EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Upper Fal Estuary – Cornwall

2010

Cover photograph: The Upper Fal Estuary.

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STATEMENT OF USE: This report provides information from a study of the information available relevant to perform a sanitary survey of bivalve mollusc harvesting areas in the upper Fal 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 & Aquaculture Science (Cefas) undertook this work on behalf of the Food Standards Agency (FSA).

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

RECOMMENDED BIBLIOGRAPHIC REFERENCE: Cefas, 2010. Sanitary Survey of the Upper Fal Estuary (Cornwall). Cefas report on behalf of the Food Standards Agency, to demonstrate compliance with the requirements for classification of bivalve mollusc production areas in England and Wales under of Regulation (EC) No. 854/2004.

Contents

EXECUTIVE SUMMARY

Under EC Regulation No. 854/2004[1] (Annex II Chapter II Paragraph 6), there is a requirement for competent authorities intending to classify bivalve mollusc production and relaying areas (BMPAs) to undertake a number of tasks collectively known (in England and Wales) as 'sanitary surveys'. The main purpose of these surveys is to inform the sampling plans for the microbiological monitoring programme and classification of BMPAs. Other wider benefits of these surveys include the potential to improve identification of pollution events and the sources of those events such that in the future remedial action can be taken to the benefit of the fisheries.

The sanitary survey was initiated as a result of concerns expressed by the shellfish industry regarding the classification status of the area, as based on the ongoing *E. coli* monitoring. This report documents the quantitative assessment made of the levels of microbiological contamination in bivalves from the Upper Fal Estuary, Cornwall and presents the recommended sampling plan as a result of a sanitary survey undertaken by Cefas (The Centre for Environment, Fisheries and Aquaculture Science) on behalf of the Food Standards Agency (FSA).

The assessment is supported by published relevant information for the upper Fal catchment area and new information obtained from a shoreline survey performed in the upper estuary. The sampling plan revisits information on the existing location of monitoring points, their sampling frequency and depth of sampling for the existing production areas of wild native oysters and wild and farmed mussels in the upper estuary.

In general, it was concluded that the main sources of pollution likely to impact on the BMPAs are:

- continuous sewage discharges to tidal waters in the Truro and Tresillian Rivers
- intermittent sewage discharges to tidal waters (principally to the upper Truro River)
- continuous and intermittent discharges to freshwaters discharging into the upper Fal estuary
- discharges from boats
- diffuse pollution to both tidal waters and indirectly via freshwater inputs (including effects from slurry spreading)

Small sewage discharges to Coombe Creek, Ruan Creek and at King Harry Ferry may have some significant local impact. There will also be seasonal fluctuations in the proportion of microbiological sources of contamination from wildlife (birds), boats (moored yachts) and the human population (as a result of tourism).

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

The margins and tributaries of the upper reaches of the estuary are the areas potentially most vulnerable to contamination. These have less available dilution due to restricted water depth and potentially being subject to contamination from both upstream and downstream sources, although effects from the former are likely to dominate. The locations of existing representative monitoring points (RMPs) were reviewed to determine whether new monitoring points were necessary to adequately reflect the impact of pollution sources across the bivalve mollusc production areas.

Summary Recommendations

- The RMPs above Malpas should be discontinued due to the combination of a lack of commercial fishing and difficulty of access. The extent of the classified area should be amended accordingly. The previous RMP at Malpas should be re-instated in light of minor commercial interest in this area – this would then serve as the northernmost RMP.

- The *O. edulis* RMPs at Maggoty Bank, Tolverne and Coombe Creek should be maintained to cover the native oyster fishery here. Monitoring at Grimes Bar should not be undertaken unless commercial interest in the area resumes. The classified area should therefore be reduced at the northern end to exclude this bed. Due to the sewage inputs to Cowlands Creek, the classified area should be redefined to exclude the upper part of this inlet. [A review of the *O. edulis* RMPs at Pill Creek and Turnaware Bar, and the associated classified area, is included in a sanitary survey of the Lower Fal estuary, including Carrick Roads.]

- Given the likely sources of contamination within the upper estuary, both remote and localised, the RMP at King Harry Reach should be moved to the northern end of the upper set of mussel lines. The current RMP for mussels at T Pontoon/South Wood should be discontinued as there is no current commercial activity in this area. The lower limit of the classified area should then be moved closer to the current location of the mussel farms.

- As sampling is undertaken from bags, and thus variability in density/availability of commercial stock is not an issue, a maximum tolerance of 10 metres should be specified around each RMP.

- Given that limited stratification was seen in the salinity profiles taken at the time of the shoreline survey, and that rainfall-associated contamination events are deemed to be a source of additional faecal pollution, bags placed for the purposes of sampling should be located between one and three metres below the surface.

- Further investigations should be undertaken of the potential commercial gathering of cockles in the Upper Fal and the poches seen at South Wood. The sampling plan should be reviewed to take account of these activities if classification is needed.

- Further improvements to the CSOs in the upper estuary should be supported as these would be likely to reduce the contamination of the shellfisheries from this source.

- Field level data on the monthly application of biosolids would assist future re-assessment of the sanitary survey for the area.

The following RMPs were recommended for ongoing monitoring:

RMP ID	RMP NAME	SPECIES	NGR
B033F	Maggoty Bank	*O. edulis*	SW84924143
B033H	Tolverne	*O. edulis*	SW84804037
B033V	Coombe Creek	*O. edulis*	SW84004030
B033Y	R Pontoon/Tregothnan	*Mytilus* spp.	SW85024095
B33AL	Ruan Creek	*Mytilus* spp.	SW85784054
TBA	King Harry Reach 2	*Mytilus* spp.	SW84143938

1 INTRODUCTION

This report documents information arising from a review of existing information sanitary survey relevant to the Upper Fal Estuary Bivalve Mollusc Production Area (BMPA). The sanitary survey was prompted by the FSA as a review of the existing sampling regime in order to ensure that the ongoing monitoring programme adequately reflects the known sources of contamination. A desk based assessment of existing relevant information has been made and the results of this are presented in Section 2. The results of a shoreline survey, undertaken in the Upper Fal vicinity are presented in Section 3. In Section 4, the results of the desk study and shoreline survey are reviewed in an overall assessment of the pollution sources likely to affect the levels of microbiological contamination in the BMPAs, along with recommendations in respect of the monitoring programme. A sampling plan, derived from an evaluation of the above information, is set out in the Appendix. This includes the location of representative monitoring points (RMPs) and required frequency of sampling for each species across the Upper Fal production areas.

Filter-feeding bivalve shellfish (e.g. oysters, clams, cockles, 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 in humans. Examples of such infections are gastroenteritis due to norovirus or *Salmonella* and hepatitis due to hepatitis A virus. Infectious disease outbreaks are more likely to occur when bivalves are harvested from BMPAs impacted by sources of human and or animal faecal 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 Regulation (EC) No. 854/2004[2], 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 a ‘sanitary survey’ in and around BMPAs and their associated hydrological catchments and coastal waters in order to establish the appropriate RMPs

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

for the monitoring programme (Annex II (Chapter II paragraph 6) of the Regulation refer).

Cefas is performing sanitary surveys for new BMPAs in England and Wales, on behalf of the FSA. The purpose of these sanitary surveys is to demonstrate compliance with the requirements stated in 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 areas;

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 e.g. rainfall readings, waste-water treatment, etc.;

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

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

EC Regulation 854/2004 also specifies the use of *Escherichia coli* as an indicator of microbiological contamination in bivalve molluscs. This bacterium is present in animal and human faeces in large numbers and is therefore indicative of contamination of faecal origin. Both sewage and agricultural inputs to river systems upstream of estuaries are thought to significantly impact on a number of coastal and estuarine BMPAs in England and Wales (Younger *et al*., 2003) and it is important that these impacts are documented and understood.

In addition to better targeting the location of RMPs and frequency of monitoring, it is believed that sanitary surveys may also serve to help to target future water quality improvements within a BMPA. 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 specific point source discharge improvements or as a result of proactive changes in land management practices. Improvements in water quality may result following such remediation effort.

2 DESK STUDY

2.1 GENERAL DESCRIPTION OF THE COASTAL AREA

The Fal Estuary is situated in Cornwall, on the south coast of England (50° 05.85'N, 5° 08.25'W; Figures 1 and 2). The estuary is a Ria, a drowned river valley. The mouth faces south. The estuary is long and narrow, running 18 km inland with many small tributary creeks and tidal inlets providing more than 127 km of coastline. Water depths vary up to a maximum of 33 m. It is largely undeveloped, with large stretches of woodland on its shores, although the city of Truro is located at the head of the estuary and the town of Falmouth is situated towards the southern end. This report focuses on the Upper Fal estuary north of Turnaware Point.

Most of the estuary is within the Mylor and Roseland to Portpean Area of Outstanding Natural Beauty and is a marine Special Area of Conservation noted for its large shallow inlets and bays, mudflats and sand flats not covered by seawater at low tide, and those that are slightly covered by seawater at all times (Langston *et al.*, 2006).

The Fal Estuary is affected as a consequence of an historic and prolific mining period spanning hundreds of years when Cornwall produced much of the world's metal resources. This has left a legacy of metal contamination in the area particularly in the Carnon River and Restronguet Creek. There remains an on-going problem of release and remobilization of metal contaminants from numerous land-based sources in addition to disturbance of contaminated marine sediments.

In addition, as a significant port in the southwest, the Fal Estuary also suffers from a legacy of Tri-Butyl Tin (TBT; used as antifouling for ships and boats), with remobilization and resuspension of contaminated sediment now being the largest contributing factor.

A report from the Marine Biological Association (MBA, 2003) documented that the Fal Estuary suffers from agricultural runoff and enrichment by sewage discharges and/or combined sewer overflows (CSOs) which in turn creates high nutrient loadings in the upper estuary leading to eutrophic conditions and occasional toxic algal blooms. Persistent problems of high nitrification led to the Truro, Tresillian and Fal Estuaries being defined as Sensitive Areas under the Nitrates Directive (91/676/EC). EA data for January 1994 to March 1996 indicated the highest Total Inorganic Nitrogen (TIN) concentrations were from Ladock and Newham adjacent to the respective Wastewater Treatment Works (WwTWs) at both sites, however the highest loads (accounting for flow) were from the Tresillian and Kenwyn Rivers.

High nitrate levels have led to a classification of Nitrate Vulnerable Zones (NVZs) around the entire Fal Estuary, which in turn led to a change in farming practices in recent years with farmers now spreading slurry on fields in a less frequent but much more intensive manner than previously, due to enforced closed periods under NVZ guidelines. This closed period leads to a build up of slurry on a farm; often this means that on the first available 'dry-weather' window all farms are out spreading. If such a significant burst of spreading activity is followed by a rainfall event the rivers can turn brown due to the slurry loading.

From the above there are clear implications that the landscape surrounding the upper Fal impacts directly on its water quality either as a consequence of the historic land use or through current agricultural practices.

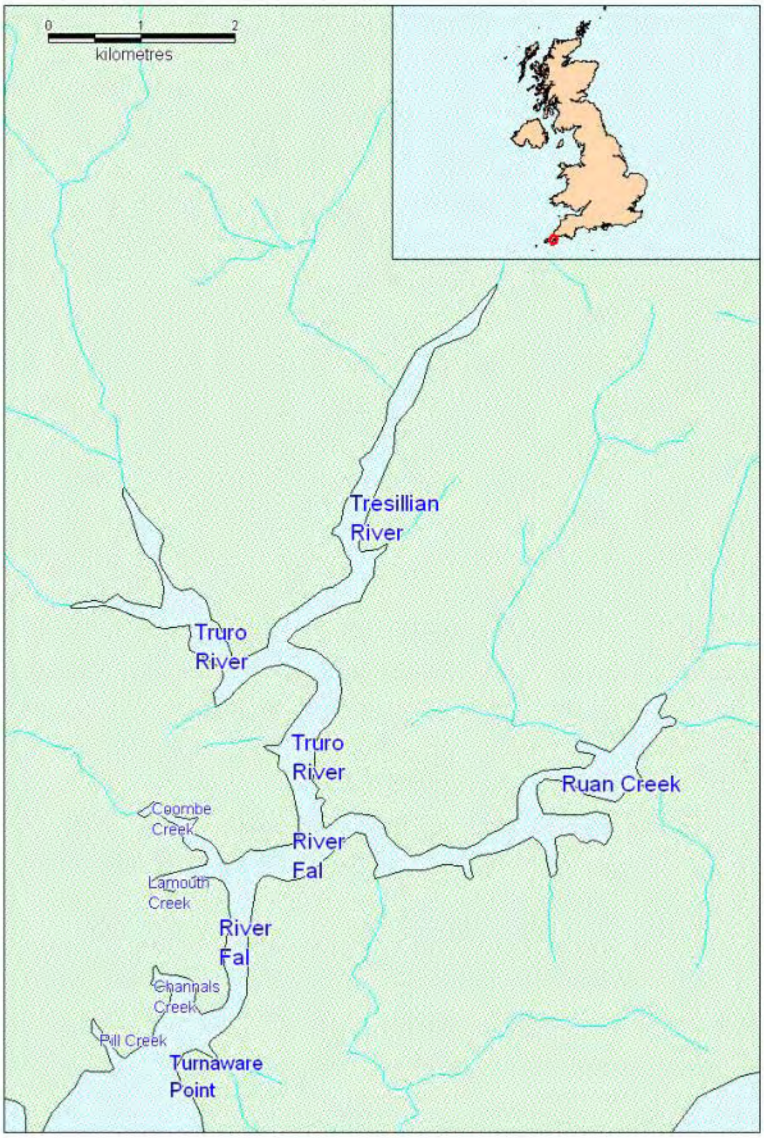
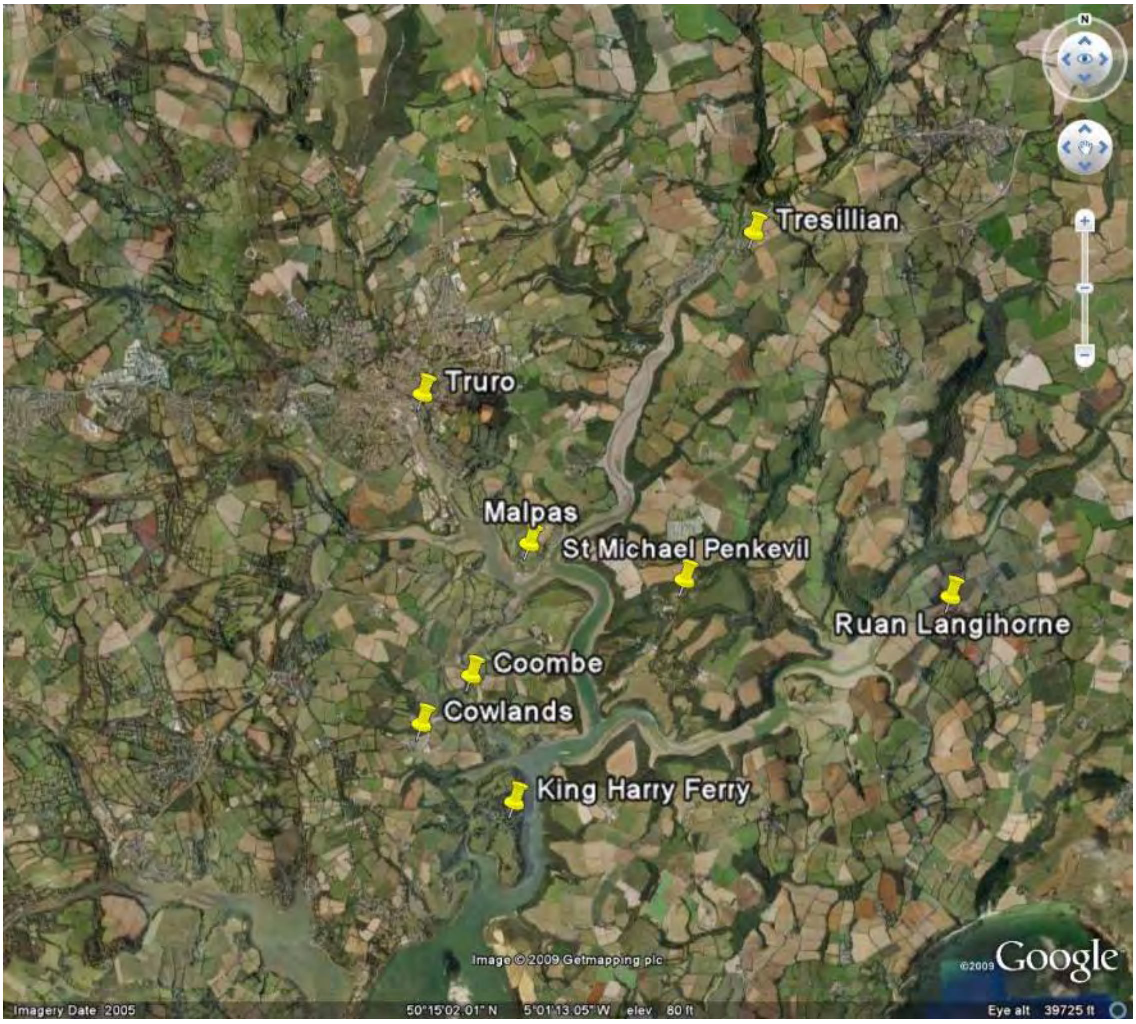


Figure 1. Location of the Upper Fal Estuary showing its location and tributaries.



Reproduced under licence Google EarthTM mapping service.

Figure 2. Google Earth (2009) image of the Upper Fal Estuary showing its main settlements.

2.2 DESCRIPTION OF BIVALVE MOLLUSCAN SHELLFISHERIES

2.2.1 Bivalve Molluscan Species, Location and Extent

The major commercial fishery in the upper Fal is the farming of mussels on lines suspended from rafts and buoys (see Figures 3 and 4). Wild native oysters beds also extend into the upper Fal. The location of the shellfish beds and farms in the Upper Fal is shown in Figure 5 and 6.

The area where the native Fal Oyster is produced can be described as within the Truro Port Fishery. The legal limits of this are described in the fishery order (1936, amended 1975) as all those parts of the Truro and Falmouth Harbours and of the bed of the Truro, Fal and Tresillian Rivers containing an area of 2721 acres (1,101 hectares) .

Information from Falmouth and Truro PHA indicated that only the following areas in the Upper Fal were of current commercial interest:

Maggoty Bank: *O. edulis* dredged during the season
Ruan Creek: *Mytilus* spp. lay-up and growing on
King Harry Reach: *Mytilus* spp. in current use
Pill Creek: *O. edulis* lay-up.

Information from Truro Harbour Authority indicates that there is some commercial gathering of native oysters and mussels as far up as the Malpas Pontoon. Gathering of oysters and mussels also extends into Ruan Creek from the River Fal.

Beds of the common cockle (*Cerastoderma edule*) occur opposite Malpas point. The edible periwinkle (*Littorina littorea*) is also found here. Both are subject to some commercial gathering. Bagged cockles were also noted on the shore at Roundwood Point during the shoreline survey. There is currently no commercial harvesting of any species in the Truro or Tresillian Rivers above Malpas.

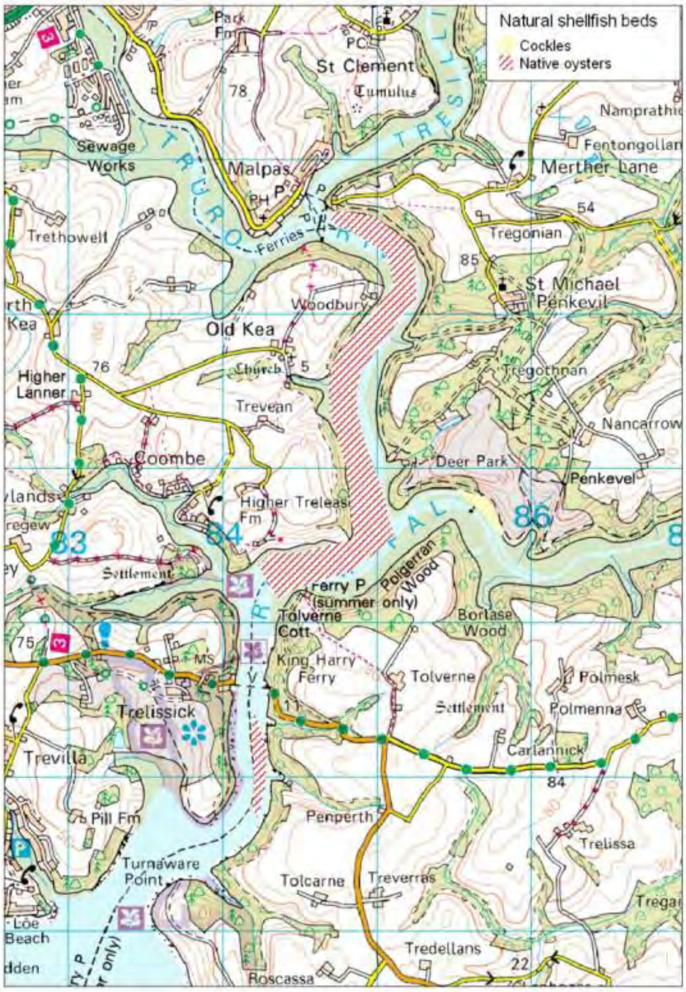


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Figure 5. Natural shellfish beds in the Upper Fal Estuary.

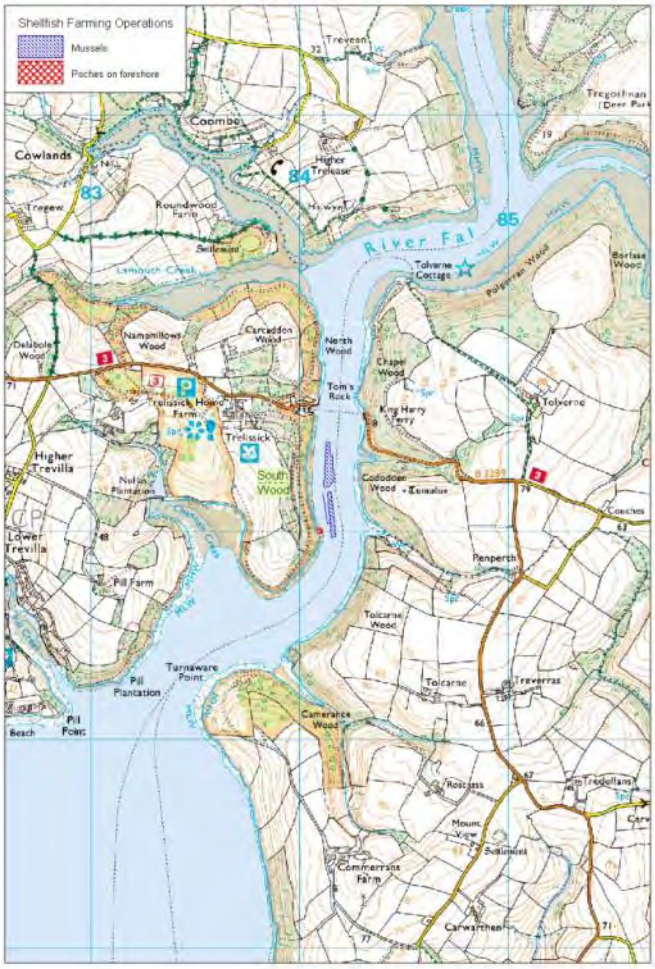


Figure 6. Shellfish farming operations in the Upper Fal Estuary at the time of the shoreline survey

2.2.2 Growing Methods

Currently, mussel farming in the upper estuary is undertaken using lines suspended from buoys or rafts (see Figures 3 and 4).

As well as the lines in the area below King Harry Ferry, there are currently lines for the collection of seed hanging from Ruan Pontoon – these are not grown to harvestable size at this location but transferred to South Wood for growing on. Wild mussels occur in some parts of the upper estuary and are gathered commercially to some extent.

Fal oysters grow naturally on the sea bed within the fishery area. This is a wild fishery where the oysters typically are not cultured or bred. There is a small amount of husbandry of the wild and natural beds as during the process of fishing the substrate (cultch) is moved by the dredge which provides de-silting of the substrate; occasional extra dredging of the beds without harvesting (described as harrowing) further improves the oyster beds and encourages a good spatfall to settle. Native oyster halfware is supplied from the Fal to other locations for growing on, including the nearby Helford.

Poches of what were presumed to be oysters were seen on the intertidal area by South Wood. This has not been identified to the Port Health Authority as an area being used for the farming of oysters.

Figure 3. Buoyed mussels lines in the upper Fal.

Figure 4. Mussels rafts in the Fal.

2.2.3 Existing Production/Relaying Areas

The limits of the classified production areas in the Upper Fal are shown in Figures 7 (mussels) and 8 (native oysters). The area is not currently classified for any other species. There are no designated relaying areas in the Upper Fal.

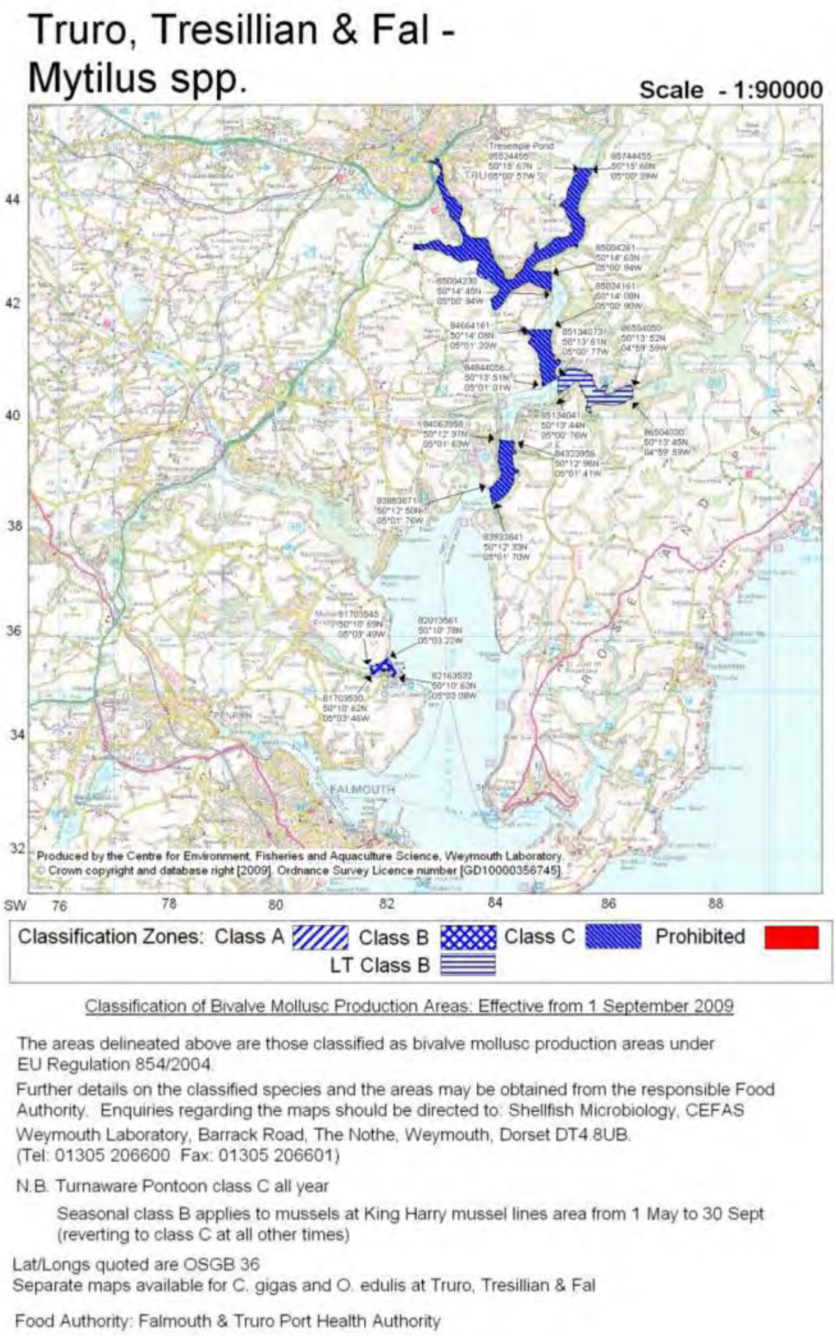
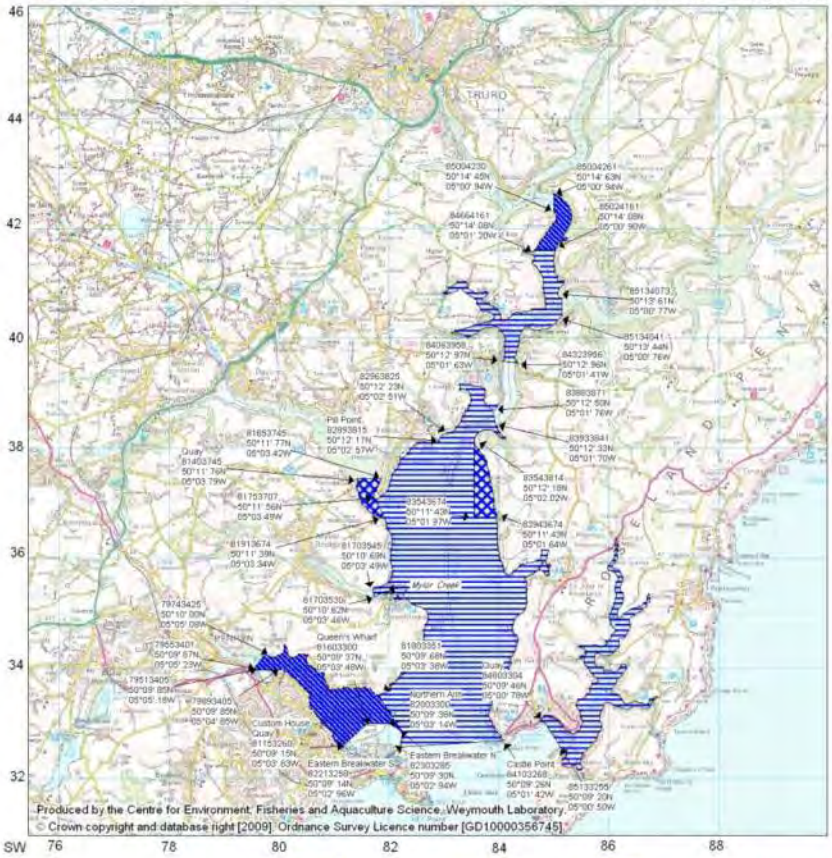


Figure 7. Existing production area and classification status of mussels in the Fal Estuary, as at 1 September 2009.

Truro, Tresillian & Fal -
O. edulis

Scale - 1:90000



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

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 OSGB 36
Separate maps available for C. gigas and Mytilus spp. at Truro, Tresillian & Fal

Food Authority: Falmouth & Truro Port Health Authority

Figure 8. Existing production area and classification status of native oysters in the Fal Estuary, as at 1 September 2009.

2.2.4 Seasonality of Harvest

The spawning season for native oysters occurs between June and August (Laing *et al*., 2005). Under the Truro Port Fishing Order 1936 (revised 1975) the oyster dredging season runs from 1st October to 31st March. Annual Licences are issued by the Harbour Authority; 53 licences were issued for the 2008/9 season (Paul Ferris, Truro Harbour Authority, person. comm.).

Farmed mussels are harvested year-round, subject to the classification status of the area being class B and the area not being closed due to the presence of algal biotoxins above statutory limits.

2.2.5 Harvesting Techniques

Figure 9. Sailing boat used to dredge for oyster in the Fal Estuary.

The oysters are taken within the Truro Port Fishery area by sailing or rowing vessels using traditional methods. There is specific legislation which controls the fishing methods used in the fishery. The fishing methods described below distinguishes the Fal Oyster from other native oysters. The fishing method uses dredges which are towed across the sea bed by traditional sailing or rowing boats (see Figure 9); there is no motor power used to harvest the oysters. This method is unique to the area.

After harvesting oysters from the native beds the fishermen often keep the oysters in lays in the adjacent rivers and creeks of the Fal and Helford estuaries. The lays are more accessible than the fishery and provide a short term storage period. The main benefit of laying-up oysters is to manage the peaks in supply and demand and to serve as a use for purification. Traceability is maintained by the fishermen for movement of oysters to the lays and again when they are moved off the lays at the end of the storage period.

Mussels on the raft system are harvested using equipment located on the rafts themselves (see Figure 4). The other lines are harvested from boats.

