EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT
Blackwater & Dengie

2013

Cover photo: Oyster trestles at Goldhanger

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STATEMENT OF USE: This report provides a sanitary survey relevant to bivalve mollusc beds within the Blackwater estuary and off Dengie, as required under EC Regulation 854/2004 which lays down specific rules for official controls on products of animal origin intended for human consumption. It provides an appropriate hygiene classification zoning and monitoring plan based on the best available information with detailed supporting evidence. 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	06/03/13	None received
Maldon DC	06/03/13	22/03/13
Kent & Essex IFCA	06/03/13	08/04/13
Anglian Water	06/03/13	None received

DISSEMINATION: Food Standards Agency, Maldon District Council, Environment Agency, Kent and Essex IFCA.

RECOMMENDED BIBLIOGRAPHIC REFERENCE: Cefas, 2013. Sanitary survey of the Blackwater and Dengie. 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.

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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 shellfish hygiene. Improved monitoring should lead to improved detection of pollution events and identification of the likely sources of pollution. Remedial action may then be possible either through funding of improvements in point sources of contamination or as a result of changes in land management practices.

This report documents the information relevant to undertake a sanitary survey for Pacific oysters (*Crassostrea gigas*), native oysters (*Ostrea edulis*) and mussels (*Mytilus* spp.) within the Blackwater estuary and cockles (*Cerastoderma edule*) at Dengie Flats. The area was prioritised for survey in 2012-13 by a shellfish hygiene risk ranking exercise of existing classified areas.

1.2 AREA DESCRIPTION

SITE DESCRIPTION

The Blackwater Estuary is a macro tidal estuary approximately 23 km in length and situated on the Essex coast, in the east of England. It is one of the largest estuarine complexes in East Anglia. The estuary receives runoff from two lowland river catchments (Chelmer and Blackwater) and flows into the southern North Sea. Dengie Flats is a large intertidal area on the open coast adjacent to the Dengie Peninsula, which lies between the Blackwater estuary and the Crouch Estuary.

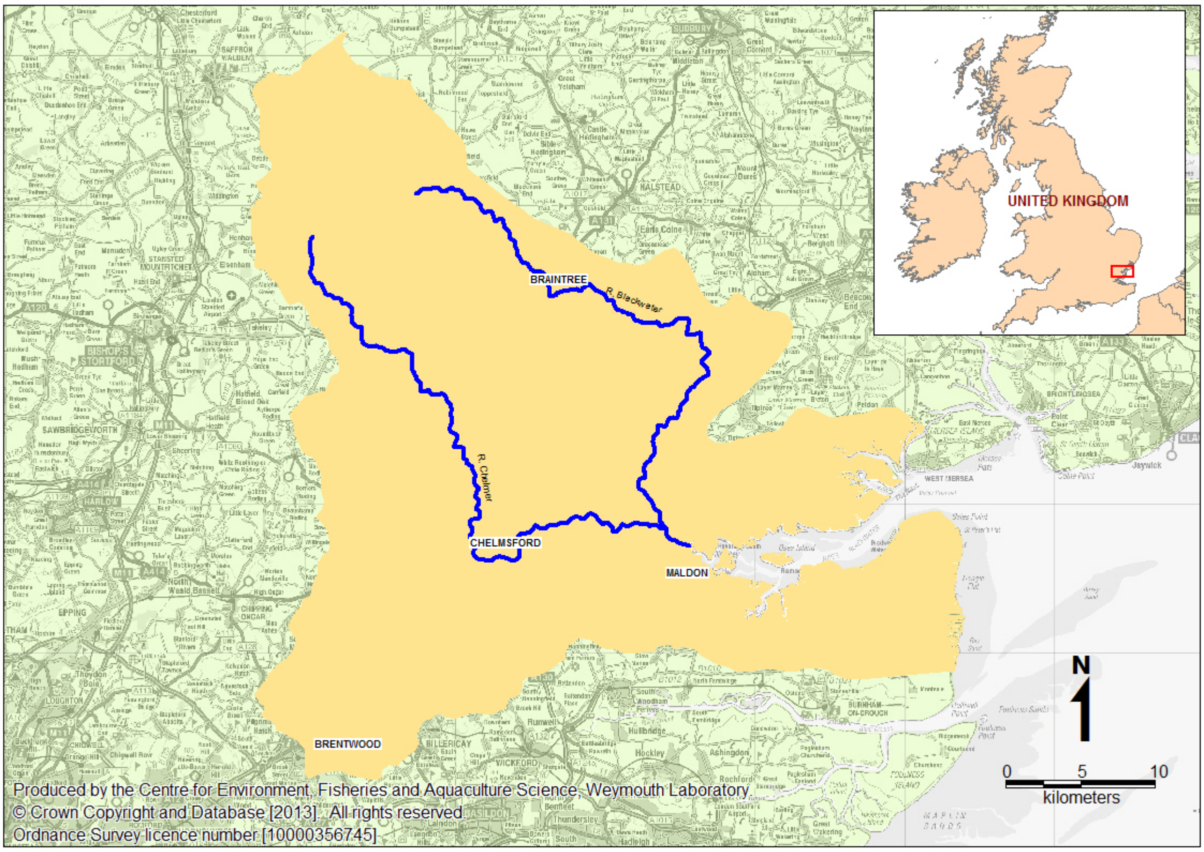


Figure 1.1 Location of the Blackwater Estuary

The survey area encompasses a rich variety of estuarine habitats; extensive areas of intertidal mudflats, saltmarsh, shingle banks, sandflats and some small islands. The catchment is relatively low lying and prone to flooding consequently the majority of the coastline is protected by seawalls. Large parts of the Dengie Peninsula are reclaimed land. The Blackwater estuary falls under several national and international designations: the Essex Estuaries SAC, SSSI, SPA, NNR, and Wetland Ramsar sites owing to the range of biodiversity the estuary supports, such as large numbers of internationally and nationally important flocks of wading and migratory birds.

The intertidal mudflats sustain a large variety of marine invertebrates; a source of food for the birds that frequent the mudflats and shellfish for human consumption. Native oysters (*Ostrea edulis*) have been harvested from the Blackwater Estuary since Roman times, and a naturally sustaining population of Pacific oysters has developed here in recent years. Dengie Flats supports commercial cockle beds as well as native oysters.

CATCHMENT

Figure 1.2 shows the land cover within the hydrological catchment draining to the survey area.

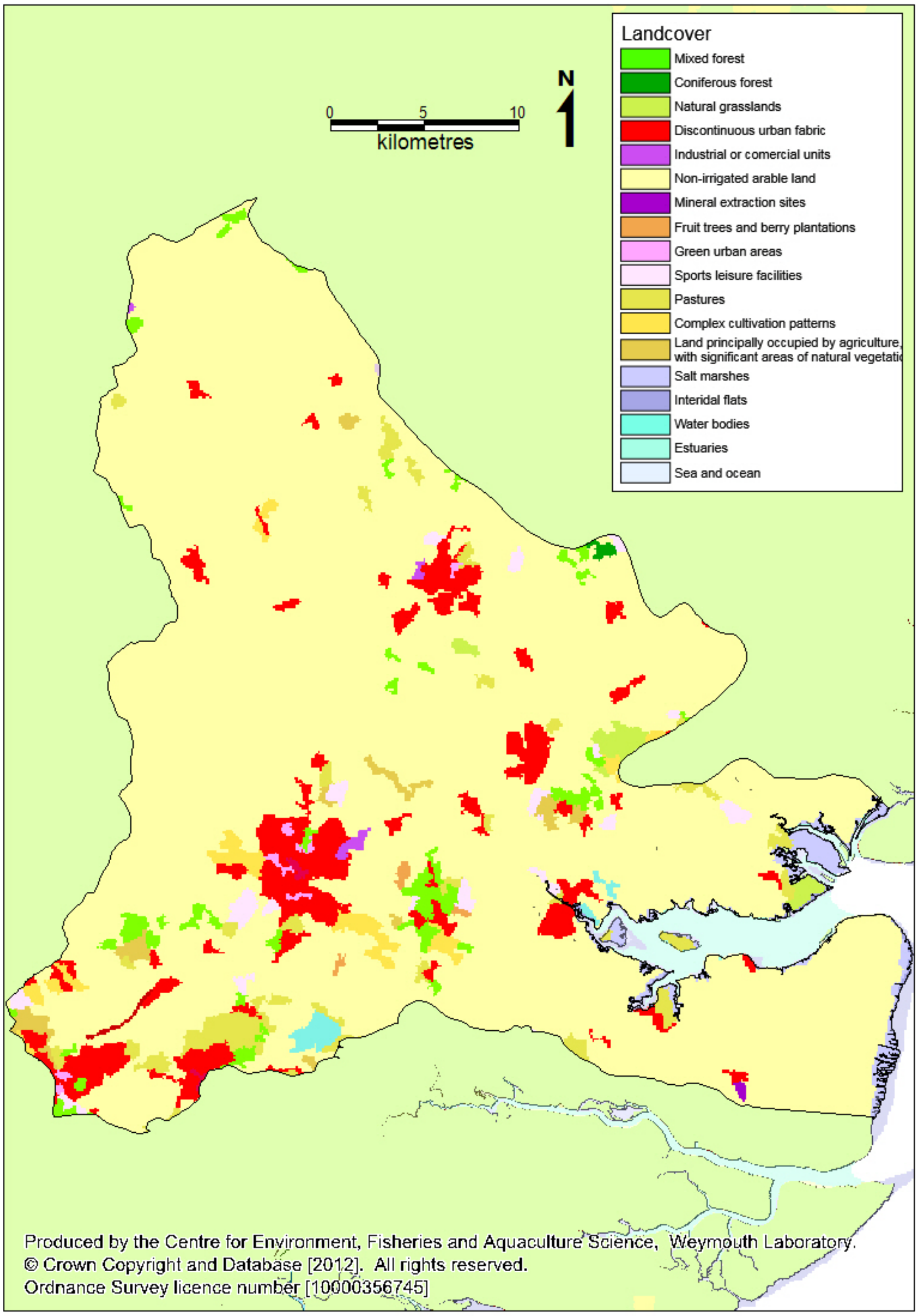


Figure 1.2 Land Cover in the Blackwater Estuary

The Blackwater catchment covers an approximate area of 1,200 km² of which around 70% is arable farmland (Figure 1.2). There are several clusters of urbanised land which represent the main towns of Chelmsford, Maldon, Braintree and Witham. Surrounding the urbanised regions are leisure facilities, mixed woodland and a few mineral extraction sites. Osea Island and Northey islands both connected to the main land by tidal causeways are largely uninhabited. Osea is a privately owned island with one settlement in the centre of the island and is predominantly pasture land. Northey Island has two houses situated on the western tip and is over 75% saltmarsh. The Dengie Peninsula is sparsely populated and is all used for arable farming.

Highest faecal coliform contributions arise from developed areas, with intermediate contributions from the improved pastures and lower contributions from the other land cover types (Kay *et al*. 2008a). The contributions from all land cover types would be expected to increase significantly after marked rainfall events, particularly for improved grassland which may increase up to 100 fold.

For the most part, the underlying bed rock is largely low-permeability clay. In the northern reaches of the catchment however, the bed rock is high permeability chalk. The low permeability of most of the catchment means that there are relatively high runoff rates (Environment Agency, 2009).

2. RECOMMENDATIONS

Sampling plans are provided for Pacific oysters, native oysters and cockles, as these are the commercially harvested species. All zones within the Blackwater estuary contain some private grounds so the native oyster fishery here may still be active. Although the native oyster fishery is closed on the public grounds within the zones off Dengie, it is understood it may open here in April 2013. Sources identified should have some stock present and be safely accessible, but this cannot be confirmed without a further site visit. Some adjustment to RMP locations may therefore be required but the principles identified in this report and recommendations should be applied as far as possible. Mussels are present in some parts of the Blackwater and some areas are currently classified for this species but they are not harvested commercially. If a classification is required for mussels, the same zoning and monitoring recommendations as for oysters may be applied as required, with mussels as the species sampled.

PACIFIC AND NATIVE OYSTERS

The following six zones are recommended for oysters:

Osea South. This zone covers the area to the south of Osea Island. It holds stocks of Pacific oysters, and occasional native oysters, although natives are not harvested at present. Sources of contamination are primarily catchment sources entering at the head of the estuary, and contamination from these may not impact on the lower reaches of this zone on smaller tides. The drainage channel from the Maldon STW discharge runs under the Osea Island causeway and through this zone to the main estuary channel, although the bacterial loading it generates is small. There are also some sources to Lawling Creek and Mayland Creek, including some small watercourses and two small sewage works and a few intermittent discharges. It is recommended that the RMP for this zone is located off Decoy Point by the upstream boundary of this zone. Microbiological monitoring results indicating higher levels of contamination at Ford Creek and Southey Creek compared to the mouth of Lawling Creek support this conclusion. The LEA advises that the best practical option is to sample from a deployment bag hung from the North Double Buoy.

The species sampled should be Pacific oysters, which can be used to classify both Pacific and native oysters. Sampling should be from deployment bag, and a tolerance of 10m applies. Sampled stock should be allowed to equilibrate for at least two weeks *in situ*. The sampling frequency should be monthly and year round. Sampled stock should be of a market size.

Goldhanger. This zone lies to the north of Osea Island and includes the trestle site at Goldhanger. Species present are Pacific oysters and occasional native oysters although natives are not harvested at present. Sources of contamination impacting directly on this zone are limited to minor watercourses, the most significant of which discharges by Bounds Farm and appeared to be carrying sewage at the time of shoreline survey. Contamination from sources at the head of the estuary would take two tides to reach this zone and so would not create much of a gradient across it. An RMP located on the lower intertidal by the drainage channel from Bounds Farm Stream should be suitably representative of the zone.

The species sampled should be Pacific oysters, which can be used to classify both Pacific and native oysters. Sampling may be via hand or dredge, and a tolerance of 100m applies. The sampling frequency should be monthly and year round. Sampled stock should be of a market size.

Central Blackwater. This zone covers the middle reaches of the Blackwater estuary. Species present are Pacific and native oysters, as well as some mussels which are not exploited commercially. Sources of contamination include two watercourses discharging to the head of Thirslet Creek, one of which receives effluent from a small sewage works, a watercourse receiving the effluent from a small sewage works at Ramsey Marshes, and some moorings and a small private sewage discharge by the Marconi Sailing club. There are also some intermittent discharges and moorings off St Lawrence. There are therefore two obvious possibilities for RMP location within this zone, either at the head of Thirslet Creek or by the freshwater outfall from Ramsey Marshes. Sources around Ramsey Marshes are more numerous and varied so on balance the RMP should be located here.

The species sampled should be Pacific oysters, which can be used to classify both Pacific and native oysters. Sampling may be via hand or dredge, and a tolerance of 100m applies. The sampling frequency should be monthly and year round. Sampled stock should be of a market size.

Outer Blackwater. This zone includes the outer reaches of the Blackwater estuary and the area off the northern tip of the Dengie peninsula. Species present are Pacific and native oysters. There is a cluster of sources of contamination at Bradwell, including a small sewage works, two intermittent discharges, a marina and moorings, and a bird colony on Pewet Island. The Bradwell Power Station discharge may contribute to the bacterial loading received by the estuary but the effluent will be highly diluted and the discharge is to deeper water. An RMP located on the lower intertidal just east of the Bradwell Marina should capture contamination from these sources.

The species sampled should be Pacific oysters, which can be used to classify both Pacific and native oysters. Sampling may be via hand or dredge, and a tolerance of 100m applies. The sampling frequency should be monthly and year round. Sampled stock should be of a market size.

St Peters & Bachelor. This zone includes the lower intertidal and subtidal off the northern part of the Dengie peninsula. Only native oysters occur here. Sources of contamination here include a freshwater outfall from the Dengie Marshes and the ebb plume from the Blackwater. Diffuse pollution from wildlife may also be of some significance. This area was affected by a large contamination event in late 2011 and early 2012. The source of contamination was not determined but it affected only the area off Dengie and not the adjacent estuaries, suggesting it arose from the east shore of the Dengie peninsula. The hydrography of the area would also support this conclusion. It is therefore recommended that the existing RMP at Bachelor Spit be retained to best capture contamination originating from the Dengie shore.

The species sampled should be native oysters. Sampling should be via dredge, and a tolerance of 100m applies. The sampling frequency should be monthly although May and June will not require sampling. A minimum of 10 samples per year are required to maintain the classification. Sampled stock should be of a market size.

Ray Channel. This zone includes the lower intertidal and subtidal off the southern part of the Dengie peninsula. Only native oysters occur here. Sources of contamination here include two freshwater outfalls from the Dengie Marshes and the ebb plume from the Crouch. Diffuse pollution from wildlife may also be of some significance. This area was affected by a large contamination event in late 2011 and early 2012. The source of contamination was not determined but it affected only the area off Dengie and not the adjacent estuaries, suggesting it arose from the east shore of the Dengie peninsula. The hydrography of the area would also support this conclusion. It is therefore recommended that the RMP be located in the Ray Channel to best capture contamination originating from the Dengie shore.

The species sampled should be native oysters. Sampling should be via dredge, and a tolerance of 100m applies. The sampling frequency should be monthly although May and June will not require sampling. A minimum of 10 samples per year are required to maintain the classification. Sampled stock should be of a market size.

COCKLES

The cockle fishery is likely to open later in 2013. The following two zones are recommended for cockles.

Dengie Flats. This zone includes the intertidal area adjacent to the east coast of the Dengie peninsula. Sources of contamination are three freshwater outfalls, as well as diffuse contamination from wildlife. The ebb plumes from the Crouch and Blackwater estuaries may also be an influence. This area was affected by a large contamination event in late 2011 and early 2012. The source of contamination was not determined but it affected only the area off Dengie and not the adjacent estuaries, suggesting it arose from the east shore of the Dengie peninsula. The hydrography of the area would also support this conclusion. It is therefore recommended that the RMP be located in the path of the Grange Outfall stream, as high up the intertidal as possible.

The species samples should be cockles. Sampling may be via either hand gathering or suction dredging. It is recognised that there is some uncertainty whether a small craft can be landed here for hand sampling, and that the use of a suction dredge may be prohibitively costly. The sampling frequency should be monthly although the months of December and January will not require sampling. A total of 10 samples per year will be required to maintain a full classification.

Buxey Sands. This zone includes the sandspit protruding from the south of Dengie Flats. Sources of contamination are freshwater outfalls, as well as diffuse contamination from wildlife. The ebb plume from the Crouch estuaries may also be an influence. This area was affected by a large contamination event in late 2011 and early 2012. The source of contamination was not determined but it affected only the area off Dengie and not the adjacent estuaries, suggesting it arose from the east shore of the Dengie peninsula. The hydrography of the area would also support this conclusion. It is therefore recommended that the RMP be located at the northern inshore part of the Buxey Sands.

The species samples should be cockles. Sampling may be via either hand gathering or suction dredging. It is recognised that there is some uncertainty whether a small craft can be landed here for hand sampling, and that the use of a suction dredge may be prohibitively costly. The sampling frequency should be monthly although the months of December and January will not require sampling. A total of 10 samples per year will be required to maintain a full classification.

3. SAMPLING PLAN

GENERAL INFORMATION

Location Reference

Production Area	Blackwater
Cefas Main Site Reference	M014
Ordnance survey 1:25,000 map	Explorer 176
Admiralty Chart	1975

Shellfishery

Species/culture	Native oysters (*Ostrea edulis*) Pacific oysters (*Crassostrea gigas*) Cockles (*Cerastoderma edule*)	Wild & cultured Wild & cultured Wild
Seasonality of harvest	September to April (native oysters) Variable within the June to November window (cockles) Year round (all other species)	

Local Enforcement Authority

Name	Maldon District Council Princes Road Maldon Essex CM9 5DL
Environmental Health Officer	Malcolm Sach
Telephone number ☎	01621 875830
Fax number	01621 875899
E-mail	malcolm.sach@maldon.gov.uk

REQUIREMENT FOR REVIEW

The Guide to Good Practice for the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2010) indicates that sanitary assessments should be fully reviewed every 6 years, so this assessment is due a formal review in 2019. The assessment may require review in the interim should any significant changes come to light, such as the upgrading or relocation of any major discharges.

Table 3.1 Number and location of representative monitoring points (RMPs) and frequency of sampling for classification zones

Classification zone	RMP code	RMP name	NGR	Latitude & Longitude (WGS84)	Species Sampled	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Osea South	B014U	North Double Buoy	TL 8970 0620	51° 43.00' N 00° 44.80' E	Pacific oyster	Wild	Hand/dredge	Bagged	10m	Monthly	New RMP. Represents Pacific and native oysters
Goldhanger	B014V	Goldhanger	TL 9116 0795	51° 44.26' N 00° 46.03' E	Pacific oyster	Wild	Hand/dredge	Hand	100m	Monthly	New RMP. Represents Pacific and native oysters
Central Blackwater	B014W	Ramsey Marsh	TL 9351 0601	51° 43.10' N 00° 47.90' E	Pacific oyster	Wild	Hand/dredge	Hand	100m	Monthly	New RMP. Represents Pacific and native oysters
Outer Blackwater	B014X	Bradwell	TL 9954 0858	51° 44.42' N 00° 53.33' E	Pacific oyster	Wild	Hand/dredge	Dredge	100m	Monthly	New RMP. Represents Pacific and native oysters
St Peters & Bachelor	B014A	Bachelor Spit	TM 0880 0590	51° 42.78' N 01° 01.26' E	Native oyster	Wild	Dredge	Dredge	100m	Monthly (excluding May and June)	Represents native oysters only
Ray Channel	B014Y	Ray Channel	TM 0644 0142	51° 40.41' N 00° 59.06' E	Native oyster	Wild	Dredge	Dredge	100m	Monthly (excluding May and June)	New RMP. Represents native oysters only
Dengie Flats	B014Z	Grange Outfall	TM 0498 0188	51° 40.69' N 00° 57.81' E	Cockle	Wild	Suction dredge	Dredge	100m	Monthly	New RMP. Represents cockles only
Buxey Sands	B144A	Buxey Sands	TM 0716 0136	51° 40.36' N 00° 59.68' E	Cockle	Wild	Suction dredge	Hand/ dredge	100m	Monthly	New RMP. Represents cockles only

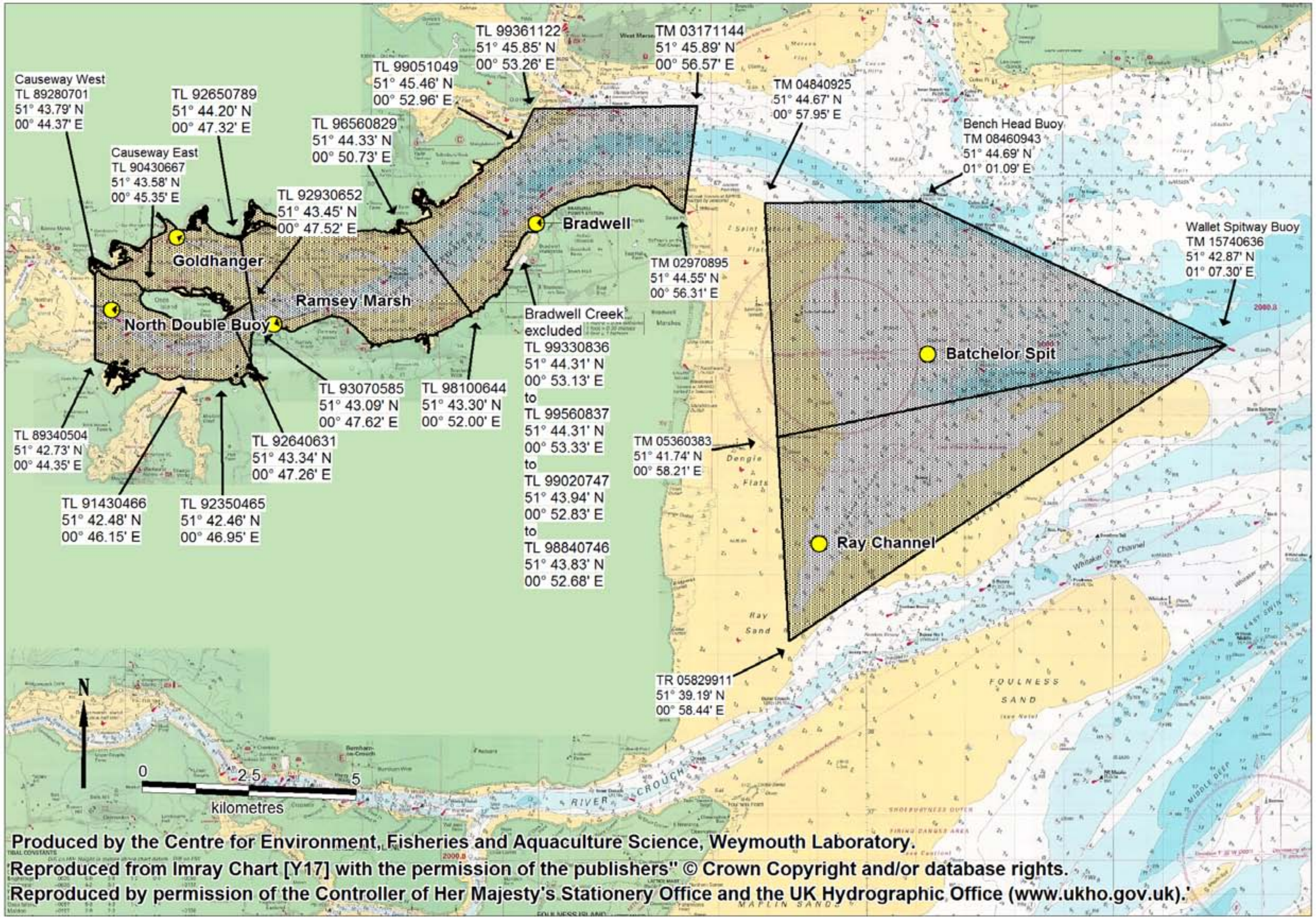


Figure 3.1 Recommended classification zone boundaries and RMP locations (native oysters)

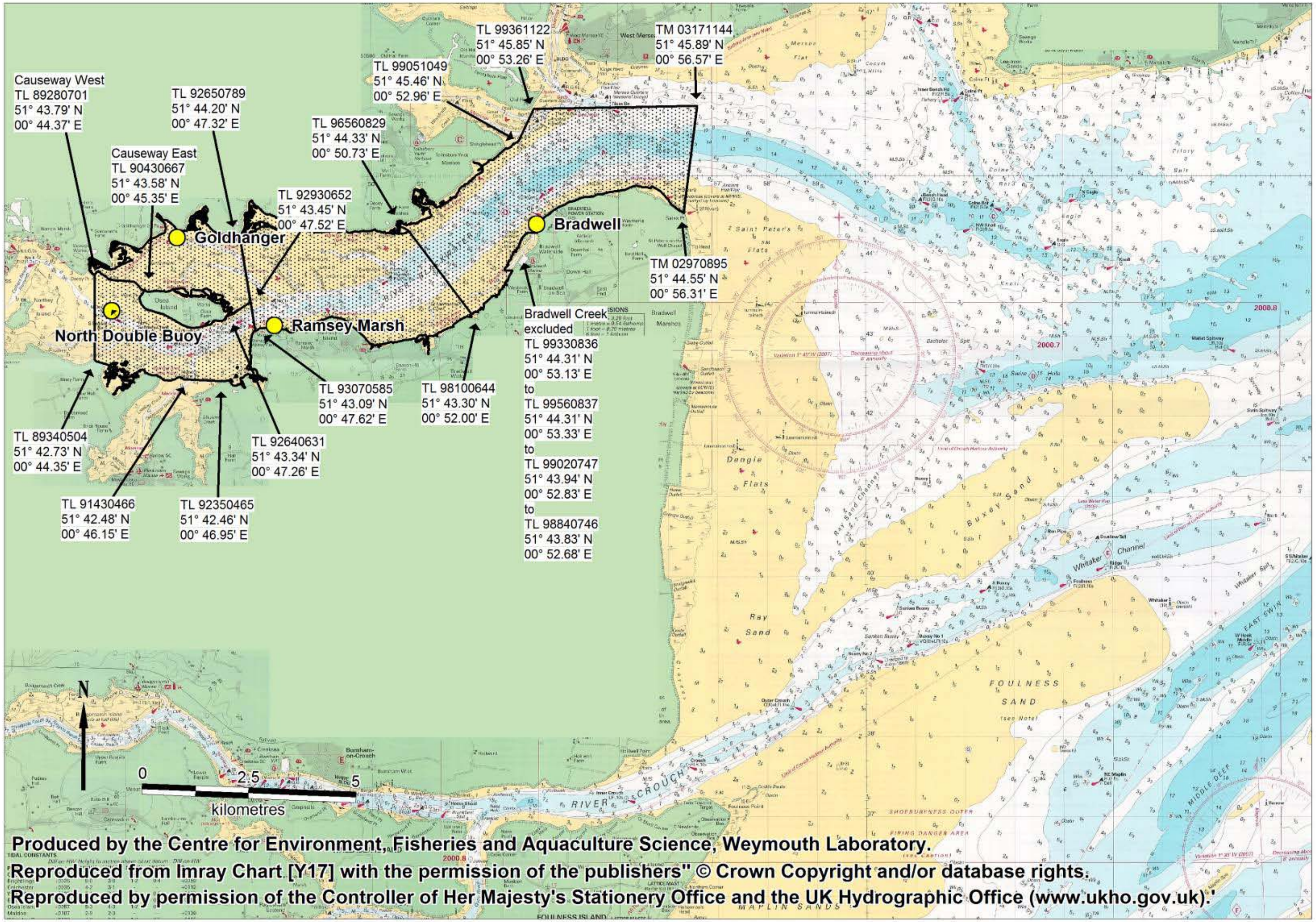


Figure 3.2 Recommended classification zone boundaries and RMP locations (Pacific oysters)

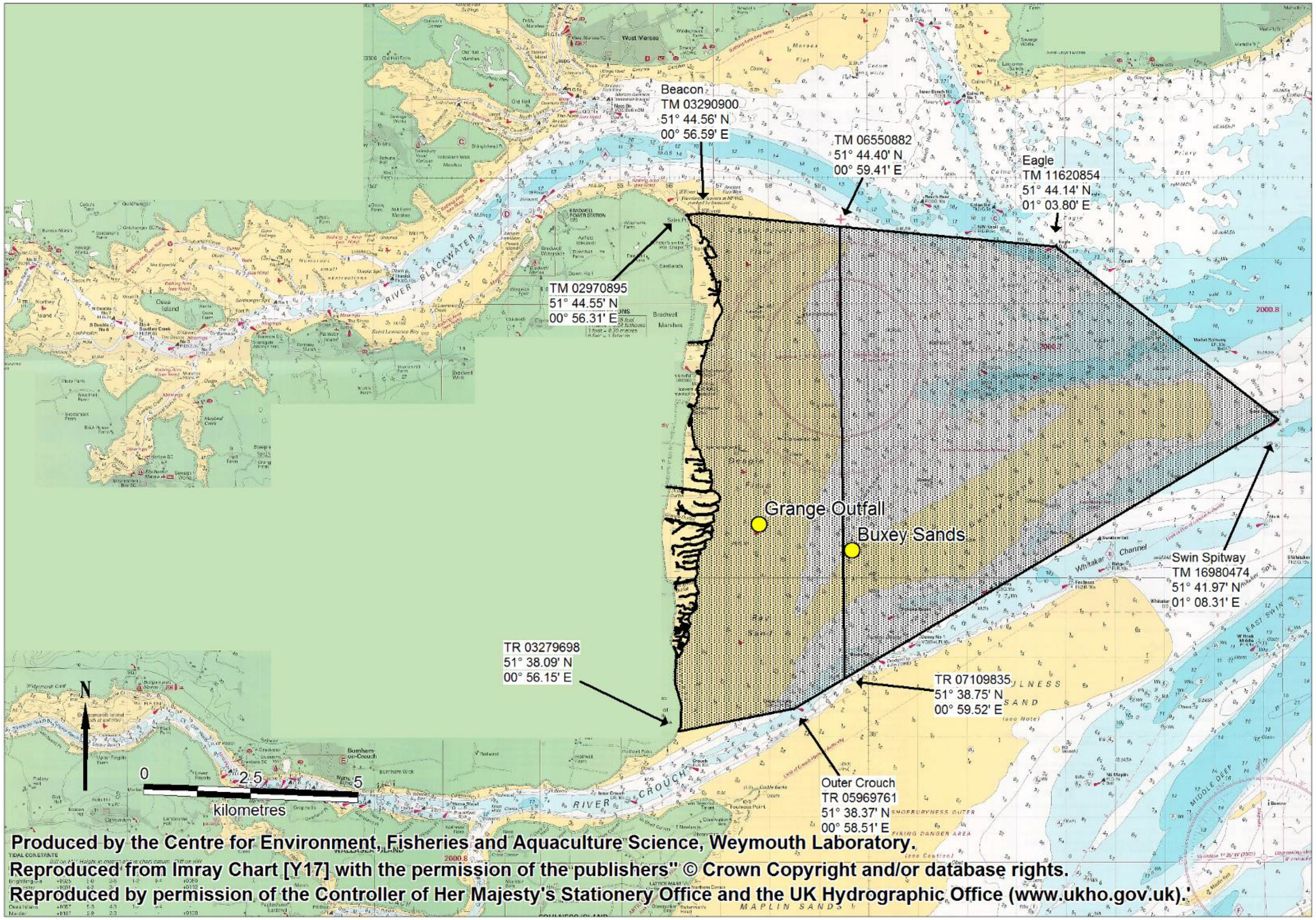


Figure 3.3 Recommended classification zone boundaries and RMP locations (cockles)

4. SHELLFISHERIES

SPECIES, LOCATION AND EXTENT

The Blackwater production area includes the main body of the Blackwater estuary and the intertidal and subtidal area extending east from the Dengie Peninsula. Tollesbury Fleet, Salcott Channel, Strood Channel and Mersea Flats fall within the adjacent West Mersea Production area.

Within the Blackwater production area, most of the outer estuary falls within the Tollesbury and Mersea (Blackwater) Fishery Order 1999 which is a private fishery. Most of the inner reaches of the estuary are owned by Maldon Council who lease the area to the Maldon Oyster Company. There are some public grounds around St Lawrence on the south shore. The area off Dengie is a public fishery. Figure 4.1 shows the shows the location of private grounds, oyster trestles and cockle beds.

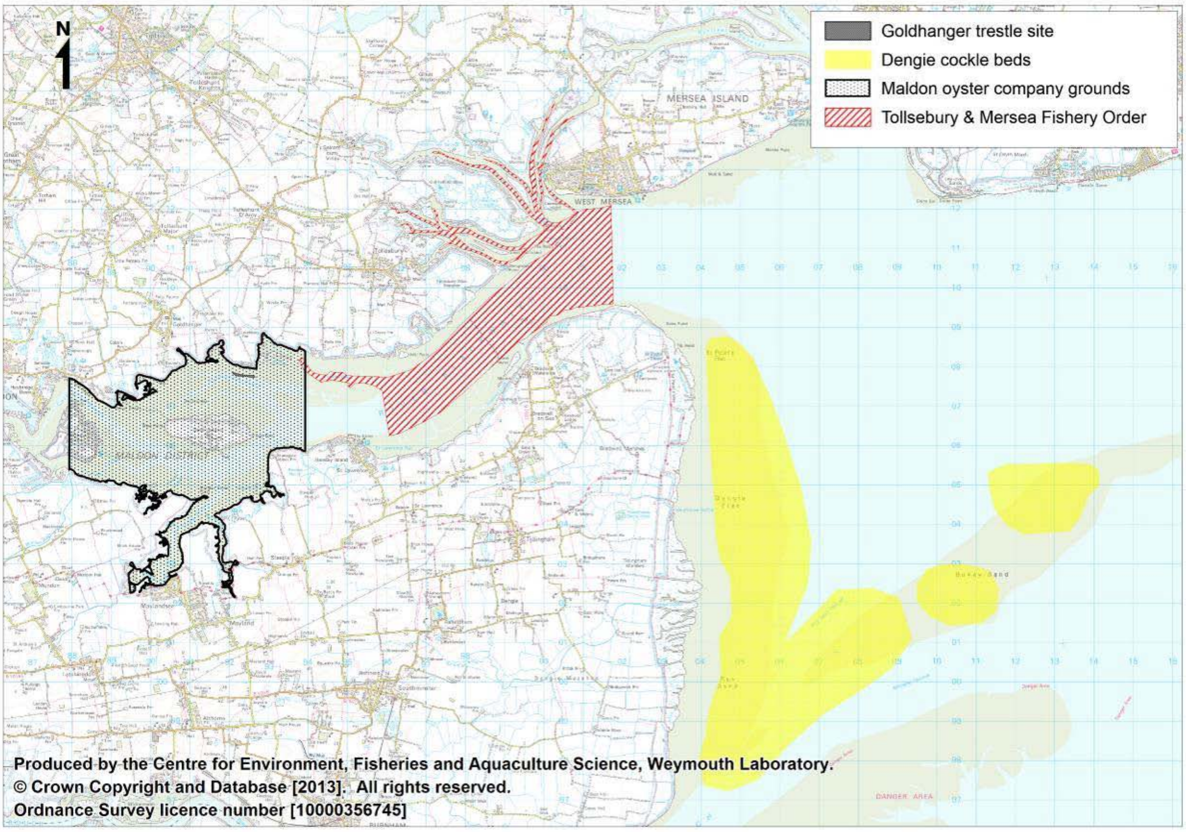


Figure 4.1 Blackwater fisheries

PACIFIC OYSTERS

Pacific oysters are naturally occurring throughout the Blackwater estuary. The main concentrations are in the less muddy intertidal areas. They may be harvested directly or moved to oyster lays in the neighbouring West Mersea Production area. They are also cultured on trestles at Goldhanger.

