sources of pollution at the mouth of the estuary[24].

Historical data from the Shellfish Hygiene monitoring programme suggests the following trend in the levels of contamination between beds: Wiseman's>Pont Pill (Pacific oysters); Wiseman's>Pont Pill> Pont Pill - Relay (mussels)[25].

[20] Appendix IV.
[21] Appendix V.
[22] Appendix V.
[23] Appendix XI.
[24] Appendix VII.
[25] Appendix XII.

Correlation analyses between rainfall and levels of *E. coli* in bivalves showed significant positive relationships (Spearman's *rho* coefficient; 95% confidence level) between levels of rainfall and levels of the microbiological indicator in mussels from Pont Pill - Relay and in Pacific oysters from Pont Pill when sampling occasions occurred two, five and seven days after the rainfall event[26].

Statistically significant correlations were also obtained between rainfall and levels of *E. coli* in mussels from Pont Pill when sampling occurred five and seven days after the rainfall event. This indicates that bivalves growing at Pont Pill are particularly affected by rainfall-dependent discharges and/or diffuse pollution from the catchment after rainfall events. Consideration is given in the sampling plan for recommending an RMP in the confluence of these pollution sources.

Analysis of historical data from the Shellfish Hygiene monitoring programme evidenced an increase in geometric means of *E. coli* in bivalves during summer months[27]. This could be related to increasing human presence in the catchment due to tourism related activities.

4. RECOMMENDATIONS

The results from the sanitary survey suggest that two classification zones (CZs) may adequately represent the variation of microbiological contamination across and between bivalve mollusc beds in the Fowey Estuary:

- one CZ encompassing mussel and Pacific oyster beds at Wiseman's Reach, defined by lines approximately 10m from the edge of the beds and from the Mean High Walter Line to the limit of the administrative boundary along the river channel as shown in Figure 5.1;

- a second CZ to encompass mussel and Pacific oyster beds at Pont Pill defined by lines approximately 10m from the edge of the beds and from the Mean High Water Line to a line along the middle of the creek as shown in Figure 5.1;

- one Representative Monitoring Point (RMP) for mussels and pacific oysters situated in the northernmost bed will best represent the extent of microbiological contamination from sewage discharges and diffuse pollution from agricultural land and birds delivered from the wider catchment to the River Fowey, River Lerryn and Penpoll Creek.

- one RMP for mussels and Pacific oysters situated in the westernmost bed will best represent the extent of contamination delivered from sewage discharges at Fowey and runoff delivered to Pont Pill, particularly during rainfall events.

[26] Appendix XII.
[27] Appendix I.

§ The recommended maximum tolerance for RMPs is 10 metres. This tolerance minimises the effects of spatial variability in the extent of contamination whilst preserving the fixed geographical location.

5. SAMPLING PLAN

GENERAL INFORMATION

LOCATION REFERENCE

Production Area	Fowey Estuary
Cefas Main Site Reference	M070
Cefas Area Reference	FDR 3529
Ordnance survey 1:25,000 map	OS Explorer 107: St. Austell & Liskeard
Admiralty Chart	UKHO Chart 31: Harbours of the South Coast of Cornwall Imray C6: Salcombe to Lizard Point

SHELLFISHERY

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

LOCAL ENFORCEMENT AUTHORITY

Name of Local Enforcement Authority	Fowey Port Health Authority 24B Station Road FOWEY Cornwall PL23 1DF
Port Health Officer	John Pegg
Telephone number (	01726 832740
E-mail š	fowey@cieh.org.uk

REQUIREMENT FOR REVIEW

The need for this sampling plan to be reviewed will be assessed by the competent authority within six years or in light of any obvious known changes in sources of pollution of human (e.g. improvements in sewage treatment works) or animal origin likely to be a source of contamination for the bivalve mollusc production area.

Table 5.1 Number and location of representative monitoring points (RMPs) and frequency of sampling for classification zones in the Fowey Estuary.

Classification zone			**Wiseman's**	**Wiseman's**	**Pont Pill**	**Pont Pill**
RMP			**B070Z**	**B70AA**	**B70AB**	**B70AC**
RMP name			**Wiseman's**	**Wiseman's**	**Pont Pill**	**Pont Pill**
Geographic grid references (datum) of sampling points	**Eastings** **Northings**		212590 53130	212590 53130	213020 51570	213020 51570
	NGR		SX 1259 5313	SX 1259 5313	SX 1302 5157	SX 1302 5157
	WGS84	**Latitude** **Longitude**	50°20.89'N 4°38.13'W	50°20.89'N 4°38.13'W	50°20.05'N 4°37.72'W	50°20.05'N 4°37.72'W
Species			*Mytilus* spp.	*Crassostrea gigas*	*Mytilus* spp.	*Crassostrea gigas*
Growing method			Farmed	Farmed	Farmed	Farmed
Harvesting technique			Hand-picking	Hand-picking	Hand-picking	Hand-picking
Sampling method			Hand-picking	Hand-picking	Hand-picking	Hand-picking
Depth (m)			Riverbed	Depth of bags	Riverbed	Depth of bags
Tolerance for sampling points (m)			10	10	10	10
Frequency of sampling (FULL Classification)			At least monthly	At least monthly	At least monthly	At least monthly

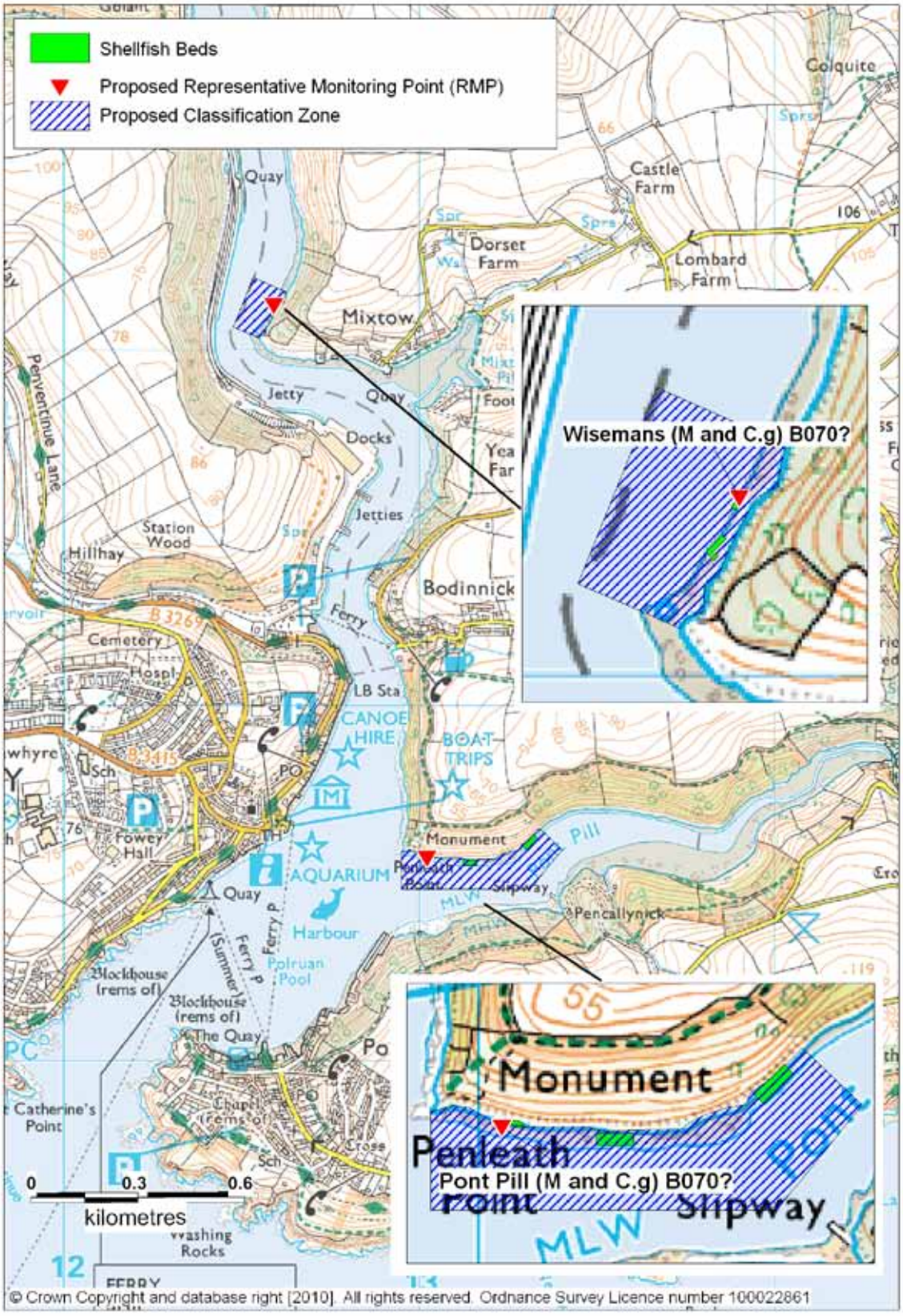


Figure 5.1 Location of recommended representative monitoring points (RMP) and classification zone boundaries for mussels and Pacific oysters in the Fowey Estuary.

Appendix I
HUMAN POPULATION

The distribution of human population by Super Output Area Boundary totally or partially included within river catchment areas is shown in Figure I.1. Population density has its maximum in the town of Fowey (16 people per hectare). Other densely populated areas are Bodmin, Liskeard and St Austell. This compares with densities at Cornwall and Isles of Scilly (1.3 people per hectare) and England as a whole (3.2 people per hectare) (Office for National Statistics, pers. comm.).

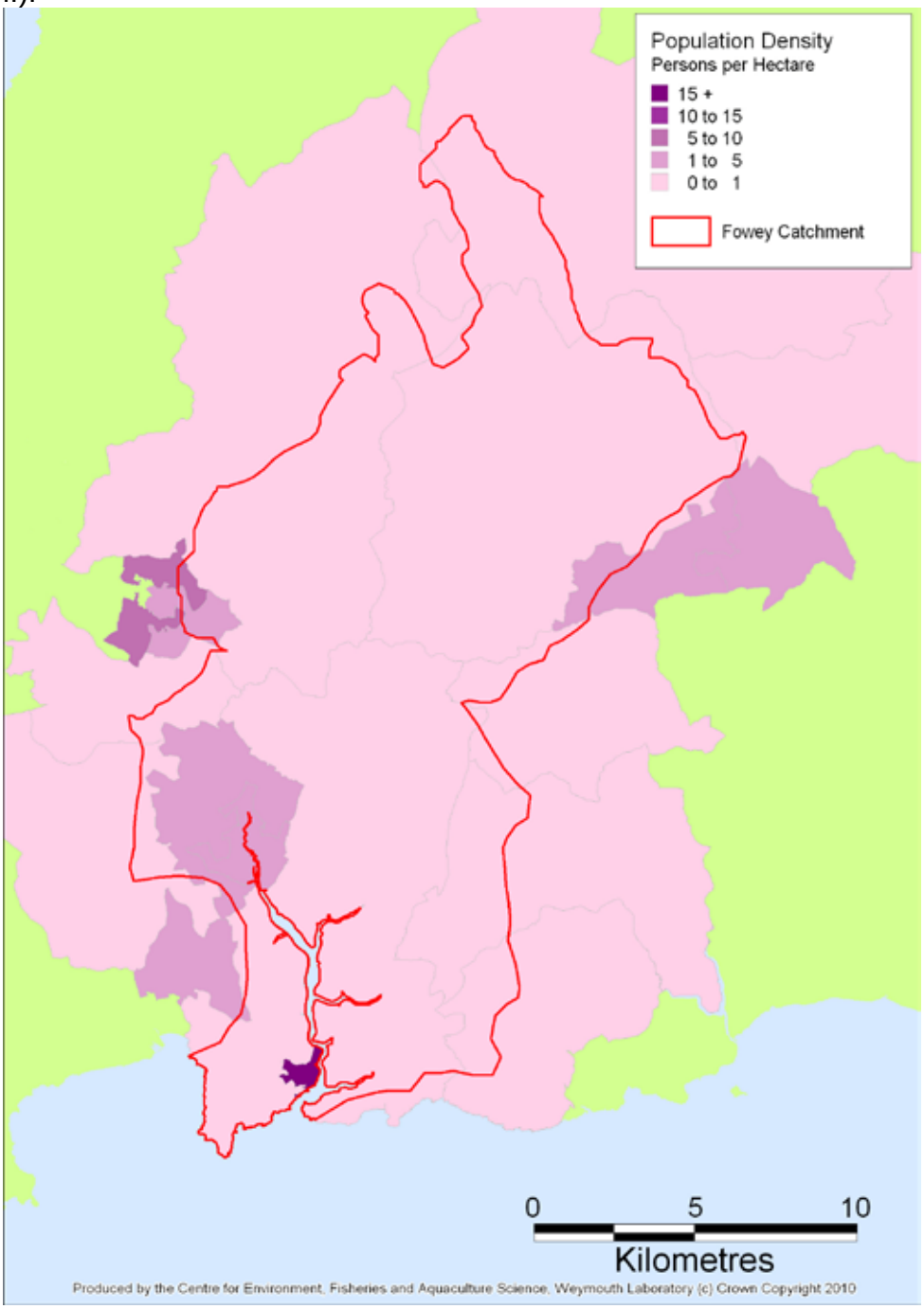


Figure I.1 Human population density in catchments draining to the Fowey Estuary.
Source: ONS, Super Output Area Boundaries. Crown copyright 2004. Crown copyright material is reproduced with the permission of the Controller of HMSO.

Total resident population within river catchments draining to the estuary is summarised in Table I.1.

Table I.1 Human population in river catchments draining to the Fowey Estuary.

River catchment	Population
Fowey	2,459
Fowey (tidal)	7,934
Total	10,393

Data from Office for National Statistics (2007).