2.2.6 Conservation Controls

Oysters

The legal limits of the Truro Port Fishery are described in the fishery order (1936 amended 1975) as all those parts of the Truro and Falmouth Harbours and of the bed of the Truro, Fal and Tresillian Rivers containing an area of 2721 acres (1,101 hectares). This area is north of a line drawn between Trefusis Point and St Mawes Castle to Mean Low Water Mark of an Ordinary Tide. The edge of the fishery is the Mean Low Water Mark and this coincides with the coast except at the entrance of each creek indicating the upper limits of the fishery at Mylor, St Just and Malpas. The Fal oyster season starts on the 1st October and closes on the 31st March, the working hours are 0900hrs to 1500hrs Monday to Friday and 0900hrs to 1300hrs on Saturday.

Mussels

The farmed mussels within the Upper Fal are not subject to any conservation controls and there are no limits on stock control grounds on the period when the shellfish can be harvested.

2.3 CLIMATE IN THE CATCHMENT AREA

The South West is one of the warmest and wettest regions in the country and there is significant variation in the area.

2.3.1 Rainfall

The coastal area across the Fal (tidal) and Helford catchments receive 900–1,000mm of rain per year (Met Office, 2007). This compares with an average annual rainfall for England and Wales of approximately 1,250mm (Perry, 2006).

Data from rainfall gauges located at Newham (near the confluence of the Truro River and Calenick Creek) and Truro College (located at Treliske to the west of Truro) were obtained from the Environment Agency. Figures 10 and 11 show the total rainfall by month for the two locations. They indicate that January, February, October, November and December are the wettest months on average and during these months there may therefore be an increased risk of contamination from land run-off and rainfall associated sewer overflows.

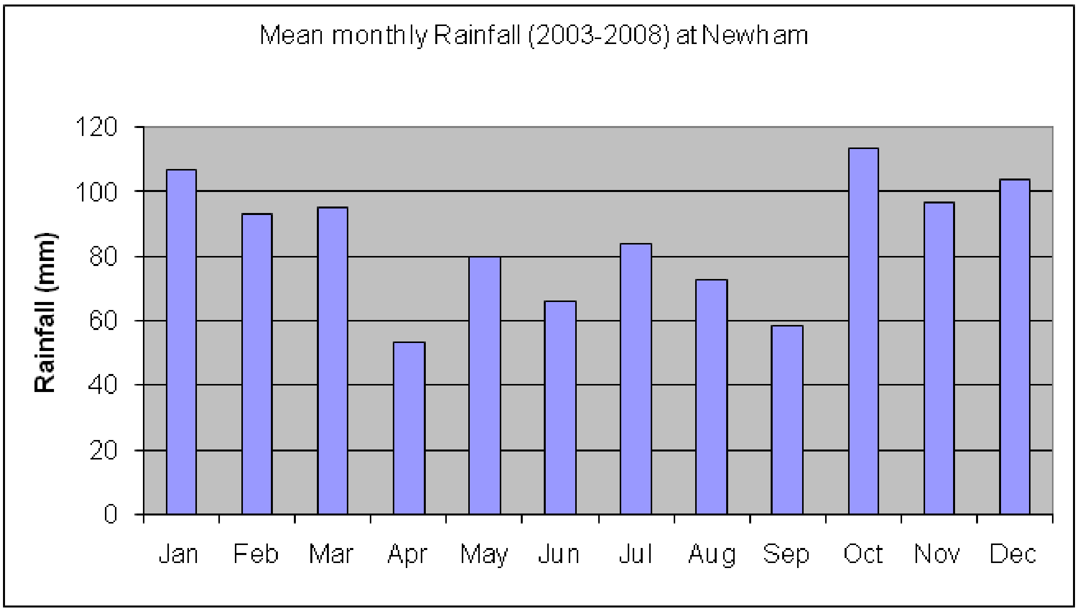


Figure 10. Monthly variation in total rainfall at Newham for 2003-2008.
Data provided by the Environment Agency

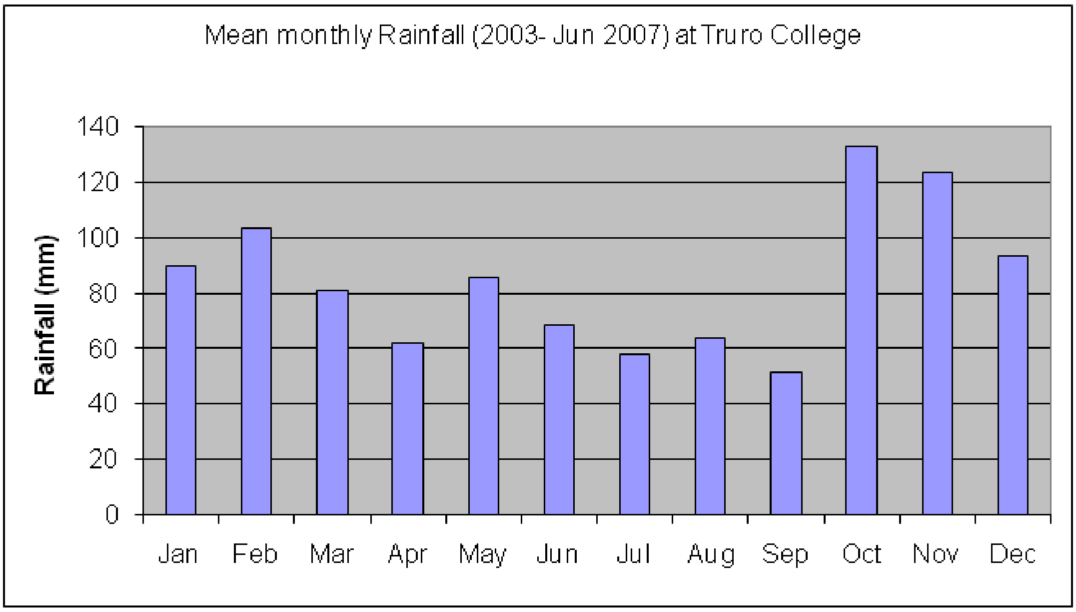


Figure 11. Monthly variation in total rainfall at Truro College for 2003-2007.
Data provided by the Environment Agency

Further information can be gained from examining these figures with annual variations shown, as in Figures 12 and 13.

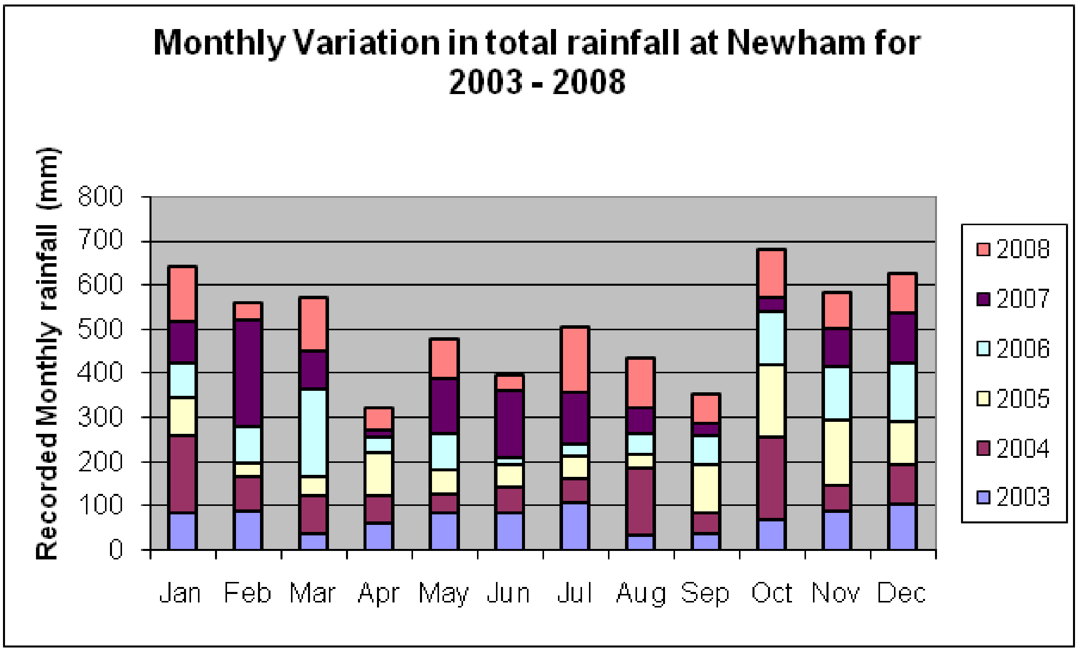


Figure 12. Year-to-year variation in monthly rainfall at Newham for 2003–2008.
Data provided by the Environment Agency

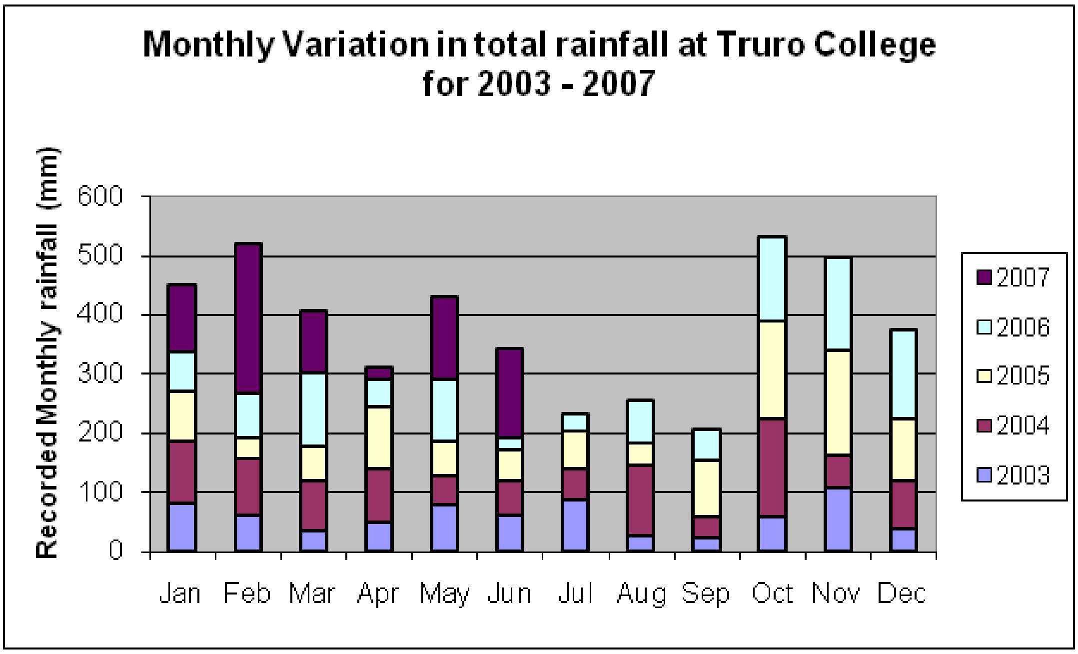


Figure 13. Year-to-year variation in monthly rainfall at Truro College for 2003-2007.
Data provided by the Environment Agency

The high rainfall in February 2007 coincided with two recorded slurry incidents on the catchment area, and therefore this gave an increased risk of microbial contamination at that time. Increased land run-off might also be expected in October when rainfall increases markedly after the dry summer months.

2.3.2 Air Temperature

As in most of the South Western region of the country, the climate is relatively mild. The Meteorological Office statistics for St Mawgan, in North Cornwall, show the average minimum temperature in February to be 3.5 ºC and the average maximum temperature in August to be 19.1ºC (over the years 1971-2000 inclusive)(Meteorological Office, 2010). St Mawgan is located approximately 25 km north of the Upper Fal near the north Cornwall coast. A private weather station in the immediate area shows that maximum temperatures vary from approximately 12ºC in winter to 29ºC in summer and the minimum temperatures from approximately -3ºC in winter to 12ºC in summer (www.kerrobert.plus.com). The air temperature will influence the temperature of the seawater, most directly in shallower areas, and also the temperature of exposed intertidal shellfish.

2.3.3 Sunshine

The sunniest parts of the United Kingdom such as along the South coast of England, achieve annual average figures of around 1,750 h of sunshine. The dullest parts of England are the mountainous areas, with annual average totals of less than 1,000 h (Meteorological Office, 2007b; see Figure 14). The average annual sunshine duration recorded in the Falmouth catchment ranges from 1541 h to 1885 h in most of the Western and Southern areas and from 1471 h to 1540 h in the Northern areas (Meteorological Office, 2007a). It is generally accepted that the most rapid die-off or low persistence of bacteria occurs in marine and freshwaters in coastal areas with high sunlight intensities. Studies aiming to analyse the effect of incident solar radiation on the levels of microbiological contamination in specific surface waters are complex and influenced by the level of turbidity in the waters and they are not within the scope of this assessment.

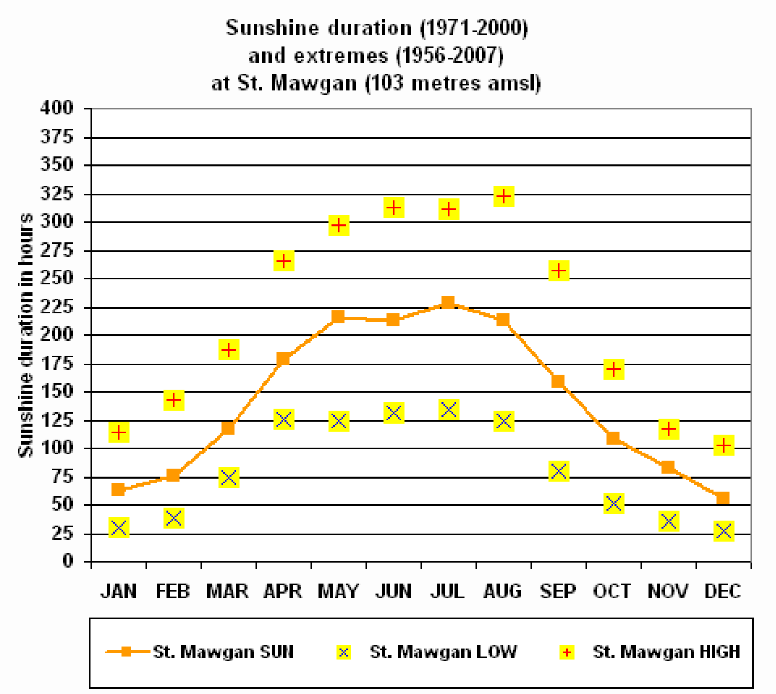


Figure 14. Monthly variation in sunshine duration hours at St. Mawgan for 1971–2000 with extremes 1956-2007.
Data provided by the Meteorological Office

2.3.4 Wind

Wind data between 1969 and 2007 from St Mawgan meteorological station had been analysed by the Meteorological Office (2007). As noted above, St Mawgan is located away from the Upper Fal estuary, towards the north Cornwall coast, and is a little over 100 m above sea level. Care must therefore be taken in relating the wind conditions at St Mawgan to those in the Upper Fal estuary.

Figure 15 below represents the mean wind speed and maximum gust strength for each month over the identified period. For the region as a whole, the predominant winds are from the westerly and south westerly directions.

Whilst the contours of the land around an estuary will modify the prevailing wind to some extent, in the Fal the potential for wind driven advection of potentially contaminated surface waters is predominately from the head towards the mouth of the estuary. The way that wind can affect surface currents and how these may influence the transport of pollution in the Fal Estuary is also considered in Section 2.5.5.

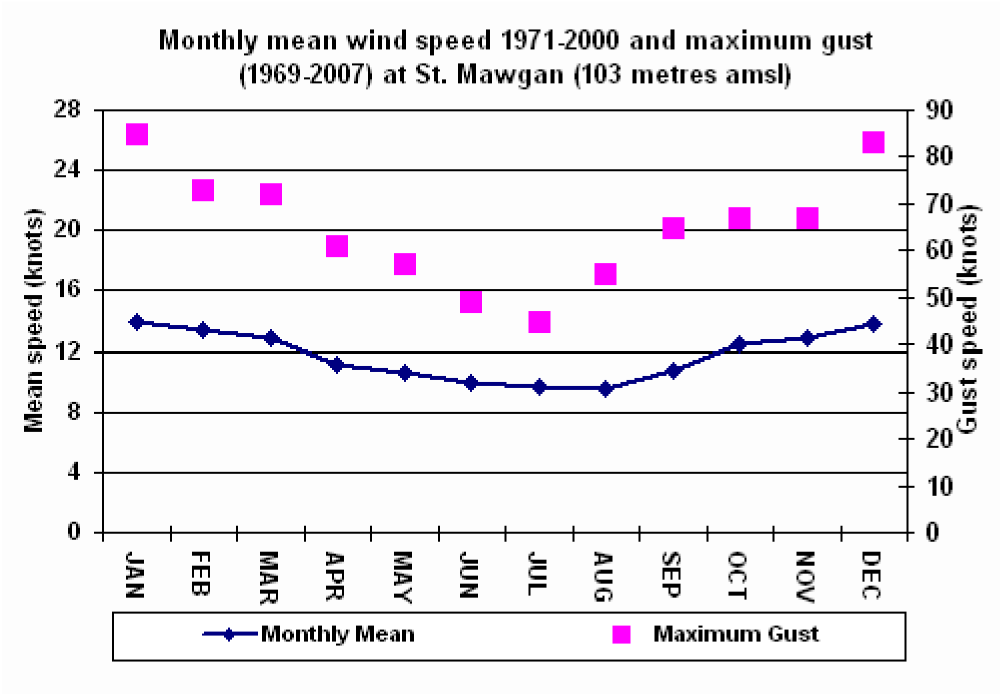


Figure 15. Monthly variation in mean wind speed and maximum gust at St. Mawgan for 1971–2000 with extremes 1956-2007.
Data provided by the Met Office

2.4. SOURCES OF AND VARIATION IN MICROBIOLOGICAL POLLUTION

2.4.1 Land Use/Land Cover

Most of the area (59 %) is utilised for agricultural purposes (Figure 16) with permanent grassland contributing up to 64% of the total and temporary grassland a further 24%. Rough grazing makes up 3%. 5% by area is woodland and 4% is set-aside. The area is dominated by 1317 farms. Of these, 69% of the holdings, and 61% by area, are owned and the remainder rented. The farms are generally small, with 63% being less than 20 ha in area and only 5% (56 farms) greater than 100 ha in area (Figure 17).

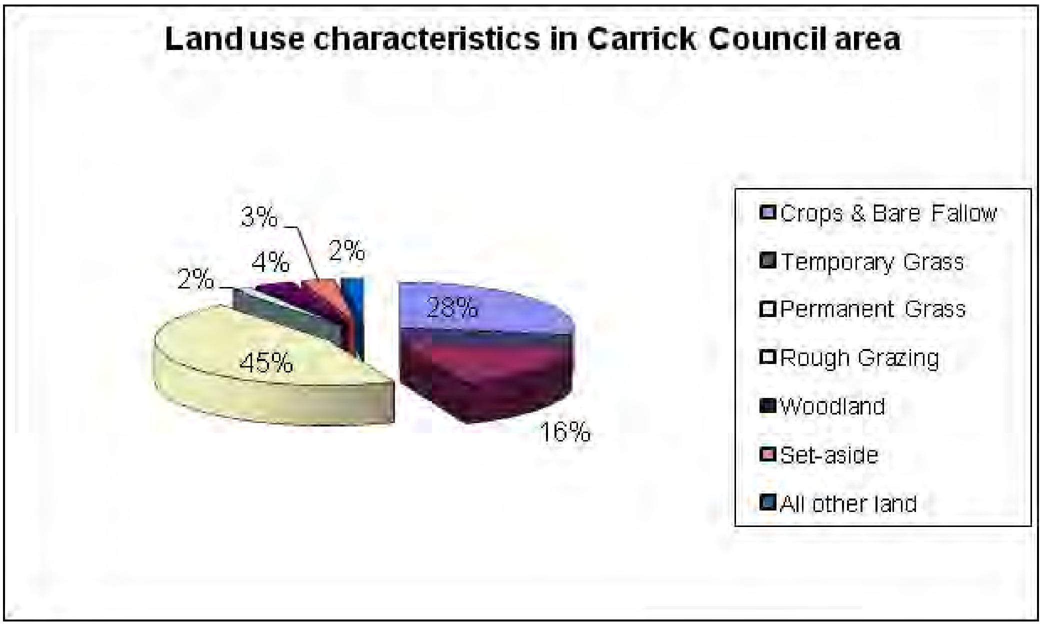


Figure 16. Land use characteristics in Carrick Council area encompassing the Upper Fal Estuary Catchments.
Data derived from Defra 2007 June Agricultural Survey.

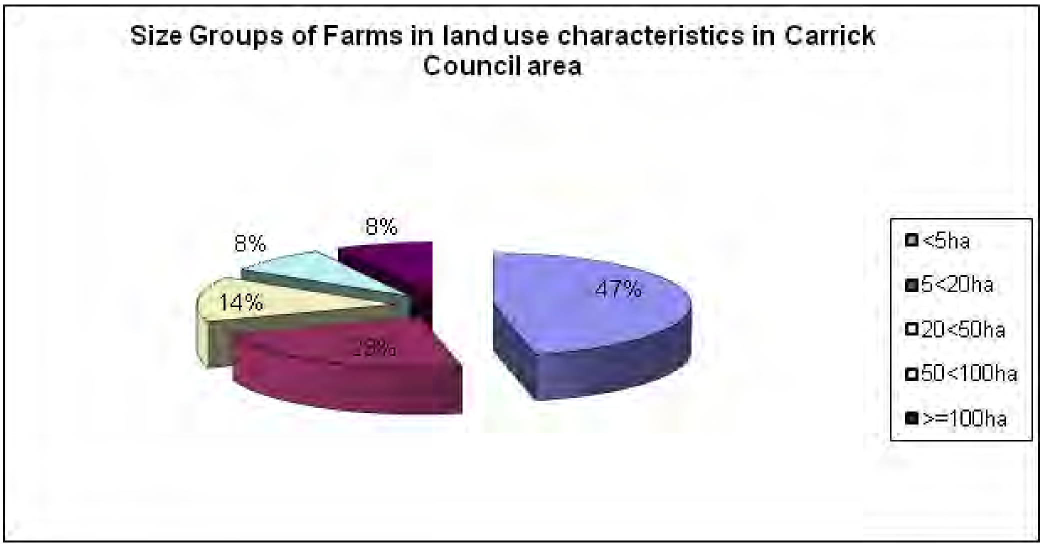


Figure 17. Size groups of farms in land use characteristics in Carrick Council Area encompassing the Upper Fal Estuary Catchments.
Data derived from Defra 2007 June Agricultural Survey.

Figure 18 shows the proportion of farms stocking various livestock types. A total of 44,185 ha of the catchment block are used for livestock, of which 50% are for sheep, 35% for dairy cattle, 12% for beef cattle, 3% for pigs and a negligible quantity for goats, respectively. The relative proportions of cereal crops grown in the catchment (data for 2000); show that 29% of land given over to cereal crops is for winter barley and 23% to summer barley, 33% to wheat, 13% to maize and 2% to oats, respectively; whilst other crops make up a negligible proportion (<0.5%); where linseed oil and potatoes each account for 34% of the total area given over to other crops. Horticultural use accounts for a further 23% and 9% for turnips and other root vegetables.

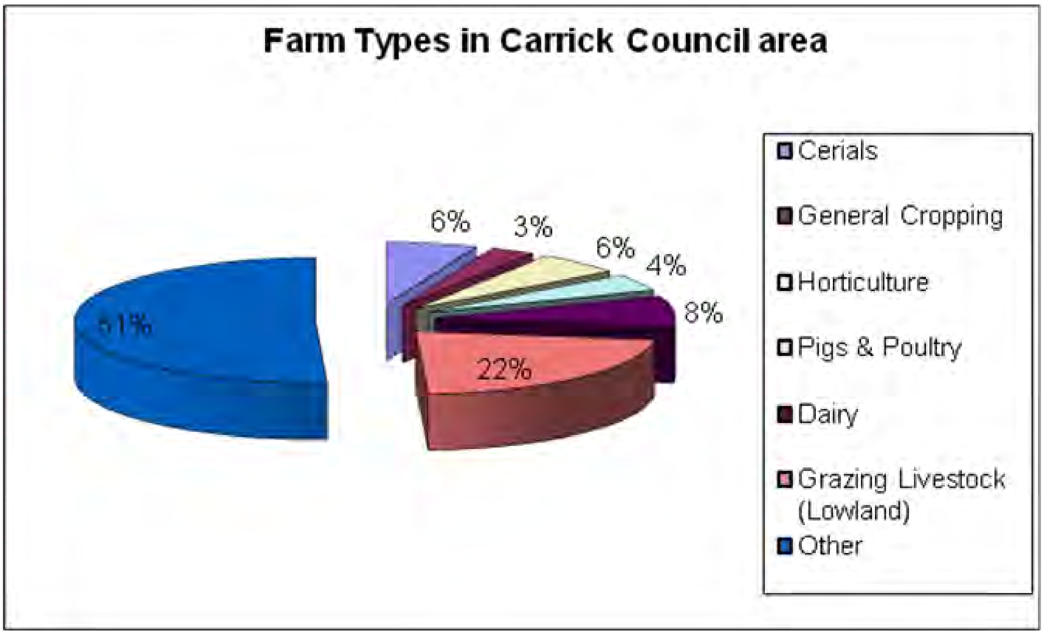


Figure 18. Farm types in Carrick Council area encompassing the Upper Fal Estuary Catchments.
Data derived from Defra 2007 June Agricultural Survey.

Mixed farms include holdings with mixtures of pigs and poultry and holdings where one of these groups is dominant, but do not account for more than 4% of farm types.

2.4.1.1 Domestic Animals

Sheep and Cattle represent more than 85% of the population of domesticated animals in terms of numbers in the catchment. There are approximately 150,000 farmed animals in the Fal catchment. Cattle represent 26% in terms of animal numbers in the catchment (43% if poultry are excluded (as they tend to be housed rather than free ranging)(Table 1).

Table 1. Numbers of farmed animals in the Fal catchment.

Animals	Number
Dairy	18,781
Beef	19,440
Cattle	38,221
Pigs	13,172
Sheep	35,425
Ewes	18,055
Goats	615
Horses	1,591
Various Poultry	59,938

Data from June 2007 Agricultural Census (Defra, 2008).

In addition to farm animals, dog faeces could contribute to background levels of contamination in water bodies receiving run-off from urbanised catchments (see Leeming *et al*., 1996; Whitlock *et al*., 2002). Dogs defecating on the foreshore (as witnessed during the survey) in the vicinity of harvesting areas may be also present a localised source of additional contamination in some instances.

Several studies have documented the strong association between intensive livestock farming areas and faecal-indicator concentrations of microorganisms in streams and coastal waters, especially during high-flow conditions, both from point and non-point sources of contamination (e.g. Crowther *et al*., 2002 and references therein). There is some evidence that the surrounding landscape of the upper Fal does influence its water quality especially during high rainfall events or following particular agricultural practices.

No information was available on seasonal variations in farmed animals. Information on manure application (rates/seasonality) in the catchment area was not available at the time of writing this report.

2.4.2 Human Population and Activities

2.4.2.1 General

Population statistics for the area are collated by administrative ‘ward’ and at the District Council area level (Figure 19, Table 2). The district has a dispersed settlement pattern containing many small villages and hamlets, mostly below 3,000 people, and many smaller groups of settlement (Table 3) (Carrick District Council, 2005). In terms of density the region has less than the average for England and Wales (3.4) where for Carrick 1.9 persons per hectare is the average.

The population estimate for the Fal, Lizard, Carrick Roads river catchment is 50,755 (National Statistics, 2007). The main population centre in the upper Fal catchment, however, is Truro; with the eight wards combined giving a catchment (see Table 3) population of 37,600.

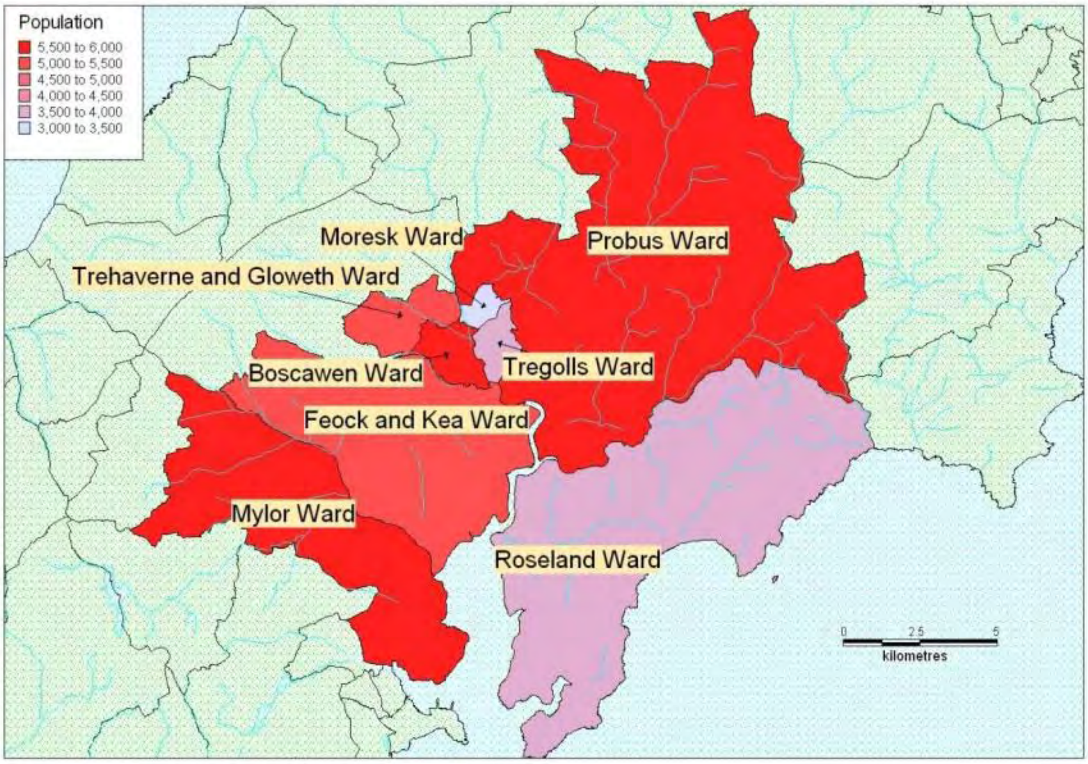


Figure 19. Human population by ward.
Office for National Statistics 2001 Population Census.

Table 2. Human population numbers by wards of Carrick District Council.

Ward Name	Total Population (2001)
Roseland	3,521
Feock & Kea	5,195
Probus	5,861
Tregolls	3,530
Boscawen	5,516
Moresk	3,346
Trehaverne	5,039
Mylor	5,592

Data from Office for National Statistics 2001 Census.

The settlements located in the immediate vicinity of the Upper Fal estuary are given below:

Table 3: Principal settlements in the immediate vicinity of the Upper Fal Estuary.

Settlement (parish)	Population (1991)
Truro	16730
Feock	3490
Ladock	1370
Philleigh	170
Ruanlanihorne	270
St.Clement	1160
St.Michael Penkevil	210
Tregony	740
Kea	1480

Source: Carrick District Council (2005)

2.4.2.2 Tourism

Tourism plays a significant part of the local economy and is seasonally variable. Tourism-related activities are both water-based (e.g. boating, fishing, canoeing) and land-based (e.g. walking, bird-watching, cultural) (Cornwall and the Isles of Scilly Advisory Group, 1999). In 2007, the Carrick District received 3.4M overnight visitors (Visit Cornwall, 2007). The vast majority of these visits were for leisure/holiday (South West Tourism Research Department, 2007) and during the summer (June–September) (South West Tourism, 2006).

There are significant tourism interests which include the National Trust property at Trelissick which receives visitors throughout the year and is a popular dog walking area. Other tourism related activities in the estuary include sailing, kayaking, fishing, horse riding, dog walking and bird watching. Most of these activities have the potential to increase background levels of contamination in the estuary.

The microbiological load attributed to tourism is therefore expected to fluctuate on a seasonal basis in line with changes in visitor numbers and occupancy of holiday accommodation. Tourism will result in significant seasonal fluctuations in the population and quantity of sewage discharged within the Fal catchment.

Human population in the Upper Fal catchment area, as in the entire Carrick Council district, increases during the holiday season. It is estimated that the population temporarily doubles in average years during the peak season, which lasts from Easter and declines from late August to the end of October, with a sharp peak during the national school holidays in July and August (Carrick District Council, 2002), when the percentage of tourism occupancy exceeds 90% (Figure 26).

The levels of microbiological contamination in shellfish production areas located in developed catchments frequently correlate with human population and land uses in adjacent shorelines and uplands (Mallin *et al*., 2001).

