EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Fal Estuary (lower) and Percuil River

(Cornwall)

2010

(amended 2012)

Cover photo: East Bank.

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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 lower 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 STATUS: Food Standards Agency, Falmouth & Truro Port Health Authority, Cornwall Sea Fisheries Committee, Environment Agency.

RECOMMENDED BIBLIOGRAPHIC REFERENCE: Cefas, 2012. Sanitary Survey of the lower Fal Estuary and Percuil River (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

1 INTRODUCTION

1.1 LEGISLATIVE REQUIREMENT

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

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

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

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

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

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

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

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

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

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

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

In addition to better targeting the location of RMPs and frequency of sampling for microbiological monitoring, it is believed that the sanitary survey may serve to help to target future water quality improvements and better analyse their effects on BMPAs. Improved monitoring should lead to improved detection of pollution events and identification of the likely sources of pollution. Remedial action may then be possible either through funding of improvements in point sources of contamination or as a result of changes in land management practices.

This report documents information relevant to undertake a sanitary survey for a new production area for queen scallops (*A. opercularis*), existing production areas for mussels (*Mytilus* spp.) and native oysters (*O. edulis*) in the lower Fal Estuary (Cornwall), and historic production areas in Percuil River.

A draft report was issued for consultation in 2010. In light of new information subsequently received on fisheries and changes in harvesting, this final report is dated 2012.

1.2 SITE DESCRIPTION

FAL ESTUARY (LOWER)

The Fal Estuary, national grid reference (NGR) SW825342, is situated in south Cornwall, southwest coast of England. The estuary is sheltered, branched with many large and small tributaries and has a long shoreline (Table 1.1). It is a type 3b Ria without spits (Halcrow Group Ltd., 2002).

Table 1.1 Main characteristics of the Fal Estuary.

Geomorphological type	3b drowned river valley or ria
Shoreline length (km)	127
Core area (ha)	2,482
Intertidal area (ha)	746

Data from the Estuary Guide (ABPmer and Wallingford 2009)

The estuary narrows significantly towards its upper reaches. The bivalve mollusc production areas (BMPAs) assessed for the purposes of this sanitary survey are situated in Carrick Roads, a deep sub-tidal area which extends from Turnaware Point towards the mouth of the estuary at Falmouth (Figure 1.1).

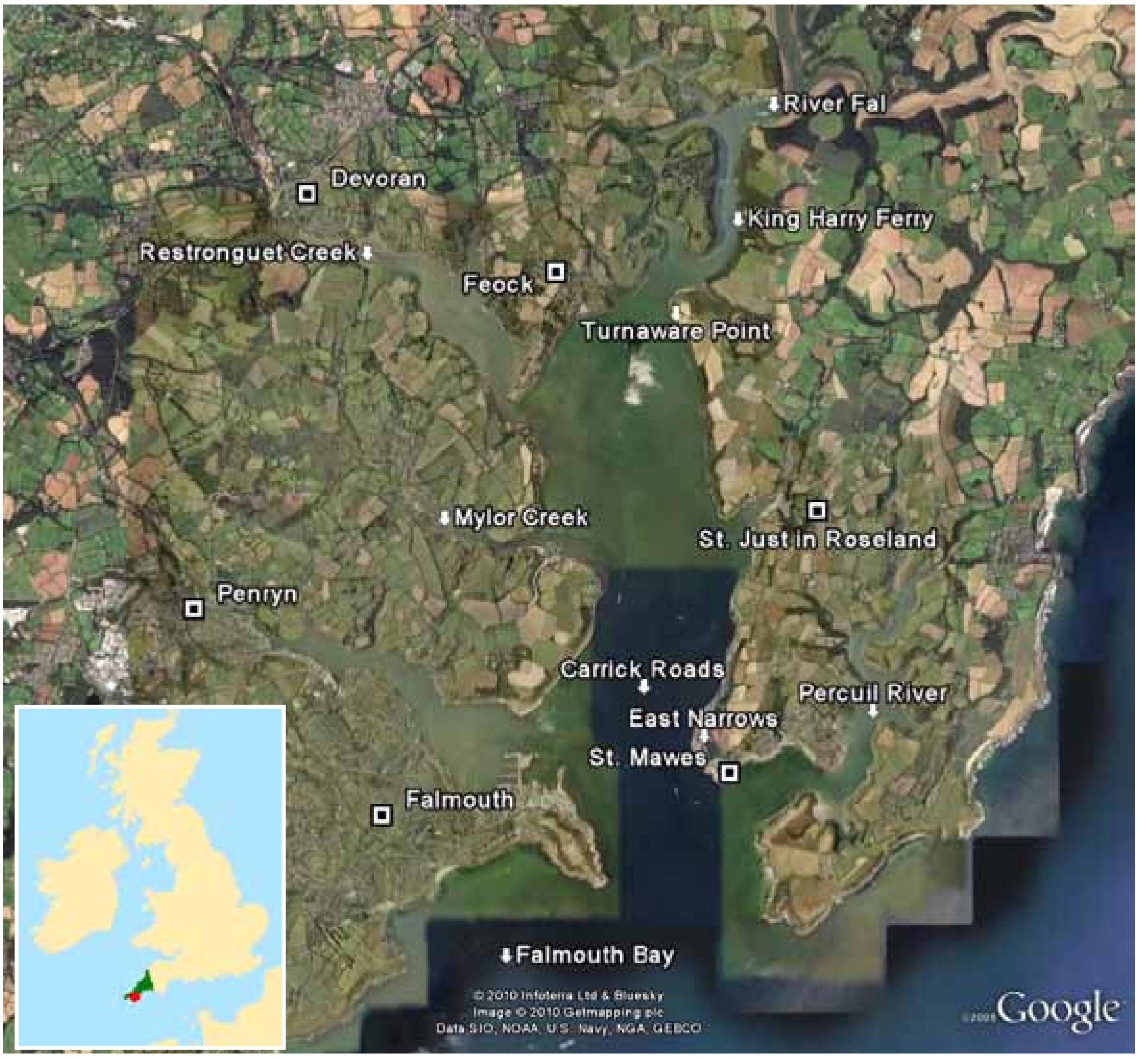


Figure 1.1 Aerial view of the Fal Estuary.
Reproduced under licence Google Earth™ mapping service.

Substrates in the lower Fal include rocky intertidal areas (Figure 1.2A), rockpools, gravel, intertidal sediments, subtidal rocks and sediments, fine and sandy muds (Figure 1.2B) and maerl debris (Potts and Swaby, 1993).

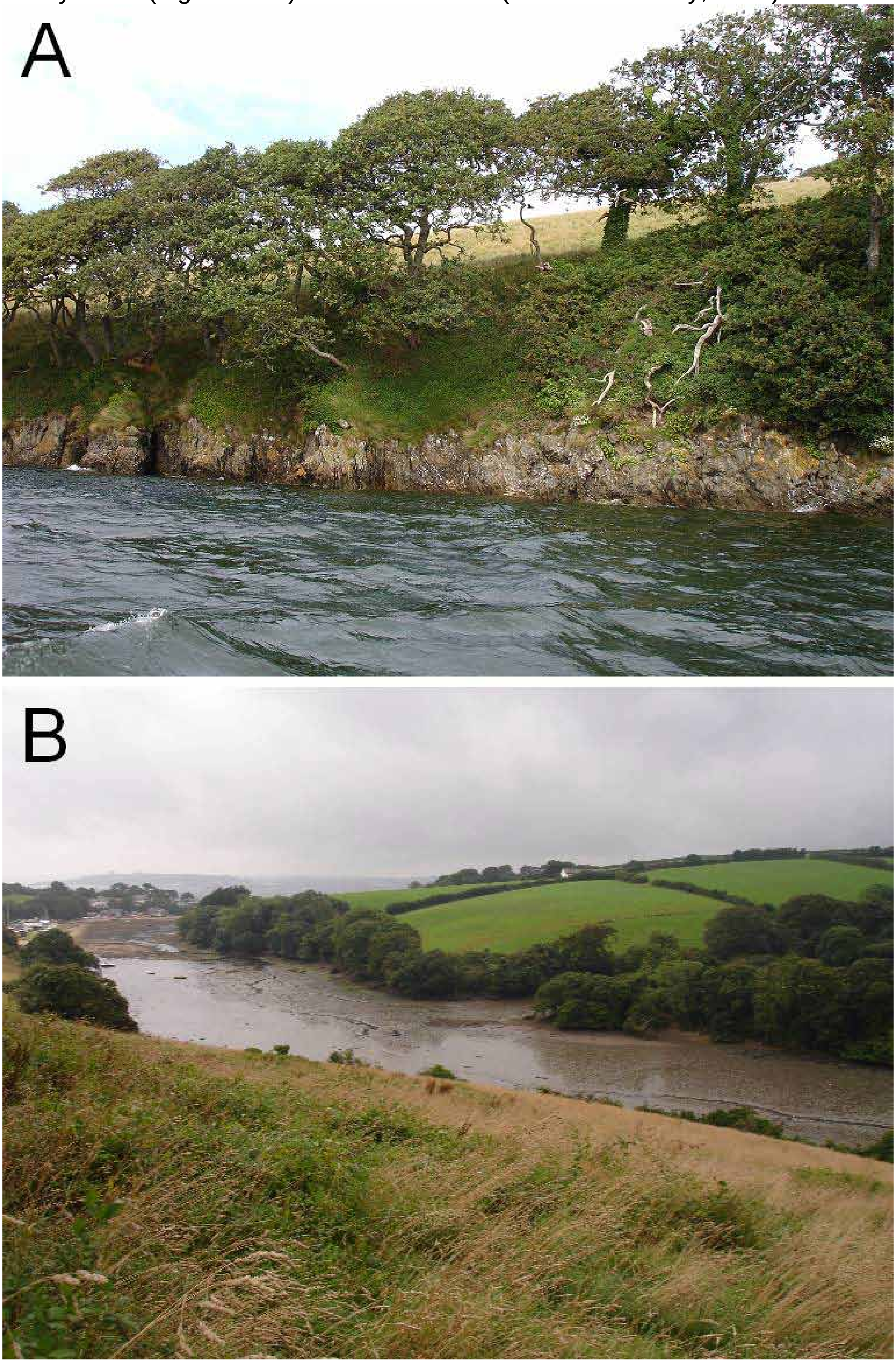


Figure 1.2 Rocky shore at East Bank (A) and intertidal mudflat at St. Just Creek (B).

Areas of saltmarsh occur in the upper reaches of Restronguet Creek. Saltmarsh contributes significantly to pollution control and water quality through nutrient cycling (e.g. nitrogen and phosphorous release during decomposition of organic matter) and sediment retention (e.g. adsorption of pollutants onto sediment particles) (Adnitt *et al*., in press).

Carrick Roads forms one of the largest natural harbours in the world. At Falmouth, the seafront is lined by slipways, moorings, boatyards and fishing docks (Figure 1.3).

Figure 1.3 View of Falmouth Harbour and town.
Courtesy of Mike Hancock.

Commercial uses of the estuary include shipping, marine services, fisheries and tourism. 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).

CATCHMENT CHARACTERISATION

The BMPAs are under the influence of pollution sources from the following river catchments: Fal (106km^2), Tresillian-Trevella-Kenwyn (131km^2), Carnon and Kennal Vale (78km^2), Fal (tidal)-Tresillian-Truro (64km^2) and the northern parts of Helford-Lizard-Carrick Roads (287km^2). These catchments are essentially rural in character.

The characteristics of the Helford-Lizard-Carrick Roads river catchment were already described as part of a sanitary survey undertaken for BMPAs in the Helford Estuary (Cefas, 2008).

There are a number of other small rivers and streams within these river catchments. A description of the hydrology of these catchments is given in the Appendix III.

Natural grassland, pastures and arable land are the dominant land covers. Significant patches of forest occur in the river valleys (Figure 1.4). The main urbanised areas occur at the head and the mouth of the estuary.

Areas of grassland and pastures supporting livestock production could represent high risk of pollution of diffuse origin to the estuary.

Elevation in the Fal catchment varies between 9m and 301m (weighted average = 126.5 m) (NERC, 2005). More than 87% of the catchment is above 60m elevation (NERC, 2005).

Steep land is expected to generate significant volumes of surface runoff and potentially microbiological contamination of faecal origin, which can be drained into watercourses under heavy and/or prolonged rainfall.

Catchment geology comprises three main bedrock types: Devonian metasediments (known as “killas”), granites, and ophiolites. The metasediments and granites are minor aquifers (Cornwall County Council and Environment Agency, 2006). Grassland on impermeable soils means that surface or sub-surface runoff is the most likely route of pollution across the catchment (Mawdsley *et al*., 1995).

The Fal catchment contains a wide range of habitats that support a remarkable diversity of plants and animals. These are recognised through various habitat conservation designations. The Fal Estuary is a Special Area of Conservation (SAC), designated under the EC Habitats Directive on the Conservation of Natural Habitats and wild fauna and flora. There are several areas classified as Sites of Special Scientific Interest (SSSI) as well as Local and National Nature Reserves (LNR and NNR) (Figure 1.5). Most of the estuary is within the Mylor & The Roseland to Porthpean Area of Outstanding Natural Beauty.

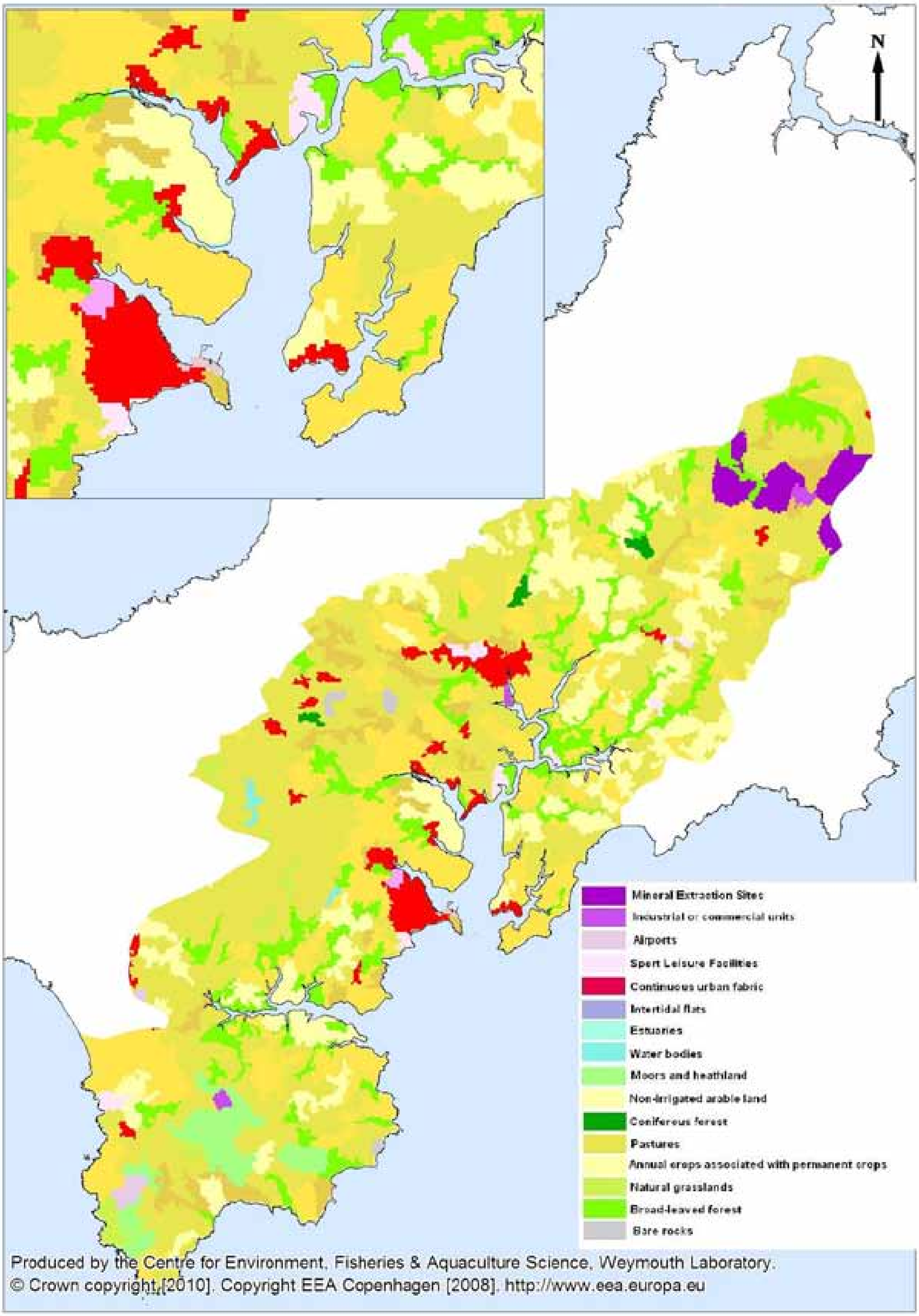


Figure 1.4 Land cover in the Fal sub-catchments.

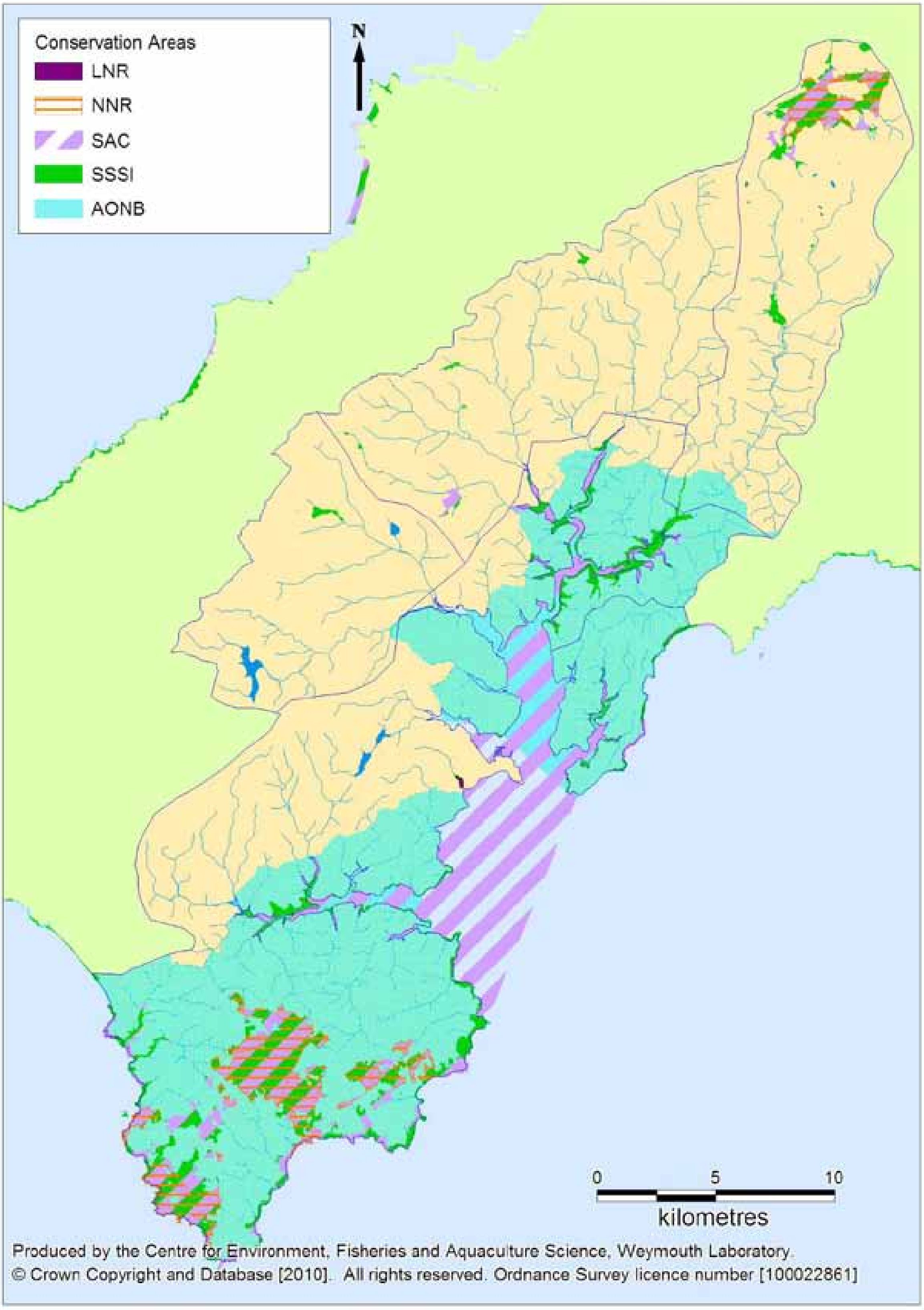


Figure 1.5 Nature conservation designations in the Fal catchment.
Boundary data from and regularly updated by Natural England (2008).
(http://www.naturalengland.org.uk).

2. SHELLFISHERIES

2.1 SPECIES, LOCATION AND EXTENT

QUEEN SCALLOPS

The sanitary survey was prompted by an application for classification of wild queen scallops (*A. opercularis*) in the eastern part of Carrick Roads (Figure 2.1). This is an area currently classified for native oysters.

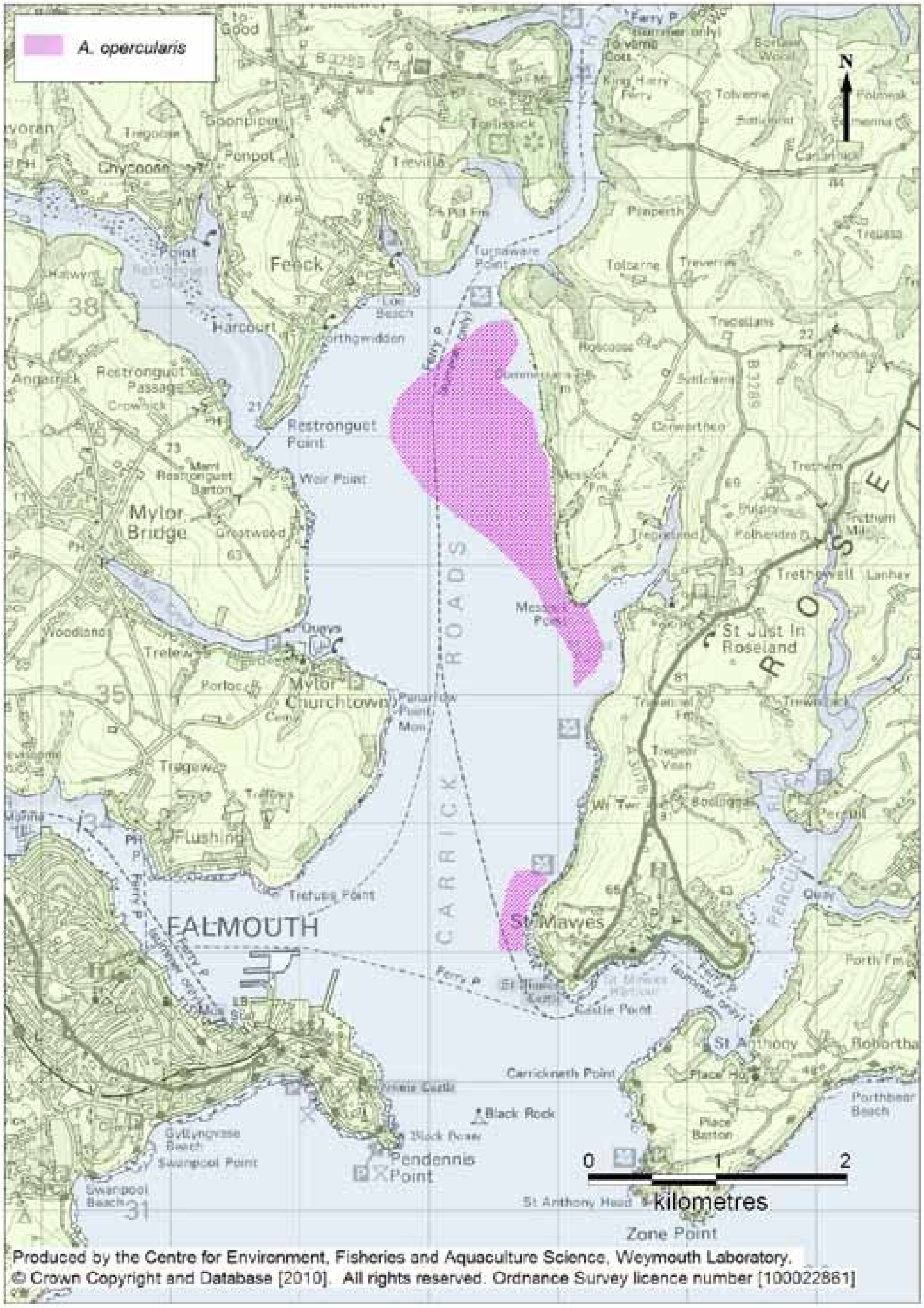


Figure 2.1 Location of the proposed harvesting area for queen scallops in the lower Fal Estuary.

The queen scallop is one of two species of scallops cultivated in the UK. It may be found in great abundance on firm sandy gravel, sandy mud, or shelly ground to a depth of 180m or more (Tebble 1976).

Scallops on the seabed are particularly vulnerable to predation from crabs and starfish (Laing and Spencer, 2006).

NATIVE OYSTERS

The harvesting of native oysters (*O. edulis*) (see Orton, 1925, 1927, 1940), mussels (*Mytilus* spp.) and Pacific oysters (*Crassostrea gigas*) in the Fal Estuary for commercial purposes is an activity with more than two centuries history. The Truro Oyster Fishery is the second largest fishery for the native oyster in the United Kingdom (Walker and Laing, 2006).

Despite the decline in the native oyster fisheries seen in the past (see Davidson, 1976) for which Bonamiosis, pests, competition from limpets (Fitzgerald, 2007), chemical contaminants (Langston *et al.*, 2003, 2006) and TBT (Laing *et al.*, 2005) had contributed, the small fishery using sailing dredgers and hand-dredging has been recovering in Carrick Roads (Walmsley and Pawson, 2007).

In March 2009, members of the Carrick Maritime Division of Carrick District Council and the Shellfish Resource Team of Cefas undertook a stock assessment for native oysters. The assessment included sampling across the inner and outer harbour, in three main sections: river (Malpas to Turnaware Point), harbour (Turnaware Point to the old fishery limit line Penarrow Point-Messack Point) and outer harbour section (parts of Falmouth and St. Mawes Banks south and the old fishery limit).

Results indicated high abundance of large oysters (exceeding minimum landing size of 65mm length) across the three sections surveyed. The highest density (approximately 40 oysters per dredge haul) was found in the harbour section. Medium sized oysters (50–64mm), those that are likely to grow sufficiently to enter the fishery in the following two seasons, were found widely distributed throughout the survey area and were locally abundant at Turnaware Point, around the mid point of the Eastern Bank and lower half of the Western Bank (Figure 2.2). Figure 2.3 shows the extent of native oyster beds in the wider estuary.

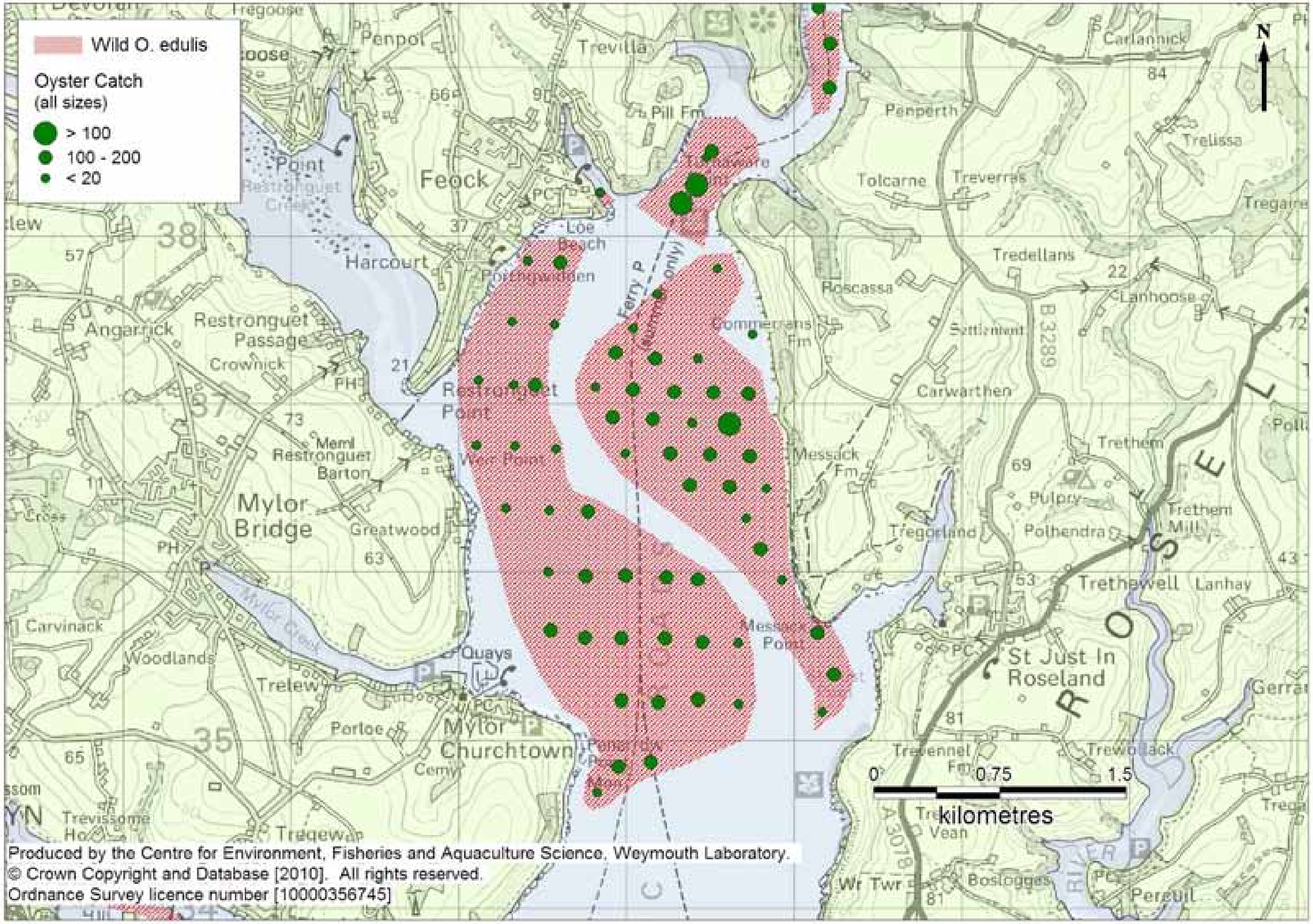


Figure 2.2 Densities of native oysters in Carrick Roads, lower Fal Estuary.
Data from Vanstaen (2009).

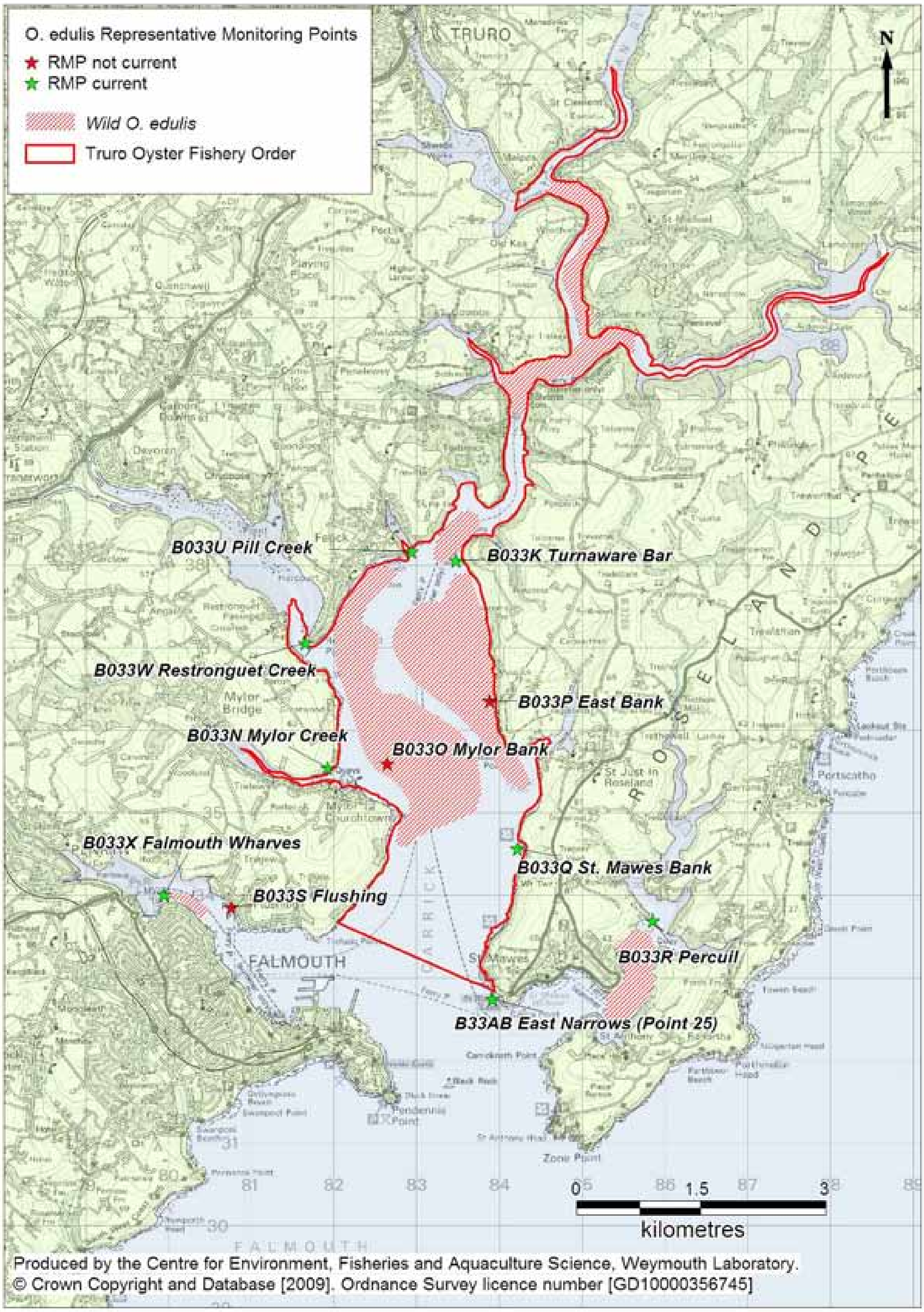


Figure 2.3 Location of native oyster beds surveyed by Cefas Shellfish Resource Team (March 2009), and boundary of Truro Oyster Fishery and location of representative monitoring points in the lower Fal Estuary and Percuil River.

PACIFIC OYSTERS

The Pacific oyster (*C. gigas*) is a non-native species in the UK (Spencer *et al.* 1994), was introduced in the Percuil River in 1974 (Wright and Pipkin, 2008). Cultivation operations have now ceased. Figure 2.4 shows the extent of beds previously identified and non-current RMPs mentioned in this report.

Figure 2.4 Location of past Pacific oyster beds and representative monitoring points in Percuil River.

MUSSELS

Mussels are often found in sheltered coasts and estuaries, just below the low water, where a food supply of suspended organic detritus and phytoplankton is available (Tebble 1976). Orton (1927) highlighted the presence of harvestable stocks in certain parts of the River Fal.

Both *Mytilus galloprovincialis* and *Mytilus edulis* have been recorded in the coasts of Cornwall (National Biodiversity Network Gateway 2009). Literature indicates however that both species present large morphological, physiological and behavioural similarities and are therefore difficult to differentiate for commercial purposes due to adaptations to environmental conditions (see Wijsman and Small, 2006). Data from molecular analyses have highlighted high levels of hybridisation[1] and gene introgression[2] between these species along the West coast of Cornwall. In the context of this sanitary survey, taxonomy of mussels is referred at genus level.

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

Nowadays, harvesting of wild mussels occurs along Truro River, the lower Tresillian River, stretches of the River Fal and in the lower reaches of Mylor Creek. Figure 2.5 shows the extent of the bed and RMPs in the lower estuary.

