EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Walton Backwaters (Essex)

2011

Cover photo: Oyster dredger at Kirby Creek.

CONTACTS:

For enquires relating to this report or further information on the implementation of sanitary surveys in England and Wales:

Simon Kershaw/Carlos Campos
Food Safety Group
Cefas Weymouth Laboratory
Barrack Road,
The Nothe
WEYMOUTH
Dorset
DT43 8UB

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

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

Karen Pratt/Mariam Aleem
Hygiene Delivery Branch
Enforcement and Delivery Division
Food Standards Agency
Aviation House
125 Kingsway
LONDON
WC2B 6NH

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

STATEMENT OF USE: This report provides information from a study of the information available relevant to perform a sanitary survey of bivalve mollusc classification zones in Walton Backwaters (Essex). Its primary purpose is to demonstrate compliance with the requirements for classification of bivalve mollusc production areas, 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	24/09/2010	06/01/2011
Local Enforcement Authority	24/09/2010	09/02/2011
Sea Fisheries Committee	24/09/2010	07/01/2011

DISSEMINATION: Food Standards Agency, Tendring District Council, Environment Agency, Kent & Essex Sea Fisheries Committee.

RECOMMENDED BIBLIOGRAPHIC REFERENCE: Cefas, 2011. Sanitary survey of Walton Backwaters (Essex). Cefas report on behalf of the Food Standards Agency, to demonstrate compliance with the requirements for classification of bivalve mollusc production areas in England and Wales under of EC Regulation No. 854/2004.

CONTENTS

1. INTRODUCTION

1.1 LEGISLATIVE REQUIREMENT

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

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

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

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

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

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

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

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

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

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

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

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

This report documents information relevant to undertake a sanitary survey for wild and farmed Pacific oysters (*Crassostrea gigas*), farmed native oysters (*Ostrea edulis*) and wild Manila clams (*Tapes philippinarum*) commercially harvested in Walton Backwaters together with new information obtained from a shoreline survey undertaken in the estuary.

1.2 SITE DESCRIPTION

HAMFORD WATER

Walton Backwaters (also known as "Hamford Water"; TM 235255) is a tidal inlet on the north Essex coast, England. It is a large and shallow estuarine basin comprising tidal creeks, intertidal mud and sand flats, saltmarshes, islands, beaches and marsh grasslands and has a relatively long shoreline (Figure 1.1; Table 1.1).

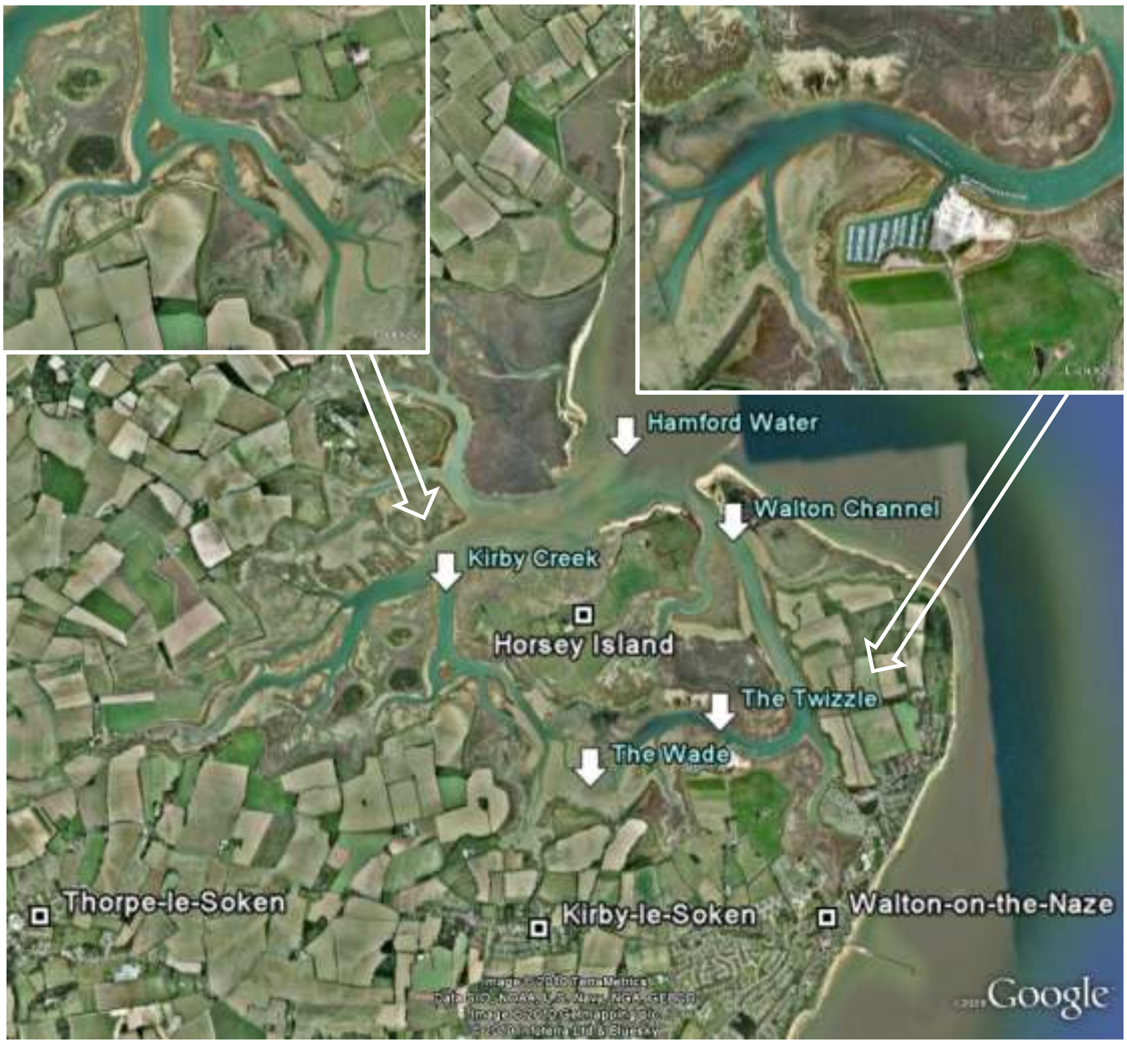


Figure 1.1 Aerial view of Walton Backwaters.
Reproduced under licence Google Earth™ mapping service.

The entrance to the estuary is about 1.5km wide, and divides into two main channels either side of the central island Horsey Island.

Hamford Water encompasses 863 hectares of saltmarsh (Boorman, 2003). Saltmarsh contributes significantly to pollution control and water quality through nutrient cycling (e.g. nitrogen and phosphorous release during decomposition of organic matter) and sediment retention (e.g. adsorption of pollutants onto sediment particles) (Adnitt *et al.*, in press).

Table 1.1 Main characteristics of Hamford Water.

Geomorphological type	Tidal inlet (embayment)
Shoreline length (km)	54
Core area (ha)	2,377
Intertidal area (ha)	1,570

Data from the Estuary Guide (ABPmer and HR Wallingford, 2009).

Commercial uses of the estuary include commercial shipping and tourism. Tourism-related activities are both water-based (e.g. canoeing, sailing) and land-based (e.g. walking, birdwatching).

CATCHMENT

The river catchment draining to Walton Backwaters bivalve mollusc production area (BMPA) is shown in Figure 1.2. The catchment receives very low freshwater inputs and is essentially rural in character, although Walton-on-the-Naze (south of BMPA) and Harwich (north of BMPA) are significant urbanised areas.

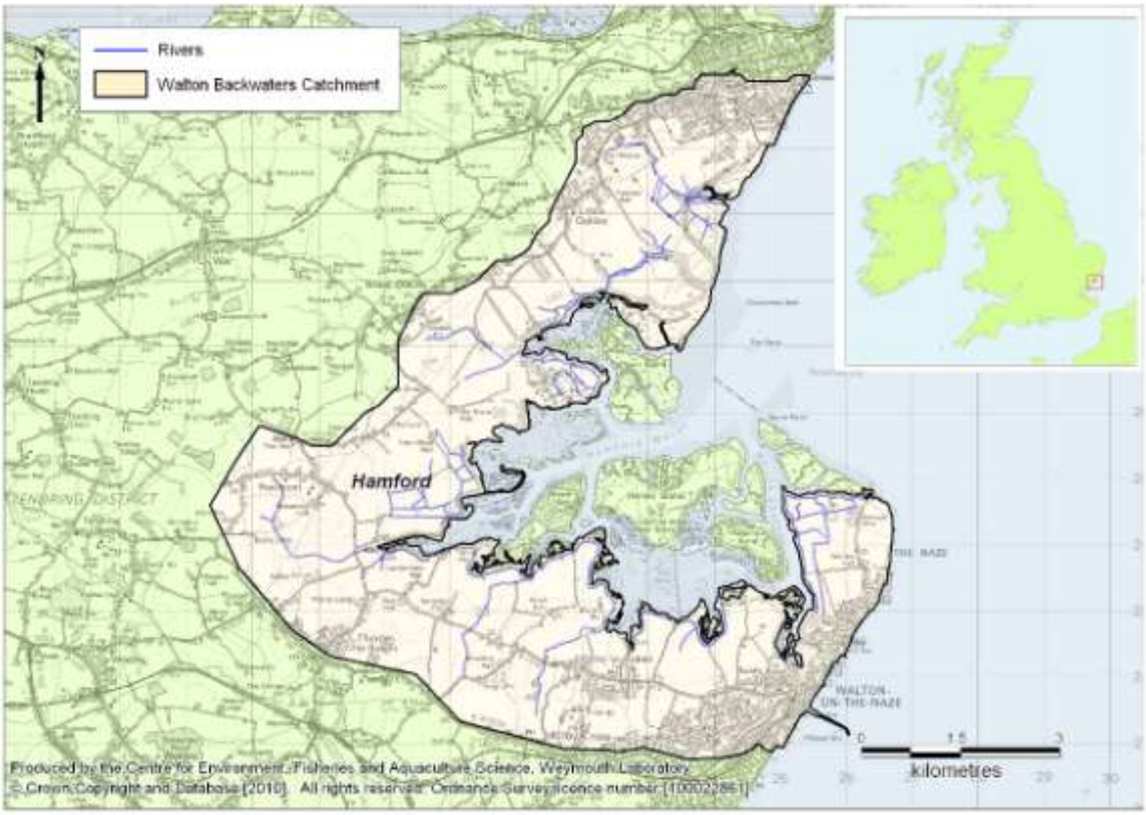


Figure 1.2 Location of catchment draining to Hamford Water.

The dominant land uses are arable land, areas of natural and improved grassland and deciduous woodland (Figure 1.3).

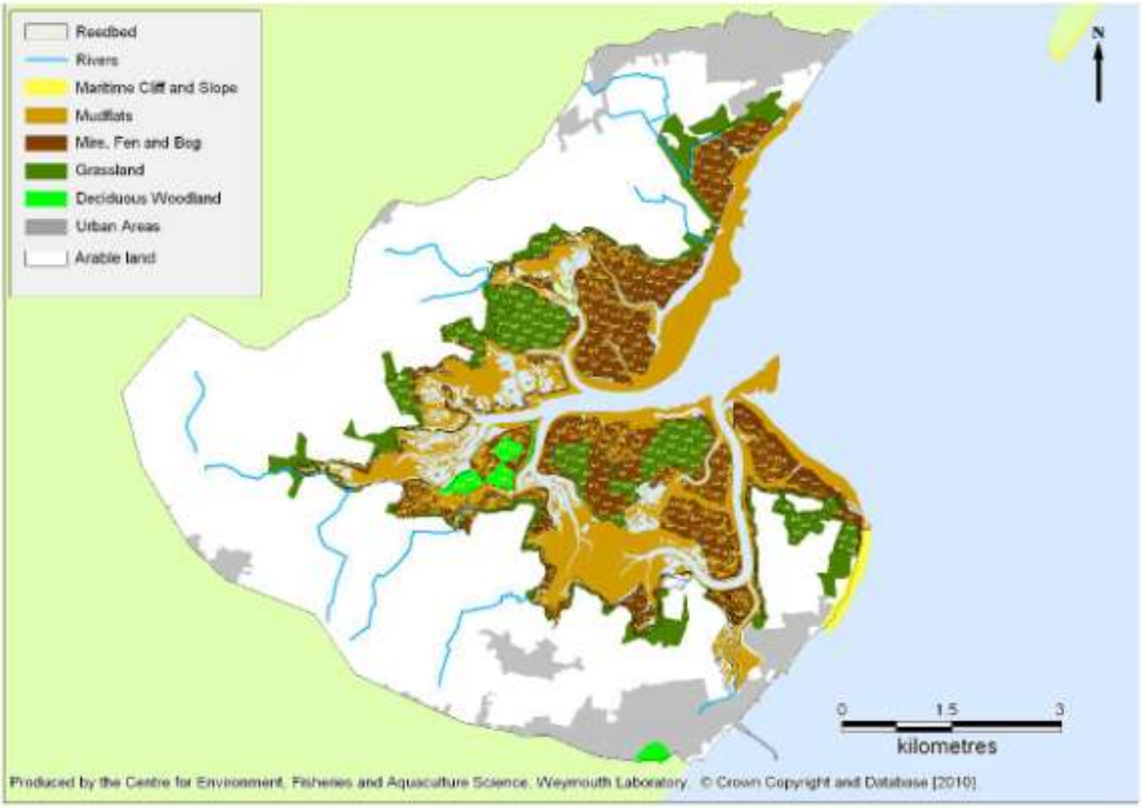


Figure 1.3 Land cover in the catchment draining to Hamford Water.

The main surface hydrogeological unit in the catchment is the relatively impermeable London clay with localised areas of sand and gravels cover (Environment Agency, 1998).

Grassland on impermeable soils means that surface or near-surface runoff is the most likely route of pollution across the catchment (Mawdsley *et al*., 1995).

Catchment topography comprises mainly flat land with gentle gradients across the catchment to sea level. The elevation in the catchment ranges 0-40m (weighted average = 25.3m) (NERC, 2005). Approximately 85% of the catchment is within the elevation range 20–40m (NERC, 2005).

Hamford Water is a Site of Special Scientific Interest (SSSI), a wetland of international importance under the Ramsar Convention and a Special Protection Area under the EEC Directive on the Conservation of Wild Birds. Part of the site is a National Nature Reserve.

2. SHELLFISHERIES

2.1 SPECIES, LOCATION AND EXTENT

This sanitary survey was prompted by an application for year-round classification of wild and farmed native oysters (*Ostrea edulis*), wild and farmed Pacific oysters (*Crassostrea gigas*) and wild Manila clams (*Tapes philippinarum*) from Naze Oysters Ltd.

The harvesting of bivalve molluscs for human consumption is a traditional activity in Walton Backwaters. The native oyster fishery has flourished from the deposit of half-grown Solent oysters (Spencer, 2002) on the beds situated along Kirby Creek and The Twizzle (Figure 2.1).

A pond at Mill Lane is used as holding area for class B native oysters from The Twizzle and Kirby Creek beds prior to depuration (Figure 2.2).

Figure 2.2 Aerial view of Mill Lane holding pond.
Reproduced under licence Google Earth™ mapping service.

Figure 2.1 Location of new and classified bivalve mollusc beds and representative monitoring points in Walton Backwaters.

Native oysters can tolerate salinities down to 23ppt although they prefer more fully saline conditions (>30ppt) (Laing *et al.*, 2005).

Temperature is the most important factor limiting growth rate of this species. Growth rates reach a maximum in July/August when temperatures peak (usually 16–18°C) and then falls off again as the temperature drops to below 8–9°C in November/December (Laing *et al.*, 2005).

The cultivation of the Pacific oyster, which is a non-native species in the UK, is now regularly established in many estuaries of England and Wales. Pacific oysters reach market size in 4 years or less. They grow well in areas where salinity and temperature vary between 8–30°C and 20–30ppt in sandy and firm/solid substrate (Laing and Spencer, 2006).

The Manila clam was also introduced to the UK in 1980 (Laing and Child, 1996). Manila clams are ready for harvesting in 2–3 years. They grow under the same water temperature range as Pacific oysters and under salinities varying between 25–35ppt in mud and muddy/sand substrate.

2.2 GROWING METHODS AND HARVESTING TECHNIQUES

Commercially harvested bivalves grow in the riverbed (Figure 2.3) and are dredged using iron-frame dredges from vessel over the tidal cycle.

Figure 2.3 Oyster dredger operated at Walton Backwaters.

2.3 SEASONALITY OF HARVEST, CONSERVATION CONTROLS AND DEVELOPMENT POTENTIAL

In Walton Backwaters, native and Pacific oysters have been harvested seasonally (1 September–31 March). The current application requires extending the classification regime to year-round for native and Pacific oysters and represents a new application for classification of Manila clams.

The current estimated annual Pacific oyster and native oyster productions are 10 tonnes for both species.

Horsey Island Oyster Fishery Order (1963) covers an area of approximately 61 acres below the Low Water Mark in Kirby Creek and the Twizzle to the west and south of Horsey Island and Hedge-end Island, respectively (Ministry of Agriculture, Fisheries and Food, 1963).

The Several Order, which has been in operation for 60 years, expires on 31 May 2023. Within its geographical limits, the Order confers exclusive right to the several oyster fishery to the grantees W.J. Backhouse and N.C. Backhouse. The extent of the area covered by the Fishery Oder is shown in Figure 2.4.

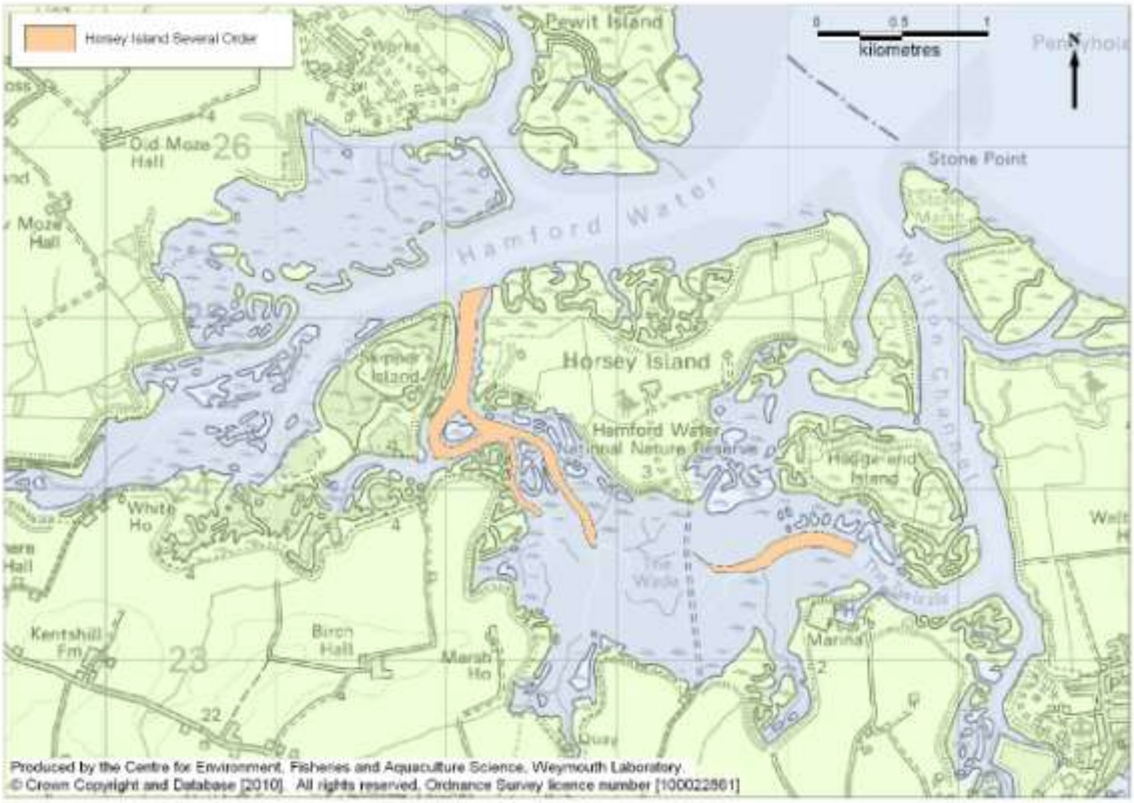


Figure 2.4 Area covered by the Horsey Island Oyster Fishery Order (1963).

Most of the foreshore is leased by the NCC from the Crown Estate.

2.4 HYGIENE CLASSIFICATION

Table 1.2 Historical classifications of bivalve molluscs in Walton Backwaters.

Bed name	Bed ID	Species	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Twizzle	B011Q/B011F	*O. edulis*	B	B	B	B	B1	B	B*	B*	B*	B*	B*	B*	B*	B-LT*	B-LT*	B-LT*	B-LT*	B-LT*
Twizzle	B011Q/B011F	*C. gigas*	B	B	B	B	B1	B	B*	B*	B*	B*	B*	B*	B*	B-LT*	B-LT*	B-LT*	B-LT*	B-LT*
Kirby Creek	B011R/B011G	*O. edulis*	B	B	B	B	B1	B	B*	B*	B*	B*	B*	B*	B*	B-LT*	B-LT*	B-LT*	B-LT*	B-LT*
Kirby Creek	B011R/B011G	*C. gigas*	B	B	B	B	B1	B	B*	B*	B*	B*	B*	B*	B*	B-LT*	B-LT*	B-LT*	B-LT*	B-LT*
Mill Lane	B011E	*O. edulis*	A	A	B	B	B1	B	B*	B*	B*	B*	B*	B*	B*	B-LT*	B-LT*	B-LT*	B-LT*	B-LT*

** - seasonal classification applies.*
1 - Classification was provisional due to insufficient sample results, either in number or period of time covered.
LT - Long-Term classification system applies. N.B. 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.
NB. Classifications may change via interim updates. The classifications given in Table 1.2 are valid at time of writing the report.

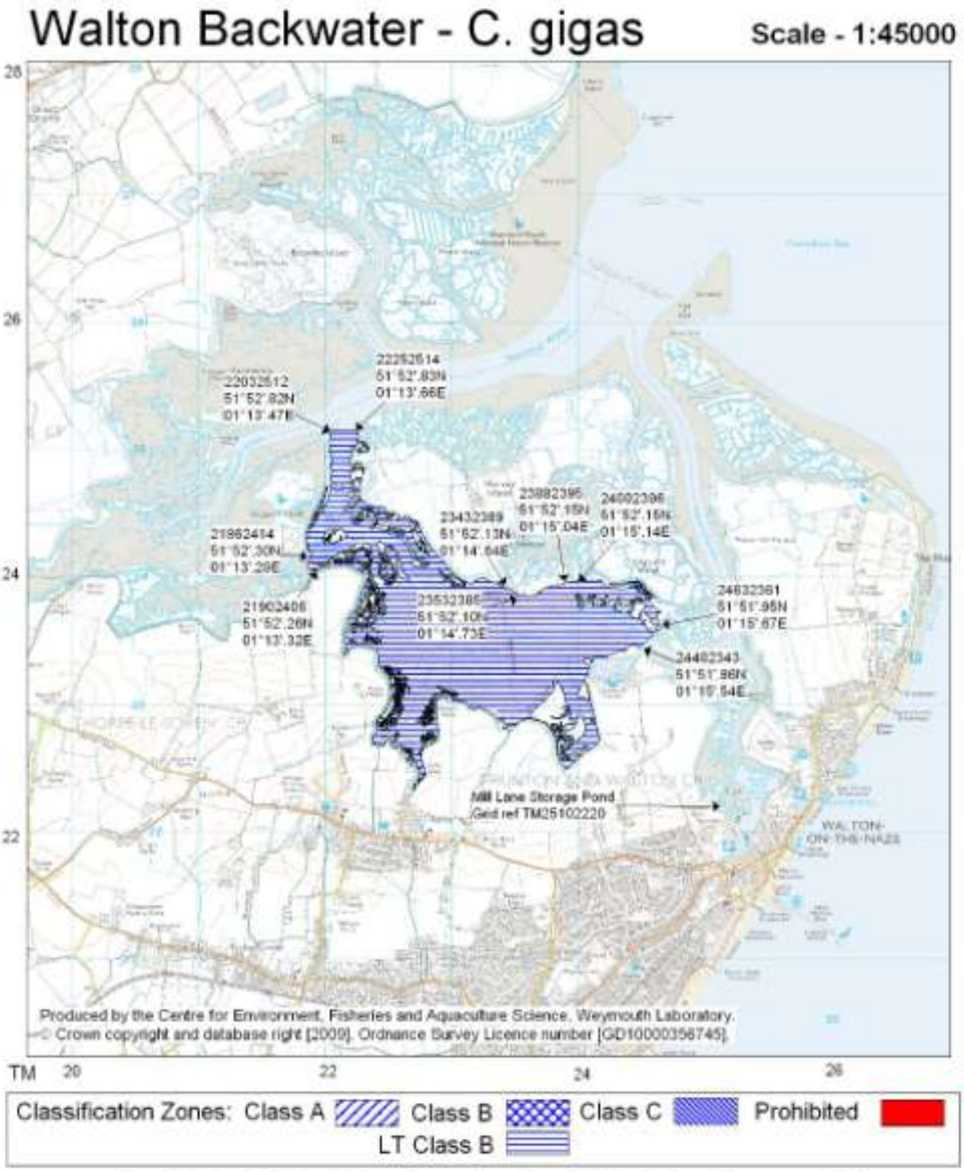
Table 1.3 summarises the post-harvest treatment required before bivalve molluscs can be sold for human consumption.