In the upper Fal Estuary, there appeared to be no positive relationship between the percentage of tourism occupancy (see Section 2.4.2.2) and the monthly geometric means of *E. coli* in shellfish from the appropriate sampling points (see Figure 20). However, this lack of an apparent relationship may be due to the shellfish *E. coli* levels being dependent on a number of interacting factors, only some of which (such as the dry weather sewage discharge flows) will be directly related to the population in the area at any particular time.

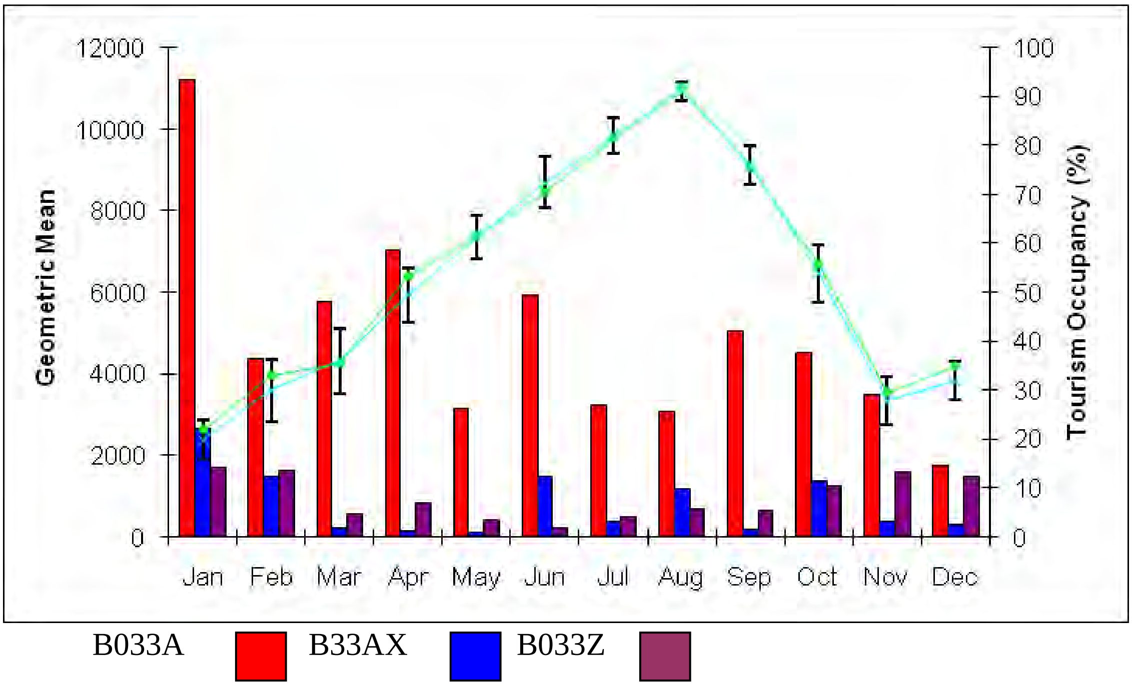


Figure 20. Monthly variation of percentage of tourism occupancy (2006 values and average ± Standard Deviation values between 1993 and 2006) for Cornwall and monthly geometric means of E. coli (100gF/L) in mussels from Calenick Creek (B033A), mussels at King Harry Reach (B33AX) and mussels at T Pontoon/South Wood (B033Z).

Data on percentage of occupancy from Cornwall Tourist Board (2006).

2.4.2.3 Industry

The largest businesses in the region are the wholesale and retail trades (18%), with less than 10.8% being industry. There are no significant relevant industries (e.g. manufacturing, construction) in the catchment (see Hewett, 1995) other than mining and quarrying which at 2% is significantly more than the average of just 0.25% for England. The China clay industry is also significant (see Figure 21).

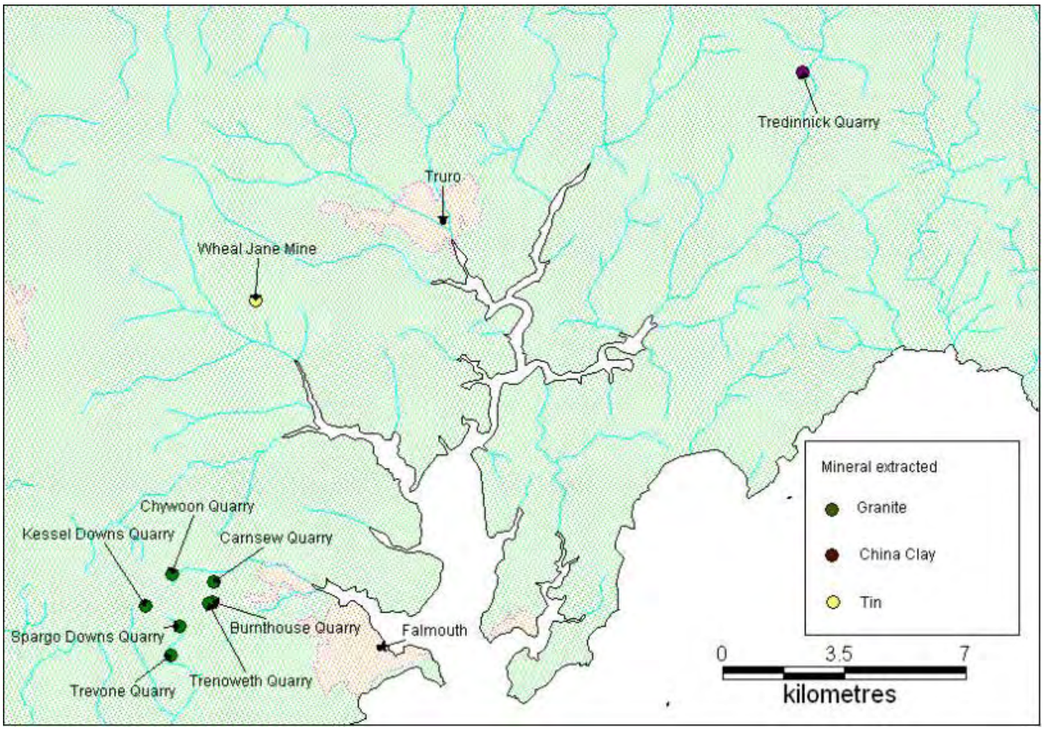


Figure 21. Mining operations in the area surrounding the upper Fal.

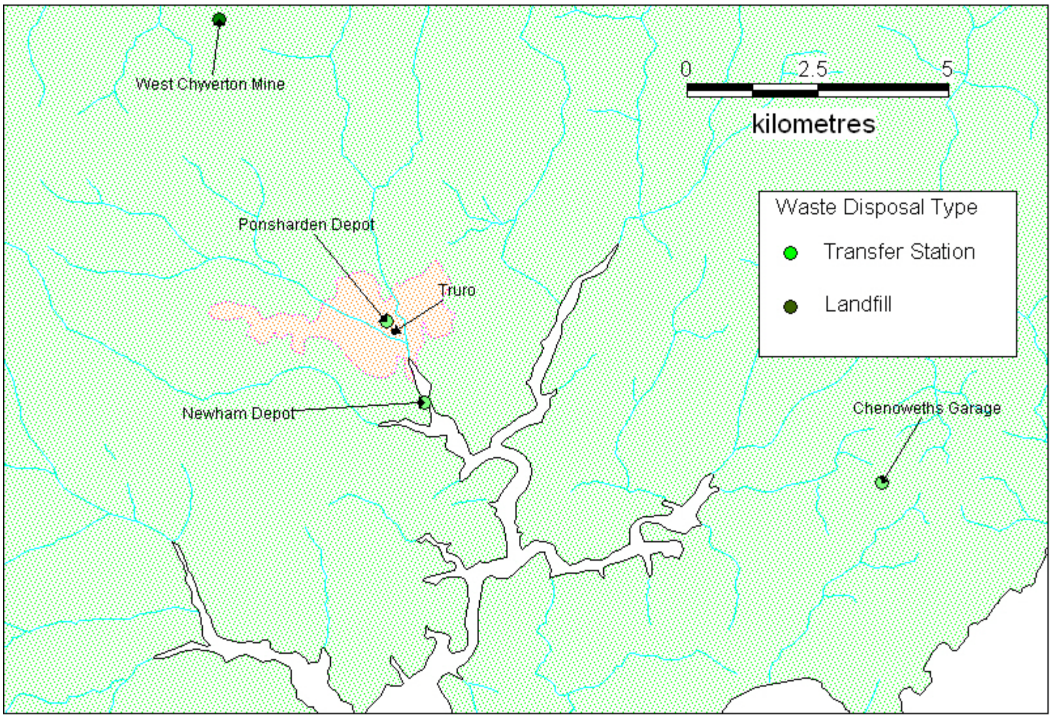


Figure 22. Waste disposal operations in the area surrounding the upper Fal.

There is very limited active waste disposal in the catchment (see, Figure 22). A number of locations that landfill sites no longer serve that function.

2.4.3 Inventory of Pollution Sources of Human Origin

2.4.3.1 Point Source Discharges

The main Sewage Treatment Works (STWs) are located at Newham (Truro) and Ladock Valley. Small, but potentially locally significant inputs from small treatment works occur in Coombe Creek and at the head of Ruan Creek. Outside of the main centres of population, the majority of residential properties in the catchment are not connected to main sewer and are served by septic tanks or cesspits, or discharge untreated sewage.

The main input to the Upper Fal from an STW occurs at the Newham works which serves the Truro Area. In 2003, extensive work was carried out to a cost of around £8 million to add the village of Malpas to the mains system and to improve the output from the Newham works. This included the addition of UV disinfection prior to discharge and the addition of a new storm water storage tank.

Table 4 lists the information on discharges to tidal waters provided by the Environment Agency (EA). Figure 23 shows the data held by Cefas on sewage discharges to tidal waters in the Upper Fal. The EA has also highlighted that septic tanks discharge to the stream by the slipway at King Harry Ferry – this is just upstream from the mussel farming operations. There are also other sewage inputs to the freshwater systems in the catchment and these will enter the estuary via the main rivers and creeks.

Cefas is not aware of any other seasonal differences in the level of sewage treatment applied (e.g. seasonal disinfection) that would have significance for the classification microbiological monitoring programme.

There are a large number of Combined Sewer Overflows (CSOs) in the Upper Fal, mainly in the Truro area. The EA identified that the majority of these discharges either already met, or had been improved to meet, the design limit of a maximum of 10 significant (>50m^3/day) spills per year (on an agglomerated basis). This design limit was intended to ensure that shellfish comply with class B.

Table 5 summarises the CSO spill information produced by SWW and provided to Cefas by the EA. These relate to discharges to both the marine and freshwater environments in the Upper Fal area. Interpretation of the data is complicated by problems with interpreting the records from some locations as well as recorder and data transfer problems. Apart from the Ladock Valley STW overflow, all of the spills are from CSOs and pumping stations aggregated together by the EA: this means that the target of 10 spills per annum should apply to the total number of occasions when a significant spill (>50 m^3) has occurred from any of the discharges included in the same aggregation. An EA report of investigations on the Fal estuary designated shellfish water identified that the spill frequency of the CSO at Newham PS was worthy of further investigation. The table shows that a small number of other CSOs operated for considerable lengths of time during the three year period and thus could also contribute to the contamination in the estuary. Table 6 shows the shellfish hygiene *E. coli* results at selected sites in the Upper Fal for the period from March 2006 to April 2009 together with the recorded spill durations (for events ending within 24 h of sampling) for the monitored intermittent discharges in Truro. Interpretation of this data is limited by the fact that shellfish samples have only been collected within 24 hours of recorded CSO spill events on a limited number of occasions (sampling is not currently intended to be targeted at spill events). Occasions when sampling yielded *E. coli* results above the 4600 per 100g class B limit did not necessarily coincide with recorded spill within the previous 24 hours. This may be at least partially due to complicating factors such as the interaction between tidal state, time and size of spill, and subsequent delay before sampling. The data does not, therefore, preclude the possibility of a contribution to some of the high results arising from CSO spills.

A study employing conservative fluorescent tracer particles introduced to surface waters above the main Falmouth discharge towards the mouth of the estuary in Carrick Roads established a degree of connectivity between lower and upper estuary waters under certain tidal states (Marsh, 2007). However, it is not thought likely that significant sewage contamination will enter the Upper Fal from the discharges in the Lower Fal (Carrick Roads and adjacent creeks) as earlier modelling undertaken in support of the sewage improvements at Falmouth showed that this was unlikely to occur. Given the high level of treatment of the continuous discharges from the main sewage works in the area, it is likely that, in dry weather, the effect of inland discharges impacting via freshwater courses and local inputs from private discharges will predominate over those of the public discharges. In periods of wet weather, significant additional contamination may arise from the many CSOs in the area once the available storage has been exceeded.

Table 4. Sewage discharges to saline waters in the Upper Fal Estuary

PERMIT NUMBER	DISCHARGE SITE NAME	RECEIVING WATER	OUTLET TYPE	ISSUED DATE	EFFECTIVE DATE	OUTLET NUMBER	OUTLET GRID REF	TREATMENT
CONTINUOUS DISCHARGES								
302707	TRURO (NEWHAM) STW	TRURO RIVER ESTUARY (E)	Sewage - water company	16-May-03	10-Aug-04	1	SW8341043290	UV DISINFECTION
302508	LADOCK VALLEY STW	TRESILLIAN RIVER ESTUARY (E)	Sewage - water company	12-Feb-03	22-Jul-03	1	SW8614045800	UV DISINFECTION
INTERMITTENT DISCHARGES								
301696	TABERNACLE STREET CSO	TRURO RIVER (E)	Sewage - water company	01-Oct-00	01-Oct-00	1	SW8269544716	NONE
302681	TRELANDER HIGHWAY CSO	RIVER ALLEN (E)	Sewage - water company	14-Feb-03	14-Feb-03	1	SW8292044790	SCREENING
302679	MITCHELL HILL CSO	RIVER ALLEN (E)	Sewage - water company	14-Feb-03	14-Feb-03	1	SW8280044860	SCREENING
302707	TRURO (NEWHAM) STW	TRURO RIVER ESTUARY (E)	Sewage - water company	16-May-03	10-Aug-04	1	SW8341043290	SCREENING
302680	FAIRMANTLE STREET CSO	RIVER KENWYN (E)	Sewage - water company	14-Feb-03	14-Feb-03	1	SW8286044640	SCREENING
302508	LADOCK VALLEY STW	TRESILLIAN RIVER ESTUARY (E)	Sewage - water company	12-Feb-03	22-Jul-03	2	SW8709047040	SCREENING

Data from the Environment Agency

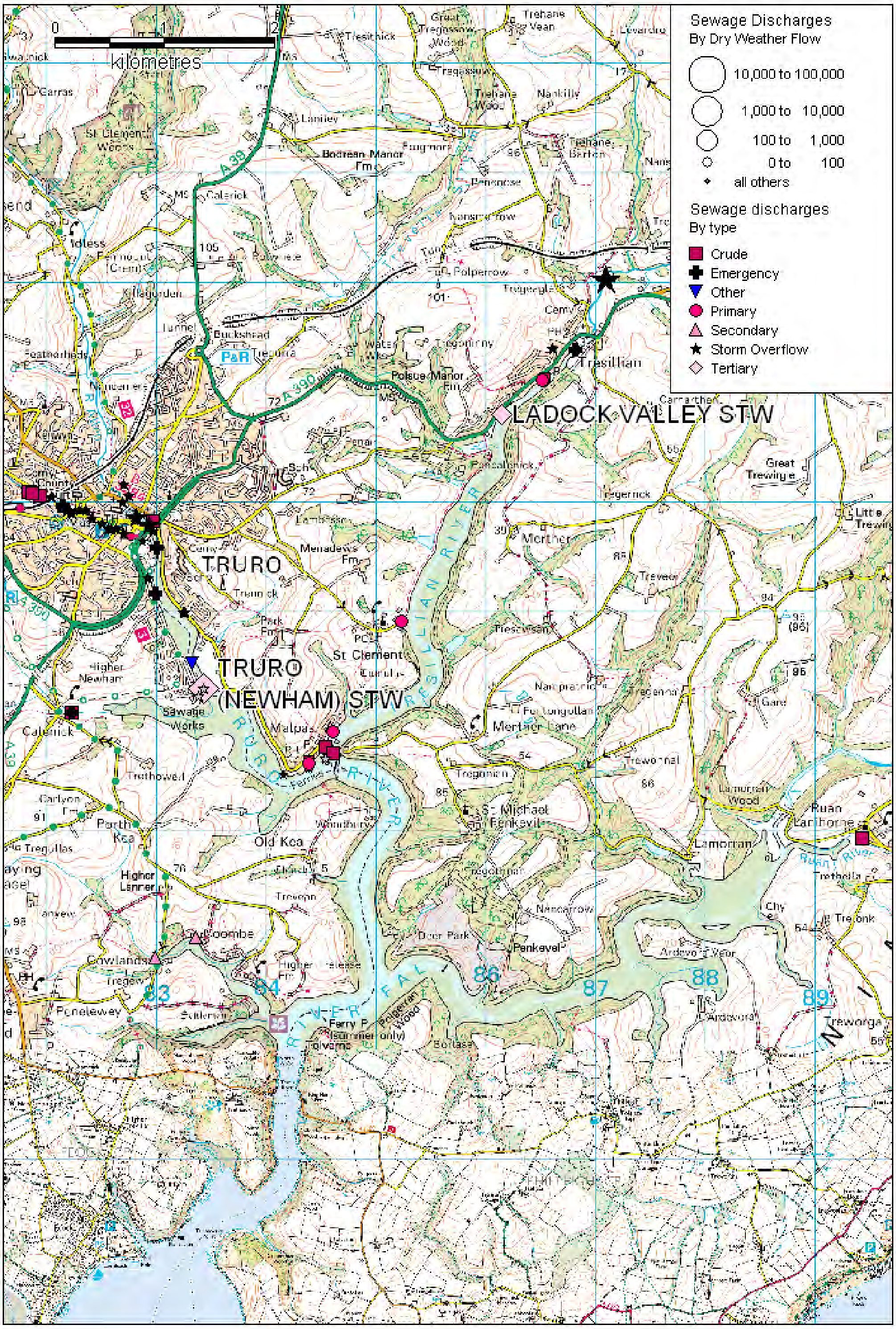


Figure 23. Sewage discharges to saline waters in the upper Fal area.
The main continuous sewage discharges are labelled.

Table 5. Combined sewage spill events in the upper Fal.

SITE	TOTAL SPILL EVENTS			TOTAL DURATION (HOURS)		
	2006/2007	2007/2008	2008/2009	2006/2007	2007/2008	2008/2009
Boat Yard PS - Malpas	8	1	0	11.89	0.39	0.00
Bosvigo Lane CSO	4	2	28	5.00	1.00	185.98
Campfield Hill CSO	4	2	4	1.00	0.50	1.00
Castle Street CSO	4	0	2	1.00	0.00	0.50[1]
Edward Street CSO	0	3	3	0.00	1.25	0.75[1]
Fairmantle Street CSO	7	0	0	5.75	0.00[2]	0.00
Francis Street CSO	0	23	17	0.00	30.21	6.00
Hendra Rd CSO	37	24	16	6.39	2.75	3.92
Ladock Valley STW	2	1	8	4.04	0.02	10.68
Lemon Mewes CSO	1	0	0	0.05	0.00	0.00
Little Castle Street CSO	15	24	24	7.75	9.68	15.75
Mitchell Hill CSO	0	4	4	0.00	35.75	217.50[1]
Newham STW CSO	5	6	31	251.44	52.53	42.90
Pauls Terrace CSO	21	2	6	6.50	0.50	1.50[1]
Roberts Ope CSO	43	63	12	37.82	64.21[3]	7.49
St Georges Rd CSO	0	0	1	0.00	0.00[2]	0.25
Trelander Highway CSO	61	24	3	241.67	5.12	1.04
Victoria Lodge PStn	13	3	3	943.48[1]	1.20	6.72
Victoria Quay PStn	7	1	0	7.41	0.39	0.00

[1]Possible sensor malfunction reported by Water Company
[2] Primary communication failure - no data
[3] Unable to distinguish between tidal surcharge and real storm events

Table 6. Shellfish hygiene monitoring results and spills from monitored intermittent discharges in Truro ending within 24hours of sampling, March 2006 to April 2009.

Date	*E. coli* per 100 g FIL				Assets spilling within 24hrs prior to sampling	Spill duration (hours)
	Calenick Creek (M)	King Harry Reach	Maggoty Bank (O.ed)	R Pontoon /Tregothnan (M)		
25-Apr-06			220	700		
23-May-06			16000[1]	3500		
28-Jun-06	2400		200	750		
25-Jul-06	2400		500	70		
21-Aug-06			750			
22-Aug-06				5400		
11-Sep-06	500		500	500		
25-Sep-06		20				
9-Oct-06	130	310	1700	750	Victoria Quay PSCSO/EO Boat Yard PS CSO/EO Hendra Rd CSO Castle Street CSO Paul's Terrace CSO Trelander Highway Tregolls Rd CSO	0.03 0.03[2] 0.10[2] 0.75[3] 0.25 1.09[2]
24-Oct-06		3450			Roberts Ope CSO Trelander Highway Tregolls Rd CSO	0.29 0.73
6-Nov-06		3500	5400	220		
20-Nov-06		1300			Trelander Highway Tregolls Rd CSO Hendra Rd CSO Truro	1.15[2] 0.07
5-Dec-06	1400	3500	750	9100	Trelander Highway Tregolls Rd CSO Roberts Ope CSO	1.31[2] 2.46
20-Dec-06		500				
23-Jan-07	3500	220				
6-Feb-07		18000				
20-Feb-07	18000		1100			
26-Mar-07	200		40	70		
27-Mar-07		20				
23-Apr-07	1300	50	130	220		
8-May-07	700	70	50	2400		
21-May-07		70				
4-Jun-07			500	2200	Truro (Newham) STW	22.08
12-Jun-07	9100					
23-Jul-07		70				
7-Aug-07				18000		
8-Aug-07	18000		18000			
13-Aug-07		310				
20-Aug-07			310		Roberts Ope CSO	0.46
21-Aug-07		16000			Roberts Ope CSO	0.46
4-Sep-07		90				
17-Sep-07		90				
24-Sep-07	5400			5400		
1-Oct-07			3500			
16-Oct-07	2400	160	310	500		
13-Nov-07	700	220	430	310		
11-Dec-07		310	1700	3500		
18-Dec-07	1700					

Date	*E. coli* per 100 g FIL				Assets spilling within 24hrs prior to sampling	Spill duration (hours)
	Calenick Creek (M)	King Harry Reach	Maggoty Bank (O.ed)	R Pontoon /Tregothnan (M)		
14-Jan-08	5400	18000	1300	16000	Roberts Ope CSO Edward St o/s Trecara House CSO	1.83 0.25
21-Jan-08		1400		1100	30 Francis Street CSO	0.25
28-Jan-08	5400	9100				
5-Feb-08				5400	30 Francis Street CSO	0.25
12-Feb-08		20	310			
4-Mar-08		160	500	2400	Little Castle St jct Kenwyn St CSO	0.46
7-Apr-08	230	500	130	50		
6-May-08	330	230	130	130		
10-Jun-08	700	50	230	490		
7-Jul-08	5400		16000	16000	Little Castle St jct Kenwyn St CSO Hendra Rd CSO Bosvigo Lane CSO	0.50[2] 0.17 0.75
5-Aug-08	2400	330	18000	18000	Bosvigo Lane CSO	7.25
1-Sep-08	18000	9200		9200		
6-Oct-08	16000	49000	460	1700		
3-Nov-08	1700	20	330	3500		
8-Dec-08		20				
15-Dec-08	3500		1100	2600		
19-Jan-09	5400	130	1100	11000	Newham SPS	0.12
16-Feb-09	700		50	1300		
16-Mar-09	170	50	50	170		

[1]Values in red represent shellfish *E. coli* concentrations above the class B 4600 per 100 g limit
[2]Figure represents the total duration over two separate events
[3] Figure represents the total duration over three separate events

2.4.3.2 Boats and Shipping

The estuary is of limited regional significance for commercial shipping, however, due to the economic downturn up to 7 large ships (car carriers, banana boats and bulk cement carriers) have been laid up in the deep water channel in the Truro River up to Malpas (Guardian 31 January 2009). These ships were still present at the time of the shoreline survey. While the Fal has traditionally been used for ships to lay-up this has not been a regular use since 1999/2000.

The Upper Fal is less well used as a boating area than the lower reaches, although there is some, mainly recreational, boating activity. There are several moorings at the top of the Fal (at Malpas and Truro)

The King Harry Ferry operates every 20 minutes, daily all year round and connects St Mawes and the Roseland Peninsula with Feock, Truro and Falmouth. Enterprise ferries also operate a year round boat servce between Truro and St Mawes and Truro and Falmouth

There are yacht and small craft moorings in the Truro river approximately 2 nautical miles above King Harry ferry at Mopus Reach (off Malpas point), and at the mouth of Cowlands and Lamouth Creek and approximately 1 nautical mile downstream of the ferry off Pill Point. During the shoreline survey a large number of unoccupied mooring buoys were noticed indicating significant increases in seasonal activity being highest during the summer months (see Figure 24).

The potential pollution of BMPAs by recreational boats (see Figure 23) is an issue that has received a great deal of attention (see Milliken and Lee, 1990). In the Upper Fal Estuary boats are certainly a potential source affecting the background levels of microbiological contamination. Guillon-Cottard *et al*. (1998) investigated the contribution of boats as a source of microbiological contamination for mussels. This study was undertaken in a recreational harbour with a capacity for 650 boats, without any sewage discharge in its vicinity and under stable environmental conditions. The authors concluded that the increased levels of faecal coliforms in bivalves collected from the harbour were directly linked to sewage discharges from toilets flushing straight into the seawater. Similarly, Sobsey *et al*. (2003) found faecal coliform levels exceeding the standards for bivalves for human consumption in water samples taken a distance of 305 m from boats on a busy holiday weekend.

Additional contribution may therefore arise from boats in the Upper Fal, particularly during the summer season when use/occupancy will be higher. The principal concentration of such contamination will be from the areas highlighted above but other inputs may occur throughout the Upper Estuary, especially where there are pontoons or other moorings.

Figure 24. Boats moored in Fal Marina.

2.4.4 Inventory of Pollution Sources of other Animal Origin

2.4.4.1 Birds

The Fal Complex consists of a series of slow-current tidal creeks and rivers with typically low freshwater input and supporting a variety of marine habitats. The major intertidal areas occur in the network of creeks and river branches flowing into Carrick Roads. Much of the main channel itself is sided by rocky shore at low tide. The Upper Fal catchment consequently supports a variety of wildfowl and shore, woodland and farmland species of birds.

The Upper Fal contains two designiated Sites of Special Scientific Interest (SSSIs): Malpas Estuary SSI and Upper Fal Estuary and Woods SSI. The SSI citations by English Nature (now Natural England state the following with respect to birds:

Malpas Estuary: The major habitat feature of the site is tidal mudflats which are feeding grounds for wildfowl and wading birds, including nationally important numbers of a rare wader. The site also includes saltmarsh, adjoining ancient semi-natural woodland and a heronry. The site is primarily important for wildfowl and wading birds. The Truro River section regularly supports nationally important numbers of Black-tailed Godwit Limosa limosa during autumn and winter. The site is also used for feeding by up to 500 Dunlin *Calidris alpina*, 200 Shelduck *Tadorna tadorna*, 300 Teal *Anas crecca*, and smaller numbers of other waders including Redshank *Tringa totanus*, Greenshank *T. nebularia*, Curlew *Numenius arquata*, Whimbrel *N. phaeopus* and Oystercatcher *Haematopus ostralegus*. The use which birds make of the different parts of the site and its relationship to feeding areas in other parts of the Fal complex of estuaries, varies with time of year, weather and tide.

Upper Fal Estuary and Woods: The upper reaches which constitute this site are, for the most part, sediment-filled, with mudflats backed by low rocky cliffs. They are of major importance for the wintering wading birds and for the ancient semi-natural woodlands which clothe much of their banks. The mudflats within the site support nationally important numbers of Black-tailed Godwit *Limosa limosa* during autumn and winter. They are also important feeding grounds for large populations of a number of other wintering waders and wildfowl. In particular, the site supports Curlew *Numenius arquata*, Dunlin *Calidris alpina*, Shelduck *Tadorna tadorna*, Redshank *Tringa totanus* and Golden Plover *Pluvialis apricaria*. On the Tresillian River there are habitats which support Greenshank *Tringa nebularia*, Spotted Redshank *Tringa erythropus*, Little Grebe *Tachybaptus ruficollis* and Kingfisher *Alcedo atthis*. Small but growing numbers of Little Egret *Egretta garzetta* now occur within the complex. The site is important for Grey Herons *Ardea cinerea* and there is a major heronry.

Bird numbers in certain parts of the estuary are counted as part of the national Wetland Bird Survey (WeBS). Figures 25 and 26 illustrate the areas of the estuary covered in the WeBS core count and low tide count sectors. Twenty-seven species of waterbird were recorded on the Fal Complex, most in fairly small average winter numbers. Species such as Little Egret and Greenshank were thinly but widely spread around the site, whereas wildfowl including Mute Swan and Mallard were most highly concentrated on the lower Tresillian River. Mean Shelduck density was highest on the Tresillian River, with the nearby Truro River also holding notably high mean densities. The same area supported aggregations of Oystercatcher and Lapwing, and these species were also concentrated on the Percuil River. Black-tailed Godwit density was greatest on the Truro River and at Restronguet Creek, whilst the muddy sediment at the latter also attracted Redshank, found also at high density on the upper reaches of the Tresillian River.

In summary, the Upper Fal estuary supports a variety of waterbirds, although the total numbers are not very. The larger number present over the autumn and winter months may affect the background levels of microbiological contamination in the estuary at these times. There is no specifically identified spatial aspect that should be taken into account in the overall sanitary survey assessment.