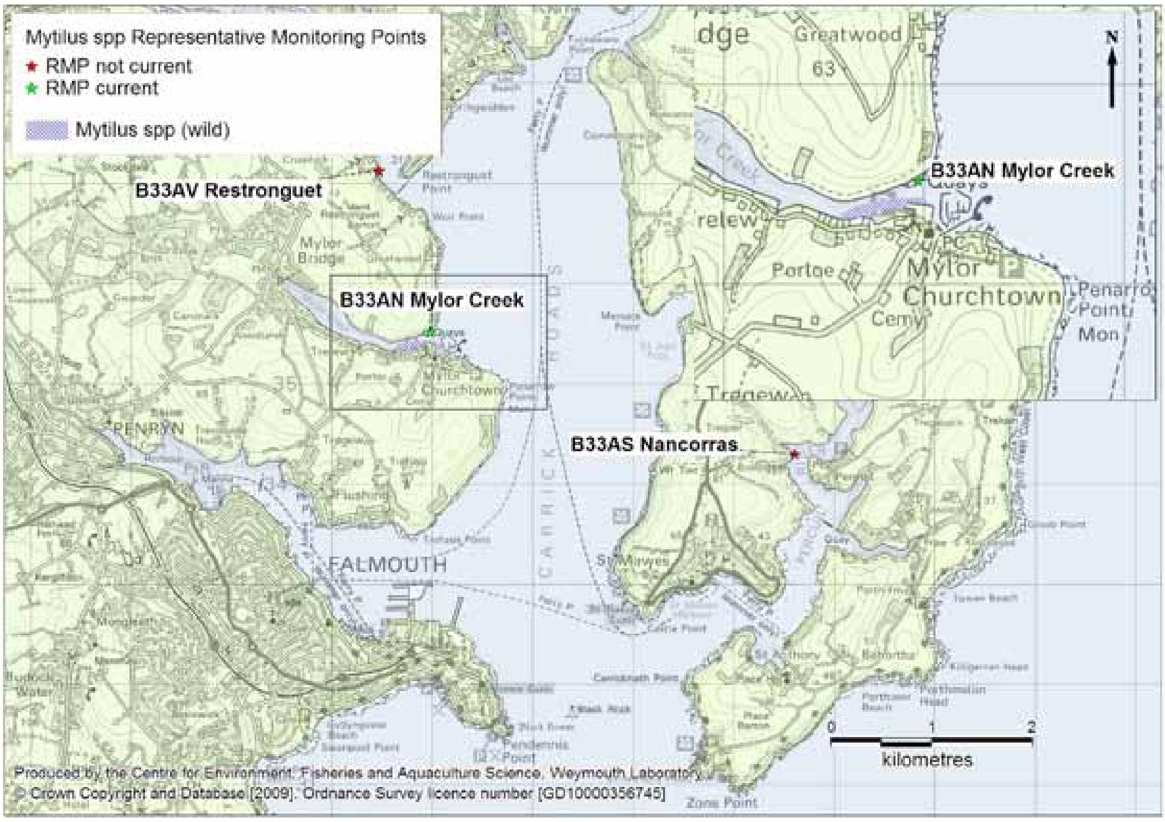


Figure 2.5 Location of mussel beds and representative monitoring points in the lower Fal Estuary.

HYGIENE CLASSIFICATION

Table 2.1 summarises the post-harvest treatment required before bivalve molluscs can be sold for human consumption. Table 2.2 summarises the historical classifications attributed to bivalve mollusc beds.

Table 2.1 Criteria for classification of bivalve mollusc production areas.

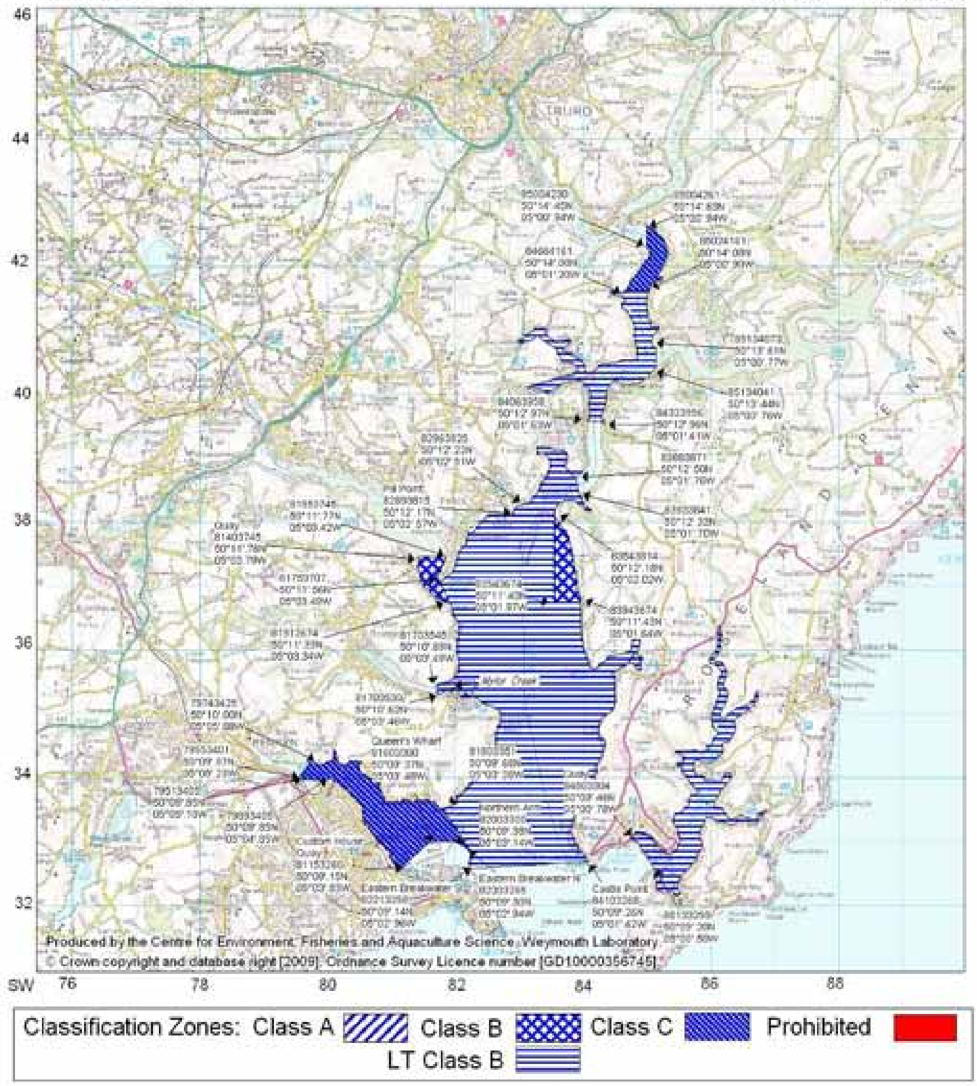
Class	Microbiological standard[1]	Post-harvest treatment required
A	Live bivalve molluscs from these areas must not exceed 230 Most Probable Number (MPN) *E. coli* $100g^{-1}$ FIL[2]	None
B	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution MPN test of 4,600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

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

The location and extent of classification zones as at September 2009 and corresponding classification status for these species are shown in Figures 2.6–2.8.

Truro, Tresillian & Fal - O. edulis

Scale - 1:90000



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 2.6 Classification zones for native oysters in the Fal Estuary.

Truro, Tresillian & Fal - Mytilus spp.

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. Turnaware Pontoon class C all year

Seasonal class B applies to mussels at King Harry mussel lines area from 1 May to 30 Sept (reverting to class C at all other times)

Lat/Longs quoted are OSGB 36

Separate maps available for C. gigas and O. edulis at Truro, Tresillian & Fal

Food Authority: Falmouth & Truro Port Health Authority

Figure 2.7 Classification zones for mussels in the Fal Estuary.

Truro, Tresillian & Fal -
C. gigas

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 Mytilus spp. and O. edulis at Truro, Tresillian & Fal

Food Authority: Falmouth & Truro Port Health Authority

Figure 2.8 Classification zone for Pacific oysters in the Percuil River.

Table 2.2 Historical classifications of bivalve mollusc beds in the lower Fal Estuary and Percuil River to 2009.

BMPA	Bed name	RMP ID	Species	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Fal	Mylor Creek	B033N	*O. edulis*	B	B	B	B	B	B	B	B	B	B	B	B	B-LT	B-LT	B*	B-LT	B-LT
	St Mawes Bank	B033P/Q	*O. edulis*	B	B	B	B	B	B	B	B	B	B	B	B	B-LT	B-LT	B-LT	B-LT	B-LT
	Flushing	B033X	*O. edulis*	B	B	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
	Restronguet Creek	B33AV	*Mytilus* spp.	-	-	-	-	-	-	-	-	n/c	n/c	n/c	n/c	B	B[1]	D/C	n/c	n/c
	Restronguet Creek	B033W	*O. edulis*	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	B[1]	B[3]
	Falmouth Wharves	B033X	*O. edulis*	B	-	-	C	C	C	C	C	C	C	B	B	B[2]	C	C	C	C
	Turnaware Bar	B033K	*O. edulis*	B	B	B	B	B	B	B	B	B	B	B	B	B-LT	B	B	B	B
	East Bank	B033P/Q	*O. edulis*	A	B	B	B	B	B	B	B	B	B	B	B	B-LT	B-LT	B-LT[2]	B-LT	B-LT
	Pill Creek	B033U	*O. edulis*	-	-	-	-	-	-	-	-	-	-	-	B	B-LT	B-LT	B-LT	B-LT[2]	B-LT[1]
	East Narrows	B33AB	*O. edulis*	-	-	-	-	-	-	-	-	-	-	-	B	B-LT	B-LT	B-LT	B-LT	B-LT[1]
	Mylor Bank	B033O/U/N/P	*O. edulis*	A	B	B	B	B	B	B	B	B	B	B	B	B-LT	B-LT	B-LT	B-LT	B-LT
	Mylor Creek	B33AN	*Mytilus* spp.	A	-	-	-	-	-	B	B	B	B	B	B	B*	B*	B-LT	B-LT[2]	B
Percuil	Percuil	B033R	*O. edulis*	-	B	B	B	B	B	B	B	B	B	B	B	B-LT	B-LT	B-LT[2]	B-LT	B-LT
	Percuil	B033R	*C. gigas*	B	-	-	-	-	-	B	B	B	B	B	B	B-LT	B-LT	B-LT[2]	B-LT	B-LT

[1] - Classification was provisional due to insufficient sample results, either in number or period of time covered.
[2] - Area classified at higher level, although shows marginal compliance.
[3] - Area classified at higher level, due to results close to the tolerance limit. A downgrade may be possible if further failures are returned.
n/c - Not classified
LT - Long-term classification system applies. NB. Long-term (LT) classification system was introduced in England and Wales alongside the annual classification system, and applies to class B areas only. New class B areas will initially be given annual classification until they meet criteria for a long-term classification.

2.2 Growing methods and harvesting techniques

Queen scallops
Queen scallops grow naturally on the riverbed. The commercial interest for this species was prompted by the fact that these are considered by-catch during oyster dredging operations (Gary Cooper, Cornwall Port Health Authority, pers. comm.).

Native Oysters
Harvesting of native oysters in the Truro Fishery consists of dredging stock from the licensed fishery. The two types of vessel are punts, which are propelled by oars (Figure 2.8A) and sail powered smacks (the Falmouth Working Boats) (Figure 2.8B). No powered winches are permitted on either type of vessel (Walker and Laing, 2006).

Pacific oysters
During the earlier desk study stage of the sanitary survey, the Local Enforcement Authority informed Cefas that the Duchy of Cornwall Oyster Farm Ltd who own the rights to the shellfish beds in the River Percuil intend to develop farming operations for Pacific oysters and asked Cefas to maintain classification of this BMPA until there are further developments on this matter. However as at August 2012 Cornwall Port Health Authority advise that there is now no commercial interest for Pacific oysters here.

Mussels
Mussels at Mylor Creek grow naturally on the riverbed. These are harvested by hand over low water periods of the tidal cycle.

Figure 2.8 Vessels used in the Truro Oyster Fishery: oyster punt (A) and oyster smack (B).

2.3 Seasonality of harvest and conservation controls

The Truro Port Fishery is managed under a Regulating Order which confers upon the Carrick District Council the right of regulating the fishery for oysters and mussels within the area shown in Figure 2.1 (Ministry of Agriculture, Fisheries and Food, 1975). The order delegates on the council the right to issue individual licences valid for a period not exceeding six months.

A summary of harvesting seasons and restrictions on times of harvesting is given in table 2.3 below. The native oyster season runs from 1 November to 31 March each year. Permitted working hours are 09:00 to 15:00, from Monday to Friday and 09:00 to 13:00 on Saturday (Walker and Laing, 2006). The minimum landing size for native oysters is 67mm. Queen scallops will be harvested during the native oyster season. Mussels are harvested on a year-round basis.

Table 2.3 Summary of bivalve mollusc harvesting seasons in the lower Fal Estuary.

Species	Month											
	N	D	J	F	M	A	M	J	J	A	S	O
**A. opercularis*	¿ Harvesting season											
O. edulis	¿ Harvesting season											
Mytilus spp.	Year round											

* *Species requiring classification.*
¿ 09:00–15:00 Mon-Fri 09:00–13:00 Sat.

2.4 Capacity of area and socio-economy

The Managed (Regulated) fishery produces around 50 tonnes of native oysters per year. In addition, about 10 tonnes of native oysters are harvested annually from relaying undersized native oyster stock (Ian Laing, pers. comm.). In 2009, approximately 180 tonnes of mussels were harvested in the Fal Estuary (Robert Packham, pers. comm.).

Currently, there are 50 licences issued for native oyster dredging in the Fal (Paul Ferris, pers. comm., 2010).

3. OVERALL ASSESSMENT

AIM

This section presents an overall assessment of pollution sources on the microbiological contamination of bivalve mollusc beds in the lower Fal Estuary and Percuil River[3] as a result of a sanitary survey undertaken by Cefas on behalf of the Food Standards Agency. Its main purpose is to inform the sampling plan for the microbiological monitoring and classification of bivalve mollusc production areas (BMPAs) in this geographical area. Cefas is undertaking a separate sanitary survey for BMPAs in the upper Fal Estuary.

The present survey was prompted by an application for microbiological monitoring and classification of wild queen scallops (*A. opercularis*) at Carrick Roads[4]. The assessment is made in relation to this bed and beds classified beds for native oysters (*O. edulis*), Pacific oysters (*C. gigas*) and mussels (*Mytilus* spp.)[5] at the time of the application (2009).

SHELLFISHERIES

The area requiring classification for scallops includes parts of the meandering deep water channel at Carrick Roads and subtidal areas just North of Messack buoy, the southeast part of Mylor Pool and St. Mawes Bank[6].

The 2009 classified zones for native oysters include much of the subtidal areas of Mylor Pool and St. Mawes Bank, the intertidal areas of Penryn Creek (western side), off Messack and intertidal areas in the lower Percuil River (eastern side)[7]. The 2009 zone for Pacific oysters includes intertidal areas in the mid reaches of Percuil River[8]. The 2009 classification zone for mussels includes intertidal areas at the mouth of Mylor Creek[9].

These beds fall under the jurisdiction of Falmouth & Truro Port Health Authority (Local Enforcement Authority).

Conservation controls determine that harvesting for native oysters occurs between 1 November and 31 March each year[10]. This is also the harvesting period for the species requiring classification (queen scallops). Mussels and Pacific oysters are harvested on a year-round basis.

[3] 1. Introduction, 1.2. Site Description.
[4] Figure 2.7.
[5] Figure 2.2–2.3.
[6] Figure IV.1.
[7] Figure IV.4.
[8] Figure IV.2.
[9] Figure IV.3.
[10] 2.3. Conservation controls.

FRESHWATER INPUTS

The catchment (total area = 667km^2) assessed for the purposes of this sanitary survey is drained by a river network formed by the Rivers Fal, Allen and Kenwyn and the River Percuil. The river network is formed by other less significant freshwater inputs[11]. These watercourses constitute the most significant routes of contamination of faecal origin from the wider catchment to the Fal Estuary.

Hydrographs for the River Fal at Tregony show higher flows in watercourses during autumn–winter months than those during the summer. Water levels in the rivers Fal and Allen are characterised by a fast response to rainfall events and a relatively sharp recession limb. This response is caused by the steep topography of the catchment, relatively high rainfall totals and low permeability of the main geological formations. Historical data from the National River Flow Archive shows that the levels of runoff increase substantially from September to January. This suggests that the Fal is highly responsive catchment and that the native oyster harvesting season (November–March) corresponds to the period of higher risk of runoff contamination.

AGRICULTURE

The Fal is a rural catchment, predominantly used for agricultural purposes[12]. Defra considers that the catchment is at risk of diffuse water pollution from agricultural land.

Soil erosion and compaction and over application of slurry at the wrong time of year may promote periods of water quality deterioration in watercourses. The period of higher risk is February–March, when a significant number of farmers spread manures prior to the growing season and autumn months, when biosolids are applied for winter cereals. Winter is also critical since large quantities of slurry are applied more frequently because many farms do not have adequate storage capacity.

Livestock production (>184,000 farmed animals) is based on sheep farming. in the uplands and mixed cattle and sheep in areas of improved and natural grassland in the valleys[13]. At the time of the shoreline survey, no livestock were evident on land immediately adjacent to the estuary.

A deterioration in microbial water quality is expected to occur from faecal matter deposited in these areas when farm yard manure and slurries are spread in agricultural fields from the wider catchment shortly before/during rainfall events, in particular when these are spread near a watercourse.

It is estimated that the harvesting area for native oysters and queen scallops will be at higher risk of microbial pollution during the autumn-winter period due to a

[11] Appendix III.
[12] Figure 1.4.
[13] Appendix VIII.

combination of the increased run-off from the wider catchment and the impermeable characteristics of the geological formations.

HUMAN POPULATION

Human population (approximately 113,300) is considerably higher than the total number of cattle (approximately 61,800 animals) and sheep (approximately 34,795 animals) farmed in the catchment. Bivalve mollusc beds in the vicinity of the urbanised areas of Falmouth/Penryn (resident population = 20,775 people) at the mouth and, to a lesser extent, Truro (17,431 people) and the head of the estuary will be liable to impact from point source discharges and runoff from impermeable land.

There are tourist attractions in the catchment receiving more than 100,000 visitors per year. Therefore, the contribution of human sources is expected to markedly increase during the summer tourist season.

SEWAGE DISCHARGES

A programme of work has been undertaken by the Environment Agency to upgrade a number of sewage discharges that have, or once had, the potential to influence the Fal Estuary Shellfish Water. Most of the upgrades were completed in 2002/2003.

A number of continuous and intermittent water company sewage discharges representing a significant or potentially significant impact on the microbial water quality of the estuary occur within 10km of the estuary and its tidal limit. The most significant continuous discharges to BMPAs are associated with the urbanised areas of Falmouth and Penryn, in the lower estuary, and Truro, in the upper estuary:

- Carnon Downs sewage treatment works (STW) (secondary; DWF = 1,010 $m^3 d^{-1}$);
- Falmouth STW (UV; DWF = 9,500 $m^3 d^{-1}$);
- Truro (Newham) (UV; DWF = 7,020 $m^3 d^{-1}$);
- St Mawes (UV; DWF = 800 $m^3 d^{-1}$);
- Ladock Valley (UV; DWF = 675 $m^3 d^{-1}$); and
- Mylor Bridge (UV; DWF = 441 $m^3 d^{-1}$).

Two other continuous discharges considered to have potential local significance are:

- St. Mawes Castle Visitor Toilets (primary; DWF = 2.5 $m^3 d^{-1}$); and
- 1&2 King Harry Cottages (secondary; DWF = 0.28 $m^3 d^{-1}$).

Forty-seven intermittent discharges (combined sewer overflows, emergency overflows and overflows from pumping stations) discharge to the estuary or its tributaries. The majority of these discharges are designed to spill less than ten times per year in line with the Environment Agency's standard for consenting intermittent discharges to Shellfish Waters[14]. Most of these discharge to creeks on the eastern side of the estuary. Commercial Road PSCSO/EO, which discharges to Penryn River in the proximity of Falmouth Wharves native oyster bed, recorded 16 spill events (130h in total) in 2009.

BOATS

Within Falmouth Harbour limits, there are approximately 4,700 moorings, 588 of these are deep water lay-up moorings for vessels up to 219m in length in Falmouth. Penryn holds approximately 350 moorings.

It has long been established that sewage discharged from boats could represent a significant public health risk for bivalve mollusc beds. A significant number of people are likely to stay overnight. However, the contribution of these sources is difficult to quantify due to the intermittent nature of these discharges. Bivalve mollusc beds in Penryn River, Falmouth Bank, lower Percuil River and, to a lesser extent, Mylor Creek will be the most vulnerable areas to pollution from moored boats.

SUMMARY OF POLLUTION SOURCES

An overview of sources of pollution likely to affect the levels of microbiological contamination in BMPAs in the lower Fal Estuary is shown in Table 3.1 and Figure 3.1.

[14] The Environment Agency's design standard for consenting intermittent discharges to Shellfish Waters is that, in aggregation of both frequency and volume, there should be no more than 10 significant spills per annum on average to the Shellfish Water as a whole. The definition of a significant spill can be considered on a site-specific basis, but 50m3 is taken as the default value.

Table 3.1 Qualitative assessment of variation in microbiological pollution load to the lower Fal Estuary.

Pollution source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
STW*	Orange	Orange	Red	Red	Red	Red	Red	Red	Red	Red	Red	Orange
Farmyard manure/slurries application to land	Red	Red	Red						Red	Red	Red	Red
Sewage sludge application to land		Red	Red						Red			
Freshwater inputs						Orange	Orange	Orange	Red	Red	Red	Red
Rainfall						Orange	Orange	Orange	Red	Red	Red	Red
Waterbirds	Red	Red	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Red
Peak human population (tourist season)			Red	Red	Red	Red	Red	Red	Red			
Boats†			Red	Red	Red	Red	Red	Red	Red			

** Assessment based on the quality of UV-treated effluent discharges from four WwTW and therefore merely indicative of the load attributed to these sources.*
† Increased number of days on board.
Red - high risk; orange - moderate risk.

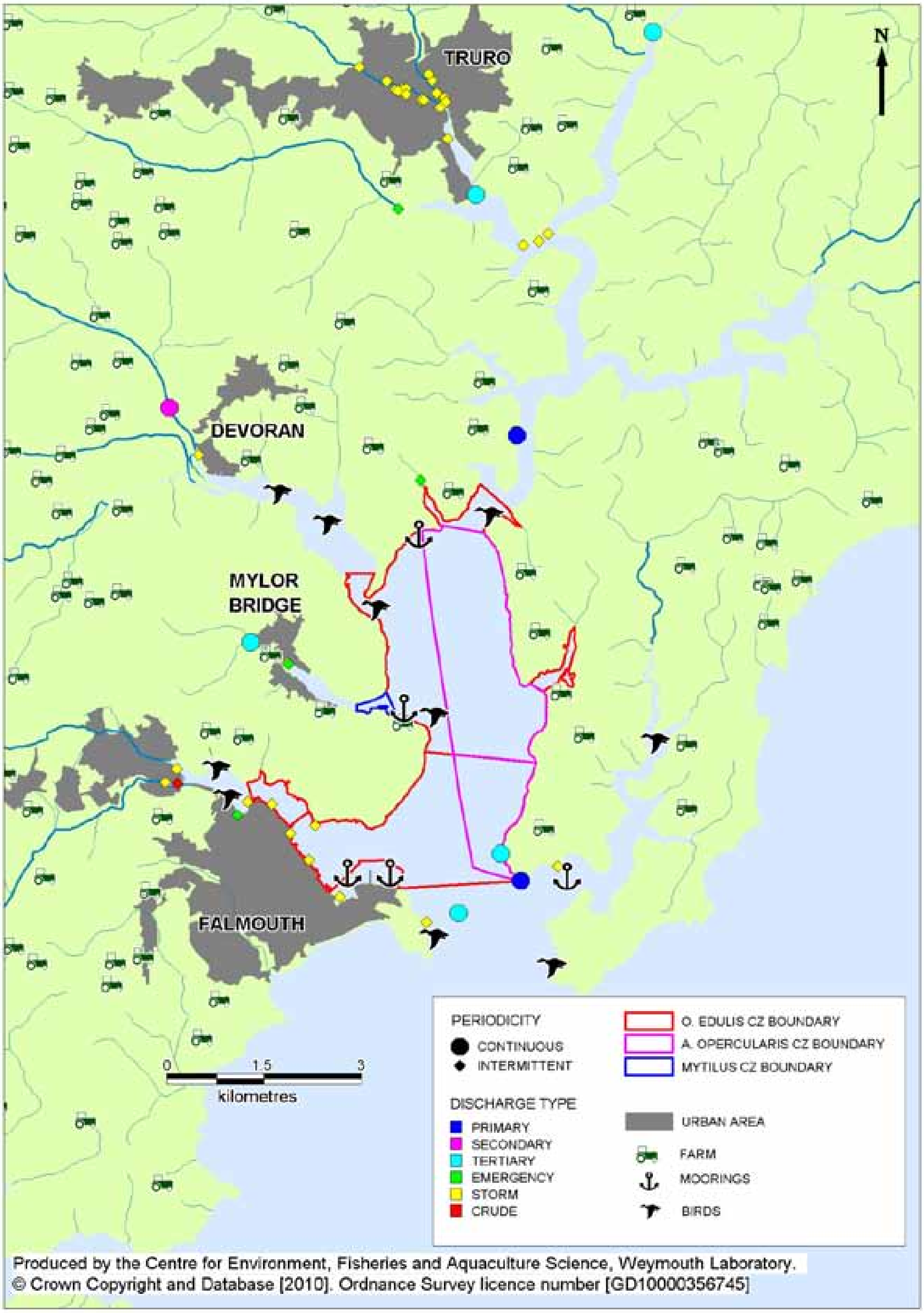


Figure 3.1 Significant sources of microbiological pollution to the Fal Estuary.

HYDRODYNAMICS

The main channel at Carrick Roads is relatively deep and meandering, in particular the area encompassing the native oyster and queen scallop beds. Depths increase to 33m relative to Chart Datum just south of East Narrows and at the mouth of Saint Mawes Harbour. Native oyster and queen scallop beds are sub-tidal and therefore covered by water and potentially impacted by inputs of contamination during the whole tidal cycle.

In contrast, areas of the mussel bed in Mylor Creek, native oyster beds in Falmouth Wharves and Percuil River and Pacific oyster bed at Percuil River are fairly shallow and contain significant proportions of intertidal drying areas at low water spring tides. Bivalves growing in these areas will not be exposed to contamination during periods of low water. Contaminated runoff from retained seawater and/or washed off by rainfall falling on the surface of mudflats into these creeks will be conveyed to the main estuary during the ebb tide. Nearshore shallow areas are therefore likely to represent worst-case conditions.

Overall, the Fal is an ebb dominant macro-tidal estuary (mean ranges are 4.6m and 2.2m on spring and neap tides respectively). The longer and slower ebb tide is likely to promote the dispersion of pollution towards the sea, in particular that from sources situated near the mouth of the estuary.

The long tidal length (approximately 20km to Tresillian) indicates that significant distances may be involved in the transport of microbial contaminants along the estuary between developed areas at the mouth (Falmouth/Penryn areas) to the upper reaches of Carrick Roads.

There is a substantial attenuation in current speeds between Pendennis Point (peak currents on springs<0.5m s^{-1}) and Penarrow Point. Therefore, freshwater flows could be more important than tidal flows in determining the persistence of faecal contamination in inner areas of Carrick Roads. Therefore, representative monitoring points situated in upstream areas of beds will also best represent worst-case conditions.

Depth averaged concentrations of suspended particulate matter are higher in the Fal (28mg l^{-1} if tidal limit to Tresillian) than in other estuaries in the southwest UK. Turbidity levels and remobilisation of contaminants could increase due to sewage discharges and following dredging activities. Numerical modelling simulations of sediment release in the water column at Falmouth Bank evidenced a confinement of suspended sediments associated with the plume to the western side of the Fal Estuary under spring tidal conditions.

The high number of point-source discharges and re-suspension of contaminated sediments associated with human activity (e.g. boating activities, dredging) may be responsible for deterioration in microbiological quality of native oysters at Falmouth Wharves.

Excursion drogues and dye tracing studies have identified two potential plume impacts from discharges at Falmouth STW: (a) advection of a neap flood tide under moderate to strong east to southeast wind conditions towards Penryn River and (b) advection of a neap flood tide under light to moderate westerly winds towards St. Mawes Bank impacting shellfish beds in the upper reaches of Carrick Roads.

SUMMARY OF MICROBIOLOGICAL DATA

Analysis of historical data (2004–2008) from the Bathing Waters (BW) monitoring programme indicates higher levels of faecal contamination in surface waters at Swanpool relative to those at Gyllyngvase. However, the microbial quality of waters at Gyllyngvase showed occasional periods of deterioration suggesting some vulnerability to intermittent episodes of contamination in the outer estuary mouth. Overall, all results were below the Imperative value (CFU Faecal coliforms = 1,000ml^{-1}) and both bathing waters have achieved “excellent” classifications suggesting the lack of appreciable sources of pollution seaward of the mouth of the estuary.

Levels of faecal coliforms monitored in designated Shellfish Waters have been low (geometric means in 2008 would be equivalent to class A shellfish) since 2004 and suggest the following spatial gradient of contamination in the lower Fal Estuary: Penryn>Carrick Roads>Percuil.

Results from microbial source tracking studies undertaken in freshwater inputs across the Fal catchment indicate predominance of animal sources in the upper reaches of the catchment and mixed animal/human sources in sites sampled in the lower River Fal. This indicates that bivalve molluscs at Carrick Roads are likely to be affected by the combined effect of faecal contamination from dairy washings and surface runoff from agricultural land, and sewage discharges.

Historical levels of *E. coli* in classified native oyster beds following the improvements in STW indicate the following spatial pattern of faecal contamination in the estuary: Falmouth Wharves>Mylor Creek>Pill Creek>Turnaware Bar>Percuil>East Bank>St. Mawes Bank. This spatial gradient is consistent with that identified for Shellfish Waters data and confirms that the presence of large STWs at Falmouth and Penryn will have a significant negative impact on the quality of the waters on the western side of the estuary.

Statistically significant positive relationships were found between rainfall and levels of *E. coli* in native oysters from all current representative monitoring points across the estuary, except in oysters from Restronguet Creek. The strength of these correlations varied according to the monitoring point and the time of sampling relative to the rainfall event. Higher coefficients were computed when sampling took place 4–6 days after the rainfall event.

The highest significant correlation coefficient between rainfall and *E. coli* was detected in native oysters from Pill Creek. This indicates significant impact of rainfall-dependent discharges and runoff from agricultural land from the upper Fal Estuary on native oysters in the upper Carrick Roads.

Significant positive relationships were also detected between river flows and levels of *E. coli* in native oysters from Turnaware Bar and St. Mawes Bank. Strong correlation was computed when the time lag between the increase in water levels in the River Fal and Kenwyn and sampling did not exceed 48h. This indicates a fast response of *E. coli* accumulation in oysters to river flows at these beds.

4. RECOMMENDATIONS

NATIVE OYSTERS

4.1 It is recommended that the currently harvested native oyster beds in the lower Fal Estuary be represented by seven classification zones (CZs), each with its own representative monitoring point (RMP). This represents an increase in the total number of currently classified CZs (from five to seven) and is justified by the presence of sources of pollution each impacting on different areas within the lower Fal.

4.2 A CZ at Turnaware Bar is recommended. This CZ will be defined by lines crossing the main river channel at Pill Farm-creek at Tolcarne and Loe Beach-Turnaware Point. The edges of the CZ on land will be defined by the Mean High Water Line.

4.3 An RMP situated in the northern edge of Turnaware Bar CZ will be representative of microbial contamination from sewage discharges and diffuse pollution delivered from Fal, Fal (tidal) and Tresillian catchments via the rivers Fal, Allen, Truro, Kenwyn and Tresillian and faecal contamination from birds in the upper reaches of these rivers, transported down the river during ebb tides and/or during periods of high river flow discharges.

4.4 A CZ at Mylor Pool is recommended. This will include native oyster beds situated at East Bank and Mylor Pool. This CZ will be defined by lines crossing the main river channel at Loe Beach-Turnaware Point and just South of Penarrow Point-southern edge of the woodland at Tregear Vean. The enforceable lines will also cross the mouths of Restronguet Creek at Weir Point-Restronguet Point, St. Just Pool at Messack Point-St. Just in Roseland and of Mylor Creek at Mylor Churchtown.

4.5 An RMP situated in the southern edge of Mylor Bank will be representative of contamination from point and diffuse sources delivered to Carrick Roads via the River Fal and its tributaries (see 4.3), Mylor Creek, Restronguet Creek and St. Just Pool transported during ebb tides and/or during periods of high river flow discharges and contamination from Falmouth area during flood tides.

4.6 A CZ at Falmouth Bank is recommended. This will cover covering the eastern part of the lower Fal estuary encompassing Falmouth Bank.

4.7 An RMP situated in Falmouth Bank off Trefusis Point will be representative of contamination from point and diffuse sources (runoff from agricultural land and any pollution from boats and boating activities) influencing water quality in vicinity of Falmouth Bank transported across the estuary mostly during the ebb stage of the tide.

4.8 A CZ at Falmouth Wharves is recommended. This will include the native oyster bed at Penryn River between the eastern edge of Falmouth Yacht Marina and Greenbank Quay. This CZ will be defined by lines crossing Penryn River at eastern edge of Falmouth Yacht Marina-Trevissome Ho and at Greenbank Quay-Flushing Ferry Passage.

4.9 An RMP (Falmouth Wharves) situated in the western edge of the CZ will be representative of contamination from point and diffuse sources (runoff from agricultural land and any pollution from boats and boating activities) influencing water quality in Penryn River during periods of high river flows and/or during the ebb stage of the tide.

4.10 A CZ at Restronguet Creek is recommended. This will encompass native oyster beds at the mouth of the creek. This CZ will be defined by lines crossing the creek at Weir Point-Restronguet Point and Restronguet Passage/south of Harcourth.

4.11 An RMP (Restronguet) situated at Weir Point will be representative of faecal contamination delivered from Carnon and Kennal Vale and Fal (tidal) catchments via rivers Carnon and Kennal during periods of high rivers and any contamination from Carrick Roads impacting the creek during the flood tide.

4.12 During the period of external consultation of this report, the LEA informed Cefas that they wish to maintain the existing CZ and associated RMP at Mylor Creek for native oysters (B033N) since fishermen use the area to leave stock for collection, sometimes during a complete tidal cycle. The LEA proposed alternative geographic grid references for RMPs recommended in 4.2, 4.5, 4.7 and 4.14 to maintain safe distances from boating activity in Carrick Roads and Percuil River.

4.13 A CZ covering the eastern part of the lower Fal estuary (St Mawes) is recommended. This will include the native oyster bed extending over St Mawes bank.

4.14 An RMP (East Narrows) is recommended below St Mawes bank to be representative of faecal contamination delivered to the eastern part of lower Fal estuary in the St Mawes CZ.

4.15 The recommended maximum tolerance for all native oyster RMPs is 50 metres. This tolerance takes into consideration that there have been fluctuations in harvestable stocks[15] and, therefore, it might be difficult to obtain sufficient animals for a sample under certain circumstances.

[15] See Walker and Burnett (2008), Vanstaen (2009).

4.16 Consideration could be given by the Local Enforcement Authority (LEA) to sampling native oysters during/immediately after rainfall events in order to reflect the potential worst-case scenario of microbiological contamination, if the recommendations of the Good Practice Guide for Microbiological Monitoring of Bivalve Mollusc Harvesting Areas (Cefas-CRL) are adopted in England and Wales at some time in the future. The LEA could also consider sampling native oysters at Turnaware Bar and St. Mawes Bank when river flows in the Rivers Fal and Kenwyn exceed the mean flow.

MUSSELS

4.17 The recommended CZ at Mylor Creek will include the mussel bed at the mouth of the creek and will be defined by lines crossing the creek at Mylor Churchtown and at Porloe.

4.18 An RMP situated at Mylor Churchtown Quay was initially recommended by Cefas as representative of faecal contamination from the northern areas of Helford-Lizard-Carrick Roads catchment delivered to Mylor Creek during period of high river flows and any contamination from Carrick Roads impacting the creek during the flood tide. During the period of external consultation of this report, the LEA proposed the bed be monitored using the existing RMP at Mylor Creek (B33AN) as this is accessible at all states of the tide and is away from boating activity using the quay. Furthermore, fishermen use Mylor Creek to leave bagged mussels for collection, sometimes during a complete tidal cycle..

4.19 The recommended maximum tolerance for this RMP is 10 metres. It is considered that this tolerance preserves the fixed location concept and minimises the effect of spatial variability in the extent of microbial contamination.

QUEEN SCALLOPS

4.20 Two classification zones are recommended for Queen scallops to include beds along the eastern parts of Carrick Roads, as requested by Cornwall Port Health Authority. These will cover the beds in north east of the lower estuary (Messack) and those to their south on St Mawes bank .

4.21 An RMP (Commerrans) situated towards the northern part of the scallop fishery in the Messack CZ will be representative of microbial contamination from sewage discharges and diffuse pollution delivered from the Fal, Fal (tidal) and Tresillian catchments via the rivers Fal, Allen, Truro, Kenwyn and Tresillian and faecal contamination from birds in the upper reaches of these rivers, transported down the river during ebb tides and/or during periods of high river flow discharges. Influence over this area on the flood tide from St Just may also be reflected by this RMP.

4.22 Am RMP (St Mawes) on the south side of St Mawes bank is recommended to be representative of faecal contamination delivered to the eastern part of lower Fal estuary.

4.23 The recommended maximum tolerance for this RMP is 50 metres for the same reasons stated in 4.15.

OTHER

4.24 A CZ at Percuil is not recommended following advice from the Cornwall Port Health Authority (August 2012) that there are no current shellfish stocks. Should this area require classifying in the future we recommend situating an RMP towards the north eastern boundary of the zone to reflect contamination from upstream sources.