Table 1.3 Criteria for classification of bivalve mollusc production areas.

Class	Microbiological standard[1]	Post-harvest treatment required
A[2]	Live bivalve molluscs from these areas must not exceed 230 Most Probable Number (MPN) of *E. coli* $100g^{-1}$ Fluid and Intravalvular Liquid (FIL)	None
B[3]	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution MPN test of 4,600 *E. coli* $100g^{-1}$ FIL in more than 10% of samples. No sample may exceed an upper limit of 46,000 *E. coli* $100g^{-1}$ FIL	Purification, relaying or cooking by an approved method
C[4]	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution Most Probable Number (MPN) test of 46,000 *E. coli* $100g^{-1}$ FIL	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 zone boundaries are shown in Figures 2.5−2.6.



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

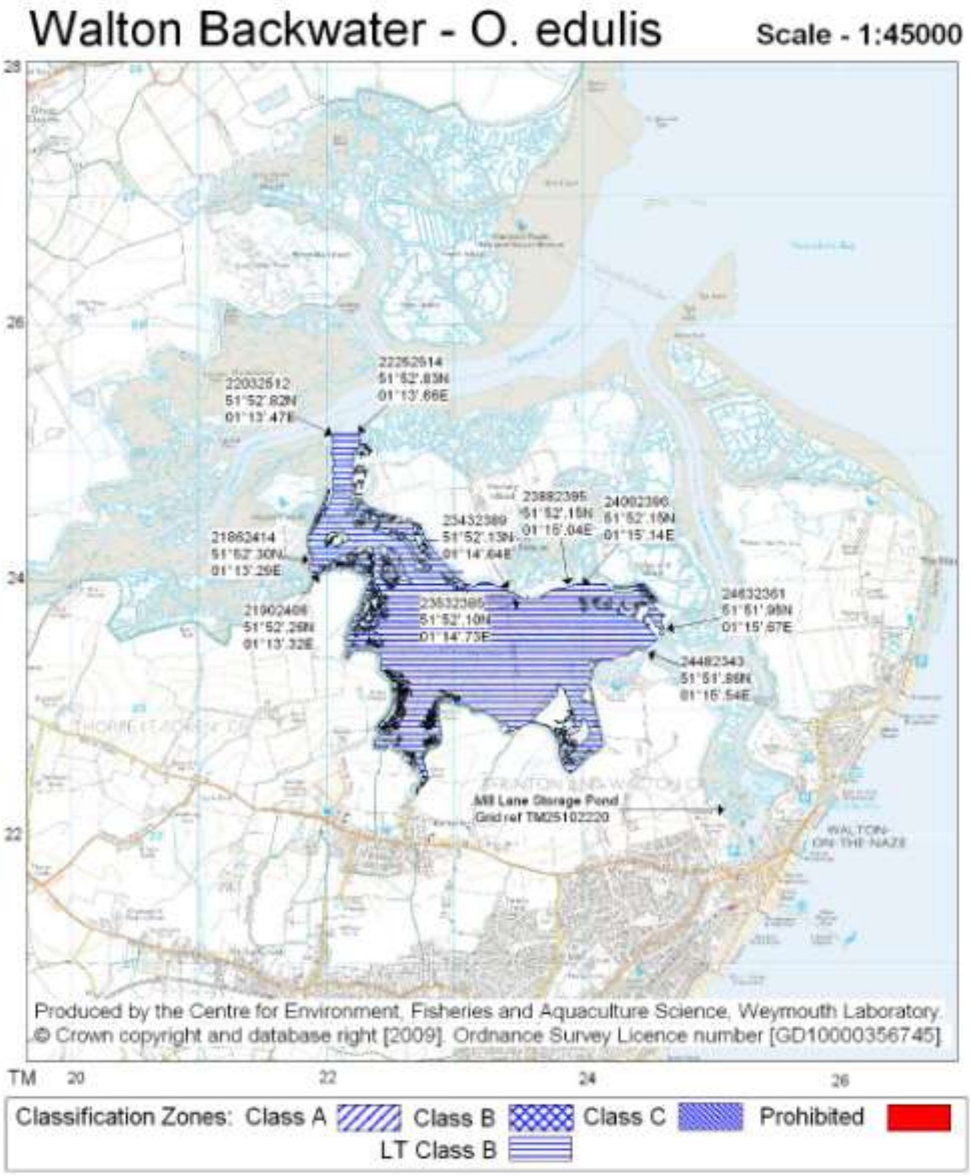
The areas delineated above are those classified as bivalve mollusc production areas under EU Regulation 854/2004.

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
Oysters at Twizzle, Kirby Creek and Mill Lane are seasonal LT Class B from 1 September to 31 March (unclassified at other times).
Separate map available for O. edulis at Walton Backwaters

Food Authority: Tendring District Council

Figure 2.5 Classification zones and current classification status for Pacific oysters in Walton Backwaters.



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
Oysters at Twizzle, Kirby Creek and Mill Lane are seasonal LT class B from 1 September to 31 March (unclassified at other times).
Separate map available for C. gigas at Walton Backwaters

Food Authority: Tendring District Council

Figure 2.6 Classification zones and current classification status for native oysters in Walton Backwaters.

3. OVERALL ASSESSMENT

AIM

This section presents an overall assessment of pollution sources on the microbiological contamination of bivalve mollusc beds in Walton Backwaters 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 the bivalve mollusc production area (BMPA) in this geographical area.

SHELLFISHERIES

The areas requiring an extension to year-round classification for native oysters (*O. edulis*) and Pacific oysters (*C. gigas*) include most of the intertidal and subtidal areas along the meandering Twizzle channel and Kirby Creek in Hamford Water, which have been classified on a seasonal basis in the past. The applicant (Naze Oysters Ltd) also requested year-round classification for Manila clams (*T. philippinarum*). This is a new species to be harvested in the same areas as the oyster beds.

These beds fall under the jurisdiction of Tendring District Council Local Enforcement Authority.

POLLUTION SOURCES

FRESHWATER INPUTS

The catchment (total area = 13,129 hectares) assessed for the purposes of this sanitary survey is drained by very small streams, no major rivers discharge to Hamford Water. Contamination of faecal origin from the catchment impacting on the water quality is therefore limited to that associated with localised freshwater inputs.

Bacteriological investigations undertaken by the Environment Agency (EA) in recent months indicate that Kirby Creek and Mill Lane creek receive high levels of faecal contamination (point and diffuse sources). It should be stressed that Kirby Quay is less than 1.2km from Kirby Creek bed and Mill Lane creek is 2.7km from the Twizzle bed.

AGRICULTURE

The catchment draining to Hamford Water is essentially rural and predominantly used for agricultural purposes. Defra considers that this catchment is at risk of diffuse water pollution from agricultural land. A significant proportion of the land is arable, although significant areas of natural and improved grassland supporting livestock grazing also occur in the southern catchment. Cattle grazing in fields at Coles Lane were observed during the shoreline survey. The farm is fenced but has direct hydrological connections to the tidal inlet. Sheep were also observed grazing saltmarsh areas in the western part of Horsey Island, less than 100m from the Kirby Creek bed.

Following rainfall events, water quality is likely to deteriorate in watercourses and receiving waters subject to runoff from livestock production, or runoff from land where ‘biosolids’ (manures/human sewage sludge) have recently been applied. However, the low lying topography and low freshwater inputs across the catchment indicate that this risk of contamination would be lower than that expected in catchments with steep sided topography and complex riverine network.

Preliminary results from microbial source tracking studies undertaken by the EA indicate that Hamford Water is impacted by mixed human/ruminant sources. In one sampling occasion, the *Bacteroidetes* ruminant marker was detected in water from both The Twizzle and Kirby Creek.

Human Population

Human resident population in the catchment (60,820 people) is considerably higher than the total number of cattle (approximately 1,550 animals) and sheep (1,850 animals) farmed in the catchment. Bivalve mollusc beds in the vicinity of the urbanised area of Frinton-on-Sea/Walton-on-the-Naze (resident population = 17,175 people) will be liable to impact from point source discharges and runoff from impermeable land.

Human population in the catchment fluctuates seasonally due to tourism. Hamford Water is an important centre for sailing and birdwatching. It is estimated that Walton-on-the-Naze receives over 140,000 visitors per year. Walton holiday accommodation offers over 900 static caravans.

Sewage Discharges

There are no major continuous sewage treatment works discharging directly into Hamford Water as effluents from Walton STW discharge into the sea.

Concentrations of *E. coli* in effluent discharges from Walton STW have been consistent with those given in the literature. Furthermore, no significant seasonal variations were found in the microbiological quality of effluent discharges from this source. However, there have been occasions when the quality of the effluent has deteriorated to concentrations characteristic of sewage receiving primary treatment.

Overall, the most significant water company sewage discharge to shellfisheries is Main Maltings PS. Pumping stations serving Little Oakley and Meadows Corner discharge to the north shore (approximately 3km from the shellfish beds) are considered less significant due to the higher dilution available. However, analysis of historical sewage spill events shows that Little Oakley has spilled for significantly longer periods and more frequently than Main Maltings PS.

BOATS

Titchmarsh Marina offers 490 floating pontoon berths and the Walton Yacht Basin in Foundry Basin operates moorings for 60–70 boats. Although shore-side toilet facilities are provided for berth holders, no pump-out facilities are available at Titchmarsh Marina for foul water holding tanks. This increases the risk of waste discharges from boats. Information gathered during the shoreline survey suggests that some people are staying overnight.

It has long been established that sewage discharged from boats could represent a significant public health risk for bivalve mollusc beds. However, the contribution of these sources is difficult to quantify due to the intermittent nature of these discharges. RMPs situated in areas where moorings are established will monitor potential contamination from these sources.

BIRDS

Hamford Water supports large communities of waterbirds. Low tide counts of 18 significant species of waterbirds in nine sectors show that Dugmore Creek holds the highest concentration of birds. Two of the most abundant species (Dunlin and Lapwing) prefer the inner areas of Hamford Water to the west and north of Landermere Creek.

As expected, a clear seasonal variation in the total number of waterbirds was identified with a significant increase from September to December.

Analysis of species specific mitochondrial DNA (mtDNA) in surface waters at three sites in Hamford Water to discriminate between human and avian sources of faecal contamination identified the marker at all sites. This indicates that birds constitute a potentially significant source of contamination to shellfisheries.

SUMMARY OF POLLUTION SOURCES

An overview of sources of pollution likely to affect the levels of microbiological contamination in Walton Backwaters is shown in Table 3.1 and Figure 3.1.

Table 3.1 Qualitative assessment of changes in pollution load in Walton Backwaters.

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

** Assessment based on the quality of UV-treated effluent discharges from Walton STW and therefore merely indicative of the load attributed to these sources.*

† Increased number of days on board.

Red - high risk; orange - moderate risk.

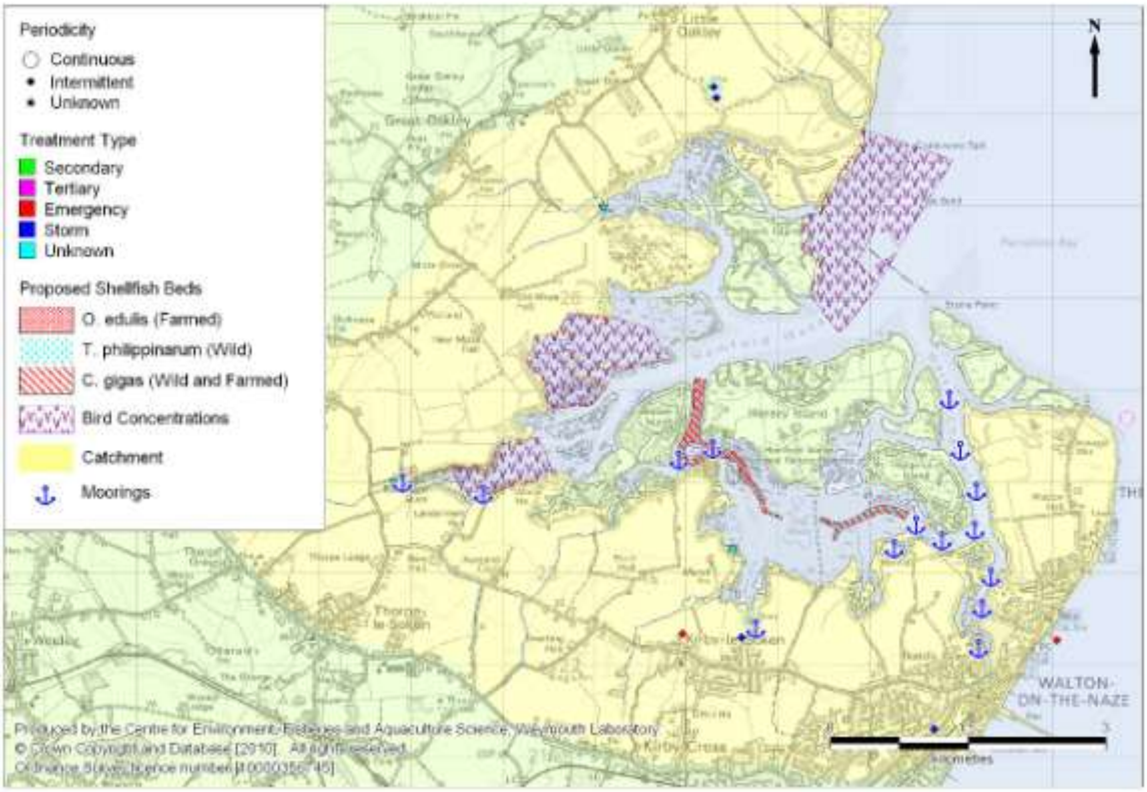


Figure 3.1 Significant sources of microbiological pollution to Walton Backwaters.

HYDRODYNAMICS

Hamford Water is shallow and significant parts dry completely at Low Water Springs. The inlet has a dendritic outline. There is a pool with 5.7m below Chart Datum (CD) in its deepest area just south of Pewit Island. Bivalve mollusc beds established at Kirby Creek are less than 2.2m depth relative to CD, whereas those beds at Twizzle Creek are 2.2m depth at Titchmarsh Marina.
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, RMPs situated in shallow areas are likely to demonstrate worst-case contamination levels, although these may not necessarily be representative.

Overall, Hamford Water is an ebb dominant, meso-tidal inlet. There is negligible moderation of the tide within the inlet. Therefore, for most of the time, water quality within the inlet will be determined by the effect of pollution sources situated in inner parts of Hamford Water. Furthermore, the short tidal excursion (approximately 6km) indicates that short distances are involved in the transport of microbial contaminants across the inlet.

Salinity-temperature measurements suggest that the body of water off Titchmarsh Marina is not homogeneous as there is a period of the tidal cycle characterised by low salinities. A significant fraction of contaminants may persist in the less flushed areas such as those at the south of Horsey Island and affect the microbial quality of bivalves.

SUMMARY OF EXISTING MICROBIOLOGICAL DATA

Analysis of historical data from the Bathing Waters (BW) monitoring programme (for beaches outside Hamford Water) indicates higher levels of faecal contamination in surface waters at Walton relative to those at Dovercourt. The microbial quality of waters at Walton showed occasional periods of deterioration suggesting some vulnerability to intermittent episodes of contamination in the outer Hamford Water but considering the ebb dominant nature of Hamford Waters the occurrence of pollution derived from seaward is thought to be minimal. However, all results in recent years have been below the Imperative value (2,000 CFU $100ml^{-1}$).

Levels of faecal coliforms from shellfish flesh monitored in the designated Shellfish Water have been equivalent to those required for class B shellfish. Faecal coliform data amalgamated by season show higher levels of contamination during the summer–autumn period than that during the winter–spring period, although these differences are less than $1Log_{10}$.

Results from microbial source tracking studies undertaken in freshwater inputs in the lower shores of Hamford Water indicate impact by mixed human/ruminant sources. This indicates that bivalve molluscs at Walton Backwaters are likely to be affected by the combined effect of faecal contamination from dairy washings and surface runoff from agricultural land and sewage discharges.

The presence of the species specific mtDNA marker to discriminate between human and avian sources of faecal contamination also indicated that birds constitute a potentially significant source of contamination to shellfisheries.

Analysis of historical data from the Shellfish Hygiene monitoring programme was constrained by the low number of *E. coli* results in recent years upon which an informed assessment can be made with a view of supporting the year-round classification of bivalve mollusc beds requested by Naze Oysters Ltd. The most significant conclusions drawn from the analysis are:

- The number of results above the class B threshold (MPN>4,600 *E. coli* $100g^{-1}$ FIL) in native oysters from the Twizzle and Kirby Creek beds represent 6% of the total number of samples from each sampling point. Most of these results were detected during the summer-autumn period.
- The highest result (MPN *E. coli* $100g^{-1}$ FIL = 350,000) was detected in Pacific oysters from Mill Lane on 31 May 1994.
- Three results above the limit of detection (MPN *E. coli* $100g^{-1}$ FIL > 18,000) were detected in native oysters from The Twizzle (21 October 1996; 12 September 2005) and Kirby Creek (12 September 2000).

- Descriptive statistics evidence a relationship in contaminating levels for native oysters as follows: Kirby Creek ≈ Twizzle > Mill Lane.

- Native oysters tend to show higher levels of *E. coli* contamination than Pacific oysters in beds where both species were commercially harvested and monitored over similar timescales[1].

- Higher levels of the microbiological indicator were detected in native oysters from Kirby Creek during the summer relative to those during the rest of the year. However, the difference between seasonal *E. coli* at this bed is less than $1Log_{10}$. Analysis of monthly geometric means indicates an increase in the levels of contamination at this site from May to September.

- The difference between levels of *E. coli* in native oysters from Mill Lane holding pond in the summer is $1Log_{10}$ higher than that in the autumn/winter.

Statistically significant positive correlations were obtained between rainfall and levels of *E. coli* in native oysters from Mill Lane when the rainfall event occurred one and five days before sampling and in Pacific oysters from Twizzle channel when the rainfall event occurred three days before sampling. This indicates significant impact of rainfall-dependent discharges and/or runoff from agricultural land on the microbial quality of bivalves at these beds.

4. RECOMMENDATIONS

4.1 It is recommended that the currently classified native oyster and Pacific oyster beds in Walton Backwaters main channel be represented by three classification zones (CZs), each with its own representative monitoring point (RMP).

4.2 It is recommended that the location of the RMP for the currently classified holding pond for native oysters at Mill Lane should maintained as this adequately reflects the impact of pollution sources.

4.3 The CZs in Walton Backwaters main channel will be defined by a line crossing the mouth of Kirby Creek at the confluence with Landermere Creek, a line crossing Kirby Creek at Stock's Marsh (TM 2256 2444)-south of Honey Island (TM 2236 2402), a line crossing The Wade along the Island Road and a line crossing The Twizzle at western side of Titchmarsh Marina entrance (TM 2448 2343)-south shores of Hedge-end Island (TM 2463 2361). The edges of these CZs on land will be defined by the Mean High Water Line Mark.

4.4 An RMP situated at the main channel of Kirby Creek at Landing Place (TM 2214 2478) for three species (native oysters, Pacific oysters and Manila clams)

[1] Inter-species comparisons of *E. coli* contamination in bivalves from other harvesting areas in England and Wales undertaken by Cefas also evidenced this relationship when *E. coli* levels are high.

will be representative of contamination from point and diffuse sources delivered to Kirby Creek, Landermere Creek and to the main channel of Hamford Water.

4.5 An RMP situated at the eastern edge of the bed at The Wade (TM23022361) for three species (native oysters, Pacific oysters and Manila clams) will be representative of contamination from point and diffuse sources delivered to Kirby Quay Creek from Kirby-le-Soken area.

4.6 An RMP situated at the eastern edge of The Twizzle bed (TM24272367) for three species (native oysters, Pacific oysters and Manila clams) will be representative of contamination from point and diffuse sources delivered to the Twizzle Creek via Walton Channel and Sole Creek at Walton-on-the-Naze.

4.7 This represents an increase in the total number of RMPs in Walton Backwaters production area from four to ten and is justified by the presence of sources of pollution each impacting on different areas within Hamford Water and the existence of a new species requiring classification. Cefas will review the monitoring regime once sufficient number of results is obtained to inform the year-round classification for the three species requested by Naze Oysters Ltd.

4.8 Unless the ongoing sanitary survey assessment identifies otherwise, the results of the bacteriological survey will form part of the preliminary monitoring towards classification for these beds. Cefas intends to review the classification status once results from monitoring over this period are available alongside the overall assessment from the sanitary survey.

5. SAMPLING PLAN

General Information

Location Reference

Production Area	Walton Backwaters
Cefas Main Site Reference	M011
Cefas Area Reference	FDR 4192
Ordnance survey 1:25,000 map	OS Explorer 184 Colchester: Harwich and Clacton-on-Sea
Admiralty Chart	Admiralty 1408: Harwich and Rotterdam to Cromer Imray C28: Harwich to Wells-Next-the-Sea

Shellfishery

Species/culture	Manila Clams (*Tapes philippinarum*) Native Oysters (*Ostrea edulis*)	Wild Farmed
	Pacific oysters (*Crassostrea gigas*)	Farmed and Wild
Seasonality of harvest	Manila Clams (year round) Native Oysters (year round) Pacific Oysters (year round)	

Local Enforcement Authority

Name	Tendring District Council Environmental Services, Food & Safety Team, Council Offices, Thorpe Road, Weeley, Clacton-on-Sea Essex CO16 9AJ
Environmental Health Officer	Edward King
Telephone number ☎	01255 686752
Fax number	01255 686404
E-mail	edking@tendringdc.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 Walton Backwaters production area.