NATIVE OYSTERS

This species occurs naturally throughout the survey area, both off Dengie and in the Blackwater estuary. They are mainly found in the subtidal areas of the outer estuary and off Dengie. Stocks are now at a very low level and the public fishery is currently closed. Some limited harvesting and on-growing of this species may still continue within the private grounds, although this species is not currently being harvested by the Maldon Oyster Company.

MUSSELS

There are some minor mussel beds within the Blackwater estuary, although this species does not tend to occur naturally in significant amounts. They are present within Thirslet Creek, although stocks here are being displaced by Pacific oysters to such an extent that the LEA is finding it increasingly difficult to sample this area. This bed is not of commercial interest. There are also some mussel stocks present within the Maldon Oyster Company grounds around the mouth of Lawling Creek, and just west of Osea Island but these are not harvested commercially. Outside of the estuary, there are some mussels within Swire Hole which have historically been used as a source of seed for on-growing on occasion. The LEA has noted that there are significant stocks of (generally undersized) mussels at the RMP they sample by dredge at Ray Sands. The previous survey of the upper reaches of Blackwater was prompted in part by interest in relaying seed mussels south of Osea Island. This fishery was never developed, and the C classification for mussels here would preclude sales direct to the live market.

COCKLES

There are significant cockle stocks on the lower intertidal areas of Dengie Flats and Buxey Sands. The approximate locations of the main concentrations are shown in Figure 4.1. The area falls outside of the Thames Estuary Cockle Fishery Order and is managed via Kent & Essex IFCA byelaws. It has been closed for the past three years, and currently there are reasonable densities of adult cockles present here.

4.2 GROWING METHODS AND HARVESTING TECHNIQUES

Naturally occurring Pacific oysters may be collected by hand or dredge. Those taken from the Maldon Oyster Company Grounds may be on-grown on trestles at Goldhanger, and those taken from the Tollesbury & Mersea Fishery Order may be on-grown on oyster lays within the West Mersea production area. Naturally occurring native oysters are collected by dredge, and may also be on-grown within the West Mersea production area, but Goldhanger is not currently classified for this species. Mussels are not harvested on a commercial basis within the survey area. Cockles are harvested by suction dredge. Hand gathering of cockles is unlikely to occur off Dengie as access to the foreshore is difficult, the foreshore itself is treacherously soft in places, and it may be difficult for a hand gatherer to find a local processor willing to accept small batches.

4.3 Seasonality of harvest, conservation controls and development potential

There are no specific conservation controls applying to Pacific oysters such as a closed season or minimum landing size. Harvesting may occur at any time of the year. Pacific oyster stocks have become more numerous and widespread in recent years in the south east of England, and it is likely that their expansion will continue on the whole, as recruitment occurs on an annual basis. The recent occurrence of oyster herpes virus in the area does not appear to have had a major effect on naturally occurring stocks of this species here, although some mortalities have occurred at the trestle site at Goldhanger.

There is a closed season for native oysters which runs from May to August inclusive, and applies to both the public and private grounds. A minimum landing size of 70mm applies to this species. A maximum width of dredge (or dredges) of 4m applies. Native oyster fishing was closed by the Kent and Essex IFCA in May 2012 for at least one year to aid stock recovery, although this only applies to public grounds. The IFCA hopes to open the area subtidal area between Dengie Flats and Buxey Sands for oyster dredging in April 2013, probably only for a short period, but a formal decision on this has yet to be made. If the public fishery is fully re-opened in the future it may be subject to additional management measures to help sustain any recovery. It remains uncertain whether a significant recovery will occur over the next few years.

There is no closed season for mussels. No more than 10% by weight of a representative sample of the catch can pass through a space 18mm in width within the district. Dredging for seed mussels requires authorisation from the IFCA, and seed mussels cannot currently be moved out of the area due to disease controls. The relatively sparse stocks in the Blackwater estuary are unlikely to be of commercial interest and are being displaced by Pacific oysters in places. The stocks on Ray Sands may potentially be of commercial interest either as seed stock or even as market stock if they survive to maturity.

The cockle beds off Dengie are regulated via K&E IFCA Byelaws. These indicate a maximum vessel size (14m) and specify permissible dredge configurations, including a minimum bar spacing of 16mm. The fishery is open to any suitable boats but a permit and prior approval of the vessel and gear via an annual inspection is required. A maximum of 13.6 m^3 of cockles may be retained per vessel per day, although this daily TAC may be reduced to extend the fishery. Hand gatherers using rakes also require a permit. No more than 10% by weight of a representative sample of the catch can pass through a space 16mm in width. The fishery is only opened at the discretion of the K&E IFCA, based on stock status and other considerations. It was not opened in 2010, 2011 or 2012 to prevent boats from other areas affected by unexplained cockle mortalities from fishing the area and potentially importing diseases. The IFCA hopes to open this area for harvesting in 2013. If the fishery does open, it will be within the June to November (inclusive) window at which point meat yields are best, most typically during the latter half of this period. There is likely to be considerable interest in these beds if they are reopened.

Cockle stocks tend to fluctuate in their size and distribution from year to year. Success of spatfalls may vary greatly between years and stocks may be affected by storms, temperature extremes, diseases, predation and of course exploitation. Whilst the stock biomass fluctuates significantly from year to year, the locations of cockle beds within the outer Thames estuary tend to be reasonably stable. Recent closures have removed fishing pressure and so stocks may be at relatively high levels at present.

4.5 HYGIENE CLASSIFICATION

Table 4.1 lists all classifications within the Blackwater production area from 2004 onwards.

Table 4.1 Classification history for the Blackwater, 2004 onwards

Area	Species	2004	2005	2006	2007	2008	2009	2010	2011	2012
Bench Head	Native oyster	A	B-LT	A	A	-	-	-	-	-
St Peters Flats	Native oyster	A	B-LT	A	A	-	-	-	-	-
The Nass	Native oyster	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Ray Sands	Native oyster	-	-	-	B	A	B	B-LT	B-LT	C
Bachelor Spit	Native oyster	A	B-LT	B-LT	B-LT	A	A	B-LT	B-LT	B-LT
Goldhanger	Pacific oyster	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Thirslet Creek	Pacific oyster	-	-	-	A	B	B	B-LT	B-LT	B-LT
Osea Island	Pacific oyster	B	B	B	B	B	-	-	-	-
South of Osea Island	Pacific oyster	-	-	-	-	-	-	-	-	C
Buxey Sand	Cockles	B	-	-	-	-	-	-	-	-
Ray Sands	Cockles	A	A	B	B-LT	A	A	B-LT	B-LT	C
Dengie Flats	Cockles	A	A	B	B-LT	B-LT	A	B-LT	B-LT	C
Thirslet Creek	Mussels	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
South of Osea Island	Mussels	-	-	-	-	-	-	-	-	C

LT denotes long term classification

Cockles at Buxey Sand are temporarily declassified, and are currently sampled on a quarterly basis to maintain this status. Some areas off Dengie which have formerly held an A classification but this status has declined to a C at present. Classifications within the Blackwater estuary have been much more stable over the years. The area south of Osea Island has recently been awarded a C classification for mussels and Pacific oysters on the basis of mussel sampling results. Most of the outer estuary is not currently classified for the harvest of Pacific oysters.

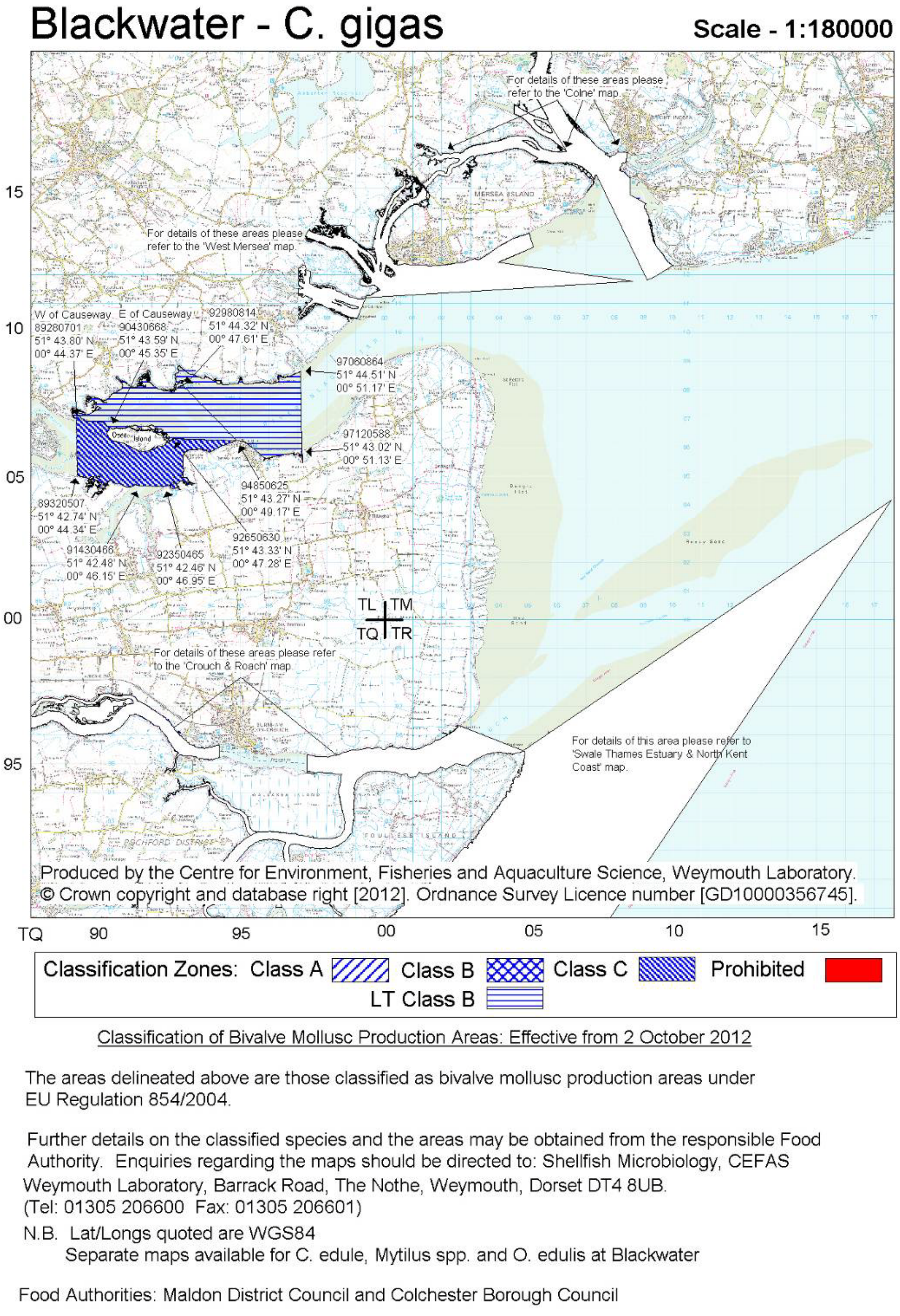
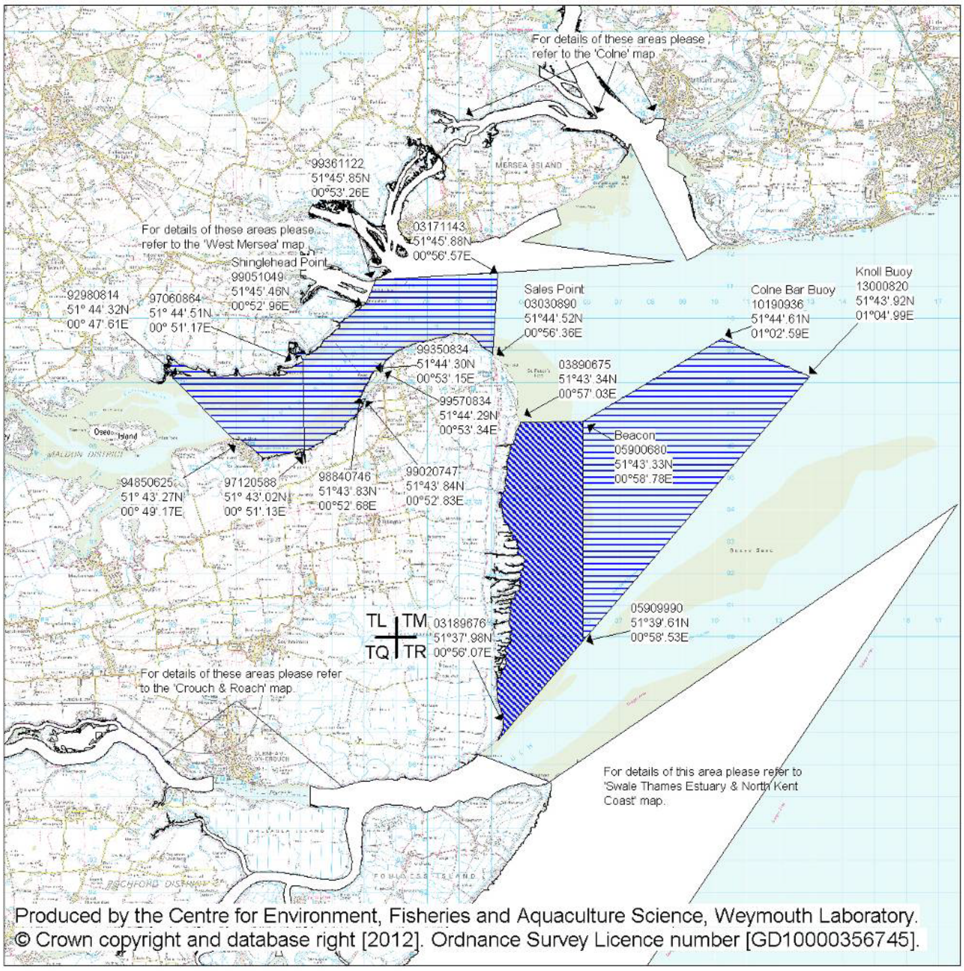


Figure 4.2 Current Pacific oyster classifications

Blackwater - O. edulis

Scale - 1:180000



TQ

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

Classification of Bivalve Mollusc Production Areas: Effective from 2 October 2012

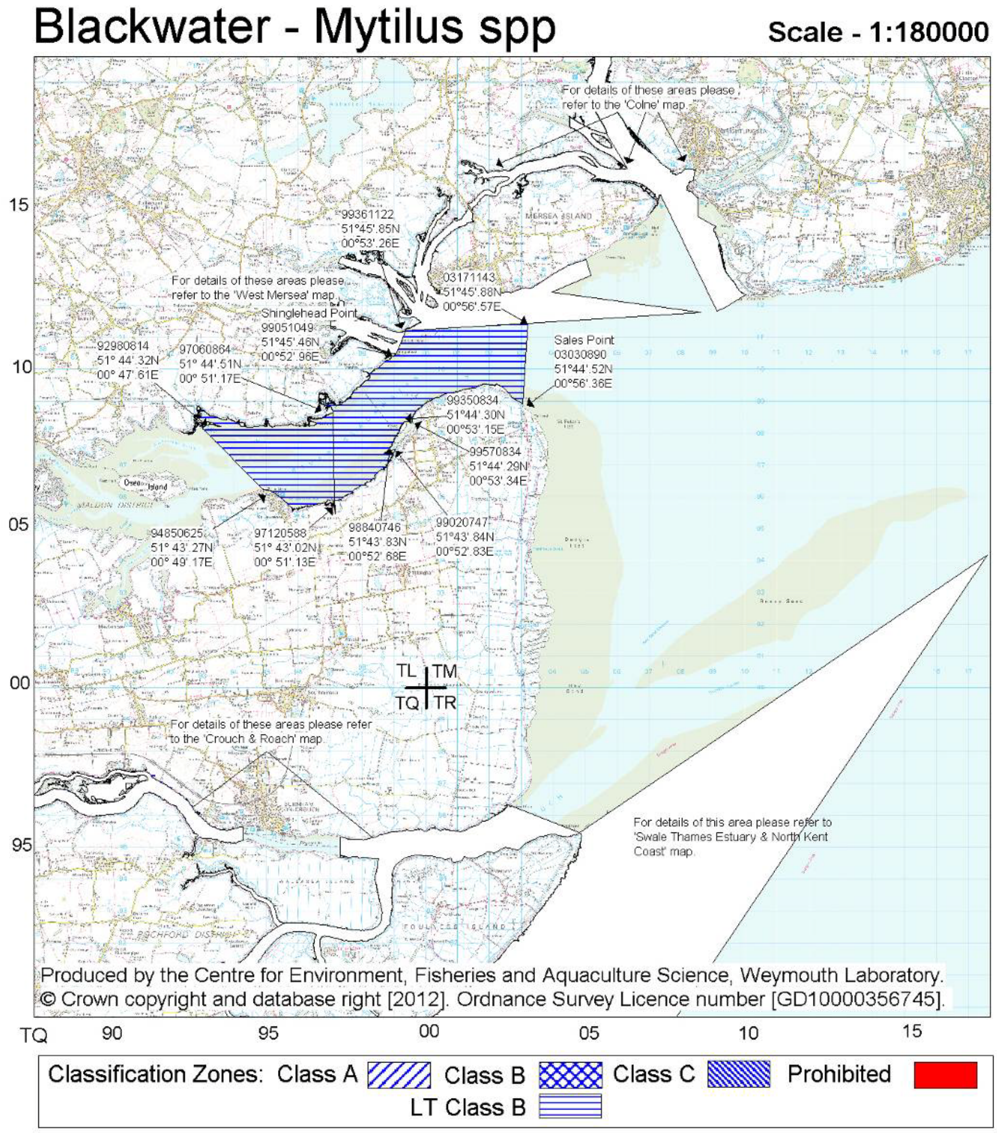
The areas delineated above are those classified as bivalve mollusc production areas under EU Regulation 854/2004.

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

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

Food Authorities: Maldon District Council and Colchester Borough Council

Figure 4.3 Current native oyster classifications



Classification of Bivalve Mollusc Production Areas: Effective from 2 October 2012

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

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

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

Food Authorities: Maldon District Council and Colchester Borough Council

Figure 4.3 Current mussel classifications

Classification of Bivalve Mollusc Production Areas: Effective from 1 September 2012

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

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

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

Food Authorities: Maldon District Council and Colchester Borough Council

Figure 4.4 Current mussel classifications

Table 4.2 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*/100 g Flesh 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*/100 g FIL in more than 10% of samples. No sample may exceed an upper limit of 46,000 *E. coli*/100 g 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*/100 g FIL	Relaying for at least two months in an approved relaying area or cooking by an approved method
Prohibited[6]	>46,000 *E. coli*/100 g 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.

[6] Areas which are not classified and therefore commercial harvesting of LBMs cannot take place. This also includes areas which are unfit for commercial harvesting for health reasons e.g. areas consistently returning prohibited level results in routine monitoring and these are included in the FSA list of designated prohibited beds

In addition to these post harvest treatment requirements, all cockles harvested via suction dredge have to be cooked by an approved method as dredged cockles do not respond properly in purification tanks.

5. OVERALL ASSESSMENT

AIM

This section presents an overall assessment of sources of contamination, their likely impacts, and patterns in levels of contamination observed in water and shellfish samples taken in the area under various programmes, summarised from supporting information in the previous sections and the Appendices. Its main purpose is to inform the sampling plan for the microbiological monitoring and classification of the bivalve mollusc beds in this geographical area.

SHELLFISHERIES

FISHING RIGHTS

Most of the outer Blackwater estuary falls under the Tollesbury and Mersea Fishery Order, and most of the inner estuary is also a private fishery leased to the Maldon Oyster Company by Maldon Council. There are public grounds by Ramsey Island on the south shore of the estuary, and the area off Dengie is also a public fishery managed by the Kent & Essex IFCA.

PACIFIC OYSTERS

Pacific oysters occur naturally throughout the Blackwater estuary, primarily on the less muddy intertidal areas. They may be harvested direct from the area via hand or dredge. Stocks are also moved from the outer estuary to oyster lays within the creeks by Mersea Island, although this practice may be curtailed at present due to an occurrence of oyster herpes in the Blackwater. There is a large trestle site at Goldhanger where Pacific oysters are on-grown. Most of the outer Blackwater is not currently classified for this species, although there are stocks present. Classification is required year round.

NATIVE OYSTERS

At present stocks of this species are at an all time low. Historically, the main concentrations are in the subtidal areas in the outer Blackwater estuary, and in the triangle between Dengie Flats and Buxey Sand. Occasional specimens are thought to persist in the subtidal creeks of the upper estuary. The public fishery has been closed by the IFCA to encourage recovery. It is anticipated that the area off Dengie will be opened in April 2013, for a period at least. Harvesting via dredge from the private grounds in the outer estuary may continue, and stocks may be moved from here for on-growing in the tidal creeks by Mersea Island. There is currently no harvesting of native oysters within the Maldon Oyster Company grounds which are not classified for this species. There is a closed season for native oysters which runs from May to August inclusive. A minimum of 10 samples per year are required for continued classification, so it may not be necessary to sample this species during the first two months of the closed season (May and June).

COCKLES

There are significant commercial cockle beds off Dengie, extending across the lower intertidal along Dengie Flats, and out on Buxey Sand. This fishery has been closed for the last three years to avoid importation of diseases from other areas affected by cockle mortalities by visiting boats. Management measures to prevent this are being investigated by the IFCA, with a view to opening the fishery later in 2013. Should this occur it will open sometime in the June to November window, and there is likely to be considerable commercial interest. Exploitation will be via suction dredge, and cockles collected in this manner have to be cooked as they do not respond well in purification tanks. Buxey Sand is temporarily declassified, and cockles are still sampled from its outer reaches on a quarterly basis. Dengie Flats is currently classified on the basis of mussel samples taken from Ray Sand.

MUSSELS

There are no commercially exploited mussel beds within the survey area at present. The Blackwater estuary does not appear to provide particularly favourable conditions for naturally occurring mussel beds. There are some small patches of mussels within the estuary at Thirslet Creek and around Osea Island which are used for classification sampling. The mussels at Thirslet Creek are sparse and are being overtaken by Pacific oysters. Off Dengie, there are some patches of mussels, within the Swire Hole and at the Ray Sand RMP and possibly in other areas. There is no firm information on their distribution here however. Stocks are thought to be mainly seed sized rather than harvestable size, at Swire Hole and Ray Sand at least. As such there is presently no need for this species to be classified.

SAMPLING PRACTICALITIES

Pacific oysters are widespread throughout intertidal areas and represent a relatively easy sampling option. They are considered a suitable surrogate for native oysters on the basis of their relative accumulation of *E. coli* (Younger & Reese, 2011) although the latter have a different distribution and favour subtidal areas. The use of Pacific oysters to represent native oysters would not only reduce laboratory costs but would allow the more abundant and widespread lower value species to be sampled. This would not be practical off Dengie as stocks here are of native oysters.

There are some limited areas where mussels can be sampled. Mussels are considered a suitable surrogate species for the classification of native and Pacific oysters although they tend to accumulate *E. coli* to slightly higher levels (Younger & Reese, 2011). Mussel sampling via dredge is used to classify cockles on Dengie Flats. This is perhaps a less robust practice as whilst the two species accumulate *E. coli* to similar levels in statistical terms, a tendency for cockles to return more extreme high results has been noted. No parallel monitoring of the two species has been undertaken at this location. The one cockle RMP on Ray Sands is sampled by hand by landing a small vessel on the intertidal sandbank. Direct sampling of cockles on Dengie Flats would have to employ a similar tactic if possible as access to the shore here is problematic and the intertidal area is vast and treacherous in places. The LEA advises that the use of a suction dredger for sampling would be prohibitively expensive.

Where there is the possibility of class A compliance, or where class B compliance is borderline, the species sampled should be the species to be classified to be sure a fair classification results. Pacific oysters should therefore be classified on the basis of Pacific oyster rather than mussel sample results in the upper reaches of the Blackwater estuary.

POLLUTION SOURCES

FRESHWATER INPUTS

All freshwater inputs will carry some contamination from land runoff and so will require consideration in this assessment. The Blackwater is the estuary of a lowland river catchment with an area of about 1200km^2, most of which is used for arable farming although there are significant conurbations within it. Most of the catchment is relatively impermeable clay so in general rates of runoff will be high but the very upper reaches are underlain by high permeability chalk.

The majority of freshwater inputs (draining about 80% of the catchment) are via the rivers Blackwater and Chelmer, which drain to the head of the estuary. Flow gauging records indicate that their combined mean discharge is about 3.3 m^3/sec. They also indicate significant seasonal variation with much higher average and peak flows during the colder months of the year. Therefore the impacts of freshwater inputs are likely to be greatest at the head of the estuary, and may be considerably higher on average in winter.

As well as the rivers draining to the head of the estuary, there are a series of smaller streams and field drains discharging at various locations around the estuary and to the foreshore adjacent to Dengie Flats. On the north shore, all freshwater inputs to the lower and middle reaches of the estuary were sampled and measured allowing a spot estimate of the bacterial loading they were generating at the time. The largest measured loadings were from two streams discharging to the head of Thirslet Creek, with a combined *E. coli* loading of 2.5x10^{12} cfu/day. Also of potential significance was a freshwater outfall by Bounds Farm, which will feed into the upper reaches of Goldhanger Creek. The volume it was discharging was not particularly high but it carried >10,000 *E. coli* cfu/100ml and so was carrying at least 1.5x10^{11} cfu/day. Sewage fungus and odour was noted at this outfall, which would suggest a sustained sanitary input. On the south shore of the Blackwater most freshwater outfalls could not be sampled or measured during the survey. Of those that were sampled, two discharging to the head of Mayland Creek were carrying the highest concentrations of *E. coli* (2800 and 3600 cfu/100ml). Ordnance Survey maps show there are small streams draining to the heads of both Lawling Creek and Mayland Creek, both of which are enclosed. Therefore there are likely to be higher levels of contamination within these creeks relative to the more open areas, particularly in their upper reaches.

There are only three freshwater inputs to the Dengie foreshore. Two of these are from field drains serving the very low lying land immediately adjacent to the sea defences and require pumping to raise the water to the foreshore. The pumps operate intermittently so no flow gauging was undertaken for the one that was running at the time, but a sample of water from the ditch adjacent to one of these only contained 120 *E. coli* cfu/100ml. The third is a stream which is impounded by earth banks in its lower reaches to keep it sufficiently raised so it discharges via gravity. It drains a larger area than the two pumping stations and has the village of Southminster in its catchment. This was only carrying 5.8×10^{10} *E. coli* cfu/day at a very similar concentration to that observed in the drainage ditch.

All significant surface water outfalls had defined drainage channels running across the intertidal. Shellfish lying within or immediately adjacent to these are likely to carry elevated levels of contamination, particularly for the more heavily contaminated and larger outfalls, so RMPs should be sited accordingly.

HUMAN POPULATION

Total resident population within the Blackwater catchment area was 458,316 at the time of the last census for which data were available (2001). Highest population densities are found within the towns of Chelmsford, Maldon, Witham and Braintree. Outside of these population densities were generally low, although there are small population centres at Maylandsea, St Lawrence and Bradwell, all on the south shore of the Blackwater. The pattern of impacts from human sewage discharges will be largely dependent on the nature of the sewage disposal infrastructure for the area.

The Essex coast is a popular holiday destination so the population within coastal towns is likely to increase during the summer months. Attractions include maritime history and culture, watersports, wildlife watching and other outdoor pursuits. Increased population numbers will result in increased volumes of sewage being treated by sewage works so there may be some seasonality in the bacterial loadings generated by these.

SEWAGE DISCHARGES

The catchment is served by a series of water company owned sewage works, most of which provide secondary treatment. Over 90% of sewage effluent from these (in terms of volume) is discharged to the estuary upstream of the shellfisheries, or to watercourses which drain to the estuary upstream of the shellfisheries. These include the Chelmsford and Witham STWs which discharge to the Chelmer just below the tidal limit and contribute an estimated combined bacterial loading of about 2.0×10^{14} faecal coliforms/day. Although significant bacterial die-off is likely to occur during transit from those discharges higher up in the catchment, higher levels of sewage derived contamination are expected towards the head of the estuary on this basis. There are some smaller water company sewage works discharging direct to the middle and lower reaches of the estuary or watercourses feeding into it. The largest of these is the Maldon STW, which discharges to the north shore by Decoy Point. It provides secondary treatment and a final effluent lagoon, and discharges to a drainage ditch which in turn discharges to the estuary. Testing data indicate there are generally low levels of faecal coliforms in the effluent such that the average bacterial loading it generates is around 1.7×10^{11} cfu/day. The drain to which it discharges was not flowing at the time of shoreline survey and only contained 50 *E. coli* cfu/100ml. It is therefore concluded that the impacts from this are minor, although there may be some impacts in the vicinity of the drainage channel it follows across the intertidal.

None of the permitted continuous discharges are likely to be responsible for the high *E. coli* levels and presence of sewage fungus observed in the freshwater outfall by Bounds Farm. Tolleshunt D'Arcy STW is a small works providing secondary treatment, and generates and estimated bacterial loading of 6.9×10^{11} faecal coliforms per day and discharges to a watercourse draining to the head of Thirslet Creek.

Latchington STW is another small secondary works which discharges via lagoon to a stream which feeds into the head of Lawling Creek, and generates an estimated faecal coliform loading of 2.1×10^{12} cfu/day. Another similar sized works (Mayland STW) discharges directly to the head of the adjacent Mayland Creek, although this has a final effluent lagoon so the effluent is likely to carry lower concentrations of faecal indicator bacteria. Stone Lawrence STW is another small secondary works which discharges to a watercourse which flows into the estuary just west of St Lawrence and generates an estimated bacterial loading of 1.1×10^{12} faecal coliforms/day. There is another small works at Bradwell-on-sea which discharges to the drains by Bradwell. This provides secondary treatment and a final effluent lagoon so the bacterial loading entering the estuary from this should be very small. Finally, the Tillingham STW, another small secondary works generating an estimated bacterial loading of 8.6×10^{11} faecal coliforms/day discharges to the Bradwell Brook. This watercourse feeds into the drainage ditches in the low lying land by Dengie Flats, and eventually makes its way out into coastal waters via the northern pumping station which drains the area.

There are also some significant sewage discharges to the Crouch estuary which will add to the levels of faecal indicator bacteria carried by the ebb plume from this estuary, which may in turn have some impact on the shellfish beds off the southern end of the Dengie peninsula.

As well as the continuous sewage discharges, there are a number of intermittent overflow discharges associated with the water company sewerage networks. These are generally clustered around settled areas and most are by the south shore or at Maldon. No spill records from these discharges was available at the time of writing, so it is difficult to assess their significance aside from noting their location and their potential to discharge large volumes of untreated sewage. Such events may occur either under storm conditions when the sewers are inundated with runoff which may happen after intense rainfall events, or in the event of an emergency such as a pump failure or blockage which may occur at any time. Typically, spills are too infrequent for their impacts to be captured reliably under monthly classification sampling.

In addition to the water company owned discharges, there are numerous consented private discharges in the vicinity. These are generally small and serve one or a handful of properties and provide treatment via package plant or septic tank. Of potential significance there are three to the lower estuary which are consented to discharge $10m^3$/day or more. One is from the Bradwell power station and this is a mix of large amounts of seawater used by the plant and $136m^3$/day of secondary treated sewage effluent off Bradwell. The effluent will be very dilute so will not create much of a hotspot of contamination. A sailing club discharges up to 10m^3/day of secondary treated effluent to the estuary via a borrow dyke just west of St Lawrence, and finally a caravan park discharges up to 46m^3/day of effluent to the drainage ditches just east of the mouth of Mayland Creek.

AGRICULTURE

The majority of agricultural land within the Blackwater catchment is used for arable farming, and organic fertilisers may be applied to these areas periodically, with timing depending on crop cycles. There are some smaller pockets of pasture where grazing animals will deposit faecal matter directly. There are relatively low overall numbers and densities of grazing animals (cattle and sheep) within the catchment. During the shoreline survey livestock were by Steeple Creek, between Lawling Creek and Mayland Creek, east of Mill Creek and east of Goldhanger. Land use adjacent to Dengie Flats was exclusively for arable farming. The land adjacent to Dengie Flats is all used for arable farming. There are also significant numbers of poultry and a few pigs in the catchment, the manure from which is typically collected and applied tactically to nearby farmland. Sewage sludge may also be used as fertilizer, but no information on local practices was available at the time of writing. A delivery of what appeared to be sewage sludge was taking place at the gate of a farm on the southern end of the Dengie peninsula at the time of shoreline survey.

The primary mechanism for mobilisation of faecal matter deposited or spread on farmland to coastal waters is via land runoff, so fluxes of livestock related contamination into the estuary will be highly rainfall dependent. Rainfall and river flows are generally highest during the winter months, but high rainfall events may occur at any time of the year. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the 'first flush'). Numbers of sheep and cattle will increase in the spring with the birth of lambs and calves, and decrease in the autumn when animals are sent to market. The seasonal pattern of application of manures and slurries is uncertain. Cattle may be housed indoors in winter so applications of slurry to pastures in these farms may be more likely during the winter and spring.

BOATS

Overboard discharges made by boats may be a significant source of contamination to the survey area at times. The Blackwater estuary is heavily used by a variety of craft, principally leisure craft such as yachts and cabin cruisers. There are marinas at Bradwell and Maylandsea but none of these has sewage pumpout facilities. There are also hundreds of dry and wet moorings, the main concentrations of which are in the upper reaches of the estuary around Maldon and Heybridge Basin, Maylandsea, Ramsey Island and Bradwell Waterside. A small number of commercial fishermen work within the estuary, from the Maldon/Bradwell area. A few houseboats were observed at Heybridge Basin and Maylandsea. There is very little, if any, commercial shipping within the estuary. Watersports such as windsurfing, canoeing and dinghy sailing are popular pursuits within the estuary. Off Dengie boat traffic is likely to be much less intense, and probably mainly limited to fishing vessels working the area as there are no navigation routes or moorings, anchorages etc in the area.

Commercial shipping is not permitted to discharge to inshore waters so should be of no impact. Smaller vessels such as sailing dinghies will not have onboard toilets and so are unlikely to make discharges. It is likely that the larger of the private vessels (yachts, cabin cruisers, and fishing vessels) which have onboard toilets make overboard discharges from time to time. This may occur whilst boats are on passage, and it is quite likely that any boats in overnight occupation on the moorings will make a discharge at some point during their stay. Occupied houseboats are also likely to make regular overboard discharges. On this basis, the main navigation routes and mooring/anchorage areas are most at risk from overboard discharges. Boat occupancy levels and hence the likelihood of overboard discharges will be significantly higher during the summer. It is difficult to be more specific about the impacts of boats without any firm information about the locations, timings and volumes of such discharges. As they may be considered as a more diffuse source of contamination, RMPs located within areas of moorings berths and anchorages should adequately capture any impacts on shellfish hygiene.

WILDLIFE

Overwintering waterbirds (wildfowl and waders) represent the largest aggregations of wildlife which may impact on shellfish hygiene in the area. Over the five winters up until 2010 an average total count of 72,450 overwintering and wildfowl were recorded within the Blackwater estuary and 59,846 were recorded on the Dengie flats. The shoreline survey confirmed a significant winter presence of waders and geese in the area. Some species such as waders will forage (and defecate) directly on the shellfish beds across a wide area. They may tend to aggregate in certain areas holding the highest densities of invertebrates of their preferred size and species, but this will change from year to year. Although they may contribute significant amounts of faecal indicator organisms, as a diffuse input they will have no influence on RMP locations. Other species, such as geese will graze on saltmarshes pastures, and crops so their faeces will be carried into coastal waters via land runoff from these areas in the same manner as that originating from livestock. Geese may also graze on any seagrass beds in the intertidal areas.

Whilst most of the overwintering population migrate elsewhere in the summer, a much smaller but nevertheless potentially significant population of resident and breeding birds will remain. A survey of breeding seabirds (gulls, terns etc) recorded 712 pairs counted nesting within or on the shores of the Blackwater estuary. The majority of these (634 pairs) use Pewet Island as a nesting site. Seabirds are likely to forage widely throughout the area, therefore faecal inputs could be considered as diffuse. However, it is expected to be more concentrated in the immediate vicinity of their nest sites. Impacts may be felt either via a higher concentration of droppings in the adjacent intertidal or via runoff from the Island.

The Essex estuaries support a combined population of about 100 harbour seals. Dengie Flats and Buxey Sands are regularly used as haulout sites, although their exact locations are uncertain. They forage widely and numbers are not large so their impacts will be very minor and generally diffuse, although contamination is likely to be more intense and regularly occurring in the immediate vicinity of their haulout sites. Given the large area they are likely to forage over impacts are likely to be minor, and unpredictable in spatial terms so will not be an influence on the sampling plan.

Rats are a potential source of microbiological contamination within the shellfish area. Populations are likely to be large with higher numbers present in urban areas. However, numbers are not known and given their wide distribution it makes it difficult to determine. No other wildlife species which have a potentially significant influence on levels of contamination within shellfish within the survey area have been identified.

Domestic animals

Dog walking takes place along coastal paths and on beaches within the area and so represents a diffuse source of contamination to the near-shore zone. The intensity of dog walking activity is likely to be greatest near population centres such as Maldon. As a diffuse source this will have little influence on the location of RMPs.

Summary of Pollution Sources

An overview of sources of pollution likely to affect the levels of microbiological contamination to the shellfish beds is shown in Table 5.1 and Figure 5.1.

Table 5.1 Qualitative assessment of seasonality of important sources of contamination.

Pollution source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Agricultural runoff												
Continuous sewage discharges												
Intermittent sewage discharges												
Urban runoff												
Waterbirds												
Boats												

Red - high risk; orange - moderate risk; yellow - lower risk.