5. SAMPLING PLAN

GENERAL INFORMATION

Location Reference

Production Areas	Lower Fal Estuary Percuil River
Cefas Main Site Reference	M033
Cefas Area Reference	FDR 3562 FDR 4785
Ordnance survey 1:25,000 map	OS Landranger 204: Truro & Falmouth, Roseland Peninsula OS 105: Falmouth & Mevagissey, Truro & St. Mawes OS 104: Redruth & St. Agnes, Camborne & Perranporth
Admiralty Chart	Imray Y58: River Fal, Falmouth to Truro

Shellfishery

Species	Culture	Seasonality of harvest
Native oysters (*O. edulis*)	Wild	1 November–31 March
Mussels (*Mytilus* spp.)	Wild	Year round
Queen scallops (*A. opercularis*)	Wild	1 November–31 March

Local Enforcement Authority

Name of Local Enforcement Authority	Cornwall Port Health Authority The Docks FALMOUTH, Cornwall TR11 4NR
Telephone number (	01326211581
E-mail š	fal@cieh.org.uk
Manager	Gary Cooper
E-mail š	g.cooper@cieh.org.uk
Port Health Officer	Terry Stanley
E-mail š	t.stanley@cieh.org.uk
Telephone number (	01326211581
Fax number	01326211548

Table 5.1 Recommended number and location of representative monitoring points (RMPs) and frequency of sampling for bivalve mollusc classification zones in the lower Fal Estuary and Percuil River.

RMP	RMP Name	Classification zone	Geographic grid references of sampling points: OSGB36 datum Easting	OSGB36 datum Northing	OSGB36 datum NGR	WGS84 datum Latitude	WGS84 datum Longitude	Species	Growing method	Harvesting technique	Sampling method	Depth	Tolerance (m)	Frequency
Fal Estuary														
B33BF	Turnaware Bar	Turnaware Bar	183450	38540	SW 8345 3854	50°12.43'N	05°02.17'W	*O. edulis*	Wild	Dredging	Dredging	Riverbed	50	Fortnightly (September–February). At least monthly (March–August*)
B33BE	Restronguet	Restronguet Creek	181470	37190	SW 8147 3719	50°11.66'N	05°03.79'W	*O. edulis*	Wild	Dredging	Dredging	Riverbed	50	At least monthly
B33BG	Mylor Pool	Mylor Bank	182980	35100	SW 8298 3510	50°10.26'N	05°02.45'W	*O. edulis*	Wild	Dredging	Dredging	Riverbed	50	Fortnightly (September–February). At least monthly (March–August*)
B033X	Falmouth Wharves	Falmouth Wharves	179940	34000	SW 7994 3400	50°09.91'N	05°04.96'W	*O. edulis*	Wild	Dredging	Dredging	Riverbed	50	Fortnightly (September–February). At least monthly (March–August*)
B33BH	Trefusis Point	Falmouth Bank	182110	35110	SW 8211 3511	50°09.69'N	05°03.12'W	*O. edulis*	Wild	Dredging	Dredging	Riverbed	50	Fortnightly (September–February). At least monthly (March–August*)
B33AB	East Narrows	St. Mawes	183910	32740	SW 8391 3274	50°09.31'N	05°01.59'W	*O. edulis*	Wild	Dredging	Dredging	Riverbed	50	Fortnightly (September–February). At least monthly (March–August)
B033N	Mylor Creek	Mylor Creek	181960	35460	SW 8196 3546	50°10.74'N	05°03.32'W	*O. edulis*	Wild	Dredging	Hand-picking	Riverbed	10	Fortnightly (September–February). At least monthly (March–August)
B33AN	Mylor Creek	Mylor Creek	181960	35510	SW 8196 3551	50°10.76'N	05°03.32'W	*Mytilus* spp.	Wild	Hand-picking	Hand-picking	Riverbed	10	Fortnightly (September–February). At least monthly (March–August)

B033?	Commerrans	Messack	183470	38070	SW 8354 3807	50°11.97'N	05°02.13'W	*A. opercularis*	Wild	Dredging	Dredging	Riverbed	50	Preliminary classification: 10 samples taken over, at least, 3 months (interval between sampling not less than 1 week)
B033?	St Mawes	St Mawes Bank	183670	33330	SW 8367 3333	50°09.63'N	05°01.45'W	*A. opercularis*	Wild	Dredging	Dredging	Riverbed	50	Preliminary classification: 10 samples taken over, at least, 3 months (interval between sampling not less than 1 week)

(*) The Local Enforcement Authority could consider suspending native oyster sampling during the closed harvest season (April–August).

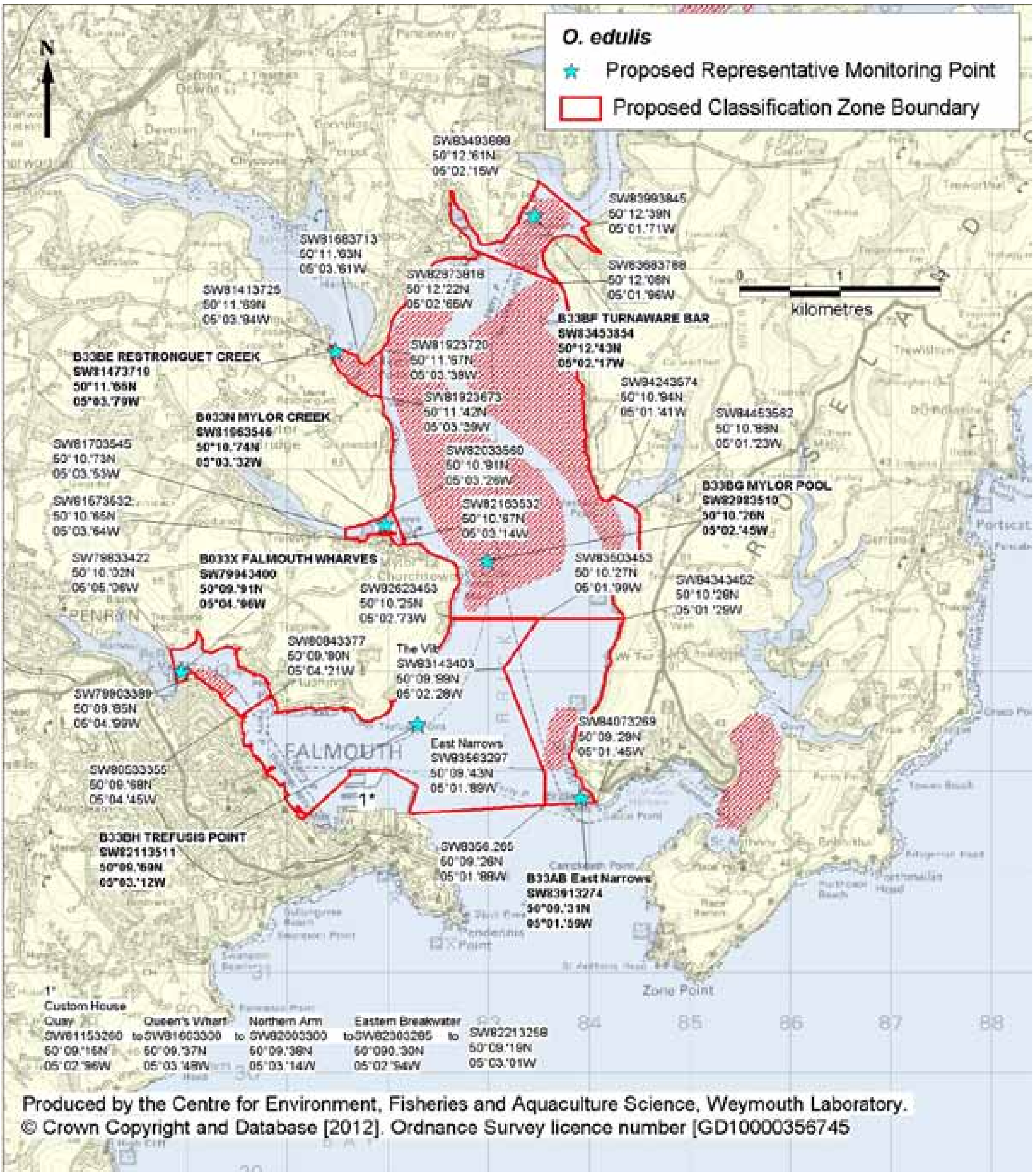


Figure 5.1 Location of recommended representative monitoring points (RMPs) and classification zone boundaries for native oysters in the lower Fal Estuary and Percuil River.

Only beds in the river and harbour sections surveyed by Cefas Resource Team in 2008-2009 are shown. Harvestable stocks also occur in the outer harbour section.

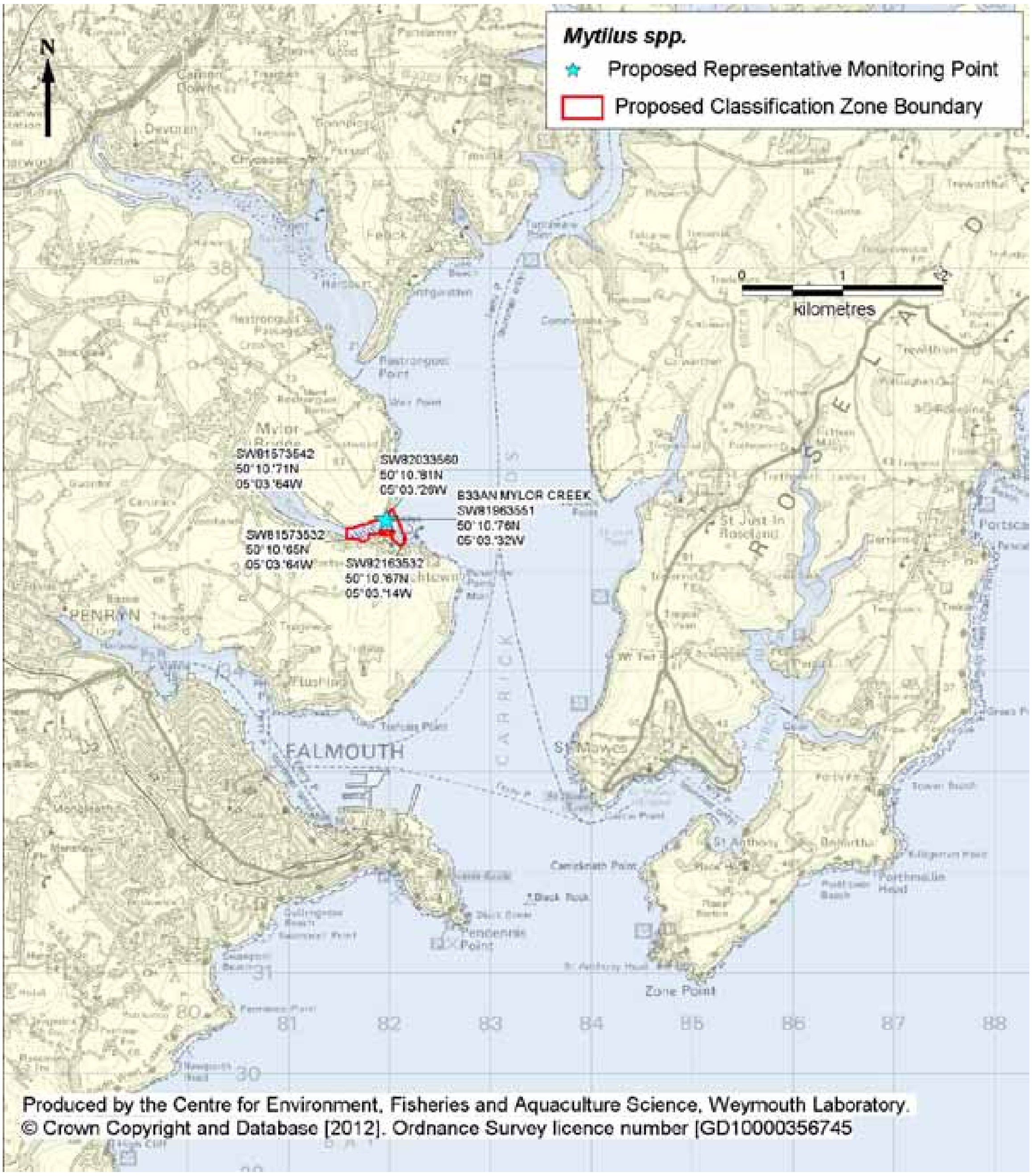


Figure 5.2 Location of recommended representative monitoring point (RMP) and classification zone boundaries for mussels in the lower Fal Estuary.

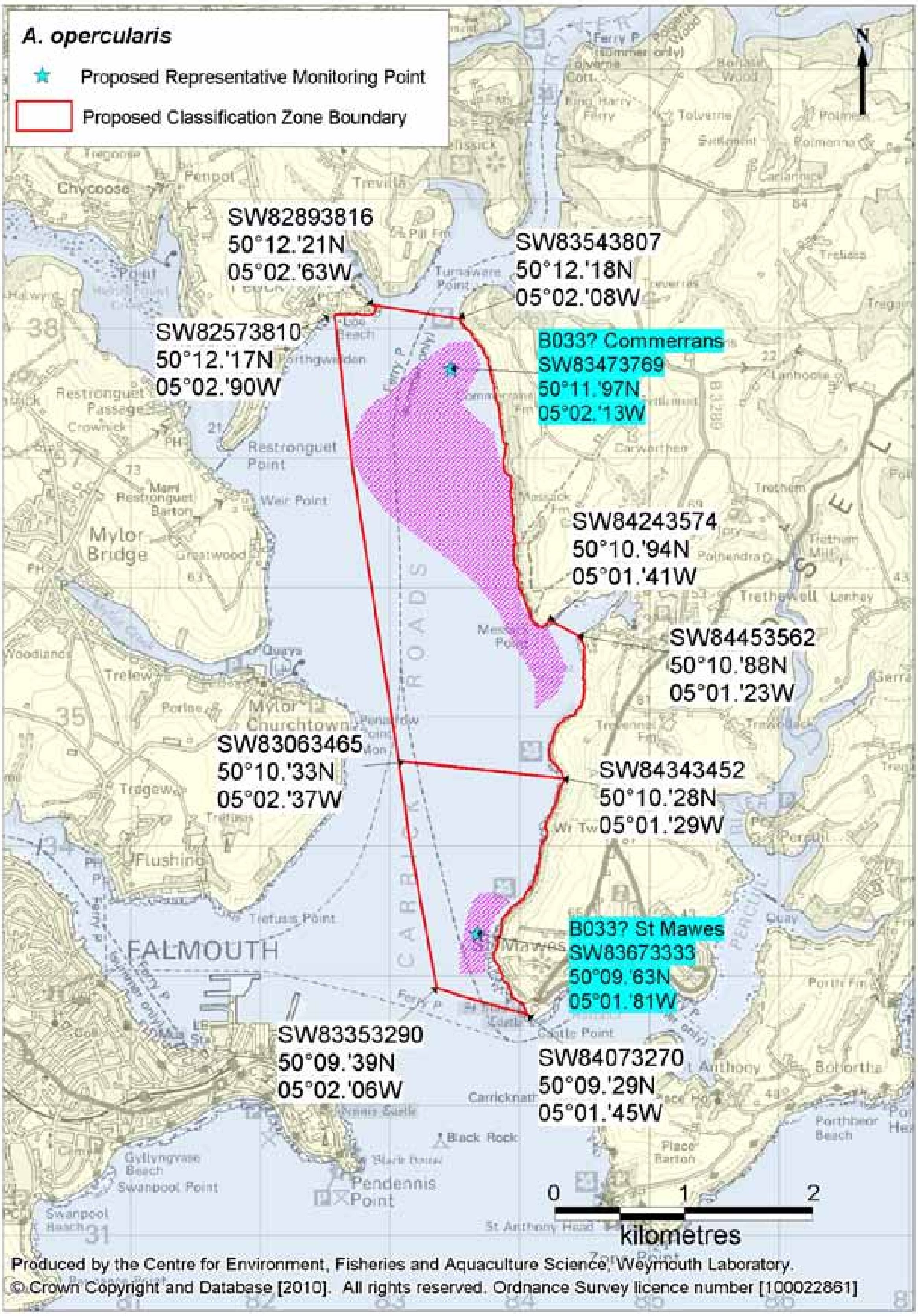


Figure 5.3 Location of recommended representative monitoring point (RMP) and classification zone boundaries for queen scallops in the lower Fal Estuary.

REQUIREMENT FOR REVIEW

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

APPENDICES

APPENDIX I
HUMAN POPULATION: DENSITY AND ACTIVITIES

The distribution of resident human population by Super Output Area Boundary[16] totally or partially included within the river catchment areas draining to the Fal Estuary is shown in Figure I.1. Eastern parts of the Fal tidal catchment are considerable less populated than western and northern areas.

The maximum density is 79 people per hectare at Falmouth. The main urbanised areas within river catchments are Falmouth/Penryn (total population = 20,775) and Truro (17,431) (Office for National Statistics, pers. comm.). These urbanised areas account for the majority of the population within Helford-Lizard-Carrick Roads and Carnon-Kennal Vale river catchments (see Table I.1).

Table I.1 Human population in the Fal river catchments.

River catchment	Resident population
Fal	13,424
Fal (tidal), Tresillian, Truro	11,299
Tresillian, Trevella, Kenwyn	22,882
Carnon and Kennal Vale	14,971
Helford, Lizard, Carrick Roads	50,755
Total	113,331

Source: Office for National Statistics, Crown copyright 2007. Crown copyright material is reproduced with the permission of the Controller of HMSO.
NB. Based on provisional mid-2005 population estimates for river catchment areas within England and Wales.

Urbanised areas contain the majority of point-sources of pollution (continuous and intermittent sewage discharges) in these catchments. An inventory of the significant sewage discharges to the estuary is presented in the Appendix VII. Urbanised areas also contain the vast majority of impervious surfaces[17] (e.g. roads, parks, pavements), which are known to contribute with significant loads of microbiological contaminants (Ellis and Mitchell, 2006)[18]. In general, bivalve molluscs commercially harvested in the vicinity of urbanised areas tend to show deteriorated microbiological quality.

Human population in these catchments fluctuates seasonally due to tourism. 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).

[16] Super Output Area (SOA) boundaries are in part derived from Ordnance Survey information and some SOA boundaries which follow ward or parish boundaries reproduce limited parts of the OS Boundary-Line product.
[17] In the context of the present report, impervious surfaces are any surface in the urban landscape that does not infiltrate rainfall.
[18] Concentrations of *E. coli* (MPN 100ml^{-1}) quoted in literature are: 10–10^{3} for residential areas and highways and 10^{2}–10^{4} for roof runoff and commercial areas (Ellis & Mitchell 2006)

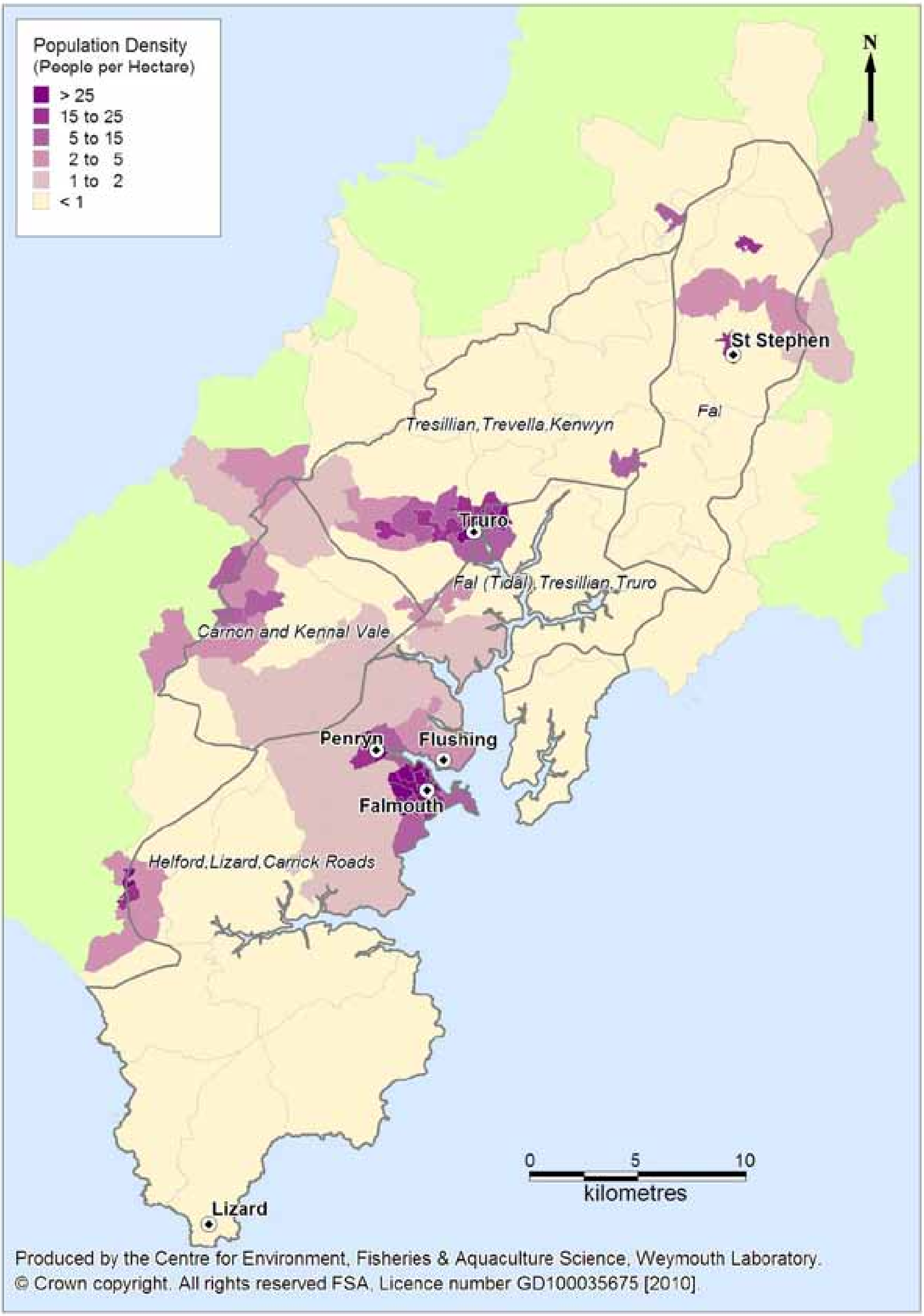


Figure I.1 Human population density in the Fal river catchments.
Source: ONS, Super Output Area Boundaries. Crown copyright 2004.
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Many tourists staying in resorts in Falmouth area spend 7 nights (South West Tourism Research Department, 2002). The most popular activities are walking, shopping and water-based activities (e.g. sailing, surfing, swimming, fishing) (South West Tourism Research Department, 2007).

The Falmouth Tourist Information Centre surveyed tourism activities in the town during the 2005 summer tourist season (July–September). It was found that half of all visitors were visiting a tourist attraction. The National Maritime Museum Cornwall, Pendennis Castle (Visit Cornwall, 2009) and Penryn Museum (Discover Falmouth, 2009) are some of the most visited attractions.
Truro Cathedral is also significant, with an estimated number of 140,000 visitors in 2007 (Enjoy England, 2007).

The survey also found that 42% of overnight visitors spent half a day on the beach and 25% of these swam in the sea. An assessment of the overall water quality in two designated bathing waters (Gyllynvase and Swanpool) in the proximity of BMPAs is given in the Appendix XI.

Boat trips between Falmouth and Truro (see Discover Falmouth, 2009) will also increase human impact in the estuary on a seasonal basis (May–September). An assessment of the potential impact of boats and boating activities in the water quality of the estuary is given in the Appendix X.

Seasonal changes in human population due to tourism will result in increased microbiological loads from sewage treatment plants on a seasonal basis (Younger *et al.*, 2003). An assessment of the impact of the most significant sewage discharges to the estuary is given in the Appendix VII.

APPENDIX II
HYDROMETRIC DATA: RAINFALL

The southwest of England is one of the wettest regions in the UK. The pattern of rainfall variation is heavily influenced by the topography, which forces the moisture-laden air to precipitate high levels of rainfall throughout the upper reaches of the catchments. 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).

Figure II.1 shows the location of the main freshwater inputs to the estuary and Allet gauging station (tipping bucket; Easting/Northing: 79561/48535).

Figure II.2 shows that, on average, the period October–February is the wettest and May–September is the driest.

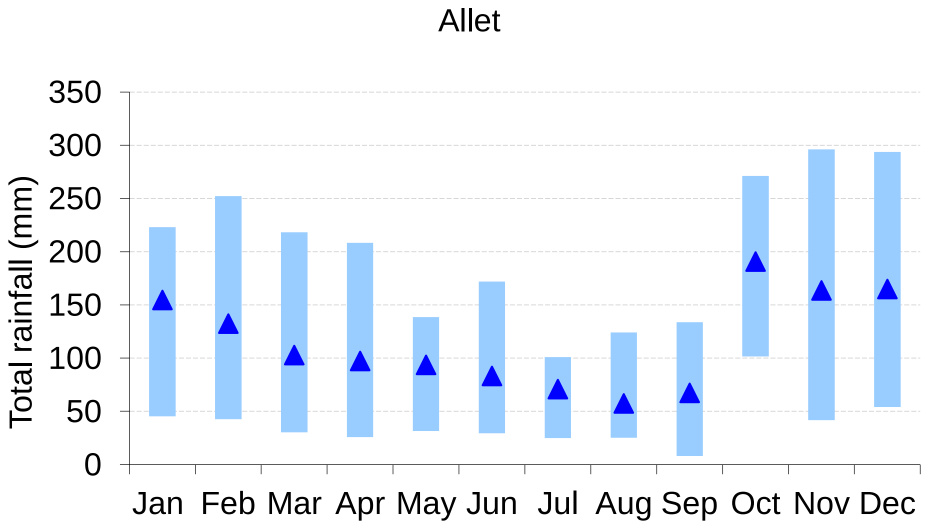


Figure II.2 Box-and-whisker plots of monthly variation in rainfall at Allet for the period 2005–2008.

Rainfall may lead to the discharge of raw or partially treated sewage from combined sewer overflows (CSO) and other intermittent discharges as well as runoff from faecally contaminated land (Younger *et al.*, 2003). Representative monitoring points located in parts of shellfish beds closest to discharges and freshwater inputs will reflect the combined effect of rainfall on the contribution of individual pollution sources. Results from analyses of the relationships between the levels of *E. coli* in bivalve molluscs from ten RMPs in the lower Fal Estuary and rainfall levels are given in the Appendix XII.

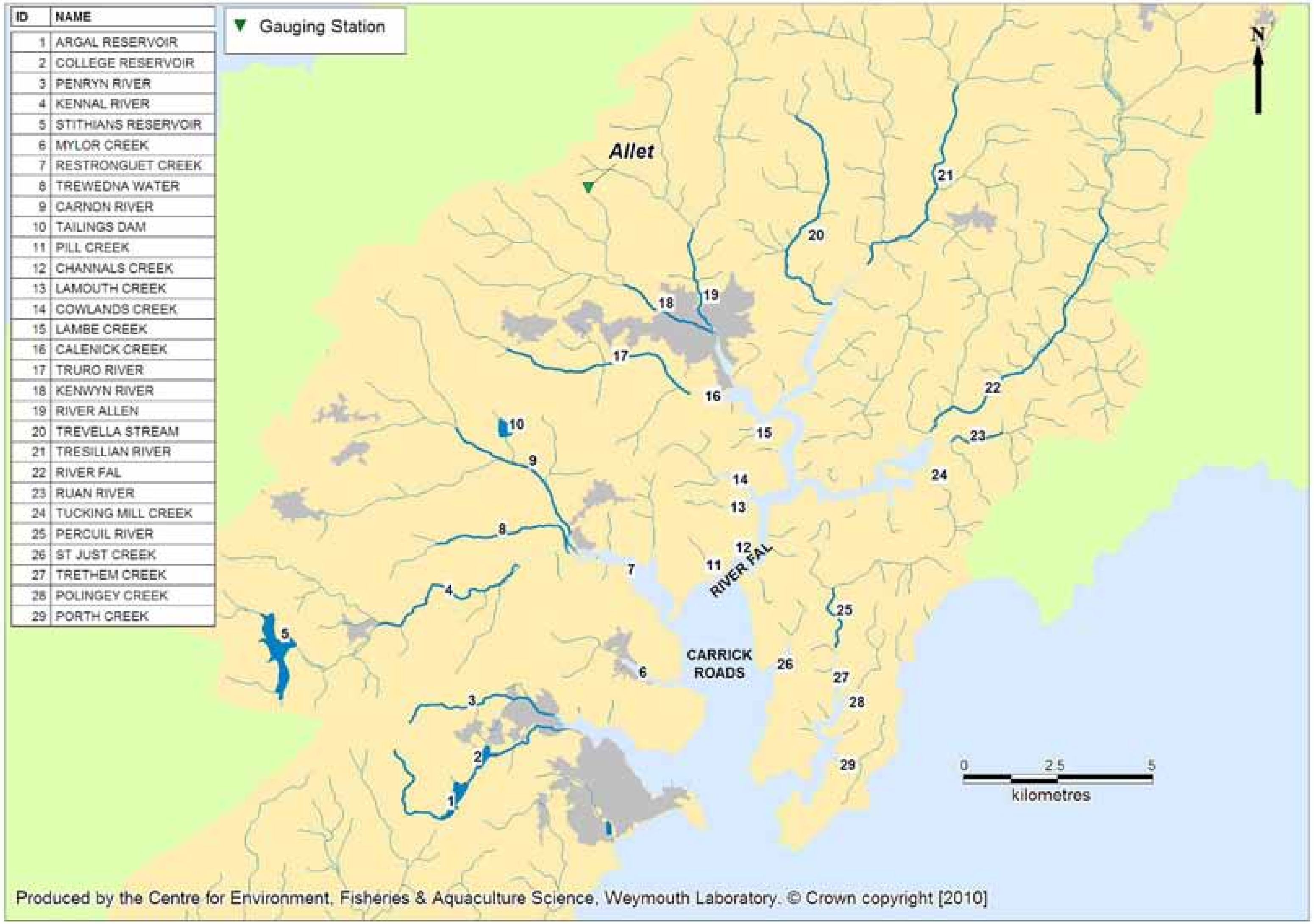


Figure II.1 Freshwater inputs to the Fal Estuary and location of rain gauging station mentioned in this report.

APPENDIX III
HYDROMETRIC DATA: FRESHWATER INPUTS

The Rivers Fal, Allen, Kenwyn are the main freshwater inputs to the Fal Estuary (Figure III.1). There are a number of other smaller tributaries in the catchment, such as the Tresillian River, Carnon River, Kennal River and Penryn River. Two watercourses discharge to Trethem Creek and Polingey Creek. These join at Nancorras to form Percuil River. Porth Creek is a less significant freshwater input at the mouth of the river (Figure III.1).

The upper River Fal has its headwaters near St. Dennis to just downstream of the point where Coombe Stream joins Grampound Road; the lower River Fal covers the river catchment area from this point to the tidal limit at the confluence with Ruan River at Ruan Lanihorne.

Table III.1 indicates a potentially significant higher contribution of the River Fal than that from the River Kenwyn for overall microbial delivery to the lower estuary.

Table III.1 Summary statistics of flows at rivers Fal and Kenwyn During the period January 2005–December 2008.

River	Fal	Kenwyn
Catchment area (km^2)	64.4	78.1
Mean flow ($m^3 s^{-1}$) (2005–2008)	1.724	0.314
2005	1.493	0.278
2006	1.483	0.266
2007	1.974	0.369
2008	1.945	0.344
Lowest flow ($m^3 s^{-1}$) (date)	0.278 (26 September 2006)	0.036 (21–23 September 2006)
Highest flow ($m^3 s^{-1}$) (date)	9.99 (9 February 2007)	3.15 (4 March 2007)

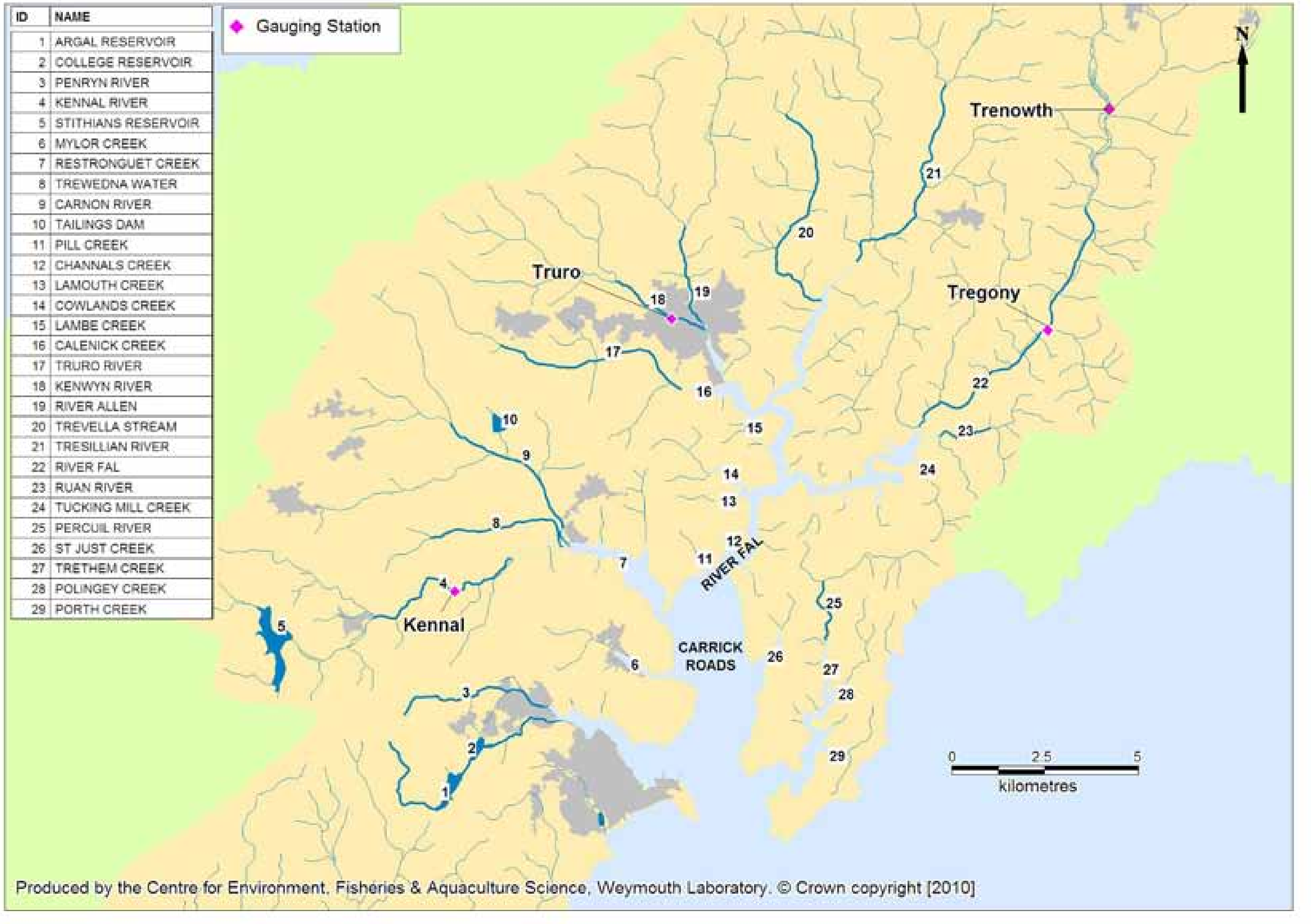
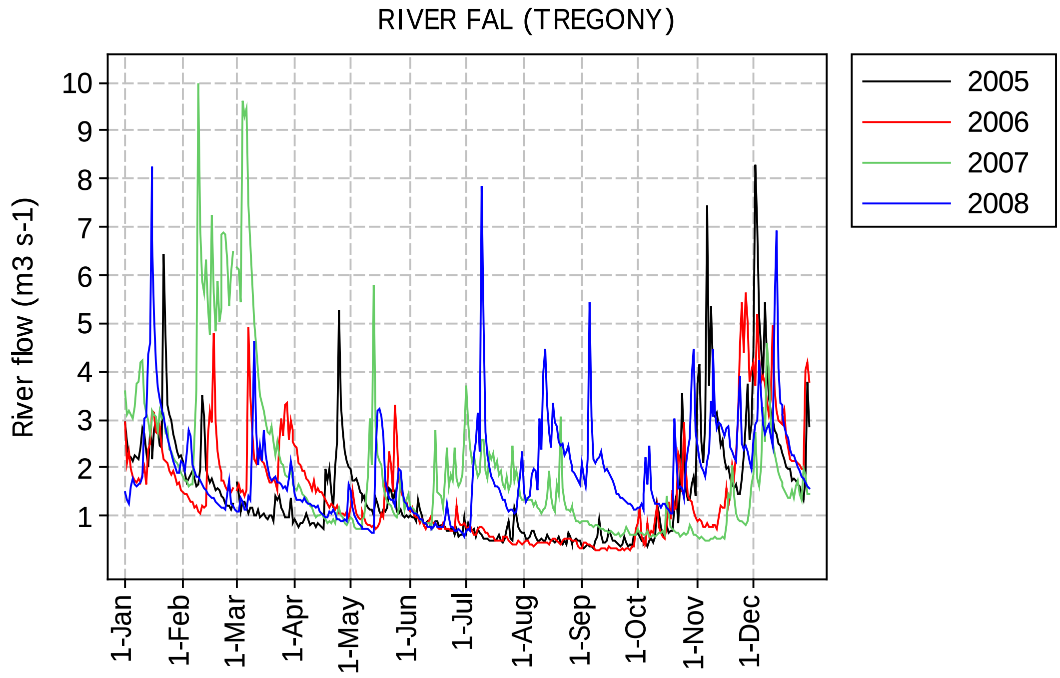


Figure III.1 Freshwater inputs to the Fal Estuary and location of gauging stations mentioned in this report.