Classification zone	Kirby Creek	Kirby Creek	Kirby Creek	The Wade	The Wade	The Wade	Twizzle	Twizzle	Twizzle	Mill Lane
RMP	**B011G**	**B011R**	**B011T**	**B011U**	**B011V**	**B011S**	**B011F**	**B011W**	**B011Q**	**B011E**
RMP name	**Kirby Creek**	**Kirby Creek**	**Kirby Creek**	**The Wade**	**The Wade**	**The Wade**	**Twizzle**	**Twizzle**	**Twizzle**	**Mill Lane**
Geographic grid references (datum) of sampling points – **Easting** / **Northing**	622140 224780	622140 224780	622140 224780	623020 223610	623020 223610	623020 223610	624270 223670	624270 223670	624270 223670	625120 222310
NGR	TM 2214 2478	TM 2214 2478	TM 2214 2478	TM 2302 2361	TM 2302 2361	TM 2302 2361	TM 2427 2367	TM 2427 2367	TM 2427 2367	TM 2512 2231
WGS84 – **Latitude** / **Longitude**	51°52.’64N 01°13.’55E	51°52.’64N 01°13.’55E	51°52.’64N 01°13.’55E	51°51.’99N 01°14.’63E	51°51.’99N 01°14.’63E	51°51.’99N 01°14.’63E	51°51.’99N 01°15.’36E	51°51.’99N 01°15.’36E	51°51.’99N 01°15.’36E	51°51.’24N 01°16’.05E
Species	*O. edulis*	*C. gigas*	*T. philippinarum*	*O. edulis*	*T. philippinarum*	*C. gigas*	*O. edulis*	*T. philippinarum*	*C. gigas*	*O. edulis*
Growing method	Riverbed cultivation	Riverbed cultivation	Riverbed cultivation	Riverbed cultivation	Riverbed cultivation	Riverbed cultivation	Riverbed cultivation	Riverbed cultivation	Riverbed cultivation	Bags on trestles
Harvesting technique	Dredging	Dredging	Dredging	Dredging	Dredging	Dredging	Dredging	Dredging	Dredging	Hand-picked from bags
Sampling method	Dredging	Dredging	Dredging	Dredging	Dredging	Dredging	Dredging	Dredging	Dredging	Hand-picked from bags
Depth (m)	Riverbed	Riverbed	Riverbed	Riverbed	Riverbed	Riverbed	Riverbed	Riverbed	Riverbed	Depth of bags
Tolerance for sampling points (m)	50	50	50	50	50	50	50	50	50	10
Frequency of sampling (FULL Classification)	At least monthly*	At least monthly*	Preliminary classification: 10 samples taken over, at least, 3 months (interval between sampling not less than 1 week)*	At least monthly*	Preliminary classification: 10 samples taken over, at least, 3 months (interval between sampling not less than 1 week)*	At least monthly*	At least monthly*	Preliminary classification: 10 samples taken over, at least, 3 months (interval between sampling not less than 1 week)*	At least monthly*	At least monthly

NB. * The results of the bacteriological survey will count towards year-round classification of these beds.

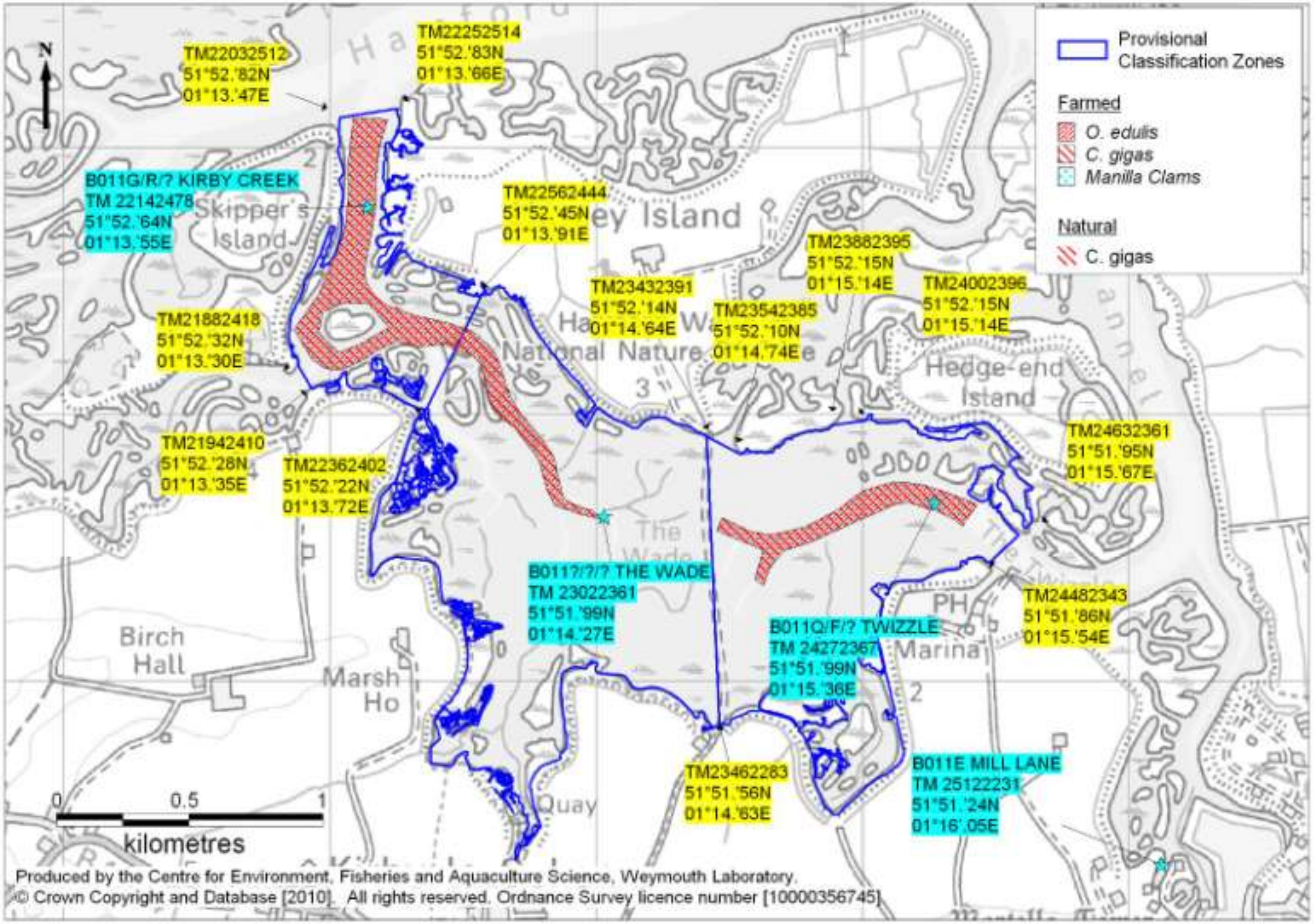


Figure 5.1 Classification zone boundaries for native oysters, Pacific oysters and Manila clams in Walton Backwaters.

APPENDICES

APPENDIX I
HUMAN POPULATION

The distribution of resident human population by Super Output Area Boundary[2] totally or partially included within the river catchment is shown in Figure I.1. Total resident human population in the catchment is 60,820 (Office for National Statistics, 2007; mid-2005 estimates). There are two areas of high population density in the catchment: Frinton-on-Sea/Walton-on-the-Naze and Harwich. Approximately 2.5km south of the bivalve mollusc beds are also Kirby Cross, Thorpe-le-Soken, Great Oakley and Kirby Le Soken. The urban areas of Frinton-on-Sea and Walton-on-the-Naze have a combined population of 17,175 (Office for National Statistics, 2008; mid-2006 estimates based on 2001 Census data).

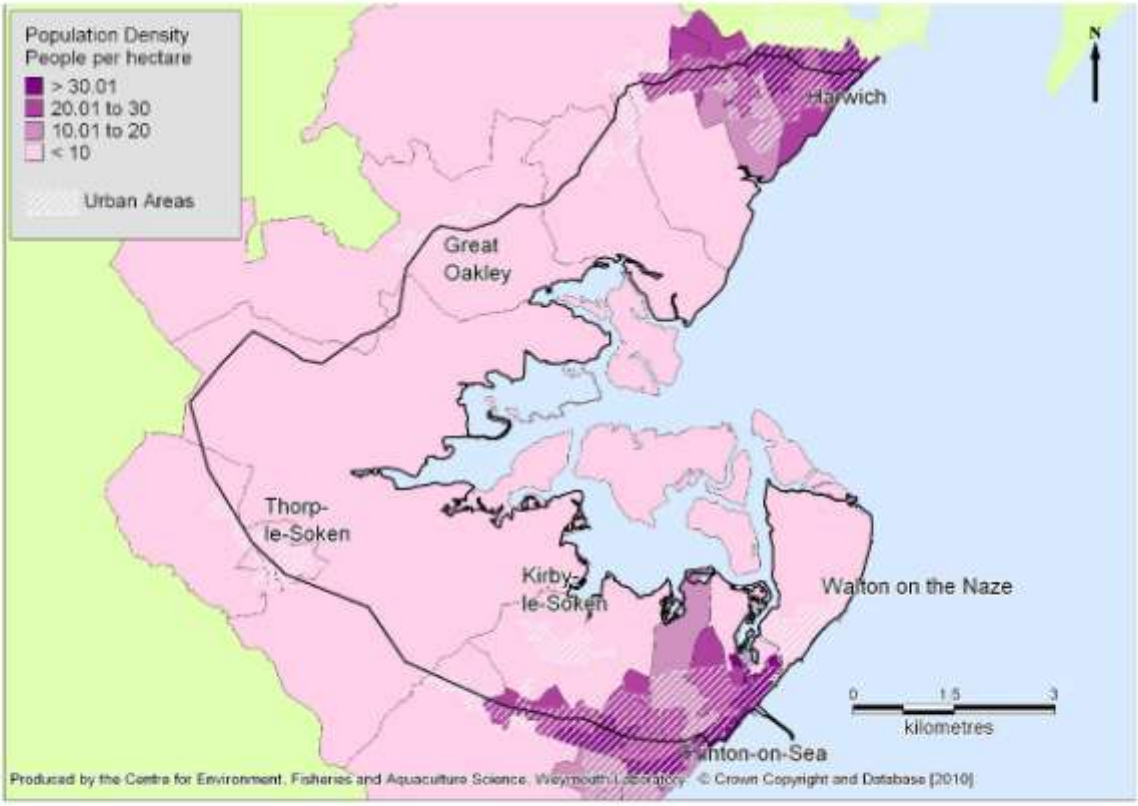


Figure I.1 Human population density in the Walton river catchment.
Source: ONS, Super Output Area Boundaries. Crown copyright 2004. Crown copyright material is reproduced with the permission of the Controller of HMSO.

Harwich is important for its ferry terminals and freight-only ports, with road and rail links to the midlands, London, and South-East (Harwich International Port Ltd, 2005). Approximately 1 million passengers travel through Harwich port every year on ferries from Denmark and the Netherlands (Harwich International Port Ltd, 2005).

[2] 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.

Human population in the catchment fluctuates seasonally due to tourism. Tourism is one of the largest industries in Essex, with 36 million day visitors, 3.1 million overnight visits, and 549,000 overnight overseas visits in 2007 (Essex County Council, 2010). Walton has a range of tourist attractions, including wildlife boat trips to see seals and seabirds at Walton Backwaters, Walton Maritime Museum and wildlife walks.

The Naze is a peninsula situated north of Walton-on-the-Naze, and is popular for visitors for its educational and recreational value. It is a Site of Special Scientific Interest (SSSI) for its 55 million year-old fossil cliffs which holds pyritised wood, sharks teeth and shells (Naze Tower, 2010). The Naze Tower is also popular for tourists, which is a unique 18th Century navigational tower listed as a grade 2* heritage site. The Naze is also popular for its wildlife, walks, and beach and sees an estimated 140,000 visitors a year (Naze Protection Society, 2010). Educational visits by schools, universities and specialist groups are estimated at over 20,000 students per year (Naze Protection Society, 2010).

The Naze Marine Holiday Park is situated on the eastern bank of the Walton channel and has 550 static caravans. To the east, Willows Caravan Park has approximately 100 static caravans, and to the west, Martello Caravan Park has approximately 250 static caravans for sale and hire.

Urbanised areas contain the majority of point-sources of pollution (continuous and intermittent sewage discharges) in these catchments. Urbanised areas also contain the majority of impervious surfaces[3] (e.g. roads, parks, pavements), which are known to contribute with significant loads of microbiological contaminants (Ellis and Mitchell, 2006)[4]. Bivalve molluscs commercially harvested in the vicinity of urbanised areas tend to show deteriorated microbiological quality.

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

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

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

APPENDIX II
HYDROMETRIC DATA: RAINFALL

Rainfall variation across England and Wales tends to be associated with Atlantic depressions or with convection, atmospheric humidity and altitude (Met Office, 2007). The driest parts of eastern England experience around 500mm of total rainfall per annum (Met Office, 2007). This compares with an average annual rainfall for England and Wales of approximately 1,250mm (Perry, 2006).

Figure II.1 shows monthly averaged and monthly total rainfall monitored daily in a telemetric gauge operated by the Environment Agency at Great Oakley (Easting/Northing: 621050/227150) (representative of the lower catchment) for the period January 2000–April 2010.

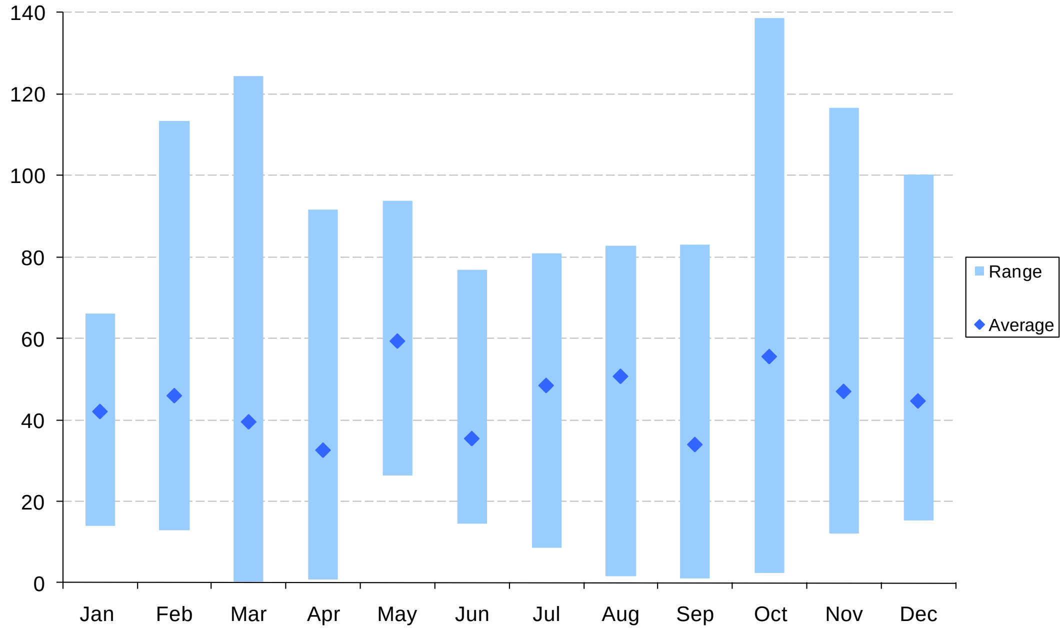


Figure II.2 Monthly variation of rainfall recorded at Great Oakley gauging station for the period January 2000–April 2010.
Data from the Environment Agency.

Average rainfall levels above 100mm occurred during the period October–December and February–March (overall wettest period). The driest period was June–September. The number of days with rainfall totals ≥1mm tends to follow a similar seasonal pattern (Met Office, 2007).

Rainfall may lead to the discharge of raw or partially treated sewage from combined sewer overflows (CSO) and other intermittent discharges as well as runoff from faecally contaminated land (Younger *et al.*, 2003). Representative monitoring points located in parts of shellfish beds closest to discharges and freshwater inputs will reflect the combined effect of rainfall on the contribution of individual pollution sources.

Results from analyses of the relationships between the levels of *E. coli* in bivalve molluscs commercially harvested in Walton Backwaters and rainfall levels are given in the Appendix XII.

APPENDIX III
HYDROMETRIC DATA: FRESHWATER INPUTS

There are no major rivers discharging to Hamford Water, only small streams at Kirby-le-Soken and Baumont at Quay Farm (south shores) and Great Oakley (Figure III.1). These represent the only freshwater inputs in the vicinity of bivalve mollusc beds.

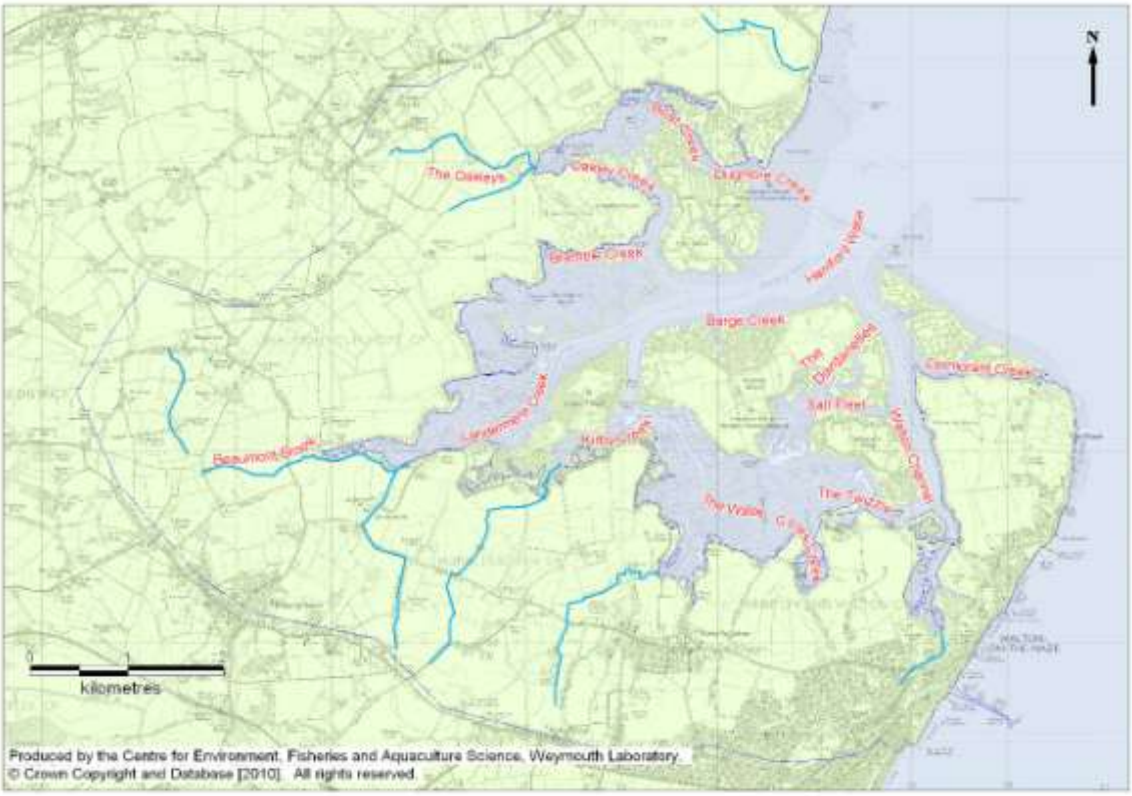


Figure III.1 Freshwater inputs to Hamford Water.

APPENDIX IV
HYDROGRAPHIC DATA: BATHYMETRY

Hamford Water is a shallow tidal inlet lying approximately with about 4km south of Harwich. Most of it dries completely at Low Water Springs. The entrance is about 1.3km wide. From the entrance, one main channel divides into various secondary channels with a dendritic outline north of Horsey Island. There is a deep pool with 5.7m below Chart Datum (CD) in its deepest area just south of Pewit Island. One of these secondary channels is Kirby Creek, which limits the western Horsey Island, where bivalve mollusc beds are established. This creek is 2.2m deep at the entrance between Horsey Island and Skipper's Island.

A secondary channel (Walton Channel) extends from the entrance to Hamford Water along the eastern and southern edges of Horsey Island. Soundings decrease substantially from the entrance (6.3m below CD) to chart datum levels at Foundry Reach. From this point, Walton Channel becomes Twizzle Creek to the south of Hedge End Island where bivalve mollusc beds are established. The deepest area of Twizzle Creek in this stretch is 2.2m below CD at Titchmarsh Marina.

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

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

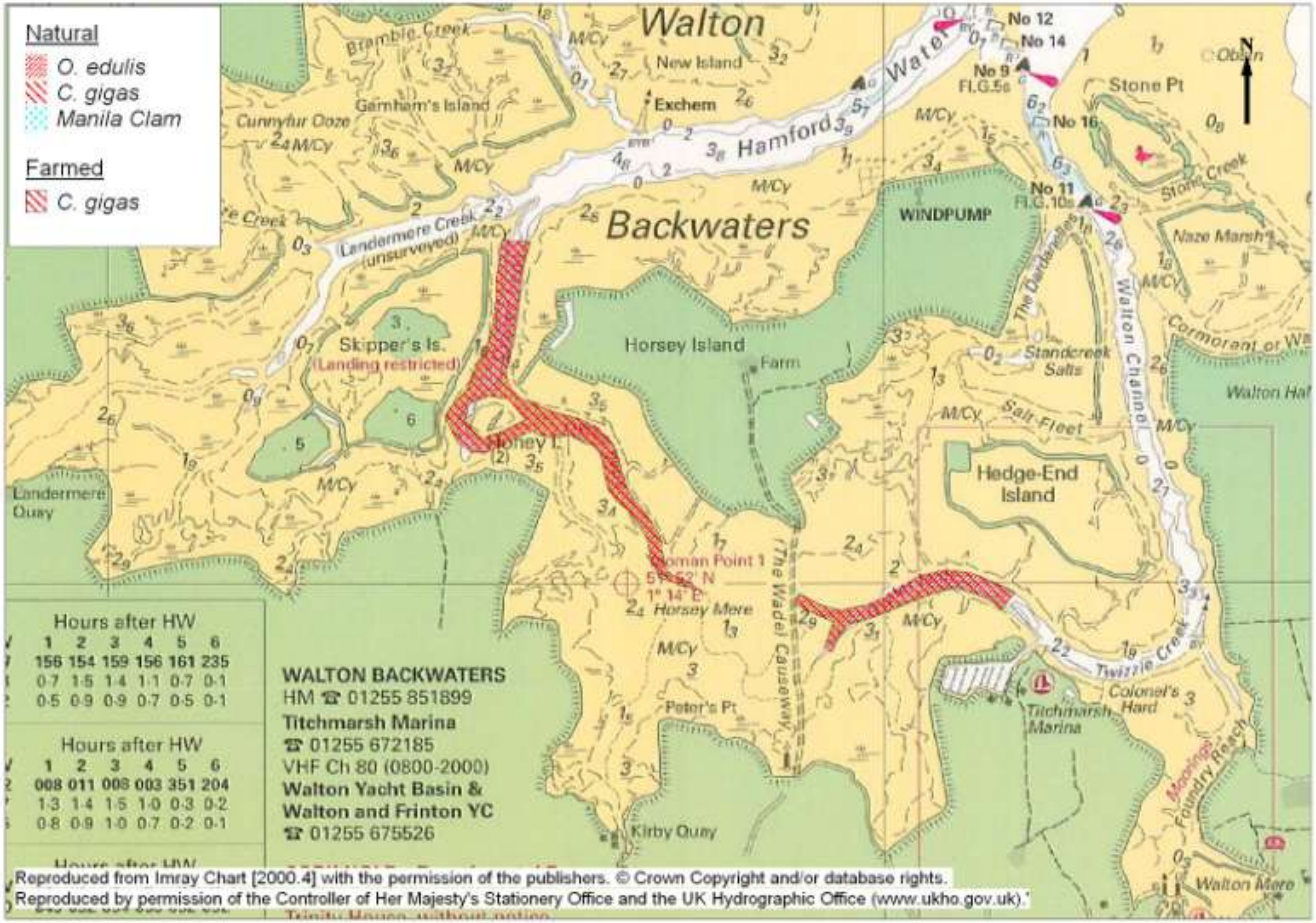


Figure IV.1 Bathymetry in Hamford Water showing location of classified bivalve mollusc beds.
Reproduced from Imray Chart 2000.4 with the permission of the publishers.

APPENDIX V
HYDRODYNAMIC DATA: TIDES AND CURRENTS

Hamford Water has a meso-tidal regime with semi-diurnal tides (i.e. two tidal cycles per day) at the entrance of the estuary (Table V.1).

Table V.1 Tide levels and ranges at Hamford Water.

Port	Height (m) above Chart Datum				Range (m)	
	MHWS	MHWN	MLWN	MLWS	Springs	Neaps
Walton	4.2	3.4	1.1	0.4	3.8	2.3
Bramble Creek	4.5	3.7	1.4	0.7	3.8	2.3

Data from Imray Laurie Norie & Wilson Ltd. (2006).

The tidal range at the entrance to Walton Backwaters is similar to that at Harwich and there is negligible moderation of the tide within the inlet (Guthrie and Cottle, 2002).

Tidal excursion (mouth to the limit of reversing tidal currents) between the entrance and Beaumont is estimated to be approximately 6km. Microbial contaminants may be transported over these distances with the tidal wave along the tidal inlet.