Urbanised areas contain the majority of point-sources of pollution (continuous and intermittent sewage discharges) in these catchments. An inventory of the most significant sewage discharges to the estuary is given in the Appendix VII.

Urbanised areas also contain the vast majority of impervious surfaces[28] (e.g. roads, parks, pavements), which are known to contribute with significant loads of microbiological contaminants (Ellis and Mitchell, 2006)[29]. Therefore, bivalve molluscs commercially harvested in the vicinity of urbanised areas tend to show deteriorated microbiological quality.

Tourism is very significant to the local economy. The Eden Project is one of the top tourism attractions in England, with over 1.1M visitors in 2007 (South West Tourism, 2007). Another locally significant attraction is Bodmin and Wenford Railway, with over 46,000 visitors in 2007 (South West Tourism Research Department, 2007).

More than two thirds of tourists visit Cornwall during the period June–August (Visit Cornwall, 2005; South West Tourism Research Department, 2007). About three quarters of these visits last for seven nights or less and over 60% of trips are short breaks and extra holidays (Visit Cornwall, 2005).

The microbiological load attributed to tourism is expected to fluctuate on a seasonal basis in line with changes in visitor numbers and occupancy rates of holiday accommodation. Analysis of seasonal variation of faecal coliforms in effluent discharges from Fowey Sewage Treatment Works is presented in the Appendix VII. Analysis of seasonal variation of levels of *E. coli* in bivalve molluscs from classified beds in the Fowey is presented in the Appendix XII.

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[28] In the context of the present report, impervious surfaces are any surface in the urban landscape that does not infiltrate rainfall.

[29] Concentrations of *E. coli* (MPN 100ml^{-1}) quoted in literature are: $10-10^3$ for residential areas and highways and 10^2-10^4 for roof runoff and commercial areas (Ellis and Mitchell, 2006).

Appendix II
HYDROMETRIC DATA: RAINFALL

The southwest of England is one of the wettest regions in the United Kingdom. The rainfall pattern is heavily influenced by the topography, which forces the moisture-laden air to precipitate high levels of rainfall across the upper reaches of the catchments. Annual rainfall totals in coastal areas of Cornwall are 900–1,000mm. However, upland areas such as Bodmin moor receive more than 2,000mm. These figures compare to around 500mm of rainfall totals typical of driest parts of Eastern England and yearly averages of 897mm for England and Wales (Met Office, 2007).

Figure II.1 shows monthly averaged and monthly total rainfall monitored daily in a gauge operating at Restormel (grid reference: 20 SX 098 624) (representative of the lower catchment) for the period January 2000–December 2008 . On average, October–December is the wettest period.

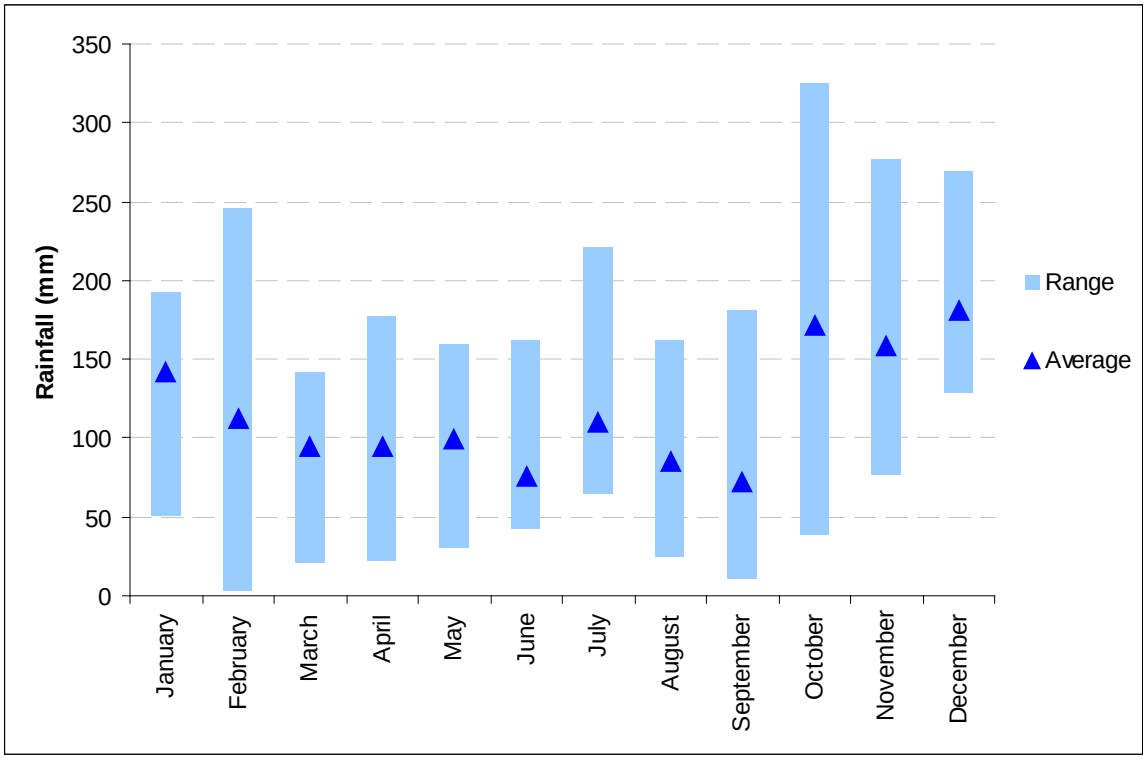

Figure II.1 Monthly variation of rainfal for the period January 2000–December 2008 at Restormel gauging station.
Data from the Environment Agency (2009).

Rainfall may lead to the discharge of raw or partially treated sewage from combined sewer overflows (CSOs) and other intermittent discharges as well as runoff from faecally contaminated land (Younger *et al*., 2003). Therefore, levels of microbiological contamination in bivalves are expected to increase during autumn-winter months.
An inventory of the most significant sewage discharges to the Camel Estuary is listed in Appendix VII.

Appendix III

HYDROMETRIC DATA: FRESHWATER INPUTS

The River Fowey flows from its headwaters on Bodmin Moor [altitude = 290m above Ordnance Datum (OD)] in a southerly direction to where it enters the tidal limit at Lostwithiel is approximately 35km (Cornwall Rivers Project, 2006) (Figure III.1). The main tributary of the River Fowey is the River Lerryn (Figure III.1).

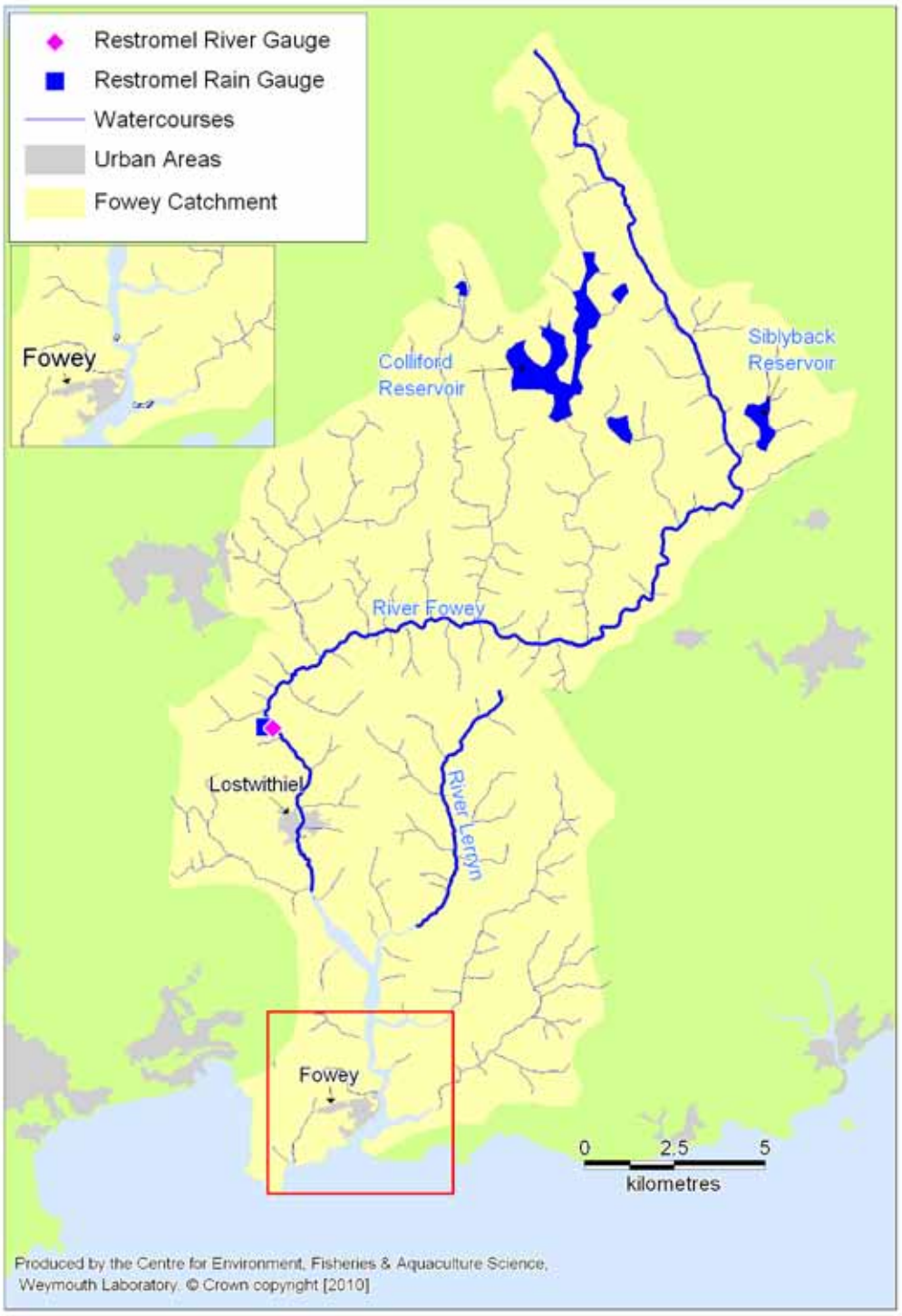

Figure III.1 Rivers and streams in catchments draining to the Fowey Estuary.

Water levels in the River Fowey are characterised by rapid rises and falls in response to rainfall (Cornwall County Council *et al.*, 2004). The river catchment includes two reservoirs (Colliford and Siblyback), which tend to reduce flood peaks (particularly in the autumn), extend the period of relatively high flows and increase low flows (Cornwall County Council *et al.*, 2004).

Table III.1 summarises the hydrological characteristics of the River Fowey at Restormel. Q95 and Q10 represent the averaged flow that is exceeded for 95% and 10% of the time, respectively.

Table III.1 Hydrological characteristics in the River Fowey.

	Gauging station at Restormel [(a)]
Catchment Area (km^2)	169
Level of Station (m OD)	9.2
Maximum altitude (m OD)	420
Mean flow ($m^3 s^{-1}$)	4.824
95% exceedance (Q95) ($m^3 s^{-1}$)	0.832
10% exceedance (Q10) ($m^3 s^{-1}$)	10.870

[a] *data for the period 1960−1990.*
Data from the National River Flow Archive (NERC-CEH, 2010).

Figure III.2 illustrates the seasonal pattern of runoff within the Fowey catchment in response to rainfall.

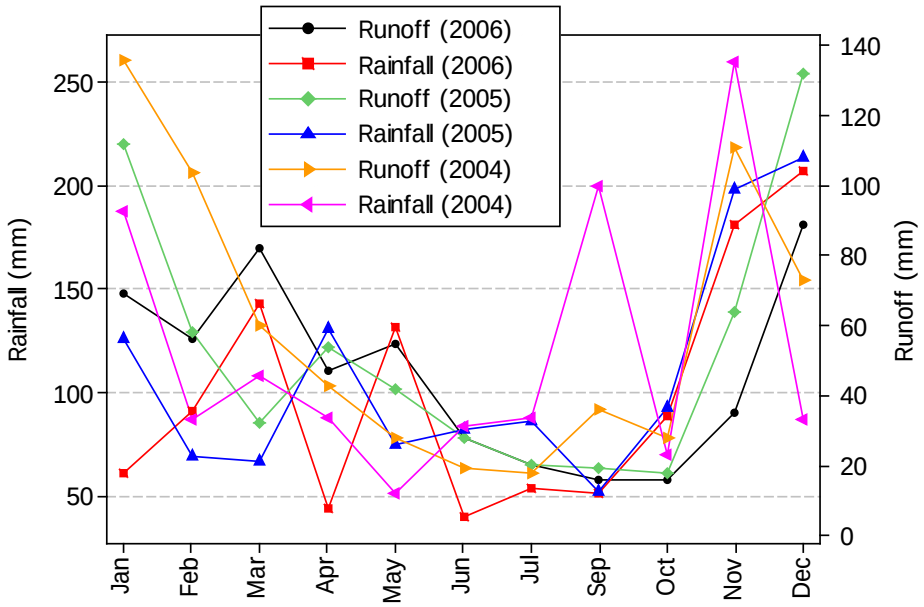

Figure III.2 Monthly variation in rainfall-runoff for River Fowey at Restormel during the period January 2004–December 2006.
Data from the National River Flow Archive (NERC, 2010).

Significantly higher geometric means of faecal indicator microorganisms have been found on watercourses during high-flow conditions relative to those during low flow conditions in UK coastal catchments with >50% of improved grassland (Crowther *et al*., 2002; Stapleton *et al*., 2006).

Considering that the percentage of grassland in the Fowey catchment is approximately 64% (CEH, 2005), it is expected that levels of faecal contamination in the estuary will increase substantially during the period November–January.

Appendix IV
HYDRODYNAMIC DATA: BATHYMETRY

The Fowey Estuary is a shallow type 3b Ria without spits with intertidal drying areas along its margins and tributaries. The mouth is exposed to the south and is relatively deep (Halcrow Group Ltd., 2003).