Figure III.2 shows increased flow rates in the rivers Fal and Kenwyn during autumn-winter months. Peak flows occur throughout the year, in particular in the River Fal.



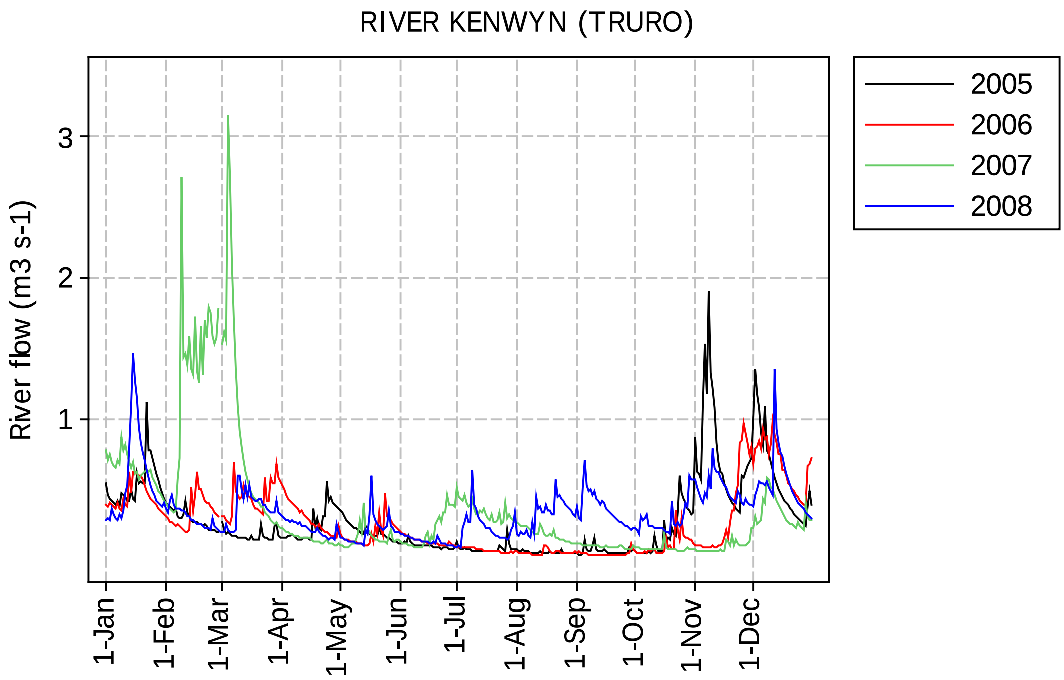


Figure III.2 Hydrograph for rivers Fal and Kenwyn during the period 2005–2008.

The steep topography of the catchment combined with the relatively high rainfall totals and low permeability of the geological formations result in a “flashy” hydrological regime in these rivers, i.e. with a quick time to peak and a relatively sharp recession limb characteristic of hydrographs (Environment Agency, 2006).

Figure III.3 shows a clear seasonal pattern in the rainfall-runoff response in the Fal river catchment. During autumn months, the response is mostly driven by significant increases in rainfall levels in October to peak in December. The period of high runoff (November–March) represents a potentially higher risk of contamination for native oysters and scallops, which are commercially harvested in the estuary during these months.

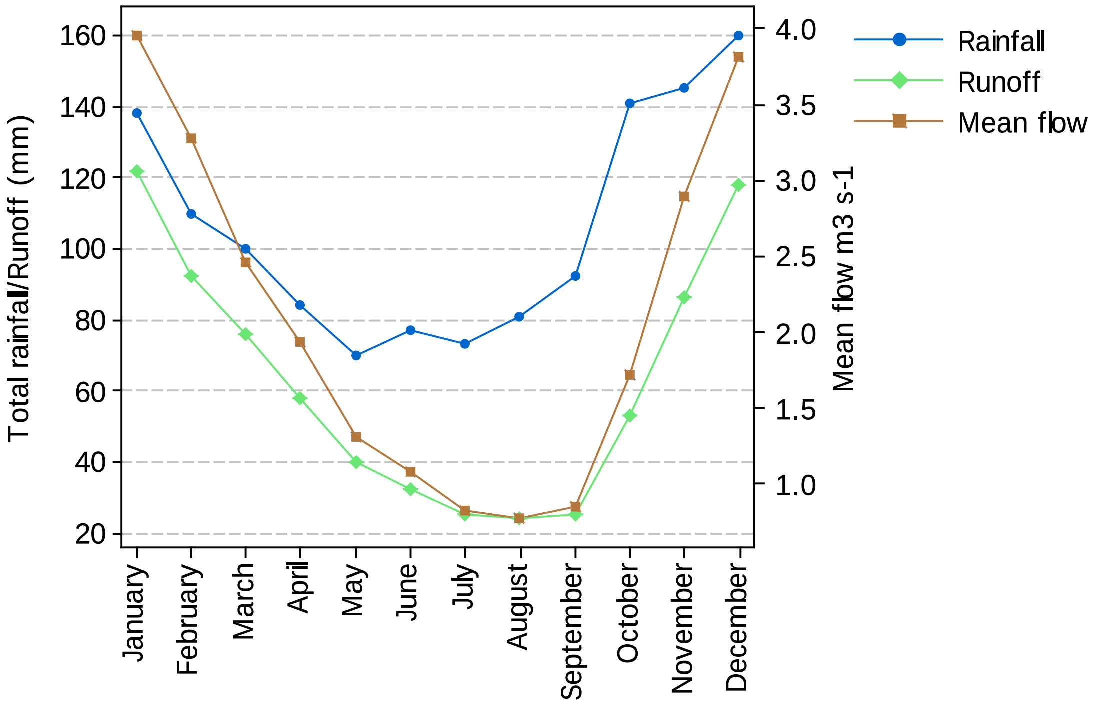


Figure III.3 Monthly variation of rainfall, runoff and mean river flow for the River Fal at Tregony for the period July 1978–December 2005.
Data from the National River Flow Archive (NERC, 2009).
NB. In the context of this report, runoff can be understood as the passage of water on the surface of the Earth.

APPENDIX IV
HYDRODYNAMIC DATA: BATHYMETRY

The upper reaches of Carrick Roads relevant to this assessment are fairly shallow and dendritic. Restronguet Creek, Penryn River and Percuil River have one or more secondary channels. Significant areas of these creeks dry on low water springs.

In contrast, areas of the main meandering channel at St. Just Pool (middle section of Carrick Roads) and the mouth are relatively deep. Maximum depths just south of East Narrows and at the mouth of Saint Mawes Harbour are 33m relative to Chart Datum (CD)[19].

Charted depths in areas where bivalve mollusc beds are established are shown in Figures IV.1–IV.4. The area requiring classification for Queen scallops includes parts of the meandering channel, which is 27m maximum depth at St. Just Pool and extensive areas between 0 and 5m depth, including those North of Messack buoy, the southeast part of Mylor Pool and St. Mawes Bank (Figure IV.1).

Maximum depths within Percuil River to the limit of Falmouth Harbour at Polvarth Point are 4.6m. The area where the Pacific oyster bed is located dries at low water springs (1.8m above LWS) (Figure IV.2).

The mouth of Mylor Creek is 0.3–0.4m deep (Figure IV.3).

The native oyster beds occurring North of Cross Roads buoy are 0–5m deep. The bed within Falmouth Harbour just North of Greenbank Quay is in drying areas (1.2m above LWS) (Figure IV.4). The native oyster bed at Percuil River includes both drying areas and areas between 0 and 5m depth at CD (Figure IV.4).

[19] Approximately the level of Lowest Astronomical Tide.

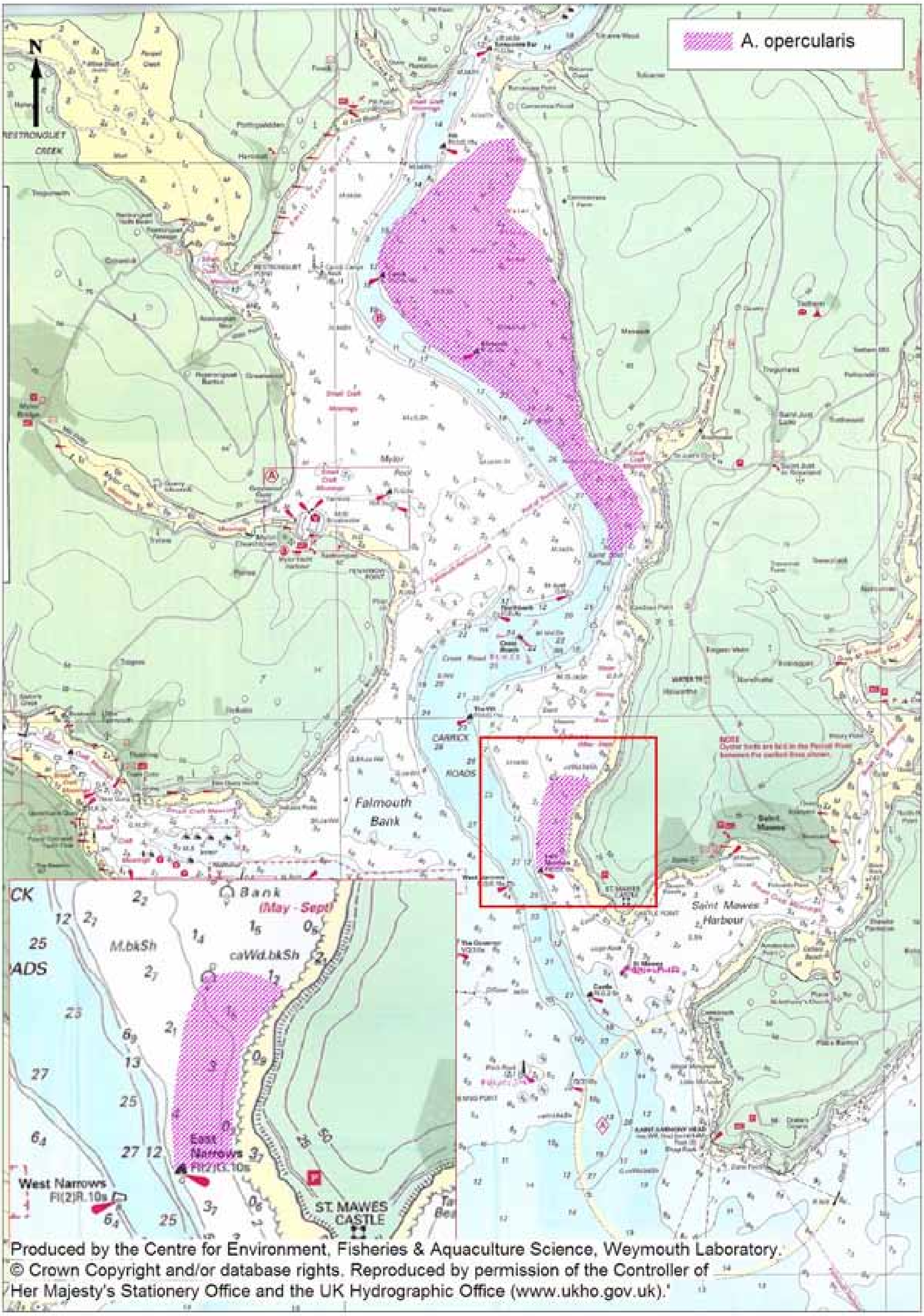


Figure IV.1 Bathymetry in Carrick Roads and East Narrows showing location of the proposed scallop bed.

Reproduced from Imray Chart Y58 - River Fal (Falmouth to Truro) with the permission of the publishers.

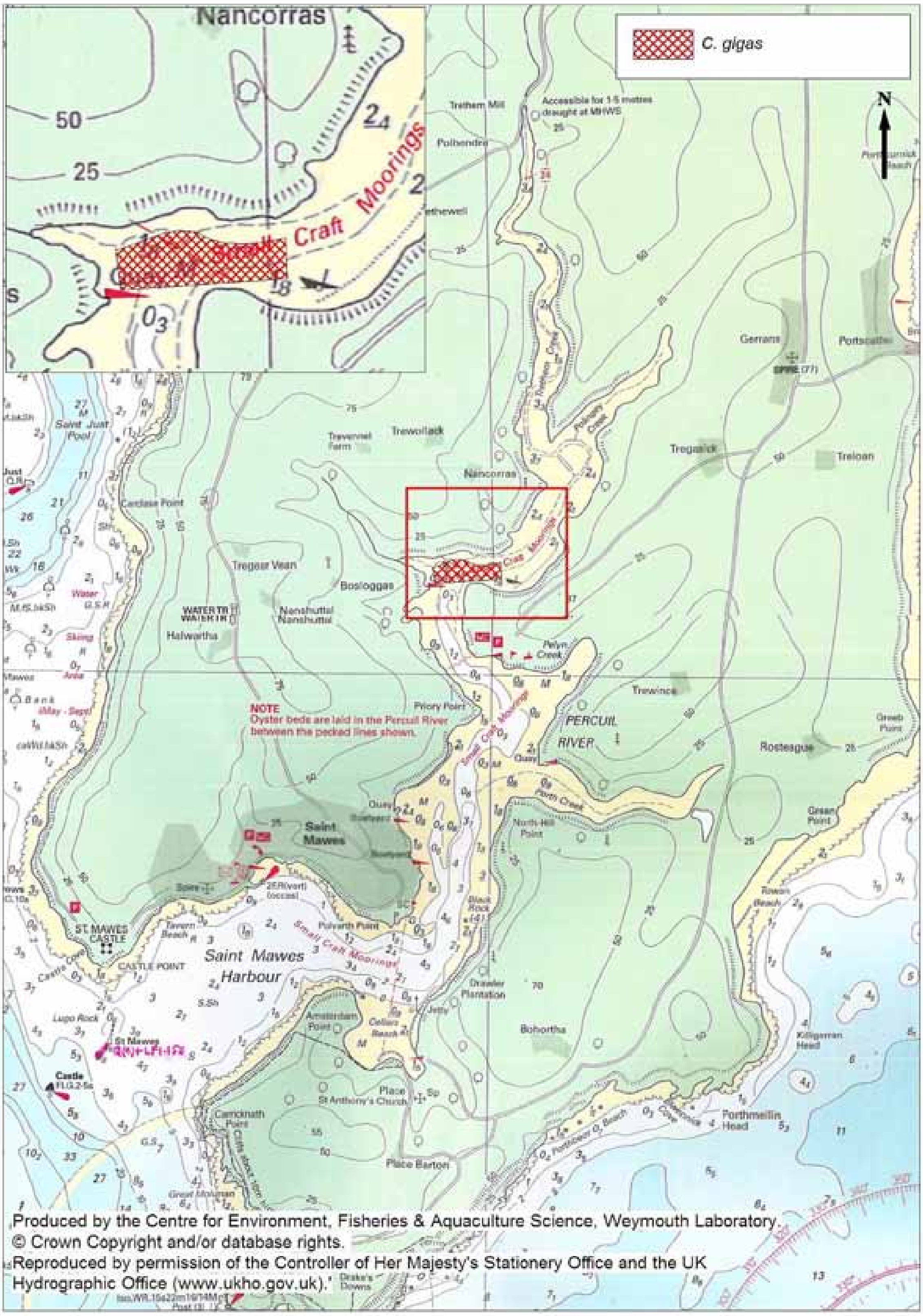


Figure IV.2 Bathymetry in Percuil River and St. Mawes Harbour with location of Pacific oyster bed.

Reproduced from Imray Chart Y58 - River Fal (Falmouth to Truro) with the permission of the publishers.

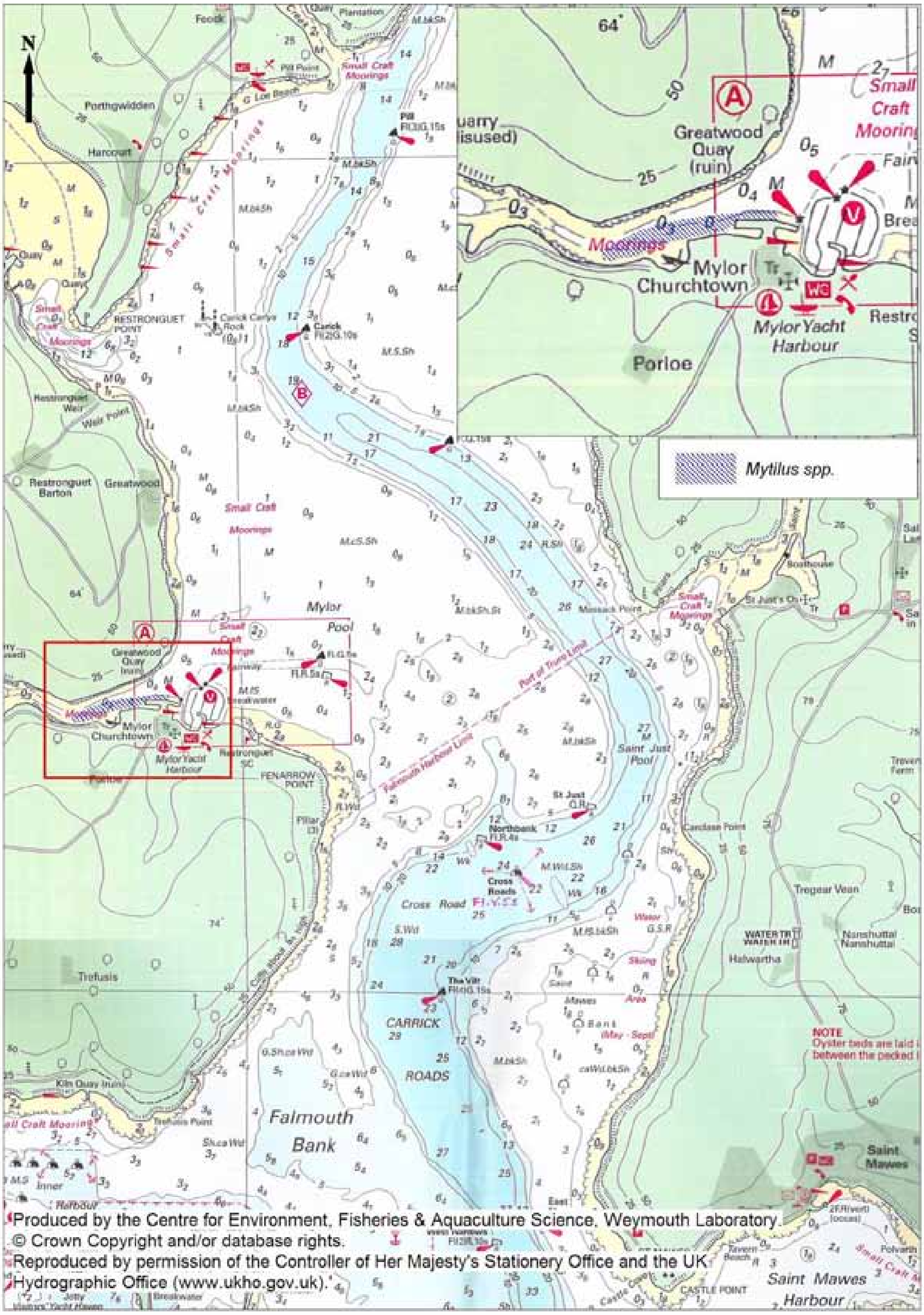


Figure IV.3 Bathymetry in Carrick Roads and Falmouth Bank showing location of mussel bed at Mylor Creek.

Reproduced from Imray Chart Y58 - River Fal (Falmouth to Truro) with the permission of the publishers.

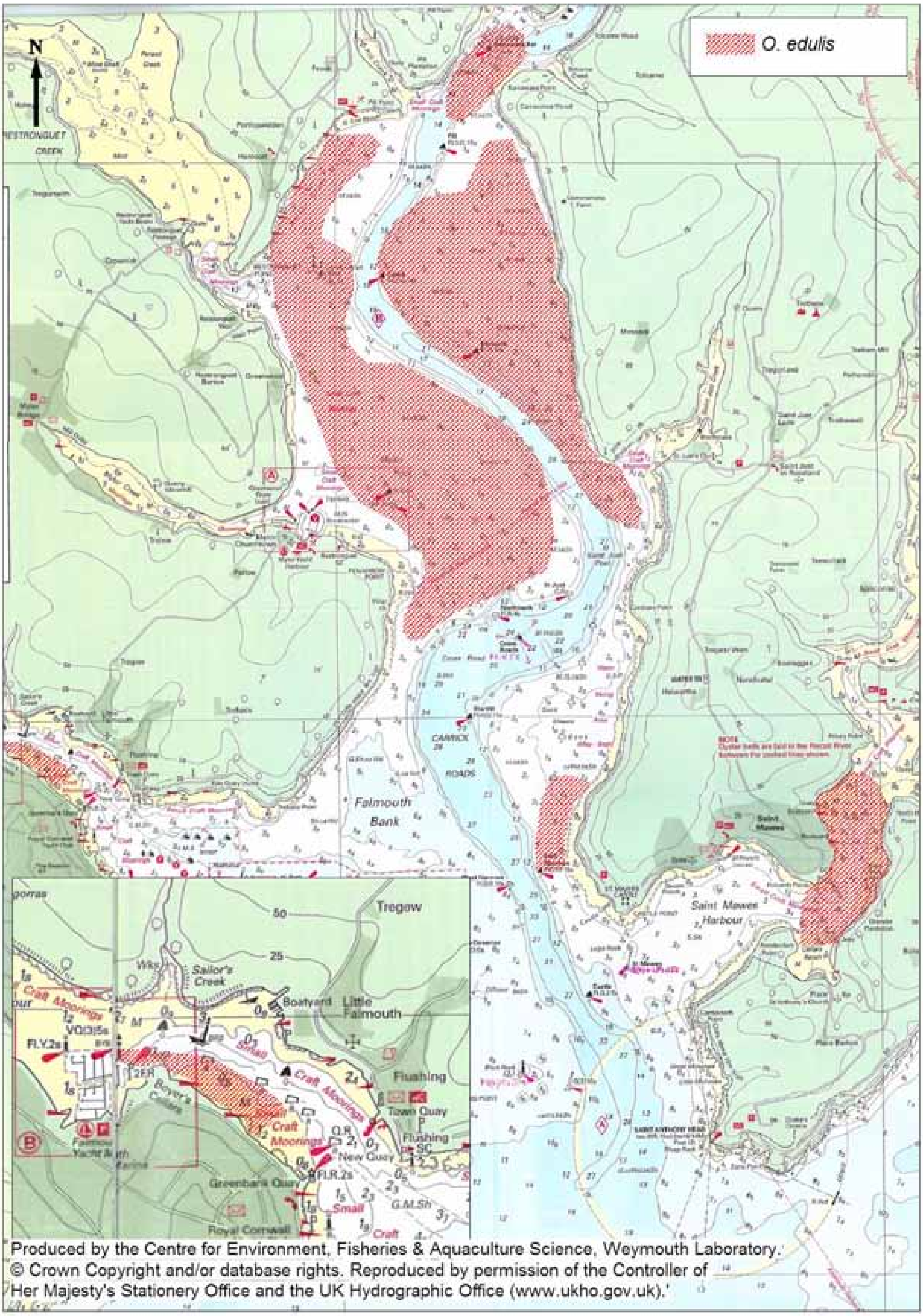


Figure IV.4 Bathymetry in Carrick Roads and Mylor Pool showing location of Native oyster beds.
Reproduced from Imray Chart Y58 - River Fal (Falmouth to Truro) with the permission of the publishers.

Sedimentation of microbiological contaminants and re-suspension of potentially contaminated sediment are expected to dominate within the muddy shallow creeks of the Fal Estuary. Extensive drying areas often produce continued drainage long after the tide has receded and the mudflats are exposed (see Whitehouse *et al*., 2000). Contaminated runoff from retained seawater and/or washed off by rainfall falling on the surface of mudflats into these creeks will be conveyed along the channel(s). Therefore, nearshore shallow areas are likely to represent worst-case conditions. In contrast, deeper estuarine areas at Carrick Roads will contain more water for dilution and dispersion of contaminants.

Native oysters and queen scallops in subtidal areas have the potential to accumulate microbiological contamination over the whole tidal cycle. Pacific oysters and mussels cultivated in intertidal areas are exposed during significant periods of the tidal cycle. Furthermore, solar radiation will increase decay rates of microbial contaminants in shallow areas, although there is growing evidence that wetting/drying may allow some microorganisms to persist or even replicate. Consideration is given to these factors for the purposes of informing the sampling plan.

APPENDIX V
HYDRODYNAMIC DATA: TIDES AND CURRENTS

The Fal Estuary has an asymmetrical macro-tidal regime with semi-diurnal tides (i.e. two tidal cycles per day) at Falmouth. At Truro, tidal amplitude is within the mesotidal range. Table V.1 displays information on predicted tides and ranges for Falmouth and Truro ports.

Table V.1 Tidal constants for Falmouth and Truro.

	Height (m) above Chart Datum				Range (m)	
Port	MHWS	MHWN	MLWN	MLWS	Spring	Neap
Falmouth	5.4	4.3	2.1	0.8	4.6	2.2
Truro	3.5	2.4	Dries	Dries	-	-

Predictions for these secondary ports are based on Plymouth (Devonport).
Data from Imray Chart Y58 - River Fal (Falmouth to Truro).

Tidal lengths (mouth to the limit of reversing tidal currents) are estimated to be approximately 20km to Tresillian and 17km to Truro (Uncles *et al*., 2002) and 19km to Ruan Lanihorne, in the confluence of Ruan River with the River Fal. Microbial contaminants may be transported over these distances with the tidal wave along the estuary. Furthermore, differences in tidal length between tributaries will determine that tides will act differently in this transport and, therefore, in the volume of contamination impacting BMPAs. Most significantly, the stronger tidal wave along the rivers Kenwyn and Allen will increase the impact of pollution sources of human origin since these are concentrated at Truro.

The lower estuary is ebb dominant, i.e. the ebb tide is longer and slower than the flood tide (South West Water Ltd., 1998), although the currents at the mouth appear to be slightly flood dominated (Futurecoast, 2002). Ebb dominance and the long tidal excursion means that contamination from sources at Falmouth/Penryn may not be particularly relevant to the overall water quality in the upper Carrick Roads. However, other studies have suggested that certain parts of the estuary are flood dominant (Halcrow Group Ltd., 2002; Royal Haskoning, 2009a). This may result of periods when contamination will be retained longer than would be the case for an ebb dominant regime.

Within the estuary, the tidal wave tends to act as a standing wave with maximum currents at mid flood and mid ebb and slack water near high and low water throughout the estuary occurring almost simultaneously (South West Water Ltd., 1998).

Figure V.1A shows the pattern of tidal vector at peak flood and ebb tides. Peak spring ebb tidal currents have maximum speeds off Pendennis Point, where there is convergence of the headlands. At this point, current speeds are largely rectilinear and less than 0.5m s^{-1} (Figure V.1B). This is consistent with velocities of around 0.5m s^{-1} during the flood and 0.4m s^{-1} during the ebb on a spring tide found by Posford Duvivier Oceanography Consent Support document (Posford Duvivier and South West Water *in* South West Water, 1998).

On neap tides, velocities of 0.2m s^{-1} during the flood and 0.15m s^{-1} during the ebb have been recorded at the mouth of the estuary (Posford Duvivier and South West Water *in* South West Water, 1998).

Within Penryn River peak spring ebb and flood tidal currents are less than 0.2m s^{-1} compared with up to 0.8m s^{-1} off Pendennis Point during the flood tide.

In conclusion, areas along upper Carrick Roads and the mouths of creeks have lower flushing times, and this may result in the retention of microbial contaminants from nearby pollution sources.

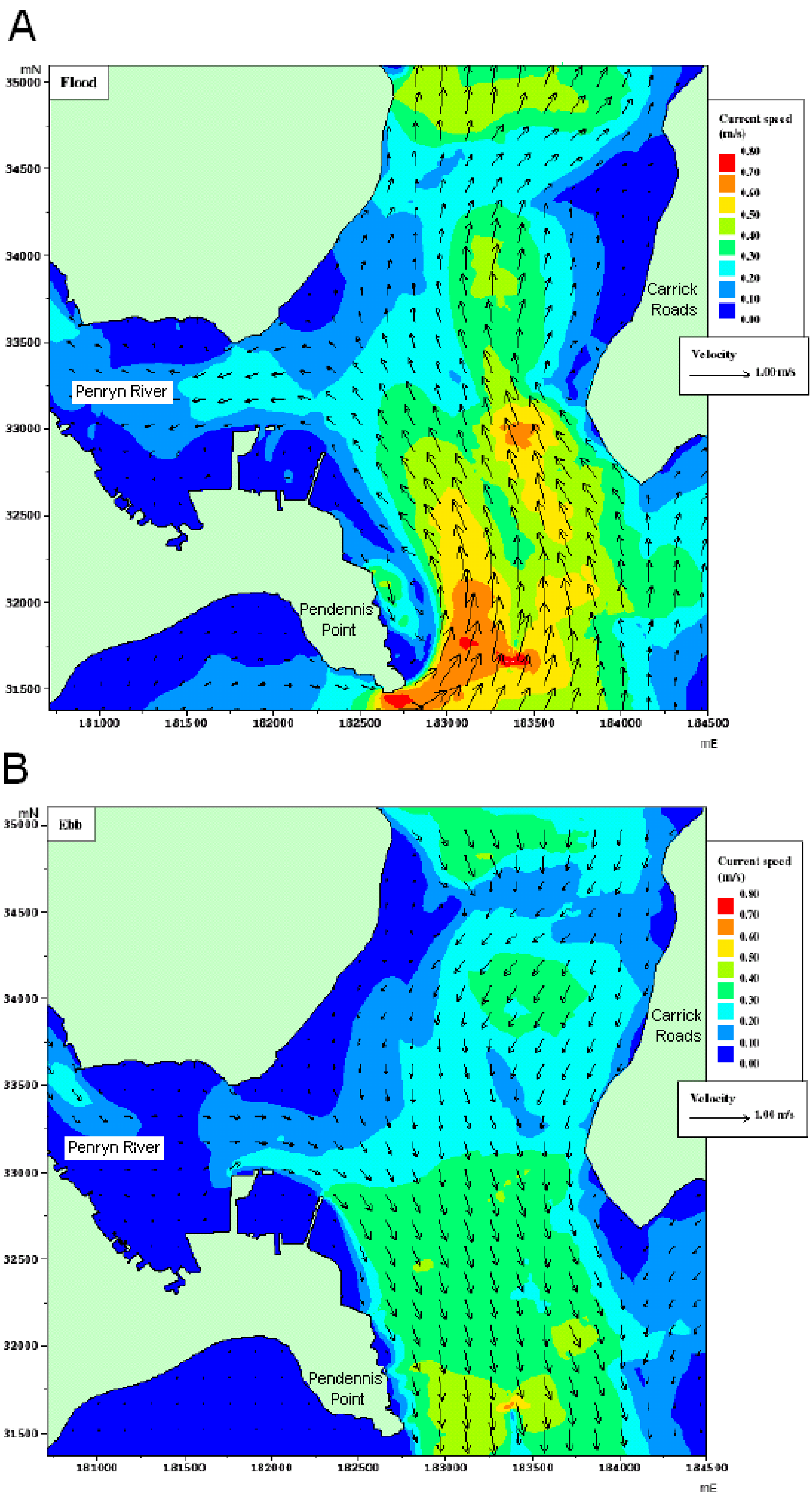


Figure V.1 Peak spring flood (A) and ebb (B) tidal currents at Carrick Roads.
Reproduced from Royal Haskoning (2009) under permission of Nicola Solly.

Wind waves may also affect sediment deposition and re-suspension in shallow waters and affect transport and delivery to harvesting areas.

Penryn River does not appear to be long or large enough to efficiently disperse microbial contaminants, particularly considering the high number of point-source discharges along the river (Appendix VII) and the presence of significant boating activity (Appendix X).

The dynamic equilibrium of the estuary is more complex at the mouth, where estuarine flows interact with tidal currents and waves from the open coast (HR Wallingford, 2006). The turbulence created by these interacting factors may promote mobilisation of contaminants during the ebb tide. Negative impacts to shellfish beds may occur during the flood tide and following periods of high sewage discharges from Falmouth STW.

Literature indicates that the incoming and outgoing flows at the Falmouth Harbour entrance are complicated by eddies during both the flood and ebb stages of the tide by virtue of interaction of different water bodies (see Royal Haskoning, 2009a). The impact of these processes on the microbial status of BMPAs is difficult to assess without a more accurate knowledge of their scale and persistence.

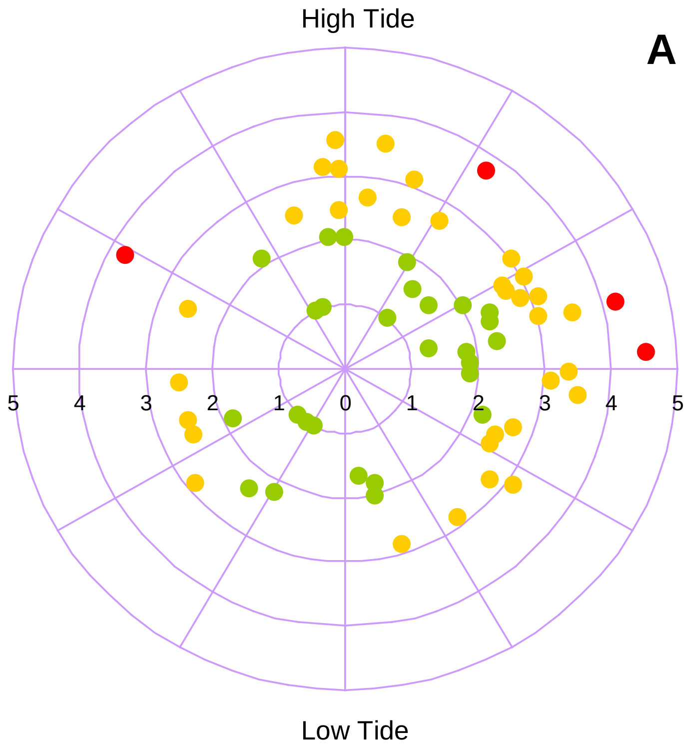
The maximum depth averaged concentrations of suspended particulate matter are estimated to be 28mg l^{-1} (if tidal limit to Tresillian is considered) and 20mg l^{-1} (if tidal limit to Truro is considered) (Uncles *et al.*, 2002). These are higher than those characteristic of other estuaries in the southwest UK. A major source of turbidity in the estuary is currently considered to be sediment re-suspension (Halcrow Group Ltd., 1998; Langston *et al*., 2006), the levels of turbidity in parts of the cSAC suggest outside sources. Sewage discharges in the Truro/Tresillian could increase turbidity locally, and during algal blooms, it is likely that the suspended organic component includes significant amounts of microalgae. Temporally and spatially limited resuspension events also arise from dredging activity and may remobilise contaminants locally (Langston *et al*., 2006)[20]. Seabed sediments in the lower Fal Estuary are essentially muddy, with significant areas of sandy bottoms at Mylor Pool, Falmouth Bank and the lower Percuil River (Royal Haskoning, 2009a). Although literature has indicated significant long-term reductions of turbidity levels near King Harry Ferry and at the mouth of Restronguet Creek (Langston *et al*., 2003), more limited re-suspension events such as dredging activities could also remobilise contaminants locally (Langston *et al*., 2006). Recent numerical modelling simulations of sediment release in the water column at Falmouth Bank to assess the impact of capital dredging evidenced a general confinement of suspended sediment concentrations associated with the plume to the western side of Falmouth Harbour under spring tidal conditions (Royal Haskoning, 2009a). Areas of the estuary where maximum sediment concentrations are expected to occur are considered when recommending best locations of RMPs.

[20] In the past, Maerl extraction was a significant source of turbidity in the lower estuary. This extraction ceased in 2004.

Lee and Morgan (2003) found that tide is one of the main environmental factors influencing the levels of *E. coli* in native oysters. Their study highlighted that the effect varied between three production areas and studied individual sampling points within these production areas.

Correlations between the levels of *E. coli* in bivalves monitored at ten current RMPs in the lower Fal Estuary and tidal levels (high/low tide) and range (springs/neaps) were performed for time periods summarised in Table XII.1 (see Appendix XII) using circular statistics. In most cases, no statistically significant differences were found between tidal stage and levels of *E. coli* in bivalves.

Figure V.2 shows two examples of graphical displays for which significant correlations were found between levels of the indicator and spring/neap cycle (*r* circular linear correlation coefficient = 0.452; p = 0.00000332). Despite the significance of the correlation coefficient, it is apparent that the *E. coli* results are not representative of the full range of tidal variation and therefore the analysis is not sufficiently robust to inform a recommendation on a modified sampling regime based on tides.