At the moment, Hamford Water is thought to be a source of fine sediment (Halcrow Group Ltd, 2003). The movement of suspended sediment in Hamford Water is due to tidal movements (Mouchel, 1997). Concentrations of approximately 100mg l^{-1} on spring tides and 20mg l^{-1} on neap tides were recorded in Hamford Water in 2003 (Posford Haskoning and HR Wallingford, 2003 *in* Royal Haskoning, 2003). Monitoring of tidal currents just outside the tidal inlet indicated that tidal streams there reach 0.9m s^{-1} on spring tides (HR Wallingford, 1998 *in* Royal Haskoning, 2003). Suspended material is advected in and out of Hamford Water by tidal currents with some deposition occurring and any material remaining in suspension eventually being carried offshore (Royal Haskoning, 2003).

Overall, the tidal inlet is considered to be well-mixed and ebb dominant (Halcrow Group Ltd, 2003), i.e. the ebb tide is longer and slower than the flood tide. Ebb dominance means that contamination from pollution sources at upstream areas of Hamford Water may be particularly relevant to the overall water quality of bivalve mollusc beds in Walton Backwaters.

Tidal flushing will exert a significant influence in flushing the estuary. A significant fraction of contaminants may persist in the less flushed areas such as those at the south of Horsey Island and influence the microbial quality of bivalves.

The minor variations in salinity ranges shown in Table V.2 indicate that the inner areas of Hamford Water receive fully saline waters suggesting that overall the tidal inlet is well flushed.

Table V.2 Surface water temperature, salinity, suspended solids and turbidity in Hamford Water.

Site	Minimum–maximum (n)			
	Temperature (°C)	Salinity (ppt)	Suspended solids (dried at 105°C; mg l^{-1})	Turbidity (NTU)
The Twizzle (off Titchmarsh Marina)	0.74–20.57 (13)	29.94–34.52 (13)	6.9–10.6 (4)	-
The Wade (SW of Hedge-end Island)	-	29.843–34.48 (14)	-	-
Kirby Creek (E of Skipper's Island)	-	29.329–34.44 (14)	-	-
Walton Channel (Walton Yacht Club)	1.12–21.08 (15)	-	-	3–17.9 (15)

Data supplied by the Environment Agency.
n - number of samples.
NTU - nephelometric turbidity units.

The salinity-temperature diagram shown in Figure V.1 suggests that the body of water off Titchmarsh Marina is not homogeneous as there is a period of the tidal cycle characterised by high temperatures and low salinities. This is likely to affect the filtration activity and uptake of contaminants by bivalves.

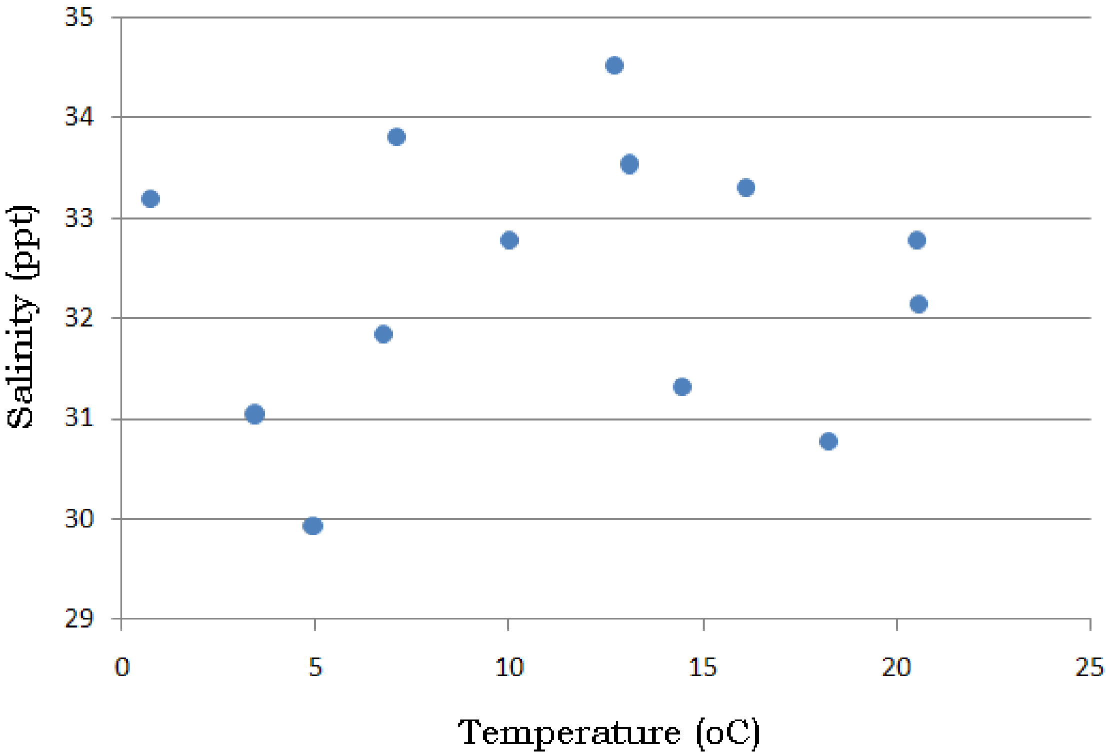


Figure V.1 Temperature-salinity diagram for surface waters in the Twizzle channel off Titchmarsh Marina.

APPENDIX VI
METEOROLOGICAL DATA: WIND

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

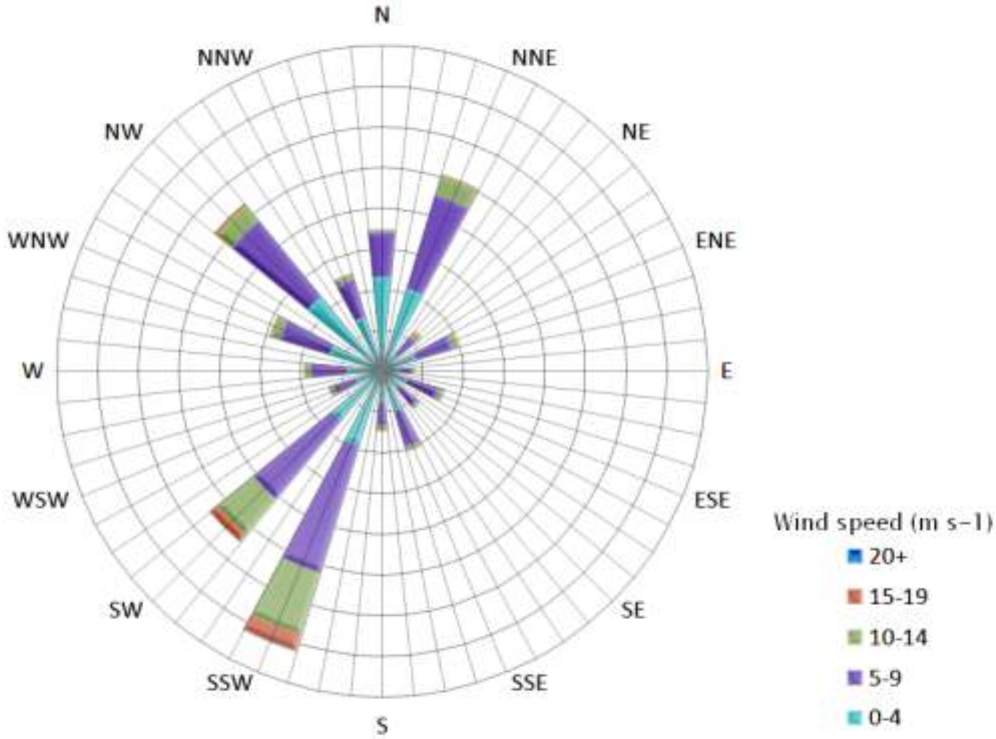


Figure VI.1 Wind speed and direction at Ipswich for the period January 2005–May 2010.
Data supplied by Garrath Bond.

Given the relatively sheltered location of Walton Backwaters, wind driven currents are not expected to significantly influence water movements and hence circulation of contaminants within the estuary. However, strong wind conditions are expected to impinge effluent plumes upon the shore in the broader and shallower areas of the estuary.

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 Hamford Water are treated in a number of sewage treatment works (STWs).

Sewage effluents in the catchment draining to Hamford Water are treated in Walton sewage treatment works (STW) (tertiary treatment; reedbed), which is associated with the urbanised areas of Walton-next-the-Sea and Great/Little Oakley and does not discharge directly to West Kirby creek or The Twizzle.

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 is Main Maltings PS. Kirby-Le-Soken SPS is listed in the Environment Agency Pollution Reduction Plan has having a significant or potentially significant impact on the designated Shellfish Water (Environment Agency, 2009). However, this pumping station does not have a permitted discharge and should not discharge to the creek under either storm or emergency conditions. There have been pollution incidents associated with the Kirby sewerage system and Kirby-Le-Soken SPS. The EA has undertaken investigations to determine potential sources of pollution in the area.

Figure VII.1 shows the locations of continuous and intermittent sewage discharges likely to be a source of microbiological contamination to bivalve mollusc beds. Further details are summarised in Table VII.1.

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

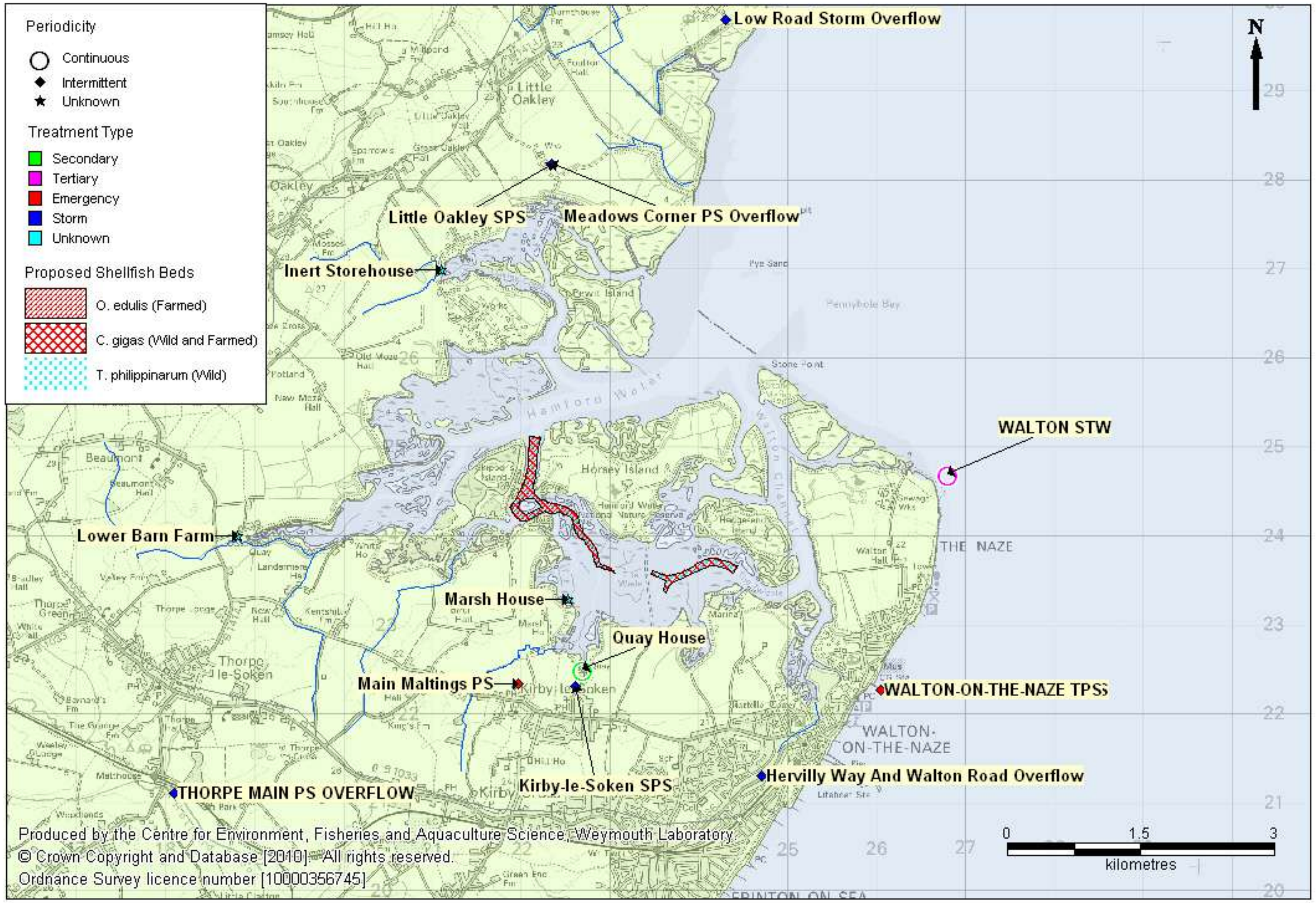


Figure VII.1 Significant sewage discharges to Hamford Water.

For details on discharges, refer to Tables VII.1–VII.2.

N.B. There have been pollution incidents associated with Kirby-Le-Soken SPS. This pumping station does not have a permitted discharge.

Table VII.1 Significant continuous sewage discharges to Hamford Water.

Discharge name	Treatment	DWF ($m^3\ d^{-1}$)	Population equivalent (annual)	Approximate (fluvial) distance to nearest edge of the nearest BMPA (km)	NGR of outfall
Walton STW*	Tertiary (reedbed)	6,364	26,600	4.2	TM 2680 2470
Quay House*	Secondary	1	n/a	1.2	TM 2269 2250

DWF - dry weather flow.
STW - sewage treatment works.
[1] Maximum volume.
** not listed on the EA Pollution Reduction Plan.*

Table VII.2 Significant intermittent sewage discharges to Hamford Water.

Discharge name	Type	Approximate (fluvial) distance to nearest edge of the nearest BMPA (km)	NGR of outfall
Main Maltings PS*	EO/SSO	2.0	TM 2196 2234
Little Oakley SPS*	SSO	3.3	TM 2233 2818
Walton-on-the-Naze TPS*	EO/SSO	7.6	TM 2604 2227
Kirby-le-Soken SPS	EO/SSO	1.4	TM 2260 2230
Thorpe Main PS Overflow*	SSO	5.6	TM 1808 2110
Hervilly Way/Walton Road Overflow*	SSO	3.6	TM 2470 2130
Meadows Corner PS Overflow*	SSO	3.2	TM 2233 2818
Low Road Storm Overflow*	SSO	6.0	TM 2430 2980

EO - emergency overflow.
PS - pumping station.
SPS- sewage pumping station.
SSO - sewage storm overflow.
STW - sewage treatment works.
** not listed on the EA Pollution Reduction Plan.*

The geometric means of levels of *E. coli* in effluent discharges post reedbed from Walton STW shown in Table VII.4 are consistent with reference values given in the literature (Kay *et al.*, 2008). There were however occasions when the quality of the effluent had deteriorated to concentrations characteristic of sewage receiving primary treatment.

Table VII.4 Summary statistics of levels of **E. coli** ***in effluent discharges from Walton STW for the period April 2004–September 2005.***

Year	n	Minimum	Maximum	Median	Geometric mean
2004	18	4×10^2	2×10^6	3.2×10^4	3.8×10^4
2005	24	6×10^3	2.6×10^6	3×10^4	3.3×10^4
2004–2005	42	4×10^2	2.6×10^6	3×10^4	3.5×10^4

Data from the Environment Agency.

Side-by-side box-and-whisker plots of levels of *E. coli* grouped by season indicate a fairly constant seasonal variation in the microbiological quality of effluent discharges from Walton STW (Figure VII.2).

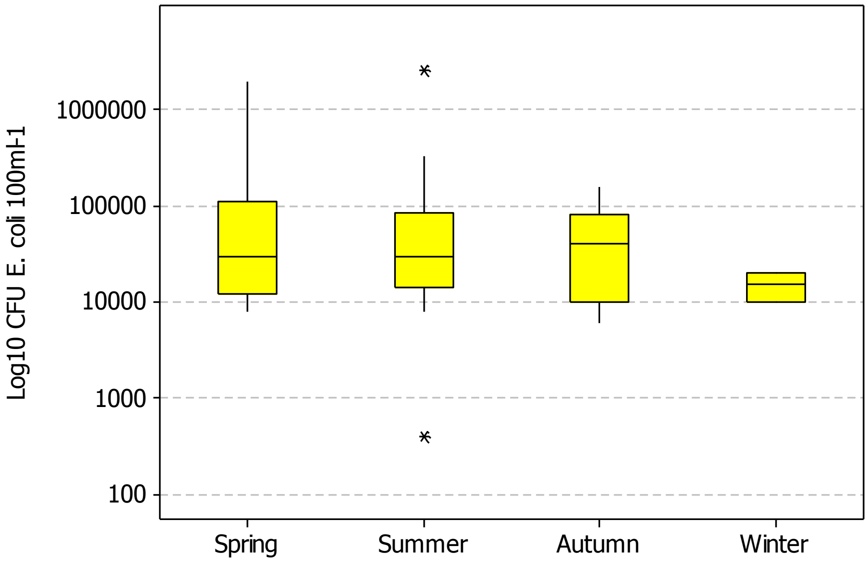


Figure VII.2 Seasonal levels of **E. coli** ***in effluent discharges from Walton STW for the period April 2004–September 2005.***

Table VII.4 indicates that Walton-on-the-Naze TPS has contributed with a high number of sewage spill events. In terms of duration, Little Oakley has spilled significantly longer than Walton-on-the-Naze TP and Main Maltings PS.

No spill events have been recorded during the period May–July. Figure VII.3 shows a series of spill events from the three intermittent discharges listed above that are monitored by Anglian Water. The graph evidences that in general spill events have occurred simultaneously.

Table VII.4 Sewage spill events and spill duration from three significant intermittent discharges for the period January 2009–April 2010.

Month	Date	Little Oakley	Walton-on-the-Naze TPS	Main Maltings PS
January	20/01/2009	4.6	1.49	6.6
	24/01/2009	-	2.55	-
	30/01/2009	-	-	0.01
February	07/02/2009	2.42	-	-
	10/02/2009	4.76	4.64	3.39
	11/02/2009	24	11.87	24
	12/02/2009	24	-	22.23
	13/02/2009	1.25	-	-
	27/02/2009	0.21	-	-
	28/02/2009	2.24	-	-
March	05/03/2009	-	0.27	
	27/03/2009	3.94	-	-
April	08/06/2009	-	0.23	-
	16/06/2009	-	3.02	-
	17/06/2009	-	0.02	-
August	27/08/2009	0.06	-	-
September	16/09/2009	-	0.59	-
October	22/10/2009	-	1.19	-
November	02/11/2009	-	0.78	-
	14/11/2009	-	3.24	-
	29/11/2009	-	0.38	-
	30/11/2009	-	0.54	-
December	03/12/2009	3.95	4.66	-
	04/12/2009	-	1.39	2.17
	11/12/2009	0.06	-	-
January	15/01/2010	-	0.53	-
	16/01/2010	1.71	-	-
February	23/02/2010	-	2.1	-
	26/02/2010	-	1.24	-
	27/02/2010	-	0.06	-
March	01/03/2010	7.28	7.53	9.87
	02/03/2010	-	-	3.65
	11/03/2010	4.44	-	-
	30/03/2010	-	0.44	-
Total No. of spill events		15	22	8

N.B. One spill event from Little Oakley on 14 June 2009 was excluded from the dataset due to data quality reasons.

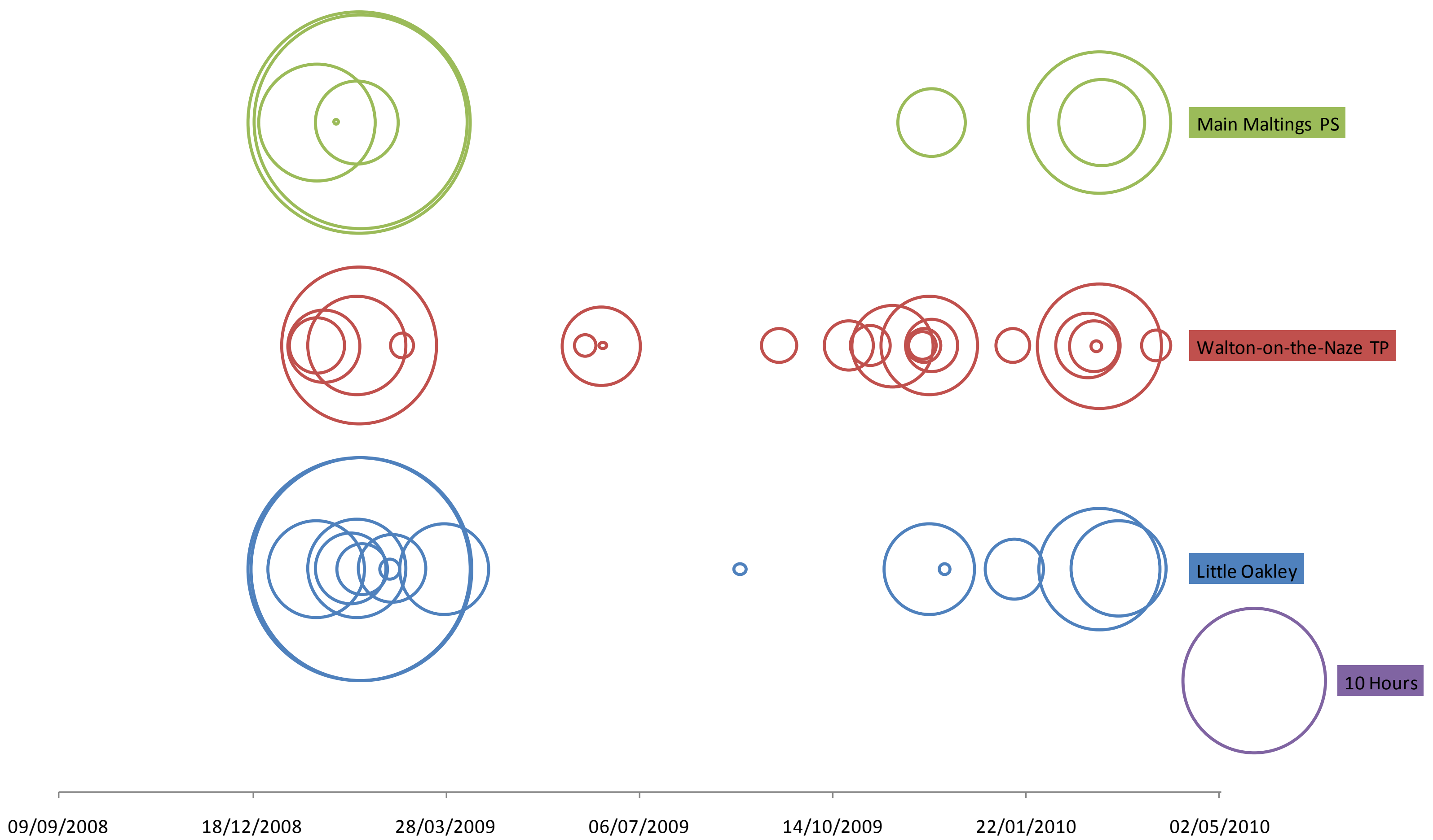


Figure VII.3 Time series of sewage spill events from three intermittent discharges to Hamford Water.
N.B. Bubble area is proportional to spill duration. See violet bubble for reference.

There are four pollution incidents involving sewage or contaminated water recorded in the Environment Agency's National Incident Recording System (NIRS) both representing a significant effect on water quality in Hamford Water (Table IX.3).

No sampling for the Shellfish Hygiene monitoring programme was undertaken immediately after the reported date and therefore no association could be established between these incidents and *E. coli* results in shellfish.

Table VIII.3 Serious water pollution incidents in the Walton catchment for the period 2003–2009.

Grid reference	Reported date	Cause	Premises type	Pollutant	Water impact level
n/a	28/08/2003	Sewer failure or overflow	Nursing and residential homes	Crude sewage	Category 3 (Minor)
TM 21962 22340	06/11/2005	Sewer failure or overflow	Pumping station	Grey water	Category 2 (Significant)
n/a	05/07/2006	Unauthorised discharge or disposal		Other contaminated water	Category 3 (minor)
n/a	03/12/2009	Other authorised activity	Pumping station	Storm sewage	Category 3 (minor)

Data from the Environment Agency.
n/a - not available.
NB. Pollution incidents within 3km from Hamford Water.

