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EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Thames Estuary (Maplin Sands)

February 2015

Food Standards Agency

Cover photo: The Broomway (a public right of way across Maplin Sands)

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Statement of use

This report provides a sanitary survey relevant to bivalve mollusc beds in the outer Thames Estuary (Maplin Sands), 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).

Report prepared by

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Revision history

Version	Details	Approved by	Approval date
1	Draft for internal consultation	Fiona Vogt	18/02/2015
2	Draft for client/consultee comment	Simon Kershaw	25/02/2015
3	Final	Simon Kershaw	21/04/2015

Consultation

Consultee	Date of consultation	Date of response
London Port Health Authority	26/02/2015	02/04/2015
Environment Agency	26/02/2015	02/04/2015
Kent & Essex IFCA	26/02/2015	-
Anglian Water	26/02/2015	02/04/2015
Shellfish Association of Great Britain	26/02/2015	-
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Dissemination

Food Standards Agency, London Port Health Authority. The report is available publicly via the Cefas website.

Recommended Bibliographic Reference

Cefas, 2015. Sanitary survey of the Thames Estuary (Maplin Sands). 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 EC regulation No. 854/2004.

Contents

1. Introduction

1.1. Legislative Requirement

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

When consumed raw or lightly cooked, bivalves contaminated with pathogenic microorganisms may cause infectious diseases (e.g. Norovirus-associated gastroenteritis, Hepatitis A and Salmonellosis) in humans. Infectious disease outbreaks are more likely to occur, 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 cockles (*Cerastoderma edule*) on the north shore of the Thames production area between Shoebury Boom and the mouth of the Crouch Estuary. The area was prioritised for survey in 2014-15 by a shellfish hygiene risk ranking exercise of existing classified areas.

1.2. Area description

The survey area is situated on the north shore of the outer Thames Estuary, between the Shoebury Boom and Crouch Estuary. The intertidal area here (Maplin Sands) is usually the most productive area within the Thames Estuary cockle fishery.

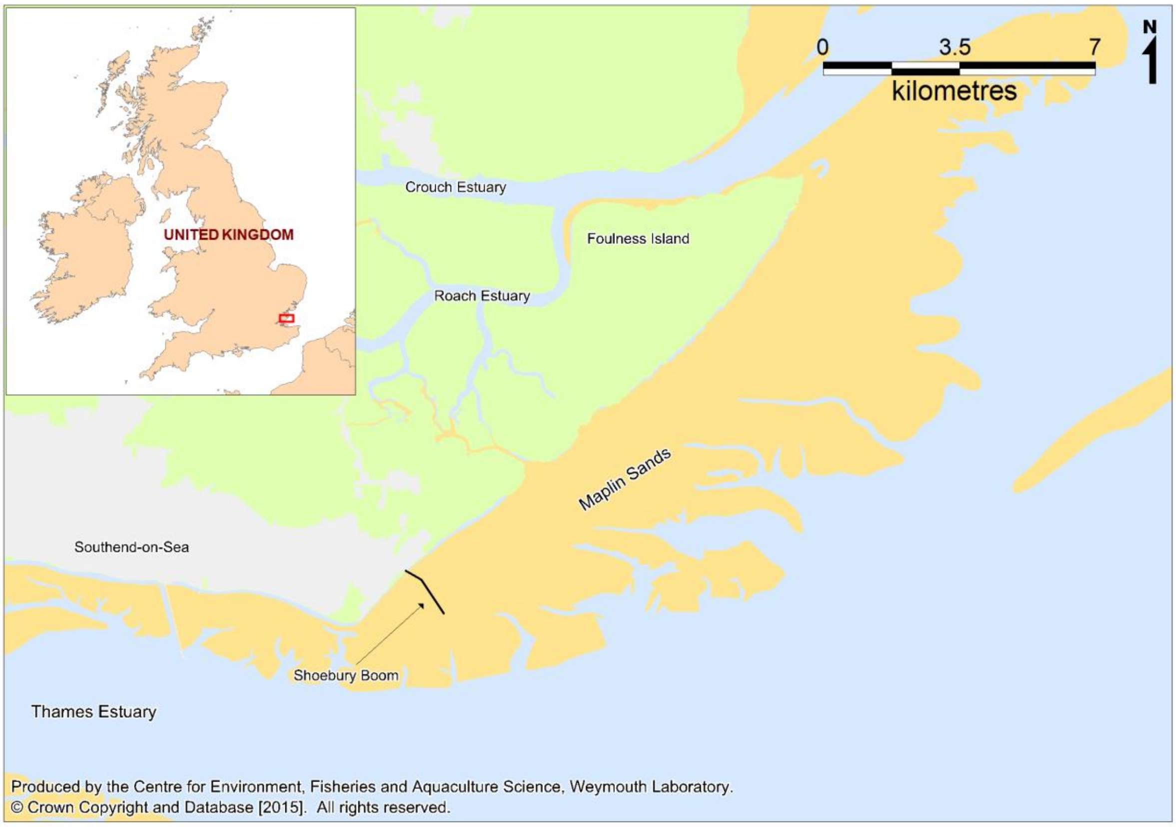


Figure 1.1: Location of the survey area

Maplin Sands covers an area of about 100 km^2 and the substrate is a mix of sand, mud, shell and shingle. The seaside town of Southend-on-Sea lies to the west of the survey area. There is an intertidal connection between the Roach Estuary and Maplin Sands at Havengore. Foulness Island backs the shore to the east of this connection. It is a low lying island surrounded by sea defences, and is largely owned by the Ministry of Defence military so civilian access is restricted. There are also restrictions on vessel access to Maplin Sands due to the firing range. The mouth of the Crouch/Roach estuary complex lies to the north of Foulness Island.

1.3. Catchment

Figure 1.2 illustrates landcover within the catchment considered in this survey, which covers an area of about 47 km^2, and includes the coastal strip between Southend Pier and Havengore Creek, as well as the whole of Foulness Island. There are no major rivers draining directly to the survey area, with freshwater inputs limited to a few small watercourses and engineered drainage outfalls. To the west of Shoebury Boom, the catchment is almost completely urbanised. To the east, land cover is predominantly arable farmland, with some small pockets of pasture, most of which is towards the western end of Foulness Island. There are also some small areas of saltmarsh on the seaward side of the sea defences at the western end of Foulness Island.

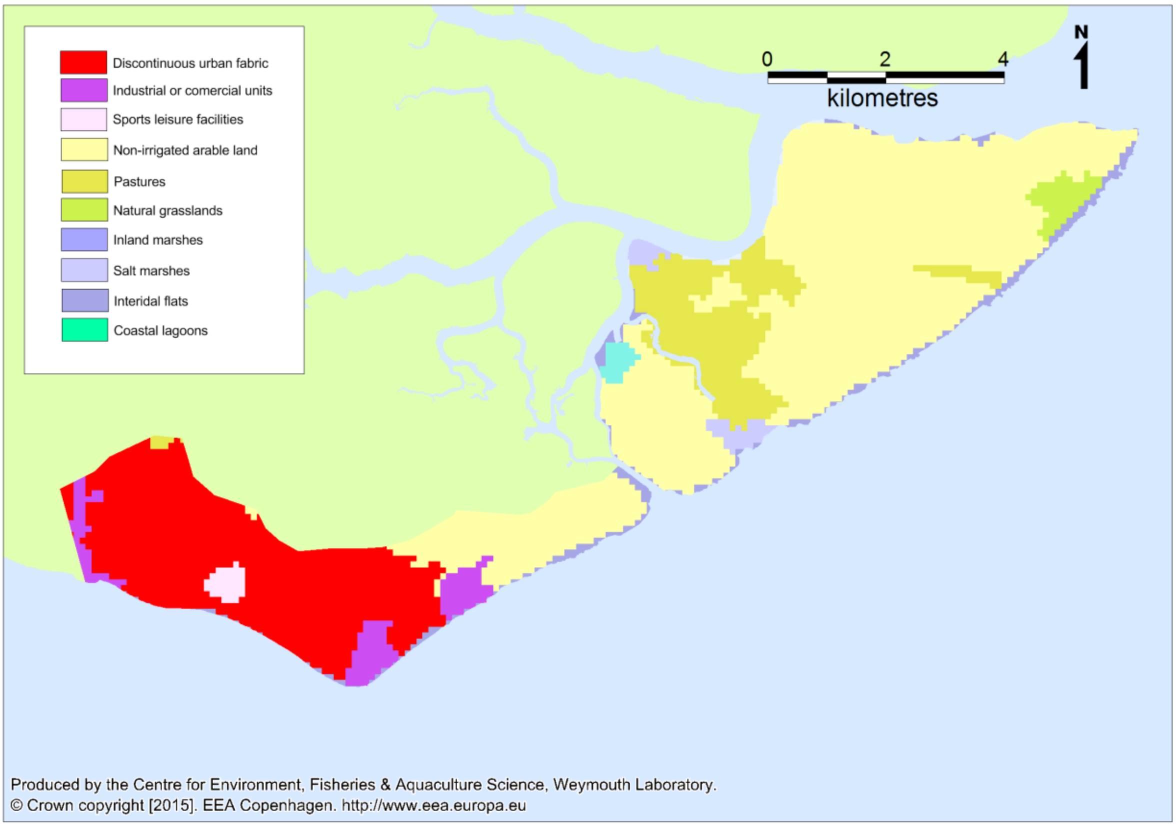


Figure 1.2: Landcover in the Maplin Sands catchment area

Different land cover types will generate differing levels of contamination in surface runoff. Highest faecal coliform contribution arises from developed areas, with intermediate contributions from the improved pastures and lower contributions from the other land 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 the contributions from which increase up to 100 fold.

The underlying geology is described as being of mixed permeability throughout (NERC, 2012). The catchment is low lying, with a maximum elevation of around 25 m at its western end. Foulness Island is particularly flat, with elevations at about sea level throughout.

2. Recommendations

The following three cockle zones are recommended:

Maplin West

The main contaminating influences to this zone are the Southend STW, and other sources to the west. More diffuse and unpredictable sources directly to this zone include seals and overwintering birds. There may also be some contamination from boats, mainly outside of the zone. Microbiological monitoring indicates a gradient of increasing levels of contamination towards the western end of the zone. It is therefore recommended that the RMP be located at the south western corner of this zone.

Maplin Central

There is likely to be a slight underlying increase in levels of contamination towards the western end of this zone due to sources in the Southend area such as the STW. This will not be so marked as it is within the Maplin West zone as it is more remote from these sources. More diffuse and unpredictable sources directly to this zone include seals and overwintering birds. There may also be some contamination from boats, mainly outside of the zone although there will be some limited traffic in and out of Havengore Creek. The ebb plume from Havengore Creek is likely to cause an increase in levels of faecal indicator bacteria in its path, and will travel in a broadly easterly direction. It is therefore recommended that the RMP is located in the path of this plume, and as close to the shore as firing range activities permit (~ 1.7 km from land).

Maplin East

The influence from sources to the west (e.g. Southend STW) will be minor within this zone as they are remote from it. More diffuse and unpredictable sources directly to this zone include seals and overwintering birds. There may also be some contamination from boats, mainly outside of the zone, and particularly along the Crouch approach channel. The ebb plume from the Crouch Estuary is likely to be a significant influence along the northern edge of this zone. It is therefore recommended that the RMP is located as close to the channel and as far inshore as stocks extend and firing range activities permit.

Sampling requirements

The species sampled should be cockles of a harvestable size (>16 mm) and should be collected by dredge. Sampling should be on a monthly basis, although the first two months of the closed season (December and January) do not necessarily need to be sampled assuming samples are successfully submitted for the remaining 10 months of the year. A tolerance of 100 m applies.