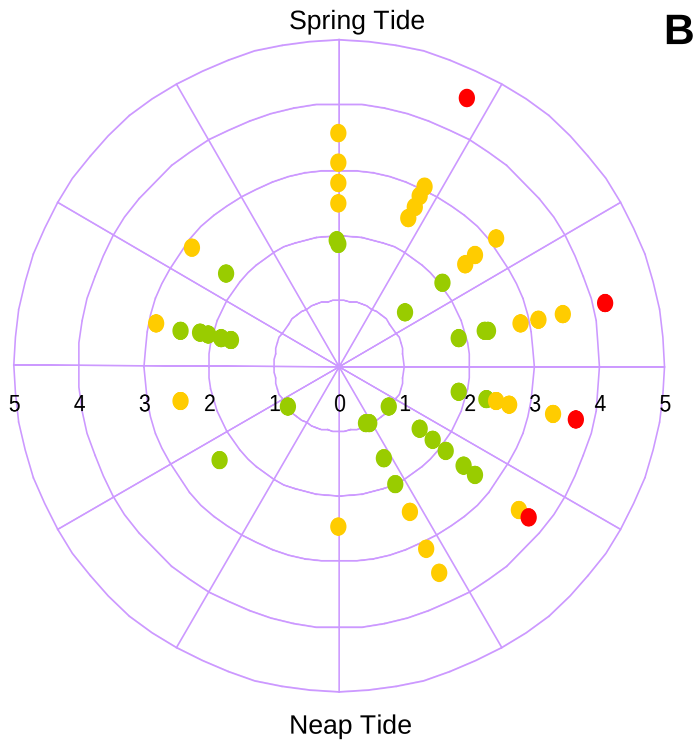


Figure V.2 Circular scatterplots of levels of* log$_{10}$ E. coli *in native oysters from Turnaware Bar; A - according to tidal levels and B – according to tidal range.
Green - class A (MPN of E. coli ≤ 230 100g^{-1} FIL).
Yellow - class B (MPN of E. coli ≤ 4,600 100g^{-1} FIL in 90% of samples).
Red - class C (MPN of E. coli ≤ 46,000 100g^{-1} FIL).

APPENDIX VI
METEOROLOGICAL DATA: WIND

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

Wind data for the period January 1992–December 1998 from Culdrose meteorological station (western limit of the Helford, Lizard river catchment) was analysed. Figure VI.1 shows that the prevailing wind is south-westerly. The analysis demonstrated that, during 35% of the time, wind always blew from the range of directions South–West.

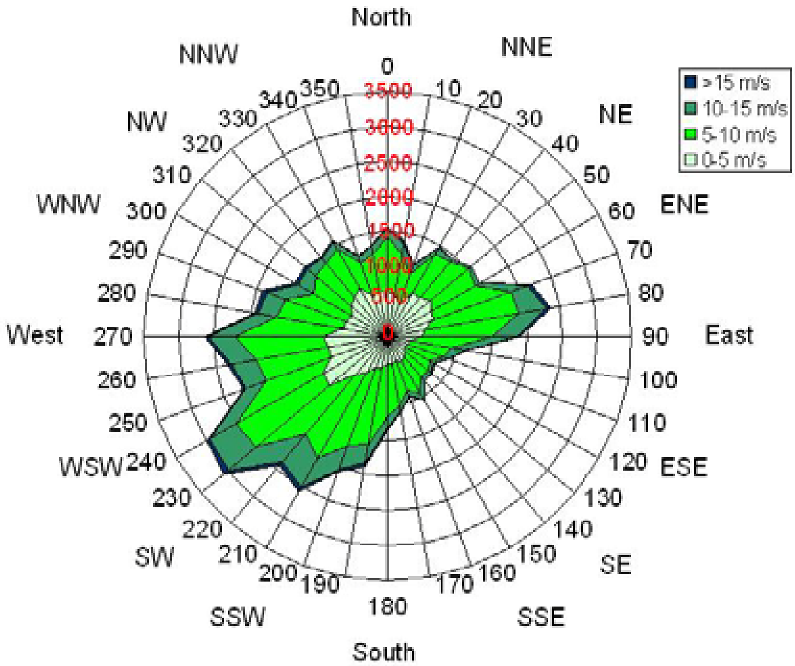


Figure VI.1 Wind rose showing mean wind speed direction and by hourly count over the period 01 January 1992–31 December 1998.
Derived from Culdrose meteorological station.
Data provided by the Environment Agency (2007).

Numerical modelling studies undertaken by Metocean and South West Water Ltd. indicates that steady uniform wind conditions of 10m s^{-1} from the southeast could promote a depth-averaged current of about 0.05m s^{-1} to the northwest near Falmouth Bay; a similar wind from the southwest could give rise to a current of similar magnitude towards the northeast (Metocean and South West Water *in* South West Water, 1998). Southerly winds are liable to produce northerly wind-induced currents within Carrick Roads (Posford Duvivier and South West Water *in* South West Water, 1998).

Whilst the contours of the land around the estuary will modify the prevailing wind to some extent, in the Fal the potential for wind driven advection of potentially contaminated surface waters is predominantly from the mouth towards the head of the estuary. Winds from the eastern sectors favour movement of the sewage plume from Falmouth STW into the Penryn River, whereas winds from the western sectors induce movement of this plume into Carrick Roads (South West Water, 1998).

Excursion drogues and dye tracing studies carried out by Wallace Evans and the Environment Agency have identified two potential plume impacts from discharges at Falmouth STW: (a) advection of a neap flood tide under moderate to strong east to southeast wind conditions towards Penryn River and (b) advection of a neap flood tide under light to moderate weasterly winds towards St. Mawes Bank impacting shellfish beds in the upper reaches of Carrick Roads (see South West Water Ltd., 1998 and references therein).

APPENDIX VII

SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: SEWAGE DISCHARGES

Sewage discharges pose a significant risk of contamination of faecal origin to bivalve molluscs. The risk varies depending on the characteristics and absolute levels of the domestic and trade effluent components and volume of discharge. Sewage effluents in the catchment draining to the Fal Estuary are treated in a number of sewage treatment works (STWs).

Figure VII.1 shows the locations of continuous and intermittent sewage discharges likely to be a source of microbiological contamination to bivalve molluscs. The larger STWs are associated with the urbanised areas of Falmouth, Penryn, and further upstream at Truro. Smaller discharges are located in the vicinity of Mylor Bridge, Carnon Downs and St Mawes. All of these continuous discharges receive UV disinfection, except Carnon Downs which is secondary treated. Continuous sewage discharges are listed in Table VII.1.

The sewerage infrastructure is also served by a number of combined sewer overflows (CSO), emergency overflows (EO) and overflows from sewage pumping stations (PS). Of particular significance to bivalve mollusc beds are those intermittent discharges in Carrick Roads, lower Fal Estuary, listed in Table VII.2. There are many intermittent discharges in the upper Fal Estuary that could potentially impact the microbiological status of BMPAs in the lower estuary, and these are also listed in Table VII.2. Many of the intermittent discharges to the Fal estuary are designed to discharge less than 10 significant (>50m^3) storm spills per year on average, aggregated with other impacting CSOs, in order to meet water quality standards in the Shellfish Water (EA Shellfish Waters Policy: Standards for Consenting Discharges to Achieve the Requirements of the Shellfish Waters Directive (Microbial Quality) (Environment Agency, 2001).

In addition to water company discharges, there are numerous small sewage discharges from private properties discharging either directly to the estuary or slightly inland. On Figure VII.1, black asterisks represent these discharges that may impact on shellfisheries and contribute to overall background levels of microbiological contamination.

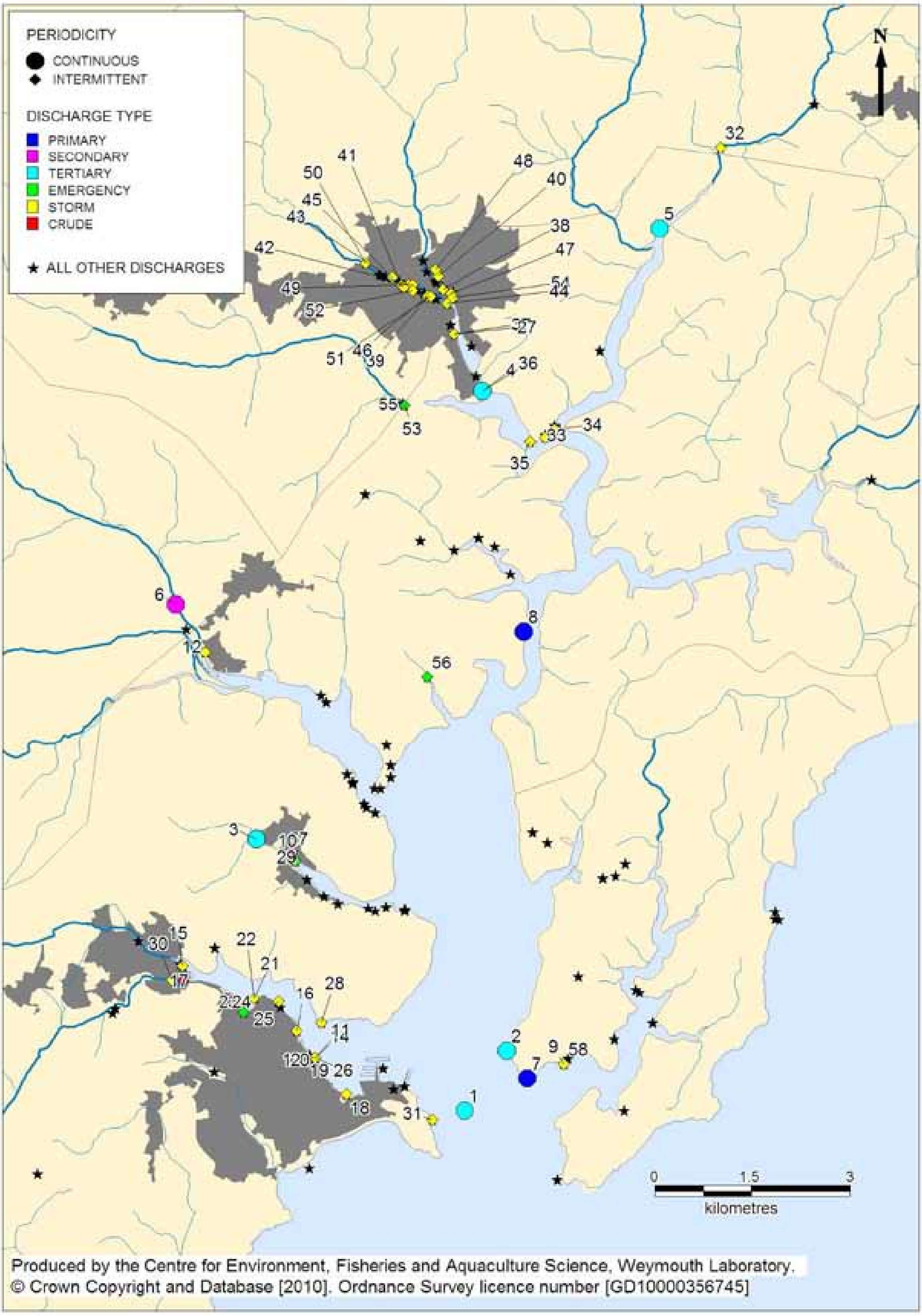


Figure VII.1 Significant sewage discharges to the Fal Estuary.

In terms of impacts from sewage discharges on the proposed new scallop bed, only St Mawes STW, which receives UV disinfection, discharges within 50m of the new scallop bed. There are very few other point sources of sewage pollution on the eastern bank of the Fal from St Mawes in the south to Turnaware Point in the north. Of the few discharges present in this area, many are septic tank soakaways or discharges from single dwellings (again shown as black asterisks on Figure VII.1).

Most notable of these non-water company discharges, in terms of proximity to the proposed scallop bed, is St Mawes Castle visitor toilets (discharge No. 7 on Figure VII.1). This primary treated effluent discharges approximately 40m from the currently classified BMPA and 0.7km to the nearest edge of the proposed scallop bed. Further north, approximately 2km upstream of the upper end of the new bed, there are two National Trust holiday cottages (discharge No. 8 on Figure VII.1) that discharge within 10m of the Class C mussel beds (reviewed under a different sanitary survey report for the Upper Fal Estuary) near King Harry Ferry, and approximately 2km from the proposed scallop bed. This discharge is due be upgraded to receive secondary treatment via a package works.

The Class C native oyster beds in the Penrhyn River are impacted by numerous intermittent discharges (See Fig VII.1 and Table VII.2) particularly from Falmouth on the south side of the estuary and upstream from Penrhyn. These beds will also be influenced by the water in Carrick Roads, which includes both the continuous UV treated discharge and the storm overflows from Falmouth STW, which is <1.5 km from the edge of this classification zone.

The Class B mussels and native oysters at the mouth of Mylor Creek are impacted by water quality in Carrick Roads but also from upstream impacts in the creek from Mylor Bridge STW, Mylor Bridge PS and Stepping Stones CSO. There are also several small, domestic discharges throughout Mylor Creek that will have some influence on local water quality.

At the mouth of Restronguet Creek there are Class B native oyster beds which are impacted by water quality in Carrick Roads and from several local domestic properties. Effluent from Carnon Downs STW, approximately 4km upstream of the shellfish beds, receives secondary treatment. This will be the main contributor of point-source contamination to bivalve mollusc beds in Restronguet Creek, and to a lesser extent, those in the northern areas of Carrick Roads.

Shellfish beds at Turnaware Bar will be impacted by pollution sources in the upper Fal, as illustrated in Figure VII.I and also from downstream sources due to tidal movements. As with the proposed scallop bed, the National Trust holiday cottages may also have a local impact as will Lower Trevilla PS CSO/EO which is approximately 0.7km from the edge of the BMPA.

There are very few point sources of pollution in the Percuil River, other than from a few domestic properties: the effluent from most of these undergoes biological treatment. At St Mawes, at the mouth of the Percuil River, there are two pumping stations, a private discharge and St Mawes castle visitor toilets which will influence water quality in the Percuil River.

Table VII.1 Significant continuous sewage discharges to the Fal Estuary.

Discharge No.	Discharge name	Treatment	DWF (m^3 d^{-1})	Population equivalent (annual)	Approximate (fluvial) distance to nearest edge of the nearest BMPA (km)	NGR
1	Falmouth STW	UV	9,500	33,046	0.4	SW 8314 3220
2	St Mawes STW	UV	800	1,066	0	SW 8379 3312
3	Mylor Bridge STW	UV	441	Unknown	2.0	SW 7993 3638
4	Truro (Newham) STW	UV	7,020	24,018	0	SW 8341 4329
5	Ladock Valley STW	UV	675	Unknown	3.0	SW 8614 4580
6	Carnon Downs STW*	Secondary	1,010	Unknown	4.0	SW 7868 4000
7	St. Mawes Castle Visitor Toilets*	Primary	2.5[1]	Unknown	0.04	SW 8410 3270
8	1 & 2 King Harry Cottages*	Secondary	0.28[1]	Unknown	2.0	SW 8404 3958

DWF - dry weather flow.
STW - sewage treatment works.
UV - ultra-violet disinfection.
BMPA - bivalve mollusc production area.
[1] *Maximum volume.*
** not listed on the EA PRP.*

Table VII.2 Significant intermittent sewage discharges to the Fal Estuary.

Discharge No.	Discharge name	Type	Approximate (fluvial) distance to nearest edge of the nearest BMPA (km)	NGR
9	St Mawes No 2 PS CSO	PS CSO/EO	0.2	SW 8467 3292
10	Stepping Stones - Mylor Bridge CSO	CSO	1.3	SW 8050 3606
11	Market Street CSO	CSO	0	SW 8083 3302
12	Devoran PS CSO	PS CSO/EO	3.3	SW 7913 3927
13	Smithick Hill CSO	CSO	0	SW 8083 3302
14	Prince Of Wales Pier PS CSO	PS CSO/EO	0	SW 8083 3302
15	Commercial Road PS CSO	PS CSO/EO	0	SW 7879 3443
16	Dunstanville Terrace CSO	CSO	0	SW 8054 3343
17	Commercial Road CSO	CSO	1.2	SW 7880 3420
18	Grove Place No. 1 CSO	CSO	0	SW 8131 3245
19	High Street CSO	CSO	0	SW 8083 3302
20	Killigrew Street CSO	CSO	0	SW 8083 3302
21	24 North Parade CSO	CSO	0	SW 7989 3392
22	North Parade Off Pendarves Road CSO	CSO	0	SW 7989 3392
23	Yacht Marina, Old Hill CSO	CSO	0.4	SW 7973 3371
24	Old Hill S.P.S. – CSO	SPS CSO/EO	0.4	SW 7973 3371
25	No. 2 Tehidy Terrace CSO	CSO	0	SW 8026 3388
26	Webber Street CSO	CSO	0	SW 8083 3302
27	Newham Road PS CSO/EO	PS CSO/EO	0	SW 8297 4416
28	Flushing SPS	SPS EO	0	SW 8093 3355
29	Mylor Bridge PS	PS	1.4	SW 8052 3604
30	St Thomas Street CSO	CSO	1.4	SW 7861 3422
31	Falmouth STW CSO	CSO	0.5	SW 8264 3206
32	Ladock Valley STW CSO	CSO	10.7	SW 8709 4704
33	Victoria Quay PS CSO/EO	PS CSO/EO	5.3	SW 8438 4257
34	Boatyard PS CSO	CSO	5.3	SW 8452 4269
35	Victoria Lodge PS CSO	PS CSO/EO	5.3	SW 8414 4251
36	Truro (Newham) STW CSO	CSO	7.0	SW 8341 4329
37	Newham PS CSO	PS CSO/EO	7.9	SW 8297 4416
38	Mitchell Hill CSO	CSO	8.7	SW 8280 4486
39	Lemon Mews CSO	CSO	8.8	SW 8256 4474
40	Campfield Hill CSO	CSO	8.8	SW 8273 4505
41	St. Georges Road CSO	CSO	9.2	SW 8216 4491
42	Edward Street CSO	CSO	9.2	SW 8227 4492
43	Francis Street CSO	CSO	9.2	SW 8220 4489

Table VII.2 Significant intermittent sewage discharges to the Fal Estuary (cont.)

Discharge No.	Discharge name	Type	Approximate (fluvial) distance to nearest edge of the nearest BMPA (km)	NGR
44	Fairmantle Street Car Park CSO	CSO	8.3	SW 8286 4464
45	Hendra Road CSO	CSO	9.2	SW 8202 4504
46	King Street CSO	CSO	8.7	SW 8257 4476
47	Trelander Highway CSO	CSO	8.4	SW 8292 4479
48	Pauls Terrace CSO	CSO	8.9	SW 8267 4515
49	Castle Street CSO	CSO	8.9	SW 8233 4492
50	Bosvigo Lane CSO	CSO	9.8	SW 8161 4525
51	Roberts Ope CSO	CSO	8.7	SW 8261 4475
52	Little Castle Street CSO	CSO	9.0	SW 8233 4483
53	Calenick Street CSO	CSO	7.9	SW 8221 4307
54	Radio Cornwall CSO	CSO	8.1	SW 8295 4473
55	Calenick PS overflow *	EO	8.0	SW 8221 4307
56	Lower Trevilla PS CSO/EO*	PS CSO/EO	0.7	SW 8255 3887
57	Mylor Bridge PS*	EO	1.4	SW 8052 3604
58	St Mawes No 1 PS	EO	0.2	SW 8467 3292

CSO - combined sewer overflow.
EO - emergency overflow.
PS - pumping station.
SPS- sewage pumping station.
SSO - sewage storm overflow.
STO - storm tank overflow.
STW - sewage treatment works.
BMPA - bivalve mollusc production area.
** not listed on the EA PRP.*

Table VII.3 presents summary statistics for levels of faecal coliforms monitored in the final UV-treated effluent from five sewage treatment works discharging to the Fal Estuary during the period October 2006–June 2009.

Geometric means of faecal coliforms in effluent discharges from Falmouth STW and Ladock Valley STW are higher than the average levels given in the literature for a range of UV-treated effluents in the UK (Kay *et al*., 2008). Maximum levels of the microbiological indicator indicate the existence of periods when the quality of the final effluent had deteriorated.

Table VII.3 Summary statistics of presumptive levels of faecal coliforms in the final effluent post UV disinfection monitored in five sewage treatment works discharging to the Fal Estuary for the period October 2006–June 2009.

STW Name	Number of samples	CFU faecal coliforms 100ml^{-1}					
		Minimum	Maximum	Median	Geometric mean	95% CI for mean Lower	Higher
Falmouth STW	72	1	160,003	1,100	794	36	103
Truro (Newham) STW	72	0	41,000	33	61	36	106
St Mawes STW	72	0	500	13	14	10	20
Ladock Valley STW	72	5	760,000	1,700	2,150	1,047	4,422
Mylor Bridge STW	72	0	840	7	10	7	15

CI - Confidence interval.
STW - sewage treatment works.
CFU - colony forming units.

Side-by-side box-and-whisker plots of faecal coliform data amalgamated by season (Figure VII.2) show deteriorated quality of the effluent discharge (as evidenced by the distribution of faecal coliform levels) from Falmouth STW, Ladock Valley STW and Mylor Bridge STW during summer. The qualities of the effluents from Falmouth STW and Ladock Valley are below typical levels in UV-treated effluents mentioned in the literature.

Statistically significant differences (Kruskal-Wallis test[21]: H = 10.05; p = 0.018) were detected between levels of faecal coliforms in effluent discharges from Falmouth STW in summer and those in winter.

One-way ANOVA combined with Tukey HSD post-hoc test (95% confidence level) revealed statistically significant differences in the levels of faecal coliforms in effluent discharges of Ladock Valley STW ($F_{(3,68)}$ = 5.89; p = 0.001) between summer and winter.

Statistically significant differences (Kruskal-Wallis test: H = 10.26; p = 0.017) were also detected between levels of faecal coliforms in effluent discharges from Mylor Bridge in summer and those in winter.

Deterioration in the microbiological quality of effluent discharges from Falmouth STW and Ladock Valley STW during summer may contribute to seasonal variations in the levels of microbiological contamination retained and accumulated by bivalve molluscs. Results from analyses of seasonal variations of *E. coli* levels in bivalves are given in the Appendix XII.

Table VII.4 indicates that the three top discharges recording the highest number of spill events and spill duration in 2009 include storm and emergency overflows discharging to creeks on the western side of the estuary. High numbers of spill events have occurred from Commercial Road PSCSO/EO, which discharges to Penryn River and is in close proximity to Falmouth Wharves native oyster bed.

[21] Datasets were found to be not normally distributed and therefore the assumptions of parametric analysis of variance were violated.

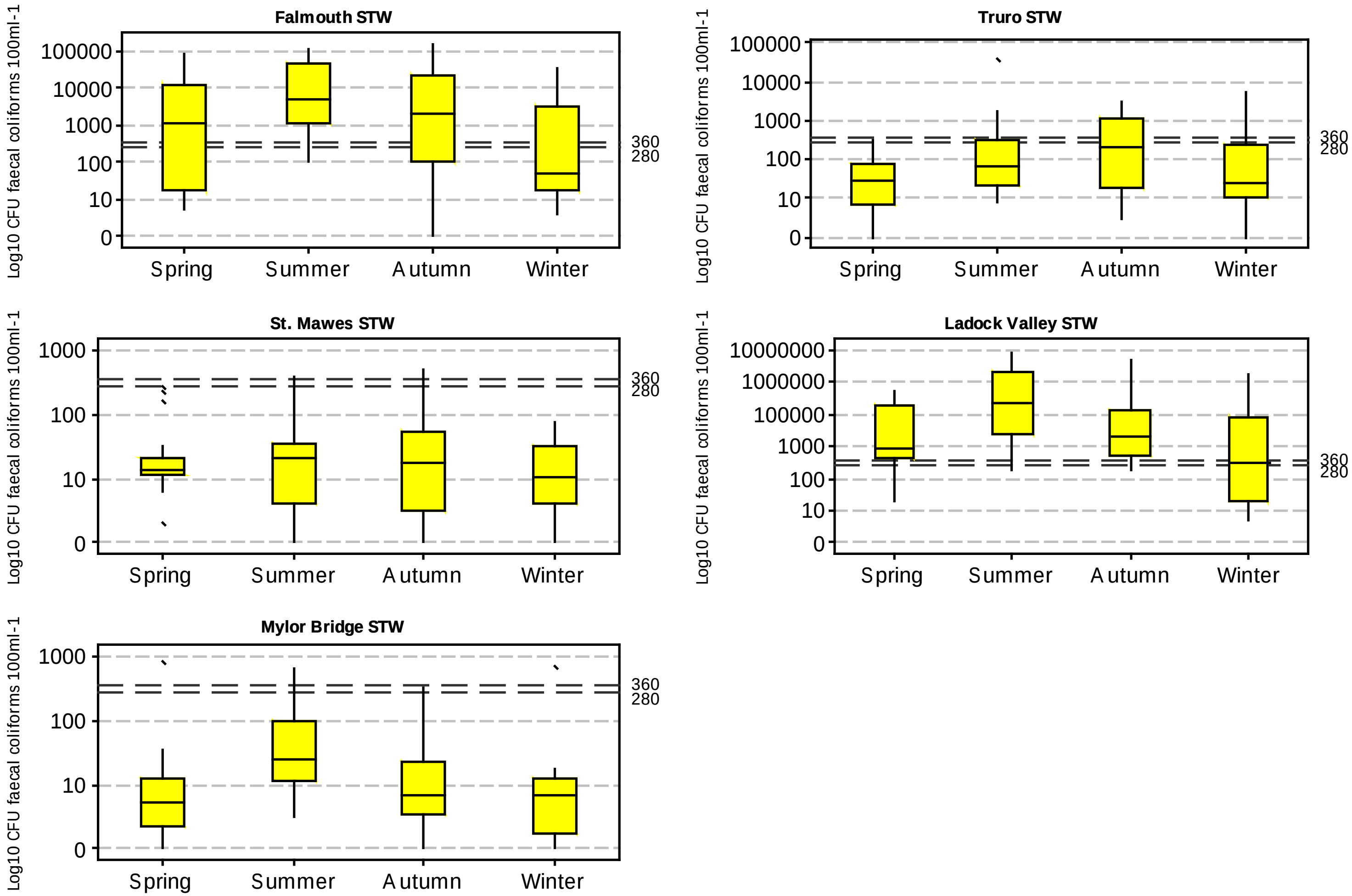


Figure VII.2 Box-and-whisker plots of seasonal levels of faecal coliforms in the final effluent post UV disinfection monitored in five sewage treatment works discharging to the Fal Estuary.

N.B. Spring: March−May; Summer: June−August; Autumn: September−November; Winter: December−February. Reference lines correspond to typical levels of faecal coliforms in UV-treated effluents under base-flow and high flow conditions as observed in a range of effluents by Kay et al. *(2008). Data from the Environment Agency.*

Table VII.4 Total number of sewage spill events and spill duration from sixteen significant intermittent discharges for the period 2006–2009.

Discharge No.	Discharge name	Total spill events				Total duration (hours)			
		2006	2007	2008	2009	2006	2007	2008	2009
15	Commercial Road PSCSO/EO Penryn, Falmouth	-	97	60	16	-	623.1	481.9	130.8
10	Mylor Bridge Stepping Stones PSCSO/EO	4	18	10	3	2.6	73.7	16.4	70.1
12	Devoran PS	-	17	12	2	-	133.1	258.2	57.5
31	Falmouth STW	-		2	12	-		5.3	43.9
14	Prince of Wales Pier PSCSO/EO, Falmouth	26	47	36	11	20.2	27.9	67.4	21.3
21	North Parade CSO, Falmouth	34	108	59	4	24.1	125.5	640.6	4.3
18	Grove Place	-	1	7	2	-	0.4	2.7	2.9
24	Old Hill PSCSO/EO (Junction of North Parade and Falmouth Road), Falmouth	9	28	8	2	4.9	13.6	29.7	2.4
25	Tehidy Terrace CSO, Falmouth	6	5	3	2	0.2	0.6	0.9	0.2
22	Pendarves Road	24	21	3	1	3.8	5.7	0.7	0.2
23	Yacht Marina	3	4*	5	-	0.3	15.3	33.7	-
30	Falmouth STW, via Bar Road CSO	14	13	13	-	21.0	55.4	18.0	-
	Thomas Street o/s 58 CSO Penryn	10	51	3	-	4.4	44.3	1.6	-
30	St Mawes PSCSO/EO No 1 (at harbour), Kings Road	8	9	-	-	0.4	5.7	-	-
58	Flushing Town Quay PSCSO/EO	7	-	-	-	251.5	-	-	-

** Spurious, level increased suddenly lasting for a long period. Suspected instrument fault.*

Davies *et al*. (2008) carried out a molecular microbial source tracking study to understand the relative contributions of individual sources of faecal pollution impacting the shellfisheries in the Fal Estuary using quantitative polymerase chain reaction (qPCR) analysis together with total microbial population normalisation techniques. The study site was King Harry Ferry, an area impacted by sewage discharges and diffuse sources associated with livestock production areas. Water was sampled on a weekly basis over a month (May–June). Results showed persistent human faecal indicators in mussel beds at King Harry Ferry and suggested that significant levels of contamination from pollution sources of human origin were impacting the estuary at this point. Inputs from livestock production areas were also considered to be relevant (see Appendix VIII).

APPENDIX VIII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: AGRICULTURE

Agriculture is one of the main activities in river catchments draining to the Fal Estuary. Approximately 59% of the catchment area is utilised for these purposes, in particular cattle and sheep production (Figure VIII.1) and cereals (Cornwall County Council and Environment Agency, 2006).

Figure VII.1 Sheep grazing in Commerrans Farm and view of eastern part of Carrick Roads off Messack and Port of Falmouth at the distance.
Photo courtesy W.P. Thinrod.

High numbers of farms exist in northern areas of Helford-Lizard-Carrick Roads, Carnon and Kennal Vale, Tresillian, Trevella and Kenwyn catchments (Figure VIII.3). Densities of cattle and sheep are higher in Helford-Lizard-Carrick Roads, Fal and Tresillian catchments (Figure VIII.4).

Figure VII.2 Evidence of soil poaching by livestock in one farm at East Bank.

Figure VIII.3 Location of farms in the Fal river catchments.

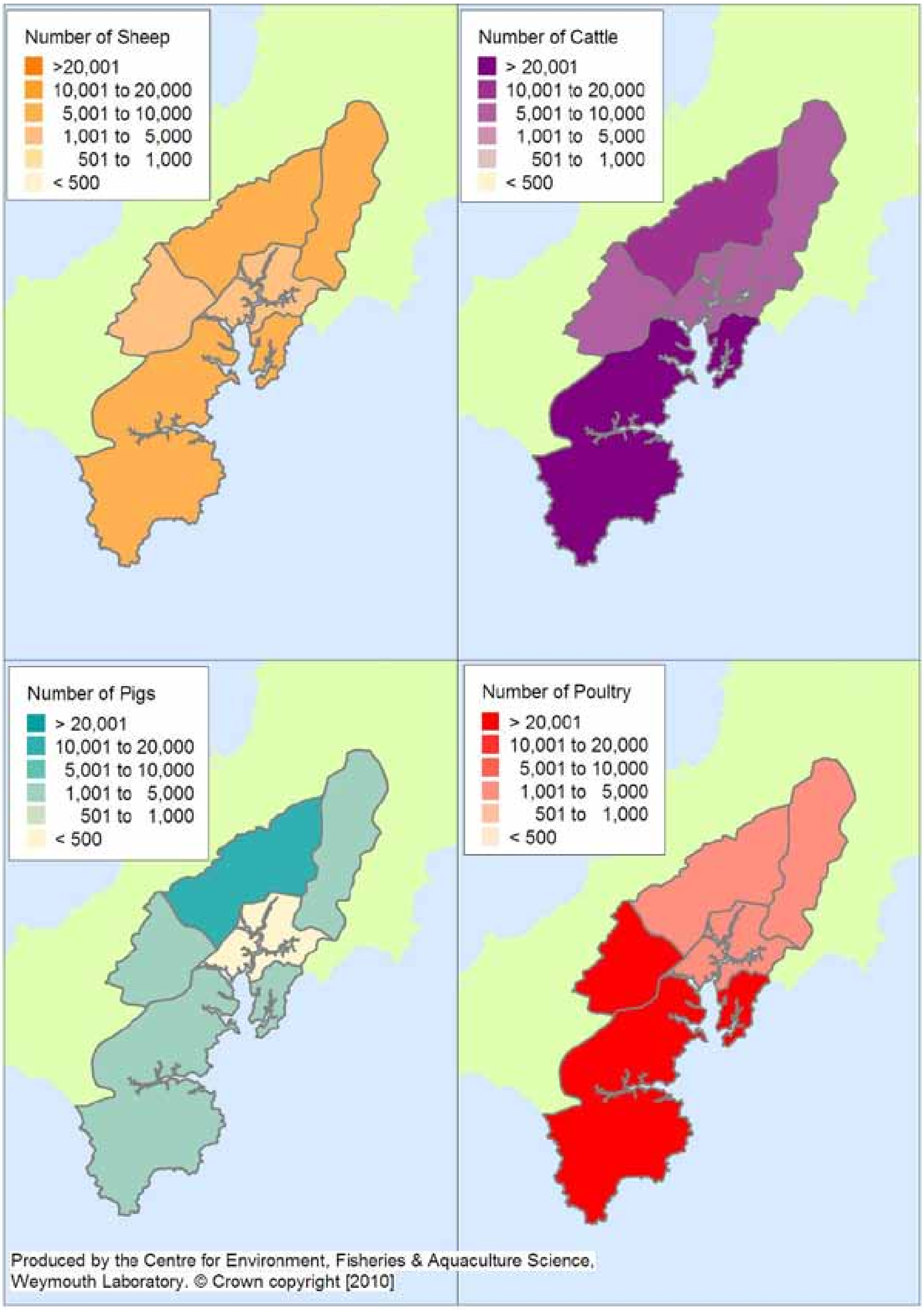


Figure VIII.4 Numbers of farmed animals in the Fal river catchments.
Based on livestock numbers supplied by Defra, Farming Statistics.

There are over 180,000 farmed animals in these catchments (Table VIII.1). Numbers of cattle (61,837 animals) and sheep (34,795) constitute 52% of the total number of farmed animals.

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

Site	Poultry	Pigs	Cattle	Sheep	Other livestock
Helford, Lizard, Carrick Roads	26,898	3,639	27,031	9,876	1,137
Carnon and Kennal Vale	32,214	1,071	6,495	1,595	668
Tresillian, Trevella, Kenwyn	2,113	11,203	12,104	9,011	1,007
Fal	4,626	1,385	9,134	9,488	402
Fal (tidal), Tresillian, Truro	1,030	226	7,073	4,825	241

Data from Defra (2009), Farming Statistics - June 2008 Agricultural Survey.
NB. Other livestock consists of horses, goats, deer and others.

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

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

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

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

The Fal catchment is considered to be at risk of diffuse water pollution from agriculture (English Nature, 2003; Defra, 2007). The main issues causing concern are soil erosion under field vegetables, potatoes, bulbs and maize and compaction in arable fields and grassland and the over application of slurry at the wrong time of year (Horsey, 2006). Parts of the estuary are known to be at risk of eutrophication (Langston *et al.*, 2003).

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

Table VIII.3 summarises pollution incidents impacting water quality in the Fal Estuary recorded in the Environment Agency's National Incident Recording System (NIRS) for the period 2005–2009. The location of these incidents is shown in Figure VIII.5.

Table VIII.3 Serious water pollution incidents in the Fal catchment for the period 2005–2009.

Map ID	Date/time first reported	NGR	Cause	Source	Pollutant	Receiving waters
1	27/07/2005 15:30	SW90568 42626	Unauthorised discharge or disposal	Beef farm	Silage liquors (seepage of silage effluent)	-
2	09/02/2007 17:39	SW84151 44259	Storage tank or container failure (unbunded)	Beef farm	Slurry and dilute slurry	Truro River (tidal)
3	23/02/2007 10:39	SW82177 38110	Other extreme weather conditions	Market gardening/ horticulture	Other agricultural material or waste	-
4	27/05/2008 15:50	SW98307 59501	Control system failure	Dairy farm	Slurry and dilute slurry (contents of tin tank)	Headwaters of the Fal
5	15/07/2008 12:00	SW85105 39522	Unauthorised discharge or disposal	Dairy farm	Silage liquors (silage and dairy washings)	-
6	21/01/2009 14:00	SW89310 44950	Unauthorised discharge or disposal	Dairy farm	Slurry and dilute slurry (dirty water)	-

Data from the Environment Agency.
NB. Incident No.2 classified as impact category 2 (significant damage to the aquatic system). All other incidents were classified as impact category 3 (minor damage to water quality and ecosystems).

Results from the microbial source tracking investigations undertaken by the Environment Agency in the Fal Estuary and tributaries are summarised in Table VIII.4. The locations of sites sampled are shown in Figure VIII.6.

Figure VIII.5 Location of serious water pollution incidents in the Fal catchment for the period 2005–2009.

Table VIII.4 Summary of results from microbial source tracking analyses carried out in the Fal Estuary between 2008–2009.