APPENDIX VIII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: AGRICULTURE

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 catchment draining to Hamford Water is considered to be at risk of diffuse pollution from agricultural land (Environment Agency, 2009). The Environment Agency has proposed an action plan to tackle diffuse water pollution targeting livestock management and land drainage practices and modifications of farm structures and storage facilities (Environment Agency, 2009).

The catchment contains over 16,600 farmed animals. Cattle and sheep represent 9.4% and 11.1% of the total number, respectively.

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

Catchment	Cattle	Pigs	Sheep	Poultry	Other livestock
Holland and Hamford	1,554	1,821	1,850	11,091	288

Data from June 2009 Agricultural Survey supplied by Defra, Farming Statistics.

The concentration of faecal coliforms excreted in the faeces of humans and farm animals and corresponding excretion rates are summarised in Table IX.1.

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

Farm animal	Faecal coliforms (No. g^{-1} wet weight)	Excretion rate (g day^{-1} wet weight)
Human	13,000,000	150
Pig	3,300,000	2,700
Cow	230,000	23,600
Sheep	16,000,000	1,130

Data from Geldreich (1978).

There is a company based at Horsey Island specialised in horse breeding.

The Environment Agency has undertaken microbial source tracking investigations in three sites across the catchment (Figure VIII.1). Results from one of the sampling occasions were indicative of faecal inputs from ruminant sources impacting water quality at Kirby Creek and the Twizzle (Table IX.2). However, overall the results indicate that water at Walton Backwaters would be impacted by mixed human/ruminant sources. It should be stressed that only 6 samples had been analysed at the time of writing this report.

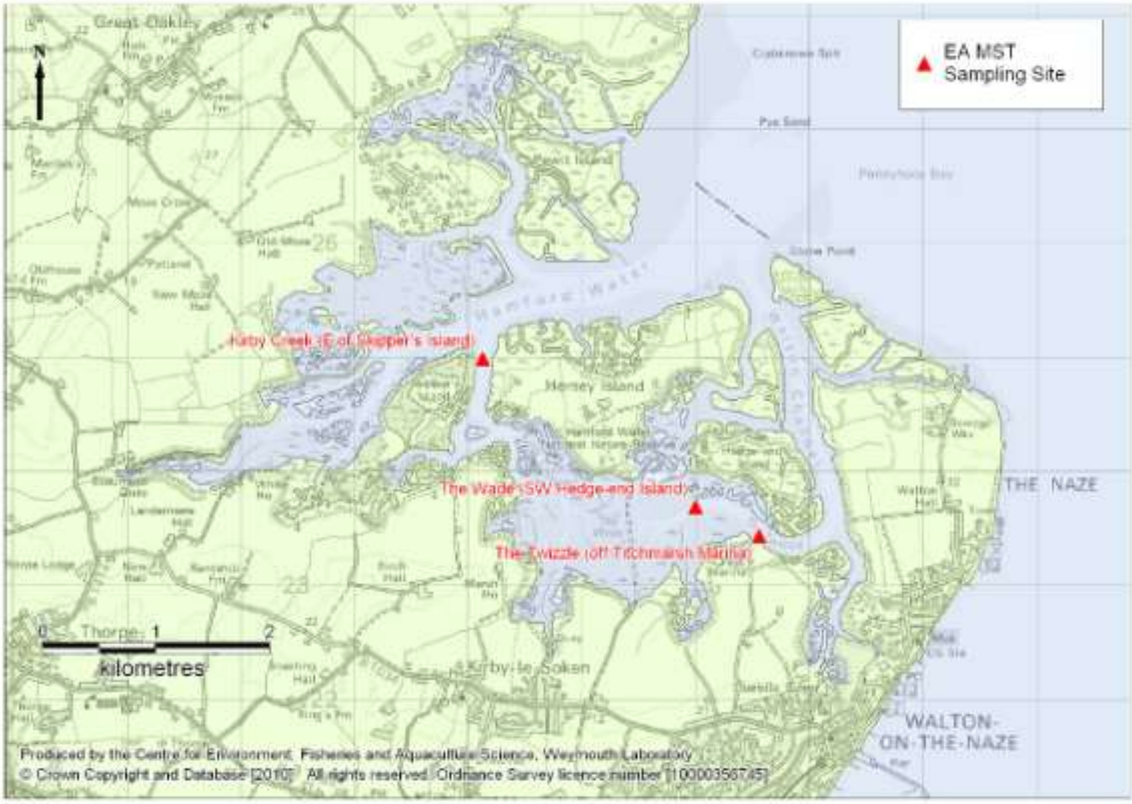


Figure VIII.1 Sites sampled for microbial sources tracking studies.

Table IX.2 Results of microbial source tracking studies undertaken at three sites in Hamford Water during the period May–November 2009.

Sampling site	Collection date	*Bacteroidetes* marker (ruminant)	*Bacteroidetes* marker (all)	*Bacteroides* HF183 primer
The Twizzle (off Titchmarsh Marina)	28 May 2009	Absent	Present	Present
Kirby Creek (E of Skipper's Island)	30 October 2009	Absent	-	-
The Wade (SW of Hedge-end Island)	30 October 2009	Absent	Present	Present
Kirby Creek (E of Skipper's Island)	30 October 2009	-	Present	Present
Kirby Creek (E of Skipper's Island)	5 November 2009	Present	Present	Present
The Twizzle (off Titchmarsh Marina)	5 November 2009	Present	Present	Present

Data supplied by the Environment Agency.

APPENDIX IX
SOURCES AND VARIATION AND MICROBIOLOGICAL POLLUTION: BOATS

Swinging moorings are established along the Walton Channel to the north cardinal buoy marking the spit separating Foundry Reach and Twizzle Creek. Leaving the cardinal buoy to port and branching of to starboard into Twizzle Creek, the line of moorings lead to Titchmarsh Marina. These moorings are owned by Frank Halls & Co., Bedwell & Co. or are privately owned.

Figure IX.1 Location of moorings in the Walton Backwaters.

Titchmarsh Marina offers 490 deep water floating pontoon berths and the Walton Yacht Basin in Foundry Basin operates moorings for 60–70 boats. At the time of the shoreline survey, the harbourmaster informed Cefas officer that there are no pump-out facilities available at Titchmarsh Marina.

An assessment of the potential impact of sewage discharges from boats and marinas on the microbiological status of bivalve mollusc beds requires detailed quantitative information on boat movements, occupancy rates and seasonality and accurate knowledge on dilution of contaminants in receiving waters. At the time of writing this report, no information was made available to Cefas on these practices.

The hypothesis that waste discharges from boats in or near the designated Shellfish Water may be contributing to the faecal indicator organism load is referred in the Environment Agency Pollution Reduction Plan (2009). The agency pointed out this possibility on the basis of MST results indicating human sources of contamination. The results summarised in the Appendix IX corroborate faecally-contaminated water from human sources.

The high numbers of moorings along the Twizzle Channel and parts of Kirby Creek suggest that boats can be considered a locally significant source of contamination in Hamford Water. Bivalves commercially harvested at Walton Backwaters may be affected by intermittent discharges from boats. Overall, it can be assumed that summer is the season of highest risk of contamination.

APPENDIX X
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: BIRDS

Hamford Water provides a diversity of natural habitats for large communities of waterbirds. Bird populations have been regularly surveyed by BTO/WeBS in nine areas (sectors). These represent only a small portion of the site as observations in extensive areas of saltmarshes and creeks are often difficult. However, four of these sectors encompass areas where bivalve mollusc beds are established and are therefore informative for the purposes of this sanitary survey.

Figure X.1 shows low tide counts of 18 significant species of waterbirds during the winter for the period 1997–1998. The relationship between the numbers of waterbirds roosting and feeding at Hamford Water is complex, involving a variety of movements between the site and other nearby sites. Overall, Dugmore Creek held the highest concentration of birds although this was largely driven by Lapwing, Dublin and Grey Plover. Dunlin and Lapwing also preferred the inner areas of Hamford Water to the west and north of Landermere Creek.

Figure X.2 shows a significant increase in the total number of waterbirds from September to December. The Black-headed gull shows an inverse tendency being more abundant in March.

Studies in the UK have found significant concentrations of microbiological contaminants (thermophilic campylobacters, salmonellae, faecal coliforms and faecal streptococci) from intertidal sediment samples supporting large communities of birds (Obiri-Danso and Jones, 2000). For example, geometric means of *E. coli* detected in faecal samples of Starling (*Sturnus vulgaris*) can be $4.6x10^{7}$CFU $100g^{-1}$ (Environment Agency, 2003; Whither *et al*., 2003). Feare (2001) suggests that approximately 10% of the faecal matter could be deposited under a roost, suggesting the potential significant contribution of contamination in these areas.

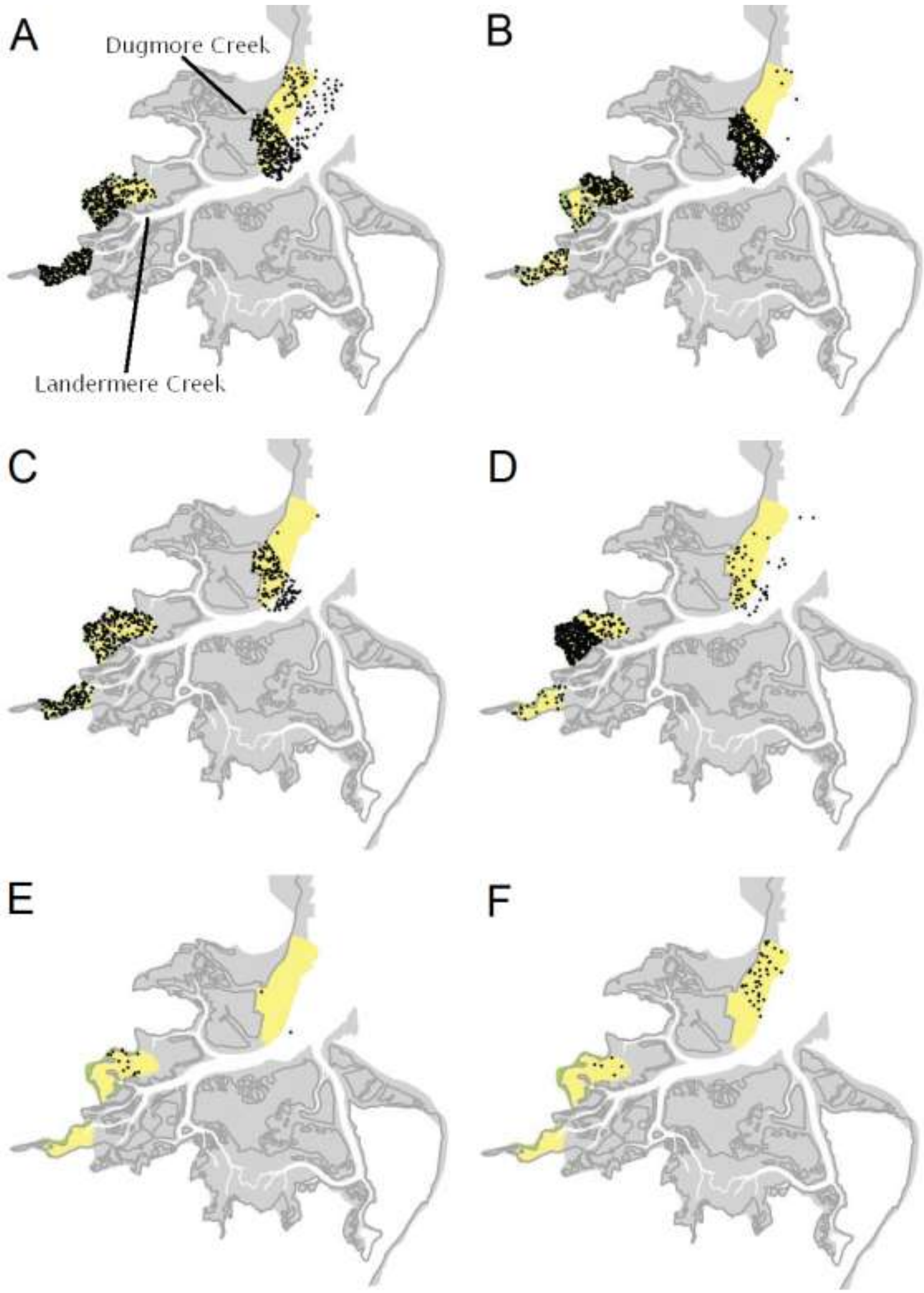


Figure X.1 Distribution of waterbirds in Hamford Water.
Data from Wetland Bird Survey. A–Dark-Bellied Brent Goose; B–Shelduck; C–Wigeon; D–Teal; E–Pintail; F–Avocet.

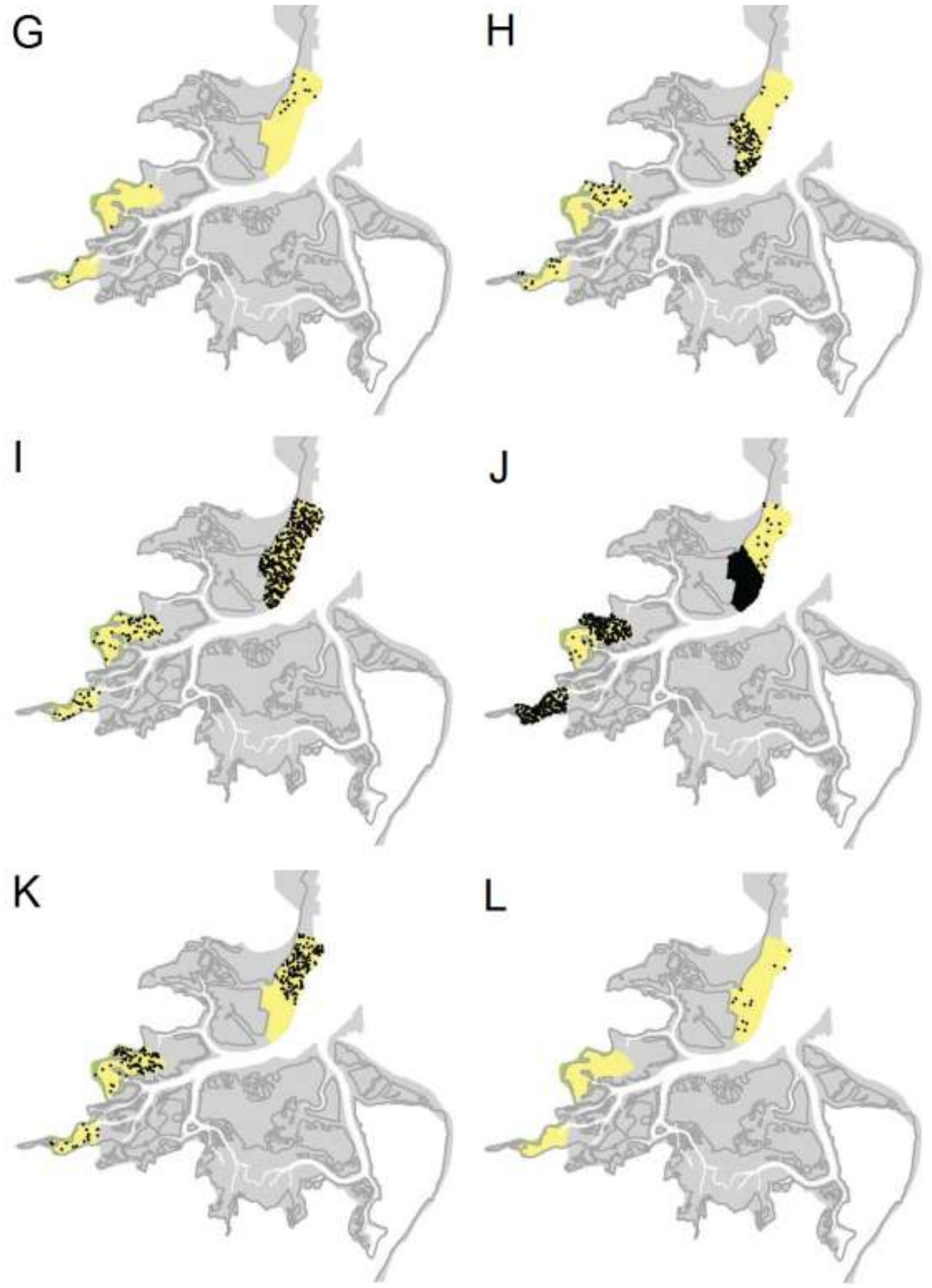


Figure X.1 (cont.) Distribution of waterbirds in Hamford Water.
Data from Wetland Bird Survey. G–Ringed Plover; H–Golden Plover; I–Grey Plover; J–Lapwing; K–Knot; L–Sanderling.

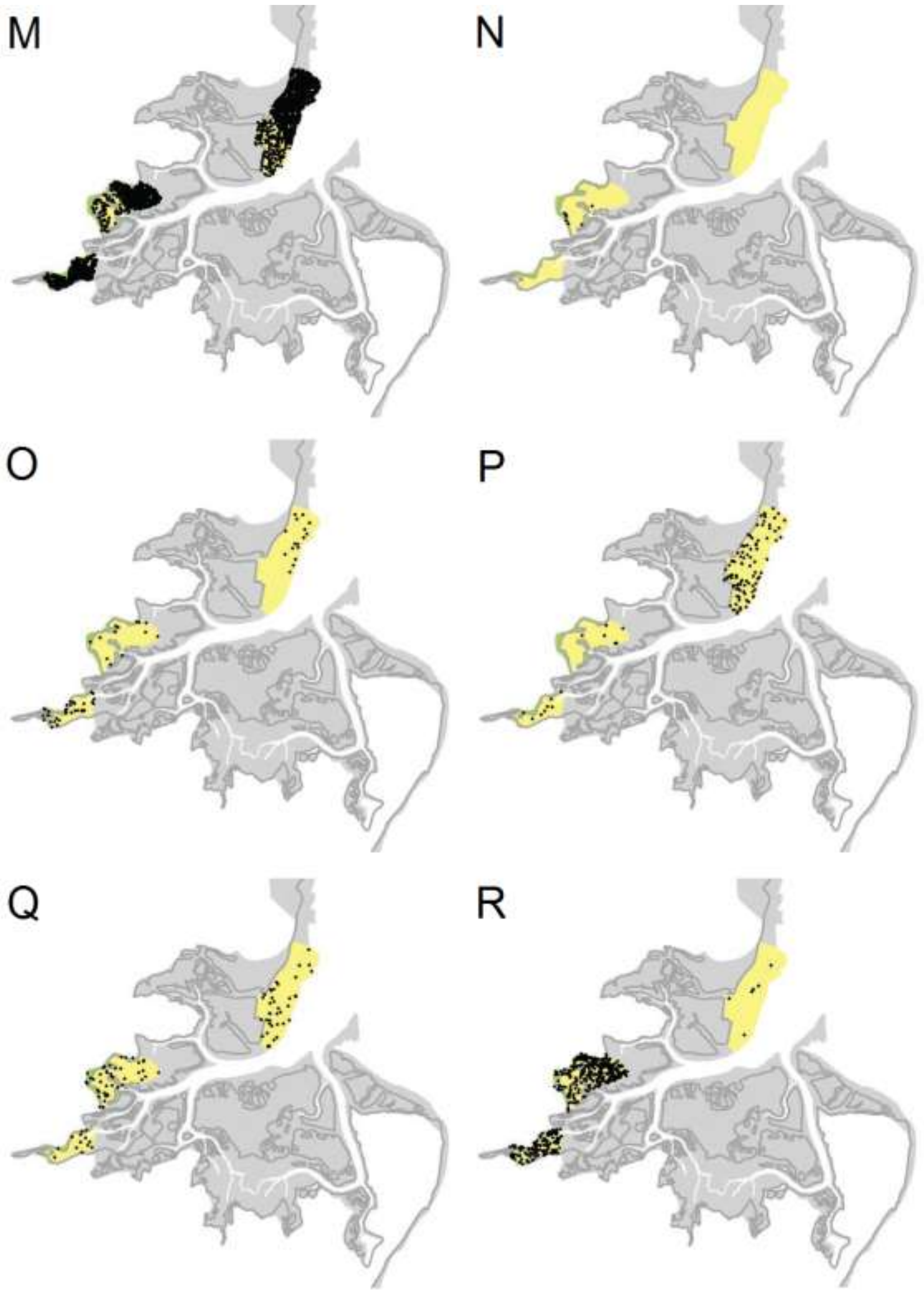


Figure X.1 (cont.) Distribution of waterbirds in Hamford Water.
Data from Wetland Bird Survey. M–Dunlin; N–Ruff; O–Black-Tailed Godwit; P–Bar-Tailed Godwit; Q–Curlew; R–Redshank.

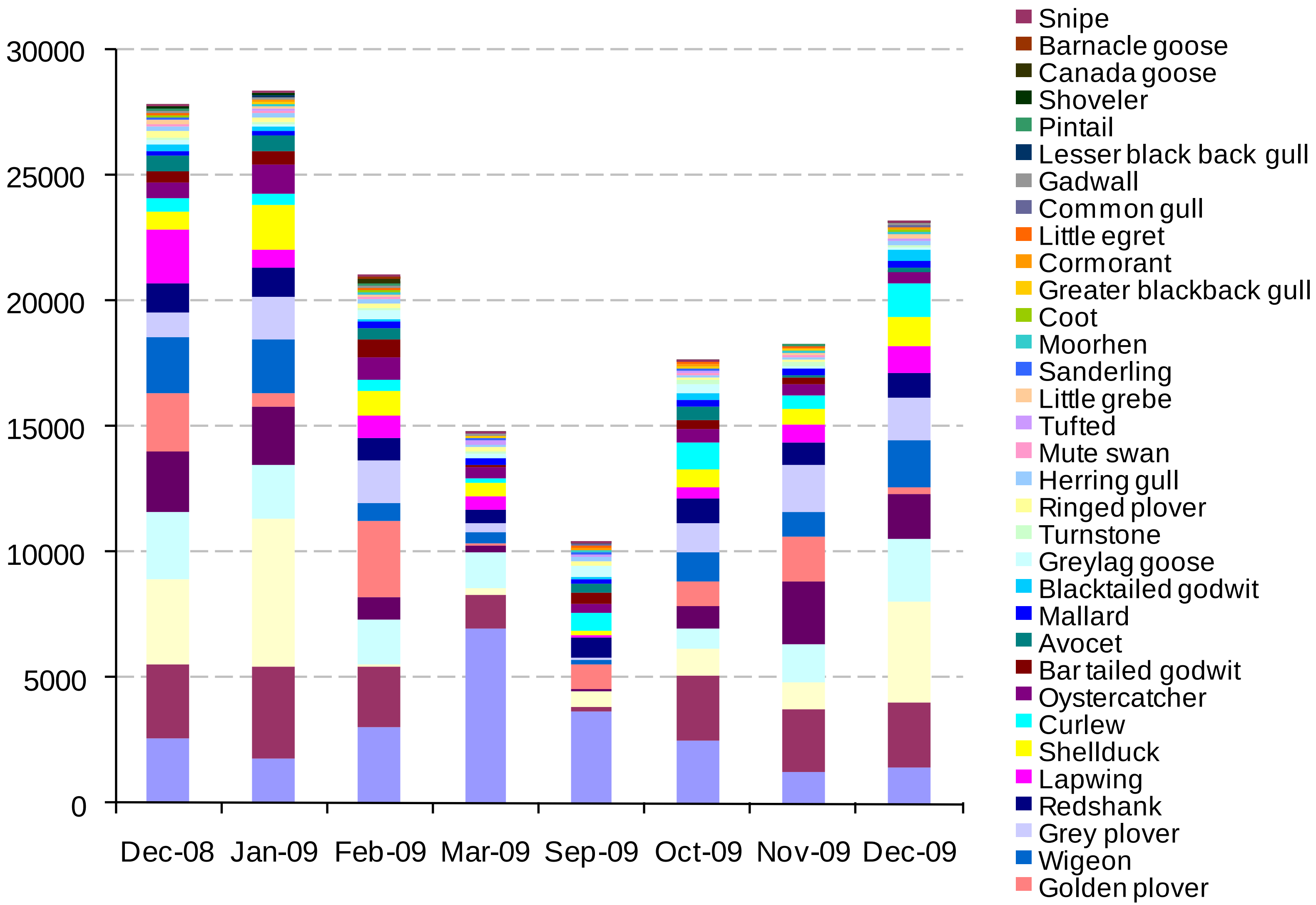


Figure X.2 Total numbers of common species of waterbirds in Hamford Water for the period 2005–2009.
Data from Wetland Bird Survey (WeBS).