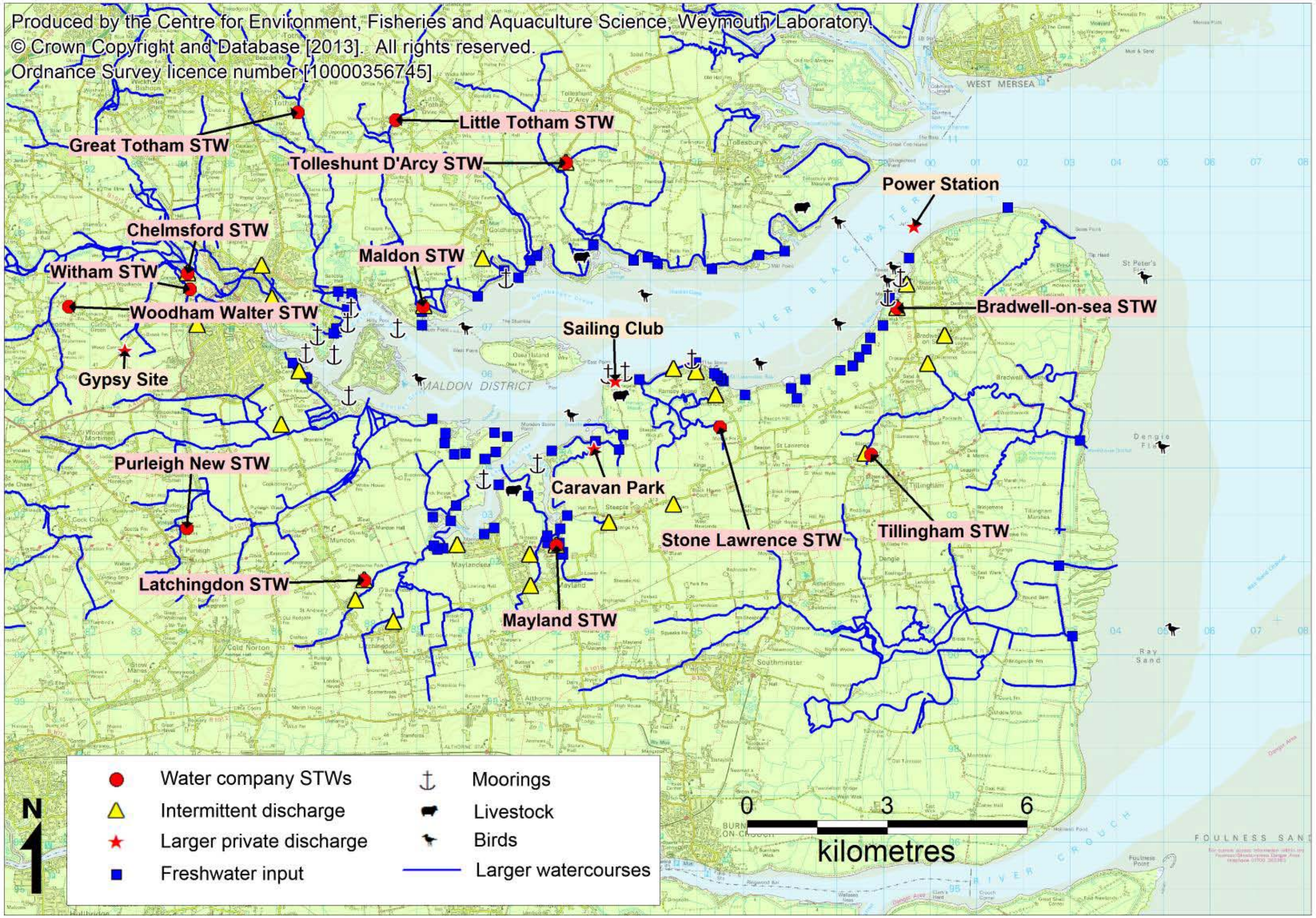


Figure 5.1 Significant sources of microbiological pollution to the area

HYDROGRAPHY

This survey considers two areas which are fairly distinct hydrographically, the enclosed Blackwater estuary and the open coast to the east of the Dengie Peninsula. The Blackwater estuary is approximately 21.2 km from its head to its mouth and between 2 and 3 km wide throughout. Its perimeter is surrounded by sea walls. The main subtidal channel is relatively deep and wide at the mouth, becoming narrower and shallower in the upper reaches, where there are several subtidal side channels across the intertidal areas. Branching from these subtidal channels are a series of intertidal drainage channels which will carry any freshwater inputs at lower states of the tide. The estuary is largely intertidal, more so in the upper reaches. There are also two relatively large islands in its upper reaches. The main channel here runs south of Osea Island, then north of Northey Island before reaching the tidal limit at Maldon.

The Dengie Flats are an extensive area of gently sloping intertidal mudflats, fringed with saltmarsh and cover an area of 25.9km² and extending approximately 3km eastwards. The flats are flanked by the Blackwater estuary channel to the north and the Crouch estuary channel to the south. The northern part of Dengie Flats slopes gently into the subtidal. There is an intertidal sandspit (Buxey Sands) protruding a further 10km east from the southern tip of Dengie Flats, running parallel to the Crouch channel. There is a scoured channel (Swire Hole) to the north of the tip of Buxey Sands.

Tidal amplitude is relatively large, at 4.9m on spring tides and 3.1m on neap tides at Osea Island. This drives extensive water movements throughout the area. In the North Sea tidal streams flood down the Essex coast towards the Thames Estuary in a south westerly direction, and flow in the opposite direction on the ebb. The Blackwater and Colne estuaries form an indentation to the Essex coast. Tidal streams flood in a north westerly direction into the Blackwater and a westerly direction onto Dengie Flats, aligning with the orientation of the main Blackwater Channel and the Swire Hole.

Within the estuary, tides will progress up the main channel and associated side channels and intertidal creeks, spilling and spreading over the intertidal. On the ebb the reverse will occur. An estimate of tidal excursion within the estuary, based on a tidal diamond at its mouth is in the order of 10km on spring tides and 7km on neap tides, although this may be a significant overestimate for shallower and intertidal areas. This suggests that sources discharging to the head of the estuary will only impact in the upper reaches before the tidal streams reverse and carry contamination back up. Results of a modelling study supported this conclusion, and indicated that material discharged from Maldon will be carried down the main channel to about Osea Island on spring tides, at which point the currents will reverse and carry contamination back up-estuary. On the second ebb tide contamination will be carried further out of the estuary, such that on the second flood it may be carried up Goldhanger Creek towards the trestle site. During passage the contamination will be subject to a significant degree of mixing and dilution. There may therefore be a quite steep increase in levels of contamination in shellfish around the main channel south of Osea Island and further up-estuary.

There are three tidal streams by Dengie. Two are associated with the tide flooding and ebbing into and out of the adjacent Blackwater and Crouch estuaries. The ebb plume from the Blackwater may be of influence at the northern end of Dengie Flats, and that from the Crouch may have some impact on the southern end of Dengie Flats and the southern half of Buxey Sand. The other tidal stream floods in through the Swire Hole, after which it will spread across the Dengie Flat, with the reverse occurring on the ebb. This indicates that apart from the northern and southern extremities, this area will only be subject to contamination from local sources.

Freshwater inputs to the Blackwater are low in relation to tidal exchange, so it is considered well mixed and density driven circulation is unlikely to be of importance. There may be a small horizontal gradient of decreasing salinity in its very upper reaches particularly at times of high freshwater discharge, which is typically associated with increasing levels of contamination. Some variation in surface salinity readings was found in its middle reaches, as well as a slight decrease in average salinity at the up-estuary site in the main channel. Freshwater inputs to the Dengie Flats are minor, and as it is an open coast no influence of freshwater on hydrography is anticipated.

Strong winds will modify surface currents. The prevailing south-westerly winds will tend to push surface water in a north-easterly direction, towards the mouth of the Blackwater and towards West Mersea and the Colne estuary. Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables, so a great range of scenarios may arise. Where strong winds blow across a sufficient distance of water they may create wave action, and where these waves break contamination held in intertidal sediments may be re-suspended. Given the enclosed nature of the inner Blackwater, energetic wave action is not anticipated here. The outer Blackwater and Dengie Flats are exposed to the North Sea to the east, so easterly winds may result in significant wave action on the Dengie Flats and Buxey Sands.

SUMMARY OF EXISTING MICROBIOLOGICAL DATA

The area has been subject to considerable microbiological monitoring over recent years, deriving from the Bathing Waters and Shellfish Waters monitoring programmes as well as shellfish flesh monitoring for hygiene classification purposes. Figure 5.2 shows the locations of the monitoring points referred to in this assessment.

Figure 5.2 Location of microbiological sampling points referred to in this assessment.

WATER SAMPLES

Only one site on the south shore of Mersea Island was sampled under the Bathing Waters monitoring programme, where around 20 water samples were taken each bathing season (May-September) and tested for faecal coliforms. Results indicate that contamination here is light, with a geometric mean of 10.1 cfu/100ml and a maximum result of 1360 cfu/100ml. Results have been consistent over the past decade. Significant correlations were found between levels of faecal coliforms and both of the spring/neap and high/low tidal cycles. Levels of faecal coliforms found tended to be lower around low water and on the earlier stages of the flood tide, and lower during neap tides. This suggests some influence of sources to east and in relatively close proximity. Some influence of recent rainfall on levels of faecal coliforms was detected here up to four days after a rainfall event.

Water samples were taken on a quarterly basis and tested for faecal coliforms from three locations under the Shellfish Waters monitoring programme. The Dengie site was only sampled on three occasions so it is difficult to draw any meaningful conclusions from results here. At Blackwater and Osea Island the average result was quite low (3.2 and 5.3 faecal coliforms cfu/100ml respectively) but the maximum result was much higher at Osea Island. Similar seasonality was found at these two monitoring points, with higher average results in the winter. A significant correlation was found between faecal coliform levels and the spring/neap tidal cycle at Osea Island but no strong patterns were apparent when these data were plotted. A weak and slightly delayed influence of rainfall was found at Osea Island, but not at Blackwater.

SHELLFISH FLESH SAMPLES

Since 2003, one location was sampled for cockles, four locations were sampled for mussels, six locations were sampled for native oysters and five locations were sampled for Pacific oysters. All samples were tested for *E. coli* under the hygiene classification programme. Two native oyster RMPs were sampled on five or less occasions so were not considered further in the analyses of results.

Across the four mussel RMPs the average *E. coli* result fell in the following order: Ford Creek>Lawling Creek>Thirslet Creek>Ray Sands. This suggests higher levels of contamination towards the upper reaches of the Blackwater and lower levels of contamination outside of the estuary. Results were quite variable at all mussels RMPs.

Across the four native oyster RMPs sampled on more than five occasions the average *E. coli* results fell in the following order: The Nass>St Peters Flats>Ray Sands>Bachelor Spit. Differences between the latter three were very small. This is suggestive of higher average levels of contamination in the outer Blackwater estuary compared to the area off Dengie. Perhaps surprisingly, the proportion of results exceeding 4600 *E. coli* MPN/100g was lower at the Nass (1.8%) compared to the other three RMPs (4.5, 6.8 and 3.6% respectively). A comparison of paired (same-day) samples was only possible between Bachelor Spit and Ray Sands, and sample results from these two locations were strongly correlated on a sample by sample basis. This suggests they are under very similar contaminating influences and sampling of both may not be necessary.

Across the five Pacific oyster RMPs the average *E. coli* result fell in the following order: Southey Creek>Ford Creek>Goldhanger Creek>Lawling Creek>Ford Creek. There was very little difference between the average results at Ford Creek and Lawling Creek. Thirslet Creek, which is the most easterly RMP had significantly lower results than all other RMPs except Lawling Creek. Again this is suggestive of increased levels of contamination in the upper reaches of the estuary.

Mussel results at Ford Creek and Lawling Creek were indicative of a C classification, (18.2 and 50.0% exceeding of 4600 *E. coli* MPN/100g) whereas Pacific oyster monitoring results from these locations were more aligned with a B classification (2.4 and 0.0% exceeding 4600 *E. coli* MPN/100g). This suggests that the current practice of using mussels sample results on which to base a Pacific oyster classification in this area is unfair to the harvester and should be discontinued.

Two RMPs for native oysters (Comparisons of these sites revealed a significant correlation (Pearson's correlation, $r=0.774$, $p<0.001$). Four RMPs for Pacific oysters were sampled on the same day on 21 occasions and the results of correlations between these sites are summarised in table XII.2 and significant results are highlighted in yellow. Non-significant results suggest that some sites are influenced by a different range of sources which react in a different manner to environmental conditions. It was not possible to undertake meaningful paired comparisons between mussel RMPs as fewer than 20 same day samples were taken for each of these pairings.

The cockle on Buxey Sands generally returned very low results, with only 7.1% exceeding 230 *E. coli* MPN/100g. As this was the only cockle RMP sampled no geographic comparisons were possible.

Since 2003 results from most RMPs sampled throughout have been reasonably consistent. The exception to this is native oysters at St Peters Flats, where results appear to have deteriorated on average since 2008.

During the period November 2011 to February 2012 some very high results were recorded on three consecutive sampling runs in the area off Dengie (up to 360,000 *E. coli* MPN/100g). This suggests a widespread and ongoing contamination episode throughout the period affecting RMPs a considerable distance offshore. Rainfall in the weeks preceding these samplings was low (0.2-2.4mm recorded at Mersea). No particularly high *E. coli* results were returned from either the Roach or the Blackwater estuaries during this period, although they were not sampled on the exact same days as the Dengie area. The hydrography of the area would also suggest that a source local to Dengie Flats was responsible. The most probable source is perhaps agricultural, carried to Dengie Flats via one of the three watercourses draining to the foreshore, but there is no firm evidence to support this. Investigations revealed some demolition works at Bradwell Power Station around the time but this was not thought to be related (John Daniels, pers comm.). This unexplained event remains a concern and should perhaps be subject to a detailed investigation, including the bacteriological testing of freshwater inputs to the Dengie Foreshore should it occur again.

Significant seasonal variation was observed at the two mussel RMPs which were sampled on more than 20 occasions (Thirslet Creek and Ray Sands) and results were highest on average during the winter in both cases. Across the four native oyster RMPs there was significant seasonal variation at all but St Peters Flats. At the Nass, *E. coli* levels were significantly higher during the autumn than the winter. At Bachelor Spit, *E. coli* levels were significantly higher in the winter that during any other season, and at Ray sands they were significantly higher during the winter than spring and summer. Significant seasonal variation was observed at the cockle RMP at Buxey Sands, with highest results on average during the winter.

Some influence of tide was found at some RMPs. Across the high/low tidal cycle, patterns were observed in native oyster results at St Peters Flats, where levels of *E. coli* in native oysters appeared to be lower on average during the later stages of the flood tide, and at Nass where results were lower on average around high water and during the early part of the flood tide. The reasons for this are unclear. No obvious variation across the high/low tidal cycle was observed at the other RMPs. Across the spring/neap tidal cycle the higher individual results were recorded as tide size decreased from spring to neap at all four native oyster RMPs. A similar pattern was observed for mussels at Ray Sands. The higher levels of *E. coli* at Buxey Sands tentatively appeared to occur around the spring tides. Again, the reasons for these effects are unclear.

Rainfall had a consistent influence on levels of contamination only for native oysters at St Peter Flats. This suggests that runoff from the Dengie may be an influence here, although such an effect did not extend to other RMPs off the Dengie. Some occasional weak correlations were found at other sites, but not consistently so, even for RMPs towards the upper end of the estuary. It can therefore be concluded that rainfall is not a major driving factor for *E. coli* contamination in shellfish flesh in the Blackwater estuary.

APPENDICES

APPENDIX I
HUMAN POPULATION

Figure I.1 shows population densities in census output areas within or partially within the Blackwater catchment area, derived from data collected from the 2001 census. Equivalent data from 2011 census was unavailable at the time of writing.

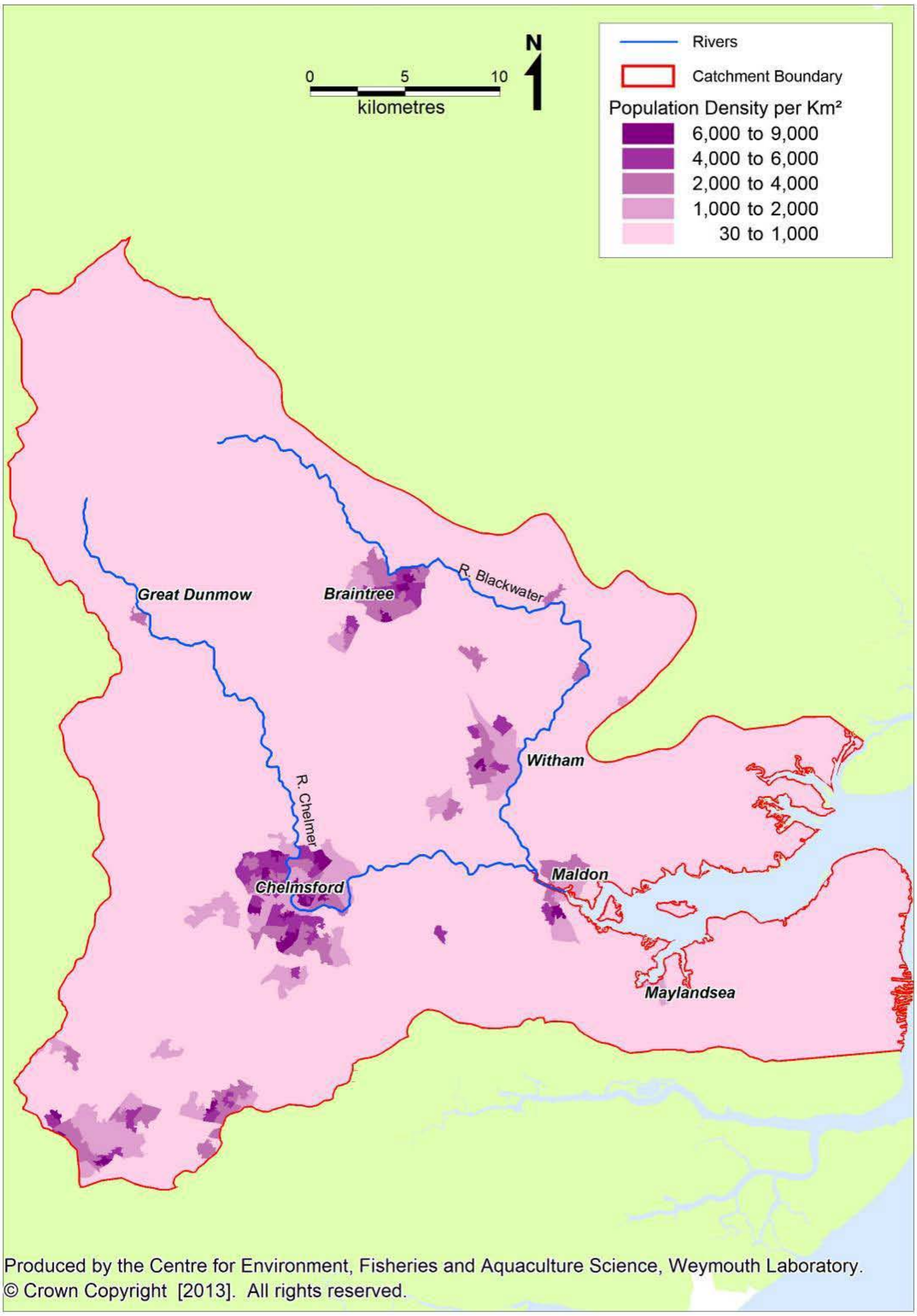


Figure I.1 Human population density in Census Areas in the Blackwater Catchment.
Source: ONS, Super Output Area Boundaries (Lower layer). Crown copyright 2004. Crown copyright material is reproduced with the permission of the Controller of HMSO.

Total resident population within the Blackwater catchment area was 458,316 at the time of the last census. Figure I.1 indicates that the highest population densities are found within the towns of Chelmsford, Maldon, Witham and Braintree. The catchment area is predominantly rural/agricultural land, this is reflected in the relatively low population densities throughout the catchment between 30 and 1,000 persons per km².

Significant numbers of tourists are attracted to the area because of its variety of both marine and land based activities and its close proximity to London. Activities include maritime history and culture, a multitude of watersports, birdwatching, scenic coastal and countryside walks and other outdoor pursuits (Maldon District Council and Colchester Borough Council, 1996). Visitors to the area tend to stay in the various guesthouses, B&B's, caravan parks and camping sites. In 2010 4,163,000 trips (both day and staying trips) were made to Chelmsford, it can therefore be assumed that the number of visitors is likely to be considerably higher. The Maldon district attracts in the region of two million plus tourists each year.

A study undertaken by East of England Tourism revealed that whilst occupancy rates for serviced accommodation are highest during the summer months, occupancies in the spring and winter months are still significant (Tourism South East, 2009). Consequently, bacterial loadings from sewage treatment works are likely to be more elevated during the summer and to a lesser extent during other holiday periods.

In conclusion during the summer months when tourism is at its highest the total population will be higher and bacterial loadings from sewage treatment works serving the area will increase accordingly. Deterioration in the microbiological quality of water and bivalve molluscs is frequently detected in coastal areas that are impacted by pollution sources associated with tourism activities, possibly due to increased loads from sewage treatment plants (Younger *et al.*, 2003).

APPENDIX II
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: SEWAGE DISCHARGES

Details of all consented discharges within the Blackwater estuary hydrological catchment and nearby coastal waters were taken from the Environment Agency's national discharge database (July 2012). The locations of the water company owned sewage treatment works are shown in Figure II.1. Further details of these treatment works are presented in Table II.1.

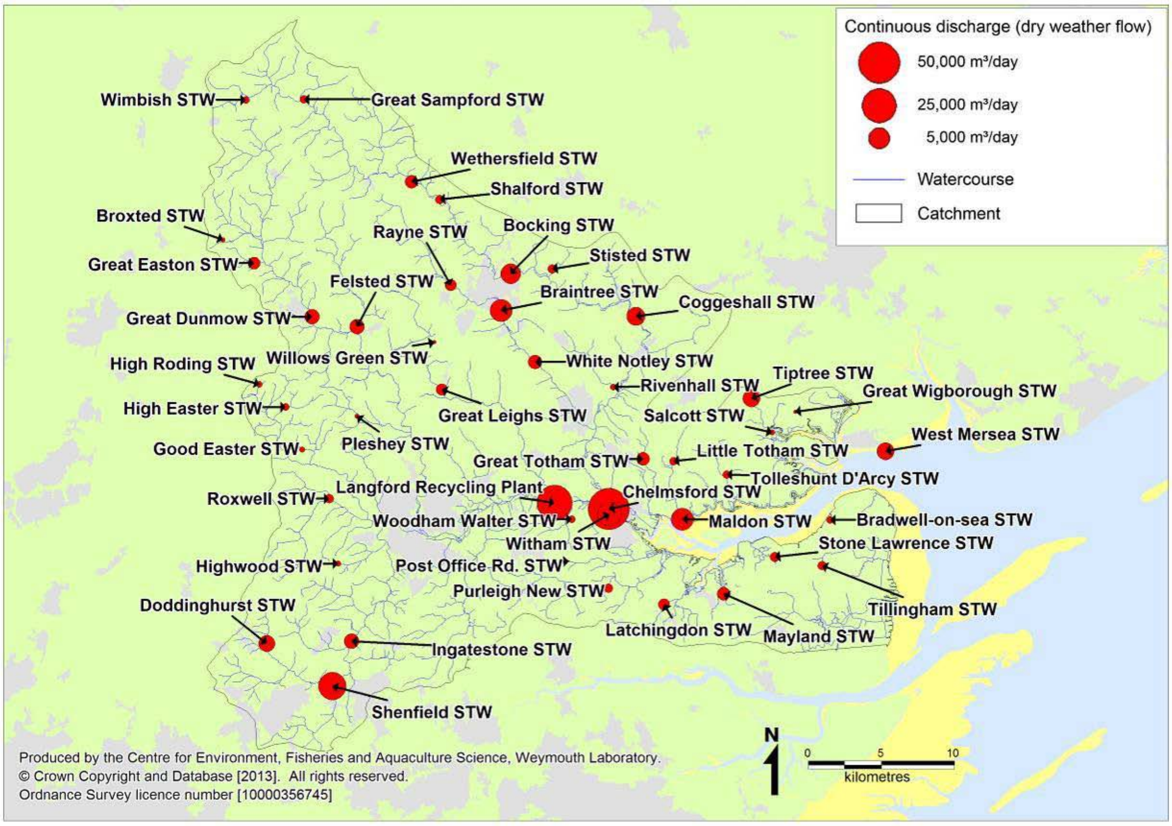


Figure II.1 Water company sewage treatment works discharging within the Blackwater estuary catchment and to nearby coastal waters

For two of these sewage works (Maldon and West Mersea) some bacteriological testing of final effluents had been undertaken. Results are presented in Table II.2 and figure II.2, and for these works the geometric mean result was used, together with the consented dry weather flow to give estimates of the bacterial loading that each generates (Table II.1). For all the other sewage works, estimates of their bacterial loading were made based on their consented dry weather flow and the geometric mean base flow levels of faecal coliforms from a range of UK STWs providing secondary treatment (Table II.3). Some of these works provide additional treatment for nutrient removal or have final effluent lagoons, which are likely to further reduce levels of faecal indicators. The estimates are intended for broad comparative purposes only, and bacterial concentrations in effluents are likely to vary significantly between different treatment works, and with time at individual treatment works. Although levels of *E. coli* are usually correlated to faecal coliforms levels of at a ratio approaching roughly 1:1, the ratio depends on a number of factors, such as environmental conditions and the source of contamination so caution should be exercised when comparing the two.

Table II.1 Details of the continuous water company sewage discharge to the area

Name	Location	DWF (m^3/day)	Treatment Level	Estimated bacterial loading (cfu/day)	Receiving Water
Bocking STW	TL7736024280	4518	Secondary + phosphate stripping	$1.5x10^{13}$*	River Blackwater
Bradwell-on-sea STW	TL9929007400	155	Secondary + FE lagoon	$5.1x10^{11}$*	Unnamed watercourse
Braintree STW	TL7669021760	6859	Secondary	$2.3x10^{13}$*	River Brain
Broxted STW	TL5760026600	24	Secondary	$7.9x10^{10}$*	Tilty Brook
Chelmsford STW	TL8409008140	52050	Secondary	$1.7x10^{14}$*	Blackwater estuary
Coggeshall STW	TL8595021360	3025	Secondary + phosphate stripping	$1.0x10^{13}$*	River Blackwater
Doddinghurst STW	TQ6062098920	2325	Secondary + phosphate stripping	$7.7x10^{12}$*	River Wid
Felsted STW	TL6681020660	1630	Secondary	$5.4x10^{12}$*	Stebbing Brook
Good Easter STW	TL6303012220	44.2	Secondary	$1.5x10^{11}$*	Wares Brook
Great Dunmow STW	TL6371021340	1509	Secondary + reedbed	$5.0x10^{12}$*	River Chelmer
Great Easton STW	TL5974025000	874	Secondary	$2.9x10^{12}$*	River Chelmer trib.
Great Leighs STW	TL7263016350	650	Secondary	$2.1x10^{12}$*	River Ter
Great Sampford STW	TL6316036250	200	Tertiary (Biological)	$6.6x10^{11}$*	River Pant trib
Great Totham STW	TL8645011580	1100	Secondary	$3.6x10^{12}$*	Spicketts Brook
Great Wigborough STW	TL9690014800	17.6	Unspecified	$5.8x10^{10}$*	Unnamed watercourse
High Easter STW	TL6192015130	128	Secondary	$4.2x10^{11}$*	Parsonage Brook
High Roding STW	TL6010016700	103	Secondary	$3.4x10^{11}$*	High Roding Brook
Highwood STW	TL6550004400	45	Secondary	$1.5x10^{11}$*	Sandy Brook
Ingatestone STW	TQ6642099070	1695	Secondary + phosphate stripping	$5.6x10^{12}$*	River Wid
Langford Recycling Plant	TL8037008560	30000	Tertiary (UV)	Not estimated	River Chelmer
Latchingdon STW	TL8788001590	637	Secondary + lagoon	$2.1x10^{12}$*	Latchington Brook
Little Totham STW	TL8855011410	183	Tertiary (Biological)	$6.0x10^{11}$*	Penny's Brook
Maldon STW	TL8914007430	6800	Secondary + lagoon	$1.7x10^{11}$**	Penny's Brook
Mayland STW	TL9199002330	1100	Secondary + lagoon	$3.6x10^{12}$*	Mayland Creek
Pleshey STW	TL6680014500	29.12	Unspecified	$9.6x10^{10}$*	Walthambury Brook
Post Office Rd. STW	TL8134004570	0.32	Secondary	$1.1x10^{9}$*	Woodham Motrimer Brook
Purleigh New STW	TL8408002700	260	Secondary	$8.6x10^{11}$*	Mundon Wash
Rayne STW	TL7323023500	650	Secondary + sand filtration	$2.1x10^{12}$*	Pods Brook
Rivenhall STW	TL8440016510	80	Secondary	$2.6x10^{11}$*	Rivenhall Brook
Roxwell STW	TL6491008860	232	Secondary	$7.7x10^{11}$*	Newland Brook
Salcott STW	TL9530013400	56	Secondary	$1.8x10^{11}$*	Salcott Creek
Shalford STW	TL7249029360	304	Secondary	$1.0x10^{12}$*	River Pant

Name	Location	DWF (m^3/day)	Treatment Level	Estimated bacterial loading (cfu/day)	Receiving Water
Shenfield STW	TQ6510096000	12650	Secondary + phosphate stripping	$4.2x10^{13}$*	River Wid
Stisted STW	TL8020024600	300	Secondary	$9.9x10^{11}$*	Stisted Brook
Stone Lawrence STW	TL9550004850	322	Secondary	$1.1x10^{12}$*	River Blackwater trib.
Tillingham STW	TL9873004270	261	Secondary	$8.6x10^{11}$*	Bradwell Brook
Tiptree STW	TL9389015720	2567	Secondary	$8.5x10^{12}$*	Virley Brook
Tolleshunt D'Arcy STW	TL9220010500	210	Secondary	$6.9x10^{11}$*	Bowstead Brook
West Mersea STW	TM0310012100	2900	Tertiary (UV)	$7.8x10^{8}$***	North Sea
Wethersfield STW	TL7056030590	955	Secondary	$3.2x10^{12}$*	River Pant
White Notley STW	TL7903018230	1225	Secondary + lagoon	$4.0x10^{12}$*	River Brain
Willows Green STW	TL7210019600	17.12	Secondary	$5.6x10^{10}$*	River Ter
Wimbish STW	TL5918036200	118.24	Secondary	$3.9x10^{11}$*	River Pant trib.
Witham STW	TL8414007800	8100	Secondary	$2.7x10^{13}$*	Blackwater estuary
Woodham Walter STW	TL8155007430	132	Secondary	$4.4x10^{11}$*	Woodham Walter Brook

*Faecal coliforms (cfu/day) based on geometric base flow averages from a range of UK STWs providing secondary treatment (Table II.3).
** Faecal coliforms (cfu/day) based on geometric mean final effluent testing data (Table II.2)
*** *E. coli* (cfu/day) based on geometric mean final effluent testing data (Table II.2)

Table VII.2 Summary statistics for final effluent testing data

Sewage works	No.	Date of first sample	Date of last sample	Parameter measured	Geometric mean result (cfu/100ml)	Minimum	Maximum
Maldon STW	36	25/01/2007	07/12/2009	Faecal coliforms	2512	59	79,200
West Mersea STW	64	07/01/2008	11/12/2010	*E. coli*	27	1	9,800

Data from the Environment Agency

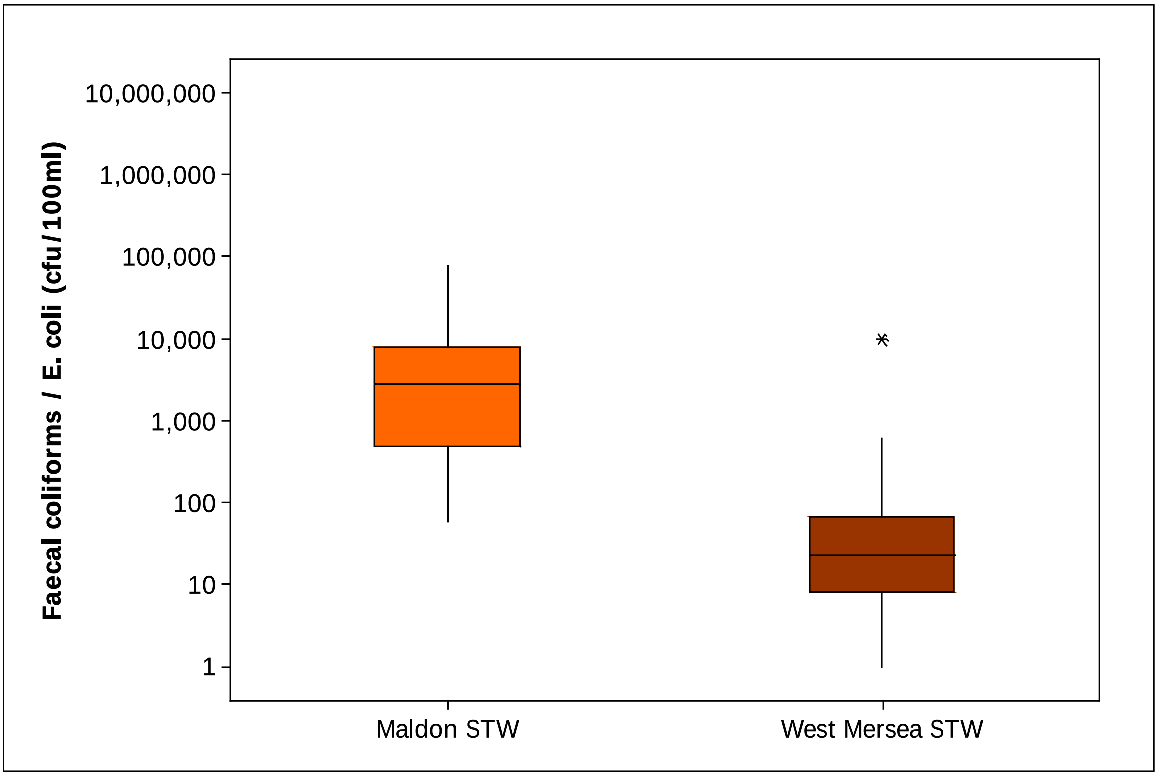


***Figure II.2. Boxplot of bacterial concentrations measured in final effluent samples. Those in orange are faecal coliforms and those in brown are* E. coli.**
Data from the Environment Agency

Table II.3 Summary of reference faecal coliform levels (cfu/100ml) for different sewage treatment levels under different flow conditions.

Treatment Level	Flow			
	Base-flow		High-flow	
	n	Geometric mean	n	Geometric mean
Storm overflow (53)	-	-	200	$7.2x10^6$
Primary (12)	127	$1.0x10^7$	14	$4.6x10^6$
Secondary (67)	864	$3.3x10^5$	184	$5.0x10^5$
Tertiary (UV) (8)	108	$2.8x10^2$	6	$3.6x10^2$

Data from Kay et al. (2008b).
n - number of samples.
Figures in brackets indicate the number of STWs sampled.

The majority of sewage (>90% in terms of volume) is discharged to the estuary upstream of the shellfisheries, or to watercourses which drain to the estuary upstream of the shellfisheries. Although significant bacterial die-off is likely to occur during transit from those discharges higher up in the catchment, higher levels of sewage derived contamination are expected towards the head of the estuary on this basis.

The discharges from Chelmsford STW and to a lesser extent the Witham STW are likely to be highly significant contaminating influences in the upper estuary and beyond on the basis of the volume of effluent they receive and the level of treatment they provide. Bacteriological testing data from Maldon STW indicate that the treatment here, which incorporates a final lagoon with a long residence time, results in relatively low bacterial concentrations in the effluent. There are several small sewage works discharging to various watercourses and creeks on both the north and south shore of the Blackwater estuary. Those discharging either directly or via watercourse to enclosed creeks, such as the Mayland and Latchingdon STWs are likely to be a significant influence within these creeks although the latter has a lagoon which will reduce bacterial loadings. The only sewage works discharging to a watercourse which drains directly to the area off the Dengie Peninsula is Tillingham STW which is relatively small but may nevertheless be of some influence to this fishery. Sewage discharges to the Crouch Estuary, primarily the Burnham-on-Crouch STW (CEFAS, 2012) may be of some significance towards the southern end of the shellfisheries off Dengie. The location of the West Mersea STW discharge and the quality of effluent it produces indicate that it will have no influence on shellfish hygiene within the survey area.

The Langford recycling plant is a water company asset (Northumbrian Water Ltd.) which takes final effluent from Chelmsford STW, and uses biological, chemical and ultra-violet light treatments to disinfect, and remove nutrients from waste water that would otherwise be discharged direct to the Blackwater estuary (Warren, 2007). The purpose of this is to increase the volume of water available for abstraction in the lower River Chelmer. The final effluent from this is likely to be of very high quality due to the high level of treatment it receives. Its impacts on water quality in the Blackwater estuary are therefore likely to be negligible despite the large volume of water which pass through it.

In addition to the continuous sewage discharges, there are a large number of intermittent water company discharges associated with the sewerage networks serving the area. Figure II.3 shows the locations of these as well as private discharges directly to or within close proximity (~2km) of the estuary and Dengie Flats. Table II.4 presents details of the intermittent discharges, and details of the larger private discharges (>10m^3/day maximum permitted flow) are presented in Table II.5. In addition there are many other intermittent outfalls and private discharges distributed around the more inland areas of the catchment which are not shown in Figure II.3.