Sampling site	Sampling location	Sampling date	Overall source (%) Human	Ruminant	Comment
River Fal	King Harry Ferry	09 December 2008	31	69	No other sources suspected
Cowlands North Creek		23 October 2008	33	67	No other sources suspected
Cowlands North Creek		09 December 2008	48	52	No other sources suspected
River Fal	Off Boat House	18 November 2008	28	72	No other sources suspected
River Fal	Off Boat House	09 December 2008	54	46	No other sources suspected
Ruan River	At Ruan Bridge	23 October 2008	0.1	99.9	No other sources suspected
Tidal Fal, Truro and Carnon	Victoria Quay Malpas	20 May 2008	72	28	No other sources suspected
Tidal Fal, Truro and Carnon	Victoria Quay, River Fal Estuary	29 May 2008	87	13	No other sources suspected
Tidal Fal, Truro and Carnon	Victoria Quay, River Fal Estuary	04 June 2008	83	17	No other sources suspected
Tidal Fal, Truro and Carnon	King Harry Stream	13 June 2008	Detected	Not detected	Other sources of contamination cannot be eliminated
Tidal Fal, Truro and Carnon	West Cowlands Stream	13 June 2008	Not detected	Not detected	Other sources of contamination cannot be eliminated
Tidal Fal, Truro and Carnon	Victoria Quay, River Fal Estuary	30 June 2008	91	9	No other sources suspected
Tidal Fal, Truro and Carnon	Lamorran Pond	25 November 2008	0.2	99.8	No other sources suspected
Tidal Fal, Truro and Carnon	Ruan	25 November 2008	Detected	Detected	Other sources of contamination cannot be eliminated
Tidal Fal, Truro and Carnon	River Fal at Set Bridge	25 November 2008	58	42	No other sources suspected
Tidal Fal, Truro and Carnon	Polmesk Creek (seawater)	10 December 2008	45	55	No other sources suspected
Tidal Fal, Truro and Carnon	Tolvern Bank	19 January 2009	56	44	No other sources suspected
Tidal Fal, Truro and Carnon	Tolvern	19 January 2009	64	36	No other sources suspected
Tidal Fal, Truro and Carnon	Tolvern North	19 January 2009	43	57	No other sources suspected
Tidal Fal, Truro and Carnon	Tolvern South	19 January 2009	49	51	No other sources suspected
Tidal Fal, Truro and Carnon	Coombe Creek	19 January 2009	39	61	No other sources suspected
Tidal Fal, Truro and Carnon	King Harry Reach	19 January 2009	53	47	No other sources suspected
Tidal Fal, Truro and Carnon	Turnaware Pontoon	19 January 2009	54	46	No other sources suspected
Tidal Fal, Truro and Carnon	Pill Creek	19 January 2009	38	62	No other sources suspected
Tidal Fal, Truro and Carnon	Ruan Creek	19 January 2009	41	59	No other sources suspected
Tidal Fal, Truro and Carnon	Tolvern Barton North	19 January 2009	40	60	No other sources suspected
Tidal Fal, Truro and Carnon	Truro Tresillian (confluence at Malpas)	19 January 2009	37	63	No other sources suspected
Tidal Fal, Truro and Carnon	Trelissik Pontoon at King Harry Ferry	09 February 2009	3	97	No other sources suspected

Tidal Fal, Truro and Carnon	Trelissick Pontoon at King Harry Ferry	09 February 2009	Not detected	Not detected	Samples collected under heavy rainfall
Tidal Fal, Truro and Carnon	Trelissick Pontoon at King Harry Ferry	11 February 2009	7	93	No other sources suspected. Dry weather. EA Sampling Team washing sediment samples upstream
River Fal	At Set Bridge	09 December 2008	15	85	No other sources suspected
River Fal	At Set Bridge	02 February 2009	56	44	No other sources suspected
River Fal (West area)	Ruan River	20 June 2008	0.3	99.7	No other sources suspected
River Fal (West area)	At Set Bridge	20 June 2008	11	89	No other sources suspected
River Fal (West area)	At Set Bridge	01 July 2008	58	42	No other sources suspected
River Fal (West area)	At Set Bridge	07 July 2008	89	11	No other sources suspected
River Fal (West area)	Lamorran Wood Stream	07 July 2008	0.2	99.8	No other sources suspected
River Fal (West area)	Penkeviel Wood Stream	07 July 2008	0.2	99.8	No other sources suspected
River Fal (West area)	Tolvern Stream (downstream of Tolvorn Farm)	07 July 2008	Not detected	100	No other sources suspected
River Fal (West area)	Ruan River	07 July 2008	0.01	99.99	No other sources suspected
River Fal (West area)	At Set Bridge	21 October 2008	Not detected	Not detected	Other sources of contamination cannot be eliminated
River Fal (West area)	Ardevora Stream	25 November 2008	100	Not detected	No other sources suspected
River Allen	At Moresk Laundry	23 July 2008	15	85	No other sources suspected
River Allen	At Moresk Laundry	23 October 2008	98	2	No other sources suspected
River Allen	At Moresk Laundry	09 December 2008	62	38	No other sources suspected
River Kenwyn	At kenwyn gauging station	23 June 2008	92	8	No other sources suspected
River Kenwyn	At kenwyn gauging station	23 July 2008	Detected	Detected	Other sources of contamination cannot be eliminated
River Kenwyn	At kenwyn gauging station	26 August 2008	47	53	No other sources suspected
River Kenwyn	At kenwyn gauging station	24 September 2008	99.8	0.2	No other sources suspected
Tresillian/Trevella/Kenwyn	River Kenwyn, Truro at Bosvigo Bridge	20 June 2008	67	33	No other sources suspected
Tresillian/Trevella/Kenwyn	Old Kea Stream	20 June 2008	Detected	Detected	Other sources of contamination cannot be eliminated
Tresillian/Trevella/Kenwyn	River Allen at Morek Bridge	01 July 2008	22	78	No other sources suspected
Tresillian/Trevella/Kenwyn	River Kenwyn at Bosvigo Bridge	01 July 2008	94	6	No other sources suspected
Tresillian/Trevella/Kenwyn	Calenick Stream	01 July 2008	0.3	99.7	No other sources suspected
Tresillian/Trevella/Kenwyn	Fal River at Trelissik Pontoon	07 July 2008	45	55	No other sources suspected

Tresillian/Trevella/Kenwyn	River Tresillian	07 July 2008	1	99	No other sources suspected
Tresillian/Trevella/Kenwyn	River Allen at Moresk Bridge	07 July 2008	2	98	No other sources suspected
Tresillian/Trevella/Kenwyn	River Kenwya at Bosvigo Bridge	07 July 2008	0.5	99.5	No other sources suspected
Tresillian/Trevella/Kenwyn	Calenick Stream	07 July 2008	17	83	No other sources suspected
Tresillian/Trevella/Kenwyn	Coombe Stream	07 July 2008	0.7	99.3	No other sources suspected
Tresillian/Trevella/Kenwyn	Old Kea Stream	07 July 2008	Not detected	100	No other sources suspected
Tresillian/Trevella/Kenwyn	West Cowlands Stream (downstream of Higher Lawner Farm)	07 July 2008	0.4	99.6	No other sources suspected
Tresillian/Trevella/Kenwyn	Fal Estuary at Victoria Quay	07 July 2008	10	90	No other sources suspected
Tresillian/Trevella/Kenwyn	River Allen at Lemon Quay	09 July 2008	Detected	Detected	Other sources of contamination cannot be eliminated
Tresillian/Trevella/Kenwyn	River Kenwyn at Lemon Quay	09 July 2008	35	65	No other sources suspected
Tresillian/Trevella/Kenwyn	River Allen at Idless Village	09 July 2008	0.03	99.97	No other sources suspected
Tresillian/Trevella/Kenwyn	River Kenwyn at New Mills	09 July 2008	0.2	99.8	No other sources suspected
Tresillian/Trevella/Kenwyn	River Trevella	09 July 2008	Detected	Detected	Other sources of contamination cannot be eliminated

Data from the Environment Agency.

Figure VIII.6 Location of sites sampled for source tracking analyses.

The results indicate a dominance of pollution sources of animal origin in stations along the rivers Allen, Kenwyn and Tresillian. Most of the results from stations along the River Fal are indicative of impacts from both human and animal sources and, in some stations (e.g. Ardevora Stream; Tolvern) a dominance from human sources. There seems to be some level of connectivity between these freshwater inputs and the dominance of mixed human/animal sources detected in stations at King Harry and Turnaware Pontoon. These results indicate that bivalve mollusc beds at Carrick Roads are likely to be affected by the combined effect of faecal contamination from dairy washings and surface runoff from agricultural land sewage discharges.

The middle and lower areas of the River Fal were also subject to a study carried out by Environmental Tracing Systems Ltd. in March–April 2007 aimed to evaluate the impact of diffuse pollution sources impacting on the shellfisheries (Environmental Tracing Systems Ltd., 2007). The study involved Acoustic Doppler Current Profiler (ADCP) survey, bacteriological monitoring and source typing and tracing. The study confirmed high inputs of contamination from bovine sources impacting water quality of Cowlands Creek during and after rainfall events, both downstream of the farm and within the tidal waters of the creek itself. The fluorescent tracers released at Carlyon Farm were detected lower in the catchment at the tidal limit in Cowlands Creek. It was also concluded that runoff from dirty water pits via the irrigation system showed a relatively fast initial arrival, which was assumed to result from direct surface runoff, followed by a more gradual and steady increase as more tracer particles were being washed.

APPENDIX IX
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: BIRDS

The Fal Estuary is of national and international significance in terms of birds.

Twenty-seven species of waterbirds were recorded in the Fal complex in 2004/05 (mean number birds = 1.170; mean bird density = 3.7 birds per ha), mostly in fairly small average winter numbers (Banks *et al.*, 2006). Table IX.1 summarises numbers of fifteen species of waterbirds in the Fal Complex.

The estuary is notable for Black-necked Grebe, Greenshank, Dunlin and Curlew. Figure IX.1 shows that Dunlin and Curlew tend to be distributed in intertidal areas of Truro and Tresillian rivers, Lamorran and, with more relevance to this assessment, Restronguet Creek, Penryn and Percuil River.

Oystercatcher and Lapwing are concentrated on Percuil River and Black-tailed Godwit on Truro River and Restronguet Creek (Banks *et al.*, 2006).

Previous studies in the UK have found significant concentrations of microbial contaminants in intertidal sediment samples collected from estuaries supporting large communities of birds (Obiri-Danso and Jones, 2000). For example, literature suggests that the typical microbial loading for ducks is 3 x 10^7 coliforms g^{-1} (excretion rate = 336g day^{-1}) (Geldreich, 1966). Feare (2001) suggested that approximately 10% of faecal matter could be deposited under a roost, indicating the potentially significant contribution of contamination in these areas.

Due to the high numbers of overwintering birds in the area, winter may be a time of increased microbial contamination from birds. This is particularly important in Restronguet Creek, River Penryn and River Percuil. Microbial pollution from birds may be washed into Carrick Roads during the flood tide.

Table IX.1 Low tide counts of waterbirds in the Fal Estuary.

Common name	Scientific name	Peak No.	Mean No.	Mean density	Season[†]
Curlew	*Numenius arquata*	305	245	0.78	Year round. Coastal numbers increase from July and reach a peak in January–February
Redshank	*Tringa totanus*	213	180	0.58	Year round. Greatest concentrations in Scotland and NW England.
Dunlin	*Calidris alpina*	231	141	0.45	Year round on the coast. On breeding grounds from April–July. Greatest concentrations on estuaries during winter.
Shelduck	*Tadorna tadorna*	154	129	0.41	Year round.
Black-tailed Godwit	*Limosa limosa*	114	106	0.34	Year round. Greater concentrations in Autumn and Winter.
Mallard	*Anas platyrhynchos*	85	80	0.26	Year round.
Little Egret*	*Egretta garzetta*	-	72	-	Year round with greater concentrations in Autumn and Winter.
Lapwing	*Vanellus vanellus*	133	66	0.21	Year round.
Oystercatcher	*Haematopus ostralegus*	61	47	0.15	Year round.
Greenshank*	*Tringa nebularia*	-	30	-	October–March
Wigeon	*Anas penelope*	55	20	0.06	Year round. Greater concentrations in Winter.
Teal	*Anas crecca*	30	17	0.05	Year round with greater concentrations in Winter.
Black-necked Grebe*	*Podiceps nigricollis*	-	14	-	Year round with greater concentrations in Winter.
Turnstone	*Arenaria interpres*	8	3	0.01	Mainly year round with greatest concentrations from July–May.
Ringer Plover	*Charadrius hiaticula*	2	1	-	Year round.

Data from Banks et al. *(2006).*
** Mean counts over the period 2000–2005.*
[†] *Data from RSPB (2009).*

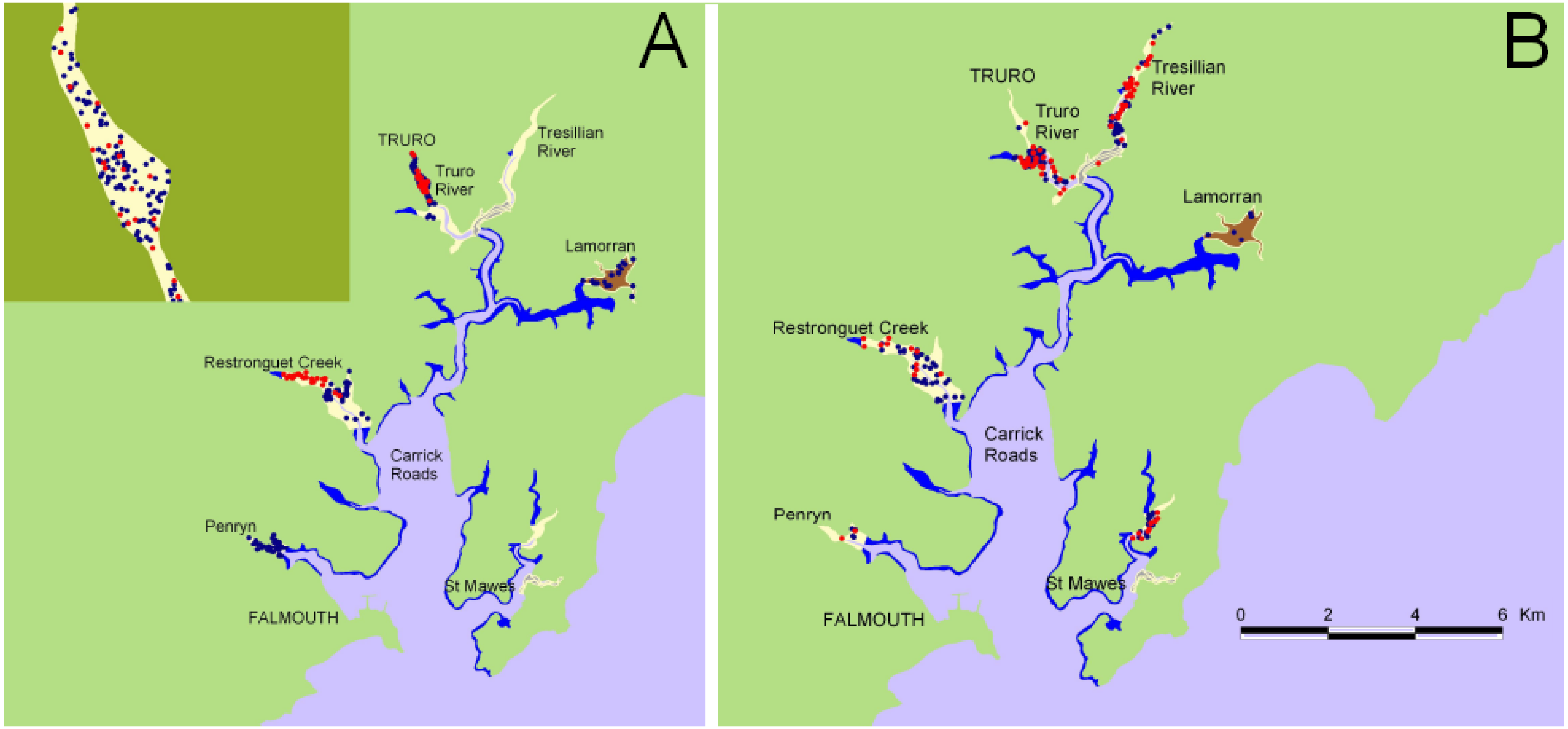


Figure IX.1 Low tide distribution of Dunlin (A) and Curlew (B) for the winters of 1995–1996 (blue) and 2004–2005 (red).
1 dot = 3 birds. Inset shows Truro River in detail.
Yellow - intertidal; pale green - nontidal; pale blue - subtidal. Blue dots - winter surveys of 1995/96; Red dots - winter surveys of 2004/05.
Brown areas not surveyed in later winter; dark blue areas not surveyed.
Modified from Banks et al. *(2006) with the permission of Neil Calbrade on behalf of the authors.*

APPENDIX X
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: BOATS

The Fal Estuary is the third largest natural harbour in the world. It provides sheltered anchorages and offers a number of facilities for commercial vessels, including ship repair at the shipyard. Falmouth Docks & Engineering Co. Ltd operates five berths and three graving docks. A&P Falmouth is the largest ship repair complex in southwest England, with tree graving docks (one of these for vessels up to 250m), six wet berths for vessels up to 240m in length and 8m draught and five wet berths for vessels up to 240m overall length (Land & Marine Publications Ltd., 2003).

Commercial and recreational fishing vessels and leisure craft are also major users of the harbour. The eastern side of Carrick Roads, which includes the stretch of coast from St. Mawes to St. Just is a designated water ski area.

Approximately 30 recreational sailing clubs operate in and around Falmouth Harbour (Royal Haskoning, 2009b). The main clubs are Royal Cornwall Yacht Club, Falmouth Town Regatta, Flushing Sailing Club, St. Mawes Sailing Club, Mylor Yacht Club and Restronguet Sailing Club. There are two public slipways at Mylor, Grove Place Boat Park and just North of Pendennis Marina Village.

The entire Fal Estuary holds approximately 4,700 leisure craft moorings. Of these, 1,500 are located within the Port of Truro and about 350 in Penryn (Royal Haskoning, 2009b). Falmouth Harbour Commissioners operate 588 deep water lay-up moorings (Harriett Knowles, pers. comm.) for vessels up to 219m in length (Land and Marine Publications Ltd, 2003) situated between Customs House Quay and Greenbank Quay and between Flushing New Quay and Kiln Quay (Falmouth Harbour Commissioners, 2007). Of these, two fifths are private moorings and the remaining are owned and hired from Falmouth Harbour Commissioners.

Falmouth has 19 moorings for visiting boats and these are located on or near the main channel: 8 moorings to accommodate yachts up to 12.2m, 7 moorings to accommodate yachts up to 18.2m and 4 moorings to accommodate yachts up to 24.3m. An anchorage area situated near the Yacht Haven between Custom House Quay and Falmouth Docks is also available for small craft (Falmouth Harbour Commissioners, 2007).

There are dinghy berths available at Grove Place Boat Park which also boasts a slipway for launch and recovery at most states of the tide. There are also outhauls for vessels up to 4.8m on Custom House Quay, King Charles Quay and North Quay (Falmouth Harbour Commissioners, 2007).

The Visitors Yacht Haven pontoons provide berthing for up to 100 vessels. There are 19 visitor's deep water moorings for single vessels although more than one vessel may occupy a visitors mooring.

Summer mooring areas at Greatwood, Restronguet, Feock, Mylor and Loe Beach are for use from 1 April–30 September (Carrick District Council, no date).

Therefore, the risk of pollution from boats near these areas will correspond to the spring-summer period.

The location of slipways, sailing clubs and mooring areas is shown in Figure X.1.

The inner Port of Pendennis Marina is accessed by a tidal gate, which opens 3h before and after High Water (Adlard Coles Nautical, 2008). Therefore, any pollution from boats and runoff from the shore is expected to be retained within the marina over low water periods of the tidal cycle.

Marinas and ports have historically been identified as major sources of faecal contamination (see Sobsey *et al*., 2003). This is based on the assumption that some boat owners will, at some time, illegally discharge their head (onboard toilet) into harbour waters. The Port of Falmouth Marina is currently the only marina that provides pump-out facility for vessels fitted with holding tanks (Adlard Coles Nautical, 2008).

According to Falmouth Harbour (Amended) Bye-laws 1996, no person shall deposit or throw into the waters of the harbour any rubbish or other material whatsoever or place it in such a position that it is likely to fall, blow or drift into the harbour (Falmouth Harbour Commissioners, 1996).

An assessment of the potential impact of sewage discharges from boats and marinas on the microbiological status of BMPAs requires detailed quantitative information on boat movements, occupancy rates and seasonality and accurate knowledge on dilution of contaminants in receiving waters. The high numbers of moorings in parts of the lower estuary suggest that boats can be considered a locally significant source of contamination in the estuary. Native oysters from Falmouth Wharves, an area extensively occupied by mooring areas, have shown an increase in the levels of *E. coli* during summer (see Figure XII.1). Overall, it can be assumed that summer is the season of highest risk of contamination.

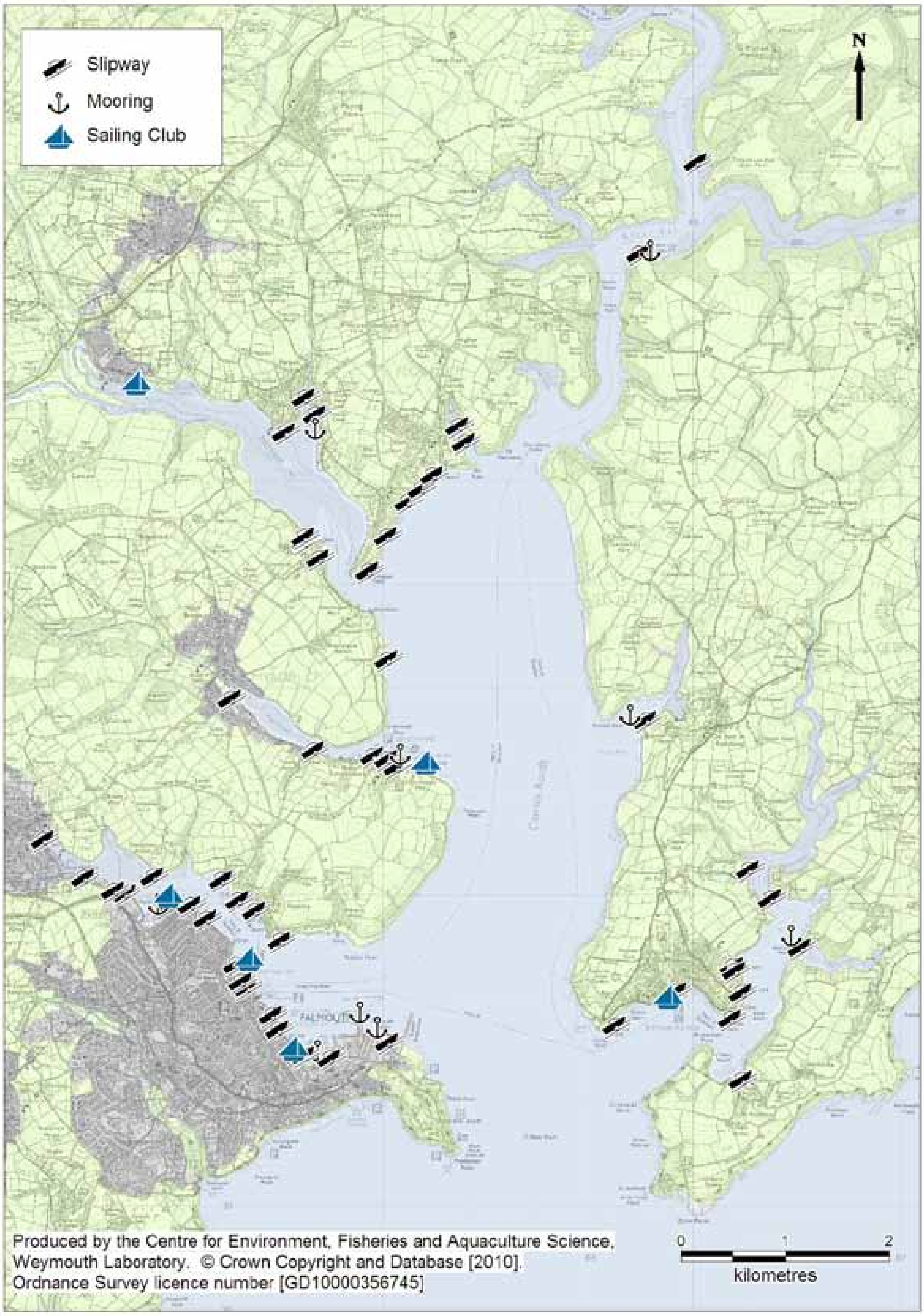


Figure X.1 Location of mooring areas, sailing clubs and slipways in the lower Fal Estuary.

APPENDIX XI
MICROBIOLOGICAL DATA: WATER

BATHING WATERS

There are two bathing waters in Falmouth Bay designated under the Directive 2006/7/EC (European Communities, 2006a)[22]: Gyllyngvase and Swanpool (Figure X.1). These are approximately 3.7km and 4km from the nearest RMP (East Narrows), respectively.

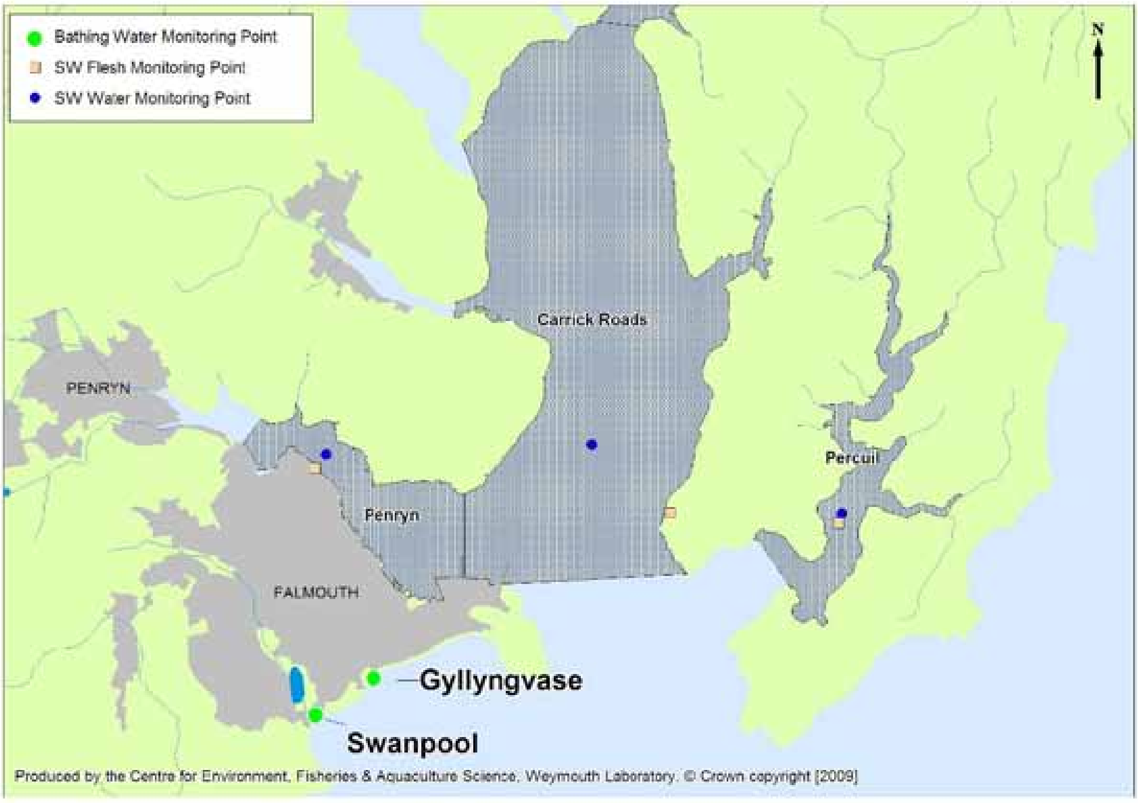


Figure XI.1 Location of designated Bathing Waters and Shellfish Waters in the lower Fal Estuary.

The overall quality of these Bathing Waters is summarised in Table XI.1.

[22] The bathing season runs from 15 May to 30 September. Water is sampled throughout the season. Levels of bacteria must not exceed the Imperative (I) value (2,000 faecal coliforms 100ml^{-1}) and the Guideline (G) value (100 faecal coliforms 100ml^{-1}) represents the ideal maximum value. Bathing waters in England and Wales are classified as:
Poor - fails at least one coliform I standard;
Good - passes coliform I standards but fails at least one coliform G standard;
Excellent - passes coliform G standard and faecal streptococci standards.

Table XI.1 Overall quality of Gyllyngvase and Swan Pool Bathing Waters for the period 2004−2008.

Compliance	Bathing Water	Bathing season				
		2004	2005	2006	2007	2008
Excellent (Guideline Pass)	Gyllyngvase	√	√	√	√	√
	Swanpool	√	√	√	√	√
Good (Mandatory Pass)	Gyllyngvase					
	Swanpool					
Poor (Mandatory Fail)	Gyllyngvase					
	Swanpool					

Data from the Environment Agency (2009).
NB. The descriptions in this table are based on compliance monitoring and assessment against the current Bathing Water Directive. This will be replaced by assessment against the Directive in 2014.

Table XI.2 shows that, under the revised BW Directive, the two BWs meet excellent status.

Table XI.2 Overall quality of Gyllyngvase and Swan Pool Bathing Waters for the period 2004−2008.

	Bathing season	
Bathing Water	2004–2007	2005–2008
Gyllyngvase	Excellent quality	Excellent quality
Swanpool	Excellent quality	Excellent quality

Data from the Environment Agency (2009).

Table XI.3 shows summary statistics during the bathing seasons 2004–2008. Levels of faecal coliforms in surface waters have been higher at Swanpool than those at Gyllyngvase.

Table XI.3 Summary statistics of levels of faecal coliforms in Gyllyngvase and Swanpool Bathing Waters for the period 2004−2008.

	CFU Faecal coliforms 100ml^{-1}					
	Gyllyngvase			Swanpool		
Bathing season	Min.	Max.	Geometric mean	Min.	Max.	Geometric mean
2004	<2	114	3	<2	209	6
2005	<2	462	3	<2	120	5
2006	<2	40	4	<2	108	8
2007	<2	10	2	<2	840	15
2008	<2	231	3	<2	538	5
2004–2008	<2	462	3	<2	840	7

Data from the Environment Agency (2009).
Number of samples per year = 20 (21 samples in 2006).
Min. - minimum.
Max. - maximum.

The higher variation of levels of faecal coliforms in the water at Swanpool relative to that at Gyllyngvase is represented by the higher box height in Figure XI.2. The distribution of the levels of the microbiological indicator at Gyllyngvase is more symmetric as shown by the similar sizes of top and bottom box halves. However, the outlier values represented by asterisks in the figure suggest the existence of occasional periods when the microbial quality of the waters had deteriorated.

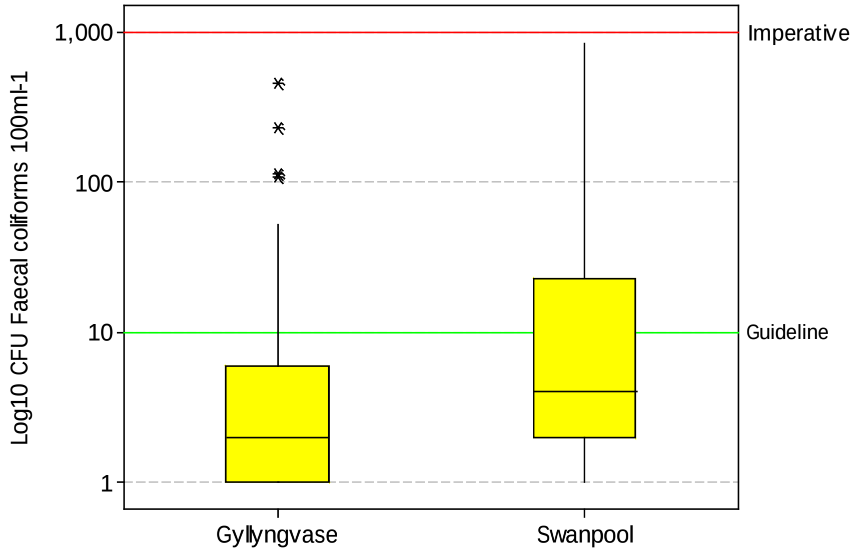


Figure XI.2 Box-and-whisker plots of levels of faecal coliforms in Gyllyngvase and Swan Pool Bathing Waters for the period 2004–2008.
Data from the Environment Agency (2009).

SHELLFISH WATERS

Three Shellfish Waters in the lower Fal Estuary designated under the Directive 2006/113/EC (European Communities, 2006b) are assessed for the purposes of this sanitary survey: Carrick Roads, Penryn and Percuil (Figure XI.1).

Table XI.4 shows summary statistics for levels of faecal coliforms in surface waters during the period January 2004–November 2008.

Table XI.4 Summary statistics of levels of faecal coliforms in designated Shellfish Waters in the lower Fal Estuary for the period 2004–2008.

	CFU Faecal coliforms 100ml^{-1}											
	Carrick Roads				Penryn				Percuil			
Year	Min.	Max.	Median	Geometric mean	Min.	Max.	Median	Geometric mean	Min.	Max.	Median	Geometric mean
2004 (n=5)	2	8	2	3	2	41	20	10	2	13	2	3
2005 (n=4)	2	2	2	2	2	3,080	33	45	2	11	2	3
2006 (n=4)	2	2	2	2	2	124	46	26	2	13	2	3
2007 (n=4)	2	1,200	3	12	2	169	19	18	2	118	6	9
2008 (n=4)	2	6	2	3	4	81	6	14	2	2	2	2
2004–2008	2	1,200	2	3	2	3,080	21	19	2	118	2	3

Data from the Environment Agency (2009).
n - number of samples per year.
Min. - minimum.
Max. - maximum.

APPENDIX XII
MICROBIOLOGICAL DATA: SHELLFISH FLESH

Table XII.1 shows summary statistics for levels of *E. coli* in bivalves from ten current RMPs for 2004-2009. This corresponds to the period after completion of the upgrades to sewage discharges having the potential to influence the quality of the designated Shellfish Water (see Environment Agency, 2008)[23].

Cumulative sum (CUSUM) analysis was computed for Shellfish Hygiene monitoring data summarised in Table XII.1 (not shown). No step changes in the levels of *E. coli* were detected after January 2004, suggesting that no significant changes have occurred in the overall microbiological quality of bivalves.

Sampling effort has been consistent for Native oysters and mussels at all RMPs over the years, except for oysters at Restronguet Creek.

Levels of *E. coli* above the limit of detection were detected in mussels from Mylor Creek and in Native oysters from most RMPs across the lower estuary. Many of these have occurred in recent years and during winter months. Despite the improvements in point-sources of pollution in recent years, the microbiological quality of Native oysters and mussels in the lower Fal Estuary has shown periods of deterioration from time to time.

Based on summary statistics and when only datasets with similar sampling effort for Native oysters are considered, the following spatial pattern of faecal contamination in the estuary can be recognised: Falmouth Wharves>Mylor Creek>Pill Creek>Turnaware Bar>Percuil>East Bank>St. Mawes Bank. This suggests higher levels of faecal contamination in oysters from western parts of Carrick Roads than those in oysters from the eastern parts and similar levels of contamination in oysters from the upper reaches of Carrick Roads and those from the upper reaches of Percuil River. The lower levels of contamination were detected in oysters from East Narrows, the southernmost monitoring point of the Fal Estuary.

The distribution of *E. coli* levels in native oysters from St. Mawes Bank and Percuil River and in mussels from Mylor Creek is leptokurtic. This indicates high frequency of levels near the mean due to low variations within the dataset. Contrarily, the distribution of *E. coli* levels in native oysters from all other RMPs is platykurtic, suggesting a flat peak around the mean due to large variations within the dataset. These large variations suggest that, from time to time, there are occasional deteriorations in the microbial quality of native oysters, modifying the underlying low levels of contamination detected during most of the time.

These results are considered for the purposes of recommending an adequate monitoring location for the new scallop bed and assessing the representativeness of current RMPs (see Section 4).

[23] Improvements were carried out before January 2004, except for Newham PS CSO (which had increased pass forward flow and additional storage) and Pendeen Road CSO (which was sealed) in 2006.

Table XII.1 Summary statistics of* E. coli *levels in bivalve molluscs from ten RMPs in the Fal Estuary for the period January 2004–August 2009.