3. Sampling Plan

3.1. General Information

Location Reference

Production Area	Thames
Cefas Main Site Reference	M016
Ordnance survey 1:25,000 map	Explorer 176
Admiralty Chart	1185. 1975

Shellfishery

Species/culture	Cockles	Wild
Seasonality of harvest	Open season within June to November window	

Local Enforcement Authority

Name	London Port Health Authority River Division (Lower) The Quarantine Station Mark Lane Denton Nr. Gravesend Kent. DA12 2QE
Environmental Health Officer	Jackie Ingram
Telephone number ☎	01474 363033
Fax number	01474 353354
E-mail	Jackie.Ingram@cityoflondon.gov.uk

3.2. 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, 2014) indicates that sanitary assessments should be fully reviewed every 6 years, so this assessment is due a formal review in 2021. The assessment may require review in the interim should any significant changes in sources of contamination 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 at Maplin Sands

Classification zone	RMP*	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency
Maplin West	TBA	East of Shoebury Buoy	TQ 9640 8282	51° 30.610'N 00° 49.732'E	Cockles	Wild	Dredge	Dredge	100 m	Monthly
Maplin Central	TBA	East of Havengore Creek	TR 0050 8769	51° 33.148'N 00° 53.438'E	Cockles	Wild	Dredge	Dredge	100 m	Monthly
Maplin East	TBA	Crouch Approach	TR 0677 9599	51° 37.483'N 00° 59.150'E	Cockles	Wild	Dredge	Dredge	100 m	Monthly

**RMP codes will be generated once the report has been agreed and finalised.*

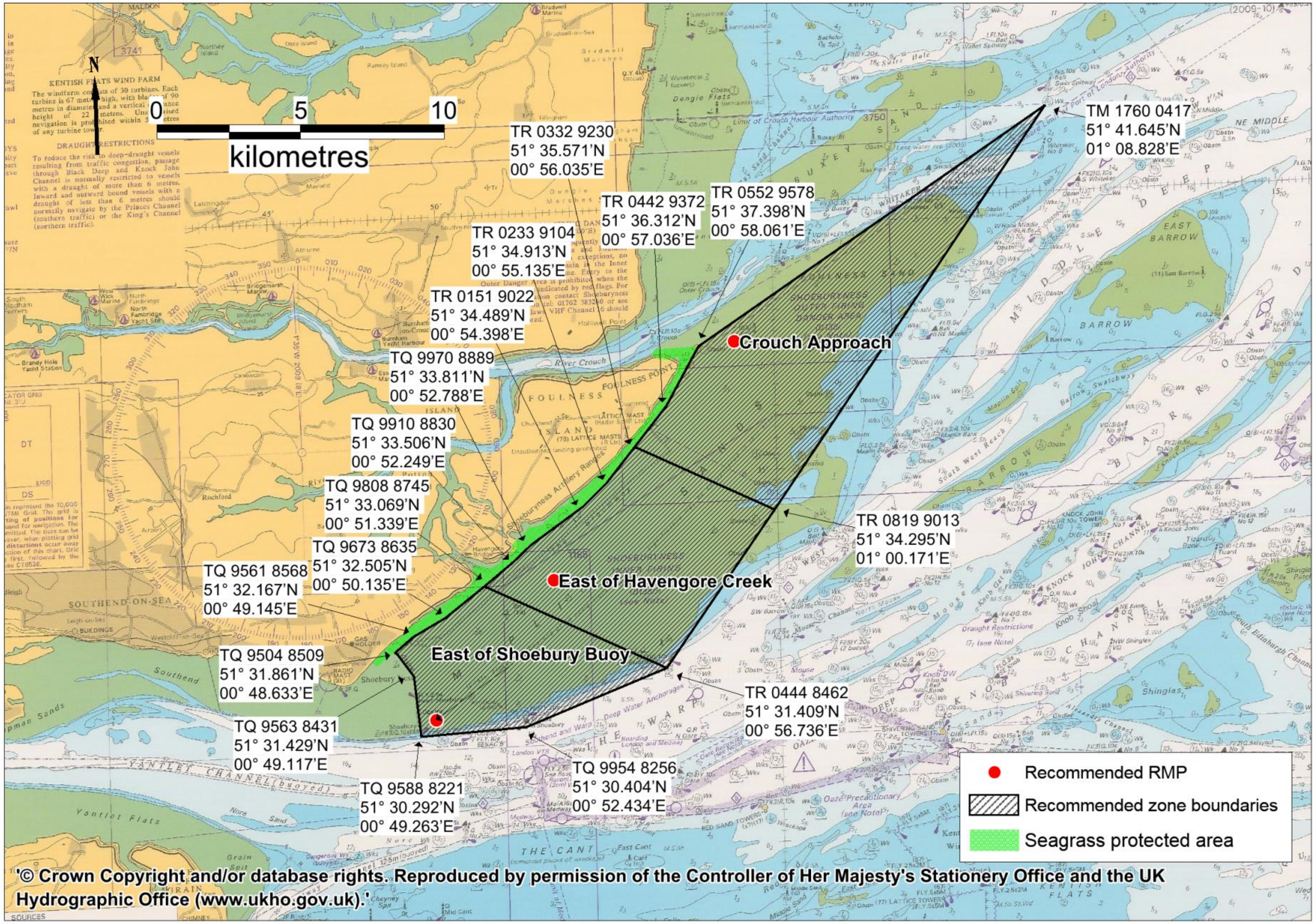


Figure 3.1: Recommended zoning and monitoring arrangements (cockles)

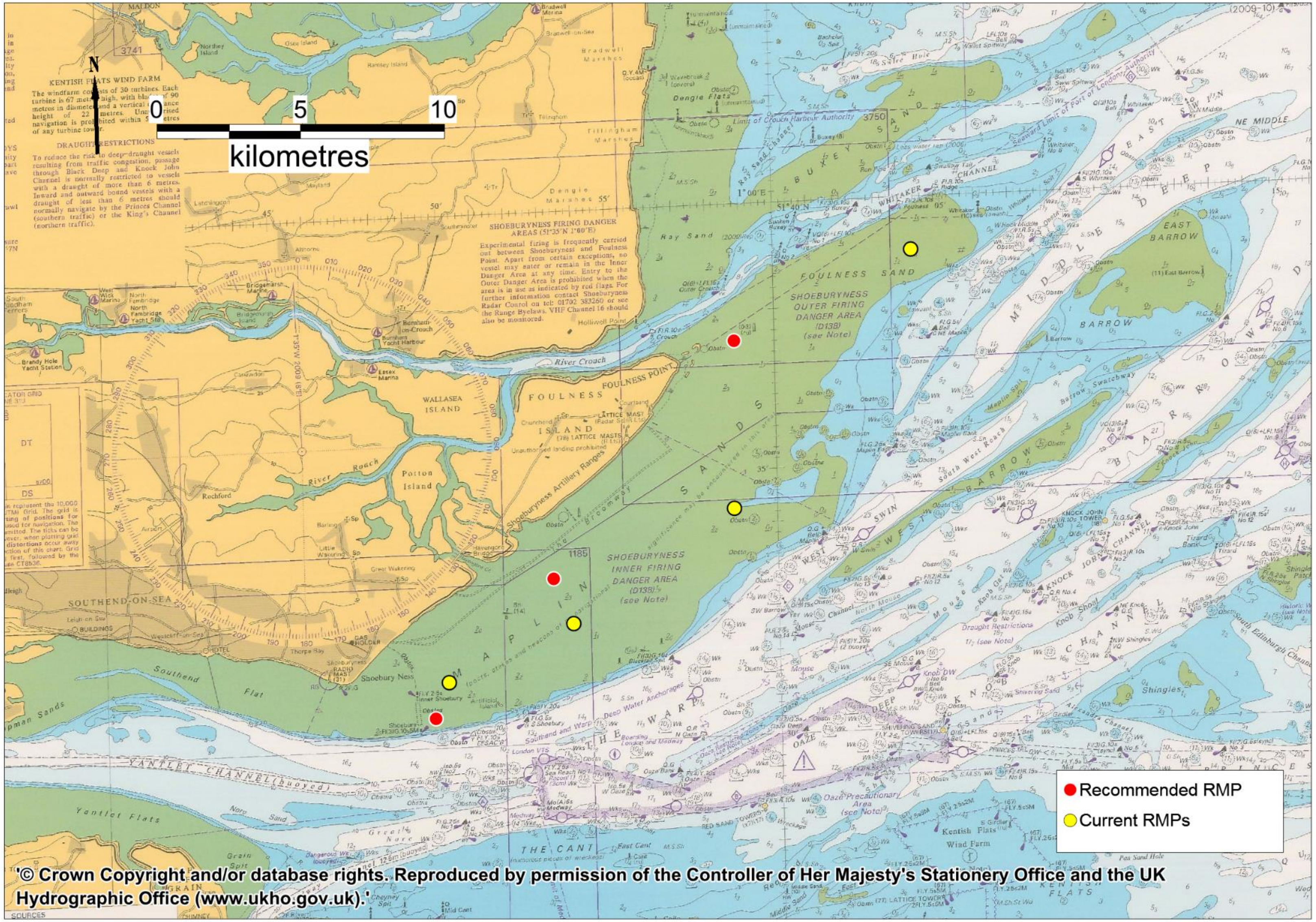


Figure 3.2: Comparison of current and recommended RMPs

4. Shellfisheries

4.1. Species, location and extent

The only bivalve species which is harvested commercially in the area is cockles.

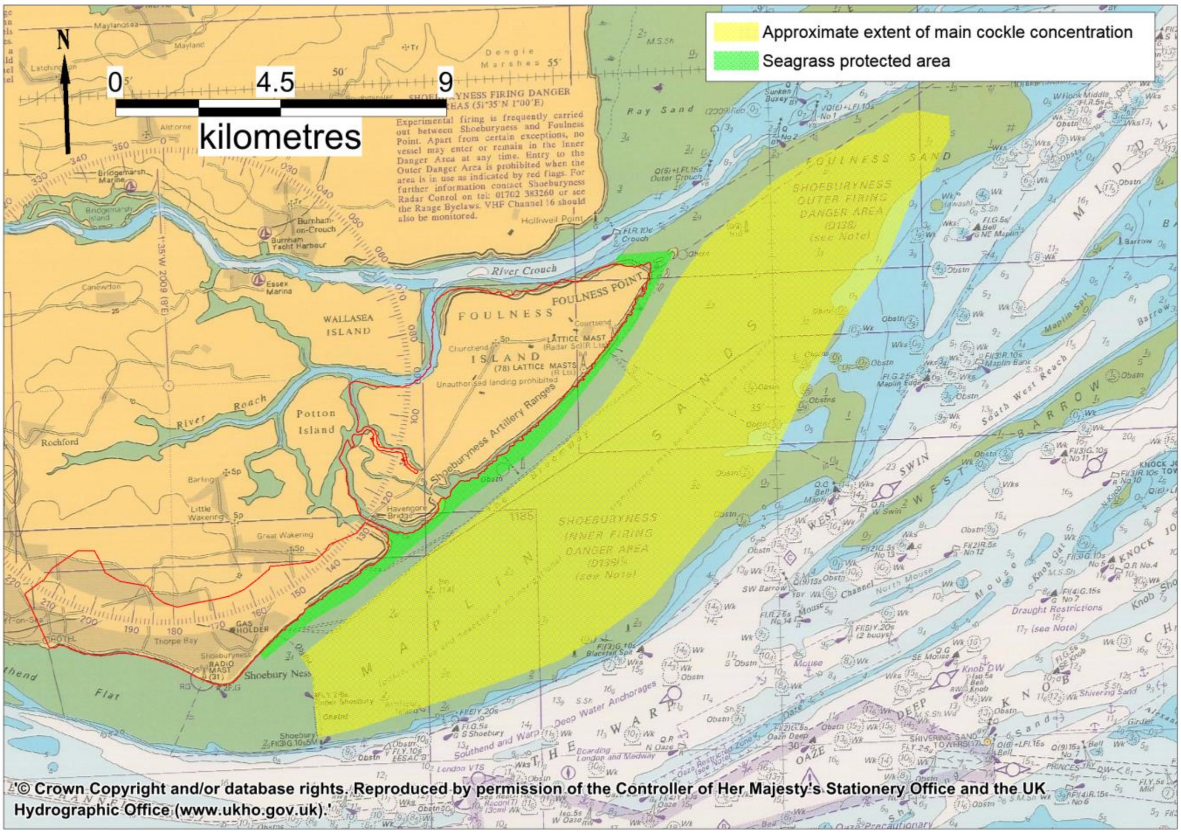


Figure 4.1: Cockle distribution

Maplin Sands represents the most productive area within the Thames Estuary cockle fishery. They are essentially a continuous presence throughout the intertidal area, most of which (apart from the upper shore) holds stock at commercially exploitable densities. Although there are some fluctuations in stock biomass from year to year, their distribution does not vary significantly. The latest survey data available (Autumn 2012) estimated the total biomass of harvestable sized cockles at just over 18,000 tonnes from Shoebury Boom through to the Crouch channel.

4.2. Growing Methods and Harvesting Techniques

Cockles are wild stocks, and are harvested using suction dredges by individuals who hold a licence under the Thames Estuary Cockle Fishery Order (1994).

4.3. Fishery management

The Maplin Sands area falls within the Thames Estuary Cockle Fishery Order (1994). Within this fishery only a limited number of licences (14) are issued to dredge for this species. Quotas are assigned on the basis of stock surveys. The exact timing of the open season varies from year to year but falls within the June to November (inclusive) window at which point meat yields are best. Effort limitations (days per week) and gear restrictions apply. Specific areas may be closed on the basis of stock survey information. Whilst the fishery is in progress effort is actively managed by the Kent and Essex IFCA with the aims of maximising yield without depleting stocks. A maximum of 13.6 m^3 of cockles may be retained per vessel per day. Dredges must have a minimum bar spacing of 16 mm, and no more than 10% of the catch must pass through a space of 16 mm in width. These measures have proved effective in supporting a sustainable, reliable fishery, although there is obviously some natural variation in stock strength from year to year.

There is a strip of seagrass that covers the upper intertidal throughout the survey area. The IFCA have recently introduced a byelaw prohibiting the use of bottom towed fishing gear within this area. It does not coincide with the main stock concentrations which are located further from down the shore but should nevertheless be excluded from the classified area.

4.4. Hygiene Classification

Table 4.1 lists all classifications within the survey area since 2005.