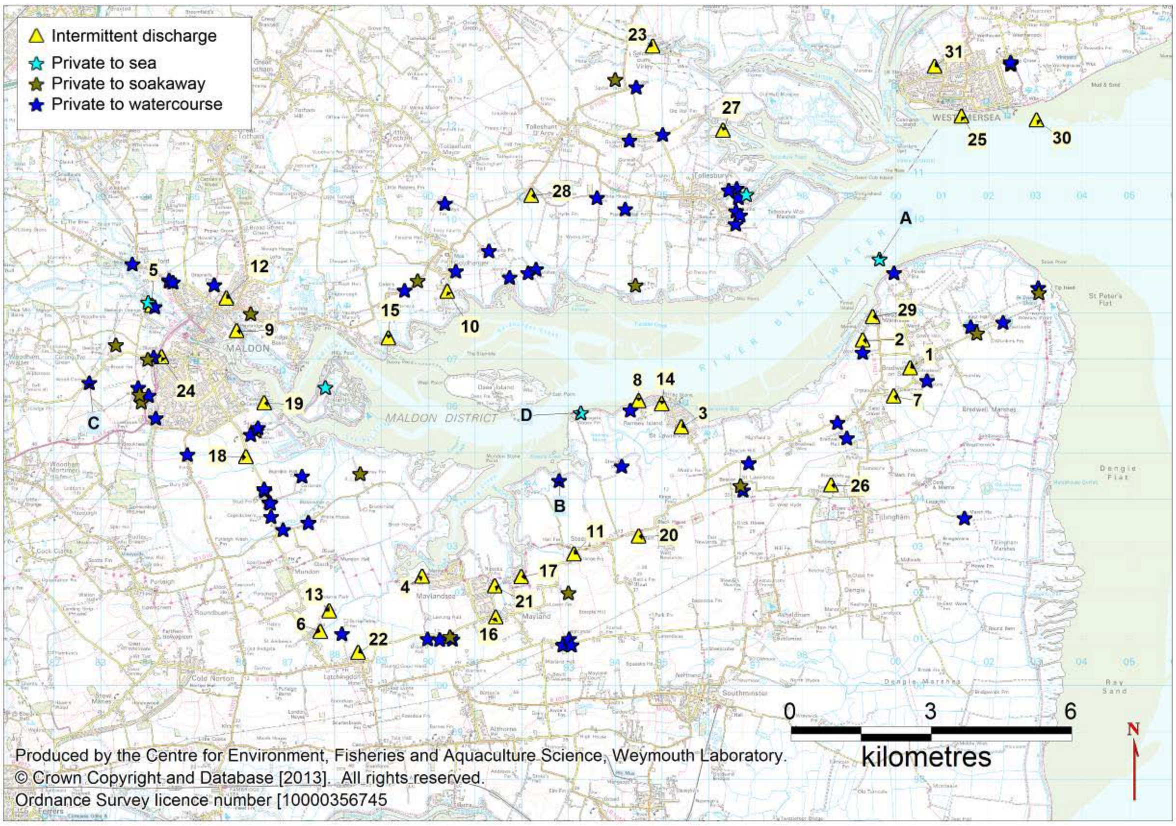


Figure II.3 Intermittent and private discharges within 2km of the survey area

Table II.4. Intermittent discharges within 2km of the survey area

No.	Name	Location	Receiving water
1	Bradwell Village Hall PS	TM0030806803	Bradwell Brook trib.
2	Bradwell STW	TL9929007400	Bradwell Creek trib.
3	Caravan Park PS	TL9541005540	Motts Farm Drain
4	Cardnells PS	TL8986702337	Unnamed drain
5	Chelmsford STW	TL8409008140	Blackwater Estuary
6	Deadaway Bridge PS	TL8768901152	Latchingdon Brook
7	Delameres Farm SPS	TL9995106201	Bradwell Brook trib.
8	Esplanade West	TL9450006100	Blackwater Estuary
9	Fambridge Rd. Maldon	TL8590007600	Blackwater Estuary
10	Fish Street SPS	TL9040808447	Bounds Farm Ditch trib.
11	Grange Farm SPS	TL9311602816	Steeple Brook trib.
12	Heybridge	TL8567908298	Heybridge
13	Latchingdon STW	TL8788001590	Latchington Brook
14	Lawrence Drive PS	TL9499006030	Motts Farm Drain
15	Maldon (Osea Road) STW	TL8915007440	Pennys Brook
16	Mayland Green PS	TL9144001462	Mayland Brook
17	Mayland STW	TL9199002330	Mayland Creek
18	Mundon Road	TL8610004900	Linbourne Creek trib.
19	Park Drive	TL8649006050	Unnamed drain
20	Poplars Farm SPS	TL9450003200	Ramsey Marsh trib.
21	PS at Nipsells Chase	TL9142002130	Mayland Brook trib.
22	Ramsey Chase	TL8850000700	Mundon Brook
23	Salcott SPS	TL9480013700	Virley Brook
24	SPS at London Road Maldon	TL8429407035	River Blackwater trib.
25	SSO Kingsland Rd W. Mersea	TM0140012200	North Sea
26	Tillingham STW	TL9861004290	Bradwell Brook
27	Tollesbury STW	TL9630011900	Tollesbury Fleet
28	Tolleshunt D'Arcy STW	TL9220010500	Bowstead Brook

29	Waterside	TL9950007900	Bradwell Creek
30	West Mersea STW	TM0301012120	River Blackwater
31	Whitaker Way SPS	TM0082813265	Strood Channel trib.

The intermittent discharges are generally located around settled areas and most are by the south shore or to the very upper reaches of the estuary. There are clusters around the head of Lawling and Mayland Creeks, at St. Lawrence and at Bradwell. On the north shore, there are individual intermittent outfalls at Maldon STW, to a watercourse by Bounds Farm, and to a watercourse draining to the head of Thirslet Creek. Spill events may occur either under storm conditions when the sewers are inundated with runoff which may happen after intense rainfall events, or in the event of an emergency such as a pump failure or blockage which may occur at any time. Typically, spills are too infrequent for their impacts to be captured reliably under monthly classification sampling. Those with larger catchments and which receive larger amounts of surface water may be prone to spill larger volumes. No spill records from these discharges was available at the time of writing, so it is difficult to assess their significance aside from noting their location and their potential to discharge large volumes of untreated sewage.

In addition to the water company owned discharges, there are numerous consented private discharges in the vicinity. Where specified, these are generally treated by either septic tank or small treatment works such as package plants. The vast majority of these are small, serving one or a small number of properties. Only eight have consented maximum flows of over $10m^3$/day (Table II.5).

Table II.5. Private sewage discharges of over $10m^3$/day within 2km of the estuary

Ref.	Property served	Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
A	Power Station	TL9965009150	Secondary	504900	Sea
B	Caravan Park	TL9280004400	Unspecified	46	Watercourse
C	Gypsy Site	TL8275006500	Biological filtration	20	Watercourse
D	Sailing Club	TL9326005850	Secondary	10	Watercourse

Data from the Environment Agency

The main Power Station discharge (A) has a consented discharge rate of $504900m^3$/day, or about $6m^3$/sec. Most of this is trade effluent (seawater used by the plant and other process effluents) although secondary treated sewage effluent comprises about $136m^3$/day or 0.03% of this discharge. The effluent will therefore contain very low concentrations of faecal indicator bacteria and as such should not create a particular hotspot of contamination. Discharges B and D may have some localised impacts in the vicinity of their outfalls. Discharge C is to a watercourse to the head of the estuary, so any impacts from this will be felt alongside other sewage discharges and catchment sources entering the estuary upstream of the fisheries.

APPENDIX III
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: AGRICULTURE

The vast majority of agricultural land within the Blackwater and Dengie catchment is used for arable farming, although there are relatively small pockets of pasture (Figure 1.2). Table VIII.1 and Figure VIII.1 present livestock numbers and densities for the catchments draining to the survey area. These data were provided by Defra and is based on the 2010 census. Geographic assignment of animal counts in this dataset is based on the allocation of a single point to each farm, whereas in reality an individual farm may span the catchment boundary. Nevertheless, the data should give a good indication of the numbers of livestock within the area.

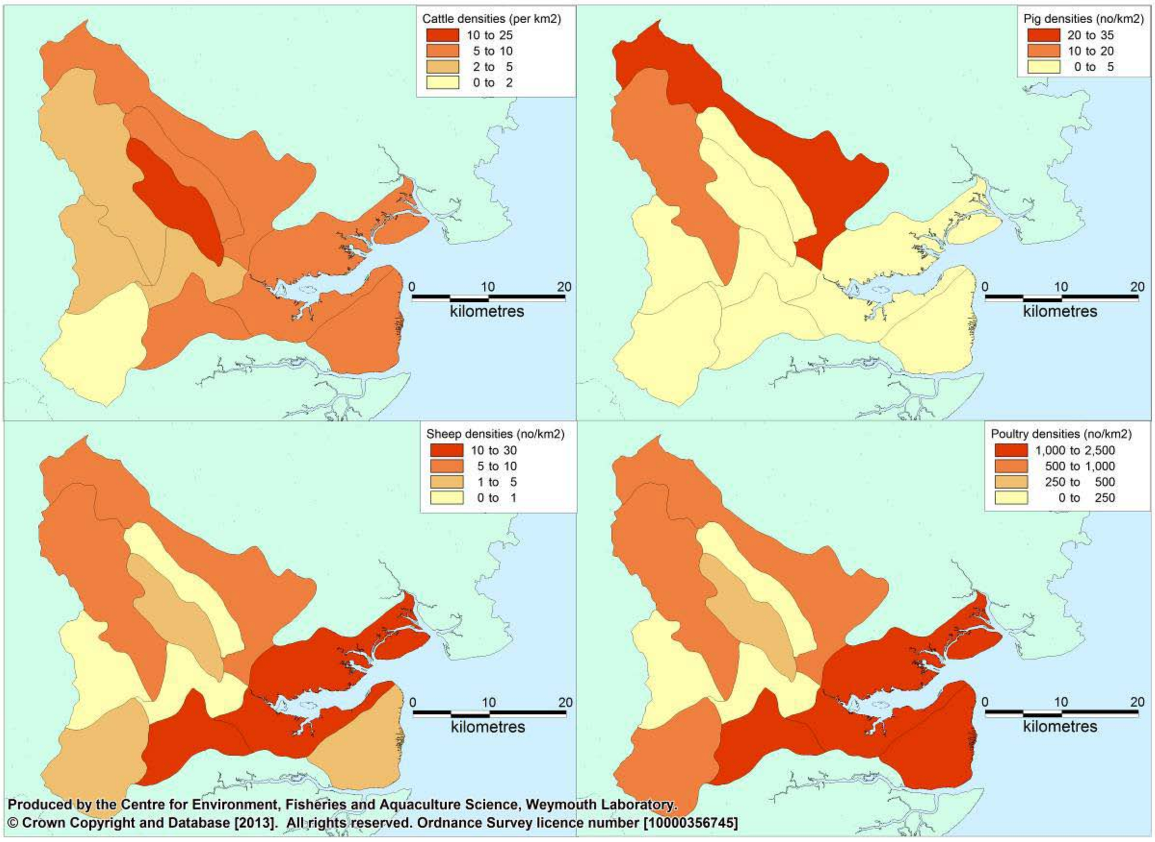


Figure VIII.1. Livestock densities within the catchment.

Table III.1 Summary statistics from 2010 livestock census

	Numbers				Density (animals/km^2)			
Catchment name	Cattle	Pigs	Sheep	Poultry	Cattle	Pigs	Sheep	Poultry
Blackwater Estuary	1,282	*	5,970	470,807	5.8	*	27.0	2,132
Blackwater Pant	1,240	7,954	2,199	209,668	5.0	32.4	8.9	853
Brain	345	*	*	2,507	5.2	*	*	38
Can & Roxwell Brook	259	*	*	*	2.7	*	*	*
Chelmer (Lower)	286	*	*	*	4.2	*	*	*
Chelmer (Upper)	459	3,003	1,290	127,819	2.3	15.3	6.6	650
Dengie	675	*	425	243,979	6.6	*	4.2	2,385
Sandon Brook	618	383	2,448	142,758	7.4	4.6	29.4	1,713
Ter	1,867	*	87	23,518	22.9	*	1.1	289
Wid	251	*	216	97,638	1.8	*	1.5	701
TOTAL	7,282	>11,340	>12,635	>1,318,694	5.6	>8.7	>9.7	>1,015.2

*Data suppressed to prevent disclosure of information about individual holdings

The concentration of faecal coliforms excreted in the faeces of animal and human and corresponding loads per day are summarised in Table VIII.1.

Table VIII.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)	Faecal coliform load (No. day^{-1})
Chicken	1,300,000	182	2.3×10^8
Pig	3,300,000	2,700	8.9×10^8
Human	13,000,000	150	1.9×10^9
Cow	230,000	23,600	5.4×10^9
Sheep	16,000,000	1,130	1.8×10^{10}

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

There are relatively low numbers and densities of grazing animals (cattle and sheep) within the area, which deposit faeces directly on pastures. Their impacts are likely to be relatively minor overall, although they may be of local significance for example where there is an area of grazing marsh immediately adjacent to a shellfishery. Livestock were observed in several locations around the Blackwater, including Ramsey Marsh by Steeple Creek, the headland between Lawling Creek and Mayland Creek, east of Mill Creek and to the east of Goldhanger. Land use adjacent to Dengie Flats was exclusively for arable farming.

As well as direct deposition by livestock, slurry is also collected from livestock sheds when cattle are housed indoors and subsequently applied to fields as fertilizer. Large numbers of poultry and a few pigs are also raised within the catchment. Manure from pig and poultry operations is typically collected, stored and spread on nearby farm land (Defra, 2009). Sewage sludge may also be used as fertilizer, but no information on local practices was available at the time of writing. On the shoreline survey one farm at the southern end of the Dengie Peninsula did appear to be receiving a delivery of sewage sludge at its gate.

The primary mechanism for mobilisation of faecal matter deposited or spread on farmland to coastal waters is via land runoff, so fluxes of livestock related contamination into the estuary will be highly rainfall dependent. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the ‘first flush’). Most of the major watercourse will be impacted in some extent by agriculture, but the smaller watercourses draining areas of pasture adjacent to the estuary may be of most impact on the shellfisheries.

There is likely to be seasonality in levels of contamination originating from livestock. Numbers of sheep and cattle will increase significantly in the spring, with the birth of lambs and calves, and decrease in the autumn when animals are sent to market. Highest sheep counts on the grazing marshes on the south shore of the estuary are reported to occur from April to October. During winter cattle may be transferred from pastures to indoor sheds, and at these times slurry will be collected and stored for later application to fields. Timing of these applications is uncertain, although farms without large storage capacities are likely to spread during the winter and spring. Poultry/pig manure and sewage sludge may be spread at any time of the year. Therefore peak levels of contamination from sheep and cattle may arise following high rainfall events in the summer, particularly if these have been preceded by a dry period which would allow a build up of faecal material on pastures, or on a more localised basis if wet weather follows a slurry application which is more likely in winter or spring.

APPENDIX IV
SOURCES AND VARIATION AND MICROBIOLOGICAL POLLUTION: BOATS

The discharge of sewage from boats is potentially a significant source of bacterial contamination of shellfisheries within the Blackwater estuary. There is significant boat traffic within the Blackwater estuary; it is a popular place for commercial fishing and small pleasure craft. Figure IX.1 presents an overview of boating activity derived from the shoreline survey, satellite images and various Internet sources.

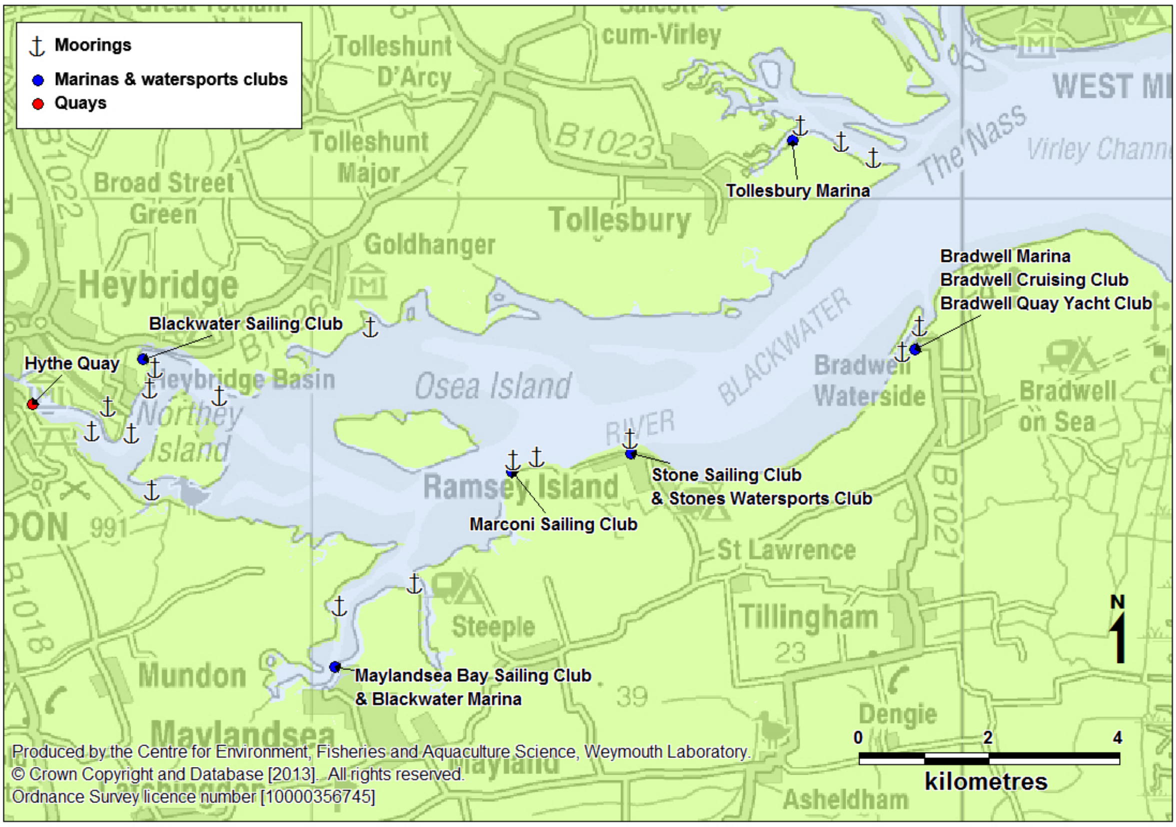


Figure IX.1 Location of mooring areas and sailing clubs in the Blackwater Estuary

Hythe Quay in Maldon was once an important and busy commercial port, however today commercial shipping is almost nonexistent. The sheltered waters of the estuary are popular with yachtsmen and are also used by other small recreational craft such as canoes, windsurfers and sailing dinghies. Within the estuary there are three marinas collectively holding around 800 berths but none of these has sewage pumpout facilities (Reeds, 2011). In addition to this there are hundreds of dry and wet moorings scattered along the edge of the main channels and close to the shore. The main concentrations of these are in the upper reaches of the estuary around Maldon and Heybridge Basin, Maylandsea, Ramsey Island and Bradwell Waterside. There are also several public slipways where smaller craft can be launched. There is a large inshore fishing fleet based at West Mersea. A small number of commercial fishermen work within the estuary, from the Maldon/Bradwell area (Marine Management Organisation, 2010), and some charter fishing boats also use the estuary. Thames barges cruise through the Blackwater waters giving tourists an insight into the area's history and wildlife. Small numbers of houseboats were recorded at Heybridge Basin (3) and Maylandsea (2).

Private vessels of sufficient size to have onboard toilets, such as yachts, cabin cruisers and fishing vessels are likely to make overboard discharges from time to time. Those in overnight occupation on moorings or at anchor may be more likely to make overboard discharges as access to facilities on land requires rowing ashore. Houseboats in occupation are also likely to make discharges. Occupied yachts on pontoon berths may be less likely to make overboard discharges as this is somewhat antisocial in the crowded marina setting, and on land facilities are more easily accessible. Peak pleasure craft activity is anticipated during the summer and it is probable that more moorings will be occupied at this time, so associated impacts are likely to follow this seasonal pattern within the Blackwater estuary.

The areas that are at highest risk from overboard discharges made by boats on moorings are therefore around Maldon and Heybridge Basin, Maylandsea, Ramsey Island and Bradwell Waterside. The main navigation channels are also likely to be subject to overboard discharges made by boats on passage. The area off Dengie is not likely to see much boat traffic, aside from fishing vessels working the area, as most traffic will be navigating the adjacent channels into the Crouch and the Blackwater estuaries. The risk of contamination from boats is likely to be much higher during the summer. It is difficult to be more specific about the potential impacts from boats and how they may affect the sampling plan without any firm information about the locations, timings and volumes of such discharges.

APPENDIX V
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: WILDLIFE

The Blackwater estuary falls within several national and international designations for nature conservation, it forms part of the Essex Estuaries European Marine Site SAC for its intertidal and subtidal habitats. Northey Island situated in the upper reaches of the estuary has been designated as a nature reserve. The estuary contains extensive areas of mudflats which are fringed by salt marsh. These areas have also been designated as a Ramsar Site, SSSI and SPA as they sustain international and nationally important assemblages of overwintering birds and wildfowl and nationally important plant and invertebrate species. The Blackwater estuary holds around 15,392 Dark-bellied Brent Geese which is equivalent to 5.1% of the world's population (JNCC, 2001). Sections of the Tollesbury Flats located on the northern border of the estuary, are closed to the public because they are frequented by a significant number of wildfowl and overwintering birds and a population of bearded tits (Natural England, 2012). The surrounding terrestrial habitats, sea wall, marsh, fleet and ditch systems, as well as semi-improved grasslands are also of high conservation interest (JNCC, 2001).

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). Over the five winters up until 2010 an average total count of 72,450 overwintering and wildfowl were recorded within the Blackwater estuary and 59,846 were recorded on the Dengie flats (situated to the east of the main estuary) (Holt *et al*, 2012). Species recorded include Dark Bellied Brent Goose, Golden Plover, Grey Plover, Knot, Dunlin and Black Tailed Godwit. Within the estuary they are relatively widespread. Dunlin and Brent Geese tend to dominate the central regions of the north shore of the estuary, whereas Knot, Redshank and Lapwing dominate the channels entering the estuary on the north, south and western shores of the main estuary (Musgrove *et al*, 2003). Some species, such as Grey Plover forage upon shellfish and so will forage (and defecate) directly on the shellfish beds across a wide area. They may tend to aggregate in certain areas holding the highest densities of bivalves of their preferred size and species, but this will change from year to year. The shoreline survey confirmed a significant winter presence of waders and geese in the area. Contamination via direct deposition may be quite patchy, with some shellfish containing quite high levels of *E. coli* with others a short distance away unaffected. Due to the diffuse and spatially unpredictable nature of contamination from wading birds it is difficult to select specific RMP locations to best capture this, although they may well be a significant influence during the winter months.

Small numbers of waders will remain in the area to breed in the summer, but the majority migrate elsewhere to breed. Breeding seabirds (gulls, terns etc) were subject to a survey in the early summer of 2000 (Mitchell *et al*, 2004). Although numbers were considerably lower than overwintering wildfowl populations they were still significant with 712 pairs counted nesting within or on the shores of the estuary. The majority of these (634 pairs) use Pewet Island as a nesting site. Seabirds are likely to forage widely throughout the area, therefore faecal inputs could be considered as diffuse. However, it is expected to be more concentrated in the immediate vicinity of their nest sites. Impacts may be felt either via a higher concentration of droppings in the intertidal or via runoff into tidal creeks.

Considerable numbers of breeding harbour seals are present within the Essex estuaries; around 100 have been recorded. They can be sighted all year round and they utilise the extensive mudflats to haul out (Marine Management Organisation, 2011). Dengie Flats and Buxey Sands are regularly used as haulout sites. A few grey seals have also been sighted in the vicinity. They forage widely and numbers are not large so their impacts will be very minor and generally diffuse, although contamination is likely to be more intense and regularly occurring in the immediate vicinity of their haulout sites.

A small number of otters have been recorded in the upper reaches of the Blackwater tributaries, however exact numbers are not known (Tansley, 2009) (Blackwater Valley Countryside, 2011). Otters and water voles generally tend to favour the more secluded areas with access to watercourses. However, given their likely wide distribution and small numbers they have no material bearing on the sampling plan. Rats will also be present within the survey area; populations likely to be large with higher numbers present in urban areas. Potentially they could be a source of microbiological contamination within the shellfish area; however, exact numbers are not known and given their wide distribution it makes it difficult to determine.

No other wildlife species which have a potentially significant influence on levels of contamination within shellfish on the Blackwater estuary have been identified. Although not strictly wildlife, dog walking takes place along coastal paths that run adjacent to the shoreline of the estuary and could represent a potential source of diffuse contamination to the near shore zone.

APPENDIX VI
METEOROLOGICAL DATA: RAINFALL

The Blackwater river catchment is located in the east of England, which is one of the driest and warmest regions in the country. The Mersea weather station, which is within the catchment area, received an average of 483mm per year between 2003 and 2012. Figure II.1 presents a boxplot of daily rainfall records by month at Mersea.

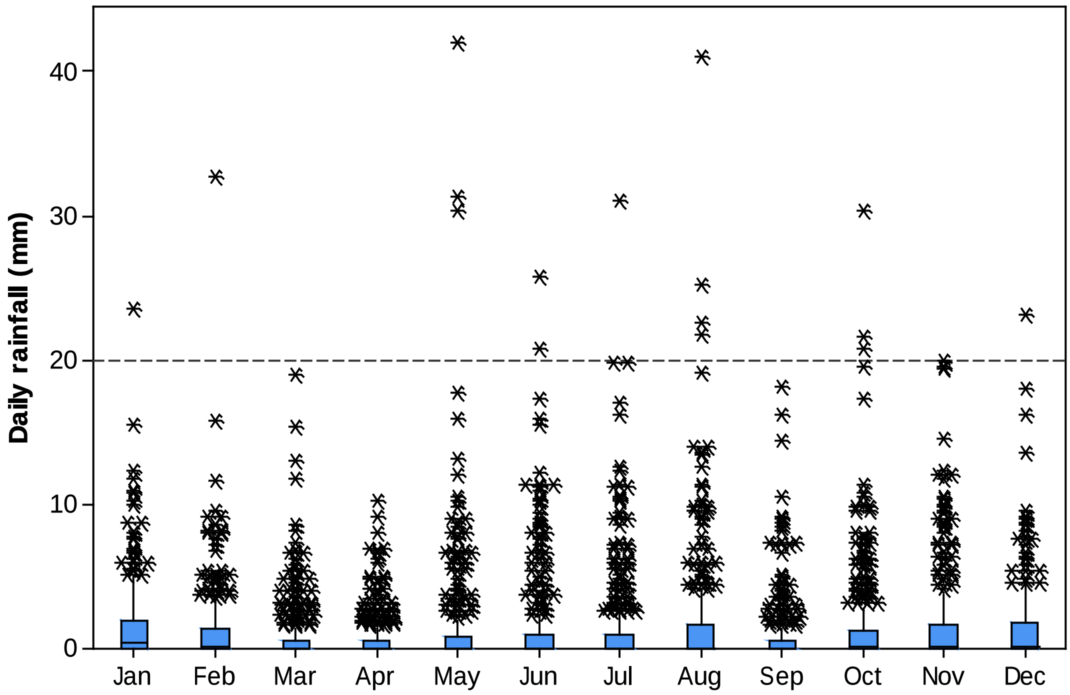


Figure II.1 Boxplot of daily rainfall totals at Mersea, January 2003 to August 2012.
Data from the Environment Agency

Rainfall records from Mersea, which is representative of conditions in the vicinity of the shellfish beds, indicate relatively low seasonal variation in average rainfall. Rainfall was lowest on average in March, April and September and highest on average in November and August. Daily totals of over 20mm were recorded on 0.45% of days and 52.5% of days were dry. High rainfall events, whilst relatively rare, tended to occur most during the summer and autumn but events of over 20mm were recorded in all months apart from March, April September and November.

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 rainfall dependent discharges and freshwater inputs will reflect the combined effect of rainfall on the contribution of individual pollution sources. Relationships between levels of *E. coli* and faecal coliforms in shellfish and water samples and recent rainfall are investigated in detail in Appendices XI and XII.

APPENDIX VII
METEOROLOGICAL DATA: WIND

Eastern England is one of the more sheltered parts of the UK, since the windiest areas are to the north and west, closer to the track of Atlantic storms (Met Office, 2012). The strongest winds are associated with the passage of deep depressions across or close to the UK. The frequency of depressions is greatest during the winter months so this is when the strongest winds normally occur.

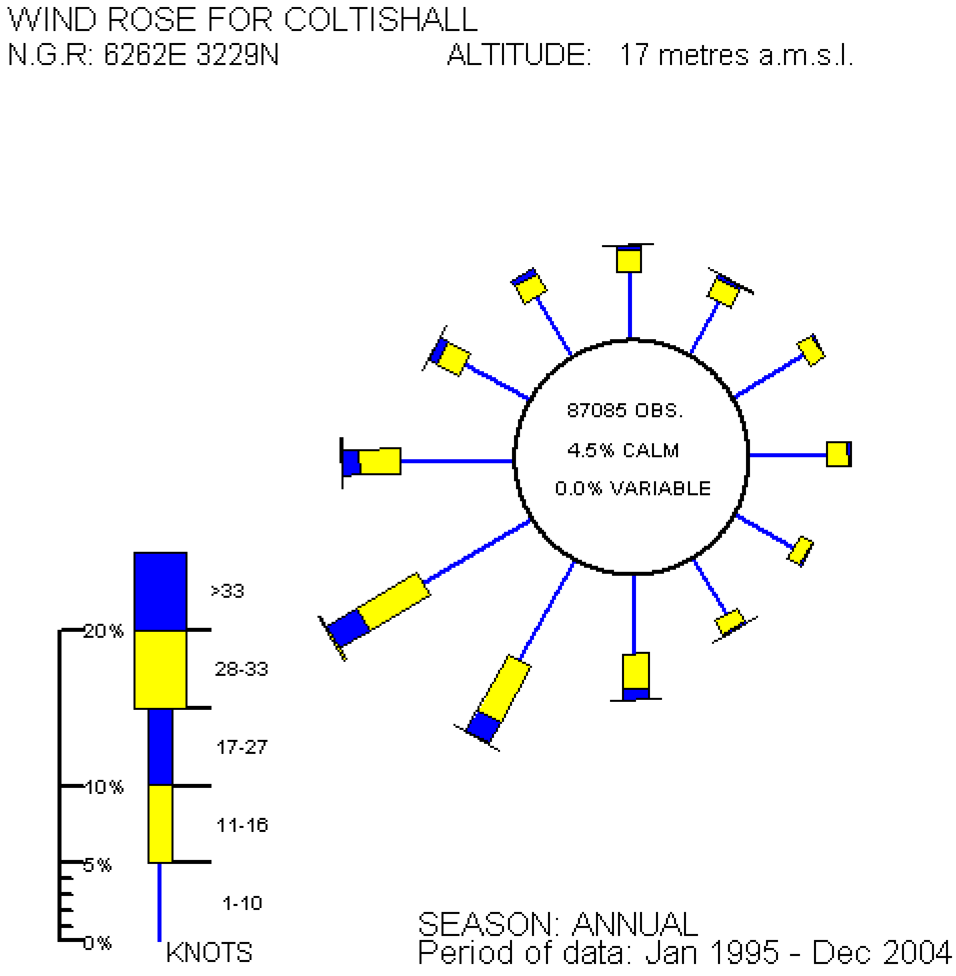


Figure VI.1 Wind rose for Coltishall
Produced by the Meteorological Office. Contains public sector information licensed under the Open Government Licence v1.0

The wind rose for Coltishall, typical of open, level locations across the region. There is a prevailing south-westerly wind direction throughout the year. During spring there is also a high frequency north-easterly wind due to a build up of high pressure over Scandinavia (Met Office, 2012). Periods of very light or calm winds are more prevalent inland, with coastal areas having similar wind directions to inland locations but higher wind speeds. The Blackwater estuary is most exposed to winds from the north east and south west which will blow up or down the estuary. The surrounding land is low lying and does not offer much shelter to winds from other directions. Dengie Flats is exposed to the open North Sea to the east but again the adjacent land is low lying and offers little shelter from winds from other directions.

APPENDIX VIII
HYDROMETRIC DATA: FRESHWATER INPUTS

The two main inputs to this catchment are the River Chelmer and the River Blackwater which make up 53% and 28% of the 1200 km² catchment area respectively. The River Blackwater flows from Bocking near Braintree. Upstream of this the river is called the River Pant. The River Pant rises to 107m above mean sea level near the village of Sewards End. From here the Pant/Blackwater runs approximately 109 km to the tidal limit at Beeleigh Falls near Maldon. A major tributary to the River Blackwater is the River Brain which runs for about 19 km before joining the Blackwater near Wiltham. Water levels in the River Blackwater are augmented at times of drought by transfer of water from outside the catchment (Environment Agency, 2007).

The River Chelmer flows approximately 73 km from its source near the village of Debden Green to the tidal limit at Beeleigh Falls near Maldon. Major tributaries are the River Can (19km), the River Wid (25.4km) and the River Ter (32 km). Water is abstracted for transfer to the Hanningfield Reservoir, upstream of the river gauging station.

The Chelmer and Blackwater rivers both flow through urban and rural areas with most of the rural land use being for arable crop production. However some rural areas are also used for grazing livestock. For the most part, the underlying bed rock is largely low-permeability clay. In the most northern reaches of the catchment however, the bed rock is high permeability chalk. The low permeability of the catchment means that there are relatively high runoff rates that flow directly into the watercourses (Environment Agency, 2009).

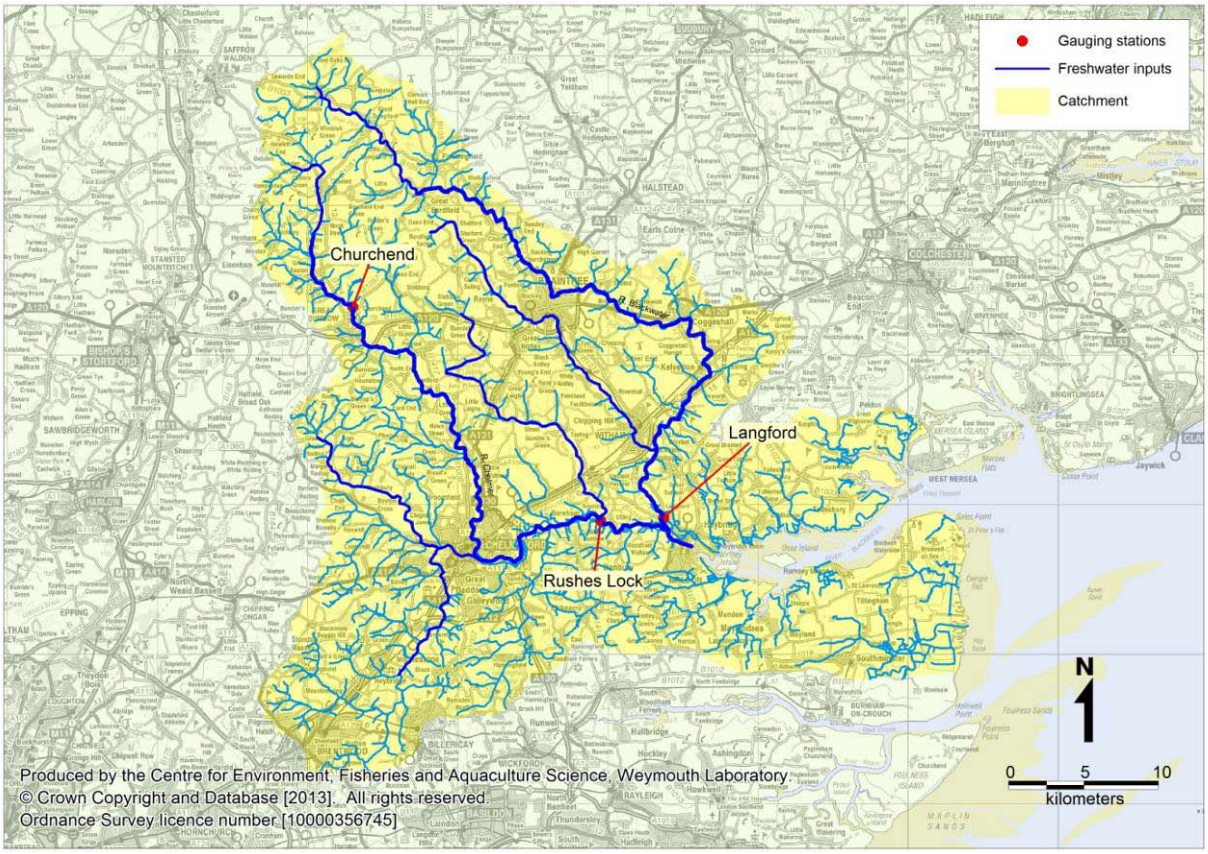


Figure VIII.1: Watercourses within the survey catchment area

These rivers will receive microbiological pollution from point and diffuse sources such as STW discharges and urban and agricultural runoff. They are therefore potentially a significant source of microbiological contamination for the shellfisheries in the estuary. Summary statistics for the three flow gauges on these rivers are presented in Table VIII.1. The shellfisheries areas at Blackwater start downstream of the point where both the Rivers Blackwater and Chelmer join the estuary and so it is likely that there will be a gradient of the effect on shellfisheries from freshwater inputs. However, several smaller watercourses discharge within the length of the shellfishery areas and so may have a greater influence.

Table VIII.1: Summary flow statistics for flow gauge stations on watercourses draining into the Blackwater estuary

Watercourse	Station name	Catchment area (km^2)	Mean annual rainfall 1961-90 (mm)	Mean flow (m^3s^{-1})	Q95[1] (m^3s^{-1})	Q10[2] (m^3s^{-1})
Blackwater	Langford	337	570	1.376	0.224	2.884
Chelmer	Rushes Lock	534	583	1.909	0.132	4.830
Chelmer	Churchend	73	591	0.357	0.052	0.774

[1]Q95 is the flow that is exceeded 95% of the time (i.e. low flow). [2]Q10 is the flow that is exceeded 10% of the time (i.e. high flow). Data from NERC (2012).

