EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Upper Blackwater Estuary (Essex)

2011

Cover photo: Southey Creek and Osea Island.

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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 production areas in Osea Island and western part of the Blackwater Estuary. Its primary purpose is to demonstrate compliance with the requirements for classification of bivalve mollusc production areas, as determined 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).

CONSULTATION:

Consultee	Date of consultation	Date of response
Environment Agency	23/09/2010	06/01/2011
Maldon District Council	06/08/2010	07/02/2011
Kent & Essex Sea Fisheries Committee	23/09/2010	07/01/2011

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CONTENTS

1. INTRODUCTION

LEGISLATIVE REQUIREMENT

Filter feeding, bivalve molluscan shellfish (e.g. cockles, mussels) 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 areas;

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

(c) determine the characteristics of the circulation of pollutants by virtue of current patterns, bathymetry and the tidal regime 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 sanitary survey was prompted by an application for microbiological monitoring and classification of farmed mussels (*Mytilus* spp.) and native oysters (*Ostrea edulis)* at South of Osea Island, in the Blackwater Estuary. A desk based assessment of existing information has been undertaken and the results of the shoreline surveys are drawn together in an overall assessment of the potential sources of pollution likely to impact on the levels of microbiological contamination for bivalve mollusc classification zones (CZs). The results from the shoreline surveys undertaken in the estuary are set out in the Appendix XIII.

The sampling plan for microbiological monitoring, derived from the overall assessment, is presented in Section 4. The sampling plan includes the recommended boundaries of CZs, locations of representative monitoring points (RMPs) and sampling frequency for farmed mussels (*Mytilus* spp.) south of Osea Island and classified mussels, native oysters (*O. edulis*) and Pacific oysters (*Crassostrea gigas)*] in the western part of the Blackwater Estuary.

SITE DESCRIPTION

BLACKWATER ESTUARY

Situated in Essex, on the East coast of England, the Blackwater is a wide, shallow estuary of approximately 23km in length formed from pre-existing valleys which were flooded at the end of the last Ice Age (Figure 1.1). It is characterised by low-lying land comprised of reclaimed saltmarshes (Halcrow Group Ltd., 2003). At low tide, much of the estuary becomes mud flats fringed by salt marsh on the upper shores, with shingle, shell banks and offshore islands an additional feature of the tidal flats.

The whole length of the estuary is enclosed by seawalls (Halcrow Group Ltd., 2003). Saltmarshes are under constant erosion, and continued inward progression by deposition by the tides is prevented by man-made sea defences (Maldon District Council and Colchester Borough Council, 1996). The islands of Osea and Northey force the estuary to subdivide producing large areas of mudflat with little or no saltmarsh (Shepherd *et al.*, 2005). Table 1.1 summarises the main characteristics of the Blackwater Estuary.

Figure 1.1 Aerial view of Blackwater Estuary.
Google Earth™ mapping service, 2009.

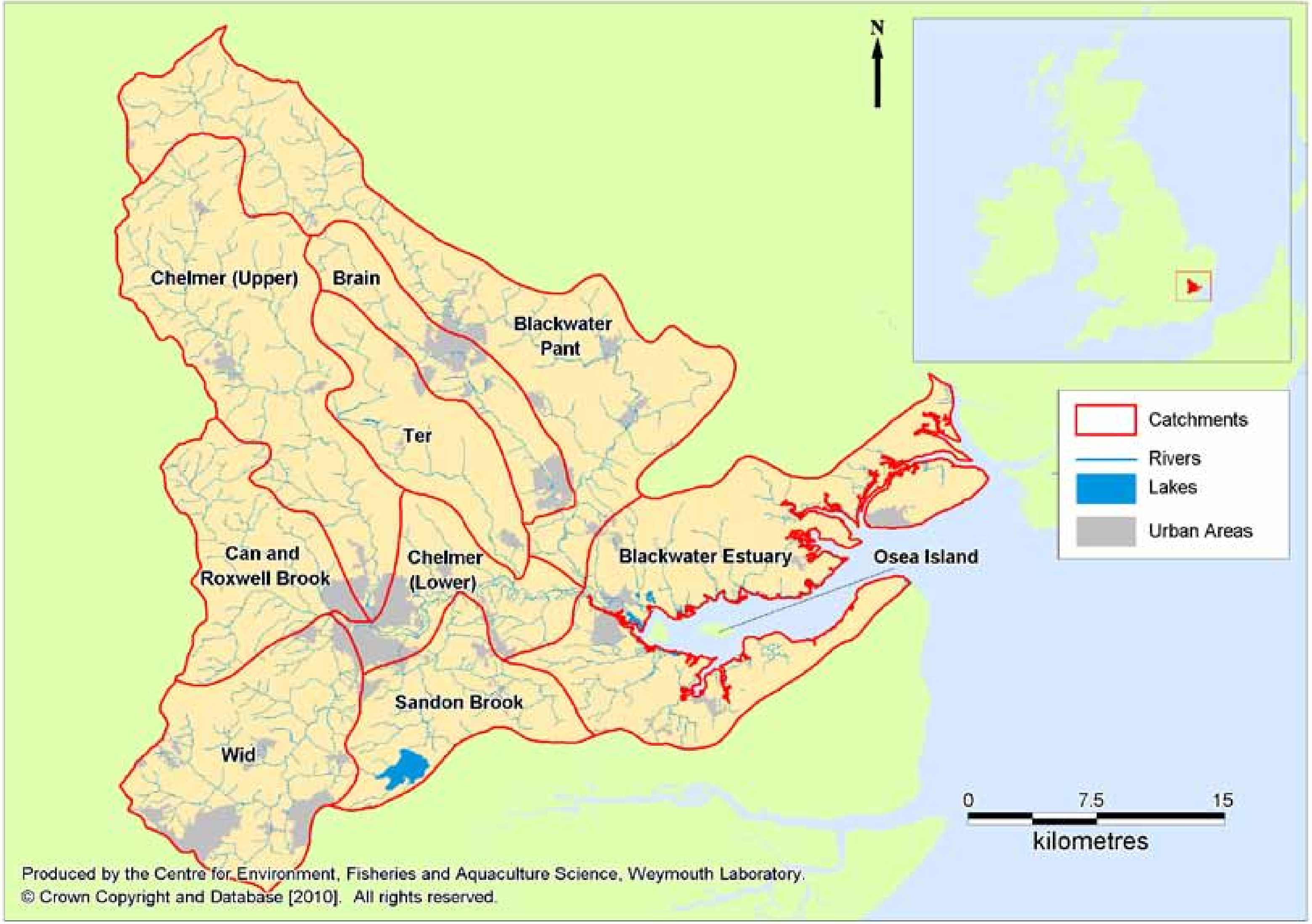

Figure 1.2 Location of the Blackwater Estuary and associated river catchments.

Table 1.1 Main characteristics of Blackwater Estuary.

Geomorphological classification	Coastal plain/spit enclosed
Shoreline length (km)	107.5
Core area (ha)	5184.3
Intertidal area (ha)	3320

Data from ABPmer and Wallingford (2009).

Osea Island is a small island on the western part of the estuary (Figure 1.2) which forms a low ridge bordered to the north and east by saltmarsh. The island is flat and low-lying with one settlement at Osea Farm (Essex County Council, 2008).

CATCHMENT

The estuary drains a total area of approximately 1200km^{2}. The main freshwater inputs are from the Blackwater and Chelmer Rivers (Figure 1.2), collectively receiving discharges from a population of about 400,000 (Chesman *et al.*, 2006)

Land cover within the catchment is shown in Figure 1.3. The Blackwater Estuary is fringed predominantly by low lying arable land (Maldon District Council and Colchester Borough Council, 1996). However, livestock farming is also important, with a total animal population at 45,000 in 2005.

The geology of the catchment comprises mainly of boulder clay and morainic drift with less significant areas of glacial sand and gravel across the catchment and small areas of clay and river terrace deposits (mainly sand and gravel) and alluvium in the lower reaches of the catchment (NERC, 2005). These formations are essentially of very low permeability. However, some areas in the upper catchment are highly permeable (NERC, 2005).

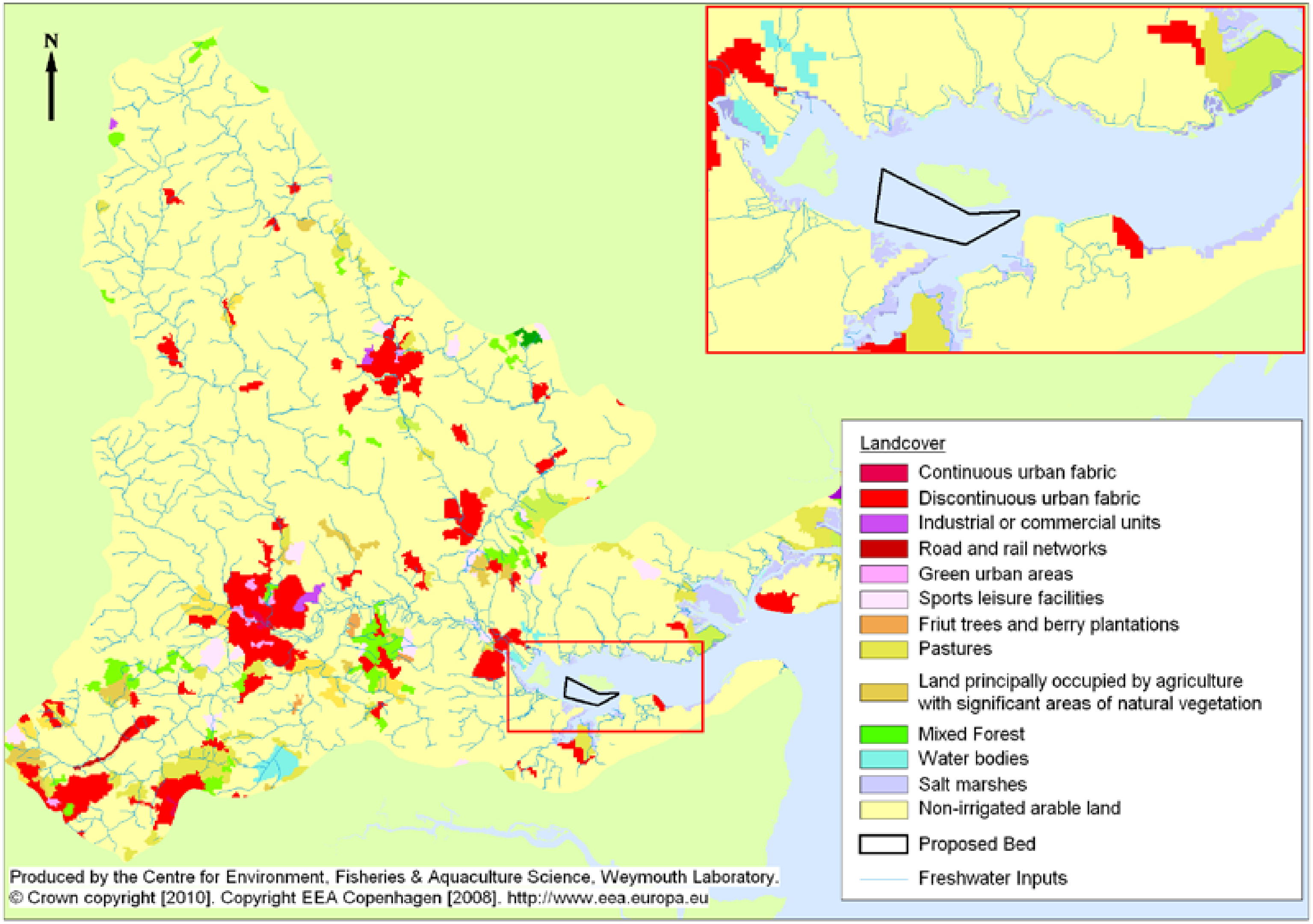

Figure 1.3 Land Cover in the Blackwater Estuary catchment.

The surrounding terrestrial habitats, the sea wall, ancient grazing marsh and its associated fleet and ditch systems, plus semi-improved grassland, are of high conservation interest (Figure 1.4).

The Blackwater Estuary is a designated Ramsar site under the Convention on Wetlands of International importance. Its mudflats and saltmarshes support nationally and internationally important overwintering waterfowl. The surrounding terrestrial habitats, sea wall, marsh, fleet and ditch systems, as well as semi-improved grasslands are also of high conservation interest. The variability of habitats support nationally scared plants and nationally important rare invertebrates. Of these, 16 are British Red Data Book species (JNCC, 2008)

Blackwater Estuary is also a designated SPA under the EC Directive on the Conservation of Wild Birds (79/409/EEC) (The Wild Birds Directive). The saltmarsh area is the largest in Essex, and the fifth largest in the UK (over 1000 hectures) (Chesman *et al.*, 2006), making the site internationally important for a wide range of overwintering waterbirds, including raptors, geese, ducks and waders. The site is also important in summer for breeding terns. The species assemblage qualifies the site to be a wetland if international importance (JNCC, 2001).

All Essex Estuaries are listed as Special Areas of Conservation (SAC) under under the EC Directive on the Conservation of Natural Habitats and of Wild Flora and Fauna (92/43/EEC) (also known as the 'Habitats Directive'). Blackwater Esturary supports variety of internationally important habitats including estuarine, mudflats, sandflats, *Salicornia* colonizing mud, *Spartina* swards and Atlantic salt meadows (Chris Blandford Associates, 2006).

Blackwater Estuary is designated as a National Nature Reserve (NNR), comprising two main areas with Old Hall Marshes in the North, and Tollesbury Flats in the South managed by the RSPB and Natural England respectively (Natural England, 2009).

The entire Blackwater Estuary is a designated Site of Special Scientific Interest (SSSI) under the Wildlife and Countryside Act (1981), as amended by the Countryside Right of Way (CRoW) Act 2000.

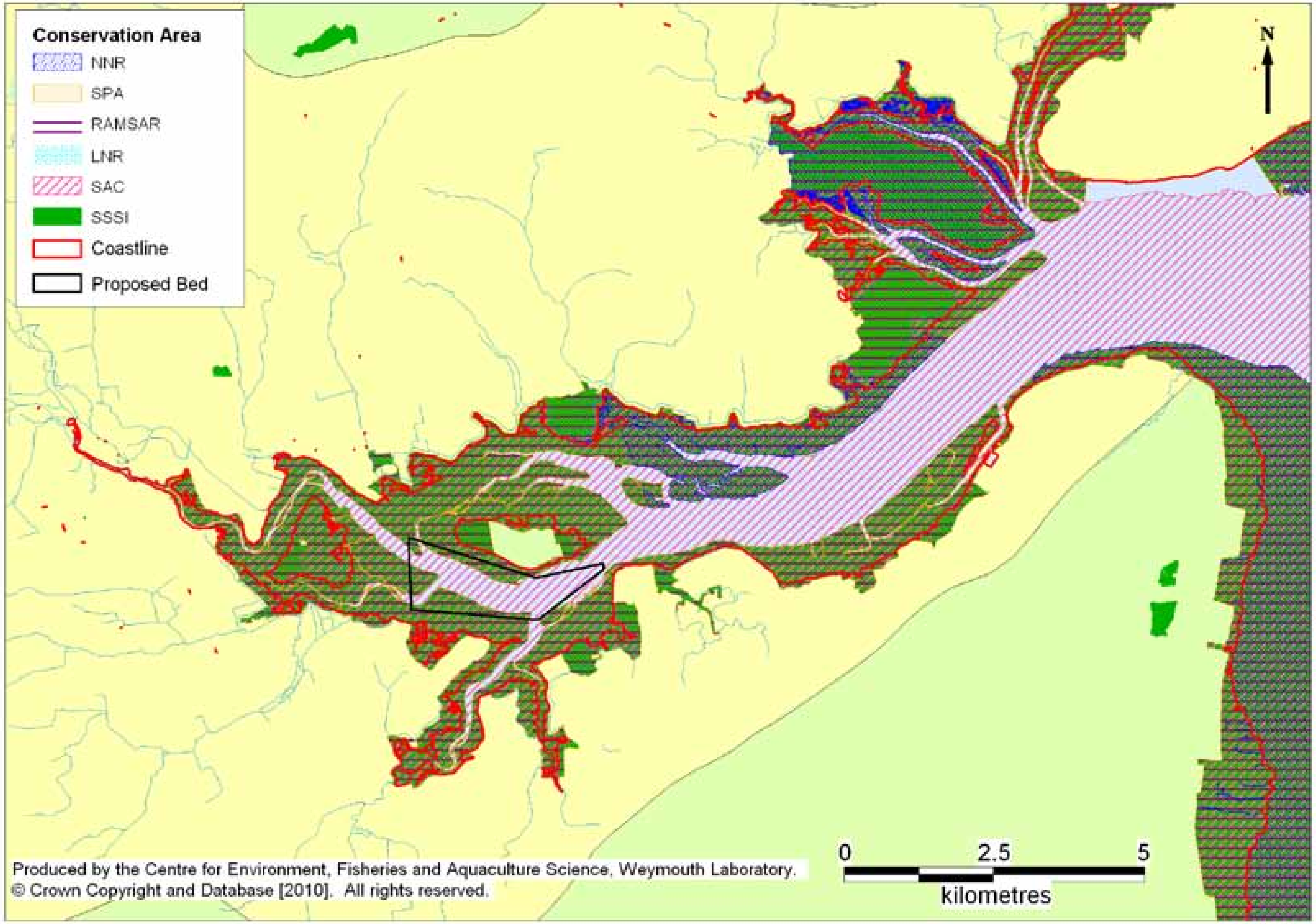

Figure 1.4 Nature conservation designations in the Blackwater Estuary.
Boundary data from and regularly updated by Natural England (2009). (http://www.naturalengland.org.uk).

2. SHELLFISHERIES

2.1 SPECIES, LOCATION AND EXTENT

The harvesting of native oysters (*Ostrea edulis*) and mussels (*Mytilus* spp.) is a century-old activity in the Blackwater Estuary. The first company to be granted a lease was the Blackwater Oyster Breeding Company in 1878 which was replaced by the Maldon Oyster Company in 1960 (Maldon Oysters, 2008).

In the past, native oyster fishery was severely affected by adverse weather conditions (Davidson, 1976) and *Bonamia* (Laing and Spencer, 2006). Mortalities arising from this infection were high on the natural and relaying beds in the estuary during the 1980s (Spencer, 2002). However, periods of good recruitment have been recorded since the 1950s (Davidson, 1976).

Nowadays, native oyster beds occur across the estuary from the Upper Collins Creek to the mouth at Mersea Island. The bivalve mollusc beds in the wider Blackwater are shown in Figure 21A.

Maldon Oyster Co. submitted an application for classification of mussels and native oysters at Southey Creek between The Barnacle and North Double navigation buoy, and only this area and the western part of the bed along the River Blackwater is considered in this sanitary survey (Figure 2.1B).

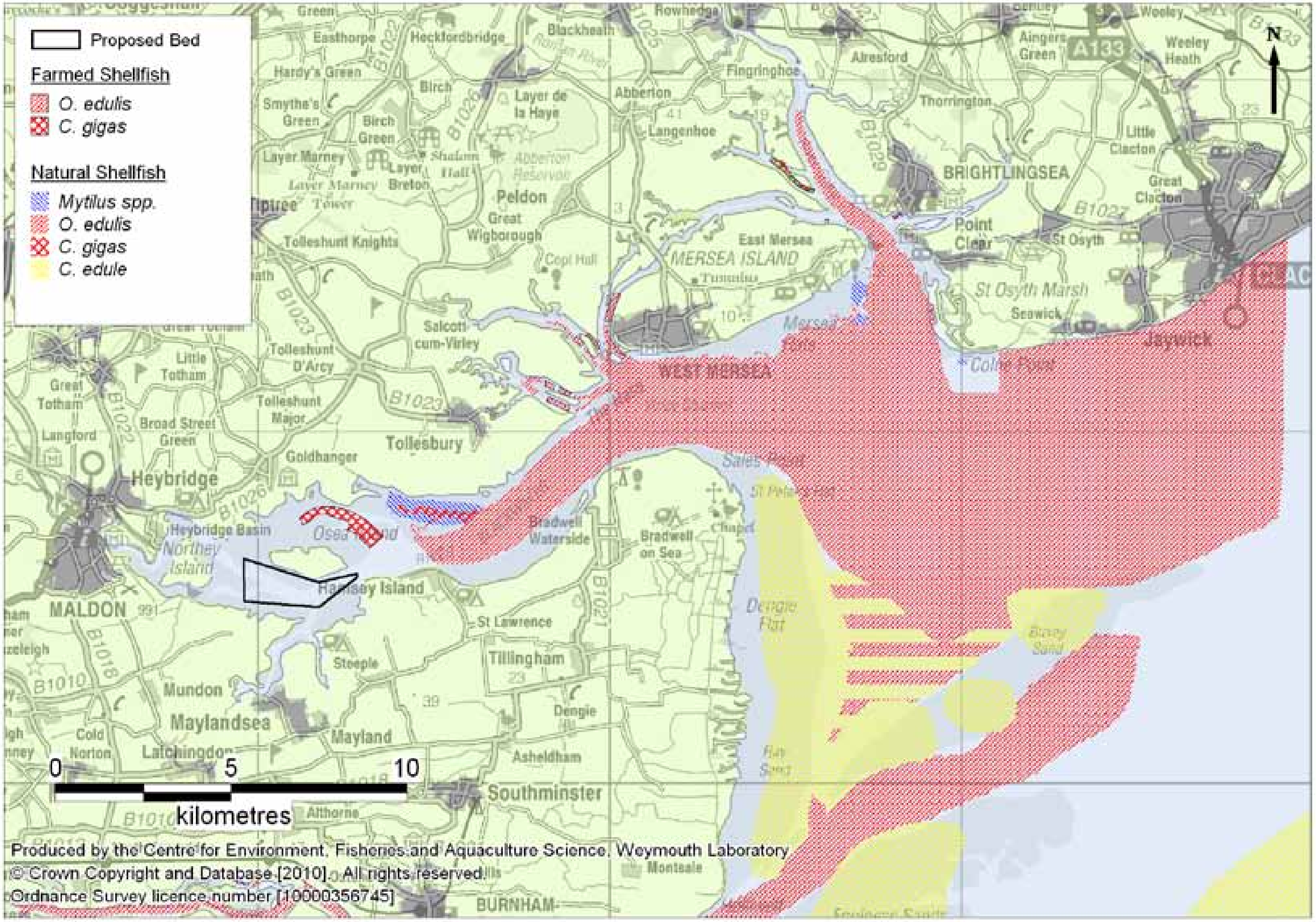

Figure 2.1A Location of bivalve mollusc beds in the Blackwater Estuary.