Table 4.1: Classification history for Thames (Maplin Sands), 2005 onwards

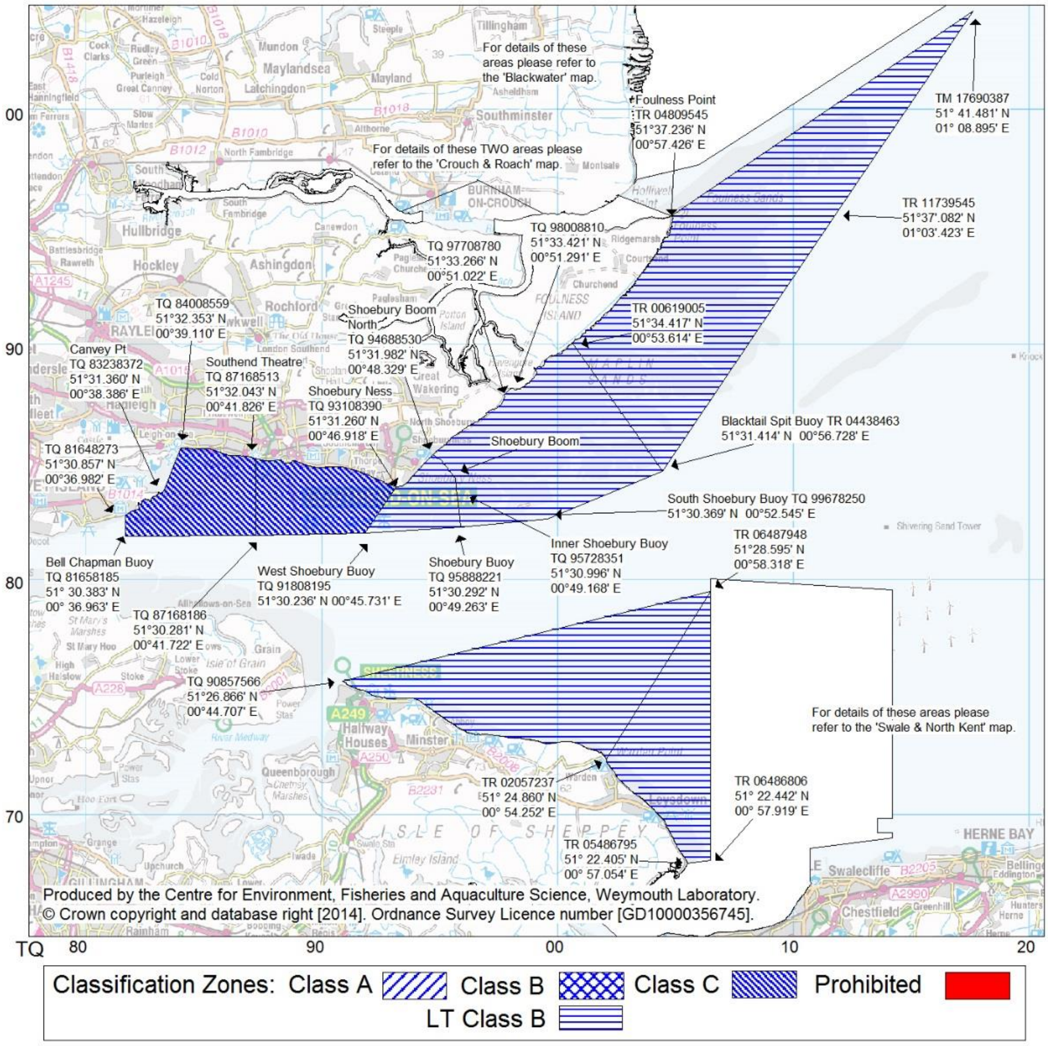
Area	Species	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Mid Maplin Sands	Cockles	A	A	B	B	B	B-LT	B-LT	B-LT	B-LT	B-LT
NE Maplin Sands	Cockles	A	A	A	A	B	B-LT	B-LT	B-LT	B-LT	B-LT
Foulness Sands	Cockles	A	A	A	A	A	B	A	A	B	B
East Shoebury Beacon	Cockles	B-LT	-	-	-	-	-	-	-	-	-
Shoebury Island	Cockles	-	A	B	B	B	B-LT	B-LT	B-LT	B-LT	B-LT

LT denotes long term classification

There have historically been A classifications within the survey area, although these have been downgraded to B in recent years. Downgrades were applied to the areas furthest east the most recently. East Shoebury Beacon and Shoebury Island refer to the same area.

Thames Estuary - C. edule

Scale - 1:250000



<u>Classification of Bivalve Mollusc Production Areas: Effective from 1 September 2014</u>

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.for this area

Food Authorities: London Port Health Authority (Thames Estuary)

Figure 4.2: Current cockle 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* 100g^{-1} Fluid and Intravalvular Liquid (FIL)	None
B[3]	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution MPN test of 4,600 *E. coli* 100g^{-1} FIL in more than 10% of samples. No sample may exceed an upper limit of 46,000 *E. coli* 100g^{-1} FIL	Purification, relaying or cooking by an approved method
C[4]	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution Most Probable Number (MPN) test of 46,000 *E. coli* 100g^{-1} FIL	Relaying for, at least, two months in an approved relaying area or cooking by an approved method
Prohibited[6]	>46,000 *E. coli* 100g^{-1} FIL[5]	Harvesting not permitted

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

5. Overall Assessment

5.1. 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.

5.2. Shellfisheries

Maplin Sands represents the most productive cockle ground within the Thames Estuary. Cockles are a continuous presence throughout most of the intertidal area, and the biomass of harvestable sized stock was recently estimated (Autumn 2012) at 18,000 tonnes. Whilst there is some annual variation in biomass, the spatial distribution of stocks does not change significantly from year to year. They are harvested by dredge by individuals holding a licence to harvest them under the Thames Estuary Cockle Fishery Order 1994, which is managed by the IFCA. Stock surveys are undertaken twice a year, from which the allowable catch is determined. The open season varies from year to year but falls within the June to November window when meat yields are highest. A minimum size of 16 mm applies. Dredging in the upper intertidal is prohibited by an IFCA byelaw to protect sensitive seagrass beds, and this area should be excluded from any classifications. No other species are exploited commercially within the survey area.

The classification sampling is undertaken by London Port Health Authority. Each sampling run requires the use of a cockle dredge to take samples from the various RMPs located around the Thames Estuary, including from the areas off Southend and North Kent. Each RMP must be visited at a suitable state of tide, and authorisation to enter the firing range is required from QinetiQ, who operate the range on behalf of the MOD. Sampling therefore incurs considerable expense, logistics are complex, and timings are critical. Four RMPs are currently sampled within the survey area, and all are located on the lower intertidal. An increase to the number of RMPs, or a significant increase in the distance travelled would compromise the logistics of the sampling run in its current form. Access to the inner areas (~1 mile, or 1.6 km from the high water mark) will not be possible on a routine basis due to firing range activities (London Port Health, pers. comm.).

5.3. Pollution Sources

Freshwater Inputs

The hydrological catchment considered in detail in this report only covers an area of about 47 km^2. This includes a narrow coastal strip at the western end and Foulness Island at the eastern end. The western end is urbanised, whereas the eastern end is rural. Elevations rise to 25 m in Southend, but Foulness and the land immediately to the west of Havengore Creek lies around sea level, and is surrounded by earth banks to prevent tidal flooding. Hydrogeology is described as being of mixed permeability throughout.

There are two small watercourses which drain to the foreshore to the west of Shoebury Boom (Willingale Stream and Shoebury Brook) both of which are highly modified and culverted in places. The former discharges through a pumping station on the Southend Seafront, and the latter discharges through a piped outfall at Shoeburyness. No bacteriological testing or flow gauging results were available for either, but given their small size, and their locations (5 and 2 km west of Shoebury Boom) it is considered their influence on shellfish hygiene at Maplin Sands will be negligible.

A series of sluice outfalls drain the low lying lands of Foulness Island and the area just to the west of Havengore Creek. Some sluices are used to let seawater in to maintain water levels in the ditches, whereas others are used to allow water to drain out. Most of the outlet sluices are to the Roach and Crouch Estuary, although two small outlet sluices were recorded during the shoreline survey on the seaward shore of Foulness Island. Neither was flowing at the time, and water samples taken from the ditches behind them contained very low levels of *E. coli* (10 or <10 cfu/100 ml). The impacts from land drainage from these low lying areas are therefore likely to be minor at most.

Human Population

Total resident population within census areas contained within or partially within the catchment was approximately 81,400 at the time of the last census (2011). The population is concentrated within the town of Southend-on-Sea, at the western end of the survey area. The eastern end of the catchment is mostly Ministry of Defence property and is sparsely populated. Southend-on-Sea is a popular resort, and Anglian Water estimate its sewage works serves an additional population of 9% of the resident population during peak holiday times. The area to the east, including Foulness Island, is mostly closed to the public, so is unlikely to experience any influxes of tourists.

Sewage Discharges

The main sewage input to the area is the Southend STW. It provides secondary treatment for a consented dry weather flow of 68,274 m^3/day, generating an estimated bacterial loading of $2.3x10^{14}$ faecal coliforms/day. Its' outfall is located about 2.8 km offshore, in 12 m of water, about 5 km to the west of the area considered in this survey. There is therefore considerable potential for dilution and dispersion of the plume as it travels towards Maplin Sands on the ebbing tide. There is one other water company owned sewage works (Foulness (Church End) STW) which is located towards the north shore of Foulness Island. It provides secondary treatment for a dry weather flow of about 14 m^3/day, and discharges to a ditch which subsequently drains to the Roach Estuary. Impacts from this plant will therefore be negligible. There are also several sewage works discharging to the Thames Estuary to the west of the area considered in detail in this report, and to the Roach/Crouch Estuary complex. These may be a minor influence at Maplin Sands.

There are 19 intermittent (overflow) discharges associated with the water company owned sewerage infrastructure within the survey area. Most of these are in Southend, and all but three are located to the west of the Shoebury Boom. Of these three, one discharges to a field drain at Wakering, one discharges to Havengore Creek, and one discharges to a ditch in the centre of Foulness Island. None discharge directly to Maplin Sands. No spill records were available for any of these discharges, so it is difficult to assess their significance, aside from noting their locations and their potential to spill untreated sewage.

Although the vast majority of properties within the survey area have access to mains sewers, there are also 22 permitted private discharges. Most are on Foulness Island, although there are five on the mainland between Shoebury and Havengore Creek. The majority are small, serving one or two properties and providing treatment via septic tanks or package plants. The three that discharge to soakaway should be of no impact on the shellfisheries, assuming they are functioning correctly. The remainder discharge to inland watercourses. These will make a minor contribution to the bacterial content of the ditches draining Foulness Island and the area to the west of Havengore Creek. Effluent from these small discharges, including the White City discharge, will mainly drain into the Roach/Crouch Estuary.

Agriculture

Outside of the urbanised area at Southend, most of the land within the catchment is used for arable farming, although there are some areas of pasture on Foulness Island. Agricultural census data from 2013 indicated that there are no farms which rear livestock within the catchment. However, the geographic assignment of animals counts is based on the allocation of a single point to each farm, whereas in reality an individual farm may span the catchment boundary. For small catchments such as this one the census results may not therefore accurately reflect the numbers of livestock generally present within the area. During the shoreline survey, 100 sheep were observed on the main area of pasture just to the east of Shelford Creek, a branch of the Roach Estuary with no direct connection to Maplin Sands. No livestock were observed in the immediate vicinity of the shore. As well as direct deposition by grazing livestock onto pastures, organic fertilizers (manures, slurries, sewage sludge) may be spread on arable farmland or pasture from time to time. No firm information on such practices within the survey area was available at the time of writing.

The primary mechanism for mobilisation of faecal matter deposited or spread on farmland to coastal waters is via land runoff. Fluxes of agricultural contamination into coastal waters will therefore be highly rainfall dependent, and the geographic pattern of impacts will largely mirror that of watercourses draining farmland. These are limited to a few minor watercourses, most of which are sluggish ditches draining land which is at about sea level. Their slow flowing nature and more lengthy retention times will promote bacterial die off. The majority of outfalls from these ditches are to the Roach/Crouch Estuary complex. It is therefore concluded that the impacts of agricultural runoff draining directly to Maplins Sands are likely to be minor.

As well as day to day variation in response to rainfall, there may be some seasonal variation in fluxes of agricultural contamination. Numbers of sheep will increase in the spring with the birth of lambs, and decrease in the autumn when animals are sent to market. The timing of applications of organic fertilizers to arable land will depend on its availability and crop cycles, and may potentially occur at any time throughout the year. Should a wet weather event follow a manure/slurry application there is the potential for localised contamination events.

Boats

There is heavy boat traffic in the Thames Estuary, encompassing a large variety of vessels. As well as a major shipping route to the various London ports, there is considerable traffic of smaller private vessels, including pleasure craft (yachts and cabin cruisers) and fishing boats. However, vessel access to the area requiring continued classification is heavily restricted due to the presence of a military firing range. When the range is active, during the daytime on weekdays, most vessels are not allowed within either the inner or outer danger areas. When the range is not active, all traffic is permitted within the outer danger area, but only vessels navigating to either Shoebury East Beach or Havengore Creek are permitted to pass through the inner danger area. Some specific vessels (such as the cockle dredgers) have been granted permission to enter the range when it is active, by arrangement with QinetiQ and often subject to certain restrictions depending on range operations.