Boxplots of mean daily flow records by month at the Churchend and Langford gauging stations are presented in Figures VIII.2 and VIII.3. Some abstraction occurs downstream of these stations so the flows reaching the estuary will be lower for much of the year. Flows were highest in the colder months at all gauging stations. At

Langford, which is the most downstream gauging station in the catchment area, flow rates hit a record flow of 53 m³/s in February 2009 following heavy rainfall events.

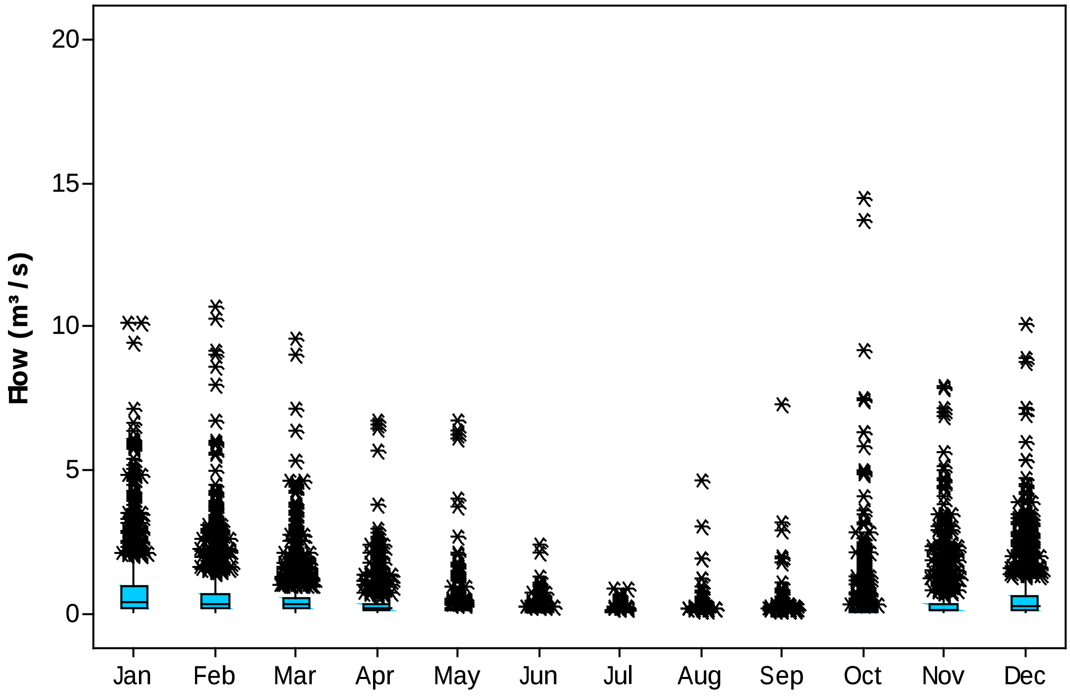


Figure VIII.2: Boxplots of mean daily flow records from the Churchend gauging station on the River Chelmer from 1963-2010 *Data from the Environment Agency*

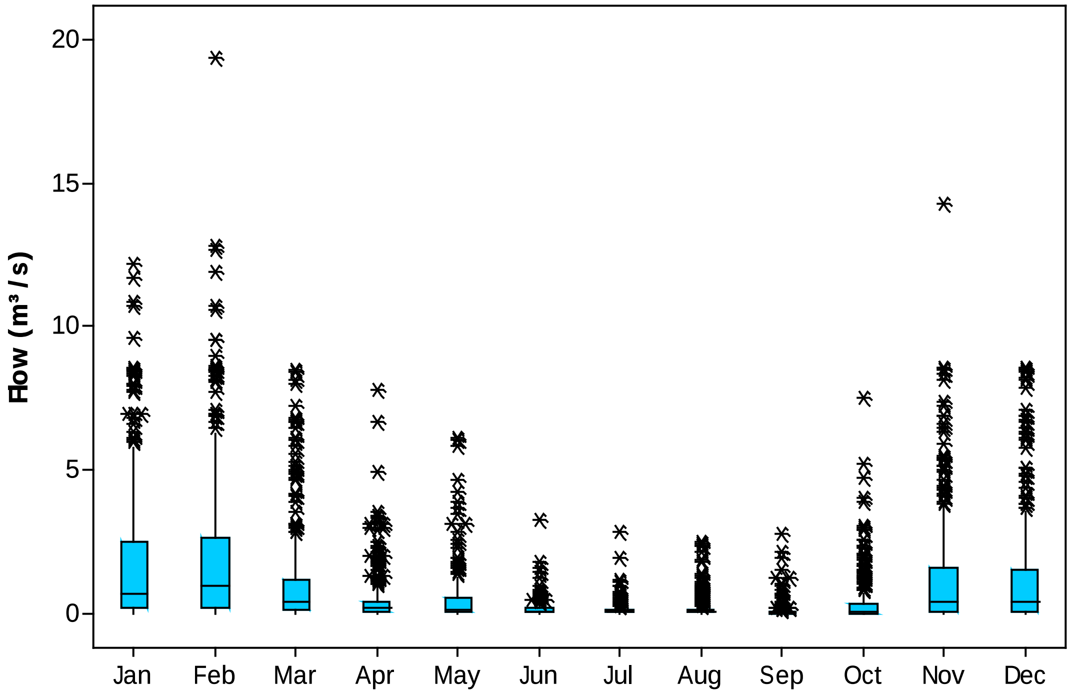


Figure VIII.3: Boxplots of mean daily flow records from the Langford gauging station on the River Blackwater from 2000-2009. Two data point from February 2009 were removed from the dataset. These data showed flows of 53 and 48 m³/s following heavy rainfall events. *Data from the Environment Agency*

The seasonal pattern of flows is not entirely dependent on rainfall as during the colder months there is less evaporation and transpiration, leading to a higher water table. This in turn leads to a greater level of runoff immediately after rainfall. Increased levels of runoff are likely to result in an increase in the amount of microorganisms carried into coastal waters. Additionally, higher runoff will decrease residence time in rivers, allowing contamination from more distant sources to have an increased impact during high flow events.

Whilst the majority of freshwater inputs within the survey area are to the head of the Blackwater estuary, there are a series of smaller watercourses discharging at intervals along the shore of the estuary and to Dengie Flats. These are generally field drains and small streams which discharge via engineered outfalls. During the shoreline survey the locations of these were recorded, and where safe access was possible water samples and spot flow gaugings were undertaken. Figure VIII.4 shows their locations and Table VIII.2 present details of those which were sampled and/or measured. Most of the outfalls on the south shore were not sampled and measured, and those towards the western end of the north shore were covered by the tide at the time.

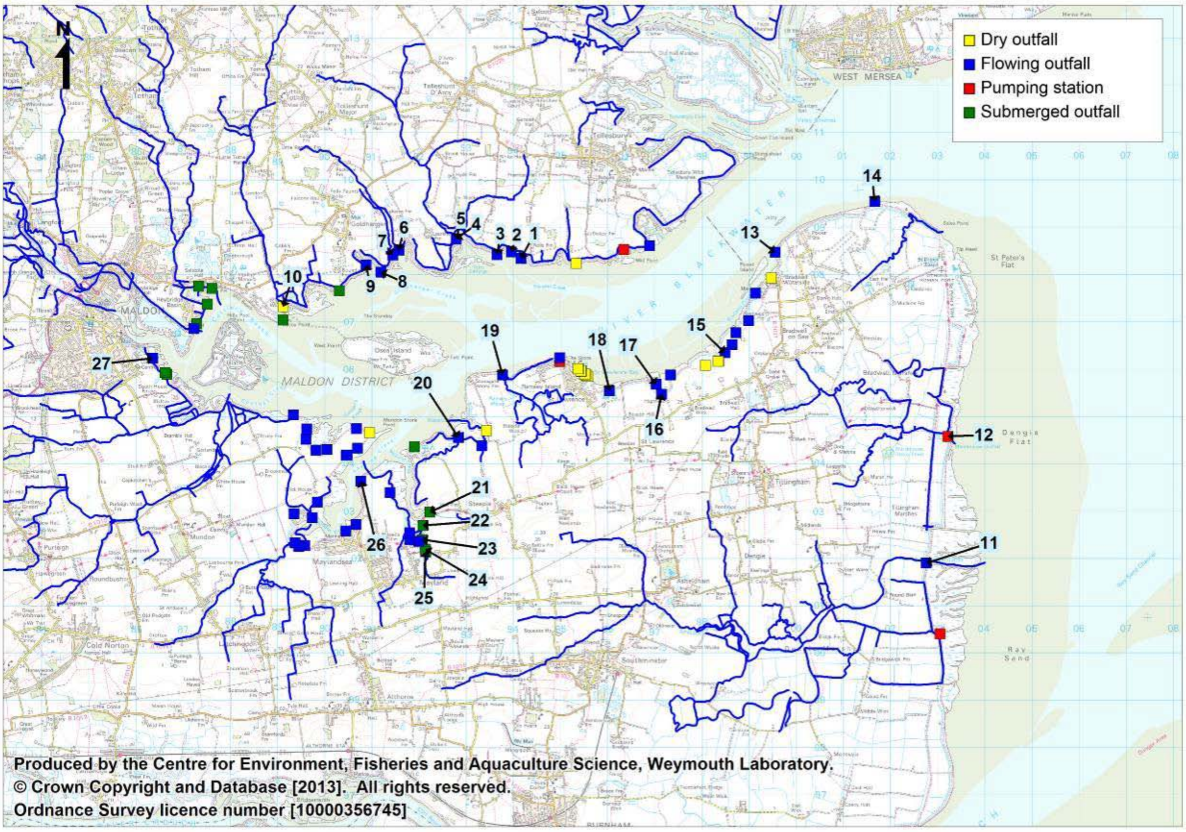


Figure VIII.4. Shoreline observations of freshwater inputs

Table VIII.2 Watercourse sampling results from shoreline survey

No.	NGR	Type	*E. coli* (cfu/100ml)	Discharge (m3/day)	Loading (*E. coli* / day)
1	TL 94158 08342	Flowing outfall	1200	341	$4.10x10^{10}$
2	TL 93950 08480	Flowing outfall	1100	259	$2.85x10^{09}$
3	TL 93648 08415	Flowing outfall	110	1101	$1.21x10^{09}$
4	TL 92784 08754	Flowing outfall	2400	59303	$1.42x10^{12}$
5	TL 92784 08745	Flowing outfall	1600	67046	$1.07x10^{12}$
6	TL 91570 08516	Flowing outfall	1100	778	$8.55x10^{09}$
7	TL 91435 08413	Flowing outfall	800	1879	$1.50x10^{10}$
8	TL 91181 08049	Flowing outfall	820	4672	$3.83x10^{10}$
9	TL 90873 08203	Flowing outfall	>10000	1479	$>1.48x10^{11}$
10	TL 89111 07324	Dry outfall (sample taken from ditch behind)	50	Not flowing	
11	TM 02752 01897	Flowing outfall	150	38880	$5.83x10^{10}$
12	TM 03211 04575	Pumping station	120		
13	TL 99542 08467	Flowing outfall	20	8056	$1.61x10^{09}$
14	TM 01660 09545	Flowing outfall	500	19804	$9.90x10^{10}$
15	TL 98480 06348	Flowing outfall	1800		
16	TL 97140 05468	Flowing outfall	1100	1127	$1.24x10^{10}$
17	TL 97023 05681	Flowing outfall	50	318	$1.59x10^{08}$
18	TL 96034 05543	Flowing outfall	5	611	$3.05x10^{07}$
19	TL 93767 05874	Flowing outfall	260		
20	TL 92827 04548	Flowing outfall	610		
21	TL 92220 02972	Submerged outfall	400		
22	TL 92075 02686	Submerged outfall	150		
23	TL 92060 02389	Submerged outfall	260		
24	TL 92131 02187	Submerged outfall	3600		
25	TL 92135 02136	Submerged outfall	2800		
26	TL 90758 03631	Flowing outfall	30		
27	TL 86346 06231	Flowing outfall	40		

The Blackwater estuary is surrounded by low lying land which is drained via a series of ditches, borrow dykes and gravity sluices as well as two pumping stations. The Dengie peninsula is very low lying, and the land adjacent to Dengie Flats requires two pumping stations to raise surface water over the sea defences and onto the foreshore. As well as these two pumping stations a stream also discharges via gravity to the Dengie foreshore. This is impounded within earth banks in its lower reaches to keep it raised and prevent it from spilling onto the low lying fields it runs through. All measured outfalls were relatively minor in terms of volumes discharged. Two outfalls nearby to each other on the north shore (4 & 5) generated the largest measured loadings. Concentrations of *E. coli* were generally low to moderate with one exception, which contained >10,000 *E. coli* cfu/100ml (9). Sewage fungus was observed at this outfall suggesting it receives regular inputs of sewage. All significant outfalls had defined drainage channels running across the intertidal. Shellfish lying within or immediately adjacent to these are likely to carry elevated levels of contamination, particularly for the more heavily contaminated and larger outfalls.

APPENDIX IX
HYDROGRAPHY

BATHYMETRY

Source data for part of the Imray chart presented in Figure IX.1 were mainly gathered in the 1980's therefore the bathymetry may be slightly different now, however important features discussed below are unlikely to have significantly changed.

The Blackwater estuary is an east facing single spit enclosed estuary it is approximately 21.2 km from its head to its mouth (Futurecoast, 2002) and between 2 and 3 km wide throughout. The main subtidal channel is relatively deep and wide at the mouth, becoming narrower and shallower in the upper reaches, where there are several side channels. It is largely intertidal (approximately 60%), so a significant proportion of water will be exchanged on each tide, but the dilution potential will be quite low away from the main channels. The intertidal areas are much more extensive in the upper reaches. It is diverted into a further two channels east of Osea Island: Southey Creek which extends to Maldon and Goldhanger Creek which branches to the north. Several smaller, shallower creeks deviate from the main channels at various points including; Bradwell, Thirslet, Saint Lawrence, Upper and Lower Collins Creeks, Lawling Creek, Earl Creek and Southey Creek Hole. Into each of these channels a series of intertidal muddy creeks of varying sizes drain. There are three islands within the Blackwater; Northey Island and Osea Island in the upper Blackwater and the smaller Pewet Island close to the mouth. Northey and Osea islands are connected to the mainland at low tide by tidal causeways. The entire perimeter of the Blackwater is protected by sea walls because the land which surrounds the Blackwater is low lying and subjected to coastal squeeze it is therefore prone to flooding. Dredging occurs in the main navigational channels approaching marinas and harbours (Futurecoast, 2002).

The Dengie Flats are an extensive area of gently sloping intertidal mudflats, fringed with saltmarsh, covering an area of 25.9km² and extending eastwards approximately 3km (Environment Agency, 2010). Mobile gravel and sand banks which form on top of the mudflats (chenier ridges) are a common feature in this region (Futurecoast, 2002). It is flanked by the Blackwater estuary channel to the north and the Crouch estuary channel to the south. The northern part of Dengie Flats slopes gently into the subtidal. There is an intertidal sandspit (Buxey Sands) protruding a further 10km east from the southern tip of Dengie Flats, running parallel to the Crouch channel. There is a scoured channel (Swire Hole) to the north of the tip of Buxey Sands which is likely to carry most of the tidal flows in and out of the central Dengie Flats area.

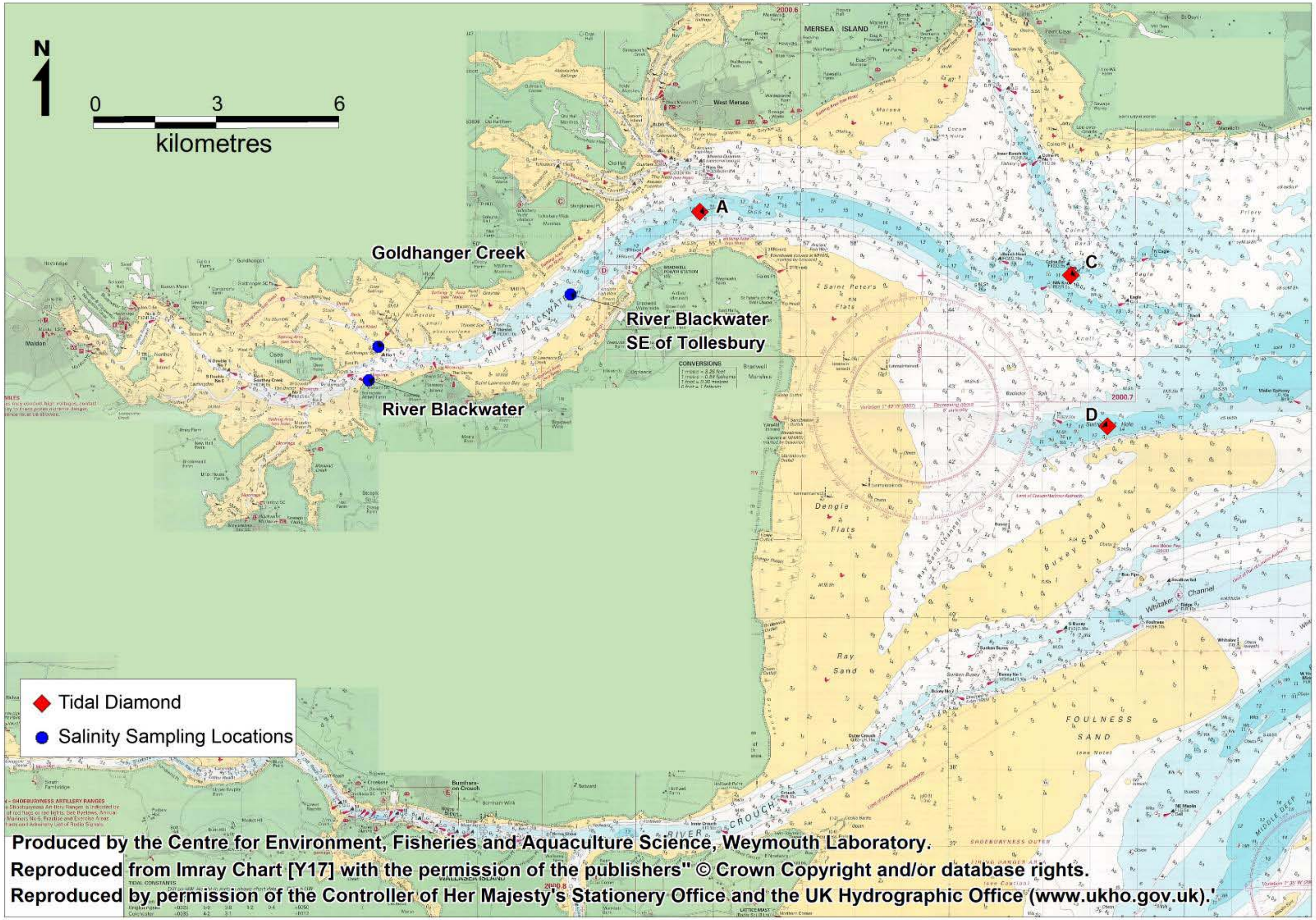


Figure IX.1 Bathymetry chart of the Blackwater and salinity locations

TIDES AND CURRENTS

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. Tidal amplitude is large, and tidal streams are likely to dominate patterns of water circulation in the area under most conditions. The Blackwater estuary is macro-tidal with a tidal range on spring tides of 4.9m and 3.1m on neap tides at Osea Island (Table IX.1).

Table IX.1 Tide levels and ranges within the Blackwater

	Height (m) above Chart Datum				Range (m)	
Port	MHWS	MHWN	MLWN	MLWS	Springs	Neaps
Bradwell Waterside	5.2	4.2	1.3	0.4	4.8	2.9
Osea Island	5.3	4.3	1.2	0.4	4.9	3.1
Maldon	2.9	-	2.3	-	-	-

Data from the Admiralty Total Tides

Offshore tidal streams flood down the Essex coast towards the Thames Estuary in a south westerly direction, and reverse on the ebb. Indentations to the coast at the Colne and Blackwater estuaries and the Crouch and Roach estuaries, cause the flood streams to be diverted in a north westerly and westerly direction and a south westerly direction into these estuaries. Table IX.2 presents the direction and rate of tidal streams at three stations in the mouth of the Blackwater and to the east of the Dengie Peninsular on spring and neap tides before and after high water. Station A is located in the mouth of the Blackwater, station C is located where the Colne and Blackwater estuary channels diverge, and station D is located in the tidal channel through which the central area of Dengie Flats drains (Figure IX.1).

Table IX.2 Tidal stream predictions for the Blackwater

	Station A Blackwater estuary mouth			Station C Colne Bar			Station D Swire Hole		
	Direction (°)	Spring rate (m/s)	Neap rate (m/s)	Direction (°)	Spring rate (m/s)	Neap rate (m/s)	Direction (°)	Spring rate (m/s)	Neap rate (m/s)
HW-6	85	0.05	0.05	90	0.05	0.05	87	0.15	0.10
HW-5	264	0.31	0.21	284	0.21	0.15	228	0.15	0.10
HW-4	262	0.46	0.31	283	0.46	0.31	253	0.72	0.46
HW-3	264	0.57	0.36	275	0.67	0.46	254	0.98	0.62
HW-2	263	0.62	0.41	275	0.72	0.46	254	0.93	0.62
HW-1	258	0.72	0.46	290	0.72	0.46	255	0.77	0.46
HW	249	0.46	0.31	291	0.36	0.26	255	0.21	0.15
HW+1	90	0.21	0.15	81	0.41	0.26	73	0.46	0.31
HW+2	86	0.51	0.36	100	0.77	0.51	75	1.08	0.72
HW+3	79	0.77	0.51	98	0.87	0.57	74	0.98	0.62
HW+4	74	0.77	0.51	99	0.67	0.46	65	0.62	0.41
HW+5	81	0.31	0.21	102	0.41	0.26	66	0.41	0.26
HW+6	86	0.21	0.15	94	0.26	0.15	71	0.05	0.05
Excursion (flood)		11.3km	7.4km	Excursion (flood)	11.3km	7.6km	Excursion (flood)	13.5km	8.7km
Excursion (ebb)		10.2km	7.0km	Excursion (ebb)	12.4km	8.1km	Excursion (ebb)	13.5km	8.9km

Data summarised from the Imray Chart Y17 (The Rivers Colne, Blackwater, Crouch and Roach)

The tidal stream principally floods up the channels and then ebbs in the opposite direction. The flood tide will convey relatively clean water originating from the open North Sea into the area and up the creeks, whereas the ebb tide will carry contamination from shoreline sources back out to sea. On a flood tide the principal tidal streams flow in a south westerly/west direction into the Blackwater and follow the main scoured channel. The channel splits into two around Osea Island, the majority of the tidal stream will follow Southey Creek south of the island and flow further upstream, north of Northey Island. A smaller proportion flows north west into Goldhanger Creek, north of Osea island. At intervals all along the main Blackwater channel smaller creeks diverge in a north and south direction, within these creeks a bi-directional pattern of tidal circulation is anticipated, travelling up on the flood and back down on the ebb. As the creeks fill, the incoming tide will spread over the extensive intertidal mudflats. Exact circulation patterns are likely to be complex, and current velocities will be lower in these shallower areas. On the ebb the reverse will occur. Contamination from shoreline sources such as freshwater outfalls will follow drainage channels cut across the intertidal towards the main subtidal channels.

Peak current velocities (Station A - 0.77 m/s, Station C – 0.87 m/s, Station D – 1.08 m/s) occur during the ebb on spring tides, indicating the estuary is ebb dominant. Currents are around 65% smaller on neap tides. Current speeds in the shallower areas are likely to be significantly slower. The tidal diamond at the estuary mouth indicates that the tidal excursion (the distance water travels during the course of a flood or ebb tide) is in the approximate order of 10km on spring tides and 7km on neap tides. This, together with the likely slower current speeds in shallower areas, suggests that sources discharging to the head of the estuary will only impact in the upper reaches of the estuary before the tidal streams reverse and carry contamination back up-estuary.

Water velocity fields for the Blackwater Estuary were simulated using the PRISM hydrodynamic model developed at the Proudman Oceanographic Laboratory; full details are listed in the Upper Blackwater Sanitary Survey (CEFAS, 2011). Results concluded that material discharged from Maldon will be carried down the main channel to about Osea Island on spring tides, at which point the currents will reveres and carry contamination back up-estuary. On the second ebb tide contamination will be carried further out of the estuary, such that on the second flood it may be carried up Goldhanger Creek towards the trestle site. During passage the contamination will be subject to a significant degree of mixing dilution before reaching the main shellfish concentrations east of Osea Island.

Dengie Flats and Buxey Sand form an elevated L shaped area between the main estuary channels of the combined outer mouth of the Blackwater and Colne to the north and the Crouch estuary to the south, backed by the Dengie Peninsular to the east. The tide here is likely to flood across this area from the two main estuary channels and from Swire Hole channel. Current speeds are likely to be significantly slower away from the main channels. During the ebb tide, water will drain back away towards the main channels. The northern section of the Dengie intertidal and subtidal area could potentially be influenced by plumes on ebb tide carrying contaminated water from the Blackwater estuary. The southernmost parts of Dengie Flats and Buxey Sands may influenced by the ebb plume from the Crouch. Intertidal areas adjacent to the central parts of the Dengie foreshore will therefore only be subjected to contamination from local sources.

In addition to tidally driven currents are the effects of freshwater inputs and wind. The flow ratio of the Blackwater estuary (freshwater input: tidal exchange) is very low and the system is predominantly well mixed. It has been estimated in the region of 1:4000 (Talbot, 1967; Fox et. al, 1999) so density driven circulation is unlikely to significantly modify tidal circulation. The upper Blackwater exhibits vertical stratification of salinity occasionally (Chesman et. al, 2006). During the summer months slightly elevated salinity readings have been recorded on an ebb tide as a consequence of evaporation which occurs over the mudflats (Fox et. al, 1999) Salinity measurements taken between 2003 and 2012 at a number of points within the estuary indicate average salinities approaching that of full strength seawater throughout (Table IX.3). Average and minimum salinities were slightly lower at the uppermost site within the main channel (River Blackwater), but were almost identical at Goldhanger and SE of Tollesbury.

Table IX.3. Summary statistics for salinity readings taken in the Blackwater 2003 -2012

Location	No.	Mean	Minimum	Maximum
River Blackwater	78	30.6	16.8	35.7
Goldhanger Creek	41	31.4	22.7	36.0
River Blackwater SE of Tollesbury	40	31.7	22.2	35.9

Data from the Environment Agency

Strong winds will modify surface currents. Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s. These currents in turn drive return currents which may travel lower in the water column or along sheltered margins. The prevailing south-westerly winds will tend to push surface water in a north-easterly direction, towards the mouth of the Blackwater and towards West Mersea and Colne estuary. Exact effects are dependent on the wind speed and direction well as state of the tide and other environmental variables so a great range of scenarios may arise. Where strong winds blow across a sufficient distance of water they may create wave action, and where these waves break contamination held in intertidal sediments may be re-suspended, although given the enclosed nature of the inner Blackwater energetic wave action is not anticipated here. The outer Blackwater and Dengie Flats are exposed to the North Sea in to the east, so easterly winds may result in significant wave action on the Dengie Flats and Buxey Sands.

APPENDIX X
MICROBIOLOGICAL DATA: SEAWATER

BATHING WATERS

There is 1 bathing water site within the survey area designated under the Directive 76/160/EEC (Council of the European Communities, 1975). Due to changes in the analyses of bathing water quality by the Environment Agency from 2012, only data produced up to the end of 2011 were used in these analyses.

Figure X.1 Location of designated bathing water and shellfish water monitoring points at Blackwater.

The bathing waters site is at West Mersea, just north of the outer Blackwater/Dengie Flats area. Twenty water samples were taken from here during each bathing season, which runs from the 15th May to the 30th September. Faecal coliforms (confirmed) were enumerated in all these samples. Summary statistics of all results from 2003 to 2011 are presented in Table X.1. Figure X.2 presents box plots of all results from the West Mersea bathing water site by year from 2003 to 2011.

Table X.1 Summary statistics for bathing waters faecal coliforms results, 2003-2011 (cfu/100ml).

n	Geo-mean	Min.	Max.	% exceeding 100 cfu/100ml	% exceeding 1000 cfu/100ml
180	10.1	<2	1360	12.8	2.2

Data from the Environment Agency

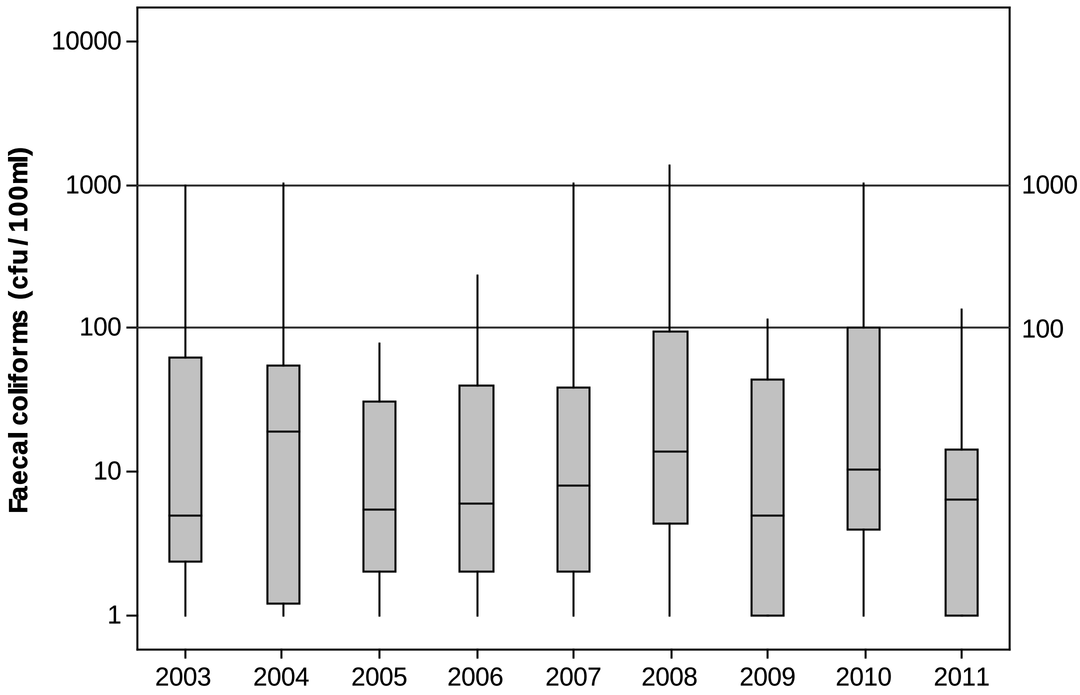


Figure X.2 Box-and-whisker plots of all faecal coliforms results by year
Data from the Environment Agency

Comparisons of the results found no significant difference by year (1-way ANOVA, p=0.557). This indicates that the level of faecal coliforms found in these bathing waters does not change significantly from year to year.

To investigate the effects of tidal state on faecal coliform results, circular-linear correlations were carried out against both the high/low and spring/neap tidal cycles. Correlation coefficients are presented in Table X.2.

Table X.2 Circular linear correlation coefficients (r) and associated p values for faecal coliform results against the high low and spring/neap tidal cycles

	high/low		spring/neap	
n	**r**	**p**	**r**	**p**
180	0.389	<0.001	0.317	<0.001

Data from the Environment Agency

Faecal coliforms concentrations varied significantly with respect to both tidal cycles. Figure X.3 presents a polar plot of $\log_{10}$ faecal coliform results against tidal state on the high/low cycle. High water at Osea is at 0° and low water is at 180°. Results of 100 faecal coliforms/100ml or less are plotted in green, those from 101 to 1000 are plotted in yellow, and those exceeding 1000 are plotted in red.

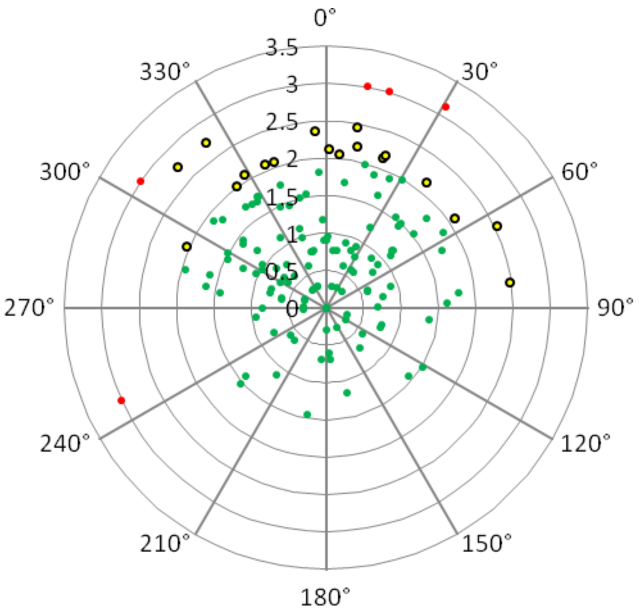


Figure XI.3. Polar plots of log_{10} faecal coliforms against tidal state on the high/low tidal cycle for West Mersea bathing waters monitoring point
Data from the Environment Agency

Sampling was targeted mostly towards high water. The levels of faecal coliforms found at the West Mersea bathing site appear to be lower during low tides than during high tides. Figure X.4 presents a polar plot of faecal coliform results against the lunar spring/neap cycle. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 100 faecal coliforms/100ml or less are plotted in green, those from 101 to 1000 are plotted in yellow, and those exceeding 1000 are plotted in red.

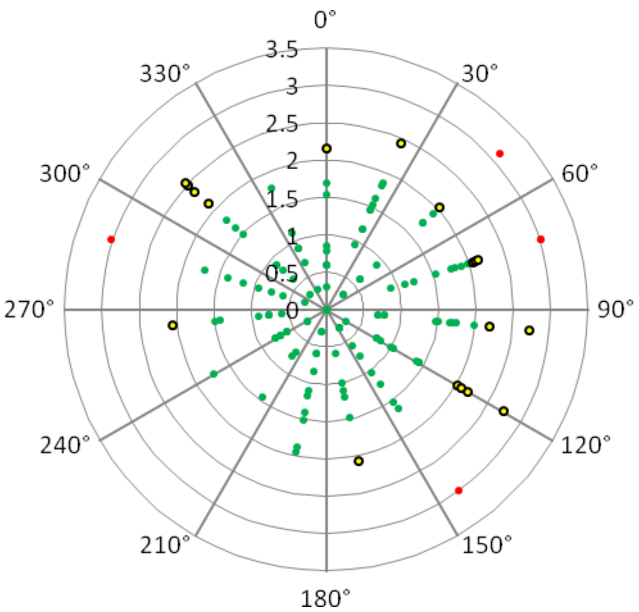


Figure X.4. Polar plots of log_{10} faecal coliforms against tidal state on the spring/neap tidal cycle for West Mersea bathing water monitoring point
Data from the Environment Agency

Levels of faecal coliforms at the West Mersea bathing waters monitoring point were highest on average during spring tides and lowest on average during neap tides.

To investigate the effects of rainfall on levels of contamination at the bathing waters sites Spearman's rank correlations were carried out between rainfall recorded at the Mersea weather station (Appendix VI for details) over various periods running up to sample collection and faecal coliforms results at the West Mersea bathing water site. These are presented in Table X.4 and statistically significant correlations (p<0.05) are highlighted in yellow.

Table X.4 Spearmans Rank correlation coefficients for faecal coliforms results against recent rainfall

		r
24 hour periods prior to sampling	1 day	0.229
	2 days	0.160
	3 days	0.226
	4 days	0.181
	5 days	0.018
	6 days	0.054
	7 days	0.016
Total prior to sampling over	2 days	0.262
	3 days	0.330
	4 days	0.334
	5 days	0.277
	6 days	0.265
	7 days	0.243

Correlations show that levels of faecal coliforms at the West Mersea bathing water site is influenced by rainfall up to four days after a rainfall event.

SHELLFISH WATERS

Figure X.1 shows the location of the shellfish water monitoring points, designated under Directive 2006/113/EC (European Communities, 2006). Table 1 presents summary statistics for bacteriological monitoring results from these points. Only water sampling results are presented as flesh results from the shellfish hygiene monitoring programme (Appendix XI) are used to assess compliance with bacteriological standards in shellfish flesh.

Table X.5 Summary statistics for shellfish waters faecal coliforms results (cfu/100ml), 2003-2012.

Site	No.	Geometric mean	Minimum	Maximum	% exceeding 100 cfu/100ml	% exceeding 1000 cfu/100ml
Blackwater	47	3.2	<2	63	0.0	0.0
Osea Island	50	5.3	<2	3330	4.0	2.0
Dengie	3	5.9	2	17	0.0	0.0

Data from the Environment Agency

The Dengie site was not included in the following analyses due to the low number of samples taken from this location. Although higher average and peak results were recorded at Osea Island, no significant differences in faecal coliform levels were found between it and Blackwater (T-test, p=0.078).

Figure X.5 indicates that there is some seasonality in levels of contamination in around the area, with highest results in the winter. Statistically significant differences were found between seasons at both sites (One-way ANOVA, p=0.012 and p<0.001 at Blackwater and Osea Island respectively). Post ANOVA tests (Tukey) showed that at Blackwater, winter had significantly higher levels of faecal coliforms than summer and autumn, but not spring. At Osea Island, there was significantly higher faecal coliform levels during the winter than all of the other seasons.