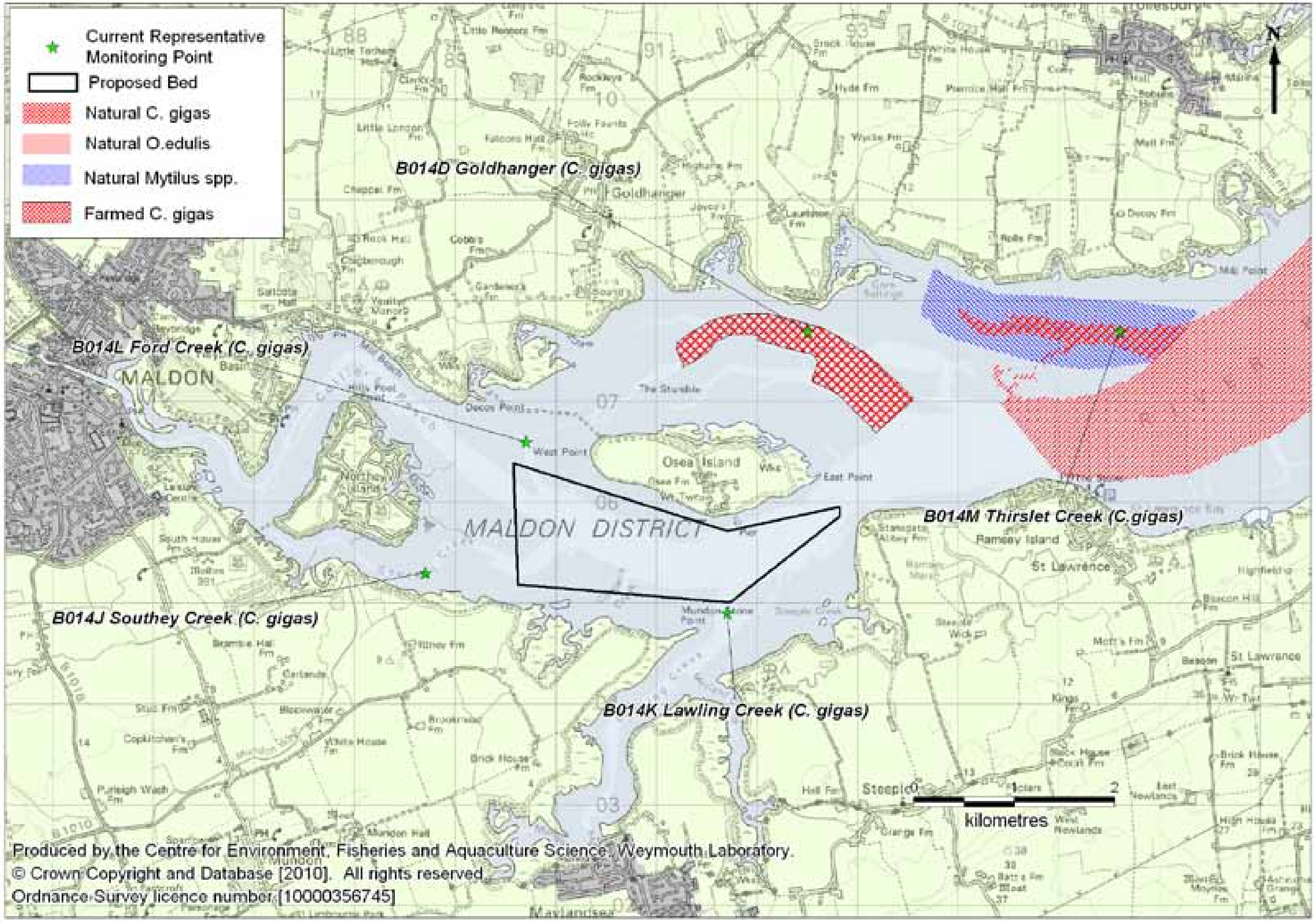

Figure 2.1B Location proposed and existing bivalve mollusc beds plus existing beds and their representative monitoring points in the western part of Blackwater Estuary.

Mussels are often found in sheltered estuaries, just below the low water, where a food supply of suspended organic detritus and phytoplankton is available (Tebble, 1976). The Essex estuaries and creeks are very productive areas which warm up rapidly in the spring and summer to provide excellent growing conditions for bivalve molluscs (Laing and Spencer, 2006). Natural mussel beds occur between Goldhanger Creek and Thirslet Spit (Figure 2.1). The applicant intends to dredge seed mussels from a site at Swire Hole (51°42.50N, 00°03.30E) to relay in the area shown in Figure 2.1 for a minimum of six months before harvesting for human consumption (Sarah Turbutt, pers. comm.).

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

The Pacific oyster (*Crassostrea gigas*) is a non-native species in the UK (Spencer *et al.*, 1994). Cultivation of this species has been undertaken in the Blackwater Estuary for more than a century. Cultivation operations are now established in Goldhanger Creek and Thirslet Creek (Figure 2.1). Maldon Oyster Co. is one of the largest producers of Pacific oysters in the UK (Maldon Oysters, 2008).

2.2 GROWING METHODS AND HARVESTING TECHNIQUES

Oysters are grown in bags supported above the riverbed on trestles (Figure 2.2A) and in the riverbed (Figure 2.2B). Some oysters are also grown on adjustable longline systems (Figure 2.2 C–D).

Pacific and native oysters are harvested by hand during periods of low water.

Mussels and seed oysters are dredged using a vessel (Figure 2.3).

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[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.

Figure 2.2 Oysters in bags on trestles (A), on the riverbed (B) and in bags on adjustable longline systems (C–D) at Goldhanger Creek.

Figure 2.3 Vessel used for dredging shellfish in the Blackwater Estuary.

2.3 SEASONALITY OF HARVEST, CONSERVATION CONTROLS AND PRODUCTION

The commercial production of bivalve molluscs in the geographical area of the estuary covered by this sanitary survey is not covered by Several, Regulating or Hybrid Order.

The annual production is estimated to be in the region of 400 tonnes for mussels and 1.5 tonnes for oysters.

The fishery falls within the jurisdiction of Maldon District Council Local Enforcement Authority.

2.4 HYGIENE CLASSIFICATION

Classifications for mussels and Pacific oysters were initially given in 1992, following the implementation of statutory controls on the commercial production of bivalve molluscs in England and Wales (Table 2.1).

Pacific oysters from Goldhanger and mussels from Thirslet Creek have met the criteria for long-term class B in recent years suggesting a degree of stability in the levels of microbial contamination in these beds.

Pacific oysters from Thirslet Creek were downgraded to class B in 2008.

Table 2.1 Historical classifications of bivalve mollusc production areas in the Blackwater Estuary.

Bed name	Osea Island	Goldhanger	Thirslet Creek	Thirslet Creek
Bed ID	B014J/K/L	B014D	B014G	B014M
Species	*C. gigas*	*C. gigas*	*Mytilus* spp.	*C. gigas*
1992	n/c	A	A	n/c
1993	n/c	A	A[1]	n/c
1994	n/c	A	A[1]	n/c
1995	n/c	A	B[1]	n/c
1996	n/c	A	B	n/c
1997	n/c	A	B	n/c
1998	n/c	A	B	n/c
1999	n/c	A[2]	B	n/c
2000	n/c	A[3]	B	n/c
2001	n/c	B	B	n/c
2002	n/c	B	B	n/c
2003	n/c	B	B	n/c
2004	B[1]	B	B	n/c
2005	B	B-LT	B-LT	n/c
2006	B	B-LT	B-LT	n/c
2007	B	B-LT	B-LT	A
2008	B	B-LT	B-LT	B
2009	n/c	B-LT	B-LT	B

N/c - not classified.
1 - classification is provisional due to insufficient sample results, either in number or period of time covered.
2 - area classified at higher level as there is evidence that exceptional factors affected the sampling results.
3 - area classified at higher level, due to results close to the tolerance limit.
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.

The location and extent of classified beds are shown in Figures 2.4 – 2.6.

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

Table 2.2 Criteria for classification of bivalve mollusc production areas.

Class	Microbiological standard[1]	Post-harvest treatment required
A	Live bivalve molluscs from these areas must not exceed 230 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 Most Probable Number (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 Most Probable Number (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.

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

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

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

N.B. Lat/Longs quoted are WGS84
Separate maps available for C. edule, Mytilus spp. and O. edulis at Blackwater

Food Authorities: Maldon District Council and Colchester Borough Council

Figure 2.4 Classification zones and current classification status for Pacific oysters in the Blackwater Estuary.

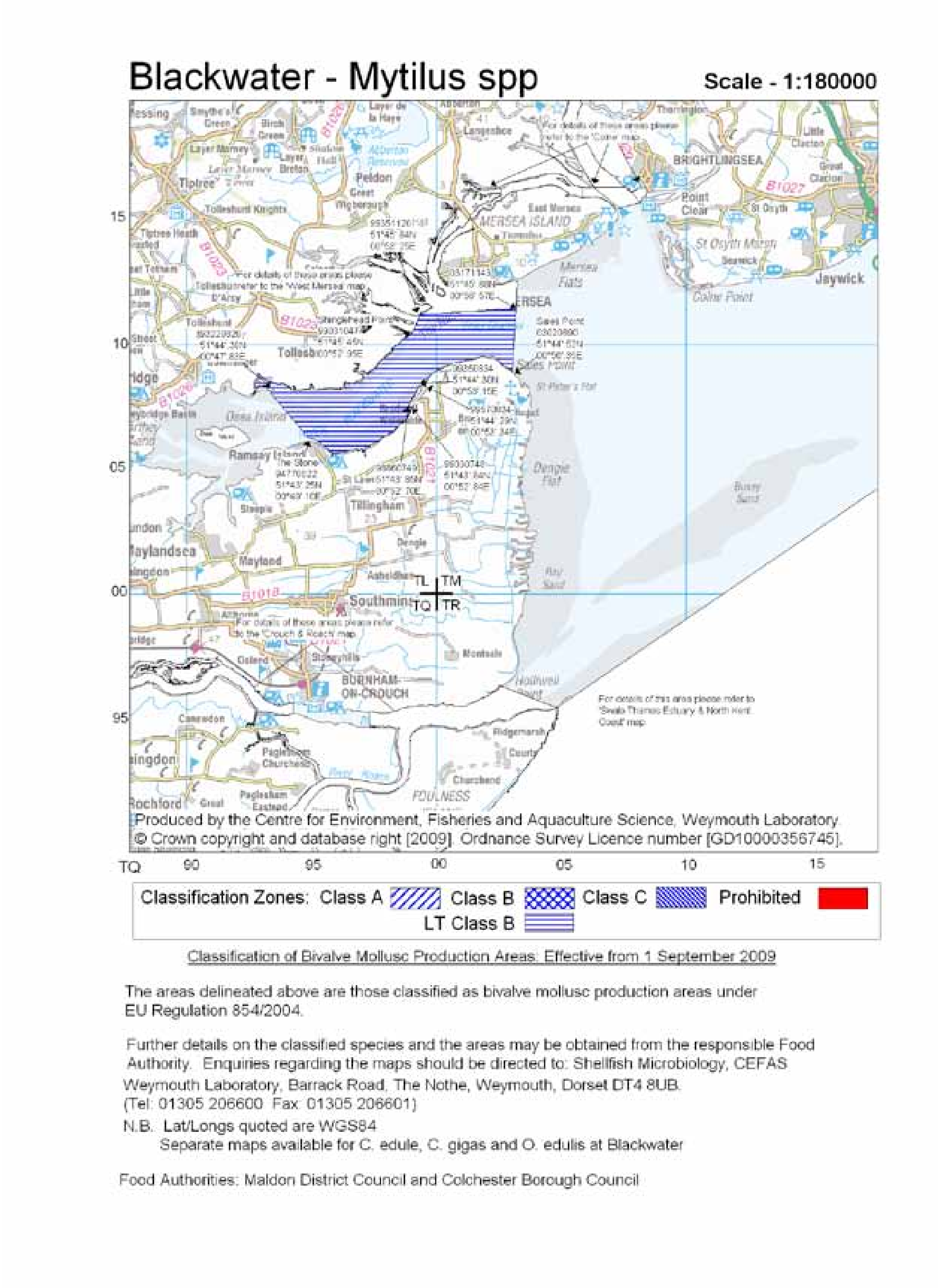

Figure 2.5 Classification zones and current classification status for mussels in the Blackwater Estuary.

Blackwater - O. edulis

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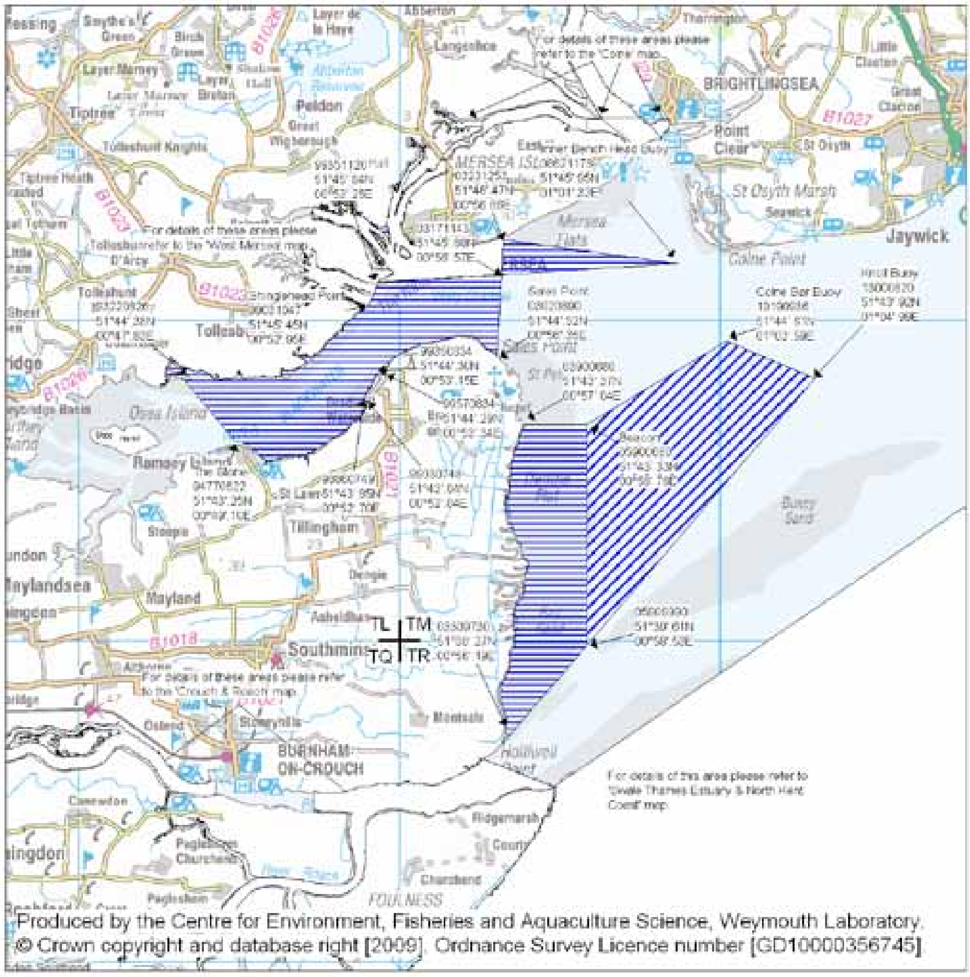

TQ

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

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N.B. Lat/Longs quoted are WGS84
Separate maps available for C. edule, C. gigas and Mytilus spp. at Blackwater

Food Authorities: Maldon District Council and Colchester Borough Council

Figure 2.6 Classification zones and current classification status for native oysters in the Blackwater Estuary.

3. OVERALL ASSESSMENT

AIM

This section presents an overall assessment of pollution sources on the microbiological contamination of bivalve molluscs in the Blackwater Estuary (East coast of England), 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 Pacific oysters (*Crassostrea gigas*), mussels (*Mytilus* spp.) and native oysters (*Ostrea edulis*) in classified beds in the upper estuary.

The present survey was prompted by an application for microbiological monitoring and classification of native oysters and mussels just south of Osea Island.

SHELLFISHERIES

The area requiring classification for native oysters and mussels includes parts of the meandering channel at the confluence of Collier's Reach, Southey Creek and Lawling Creek.
The currently classified zones for Pacific oysters include much of the intertidal and subtidal areas of Goldhanger Creek; the currently classified zones for mussels and native oysters include intertidal and subtidal areas of Thirslet Creek and parts of the main deep water channel leading to the mouth of the estuary.

These beds fall under the jurisdiction of Maldon District Council (Local Enforcement Authority).

The commercial production of bivalve molluscs in this geographical area is not covered by Several, Regulating or Hybrid Order.

FRESHWATER INPUTS

The catchment (total area = 1,200km^2) assessed for the purposes of this sanitary survey is drained by a river network formed by the Rivers Blackwater and Chelmer. The river network is formed by other less significant freshwater inputs. These watercourses constitute the most significant routes of microbial contamination of faecal origin from the wider catchment to the upper Blackwater Estuary.

Hydrographs for the River Blackwater at Langford show a relatively constant flow rate during the year. This response is caused by the low-lying gently undulating topography across most of the catchment. Therefore, the delivery of faecal contamination to receiving waters is likely to reflect this stability in river flows.

AGRICULTURE

The catchments draining to the upper Blackwater Estuary are essentially rural in character and predominantly used for agricultural purposes (cereals and breakcrops). Arable land exceeds 60% of the land in these catchments.

The period of higher risk of diffuse water pollution from agriculture is likely to be associated with spreading of biosolids during the autumn for winter cereals. Winter is also critical since large quantities of slurry are applied more frequently.

Livestock production (total number of farmed animals is over 1.5M) is based on poultry (96.5% of the total number). Cattle and sheep represent only 0.5% and 1% of this number, repectively. At the time of the shoreline survey, cattle were seen grazing fields northeast of Mayland at Steeple. High number of hydrological connections between farms and creeks were also observed in this area.

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

HUMAN POPULATION

Resident human population (approximately 382,000) is considerable higher than the total number of cattle and sheep farmed in the catchment. Maximum population densities in Chelmsford and Witham are 87 and 63 people ha^{-1}, respectively. Bivalve mollusc beds in the vicinity of these urbanised areas will be liable to impact from point source discharges and runoff from impermeable land.

In addition, human population in the catchments is likely to increase substantially during the spring-summer period. There are tourism attractions in Maldon, Braintree and Chelmsford receiving more than 10,000 people per year. Therefore, the contribution of pollution sources of human origin is expected to markedly increase during the tourist season.

SEWAGE DISCHARGES

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 Maldon, Mayland, Witham and Chelmsford:

- Chelmsford sewage treatment works (STW) (secondary; DWF = 39,300m^3 d^{-1});
- Witham STW (secondary; DWF = 8,100m^3 d^{-1});
- Mayland STW (secondary; DWF = DWF = 1,100m^3 d^{-1});
- Latchingdon STW (secondary; DWF = 637m^3 d^{-1});
- St. Lawrence STW (secondary; DWF = 300m^3 d^{-1});

- Tollesbury D'Arcy STW (secondary; DWF = 210m^3 d^{-1});
- Bradwell on Sea STW (secondary; DWF = 147m^3 d^{-1});
- Bradwell Power Station (secondary; DWF = 136m^3 d^{-1}); and
- Tiptree (secondary; DWF = 2,567m^3 d^{-1}).

Three other continuous discharges are considered to have local significance:

- Langford Recycling Plant (UV; DWF = 30,000m^3 d^{-1});
- Maldon STW (UV; DWF = 6,800m^3 d^{-1}); and
- West Mersea (UV; DWF = 2,903m^3 d^{-1}).

Thirty-two intermittent discharges (combined sewer overflows, emergency overflows and overflows from pumping stations) discharge to the estuary or its tributaries. Most of these discharge to creeks on the southern side of the estuary.

BOATS

There are over 20 sailing clubs operating around the upper estuary and moorings areas at Maldon, Ramsey Island and Lawling Creek. Blackwater Marina in Maylandsea and Tollesbury Marina do not provide pump-out facilities for boats with foul water holding tanks.
It has long been established that sewage discharged from boats could represent a significant public health risk for bivalve mollusc beds. A low number of people are likely to stay overnight. The contribution of these sources is difficult to quantify due to the intermittent nature of these discharges. Bivalve mollusc bed at Osea Island will be vulnerable to pollution from moored boats.

The Blackwater Estuary supports large communities of birds. Published literature on bird distribution and abundance highlights complex movements of waterbirds in the estuary due to diversity of natural habitats. Some of the key feeding areas are in saltmarshes and sandflats in the upper estuary in close proximity to bivalve mollusc beds.

An overview of source of pollution likely to affect the levels of microbiological contamination in BMPAs in the upper Blackwater Estuary is shown in Figure 3.1.

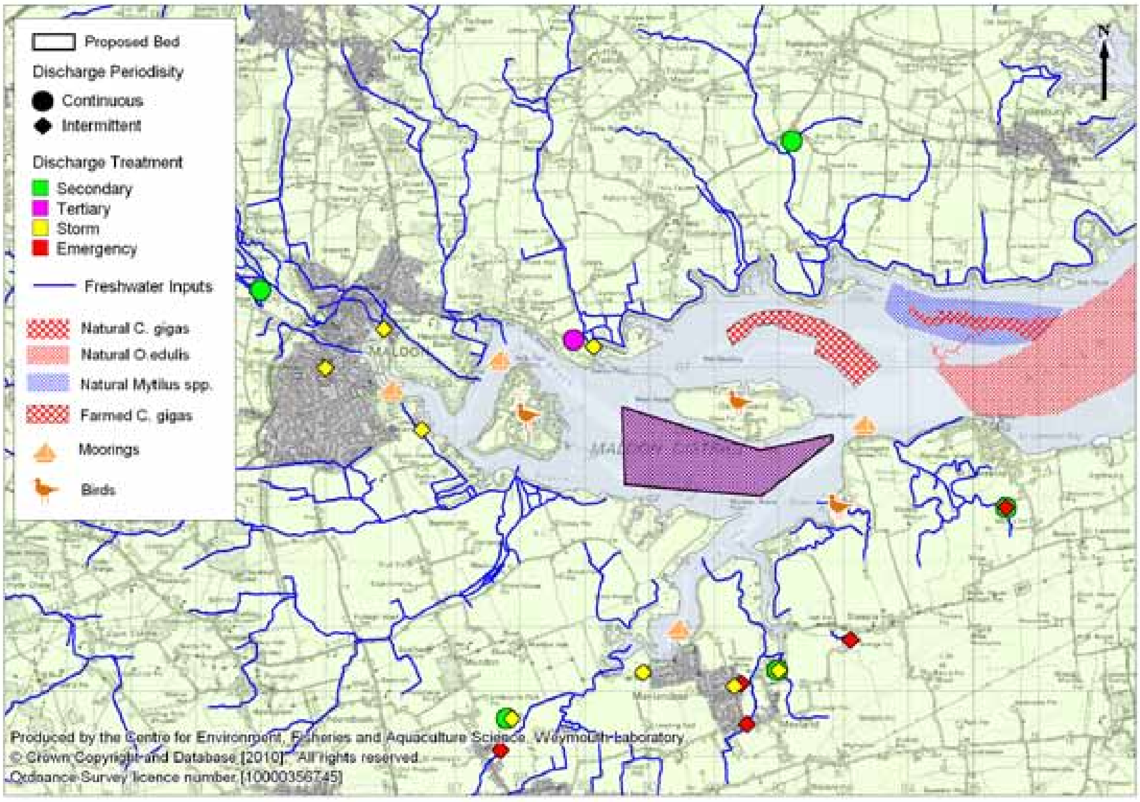


Figure 3.1 Significant sources of microbiological pollution impacting on bivalve mollusc beds in the upper Blackwater Estuary.

HYDRODYNAMICS

The main channel of Southey Creek in which the new production area for mussels and native oysters will be dredged is relatively shallow (maximum depth = 6.4m relative to Chart Datum at Goldhanger Spit). Similarly, areas of creeks where Pacific oysters, native oysters and mussels are produced are faily shallow and contain significant proportions of drying areas at Low Water Springs. 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 along the channel(s). Therefore, nearshore shallow areas are likely to represent worst-case conditions.

Overall, the Blackwater Estuary is an ebb dominant macro-tidal estuary (mean range on springs = 4.9m; mean range on neaps = 3.1m at Osea Island). The longer and slower ebb tide is likely to promote the dispersion of pollution towards to sea.

The long tidal length (approximately 22km) indicates that significant distances may be involved in the transport of microbial contaminants between the mouth of the estuary and bivalve mollusc beds.

Maximum current speeds are 1.5knots on springs and 1knot on neaps during flood tides and 1.4knots on springs and 0.9knots on neaps during ebb tides.