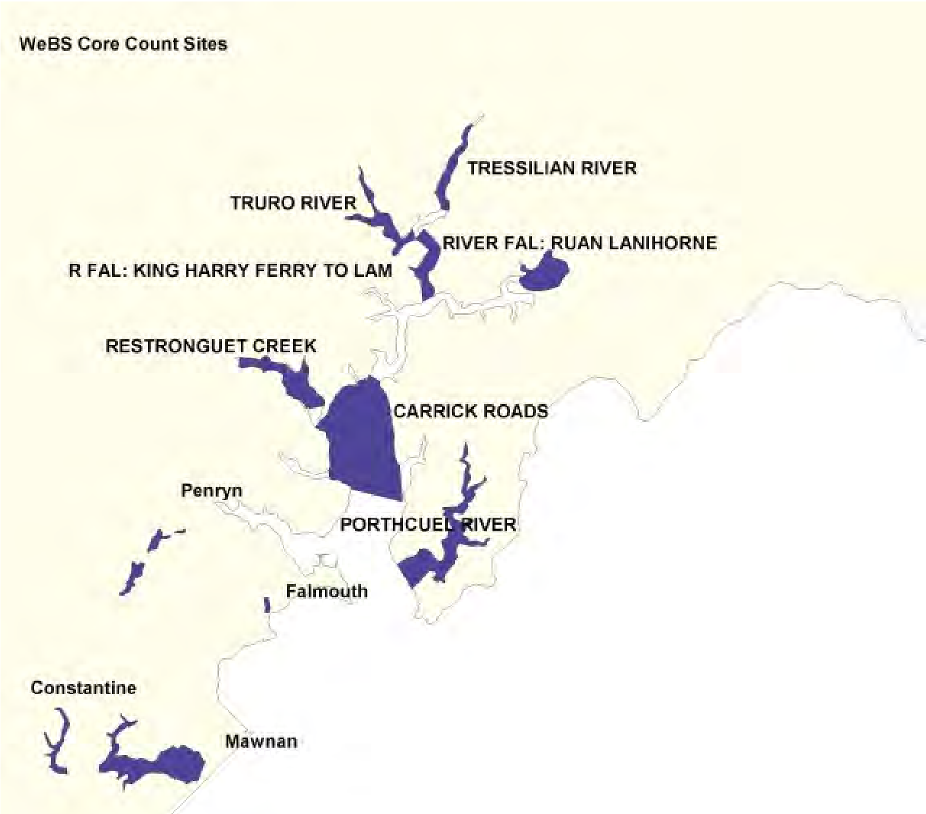


Figure 25 WeBS Core count sectors within the Fal Estuary
(Source: WeBS, 2009)

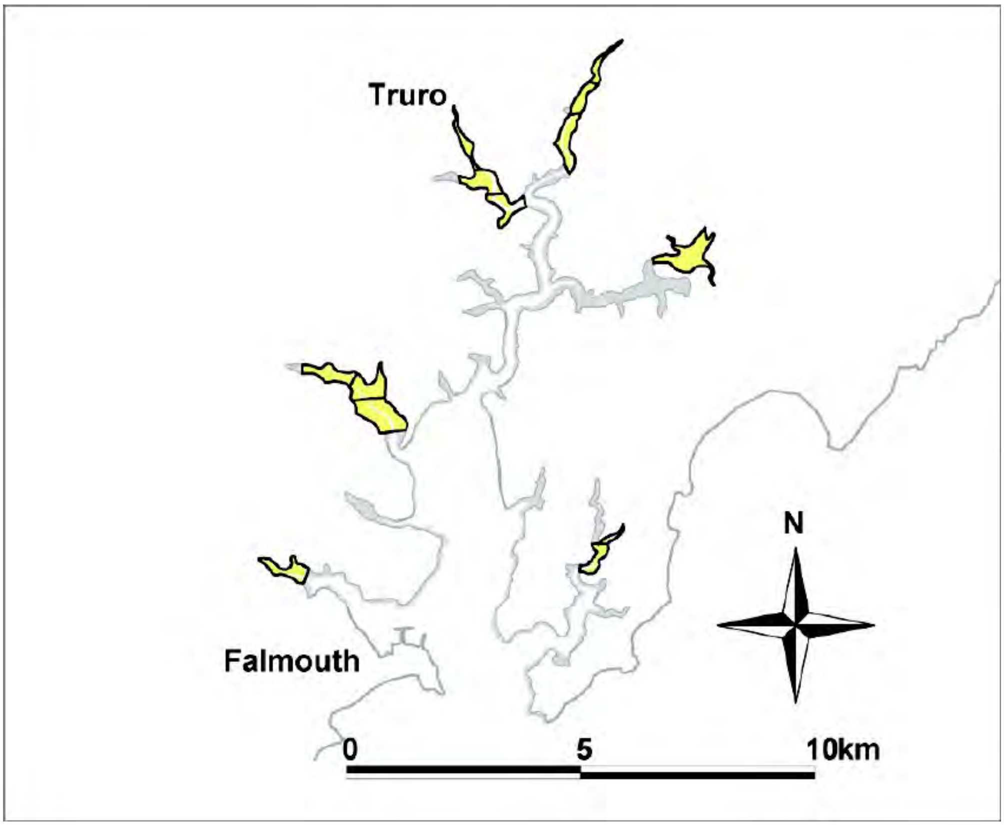


Figure 26 WeBS low tide count sectors in the Fal Estuary
Source: (Musgrove, *et al*. 2003)

2.4.5 Significant Pollution Events

There have been several pollution incidents defined by the EA as "A specific event, which is being brought to the attention of the Agency, and is within the Agency's area of responsibility and which may have an environmental and/or operational impact".

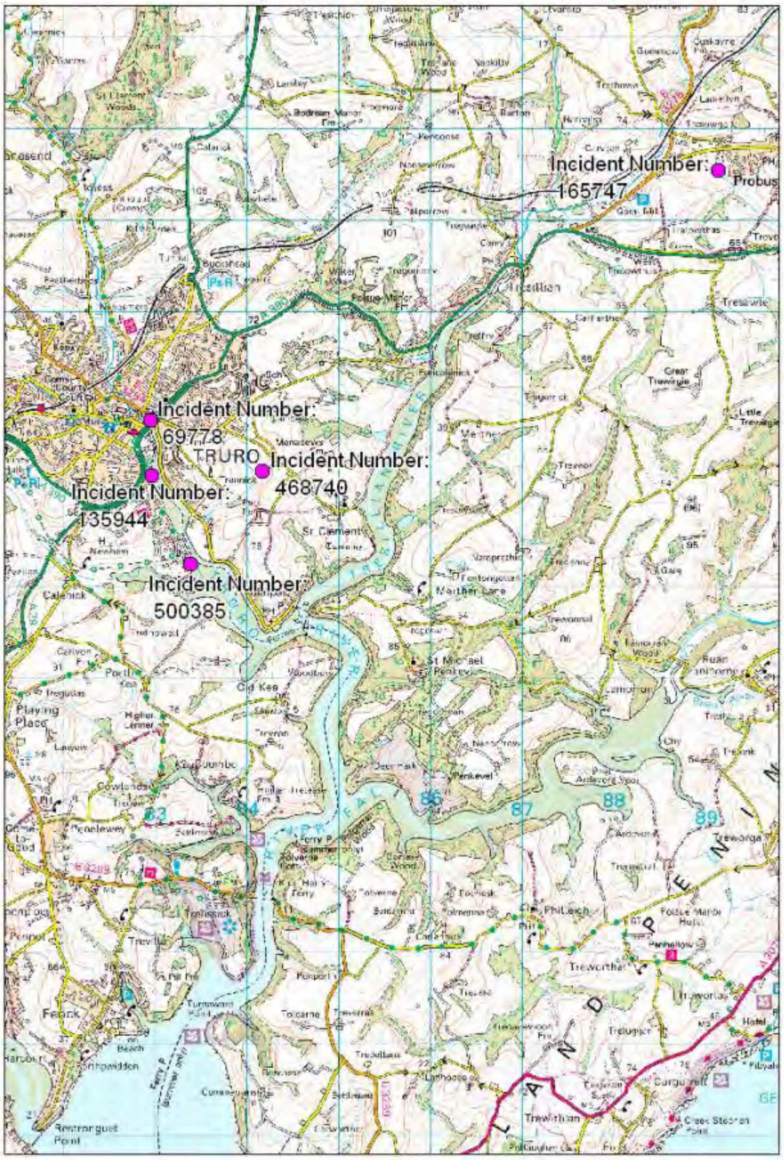
Pollution incidents are recorded and categorised by the EA according to severity (impact on the environment) across three environmental media: Water, Air and Land. Category 1 incidents are indicative of the most severe level of environmental impact. Category 4 incidents reflect negligible or no environmental impact.

The EA website "What's in your backyard?" (http://www.environment-agency.gov.uk/homeandleisure/37793.aspx) showed a total of five pollution incidents for the period 2001 to mid-2009 where the impact on the water courses was deemed to be major or significant and the pollutant had a significant faecal component (see Table 7 and Figure 27). In addition, the EA provided information on five pollution incidents related to slurry spills potentially impacting on the Upper Fal for the period January 2002 to January 2009. (see Table 8 and Figure 28)

Table 7. Faecal pollutions events in the Upper Fal deemed to have a major or significant impact on the water environment (2001 – mid-2009).

Date	Incident Number	Impact to water	Pollutant	Easting	Northing
08/04/2002	69778	Significant	Crude Sewage	182930	44810
10/02/2003	135944	Significant	Crude Sewage	182950	44210
14/06/2003	165747	Significant	Crude Sewage	189130	47540
09/02/2007	468740	Significant	Slurry and dilute slurry	184160	44260
05/06/2007	500385	Significant	Crude Sewage	183370	43240

Source: Environment Agency website: http://www.environment-agency.gov.uk/homeandleisure/37793.aspx



Produced by Cefas Weymouth Laboratory.

Figure 27. Location of the pollution incidents listed in Table 7.

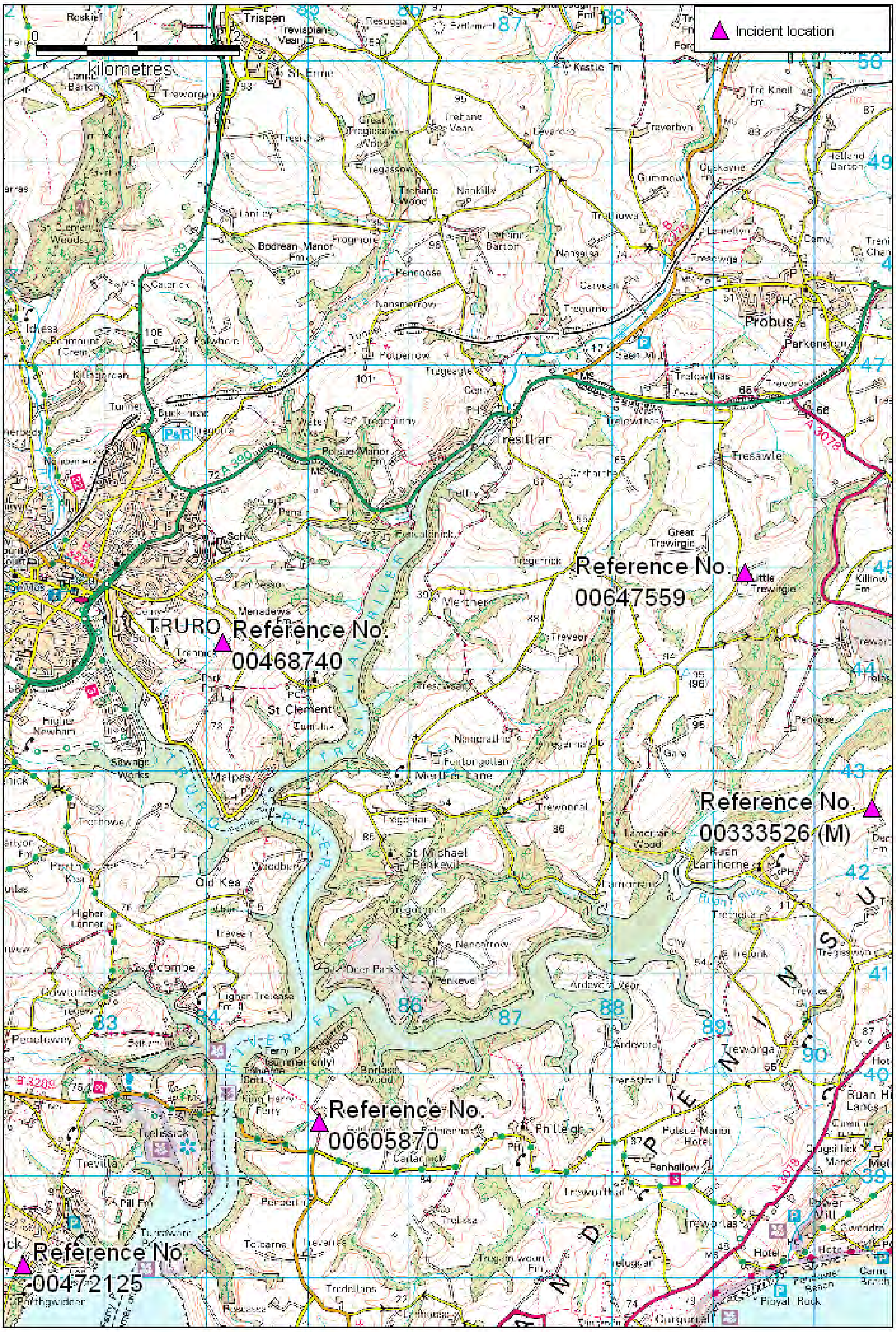


Figure 28. Location of the slurry pollution incidents listed in Table 8.

Table 8. Slurry-related pollution incidents in the Upper Fal catchment 2002-2008 inclusive.

Ref Number	Date/time	Easting	Northing	Impact Water	Cause	Source Type	Fish Kill	Pollutants
00333526 (M)	27/07/2005 15:30	190568	42626	3	Unauthorised Discharge or Disposal	Beef	N	Silage Liquors - Seepage of silage effluent.
00468740	09/02/2007 17:39	184151	44259	2	Storage Tank or Container Failure (Unbunded)	Beef	N	Slurry and Dilute Slurry
00472125	23/02/2007 10:39	182177	38110	3	Other Extreme Weather Conditions	Market Gardening/Horticulture	N	silts
00605870	15/07/2008 12:00	185105	39522	3	Unauthorised Discharge or Disposal	Dairy	N	Silage Liquors - silage and dairy washings
00647559	21/01/2009 14:00	189310	44950	3	Unauthorised Discharge or Disposal	Dairy	N	Slurry and Dilute Slurry - Dirty water

Data provided by the Environment Agency

2.5 Hydrography and hydrodynamics

2.5.1 General

The following river catchments contribute to the upper Fal estuary (Figure 29): Fal (106km^2), Tresillian-Trevella-Kenwyn (131km^2) and Fal (tidal)-Tresillian-Truro (64km^2). Freshwater inputs to the catchments covering the lower Fal estuary may potentially impact on the Upper Fal during part of the tidal cycle.

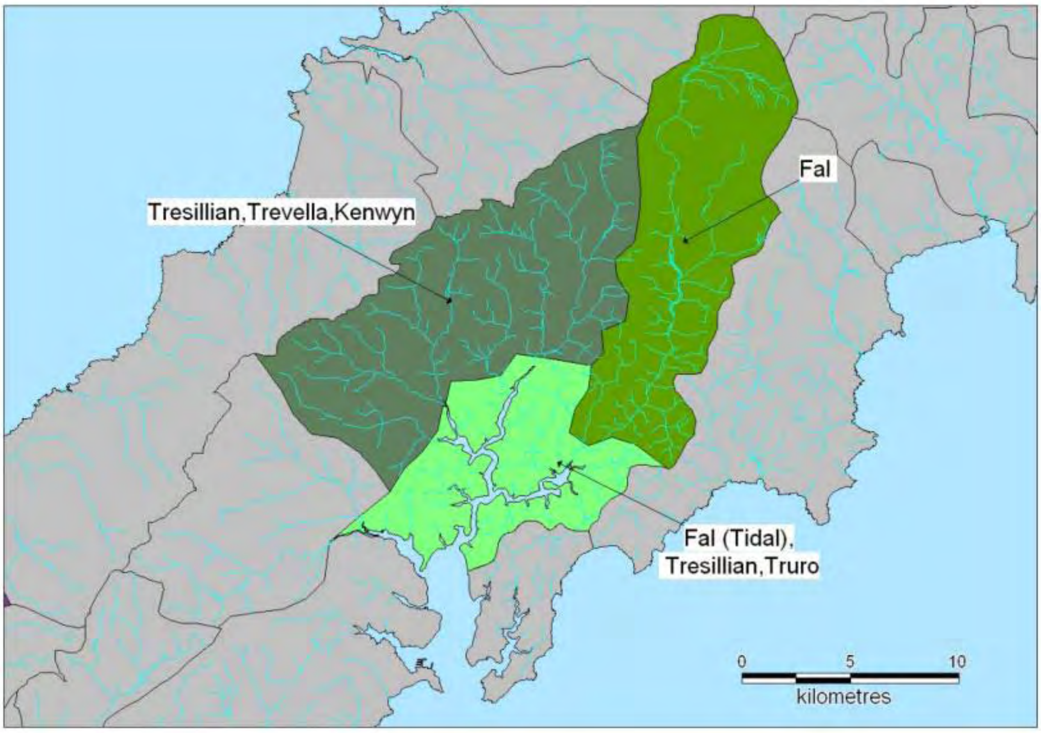


Figure 29. River catchments impacting on the Upper Fal Estuary.

2.5.2 Freshwater Inputs

The Fal Estuary receives freshwater inputs from several small tributaries. The Tresillian River rises to the west of the River Fal, near Fraddon. It flows southward through Laddock and enters tidal mud flats at Tresillian. It is joined by the Truro River at Malpas, just south of Truro, about 2 km upstream of its confluence with the River Fal. The Trevella Stream drains an area to the west of the Tresillian catchment and enters the tidal mud flats 1 km south of the Tresillian River. The River Allen drains a region to the north of Truro and the River Kenwyn to the north west. These two rivers meet in the centre of the City of Truro and become the Truro River, before the confluence with the Tresillian. The Callenick Stream drains the area to the west of Truro and flows eastward, into the Truro River.

The last survey (2001) reported that the South West had the highest proportion of 'very good' quality rivers and the lowest proportion of 'bad' quality rivers in England. In terms of chemical quality, Cornwall has the highest proportion of 'good' or 'very good' quality river stretches in the region.

Groundwater quality is generally good, except where wells penetrate into mine voids. The water table usually lies within 15 m of the ground surface. Shallow groundwater flow is mainly coincident with the topographic gradient except in the vicinity of mine dewatering and adit drainage. Water quality is generally good except in highly mineralised areas, where the trace metal concentrations may be high but is unlikely to contribute any significant microbiological loading to the upper Fal.

Continuous flow monitoring is undertaken by the Environment Agency at two water courses in the upper Fal (see Table 9).

Figure 30 shows the mean monthly flows rates from the one of the four stations: at Tregony. The flow pattern is similar at Truro on the Kenwyn.

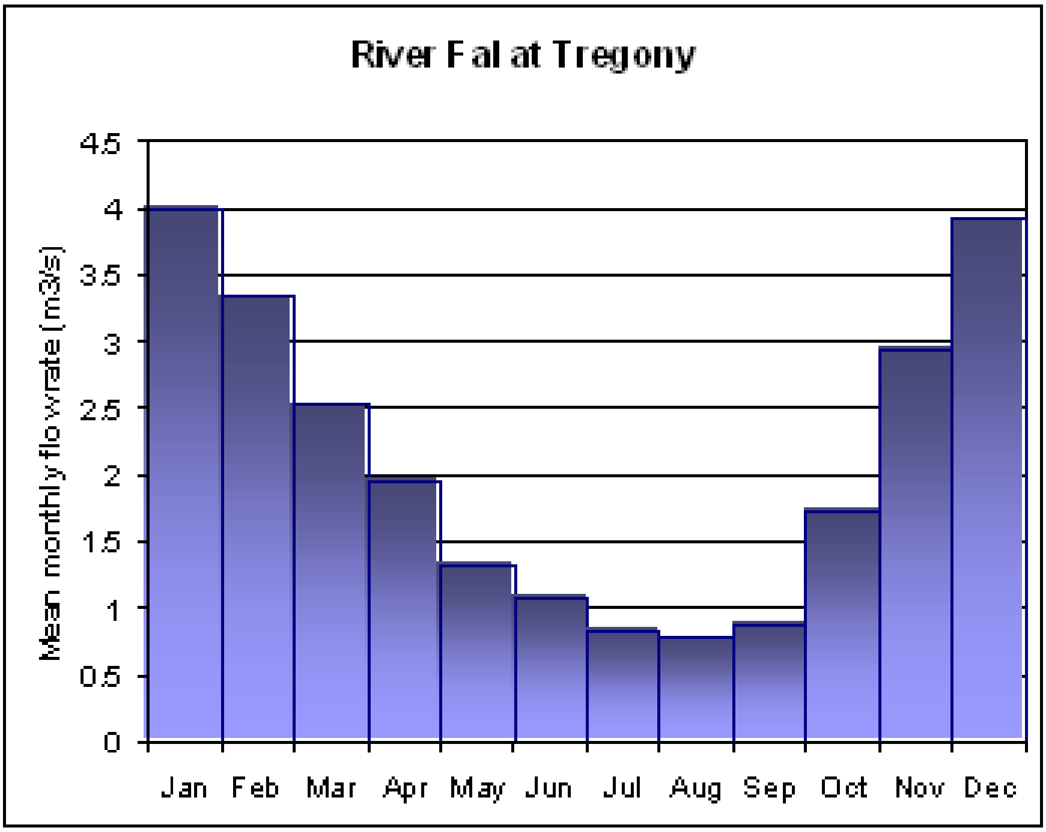


Figure 30. Mean monthly flow data for the Fal at Tregony (1978 – 2003 EA sourced.)

Table 9 lists the sub-catchment areas and gives the summary flow statistics for each station.

Table 9. Summary of % flow exceedence for the four permanent gauging stations (m^3s^{-1}) undertaken by the EA .

River	**Fal**	**Kenwyn**
Location	**Tregony**	**Truro**
No of readings	9340	12781
Date commenced	8/6/1978	31/10/1968
Flow exceedence (m^3/s)		
Max., 0% =	48.24	6.62
5% =	5.99	1.21
25% =	2.67	0.51
Median, 50% =	1.36	0.23
75% =	0.83	0.10
95% =	0.44	0.05
Min., 100% =	0.21	0.02
Mean =	2.10	0.39
Effective rainfall		
A (km^2)	91.20	19.10
q (m^3/s/km^2)	0.022982	0.020169
q (mm/year)	725	636

Flow statistics in terms of percentage flow exceedence (m^3/s) based on mean daily flow records for the River flow gauges within the Fal catchment. "A" refers to the sub-catchment area. "q" refers to the mean flow per unit area, or effective rainfall. Note that the high flow per unit area for the Carnon River probably reflects the fact that it is receiving water from outside of the catchment due to minewater drainage into the County Adit system. Source of raw data: The Environment Agency

2.5.3 Bathymetry

The estuary is a flooded river valley (ria) with significant intertidal drying areas along its margins and tributaries. The deepest part of the upper estuary lies between Turnaware Point and the Truro River. In this section, the depth of the main channel at chart datum is generally greater than 10 m and is greater than 15 m in some parts. is a deep pool, with 15 m depth at chart datum (CD) in its deepest area (Figure 31), between Fal Point and Fal Passage.

Figure 31. Bathymetry of the Upper Fal Estuary.

2.5.4 Tidal range

The mean tidal range at Falmouth varies between 2.2 m on mean neap tides to 4.6 m on mean spring tides (Table 10). At Truro, the Mean High Water Springs is 3.5 m and Mean High Water Neap is 2.4 m. At that location, the estuary dries out complete except for the water from the river (UKHO Totaltide).

Table 10. Predicted tide levels at the Fal Estuary entrance.

Level		Level (m)
Mean High Water Springs	MHWS	5.4
Mean High Water Neaps	MHWN	4.3
Mean Low Water Neaps	MLWN	2.1
Mean Low Water Springs	MLWS	0.8

2.5.5 Tidal flow and circulation

Given that the upper estuary is unlikely to be at risk of contamination from seaward sources and that advection of contaminants down the estuary with the prevailing south-westerly winds is likely to be more significant (particularly on the ebb tide), monitoring points need to be identified that reflect dominant upstream sources of contamination.

2.6 MICROBIOLOGICAL DATA

2.6.1 Historical *E. coli* data from the shellfish hygiene monitoring programme

Bivalve production areas are classified according to the time series trend of E. coli in samples of bivalves taken from representative monitoring points. Samples are collected by local authorities and submitted to official control laboratories for testing. The results are collated in England and Wales by Cefas acting on behalf of the FSA. The results are assessed against the criteria given in Table 11 and recommendations are made to the FSA who determine the final classifications. The classification status determines the post-harvest treatment, if any, to which the bivalves must be subjected prior to sale for consumption.

Table 11. EU criteria for the classification of shellfish harvesting areas

Class[1]	Microbiological standard[2]	Post-harvest treatment required
A	Live bivalve molluscs from these areas must not exceed 230 Most Probable Number (MPN) *E. coli* per 100 g of flesh and intra-valvular liquid[3]	None
B	Live bivalve molluscs from these areas must not exceed, in 90 % of the samples, 4 600 MPN *E. coli* per 100 g of flesh and intravalvular liquid. In the remaining 10 % of samples, live bivalve molluscs must not exceed 46 000 MPN *E. coli* per 100 g of flesh and intravalvular liquid. [4]	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* per 100 g of flesh and intravalvular liquid[5]	Relaying or cooking by an approved method

Notes [1] The competent authority has the power to prohibit any production and harvesting of bivalve molluscs in areas considered unsuitable for health reasons
[2] The reference method is given as ISO 16649-3.
[3] By cross-reference from EC Regulation 854/2004, via EC Regulation 853/2004, to EC Regulation 2073/2005.
[4] From EC Regulation 1021/2008.
[5] From Regulation (EC) No 854/2004.

The microbiological monitoring programme undertaken in the Upper Fal Estuary currently identifies ten RMPs (see Figure 32). The location and numbers of shellfish samples by year collected at the principal RMPs are given in Table 12 and the summary statistics for the *E. coli* results from these RMPs are given in Table 13.

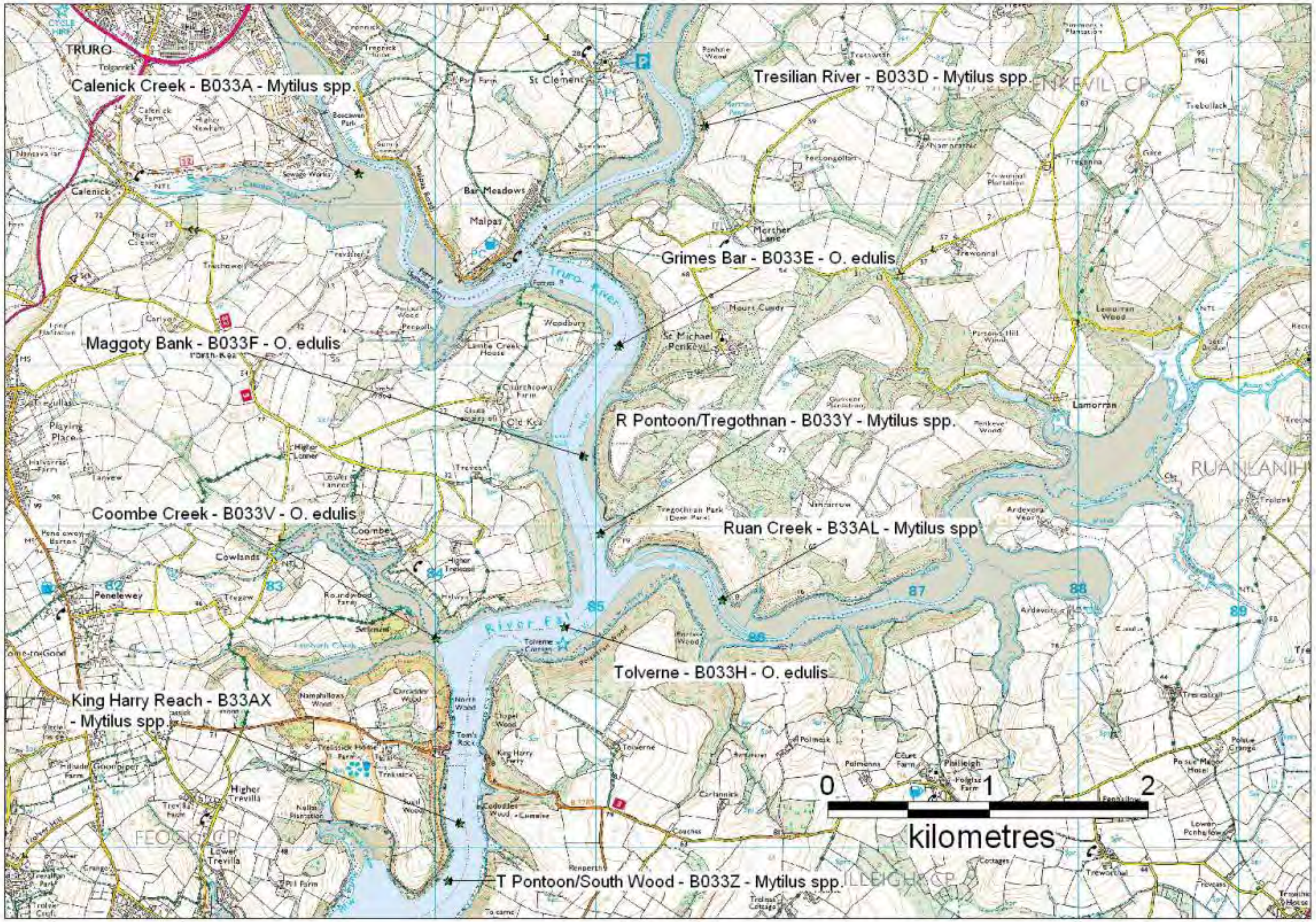


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Figure 32. Location of current representative monitoring points

2.6.1.1 *E. coli* data statistical summary

A summary of descriptive statistics for *E. coli* data monitored in shellfish from thirteen monitoring points between 1st January 2000 and 31st December 2009 is presented in Table 13. Not all of the points were monitored for the whole period. Data for other monitoring points with less than 20 results during the period have been omitted from the summary and further analyses.

The data for the individual monitoring points in the upper Fal are also presented as time series representations of levels of *E. coli*, including lowess trend lines (Figures 33–44). These figures show the long-term trends in the quality of shellfish on the respective sampling sites in the upper Fal. The majority of sites within the area of interest show a general stability in the results reported across the time periods shown. The exceptions being at Calenick Creek – where there has been an improvement in the quality over the period and at Ruan Creek and King Harry Reach where there has been an apparent worsening of the results over recent periods; though these sites were generally at a lower level of overall contamination than others in the area.

Overall quality in the area of interest would appear to have been reasonably stable over a significant period of time, indicating that there are few variables providing consistent detrimental input into the system

Table 12. Summary statistics of E. coli data from thirteen monitoring points in the upper Fal Estuary between 2000 and 2009.