Drying areas in creeks often result in a continued flow long after the tide has receded and the mudflats are exposed (see Whitehouse *et al*., 2000). Contaminated runoff from retained seawater and/or from rainfall falling on the surface of mudflats at these creeks will be conveyed along the low water channel(s).

Soundings increase from the tidal limit at Lostwithiel to a deep pool of 10.4m relative to chart datum (CD) just west of Penleath Point (Figure IV.1). Three other deep pools occur just south of Wiseman's Reach (11m deep relative to CD) and Polmort Point (12m deep relative to CD) and just East of Lower Carn Point (11m deep relative to CD). From Wiseman's Reach and further up the estuary, the intertidal is mostly constituted by drying areas. Similarly, extensive areas of Pont Pill creek dry at Low Water Springs. Less water will be available for dilution and dispersion of contaminants in these shallow areas.

Differences in bathymetry between the deep pools and drying areas may determine significant differences in the way that tides and currents take the contamination to bivalve mollusc beds, in particular affecting decay rates of microorganisms. Decay rates of microorganisms delivered to deep waters at the mouth of the estuary will be higher than those delivered to shallow areas in the upper river Fowey and Penpoll Creek. This is due to the increased loading of contaminants to surface waters from point and diffuse sources that may result in the siltation and deterioration of the water quality in less flushed areas of the estuary.

Mussels and Pacific oyster at Wiseman's Reach and Pont Pill are in drying areas (Figure IV.1). Under these circumstances, they will not retain microbiological contaminants during periods of low water.

Representative monitoring points (RMPs) situated in shallow areas and near significant pollution sources are more likely to represent the worst-case scenario of contamination.

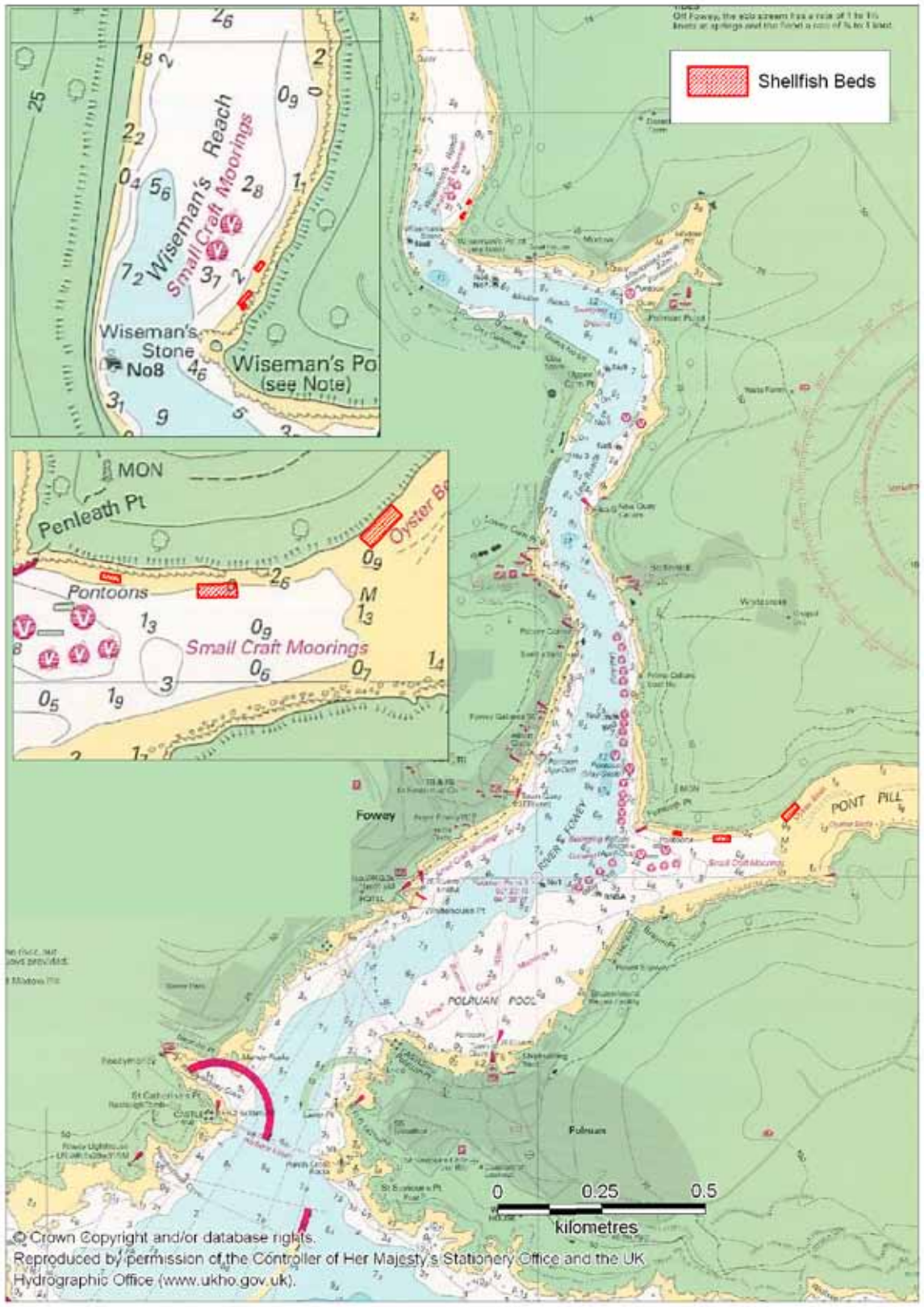

Figure IV.1 Bathymetry in the lower Fowey Estuary.
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Furthermore, microbial contaminants deposited onto the seabed may return to the water column via resuspension or diffusion processes.

Literature suggests that dredging operations may increase resuspension of contaminated sediments and promote the uptake of contaminants by bivalve molluscs. Dredging of the main channel in the Fowey Harbour has been carried out since the early 19th century. Between 35,000 and 50,000 tonnes of silt and sand have been dredged from the Fowey Harbour every year (Jane Smith, pers comm., *in* Le Quesne, 2005; Inman, 2006). Dredged material for the Fowey and nearby Par harbours is discharged at a spoil ground lying approximately 2km East of Fowey Harbour entrance, at the mouth of Lantic Bay (Friend *et al.*, 2006). These activities could cause occasional deterioration of the microbial quality of the water in the estuary and this should be taken into consideration for the purposes of recommending location of representative monitoring points.

Appendix V
HYDRODYNAMIC DATA: TIDES AND CURRENTS

The Fowey Estuary has an asymmetrical meso-tidal regime with semi-diurnal tides (two tidal cycles per day) at Fowey.

Table V.1 Tide levels and ranges in the Fowey Estuary.

	Height (m) above Chart Datum				Range (m)	
Port	MHWS	MHWN	MLWN	MLWS	Springs	Neaps
Fowey	5.4	4.3	2	0.6	4.8	2.3
Lostwithiel	1.4	0.3	Dries	Dries	-	-

Data from Imray Chart 2400.7 © Crown Copyright and/or database rights. Reproduced by permission of the Controller of Her Majesty's Stationery Office and the UK.
Hydrographic Office (www.ukho.gov.uk).

The estuary is likely to be partially mixed and ebb dominant (Halcrow Group Ltd., 2003), the flood being of shorter duration than the ebb. The tidal length (mouth to the limit of reversing tidal currents) is approximately 11km and the estimated residence (flushing) time is approximately 3 days (Uncles *et al.*, 2002).

Tidal currents of 0.40m s^{-1} are typical of offshore areas of Fowey (Friend, 1998). However, there is evidence that higher velocities occur within the estuary (e.g. 0.71m s^{-1} on 17–26 July 1987 at St. Winnow Point) (Partrac, 2005).

Salinity recorded by the Environment Agency at Wiseman's designated Shellfish Water at various tidal stages during the period August 2004–January 2009 ranged between 12.1ppt and 34ppt. The minimum level of salinity highlights the influence of the river plume in this area of the estuary (Figure V.1). However, the weak relationship obtained between salinity and levels of faecal coliforms indicates that other factors are likely to explain the variation of contamination in surface waters at Wiseman's.

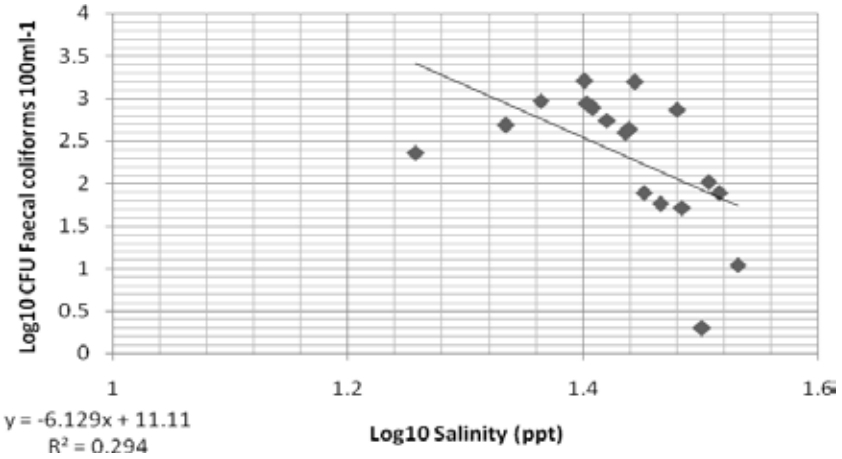


Figure V.1 Relationship between levels of faecal coliforms in surface water and salinity at Wiseman's designated Shellfish Water.
Data from the Environment Agency (2009).

Variations in salinity will determine the filtration activity of bivalves and consequently the uptake and retention of microbial contaminants.

The maximum depth averaged suspended particulate matter (SPM) is 6.5mg l^{-1}. This is lower than that in other estuaries in southwest England, such as the Helford (17mg l^{-1}) and the Dart (12mg l^{-1}) (Uncles *et al.*, 2002). However, a literature review on sources of sediment to the Fowey Estuary undertaken by Partrac Ltd. (2005) reported significant differences in maximum concentrations of suspended sediments between the main tributaries. For instance, mean concentrations ranged between 8mg l^{-1} in the River Fowey at Restormel and 15mg l^{-1} in the River Lerryn. Pont Pill at Trethake Mill and Trebant Water at East Ten Creek had mean concentrations of 10mg l^{-1} and 13mg l^{-1}, respectively. Literature indicates that turbidity is one of the key factors determining the survival of faecal coliforms in streams (Wilkinson *et al.*, 1995). The levels of suspended solids generally have more impact on the concentrations of microorganisms in shallow nearshore waters and less effect in the deeper, less turbid waters (see Stapleton *et al.*, 2007). Therefore, bivalves at Wiseman's Reach are more likely to be exposed to higher levels of SPM and, consequently, faecal contaminants than those at Pont Pill.

The low residence time suggests that the estuary is able to quickly disperse microbiological contaminants in well flushed areas such as the mouth of Pont Pill creek. Therefore, bivalves will normally show maximum concentrations of contaminants in the first hours following a pollution incident (ex. breakdown at a sewage works) occurring in this area. Sampling carried out immediately after pollution incidents is more likely to reflect the worst-case scenario of contamination.

Overall, the low maximum SPM coupled with the low residence time in the estuary suggests that the behaviour of the turbidity maximum is mainly controlled by tidal processes on short-time scales (Jay and Musiak, 1994). Therefore, tidal currents are likely to be the main factor determining the distribution of microbiological contaminants in the estuary.

Faber Maunsell was commissioned by South West Water to investigate the potential impact of continuous and intermittent discharges on the levels of bacteriological contamination impacting on the designated Shellfish Water at Mixtow. It was concluded that the levels of bacteriological contamination in the estuary vary considerably over the tidal cycle. At high water, levels of faecal coliforms were found to reduce to 54CFU 100ml^{-1} due to dilution effects during the flood tide, whereas at low water and without dilution, levels of this indicator rose to a peak of approximately 3,300CFU 100ml^{-1} before reducing again due to dilution with rising tide levels (Lowery, 2007).

The bathymetric profile of the Fowey Estuary suggests that water flows may follow a rectilinear (back and forth) pattern. Bivalve mollusc beds will be impacted by microbial contamination from pollution sources situated at the mouth of the estuary during the flood tide. Conversely, the river plume will be the primary mechanism of transport of contamination from the wider catchment.

The funnelling convergence of the estuary sides and the friction of the bed on tidal currents can produce a partial reflection of the tidal wave, squeezing it into a small cross section and thereby increasing the height of the tidal wave (see Dyer, 1995). This is likely to extend the period during which bivalves at Wiseman's will retain contamination during the flood tide.

Appendix VI
METEOROLOGICAL DATA: WIND

The southwest is one of the more exposed areas of the United Kingdom. The strongest winds are associated with the passage of the Atlantic depressions and the frequency and strength of these depressions is greatest in the winter (Met Office, 2007). As these pass the UK, the wind typically starts to blow from the south or southwest, but later comes from the west or northwest as these depressions move away.

Figure VI.1 shows that winds in the lower Fowey catchment blow within the range of directions SSW-W and the strongest winds usually blow from these sectors.

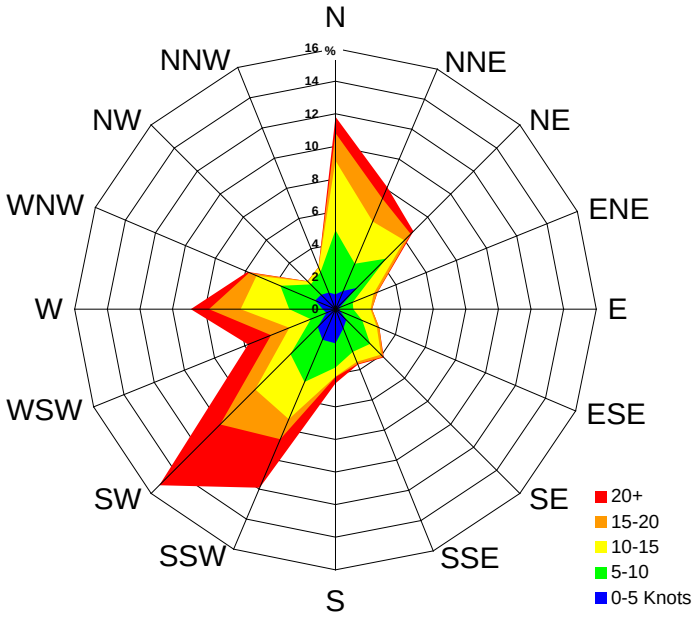


Figure VI.1 Wind speed and direction at Polruan in 2007.
Data provided by NCI Polruan meteorological station (2008).