Merchant shipping will remain in the subtidal channels and will not enter the danger areas. They are not allowed to make overboard discharges within 5.5 km of land, so should not make discharges near the edge of the western end of Maplin Sands at Shoebury, but may do so in close proximity to the edge of the danger area at the eastern end. There are several fishing ports in the area, including Burnham-on-Crouch (5 vessels), Leigh-on-Sea (27 vessels) and Southend (8 vessels). These will operate throughout the outer Thames Estuary, and some will have permission to operate within the danger area when the range is active.

The outer Thames Estuary and the Crouch/Roach Estuary are used heavily by recreational vessels such as yachts and cabin cruisers. There are six marinas in the Roach/Crouch Estuary, and one on the eastern tip of Canvey Island, but none provides sewage pump-out facilities. There are also numerous moorings for such vessels at Southend, Leigh-on-Sea, Benfleet Creek and throughout the Roach/Crouch Estuary. There will therefore be significant yacht traffic through the Crouch Estuary approach channel, and around the perimeter of the danger area. A small proportion of traffic in and out of the Roach/Crouch Estuary will use Havengore Creek, and so will navigate directly across Maplin Sands. Unlike fishing vessels and shipping, there will be seasonality in volumes of pleasure traffic, which will peak during the summer holiday season.

It is therefore concluded that whilst there is heavy boat traffic around the edges of the danger area, relatively few vessels will actually navigate over Maplin Sands. The majority of boat traffic to and from the Roach/Crouch Estuary will be via the main Crouch channel, although there will be some limited traffic through Havengore Creek. RMPs located on the outer edge of the intertidal area, particularly adjacent to the Crouch channel may best capture any impacts from boats. An increase in yacht traffic is anticipated during the summer months. 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.

Wildlife

The survey area is a large expanse of productive intertidal flats, which support large invertebrate populations and extensive eel grass beds. The area is relatively undisturbed due to the military presence, and supports important wildlife populations some of which may be a significant influence on shellfish hygiene. The main wildlife population of relevance, due to their large numbers, is overwintering waterbirds (wildfowl and waders). Foulness and Maplin Sands have been known to support about 100,000 overwintering waterbirds including about 40,000 Knots, 12,000 Oystercatchers and 13,000 Dark-bellied Brent Geese. Some species, such as waders forage upon intertidal invertebrates and so will forage (and defecate) directly on the shellfish beds across a wide area. Other species such as geese are grazers and will forage on eel grass beds in the upper intertidal, as well as coastal grasslands. Again, their impacts may be considered diffuse. More concentrated impacts may arise at roost sites, the favoured areas being the shell banks at Foulness Point, the area around the mouth of Havengore Creek, and various locations on Foulness Island.

Small numbers of waterbirds will remain in the area in the summer, but the majority migrate elsewhere to breed. There are also resident and breeding populations of seabirds (gulls terns etc) in the area. A survey undertaken in the early summer of 2000 recorded only three pairs of terns at Foulness Point, and 265 pairs of gulls and terns on a small artificial island just to the east of Shoebury Boom. Whilst these will forage widely, there may be more acute impacts in the immediate vicinity of the artificial island. However, these seabird populations are very small relative to the overwintering waterbird population.

There is a growing population of seals within the Thames Estuary. A recent estimate of numbers was 630 harbour seals, with a slightly smaller population of grey seals, the numbers of which could not be estimated accurately due to the timing of the surveys. They will range widely whilst foraging, so their impacts may be considered diffuse outside of their haulout sites, where they will rest in small aggregations. There are three regular haulout sites on Maplin Sands, two of which lie on the edge of the intertidal area off Havengore, and one of which lies just south of the Broomway, about 2.5 km east of Havengore. Whilst seals are present all year, they tend to spend more time hauled out during the moulting season (August). These haulout sites lie on areas fished for cockles, so RMPs located at these sites would best capture any contamination originating from these animals. No other wildlife species which may influence the sampling plan have been identified.

Domestic animals

Dog walking takes place on beaches and paths adjacent to the shoreline of the survey area and could represent a potential source of diffuse contamination to the near shore zone. It will be largely restricted to the area west of Shoebury due to the presence of the firing range. As a diffuse source, it 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												
Seals												
Boats												

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

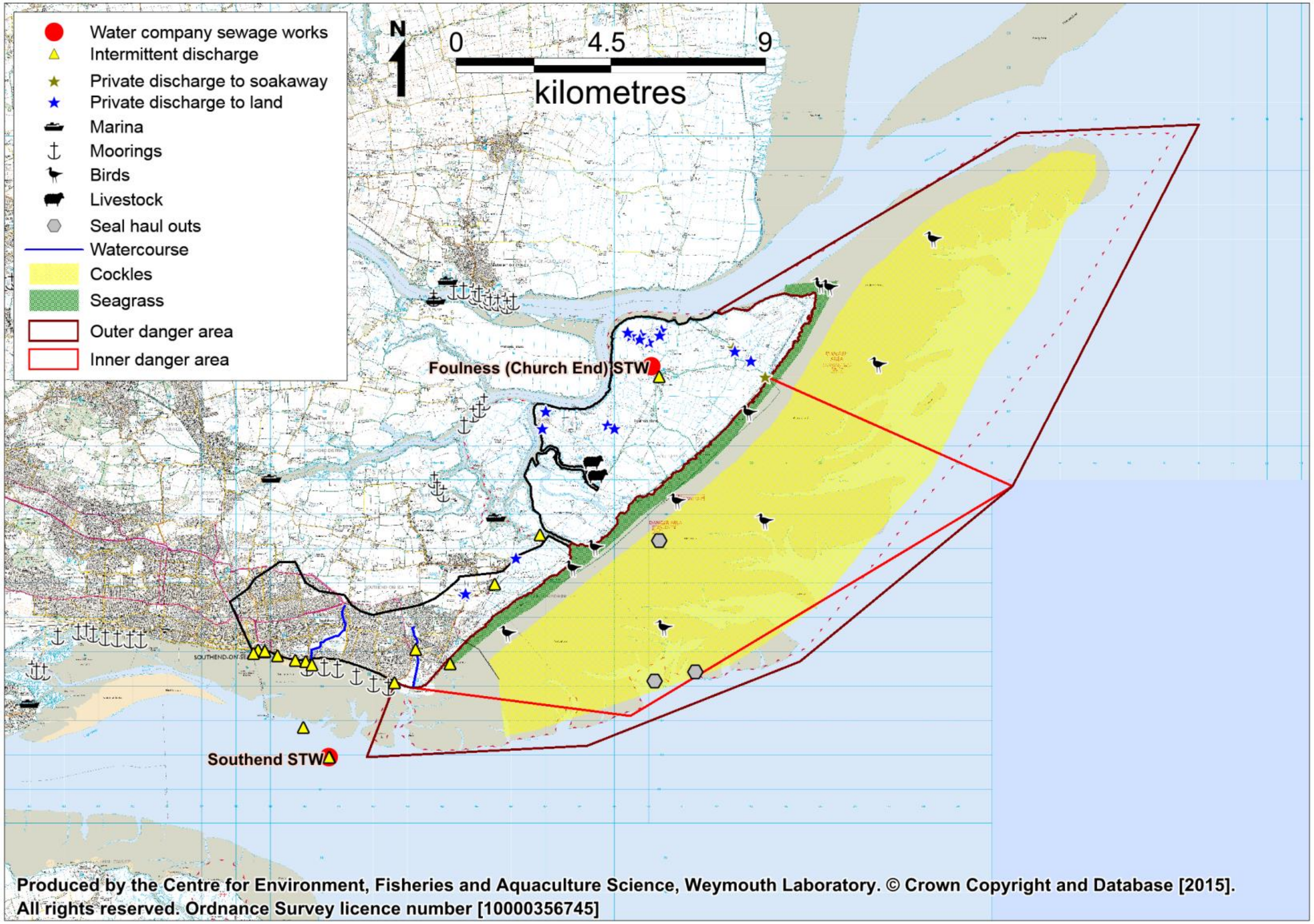


Figure 5.1: Summary of main contaminating influences

5.4. Hydrography

Maplin Sands is a large intertidal area, about 5 km in width, which is located on the north shore of the outer Thames Estuary where it opens out into the North Sea. The substrate is mainly sand, with some mud, shell and gravel. It slopes very gently between the high water mark and the edge of the intertidal area, after which there is a steeper drop-off to a depth of up to 14 m relative to chart datum in places. A subtidal channel leading into the Crouch Estuary of up to about 8 m in depth relative to chart datum lies to the north. There is an intertidal connection between the Roach Estuary and Maplin Sands via Havengore Creek. This connection is only made through the upper half of the tidal cycle.

The tidal range at the nearest tidal station (Southend) is large, at 5.26 m on spring tides and 2.90 m on neap tides, and this dominates patterns of water circulation. Tidal streams are bi-directional, moving up the Thames and Crouch Estuaries on the flood, and draining back down on the ebb. These two streams split/meet at the north eastern tip of Foulness Sands. As the tide floods, water will spread across the intertidal areas from the subtidal channels towards the high water mark. As the water deepens across the intertidal area, flows are likely to align more with offshore streams which run parallel to the coast. Tidal diamonds suggest that tidal excursions offshore from Maplin Sands are in the order of 15 to 17 km on spring tides and 9 to 11 km on neap tides. Tidal streams will be retarded across intertidal areas due to the effects of friction.

The Southend STW outfall is located in the subtidal area to the south of the Southend Flats in about 12 m of water. The plume from this outfall will be carried in an easterly direction on the ebb tide, but will generally remain in the subtidal area to the south of Maplin Sands. Its greatest impacts on shellfish hygiene within the survey area are therefore likely to arise at the south west corner of the area requiring classification. The ebb plume from the Crouch Estuary will be carried in an easterly direction during the ebb, and again it will generally remain in the subtidal channel, but some impacts are likely to be felt along the northern edge of the intertidal area considered in this survey. The ebb plume from the Havengore Creek will only be emitted during the first half of the ebb tide, and will be carried in an easterly direction.

Superimposed on tidal streams are the effects of freshwater inputs and winds, both of which can potentially cause significant modifications to water circulation patterns. As the survey area is an open coastal location, with no significant freshwater inputs directly to it, salinity related density effects are unlikely to have any effect on water circulation. Salinity measurements taken at various locations between Southend Pier and the western end of Maplin Sands show high average salinity (>30 ppt) throughout, with a slight underlying gradient of increasing salinity from west to east. This confirms that density effects are unlikely to be significant, and also suggests that an RMP at the western end of Maplin Sands may best capture contamination originating from land runoff from the wider Thames catchment. A density effect of potential relevance is that plumes from subtidal sewage outfalls such as the Southend STW, being less saline and often warmer than the receiving water, tend to float to the surface. This will limit its impacts on benthic shellfish stocks in the vicinity of the outfall, but will render its plume susceptible to advection by wind driven currents.

Strong winds will modify surface currents. Maplin Sands is most exposed to winds from the east and south. Winds typically drive surface water currents, which in turn create return currents which may flow at depth or along sheltered margins. 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. Winds with a southerly element will push surface water from offshore towards the foreshore, which will convey the plume from the Southend STW outfall over the shellfish beds when the tide is ebbing. Winds from the north may push contamination from the Crouch Estuary ebb plume onto the cockle beds. Onshore winds will also create wave action. This may resuspend any contamination held within the sediments of the intertidal zone, temporarily increasing levels of contamination within the water column until it is carried away by the tides. It is therefore concluded that shellfish beds at the western end of Maplin Sands may be subject to higher levels of contamination during southerly and south easterly winds, and during northerly winds at the eastern end, although targeting such conditions in the sampling plan is unlikely to be practical.

5.5. Summary of Existing Microbiological Data

The survey has been subject to considerable microbiological monitoring over recent years, deriving from 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.