	B033A	B033B	B033C	B033D	B033E	B033F	B033H	B033V	B033Y	B033Z	B33AL	B33AU	B33AX
	Calenick Creek (M)	Lambe Creek (M)	Malpas (M)	Tresillian River (M)	Grimes Bar (O. ed)	Maggoty Bank (O.ed)	Tolverne (O. ed)	Coombe Creek (O. ed)	Pontoon / Tregothnan (M)	Pontoon / South Wood (M)	Ruan Creek (M)	Cornish Mussels (M)	King Harry Reach (M)
Number of samples	101	62	73	111	106	111	116	109	121	125	114	38	56
Date of first sample	17/01/2000	17/01/2000	17/01/2000	17/01/2000	17/01/2000	17/01/2000	17/01/2000	14/02/2000	17/01/2000	17/01/2000	17/01/2000	20/05/2003	25/09/2006
Date of last sample	07/12/2009	25/07/2006	21/08/2006	07/12/2009	07/12/2009	07/12/2009	07/12/2009	07/12/2009	07/12/2009	07/12/2009	07/12/2009	21/08/2006	07/12/2009
Minimum *E.coli* MPN $100g^{-1}$ FIL*	130	70	160	40	40	40	<20	20	<20	20	<20	<20	<20
Maximum *E.coli* MPN $100g^{-1}$ FIL	>18000	>18000	>18000	92000	>18000	24000	>18000	>18000	24000	180000	22000	>18000	49000
Median *E.coli* MPN $100g^{-1}$ FIL	1700	1300	1100	1400	1100	500	945	500	750	500	1100	310	310
Geometric Mean *E.coli* MPN $100g^{-1}$ FIL	2110	1270	1340	1520	1120	675	980	692	1000	765	1190	406	534
90-percentile *E.coli* MPN $100g^{-1}$ FIL	16000	5400	9100	9200	9100	5400	9100	3500	9100	9100	10300	6510	16000

*FIL – Flesh and intravalvular liquid

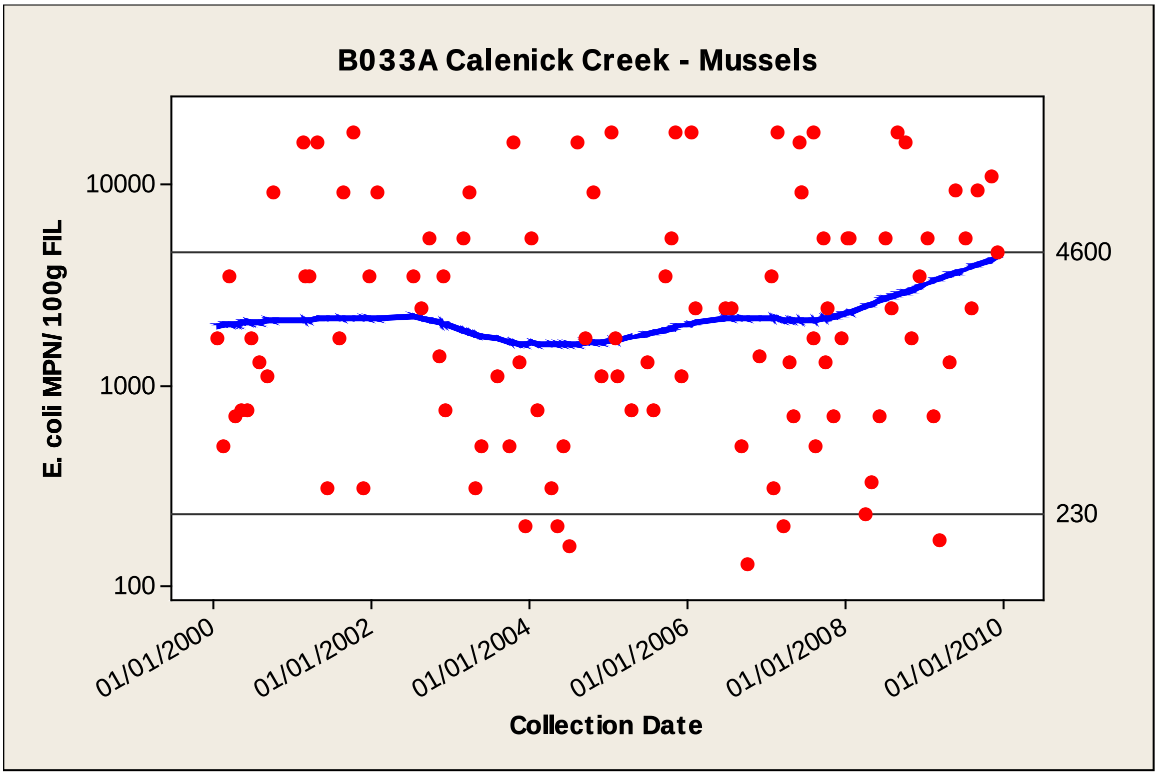

Figure 33. Time series of levels of E. coli *and lowess smoother (blue line) in Mytilus spp. from Calenick Creek (B033A).*

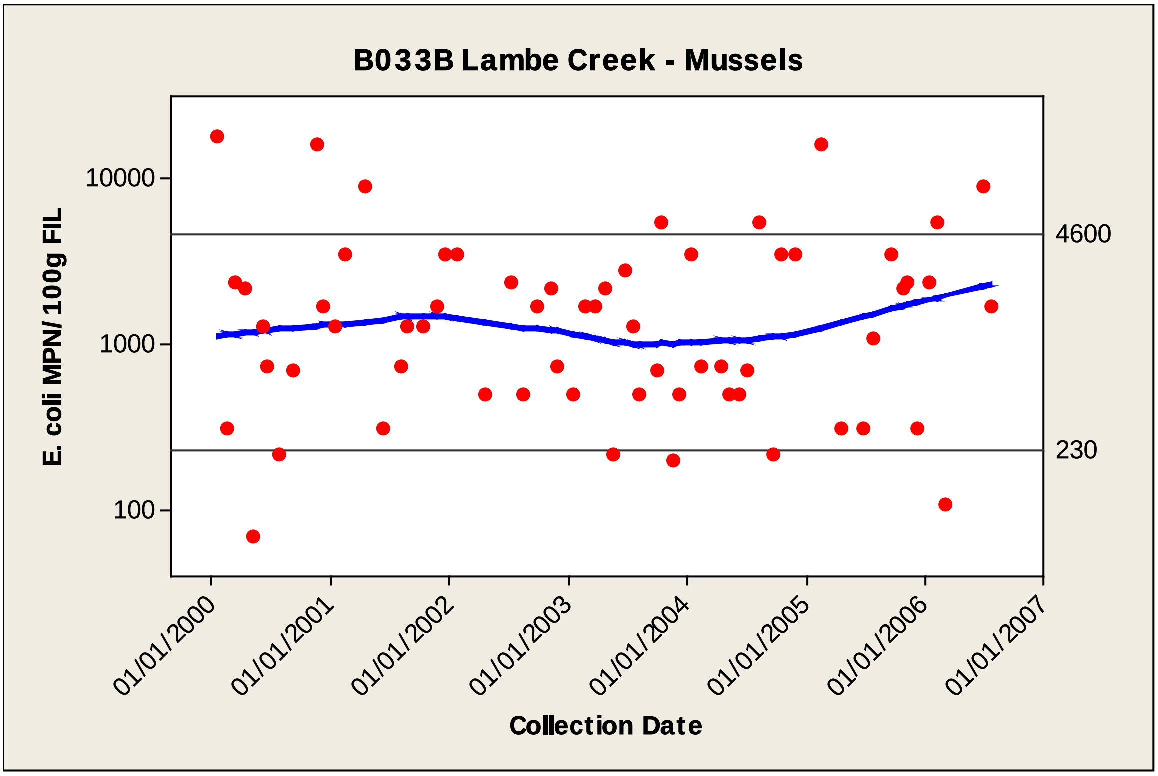

Figure 34. Time series of levels of E. coli *and lowess smoother (blue line) in Mytilus spp. from Lambe Creek (B033B).*

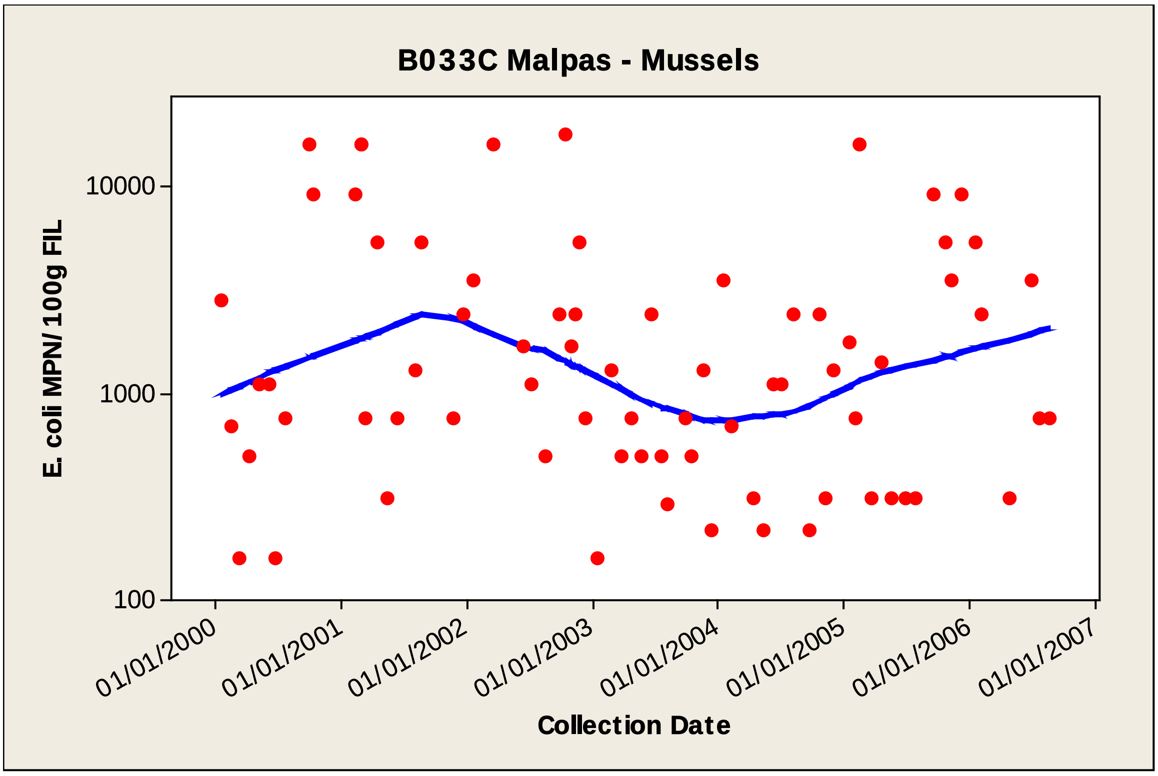

Figure 35. Time series of levels of* E. coli *and lowess smoother (blue line) in Mytilus spp. from Malpas (B033C).

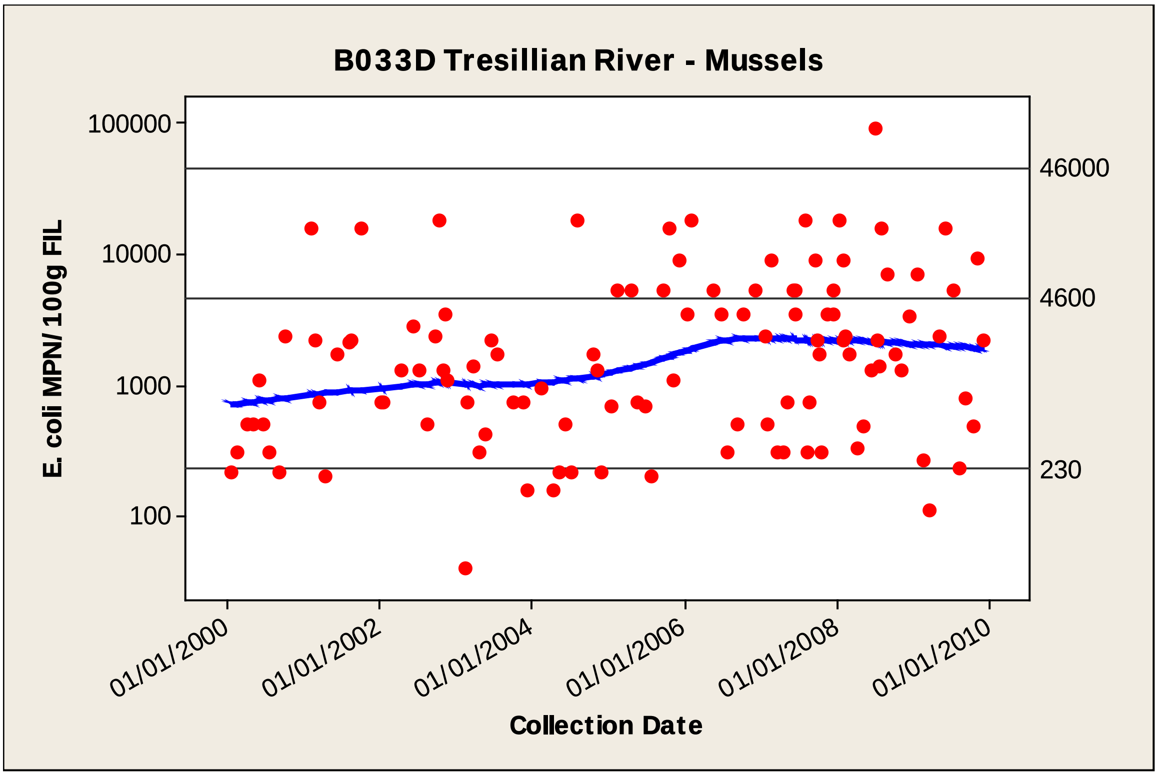

Figure 36. Time series of levels of* E. coli *and lowess smoother (blue line) In Mytilus spp. from Tresillian River (B033D).

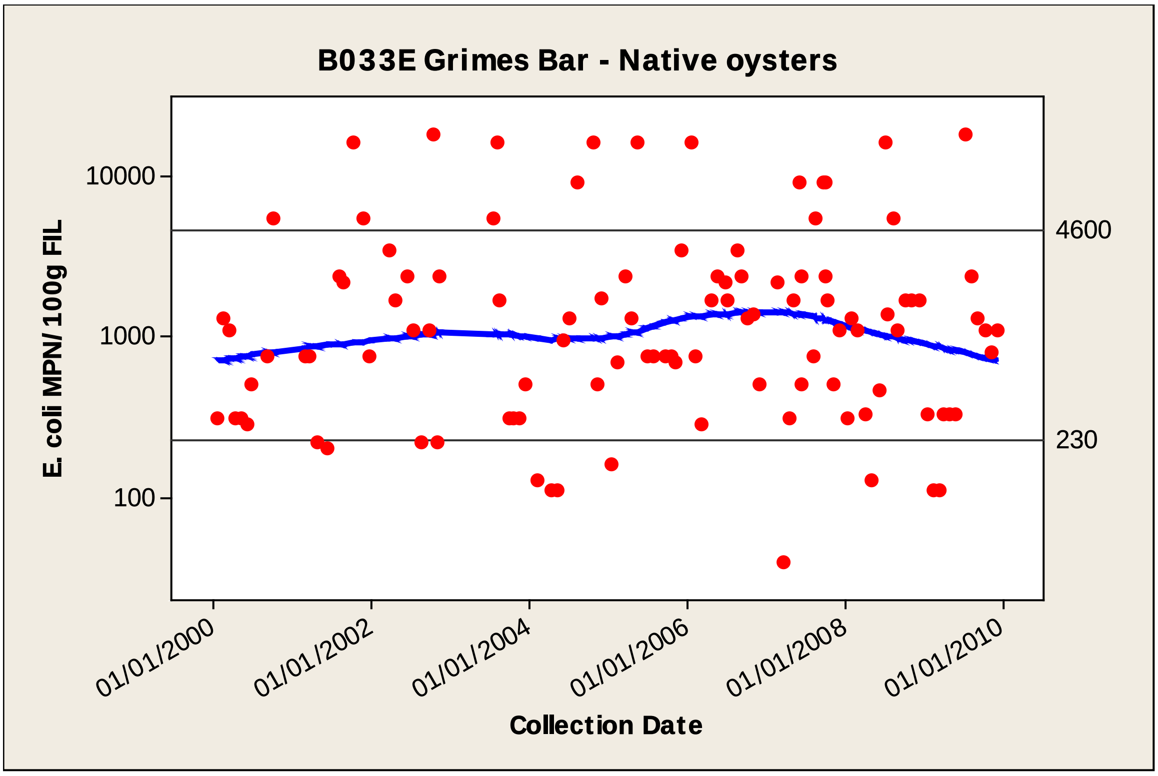

Figure 37. Time series of levels of E. coli *and lowess smoother (blue line) in O. edulis from Grimes Bar (B033E).*

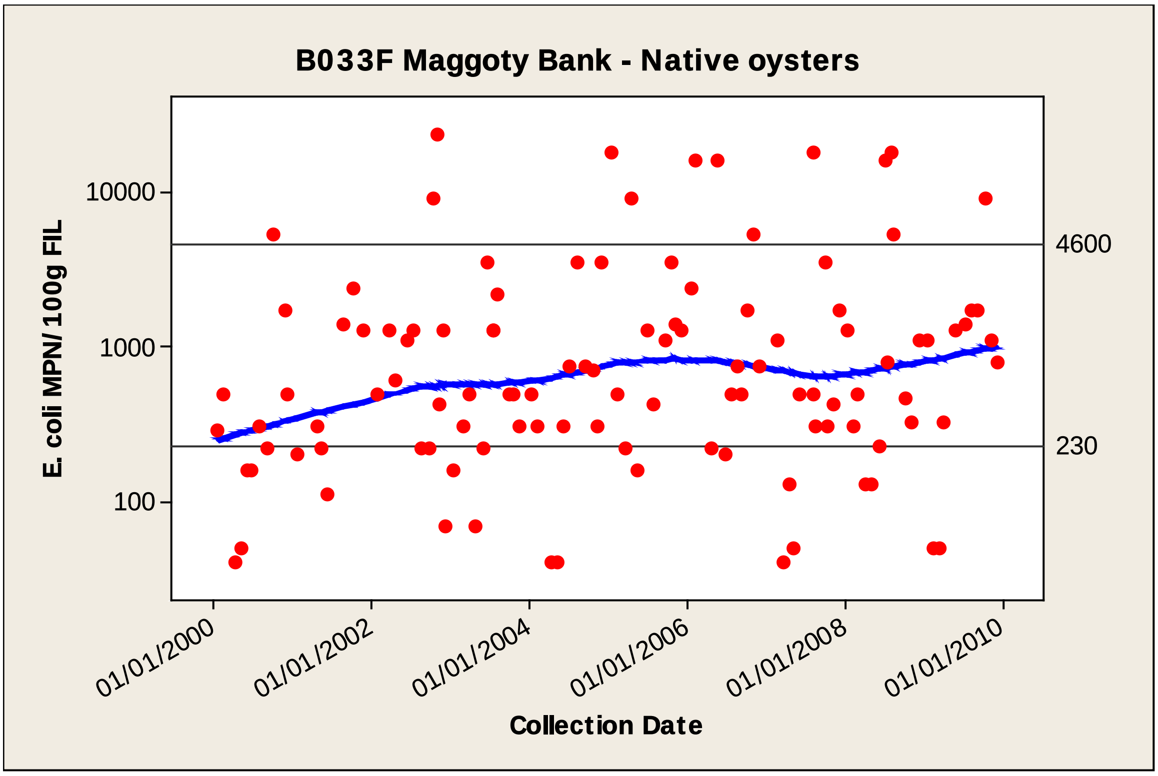

Figure 38. Time series of levels of E. coli *and lowess smoother (blue line) in O. edulis from Maggoty Bank (B033F).*

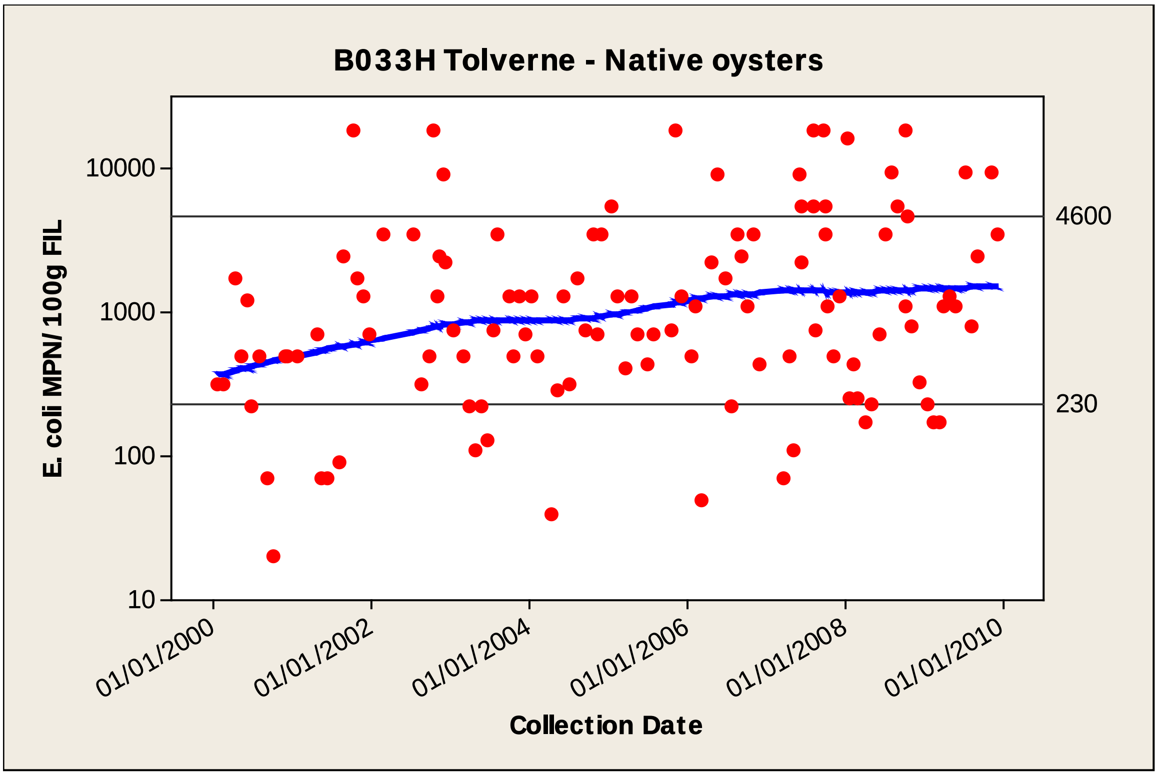

Figure 39. Time series of levels of E. coli *and lowess smoother (blue line) in O. edulis from Tolverne (B033H).*

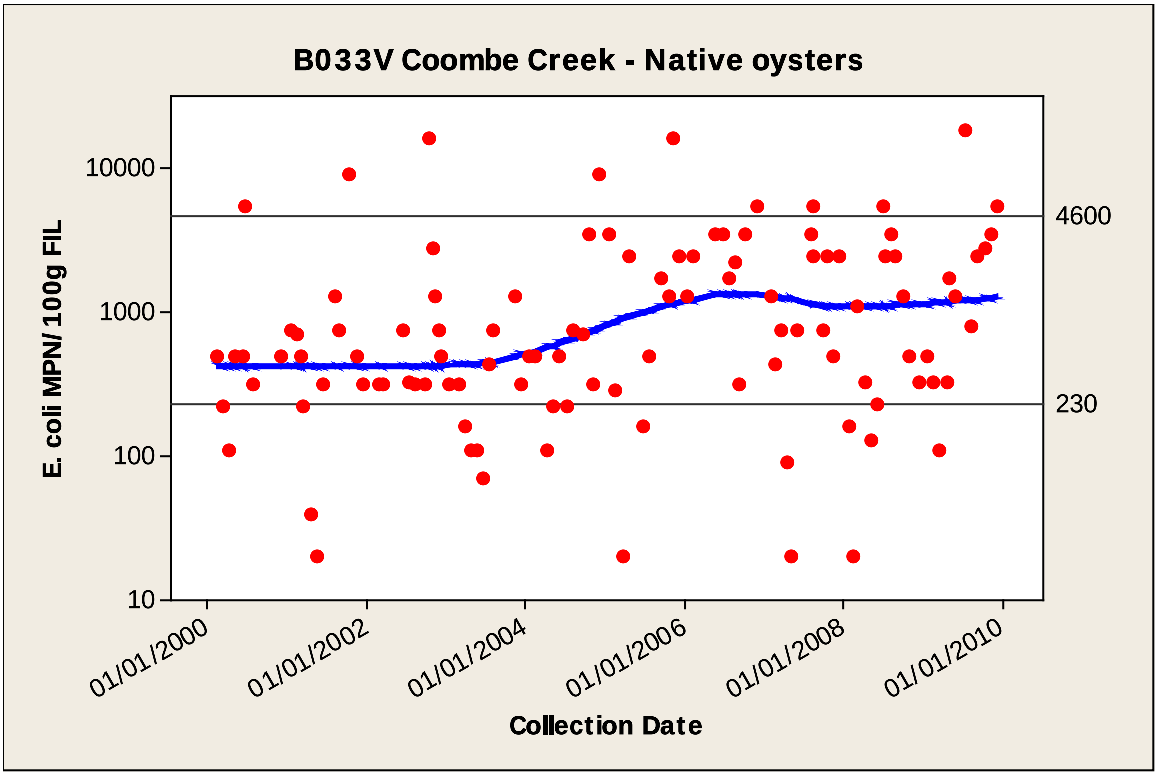

Figure 40. Time series of levels of E. coli *and lowess smoother (blue line) in O. edulis from Coombe Creek (B033V).*

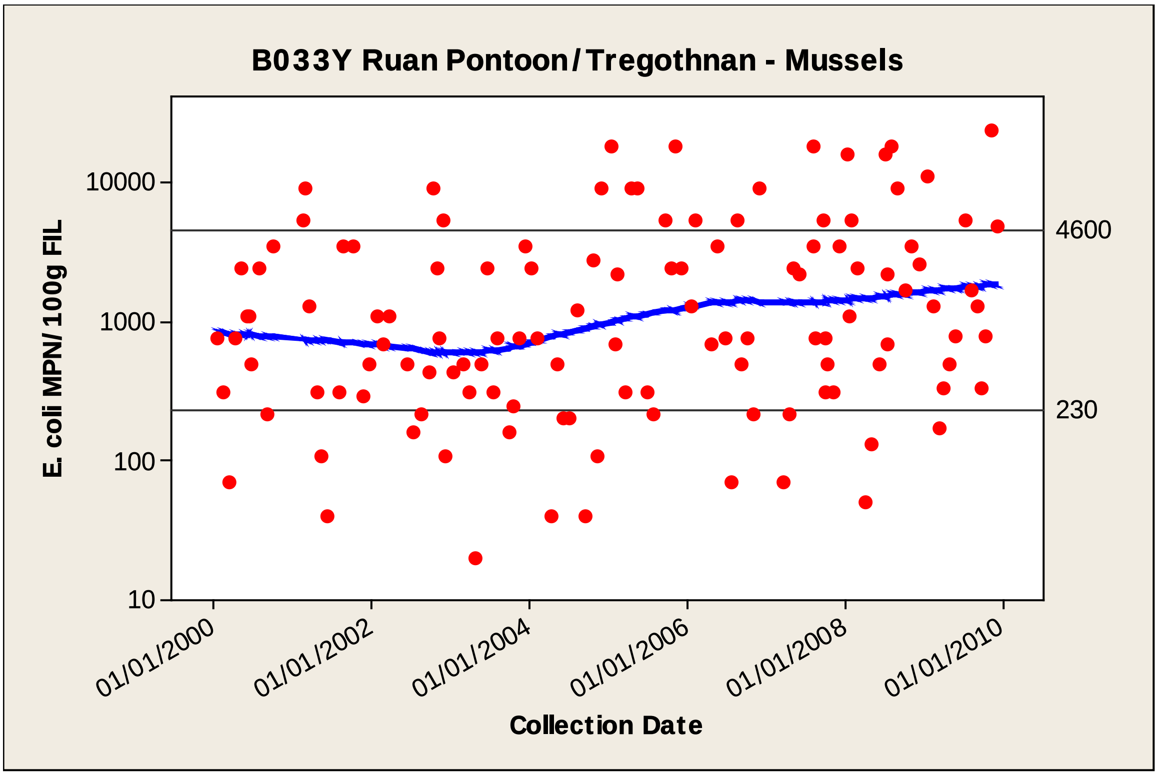

Figure 41. Time series of levels of* E. coli *and lowess smoother (blue line) in Mytilus spp. from Ruan Pontoon/Tregothnan (B033Y).

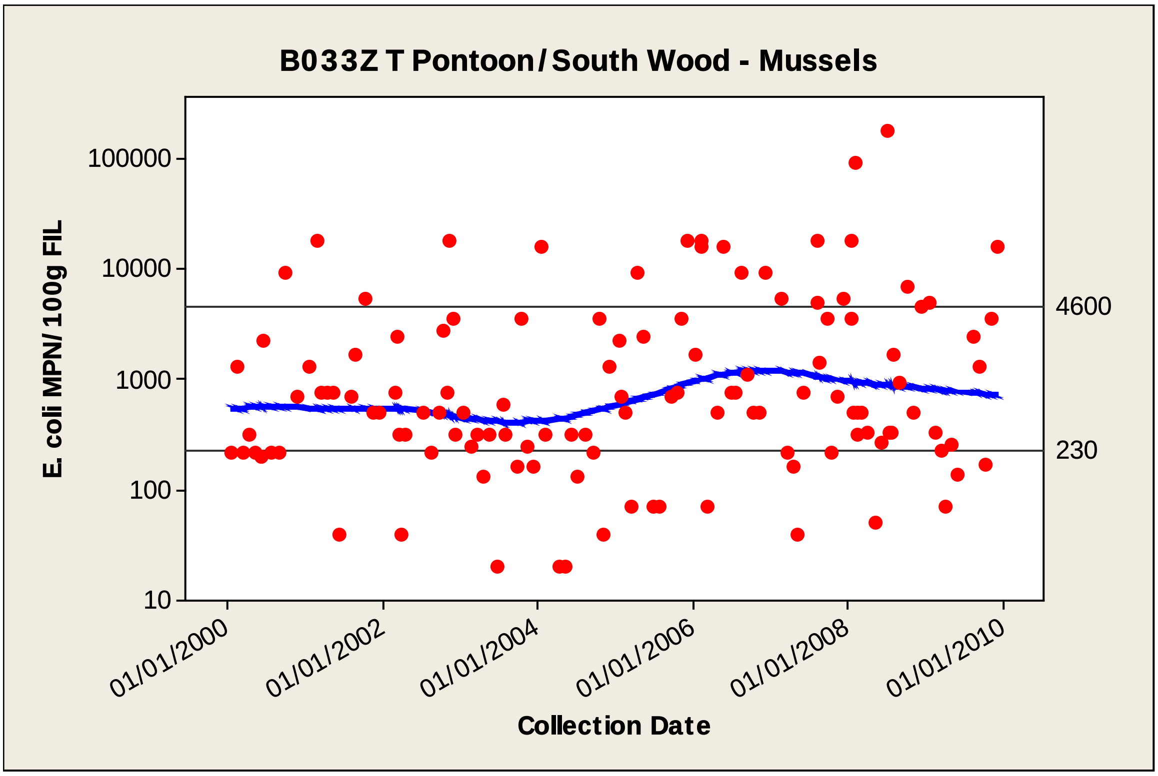

Figure 42. Time series of levels of* E. coli *and lowess smoother (blue line) in Mytilus spp. from Turnaware Pontoon/South Wood (B033Z).

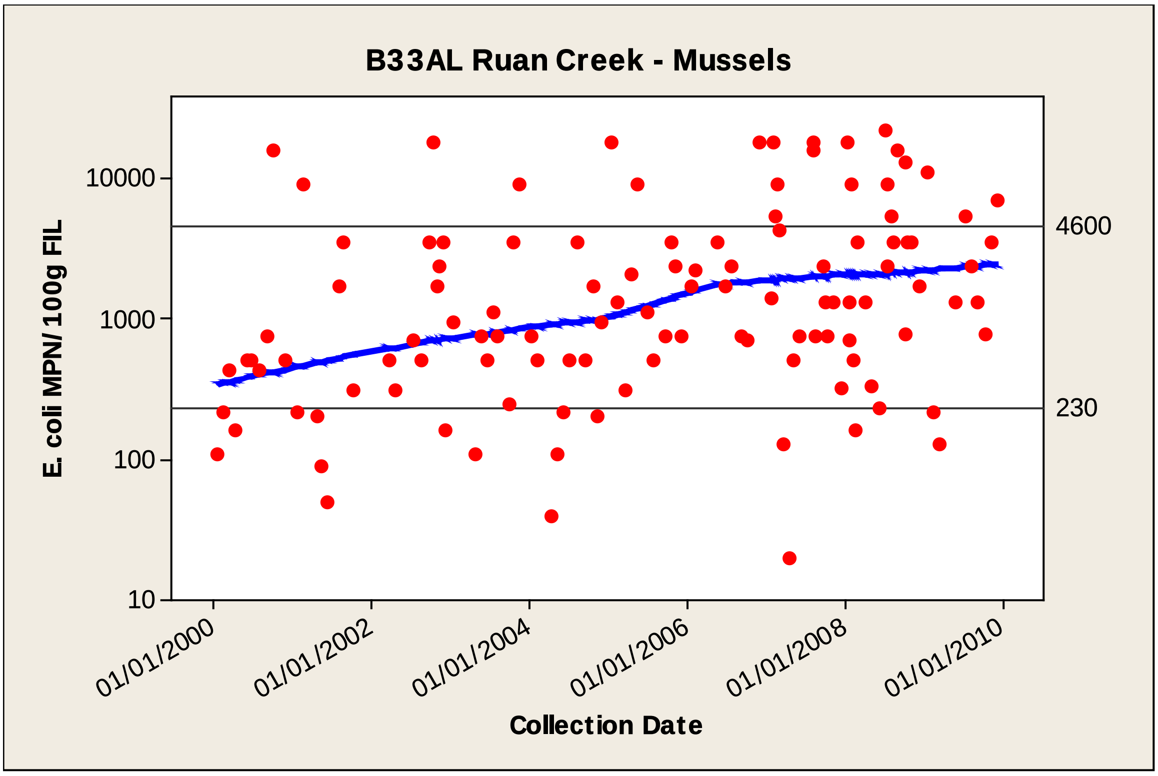

Figure 43. Time series of levels of E. coli *and lowess smoother (blue line) in Mytilus spp. from Ruan Creek (B33AL).*

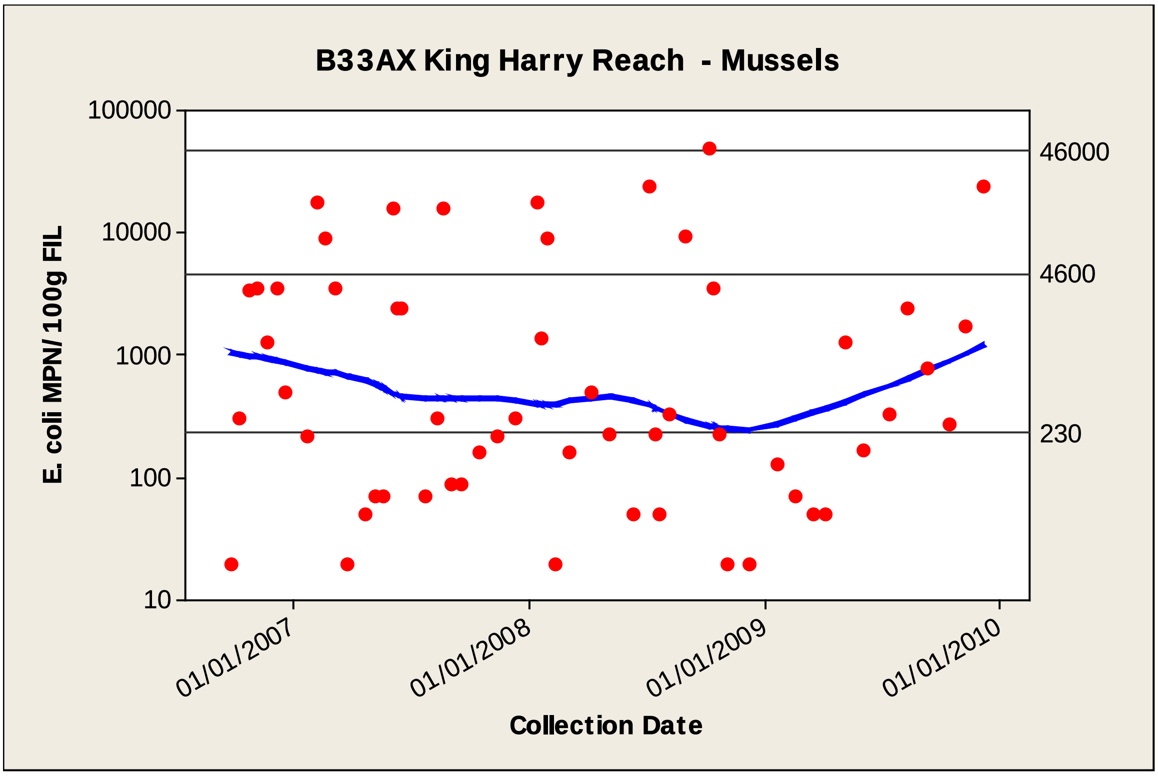

Figure 44. Time series of levels of E. coli *and lowess smoother (blue line) in Mytilus spp. from King Harry Reach (B33AX).*

2.6.1.1 Spatial variation in shellfish *E. coli* results

Figure 43 shows the geometric mean *E. coli* values from Table 13 thematically plotted against RMP location. In general, The highest geometric mean is at Calenick Creek, south of Truro and there is a general tendency for the geometric means to decrease from north to south, indicating that the predominant contaminating sources at towards the north end of the estuary. There are some deviations from this general trend. In particular, the value at Ruan Creek is higher than at nearby sampling locations, indicating that additional contamination is likely to arising within the creek.