Although the contours of the land around an estuary will modify the prevailing wind to some extent, the southwestern orientation of the Fowey Estuary implies that the potential for wind driven advection of potentially contaminated surface waters is predominantly from the mouth towards the head of the estuary. Given that the estuary is unlikely to be at risk of microbiological contamination from seaward, representative monitoring points should be located to reflect the effect of local sources of pollution.

Appendix VII

Sources and Variation of Microbiological Pollution: Sewage Discharges

Sewage discharges pose a significant risk of contamination of faecal origin to bivalve molluscs. The risk is diverse and depends from contributing human population and volume of discharge. Sewage effluents in the catchment draining to the Fowey Estuary are treated in a number of sewage treatment works (STW). The larger water company STW are associated with the urbanised areas of Fowey and Lostwithiel. The locations of sewage discharges in the catchment that are potential sources of microbiological contamination of bivalve molluscs are shown in Figure VII.1. Further details of these are given in Tables VII.1–VII.2.

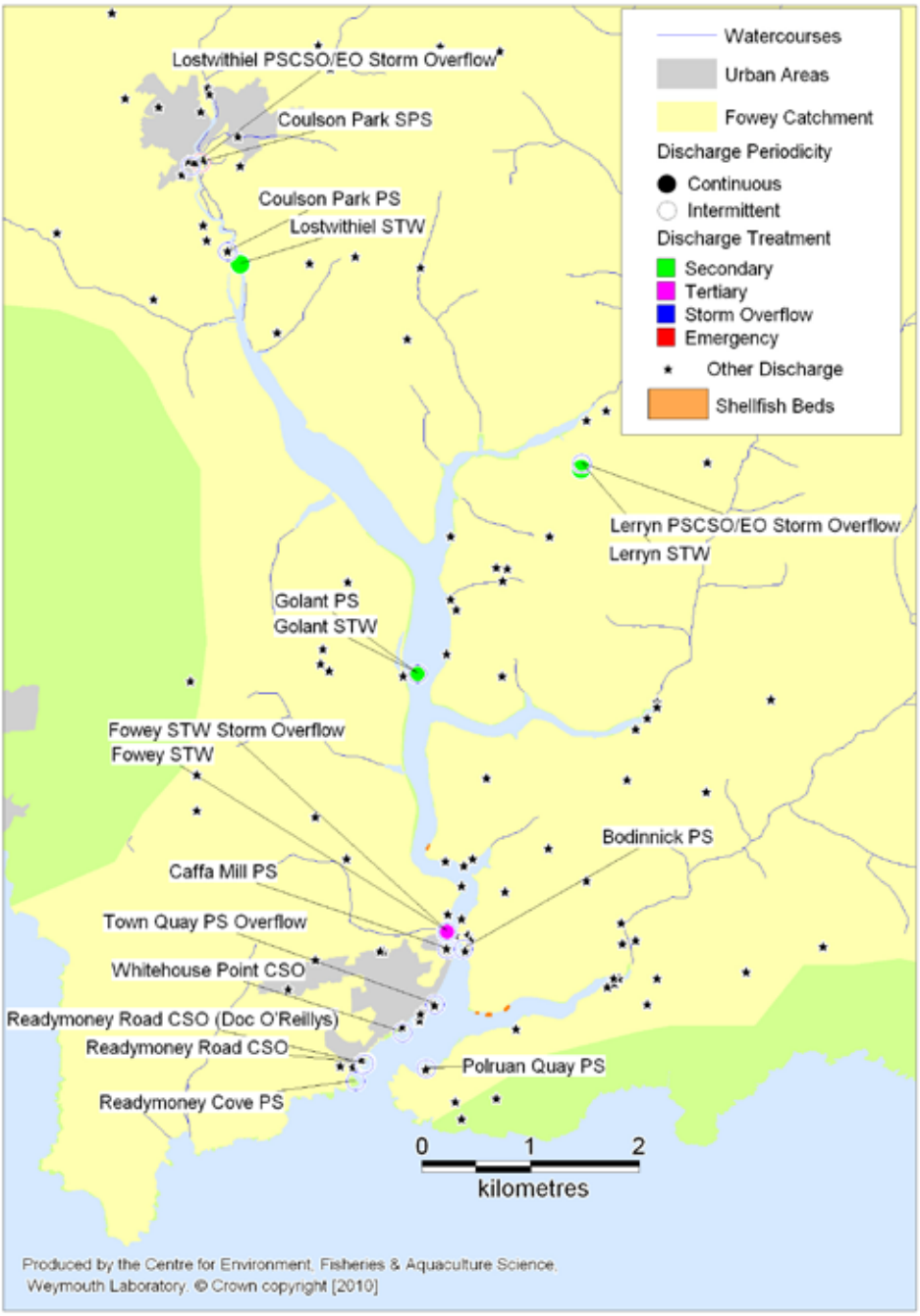


Figure VII.1 Location of sewage discharges within the Fowey catchment.

Of the continuous discharges identified in the Environment Agency (EA) Pollution Reduction Plan as having a significant or potentially significant impact on the designated Shellfish Water, only Lostwithiel does not discharge directly to the estuary.

The sewerage infrastructure is also served by a number of combined sewer overflows (CSO), emergency overflows (EO) and overflows from sewage pumping stations (PS). Of particular significance to bivalve mollusc beds are intermittent discharges in Fowey town and Polruan.

Table VII.1 Significant continuous and intermittent sewage discharges to the Fowey Estuary.

Name of discharge	Treatment	Dry weather flow (m^3 day^{-1})	Population equivalent
Continuous			
Fowey STW	UV Treated (tertiary)	1,185	-
Lostwithiel STW	Secondary	586	2,527
Lanteglos Highway STW	Primary	-	250
Lerryn STW	Secondary	79.5	18
Golant STW	Secondary	66	210
Intermittent			
Readymoney PS CSO/EO	-	-	698
Polruan PS CSO/EO	-	-	877
Town Quay PS CSO/EO	-	-	-
Caffa Mill PS CSO/EO	-	-	113
Whitehouse Point CSO	-	-	1,760
Readymoney Road (doc O'Reilly's) CSO	-	-	681
Fowey STW storm tank	-	-	-
Bodinnick PS	-	-	70
Coulson Park PS EO	-	-	-
Coulson Park PS CSO	-	-	-
Coulson Park (Lostwithiel STW) SSO	-	-	-
Lerryn PS CSO/EO	-	-	-
Lerryn STW storm tank	-	-	-
Lostwithiel PS CSO/EO	-	-	-
Golant PS	-	-	210

STW - Sewage treatment works.
PS - pumping station.
CSO - combined sewer overflow.
EO - Emergency overflow.

Lowery (2007) suggested that the continuous discharges at Lostwithiel, Lerryn and Golant represent 69% of the faecal coliform load to the estuary.

Table VII.2 presents summary statistics for levels of faecal coliforms quantified in final UV-treated effluent discharges from Fowey STW. The geometric mean of faecal coliforms is lower than the average levels given in the literature for a range of UV-treated effluents in the UK (Kay *et al.*, 2008) indicating the low contribution of this discharge to the overall microbial load to the estuary. However, three samples returned levels of the microbiological indicator below these reference levels highlighting occasional deterioration of the microbial quality of the final effluent.

Table VII.2 Summary statistics of presumptive levels of faecal coliforms in the final effluent post UV disinfection monitored in Fowey STW.

		CFU Faecal coliforms 100ml^{-1}			
Name	Period	Number of samples	Geometric mean	Minimum	Maximum
Fowey STW	October 2006–June 2009	72	16	1	700,000

Data from the Environment Agency (2009).

Side-by-side box-and-whisker plots[30] of levels of the microbial indicator indicate that this deterioration occurred in the summer (Figure VII.2). Levels of the microbiological in this season were significantly (Kruskal-Wallis test: H = 18.21; p = 0.000) higher than those in the winter.

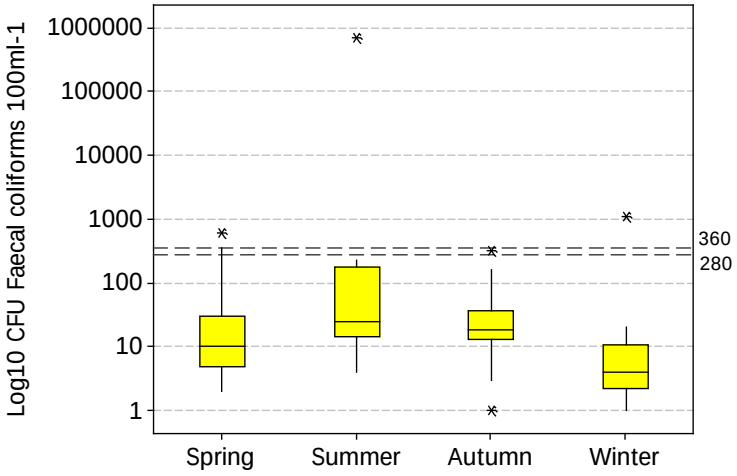


Figure VII.2 Box-and-whisker plots of seasonal levels of faecal coliforms in the final effluent post UV disinfection monitored in the Fowey STW during the period October 2006–June 2009.

NB. Spring: March−May; Summer: June−August; Autumn: September−November; Winter: December−February.

Reference lines correspond to typical levels of faecal coliforms in UV-treated effluents under base-flow and high flow conditions as observed in a range of effluents by Kay et al. (2008).

Seasonal variation in the quality of effluent discharges may contribute to seasonal variation in the levels of microbiological contamination in bivalve molluscs. Analysis of historical *E. coli* data in commercially harvested bivalve molluscs is presented in the Appendix XII.

[30] Box-and-whisker plots depict the distribution (central tendency and spread) of a data set. These plots show (a) the centre or median of the data (centre line of the box), (b) the spread or inter-quartile range (box height), (c) quartile skew (relative size of box halves) and (d) the presence of extreme values or outliers (asterisks).

Appendix VIII

SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: AGRICULTURE

Nearly 70% of the Fowey catchment is utilised for agriculture (approximately 19,200 hectares) (Cornwall County Council *et al.*, 2004). One third of farms are used for livestock production, in particular cattle and sheep. A significant proportion of the land is also used for cereals.

There are over 145,800 farmed animals in these catchments (Table VIII.1). Cattle and sheep constitute about 21% and 52% of the total number of farmed animals in the catchment, respectively.

Table VIII.1 Numbers of farmed animals in catchments draining to the Fowey Estuary.

Catchment name	Cattle	Pigs	Sheep	Poultry	Other livestock
Fowey	14,179	625	33,066	1,013	1,460
Fowey (tidal)	9,468	224	23,915	26,028	337

Data from Defra (2010), Farming Statistics - June 2008 Agricultural and Horticultural Survey.
NB. Other livestock consists of horses, goats, deer and others.

Farmyards can significantly contribute to loads of faecal indicator microorganisms to watercourses or coastal waters if they have a ready and renewable source of faecal material, a direct hydrological connection with open water channels exists and a sufficient proportion of livestock farms are present in the catchment (Edwards *et al*., 2008). The concentration of faecal coliforms excreted in the faeces of animal species and humans and corresponding loads are summarised in Table VIII.2.

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

Farm Animal	Faecal coliforms (No. g^{-1} wet weight)	Excretion rate (g day^{-1} wet weight)	Faecal coliform load (No. day^{-1})
Chicken	1,300,000	182	2.3×10^8
Cow	230,000	23,600	5.4×10^9
Pig	3,300,000	84,000,000	8.9×10^8
Sheep	16,000,000	38,000,000	1.8×10^{10}
Human	13,000,000	3,000,000	1.9×10^9

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

The Fowey catchment was considered by the Environment Agency to be at risk of diffuse water pollution from agriculture (Environment Agency, 2008).

Many farms in Cornwall do not have long-term storage capacity for slurries and manure and, therefore, maintain these as a pile in fields (Roderick and Burke, 2004; Lizbe Pilbeam, pers. comm.). For this reason, most farmers frequently apply manure and slurries during the winter, throughout the spring (February–March) for spring growth and some are applied in the autumn for winter cereals. Winter spreading is usually more frequent as farmers try to avoid over-topping their slurry stores. Fewer quantities are retained for the late spring and summer for second and third cut silage applications. Sewage sludge is usually applied to land in February–March and in September (Lizbe Pilbeam, pers. comm.).

In 2008, the Environment Agency undertook a microbial source tracking study to investigate the partial contributions of pollution sources of human and animal origins impacting on Readymoney designated bathing water (see Appendix XI). Results highlight the predominance of ruminant sources in this area (Table VIII.3).

Table VIII.3 Results of microbial source tracking study undertaken in Readymoney in 2008.

Location	Collection date	Collection time	Observations	Result
Readymoney Cove Beach	31 July 2008	13:19	Discoloured sea. Brownish heavy rain	Human (14%) and ruminant (86%) detected. No other sources of contamination were suspected.
Readymoney Cove Beach	13 August 2008	14:20	-	Human (0.9%) and ruminant (99.1%) detected. No other sources of contamination were suspected.
Readymoney Cove Beach	15 September 2008	14:30	-	Human and ruminant detected but other sources of contamination could not be eliminated.
Readymoney Cove Stream	31 July 2008	13:22	Stream extremely discoloured (dark brown) due to heavy rain	Ruminant detected, human not detected. Other sources of contamination could not be eliminated.
Readymoney Cove Stream	13 August 2008	14:23	-	Human and ruminant detected. Other sources of contamination could not be eliminated.