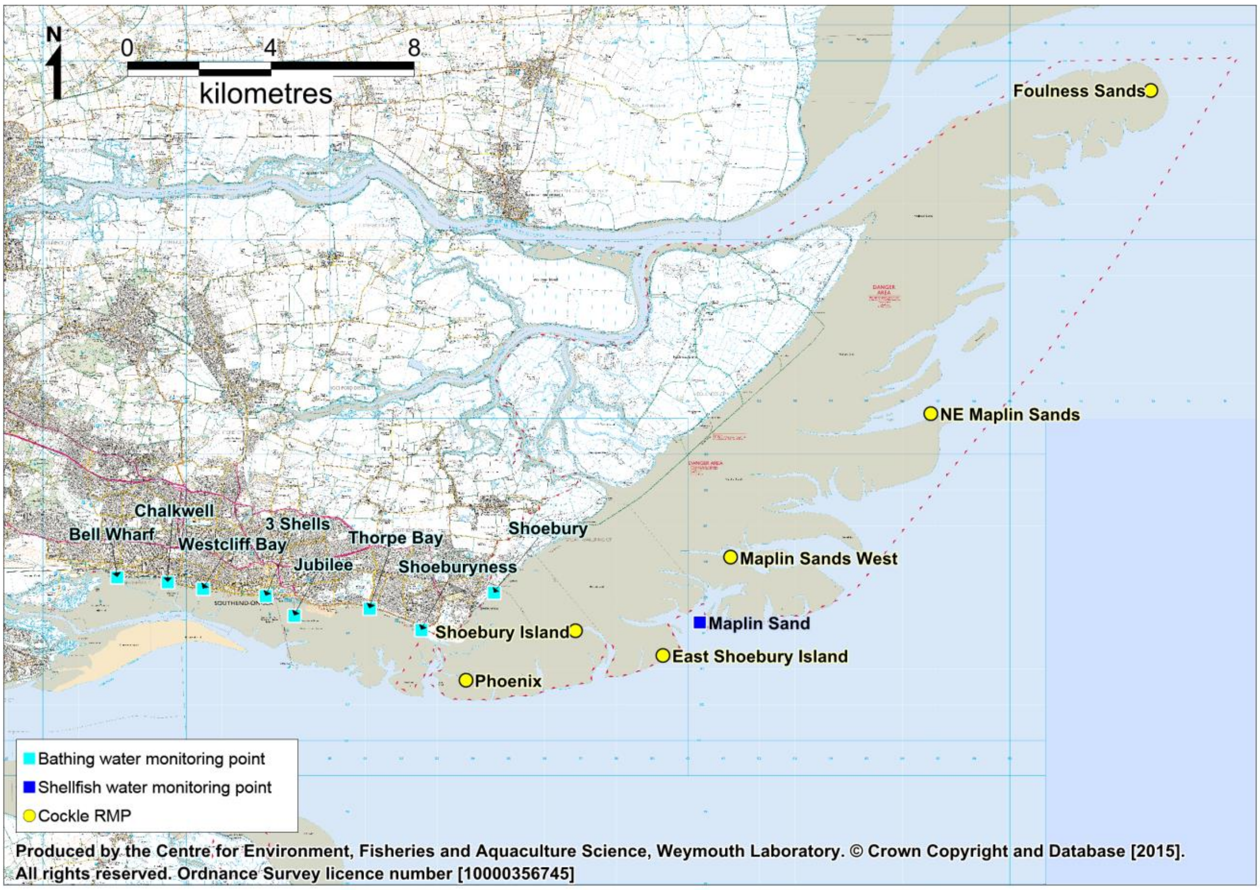


Figure 5.2: Microbiological sampling sites

Bathing waters

There are a series of eight bathing water monitoring points along the Southend foreshore, between Leigh-on-Sea and Shoebury. Around 20 water samples were taken from each point every bathing season (May-September) and enumerated for faecal indicator bacteria. Due to a change in analysis method from faecal coliforms to *E. coli* in 2011, results from 2012-2014 only were considered in this report.

The geometric mean result ranged from 13.8 *E. coli* cfu/100 ml at Shoebury to 40.1 *E. coli* cfu/100 ml at Bell Wharf. Results exceeding 1,000 *E. coli* cfu/100 ml were only recorded at Bell Wharf and Jubilee. Statistically significant differences in mean result were found. Bell Wharf had significantly higher *E. coli* concentrations than Thorpe Bay, Shoeburyness and Shoebury, and Jubilee had significantly higher *E. coli* concentrations than Shoebury. The overall geographic pattern was one of decreasing levels of contamination from west to east, with a localised elevation in the vicinity of Jubilee. Comparisons of paired (same day) samples showed statistically significant correlations between all site pairings, suggesting that they all share similar sources of contamination.

E. coli levels have remained fairly constant on average through the three year period considered. It was not possible to investigate seasonality, as all samples were taken during the bathing season. Statistically significant correlations between *E. coli* results and the high/low tidal cycle were detected at Chalkwell and Jubilee. Highest *E. coli* concentrations tended to arise around high water, although the reasons for this are unclear. A statistically significant influence of the spring/neap tidal cycle was found at Westcliff Bay, but no obvious pattern was apparent when the data was plotted. Significant positive correlations between *E. coli* results and antecedent rainfall were detected at all bathing water monitoring points. The influence peaked 2-3 days after a rainfall event, and was slightly stronger at Chalkwell, 3 Shells and Jubilee than the other sites. Significant negative correlations between *E. coli* concentrations and salinity were found at Chalkwell and 3 Shells. This, together with the rainfall correlations, suggests that there is some influence of land runoff along the Southend Seafront, but it becomes slightly weaker towards the eastern end.

Shellfish waters

Under the shellfish waters monitoring programme there is one relevant monitoring point (Maplin Sand) which has been sampled for faecal coliforms in water on a quarterly basis. Results from 2004 onwards are considered in the following analyses. The geometric mean result was 2.7 faecal coliforms/100 ml. This suggests that levels of contamination were lower than at the bathing waters sites, although the two datasets are not directly comparable. No trends of increasing or decreasing levels of contamination were apparent throughout the period considered. The seasonal variation in faecal coliform concentration was statistically significant, and results were significantly higher in the winter than in the summer. No significant influence of tide across either the high/low or spring/neap tidal cycle was detected. A significant correlation between faecal coliform results and antecedent rainfall was found, but the effect did not persist for more than one day following a rainfall event. There was no correlation between salinity and faecal coliform levels, so it is concluded that the influence of land runoff is minor at this monitoring point.

Shellfish hygiene

There are a total of six cockle RMPs of relevance to the survey area that have been sampled since 2005. One of these (East Shoebury Island) was only sampled on one occasion and so could not be included in the analyses. The other five were sampled on a more or less monthly basis from 2005 to present. None of these RMPs recorded any result exceeding 4,600 *E. coli* MPN, and the geometric mean result ranged from 38.4 *E. coli* MPN/100g at NE Maplin Sands to 176.1 *E. coli* MPN/100g at Phoenix. Phoenix had significantly higher *E. coli* levels than all other sites, and Shoebury Island had significantly higher *E. coli* levels than NE Maplin Sands and Foulness Sands. It is therefore concluded that across these RMPs there is a gradient of increasing levels of contamination from east to west. Comparisons of paired (same day) samples showed statistically significant correlations between all site pairings, suggesting that they all share similar sources of contamination.

Since 2005, there has been a trend of increasing *E. coli* levels in cockles. This was most marked at Phoenix where *E. coli* levels rose considerably on average between 2005 and 2011. All five RMPs showed statistically significant seasonality, with highest average results arising during the winter in each case. Significant correlations between tidal state on the high/low tidal cycle and *E. coli* results were found at Phoenix and Foulness Sands. However, sampling was strongly targeted to the latter part of the flood tide in both cases, and no patterns in results were apparent when the data was plotted. Significant correlations between tidal state on the spring/neap tidal cycle and *E. coli* results were found at Shoebury Island and Maplin Sands West. Sampling was targeted towards larger tides. The few samples that were taken during the smaller tides tended to have lower *E. coli* results, and higher *E. coli* results tended to occur during the larger tides. This suggests that the main contamination sources may be remote from these RMPs. Rainfall had no effect on *E. coli* levels in cockles at any RMP except for Maplin Sands West, where an influence was detected 2-3 days after a rainfall event. This suggests that there may be a local source of runoff, possibly the ebb plume from Havengore Creek.

Bacteriological survey

Due to the extensive monitoring history, and the costs and logistical difficulties in obtaining dredged cockle samples within an active firing range, no bacteriological survey was undertaken.

Appendices

Appendix I. Human Population

Figure I.1 shows population densities in census output areas within or partially within the survey catchment area, derived from data collected from the 2011 census.

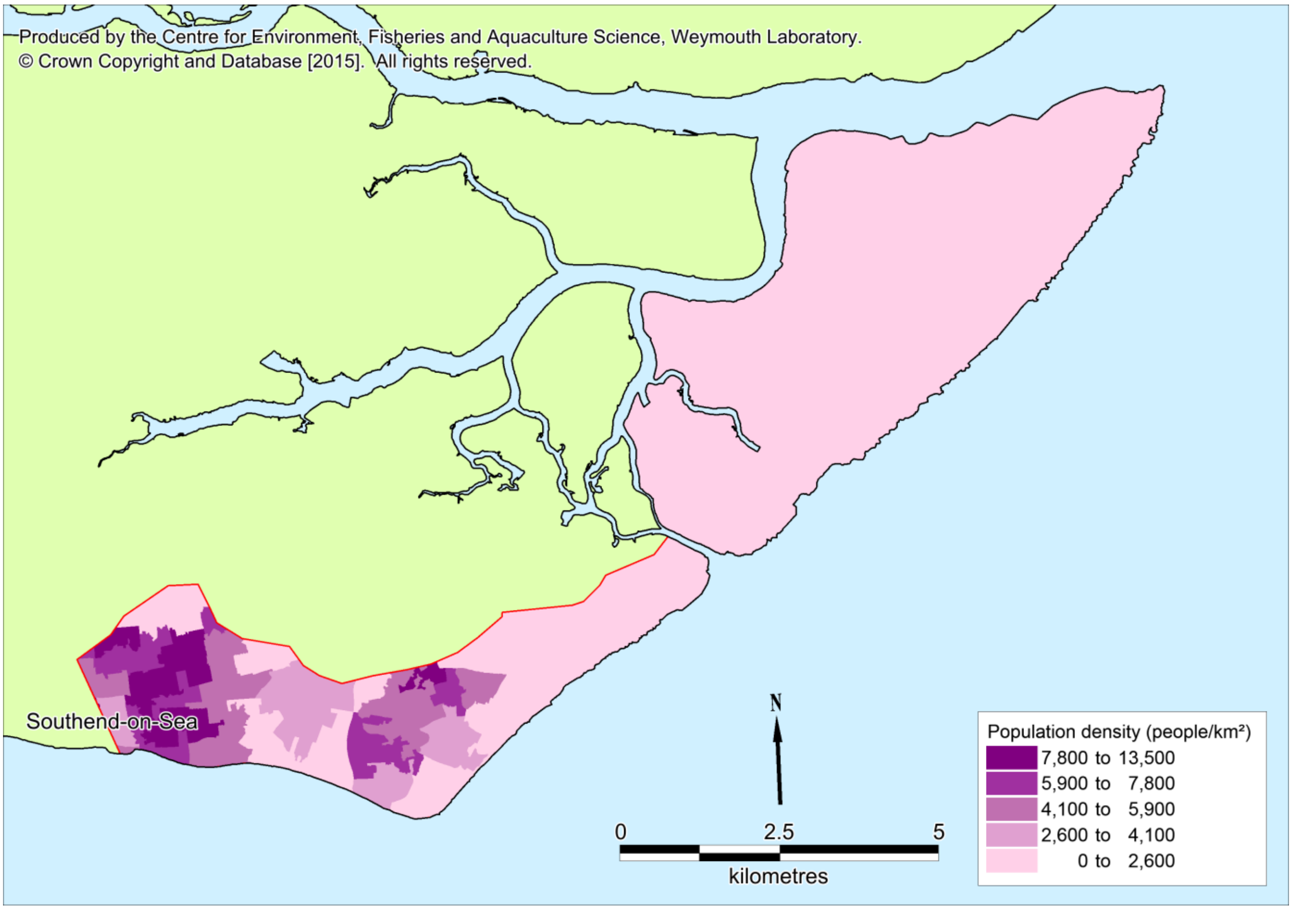


Figure I.1: Human population density in census areas in the survey catchment.

Total resident population within census areas contained within or partially within the catchment area was approximately 81,400 at the time of the last census. The population is concentrated within the town of Southend-on-Sea, the eastern half of which falls in the survey catchment. The eastern end of the catchment is mostly Ministry of Defence property and is sparsely populated. Southend-on-Sea is a popular resort which had approximately 320,300 staying visitors and 6.1 million day visitors in 2004 (Matson, 2006). Information provided by Anglian Water during the permitting process indicates Southend STW serves a resident population of 158,705, with an additional seasonal 'holiday' population of 13,898, representing an increase of 9% in the peak holiday population. The area to the east, including Foulness Island is mostly closed to the public, so is unlikely to experience any influxes of tourists.

Appendix II. Sources and Variation of Microbiological Pollution: Sewage Discharges

Details of all consented sewage discharges within the outer Thames estuary hydrological catchment were taken from the most recent update of the Environment Agency national permit database (October 2014). These are mapped in Figure II.1. There are 2 continuous water company discharges within the survey area, details of which are presented in Table II.1.

Table II.1: Details of continuous water company sewage works to the outer Thames estuary catchment

Name	NGR	Treatment	DWF (m^3/day)	Estimated bacterial loading (cfu/day)*	Receiving environment
Foulness (Church End) STW	TR0010093300	Biological filtration	14**	4.62×10^{10}	Tributary of Roach (Non tidal)
Southend STW	TQ9070081920	Activated Sludge	68,274	2.25×10^{14}	Thames Estuary

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*Faecal coliforms (cfu/day) based on geometric base flow averages from a range of UK STWs providing secondary treatment (Table II.2) unless indicated otherwise

**based on a population equivalent of 89, and assuming water use of 160 l/head/day

Table II.2: Summary of reference faecal coliform levels (cfu/100 ml) 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	7.2×10^6
Primary (12)	127	1.0×10^7	14	4.6×10^6
Secondary (67)	864	3.3×10^5	184	5.0×10^5
Tertiary (UV) (8)	108	2.8×10^2	6	3.6×10^2

Data from Kay et al. (2008b).

n - number of samples.

Figures in brackets indicate the number of STWs sampled.