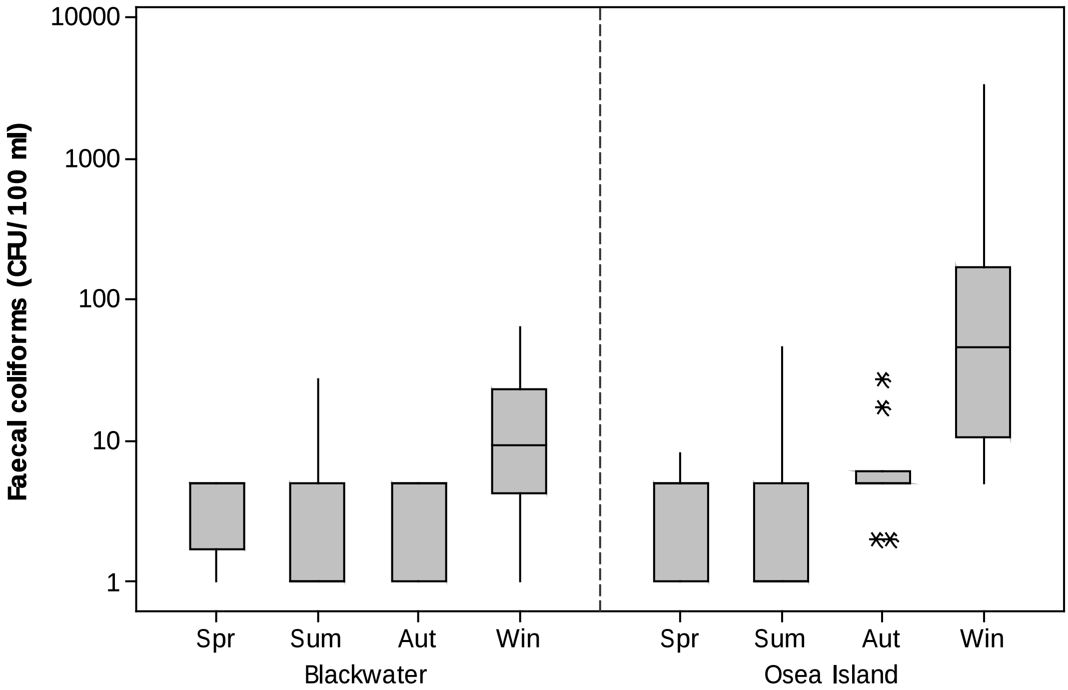


Figure X.5 Boxplot of shellfish growing waters faecal coliforms results by season
Data from the Environment Agency

A significant correlation was found between faecal coliform levels and the spring/neap tidal cycle at Osea Island (circular-linear correlation, r=0.266, p=0.036). No other significant correlations between faecal coliform levels and tidal state (including high/low and spring/neap) were found at either site. Figure X.6 presents polar plots of faecal coliform results against the lunar spring/neap cycle. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 100 faecal coliforms/100ml or less are plotted in green, those from 101 to 1000 are plotted in yellow, and those exceeding 1000 are plotted in red.

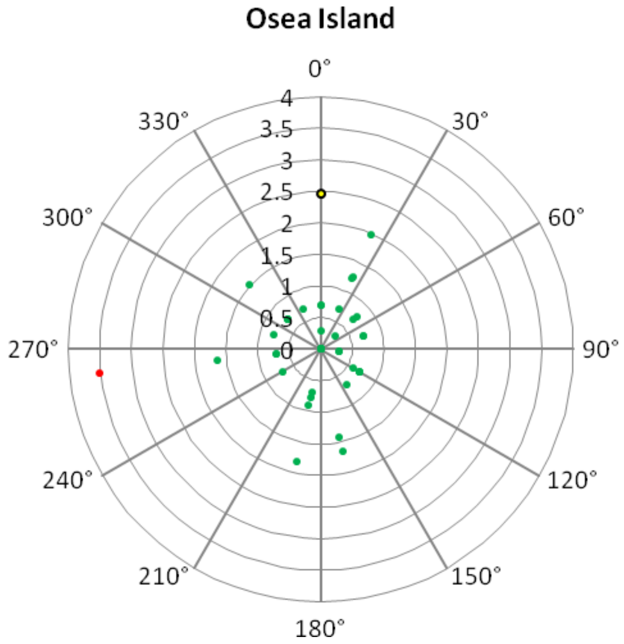


Figure X.6: Polar plots of log_{10} faecal coliforms against tidal state on the spring/neap tidal cycle for Osea Island shellfish water monitoring point

The correlation was weak, and no particular patterns are apparent in Figure XI.6. To investigate the effects of rainfall on levels of contamination at the shellfish waters sites Spearman's rank correlations were carried out between rainfall recorded at the Mersea weather station over various periods running up to sample collection and faecal coliforms results. These are presented in Table X.6 and statistically significant correlations (p<0.05) are highlighted in yellow.

Table X.6 Spearmans Rank correlation coefficients for faecal coliform results against recent rainfall

		Blackwater	Osea Island
	n	**47**	**50**
24 hour periods prior to sampling	1 day	0.123	0.205
	2 days	-0.106	0.066
	3 days	0.124	0.089
	4 days	0.204	0.289
	5 days	0.162	0.088
	6 days	-0.160	0.125
	7 days	-0.055	0.323
Total prior to sampling over	2 days	0.117	0.222
	3 days	0.163	0.261
	4 days	0.126	0.235
	5 days	0.120	0.168
	6 days	0.073	0.188
	7 days	0.018	0.225

Data from the Environment Agency

A weak and slightly delayed influence of rainfall was found at Osea Island, but not at Blackwater.

APPENDIX XI
MICROBIOLOGICAL DATA: SHELLFISH FLESH

SUMMARY STATISTICS AND GEOGRAPHICAL VARIATION

The geometric mean results of shellfish flesh monitoring from all RMPs sampled from 2003 onwards are presented in Figures XI.1 to XI.4. Summary statistics are presented in Table XI.1 and boxplots for sites sampled on 10 or more occasions Figures XI.5 to XI.7.

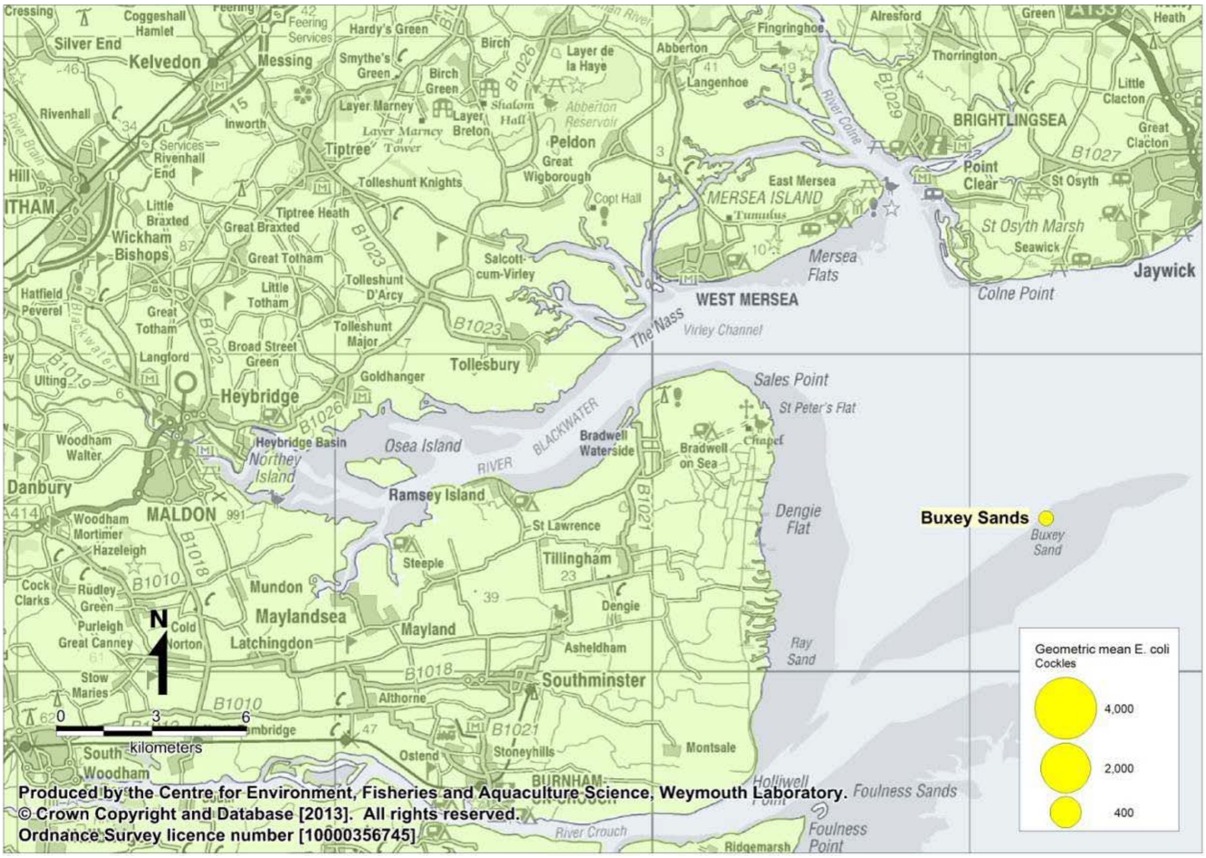


Figure XI.1 Cockle RMPs active since 2003

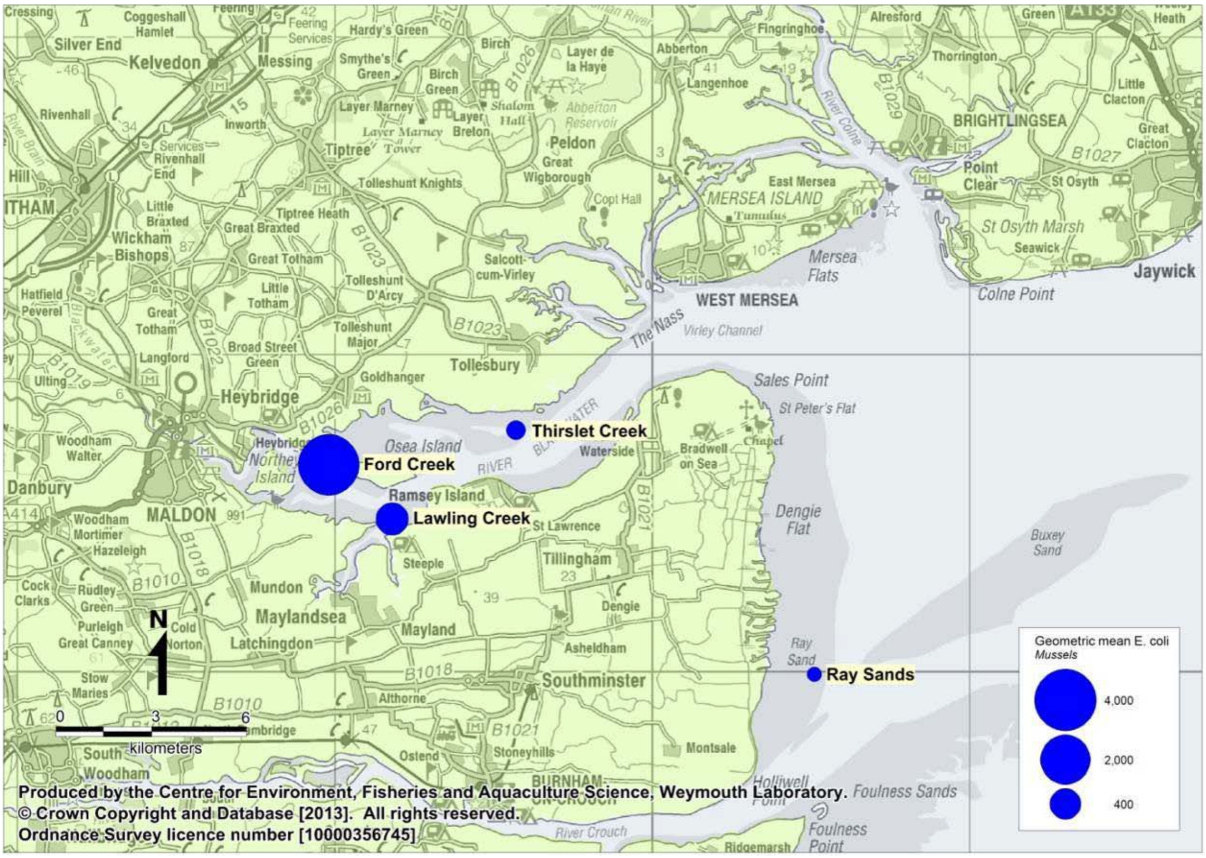


Figure XI.2 Mussel RMPs active since 2003

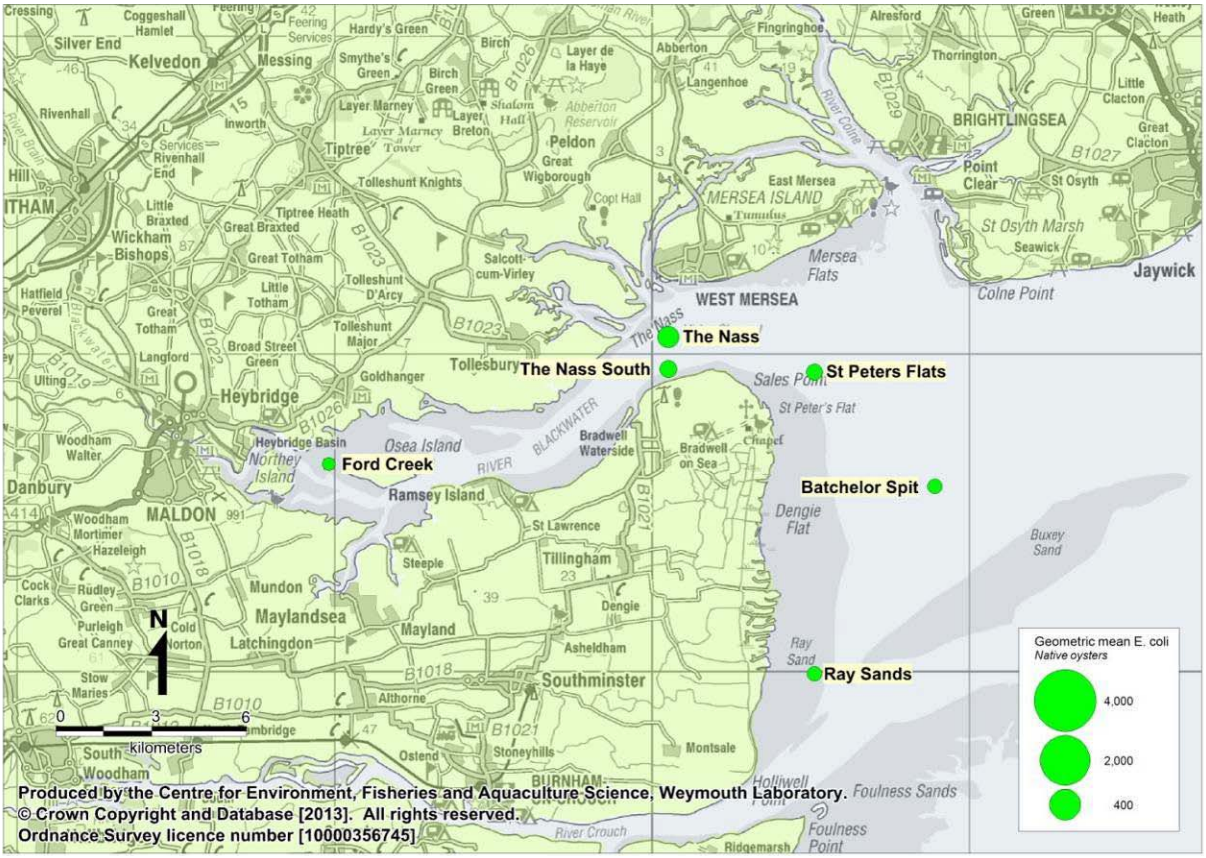


Figure XI.3 Native oyster RMPs active since 2003

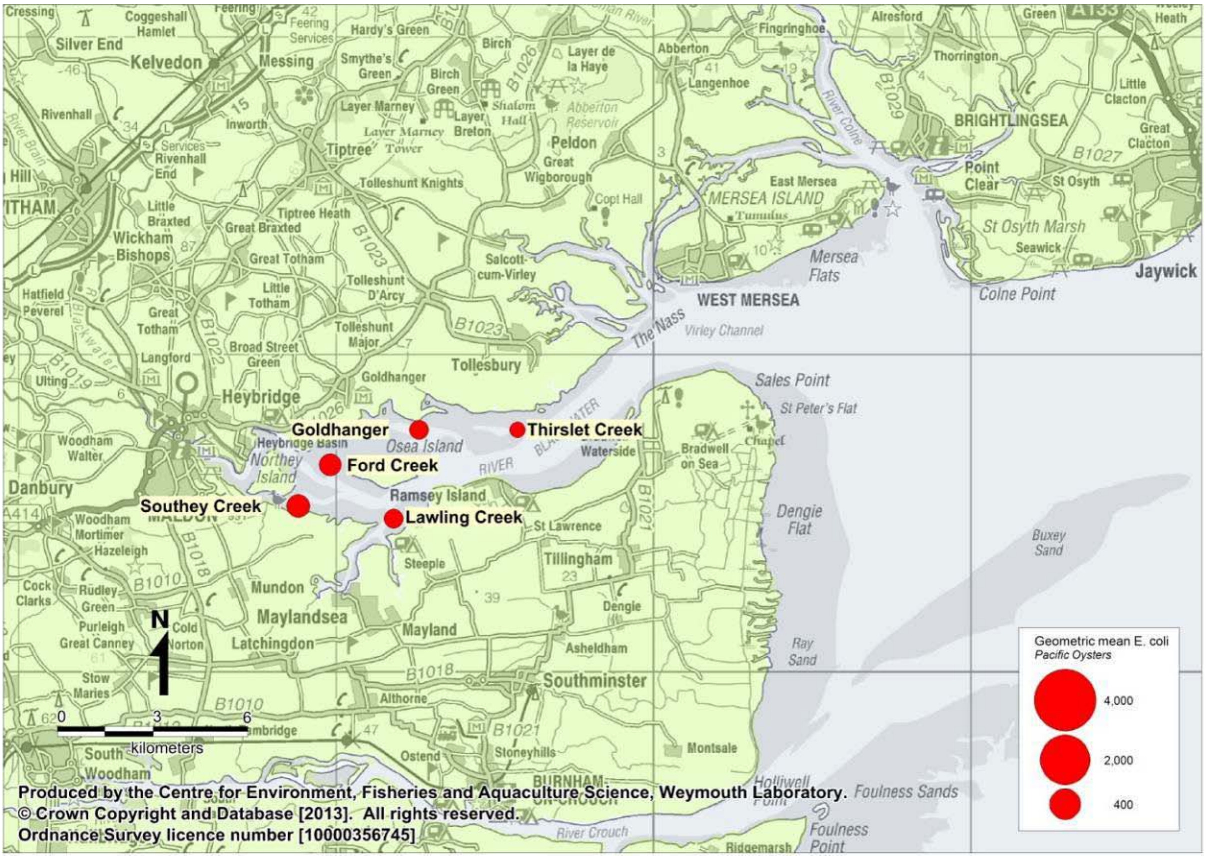


Figure XI.4 Pacific oyster RMPs active since 2003

Table XI.1 Summary statistics of* E. coli *results (MPN/100g) from cockle, mussel, native oyster and pacific oyster RMPs sampled from 2003 onwards

RMP	Species	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 230	% over 4600
Buxey Sands	Cockles	42	24/01/2003	25/07/2012	30.2	<20	2400	7.1	0.0
Ford Creek	Mussels	10	07/02/2012	29/08/2012	3804.4	490	24000	100.0	50.0
Lawling Creek	Mussels	11	19/01/2012	31/07/2012	498.9	20	14000	54.5	18.2
Ray Sands	Mussels	110	24/01/2003	04/09/2012	30.9	<20	>180000	10.9	2.7
Thirslet Creek	Mussels	115	05/02/2003	02/08/2012	82.4	<20	16000	26.1	2.6
Bachelor Spit	Native oysters	111	24/01/2003	04/09/2012	33.0	<20	35000	12.6	3.6
Ford Creek	Native oysters	1	19/01/2012	19/01/2012	20.0	20	20	0.0	0.0
Ray Sands	Native oysters	74	09/01/2006	04/09/2012	35.1	<20	160000	13.5	6.8
St Peters Flats	Native oysters	67	05/02/2003	25/07/2012	50.1	<20	17000	13.4	4.5
The Nass	Native oysters	111	11/03/2003	02/08/2012	122.0	<20	9200	33.3	1.8
The Nass South	Native oysters	5	09/06/2009	30/11/2009	55.9	20	310	20.0	0.0
Ford Creek	Pacific Oysters	41	03/04/2003	17/03/2009	138.5	<20	5400	34.1	2.4
Goldhanger	Pacific oysters	106	07/01/2003	06/08/2012	82.6	<20	2400	19.8	0.0
Lawling Creek	Pacific Oysters	41	03/04/2003	19/01/2012	82.1	<20	1400	24.4	0.0
Southey Creek	Pacific Oysters	39	03/04/2003	17/03/2009	151.5	<20	3500	43.6	0.0
Thirslet Creek	Pacific Oysters	79	01/11/2005	02/08/2012	42.5	<20	9200	12.7	1.3

Of these RMPs, two were sampled on less than 10 occasions so will not be considered in detail in the following analyses (Ford Creek – Native oysters and The Nass South).

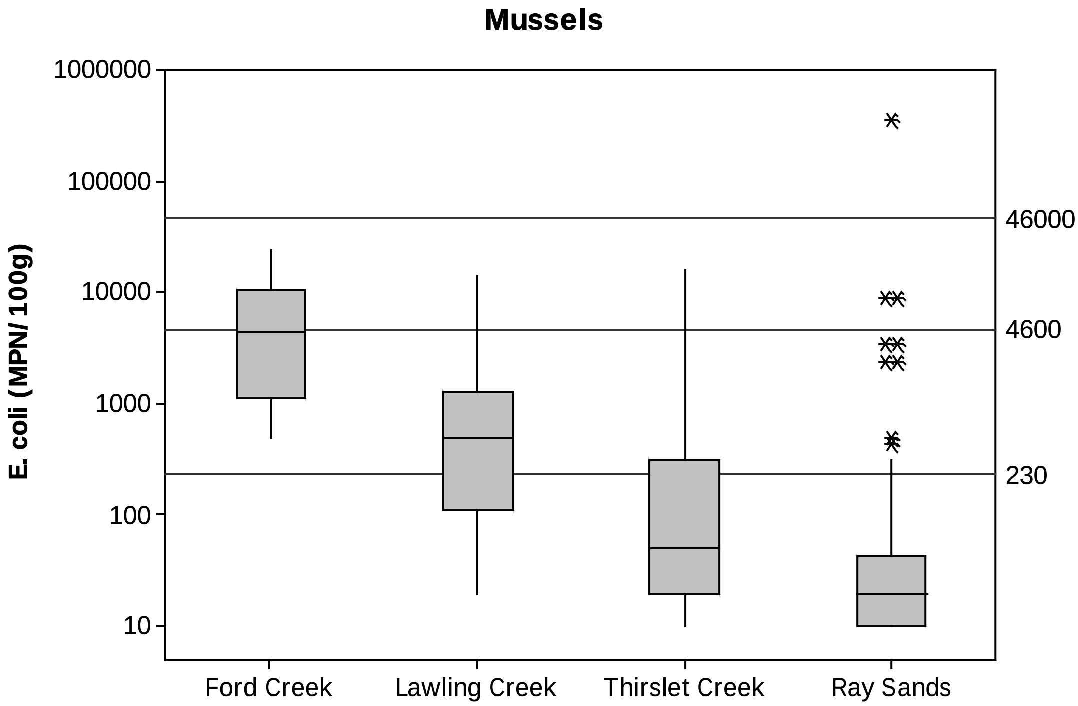


Figure XI.5 Boxplots of **E. coli** ***results from mussel RMPs sampled on 10 or more occasions from 2003 onwards.***

Across the four mussel RMPs, results were variable. At all of the mussel RMPs the maximum result for *E. coli* exceeded 10,000. The results for the Ray Sands RMP (the only one to be situated outside of the River Blackwater estuary) were particularly variable, with results ranging from less than 20 to over 180,000 *E. coli* MPN/100g. Comparisons of the results show that there is a significant difference between RMPs (One-way ANOVA, p>0.001). Posthoc tests (Tukeys) show that Ford Creek and Lawling Creek are not significantly different from each other but both have significantly higher *E. coli* results than the other two RMPs, which also differ from each other. Both Ford and Lawling Creek are situated in the upper reaches of the Blackwater estuary.

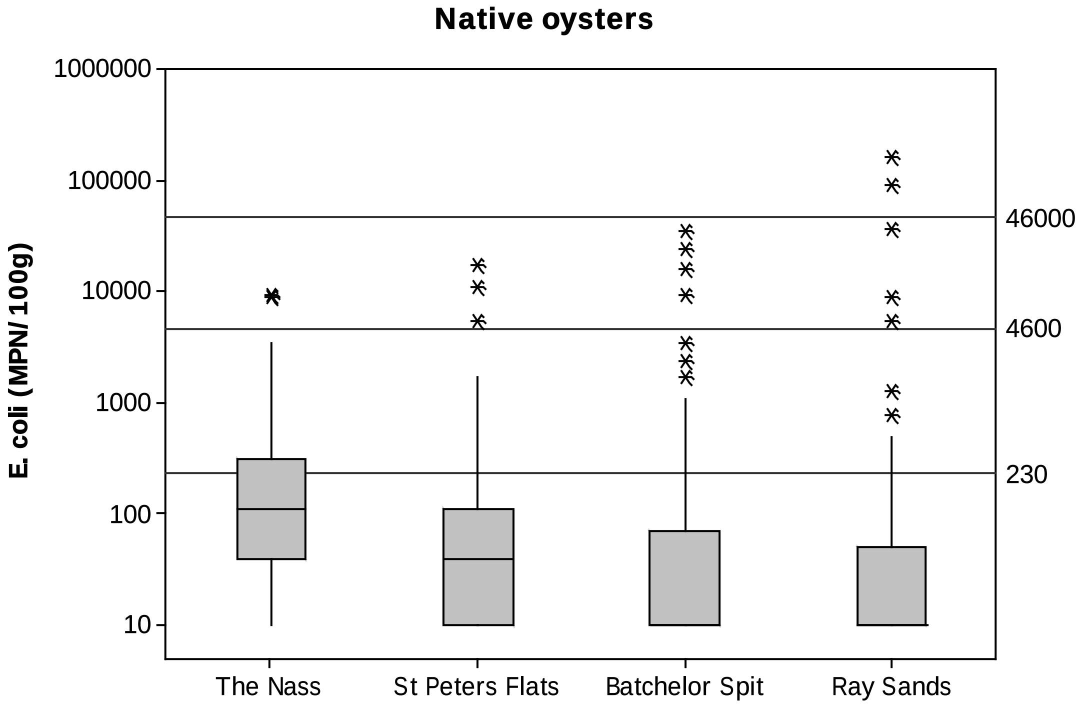


Figure XI.6 Boxplots of* E. coli *results from native oyster RMPs sampled on 10 or more occasions from 2003 onwards.

Across the four native oyster RMPs, the levels of *E. coli* were fairly low. However there was a considerable level of variation within each RMP. Comparisons of the results show that there is a significant difference between RMPs (One-way ANOVA, $p>0.001$). Posthoc tests (Tukeys) show that The Nass had significantly higher levels of *E. coli* than any of the other sites. The Nass is the only native oyster RMP in these analyses that is situated within the Blackwater estuary. None of the other RMPs had significant differences between their levels of *E. coli*. Occasionally, very high results were recorded, with two prohibited level results at Ray Sands.

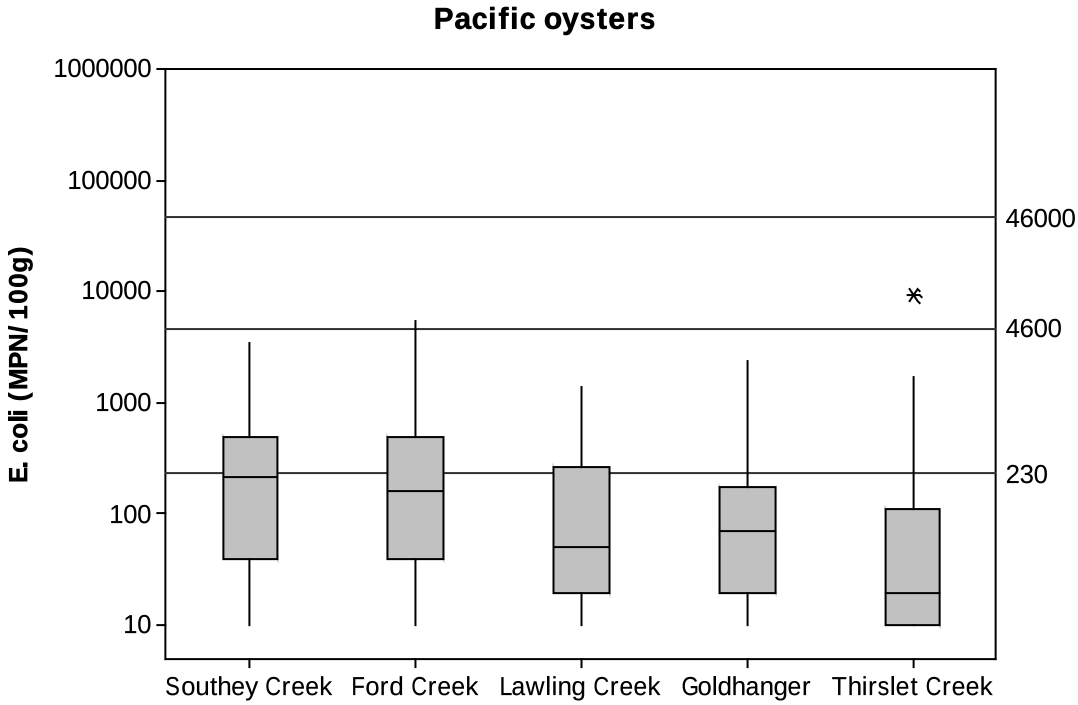


Figure XI.7 Boxplots of* E. coli *results from Pacific oyster RMPs sampled on 10 or more occasions from 2003 onwards.

Levels of *E. coli* were fairly low across the five Pacific oyster RMPs with Ford and Thirslet Creeks being the only RMPs to have any results greater that 4600 *E. coli* MPN/100g. Comparisons of the results show that there is a significant difference between RMPs (One-way ANOVA, p>0.001). Posthoc tests (Tukeys) show that Thirslet Creek, which is the most easterly RMP had significantly lower results than all other RMPs except Lawling Creek. No other significant differences were found between RMPs.

More robust comparisons of RMPs were carried out on a pair-wise basis by running correlations (Pearson's) between sites that shared sampling dates and therefore environmental conditions.

Two RMPs for native oysters (Bachelor Spit and Ray Sands) were sampled on the same day on 74 occasions. Comparisons of these sites revealed a significant correlation (Pearson's correlation, r=0.774, p<0.001). Four RMPs for Pacific oysters were sampled on the same day on 21 occasions and the results of correlations between these sites are summarised in table XII.2 and significant results are highlighted in yellow. Non-significant results suggest that some sites are influenced by a different range of sources which react in a different manner to environmental conditions. It was not possible to undertake meaningful paired comparisons between mussel RMPs as fewer than 20 same day samples were taken for each of these pairings.

Table XI.2 Pearson's correlations between E. coli results for Pacific oyster RMPs from 2003 onwards

Comparison	r	p
Ford Creek vs Goldhanger	-0.050	0.830
Ford Creek vs Lawling Creek	0.416	0.061
Ford Creek vs Southey Creek	0.434	0.049
Goldhanger vs Lawling creek	0.011	0.963
Goldhanger vs Southey Creek	-0.290	0.203
Lawling Creek vs Southey Creek	0.446	0.043

PROHIBITED LEVEL RESULTS RECORDED OFF DENGIE

During the period November 2011 to February 2012 a series of particularly high *E. coli* results were recorded at the RMPs off Dengie. Table XI.3 presents the results of all shellfish flesh samples taken from here during this period.

Table XI.3.* E. coli *results (MPN/100g) for RMPs off Dengie, November 2011 to February 2012.

	Bachelor Spit	St Peters Flats	Ray Sands	Ray Sands	Buxey Sands
	Native oysters	Native oysters	Mussels	Native oysters	Cockles
16/11/2011	9,400	11,000	>180,000	160,000	-
17/01/2012	24,000	17,000	3,500	790	230
16/02/2012	35,000	-	2,400	92,000	-

No particularly high *E. coli* results were returned from either the Roach or the Blackwater estuaries during this period, although they were not sampled on the same days as the Dengie area. The first episode (16/11/2011) was most marked at Ray Sands, although results were also elevated at St Peters Flats and Bachelor Spit. The second episode (17/1/2012) was less acute and the northern RMPs (Bachelor Spit and St Peters Flats) were affected, whereas results at the southern RMPs were not particularly elevated. The third episode (16/2/2012) saw high results at both Ray Sands and Bachelor Spit. Overall, this suggests a widespread and ongoing contamination episode throughout the period affecting RMPs a considerable distance offshore, although the geographical distribution of impacts was different during the second (and least acute) episode compared to the first and third episodes. Rainfall in the weeks preceding these samplings was low (0.2-2.4mm recorded at Mersea).

OVERALL TEMPORAL PATTERN IN RESULTS

The overall variation in levels of *E. coli* found in bivalves is shown in Figures XI.8 to XI.11. Only RMPs with data for more than one year were included.

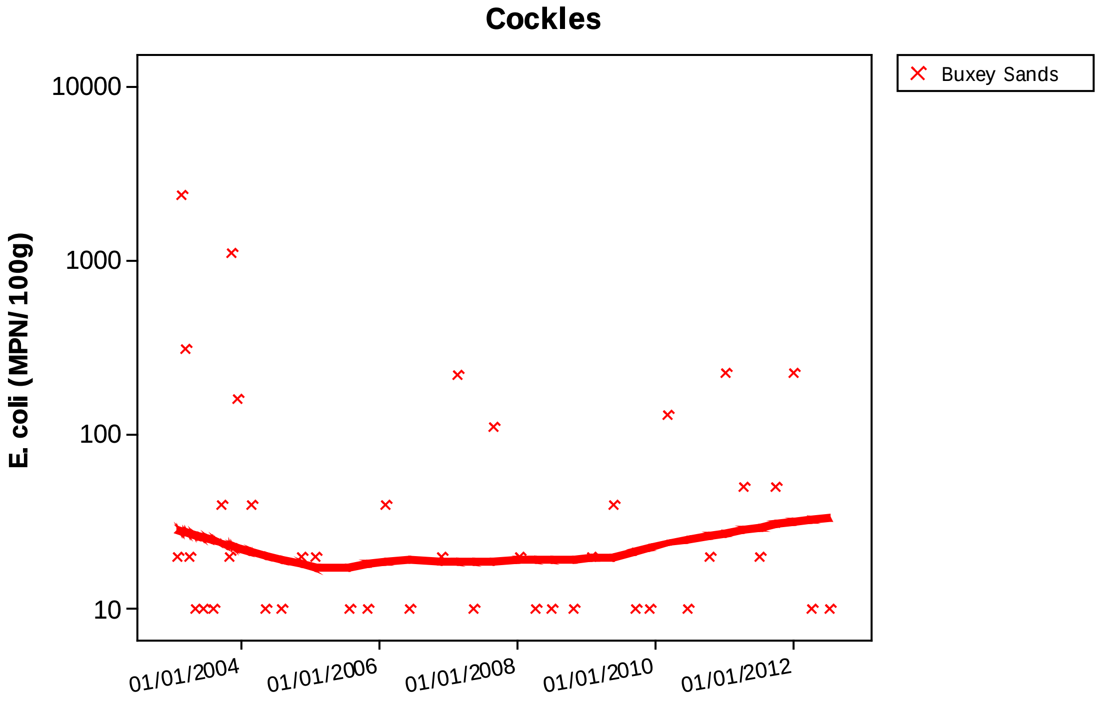


Figure XI.8 Scatterplot of* E. coli *results for cockles by RMP and date, overlaid with loess lines for each RMP

Figure XI.8 shows that over the years that cockles have been sampled, the level of *E. coli* found has remained quite consistent.

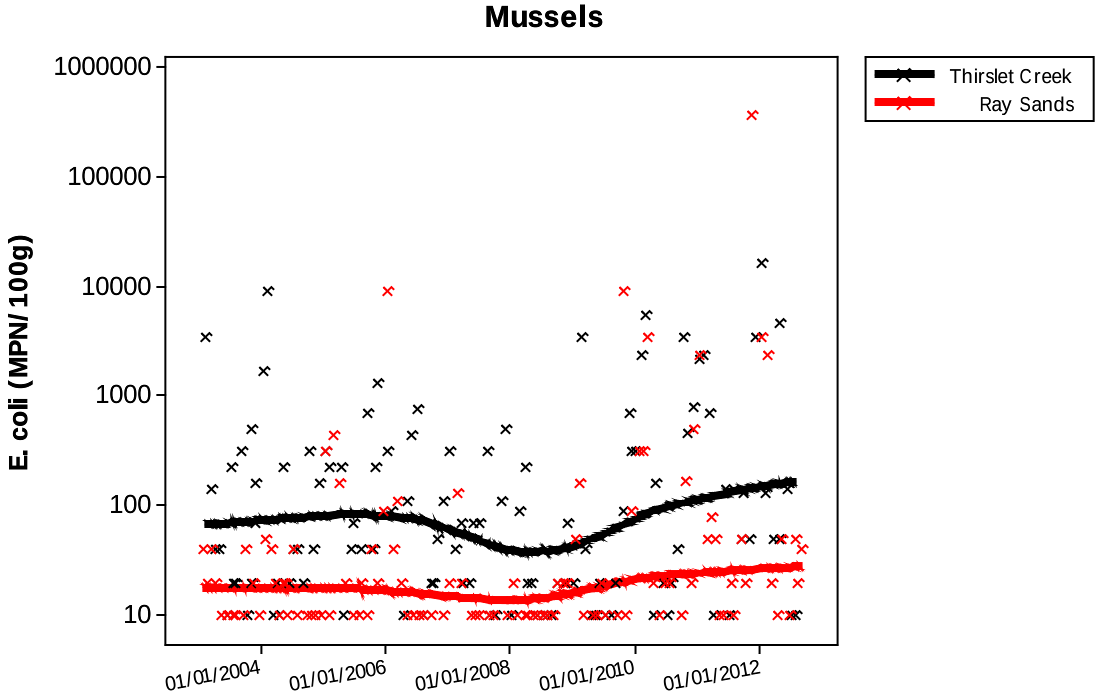


Figure XI.9 Scatterplot of* E. coli *results for mussels by RMP and date, overlaid with loess lines for each RMP

Figure XI.9 shows that the level of *E. coli* found in mussels has varied only slightly in both RMPs over the years that the data have been recorded.