Data from the Environment Agency (2009).

Appendix IX

SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: BIRDS

The Fowey Estuary does not support important populations of overwintering wildfowl. The intertidal mudflats are feeding areas for passage waders.

Only twelve species of waterbirds have been recorded in the estuary in 2004/05. Of these, Mallard and Curlew were the most abundant. Shelduck is the only other species occurring in mean numbers exceeding 30 during the winter.

Waterbirds are almost exclusively found in the upper estuary, north of St Winnow Point at the confluence of the Fowey and Lerryn Rivers. Other species only occurring on the upper section include Little Grebe, Canada Goose and Oystercatcher, all at very low densities. The lower count section, stretching approximately 2.5km south from St Winnow Point, contains less intertidal habitat. Consequently, Cormorant, Mute Swan and Grey Heron have been found in low densities at this site. The Redshank is also largely restricted to the lower reaches of the estuary.

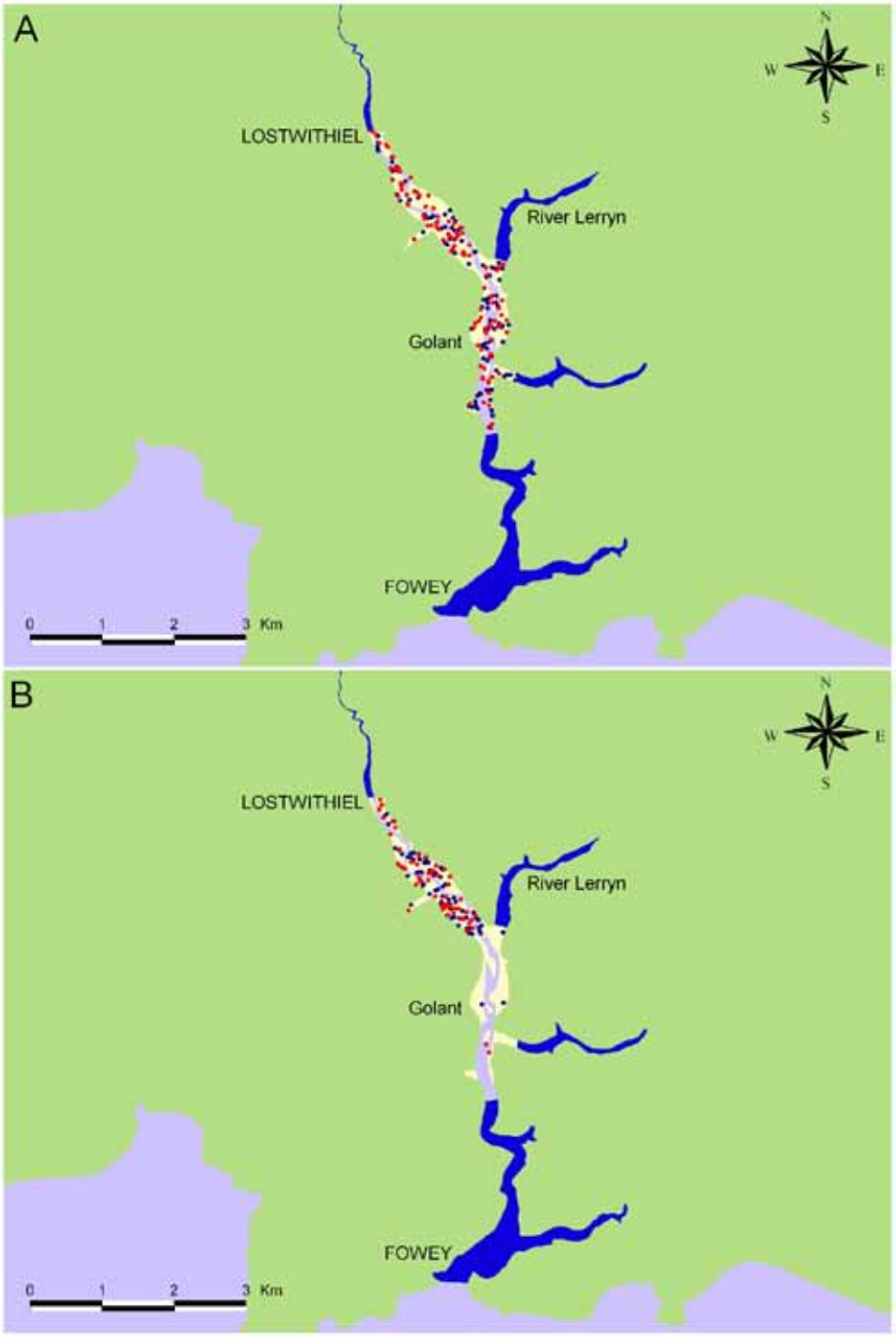


Figure IX.1 Low tide distribution of Mallard (A) and Curlew (B).
1 dot = 3 birds. Blue dots: winter 1995/96 survey; red dots: winter 2004/05 survey. Yellow - intertidal; pale blue - subtidal. Dark blue areas were never covered by the surveys. Modified from Banks et al*. (2006) with the permission of Neil Calbrade on behalf of the authors.*

Previous studies in the UK have indicated 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). For example, geometric means of *E. coli* detected in faecal samples of Starling (*Sturnus vulgaris*) can be 4.6×10^{7}CFU $100g^{-1}$ (Environment Agency, 2003; Whither *et al*., 2003). Feare (2001) suggests that approximately 10% of the faecal matter

could be deposited under a roost, suggesting the potential significant contribution of contamination in these areas.

Despite the low numbers of birds in the Fowey Estuary compared to other estuaries in England and Wales, birds are likely to contribute both to the background levels of contamination and directly to bivalve molluscs in Wiseman's. The higher risk of contamination from these sources will be during the autumn-winter period.

Appendix X
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: HARBOURS AND MARINAS

The Fowey Estuary is very popular for sailing/boating activities, though most of the harbour cannot be used over large parts of the tide, resulting in congestion of the lower harbour. Rowing and canoeing activities extend along the whole of the river, and sub aqua diving takes place by permission of the Harbour Master. Boat trips are available, both around the Harbour entrance and along the river at low and high tides. A ferry between Fowey and Mevagissey also operates in the summer season.

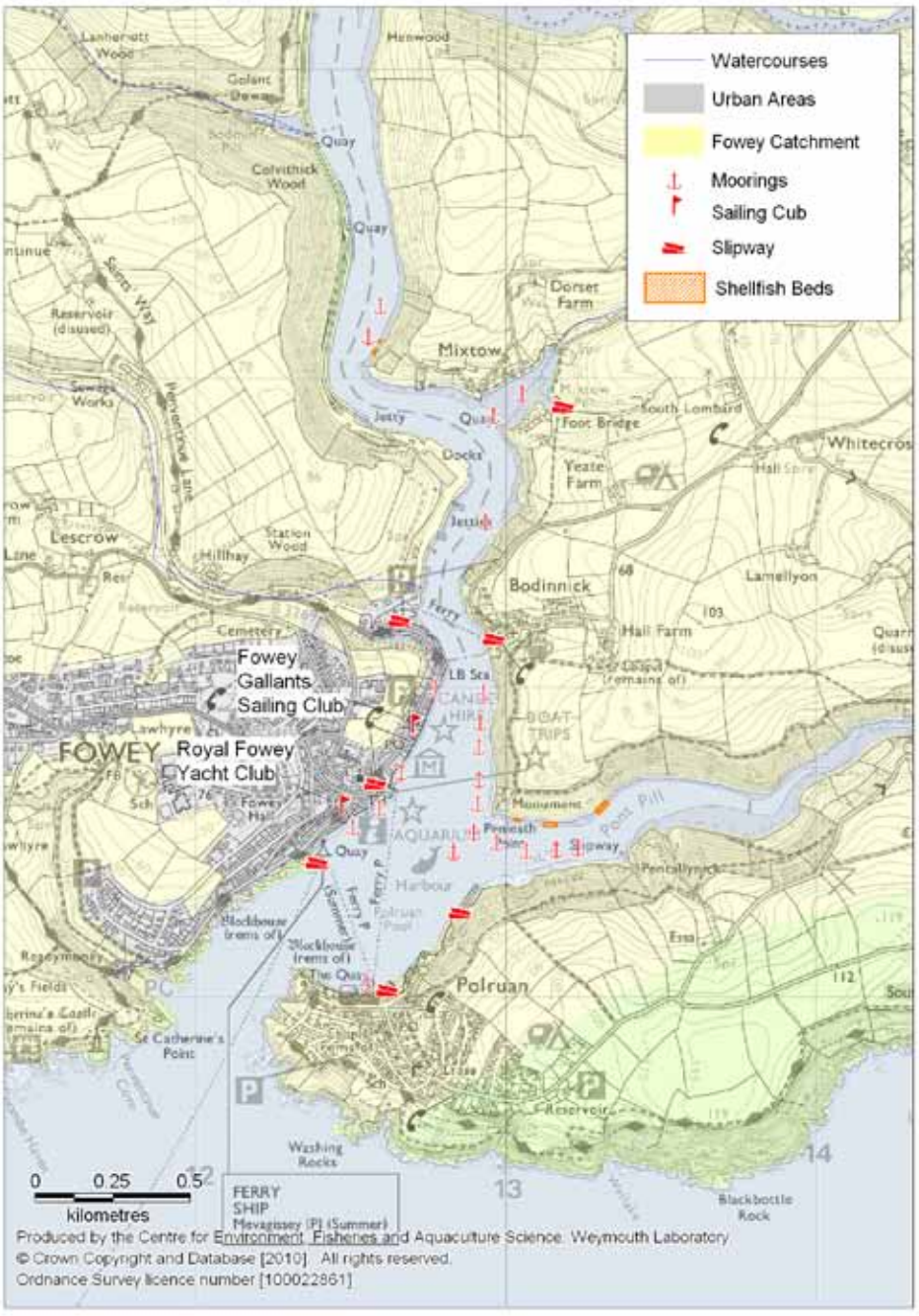


Figure X.1 Location of mooring areas, sailing clubs and slipways in the lower Fal Estuary.

There are approximately 1,500 moorings in the estuary, with extra available for visiting yachts. In 2002, there were nearly 10,000 overnight stays during the course of the season. The moorings in the harbour are fixed, and anchoring is discouraged in order to limit the detrimental effects on marine habitats, particularly the *Zostera* sp. beds. There are significant increases in seasonal activity being highest during the summer months.

Pedestrian ferries operate regularly between Polruan and Fowey, and car ferries between Bodinnick and Fowey and ferries also run between Mevagessey and Fowey in the summer (1st May–30th September).

Marinas and ports have historically been identified as major sources of faecal contamination (see Sobsey *et al*., 2003). This is based on the assumption that some boat owners will, at some time, illegally discharge their head (onboard toilet) into harbour waters. The existence of pump-out facilities in Berrils Boat Yard (Adlard Coles Nautical, 2008) will minimise the risk of pollution from these sources.

Table X.1 indicates the occurrence of high levels of faecal coliforms in estuarine waters in the vicinity of intensive boating activity.

Table X.1 Levels of faecal coliforms in surface water samples collected in areas of boating activity in the Fowey Estuary.

Sampling point	Collection date	CFU Faecal coliforms $100ml^{-1}$	Observation
Ferry Slipway	16 August 2004	116	Oil at surface
Albert Quay	27 August 2004	13,000	Slightly turbid water
Caffa Mill on Slipway	27 August 2004	654	-
IMERYS China Clay	27 August 2004	920	Works by steps at pilot boat moorings
Main Quay	27 August 2004	2,440	-
Whitehouse Quay	27 August 2004	308	-
Albert Quay	12 January 2009	818	-
Bodinwick Ferry Slipway	12 January 2009	360	-
Caffa Mill 5 Slipway	12 January 2009	2,900	Dry weather
Fowey Town Quay	12 January 2009	243	-
Whitehouse Quay	12 January 2009	280	-
Yacht Club Slipway	12 January 2009	220	-
Caffa Mill Slipway	17 February 2009	45	-
Fowey Town Quay	17 February 2009	117	-
Whitehouse Quay	17 February 2009	10	-
Yacht Club Slipway	17 February 2009	10	-

Data from the Environment Agency (2009).

Appendix XI
MICROBIOLOGICAL DATA: WATER

BATHING WATERS

Readymoney is a bathing water in the Fowey (tidal) catchment designated under the Directive 2006/7/EC (European Communities, 2006a) (Figure X.1). This is at the mouth of the estuary near Fowey, approximately 1.3km from Pont Pill bed (Figure X.1).