Southend STW is the largest water company continuous discharge, and as it only provides secondary treatment the bacterial loading it generates is very large. Its' outfall is located about 2.8 km offshore, in 12 m of water, about 5 km to the west of the area considered in this survey so there is considerable potential for dilution and dispersion of the plume before it reaches Maplin Sands on the ebbing tide. There is one other water company continuous discharge, Foulness (Church End) STW, located inland on Foulness Island. This biologically (secondary) treated discharge has a population equivalent of 89, which corresponds to a dry weather flow of about 14 m^3/day and a daily bacterial loading of 4.62×10^{10} cfu/day. This discharge is to a ditch which drains to the Roach Estuary so its impacts on Maplin Sands will be negligible. Upstream discharges to the Thames estuary may also be an influence at Maplin Sands, as will discharges to the Roach and Crouch Estuaries, but will not be discussed further here (see Cefas, 2012(a) and Cefas, 2012 (b)).

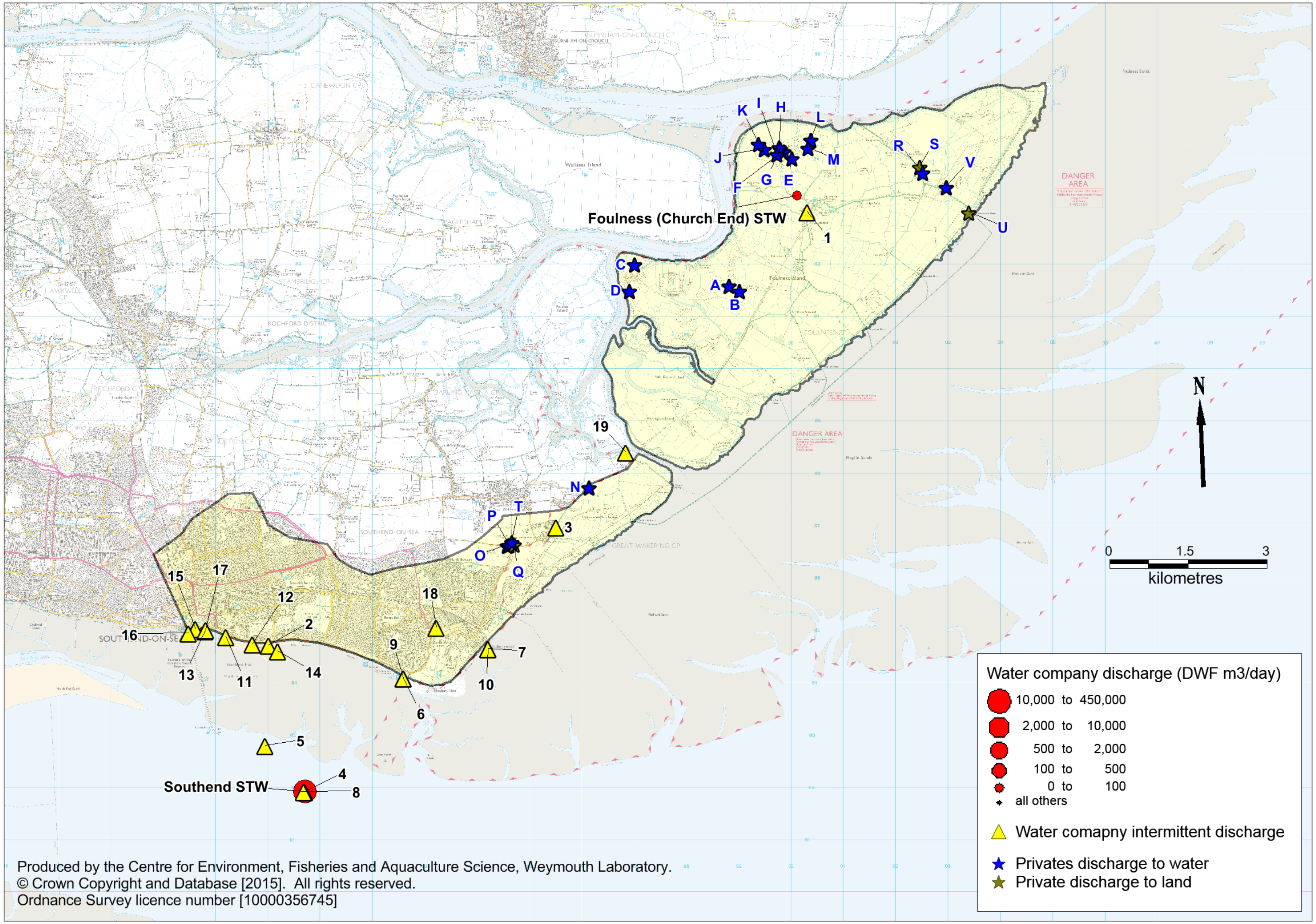

Figure II.1: Water company continuous and intermittent permitted sewage discharges to the outer Thames estuary catchment
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In addition to the continuous sewage discharges, there are 19 intermittent water company discharges associated with the sewerage networks in this catchment, details of which are shown in Table II.3.

Table II.3: Intermittent discharges to the outer Thames estuary catchment

No.	Name	Grid reference	Receiving water	Discharge type
1	Church End-Foulness PS	TR0030093000	Tributary River Roach	Pumping Station
2	Elizabeth Road Outfall	TQ9001084720	Thames Estuary	STW Storm Overflow/ Storm Tank
3	Seaview Estate PS	TQ9550086970	Tributary River Thames	Emergency Discharge And STW Storm Overflow/ Storm Tank
4	Southend Sewage Works	TQ9070081920	Thames Estuary	STW Storm Overflow/ Storm Tank
5	Southend Sewage Works	TQ8994082800	Thames Estuary	STW Storm Overflow/ Storm Tank
6	Southend Storm Overflows	TQ9259084090	Thames Estuary	Pumping Station
7	Southend Storm Overflows	TQ9420084650	Thames Estuary	Pumping Station
8	Southend Storm Overflows	TQ9068081920	Thames Estuary	Sewer Storm Overflow
9	Southend Storm Overflows	TQ9259084090	Thames Estuary	Sewer Storm Overflow
10	Southend Storm Overflows	TQ9420084650	Thames Estuary	Sewer Storm Overflow
11	Southend Storm Overflows	TQ8919084880	Thames Estuary	Sewer Storm Overflow
12	Southend Storm Overflows	TQ8970084740	Thames Estuary	Sewer Storm Overflow
13	Southend Storm Overflows	TQ8880084990	Thames Estuary	Sewer Storm Overflow
14	Southend Storm Overflows	TQ9018084610	Thames Estuary	Sewer Storm Overflow
15	Southend Storm Overflows	TQ8861085040	Thames Estuary	Sewer Storm Overflow
16	Southend Storm Overflows	TQ8848084950	Thames Estuary	Sewer Storm Overflow
17	Southend Storm Overflows	TQ8881085010	Thames Estuary	Sewer Storm Overflow
18	Towerfields Est. SPS	TQ9320785059	Tributary River Thames	Pumping Station
19	Wakering Common TPS Via Havengore	TQ9683088400	Havengore Creek	Pumping Station

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No spill records were available for any of these intermittent discharges and as such it is difficult to assess their significance, aside from noting their locations, and their potential to spill untreated sewage. Spills will mainly be associated with wet weather events, particularly within the sewerage networks which collect large amounts of surface water. Occasionally spills may be associated with mechanical failures or blockages which may occur at any time. The majority of intermittent discharges are associated with the Southend STW, and are located to the west of Shoebury Boom. The Southend sewer network is an older combined system (Scott Wilson, 2009) and is reported to be working at full capacity. It is therefore likely that regular overflow spills are a feature of this network. There are several other intermittent discharges in the catchment. One is located on Foulness Island, Church End - Foulness PS, and discharges to a tributary of the River Roach so will not impact directly. Discharge 19, Wakering Common TPS, is located just outside of the catchment and discharges to Havengore Creek. This could potentially impact in the middle reaches of the shellfishery area when it is in operation, depending on tidal circulation patterns. Two further intermittent discharges, 3 and 18, discharge <1 km inland to short watercourses so may be of potential impact when in operation. Without spill event information it is difficult to accommodate the potential impacts of these in the sampling plan, although they may from time to time generate highly significant bacterial loadings.

Although the majority of properties within the survey area are served by water company sewerage infrastructure, there are also 22 permitted private discharges. Table II.4 presents details of these.

Table II.4: Details of private sewage discharges to the outer Thames estuary catchment

Ref.	Name	Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
A	AWE Foulness	TQ9880091600	Unspecified	1	Tributary Roach Estuary
B	AWE Foulness	TQ9900091500	Unspecified	1	Tributary Roach Estuary
C	AWE Foulness STW	TQ9700092000	Unspecified	4	Tributary Roach Estuary
D	AWE Foulness STW	TQ9690091500	Unspecified	4	Tributary Roach Estuary
E	Building 19	TR0000094030	Unspecified	5	Tributary Crouch Estuary
F	Building 34a	TQ9985094160	Unspecified	0.3	Tributary River Crouch
G	Building 36	TQ9979094210	Unspecified	0.7	Tributary River Crouch
H	Building 38	TQ9976094240	Unspecified	1.2	Tributary River Crouch
I	Building 40	TQ9972094110	Unspecified	0.7	Tributary River Crouch
J	Building 48	TQ9948094210	Unspecified	0.3	Tributary River Crouch
K	Building 54	TQ9937094300	Unspecified	0.75	Tributary River Crouch
L	Building 68a	TR0037094380	Unspecified	1.8	Tributary River Crouch
M	Building 70a	TR0031094230	Unspecified	1.8	Tributary River Crouch
N	Hickman Building, Building V46	TQ9613087740	Package Treatment Plant	1.7	Tributary Havengore Creek
O	Jasmine	TQ9457086630	Unspecified	1	Tributary Thames Estuary
P	Ladylands	TQ9460086640	Unspecified	1	Tributary Thames Estuary
Q	Lansdowne House	TQ9469986657	Package Treatment Plant	2	Soakaway
R	Signal Cottage	TR0250093750	Unspecified	1	Tributary River Crouch
S	STW05 Mod Shoeburyness	TR0245093860	Unspecified	3.6	Soakaway
T	The Yard	TQ9465086700	Unspecified	3	Non-Tidal Tributary North Sea
U	Vehicle Wash Shoeburyness	TR0338092997	Reedbed	3	Soakaway
V	White City	TR0296093480	Unspecified	15	Tributary The River Crouch

The majority of private discharges are small, serving one or two properties. Where specified, these are generally treated by small septic tanks or package plants. The three that discharge to soakaway should be of no impact on the shellfisheries, assuming they are functioning correctly. Of the 19 discharging to water, the majority discharge to tributaries of the Rivers Crouch or Roach so their impacts will contribute to the loading reaching the outer Thames estuary from those rivers. Only one of these discharges (V) has a maximum consented flow of >5 m^3/day. This discharge is located approximately 0.75 km inland from the east coast of Foulness Island, and discharges to a tributary of the River Crouch. For all private discharges, a degree of bacterial die off will take place during transit given the distances from discharge to where receiving watercourses reach the shellfisheries.

Appendix III. Sources and Variation of Microbiological Pollution: Agriculture

To the east of Southend, most land within the catchment considered in this report is used for arable farming, although there are some smaller areas of pasture, all of which lie on Foulness Island (Figure 1.2). The main area of pasture lies immediately to the east of Shelford Creek, with other small pockets towards the eastern tip of the island. Agricultural census data from 2013 indicated that there are no farms which rear livestock within the hydrological catchment (Defra, pers. comm.). However, 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. For small catchments such as this one the census results may not therefore accurately reflect the numbers of livestock generally present within the area.

During the shoreline survey, 100 sheep were observed on the main area of pasture just to the east of Shelford Creek, a branch of the Roach Estuary with no direct connection to Maplin Sands. The survey mainly focussed on the shoreline, so not all parts of the catchment were visited. No livestock were observed in the immediate vicinity of the shore. As well as regular direct deposition by livestock onto pastures, organic fertilizers (manures, slurries, sewage sludge) may be spread on arable farmland or pasture from time to time. No firm information on such practices within the survey area was available at the time of writing.

The primary mechanism for mobilisation of faecal matter deposited or spread on farmland to coastal waters is via land runoff, so fluxes of agricultural contamination into the outer Thames estuary will be highly rainfall dependent. Their geographic pattern of impacts will be largely dependent on the location, size and nature of watercourses draining farmland within the area. These are limited to a few minor watercourses, most of which are sluggish ditches draining land which is at about sea level. Their slow flowing nature and more lengthy retention times will promote bacterial die off.

As well as significant day to day variation in response to rainfall, there may be some seasonal variation in fluxes of agricultural contamination. Numbers of sheep will increase in the spring with the birth of lambs, and decrease in the autumn when animals are sent to market. The timing of applications of organic fertilizers to arable land will depend on its availability and crop cycles, and may potentially occur at any time throughout the year. Should a wet weather event follow a manure/slurry application there is the potential for significant but localised contamination events. Discharge rates from the sluggish watercourses draining the area will be much lower in the summer, likely resulting in higher potential for bacterial die-off within these drains.

Appendix IV. Sources and Variation of Microbiological Pollution: Boats

The discharge of sewage from boats is potentially a significant source of bacterial contamination of shellfisheries within the outer Thames estuary. As well as a major shipping route to the various London ports, there is considerable traffic of smaller private vessels, including pleasure craft (yachts and cabin cruisers) and fishing boats. However, vessel access to the Maplin Sands area is heavily restricted due to the presence of a military firing range. Figure IV.1 presents an overview of boating activity derived from the shoreline survey, satellite images and various internet sources.