Hydrodynamic modelling simulating the movement of particles within the estuary developed by Cefas suggests that:

- After a release of a sewage plume during high water, particles carried past the production area just South of Osea Island along Southey Creek main channel on the ebb tide; and
- Under high river flows, the plume may be transported further into the estuary during the ebb so that significant impacts occur on the first flood tide.

SUMMARY OF EXISTING MICROBIOLOGICAL DATA

Analysis of historical data (1999–2009) from the Bathing Waters monitoring programme indicates that median levels of faecal coliforms in surface waters at West Mersea have been relatively low, although maximum levels indicate some vulnerability to intermittent episodes of contamination at the mouth of the estuary.

Levels of faecal coliforms in designated Shellfish Waters (SW) have decreased gradually in recent years. Comparison of annual medians of the microbial indicator does not suggest significant differences between SW.

Historical levels of *E. coli* in bivalves from classified areas suggest the following spatial differences in contaminating levels between beds:

- Southey Creek>Ford Creek>Lawling Creek≈Goldhanger>Thirslet Creek (*C. gigas*);
- The Nass>St Peters Flats (*O. edulis*).

Statistically significant positive relationships were found between daily rainfall and levels of *E. coli* in Pacific oysters from Goldhanger, Southey Creek and Lawling Creek. The strength of these correlations varied according to the monitoring point and the time of sampling relative to the rainfall event. This indicates potentially significant impact of rainfall-dependent discharges and runoff from agricultural land on bivalves commercially harvested in the upper estuary.

Significant positive correlations were also obtained between daily flows in the River Blackwater and levels of the microbiological indicator in oysters at Southey Creek, Lawling and Ford Creek, in particular when sampling took place 1 day after the increase in water levels. This indicates a fast response of *E. coli* accumulation in oysters at these sites.

Levels of *E. coli* in Pacific oysters from Ford Creek and Lawling Creek are higher during the winter than those during the spring–summer period. At both beds, the medians of the microbial indicator during the spring are within the range for class A and the medians during the winter are within the range for class B.

4. RECOMMENDATIONS FOR REPRESENTATIVE MONITORING POINTS AND CLASSIFICATION ZONE BOUNDARY

4.1 A new classification zone (CZ) for mussels and native oysters is recommended at south of Osea Island. This will be defined by lines crossing the upper estuary at Decoy Point-TL 8927 0505 (western edge), Mundon Stone Point-TL 9235 0465 (southern edge), TL 9307 0586-East Point (eastern edge) and West Point-Decoy Point (northern edge) and referred to Mean High Water Mark (MHWM).

4.2 A Representative monitoring point (RMP) for mussels and native oysters situated at Ford Creek will be representative of microbial contamination from sewage discharges at Maldon and diffuse pollution delivered to the upper Blackwater Estuary during the ebb stage of the tide.

4.3 An RMP for mussels and native oysters situated at the mouth of Lawling Creek will be representative of microbial contamination from sewage discharges at Maylandsea and diffuse pollution delivered to the upper Blackwater Estuary during the ebb and flood stages of the tide.

4.4 A CZ for Pacific oysters is recommended at Goldhanger. This will be defined by lines crossing the estuary at TL 9014 0737-The Stone (western edge), The Stone-TL 9319 0828 (eastern edge) and referred to MHWM.

4.5 An RMP for Pacific oysters situated in the centroid of Goldhanger bed will be representative of predominant microbial contamination from the upper estuary during the ebb tide and from the lower estuary during the flood tide.

4.6 A CZ for mussels and native oysters is recommended at Thirslet Creek. This will be defined by lines crossing the estuary at TL 9319 0828-The Stone (western edge), TL 9710 0578-Mill Creek (eastern edge) and referred to MHWM.

4.7 An RMP for mussels and native oysters situated at the mouth of the creek will be representative of microbial contamination from point and diffuse sources delivered to the upper Blackwater Estuary during the flood tide.

5. SAMPLING PLAN

Location Reference

Production Area	Blackwater Estuary
Cefas Main Site Reference	M014
Cefas Area Reference	FDR 3528
Ordnance survey 1:25,000 map	Explorer 176: Blackwater Estuary. Maldon, Burnham-on-Crouch & Southend-on-Sea
Admiralty Chart	Imray 2000.6: River Blackwater. Plans Tollesbury Yacht Harbour, Bradwell Marina, Maldon

Shellfishery

Species/culture	Mussels (*Mytilus* spp.) Pacific oysters (*Crassostrea gigas*) Native oysters (*Ostrea edulis*)	Wild Farmed Farmed
Seasonality of harvest	All species year round	

Local Enforcement Authority

Name	Maldon District Council Environmental Health Department Council Offices Princes Road MALDON, Essex CM9 5DL
Telephone number (	01621 854477
Environmental Health Officer	Sarah Turbutt
Telephone number (	01621 875796
Fax number	01621 875899
E-mail š	sarah.turbutt@maldon.gov.uk
Sampling Officer	Malcolm Sach
E-mail š	Malcolm.sach@maldon.gov.uk

REQUIREMENT FOR REVIEW

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

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

Classification zone			**South of Osea Island**	**South of Osea Island**	**South of Osea Island**	**South of Osea Island**	**Goldhanger**	**Thirslet Creek**	**Thirslet Creek**
RMP			**B014Q**	**B014L**	**B014R**	**B014K**	**B014D**	**B014M**	**B014G**
RMP name			**Ford Creek**	**Ford Creek**	**Lawling Creek**	**Lawling Creek**	**Goldhanger**	**Thirslet Creek**	**Thirslet Creek**
Geographic grid references (datum) of sampling points	**Easting** **Northing**		8970 0660	8970 0660	9170 0490	9170 0490	9250 0770	9560 0770	9560 0770
	NGR		TL 8970 0660	TL 8970 0660	TL 9170 0490	TL 9170 0490	TL 9250 0770	TL 9560 0770	TL 9560 0770
	WGS84	51°43.56'N 00°44.72'E	51°43.56'N 00°44.72'E	51°43.56'N 00°44.72'E	51°42.60'N 00°46.40'E	51°42.60'N 00°46.40'E	51°44.10'N 00°47.18'E	51°44.03'N 00°49.87'E	51°44.03'N 00°49.87'E
Species			*Mytilus* spp.	*O. edulis*	*Mytilus* spp.	*O. edulis*	*C. gigas*	*O. edulis*	*Mytilus* spp.
Growing method			Farmed	Farmed	Farmed	Farmed	Farmed	Farmed	Farmed
Harvesting technique			Dredging	Dredging	Dredging	Dredging	Hand-picking from bags	Dredging	Hand-picking from bags
Sampling method			Dredging	Dredging	Dredging	Dredging	Hand-picking	Dredged	Hand-picking
Depth (m)			Riverbed	Riverbed	Riverbed	Riverbed	Depth of trestles	Riverbed	Depth of trestles
Tolerance for sampling points (m)			50	50	50	50	10	10	10
Frequency of sampling (PRELIMINARY Classification)			10 samples taken over, at least, 3 months (interval between sampling not less than 1 week).	10 samples taken over, at least, 3 months (interval between sampling not less than 1 week).	10 samples taken over, at least, 3 months (interval between sampling not less than 1 week).	10 samples taken over, at least, 3 months (interval between sampling not less than 1 week).	-	-	-
Frequency of sampling (FULL Classification)			At least monthly over one year.	Fortnightly during the period December–February. At least monthly during the period January–November.	At least monthly over one year.	Fortnightly during the period December–February. At least monthly during the period January–November.	At least monthly	At least monthly	At least monthly

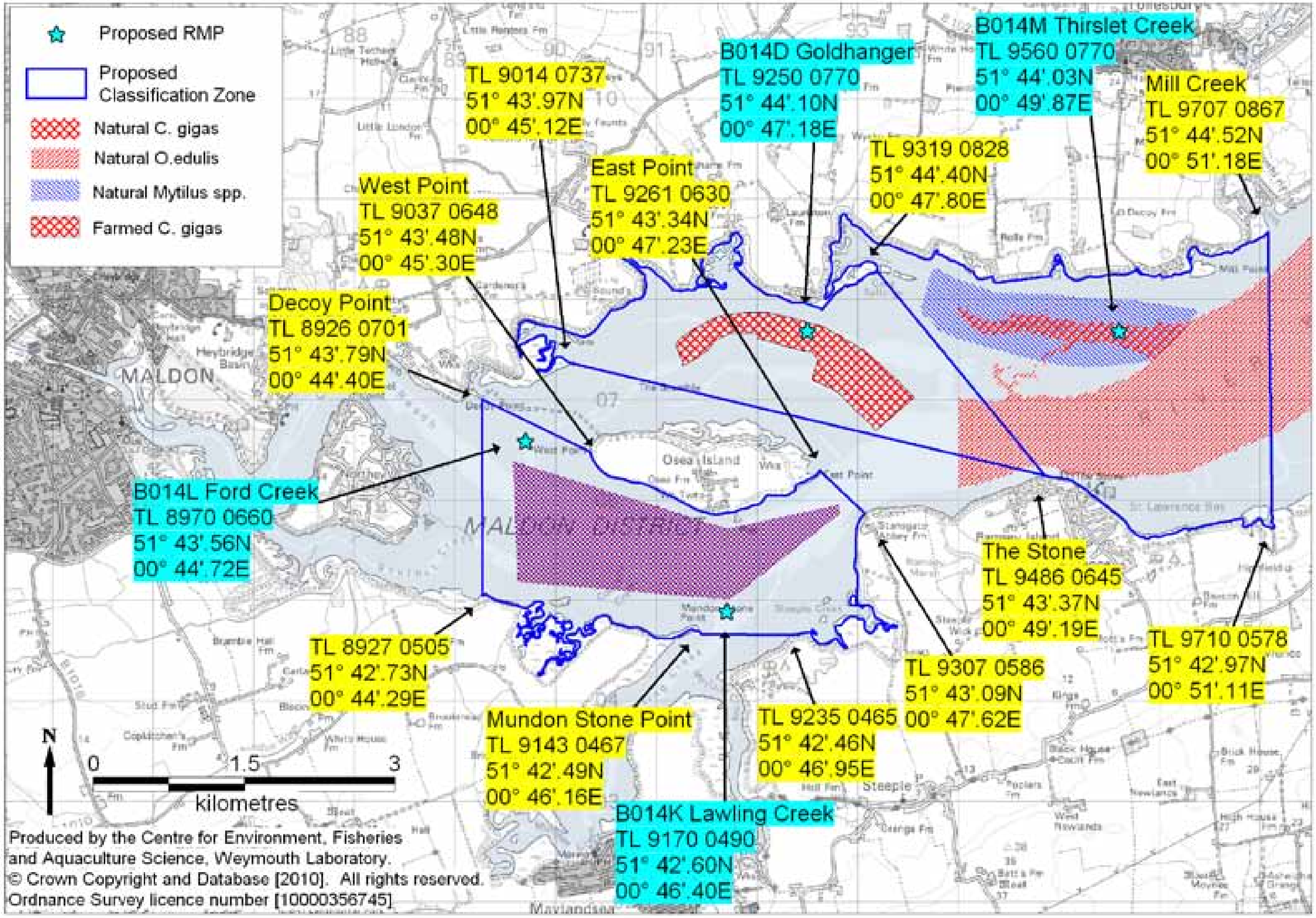


Figure 5.1 Location of recommended representative monitoring points (RMPs) and classification zone boundaries for bivalve molluscs in the upper Blackwater Estuary.

APPENDIX I
HUMAN POPULATION

The distribution of resident human population by Super Output Area Boundary[3] total or partially included within river catchment areas draining to the Blackwater Estuary is shown in Figure I.1. Maximum density within the Blackwater Estuary catchment is 79 people ha^{-1} at Maldon. However, most of the areas in this catchment are less than 1 person per hectare. Other urbanised areas within 10km from the estuary contain significant population densities, such as Chelmsford and Witham with 87 and 63 people ha^{-1}, respectively. Osea Island has a population density of 3 people ha^{-1}. Also locally significant is Maylandsea (just south of the proposed bed) with 12.4 people ha^{-1}.

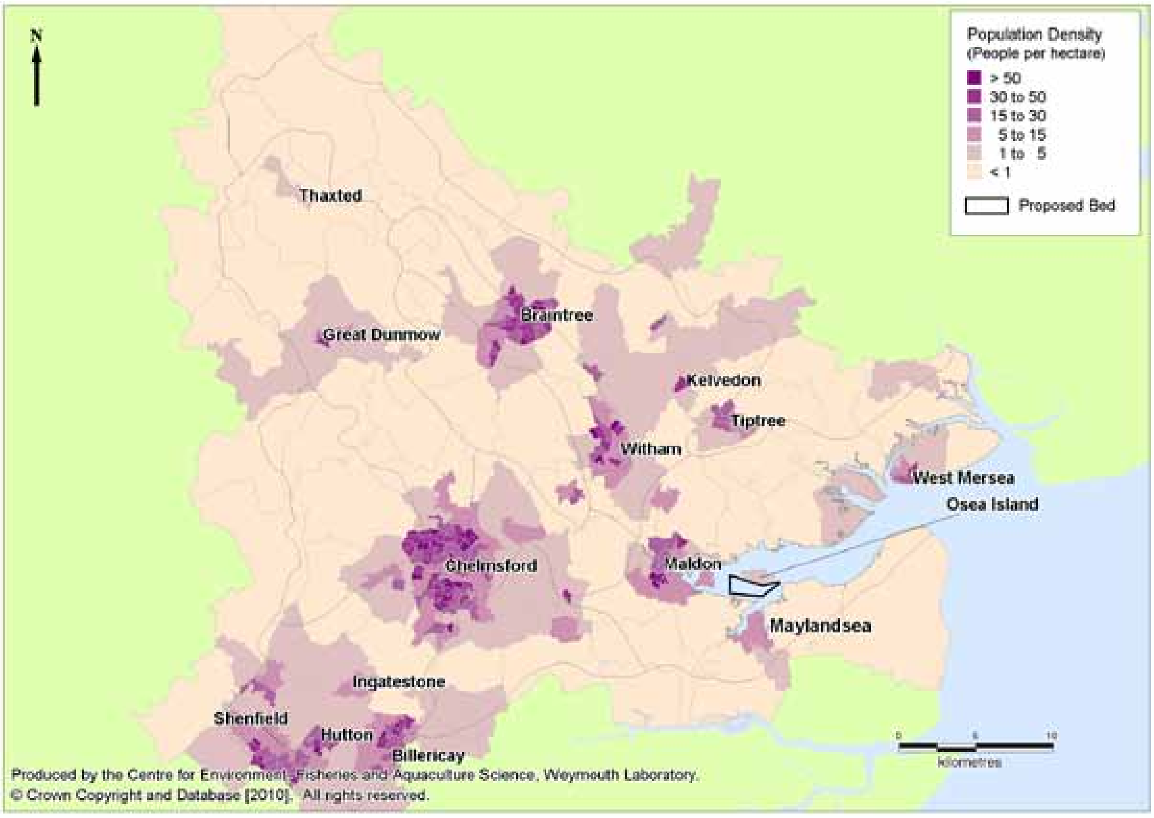


Figure I.1 Human population density in river catchments draining to the Blackwater Estuary.
Source: ONS, Super Output Area Boundaries. Crown copyright 2004. Crown copyright material is reproduced with the permission of the Controller of HMSO.

The resident population within catchment areas is shown in Table I.1. The total population is nearly 382,000 people.

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.

[3] 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.

Table I.1 Resident population in catchments draining to the Blackwater Estuary.

Catchment	Resident population
Blackwater Estuary	48,878
Sandon Brook	17,105
Chelmer (lower)	58,222
Blackwater Pant	44,508
Brain	51,845
Ter	14,183
Wid	84,319
Can and Roxwell Brook	21,489
Chelmer (upper)	41,394
Total	381,943

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 also contain the majority of impervious surfaces[4] (e.g. roads, parks, pavements), which are known to contribute with significant loads of microbiological contaminants (Ellis and Mitchell, 2006)[5]. Bivalve molluscs commercially harvested in the vicinity of urbanised areas tend to show deteriorated microbiological quality.

Owing to its maritime heritage, distinctive natural beauty, historic townscapes and proximity to London and other major towns in Essex, the Maldon District is a popular tourist destination (Maldon District Council, 2009).

Table I.2 shows that, in 2008, over 277,000 people visited 19 of the most popular attractions in Maldon, Chelmsford and Braintree districts regularly surveyed by Enjoy England, the official tourist board for England. This represents a very significant increase in human presence in the catchment and the potential for deteriorated microbial quality of effluent sewage discharges.

Results from the quarterly surveys conducted by the East of England Tourism Business Confidence Monitor suggest that numbers of tourists/visitors increased in 2009 since more than 60% of the participants in all surveys indicated to have experienced an increase in visitor numbers (East of England Tourism, 2009a–c, 2010).

[4] In the context of the present report, impervious surfaces are any surface in the urban landscape that does not infiltrate rainfall.
[5] 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).

Table I.2 Numbers of visitors per year to the main attractions in three districts in the vicinity of the Blackwater Estuary.

Attraction	Category	Year 2006	2007	2008	District
Bardfield Vineyard	Workplace	621	742	888	Braintree
Bocking Windmill	Historic property	800	800	800	Braintree
Boydells Dairy Farm	Farm	-	5,062	5,390	Braintree
Burnham-on-Crouch Museum	Museums & galleries	3,600	3,750	4,000	Maldon
Chelmsford Museum	Museums & galleries	50,036	45,885	33,041	Chelmsford
Coggeshall Grange Barn	Historic property	3,150	2,930	2,784	Braintree
Coggeshall Heritage Centre	Visitor/heritage centre	3,559	2,570	2,325	Braintree
Essex Police Museum	Museums & galleries	5,400	5,498	8,000	Chelmsford
Feeringbury Manor	Garden	363	290	297	Braintree
Finchingfield (Duck End) Postmill	Historic property	-	400	480	Braintree
Hedingham Castle	Historic property	20,854	20,694	17,769	Braintree
Maldon District Museum	Museums & galleries	1,731	2,085	2,491	Maldon
Marks Hall Estate & Arboretum	Garden	9,500	26,000	27,300	Braintree
Ponyland at Dutch Nursery	Farm	-	18,000	20,000	Braintree
Power	Museums & galleries	9,000	9,500	10,000	Maldon
RHS Garden, Hyde Hall	Garden	102,936	119,121	126,315	Chelmsford
Rural Discovery Church	Place of worship	1,000	1,000	1,000	Maldon
Saint Peters-on-the-Wall	Place of worship	11,000	12,000	10,000	Maldon
Stock Towermill	Historic property	-	840	900	Chelmsford
Tollesbury Wick Marshes	Farm	-	-	7,000	Maldon

Data from Enjoy England Visitor Attractions Survey 2008 (East of England Tourism, 2009).

Figure I.2 shows averaged percentage of room occupancy during the whole of 2008 (including weekdays and weekends) in serviced accommodation in Essex. Despite the increase in occupancy during the spring and the popularity of summer months, there is a very significant occupancy rate during the winter.

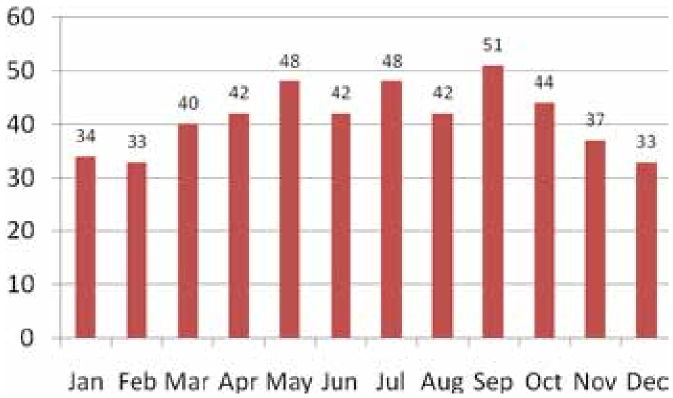


Figure I.2 Average of room occupancy (all week; %) in Essex county in 2008.
NB. Results based on 28 sample establishments. 2008 average=41%.
Data from East of England Tourism (2009).

The lack of a clear seasonality in occupancy rates for serviced accommodation may indicate a significant impact from pollution sources of human origin during the whole year.

APPENDIX II
HYDROMETRIC DATA: RAINFALL

The pattern of rainfall variation in England and Wales tends to be associated with Atlantic depressions or with convection, atmospheric humidity and altitude (Met Office, 2007). Essex is the driest county in the UK, receiving on average, less than 600mm of rain a year, which is only two-thirds of the average for England and Wales (Northumbrian Water Limited, 2010). This compares with an average annual rainfall for England and Wales of approximately 1,250 mm (Perry, 2006).

Figure II.1 shows monthly averaged and monthly total rainfall monitored daily in a tipping bucket gauge operating at Maldon (Easting/Northing: 8895/0745; representative of the lower catchment) for the period May 2000–July 2009. The highest average was recorded in October. The wettest period generally corresponded to October–November. Maximum levels of rainfall above 80mm occurred in February, May–June and August–December.

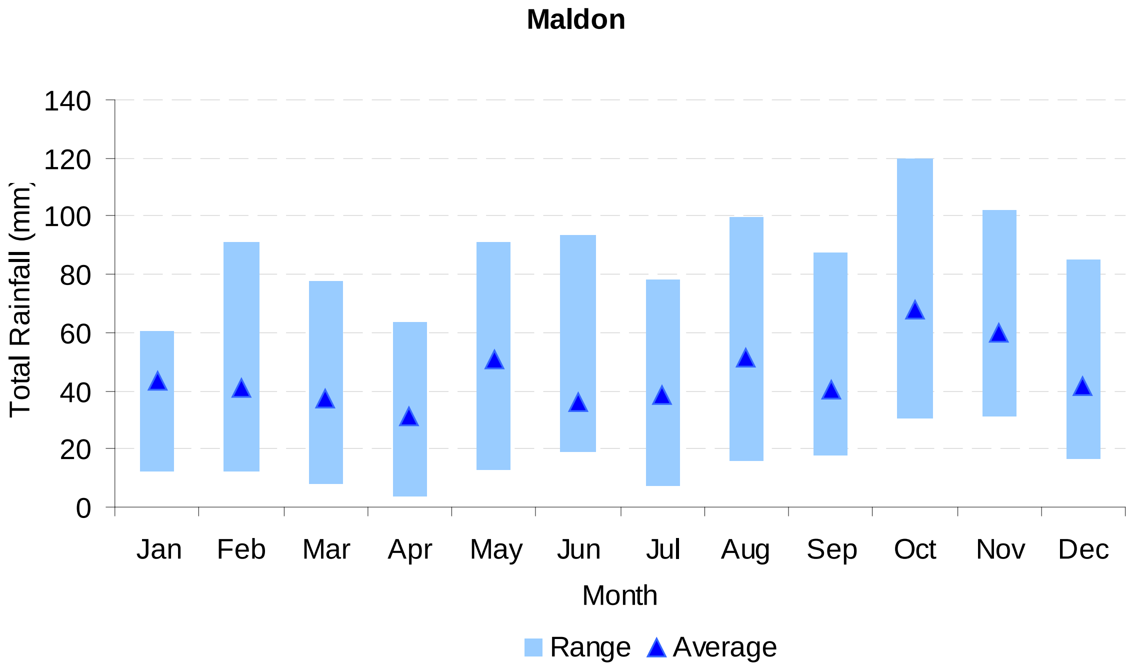


Figure II.2 Monthly variation of rainfall recorded at Maldon gauging station for the period May 2000–July 2009.
Data supplied by the Environment Agency.