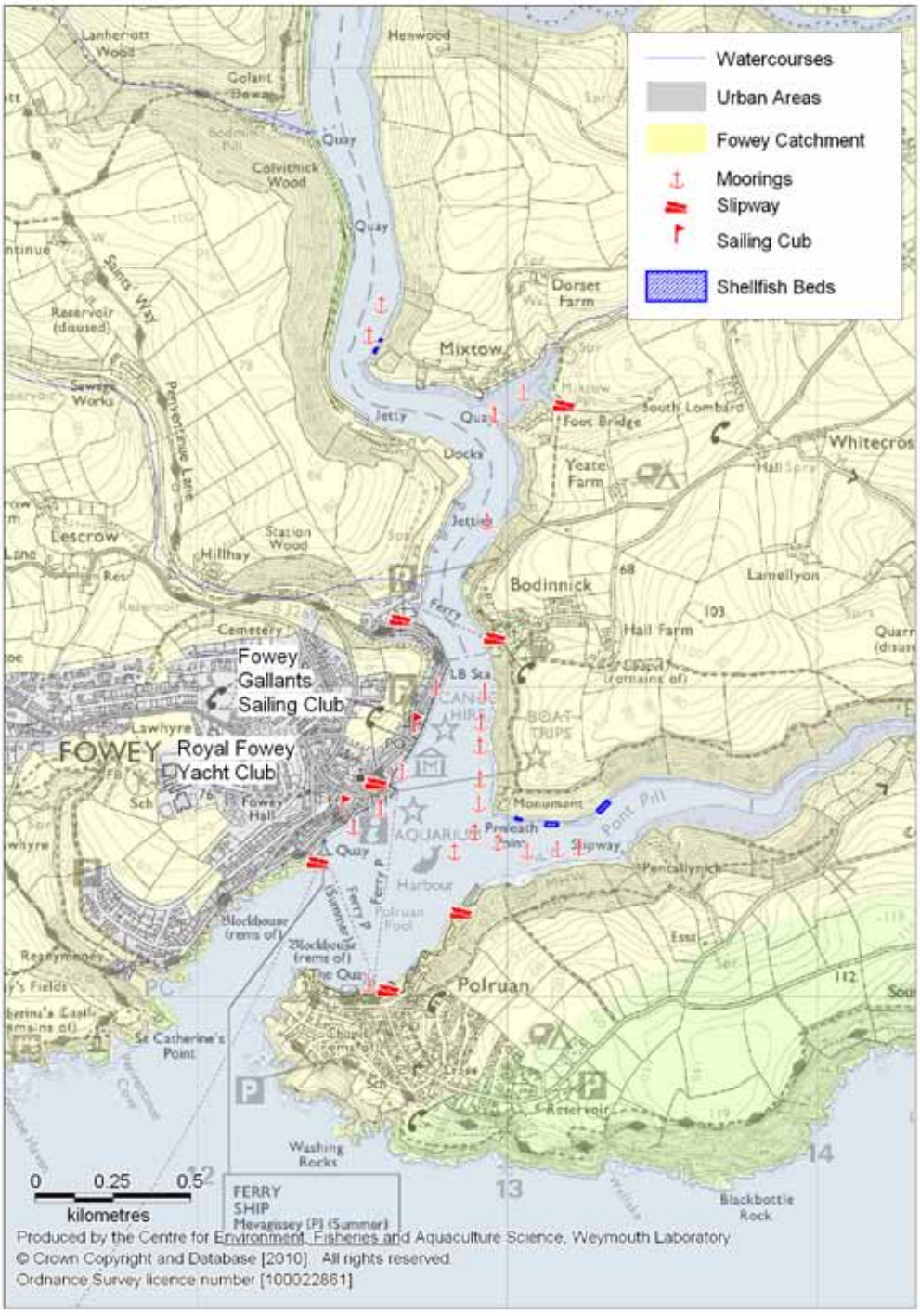


Figure XI.1 Location of designated Bathing Water and Shellfish Waters in the Fowey catchment.

Figure X.2 shows the distribution of levels of faecal coliforms for the period 2004–2009. Median values increased significantly between 2006–2008. Levels of the microbiological indicator above the Imperative value (2000 Faecal coliforms 100ml^{-1}) were detected in 2007–2009 bathing seasons suggesting periods of intermittent deteriorated microbial quality of the water at this site.

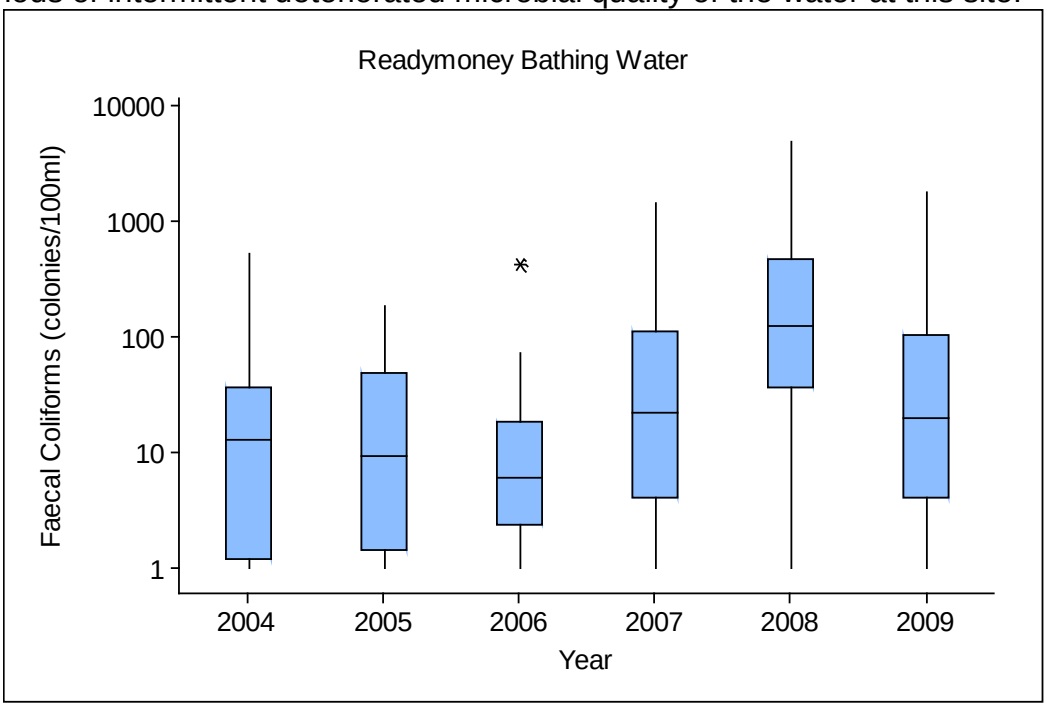


Figure XI.2 Box-and-whisker plots of levels of faecal coliforms in Designated Bathing Waters in the Fowey catchment for the period 2004−2009.
Data from the Environment Agency (2009).

SHELLFISH WATERS

The estuarine areas at Wiseman's and Pont Pill Creek are also designated Shellfish Waters under the Directive 2006/113/EC (European Communities, 2006b) (Figure XI.1).

Table XI.3 shows summary statistics of levels of faecal coliforms in surface waters in Wiseman's designated Shellfish Water during the period August 2004–January 2009. The maximum result confirms that the designated Shellfish Water has been vulnerable to episodes of deteriorated microbiological quality.

Table XI.3 Summary statistics for levels of faecal coliforms in Wiseman's designated Shellfish Water for the period August 2004–January 2009.

Minimum	2
Maximum	1,600
Median	414
Geometric mean	207
Number of samples	18

Data from the Environment Agency (2009).

Appendix XII
MICROBIOLOGICAL DATA: SHELLFISH FLESH

Table XII.1 indicates that in recent years sampling effort for Pacific oysters and mussels has been higher at Wiseman's than at Pont Pill (Table XII.1).

Table XII.1. Numbers of samples by year collected in current shellfish beds in the Fowey Estuary for the period 2004–2009.

RMP ID	B070K	B070S	B070M	B070P	B070Q
Bed name	Wiseman's	Wiseman's	Pont Pill Relay	Pont Pill	Pont Pill
Species	*C. gigas*	*Mytilus* spp.	*Mytilus* spp.	*C. gigas*	*Mytilus* spp.
Total	106	107	76	95	92
2004	10	10	9	9	9
2005	10	11	8	9	9
2006	13	12	10	11	11
2007	10	11	8	11	11
2008	10	13	10	9	9
2009	6	8	6	6	6

Descriptive statistics for *E. coli* data monitored in bivalve molluscs from these five beds suggests the following trend in the levels of contamination: Wiseman's>Pont Pill (Pacific oysters); Wiseman's>Pont Pill≈Pont Pill - Relay (mussels) (Table XII.2).

Table XII.2 Levels of E. coli in shellfish flesh at current Representative Monitoring Points (RMPs) in the River Fowey for the period January 2004 – June 2009.

						MPN *E. coli* 100g^{-1} FIL			
RMP	Bed Name	Species	n	Date of first sample	Date of last sample	Min.	Max.	Median	Geometric mean
B070K	Wiseman's	*Crassostrea gigas*	59	12/01/2004	15/06/2009	20	16,000	700	619
B070M	Pont Pill - Relay	*Mytilus* spp.	49	28/01/2004	15/06/2009	20	18,000	700	622
B070P	Pont Pill	*Crassostrea gigas*	54	26/01/2004	15/06/2009	20	16,000	460	499
B070Q	Pont Pill	*Mytilus* spp.	53	26/01/2004	15/06/2009	20	18,000	700	807
B070S	Wiseman's	*Mytilus* spp.	63	12/01/2004	15/06/2009	20	16,000	790	736

MPN - most probable number.
FIL - fluid and intravalvular liquid.
RMP - representative monitoring point.
N - number of samples.
Min. - minimum.
Max. - maximum.

The distribution of levels of *E. coli* in bivalves is graphically represented in Figure XII.1. The similar sizes of top and bottom box halves and relatively similar lengths of whiskers in mussels from Pont Pill - Relay (B070M), Pacific oysters from Pont Pill (B070P), mussels from Pont Pill (B070Q) and mussels from Wiseman's (B070S) indicate similar spread of data around median values.

Asterisks in data distributions for Pacific oysters at Wiseman's (B070K) and mussels from Pont Pill - Relay (B070M) indicate occasional periods of good microbiological quality at these sites. The 75th percentiles of *E. coli* levels in bivalves from all RMPs are within the range for class B (MPN *E. coli* ≤4,600 100g^{-1} FIL).

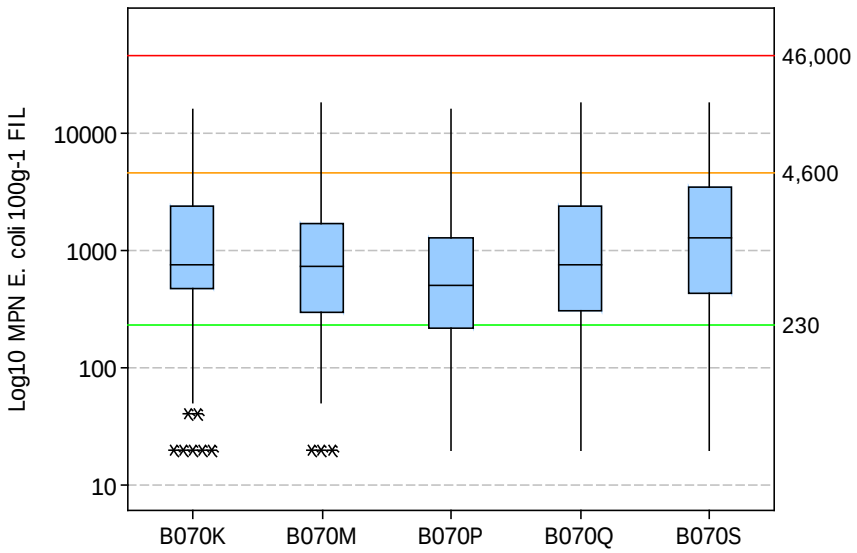


Figure XII.1 Box-and-whisker plots of levels of* E. coli *in bivalves from five representative monitoring points in the Fowey Estuary.

SEASONALITY OF *E. COLI*

All bivalve molluscs in the Fowey Estuary are subject to year-round classification. This section presents the results of an investigation to the seasonal variation of levels of microbiological contamination in currently classified bivalve mollusc beds. The aim of this investigation was to evaluate whether any variations in microbiological loads to the estuary result of seasonal variations in the levels of *E. coli* in mussels and Pacific oysters.

The analysis consisted of seasonal variation of *E. coli* levels. For this purpose, data was amalgamated by season considering spring (March–May), summer (June–August), autumn (September–November) and winter (December–February). One-way analysis of variance (ANOVA) followed by a Tukey HSD test using a significance level (α) of 0.05 was used to test differences between seasons. Side-by-side box-and-whisker plots were computed to summarise the distribution of datasets.

There were no statistically significant seasonal differences in the levels of *E. coli* in bivalves.

Seasonal levels of the microbiological indicator in mussels from Wiseman's and Pont Pill - Relay show very similar distributions around the mean values (Figure XII.2).

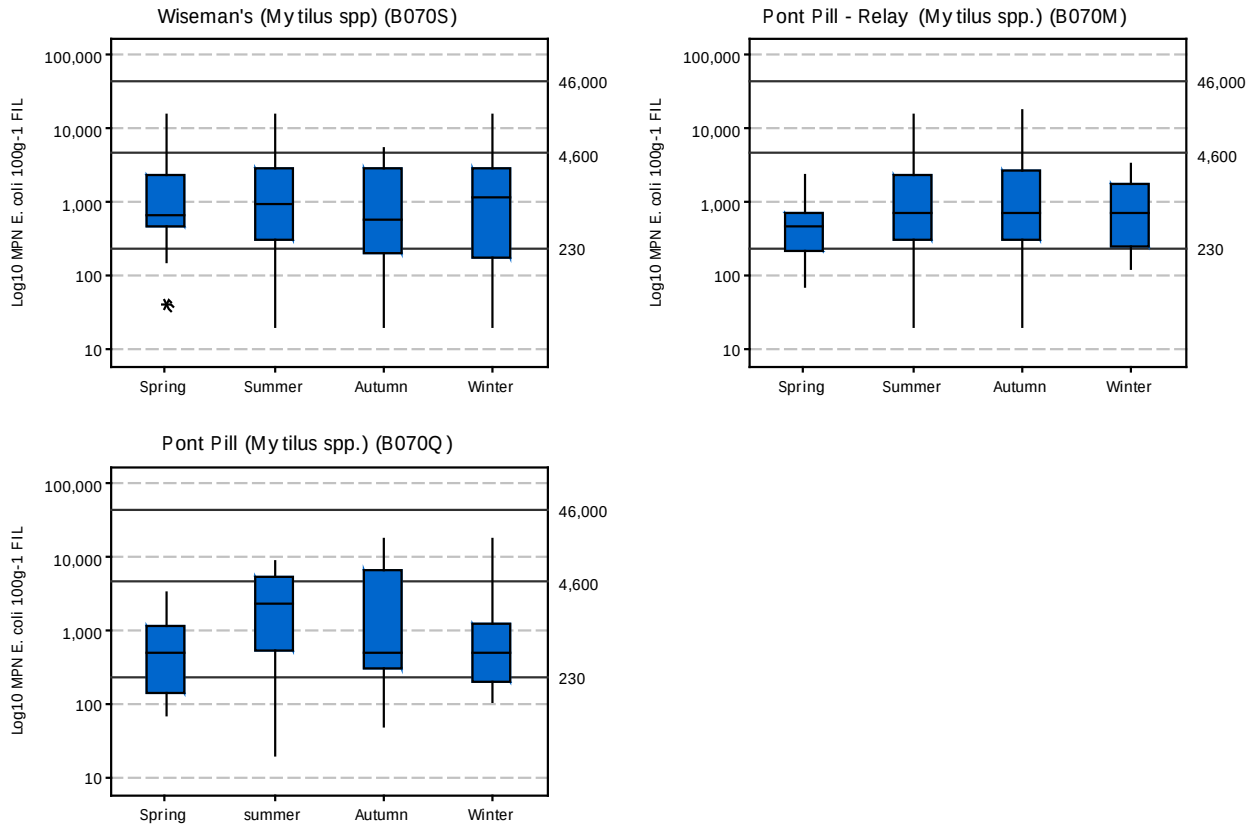


Figure XII.2 Seasonal levels of E. coli in mussels from the Fowey Estuary.