RMP	Bed name	Species	n	Date of first sample	Date of last sample	MPN *E. coli* 100g^{-1} FIL Min.	Max.	No. results >4,600	Median	Geometric mean	Coefficient of Skewness[24]	Kurtosis[25]	Log_{10} St. Dev	L
B033K	Turnaware Bar	*O. edulis*	64	13 January 2004	11 August 2009	<20	>18,000	4	310	308	0.01	-0.02	0.798	
B033N	Mylor Creek	*O. edulis*	62	13 January 2004	11 August 2009	<20	>18,000	5	310	370	0.20	-0.35	0.806	
B033P	East Bank	*O. edulis*	60	13 January 2004	11 August 2009	<20	16,000	2	160	159	0.33	-0.27	0.734	
B033Q	St. Mawes Bank	*O. edulis*	59	13 January 2004	11 August 2009	<20	>18,000	5	110	146	0.88	0.54	0.903	
B033R	Percuil	*O. edulis*	62	13 January 2004	11 August 2009	<20	>18,000	3	200	195	0.45	0.38	0.773	
B033U	Pill Creek	*O. edulis*	59	13 January 2004	11 August 2009	<20	>18,000	5	490	354	0.41	-0.01	0.762	
B033W	Restronguet Creek	*O. edulis*	27	07 November 06	11 August 2009	40	14,000	2	490	589	-0.05	-0.51	0.674	
B033X	Falmouth Wharves	*O. edulis*	60	13 January 2004	11 August 2009	20	>18,000	16	1,700	1,539	-0.23	-0.24	0.710	
B33AB	East Narrows	*O. edulis*	53	10 February 2004	11 August 2009	<20	9,100	1	110	128	0.25	-0.37	0.706	
B33AN	Mylor Creek	*Mytilus* spp.	57	13 January 2004	11 August 2009	<20	>18,000	6	330	361	0.42	0.02	0.871	

n - number of samples.
Min. - minimum.
Max. - maximum.
CI - confidence interval.
St. Dev. - standard deviation.
FIL - flesh and intravalvular liquid.

[24] The coefficient of skewness measures the degree of symmetry in the distribution of *E. coli* results. Skewness = 0 gives a perfect normal distribution; skewness <0 distribution is negatively skewed; skewness>0 distribution is positively skewed.
[25] The coefficient of kurtosis relates to the shape of the distribution. Values <0 indicate the distribution is leptokurtic (tall, thin and peaked); values >0 indicate the distribution is platykurtic (wide and flat); values=0 indicates a perfect normality.

LEVELS OF *E. COLI* AND RAINFALL

The association between levels of *E. coli* in bivalves sampled from ten current RMPs in the estuary and rainfall levels in the Fal catchment was examined for the period January 2000–February 2009.

Spearman's rank correlation coefficient (*rho*) [26] was used to estimate correlations between MPN of *E. coli* 100g^{-1} FIL and total daily rainfall monitored at Allet gauging station (Figure II.1).

Significant positive relationships were detected between rainfall and levels of the indicator in Native oysters from all monitoring points across the estuary except in oysters from Restronguet Creek[27] (Table XII.2). However, statistically significant correlations between variables varied according to the monitoring point and the time of sampling relative to the rainfall event. The highest correlation coefficients were detected between the 4th and 6th days of cumulative rainfall before the sampling occasion. The highest significant correlation coefficient between these variables was detected for Native oysters from Pill Creek and the lowest was detected for oysters from Falmouth Wharves.

Levels of the microbiological indicator in oysters from the northernmost monitoring points (Pill Creek and Turnaware Bar) were found to be positively associated with daily rainfall from the day of sampling to the 6th day before sampling.

These results are relevant to both native oysters and the new scallop bed as they suggest that levels of contamination are likely to increase in this part of the estuary during and immediately after rainfall events. This effect could be due to faecal contamination from diffuse sources and/or the effect of rainfall-dependent discharges.

Two dimensional scatterplots of levels of rainfall and *E. coli* in bivalves from each RMP with superimposed LOcally WEighted Scatterplot Smoothing (LOWESS) are shown in Figure XII.1. These plots illustrate the relationships between the two variables with the most significant relationship (i.e. largest *p*-values).

Most scatterplots show a linear relationship up to 40mm of cumulative rainfall. The spread of *E. coli* levels appears to be constant over the range of data points, particularly for levels of contamination in Native oysters from Turnaware Bar, Percuil, East Bank and Pill Creek.
The scatterplot for Native oysters in Falmouth Wharves appears to show at least two different groups of data points: one group for levels of *E. coli* detected for daily rainfall levels below 2mm and a second group that includes levels of the indicator between 6 and 16mm.

[26] This statistical test is usually defined as the linear correlation coefficient determined on the ranks of the data, in which differences between data values ranked further apart are given more weight (Helsel and Hirsch, 2002).
[27] A low number of results were used in the analysis for Restronguet Creek.

Table XII.2 Spearman's rho coefficients between rainfall recorded at Allet gauging station and MPNs of E. coli 100g^{-1} FIL in bivalves from ten monitoring points in the Fal Estuary during the period January 2000−February 2009.

		MPN *E. coli* 100g^{-1} FIL									
Rainfall		Turnaware Bar (B033K) (n=93)	Mylor Creek (B033N) (n=95)	East Bank (B033P) (n=90)	St. Mawes Bank (B033Q) (n=89)	Percuil (B033R) (n=94)	Pill Creek (B033U) (n=89)	Restronguet Creek (B033W) (n=21)	Falmouth Wharves (B033X) (n=94)	East Narrows (B33AB) (n=90)	Mylor Creek (B33AN) (n=88)
Allet	Time	*O. edulis*	*O. edulis*	*O. edulis*	*O. edulis*	*O. edulis*	*O. edulis*	*O. edulis*	*O. edulis*	*O. edulis*	*Mytilus* spp.
Daily	Day of sampling	0.232*	0.258*	0.267*	0.201	0.197	0.519*	-0.288	0.087	0.149	0.256*
	-1 day	0.216*	0.250*	0.190	0.119	0.165	0.381*	-0.160	0.400*	0.191	0.290*
	-2 days	0.431*	0.300*	0.336*	0.249*	0.310*	0.408*	-0.030	0.154	0.238*	0.403*
	-3 days	0.304*	0.323*	0.298*	0.290*	0.214*	0.397*	-0.348	0.067	0.223*	0.289*
	-4 days	0.263*	0.147	0.249*	0.029	0.128	0.251*	0.090	0.194	0.265*	0.231*
	-5 days	0.268*	0.187	0.230*	0.278*	0.185	0.295*	0.080	0.295*	0.200	0.212*
	-6 days	0.279*	0.154	0.261*	0.112	0.111	0.270*	-0.146	0.100	0.221*	0.121
	-7 days	0.143	0.059	0.183	0.160	-0.003	0.094	-0.301	0.205*	0.008	0.116
Cumulative	-2 days	0.305*	0.347*	0.281*	0.194	0.206*	0.554*	-0.205	0.295*	0.233*	0.309*
	-3 days	0.397*	0.401*	0.353	0.267*	0.283*	0.571*	-0.171	0.281*	0.296*	0.371*
	-4 days	0.425*	0.419*	0.374*	0.285*	0.266*	0.592*	-0.137	0.209*	0.297*	0.398*
	-5 days	0.469*	0.394*	0.414*	0.275*	0.290*	0.578*	-0.124	0.238*	0.341*	0.408*
	-6 days	0.472*	0.358*	0.404*	0.290*	0.290*	0.552*	-0.080	0.259*	0.351*	0.389*
	-7 days	0.464*	0.362*	0.391*	0.266*	0.285*	0.517*	-0.094	0.250*	0.362*	0.377*

** Statistically significant.*
Values <20 E. coli MPN 100g^{-1} were assigned values of 10 E. coli MPN 100g^{-1}

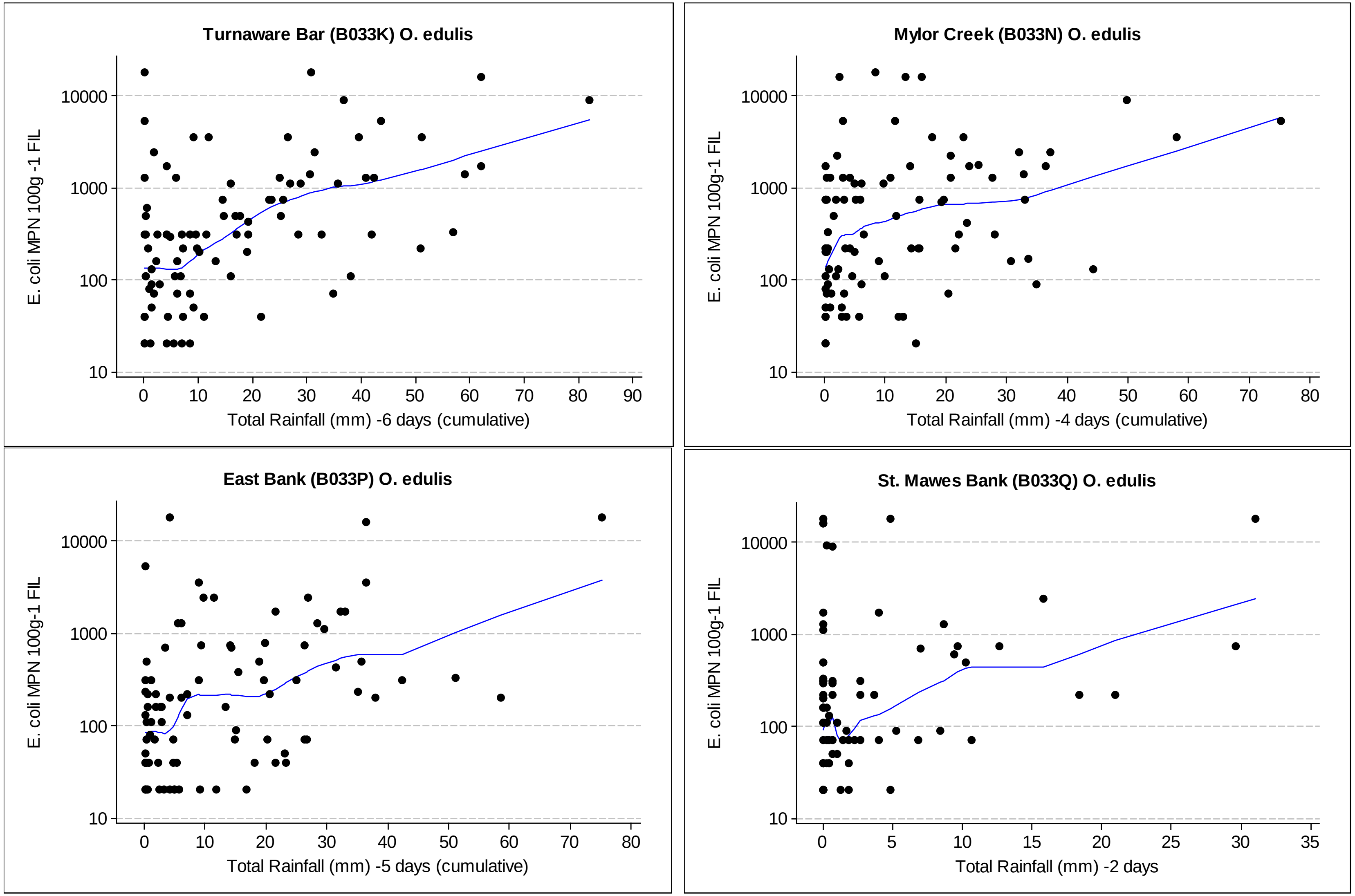


Figure XII.1 Scatterplots of rainfall recorded at Allet gauging station and levels of E. coli in Native oysters from four representative monitoring points in the lower Fal Estuary.

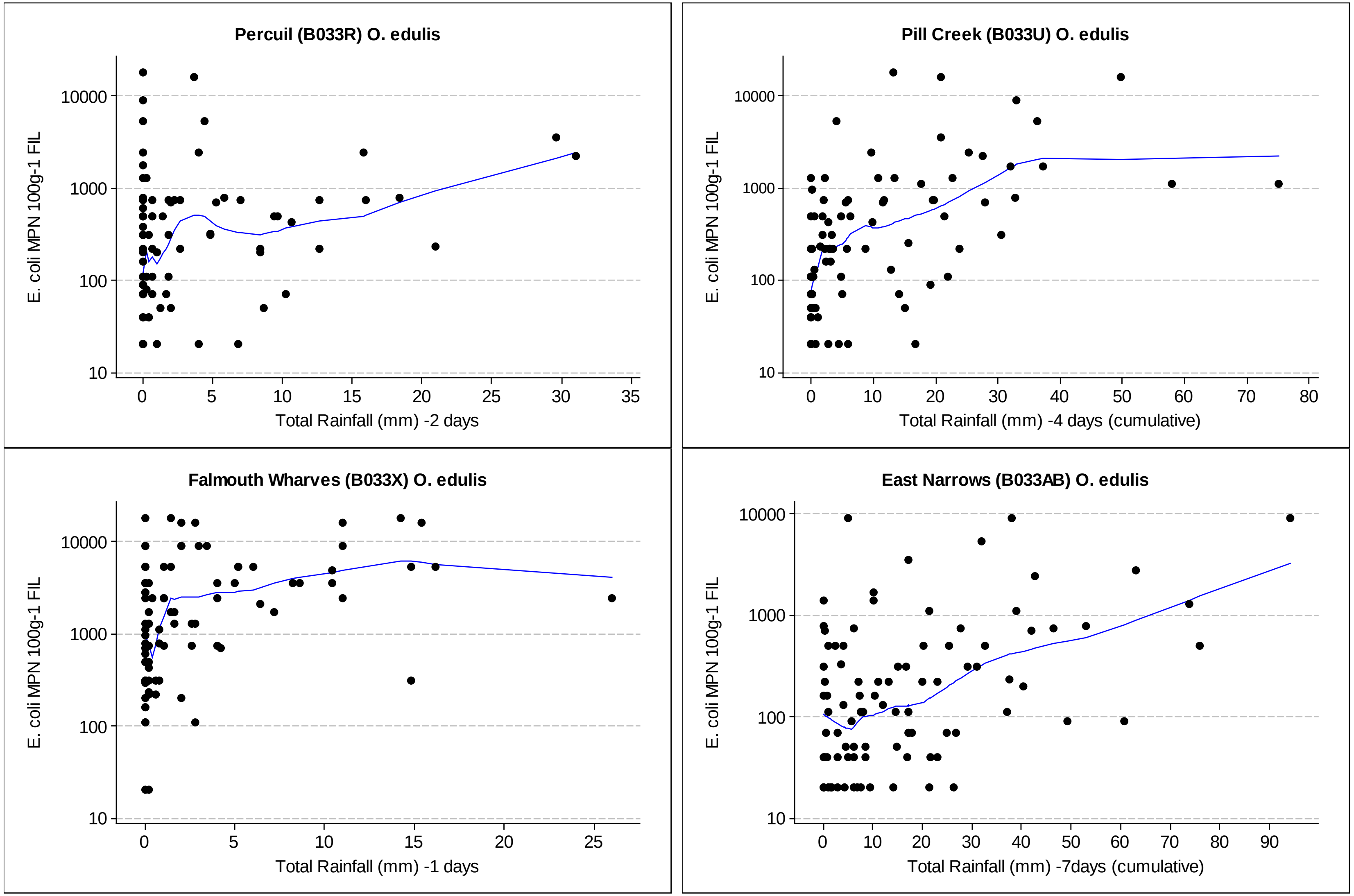


Figure XII.1 (cont) Scatterplots of rainfall recorded at Allet gauging station and levels of E. coli in Native oysters from four representative monitoring points in the lower Fal Estuary.

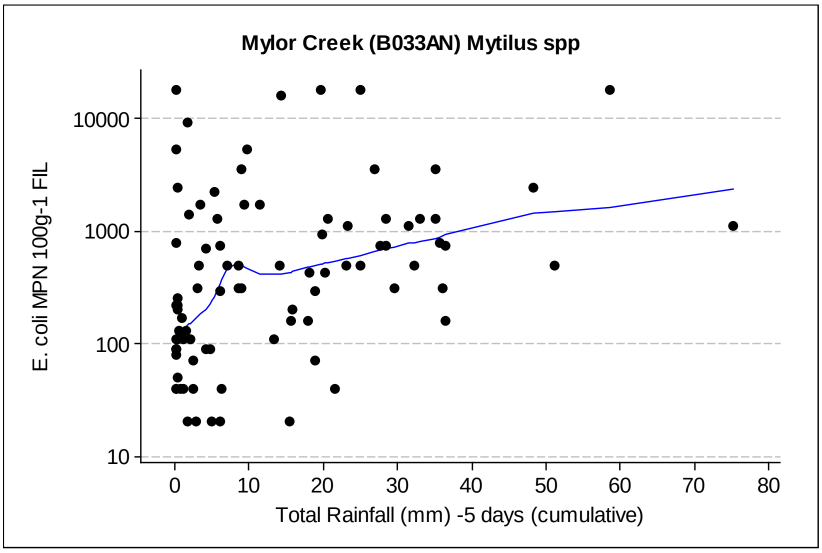


Figure XII.1 (cont) Scatterplot of rainfall recorded at Allet gauging station and levels of E. coli in mussels from one representative monitoring point in the lower Fal Estuary.

LEVELS OF *E. COLI* AND RIVER FLOWS

The association between levels of *E. coli* in bivalves sampled from ten current RMPs and river flows monitored at Tregony and Truro was examined for the period January 2000–February 2009 using Spearman's rank correlation coefficient (*rho*).

Significant positive relationships were detected between river flows and levels of the indicator in Native oysters from Turnaware Bar and St. Mawes Bank (Table XII.3). The significant relationships on the day of sampling indicate a quick response of *E. coli* in oysters to the increase in water levels.

Figure XII.2 shows a very consistent increase in *E. coli* levels in native oysters from Turnaware Bar between the mean flow (1.7m^3 s^{-1}) and 3.5m^3 s^{-1} in the River Fal at Tregony.

It is interesting to note that, despite the different mean flows characteristic of these rivers (see Table III.1), levels of *E. coli* both show very similar responses relative to the time of sampling.

Overall, these results confirm the rivers Fal and Kenwyn as the main routes of faecal contamination influencing the quality of native oysters in beds across the upper Carrick Roads.

The significant negative relationships obtained between levels of *E. coli* in native oysters from Mylor Creek and river flows on the 3rd-7th days before sampling (Table XII.3) are likely to result from dilution effects caused by the influence of seawater at the mouth of the creek.

Table XII.3 Spearman's rho coefficients between river flow recorded at Tregony and Truro gauging stations and MPNs of E. coli 100g[-1] FIL in bivalves from ten monitoring points in the Fal Estuary during the period January 2000−February 2009.

		MPN *E. coli* 100g[-1] FIL									
River Flow		Turnaware Bar (B033K) *O. edulis*	Mylor Creek (B033N) *O. edulis*	East Bank (B033P) *O. edulis*	St. Mawes Bank (B033Q) *O. edulis*	Percuil (B033R) *O. edulis*	Pill Creek (B033U) *O. edulis*	Restronguet Creek (B033W) *O. edulis*	Falmouth Wharves (B033X) *O. edulis*	East Narrows (B33AB) *O. edulis*	Mylor Creek (B33AN) *Mytilus* spp.
Tregony	Time	(n=96)	(n=99)	(n=93)	(n=91)	(n=95)	(n=92)	(n=21)	(n=96)	(n=92)	(n=90)
Daily	Day of sampling	0.294*	-0.046	0.149	0.235*	0.007	0.187	-0.141	0.046	0.020	0.199
	-1 day	0.273*	-0.075	0.161	0.255*	0.017	0.138	-0.083	0.010	0.022	0.200
	-2 days	0.184	-0.134	0.107	0.185	-0.060	0.086	-0.156	-0.110	-0.060	0.167
	-3 days	0.177	-0.186	0.060	0.166	-0.085	0.046	-0.148	-0.085	-0.095	0.144
	-4 days	0.107	-0.253*	0.043	0.133	-0.126	-0.022	-0.246	-0.094	-0.072	0.093
	-5 days	0.064	-0.248*	0.029	0.109	-0.103	-0.051	-0.148	-0.119	-0.045	0.070
	-6 days	0.011	-0.293*	-0.014	0.082	-0.161	-0.110	-0.218	-0.136	-0.121	0.019
	-7 days	0.001	-0.327*	-0.046	0.072	-0.183	-0.125	-0.242	-0.157	-0.200	-0.006
Cumulative	-2 days	0.292*	-0.050	0.166	0.252*	0.017	0.174	-0.112	0.039	0.024	0.206
	-3 days	0.277*	-0.071	0.167	0.245*	-0.002	0.159	-0.116	0.003	0.016	0.208*
	-4 days	0.267*	-0.089	0.150	0.239*	-0.008	0.147	-0.199	-0.014	-0.003	0.196
	-5 days	0.250*	-0.113	0.136	0.232*	-0.026	0.121	-0.194	-0.025	-0.007	0.189
	-6 days	0.232*	-0.139	0.119	0.218*	-0.034	0.095	-0.168	-0.034	-0.004	0.168
	-7 days	0.209*	-0.163	0.099	0.209*	-0.047	0.064	-0.196	-0.051	-0.019	0.147
Truro											
Daily	Day of sampling	0.242*	-0.073	0.152	0.236*	-0.028	0.158	-0.258	0.002	-0.033	0.226*
	-1 day	0.234*	-0.114	0.122	0.254*	-0.023	0.096	-0.268	0.007	-0.040	0.187
	-2 days	0.187	-0.166	0.109	0.210*	-0.071	0.072	-0.224	-0.078	-0.091	0.172
	-3 days	0.155	-0.200*	0.045	0.146	-0.114	0.016	-0.252	-0.114	-0.146	0.136
	-4 days	0.088	-0.252*	0.050	0.119	-0.145	-0.028	-0.378	-0.101	-0.129	0.120
	-5 days	0.111	-0.221*	0.029	0.130	-0.110	-0.018	-0.259	-0.104	-0.101	0.123
	-6 days	0.028	-0.269*	0.010	0.090	-0.162	-0.077	-0.333	-0.120	-0.164	0.081
	-7 days	0.012	-0.316	-0.036	0.075	-0.184	-0.124	-0.388	-0.152	-0.219*	0.031
Cumulative	-2 days	0.246*	-0.091	0.145	0.251*	-0.023	0.136	-0.276	0.004	-0.036	0.210*
	-3 days	0.236*	-0.111	0.142	0.248*	-0.037	0.130	-0.272	-0.017	-0.042	0.202
	-4 days	0.224*	-0.126	0.123	0.230*	-0.054	0.109	-0.270	-0.035	-0.059	0.188
	-5 days	0.205*	-0.153	0.106	0.218*	-0.069	0.078	-0.289	-0.046	-0.074	0.173
	-6 days	0.195	-0.161	0.098	0.205	-0.072	0.067	-0.270	-0.058	-0.072	0.172
	-7 days	0.180	-0.175	0.092	0.193	-0.083	0.046	-0.307	-0.060	-0.080	0.164

** Statistically significant. Values <20 E. coli MPN 100g[-1] were assigned values of 10 E. coli MPN 100g[-1].*

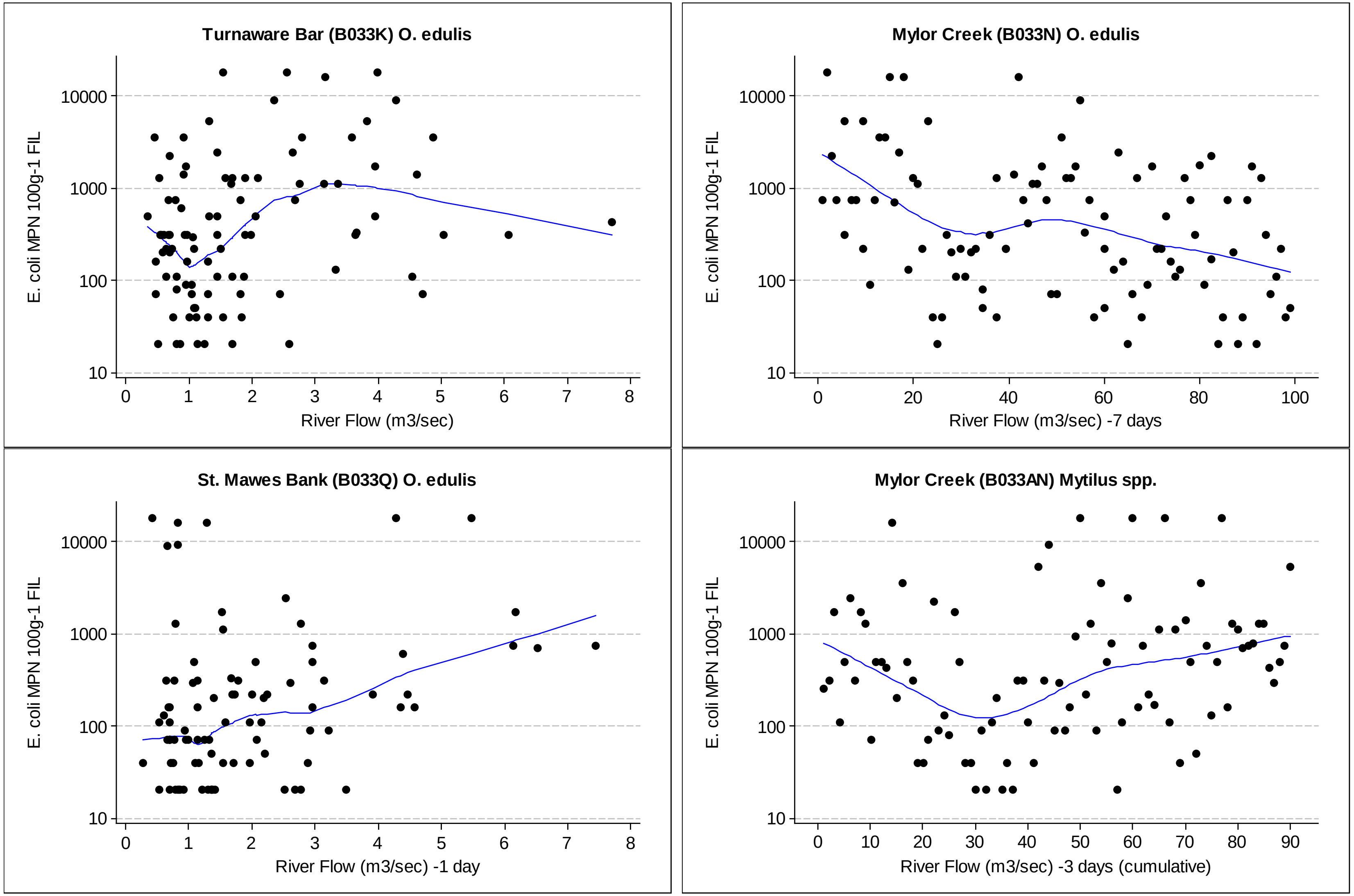


Figure XII.2 Scatterplots of river flow recorded at Tregony gauging station and levels of **E. coli** ***in native oysters and mussels from four representative monitoring points in the lower Fal Estuary.***

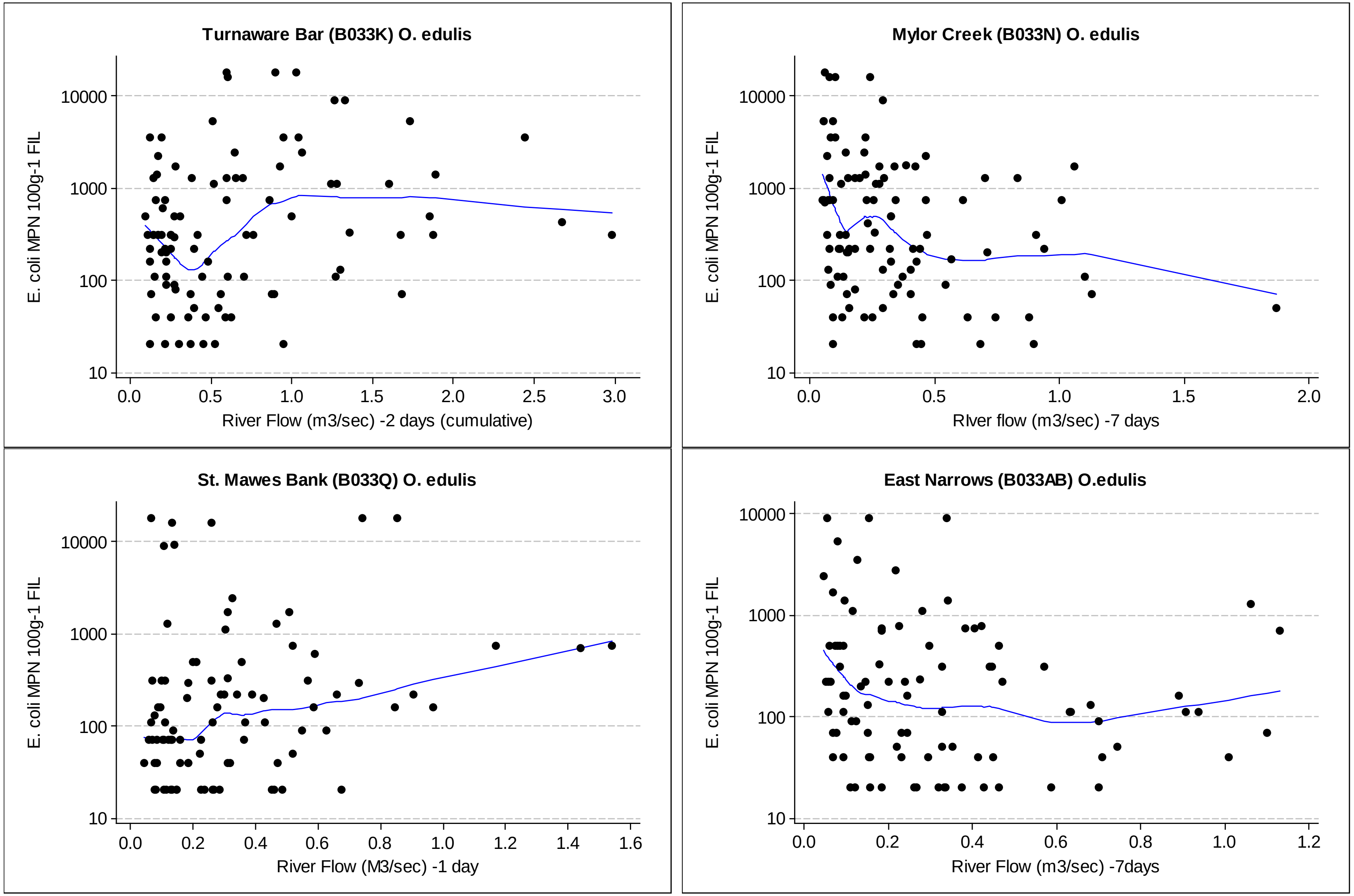


Figure XII.2 (cont.) Scatterplots of river flow recorded at Truro gauging station and levels of* E. coli *in native oysters from four representative monitoring points in the lower Fal Estuary.

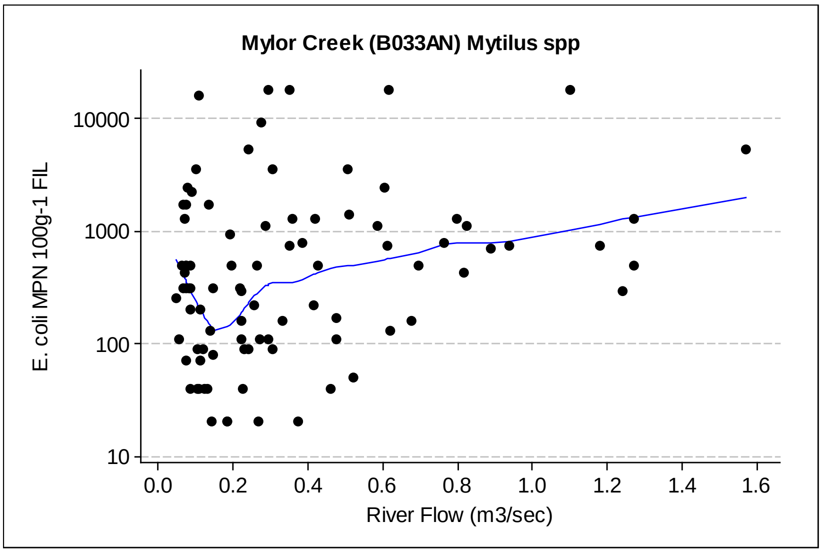


Figure XII.2 (cont.) Scatterplot of river flow recorded at Truro gauging station and levels of E. coli in mussels from Mylor Creek representative monitoring point in the lower Fal Estuary.

SEASONALITY OF *E. COLI* IN SHELLFISH FLESH

All bivalve molluscs in the lower Fal Estuary are subject to year-round classification. This section presents the results of an investigation of seasonal variation in levels of microbiological contamination in currently classified bivalve mollusc beds.

Two methods were employed. The first consisted of the analysis of monthly geometric means of *E. coli* together with the number of *E. coli* results >4,600 MPN100g^{-1} FIL in bivalves. The second method consisted of the analysis of seasonal variation of *E. coli* levels. For this purpose, data was amalgamated by season considering spring (March–May), summer (June–August), autumn (September–November) and winter (December–February). One-way analysis of variance (ANOVA) [28] followed by a Tukey HSD test using a significance level (α) of 0.05 was used to test differences between seasons. Side-by-side box-and-whisker plots[29] were computed to summarise the distribution of these datasets.

The analyses were conducted for datasets with more than 50 results[30], except Restronguet Creek (B033W), from which only 28 samples have been analysed since 2006.

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[28] All datasets were found to be normally distributed as indicated by Anderson-Daring test (95% confidence level).

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

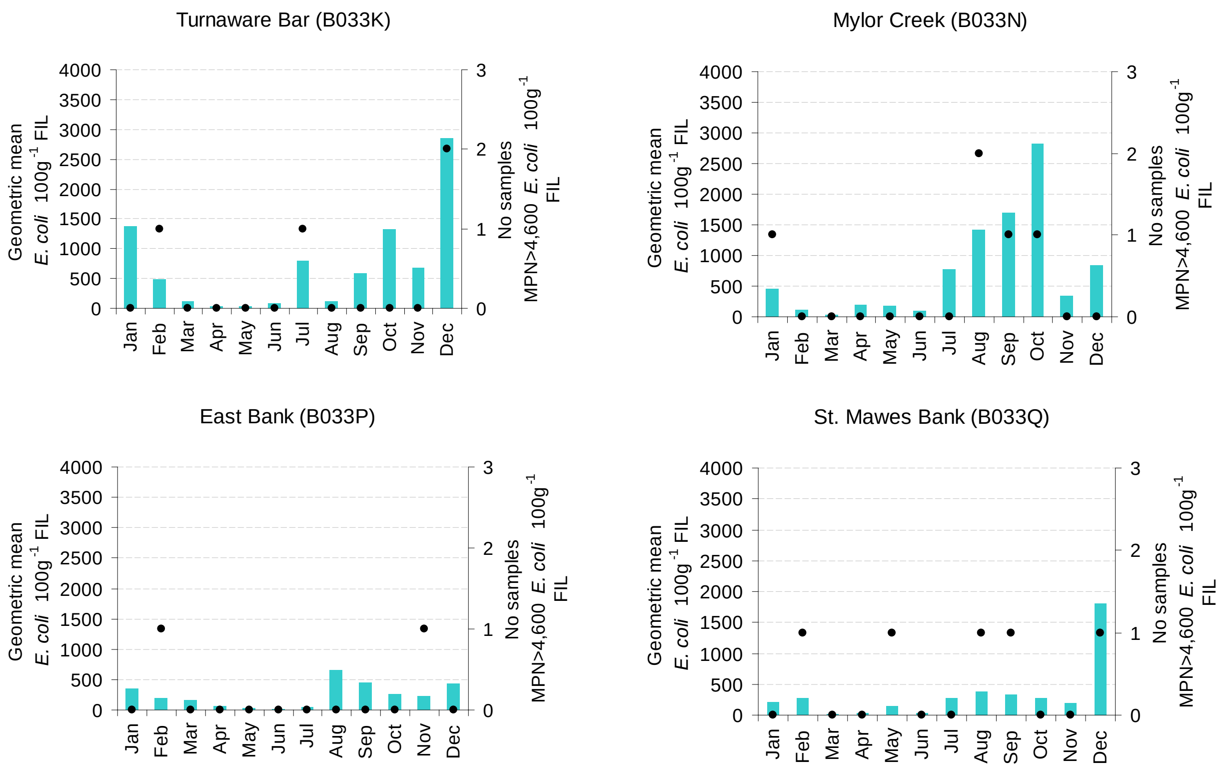
[30] The *European Union Guide to Good Practice on Microbiological Monitoring of Bivalve Mollusc Harvesting Areas* recommends that at least two years' worth of data are necessary to establish a seasonal classification (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2007).

Figure XII.1 depicts large differences in magnitude of faecal contamination detected in Native oysters across the estuary. Monthly geometric means of *E. coli* levels corroborate the spatial pattern of faecal contamination suggested by summary statistics. As expected, higher geometric means of *E. coli* were detected during autumn-winter months than those detected during spring-summer months, although very significant levels have also been detected in August.

Levels of the microbiological indicator above the class B threshold (4,600 MPN *E. coli* 100g^{-1} FIL) have been detected in Native oysters in all months except in March and June. In the case of the native oyster bed at Falmouth Wharves, which is likely to be more impacted by multiple sources of pollution, one or more of these outliers occurred in nine months, suggesting continued impact from pollution sources.

Reference should also be made to the fact that oysters from East Narrows show lower monthly geometric means and lower number of results above the class B threshold.

The analyses revealed a seasonal pattern on the levels of contamination of native oysters in the lower Fal Estuary. Overall, autumn is the season that yields higher number of peak results. Therefore, increasing monitoring frequency during this period will increase the likelihood of detecting high *E. coli* results.