Rainfall may lead to the discharge of raw or partially treated sewage from combined sewer overflows (CSOs) and other intermittent discharges as well as runoff from faecally contaminated land (Younger *et al*., 2003). An inventory of the most significant sewage discharges to the western part of the Blackwater Estuary is shown in the Appendix VII. Levels of *E. coli* in bivalves are expected to increase during and after rainfall events.

APPENDIX III
HYDROMETRIC DATA: FRESHWATER INPUTS

The Blackwater Estuary drains a total catchment area of approximately 1,200 km^2. Two main rivers flow into the head of the estuary: the River Blackwater, with a catchment area of 337km^2 and mean river flow 1.38m^3 s^{-1} and the River Chelmer, with a catchment area 533.9km^2 and mean river flow 1.93m^3 s^{-1} (Figure III.1)

The River Blackwater rises at a level of 107m above mean sea level and runs 108.5km to the tidal limit at Beeleigh Falls near Maldon. This river has a major tributary, the River Brain which runs for 19km and 29.5km of less significant tributaries. Water levels in the River Blackwater are augmented at times of drought by transfer of water from outside the catchment (Environment Agency, 1998).

The River Chelmer flows 72.6km to the tidal limit at Beeleigh Falls near Maldon. Major tributaries are the River Can (19km), the River Wid (25.4km) and the River Ter (31.7 km) and less significant tributaries with a total length of approximately 85km (Environment Agency, 1998). Water is also abstracted for transfer to the Hanningfield Reservoir, upstream of the river gauging station.

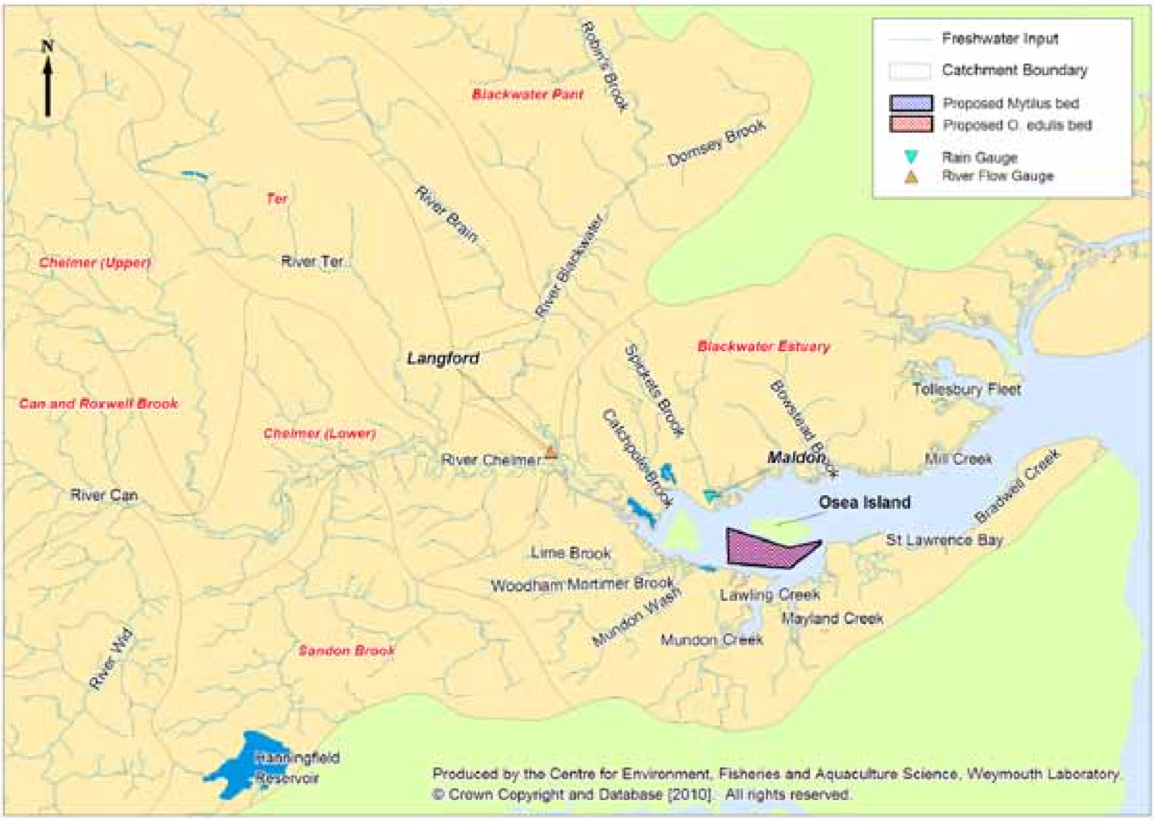


Figure III.1 Rivers and streams draining to the Blackwater Estuary and location of river and rainfall gauging stations.

Table III.1 summarises the hydrological characteristics of the River Blackwater at Langford (Easting/Northing: 83457/09024). Q95 and Q10 represent the averaged flow that is exceeded for 95% and 10% of the time, respectively.

Table III.1 Hydrological characteristics in the River Blackwater.

	Gauging station at Langford
Catchment area (km^2)	337
Level of station (m OD)	6.5
Maximum altitude (m OD)	125
Mean flow ($m^3 s^{-1}$)	1.38
95% exceedance (Q95) ($m^3 s^{-1}$)	0.224
10% exceedance (Q10) $m^3 s^{-1}$)	2.884

Data from the National River Flow Archive (NERC-CEH, 2009).

The catchment is characterised by significant areas of low-lying, gently undulating topography. Although there is an increase in average water levels during the autumn, there is a relatively constant flow rate in the River Blackwater during the year (Figure III.2). This means that microbial loads may be expected to be fairly constant during the year.

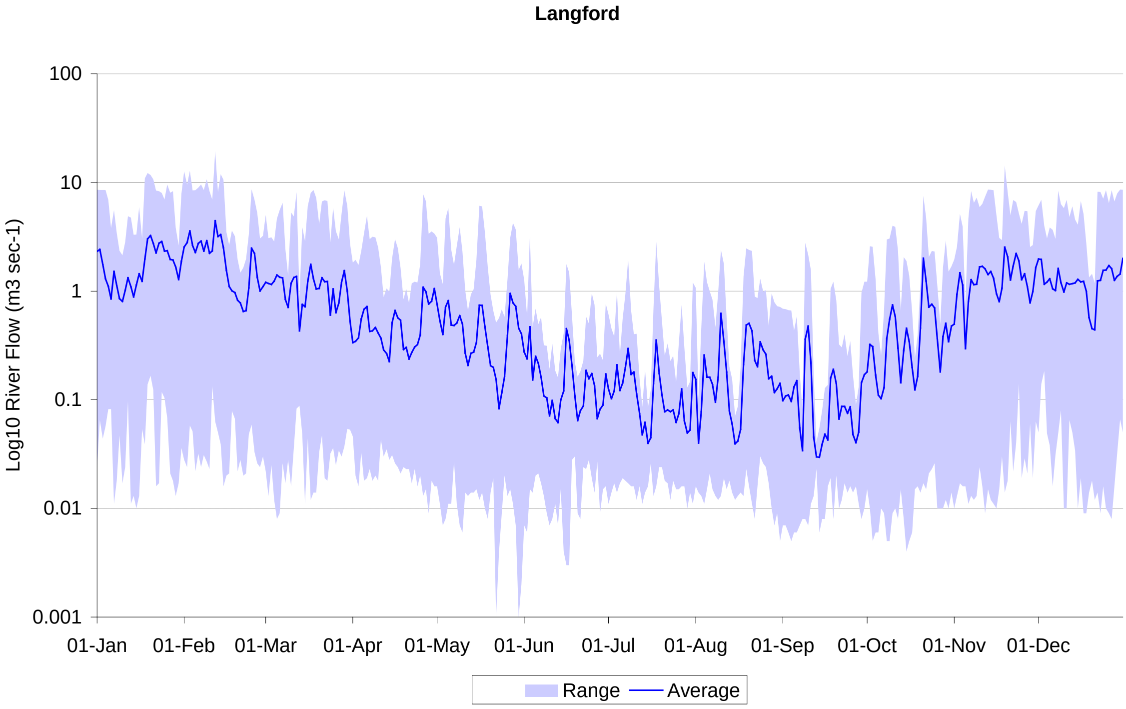


Figure III.2 Hydrograph for the River Blackwater at Langford for the period January 2000–July 2009.

Data supplied by the Environment Agency.

APPENDIX IV
HYDRODYNAMIC DATA: BATHYMETRY

The Blackwater Estuary is a shallow type 4a Single Spit enclosed estuary (Halcrow Group Ltd., 2003). The main channel width is approximately 2.7km at the mouth just south of Mersea Island. This is maintained fairly constant throughout the estuary up to Osea Island, where the main channel is diverted in two shallow channels: Southey Creek and Goldhanger Creek.

The area assessed for the purposes of this sanitary survey includes the upper estuary from the mouth of Thirslet Creek to the tidal limit at Maldon and is mostly comprised of areas drying completely at low water springs. Depths at the mouth of Thirslet Creek reach 7.2m relative to Chart Datum (CD).

Southey Creek (maximum depth = 6.4m relative to CD at Goldhanger Spit) is deeper than Goldhanger Creek (maximum depth = 3m relative to CD at Goldhanger Creek) and continues meander to the tidal limit. Southey Creek diverts again just west of Osea Island.

Figure V.1 shows the surface elevation tidal amplitude (i.e. half the tidal range) in the Blackwater Estuary. The model highlights an extensive blue area north of Osea Island drying at low water.

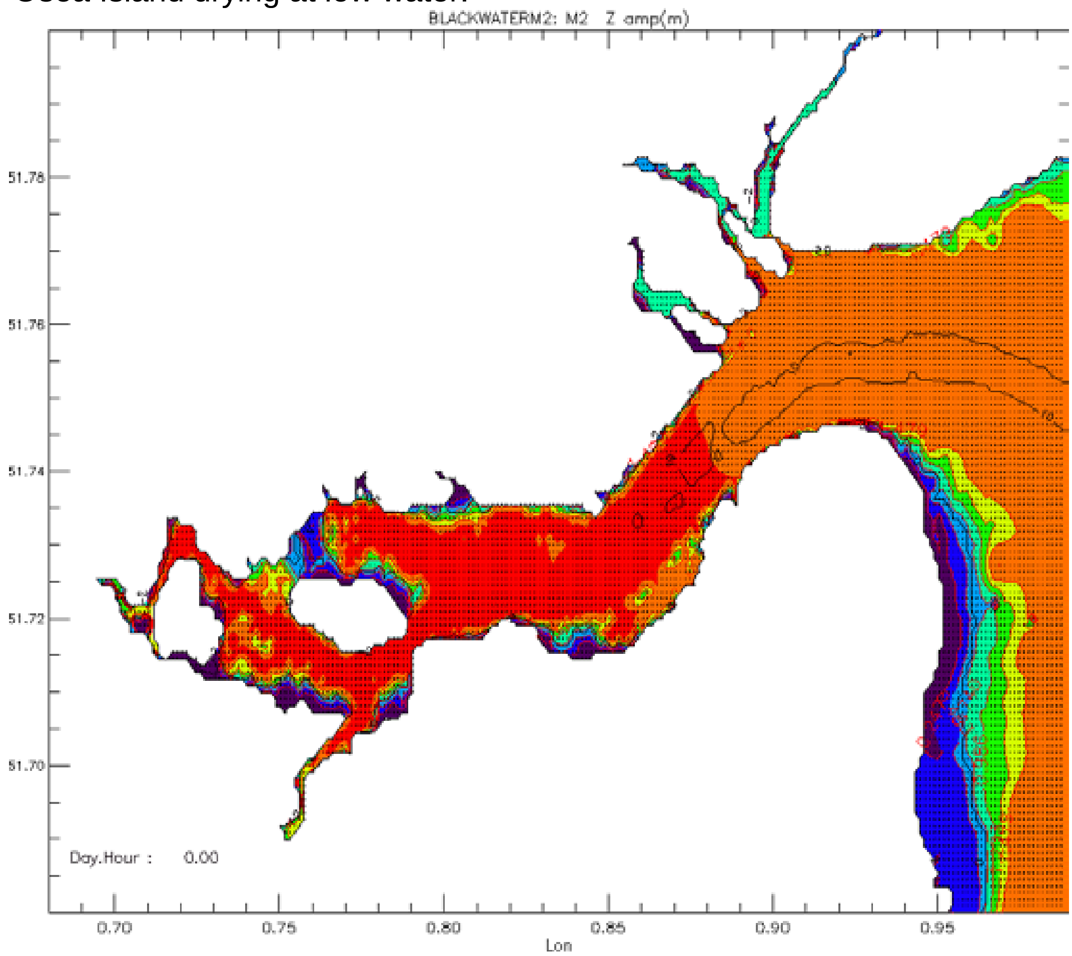


Figure V.1 Surface elevation tidal amplitude in the Blackwater Estuary.
NB. Areas in red do not dry.

Currently classified native oyster beds occur along the main river channel (Figure IV.1). The maximum depth within the area requiring classification for this species (Figure IV.1) and mussels (Figure IV.3) in Southey Creek is 3.1m relative to CD.

Wild Pacific oyster beds occur along Thirslet Creek. Maximum depth at the mouth of this creek is 3.5m relative to CD (Figure IV.2). Farmed Pacific oysters occur mostly in drying areas along Goldhanger Creek. A small portion of this bed is however between 0–3m depth (Figure IV.2).

Most of the areas from where mussels are harvested at Goldhanger Creek occur in drying areas (Figure IV.3).

Sedimentation of microbiological contaminants and re-suspension of contaminated sediment is a common feature of shallow estuaries such as the Blackwater. The potential for dispersion and dilution of microbiological contamination is likely to increase towards the mouth of the estuary.

The dendritic structure of estuaries such as the Blackwater, with muddy shallow creeks of varying sizes, often result in a continued flow long after the tide has receded and the mudflats are exposed (Whitehouse *et al*., 2000). Contaminated runoff from retained seawater and/or rainfall falling on the surface of mudflats and sandflats across the upper estuary will be conveyed along Southey Creek.

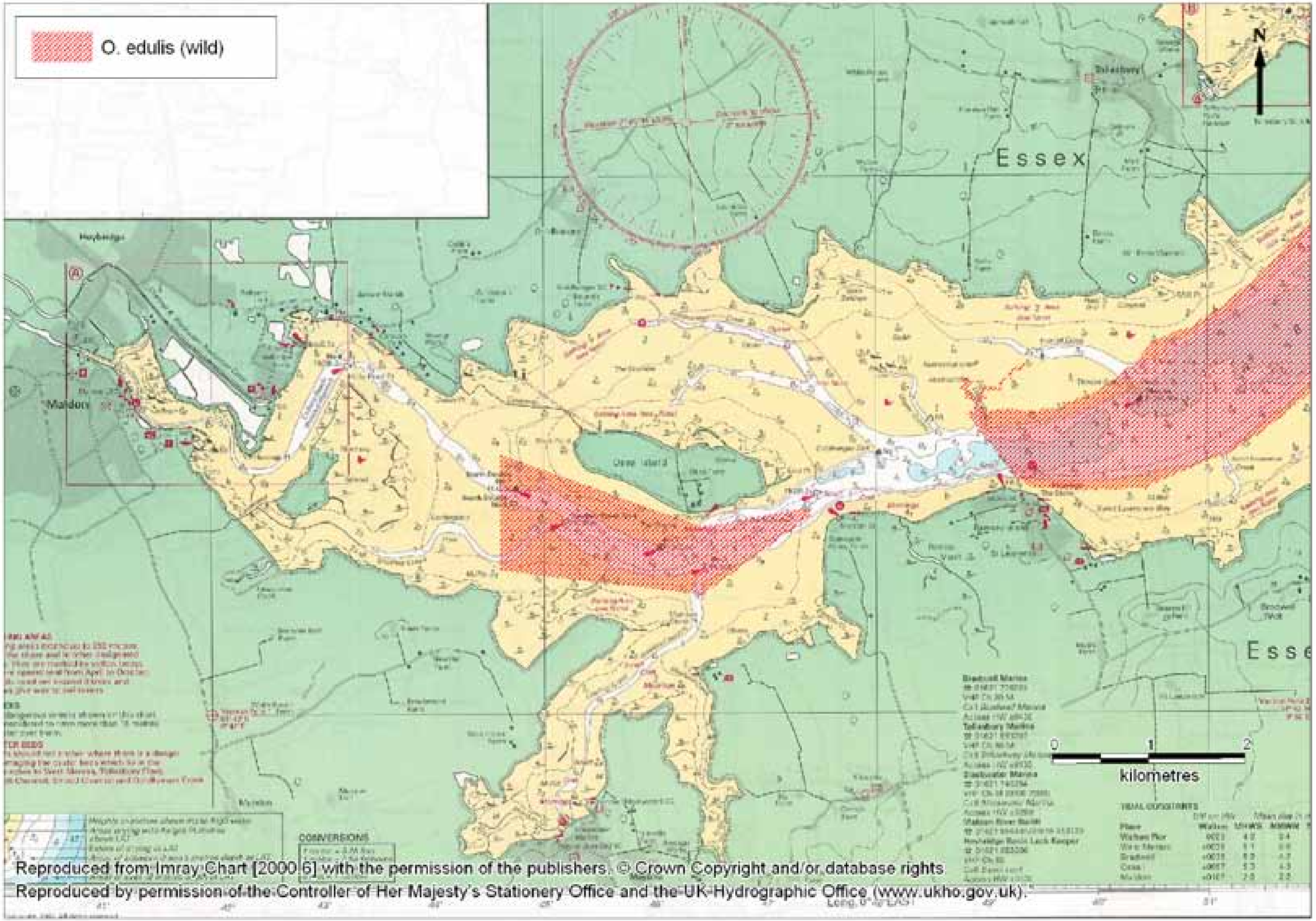


Figure IV.1 Location of native oyster beds in the upper Blackwater Estuary.

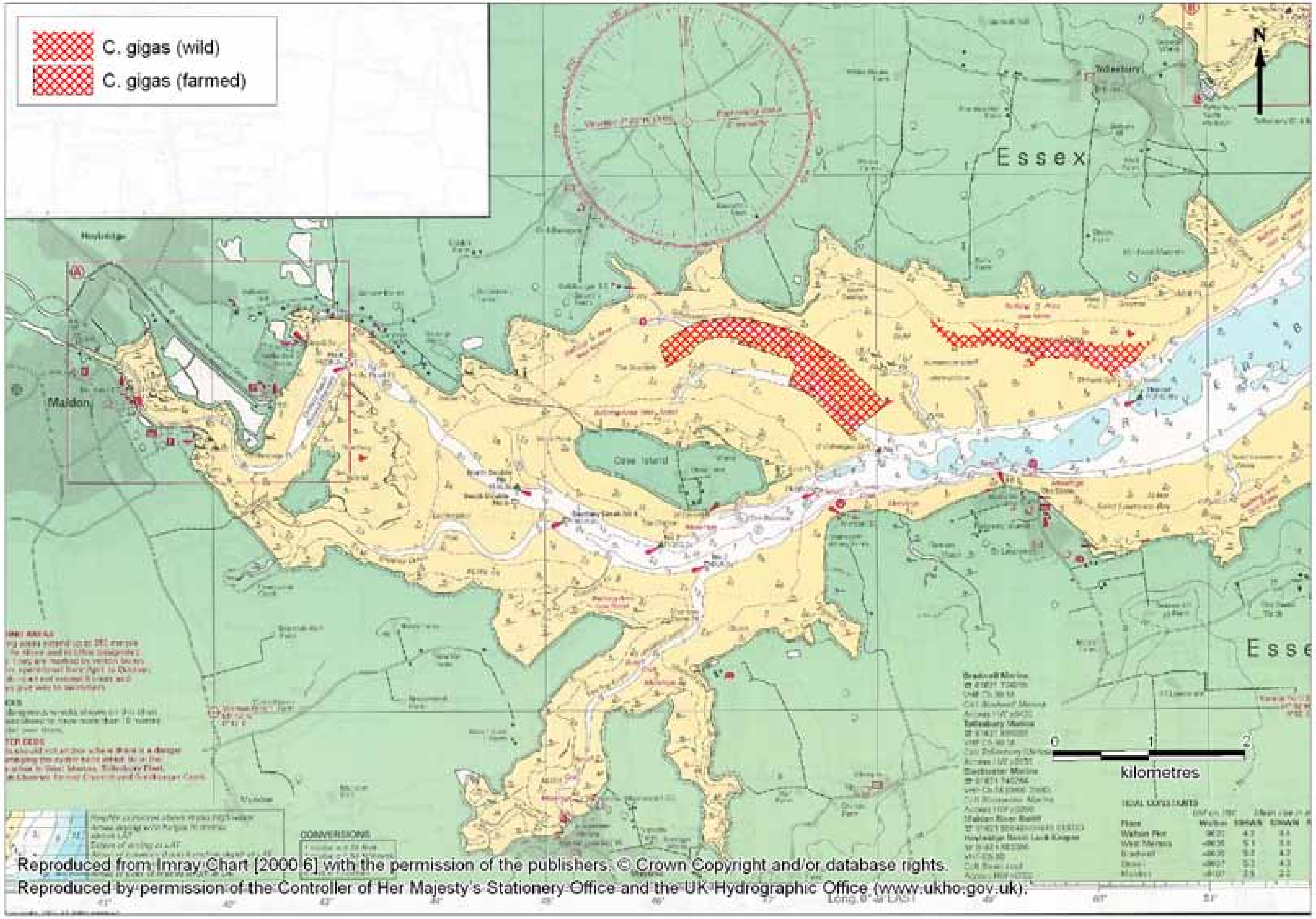


Figure IV.2 Location of Pacific oyster beds and representative monitoring points in the upper Blackwater Estuary.

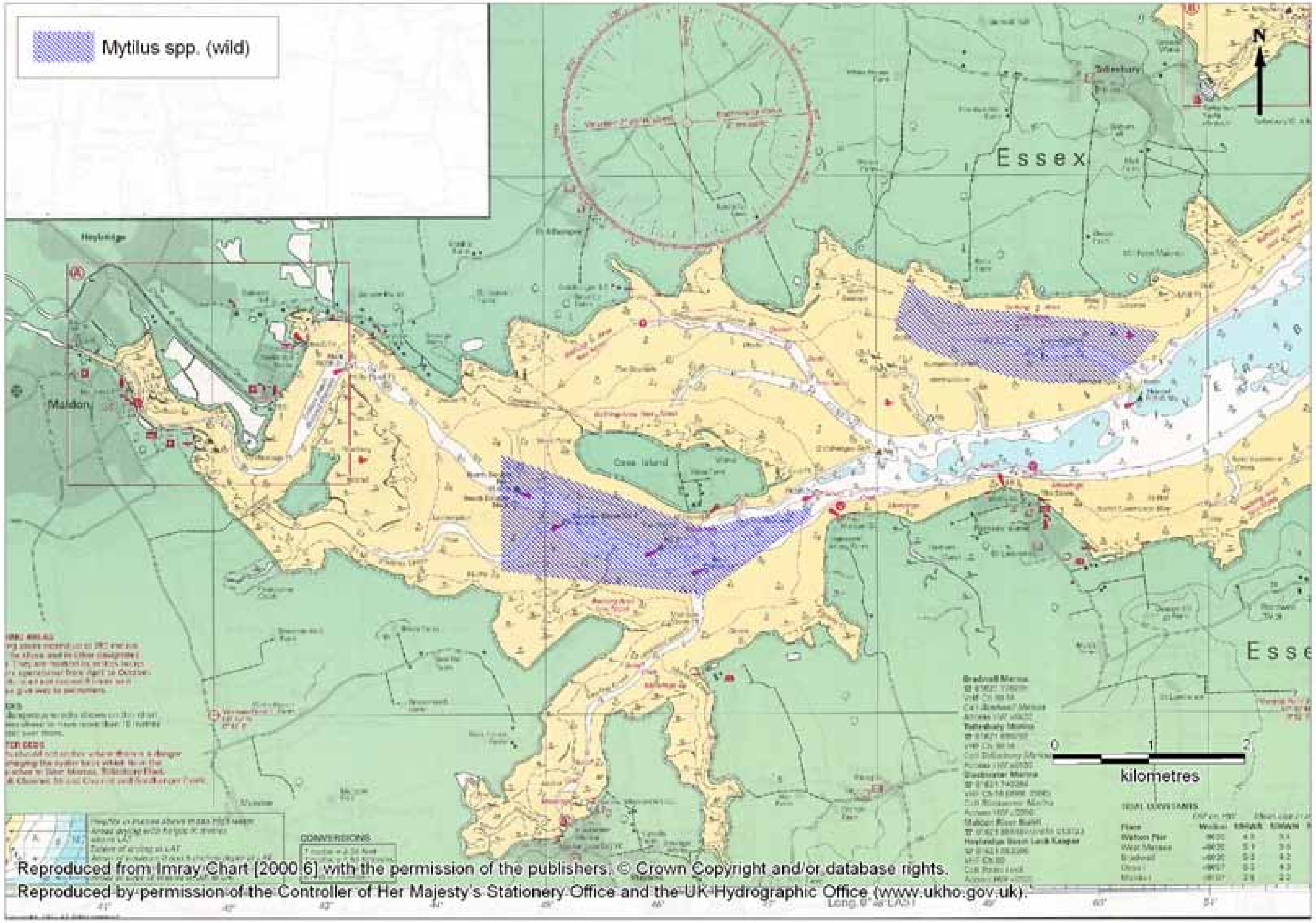


Figure IV.2 Location of mussel beds and representative monitoring points in the western part of the Blackwater Estuary.