Seasonal levels of *E. coli* in Pacific oysters from both beds show very similar distributions (Figure XII.3).

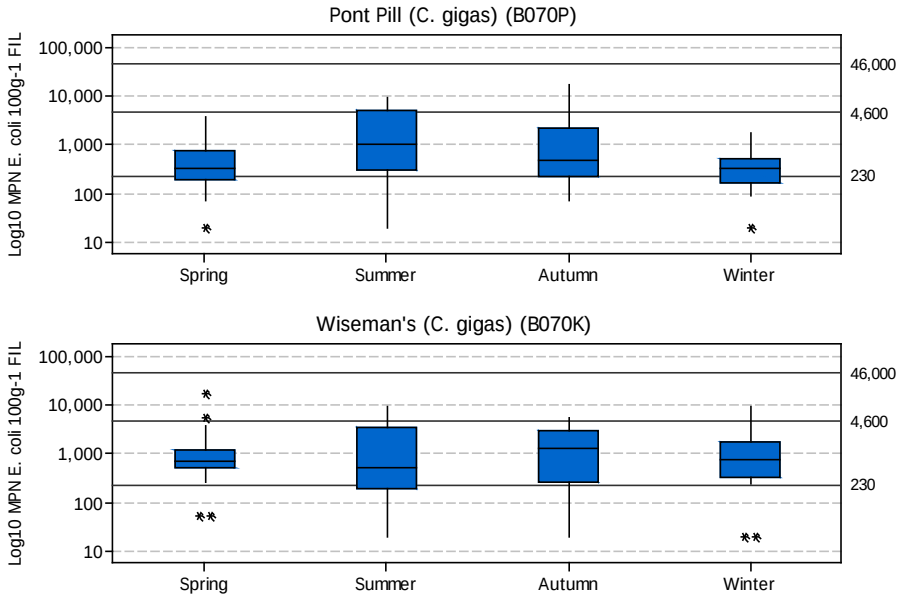


Figure XII.3 Seasonal levels of E. coli in Pacific oysters from the Fowey Estuary.

VARIATION OF *ESCHERICHIA COLI* ACCORDING TO RAINFALL

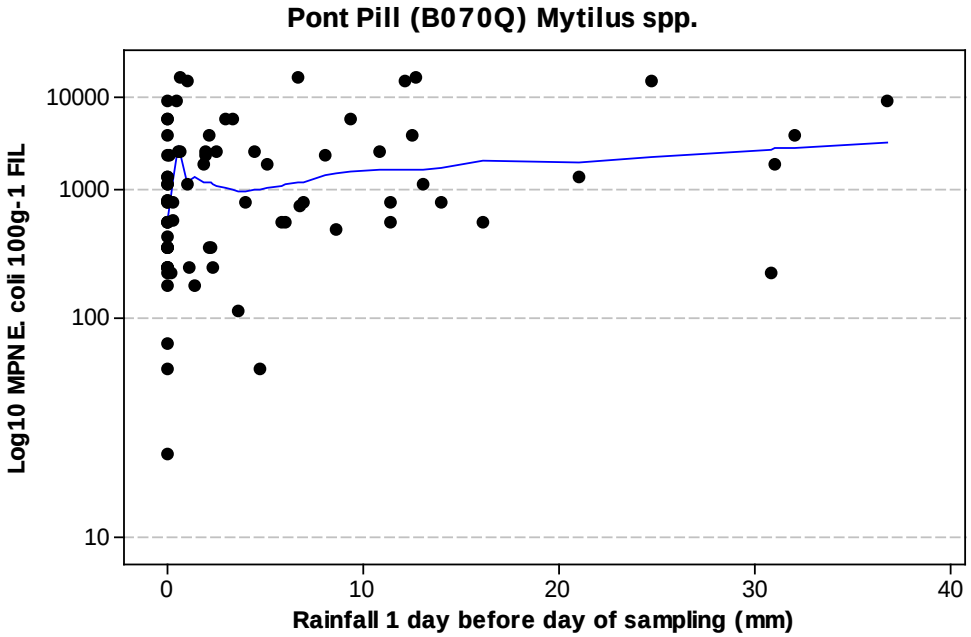
Rainfall data from Restormel rain-gauge station (Figure III.1) was correlated with *E. coli* levels in bivalve molluscs from five existing RMPs in the Fowey Estuary for data periods referred in Table XII.2.

Spearman's rho was used to estimate correlations between MPN *E. coli* 100 g^{-1} FIL and daily and total rainfall up to seven days before sampling.

Table XII.3 shows statistically significant positive correlations between levels of *E. coli* in:

- Mussels from Pont Pill and daily rainfall on the first day before sampling;
- Mussels from Pont Pill and cumulative rainfall between the second and seventh days before sampling;
- Mussels from Pont Pill - Relay and daily rainfall between the day of sampling and the first day before sampling;
- Mussels from Pont Pill - Relay and cumulative rainfall between the second and seventh days before sampling.

The relationship between variables was further explored and is graphically represented by scatterplots with superimposed Locally Weighted Scatterplot Smoothing (LOWESS) lines for statistically significant relationships (Figure XII.2). The upward trends of LOWESS lines clearly illustrate that levels of the microbiological indicator in Pacific oysters and mussels increase with increasing rainfall.



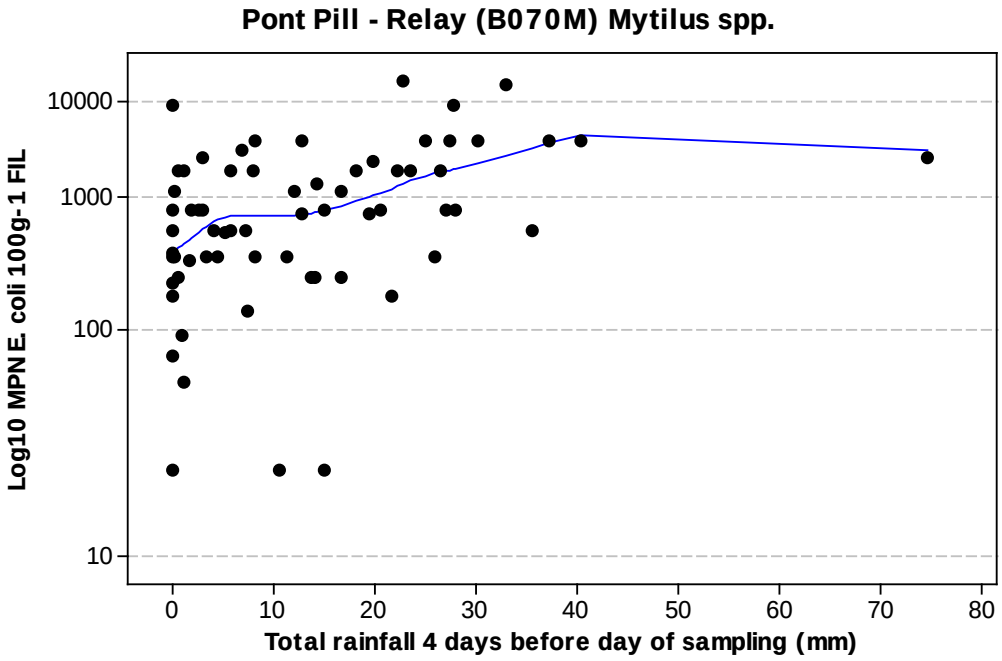


Figure XII.2 Scatterplots of levels of* E. coli *in mussels from Pont Pill and Pont Pill - Relay versus rainfall with superimposed LOWESS line.
NB. Footnote equations are regression fits.

These results suggest that the amount of *E. coli* accumulated by mussels at these sites could be determined by (a) contamination from rainfall-dependent discharges in the proximity of these beds; (b) contamination from the Fowey (tidal) catchment delivered to Pont Pill creek and/or its tributaries during periods of wet weather; and/or (c) contamination from agricultural land delivered to coastal waters via local streams during periods of wet weather.

Table XII.3 Spearman's rho coefficients between rainfall recorded at Restormel rain-gauge station and MPNs of* E. coli *100g^{-1} FIL in bivalves from five monitoring points in the Fowey Estuary for the period 2004–2009.

				Rainfall (mm)													
												Total					
RMP	Bed name	Species	n	Day of sampling	-1 day	-2 days	-3 days	-4 days	-5 days	-6 days	-7 days	-2 days	-3 days	-4 days	-5 days	-6 days	-7 days
B070S	Wiseman's	*Mytilus* spp.	94	-0.031	0.029	0.101	0.119	0.073	0.150	0.064	0.074	0.046	0.121	0.175	0.171	0.160	0.195
B070P	Pont Pill	*C. gigas*	84	-0.078	0.089	0.033	-0.131	-0.090	-0.148	-0.098	-0.096	0.050	0.004	-0.020	-0.050	-0.071	-0.085
B070Q	Pont Pill	*Mytilus* spp.	80	0.082	0.310*	0.212	0.126	0.136	0.051	-0.006	0.039	0.277*	0.305*	0.302*	0.293*	0.283*	0.256*
B070M	Pont Pill - Relay	*Mytilus* spp.	66	0.313*	0.384*	0.212	0.312*	0.189	0.124	0.214	0.231	0.455*	0.391*	0.456*	0.409*	0.398*	0.404*
B070K	Wiseman's	*C. gigas*	95	0.018	0.037	0.087	0.016	-0.038	-0.031	0.079	0.041	0.042	0.103	0.131	0.118	0.081	0.108

* Statistically significant (p<0.05).

VARIATION OF *ESCHERICHIA COLI* ACCORDING TO RIVER FLOWS

River flow data from Restormel gauge station (Figure III.1) was correlated with *E. coli* levels in bivalve molluscs from five existing RMPs in the Fowey Estuary for data periods referred in Table XII.2. The results from this analysis are useful for the purposes of assessing the combined effect of rainfall and water levels in watercourses on the levels of microbiological contamination in bivalve molluscs.

Spearman's *rho* was used to estimate correlations between MPN of *E. coli* 100 g^{-1} FIL in bivalves and rainfall up to seven days before sampling.

No statistically significant correlations were obtained between river flows and levels of *E. coli* in bivalve molluscs. This indicates that faecal contamination from local pollution sources would be more significant to the overall microbial quality of bivalve molluscs than that delivered from the wider catchment to the estuary via the River Fowey.

Table XII.4 Spearman's rho coefficients between river flow recorded at Restormel gauge station and MPNs of* E. coli *100g^{-1} FIL in bivalves from five monitoring points in the Fowey Estuary for the period 2004–2009.

RMP	Bed name	Species	n	River flow ($m^3 s^{-1}$)													
												Total					
				Day of sampling	-1 day	-2 days	-3 days	-4 days	-5 days	-6 days	-7 days	-2 days	-3 days	-4 days	-5 days	-6 days	-7 days
B070S	Wiseman's	*Mytilus* spp.	100	0.059	0.091	0.050	0.018	0.028	-0.006	-0.008	-0.047	0.076	0.076	0.057	0.052	0.043	0.042
B070P	Pont Pill	*C. gigas*	91	-0.057	-0.053	-0.024	-0.037	-0.049	-0.041	-0.015	-0.053	-0.057	-0.063	-0.050	-0.048	-0.041	-0.034
B070Q	Pont Pill	*Mytilus* spp.	88	0.048	0.080	0.045	0.015	-0.040	-0.050	-0.072	-0.082	0.062	0.055	0.059	0.040	0.026	0.018
B070M	Pont Pill - Relay	*Mytilus* spp.	71	0.073	0.080	0.089	0.025	-0.023	-0.058	-0.023	-0053	0.086	0.074	0.077	0.050	0.043	0.038
B070K	Wiseman's	*C. gigas*	100	0.140	0.138	0.148	0.142	0.105	0.117	0.129	0.091	0.146	0.146	0.146	0.139	0.136	0.137

* Statistically significant (p<0.05).