Figure 43. Geometric mean E. coli in shellfish at selected locations in the Upper Fal estuary

2.6.1.2 Classification Status

The historical classification status of shellfish beds between 2000 and 2009 is summarised in Table 13. Prior to 1999 some beds at and above Malpas in the Truro River were designated as prohibited for commercial gathering due to the extent of faecal contamination. Since then ,those beds have been consistently classified as C. Up until 2007, most other beds in the upper estuary were classified as B, except for the Tresillian River, which was downgraded to C in 2006. In 2008, the King Harry Reach mussel lines were reclassified to a seasonal B/C and Grimes Bar (oysters) and Tregothan/Ruan Pontoon and Turnaware Pontoon/South Wood (both mussels) were reclassified as C.

Table 13. Historical classification status of shellfish beds in the Upper Fal Estuary between 2000 and 2009.

BED NAME	Bed ID	SPECIES	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Grimes Bar	B033E	*O. edulis*	B	B	B	B	B	B (seasonal)	B (seasonal)	B (seasonal)	C	C
Maggoty Bank	B033F	*O. edulis*	B	B	B	B	B	B-LT	B-LT	B-LT	B-LT	B-LT
Tregothan/Ruan Pontoon	B033Y	*Mytilus* spp.	B	B	B	B	B	B (seasonal)	B (seasonal)	B (seasonal)	C	C
Calenick Creek	B033A	*Mytilus* spp.	C	C	C	C	C	C	C	C	C	C
Lambe Creek	B033B/B033A	*Mytilus* spp.	C	C	C	C	C	C	C	C	C	C
Malpas	B33AH/B033A	*Mytilus* spp.	C	C	C	C	C	C	C	C	C	C
Tresillian river all beds	B033D	*Mytilus* spp.	B	B	B	B	B	B	C	C	C	C
Ruan Creek	B33AL	*Mytilus* spp.	B	B	B	B	B	B	B-LT	B-LT	B-LT	B-LT
Turnaware Pontoon/South Wood	B033Z	*Mytilus* spp.	B	B	B	B	B	B-LT	Listed as King Harry mussel lines	Listed as King Harry mussel lines	C	C
King Harry Reach mussel lines	B33AX	*Mytilus* spp.	n/c	n/c	n/c	n/c	Listed as Cornish mussels	Listed as Cornish mussels	B (seasonal)	B (seasonal)	B (seasonal)	B (seasonal)
Cornish Mussels	B33AU	*Mytilus* spp.	n/c	n/c	n/c	n/c	B	B	Listed as King Harry mussel lines	Listed as King Harry mussel lines	Listed as King Harry mussel lines	Listed as King Harry mussel lines
Channels Creek	B033J	*O. edulis*	B	B	B	B	n/c	n/c	n/c	n/c	n/c	n/c
King Harry Ferry	B033I	*O. edulis*	B	B	B	B	n/c	n/c	n/c	n/c	n/c	n/c
Tolverne	B033H	*O. edulis*	B	B	B	B	B	B-LT	B-LT	B-LT	B-LT	B-LT
Turnaware Bar	B033K	*O. edulis*	B	B	B	B	B	B-LT	B	B	B	B
Coombe Creek	B033V	*O. edulis*	B	B	B	B	B	B-LT	B-LT	B-LT	B-LT	B-LT

LT-Long Term. n/c-not classified.

2.6.1.3 .Seasonality

Monthly geometric mean *E. coli* concentrations were calculated for each RMP for which there were at least six samples per year from 2000 to 2008. The number of samples at each RMP for which the *E. coli* results was greater than the class B limit of 4,600 100 g^{-1} was also determined. These numbers, together with the monthly geometric mean *E. coli* concentrations, are presented in Figures 44 to 53. A seasonal trend in the levels of an increase in contamination in oysters from spring to autumn is apparent. In addition, months with the highest number of results > 4,600 *E. coli* 100 g^{-1} FIL are coincident with the highest geometric means of *E. coli*.

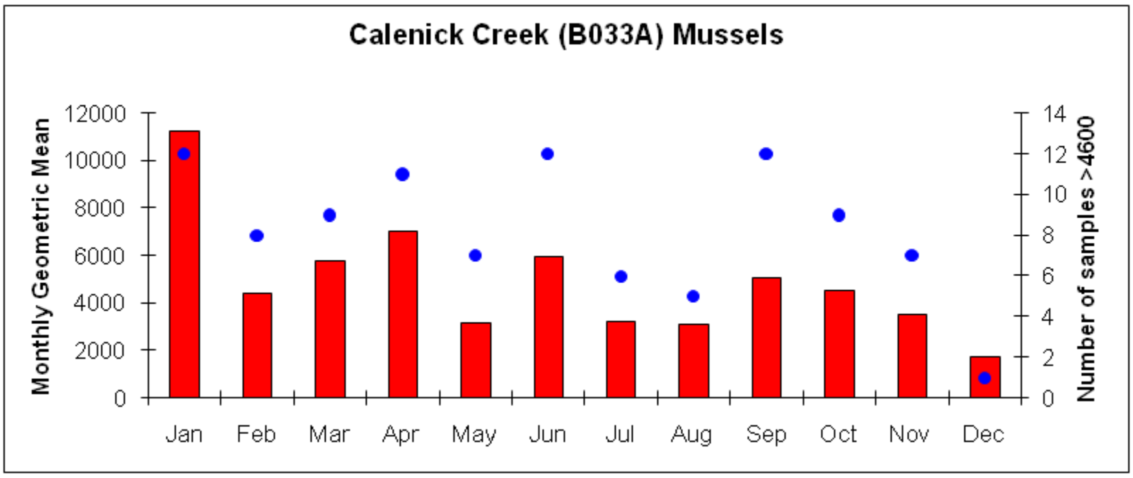

Figure 44 shows the monthly geometric mean variation of E. coli in mussels from Calenick Creek in the Upper Fal.

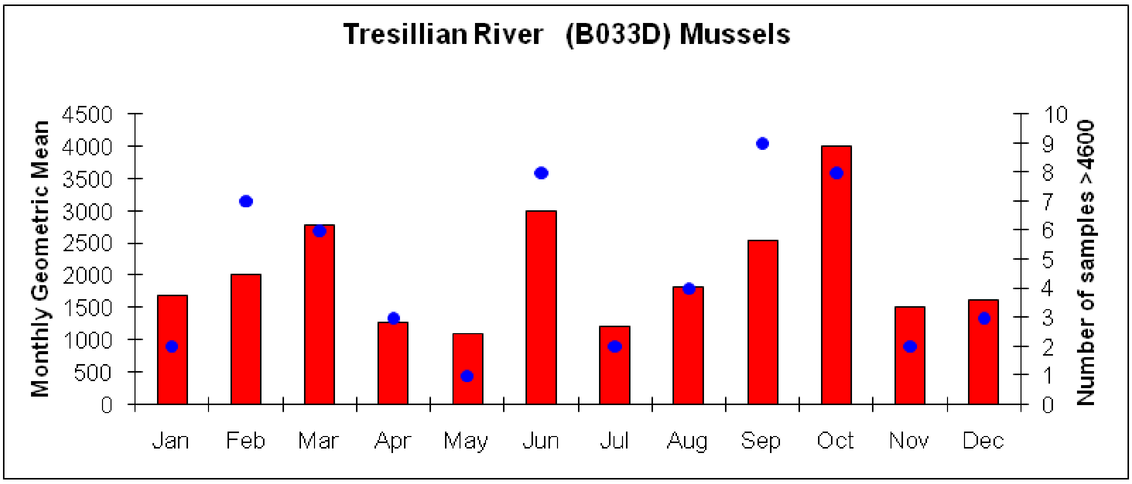

Figure 45 shows the monthly geometric mean variation of E. coli in mussels from Tresillian River in the Upper Fal.

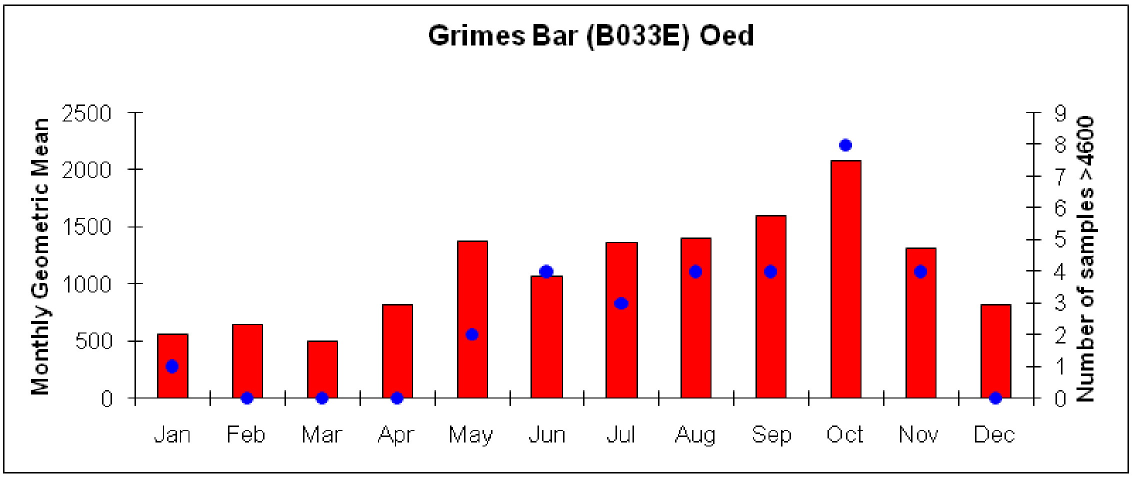

Figure 46 show the monthly geometric mean variation of E. coli in O. edulis from Grimes Bar in the Upper Fal.

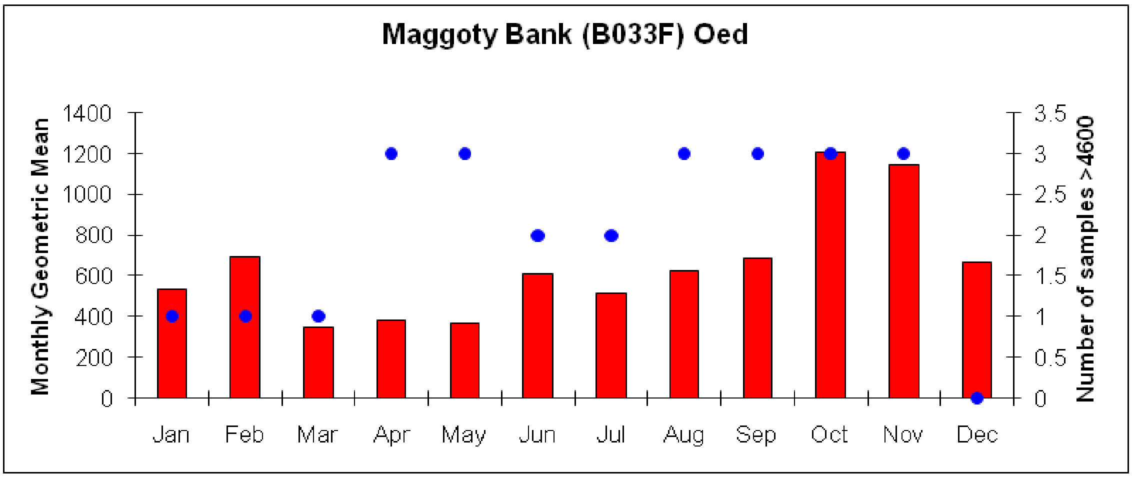

Figure 47 show the monthly geometric mean variation of E. coli in O. edulis from Maggoty Bank in the Upper Fal.

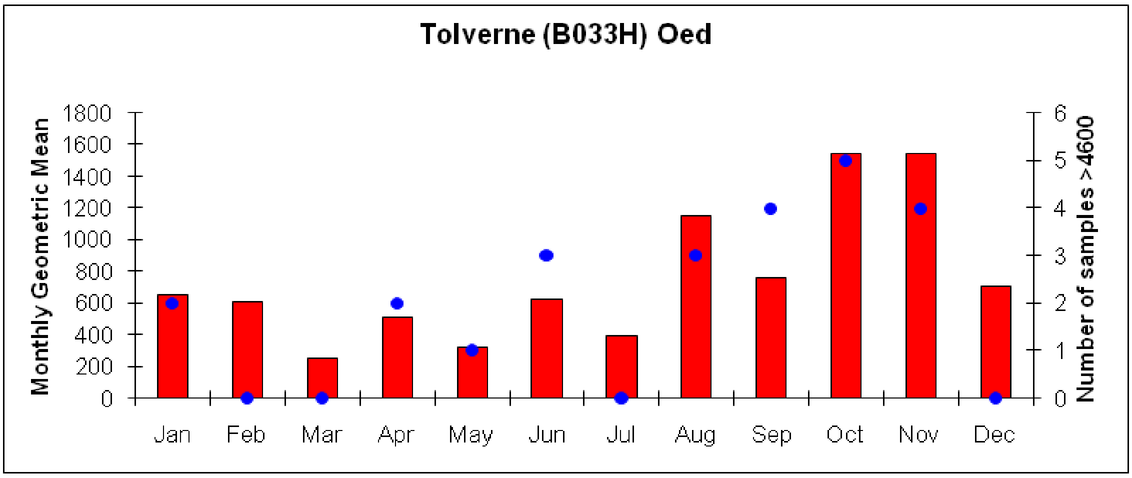

Figure 48 show the monthly geometric mean variation of* E. coli *in* O. edulis *from Tolverne in the Upper Fal.

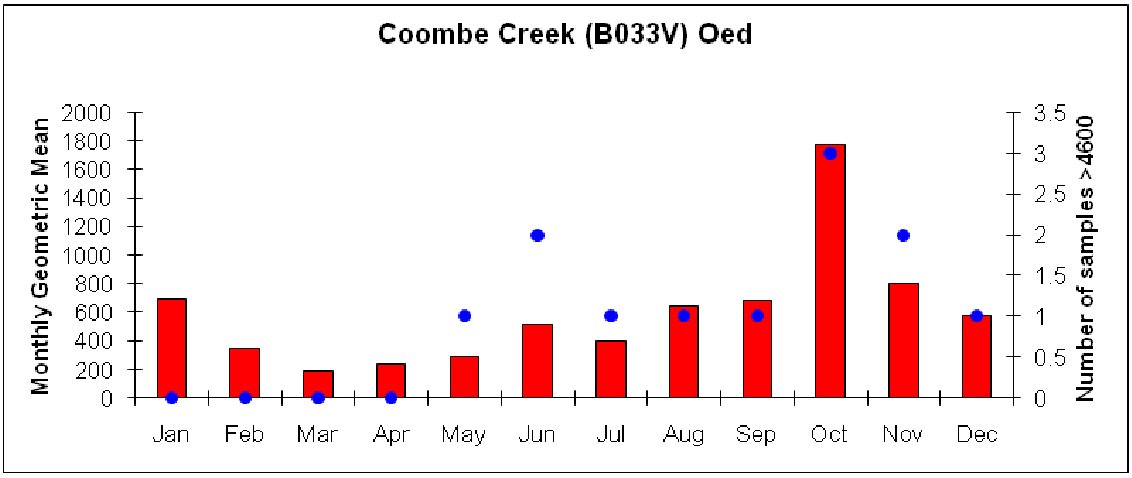

Figure 49 show the monthly geometric mean variation of* E. coli *in* O. edulis *from Coombe Creek in the Upper Fal.

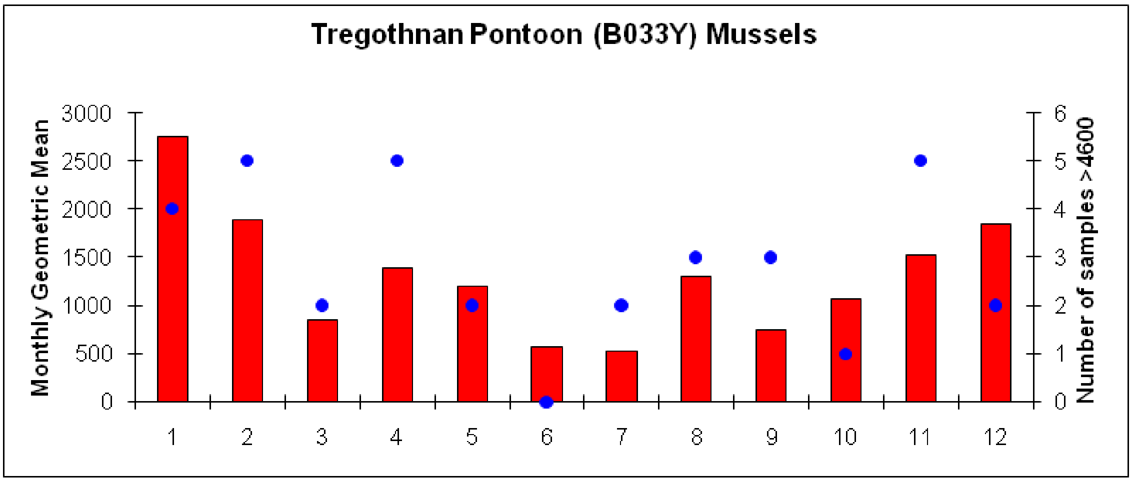

Figure 50 show the monthly geometric mean variation of* E. coli *in mussels from Tregothnan Pontoon in the Upper Fal.

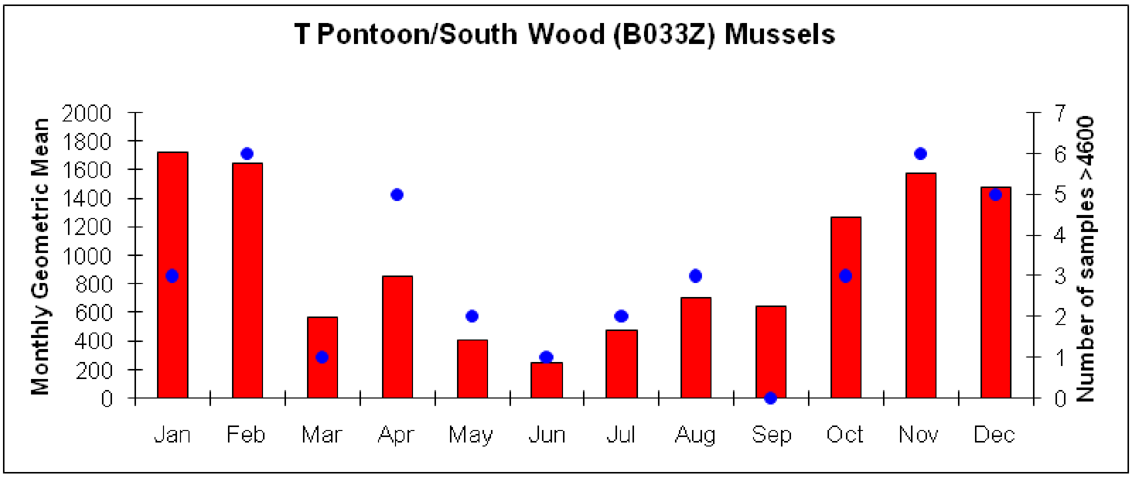

Figure 51 show the monthly geometric mean variation of* E. coli *in mussels from T. Pontoon / South Wood in the Upper Fal.

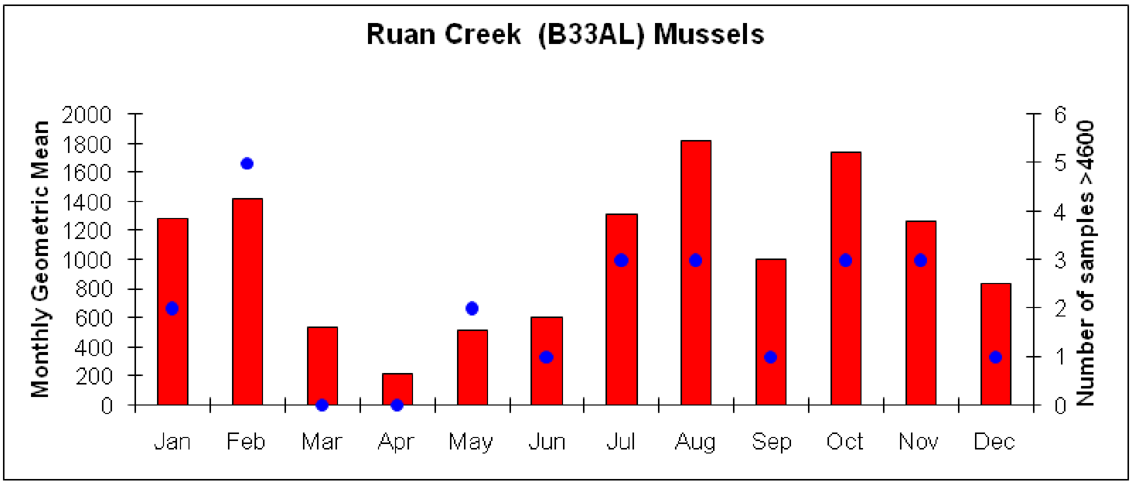

Figure 52 show the monthly geometric mean variation of* E. coli *in mussels from Ruan Creek in the Upper Fal Time.

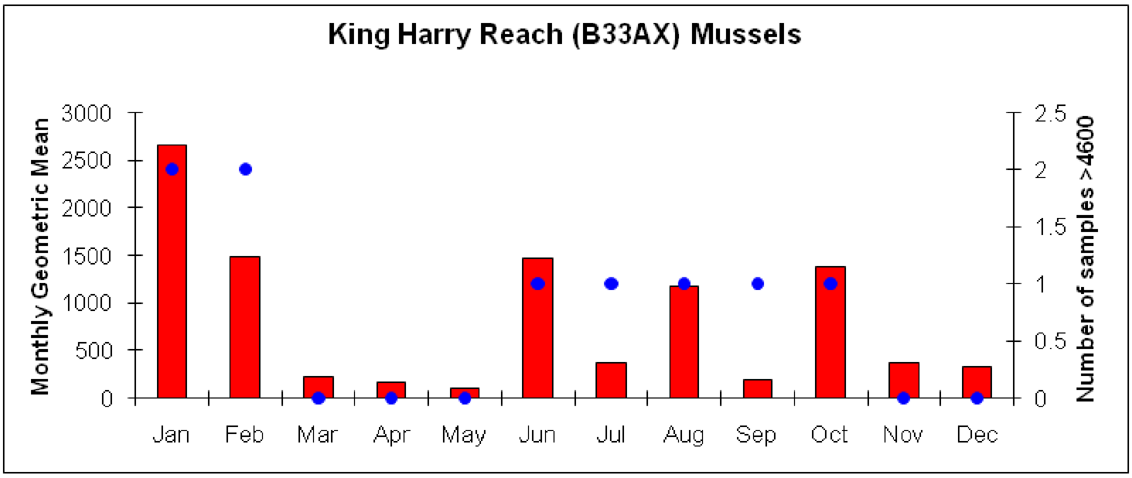

Figure 53 show the monthly geometric mean variation of* E. coli *in mussels from King Harry Reach in the Upper Fal.

2.6.1.4 Correlation with rainfall

Daily rainfall data for Truro (Newham) was supplied by the Environment Agency. Shellfish data was obtained from the classification monitoring programme. Values of <20 *E. coli* per 100g were assigned a value of 10 and values of >18000 per 100g were assigned a value of 36000. The rainfall values were summed over 2, 5 and 7 days prior to sampling. Rank correlation coefficients were determined of *E. coli* concentrations versus summed rainfall at selected sites at the top and bottom of the Upper Fal. The results are presented in Table 14.

Table 14. Spearman Rank Correlation Coefficients of* E. coli *in shellfish flesh against rainfall prior to sampling

	Spearman's Rank Correlation Coefficient			
Site	**Species**	**Two-day rainfall**	**Five-day rainfall**	**Seven-day rainfall**
Calenick Creek	*Mytilus* spp.	0.40*	0.34*	0.27*
Tresillian	*Mytilus* spp.	0.54*	0.47*	0.41*
Grimes Bar	*O. edulis*	0.42*	0.38	0.33*
King Harry Reach	*Mytilus* spp.	0.41*	0.31*	0.29
Turnaware Bar	*O. edulis*	0.44*	0.52*	0.47*

*$p<0.05$

A significant correlation was observed for all combinations except for the seven-day rainfall at King Harry's Reach, where the probability associated with the correlation coefficient was slightly greater than 0.05. The correlation coefficient was highest with the two-day rainfall value at all sites, except Turnaware Bar, where it was highest with the five-day rainfall value. Overall, the highest coefficient was obtained for two-day rainfall at Tresillian, although minor differences in coefficients are unlikely to have practical implications. Experience has shown that it is unusual to obtain correlation coefficients markedly greater than 0.5 when shellfish *E. coli* results are related to environmental variables, presumably because other confounding factors are not allowed for (largely due to restrictions of small data sets or absence of appropriate data).

Correlation does not imply cause and effect. The following are just some of the possible reasons for observation of such effects:

i. Reduced efficiency of sewage treatment
ii. Operation of CSOs
iii. Increased river loadings
iv. Direct land run-off to the estuary
v. Resuspension of contaminated sediment

In themselves, increased river loadings could be due to a variety of factors relating to point sources, diffuse sources or resuspension.

2.6.2 Microbiological data from the Shellfish Waters Directive monitoring programme

The designations in the Fal Estuary under the Shellfish Waters Directive are shown in Figure 54. The area covered by this sanitary survey report is covered by the Fal Estuary, Ruan Creek and Tresillian designated waters.

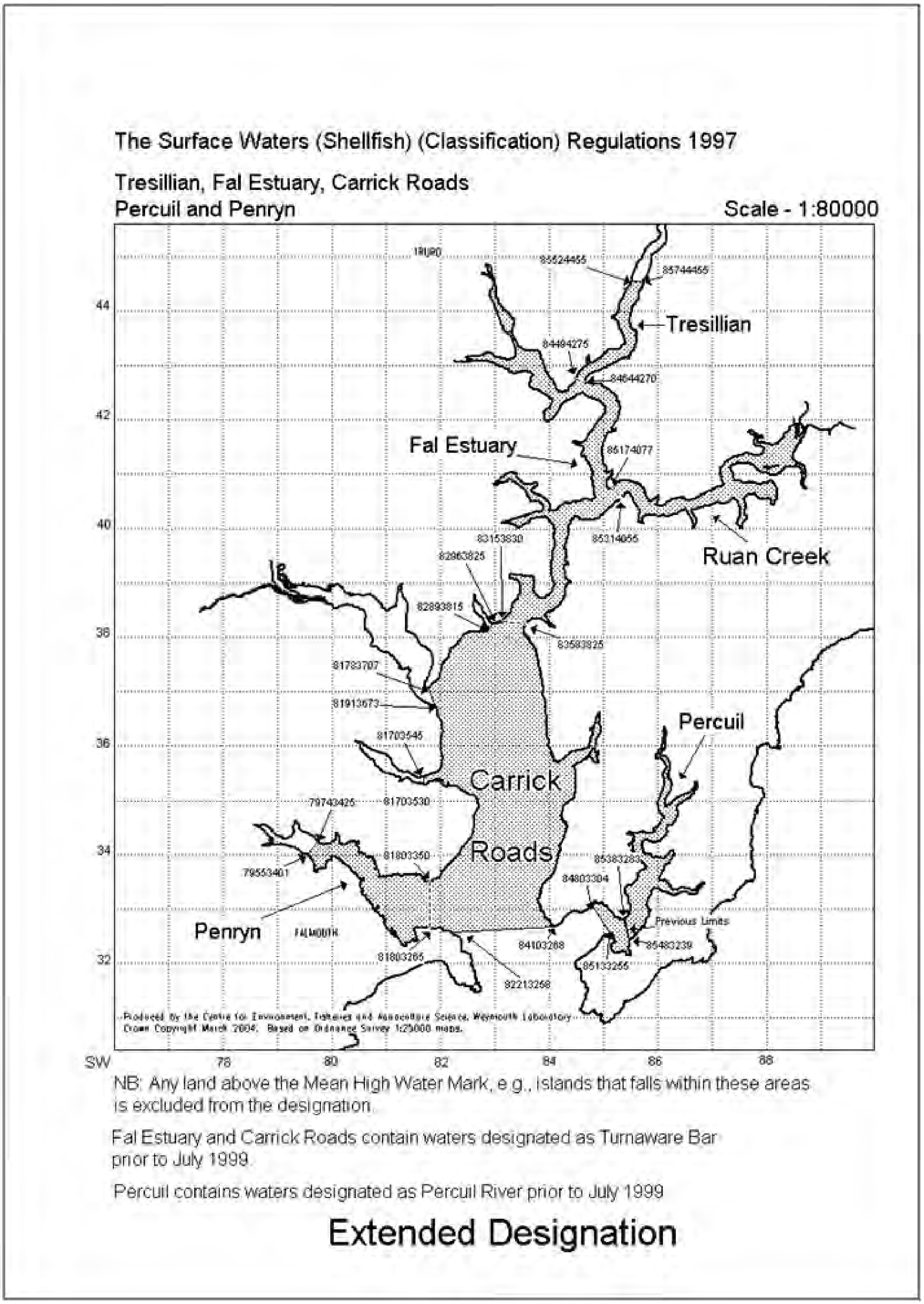

Figure 54. Designated shellfish waters in the Fal Estuary

Monitoring points for surface water and shellfish flesh samples undertaken for the purposes of the Shellfish Waters Directive are shown in Figure 55.

The required sampling frequency under the Directive is quarterly. There is a microbiological guideline value of 300 faecal coliforms per 100ml of flesh and intervalvular fluid in 75% of samples. Problems with obtaining samples in the Fal for faecal coliform analysis means that there were insufficient samples taken to assess compliance in the designated waters between 2004 and 2008. This problem has now been rectified and the results for from May 2008 to December 2009 are given below in Table 15.

The shellfish faecal coliform results confirm those from the classification monitoring: high, or relatively high, results are seen on occasions throughout the upper estuary and the level of contamination is greater at the north end of the estuary with Ruan Creek also showing higher results than at Tresillian.