APPENDIX V
HYDRODYNAMIC DATA: TIDES AND CURRENTS

The Blackwater Estuary has an asymmetrical macro-tidal regime with semi-diurnal tides (two cycles per day). At Osea Island, the mean spring tide range is 4.9 and the mean neap tide range is 3.1m (Table V.1).

Table V.1 Tide levels and ranges on the Blackwater Estuary.

	Height (m) above Chart Datum				Range (m)	
Port	MHWS	MHWN	MLWN	MLWS	Springs	Neaps
West Mersea	5.1	3.8	1.2	0.5	4.6	2.6
Bradwell	5.2	4.2	1.3	0.4	4.8	3.1
Osea Island	5.3	4.3	1.2	0.4	4.9	3.1
Maldon	2.9	2.2	-	-	-	-

Data from Imray Laurie Norie & Wilson Ltd (2005).
Predicted tidal levels are reduced to Chart Datum, which is approximately the level of Lowest Astronomical Tide (LAT).

Maximum flow ratio is very low and saltwater is likely to be present through most of the estuary (Halcrow Group Ltd., 2003). Overall, the estuary is thought to be well mixed and ebb dominant (Halcrow Group Ltd., 2003). There is some vertical stratification in the upper reaches of the estuary and slight lateral gradients in temperature and salinity (Chesman *et al.*, 2006). Furthermore, levels of turbidity in tidal waters at various sites across the estuary reported by these authors highlight significantly higher variations in tidal waters at Stansgate than those at Goldhanger Creek. This indicates that Southey Creek would be more impacted by resuspension of particles and dissolved substances in water during periods of high river flow discharges, dredging, suspended solids from sewage discharges and saltwater/freshwater fronts.

Maximum rates of tidal streams in the lower estuary at 51°45.3’N, 0°54.7’E are 1.5knots on spring and 1knot on neap flood tides. On ebb tides, these reach 1.4knots on springs and 0.9knots on neaps (Kershaw *et al*., 2007).

Water velocity fields for the Blackwater Estuary were simulated using the PRISM hydrodynamic model developed at the Proudman Oceanographic Laboratory. The model has been widely reported in the literature (e.g. Aldridge and Davies, 1993; Davies and Aldridge, 1993). Standard shallow water equations were solved on a finite difference grid in the horizontal. The model has been extensively validated for the Irish Sea (Aldridge and Davies, 1993; Davies and Aldridge, 1993; Davies and Lawrence, 1994). A key feature of the model is the ability to handle the highly dynamic wetting and drying of inter-tidal area which has a crucial influence on the predicted transport pathways within the Blackwater Estuary.

Simulation of the particle paths within the estuary was accomplished using the COSE transport model described by Aldridge *et al.* (2003). In its most general form, the model is capable of dealing with movement of material in both dissolved and particulate (sediment bound) phases, with transfer of contaminants between phases, and allowance for simultaneous transport of a number of sediment classes. For this study, a simple particle tracking option was used to follow the movement of particles allowing the main pathways to be identified (Figure V.1).

The results suggest that material carried past the BMPA along the main river channel on the ebb tide may impact bivalve molluscs on the flood tide 24h (i.e. two tidal cycles) after the initial high water release. The model also suggests that under high river flow conditions, the material may initially move further into the estuary during the ebb tide so that impacts may occur on the first flood, i.e. within 12h.

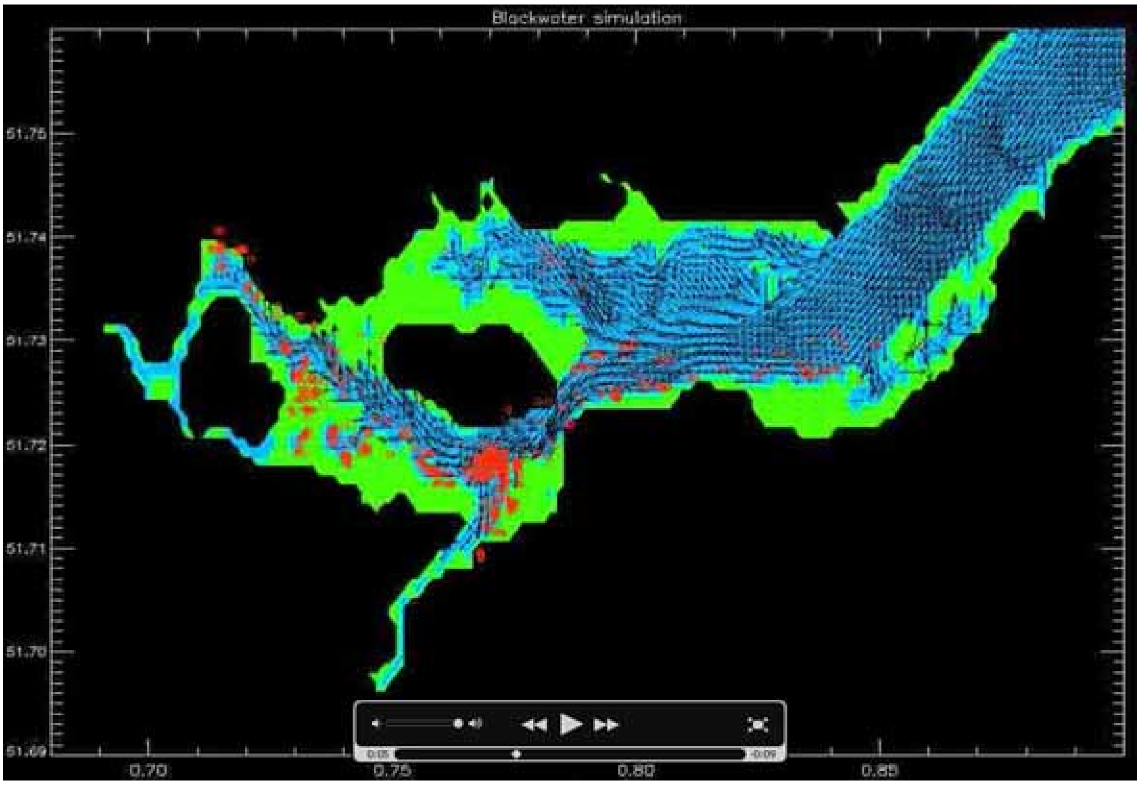


Figure V.1 Simulation model after a flood tide in the Blackwater Estuary.
NB. Tidal forcing used M2 and S2 harmonic constituents to yield elevation and depth averaged flow fields at 30 minute intervals over a spring-neap cycle of 15 days for subsequent transport calculations. The computational domain comprised 419x257 numerical grid points, giving a grid size of 101mx98m. This configuration allowed a reasonable spatial resolution of the coastline and a reasonable temporal resolution of tidal currents whilst maintaining computational efficiency. For the calculations reported here, the model was used in its depth-integrated form with bed friction coefficient set uniformly to a value of 0.0025.
Modified under permission of John Aldridge (Cefas).

APPENDIX VI
METEOROLOGICAL DATA: WIND

Eastern England is one of the more sheltered parts of the UK, since the windiest areas are to the north and west, closer to the track of Atlantic storms (Met Office, 2010). The strongest winds are associated with the passage of deep depressions across or close to the UK. The frequency of depressions is greatest during the winter months so this is when the strongest winds normally occur (Met Office, 2010).

Periods of very light or calm winds are more prevalent inland, with coastal areas having similar wind directions to inland locations but higher wind speeds (Met Office, 2010).

APPENDIX VII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: SEWAGE DISCHARGES

Sewage discharges pose a significant risk of contamination of faecal origin to bivalve molluscs. The risk is diverse and depends on the contributing human population and volume of discharge. Sewage effluents in the catchment draining to the Blackwater 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 Witham, Maldon, Mayland, West Mersea and further upstream at Chelmsford. Smaller discharges are located in the vicinity of St Lawrence and Bradwell on sea. Maldon STW and West Mersea STW receive UV disinfection, the remaining STW's are 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 the immediate Blackwater Estuary surrounding Osea Island, listed in Table VII.2.

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 dots represent these discharges that may impact on shellfisheries and contribute to overall background levels of microbiological contamination.

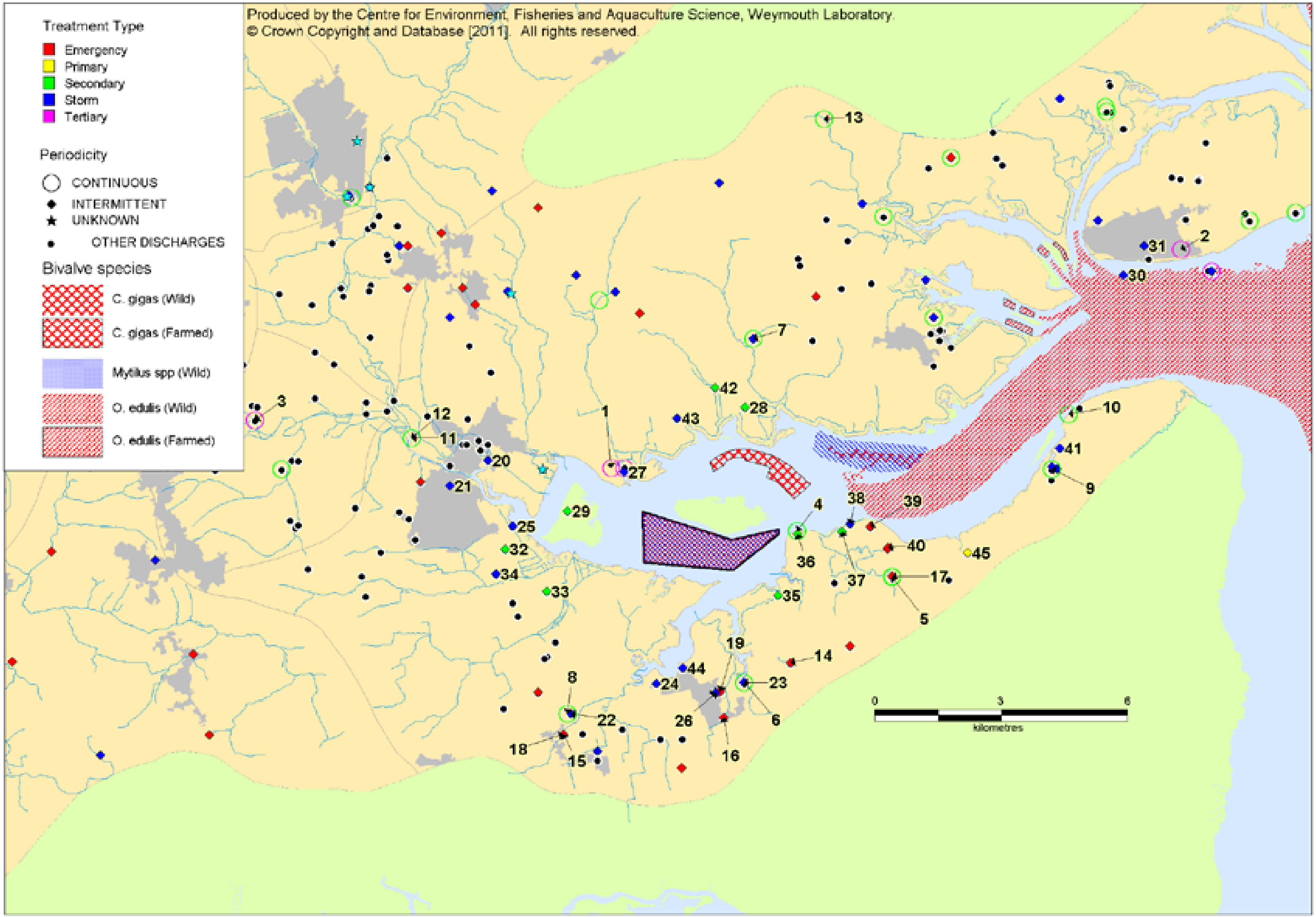


Figure VII.1 Significant sewage discharges to the Blackwater Estuary.

Table VII.1 Significant continuous sewage discharges to the Blackwater 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	Maldon STW	Retention lagoon	6,800	22,836	1.7	TL 8883 0743
2	West Mersea	UV	2,903	8,398	0.2	TM 0237 1262
3	Langford Recycling Plant	UV	30,000	2,498	11.7	TL 8037 0856
4	Marconi Sailing Club	Secondary	-	-	0.6	TL 9326 0585
5	St Lawrence STW	Secondary	300	2,498	3.1	TL 9551 0484
6	Mayland STW	Secondary	1,100	5,545	2.6	TL 9198 0233
7	Tollesbury D'arcy STW	Secondary	210	14,497	2.2	TL 9220 1050
8	Latchingdon STW	Secondary	637	5,155	5.7	TL 8780 0159
9	Bradwell on Sea STW	Secondary	147	917	0.3	TL 9930 0740
10	Bradwell Power Station	Secondary	136	14,497	2.2	TL 9220 1050
11	Chelmsford STW	Secondary	39,300	-	7.8	TL 8409 0814
12	Witham STW	Secondary	8,100	-	15.6	TL 8209 0814
13	Tiptree STW	Secondary	2,567	9,040	21	TL 9389 1572

DWF - dry weather flow.
STW - sewage treatment works.
UV - ultra-violet disinfection.
BMPA - bivalve mollusc production area.
NGR - national grid reference.

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

Discharge No.	Discharge name	Type	Approximate (fluvial) distance to nearest edge of the nearest BMPA (km)	NGR
14	Grange Farm SPS	SPS	3.5	TL 9310 0280
15	Latchingdon EO	CSO/EO	5.7	TL 8770 0110
16	Mayland Green PS	PS	3.6	TL 9150 0150
17	Stone St Lawrence - Lawrence Dr PS	PS	1.5	TL 9550 0485
18	PS at Deadaway Bridge	PS	5.7	TL 8770 0110
19	PS at Nipsells Chase	PS	3.2	TL 9142 0213
20	Fambridge Rd - Maldon	CSO/EO	4.8	TL 8590 0760
21	Heybridge	CSO/EO	5.1	TL 8500 0700
22	Latchingdon STW Overflow	CSO/EO	5.4	TL 8788 0159
23	Mayland STW Settled Storm Overflow	CSO/EO	2.9	TL 8788 0159
24	Maylandsea Esplanade West	CSO/EO	3.2	TL 8990 0230
25	Park Drive	CSO/EO	3.3	TL 8649 0605
26	The Drive CSO	CSO/EO	3.3	TL 9131 0209
27	Maldon STW Storm Overflow	CSO/EO	1.1	TL 8914 0733
28	Lauriston Cottages	Secondary	1.1	TL 9201 0887
29	Northey House & Cottage	Secondary	2.0	TL 8780 0640
30	West Mersea Whittaker Way SP	PS	0.1	TM 0100 1200
31	West Mersea Kingsland Road	SSO	0.1	TM 0150 1270
32	South Farm House	Secondary	3.4	TL 8632 0549
33	Bramble Hall	Secondary	3.0	TL 8730 0450
34	Mundon Road	SSO	3.7	TL 8610 0490
35	Steeple Bay Caravan Park	Secondary	1.1	TL 9280 0440
36	Marconi Sailing Club	EO	0.5	TL 9326 0585
37	Wade Cottage	Secondary	0.3	TL 9432 0591
38	Esplanade West Storm Overflow	SSO	0.2	TL 9450 0610
39	Lawrence Drive Pumping Station	PS	0.2	TL 9499 0603
40	Caravan Park Pumping Station	PS	0.8	TL 9541 0554
41	Waterside	SSO	0.7	TL 9950 0790
42	Highams Farm	Secondary	1.6	TL 9130 0933
43	Fish Street SPS	SSO	1.3	TL 9040 0860
44	Esplanade CSO	CSO/EO	2.7	TL 9054 0267
45	Sunnyside Cottage	Primary	1.2	TL 9730 0541

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.

Table VII.3 presents summary statistics for levels of *E. coli* monitored in the final UV-treated effluent from West Mersea sewage treatment works during the period November 2003–January 2008.

Table VII.3 Summary statistics of levels of* E. coli *in the final effluent post UV disinfection monitored in West Mersea sewage treatment works for the period November 2003–January 2008.

Year	Number of samples	CFU *E.coli* 100ml^{-1}			
		Minimum	Maximum	Median	Geometric mean
2003	5	20	300	180	
2004	27	0	1,000	36	
2005	26	5	40	1	
2006	26	5	1,270	30	
2007	26	<2	1,000	10	
2008	26	<2	430	25	

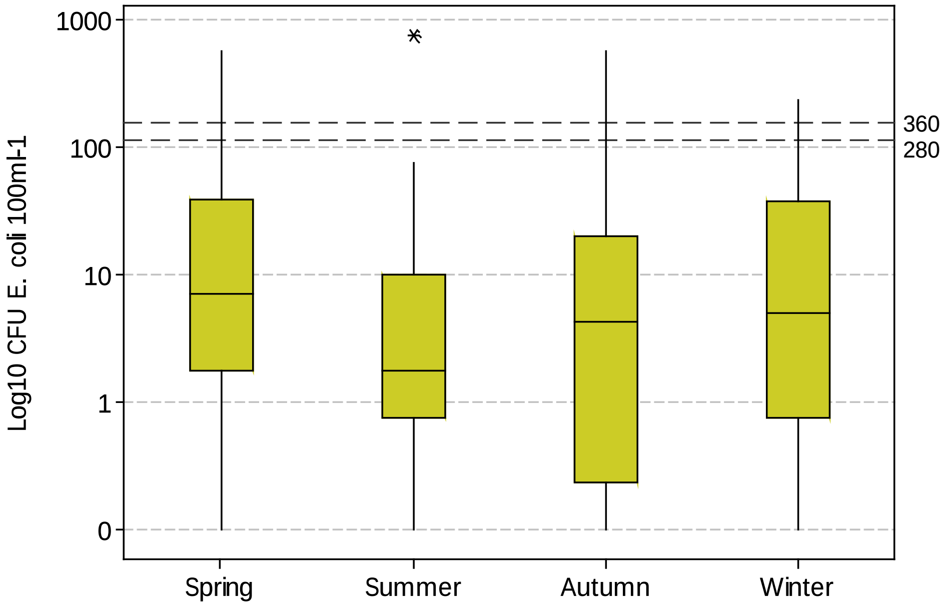


Figure VII.2 Box-and-whisker plots of seasonal levels of faecal coliforms in the final effluent post UV disinfection monitored in West Mersea sewage treatment works.
NB. Spring: March−May; Summer: June−August; Autumn: September−November; Winter: December−February.
Reference lines correspond to typical levels of faecal coliforms in UV-treated effluents under base-flow and high flow conditions as observed in a range of effluents by Kay et al. *(2008). Data from the Environment Agency (2009).*

APPENDIX VIII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: AGRICULTURE

Agricultural land covers the vast majority of the river catchments assessed in this sanitary survey with extensive areas being used for cereals and breakcrops (e.g. potatoes, field beans and peas, etc.) (Maldon District Council and Colchester Borough Council, 1996). Arable and horticulture exceed 60% of the land use in these catchments (NERC, 2005).

Livestock production in natural and improved grassland is considerably less significant. There are over 1.5M farmed animals in these catchments. Not surprisingly, poultry constitute 96.5% of the total number of farmed animals. Cattle and sheep constitute only 0.5% and 1% of this number (Defra Farming Statistics, pers. comm.).

Cattle are more abundant in the Blackwater Pant catchment, whereas higher densities of sheep are found in the Blackwater Estuary river catchment.

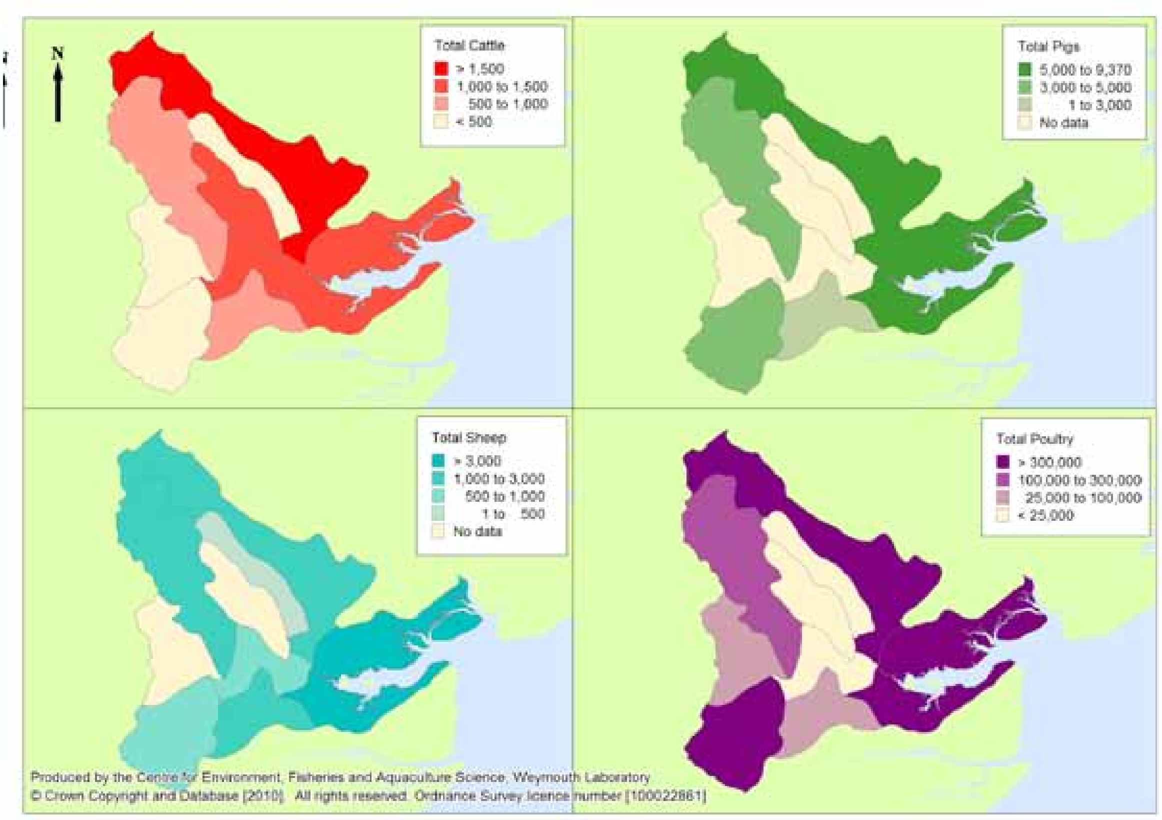


Figure VIII.1 Total number of farmed animals in catchments draining to the Blackwater Estuary.