Appendix XIII
SHORELINE SURVEY

Date of survey	23rd and 24th February 2009	
Production Area	Fowey Estuary	
Area(s) surveyed	see Figure A.2	
Commercial Species	Farmed	Pacific oysters (*C. gigas*)
	Farmed	Mussels (*Mytilus sp.*)
Harvester(s)	David Hancock Gary Rawle	
Local Authority	Fowey Port Health Authority	

On the 23rd and 24th of February 2009, staff from the Cefas Weymouth Laboratory and Fowey Port Health Authority performed a shoreline survey in the Fowey Estuary. The aim of the survey was to confirm the presence of potential sources of microbiological pollution previously identified as part of a desk study and to identify any additional potential sources of contamination in the area surveyed. The survey on the morning of 23rd February was undertaken by boat and the surveys on the afternoon of 23rd February and all day 24th February by foot. Observations and results apply to the time of the survey. Observations also relate to the location and field-of-view of the observer at the time they were made.

Tidal conditions

The survey took place between 10.45 and 16.45 on 23rd February 2009 and between 10.25 and 12.15 on 24th February 2009. The tidal curve for the two days is shown in Figure XIII.1.

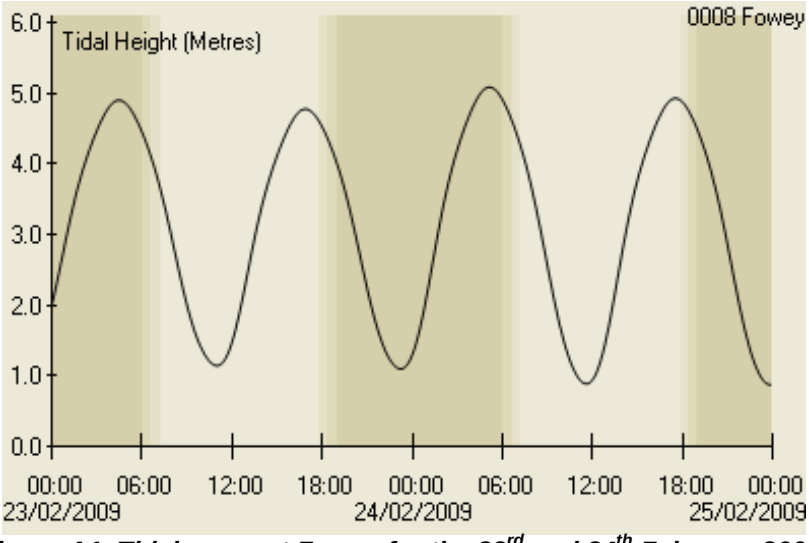


Figure A1. Tidal curve at Fowey for the 23rd and 24th February 2009.
Prediction based on Plymouth (Devonport). Admiralty TotalTide (UKHO, 2009).

Area surveyed

The principal focus of the survey was to record the location of the mussel fisheries, to record potential sources of pollution in the near vicinity, and upstream, of these, and to take associated freshwater, seawater and mussel samples. A secondary objective was to record salinity profiles in the vicinity of the mussel fisheries. The survey tracks by foot and boat are shown in Figure XIII.2.

Figure XIII.2. Area surveyed (red lines).

Weather

The weather was cloudy but dry on both days. The maximum temperature on 23rd February was 9ºC and on the 24th February was 10ºC.

3.2 RESULTS

Shellfish Farming Operations

There were three adjacent areas of mussel farming operations. The main area of mussel cultivation was sets of trestles on the east side of the river at Wisemans with mussels and oysters in poches) (Figure A.6). There were a small number of poches on the shore at the relay area on the northern shore within Pont Pill (Figure A.7) and further poches of mussels on trestles further up Pont Pill. There were also a number of poches containing mussels on the northern shore of Pont Pill at the confluence with the main estuary (Figure A.8).

The locations of the shellfisheries are shown in Figure XIII.3.

Figure XIII.3. Shellfish farming operations (green blocks) in the Fowey estuary.

Sewage Treatment Works

The locations of the following sewage treatment works and pumping stations were recorded during the survey:

Name	Location *	Figure
Lostwithiel STW	SX 10715 58676	A.9
Coulson Park PS	SX 10457 59440	A.10 (A.11)
Lerryn STW	SX 13979 56654	A.12
Lanteglos STW	SX 14676 54302	A.13
Lanteglos PS	SX 14705 54466	A.14

*The locations of sewage treatment works were recorded at the entrances.

The Coulson Park PS was associated with a storm outfall (SX 10493 59432; Figure XIII.11). In addition, a set of manhole covers was observed by the side of the stream at Lerryn (SX 13982 57042; Figure XIII.15) with a flap valve in the river bank (SX 13980 57043; Figure XIII.16).

Sewage related debris

No evidence of sewage related debris was seen on the shores during the survey.

Boats

Most of the boats seen during the survey (both moored and in boatyards) were in the vicinity of Fowey itself. Additionally there were a number of moored boats and empty moorings in the estuary above Fowey in the vicinity of Wisemans and at the entrance to Pont Pill. Moored or beached boats were also observed in many of the smaller creeks off the estuary. It would be expected that the number of moored boats would be larger during the summer months. Large ships dock at the clay docks above Fowey. The Bodinnick ferry also runs regularly across the river just above Fowey.

Land use and animals

The sides of the main estuary and the creeks are moderately wooded with fields behind. There are a number of farms in the area around the estuary. Cattle were seen in the vicinity (e.g. at Trevennic Farm; SX 09982 56904) but the main stock seen during the survey were sheep. These were mainly on the eastern side of the estuary. Evidence of slurry spreading was seen on one field (SX 14694 53838) and the Port Health Authority identified that this was more widespread in the vicinity earlier in the year.

Very small number of water birds (mainly ducks) were seen in the creeks off the main estuary.

Other observations

No other significant observations.

Water samples

Sampling took place under dry weather conditions. Eleven samples of stream/ piped flows and six samples of seawater were taken. The sampling locations are shown in Figure XIII.4 and the results given in Table XIII.1.

Salinity and temperature were recorded against depth at two locations (Pont Pill and Wiseman's) using a calibrated meter with a 30 m cable. The results are shown in Table XIII.2.

Shellfish samples

Mussels and Pacific oysters were sampled at two places in the relay area in Pont Pill (samples FYM1, FYM2, FYO1, FYO2). At Wiseman's, mussels were sampled at two locations (samples FYM3, FYM4) and oysters were sampled at one location (sample FYO3). The sampling locations are shown on the map in Figure A.5 and the results are given in Table XIII.3.

Figure XIII.4. Water sampling locations.

Table XIII.1.* E. coli *in samples of water collected at the time of the shoreline survey.

Sample no.	NGR	Sample type	Description	Flow m^3 day^{-1}	*E. coli* 100 ml^{-1}	Loading *E. coli* day^{-1}
FYW01	SX 13148 51568	Sea	Subsurface – from boil of Fowey STW discharge	-	210	-
FYW02	SX 12972 51523	Sea	Subsurface	-	110	-
FYW03	SX 12727 52266	Sea	Subsurface	-	90	-
FYW04	SX 12578 53099	Sea	Subsurface	-	800	-
FYW05	SX 12542 53242	Sea	Subsurface	-	70	-
FYW06	SX 12403 54502	Sea	Subsurface	-	50	-
FYW07	SX 12330 54768	Fresh	Stream at Golant	835	380	3.2×10^9
FYW08	SX 10585 57924	Fresh	Milltown Stream	13,200	30	3.9×10^9
FYW09	SX 10740 58631	Fresh	River; possibly below STW outlet	9,000*	70	6.3×10^9
FYW10	SX 14444 52050	Fresh	Stream at Pont	17,100	260	4.5×10^{10}
FYW11	SX 13165 53121	Fresh	Stream; Mixtow Pill	550	30	1.7×10^8
FYW12	SX 14559 54304	Fresh	River at Penpoll Creek	44,700	70	3.1×10^{10}
FYW13	SX 14604 54327	Fresh	Possible outfall pipe; slight flow	-	12,400	-
FYW14	SX 13827 56872	Fresh	Stream below Lerryn STW	5,300	900	4.8×10^{10}
FYW15	SX 13828 56939	Fresh	River above confluence with stream	45,300	900	4.1×10^{11}
FYW16	SX 13979 57046	Fresh	Broken plastic pipe from bank; trickle	-	<10	-
FYW17	SX 13984 57050	Fresh	Concrete pipe from bank - trickle; evidence of sewage fungus	-	3,900	-

***Depth and flow measured only at one point off west bank. Width obtained from satellite photography.*

Table XIII.2. Salinity profiles measured at the time of the shoreline survey.

NGR	Depth (m)	Temperature ºC	Salinity (ppt)
SX 12972 51523	0	8.9	18.0
,,	1	8.6	30.1
,,	2	8.7	32.2
,,	3	8.7	33.1
,,	4	8.6	33.5
SX 12542 53242	0	8.7	19.7
,,	1	8.6	27.5
,,	2	8.5	30.5
,,	3	8.6	32.5
,,	4	8.6	33.3
,,	5	8.7	34.0

Table XIII.3.* E. coli *in samples of shellfish collected at the time of the shoreline survey.

NGR	Sample no.	Depth*	MPN *E. coli* 100 g^{-1}
SX 13150 51580	FYM1	Shore	130
SX 13150 51580	FYO1	Shore	460
SX 13302 51622	FYM2	Trestle	110
SX 13302 51622	FYO2	Trestle	170
SX 12597 53118	FYM3	Trestle	1100
SX 12576 53097	FYM4	Trestle	1300
SX 12570 53086	FYO3	Trestle	490

**all shellfish were above water at the time of sampling.*

Figure XIII.5. Shellfish sampling locations.

Figure XIII.6. Oyster trestles at Wiseman's.

Figure XIII.7. Poches of mussels on the shore at the Pont Pill relay area.

Figure XIII.8. Poches of mussels on trestles at the Pont Pill relay area.

Figure XIII.9 Lostwithiel STW.

Figure XIII.10. Coulson Park Pumping Station.

Figure XIII.11. Coulson Park Storm Outfall.

Figure XIII.12. Lerryn STW entrance.

Figure XIII.13. Lanteglos STW.

Figure XIII.14. Lanteglos PS.

Figure A.15. Manhole covers at Lerryn.

Figure A.16. Flap valve at Lerryn.

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List of Abbreviations

AOD	Above Ordnance Datum
AONB	Area of Outstanding Natural Beauty
ANOVA	Analysis of Variance
BMPA	Bivalve Mollusc Production Area
BST	British Summer Time
CD	Chart Datum
Cefas	Centre for Environment Fisheries and Aquaculture Science
CFU	Colony Forming Units
CSO	Combined Sewer Overflow
DWF	Dry Weather Flow
EA	Environment Agency
E. coli	*Escherichia coli*
EC	European Community
EO	Emergency overflow
FIL	Flesh and intravalvular liquid
FSA	Food Standards Agency
h	hour
km	kilometre
LFA	Local Food Authority
LW	Low Water
ml	millilitres
MLWN	Mean Low Water Neap
MLWS	Mean Low Water Spring
MPN	Most Probable Number
NGR	National Grid Reference
PHA	Port Health Authority
ppt	Parts Per Thousand
PS	Pumping Station
RMP	Representative Monitoring Point
SAC	Special Area of Conservation
spp.	Species
STWs	Sewage Treatment Works
SSSI	Site of Special Scientific Interest
SWD	Shellfish Waters Directive
TC	Total Coliforms
TSS	Total Suspended Solids
UK	United Kingdom
UV	Ultraviolet

Glossary

Analysis of Variance (ANOVA)	A statistical test which compares the distribution of two or more sample groups to determine if one or more of the groups are significantly different from the others.
Bathing Water	A body of water used for bathing by a significant 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.
Biosolids	Organic manures, animal slurries and human sewage sludge
Classification of shellfish harvesting areas	A system for grading harvesting areas based on levels of bacterial indicator organisms (*E. coli*).
Coliform	Gram negative, facultatively anaerobic rod-shaped bacteria that 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 (CSO)	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.
Discharge Consent	An authorisation issued by the Environment Agency to control the discharge of polluting matter to surface or underground waters.
Dry Weather Flow (DWF)	The average daily flow to the treatment works during seven consecutive days without rain following seven days during which rain 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.
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.
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. The enterohemorrhagic strain of this bacterium O157:H7 is the cause of infection in humans, such as bloody diarrhoea and occasionally kidney failure.
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.

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 antilog of that mean. It is often used to describe the typical values of a skewed data such as one following a log-normal distribution.
Guideline (G) values	Values set in European Directives that the Member States have to endeavour to achieve
Habitat	Environmental area that is inhabited by a particular species.
Hydrodynamic modelling	In this context numerical models that approximate the detail of real fluid flow i.e. velocities and water levels as functions of time and space. Output from these models can be used together with a representation of the diffusive process in the water column (Particle Transport Models) to represent the fate and dispersion of bacteria.
Local Action Group	Local Action Groups have been formed to investigate results exceeding prescribed trigger levels in classified harvesting areas and formulate action plans to implement short term public health protection measures. Membership of the groups include representatives from the Local Food Authority (LFA), Centre for Environment, Fisheries and Aquaculture Science (Cefas), Environment Agency (EA), Marine Fisheries Agency (MFA), plus the relevant accredited shellfish testing laboratory, water company, harbour authority(ies), local shellfish industry and Food Standards Agency (FSA).
Log-normal distribution	A log-normal distribution is a distribution in which the logarithms of the values have a normal distribution. Environmental monitoring data for a range of bacteria follow a log-normal distribution.
Primary Treatment	Removal of gross sewage solids by settlement process.
Secondary Treatment	Treatment of settled sewage, generally by biological oxidation.
Septic	A term used to describe sewage in which uncontrolled anaerobic decomposition occurs.
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 wastewater 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.
Sludge	A solid waste fraction precipitated by a water treatment process.
Tertiary Treatment	Treatment applied to the effluent from a secondary treatment process in order to further reduce a component or components of that effluent, e.g. pathogenic micro-organisms or nutrients.
Waste water	Any waste water but see also "sewage".

ACKNOWLEDGEMENTS

Cefas would like to thank Kevan Connolly (Environment Agency), David Hancock (Fowey River Oysters) and Gary Rawle (Westcountry Mussels of Fowey Ltd).