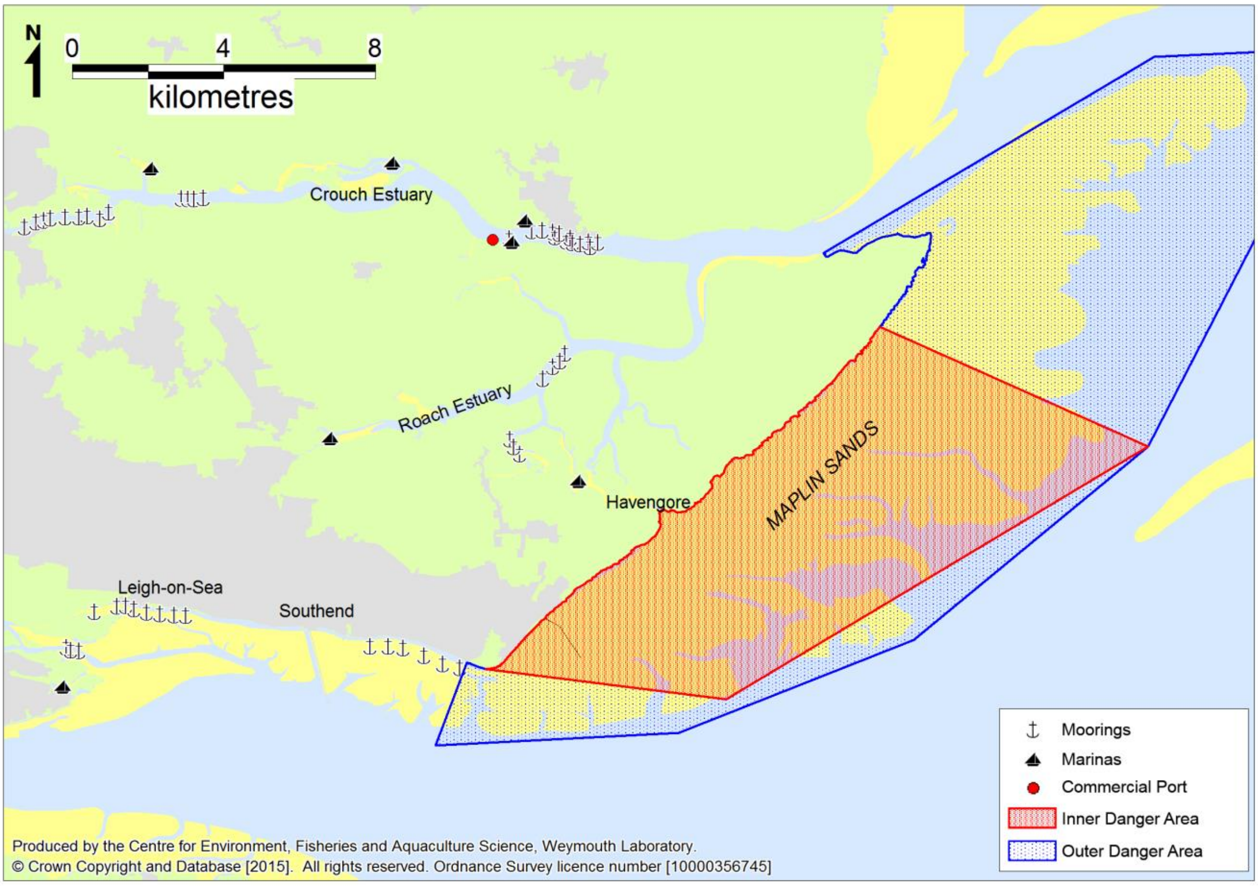

Figure IV.1: Overview of boating activity in the area

When the range is active, usually during the daytime on weekdays, most vessels are not allowed within either the inner or outer danger areas. When the range is not active, all traffic is permitted within the outer danger area, but only vessels navigating to either Shoebury East Beach or Havengore Creek are permitted to pass through the inner danger area. Passage through Havengore Creek to and from the Roach estuary is not permitted when the range is active and at night, and is only possible up to half an hour before and after high tide. Some specific vessels (such as the cockle dredgers) have been granted permission to enter the range when it is active, by arrangement with QinetiQ and possibly subject to certain restrictions depending on range operations.

The outer Thames estuary is a busy shipping lane, although these large vessels will remain in the subtidal channels and not enter the danger area. Merchant ships are not permitted to make overboard discharges within 3 nautical miles (or 5.5 km) of land[1] so should not make discharges near the edge of the western end of Maplin Sands at Shoebury, but may do so in close proximity to the edge of the danger area at the eastern end.

Local fishing ports include Burnham-on-Crouch (1 over 10 m and 4 under 10 m boats registered), Leigh-on-Sea (19 over 10 m and 8 under 10 m boats) and Southend (8 under 10 m boats) (MMO, 2015). Vessels from several other ports are also likely to operate within the outer Thames estuary. Some will have permission to operate within the danger area when the range is active.

The outer Thames estuary and the Crouch/Roach estuary are used heavily by recreational vessels such as yachts and cabin cruisers. There are numerous moorings for such vessels at Southend, Leigh-on-Sea, Benfleet Creek and throughout the Roach/Crouch estuary. There are also six marinas in the Roach/Crouch estuary, and one on the eastern tip of Canvey Island, but none provides sewage pump-out facilities (Green Blue, 2010). There will therefore be significant yacht traffic through the Crouch estuary approach channel, and around the perimeter of the danger area. A small proportion of traffic in and out of the Roach/Crouch estuary will use Havengore Creek, and so will navigate directly across Maplin Sands. Unlike fishing vessels and shipping, there will be seasonality in volumes of pleasure traffic, which will peak during the summer holiday season. There is a regatta at Burnham in August.

There are no marinas, ports or mooring areas directly within the area requiring continued classification. Overboard discharges by vessels on passage are much less likely to be made within the danger area than outside of it. Therefore, RMPs located on the outer edge of Maplin Sands, and in particular by the Crouch approach channel may best capture contamination from boats. The entrance to Havengore Creek may also be at risk. An increase in yacht traffic is anticipated during the summer months. 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.

[1] The Merchant Shipping (Prevention of Pollution by Sewage and Garbage from Ships) Regulations 2008

Appendix V. Sources and Variation of Microbiological Pollution: Wildlife

Maplin Sands is a productive area of intertidal flats that supports large invertebrate populations as well as extensive eel grass beds, which are located towards the high water mark all along the shore. There are also shell banks around the north east tip of Foulness Island. These and other features support significant wildlife populations, and so the area is subject to several conservation designations. It forms part of the Essex Estuaries European Marine Site Special Area of Conservation (SAC) and Special Protected Area (SPA), as well as being a Site of Special Scientific Interest (SSSI) and a Ramsar Site. It is relatively un-disturbed due to the presence of the firing range.

The main wildlife population of relevance to shellfish hygiene is overwintering waterbirds (wildfowl and waders). Wetland Bird Survey counts are undertaken in the area, but they are reported together with other areas as part of the Thames Estuary. Over the five winters up until 2011/12 an average total count of 159,528 overwintering and waterbirds was recorded in the Thames estuary (Austin *et al*, 2014). Counts of 57,384 and 35,560 were reported by the same survey for the adjacent Dengie Flats and the Roach/Crouch estuary complex. Foulness and Maplin Sands have been known to support about 100,000 overwintering waterbirds (JNCC, 2001) including about 40,000 Knots (*Calidris canutus*), 12,000 Oystercatchers (*Haematopus ostralegus*) and 13,000 Dark-bellied Brent Geese (*Branta bernicla bernicla*). Some species, such as waders forage upon intertidal invertebrates and so will forage (and defecate) directly on the shellfish beds across a wide area. Other species such as geese are grazers and will forage on eel grass beds in the upper intertidal, as well as salt-marsh and coastal grasslands. Again, their impacts may be considered diffuse. More concentrated impacts may arise at roost sites, the favoured areas being the shell banks at Foulness Point, the area around the mouth of Havengore Creek, and various locations on Foulness Island (Rudge, 1970). Flocks of waders were regularly sighted during the shoreline survey.

Small numbers of waterbirds will remain in the area 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). Counts of only 3 pairs of terns were recorded at Foulness Point, and 265 pairs of gulls and terns were recorded on Maplin Bank, on a small artificial island just to the east of Shoebury Boom. These represent a diffuse source of contamination away from their nest sites, and the low numbers suggest that their impacts will be minor.

Considerable numbers of harbour seals (*Phoca vitulina*) are present within the outer Thames estuary, with an estimated population of 630 (Barker et al, 2014). There is also a slightly smaller population of grey seals (*Halichoerus grypus*). Population estimates were unavailable for this species but just over 200 animals were observed during surveys in 2013. They will range widely whilst foraging, so their impacts may be considered diffuse outside of their haulout sites, where they will rest in small aggregations. There are three regular haulout sites on Maplin Sands, two of which lie on the edge of the intertidal area off

Havengore, and one of which lies just south of the Broomway, about 2.5 km east of Havengore. Whilst seals are present all year, they tend to spend more time hauled out during the moulting season (August). These haulout sites lie on areas fished for cockles, so RMPs located at these sites would best capture any contamination originating from these animals. No other wildlife species which may influence the sampling plan have been identified.

Appendix VI. Meteorological Data: Rainfall

Due to its sheltered location relative to rain-bearing weather systems feeding in off the Atlantic, Southend is within one of the drier areas of the UK, typically receiving less than 650 mm of rain a year. The Atlantic Lows are more vigorous in autumn and winter and bring most of the rain that falls in these seasons. In summer, convection caused by solar surface heating sometimes forms shower clouds and a large proportion of rain falls from showers and thunderstorms at these times (Met Office, 2012). Figure VI.1 presents a boxplot of daily rainfall records by month at Southchurch Park, central Southend.

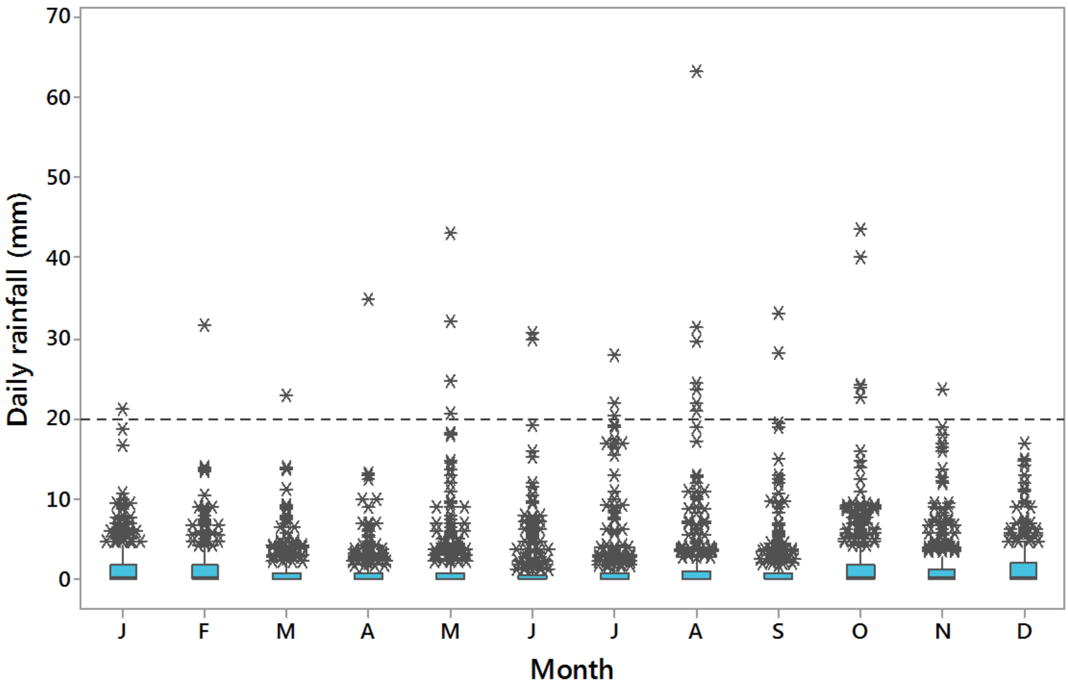

Figure VI.1: Boxplot of daily rainfall totals at Southchurch Park, January 2004 to November 2014.
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The Southchurch Park weather station received an average of 512 mm per year between January 2004 and November 2014. October had the highest average rainfall, while April had the lowest rainfall, although seasonal variation was not particularly strong. Daily totals of over 20 mm were recorded on 0.7% of days and no rainfall was recorded on 52% of days. High rainfall events, whilst relatively rare, tended to occur most during the summer and autumn, but events of over 20 mm were recorded in all months apart from December.

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

The strongest winds are associated with the passage of deep depressions and the frequency and strength of these is greatest in the winter (Met Office, 2012). As Atlantic depressions pass England and Wales, the wind typically comes from the west or northwest as the depression moves away. For this reason south east England is one of the less windy parts of England and Wales. A wind rose for Coltishall (Norfolk) shows that the prevailing wind direction is from the south-west and that the strongest winds nearly always blow from the range of directions west-southwest (Figure VII.1). The frequency of gales is relatively low.