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 these animal species and humans and corresponding daily loads are summarised in Table VIII.2.

Table A9.2 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	2,700	8.9×10^{8}
Sheep	16,000,000	1,130	1.8×10^{10}
Human	13,000,000	150	1.9×10^{9}

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

APPENDIX IX
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: BOATS

The largest inshore fishing fleet between Suffolk and Devon is based at the mouth of the Blackwater in West Mersea, generating an income of £1.5 million (Maldon District Council & Colchester Borough, 1996). The Blackwater estuary is also popular for recreational activities from traditional Thames sailing barges to jet skis. There are over 20 clubs situated around the estuary, with a combined membership of about 5,000 people (Maldon District Council & Colchester Borough, 1996). Figure IX.1 shows the location of sailing clubs and moorings in relation to the proposed mussel bed at Osea Island.

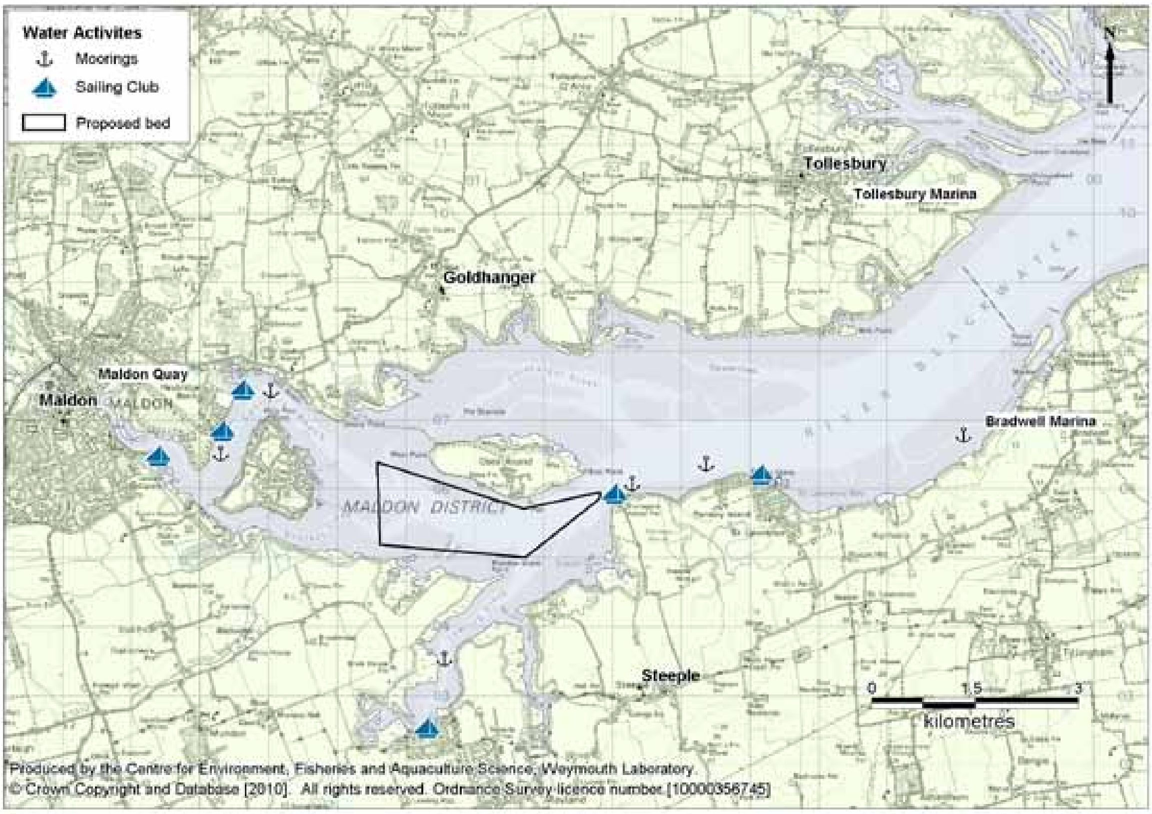


Figure IX.1 Location of mooring areas and sailing clubs in the upper Blackwater Estuary.

Maldon District Council is responsible for the standard mooring areas between Maldon to St Lawrence Bay on the south side of the River Blackwater (Maldon District Council, 2010). These moorings are half tide moorings i.e. they will be dry at low water.

There are no areas suitable for houseboats in the Blackwater Estuary owned by Maldon District Council. However further east, a number of houseboats are permanently moored, particularly fronting the coast road at West Mersea (Maldon District Council & Colchester Borough, 1996). Residential moorings are not permitted in the Maldon, Heybridge, Maylandsea, Tollesbury and Bradwell areas.

APPENDIX X
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: BIRDS

A census of the entire breeding population of seabirds was coordinated by the JNCC between 1998 and 2002 for a total of 40,000km of coastline in Britain and Ireland. Table X.1 shows the counts of seabirds from this census within a 10km radius of the proposed bed at Osea Island in the Blackwater Estuary.

Table X.1 Seabird counts within a 10km radius of proposed bed at Osea Island.

Occupied nests	Occupied nests	Total Count	Count Type
Larus argentatus	Herring gull	87 (pairs)	Occupied nests
Larus fuscus	Lesser black-backed gull	55 (pairs)	Occupied nests
Larus melanocephalus	Mediterranean gull	4 (pairs)	Occupied nests Occupied territory
Larus ridibundus	Black-headed gull	1173 (pairs)	Occupied nests
Sterna albifrons	Little Tern	99 (pairs)	Occupied nests
Sterna hirundo	Common Tern	121 (pairs)	Occupied nests

Data from Seabird 2000.

The WeBS low tide count for 2005/06 in the Blackwater Estuary is shown in Table X.2.

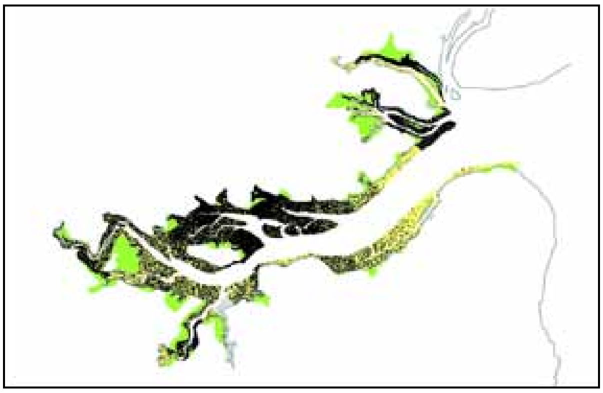
Table X.2 Waterbird counts from the Wetland Bird Survey (WeBS) low tide count for 2005/06 in the Blackwater Estuary.

Species	Peak No.	Mean	Mean Density (birds per ha)
Brent Goose	3759	2569	1.09
Shelduck	1740	1824	0.77
Wigeon	1976	2323	0.99
Teal	2664	3332	1.41
Mallard	79	80	0.03
Pintail	294	297	0.13
Oystercatcher	351	529	0.22
Ringed plover	91	75	0.04
Golden plover	8783	7390	3.14
Grey plover	687	943	0.4
Lapwing	2779	2406	1.02
Knot	4199	3907	1.66
Dunlin	10764	16764	7.11
Black-tailed Godwit	624	720	0.31
Bar-tailed Godwit	163	142	0.06
Curlew	662	681	0.29
Redshank	2131	2627	1.11
Turnstone	103	168	0.07

Reproduced from Musgrove et al. (2007) with the permission of the author.

Figures X.1 A-G show the distribution maps of the most common waterbird species from the WebS low tide counts for the 1994-95 survey. The maps show that the Blackwater Estuary is used by a wide range of waterbird species, which are relatively widespread throughout the whole estuary. Dunlin and Brent Geese tend to dominate the central regions of the north shore of the estuary, whereas Knot, Redshank and Lapwing dominate the channels entering the estuary on the north, south and western shores of the main estuary.

A



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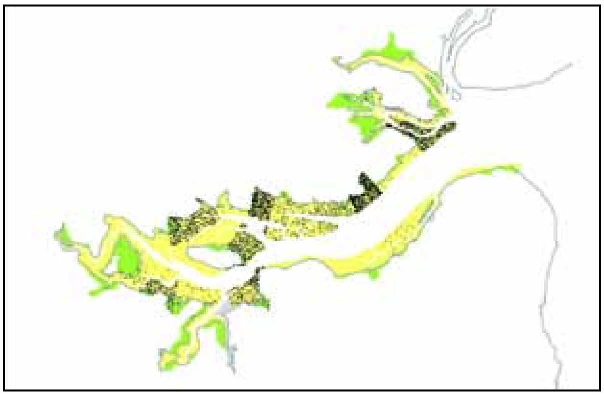

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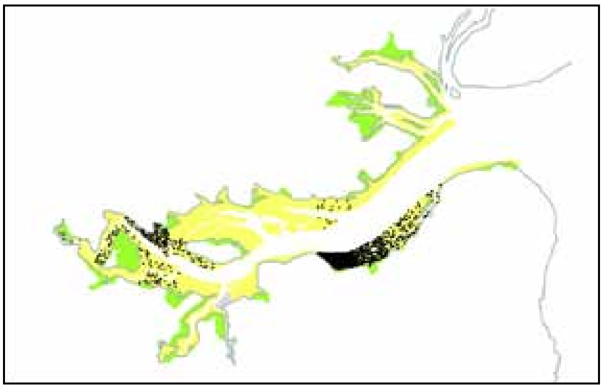

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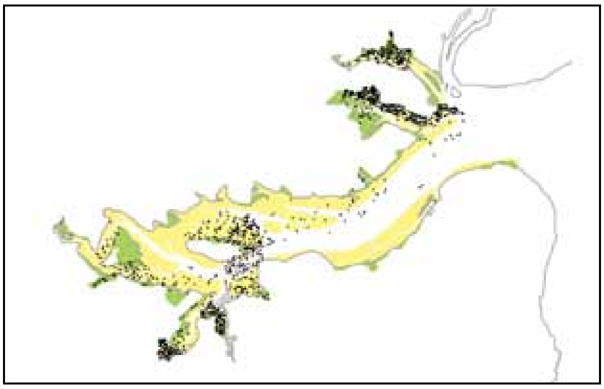

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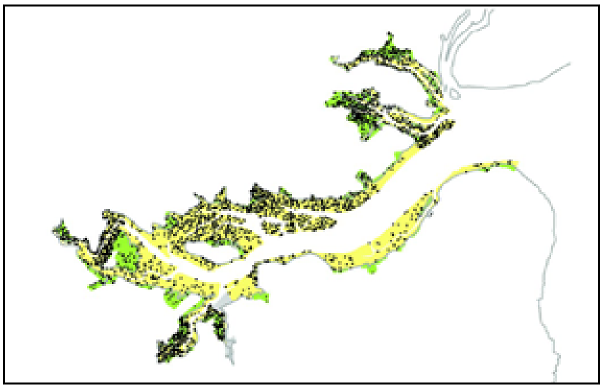

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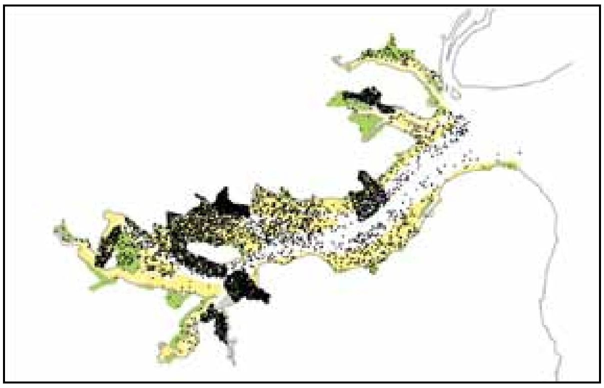

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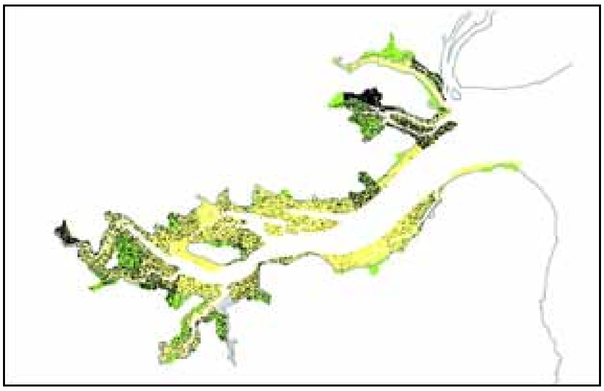

Figure X.1 Low tide waterbird distributions at the Blackwater Estuary winter 1994-1995 for A) Dunlin, B) Golden plover, C) Knot, D)Teal, E) Redshank, F) Brent Goose and G) Lapwing. Reproduced from Musgrove et al. (2003) with the permission of the author.

APPENDIX XI
MICROBIOLOGICAL DATA: WATER

BATHING WATERS

West Mersea is the only bathing water in the proximity of classified bivalve mollusc beds designated since 1991 under the Directive 2006/7/EC (European Communities, 2006a)[6] (Figure XI.1).

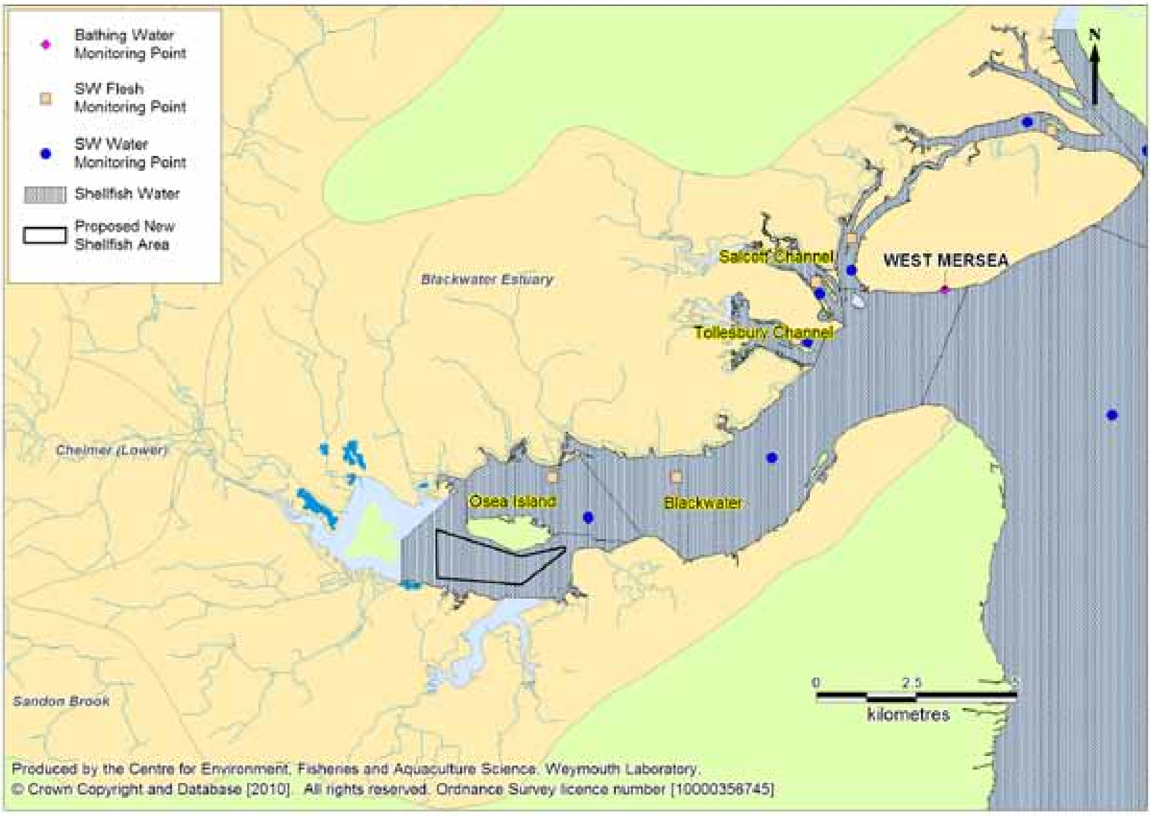

Figure XI.1 Location of the Bathing Waters and Shellfish Waters monitoring points and areas in the Blackwater Estuary.

The overall water quality for the past ten years at West Mersea has been classified as 'Good' or 'Excellent' (Table XI.1). Summary statistics for the bathing water are shown in Table XI.2 for the ten year period 1999–2009.

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[6] 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 for West Mersea bathing water for the period 1999–2009.

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Water quality	G	G	E	E	G	G	G	E	E	G	E

E - Excellent. G – Good.
Data supplied by the Environment Agency.

Table XI.2 Summary statistics for faecal coliform levels in the West Mersea bathing water for the period 1999–2009.

Year	Number of Samples	CFU Faecal Coliforms 100ml^{-1}			
		Minimum	Maximum	Geometric Mean	Median
1999	20	<10	5000	43	18
2000	20	<10	380	23	18
2001	20	<10	740	17	5
2002	20	<10	570	15	5
2003	20	<2	1000	12	5
2004	20	<2	1040	14	21
2005	20	<2	78	7	6
2006	20	<2	231	8	6
2007	20	<2	1040	12	8
2008	20	<2	1360	16	14
2009	20	<2	117	7	5
1999-2009	220	<2	5000	14	8

Data supplied by the Environment Agency.

Table XI.2 and the boxplots in Figure XI.3 show that the levels of faecal coliforms gradually reduced between 1999 and 2006. However, median levels increased again in 2007 and 2008 due to two incidents of high results (>1,000 CFU 100ml^{-1}) in July 2007 and June 2009. Figure XI.4 shows that the interquartile range of faecal coliforms has remained within the guideline levels. One sample collected on 6 September 1999 exceeded the imperative levels of faecal coliforms for bathing water standards.

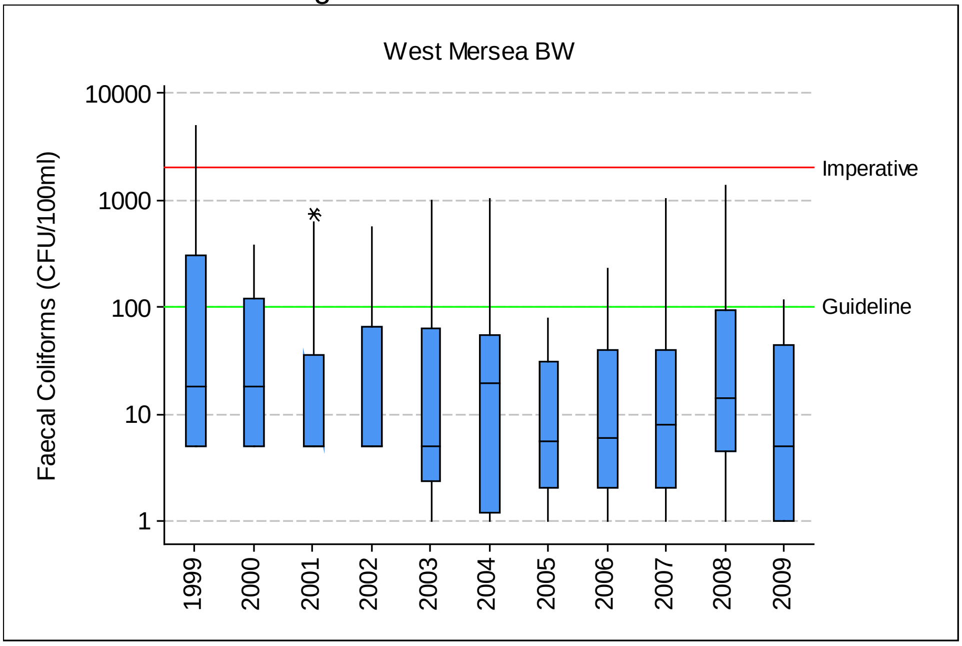

Figure XI.3 Boxplots of variation in faecal colifom levels in West Mersea bathing water for the period 1999–2009.

SHELLFISH WATERS

There are several shellfish waters within the Blackwater Estuary designated under the Directive 2006/113/EC (European Communities, 2006b) (Figure XI.1). The proposed bed to the south of Osea Island lies within the Osea Island Shellfish Water. Adjacent to this is Blackwater, Salcott Channel and Tollesbury Channel Shellfish Waters.

Table XI.3 shows the levels of faecal coliforms from shellfish samples between October 2002 and December 2008.

Table XI.3 Levels of faecal coliforms in designated shellfish waters in the Blackwater Estuary for the period October 2002–December 2008.

		CFU Faecal coliforms 100ml^{-1}			
Year	n	Min	Max	Geometric Mean	Median
Osea Island					
2002	2	<10	27	12	16
2003	7	<10	3,330	13	5
2004	4	6	8	6	6
2005	4	<2	5	2	2
2006	4	<2	5	2	3
2007	4	<2	2	1	2
2008	6	<2	45	7	6
Blackwater					
2002	2	<10	36	13	21
2003	7	<10	27	6	5
2004	4	4	8	5	5
2005	4	<2	5	2	1
2006	4	<2	5	2	3
2007	4	<2	1	1	1
2008	4	<2	1	1	1
Salcott Channel					
2002	2	<10	18	9	12
2003	7	<10	207	9	5
2004	4	<2	10	4	5
2005	4	2	5	3	3
2006	4	<2	5	3	4
2007	4	<2	8	2	2
2008	4	<2	15	3	3
Tollesbury Channel					
2002	2	<10	5	5	5
2003	7	<10	27	6	5
2004	4	<2	18	4	5
2005	4	<2	9	3	3
2006	4	<2	5	3	4
2007	4	<2	4	2	3
2008	4	<2	13	3	4

APPENDIX XII
MICROBIOLOGICAL DATA: SHELLFISH FLESH

Table XII.1 shows the summary statistics for levels of *E. coli* in bivalves from six representative monitoring points (for locations see Figure 2.1 in section 2) in the Blackwater Estuary obtained under the scope of the Shellfish Hygiene monitoring programme during the period January 2000–June 2009.

Sampling effort has been consistent over the years at all beds.

The higher number of samples returning *E. coli* results within the range for class A has been detected in native oysters from The Nass. The highest number of results exceeding the class B threshold were detected in native oysters from St Peters Flats.

Results suggest the following spatial differences in contaminating levels between beds:

- Southey Creek>Ford Creek>Lawling Creek≈Goldhanger>Thirslet Creek (*C. gigas*);
- The Nass>St Peters Flats (*O. edulis*).

Table XII.1 Summary statistics for levels of E. coli in bivalve molluscs from eight current representative monitoring points (RMPs) in the Blackwater Estuary in the proximity of Osea Island.