Table 15. Shellfish faecal coliform results from the SWD monitoring programme

Shellfish Water	Species	Collection date	Faecal coliforms /100ml[1]
Fal Estuary	*O. edulis*	06/05/2008	230
Fal Estuary	*O. edulis*	10/06/2008	230
Fal Estuary	*O. edulis*	07/07/2008	16000
Fal Estuary	*O. edulis*	03/11/2008	330
Fal Estuary	*O. edulis*	19/01/2009	1100
Fal Estuary	*Mytilus* spp.	16/03/2009	90
Fal Estuary	*Mytilus* spp.	06/04/2009	70
Fal Estuary	*O. edulis*	06/04/2009	330
Fal Estuary	*O. edulis*	14/07/2009	2200
Fal Estuary	*Mytilus* spp.	14/07/2009	330
Fal Estuary	*Mytilus* spp.	13/10/2009	270
Ruan Creek	*Mytilus* spp.	06/05/2008	460
Ruan Creek	*Mytilus* spp.	10/06/2008	230
Ruan Creek	*Mytilus* spp.	07/07/2008	22000
Ruan Creek	*Mytilus* spp.	06/10/2008	13000
Ruan Creek	*Mytilus* spp.	19/01/2009	17000
Ruan Creek	*Mytilus* spp.	03/06/2009	2400
Ruan Creek	*Mytilus* spp.	14/07/2009	5400
Ruan Creek	*Mytilus* spp.	13/10/2009	1300
Tresillian	*Mytilus* spp.	06/05/2008	490
Tresillian	*Mytilus* spp.	10/06/2008	2100
Tresillian	*Mytilus* spp.	07/07/2008	92000
Tresillian	*Mytilus* spp.	06/10/2008	2200
Tresillian	*Mytilus* spp.	19/01/2009	28000
Tresillian	*Mytilus* spp.	05/05/2009	2400
Tresillian	*Mytilus* spp.	14/07/2009	5400
Tresillian	*Mytilus* spp.	13/10/2009	460

[1]of flesh and intervalvular fluid

Produced by Cefas Weymouth Laboratory. Ordnance Survey licence number [GD100035675]

Figure 55. Monitoring points for Faecal coliform water and flesh under the Shellfish Waters Directive in the Upper Fal Estuary.

2.6.3 Microbiological data from the bathing waters monitoring programme

There are no Bathing waters in the Area of the Upper Fal. The nearest bathing waters are Gyllyngvase, Swanpool and Maen Porth in Falmouth Bay outside of the lower estuary. These sites have reflected ‘Excellent’ surface water quality from monitoring undertaken in the bathing season (with the exception of total coliform levels in July at Swanpool) from 2000 to 2007[1]. In the main concentrations of microbiological indicators obtained in the bathing season over the period for the three areas show that on rare occasions the levels of microbiological indicators do rise above the 100 CFU 100 ml^{-1} but that for the vast majority of the time the levels are well below this threshold. (Table 16). These results highlight the low likelihood of significant contamination inputs to the lower Fal estuary from seaward.

[1]Excellent: 80% compliant with the Bathing Waters Directive faecal coliform guideline standard of =/< 100 per 100ml and 90% compliant with a UK Faecal streptococci standard of =/< 100 per 100ml.

Table 16. Variation of concentrations (CFU 100ml^{-1}) and statisitics for bacteriological indicators in seawater from the three sampling sites (Gyllyngvase, Swanpool and Maen Porth) located in the Fal area for 2007.

Gyllyngvase	Total Coliforms			Faecal Coliforms			Faecal Streptococci		
Month	Min-Max	Median	Geometric mean	Min-Max	Median	Geometric mean	Min-Max	Median	Geometric mean
May	10 - 18	10	11.6	2-8	3	3.4	2-8	4	3.7
June	10	10	10	2	2	2	2	2	2
July	10 - 18	10	11.3	2-10	2	3.2	2	2	2
August	10	10	10	2-4	2	2.3	2	2	2
September	10	10	10	2	2	2	2-6	4	3.5

Swanpool	Total Coliforms			Faecal Coliforms			Faecal Streptococci		
Month	Min-Max	Median	Geometric mean	Min-Max	Median	Geometric mean	Min-Max	Median	Geometric mean
May	10-72	10	16.4	2-13	4	4.5	2-21	4	4.7
June	10 - 18	10	11.6	4-41	9.5	10.6	2	2	2
July	10-1364	151	133.7	4-840	54	59.9	2-112	25	17.4
August	10-727	10	26.5	2-538	4	12.3	2-150	2	6.3
September	18-340	179	78.2	6-78	42	21.6	2-15	8.5	5.5

Maen Porth	Total Coliforms			Faecal Coliforms			Faecal Streptococci		
Month	Min-Max	Median	Geometric mean	Min-Max	Median	Geometric mean	Min-Max	Median	Geometric mean
May	10-27	10	12.8	2-27	4	5.1	2-15	5	4.7
June	10-630	83.5	76.7	8-126	22.5	26	2-102	8	10.5
July	9-126	54	43.9	2-64	13	14.1	2-25	15	7.4
August	10-210	10	23.8	2-62	4	6	2-15	6	5.3
September	10-36	23	19	6-25	15.5	12.2	4-11	7.5	6.6

Note: these bathing waters are located in Falmouth Bay, outside of the estuary. The bathing season runs from the 15 May to 30 September.

2.6.4 Microbiological data from other bacteriological surveys

Of relevance to the upper Fal are the potential effects of agricultural runoff such as slurry, and associated bacterial loadings into catchments and ultimately into the Fal estuary; as such is considered to have a significant impact on water quality. One of the key indicators of possible impact from diffuse bacterial pollution in estuaries is the potential downgrading of shellfish harvesting areas, classified by the quantity of bacteria present in 100 g of shellfish flesh.

Monitoring data from 1993 has shown that the microbiological quality of the shellfish in the upper Fal Estuary has improved from the 1990s when harvesting of shellfish was prohibited in areas at the head of the estuary due to the extent of the microbiological contamination. However, areas in the Upper Estuary are still classified C and the mussel farming area, originally class B, has declined to a seasonal B/C. This declining quality has apparently coincided with a period of significant improvement in quality of point source discharges, including wastewater outfalls, by the local water company, South West Water (SWW). SWW have reduced the number of individual discharges along the Fal Estuary by establishing a more centralised sewerage network with principal discharges from Truro (Newham) WwTW and Falmouth WwTW (Black Rock), both of which have higher levels of treatment. Several small discharges still remain notably up the Tresillian River and Fal River.

The area around King Harry Ferry, in the Fal Estuary, midway between the City of Truro and the town of Falmouth was studied by Marsh (2007). Marsh (2007) looked at three principal sources of slurry release into the environment from one farm location.The land surrounding this study site has a high dairy farm usage typical of many southwest areas, along with other mixed use including maize, daffodils and vegetables such as cauliflower and root crops. In terms of the estuarine environment the region is very important for shellfish, both mussel and oyster, with several large mussel farms operating in the area (see Figures 5 and 6).

Figure 56 shows that four very high *E. coli* events took place prior to rainfall data being available in July 2004, October 2004 and January 2005 (two events) indicating that high *E. coli* events can occur during both summer and winter periods. This was followed by a prolonged period of lower counts. The next increases were several months later in winter months, December 2005 (two events) and February 2006; the high December counts occurred during and after a particularly prolonged period of heavy rainfall based on the local rainfall data. By comparison in February 2006, at least locally, there was very little rainfall with 2–3 weeks of dry weather preceding the high count; obviously rainfall could have been localised with heavier rain falling in a different part of the catchment. The data then shows two summertime highs in May 2006 and August 2006 both during or after rainy periods, but not particularly heavy or prolonged rain; given that prior to these the rainfall data shows extended periods when there was very little or no rainfall during this summer period it is possible that the ground was relatively dry and runoff was more rapid.

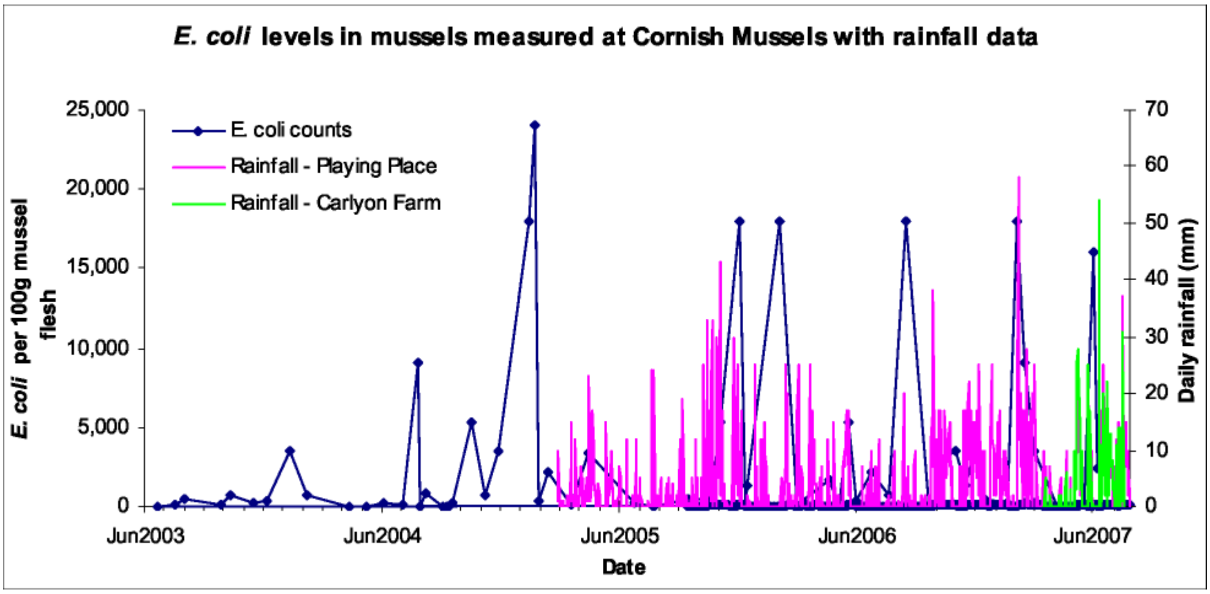

Figure 56 – **E. coli** ***levels per 100g in mussel shellfish flesh with rainfall data.***

Measured at Cornish Mussels site in King Harry ferry from summer 2003–2007 plus rainfall data measuredat Playing Place & Carlyon Farm 2005–2007.

(figure taken from Marsh, 2007).

The last significant *E. coli* events occurred in February/March 2007 (two events) just before the start of this study and in early June 2007 during this study. The rainfall in February and March was particularly high however the rainfall preceding the high *E. coli* event in June was not particularly significant and occurred 7– 14 days prior. There was a spill reported at SWW Newham WwTW facility one day prior to this high count which may explain the increased faecal pollution, however based on the source typing data no sizeable increase in human bacteria was identified in the water samples collected at the Cornish Mussel site 1–2 days after the incident.

Overall the *E. coli* data of Marsh (2007) indicate that high counts have occurred at any time during the year and such events are not confined to winter heavy or prolonged rainfall periods, although heavy or prolonged rainfall seems to have preceded several of the high counts. Obviously without a more comprehensive analysis of rainfall data for the entire catchment it is possible that localised rainfall particularly in the upper Fal River catchment around Goss Moor could have created increases in agricultural runoff that did not show in local rainfall data. Equally there could have been pollution incidents, for example spillage from a sewage works, that created some of the events and therefore do not correlate with local rainfall data. It is also important to note that counts remained low, within A or B classification, during short high rainfall and prolonged wet periods. To reinforce this fact, if *E. coli* counts are plotted against total rainfall for either the preceding 7 days or 14 days prior to the bacteria sample being collected by FTPHA, there is no correlation at all, with high rainfall periods coinciding with low *E. coli* counts and vice versa. However, up to counts of 10,000 *E. coli* per 100 g of mussel flesh there is some degree of relationship between high *E. coli* and high rainfall, but as emphasised in ICREW (2006) unravelling the possible point and/or diffuse sources of faecal pollution in such a complex environment is difficult with a single sample point. There is a suggestion of the possibility of re-suspension of viable faecal bacteria during certain hydrological conditions (J Marsh pers. comm.).

2.6.5 EA investigation at Trelissick Pontoon, River Fal - 2009

The EA undertook a study between January and April 2009 to investigate the contamination detected in the shellfish hygiene monitoring at the mussel lines in the Upper Fal. An autosampler at Trelissick Pontoon was used to collect 6 water samples at hourly intervals prior to collection of a single sample of mussels. This sampling procedure was repeated on a total of 37 occasions. Water and flesh samples were analysed for *E. coli* and faecal coliforms. Salinity, temperature and turbidity data were collected at hourly intervals using a datasonde, although data were not available for the entire period of the study.

A broader study was also carried out in the Fal Estuary by the EA during 2008/9. In this study, water samples were taken at monthly intervals at a number of stations (see Figure 63) and analysed for faecal coliforms.

The EA provided Cefas with both the raw data and a draft report on both elements of work. The results presented below represent analyses undertaken by Cefas using the raw data.

2.6.5.1 Results

Time series of *E. coli* in mussels and water are shown below (Figure 57).

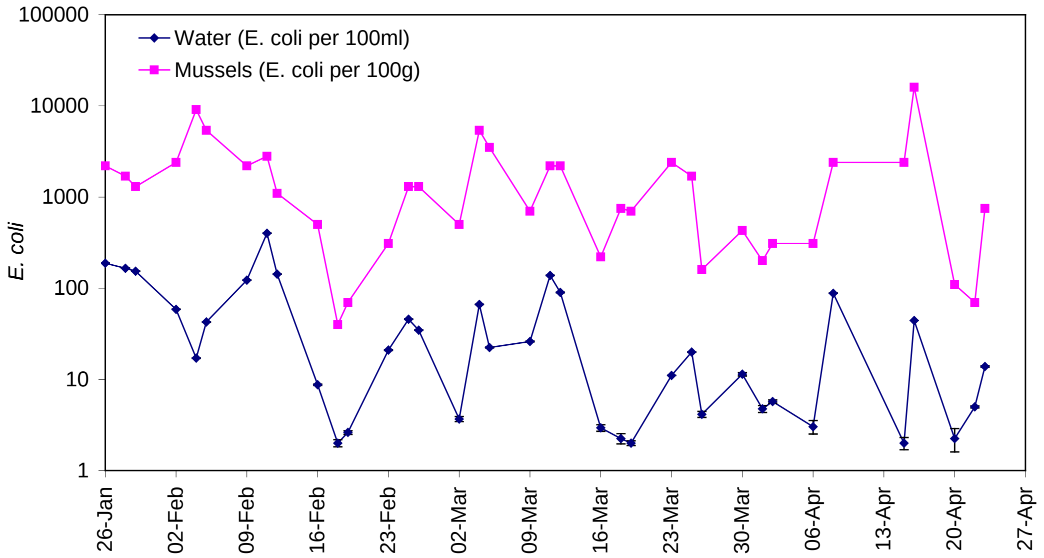

Figure 57. Time series of* E. coli *in water (geometric mean) and shellfish flesh

Summary bacteriological data for the entire study period are presented in Table 17.

Table 17: Summary of* E. coli *and faecal coliform data

	Water (per 100ml)		Mussel flesh (per 100g)	
	E. coli	Faecal coliforms	*E. coli*	Faecal coliforms
Number of samples	221	221	37	37
Geometric mean	18	20	910	1,300
Minimum	1	1	40	80
Maximum	728	1,040	16,000	16,000

The accumulation ratio (based on geometric means in Table 18) was 51 for *E. coli* and 65 for faecal coliforms.

Geometric means of the *E. coli* results in water samples taken over the six hours prior shellfish samples were positively correlated with *E. coli* levels in mussel flesh (Figure 58). This was statistically significant at P <0.001 level (n = 37, r = 0.65).

Geometric means of the FC results in water samples taken over the six hours prior shellfish samples were positively correlated with faecal coliform levels in mussel flesh, although the relationship was weaker than that for *E. coli* (Figure 59). The relationship was statistically significant at p<0.05 (n = 37, r = 0.33).

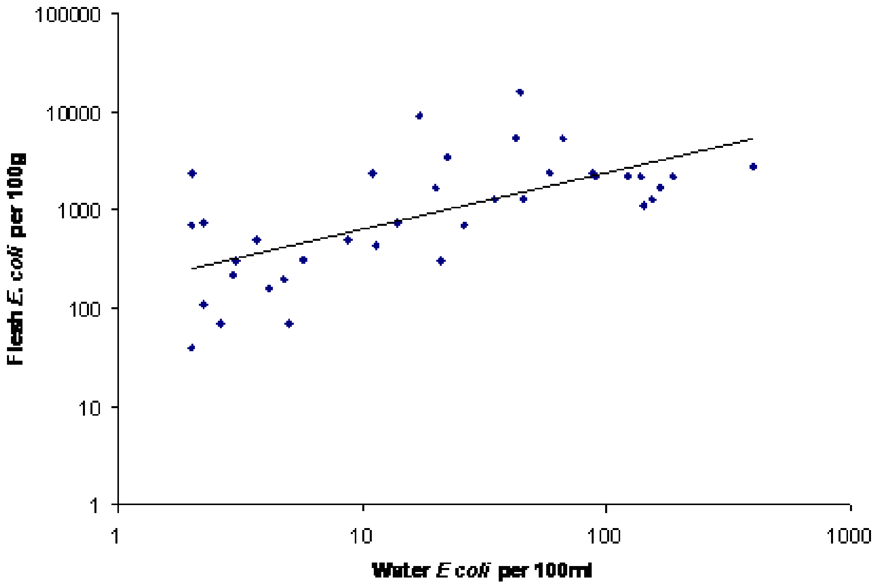

Figure 58. Relationship between* E. coli *in shellfish flesh and in water (geometric mean)

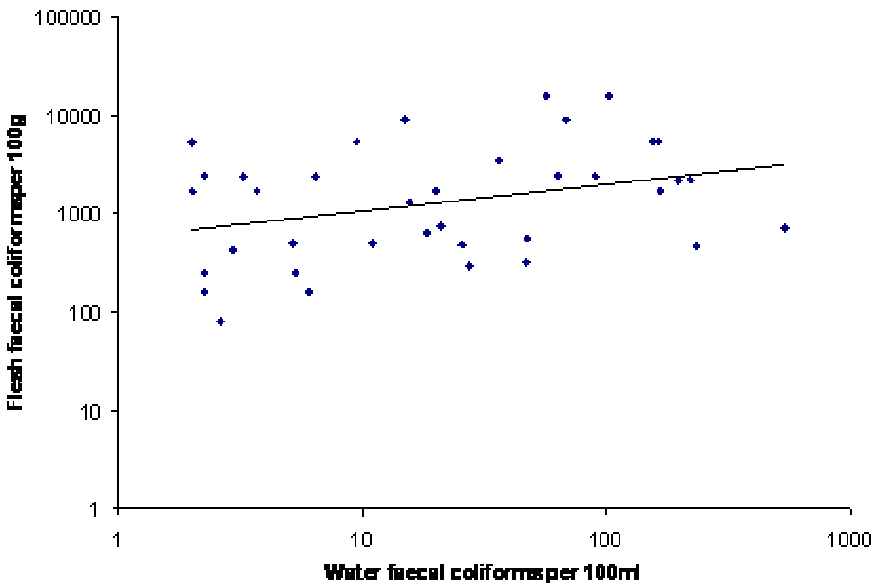

Figure 59. Relationship between faecal coliforms in shellfish flesh and in water (geometric mean)

Rainfall and river flow for the study period are illustrated in Figures 60 and 61 respectively.

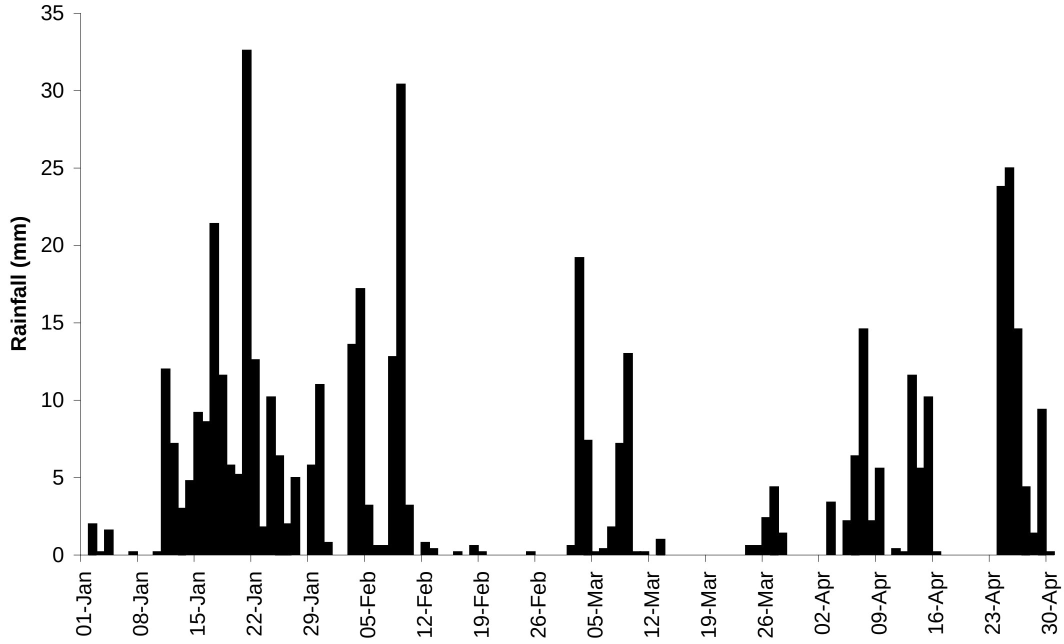

Figure 60. Daily rainfall totals at Penryn during study period.

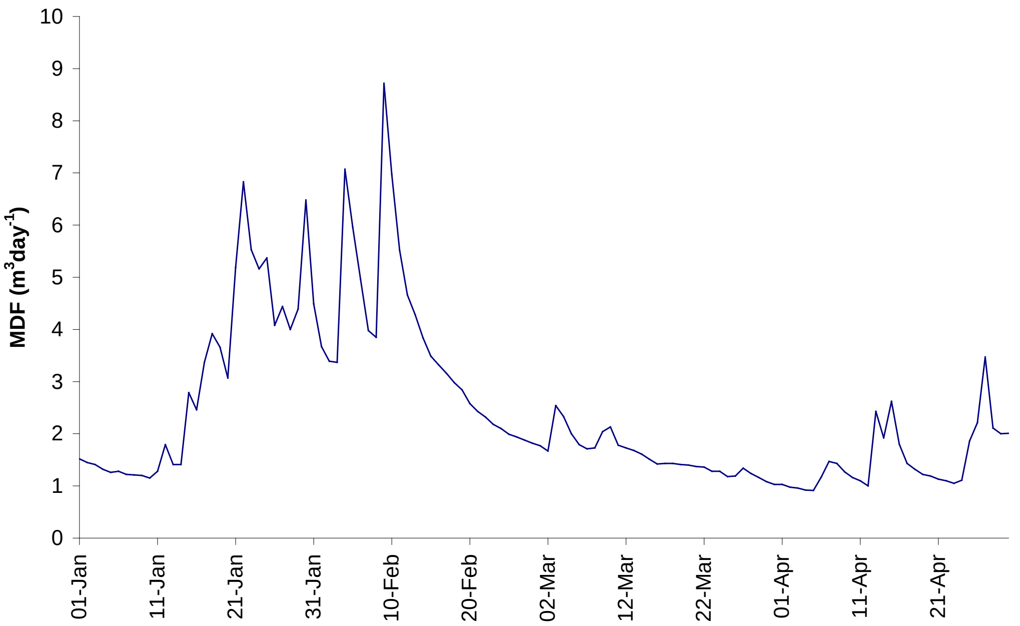

Figure 61. Mean daily flow in River Fal at Tregony during study period

E. coli levels in water (geometric mean of 6 samples) and shellfish flesh were positively correlated with total rainfall in both the 24 and 48 hours prior to sampling (Table 18).

E. coli levels in water (geometric mean of 6 samples) and shellfish flesh were positively correlated with mean daily flow in the River Fal at Tregony on the day of sampling and the day prior to sampling (Table 19).

Table 18. Results of Spearman's Rank correlation between antecedent rainfall and* E. coli *concentrations in water (geometric mean) and shellfish

	Total rainfall in 24 hours prior to sampling*		Total rainfall in 48 hours prior to sampling*	
	r_s	p	r_s	
E. coli (water)	0.38	<0.05	0.43	<0.05
E. coli (flesh)	0.56	<0.01	0.66	<0.01

* To 09:00 on day of sampling

Table 19. Results of Pearson's correlation between mean daily flow in Fal at Tregony and* E. coli *concentrations* in water (geometric mean) and shellfish.

	Flow on day of sampling		Flow on day prior to sampling	
	r	p	r	p
E. coli (water)	0.547	<0.001	0.631	<0.001
E. coli (flesh)	0.425	<0.01	0.436	<0.01

*Flow and *E. coli* concentration log transformed

The relationship between salinity and *E. coli* levels in water is shown in Figure 61. There is clear evidence of a dilution effect.

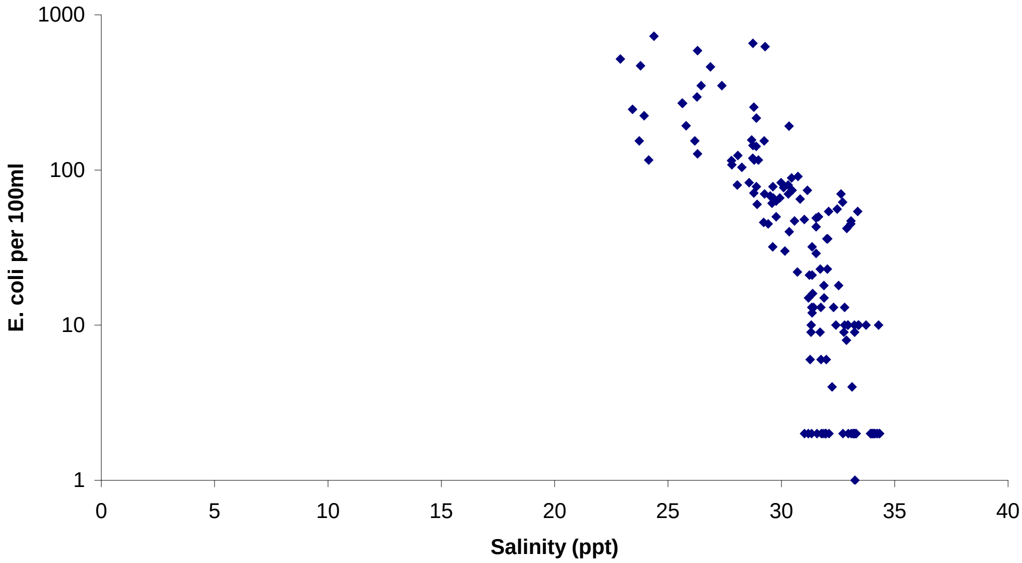

Figure 61. Relationship between salinity and* E. coli *levels in water.

The relationship between *E. coli* in water and time since high water (at Falmouth) is shown in Figure 62.

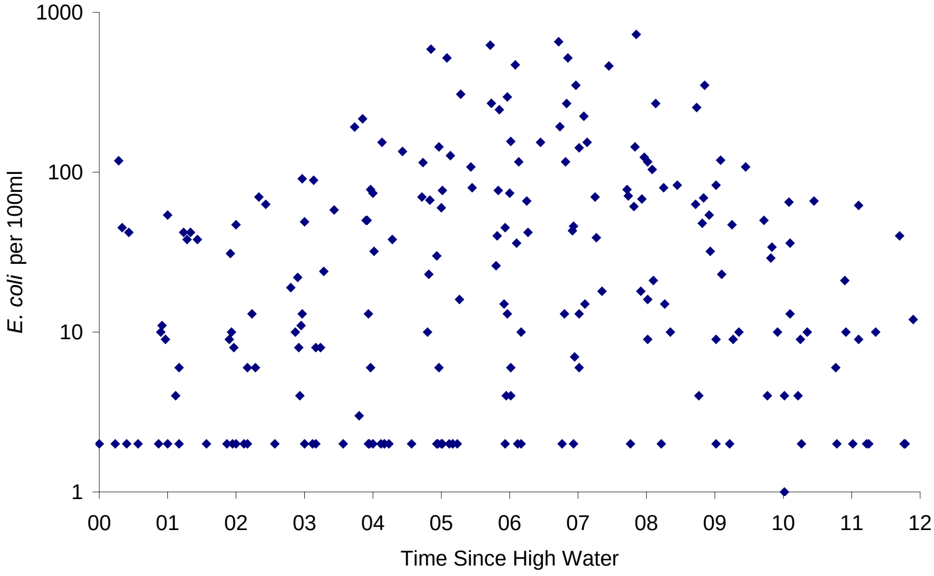

Figure 62. Relationship between* E. coli *levels in water and time since high water at Falmouth.

Peak results tended to be seen between approximately 5 and 8 hours after high water (i.e. around low water). However, low and mid-range results occurred at all states of tide and no significant difference was detected between *E. coli* levels in water for samples separated into those collected on ebb or flood tide (Mann Whitney test, $p>0.05$).

No significant difference was detected between *E. coli* levels in shellfish for samples separated into those collected where tide had been predominantly ebbing prior to sampling and those where tide had been predominantly flooding (Two sample t-test, $p>0.05$).

Table 20 shows a summary of results for the more extended EA survey of faecal coliforms in water that took place during 2008/9. Figure 63 shows the location of the sampling stations with the symbols graduated in size by the geometric mean faecal coliform results. In terms of the concentration of faecal coliforms, the most significant sources were the rivers Allen and Kenwyn. The geometric means of the four estuarine sampling stations show that the contamination within the estuary is generally greatest at the northern end and reduces towards the Carrick Roads. This does not preclude the presence of localised areas of higher contamination due to other sources.

Table 20: Summary of water faecal coliform data (no per 100 ml) for EA survey sites in Fal (2008/2009).

SITE NAME	Number of samples	Faecal coliforms per 100 ml Geometric mean	Minimum	Maximum
CALENICK STREAM AT CALENICK BRIDGE	9	430	99	1000
COWLANDS NORTH CREEK	9	2100	500	6300
COWLANDS SOUTH CREEK	8	440	117	1680
LAMOUTH CREEK	8	110	15	800
RIVER ALLEN AT MORESK LAUNDRY BRIDGE	10	3500	580	43000
RIVER FAL OFF BOAT HOUSE*	10	210	36	1090
RIVER FAL AT KING HARRY FERRY*	13	62	2	580
RIVER FAL AT SETT BRIDGE	8	1900	800	3300
RIVER FAL MID CHANNEL*	16	10	2	54
RIVER KENWYN AT KENWYN GAUGING STATION	10	2400	290	25000
RUAN RIVER AT RUAN BRIDGE	9	820	135	7300
TRESILLIAN RIVER D/S LADOCK STW	10	680	189	1600
TRESILLIAN RIVER OFF MALPAS PT*	9	320	108	1000

*Estuarine sampling stations

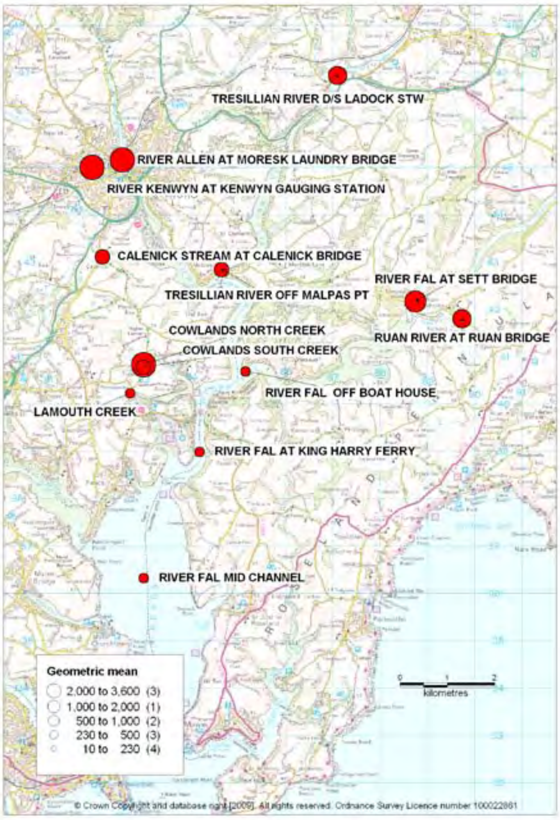

Figure 63. Geometric mean water faecal coliform data (no per 100 ml) for EA survey sites in Fal (2008/2009).
Symbols graduated by geometric mean

3 SHORELINE SURVEY

GENERAL

Date of survey	11th and 12th February 2009	
Production Area	Upper Fal Estuary	
Area(s) surveyed	see Figure 54	
Commercial Species	Wild (dredged)	Native oysters (*O. edulis*)
	Farmed	Mussels (*Mytilus sp.*)
Harvester(s)	<u>Farmed mussels</u> Steve Kestin Dave Hancock Gary Rawle Tim Edwards <u>Native oysters</u> Licensed oyster dredgermen	
Local Authority	Fal & Truro Port Health Authority (now Cornwall Port Health Authority)	

On the 11th and 12th of February 2009, staff from the Cefas Weymouth Laboratory and Fal & Truro Port Health Authority performed a shoreline survey in the Upper Fal 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 11th February was undertaken by foot and the survey on 12th February primarily by boat. Observations and results apply to the time of the survey. Observations relate to the location and field-of-view of the observer at the time they were made.