Results from source tracking studies using species specific mtDNA as indicator in surface waters at three sites in Hamford Water discriminated human from avian sources of faecal contamination. The presence of the marker at all sites indicates that birds constitute a potentially significant source of contamination to shellfisheries.

Table IX.2 Results of source tracking studies using mitochondrial DNA tests undertaken at three sites in Hamford Water during the period May–November 2009.

Sampling site	Collection date	Mitochondrial marker (human)	Mitochondrial marker (avian)
The Twizzle (off Titchmarsh Marina)	28 May 2009	Absent	Present
The Wade (SW of Edge-end Island)	30 October 2009	Absent	Present
Kirby Creek (E of Skipper's Island)	30 October 2009	Absent	Present
Kirby Creek (E of Skipper's Island)	5 November 2009	Present	-
The Twizzle (off Titchmarsh Marina)	5 November 2009	Absent	Present
Kirby Creek (E of Skipper's Island)	5 November 2009	-	Present

Data supplied by the Environment Agency.

APPENDIX XI
MICROBIOLOGICAL DATA: WATER

BATHING WATERS

There are two bathing waters at Pennyhole Bay designated under the Directive 2006/7/EC (European Communities, 2006a)[5]: Doverport (approximately 7km from the nearest bivalve mollusc bed at West Kirby) and Walton (approximately 10km from The Twizzle bed) (Figure XI.1).

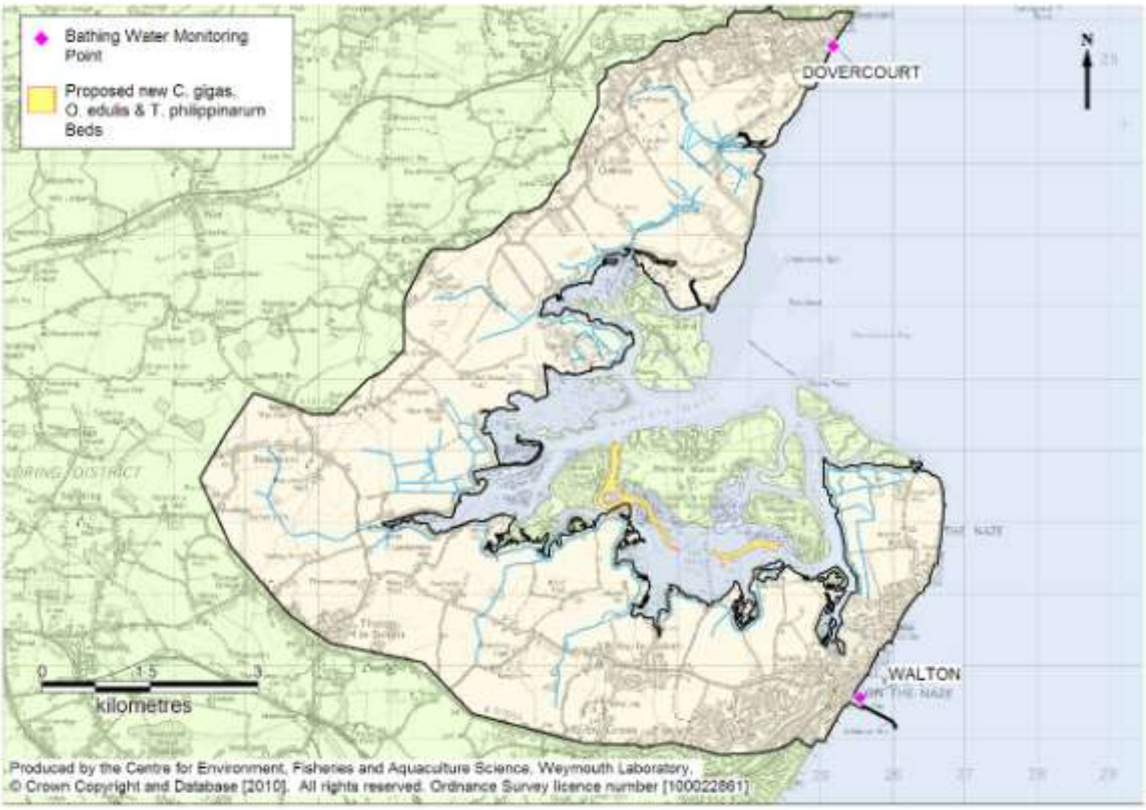


Figure XI.1 Location of designated bathing waters and associated monitoring points in Walton Backwaters.

The overall quality of this Bathing Water is summarised in Table XI.1. Under the revised BW Directive, Walton would meet "Sufficient" status and Dovercourt would maintain "Excellent" status (Environment Agency, 2009).

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

Table XI.1 Overall quality of Walton and Dovercourt designated Bathing Waters for the period 2004−2008.

	Bathing season									
Compliance	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Walton										
Excellent (Guideline Pass)										
Good (Mandatory Pass)	√	√	√	√	√	√	√	√	√	√
Poor (Mandatory Fail)										
Dovercourt										
Excellent (Guideline Pass)	√	√	√	√	√	√	√	√	√	√
Good (Mandatory Pass)										
Poor (Mandatory Fail)										

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

Side-by-side box-and-whisker plots of levels of faecal coliforms indicate an overall better microbiological quality of surface waters at Dovercourt than that at Walton. Furthermore, the 75th percentile for faecal indicator data from Dovercourt has been below the Guideline level in recent years. Outlier values represented by asterisks in the figure for Walton suggest the existence of occasional periods when the microbial quality of surface waters had deteriorated.

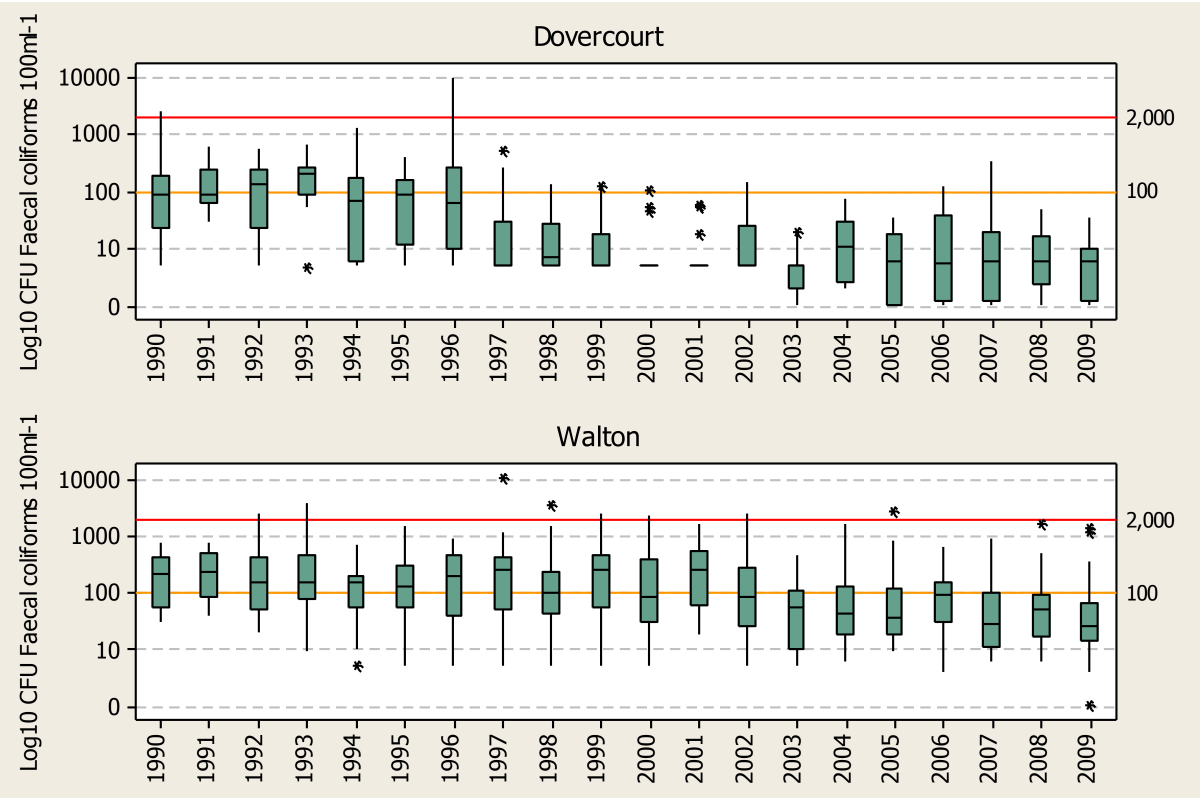


Figure XI.2 Box-and-whisker plots of levels of faecal coliforms in designated bathing waters in the vicinity of the Hamford Water for the period 2000−2009.
NB. Number of samples per year=20 (22 samples in 2000).

SHELLFISH WATER

The tidal waters between the mouth of The Twizzle channel at Hedge-end Island and the mouth of Kirby Creek, including part of the main Hamford Water channel are designated under Directive 2006/113/EC as Shellfish Water since 1999 (European Communities, 2006a) (Figure XI.3).

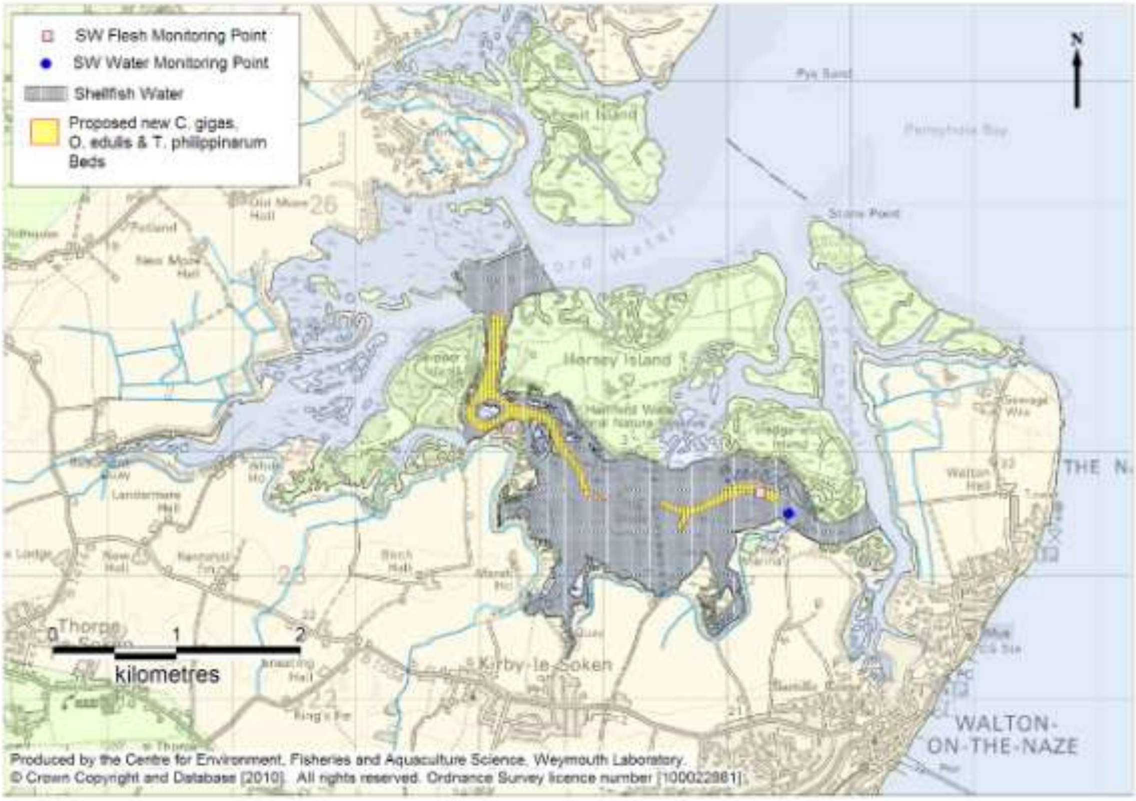


Figure XI.1 Location of designated shellfish water and associated monitoring points in Walton Backwaters.

Historical data from this monitoring programme for the period January 2009–March 2010 was analysed. Due to the low number of samples collected as part of the operational monitoring programme, results from samples collected following statutory failures and planned investigations were also included in the dataset in order to inform an assessment of the overall quality of the shellfish water.

Only one sample collected on 12 January 2010 returned a concentration of the microbiological indicator above 300 CFU 100ml^{-1} during the period. There was no sampling for the purposes of the Shellfish Hygiene monitoring programme immediately after this day.

Table XI.2 Summary statistics for levels of faecal coliforms in surface waters at the designated Shellfish Water in Hamford Water for the period January 2009–March 2010.

	CFU Faecal coliforms 100ml^{-1}
Number of samples	47
Minimum	2
Maximum	620
Median	24
Geometric mean	21

Data from the Environment Agency.

Side-by-side box-and-whisker plots of levels of faecal coliforms grouped by season indicate higher levels of contamination during the summer–autumn period than that during the winter–spring period. However, differences between seasons are less than 1Log$_{10}$. It is interesting to note that the pattern of seasonal variation is similar to that observed in native oysters from West Kirby shown in Figure XII.2 of the Appendix XII.

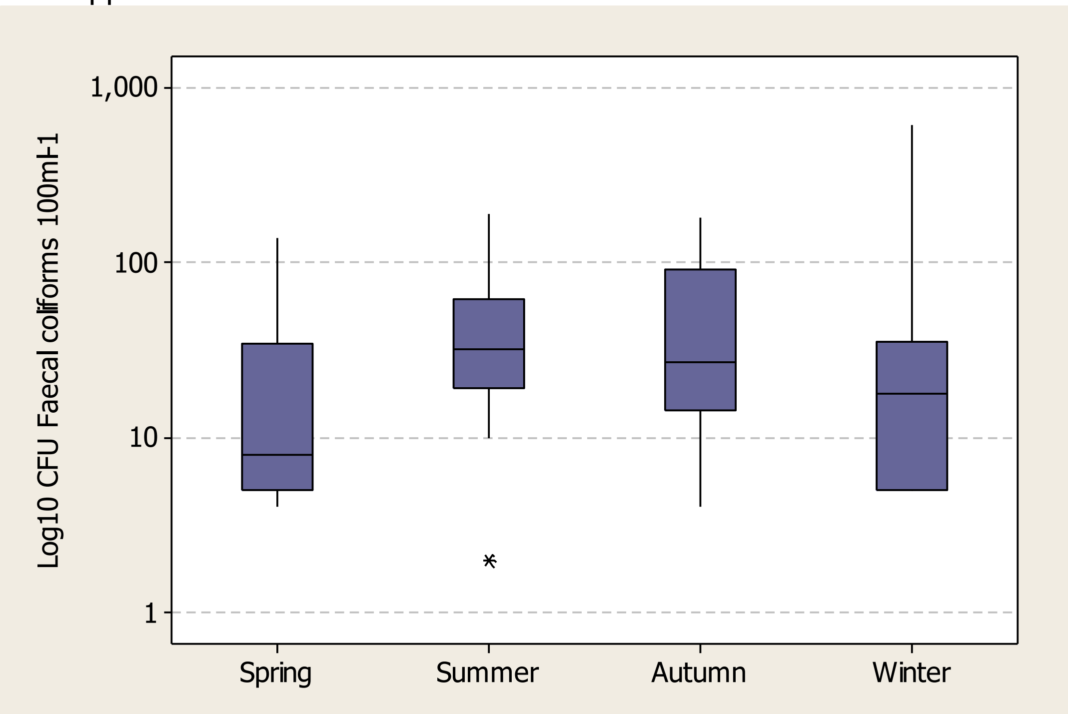


Figure XI.2 Seasonal variation of levels of faecal coliforms in near-surface water samples from the designated shellfish water in Walton Backwaters.

APPENDIX XII
MICROBIOLOGICAL DATA: SHELLFISH FLESH

Table XII.1 shows summary statistics for levels of *E. coli* in bivalves from six current RMPs for the period September 1991–January 2010. The relatively low sampling effort over the years is evident. However, it should be noted that these beds have received seasonal classifications.

Levels of *E. coli* below the limit of detection (MPN<20 *E. coli* 100g^{-1} FIL) were detected at least once in each classified bed.
The number of results above the class B threshold (MPN≤4,600 *E. coli* 100g^{-1} FIL) in native oysters from the Twizzle and Kirby Creek beds equally correspond to 6% of the total number of samples. Maximum levels of the microbiological indicator above the limit of detection were also detected in oysters from these beds. The highest result was detected in Pacific oysters from Mill Lane.

The presence of outliers (asterisks) represented in side-by-side box-and-whisker plots shown in Figure XII.1 indicate periods when the quality of bivalves deteriorated/ improved significantly in all classified beds.
Descriptive statistics evidence the following relationship in contaminating levels for native oysters: Kirby Creek≈Twizzle>Mill Lane[6].

Overall, native oysters tend to show higher levels of *E. coli* contamination than Pacific oysters in beds where both species were monitored over similar timescales. A more detailed analysis using higher number of results would be needed to corroborate this conclusion.

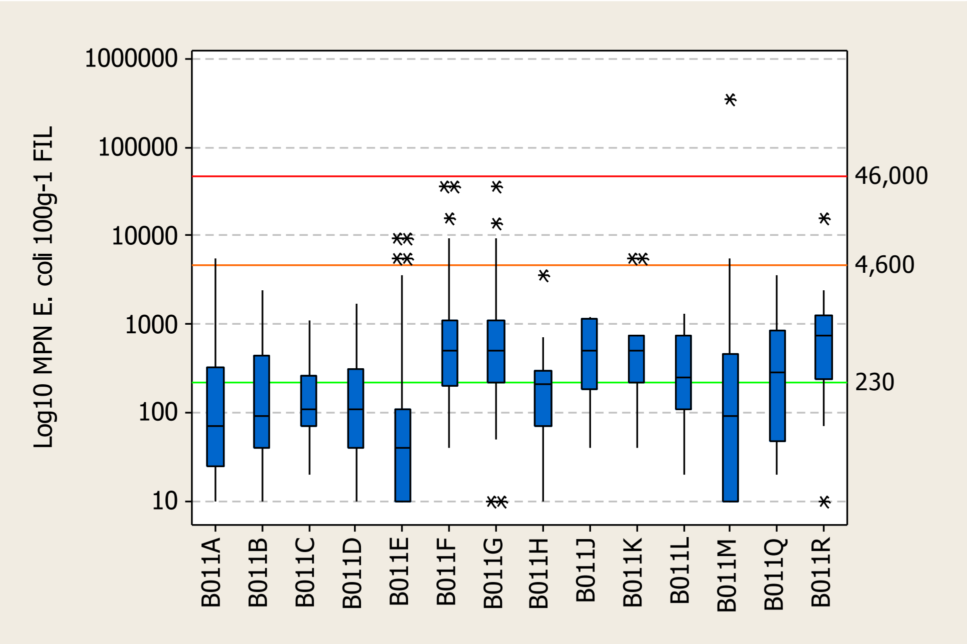


Figure XII.1 Box-and-whisker plots of levels of E. coli in bivalve molluscs from six representative monitoring points in Walton Backwaters.
NB. For bed names, refer to Table XII.1.

[6] This conclusion is based on historical datasets for which there are approximately 50 results or more.

Table XII.1 Summary statistics for E. coli levels at six current representative monitoring points (RMPs) in Walton Backwaters.

RMP	Bed name	Species	n	Date of first sample	Date of last sample	No. samples >230	No. samples >4600	Minimum	Maximum	Median	Geometric mean
						MPN *E. coli* $100g^{-1}$ FIL					
B011A	Twizzle - East	*C. gigas*	23	20 January 1992	08 June 1993	7	1	<20	5,400	70	104
B011B	Twizzle - West	*C. gigas*	24	20 January 1992	27 June 1994	8	0	<20	2,400	90	119
B011C	Kirby Creek - South	*C. gigas*	29	9 September 1991	21 September 1992	7	0	20	1,100	110	133
B011D	Kirby Creek - North	*C. gigas*	31	27 January 1992	27 June 1994	9	0	<20	1,700	110	124
B011E	Mill Lane	*O. edulis*	49	5 January 1992	30 April 2009	26	4	<20	9,100	40	49
B011F	Twizzle	*O. edulis*	155	18 October 1993	17 November 2009	107	10	40	>18,000	500	509
B011G	Kirby Creek	*O. edulis*	125	2 July 1996	17 November 2009	92	8	<20	>18,000	500	492
B011H	Twizzle - East	*O. edulis*	14	9 September 1991	19 April 1993	4	0	<20	3,500	210	174
B011J	Twizzle - West	*O. edulis*	6	18 October 1993	20 September 1994	5	0	40	1,220	500	401
B011K	Kirby Creek - South	*O. edulis*	14	8 August 1994	11 December 1995	10	2	40	5,400	500	502
B011L	Kirby Creek - North	*O. edulis*	11	21 September 1992	25 January 1994	6	0	20	1,300	250	250
B011M	Mill Lane	*C. gigas*	13	19 April 1993	19 January 2010	4	2	<20	350,000	90	136
B011Q	Twizzle	*C. gigas*	14	19 April 1993	19 January 2010	8	0	20	3,500	280	259
B011R	Kirby Creek	*C. gigas*	16	16 January 2007	19 January 2010	12	1	<20	16,000	750	551

FIL - fluid and intravalvular liquid.
RMP - representative monitoring point.
n - number of samples.

SEASONAL VARIATION OF *ESCHERICHIA COLI*

Seasonal variation of levels of *E. coli* in native oysters from Kirby Creek indicate higher levels of contamination during the summer relative to those during the spring (Figure XII.2), although there is insufficient data during the period February–April to fully support this conclusion.

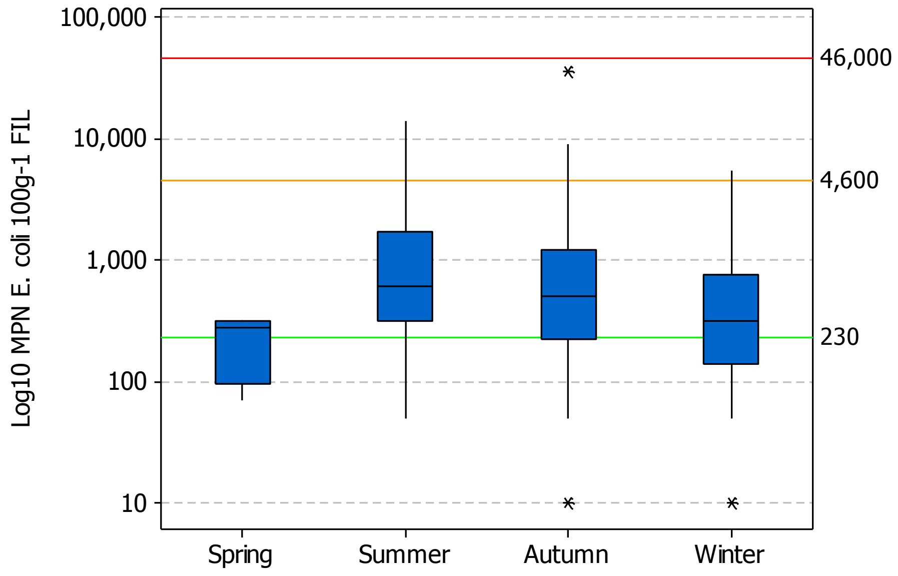


Figure XII.2 Seasonal variation of levels of* E. coli *in native oysters from Kirby Creek.

Monthly geometric means indicate an increase in the levels of contamination at this site from May to September (Figure XII.3). The higher number of *E. coli* results above the class B threshold (MPN=4,600g^{-1} FIL) was detected in September.