RMP	Bed name	Species	n	Date of first sample	Date of last sample	No. samples >230	No. samples >4600	MPN *E. coli* $100g^{-1}$ FIL				
								Min.	Max.	Median	Geometric mean	Log_{10} St. Dev
B014D	Goldhanger	*C. gigas*	96	26/01/2000	08/06/2009	21	0	<20	2,400	70	86	2.62
B014E	St Peters Flats	*O. edulis*	83	05/07/2000	09/06/2009	5	2	<20	5,400	20	36	2.92
B014F	The Nass	*O. edulis*	110	11/01/2000	09/06/2009	33	1	<20	9,100	80	100	3.02
B014G	Thirstlet Creek	*Mytilus* spp.	114	11/01/2000	09/06/2009	25	1	<20	9,100	40	68	3.03
B014M	Thirstlet Creek	*C. gigas*	40	01/11/2005	09/06/2009	4	0	<20	1,300	30	38	2.34
B014J	Southey Creek	*C. gigas*	39	03/04/2003	17/03/2009	17	0	<20	3,500	220	151	2.85
B014K	Lawling Creek	*C. gigas*	40	03/04/2003	17/03/2009	10	0	<20	1,400	60	83	2.51
B014L	Ford Creek	*C. gigas*	41	03/04/2003	17/03/2009	14	1	<20	5,400	160	138	3.00

LEVELS OF *ESCHERICHIA COLI* AND RAINFALL

The association between levels of *E. coli* in bivalves sampled from four current RMPs in the upper Blackwater Estuary and rainfall levels in the catchment was examined for the period July 2000–July 2009.

Spearman's rank correlation coefficient (*rho*)[7] was used to estimate correlations between MPN of *E. coli* 100g^{-1} FIL and daily/cumulative rainfall monitored at Maldon gauging station (Figure II.1).

Statistically significant positive correlations were obtained between daily rainfall and levels of the microbiological indicator in:

§ Pacific oysters from Goldhanger when sampling took place 5–6 days after the rainfall event;
§ Pacific oysters from Southey Creek when sampling took place 1 day after the rainfall event; and
§ Pacific oysters from Lawling Creek when sampling took place 6 days after the rainfall event.

Significant positive correlations were also found between cumulative rainfall and levels of the microbiological indicator in Pacific oysters from Goldhanger when sampling took place 6–7 days after the rainfall event (Table XII.2).

Table XII.2 Spearman's rho coefficients between rainfall recorded at Maldon rainfall gauge and levels of E. coli 100g^{-1} FIL in bivalves from four monitoring points in the upper Blackwater Estuary for the period July 2000-July 2009

		MPN *E. coli* 100g^{-1} FIL			
Rainfall		Goldhanger B014D *C. gigas*	Southey Creek B014J *C. gigas*	Lawling Creek B014K *C. gigas*	Ford Creek B014L *C. gigas*
Maldon		(n=90)	(n=39)	(n=40)	(n=41)
Daily	Day of sampling	0.067	-0.076	0.106	0.026
	-1 day	0.113	0.364*	0.160	0.039
	-2 days	0.045	0.019	0.176	-0.002
	-3 days	0.126	-0.109	-0.218	-0.120
	-4 days	0.072	-0.169	-0.036	-0.001
	-5 days	0.284*	0.088	0.124	0.142
	-6 days	0.346*	0.155	0.319*	0.181
	-7 days	0.171	0.020	0.198	-0.027
Cumulative	-2 days	0.096	0.196	0.157	0.113
	-3 days	0.077	0.171	0.242	0.180
	-4 days	0.151	0.179	0.123	0.151
	-5 days	0.130	0.174	0.140	0.200
	-6 days	0.212*	0.166	0.166	0.191
	-7 days	0.275*	0.237	0.219	0.233

** Significant at p≤0.05.*

[7] 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).

Two dimensional scatterplots of levels of rainfall and *E. coli* in Pacific oysters from these RMPs with superimposed LOcally WEighted Scatterplot Smoothing (LOWESS) for the maximum correlation coefficients are shown in Figures XII.1–XII.3.

The relationships with the most significant correlations are plotted in a scatter plot in Figures XII.1–XII.3. The scatterplots are superimposed with Locally Weighted Scatterplot Smooting (LOWESS) lines (degree of smoothing = 0.5, number of steps = 2). The upward trend of LOWESS line at the Goldhanger monitoring point (Figure XII.2) illustrates that levels of *E. coli* in oysters increase with increasing rainfall. The sample size of *E. coli* at Southey Creek and Lawling creek was relatively small, and so a clear trend in the relationship between rainfall and microbial contamination is difficult to determine from the graphs.

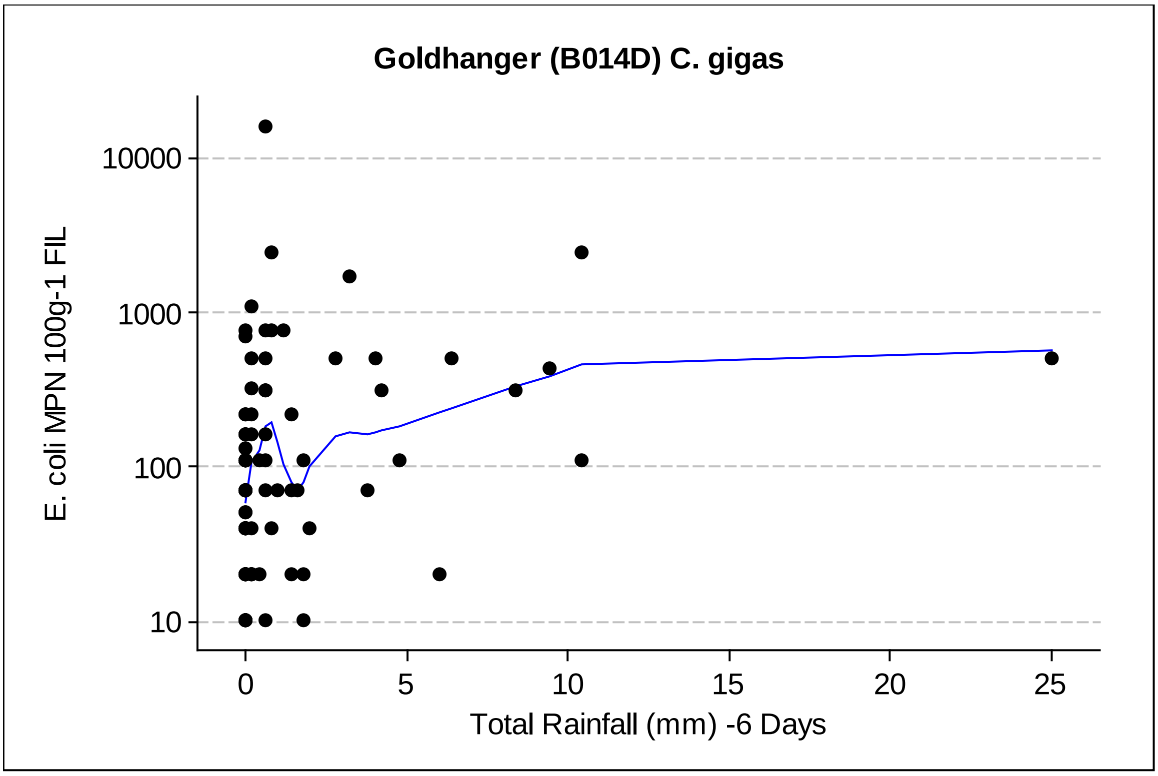

Figure XII.1 Scatterplot of levels of E. coli at Goldhanger versus total rainfall recorded at Maldon six days previous to sampling

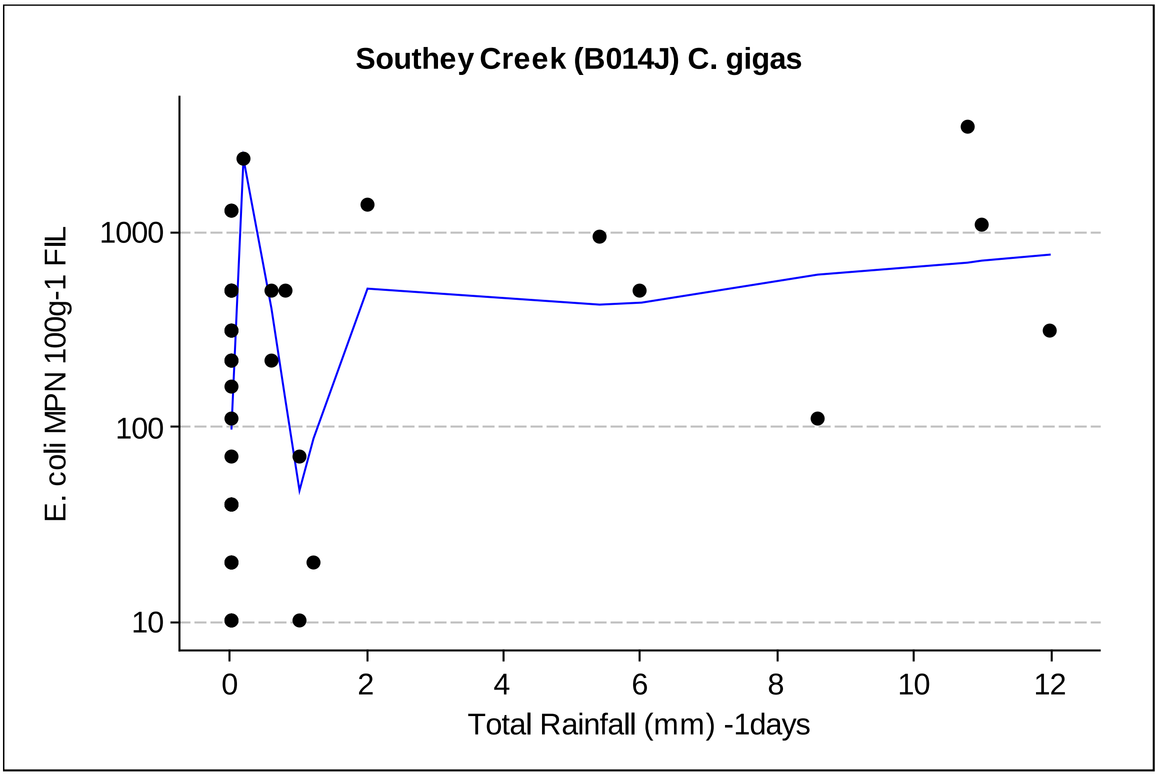

Figure XII.2 Scatterplot of levels of E. coli at Southey Creek versus total rainfall recorded at Maldon one day previous to sampling

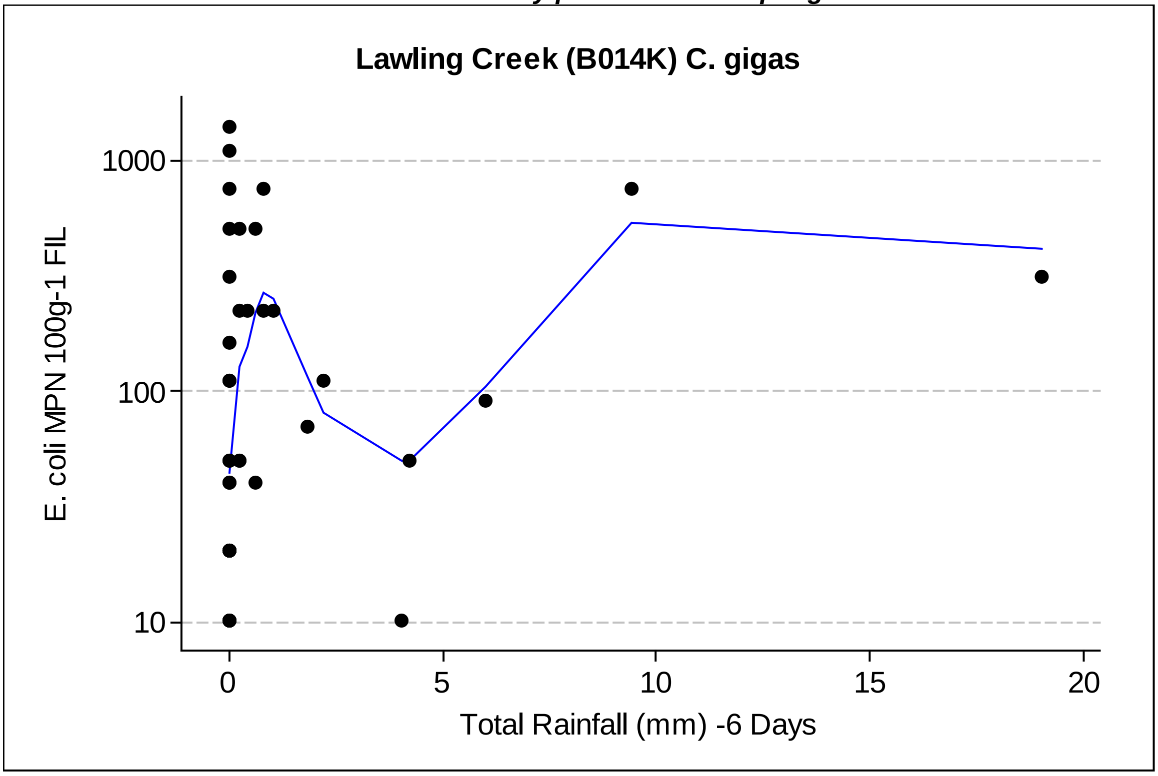

Figure XII.3 Scatterplot of levels of E. coli at Lawling Creek versus total rainfall recorded at Maldon six days previous to sampling.

VARIATION OF *ESCHERICHIA COLI* ACCORDING TO RIVER FLOW

River flow data from the Langford river flow gauging station was correlated with *E. coli* levels in bivalve molluscs from four current representative monitoring points (RMPs) (Figure 2.1) for the period January 2000–June 2009.

Statistically significant positive correlations were obtained between daily flows in the River Blackwater and levels of the microbiological indicator in oysters at Southey Creek, Lawling and Ford Creek (Table XII.3). Significant correlations were consistent for the three sites when the sampling occasion took place 1 day after the increase in water levels.

Significant correlations were also found between the levels of the microbial indicator and cumulative river flows. In this case, the strength of association between variables was very similar.

Table XII.3 Spearman's rho coefficients between river flow recorded at Langford and MPNs of E. coli 100g-1 FIL in bivalves from four monitoring points east of Osea Island for the period January 2000-June 2009.

		MPN *E. coli* $100g^{-1}$ FIL			
River flow		Goldhanger B014D *C. gigas*	Southey Creek B014J *C. gigas*	Lawling Creek B014K *C. gigas*	Ford Creek B014L *C. gigas*
Langford		(n=89)	(n=38)	(n=39)	(n=40)
Daily	Day of sampling	0.107	0.334*	0.260	0.295
	-1 day	0.173	0.280*	0.330*	0.327*
	-2 days	0.150	0.067	0.204	0.104
	-3 days	0.155	0.064	0.061	0.231
	-4 days	0.169	-0.033	0.061	0.120
	-5 days	0.118	0.225	0.237	0.177
	-6 days	0.080	0.124	0.211	0.066
	-7 days	0.113	0.078	0.224	0.149
Cumulative	-2 days	0.126	0.363*	0.303	0.347*
	-3 days	0.145	0.310	0.335*	0.303
	-4 days	0.175	0.315	0.328*	0.337*
	-5 days	0.184	0.276	0.294	0.303
	-6 days	0.173	0.299	0.306	0.307
	-7 days	0.157	0.286	0.290	0.264

** Significant at p≤0.05.*

The relationships with the most significant correlations are plotted in a scatter plot in figures XII.4-XII.6. The scatterplots are superimposed with Locally Weighted Scatterplot Smooting (LOWESS) lines (degree of smoothing = 0.5, number of steps = 2). The upward trend of the LOWESS line illustrates that levels of *E. coli* in oysters increase with increasing river flows.

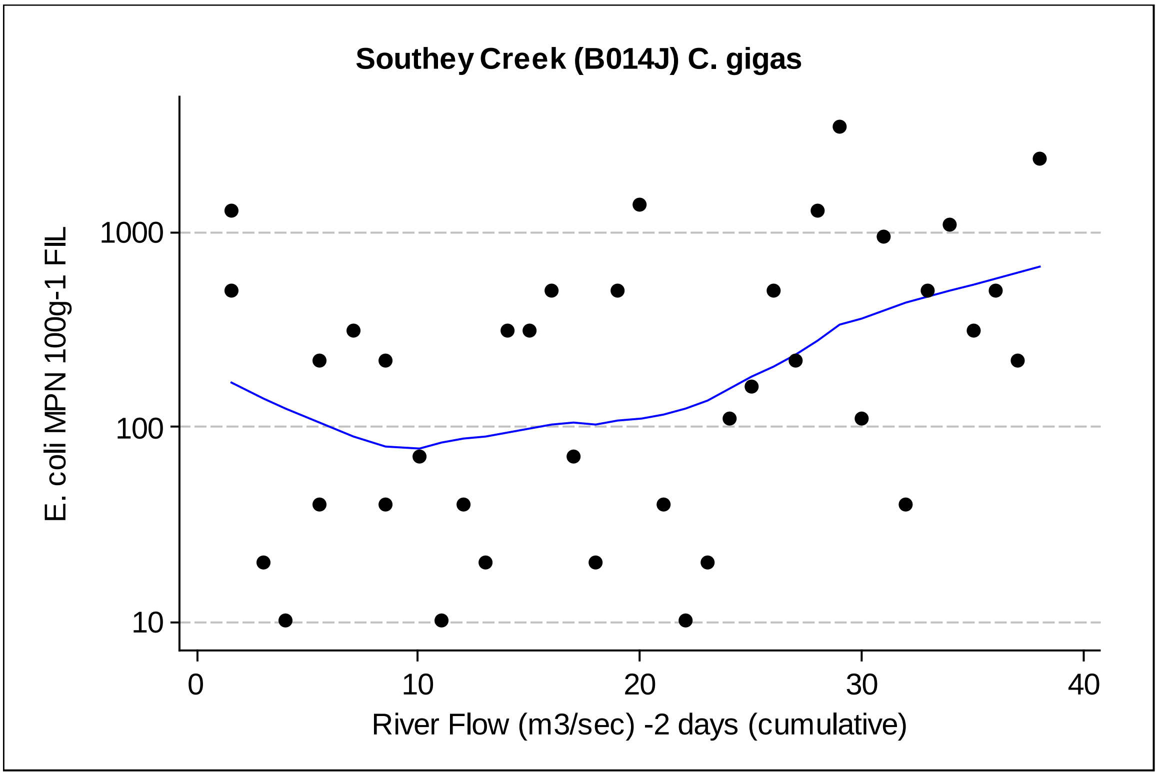

Figure XII.4 Scatterplot of levels of E. coli at Southey Creek versus cumulative river flow recorded at Langford for three days previous to sampling for the period April 2003–March 2009.

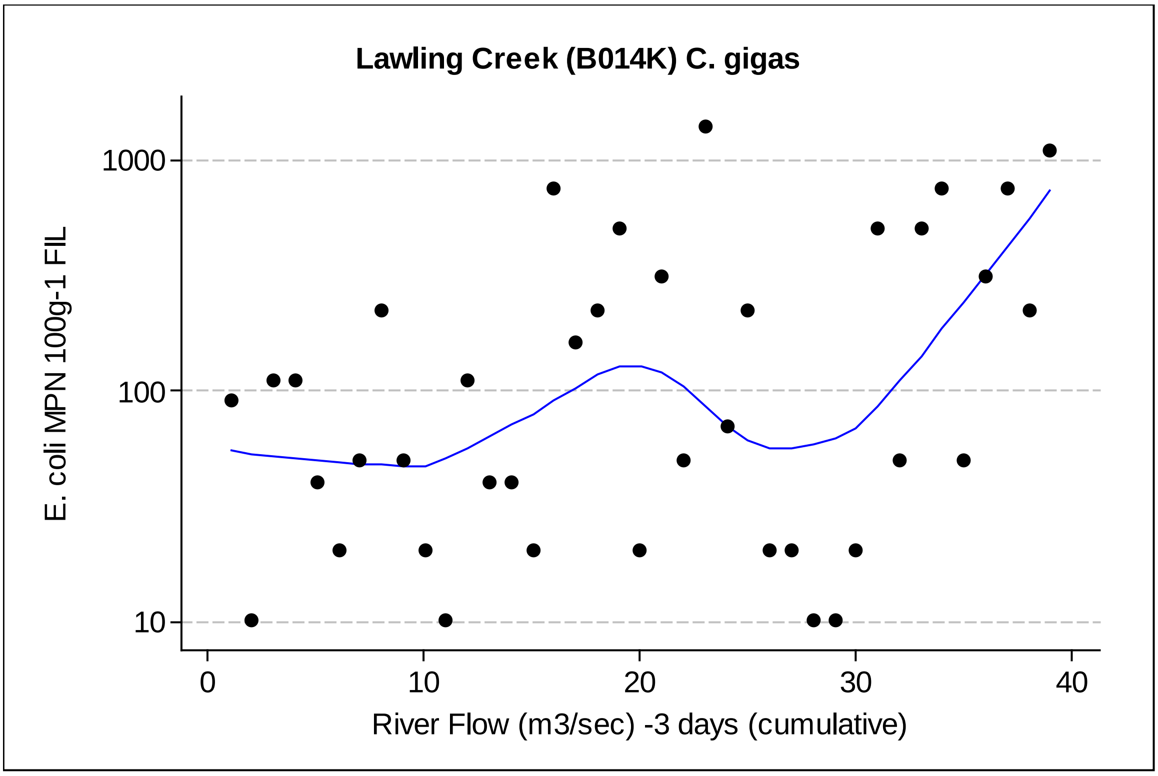

Figure XII.5 Scatterplot of levels of E. coli at Lawling Creek versus cumulative river flow recorded at Langford for three days previous to sampling for the period April 2003–March 2009.

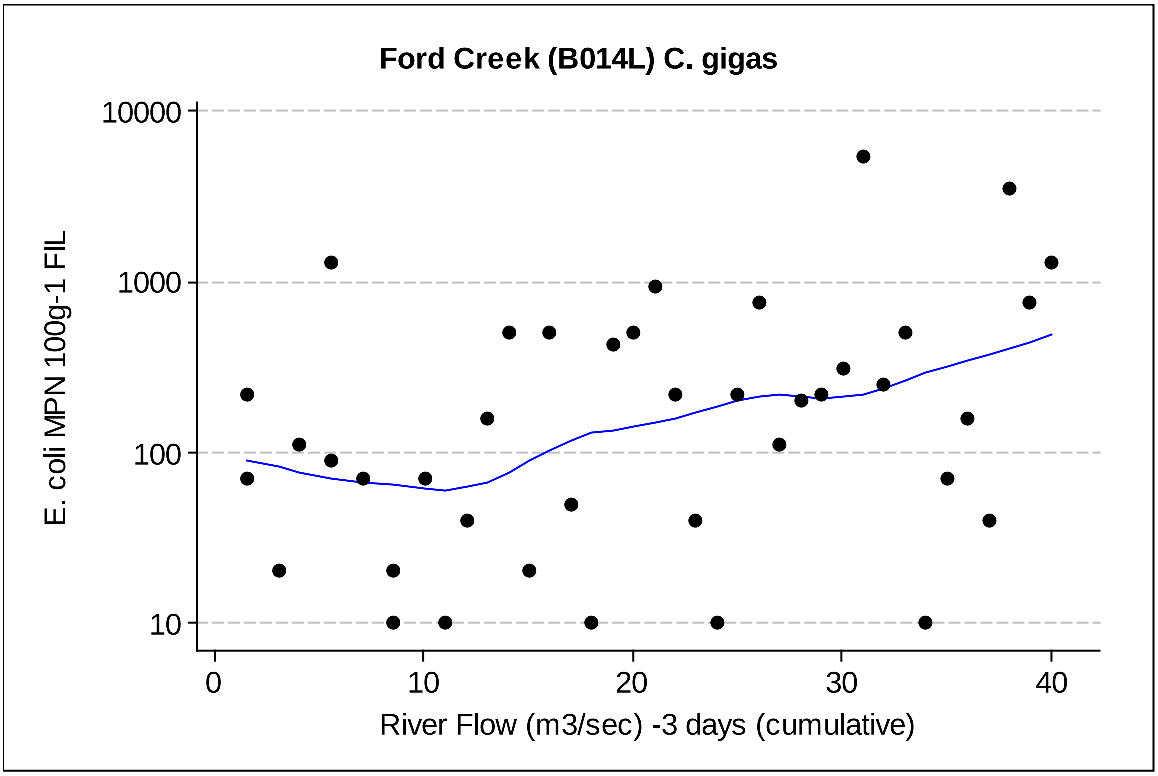

Figure XII.6 Scatterplot of levels of E. coli at Ford Creek versus cumulative average river flow recorded at Langford for three days previous to sampling for the period April 2003–March 2009.