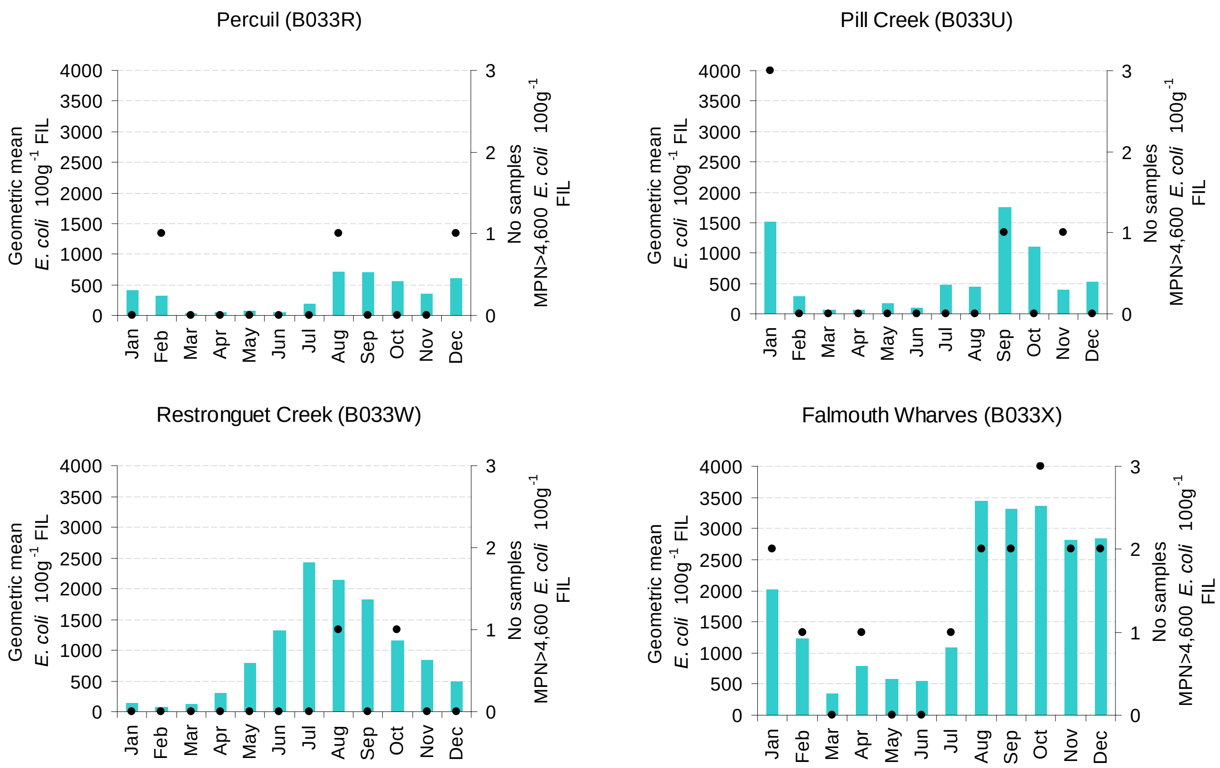


Figure XII.1 Monthly variation of geometric means of* E. coli *(bars) and number of samples with levels of* E. coli *above 4,600 (dots) in Native oysters from eight representative monitoring points in the lower Fal Estuary.

Levels of *E. coli* in mussels show the same seasonal pattern evidenced for Native oysters. A consistent increase in the levels of the microbiological indicator was detected from June to October in Native oysters and mussels from Mylor Creek.

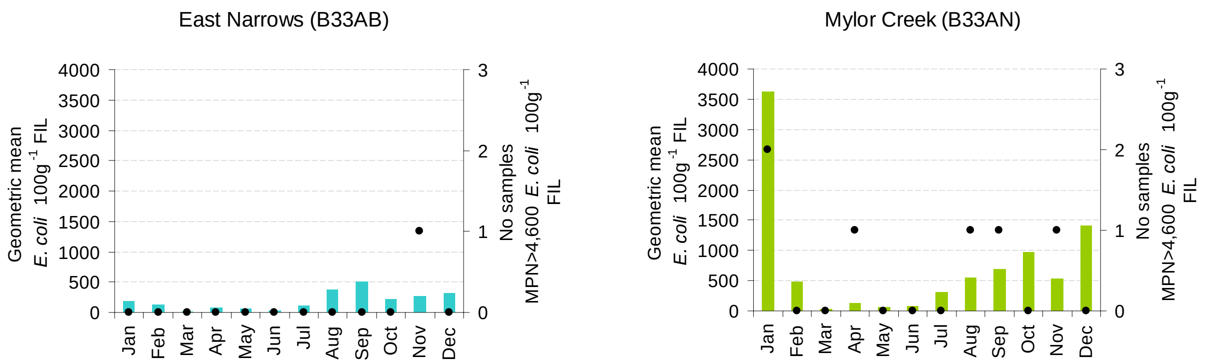


Figure XII.1 (cont) Monthly variation of geometric means of* E. coli *(bars) and number of samples with levels of* E. coli *above 4,600 (dots) in Native oysters (left) and mussels (right) from two representative monitoring points in the lower Fal Estuary.

Figure XII.2 shows seasonal variation of *E. coli* in native oysters and mussels. There is a very consistent increase in the levels of the microbial indicator in native oysters and mussels from all beds between spring and autumn. This trend is more pronounced in native oysters from Turnaware Bar, Pill Creek and Mylor Creek and in mussels from Mylor Creek. In these beds, a significant number of results are within the range for class A during the spring and within the range for class B during the autumn.

In some beds (e.g. native oysters in Turnaware Bar - B033K; mussels at Mylor Creek - B33AN), the trend continues to increase over winter.

Seasonal differences are less evident in native oysters from Falmouth Wharves.

Statistically significant differences were detected in the levels of *E. coli* during spring relative to those during the winter (Table XII.4).

Table XII.4 ANOVA tables for seasonal levels of* E. coli *in bivalves from the lower Fal Estuary.

Source	Degrees of freedom	Sum of squares	Mean squares	F-test	*p*-value
Turnaware Bar (*O. edulis*) - B033K					
Season	3	17.327	5.776	15.19	0.000*
Error	60	22.808	0.380		
Total	63	40.135			
Mylor Creek (*O. edulis*) - B033N					
Season	3	6.971	2.324	4.12	0.010*
Error	58	32.696	0.564		
Total	61	39.667			
East bank (*O. edulis*) - B033P					
Season	3	5.150	1.717	3.61	0.019*
Error	56	26.645	0.476		
Total	59	31.795			
Pill Creek (*O. edulis*) - B033U					
Season	3	7.469	2.490	5.22	0.003*
Error	55	26.250	0.477		
Total	58	33.719			
Falmouth Wharves (*O. edulis*) - B033X					
Season	3	3.988	1.329	2.88	0.044*
Error	56	25.808	0.461		
Total	59	29.797			
East Narrows (*O. edulis*) - B33AB					
Season	3	4.539	1.513	3.47	0.023*
Error	49	21.360	0.436		
Total	52	25.899			
Mylor Creek (*Mytilus* spp.) - B33AN					
Season	3	13.096	4.365	7.88	0.000*
Error	53	29.350	0.554		
Total	56	42.446			

Analyses conducted to beds for which there are more than 50 results.
Asterisks denote significant differences between levels of E. coli *in bivalves during the spring and those during the autumn.*

It is considered that increased sampling frequency (fortnightly) for native oyster and mussels during the autumn-winter period would better reflect the high risk of microbiological contamination in these beds.

Consideration could be given by the Local Enforcement Authority to suspend native oyster sampling during the closed season (April–August).

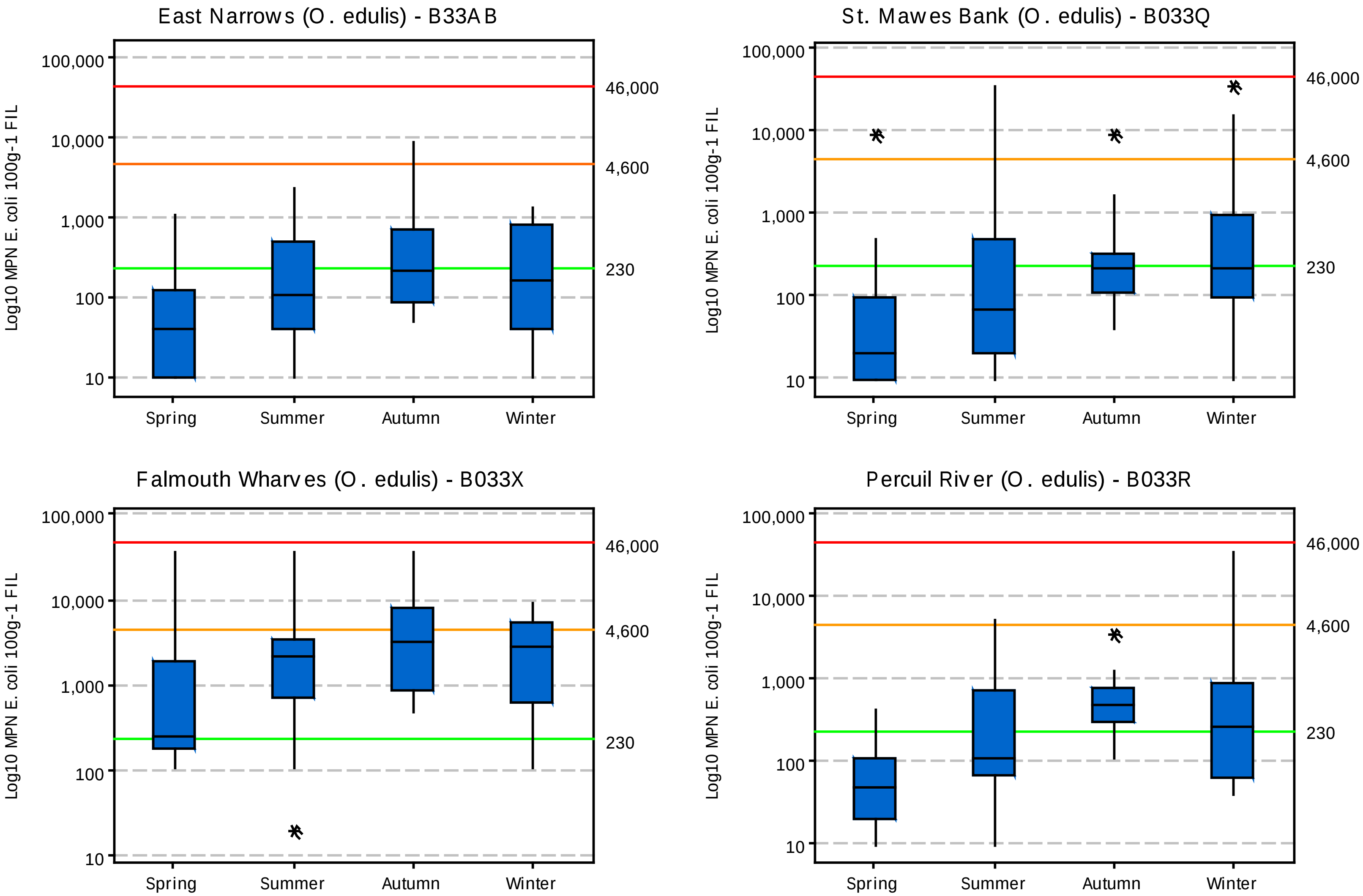


Figure XII.2 Box-and-whisker plots of seasonal variation of* E. coli *levels in native oysters from four representative monitoring points in the lower Fal Estuary.

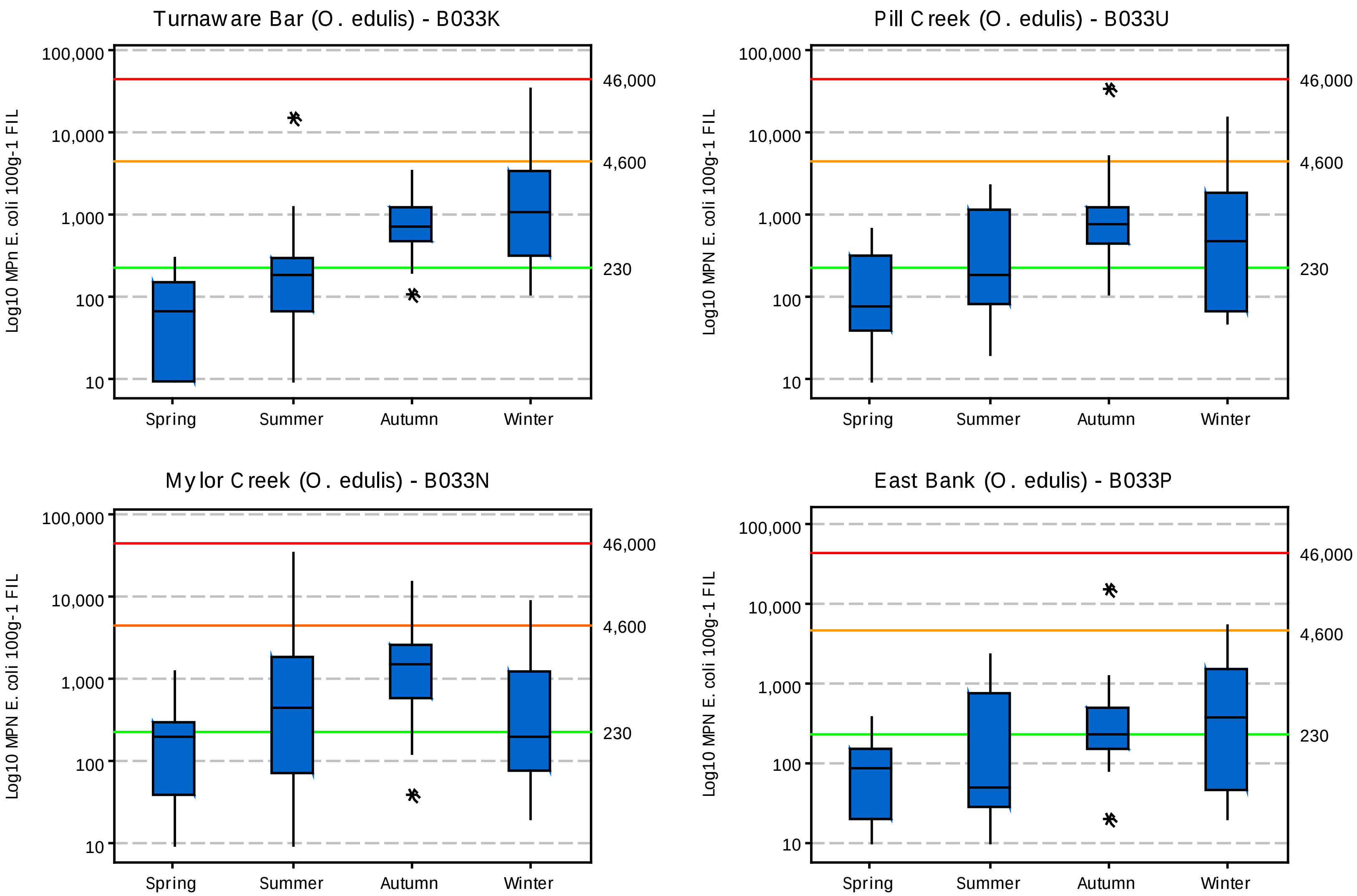


Figure XII.2 (cont) Box-and-whisker plots of seasonal variation of* E. coli *levels in native oysters from four representative monitoring points in the lower Fal Estuary.

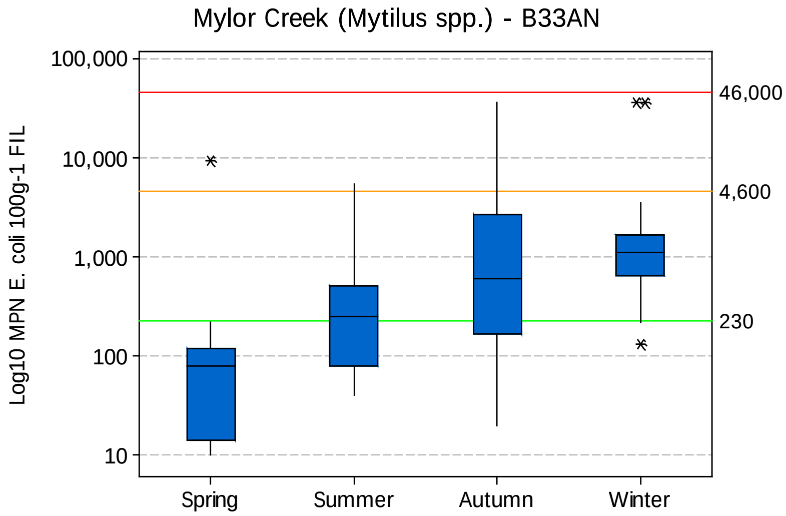


Figure XII.2 (cont) Box-and-whisker plots of seasonal variation of* E. coli *levels in mussels from Mylor Creek in the lower Fal Estuary.

APPENDIX XIII
SHORELINE SURVEY

Dates (times):
boat survey: 18 August 2009 (14:15−17:00 BST);
shoreline walk: 19 August 2009 (08:30−14:00 BST)

Cefas Officers: Simon Kershaw, Richard Acornley
Local Enforcement Authority Officer: Gary Cooper (Falmouth & Truro Port Health).

Area surveyed: boat survey in the lower Fal Estuary, followed by shoreline walk conducted along the eastern shores of Carrick Roads from St. Mawes to St. Just (Figure XII.2).

Objectives: (a) confirm the existence of pollution sources identified during the desk study; and (b) identify any additional pollution sources in the area.

The predicted times and heights of high and low waters and tidal curve on the day of the survey are given in Table XIII.1. and Figure XIII.1.

***Table XIII.1 Predicted high and low water times and heights for Falmouth on 19 August 2009**.*

	Time (height)
Low Water	11:39 (1.0m)
High Water	05:01 (4.9m)
High Water	17:17 (5.4m)

Predicted heights are in metres above Chart Datum.Republished with permission from Admiralty Total Tide (UK Hydrographic Office) by permission of Her Majesty's Stationery Office and the UK Hydrographic Office. © Crown copyright.

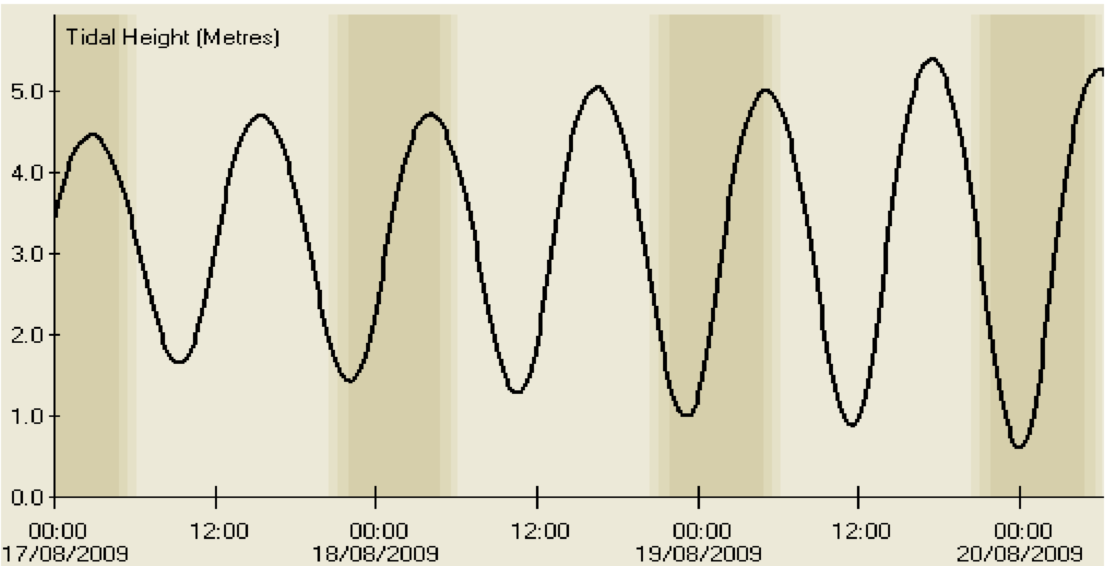


Figure XIII.1 Tidal curve at Falmouth on 18–19 August 2009.
Wells is a Secondary Harmonic port.
Predicted heights are in metres above Chart Datum Republished with permission from Admiralty Total Tide (United Kingdom Hydrographic Office) by permission of Her Majesty's Stationery Office and the UK Hydrographic Office.
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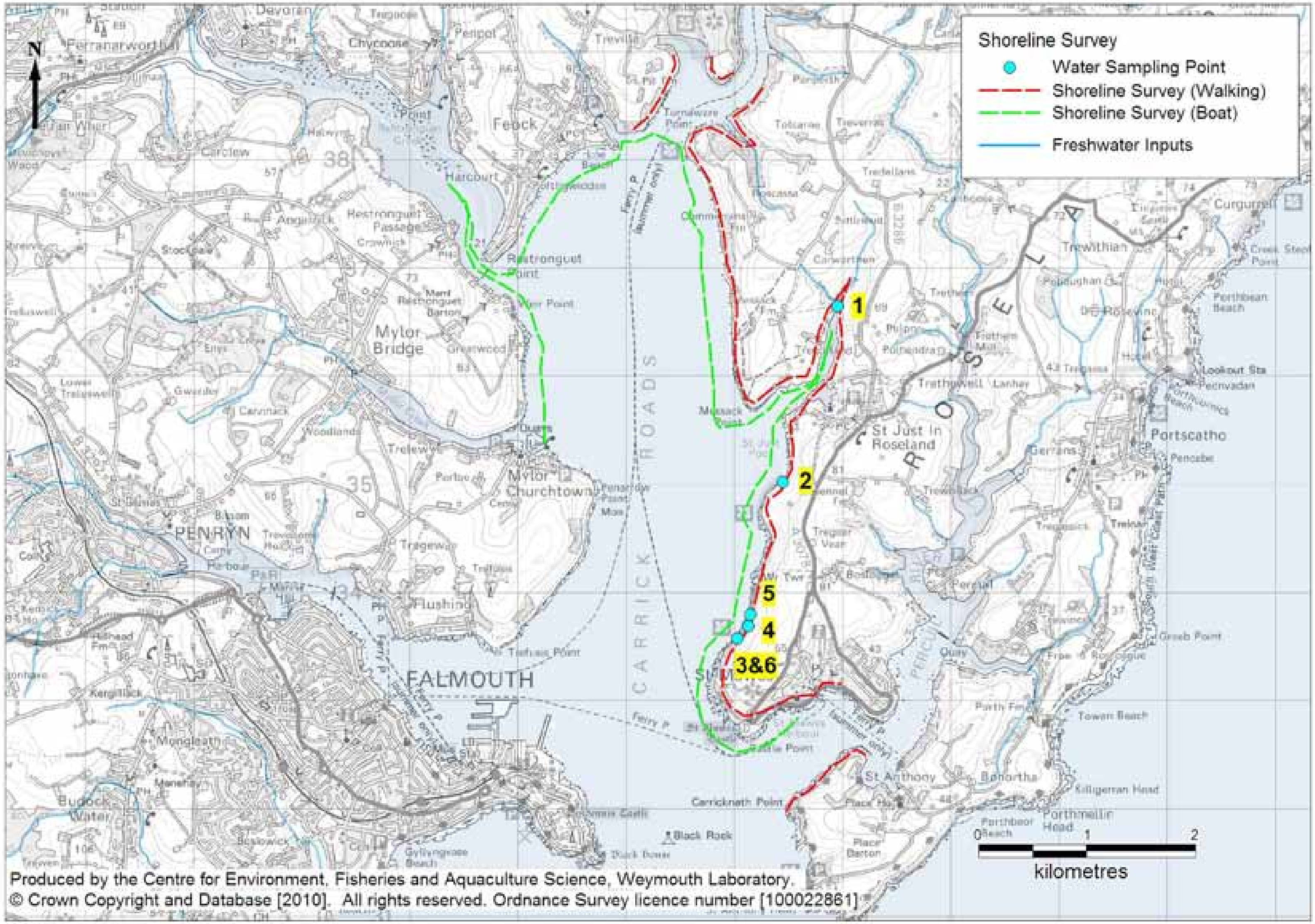

Figure XIII.2 Locations of sites surveyed and sampled in the lower Fal Estuary.

Table XIII.2 summarises the observations made during the survey.

Table XIII.2 Observations and results made during the shoreline survey.

SHORELINE SURVEY RECORD FORM		
1	**Bed ID**	**Current Shellfish Hygiene Representative Monitoring Points** Fal Estuary Mylor Creek B033N (*O. edulis*) SW81923554 Mylor Creek B33AN (*Mytilus* spp.) SW 8197 3552 Restronguet Creek M033 (*O. edulis*) SW 8165 3705 Pill Creek (*O. edulis*) B033U SW 8293 3816 Turnaware Bar B033K (*O. edulis*) SW 8347 3805 East Bank B033P (*O. edulis*) SW 8388 3635 St Mawes Bank B033Q (*O. edulis*) SW 8421 3456 East Narrows 33AB (*O. edulis*) B-LT SW 8391 3274 Percuil B033R (*O. edulis*) B-LT SW 8585 3369 Falmouth Wharves (*O. edulis*) SW79943400
2	**Production Area**	Lower Fal Estuary
3	**SWD Flesh Point**	Carrick Roads (East Narrows Point 25) B33AB (*O. edulis*) SW ID 74 Percuil - including extension (Percuil - *O. edulis*) B033R SW ID 76 Penryn Falmouth Wharves (*O. edulis*) B033X SW ID 75
4	**SWD Water Point**	Penryn SW 8035 3400 Carrick Roads 8310 3400 Percuil SW 8565 3330
5	**Extent of Survey Area**	Mylor & Restronguet creeks, coast to Pill Point and Turnaware Bar to St. Just and St. Mawes
6	**Map/Chart References**	Imray Chart Y58 River Fal Falmouth to Truro: UKHO Admiralty Chart 1156: OS Explorer 105: Falmouth and Mevagissey OS Landranger 204: Truro and Falmouth
7	**Weather Forecast**	
The inshore waters forecast issued by the Met Office, on behalf of the Maritime and Coastguard Agency: (For coastal areas up to 12 miles offshore from Tuesday 18 August 2009 at 0700 until Wednesday 19 August 2009 at 0700) **General Situation at 0700 on Tue 18 Aug 2009:** Pressure will remain high across France with fronts affecting northern and western areas of the United Kingdom at times, and here winds will be occasionally strong. **Lyme Regis to Lands End including the Isles of Scilly:** **24 hour forecast:** Southerly 3 or 4, occasionally 5 in west. Slight occasionally moderate in west. Rain or showers for a time in west. Moderate or good. **Outlook:** Southerly 4 or 5, occasionally 3 at first in east, veering southwesterly 5 or 6. Moderate or rough, occasionally slight at first in east. Fair then rain and showers. Moderate or good occasionally poor.		
8	Maximum air temperature (°C)	18/08/2009 20 19/08/2009 21
9	Maximum wind speed (knots)	18/08/2009 10 19/08/2009 14

10	Precipitation	None
11	Maximum air pressure (hPa) at sea level	18/08/2009 1015 19/08/2009 1011
12	Rivers/streams/springs	**19/08/2009** 10:55 SW 84022 33572 - stream **30** CFU 100ml^{-1} 11:00 SW 84022 33572 - stream **1,300** CFU 100ml^{-1} 11:04 SW 84122 33688 - stream **240** CFU 100ml^{-1} 11:50 NGR not recorded - stream **80** CFU 100ml^{-1} 10:55 SW 84022 33572 - stream **30** CFU 100ml^{-1} (Large gully, stream on beach just south of St Just) 13:05 SW 84952 36644 - stream **30** CFU 100ml^{-1} (Messack Farm, St Just creek stream)
13	Sewage discharges (observed)	**18/08/2009** 14:25 Weir Point boat house pipes 14:30 50° 11.44' 05°03.49' Beach stream 14:35 50° 11.51' 05°03.65' Pipe by boathouse Restronguet Creek entrance **Changed WGS84 to OSGB** 15:15 SW 84475 35877 pipe discharging 15:30 SW 83933 36346 stream **19/082009** 08:48 SW 84834 33145 St Mawes No1 P.S. Control box 10:07 SW 84834 32904 Outfall covered by tide 10:10 SW 84312 32894 Numerous SWO'sll dry on this shoreline 10:18 SW 84178 32729 Nr St Mawes Castle pipe 10:18 SW 84130 32672 St Mawes Castle zig zag pipe 10:55 SW 84022 33572 Stream - **30** cfu100ml^{-1} 11:00 SW 84022 33688 Stream - **1,300** cfu100ml^{-1} (Figure XIII.3) 11:04 SW 84122 33791 Fresh water- **240** cfu100ml^{-1} (Figure XIII.4) 11:13 SW 84224 34060 trickle by style - no sample (Figure XIII.5) 11:27 SW 84345 34494 trickle stream - no sample 11:50 Seawater sample location - **80** cfu100ml^{-1} 11:57 SW 84445 35019 Stream on beach just south of St Just in large gully – **130** cfu100ml^{-1} (Figure XIII.6) 12:46 St Just Holy Well streams SW 84894 35699 SW 84894 35705 SW 84909 35715 SW 84894 35699 stream 13:05 SW 84952 36644 Messack Farm St Just stream sampled - **40** cfu100ml^{-1} (Figure XIII.7) SW 84480 35110 small stream, algae, estuarine, not sampled, land drain (Figure XIII.8)
14	Boats/ports	**18August 2009** (15:10) St Just Creek yachts and ploughed land (Figure XIII.9) 18/08/09 SW 83665 37497 yellow jet ski platform
15	Animals	**Birds** 18/08/09 (15:35) SW 83919 36727 cliff roost 11 cormorants (Figure XIII.10), 1 gull 18/08/09 SW 83841 37074 heron 19/08/09 St Just - gulls c. 25, curlew, heron, cormorants **Dogs:** St Mawes - Dog ban on beach Lower Castle Road **Other:** St. Just - sheep on west slope

16	Sewage related debris	None
17	Samples taken	See discharges above
18	Water appearance	Clear/turbid Other
19	Bivalve Harvesting Activity	Hand-picked/raked/dredged/suspended ropes Oyster dredging commences 1st October
20	Production	Queen scallops as by-catch of oyster dredging 18/08/09 (16:34) SW 81451 35465 last withy marking OYF north shore upstream Mylor Creek 19/08/09 (09:50) Gary Cooper noted that three groups are diving for scallops mainly 'Kings' in Carrick Roads & Helford all year round. These are likely to seek classification Undersize oysters and possible cockles in Restronguet Creek
21	Land use adjacent to harvesting area	Vegetation: grassland, water meadow, marsh, chalk grassland, woodland (coniferous/deciduous/mixed), scrub Habitation: Urban, sub-urban, rural Built areas: residential, commercial, industrial Infrastructure: roads, railway
22	Topography Adjacent to Harvesting Area	Steep-sided valley/flat land

Figure XIII.3 Stream above East Bank.

Figure XIII.4 Stream above East Bank.

Figure XIII.5 Stream above East Bank.

Figure XIII.6 Stream on beach just south of St. Just.

Figure XIII.7 Stream at Messack Farm.

Figure XIII.8 Land drain pipe at St Just Pool.

Figure XIII.9 Moored boats at St. Just Pool.

Figure XIII.10 Cormorants at East Bank.

Figure XIII.11 Piped discharge at Weir Point.

Figure XIII.12 Piped discharge at St. Just.

Figure XIII.13 Piped discharge at St. Just.

Figure XIII.14 St. Mawes PS No1 control box.

Figure XIII.15 St. Mawes PS No1 outfall.

CONCLUSIONS

There was no evidence of any discharges along East Bank from Turnaware to Messack Point. However, a number of small streams and land drainage gullies above East Bank may convey contaminated land runoff to this part of the estuary in wet weather. A colony of cormorants was observed roosting on the low cliff face above East Bank at the time of the shoreline survey in August.

Several pipeline discharges and stream inputs were noted in the vicinity of St Just Pool which also contains a number of swinging moorings for small boats and some cruising yachts. These represent several sources of potential contamination and might be expected to have a localised impact on water quality from time to time.

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List of abbreviations

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

Glossary

Bathing Water	Element of surface water used for bathing by a large number of people. Bathing waters may be classed as either EC designated or non-designated OR those waters specified in section 104 of the Water Resources Act, 1991.
Bivalve mollusc	Any marine or freshwater mollusc of the class Pelecypoda (formerly Bivalvia or Lamellibranchia), having a laterally compressed body, a shell consisting of two hinged valves, and gills for respiration. The group includes clams, cockles, oysters and mussels.
Classification of bivalve mollusc production or relaying areas	Official monitoring programme to determine the microbiological contamination in classified production and relaying areas according to the requirements of Annex II, Chapter II of EC Regulation 854/2004.
Coliform	Gram negative, facultatively anaerobic rod-shaped bacteria which ferment lactose to produce acid and gas at 37°C. Members of this group normally inhabit the intestine of warm-blooded animals but may also be found in the environment (e.g. on plant material and soil).
Combined Sewer Overflow	A system for allowing the discharge of sewage (usually dilute crude) from a sewer system following heavy rainfall. This diverts high flows away from the sewers or treatment works further down the sewerage system.
Discharge	Flow of effluent into the environment.
Dry Weather Flow (DWF)	The average daily flow to the treatment works during seven consecutive days without rain following seven days during which rainfall did not exceed 0.25 mm on any one day (excludes public or local holidays). With a significant industrial input the dry weather flow is based on the flows during five working days if production is limited to that period.
Ebb tide	The falling tide, immediately following the period of high water and preceding the flood tide. Ebb-dominant estuaries have asymmetric tidal currents with a shorter ebb phase with higher speeds and a longer flood phase with lower speeds. In general, ebb-dominant estuaries have an amplitude of tidal range to mean depth ratio of less than 0.2.
EC Directive	Community legislation as set out in Article 189 of the Treaty of Rome. Directives are binding but set out only the results to be achieved leaving the methods of implementation to Member States, although a Directive will specify a date by which formal implementation is required.
EC Regulation	Body of European Union law involved in the regulation of state support to commercial industries, and of certain industry sectors and public services.
Emergency Overflow	A system for allowing the discharge of sewage (usually crude) from a sewer system or sewage treatment works in the case of equipment failure.
Escherichia coli (E. coli)	A species of bacterium that is a member of the faecal coliform group (see below). It is more specifically associated with the intestines of warm-blooded animals and birds than other members of the faecal coliform group.
E. coli O157	E. *coli* O157 is one of hundreds of strains of the bacterium *Escherichia coli*. Although most strains are harmless, this strain produces a powerful toxin that can cause severe illness. The strain O157:H7 has been found in the intestines of healthy cattle, deer, goats and sheep.
Faecal coliforms	A group of bacteria found in faeces and used as a parameter in the Hygiene Regulations, Shellfish and Bathing Water Directives, *E. coli* is the most common example of faecal coliform. Coliforms (see above) which can produce their characteristic reactions (e.g. production of acid from lactose) at 44°C as well as 37°C. Usually, but not exclusively, associated with the intestines of warm-blooded animals and birds.
Flood tide	The rising tide, immediately following the period of low water and preceding the ebb tide.
Flow ratio	Ratio of the volume of freshwater entering into an estuary during the

	tidal cycle to the volume of water flowing up the estuary through a given cross section during the flood tide.
Geometric mean	The geometric mean of a series of N numbers is the N^{th} root of the product of those numbers. It is more usually calculated by obtaining the mean of the logarithms of the numbers and then taking the anti-log of that mean. It is often used to describe the typical values of a skewed data such as one following a log-normal distribution.
Hydrodynamics	Scientific discipline concerned with the mechanical properties of liquids.
Hydrography	The study, surveying, and mapping of the oceans, seas, and rivers.
Lowess	LOcally WEighted Scatterplot Smoothing, more descriptively known as locally weighted polynomial regression. At each point of a given data set, a low-degree polynomial is fitted to a subset of the data, with explanatory variable values near the point whose response is being estimated. The polynomial is fitted using weighted least squares, giving more weight to points near the point whose response is being estimated and less weight to points further away. The value of the regression function for the point is then obtained by evaluating the local polynomial using the explanatory variable values for that data point. The LOWESS fit is complete after regression function values have been computed for each of the *n* data points. LOWESS fit enhances the visual information on a scatterplot.
Secondary Treatment	Treatment to applied to breakdown and reduce the amount of solids by helping bacteria and other microorganisms consume the organic material in the sewage or further treatment of settled sewage, generally by biological oxidation.
Sewage	Sewage can be defined as liquid, of whatever quality that is or has been in a sewer. It consists of waterborne waste from domestic, trade and industrial sources together with rainfall from subsoil and surface water.
Sewage Treatment Works (STW)	Facility for treating the waste water from predominantly domestic and trade premises.
Sewer	A pipe for the transport of sewage.
Sewerage	A system of connected sewers, often incorporating inter-stage pumping stations and overflows.
Storm Water	Rainfall which runs off roofs, roads, gulleys, etc. In some areas, storm water is collected and discharged to separate sewers, whilst in combined sewers it forms a diluted sewage.
Waste water	Any waste water but see also “sewage”.

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