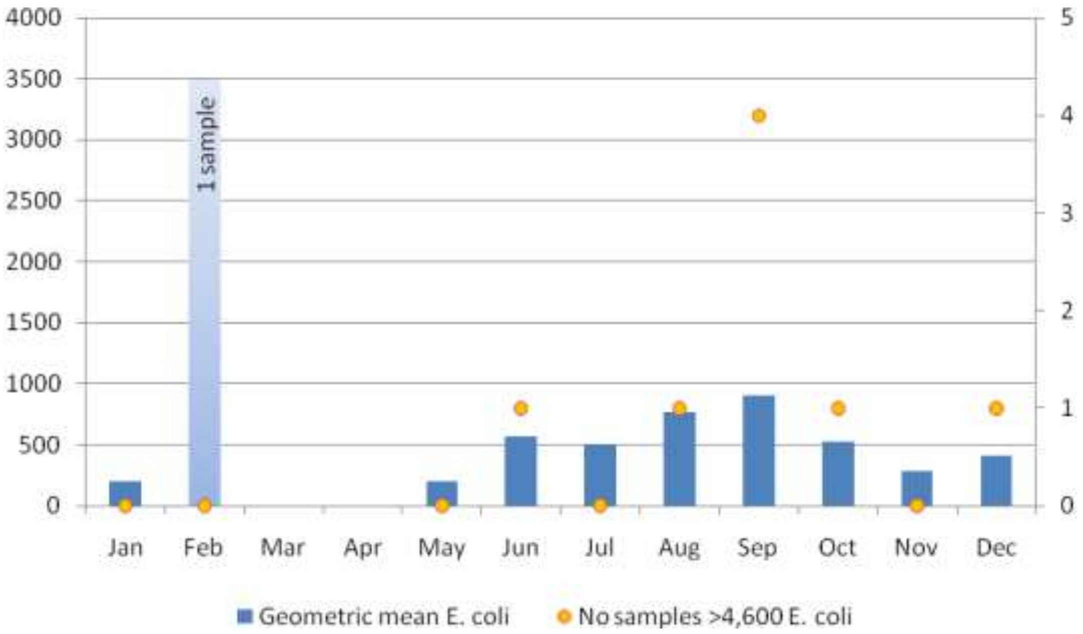


Figure XII.3 Monthly variation of levels of* E. coli *in native oysters from Kirby Creek.

Seasonal boxplots and monthly variation of levels of *E. coli* in native oysters from Mill Lane indicate significantly higher levels of contamination during the summer relative to the rest of the year, with *E. coli* results above the class B threshold occurring during the summer-autumn period (Figure XII.4 – XII.5).

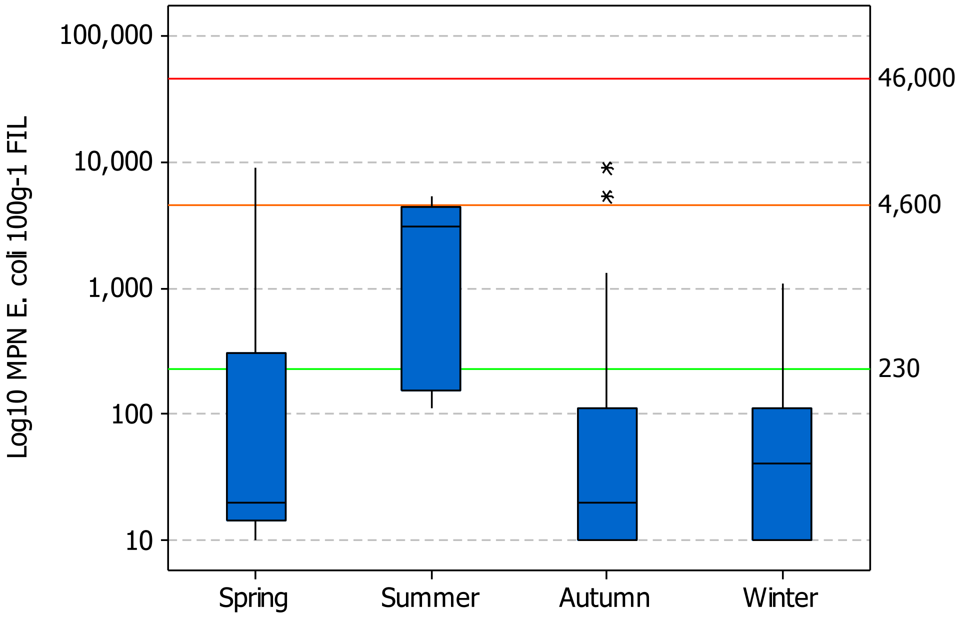


Figure XII.4 Seasonal variation of levels of* E. coli *in native oysters from Mill Lane.

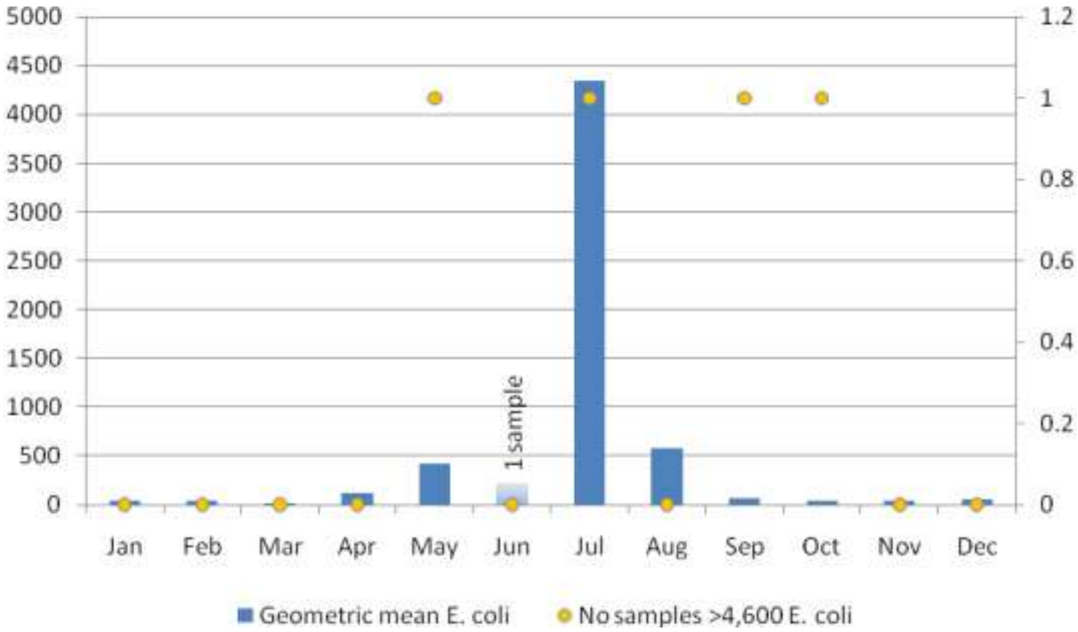


Figure XII.5 Monthly variation of levels of* E. coli *in native oysters from Mill Lane.

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

VARIATION OF *ESCHERICHIA COLI* ACCORDING TO RAINFALL

Rainfall data from the Great Oakley gauging station were correlated with *E. coli* levels in bivalve molluscs from six current representative monitoring points (RMPs) in Walton Backwaters (Figure 2.1) for the period January 2000–January 2010.

Statistically significant positive correlations were obtained between daily rainfall and the levels of the microbiological indicator in native oysters from Mill Lane (when the rainfall event occurred one and five days before sampling) and Pacific oysters from Twizzle channel (when the rainfall event occurred three days before sampling).

Statistically significant positive correlations were also obtained between cumulative rainfall and the levels of *E. coli* in bivalves from these sites and results were relatively consistent with those found for daily rainfall.

Table XII.2 Spearman's rho coefficients between rainfall recorded at Great Oakley rainfall gauge and MPNs of* E. coli *100g^{-1} FIL in bivalves from six monitoring points in Walton Backwaters for the period Jan 2000–Jan 2010.

		MPN *E. coli* 100g^{-1} FIL					
Rainfall		Mill Lane B011E (*O. edulis*)	Twizzle B011F (*O. edulis*)	Kirby Creek B011G (*O. edulis*)	Mill Lane B011M (*C. gigas*)	Twizzle B011Q (*C. gigas*)	Kirby Creek B011R (*C. gigas*)
Great Oakley		(n=87)	(n=84)	(n=74)	(n=4)	(n=7)	(n=16)
Daily	Day of sampling	0.074	-0.081	-0.055	0.105	-0.148	-0.102
	-1 day	0.235*	0.148	0.060	-0.738	-0.056	-0.168
	-2 days	0.157	-0.029	0.016	-0.600	0.491	0.381
	-3 days	0.014	-0.065	0.080	-0.800	0.964*	0.077
	-4 days	-0.100	-0.044	0.024	-0.800	0.704	0.291
	-5 days	0.217*	-0.121	0.024	-0.400	0.396	-0.195
	-6 days	0.105	-0.035	-0.022	0.000	0.236	0.152
	-7 days	-0.073	-0.130	-0.099	0.316	-0.393	0.156
Cumulative	-2 days	0.213*	0.075	-0.014	-0.400	-0.036	-0.261
	-3 days	0.255*	0.087	0.060	-0.400	0.255	0.083
	-4 days	0.247*	0.059	0.143	-0.600	0.786*	0.060
	-5 days	0.158	0.034	0.114	-0.800	0.714	0.041
	-6 days	0.204	0.005	0.146	-0.800	0.829*	-0.039
	-7 days	0.193	0.010	0.130	-0.600	0.857*	0.054

** Significant at p≤0.05.*

The relationships with the most significant correlations are plotted in a scatter plot in figures XII.6-XII.7. The scatterplots were superimposed with Locally

Weighted Scatterplot Smooting (LOWESS) lines (degree of smoothing = 0.5, number of steps = 2).

The upward trend of the LOWESS line at Mill Lane monitoring point (Figure XII.6) illustrates the increase in levels of *E. coli* in oysters when rainfall did not exceed 10mm.

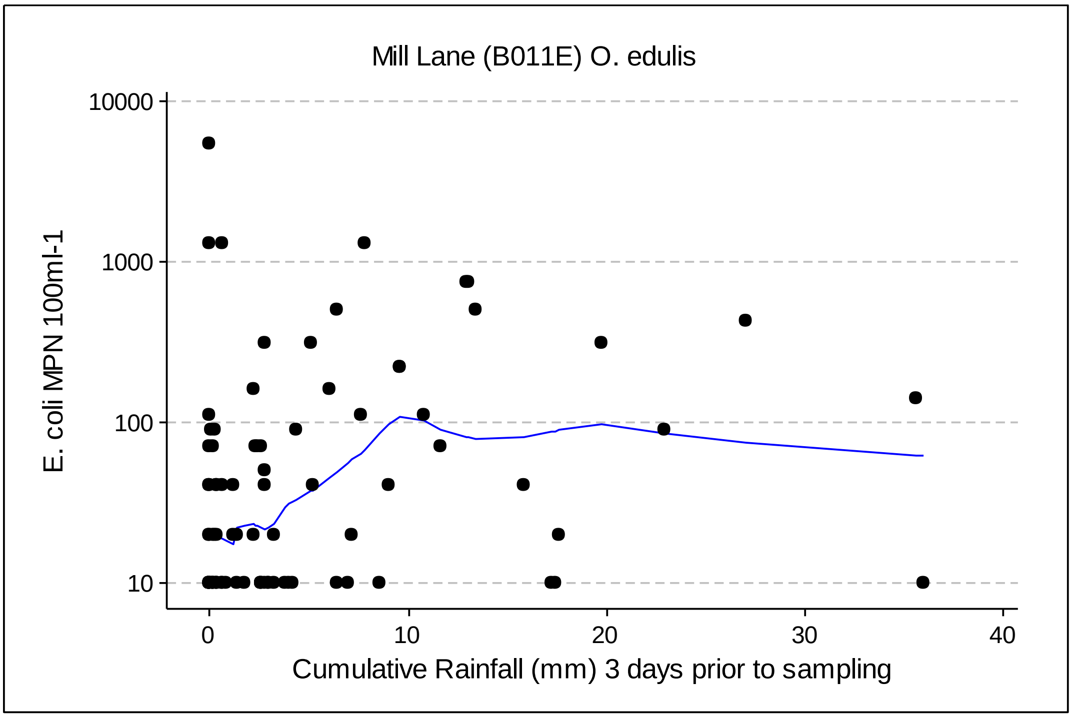


Figure XII.6 Scatterplot of levels of* E. coli *at Mill Lane versus the total cumulative rainfall recorded at Great Oakley three days previous to sampling.

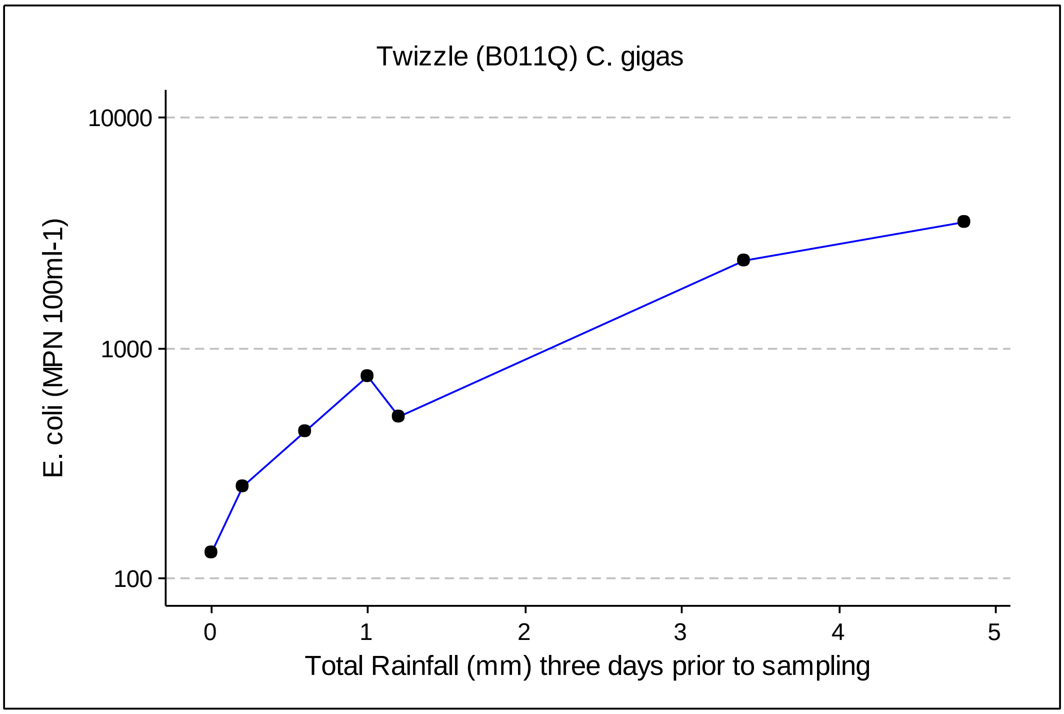


Figure XII.7 Scatterplot of levels of* E. coli *at Twizzle Creek versus total rainfall recorded at Great Oakley three days previous to sampling.

APPENDIX XIII
MICROBIOLOGICAL DATA: BACTERIOLOGICAL SURVEYS

INVESTIGATIONS UNDERTAKEN BY THE ENVIRONMENT AGENCY

The Environment Agency has been investigating the levels of microbial contamination in various sites at West Kirby/The Twizzle creeks and various points along the south shores of Hamford Water (Figure XIII.1).

Figure XIII.1 Sites sampled as part of water quality investigations undertaken by the Environment Agency during the period January 2009–March 2010.

Results from samples collected over 15 months indicate high levels of contamination of faecal origin from Kirby Quay creek and Mill Lane impacting on water quality (Table XIII.1). Overall, Coles Creek appears to be significantly less contaminated than these sites.

In terms of sites sampled where bivalve mollusc beds occur, The Twizzle off Titchmarsh Marina has been found to be more contaminated than the northern edge of Kirby Creek at Landing Place.

These results indicate significant spatial variations in the levels of contamination may occur across the channels supporting Cefas recommendation for three individual classification zones, each with its own sampling point (see justification for bacteriological survey below).

Table XIII.1 Levels of faecal coliforms in investigative water samples collected in nine sites across the catchment draining to Hamford Water during the period January 2009–March 2010.

Sampling site	Faecal coliforms (CFU 100ml^{-1})									
	Presumptive					Confirmed				
	n	Minimum	Maximum	Median	Geometric mean	n	Minimum	Maximum	Median	Geometric mean
Coles Creek sluice (SE corner)	29	<2	230	18	21	29	<2	230	18	19
Coles Creek sluice (West side)	29	<2	1,081	54	36	29	<2	216	45	28
The Twizzle (off Titchmarsh Marina)	47	2	620	27	26	50	2	620	26	23
The Wade (SW of Edge-end Island)	13	<2	80	25	16	13	<2	80	21	16
Kirby Creek (E of Skipper's Island)	13	<2	76	27	17	13	<2	76	21	16
Kirby Quay sluice	31	1,182	680,000	49,000	30,182	31	118	136,000	29,400	11,842
Marsh House Ditch (at sluice)	31	5	12,727	162	175	31	5	10,182	146	147
Mill Lane sluice	30	42	28,000	1,980	1,443	30	23	19,600	1,008	738
Sluice opposite Mill Lane car park	31	76	200,000	14,000	10,984	31	61	200,000	7,000	5,550

n - number of samples.

During the period of external consultation of the sanitary survey, Cefas received further information from the EA on inputs of faecal contamination to Hamford Water. Figure XIII.2 shows geometric means of faecal coliforms in water sampled from a higher number of points than those shown in Figure XIII.1.

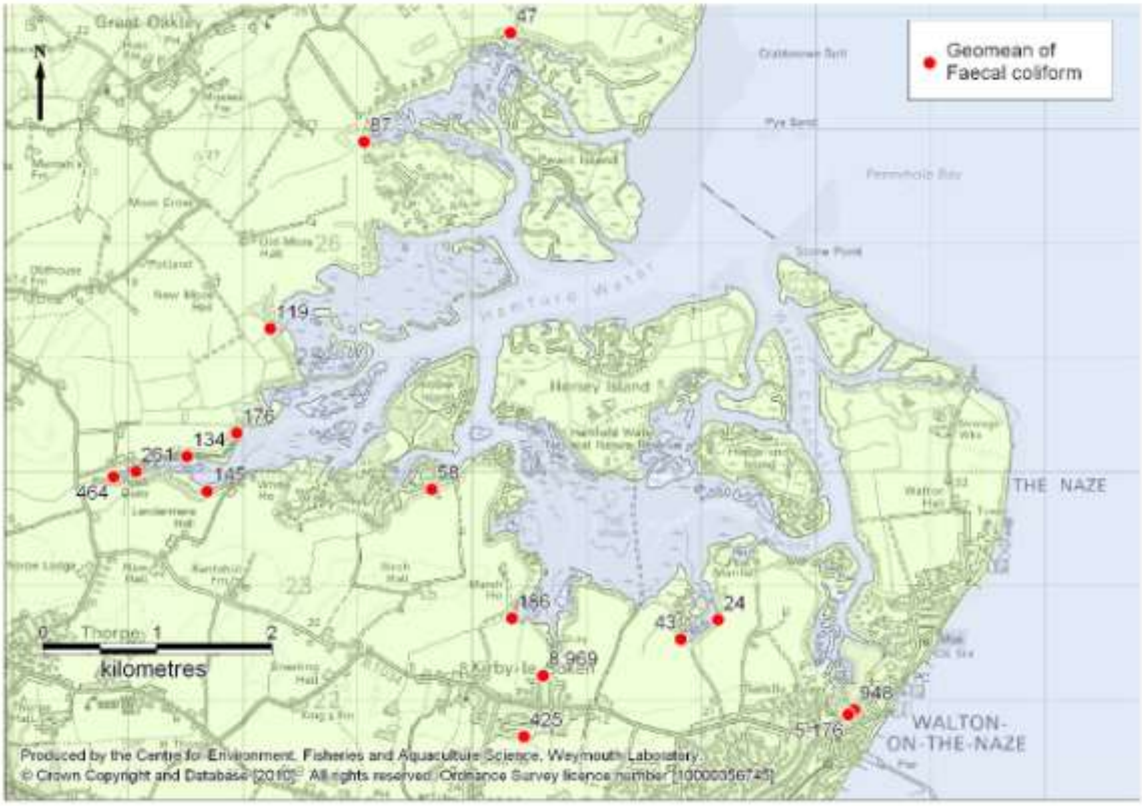


Figure XIII.2 Sites sampled as part of water quality investigations undertaken by the Environment Agency.

Results indicate low levels of microbial contamination in samples collected across the north and western shores of the tidal inlet and confirm that Kirby Quay sluice constitutes the main source of microbial contamination impacting on the shellfisheries.

BACTERIOLOGICAL SURVEY RECOMMENDED BY CEFAS

Immediately after receipt and acceptance of the application for classification of shellfish beds by Naze Oysters Ltd, it was understood that the applicant wished to progress the extension of the seasonal classification to year-round for native oysters and Pacific oysters at West Kirby and The Twizzle beds as soon as possible.

After undertaking an initial desk-based study of pollution sources required for the sanitary survey, the identification of representative positions for sampling points for the classification monitoring programme remained unclear. With the information available at that time, the extension of classification using the historical data available from the Shellfish Hygiene monitoring programme at that time[7] was objected on the basis that:

- There was insufficient data to make an assessment of classification status over the whole year;
- Where historical data for the unclassified existed, it showed generally poorer compliance (class C) then the current classified season (class B);
- Information from the desk study indicated a possible deterioration in the microbiological quality of the water during the unclassified season due to anticipated changes in seasonal patterns of pollution;
- There are differences in the geographical extension of beds requiring classification relative to those currently classified.

After undertaking the shoreline survey[8], Cefas recommended a bacteriological survey encompassing three provisional classification zones, each with its own sampling point. The locations of these classification zones and sampling points are shown in Figure 5.1 of the sampling plan.

It was recommended that these points should be sampled at least 10 times for native oysters and Manila clams at regular intervals not closer than weekly and not more than monthly and tested for the statutory indicator of contamination (*E. coli*) between June and August (inclusive) [9].

It was agreed between the competent authority and the LEA that, unless the ongoing sanitary survey assessment identifies otherwise, the results of the bacteriological survey will form part of the preliminary monitoring towards classification for these beds. Cefas intends to review the classification status once results from monitoring over this period are available along with the overall assessment from the sanitary survey.

[7] See Appendix XII.
[8] See Appendix XIII for further detail.
[9] The sampling period initially recommended was April–August. At the time of the shoreline survey, it became evident that the applicant would not provide support for sampling during this period. Agreement was then reached between Cefas, the LEA and the applicant to sample between June and August.

APPENDIX XIII
SHORELINE SURVEY

Date (time): 27 April 2010 (08:30−16:00 GMT)
Applicant: Owen Bloom (Naze Oysters Ltd)
Cefas Officer: Carlos Campos
Local Enforcement Authority Officer: Edward King (Tendring District Council).

Area surveyed: shoreline walks in parts of Hamford Water from Mill Lane to Landermere followed by boat survey along The Twizzle, Walton Channel, Hamford Water, Bramble Creek and Kirby Creek (Figure XIII.2).

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

The predicted times and heights of high and low waters and tidal curve on the day 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 Walton-on-the-Naze on 27 April 2010.

	Time-BST (height)
Low Water	05:29 (0.2m)
High Water	11:40 (4.2m)
Low Water	17:37 (0.6m)
High Water	23:51 (4.2m)

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.