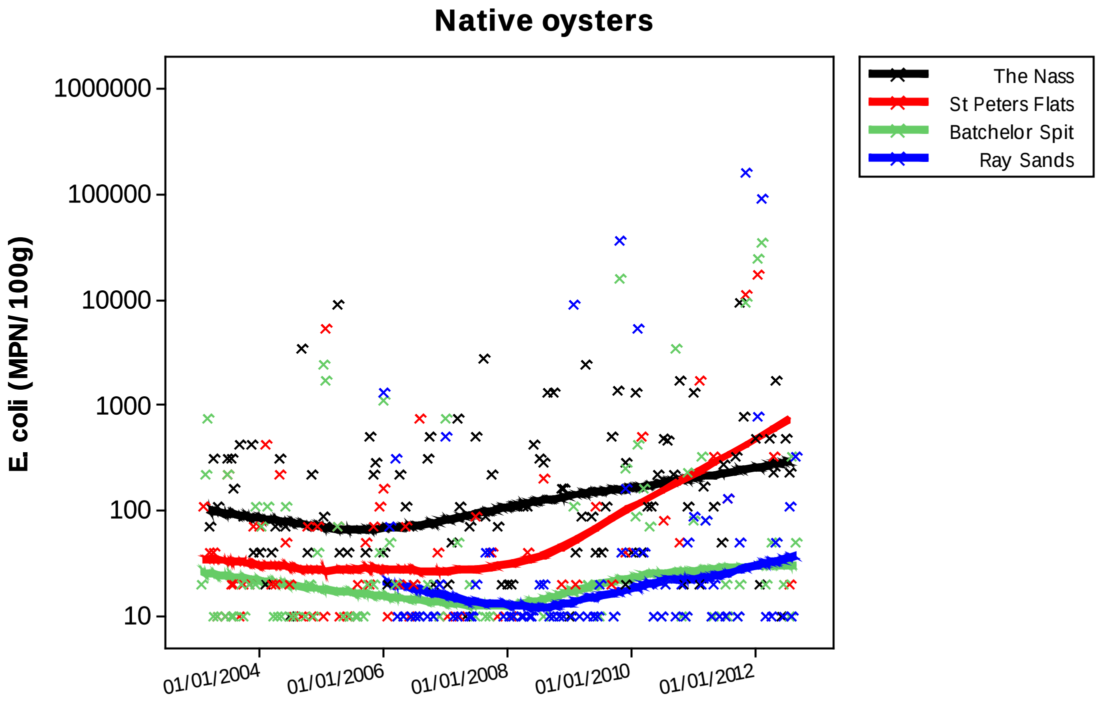


Figure XI.10 Scatterplot of **E. coli** ***results for native oysters by RMP and date, overlaid with loess lines for each RMP***

Figure XI.10 shows that the level of *E. coli* found in native oysters has varied between RMPs over time. At both Bachelor Spit and Ray Sands, results have remained generally low. Both of these RMPs are outside of the Blackwater estuary and so are probably not as heavily influenced as The Nass and St Peters Flats, which lie at the mouth of the estuary. The Nass appears to show a slight increase in *E. coli* levels. On the other hand, St Peters Flats have seen a continuing increase in *E. coli* levels from 2008 to present.

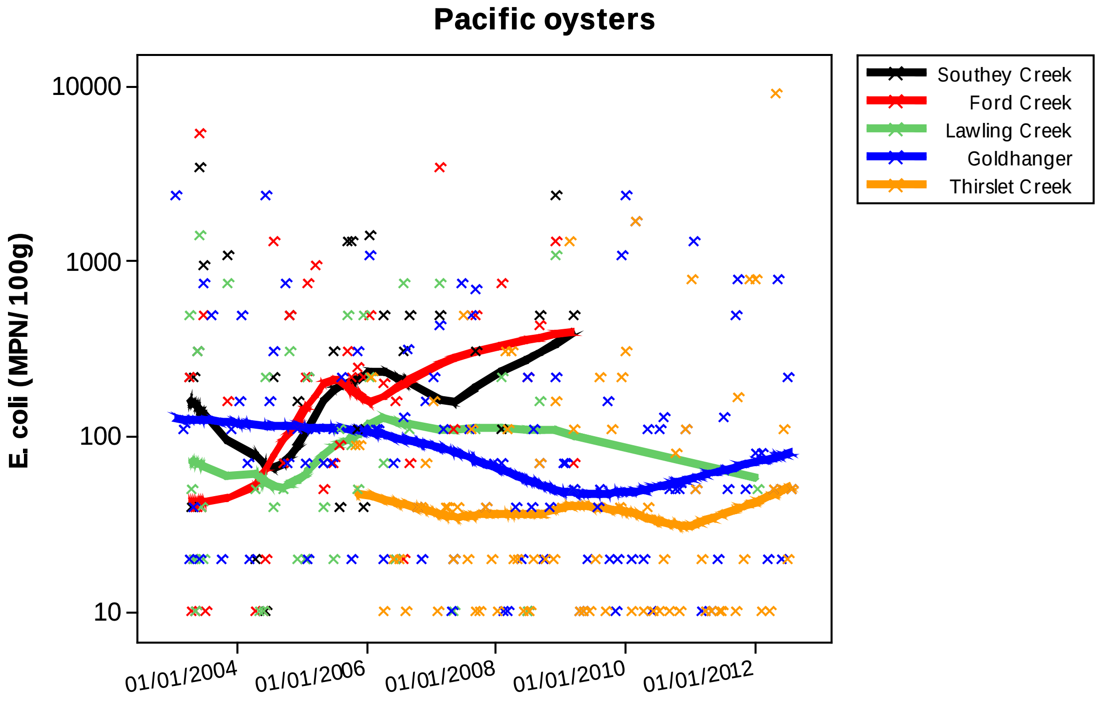


Figure XI.11 Scatterplot of* E. coli *results for Pacific oysters by RMP and date, overlaid with loess lines for each RMP

Figure XI.11 shows that the level of *E. coli* in Pacific oysters varies between RMPs. While there has been some variation at Lawling Creek, Goldhanger and Thirslet Creek, the *E. coli* results from 2003 onwards for these sites (2006 at Thirslet Creek) have remained fairly consistent. However, at both Southey Creek and Ford Creek, the levels of *E. coli* appeared to increase over time. Sampling at these two sites, which are both near the head of the estuary, ceased in 2009 and so it is not possible to determine if this trend has continued until present.

SEASONAL PATTERNS OF RESULTS

The seasonal patterns of results from 2003 onwards were investigated by RMP for all RMPs where at least 10 samples had been taken.

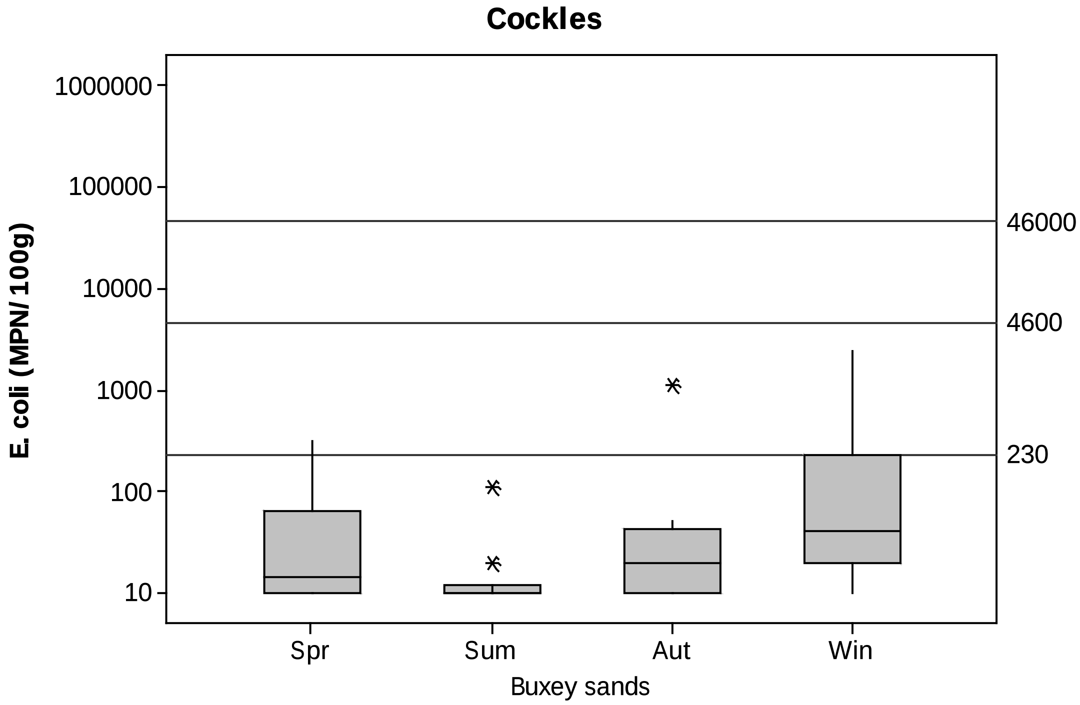


Figure XI.12 Boxplot of cockle* E. coli *results by RMP and season

There was significant seasonal variation at Buxey sands (One way ANOVA, p=0.049). A post ANOVA test (Tukey comparison) indicated that results were significantly higher in the winter than in the summer, but there were no differences between any other seasons.

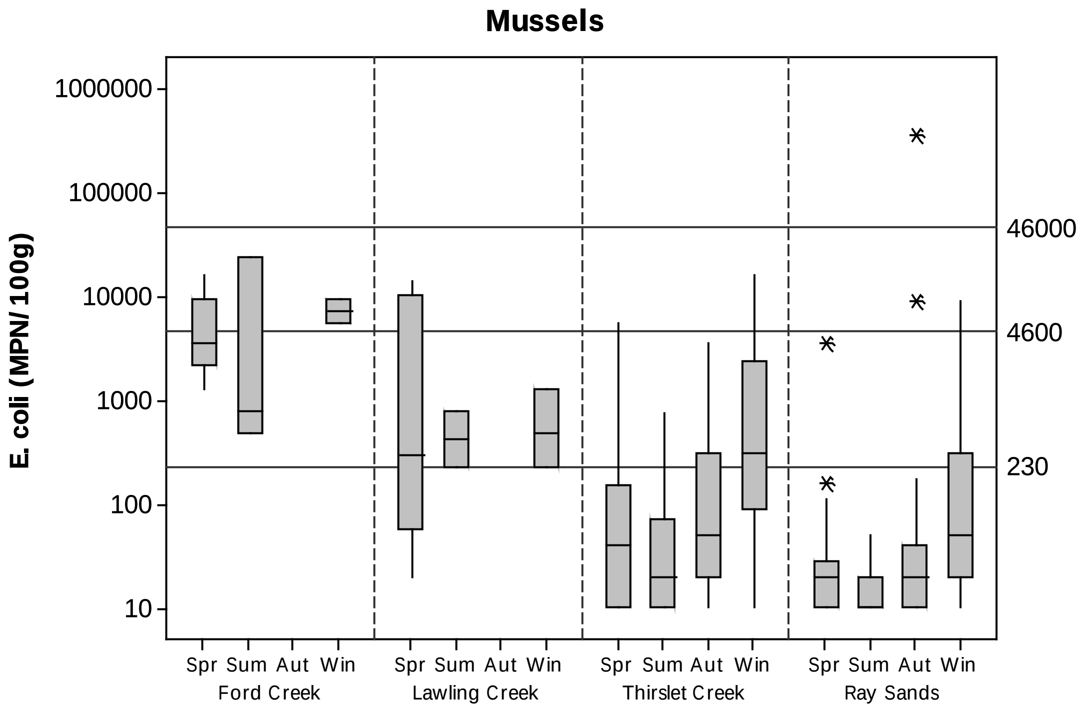


Figure XI.12 Boxplot of mussel* E. coli *results by RMP and season

Significant variation between seasons was found at the Thirslet Creek (p<0.001) and Ray Sands (p<0.001) mussel RMPs, but not Ford Creek (p=0.612) or Lawling Creek (p=0.993) (One-way ANOVA). Post ANOVA tests (Tukey) showed that at Thirslet Creek, levels of *E. coli* were significantly higher in the winter than in any other season. Similarly at Ray sands, *E. coli* levels were higher in the winter than in spring and summer, but not autumn.

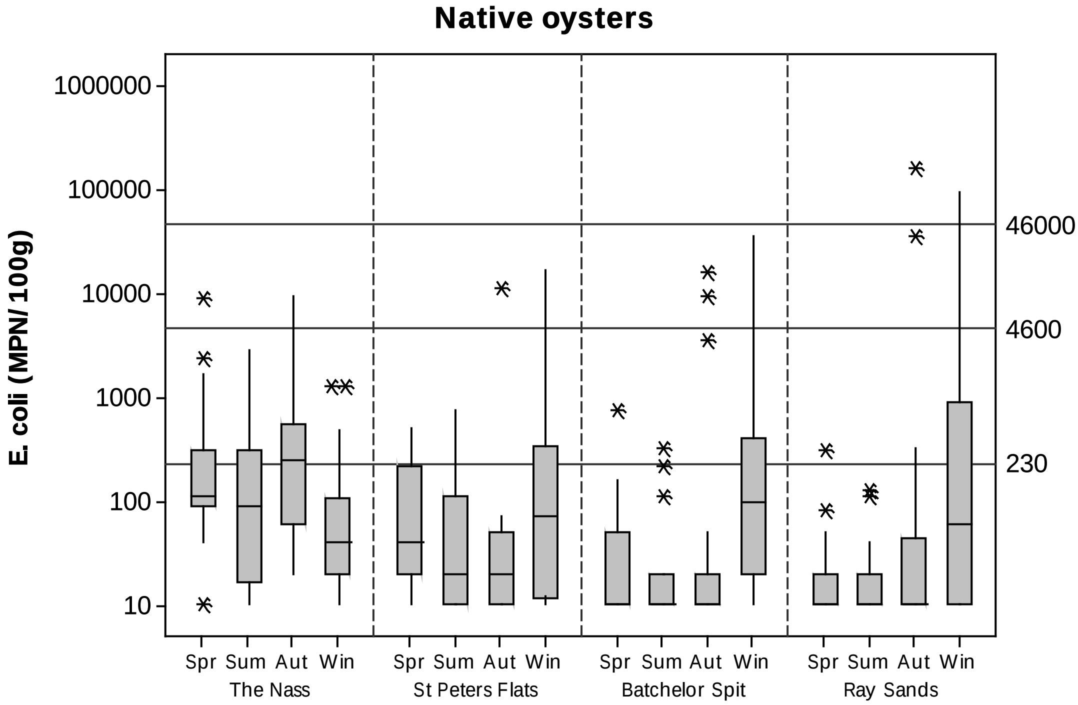


Figure XI.13 Boxplot of native oyster* E. coli *results by RMP and season

There were significant difference in *E. coli* levels in native oysters at three of the four RMPs (One-way ANOVA, p<0.001 for Bachelor Spit, p=0.005 for The Nass and p=0.008 for Ray sands). Only St Peter Flats showed no significant variation between seasons (One-way ANOVA, p=0.188). Post ANOVA tests (Tukeys comparison) showed that at the Nass, *E. coli* levels were significantly higher during the autumn than the winter. Conversely, at Bachelor Spit, *E. coli* levels were significantly higher in the winter that during any other season. As with mussels, *E. coli* levels were significantly greater in the native oysters at Ray sands during the winter than spring and summer.

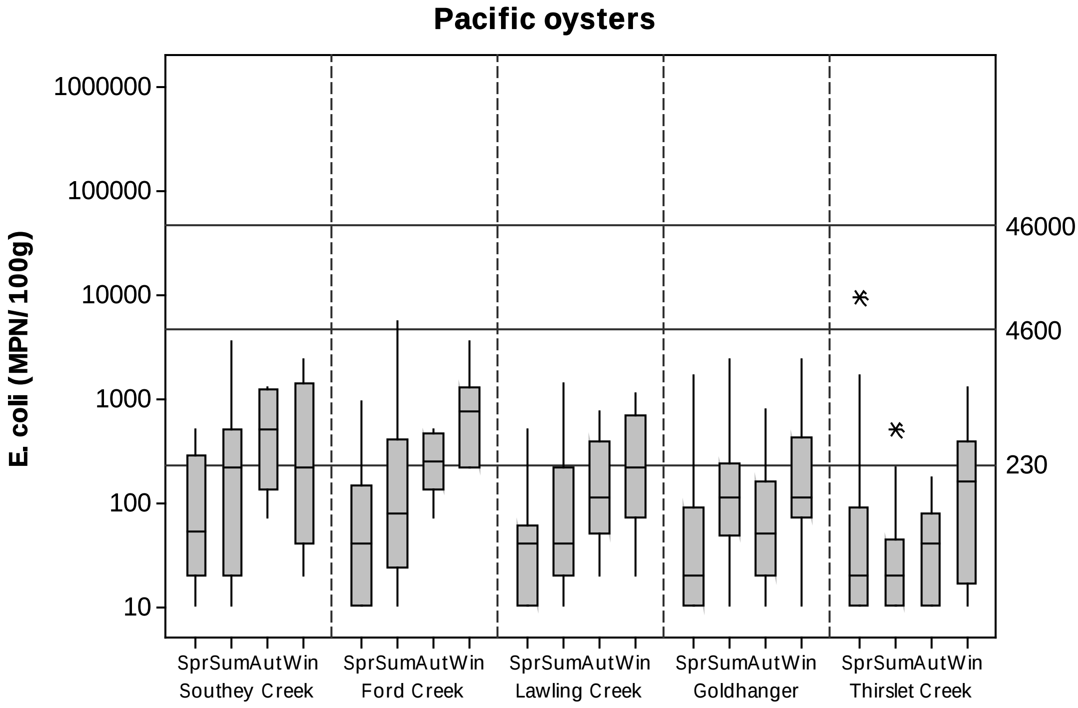


Figure XI.14 Boxplot of Pacific oyster* E. coli *results by RMP and season

In Pacific oysters, significant seasonal variation in *E. coli* numbers was found at all sites except Southey Creek (One way ANOVA, p=0.118 for Southey Creek, p=0.036 for Lawling Creek, p=0.006 for Ford Creek, p=0.001 for Goldhanger and p=0.017 for Thirslet Creek). At both Lawling Creek and Ford Creek, *E. coli* numbers were greater in winter than in the spring; at Thirslet Creek, *E. coli* levels were greater in the winter than in the summer and autumn; and at Goldhanger, *E. coli* levels were greater in the winter than in both spring and summer.

INFLUENCE OF TIDE

To investigate the effects of tidal state on *E. coli* results, circular-linear correlations were carried out against the spring/neap tidal cycle for each RMP where at least 30 samples had been taken since 2003. Results of these correlations are summarised in table XI.4, and significant results are highlighted in yellow.

Table XI.4 Circular linear correlation coefficients (r) and associated p values for* E. coli *results against the high/low and spring/neap tidal cycles

			High low		Spring neap	
Site	**Species**	**n**	**r**	**p**	**r**	**p**
Buxey Sands	Cockles	42	0.134	0.497	0.354	0.007
Ray Sands	Mussels	110	0.15	0.202	0.273	0.005
Thirslet Creek	Mussels	115	0.175	0.032	0.176	0.031
Bachelor Spit	Native oysters	111	0.142	0.115	0.263	<0.001
Ray Sands	Native oysters	74	0.15	0.202	0.273	0.005
St Peters Flats	Native oysters	67	0.253	0.017	0.249	0.019
The Nass	Native oysters	111	0.462	<0.001	0.398	<0.001
Ford Creek	Pacific Oysters	41	0.149	0.428	0.247	0.099
Goldhanger	Pacific oysters	106	0.235	0.003	0.047	0.8
Lawling Creek	Pacific Oysters	41	0.076	0.805	0.15	0.423

Southey Creek	Pacific Oysters	39	0.258	0.09	0.147	0.46
Thirslet Creek	Pacific Oysters	79	0.159	0.146	0.164	0.128

Figures XI.15 to XI.17 present polar plots of $\log_{10}$ faecal coliform results against tidal states on the high/low cycle for the correlations indicating a statistically significant effect. High water at Osea is at 0° and low water is at 180°. Results of 230 *E. coli* MPN/100g or less are plotted in green, those from 231 to 4600 are plotted in yellow, and those exceeding 4600 are plotted in red.

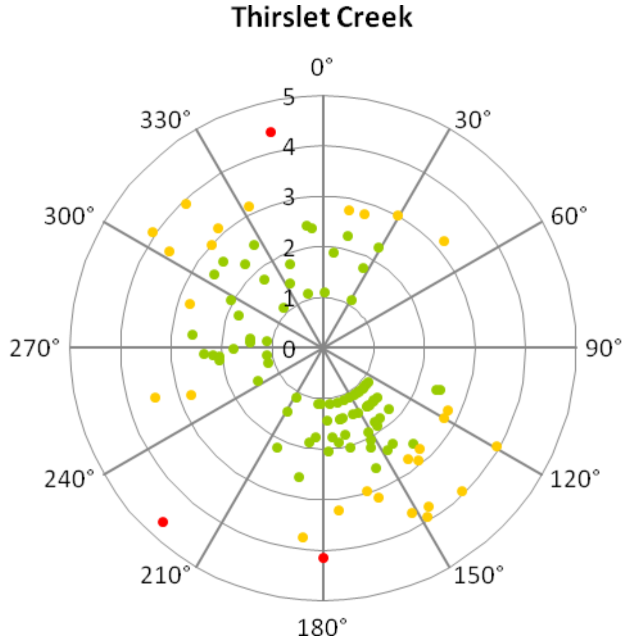


Figure XI.15 Polar plots of $\log_{10}$* E. coli *results (MPN/100g) against high/low tidal state for mussel RMPs

While significant correlations were found between *E. coli* numbers and tidal state for mussels at Thirslet creek, no strong patterns are apparent on the polar plot.

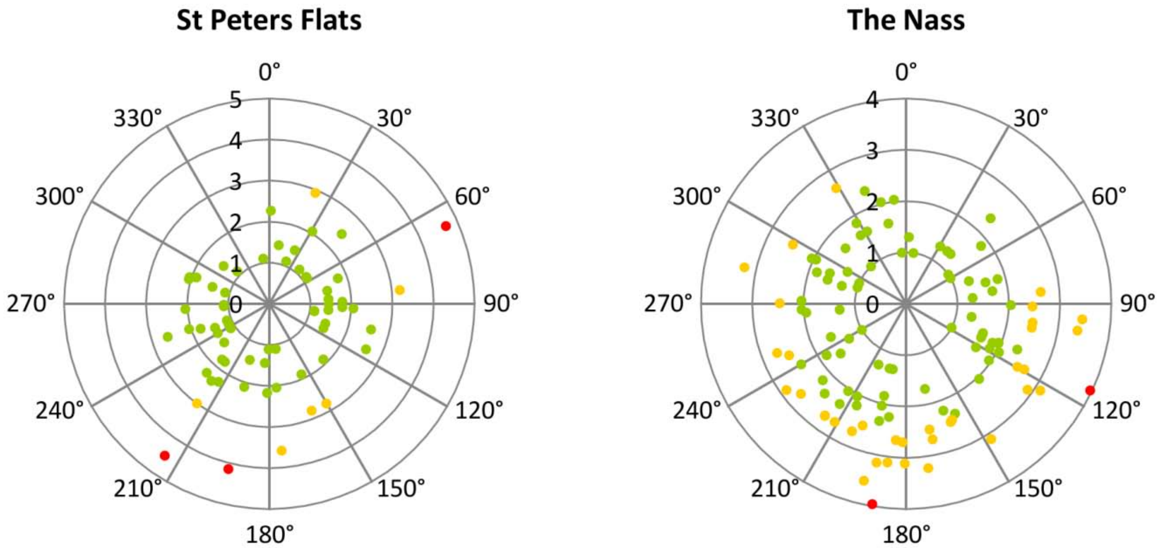


Figure XI.16 Polar plots of $\log_{10}$* E. coli *results (MPN/100g) against high/low tidal state for native oyster RMPs

At St Peters Flats, the levels of *E. coli* in native oysters appeared to be lower on average during the later stages of the flood tide. At Nass results were lower on average around high water and during the early part of the flood tide.

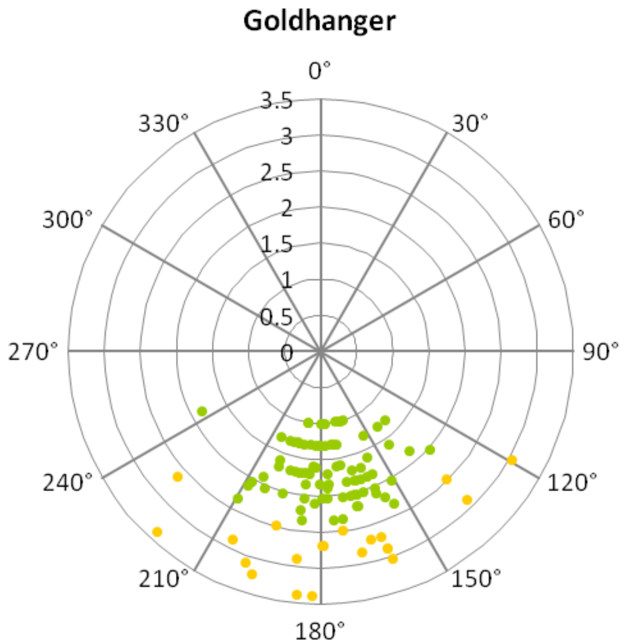


Figure XI.17 Polar plots of log_{10}* E. coli *results (MPN/100g) against high/low tidal state for Pacific oyster

At Goldhanger all of the sampling of Pacific oysters was performed during the low tide, which means that no meaningful conclusions can be drawn from this analysis.

Figures XI.18 to XI.20 present polar plots of log_{10} *E. coli* results against the spring neap tidal cycle for each RMP where a significant correlation was found. Full/new moons occur at 0º, and half moons occur at 180º, and the largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 230 *E. coli* MPN/100g or less are plotted in green, those from 231 to 4600 are plotted in yellow, and those exceeding 4600 are plotted in red.

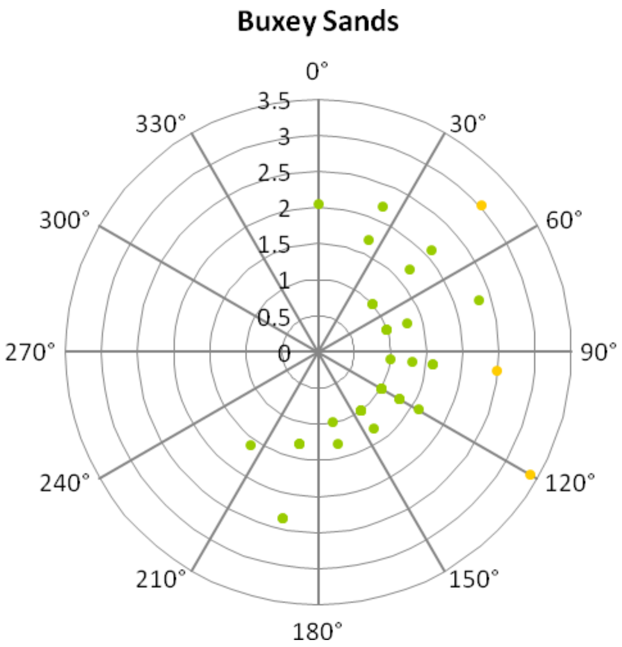


Figure XI.18 Polar plots of log_{10}* E. coli *results (MPN/100g) against spring/neap tidal state for cockle RMPs

At Buxey Sands, the vast majority of samples were collected while tide size was decreasing from spring to neap tides. The higher levels of *E. coli* appear to occur on average around the spring tides. However more data points would be needed before a firm conclusion could be drawn about any patterns at this RMP.

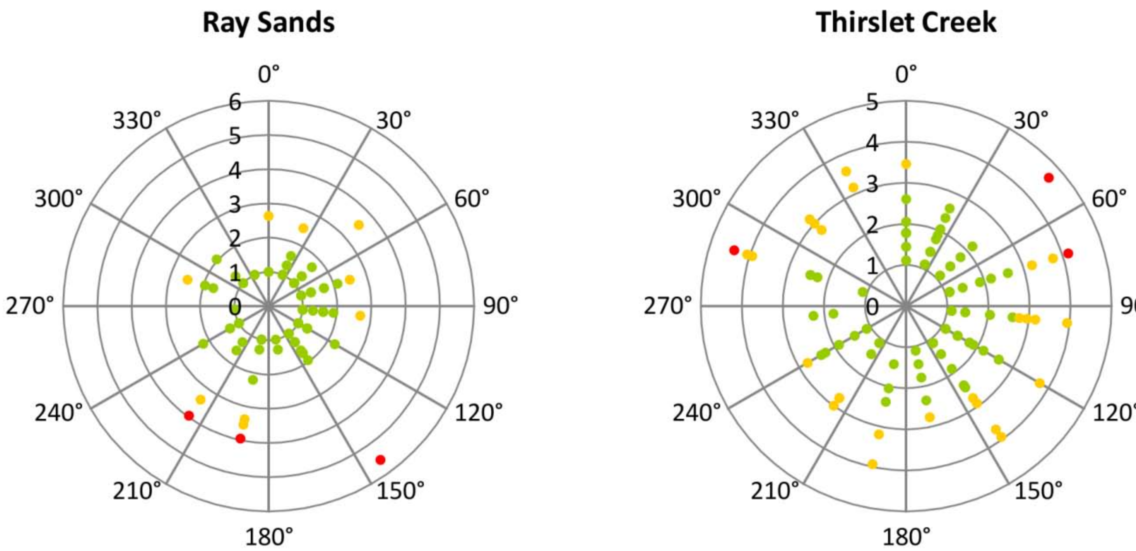


Figure XI.19 Polar plots of log_{10}* E. coli *results (MPN/100g) against spring/neap tidal state for mussel RMPs

While significant correlations were found between the levels of *E. coli* and the spring/neap tidal state at Thirslet Creek and Ray sands, no strong patterns are apparent in the polar plots. The very high results at Ray Sands occurred as tide size decreased towards neap tides.

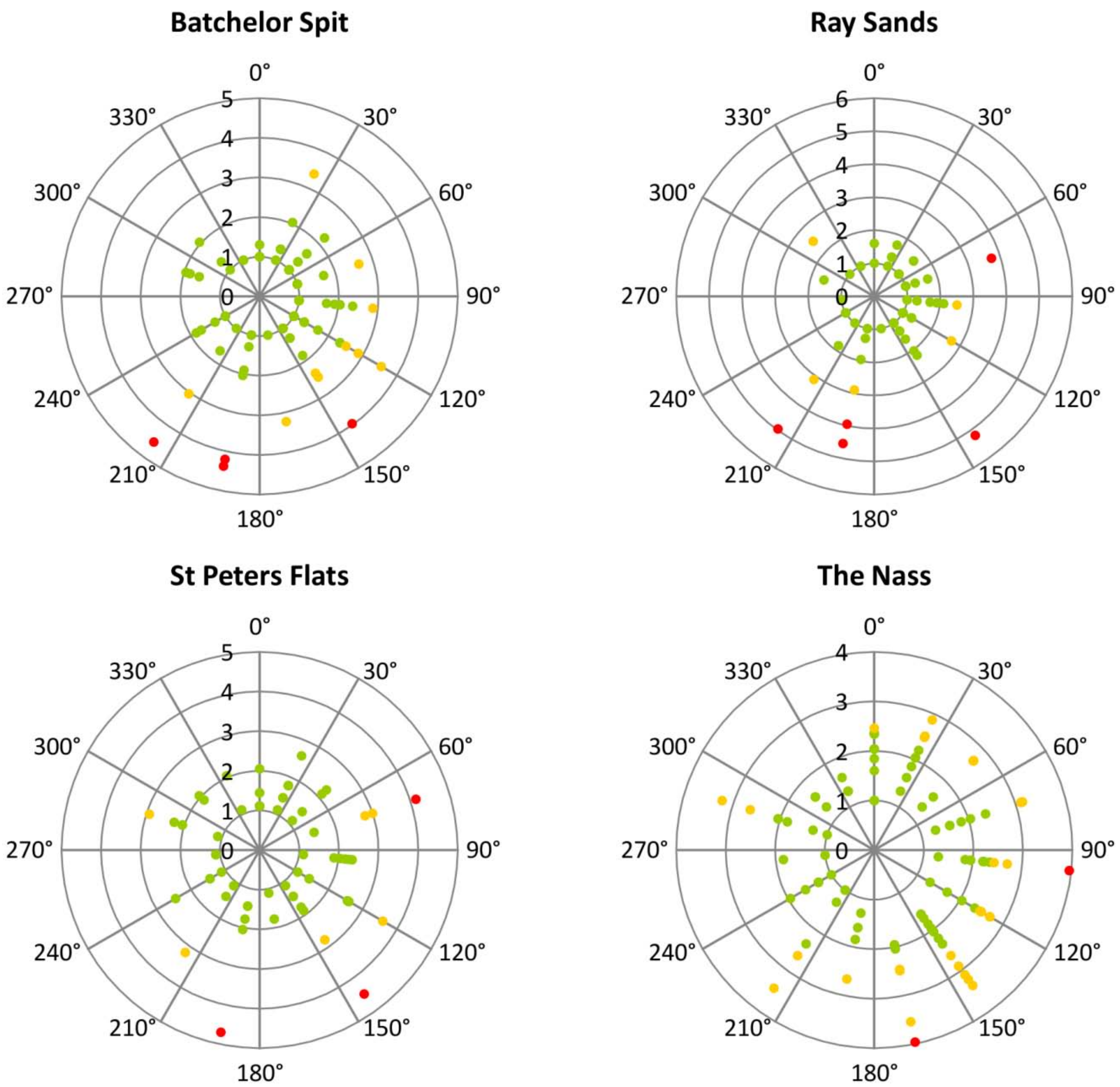


Figure XII.18 Polar plots of log_{10}* E. coli *results (MPN/100g) against spring/neap tidal state for native oysters RMPs

At all three RMPs where a significant correlation between *E. coli* numbers in native oysters and the spring/neap tidal state was found, all results above 4600 *E. coli*/100g were found in the period of decreasing tide size from springs to neaps.

INFLUENCE OF RAINFALL

To investigate the effects of rainfall on levels of contamination within shellfish samples Spearman's rank correlations were carried out between *E. coli* results and rainfall recorded at the Mersea weather station (Appendix VI for details) over various periods running up to sample collection. These are presented in Table XI.5, and statistically significant positive correlations ($p<0.05$) are highlighted in yellow.

Table XII.2 Spearman's Rank correlations between rainfall recorded at Mersea and shellfish hygiene results

	Site	Buxey sands	Ford creek	Lawling creek	Ray Sand	Thirslet creek	Bachelor spit	Ray sands	St Peter Flats	The Nass	Ford creek	Goldhanger	Lawling creek	Southey Creek	Thirslet creek
	Species	Cockles	Mussels				Native oysters				Pacific oysters				
	n	42	10	11	110	115	111	74	67	111	41	106	41	39	79
24 hour periods prior to sampling	1 day	0.229	0.016	-0.018	-0.056	-0.375	-0.42	0.077	0.044	0.133	0.028	-0.344	0.002	0.153	-0.064
	2 days	-0.357	-0.333	-0.554	0.152	0.040	0.065	0.059	0.206	0.031	0.042	-0.004	0.150	0.219	0.026
	3 days	0.088	0.019	0.292	0.021	0.042	0.131	-0.029	0.230	-0.024	0.032	-0.037	0.213	0.066	-0.001
	4 days	-0.115	-0.013	0.270	0.081	0.039	0.062	0.053	0.144	-0.098	-0.096	0.125	-0.117	-0.026	0.080
	5 days	-0.268	0.237	0.225	-0.073	0.223	-0.011	-0.128	0.095	0.014	-0.041	0.147	-0.031	-0.213	0.187
	6 days	-0.086	0.137	0.302	0.145	0.256	0.181	0.162	-0.019	-0.119	0.104	0.329	0.093	0.020	0.242
	7 days	0.114	0.083	0.224	0.145	0.149	0.108	0.204	-0.055	-0.040	0.132	0.174	0.209	0.066	0.221
Total prior to sampling over	2 days	-0.217	-0.352	-0.526	0.040	0.020	0.068	0.031	0.269	0.076	0.133	-0.011	0.189	0.160	0.046
	3 days	-0.145	-0.390	-0.357	0.018	-0.027	0.082	-0.053	0.280	0.106	0.143	-0.038	0.251	0.154	-0.010
	4 days	-0.193	-0.567	-0.270	0.027	-0.013	0.043	-0.058	0.317	0.104	0.120	0.020	0.227	0.199	0.026
	5 days	-0.240	-0.287	-0.256	-0.037	0.029	0.000	-0.107	0.307	0.092	0.092	0.017	0.223	0.149	0.046
	6 days	-0.282	-0.287	-0.256	0.017	0.054	0.064	-0.017	0.258	0.057	0.128	0.081	0.265	0.161	0.090
	7 days	-0.250	-0.202	-0.186	0.000	0.110	0.043	0.001	0.243	0.020	0.176	0.121	0.308	0.222	0.127

Rainfall affected contamination in native oysters most heavily at St Peter Flats. However, even here the correlations between rainfall and *E. coli* levels were weak. Overall no consistent pattern emerged, even at the highest reaches of the estuary, where the greatest influence from rainfall may be expected. Although some occasional correlations were detected at other RMPs, it should be noted that on average an apparently significant correlation will arise by chance on 5% of occasions. It can therefore be concluded that rainfall is not a major driving factor for *E. coli* contamination in shellfish flesh in the Blackwater estuary, even its upper reaches.