SEASONAL VARIATION OF *ESCHERICHIA COLI*

The effect of season on the levels of microbiological contamination in bivalve molluscs could be due to biological activity of these animals, variation in microbiological loading due to factors such as tourism or seasonality in rainfall patterns (Younger *et al.*, 2003).

Historical levels (January 2000–June 2009) of *E. coli* in shellfish from four current beds (Goldhanger, Southey Creek, Lawling Creek, and Ford Creek) was used to investigate the existence of seasonal variation of levels of *E. coli* in bivalves from Blackwater near Osea Island. For this purpose, data was amalgamated by season, considering spring (March– May), summer (June–August), autumn (September–November) and winter (December–February).

Box-and-whisker plots of seasonal variation of *E. coli* levels in Pacific oysters from Ford Creek and Lawling Creek indicate higherlevels of the microbial indicator during the winter relative to those during the spring-summer period (Figure XII.7). In oysters from Ford Creek, the differences in *E. coli* levels between spring and winter exceeded $1Log_{10}$.
No appreciable differences in the seasonal levels of *E. coli* were detected in Pacific oysters from Golhanger, Southey Creek and Thirslet Creek.

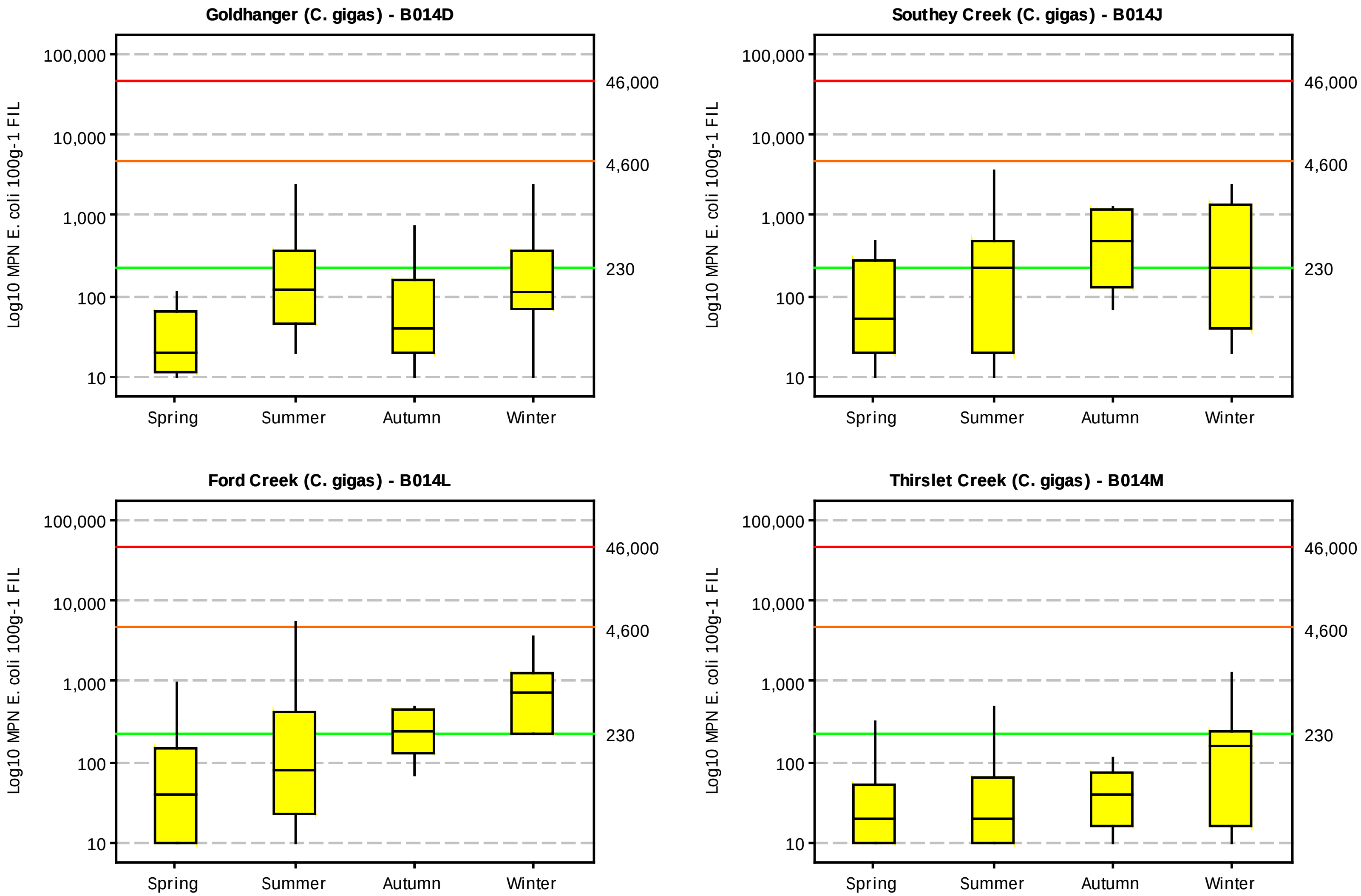

Figure XII.7 Box-and-whisker plots of seasonal variation of E. coli levels in bivalves from four current representative monitoring points (RMPs) for the period January 2000–June 2009.

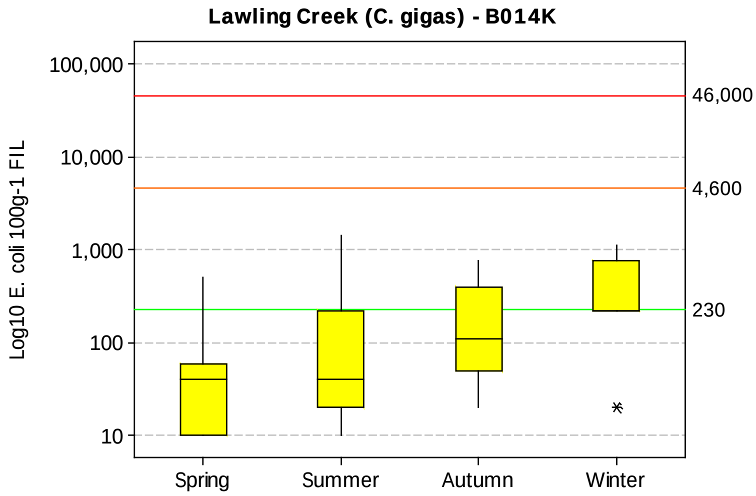

Figure XII.7 (cont.) Box-and-whisker plot of seasonal variation of E. coli levels in Pacific oysters from Lawling Creek for the period January 2000–June 2009.

APPENDIX XIII
SHORELINE SURVEY

Date (time): 14th July 2009 (06:30−11:30 GMT)
Applicant: Richard Emans
Cefas Officers: Carlos Campos, Richard Acornley
Local Enforcement Authority Officer: Malcolm Sach

Area surveyed: shoreline walk along south side of estuary south of Osea Island between Marconi Sailing Club and Maylandsea Marina. Area was also surveyed by boat from Maylandsea marina, along Lawling Creek, and west and east along the Blackwater River south of Osea Island.

Objectives: (a) confirm the existence of pollution sources identified during the desk study likely to constitute sources of microbiological contamination for bivalve mollusc beds; (b) identify any additional pollution sources in the area; and (c) confirm the extent of the new beds.

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

Table XIII.1 Predicted high and low water times and heights for Dartmouth on 14th July 2009.

	Time (height)
High Water	05:44 (4.8m)
Low Water	10:55 (0.9m)
High Water	17:46 (4.7m)
Low Water	23:17 (0.7m)

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.

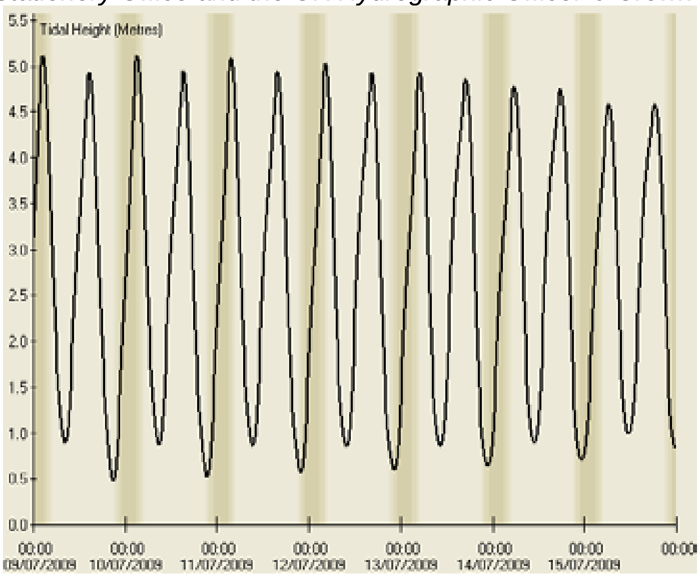

Figure XIII.1 Tidal curve at Osea Island 09-15 July.
Osea Island is a Secondary Harmonic port
Predicted heights are in metres above Chart Datum Republished with permission from Admiralty Total Tide (United Kingdom Hydrographic Office) by permission of Her Majesty's Stationery Office and the UK Hydrographic Office. © Crown copyright.

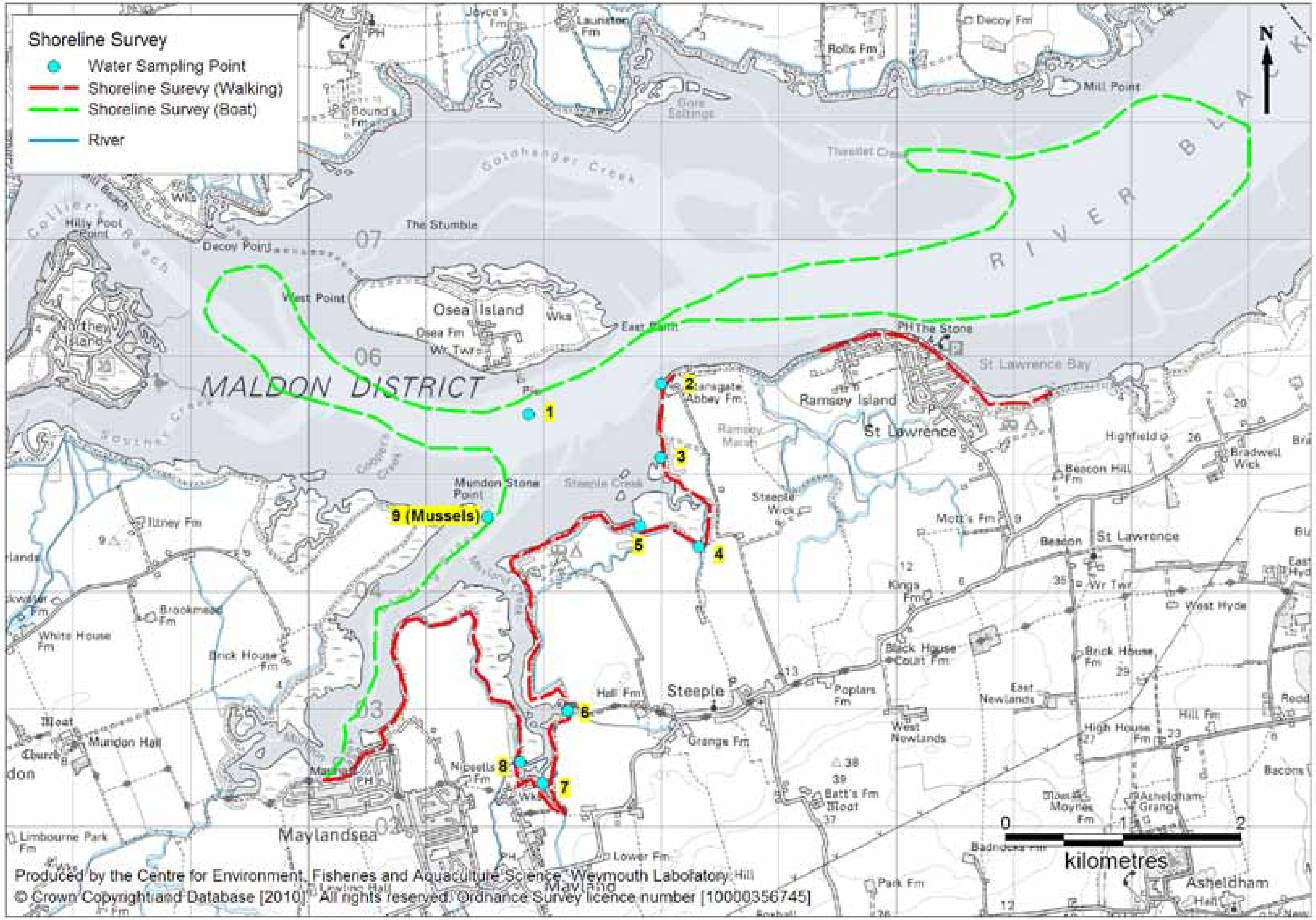

Figure XIII.2 Locations of sites surveyed and sampled in the Blackwater Estuary on the 14 July 2009.

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

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

Classification zones and ID/species	Classification zones/bed names: Goldhanger (*Crassostrea gigas*), Thirslet Creek (*Mytlius* sp and *C. gigas*), Lawling Creek (*C. gigas*), Ford Creek (*C. gigas*), Southey Creek (*C. gigas*)	
Location of beds /Coordinates OSGB36 (Easting, Northing)	Osea Island (*C. gigas* and *Mytilus* spp.) 589,570/206,390 589,610/205,190 591,730/205,010 391,700/205,720 592,820/205,960 592,820/205,870 Thirslet Creek 593,768/208,314 593,624/207,905 596,364/207,894 595,950/207,400	Goldhanger 591,260/207,337 591,196/207,573 592,460/207,783 592,544/207,194 593,558/207,025 593,165/206,704
Production area	Blackwater Estuary	
Area of beds	Goldhanger = 0.86 km^2 Thirslet Creek (*C. gigas*) = 0.22 km^2 Thirslet Creek (*Mytilus* sp) = 0.92 km^2 Osea Island = 2.45 km^2	
SWD Flesh Point	Osea Island – TL 925 077	
SWD Water Point	Osea Island – TL 934 067	
BWD Sampling point	West Mersea - TM 023 120	
Applicant	Richard Emans Maldon Oyster Company Chemlsford Essex CM3 6RF (01621 828699	
Cefas officers	Carlos Campos, Richard Acornley	
Local Enforcement Authority Officer	Malcolm Sach Maldon District Council Princes Road Maldon Essex CM9 5DL (01621 875830	
Extent of survey area	14th July 2009 (06:30-11:30): St Lawrence Bay to Maylandsea Marina (walk) Maylandsea Marina, Lawling Creek, Collier's Reach, and East along the River Blackwater	
Map/Chart references	UKHO Admiralty 3741: River Colne and Blackwater OS Explorer 176: Blackwater Estuary	

Weather	Temperature: 20.8°C Wind: 0 km/hr
Maximum air temperature	14th July 2009: 69.6°F
Wind	14th July 2009: 0 mph
Streams/springs	Stream at Steeple Farm (92209/02988) Sampled Coopers Creek (90878/05194) Not sampled Lawling Creek (91523/04637) Mussel sample
Sewage discharges (observed)	Sewerage from Osea Island properties is stored in tanks at the STW and periodically tankered away. MS commented that there are occasional problems associated with this. Steeple Stone Sluice (94705/06161) Stone Esplanade West SPS (with telemetry) (94705/06161) Outfall near slipway (95185/06149) Not sampled, no flow Large outfall near playing field (95426/05959) Not sampled, no flow Marconi Sailing Club (93222/05930) Not sampled Stansgate Abbey Farm (93017/05794) Not sampled Discharge (93003/05772) Sampled Discharge(93000/05633) Not sampled Rainbow Cottages discharge (92996/05142) Sampled Stoat Farm Sluice (93324/04381) Sampled Canney Farm No. 2 (92888/04366) Sampled Canney Farm No. 1 by caravan park (91888/04366) Not sampled, dry Steeple Farm Sluice (92209/02988) Sampled Steeple Hall sluice No. 2 (92073/02689) Not sampled Mayland STW (91989/02364) Sampled Nipsells Farm sluice No. 4 (91801/02547) Sampled Nipsells Farm No. 1 (90817/03096) Not sampled, dry Nipsells Farm Sluice No. 5 (9199/0235) Not sampled Maylandsea Bay sluice (90577/02689) Not sampled Discharge pipe by marina (90356/02498) Not sampled
Boats/port	Heybridge Basin boat moorings Approximately 50 occupied small craft moorings in front of the sailing club at Ramsey Island Marconi Sailing Club (93230/05897) Marina at Maylandsea (90390/02640)
Birds	Little egret, black headed gulls and oystercatchers on the shoreline at Ramsey Island. Approximately 50 curlew, 10 lapwings and a heron seen from mast of boat at Lawling Creek Birds also observed on Northey Island 13 swans and ducks at Canney Farm Sluice No. 2 (92823/04556)
Other animals	3 seals on shoreline at Lawling Creek 16 cows feeding near Rainbow Cottages (92996/05142) Horse faeces (91869/03743)
Strand line/Sewage Related Debris	None observed. Outfall from discharge at 93003/05772 (sampled) had strong smell of sanitary waste.

Bivalve harvesting activity and production area capacity	Oysters: MS doesn't know where the oysters have been laid – evidence of seeding from boats but no cooperation from Maldon Oysters *C. gigas* and mussels observed on intertidal along sides of Thirslet Creek (not sampled) Patch of mature mussels at Mundon Stone Point (Lawling Creek). Occasional *C. gigas* plus shells of cockle, razor clams and *Mercenaria* Sample of mussels taken at 91523/04637 Small patches of mussels at 91520/05099 and 91473/05091 (Lawling Creek) Coopers Creek (sampling point). 3 piles of small mussels deposited on intertidal.
Water appearance	Turbid
Human population	Population likely to be highly seasonal due to caravan parks at Ramsey Island and Canney Road.
Temperature Salinity	Salinity/temperature measurements: TL 91879 05460: 34.3ppt/19.4°C TL 88834 06882: 32.9ppt/18.8°C TL 92939 06120: 34.1ppt/19.3°C

Table XIII.3 Results of samples collected during the shoreline survey.

Fig.XII.10 ID	Matrix	Collection time	Easting	Northing	*E. coli* (CFU 100ml^{-1})	Water appearance
1	Seawater	07:26	91875	05509	145	Turbid
2	Water (discharge pipe)	09:40	93003	05772	1,100,000	Clear
3	Water (discharge pipe from Rainbow Cottages)	10:00	92996	05142	145	Clear
4	Farm sluice	10:29	93324	04381	62	Clear
5	Canney Farm No. 2	10:45	92823	04556	109	Clear
6	Freshwater (Stream at Steeple Farm)	11:44	92209	02988	270	Clear
7	Mayland STW	12:22	91989	02364	18,000	Turbid (brown)
8	Nipsells Farm Sluice	12:37	91801	02547	19,000	Turbid
9	Mussels (*Mytilus* spp.)	11:30	91523	04637	<20	-


Figure XIII.3 Marconi Sailing Club (93230/05897).


Figure XIII.4 Discharge by Stansgate Abbey Farm (93017/05794).

Figure XIII.5 Discharge pipe. Water sample 2 (93003/05772). [Inset: Discharge from pipe].

Figure XIII.6 Rainbow cottages discharge pipe. Water sample 3 (92996/05942).

Figure XIII.7. Discharges recorded during the shoreline survey. A – Stoat Farm sluice (93324/04381) Water sample 4; B, C – Canney Farm No. 2 (92823/04556) Water sample 5; D, E, F - Canney Farm No.1 Pipe from caravan park (dry) (91888/04366).

Figure XIII.8 Cattle at Steeplewick Farm.

Figure XIII.9 Stream at Steeple Farm (A–C). Sample 6 (92209/02988).

Figure XIII.10 Steeple Hall Sluice 2 (92073/02689).

Figure XIII.11 Bramble farm sluice.

Figure XIII.12 Nipsells Farm Sluice 5 TL 9199 0235 (left) and Mayland STW outfall (right) Sample 7. TL 91989 02364. Mayland STW can be seen in background.

Figure XIII.13 Mayland STW.

Figure XIII.14 Nipsells farm sluice No. 4. Sample 8 (TL 91801/02547).

Figure XIII.15 Nipsells farm No. 1. Not discharging, dry (90817/03096).

Figure XIII.16 Maylandsea boat yard.

Figure XIII.17 Pipe by Maylandsea Marina (90356/02498).

Figure XIII.18 Maylandsea Marina.

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List of Abbreviations

ABPmer	Associated British Ports Marine Environmental Research
AMPs	Asset Management Plans
AONB	Area of Outstanding Natural Beauty
BMPA	Bivalve Mollusc Production Area
°C	Degrees Celsius
c.f.	*Confer*
C. gigas	*Crassostrea gigas*
CD	Chart Datum
Cefas	Centre for Environment, Fisheries & Aquaculture Science
CFU	Colony Forming Units
CI	Confidence Interval
cm	Centimetre
CSO	Combined Sewer Overflow
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
g	Grams
GM	Geometric Mean
GMT	Greenwich Mean Time
ha	Hectare (10,000 square metres)
HAT	Highest Astronomical Tide
HW	High Water
ID	Identification
ISO	International Organization for Standardization
JNCC	Joint Nature Conservation Committee
km	Kilometre
LEA (LFA)	Local Enforcement Authority formerly Local Food Authority
Log_{10}	Base ten logarithm
LT	Low tide
Ltd	Limited
LW	Low water
M	Million
m	Metres
Ml	Millilitres
Mm	Millimetres
$m^3 s^{-1}$	Metres per second
MPN	Most Probable Number
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MSL	Mean Sea Level
n	Number of samples
NERC	Natural Environment Research Council
NGR	National Grid Reference
OSGB36	Ordnance Survey Great Britain 1936
Pop. Eq.	Population equivalent
ppt	Parts per thousand
PS	Pumping Station

Q10	10 percentile (10% exceedance) river flow
Q95	95 percentile (95% exceedance) river flow
RMP	Representative Monitoring Point
RSPB	Royal Society for the Protection of Birds
SEPA	Scottish Environmental Protection Agency
SFC	Sea Fisheries Committee
SAC	Special Area of Conservation
SO	Storm Overflow
spp	Species
SSSI	Site of Special Scientific Interest
STW	Sewage Treatment Works
UK	United Kingdom
UV	Ultraviolet
WeBS	Wetland Bird Survey
WGS84	World Geodetic System 1984
WWT	Wildfowl and Wetland Trust

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.
Bivalve mollusc production area	
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.
Bivalve mollusc classification zone	
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.
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.
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, gulley, etc. In some areas, storm water is collected and discharged to separate sewers, whilst in combined sewers it forms a dilutes sewage.
Waste water	Any waste water but see also “sewage”.

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