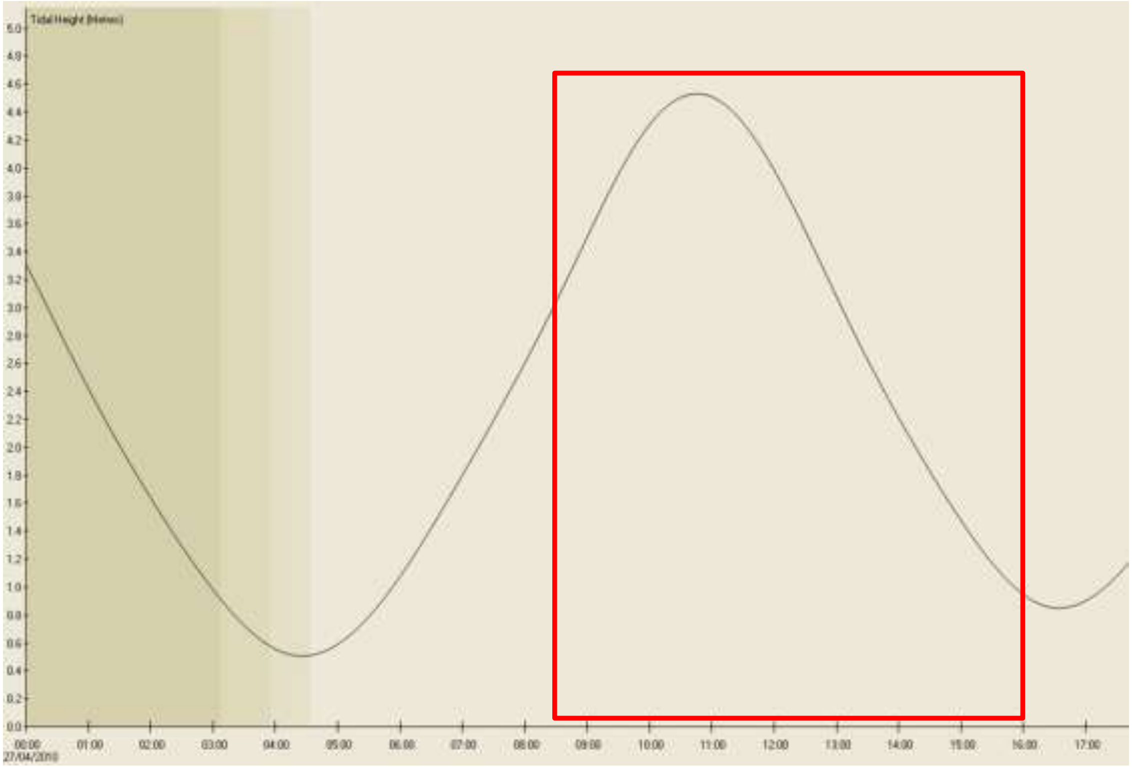


Figure XIII.1 Tidal curve at Walton-on-the-Naze on 27 April 2010.
Predicted heights are in metres above Chart Datum Republished with permission from Admiralty Total Tide (United Kingdom Hydrographic Office) by permission of Her Majesty's Stationery Office and the UK Hydrographic Office.
© Crown copyright.

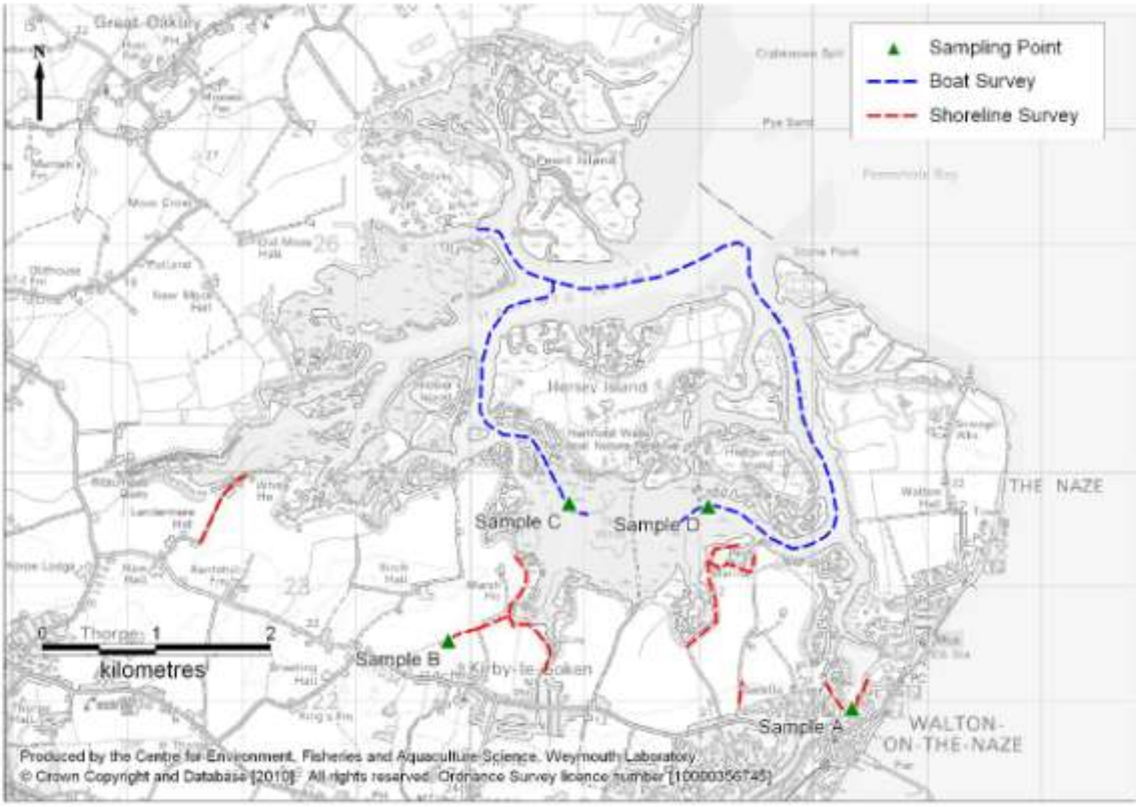


Figure XIII.2 Location of sites sampled in Hamford Water on 27 April 2010.
Red lines indicate areas where shoreline walks were carried out.

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

Table XIII.2 Results and observations made during the shoreline survey.

Production area	Walton Backwaters (M011)
Classification zones and ID/species	Mill Lane storage pond Twizzle Kirby Creek Native oysters (*O. edulis*) Pacific oysters (*C. gigas*) Manila clams (*T. philippinarum*)
Area of beds (Cefas database)	Twizzle = 0.07709km^2 Kirby Creek = 0.2881km^2
SWD Flesh Point	Walton Backwaters (TM 2427 2367)
SWD Water Point	Walton Backwaters (TM 2450 2350)
BWD Sampling point(s)	Walton (TM 2555 2158) Dovercourt (TM 2521 3060)
Applicant's details	Owen Bloom (Naze Oysters Ltd) Mill Lane Walton-on-the-Naze CO14 8PF Tel: 01255 850893
Map/Chart references	Imray Chart 2000.4 (Harwich Approaches & Walton Backwaters) OS Explorer 184 (Colchester: Harwich & Clacton-on-Sea)

Weather forecast	26 April 2010: Met Office Inshore Waters (Gibraltar Point to North Foreland): Wind: mainly west or southwest 3 or 4, becoming variable 3 or less later. Smooth or slight. Fog patches. Visibility: moderate or good, occasionally very poor
Recorded air temperature	Max. 12°C (10:00)
Recorded wind	Max. 3 knots (10:00)
Precipitation	None at time of survey
Streams/springs	Stream at Mill Lane (sampled) (see Figure XIII.3A) Stream at Lirby-le-Soken (Malting Lane) (sampled) (see Figure XIII.3B)
River flows (gauged)	Both streams trickle flow
Significant sewage discharges (Cefas database)	Hervilly Way and Walton Road Overflow (manhole observed; discharge point not observed) (Figure XIII.4) Kirby Road (not observed) Dairy buildings (observed PVC pipe at 24352/22225 with discharge point into a ditch; no sign of discharge at time of survey) (Figure XIII.5) Kirby-le-Soken PS (observed) (Figure XIII.6) Quay House (not observed) Main Maltings PS (observed; sampled downstream discharge point at 21810/22533) (Figure XIII.7) Campbells Cottage (not observed) Great Oakley (not observed from boat) Marsh House (concrete pipe with discharge point into stream at 22328/22731; no sign of discharge at time of survey) (Figure XIII.8)
Other discharges	Black PVC pipe extending from Titchmarsh Marina Bar/Restaurant at 24327/23219 with discharge point into marina (Figure XIII.9). It appeared this may be used to drain off storm water. No sign of discharge at time of survey. Two pipes from private properties crossing pond at Westwater, Mill Lane (25204/22094) (Figure XIII.10). Discharge point not identified.
Boats/port	Titchmarsh Marina (Figure XIII.11A). Facilities available: 420 sheltered berths, self service fuelling pontoon and 2 concrete slipways. Services available: boat movement (35 tonne marine travelift), dry berthing and long-term and winter storage. According to information from the harbourmaster, seasonal variation in occupancy rates is minimal and Titchmarsh Marina does not have sewage pump-out facilities. Twenty-three boats (including small dinghies, yachts and fishing boats) were moored in the creek at Westwater, Mill Lane creek adj. F. Halls & Son Boatyard (Figure XIII.11B). Approx. 40% of the moorings along Walton Channel occupied at time of survey. One yacht moored at Kirby Creek.
Dogs	One dog at Mill Lane Sluice adj. Walton Mere (Boating Lake) One dog at Marsh House.

Other animals	Bird droppings at Mill Lane Sluice (25354/21936). Waterbirds at Horsey Island, Pewit Island, Honey island and Skipper's Island (Figure XIII.12). Sheep (approx. 12 animals) grazing on saltmarsh at Horsey Island, east of Landing Place (Figure XIII.13). Colony of seals (approx. 25) at Bamble Creek and Pewit Island (Figure XIII.14) Approx. 30 cattle in fenced farm west of Coles Lane (Figure XIII.15). Two rabbits in grassland east of Coles Lane at 24516/22580. Three ducks in creek at Quay House.
Sewage related debris	Cotton buds at Mill Lane (25357/21935) (Figure XIII.16).
Samples taken	See Table XIII.2.
Bivalve harvesting activity	Bivalves are dredged using iron frames from vessel. Harvester informed that Manila clams coexist with oysters in hard subtidal bottoms of Kirby Creek; higher densities of harvestable stock have been found at Kirby Creek relative to those at Twizzle. Bivalve molluscs have been exported to Belgium.
Capacity of harvesting area	Ten tonnes of native oysters and 10 tonnes of Pacific oysters per annum.
Water appearance	Water appeared clear both in the marina and along The Twizzle and Kirby Creek channels.
Water temperature/salinity	24568/23436: 33.2ppt; 13.5°C 23911/25834: 33ppt; 13.2°C Northern limit of Kirby Creek bed (22692/24036) (13:59): 33.1ppt; 14.5°C Twizzle bed (24086/23711) (14:40): 33.3ppt; 15.4°C
Human population	Walton-on-the-Naze is a traditional seaside town. Water and land based tourism activities were noted to play an important role to local economy. Sailing and bird watching were identified at time of survey.
Topography	Topography of the area surveyed begins with an elevation of 5m along the shoreline and increases to 15m in places at Kirby-le-Soken.
Land Use	Agricultural land, mostly arable land. Urban and suburban areas in Walton-on-the-Naze and Kirby-le-Soken.
Other comments/observations	Cefas Officer and LEA made contact with owners of Campbells Cottage who informed that Campbells Cottage discharges to tidal waters no longer exist. Local residents at Kirby-le-Soken informed Cefas Officer and LEA that effluent from various private properties had been pumped onto ground surface two weeks before survey and that Kirby-le-Soken PS has not been functioning properly. Local fisherman informed Cefas Officer that there are people living permanently on boats at The Twizzle Channel. Manhole at Mill Lane (25318/21876) with effluent odour on 26th April at 21:00. A PVC pipe buried underground and discharging at 25324/21819 was inspected on 27th April indicating recent discharge. Unsure of origin. Applicant informed Cefas Officer that this is used to drain surface water.

Figure XIII.3 Sites sampled during the shoreline survey.

Figure XIII.5 Manhole cover at Hervilly Way and Walton Road Overflow.

Figure XIII.6 PVC pipe at dairy buildings.

Figure XIII.6 Kirby-le-Soken Pumping Station entrance.

Figure XIII.7 Main Maltings Pumping Station entrance.

Figure XIII.8 Marsh House Outfall.

Figure XIII.9 PVC pipe at Titchmarsh Marina.

Figure XIII.10 Pipes at Westwater, Mill Lane.

A B

Figure XIII.11 Titchmarsh Marina (A) and boats at Westwater Mill Lane creek (B).

Figure XIII.12 Waterbirds at Stock's Marsh, Horsey Island.

Figure XIII.13 Sheep on saltmarsh west of Barge Creek, Horsey Island.

Figure XIII.14 Seals at Bramble Creek.

Figure XIII.15 Cattle at Coles Lane Farm.

Figure XIII.16 Sewage related debris at Mill Lane creek.

Table XIII.2 Results of samples collected during the shoreline survey.

Sample ID	Matrix	Site sampled	Collection time	Easting	Northing	Total coliforms (CFU 100ml^{-1})	Faecal coliforms (CFU 100ml^{-1})	Salinity (ppt)	Temperature (°C)	Water appearance
A	Freshwater	Mill Lane Sluice	08:17	25347	21942	230	120	n/r	n/r	Clear
B	Freshwater	Main Maltings PS (downstream discharge point)	10:19	21810	22533	1,300	860	0.3	12.5	Brown (algae growth present in ditch)
C	Seawater	Kirby Creek	13:59	22866	23740	<10	<10	33.1	14.5	Clear
D	Seawater	The Twizzle	14:40	24086	23711	10	<10	33.3	15.4	Clear

Please refer to Figure XIII.2 for locations where these samples were collected. n/r - not recorded.

CONCLUSIONS

The following conclusions can be drawn from the shoreline survey:

1. The presence of sewage related debris in the proximity of Mill Lane Sluice suggests that Mill Lane creek could be receiving significant quantities of microbial contamination of faecal origin. However, the concentration of faecal coliforms in stream water was low at the time of the survey.

2. The absence of pump-out facilities at Titchmarsh marina and the information suggesting that some boat owners may be living on board at Walton Channel suggest that waste discharges from boats could be considered a potentially significant source of microbial contamination to Hamford Water.

3. The concentration of faecal coliforms in water sampled downstream Main Maltings PS discharge point was relatively low at the time of the survey.

4. Information from the LEA and local residents also suggested that pollution incidents associated with poor performance of Kirby-le-Soken PS have impacted water quality in recent times.

5. The high number of birds present at the time of the survey indicates that faecal matter from these animals may be a significant source of contamination.

6. The temperature and salinity measurements taken during the ebb tide suggest a fairly uniform body of surface water.

7. The concentrations of faecal coliforms below the detection limit in seawater samples indicate good microbial water quality in the Twizzle and Kirby Creek oyster beds at the time of the survey.

8. The presence of a seal colony in the vicinity of Bramble Creek will contribute to background levels of contamination in Hamford Water on a seasonal basis.

References

ABPMER LTD, HR WALLINGFORD, 2007. The Estuary Guide. A website based overview of how to identify and predict morphological change within estuaries. Website prepared for the joint Defra/EA Flood and Coastal Erosion Risk Management R&D Programme. November 2007. Available at:
http://www.estuary-guide.net/. Accessed October 2009.

ADNITT, C., BREW, D., COTTLE, R., HARDWICK, M., JOHN, S., JOHN, S., LEGGETT, D., MCNULTY, S., MEAKINS, N., STANILAND, R., in press. Saltmarsh management manual. Report by Royal Haskoning to the Environment Agency. Avalable at: http://www.saltmarshmanagementmanual.co.uk/PDFs/Chapter%201%20Introduction%20and%20Contents.pdf. Accessed November 2009.

BOORMAN, L. A., 2003. Saltmarsh review. An overview of coastal saltmarshes, their dynamic and sensitivity characteristics for conservation and management. JNCC Report No 334, JNCC, Peterborough.

EDWARDS, C.A., KAY, D., MCDONALD, A.T., FRANCIS, C., WATKINS, J., WILKINSON, J.R., WYER, M.D., 2008. Farmyards, an overlooked source of highly contaminated runoff. *Journal of Environmental Management* 87: 551−559.

ELLIS, J.B., MITCHELL, G., 2006. Urban Diffuse Pollution: key data information approaches for the Water Framework Directive. *Water and Environment Journal* 20: 19−26.

ENVIRONMENT AGENCY, 1998. North Essex. Local Environment Agency Plan. Consultation Report.

ENVIRONMENT AGENCY, 2003. An attempt to quantify faecal load from birds roosting on the piers at Blackpool. Environment Agency Report MSP-03-08.

ENVIRONMENT AGENCY, 2009. Walton Backwaters. Directive (2006/113/EC) on the quality required of Shellfihs Waters. Article 5 Programme.

ENVIRONMENT AGENCY, 2009. Water quality classification predictions for bathing waters in England and Wales under the revised Bathing Water Directive - no discounting. Available at: http://www.defra.gov.uk/environment/quality/water/waterquality/bathing/documents/bathingwaterqualitypredictions.pdf.

ESSEX COUNTY COUNCIL, 2010. http://www.visitessex.com/media/MarketResearch.aspx.

EUROPEAN COMMUNITIES, 2004b. Regulation (EC) No 853/2004 of the European Parliament of of the Council of 29 April 2004 laying down specific hygiene rules for food of animal origin. *Official Journal of the European Communities* L226: 22−82.

EUROPEAN COMMUNITIES, 2004a. EC Regulation No 854/2004 of the European Parliment and of the Council of 29 April 2004 laying down specific hygiene rules on products of animal origin intended for human consumption. *Official Journal of the European Communities* L226: 83-127.

EUROPEAN COMMUNITIES, 2005. Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs. *Official Journal of the European Union* L338, 22/12/2005:1−26.

EUROPEAN COMMUNITIES, 2006a. Directive 2006/7/EC of the European Parliament and of the Council of 15 February 2006 concerning the management of Bathing Water Quality and repealing Directive 76/160/EEC. *Official Journal of the European Communities* L64: 37−51.

EUROPEAN COMMUNITIES, 2006b. Directive 2006/113/EC of the European parliament and of the Council of 12 December 2006 on the quality required of shellfish waters (codified version). Official Journal of the European Communities L376: 14-20.

EUROPEAN COMMUNITIES, 2008. Commission Regulation (EC) No 1021/2008 of 17 October 2008 amending Annexes I, II and III to Regulation (EC) No 854/2004 of the European Parliament and of the Council laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption and Regulation (EC) No 2076/2005 as regards live bivalve molluscs, certain fishery products and staff assisting with official controls in slaughterhouses. *Official Journal of the European Union* L277: 15−17.

FEARE, C., 2001. Birds as a potential source of bacterial contamination on the Fylde coast. Wild Wings Bird Management Unpublished Report to the Environment Agency.

GELDREICH, E.E. 1978. Bacterial and indicator concepts in feces, sewage, stormwater and solid wastes. *In* Berg, G. (ed.). *Indicators of Viruses in Water and Food.* MI: Ann Arbor.

GUTHRIE, G., COTTLE, R., 2002. Suffolk coast and estuaries coastal habitat management plan. Posford Haskoning Ltd, Coastal & Rivers Report to English Nature/Environment Agency.

HALCROW GROUP LTD., 2003. Futurecoast, 2002 - Coastal processes and geomorphological study of the coastline. Department of Environment, Food and Rural Affairs. 3 CD set.

HARWICH INTERNATIONAL PORT LTD., 2005. Available at: http://www.harwich.co.uk/.

HUGHES, C., GILLESPIE, I.A., O'BRIEN, S.J., 2007. Foodborne transmission of infectious intestinal disease in England and Wales 1992-2003. *Food Control* 18: 766−772.

IMRAY LAURIE NORIE & WILSON LTD., 2006. Harwich Approaches & Walton Backwaters - 2000.4.

ISO/TS 16649-3, 2005. Microbiology of food and animal feeding stuffs -- Horizontal method for the enumeration of beta-glucuronidase-positive *Escherichia coli* -- Part 3: Most probable number technique using 5-bromo-4-chloro-3-indolyl-beta-D-glucuronide.

KAY, D., CROWTHER, J., STAPLETON, C.M., WYER, M.D., FEWTRELL, L., EDWARDS, A., FRANCIS, C.A., MCDONALD, A.T., WATKINS, J., WILKINSON, J., 2008. Faecal indicator organism concentrations in sewage and treated effluents. *Water Research* 42: 442-454.

LAING, I., CHILD, A.R., 1996. Comparative tolerance of small juvenile palourdes (*Tapes decussatus* L.) and Manila clams (*Tapes philippinarum* Adams & Reeve) to low temperature. Journal of Experimental Marine Biology and Ecology 195: 267-285.

LAING, I., SPENCER, B.E., 2006. Bivalve cultivation: criteria for selecting a site. Cefas Science Series Technical Report 136.

LAING, I., WALKER, P., AREAL, F., 2005. A feasibility study of native oyster (*Ostrea edulis*) stock regeneration in the United Kingdom. CARD Project FC1016. Native Oyster Stock Regeneration - a Review of Biological, Technical and Economic Feasibility.

LEE, R.J., YOUNGER, A.D., 2002. Developing microbiological risk assessment for shellfish purification. *International Biodeterioration and Biodegradation* 50: 177−183.

MAWDSLEY, J.L., BARDGETT, R.D., MERRY, R.J., PAIN, B.F., THEODOROU, M.K., 1995. Pathogens in livestock waste, their potential for movement through soil and environmental pollution. *Applied Soil Ecology* 2: 1−15.

MET OFFICE, 2009. Climate: Wales. Available at: http://www.metoffice.gov.uk/climate/uk/wl/. Accessed October 2009.

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD, 1963. The Horsey Island Oyster Fishery Order 1963. Statutory Instrument No. 1005.

MOUCHEL, 1997. Essex Shoreline Management Plan.

NERC, 2005. Catchment spatial information. Available at: http://www.nwl.ac.uk/ih/nrfa/spatialinfo/Index/indexCatchmentSpatialInfo.html.

OBIRI-DANSO, K., JONES, K., 2000. Intertidal sediments as reservoirs for hippurate negative campylobacters, salmonellae, and faecal indicators in three EU recognised bathing waters in North-West England. *Water Research* 34(2): 519−527.

OFFICE FOR NATIONAL STATISTICS, 2007. Mid-2005 population estimates for river catchment areas within England and Wales.

OFFICE FOR NATIONAL STATISTICS, 2008. Mid-2006 population estimates for 2001 Census defined urban areas in England and Wales by broad age and sex.

ROYAL HASKONING, 2003. Felixtowe South reconfiguration. Hydrodynamic and sedimentary regime. Environmental Statement Report to Hutchinson Ports (UK) Ltd.

SPENCER, B., 2002. Molluscan shellfish farming. Fishing News Books, Blackwell Publishing.

SPENCER, B.E., EDWARDS, D.B., KAISER, M.J. AND RICHARDSON, C.A., 1994. Spatfalls of the non-native Pacific oyster, *Crassostrea gigas*, in British waters. Aquatic Conservation: Marine and Freshwater Ecosystems 4: 203-217.

THE NAZE PROTECTION SOCIETY, 2010. http://www.nazeprotectionsociety.org.uk/.

THE NAZE TOWER, 2010. http://www.nazetower.co.uk/tower_gallery.html.

WHITEHOUSE, R.J.S., BASSOULLET, P., DYER, K.R., MITCHENER, H.J., ROBERTS, W., 2000. The influence of bedforms on flow and sediment transport over intertidal mudflats. *Continental Shelf Research*, 20: 1099-1124.

WHITHER, A., REHFISCH, M., AUSTIN, G., 2003. The impact of bird populations on the microbial quality of bathing waters. *In:* Proceedings of the Diffuse Pollution Conference, Dublin.

YOUNGER, A.D., LEE, R.J., LEES, D.N. 2003. Microbiological monitoring of bivalve mollusc harvesting areas in England and Wales: rationale and approach. In: Villalba, A., Reguera, B., Romalde, J. L., Beiras, R. (eds). Molluscan Shellfish Safety. Consellería de Pesca e Asuntos Marítimos de Xunta de Galicia and Intergovernmental Oceanographic Commission of UNESCO, Santiago de Compostela, Spain. pp. 265−277.

List of Abbreviations

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

Glossary

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

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

Acknowledgements

Cefas would like to thank Dominic Bailey (Kent & Essex Sea Fisheries Committee), Owen Bloom (Naze Oysters Ltd), John Daniels (Environment Agency), Karen Hills (Environment Agency), Edward King (Tendring DC) and Ian Knapper (Defra - Food and Farming Group).