APPENDIX XII
SHORELINE SURVEY REPORT

Date (time): 4 December 2012 (0800-16:30)
6 December 2012 (0800-14:30)
15 January 2013 (0800-16:30)
16 January 2013 (0800-16:30)
17 January 2013 (0800-12:00)

Cefas Officers: Alastair Cook & David Walker (4/12/12 & 6/12/12), Simon Kershaw (6/12/12), Rachel Parks (06/12/12, 15/01/13 - 17/01/13), Ben Stubbs (15/01/13 – 17/01/13)

Local Enforcement Authority Officers:

Area surveyed: Blackwater Estuary (Figure XII.1)

Weather (12:00 GMT):
4 December 2012 - Wind 296° 24.14km/h, temp 6.9°C
6 December 2012 - Wind 189° 13.04km/h, temp 1.7°C
15 January 2013 - Wind 294° 13.04 km/h, temp 1.6°C
16 January 2013 - Wind 351° 9.66km/h, temp 0.7°C
17 January 2013 - Wind 302° 1.61km/h, temp 1.9°C

Admiralty TotalTide – Bradwell Waterside, England 51°45'N 0°54'E BST+0000. Predicted heights are in metres above chart datum.

04/12/2012	06/12/2012 Last Quarter
High 03:11 4.9 m	High 04:39 4.7 m
High 15:43 4.7 m	High 17:19 4.6 m
Low 09:34 0.7 m	Low 11:03 0.8 m
Low 21:34 1.3 m	Low 23:11 1.4 m

15/01/2013	16/01/2013	17/01/2013
High 02:08 5.3 m	High 02:51 5.3 m	High 03:34 5.1 m
High 14:43 5.1 m	High 15:28 4.9 m	High 16:14 4.7 m
Low 08:46 0.2 m	Low 09:27 0.3 m	Low 10:06 0.5 m
Low 20:52 0.7 m	Low 21:31 0.8 m	Low 22:10 1.0 m

Objectives:

The shoreline survey aims to obtain samples of freshwater inputs to the area for bacteriological testing; confirm the location of previously identified sources of potential contamination; locate other potential sources of contamination that were previously unknown and find out more information about the fishery. A full list of recorded observations is presented in Table XII.1 and the locations of these observations are mapped in Figure XII.1. Photographs referenced are presented in Figure XII.3 – Figure XII.53.

The shoreline survey was carried out over two visits. One visit was undertaken in December 2012, when the northern shore of the Blackwater and the Dengie Flats through to Bradwell Marina were surveyed by foot. A second visit was undertaken in January 2013 when the southern shore of the Blackwater and the north eastern shore were surveyed. All significant surface water inputs to the shoreline were sampled and measured where possible (Table XII.2).

Description of Fishery

A full shellfish stock survey was beyond the scope of the shoreline survey, and this report only presents observations made during the survey. Wild stocks of Pacific oysters were observed on the south eastern shoreline, adjacent to the power station (observation 26) and Pacific oysters and mussels were observed off Mill Point (Observation 139). Farmed oysters on trestles were observed in Goldhanger Creek (observation 10&11, Figure XII.11.9). Shells of dead oysters, cockles, mussels, clams and were present on both the south eastern and north eastern shore of the Blackwater (Observation 43, 142 & 147 and Figure XII.22).

Sources of contamination

Sewage discharges

The location of Maldon STW, Waterside STW and Mayland STW were confirmed (observations 21 39 & 98). The Maldon effluent passes through a lagoon and then into drainage ditches, then into the estuary via a freshwater outfall (observation 21). This was not flowing at the time and only contained low concentrations of *E. coli* (50 cfu/100ml). A flowing freshwater outfall with an unknown source (observation 19) had a strong odour and sewage fungus and contained high levels of E *coli* (>10,000 cfu/100ml) which would suggest sustained inputs of sewage nearby. No sanitary related debris was recorded around the high water mark.

Freshwater inputs

The two main freshwater inputs to the estuary are the River Chelmer and the River Blackwater; they enter the Blackwater at Maldon, in the west. The entire Blackwater is protected by raised sea walls, behind these lie surface drainage ditches and at regular intervals (approximately every few hundred metres) it is discharged through gravity outfalls into the estuary. Consequently, drainage water is only released into the estuary at lower states of the tide when they are not inundated with seawater. The exception to this is at Melhouse Outfall on the north Blackwater (observation 140) which is pumped out into the estuary.

The Dengie Peninsula is very low lying and the land immediately adjacent to the Dengie Flats lies below the high water mark. To protect this low lying land a raised seawall creates a barrier between the land and sea. Runoff drains via a series of ditches to borrow dykes, which are pumped out intermittently by two pumping stations. There is also a stream discharging to Dengie Flats which originates at

Southminster and is kept elevated by the earth banks that enclose its lower reaches. It discharges to the foreshore by gravity through a sluice.

All significant surface water inputs to shorelines adjacent to any shellfisheries were sampled and measured (Table XII.2) apart from those where access was restricted due to inundation by the tide and/or hazardous conditions.

Boats and Shipping

Large numbers of recreational craft, including yachts and cabin cruisers were moored throughout the Blackwater mainly in the vicinity of sailing clubs or marinas. Five possible houseboats were observed in the Blackwater at Maylandsea and on the upper north shore adjacent to the Blackwater Sailing Club (observations 28, 30 & 111). These may make regular discharges to the shore when in occupation.

Livestock

Livestock were observed in several locations around the Blackwater, including Ramsey Marsh surrounding Steeple Creek (observations 79, 80 & 85), on the headland between Lawling Creek and Mayland Creek (observation 107), east of Mill Creek (observation 143, 144 & 146) and north of Goldhanger Creek (observation 6, 7, 8, 12 & 13) where over 100 sheep were observed. Land use adjacent to Dengie Flats was exclusively for arable farming.

A heap of waste was seen adjacent to the drainage ditch (observation 33), on first consideration it looked like a manure heap but on closer inspection it is likely to be a pile of weed and silt dredged from the drainage channels. There appeared to be a delivery of sewage sludge underway by the gate of a farm on the southern end of the Dengie peninsula.

Wildlife

Several flocks of birds were observed around the Blackwater, the highest densities of which were recorded on the south Blackwater shorelines in particular around 1,000 geese were recorded south of Osea Island (observation 126). The majority of sightings were of upwards of 100 birds in a single location. Dog walkers and dog excrement were observed along the Blackwater coastal paths, generally near to settlements.

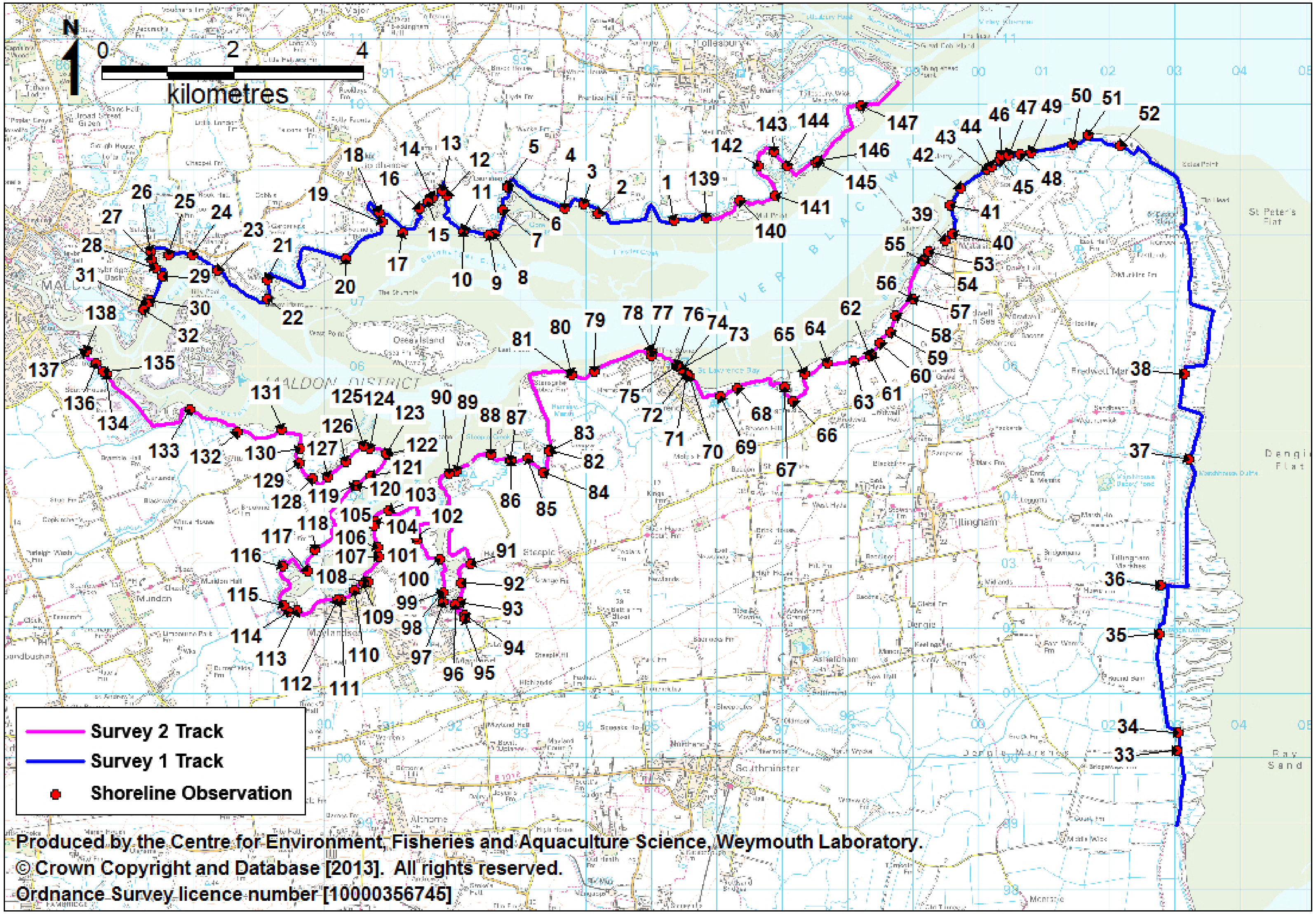


Figure XII.1: Locations of shoreline observations (see Table XII.1 for details)

Table XII.1. Details of Shoreline Observations

No	Time and Date	NGR	Photograph	Observation
1	04/12/2012 09:17	TL 95325 08238		Sluice outfall, not flowing. One dog walker
2	04/12/2012 09:38	TL 94158 08342	***Figure XII.3***	Freshwater outfall, 85cmx5cmx0.093m/s. Water sample NB1
3	04/12/2012 09:47	TL 93950 08480	***Figure XII.4***	Freshwater outfall, 30cmx3cmx0.333m/s. Water sample NB2
4	04/12/2012 09:56	TL 93648 08415	***Figure XII.5***	Freshwater outfall, 90cmx12cmx0.118m/s. Water sample NB3
5	04/12/2012 10:15	TL 92784 08754	***Figure XII.6***	Freshwater outfall, 250cmx85cmx0.323m/s. Water sample NB4
6	04/12/2012 10:19	TL 92784 08745	***Figure XII.7***	Freshwater outfall, 2 identical tunnels of 50cmx4cmx0.194m/s. Water sample NB5. Changes from arable fields to pasture here. 20 cows in field.
7	04/12/2012 10:28	TL 92712 08401	***Figure XII.8***	100 sheep on fields, 4 on dyke.
8	04/12/2012 10:34	TL 92579 08033		4 sheep on dyke
9	04/12/2012 10:35	TL 92487 08014		100s of geese on Joyces marsh. 2 sheep on dyke. Start of trestles on intertidal.
10	04/12/2012 10:50	TL 92105 08068	***Figure XII.9***	Trestles continue
11	04/12/2012 10:50	TL 92104 08068		End of trestles
12	04/12/2012 11:00	TL 91864 08618		6 cattle in field.
13	04/12/2012 11:38	TL 91782 08692		2 ponies.
14	04/12/2012 11:41	TL 91639 08572	***Figure XII.10***	Pipe outfall from marsh routed over stream. Dripping. Not possible to access to take sample
15	04/12/2012 11:45	TL 91570 08516	***Figure XII.11***	Freshwater outfall, 90cmx10cmx0.100m/s. Water sample NB6
16	04/12/2012 11:51	TL 91435 08413	***Figure XII.12***	Pipe outfall, 35cm diameter, full apart from 2cm at top, 0.226m/s, Water sample NB7
17	04/12/2012 12:05	TL 91181 08049	***Figure XII.13***	Freshwater outfall 25cmx35cmx0.618m/s. Water sample NB8. Geese x 50. Yacht on dry mooring
19	04/12/2012 12:23	TL 90873 08203	***Figure XII.14***	Freshwater outfall 100cmx8cmx0.214m/s. Water sample NB9. Odour and sewage fungus
20	04/12/2012 12:38	TL 90306 07652		Freshwater outfall, flap closed, tide in
21	04/12/2012 13:10	TL 89111 07324	***Figure XII.15***	Osea Road flood sluice. Receives Maldon STW effluent via lagoon. Not flowing. Water sample NB10 from ditch behind
22	04/12/2012 13:19	TL 89112 07034		Osea Road Sluice No. 2, covered by tide
25	04/12/2012 13:45	TL 87608 07709		Freshwater outfall, covered by tide
26	04/12/2012 13:51	TL 87322 07749		Spicketts Brook Sluice Freshwater outfall, covered by tide.
27	04/12/2012 13:55	TL 87354 07624		Geese x 20
28	04/12/2012 13:58	TL 87410 07508		2 possible houseboats.
29	04/12/2012 14:02	TL 87505 07374		Freshwater outfall, covered by tide
30	04/12/2012 14:08	TL 87319 07008	***Figure XII.16***	Houseboat and other craft on pontoons.

31	04/12/2012 14:09	TL 87276 06960		Jolly sailor sluice
32	04/12/2012 14:21	TL 87218 06859		Canal outfall
33	06/12/2012 10:49	TM 03027 00112	***Figure XII.17***	Mound of dredged weed next to drainage ditch
34	06/12/2012 10:55	TM 03044 00398		Bridgewick Pumping Station. Not Flowing
35	06/12/2012 11:19	TM 02752 01897	***Figure XII.18***	Grange outfall (approximate 3m x 50cm x 0.3ms-1). Water sample SB1
36	06/12/2012 11:38	TM 02774 02648		Howe Outfall. Not Flowing, silted up
37	06/12/2012 12:15	TM 03211 04575	***Figure XII.19***	Marsh House Pumping Station. Water sample SB2
38	06/12/2012 12:46	TM 03126 05884	***Figure XII.20***	Geese x100 flying overhead
39	06/12/2012 10:20	TL 99467 07923		Outlet (valve) adjacent to 23 caravans
41	06/12/2012 10:31	TL 99542 08467	***Figure XII.21***	Sluice outfall (Downhall Sluice). 130cmx44cmx0.163m/s. Water sample SB3
42	06/12/2012 10:42	TL 99709 08725		Dog waste bin
43	06/12/2012 10:50	TM 00108 09019	***Figure XII.22***	Bank of Dead shells (cockles, mussels, clams, oysters)
44	06/12/2012 10:52	TM 00186 09042		Litter and dog waste bins
46	06/12/2012 10:57	TM 00325 09223	***Figure XII.23***	Oysters
50	06/12/2012 11:12	TM 01423 09387		End of channel with possible occasional overflow into sea
51	06/12/2012 11:19	TM 01660 09545	***Figure XII.24***	Pipe (outfall) Weymarks Sluice, 1m pipe. 29cmx95cmx0.832m/s. Water sample SB4
52	06/12/2012 11:30	TM 02146 09367		Marker on other side of marsh (not an outfall)
54	15/01/2013 09:28	TL 99141 07626	***Figure XII.25***	Possibly fuel pipe
55	15/01/2013 09:29	TL 99129 07607		Westwick Sluice – Flowing
56	15/01/2013 09:42	TL 98983 07025	***Figure XII.26***	Pipe flowing
57	15/01/2013 09:42	TL 98983 07025		Pipe flowing
58	15/01/2013 09:48	TL 98718 06767		Pipe flowing
59	15/01/2013 09:54	TL 98633 06515	***Figure XII.27***	Pipe flowing
60	15/01/2013 10:03	TL 98480 06348		Pipe Silted. Water sample SB5
61	15/01/2013 10:12	TL 98348 06170		Pipe Not Flowing
62	15/01/2013 10:14	TL 98337 06163		Pipe Not Flowing
63	15/01/2013 10:18	TL 98069 06075		Pipe Not Flowing
65	15/01/2013 10:34	TL 97328 05875		Flowing - Bradwell Wick Sluice No. 2
66	15/01/2013 10:46	TL 97140 05468	***Figure XII.28***	Flowing - Bradwell Wick Sluice No. 1. 23cmx90cmx0.063m/s. Water sample SB6
67	15/01/2013 10:57	TL 97023 05681	***Figure XII.29***	Sluice Flowing. 8cmx40cmx0.115m/s. Water sample SB7
69	15/01/2013 11:19	TL 96034 05543	***Figure XII.30***	Flowing - Outfall from Lake next to Caravan site. 10cmx70cmx0.101m/s. Water sample SB8
70	15/01/2013 11:40	TL 95573 05842		Pipe Not flowing - Possibly drainage from gardens behind
71	15/01/2013 11:42	TL 95532 05872		Pipe Not flowing - Possibly drainage from gardens behind

72	15/01/2013 11:43	TL 95511 05897	***Figure XII.31***	Pipe Not flowing - Possibly drainage from gardens behind
73	15/01/2013 11:47	TL 95438 05951	***Figure XII.32***	Pipe Not Flowing - Gravel blocking exit
74	15/01/2013 11:49	TL 95432 05960		Pipe Not Flowing - Gravel blocking exit
75	15/01/2013 11:51	TL 95377 06004		Pipe Not Flowing
76	15/01/2013 11:51	TL 95371 06008		Pipe Not Flowing
77	15/01/2013 12:02	TL 94980 06160		Steeple Slune Sluice Pumping Station
78	15/01/2013 12:05	TL 94976 06234	***Figure XII.33***	Pipe Flowing. Water sample SB9 (sample ruined)
81	15/01/2013 12:33	TL 93767 05874	***Figure XII.34***	The Wade, Ramsey Marsh Pipe. Flowing. Water sample SB10
82	15/01/2013 13:13	TL 93423 04711		Rejoined main coastal path
83	15/01/2013 13:14	TL 93421 04694		Pipe Not Flowing
84	15/01/2013 13:20	TL 93330 04375	***Figure XII.35***	Shoat Farm Sluice Flowing
86	15/01/2013 13:32	TL 92834 04554		Canney Farm Sluice No.2 - submerged by seawater
87	15/01/2013 13:36	TL 92827 04548	***Figure XII.36***	Canney Farm Sluice No.2 sample taken from drainage ditch. Water sample SB11
90	15/01/2013 13:56	TL 91895 04356		Canney Farm Sluice No.1 - submerged by seawater
91	15/01/2013 14:27	TL 92220 02972	***Figure XII.37***	Steeple Hall Sluice No.2. Water sample SB12 (sample from drainage ditch)
92	15/01/2013 14:38	TL 92075 02686	***Figure XII.38***	Steeple Hall Sluice No.1. Water sample SB13 (sample from drainage ditch)
93	15/01/2013 14:47	TL 92060 02389	***Figure XII.39***	Pigeon Dock Sluice No. 3. Water sample SB14 (sample from drainage ditch)
94	15/01/2013 14:54	TL 92131 02187	***Figure XII.40***	Pigeon Dock No. 2. Sluice Water sample SB15 (sample from drainage ditch)
95	15/01/2013 14:57	TL 92135 02136	***Figure XII.41***	Pigeon Dock No. 1. Sluice Water sample SB16 (sample from drainage ditch)
96	16/01/2013 09:36	TL 91989 02355		Nipsells Farm Sluice No.5 - Flowing
97	16/01/2013 09:42	TL 91802 02388	***Figure XII.42***	Large pipe - Flowing
98	16/01/2013 09:47	TL 91796 02539	***Figure XII.43***	Mayland Sewage Treatment Works. Geese x 400 overhead
99	16/01/2013 09:56	TL 91796 02539	***Figure XII.44***	Nipsells Farm Sluice No.4 - Flowing
102	16/01/2013 10:29	TL 91383 03387		Nipsells Farm Sluice No.3A - Flowing
103	16/01/2013 10:32	TL 90962 03799		Pipe not flowing - Lid closed and silted up
104	16/01/2013 10:38	TL 90758 03631	***Figure XII.45***	Nipsells Farm Sluice No.2 - Flowing. Water sample SB17.
105	16/01/2013 10:39	TL 90742 03559		Birds x 200
106	16/01/2013 10:46	TL 90804 03221		Birds x 200
107	16/01/2013 10:49	TL 90822 03089		Boats moored x 12 & waders x 200
108	16/01/2013 11:00	TL 90661 02710	***Figure XII.46***	Nipsells Farm Sluice No.1
109	16/01/2013 11:03	TL 90580 02679		Sealed pipe - Not flowing

110	16/01/2013 11:08	TL 90442 02573		Maylandsea Bay Sluice
111	16/01/2013 11:13	TL 90233 02435		Houseboats x 2
112	16/01/2013 11:14	TL 90187 02429		Dripping pipe
113	16/01/2013 11:25	TL 89567 02268	***Figure XII.47***	Maylandsea West Sluice - Flowing gently. Dog Walker
114	16/01/2013 11:28	TL 89445 02246		Lawling Hall Sluice No 3 - Flowing
115	16/01/2013 11:38	TL 89367 02329	***Figure XII.48***	Lawling Hall Sluice No 2 - Flowing
116	16/01/2013 11:47	TL 89343 02937	***Figure XII.49***	Lawling Hall Sluice No 1 - Flowing
117	16/01/2013 11:57	TL 89727 02858	***Figure XII.50***	Mundon Hall Sluice - Flowing
118	16/01/2013 12:13	TL 89841 03187		Brick House Sluice No. 8 - Gentle Flow
119	16/01/2013 12:32	TL 90452 04177		Brick House Sluice No. 7 - Gentle Flow
120	16/01/2013 12:33	TL 90467 04181		Brick House Sluice No. 6 - Gentle Flow
121	16/01/2013 12:38	TL 90690 04328		Brick House Sluice No. 5 - Gentle Flow
122	16/01/2013 12:45	TL 90941 04655		Brick House Sluice No. 4 - Not Flowing
123	16/01/2013 12:47	TL 90930 04673		Pipe not flowing - Silted up
124	16/01/2013 12:51	TL 90669 04742		Brick House Sluice No. 3 - Flowing
125	16/01/2013 12:53	TL 90576 04771		Birds x 500 on mudflats
126	16/01/2013 12:58	TL 90312 04545		Birds x 1000 on mudflats
127	16/01/2013 13:11	TL 90045 04295		Brick House Sluice No. 2 - Flowing
128	16/01/2013 13:17	TL 89807 04281		Brick House Sluice No. 1 - Flowing (Gentle)
129	16/01/2013 13:24	TL 89601 04517		New Hall Sluice No. 3 - Not Flowing
130	16/01/2013 13:32	TL 89612 04730		New Hall Sluice No. 2 - Not Flowing
131	16/01/2013 13:41	TL 89331 05033		New Hall Sluice No. 1 - Flowing (Gentle)
132	16/01/2013 13:53	TL 88662 04994		Geese and Waders x 500
133	16/01/2013 14:07	TL 87921 05343		Sections of old pipes suggests sluice was historically situated here
134	16/01/2013 14:47	TL 86649 05891	***Figure XII.51***	Mundon Wash Sluice - Pipe submerged
135	16/01/2013 14:49	TL 86607 05923		Sluice - inundated by the tide
136	16/01/2013 14:52	TL 86498 06044		Geese and Waders x 600
137	16/01/2013 14:59	TL 86347 06231		South House Sluice No.1 & 2
138	16/01/2013 15:00	TL 86346 06231	***Figure XII.52***	Pipe Flowing - stopped before flow reading could be taken. Water sample SB18
139	17/01/2013 08:52	TL 95829 08264	***Figure XII.53***	Mussel and Oyster Beds
140	17/01/2013 09:06	TL 96334 08530		Melhouse Pumping Station
141	17/01/2013 09:17	TL 96881 08611	***Figure XII.54***	Melhouse Outfall - Flowing
142	17/01/2013 09:28	TL 96618 09058		Bank of Dead shells (cockles, mussels, clams, oysters)
143	17/01/2013 09:36	TL 96849 09282		Sheep x10
144	17/01/2013 09:42	TL 97050 09068		Cows x10 and sheep
145	17/01/2013 09:51	TL 97492 09128		Geese flying overhead x100

146	17/01/2013 09:52	TL 97522 09147		Sheep x 10
147	17/01/2013 10:14	TL 98176 09984		Bank of Dead shells (cockles, mussels, clams, oysters)

Sample results

Freshwater inputs were sampled and spot discharge measurements taken, to give spot estimates of their *E. coli* loadings (Table XII.2 and Figure XII.2). Due to the extensive microbiological monitoring history of the area no seawater or shellfish sampling was considered necessary.

Table XII.2: Water sample E. coli results and estimated stream loadings

Sample No.	Date and Time	Position	E. Coli (cfu/100ml)	Flow (m^3/day)	E. coli (cfu/day)*
NB1	04/12/2012 09:38	TL 94158 08342	1200	341	4.10×10^{10}
NB2	04/12/2012 09:47	TL 93950 08480	1100	259	2.85×10^{09}
NB3	04/12/2012 09:56	TL 93648 08415	110	1101	1.21×10^{09}
NB4	04/12/2012 10:15	TL 92784 08754	2400	59303	1.42×10^{12}
NB5	04/12/2012 10:19	TL 92784 08745	1600	67046	1.07×10^{12}
NB6	04/12/2012 11:45	TL 91570 08516	1100	778	8.55×10^{09}
NB7	04/12/2012 11:51	TL 91435 08413	800	1879	1.50×10^{10}
NB8	04/12/2012 12:05	TL 91181 08049	820	4672	3.83×10^{10}
NB9	04/12/2012 12:23	TL 90873 08203	>10000	1479	$>1.48 \times 10^{11}$
NB10	04/12/2012 13:10	TL 89111 07324	50		Not flowing
SB1	06/12/2012 11:19	TM 02752 01897	150	38880	5.83×10^{10}
SB2	06/12/2012 12:15	TM 03211 04575	120	Pumped intermittently	
SB3	06/12/2012 10:31	TL 99542 08467	20	8056	1.61×10^{09}
SB4	06/12/2012 11:19	TM 01660 09545	500	19804	9.90×10^{10}
SB5	15/01/2013 10:03	TL 98480 06348	1800	-	-
SB6	15/01/2013 10:46	TL 97140 05468	1100	1127	1.24×10^{10}
SB7	15/01/2013 10:57	TL 97023 05681	50	318	1.59×10^{08}
SB8	15/01/2013 11:19	TL 96034 05543	5	611	3.05×10^{07}
SB10	15/01/2013 12:33	TL 93767 05874	260	-	-
SB11	15/01/2013 13:36	TL 92827 04548	610	-	-
SB12	15/01/2013 14:27	TL 92220 02972	400	-	-
SB13	15/01/2013 14:38	TL 92075 02686	150	-	-
SB14	15/01/2013 14:47	TL 92060 02389	260	-	-
SB15	15/01/2013 14:54	TL 92131 02187	3600	-	-
SB16	15/01/2013 14:57	TL 92135 02136	2800	-	-
SB17	16/01/2013 10:38	TL 90758 03631	30	-	-
SB18	16/01/2013 15:00	TL 86346 06231	40	-	-

*Numbers of *E. coli* per day introduced to coastal waters from each input, calculated from spot gauging of discharges and corresponding water sample *E. coli* results.

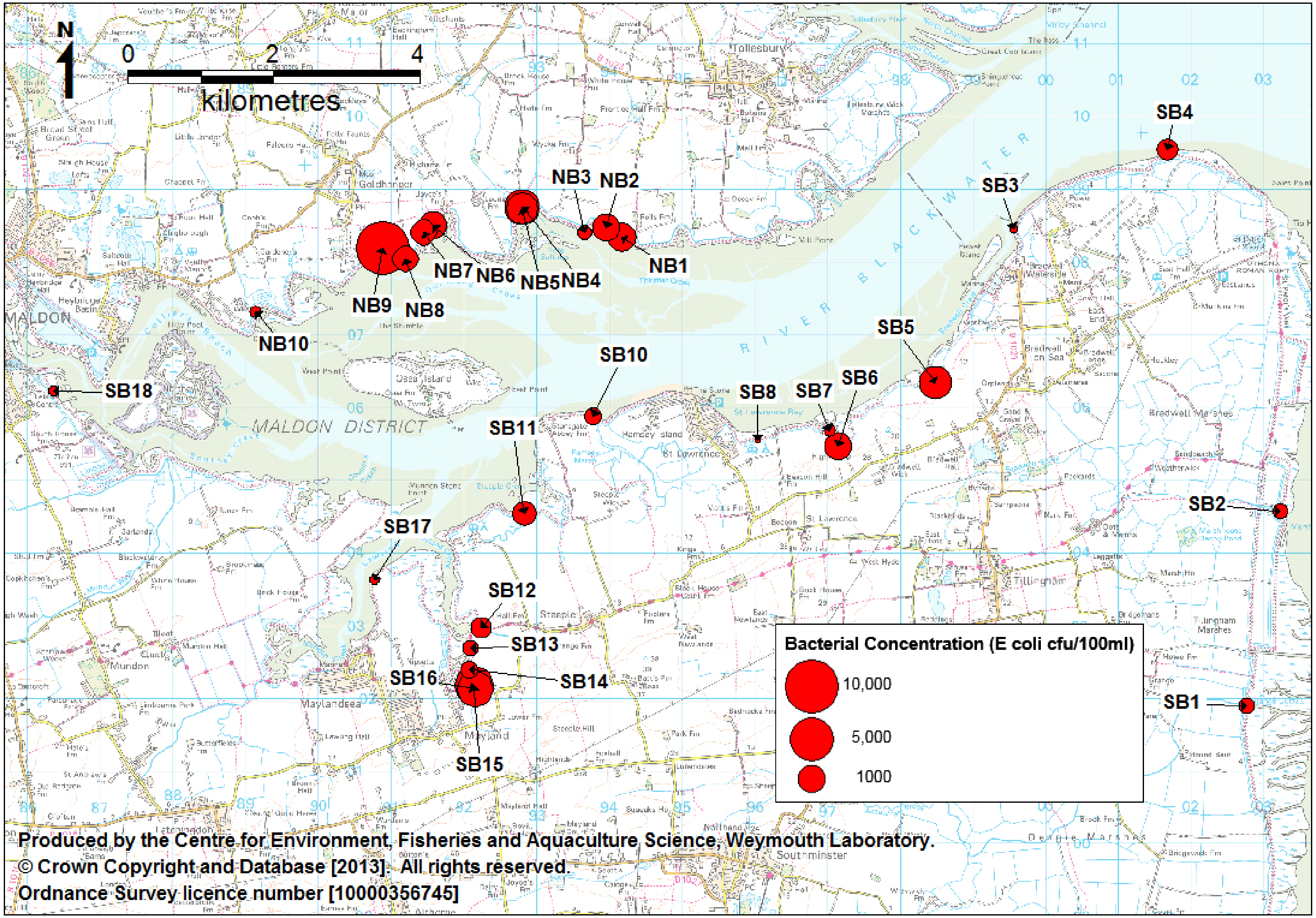


Figure XII.2: Water sample results

Figure XII.3

Figure XII.4

Figure XII.5

Figure XII.6

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Figure XII.28

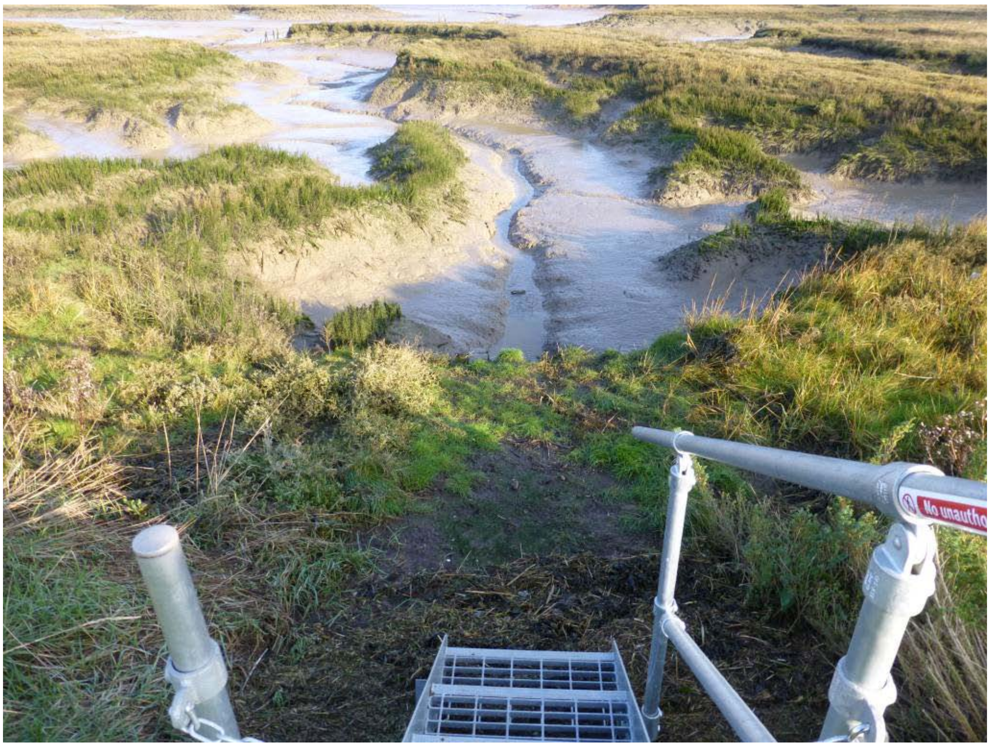

Figure XII.29

Figure XII.30

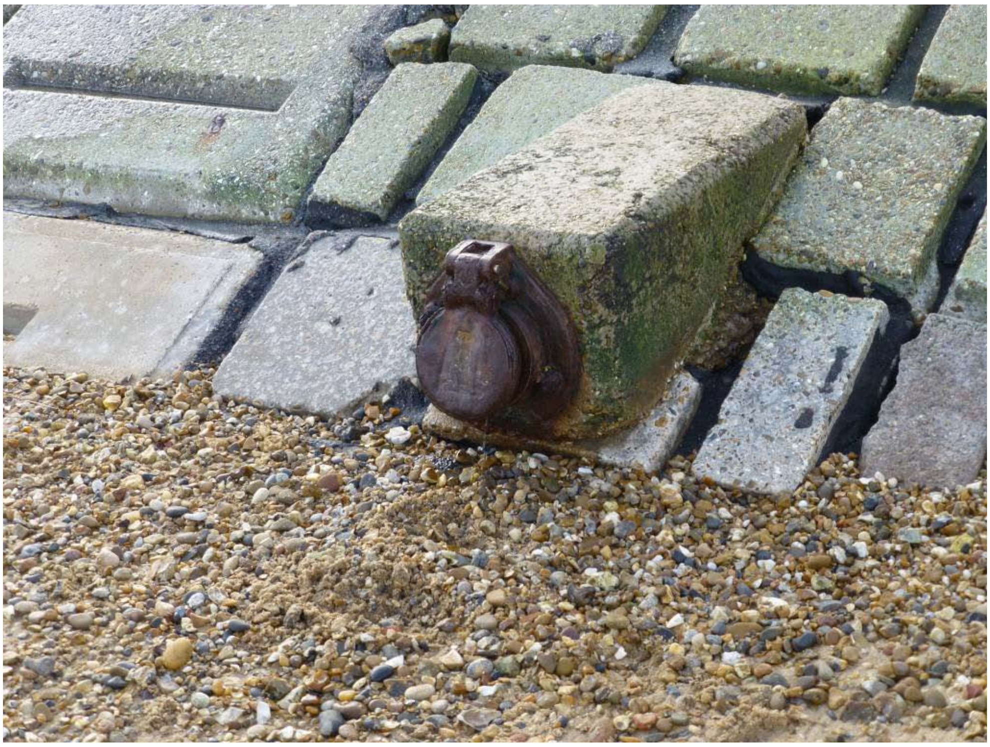

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Figure XII.51

Figure XII.52

Figure XII.53

Figure XII.54

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List of Abbreviations

AONB	Area of Outstanding Natural Beauty
BMPA	Bivalve Mollusc Production Area
CD	Chart Datum
Cefas	Centre for Environment Fisheries & Aquaculture Science
CFU	Colony Forming Units
CSO	Combined Sewer Overflow
CZ	Classification Zone
Defra	Department for Environment, Food and Rural Affairs
DWF	Dry Weather Flow
EA	Environment Agency
E. coli	*Escherichia coli*
EC	European Community
EEC	European Economic Community
EO	Emergency Overflow
FIL	Fluid and Intravalvular Liquid
FSA	Food Standards Agency
GM	Geometric Mean
IFCA	Inshore Fisheries and Conservation Authority
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
NM	Nautical Miles
NRA	National Rivers Authority
NWSFC	North Western Sea Fisheries Committee
OSGB36	Ordnance Survey Great Britain 1936
mtDNA	Mitochondrial DNA
PS	Pumping Station
RMP	Representative Monitoring Point
SAC	Special Area of Conservation
SHS	Cefas Shellfish Hygiene System, integrated database and mapping application
SSSI	Site of Special Scientific Interest
STW	Sewage Treatment Works
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.
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 skewed data such as those 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 dataset, 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”.

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