Cefas contacted some representatives of the shellfish industry prior to the shoreline survey being undertaken and attempted to contact others, without success. The purpose was to obtain local information on potentially important sources of faecal contamination. A proposal from the industry for an intensive spatial and temporal monitoring programme after the shoreline survey itself could not be followed up due to the lack of resource.

Tidal conditions

The survey took place between 10.24 and 16.27 on 11th February 2009 and between 08.38 and 10.22 on 12th February 2009. The tidal curve for the two days is shown in Figure 65.

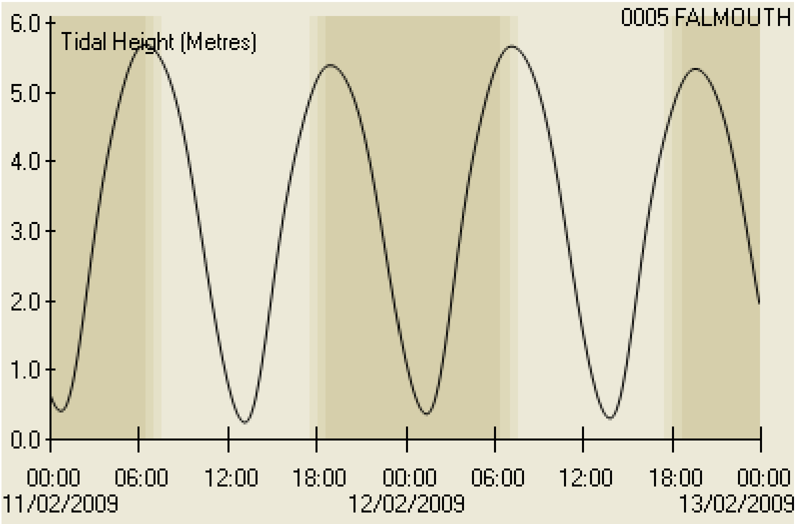

Figure 65. Tidal curve at Fal for the 11th and 12th February 2009.

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 and shown in Figure 66.

Weather

The weather was cloudy but dry with a very light breeze on 11th February and sunny with a very light breeze on the morning of 12th February.

Figure 66. Area surveyed (red lines).

3.2 RESULTS

Shellfish Farming Operations

There were three adjacent areas of mussel farming operations. Just south of Trelissick Pontoon was an area of buoyed mussel lines covering approximately 7000 square metres (Figure 80). There was a barge associated with these lines. South of this was a series of rafts covering approximately 4000 square metres (Figure 81). The density of drop lines from the rafts was greater than from the lines. Washing, debyssing and grading equipment was located on the rafts. Between the rafts and the western shore there was a single line of buoys with mussel lines (Figure 82).

During the shoreline survey on 11th February, an area of poches was observed on the foreshore near the lower end of the mussel rafts at approximately SW 8410 3900. These were assumed to contain oysters but this could not be verified as it was not possible to access the shore at this point (the observation was made from the footpath above the shore).

The location of the farmed shellfisheries are shown in Figure 67.

Figure 67. Shellfish farming operations in the Upper Fal estuary.

Sewage treatment Works/Sewage Discharges

Newham STW was noted at grid reference SW 83372 43249 (entrance to the works). Three seawater samples were taken in the estuary near the works on 24 March 2009, supplementary to the shoreline survey. These gave the following results:

Sample	Location	Coliforms /100ml	Faecal coliforms /100ml	Faecal streptococci /100 ml
1	At outfall 0.5m depth	70	30	<10
2	At outfall 1.5m depth	40	20	<10
3	40 m downstream along concrete dock wall	30	<10	<10

These samples showed that there was no appreciable contamination arising from the continuous outfall on that day.

The only two pipes that were sampled during the survey and which yielded relatively high *E. coli* results were seen at Coombe on Cowlands Creek (SW 83796 40841; Figure 66). A sample of the combined discharge gave a result of 620 *E. coli* per 100ml (equivalent to a loading, at the time of observation, of 1.8 x 10^{10} *E. coli* per day). It was not clear as to whether this contained an element of sewage or whether it was entirely land run-off.

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

Boats
A large number of boats were beached or moored in the adjacent creeks and also in the Truro River up to Malpas. A large number of empty buoys indicate that the number of moored boats would be significantly higher in summer months. Seven laid-up ships were seen in the river north of King Harry Ferry – these have skeleton crews (sometimes shared between adjacent ships)(see Figure 76).

Land use and animals
Both sides of the estuary in the vicinity of the mussel fisheries are steep sided and wooded. The eastern bank more so than the western bank in both respects. There are a number of farms on the western bank that have cattle or sheep. The National Trust estate at Trelissick is grazed by sheep (Figure 71). The farms and estate potentially drain into adjacent creeks and/or the estuary – the National Trust warden stated that its estate and farm complied with national guidelines to prevent contamination of watercourses. The National Trust estate and the foreshore in Channals Creek are used for dog-walking (Figure 70). Deer were seen on the hills on the Tregothnan estate on the eastern bank.

Other observations
Bags of oysters and cockles were noted leaning against the wall on the beach at Roundwood Point and a number of shells were scattered nearby.

Water samples
Sampling took place under dry weather conditions. Seven samples of stream/ piped flows and nine samples of seawater were taken. The sampling locations are shown in Figure 68 and the results given in Table 22.

The most significant fresh water input at the time of the survey was a large stream at SW 83080 40857, at the head of Cowlands Creek. The calculated loading at the time of observation was 1.1 x 10^{11} *E. coli* per day.

Seawater results were relatively high: 130 to 780 *E. coli* per 100ml. The two highest seawater results were taken at Malpas (580 *E. coli* per 100ml) and at the head of Cowlands Creek (780 *E. coli* per 100ml).

Salinity and temperature was recorded against depth using a calibrated meter with a 30 m cable. The results are shown in Table 23. These showed very little stratification but some increase in salinity from the top of the upper estuary, at Malpas, down towards Turnaware Bar.

Shellfish samples

Shellfish were sampled at the pontoon at Malpas (sample FS01), two places on the Trelissick Pontoon (samples FS02 and FS03), from the normal classification sampling point at the mussel rafts (sample FS04) and from Turnaware Pontoon (sample FS05). The sampling locations are shown on the map in Figure 69 and the results are given in Table 24.

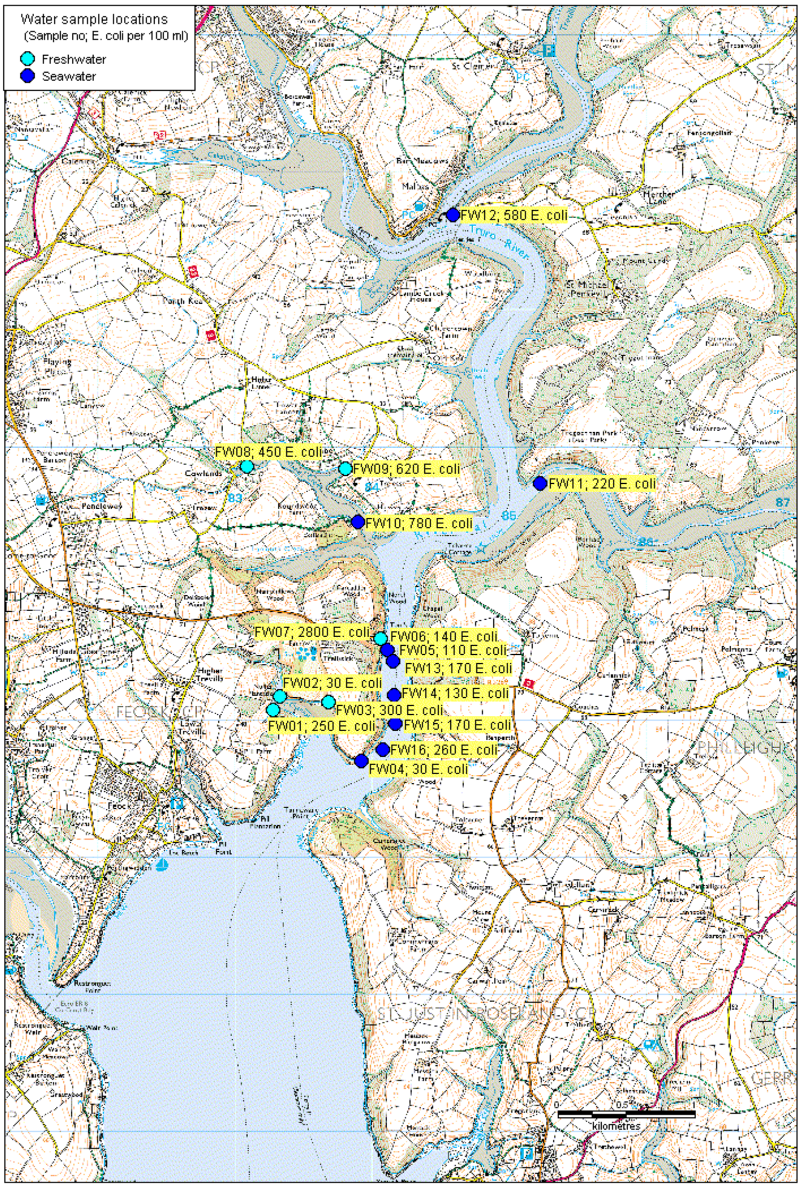

Figure 68. Water sampling locations.

Table 22. E. coli in samples of water collected at the time of the shoreline survey.

Sample no.		Sample type	Description	Flow m^3 day^{-1}	MPN *E. coli* 100 ml^{-1}	Loading *E. coli* day^{-1}
FW01	SW 83268 39078	Fresh	Stream overflowing dam from pond (Fig. 60)	3,640	250	9.1×10^{9}
FW02	SW 83318 39171	Fresh	Very small stream below farm	2,190	30	6.6×10^{8}
FW03	SW 83671 39133	Fresh	Flow from pond fed by pipe across beach (Fig. 61)	530	300	1.6×10^{9}
FW04	SW 83915 38703	Sea	Sub-surface	-	30	-
FW05	SW 84102 39513	Sea	Sub-surface	-	110	-
FW06	SW 84049 39592	Fresh	Stream flowing across slipway (Fig. 62) – not measurable	-	140	-
FW07	SW 84053 39592	Fresh	Seepage below dripping pipe, not measurable (Fig. 63)	-	2,800	-
FW08	SW 83080 40857	Fresh	Large stream combined from two smaller ones (Fig. 65)	25,200	450	1.1×10^{11}
FW09	SW 83796 40841	Fresh	Outflow from two pipes (Fig. 66)	2,840	620	1.8×10^{10}
FW10	SW 83887 40447	Sea	Sub-surface	-	780	-
FW11	SW 85219 40730	Sea	Sub-surface	-	220	-
FW12	SW 84578 42688	Sea	Sub-surface	-	580	-
FW13	SW 84146 39429	Sea	Sub-surface	-	170	-
FW14	SW 84150 39184	Sea	Sub-surface	-	130	-
FW15	SW 84164 38975	Sea	Sub-surface	-	170	-
FW16	SW 84066 38787	Sea	Sub-surface	-	260	-

Table 23. Salinity profiles measured at the time of the shoreline survey.

NGR	Depth (m)	Temperature ºC	Salinity (ppt)
SW 85219 40730	1	7.3	30.9
SW 84578 42688	1	7.1	25.5
,,	3	7.5	28.8
,,	5	7.2	26.2
SW 84146 39429	0	7.3	28.1
,,	1	7.5	29.8
,,	3	7.5	30.3
,,	5	7.7	31.0
SW 84150 39184	0	7.5	30.2
,,	1	7.6	30.2
,,	3	7.6	30.4
,,	5	7.6	30.7
SW 84164 38975	0	7.5	30.3
,,	1	7.6	30.3
,,	3	7.6	30.3
,,	5	7.7	30.7

Table 24. E. coli in samples of mussels collected at the time of the shoreline survey.

NGR	Sample no.	Depth	MPN E. coli 100 g^{-1}
SW 84578 42688	FS01	2m	2,200
SW 84150 39184	FS02	4m	2,800
SW 84098 39504	FS03	0.5m	3,100
SW 84102 39530	FS04	0.5m	2,200
SW 84066 38787	FS05	2m	3,500

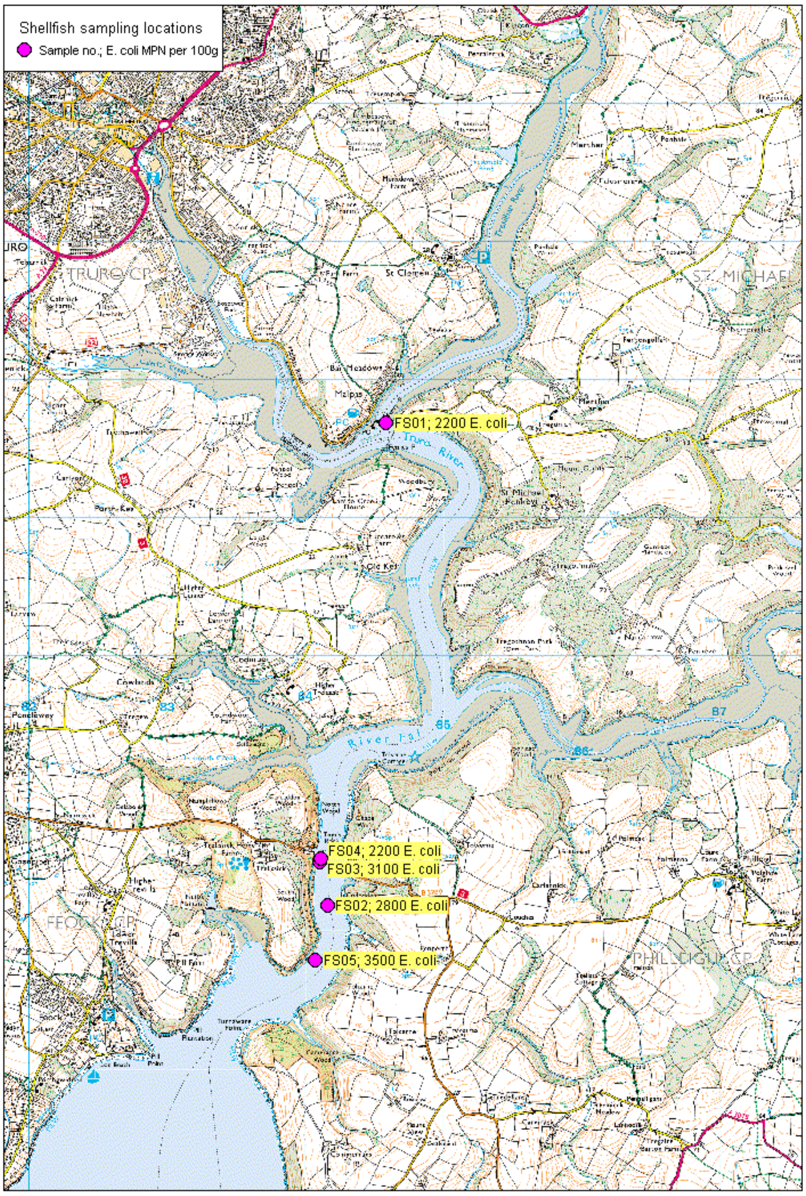

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Figure 69. Shellfish sampling locations.

Figure 70. Dogs on beach on shore of Channals Creek

Figure 71. Sheep on hill at Trelissick Estate

Figure 72. Pool behind wall at Channals Creek

Figure 73. Piped outlet at Trelissick Estate

Figure 74. Stream outlet at King Harry Ferry slipway

Figure 75. Dripping pipe at King Harry Ferry slipway

Figure 76. Laid up ships

Figure 77. Stream at upper end of Cowlands Creek

Figure 78. Pipes on Cowlands Creek at Coombe

Figure 79. Newham Sewage Treatment Works, Truro

Figure 80. Buoyed mussel lines

Figure 81. Mussel rafts

Figure 82. Single line of mussel buoys

4 OVERALL ASSESSMENT OF POLLUTION SOURCES ON THE MICROBIOLOGICAL CONTAMINATION OF BIVALVE MOLLUSC PRODUCTION AREAS

4.1 Qualitative assessment

4.1.1 The Upper Fal Estuary is located in a rural catchment but encompasses the town of Truro; the surrounding countryside is mostly used for agricultural purposes. Most of the catchment has a dispersed human settlement pattern of small villages, but with a significant seasonal influx of tourists. The information analysed for producing this report indicates that, in general, the main contributions of pollution likely to be a source of microbiological contamination for BMPAs come from continuous discharges from Newham STW and non point sources associated with agricultural land use, notably areas used for livestock production, and tourism (boating) activities.

4.1.2 The main fisheries in the Upper Fal are the mussel farming operations at King Harry Reach and native oyster dredging as far up as Maggoty Bank. Some commercial gathering of wild mussels and native oysters occurs elsewhere in the upper estuary but not above Malpas.

4.1.3 Principal microbiological parameters in water were high in the upper Fal Estuary (Truro/Tresillian area) and in the vicinity of known sewage discharges/outfalls. Values for faecal coliforms (and faecal streptococci) are sometimes elevated at locations within the upper Fal. Animal derived slurry in run-off or spillages from water side fields and farms may provide an additional source of coliforms.

4.1.4 Values for faecal coliforms in the upper Fal (MBA, 2003) likely to be from diffuse agricultural or sewage waters indicate a historic and possibly intermittent issue in Truro, Tresillian and lower Carrick Roads areas. The combination of the EC Shellfish Hygiene (91/492/EEC), Bathing Water (76/160/EEC) and Water Framework Directives (2000/60/EC) have been a significant driver for improvements to STWs and sewerage facilities in the Upper Fal. SWW have invested and made improvements (through the addition of UV disinfection) to current processes that have resulted in further improved water quality in these areas.

The water quality in the upper Fal Estuary has improved gradually over the past 10 years with the shellfish water category moving to a B (medium quality requiring depuration prior to sale). This improvement in shellfishery quality has coincided with a period of significant improvement in quality of point source discharges, including wastewater outfalls, by the local water company. SWW has reduced the number of individual discharges along the Fal Estuary by establishing a more centralised sewerage network with principal discharges from Truro (Newham) WwTW and Falmouth WwTW (Black Rock), both of which have higher levels of treatment. Several small discharges still remain notably up the Tresillian River and Fal River.

In terms of *E. coli* in shellfish, based on historical data from a range of sites throughout the Fal Estuary, the highest levels tend to have occurred in the Upper Fal Estuary areas around Malpas, Tresillian and Truro suggesting local sources of contamination in this area. The data show significant correlations with the amount of rainfall in the period prior to sampling.

Significant localised contamination was seen at the time of the shoreline survey in freshwater inputs to Cowlands Creek and in seawater at the head of the creek.

4.1.5 The geometric means of *E. coli* from the shellfish microbiological monitoring programme in the Fal show generally higher levels in mussels relative to those in native oysters.

4.1.6 Data from bacteriological surveys performed in the upper Fal catchment area indicate that the main bacterial inputs affecting the bivalves is from sources in the upper Truro River.

The upper estuary significantly drains on the ebb tide and this will have the effect of transporting contamination from the Truro and Tresillian Rivers down the estuary.

A summary of microbiological sources, pathways and potential significance to shellfisheries is given in Table 25.

4.2 Recommendations

- The RMPs above Malpas should be discontinued due to the combination of a lack of commercial fishing and difficulty of access. The extent of the classified area should be amended accordingly. The previous RMP at Malpas should be re-instated in light of minor commercial interest in this area – this would then serve as the northernmost RMP.

- The *O. edulis* RMPs at Maggoty Bank, Tolverne and Coombe Creek should be maintained to cover the native oyster fishery here. Monitoring at Grimes Bar should not be undertaken unless commercial interest in the area resumes. The classified area should therefore be reduced at the northern end to exclude this bed. Due to the sewage inputs to Cowlands Creek, the classified area should be redefined to exclude the upper part of this inlet.

  A review of the *O. edulis* RMPs at Pill Creek and Turnaware Bar, and the associated classified area, will be included in a sanitary survey being undertaken of the Lower Fal estuary, including Carrick Roads.

- Given the likely sources of contamination within the upper estuary, both remote and localised, the RMP at King Harry Reach should be moved to the northern end of the upper set of mussel lines. The current RMP for mussels at T Pontoon/South Wood should be discontinued as there is no current commercial activity in this area. The lower limit of the classified area should then be moved closer to the current location of the mussel farms.

- As sampling is undertaken from bags, and thus variability in density/availability of commercial stock is not an issue, a maximum tolerance of 10 metres should be specified around each RMP.

- Given that limited stratification was seen in the salinity profiles taken at the time of the shoreline survey, and that rainfall-associated contamination events are deemed to be a source of additional faecal pollution, bags placed for the purposes of sampling should be located between one and three metres below the surface.

- Further investigations should be undertaken of the potential commercial gathering of cockles in the Upper Fal and the poches seen at South Wood. The sampling plan should be reviewed to take account of these activities if classification is needed.

- Further improvements to the CSOs in the upper estuary should be supported as these would be likely to reduce the contamination of the shellfisheries from this source.

- Field level data on the monthly application of biosolids would assist future re-assessment of the sanitary survey for the area.

Table 25 Summary S-P-R table listing the potential major sources, their potential pathways to a known receptor in this case the shell fisheries.

Source	*Pathway*	*Significance to Receptor*
Diffuse agricultural run off during rainfall and storm events	Surface water wash off, horizontal movement of microbes associated with soil particles	Potentially significant pathway but management practices improving constantly
Diffuse agricultural run off during accidental spillages	Surface water wash off, horizontal movement of microbes associated with silage and other agricultural sources	Potentially significant pathway but management practices improving constantly
Sewage discharges from poorly treated waste or storm water overspill	Direct entry from diffuse sewages, overspill from main sewers	Potentially significant during storm water surges or accidents, largely improving
Seasonal increase due to recreating sailing/ boating activity	Direct entry from sailing vessels	Seasonal influence highest inputs during summer months
Retention of microbial contamination in upper estuary redistribution caused by tidal activity	Retention in upper Fal system as a consequence of prevailing tidal circulatory conditions	Not likely to result in significant changes in water quality
Animal and birds populations	Grazing animals linked to diffuse source highlighted above, birds seasonal influence	Linked to diffuse sources entering upper estuary currently limited information other than as in diffuse entry point (see above)

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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.
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 rainfall did not exceed 0.25 mm on any one day (excludes public or local holidays). With a significant industrial input the dry weather flow is based on the flows during five working days if production is limited to that period.
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 set in European Directives that the Member States have to

values	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, Cefas, EA, Marine Fisheries Agency, plus the relevant accredited shellfish testing laboratory, water company, harbour authority(ies), local shellfish industry and 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 (STWs)	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".

LIST OF ABBREVIATIONS

AOD	Above Ordnance Datum
AONB	Area of Outstanding Natural Beauty
ANOVA	Analysis of Variance
amsl	Above mean sea level
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 Outfall
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
MHW	Mean High Water
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

APPENDIX

EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SAMPLING PLAN

Upper Fal Estuary – Cornwall

2009

P1 General Information

Location Reference

Production Area	Upper Fal Estuary
Cefas Main Site Reference	M033
Cefas Area Reference	FDR 2756
Ordnance survey 1:25000 map **Admiralty chart**	Explorer TM 103 No 147

Shellfishery

Species/culture	*Mytilus* spp. *Ostrea edulis*	wild & rafts & buoys wild
Seasonality of harvest	*Mytilus* spp. - not applicable *O. edulis* – October to March inclusive	

Local Food Authority

Cornwall Port Health Authority	The Docks, Fal, Cornwall, TR11 4NR	
E-mail	fal@cieh.org.uk	
Sampling Officer ☎	Terry Stanley	01326 211581

P2 MONITORING POINTS AND FREQUENCY OF SAMPLING

See maps and Table below.

P3 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 bivalve mollusc production areas.

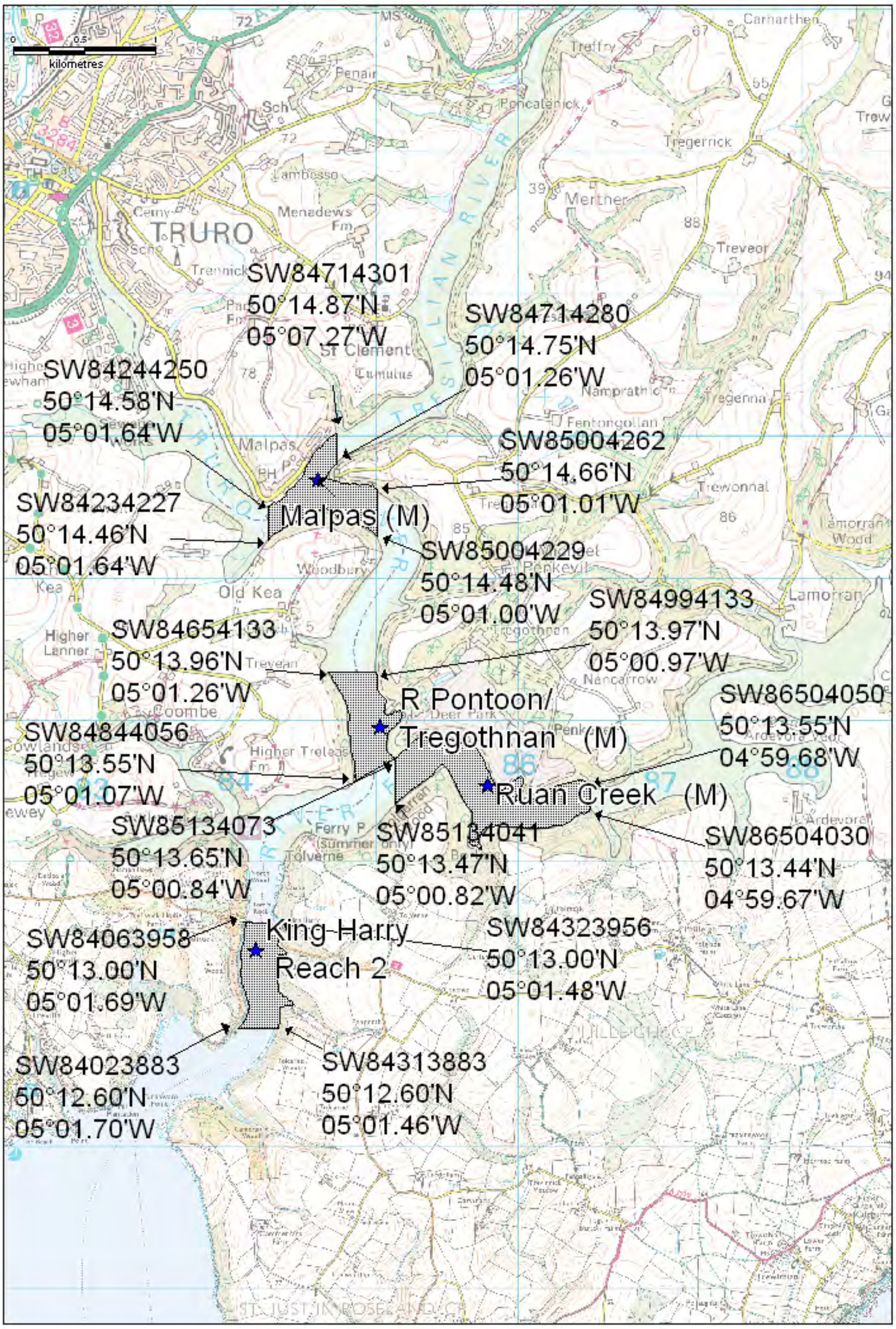

Figure A1. Location of representative monitoring points (RMPs) and production area boundaries for mussels (*Mytilus spp.*) in the Upper Fal Estuary.

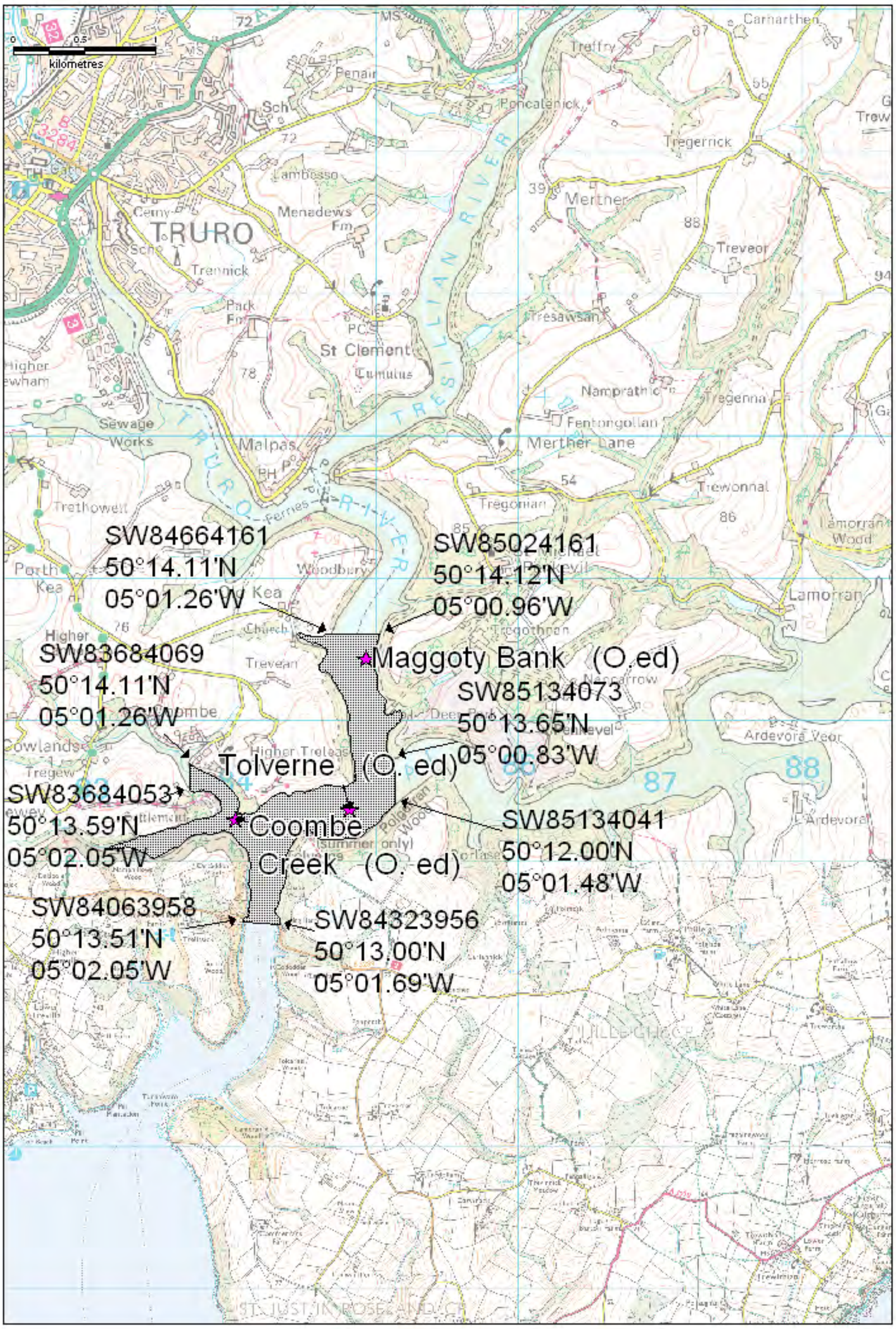

Figure A2. Location of representative monitoring points (RMPs) and production area boundaries for native oysters (*O. edulis*) in the Upper Fal Estuary.

Table A1. Location of Representative Monitoring Points (RMPs) in the Fal

Bed ID	Bed Name	Species	NGR	Tolerance (metres)	Depth (metres)	Sample frequency
B033F	Maggoty Bank (O.ed)	OYF	SW84924143	10	N/A*	Monthly
B033H	Tolverne (O. ed)	OYF	SW84804037	10	N/A	Monthly
B033V	Coombe Creek (O. ed)	OYF	SW84004030	10	N/A	Monthly
B033Y	R Pontoon/Tregothnan (M)	MUS	SW85024095	10	1-3	Monthly
B33AL	Ruan Creek (M)	MUS	SW85784054	10	1-3	Monthly
TBA	King Harry Reach 2 (M)	MUS	SW84143938	10	1-3	Monthly