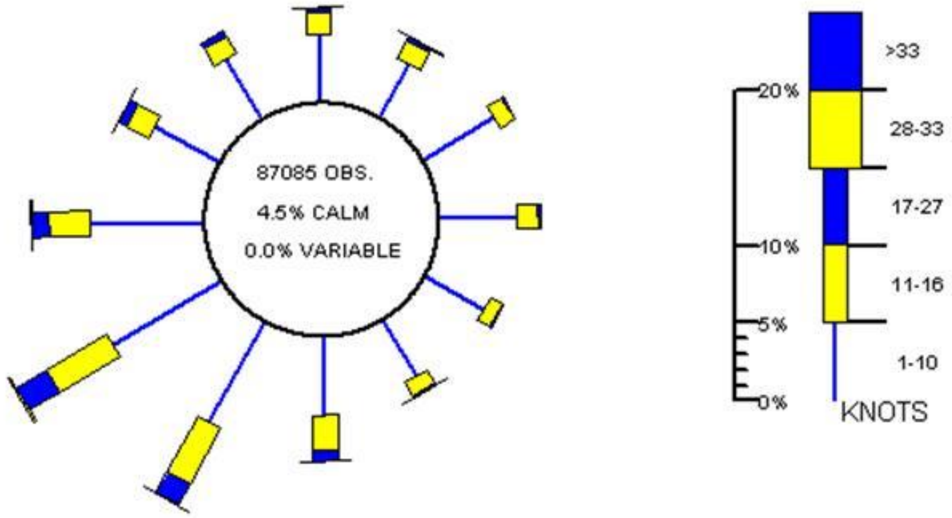

Figure VII.1: ***Wind rose for Coltishall, Norfolk.***
Produced by the Meteorological Office. Contains public sector information licensed under the Open Government Licence v1.0.

The east-west aspect of the outer Thames estuary means it is most exposed to winds from the east, although westerly winds will also align with the estuary. Therefore winds from these directions will probably have the greatest overall effect on water circulation patterns by creating surface water currents with or against the tide. Maplin Sands is most exposed to winds from a southerly and easterly direction, which may create significant wave action on the shore. Winds with a southerly element will also blow the plume from the Southend STW towards the shore. The potential impacts of wind on the circulation of water at Maplin Sands are discussed in more detail in Appendix IX.

Appendix VIII. Hydrometric Data: Freshwater Inputs

The hydrological catchment considered in details in this report only covers an area of about 47 km^2. It consists of a narrow coastal strip which is largely urbanised at its western end, and the more rural Foulness Island at its eastern end. The underlying geology is described as being of mixed permeability throughout (NERC, 2012). The catchment is low lying, with a maximum elevation of around 25 m at its western end. Foulness Island and the land immediately west of Havengore Creek is particularly flat, with elevations at about sea level throughout. These areas are fronted by earth banks to prevent tidal flooding. The locations of freshwater inputs are shown in Figure VIII.1.

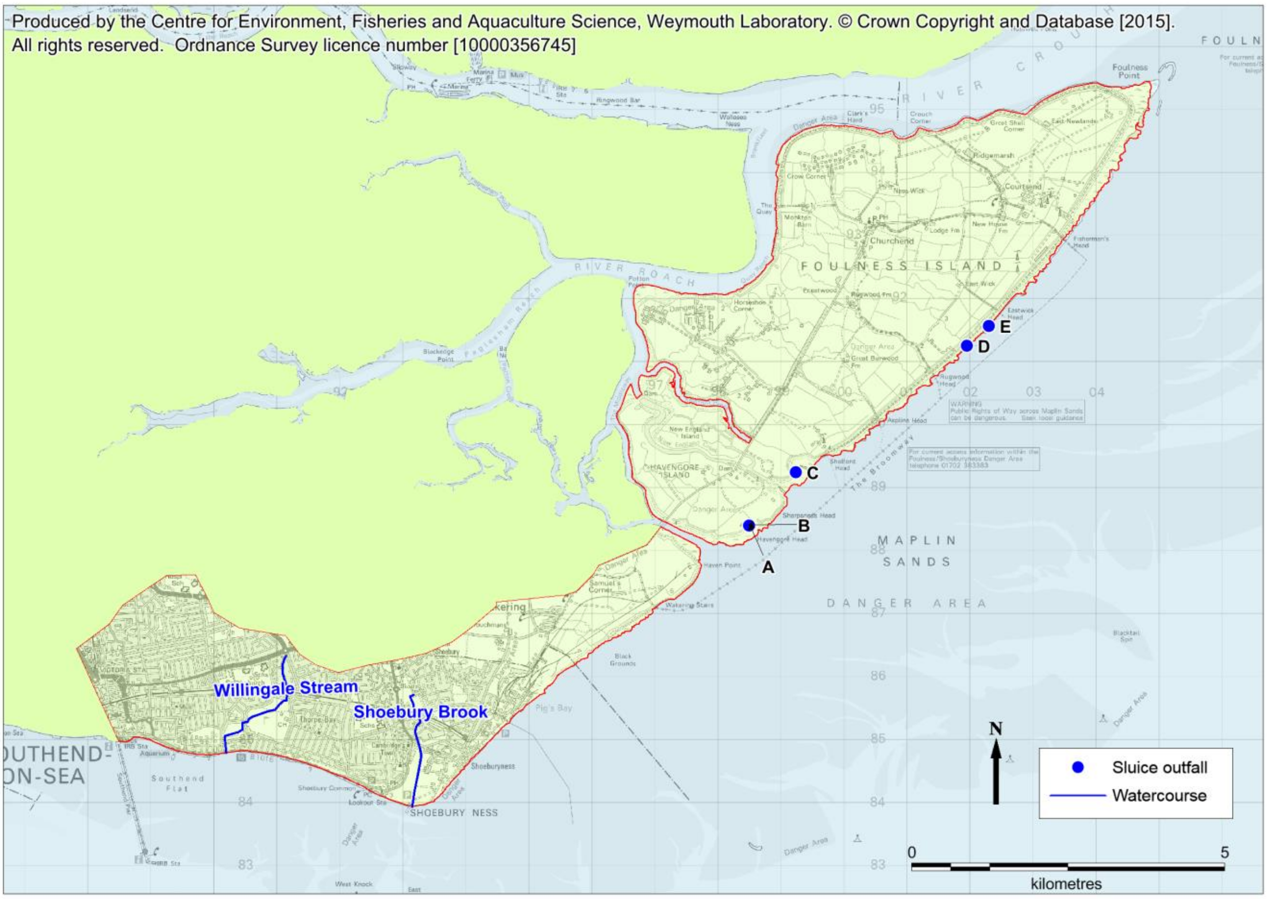

Figure VIII.1: Freshwater inputs to the Maplin Sands area

There are only two watercourses in the area (Willingale Stream and Shoebury Brook) both of which are located to the west of the Shoebury Boom. Both are small and unlikely to be of much significance, although there are no microbiological testing or flow gauging results available for either. Both are highly modified and culverted in places. The Willingale Stream discharges via a pumping station on the Southend Seafront and the Shoebury Brook discharges via a piped outfall at Shoeburyness. Aside from these there are a small number of sluice outfalls from Foulness Island, the locations of which were recorded during the shoreline survey.

Table VIII.1: Shoreline survey freshwater input observations

Observation no.	NGR	Description
A	TQ9850288396	Inlet sluice. Not flowing
B	TQ9848488402	Inlet sluice. Not flowing
C	TQ9922389251	Inlet sluice. Not flowing
D	TR0193791258	Sluice. (80 cm diameter). Not flowing
E	TR0229191571	Sluice Valved. Not flowing.

None of these were flowing at the time of survey. Samples taken from behind the sluices all contained 10 or <10 *E. coli* cfu/100 ml. The first three sluices seen are actually used to let seawater in to help maintain water levels in the ditches rather than to let freshwater out. Drainage maps provided by QinetiQ during the shoreline survey indicate that most outlet sluices on Foulness Island drain to the Roach and Crouch Estuaries rather than to Maplin Sands, and that the low lying land between Foulness and the Shoebury Boom drains via sluice to Havengore Creek. It is therefore concluded that freshwater inputs direct to the survey area are very minor and unlikely to cause significant localised hotspots of contamination on the cockle beds.

Appendix IX. Hydrography

IX.1. Bathymetry

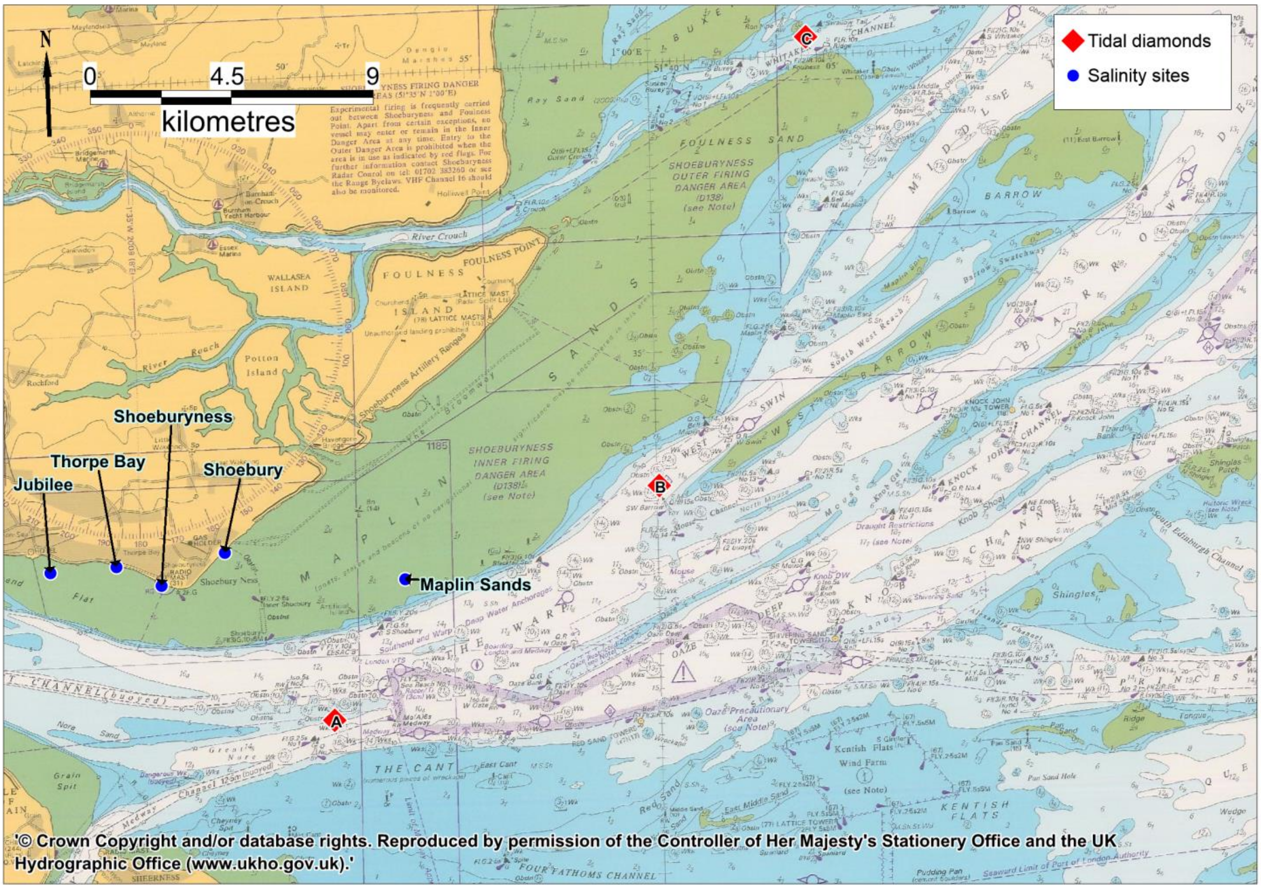

Figure IX.1: Bathymetric chart of the survey area

Maplin Sands is located on the north shore of the outer Thames estuary, where it opens out into the North Sea. It consists of the large intertidal area between Shoebury and the mouth of the Crouch estuary, which is about 5 km in width. The substrate is mainly sand, with some mud, shell and gravel. It slopes very gently between the high water mark and the edge of the intertidal area, after which there is a steeper drop-off to a depth of up to 14 m relative to chart datum in places. The Crouch estuary approach channel has depths of up to about 8 m relative to chart datum. There is an intertidal connection between the Roach Estuary and Maplin Sands via Havengore Creek. The depth through this connection at high water is reported to be 2.2 m during spring tides and 1.2 m on neap tides (Crouch Harbour Authority, 2012) so this connection exists for just under half of the tidal cycle.

IX.2. Water circulation patterns

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs.

Table IX.1 shows the tidal range at Southend.

Table IX.1: Tide levels and ranges at Southend

Port	Height (m) above Chart Datum				Range (m)	
	MHWS	**MHWN**	**MLWN**	**MLWS**	**Springs**	**Neaps**
Southend	5.68	4.50	1.60	0.42	5.26	2.90

Data from Admiralty TotalTide©

The tidal range is large, and tidal streams are likely to dominate patterns of water circulation under most conditions. Tidal streams are bi-directional, moving up the Thames and Crouch estuaries on the flood, and draining back down on the ebb. These two streams split/meet at the north eastern tip of Foulness Sands. As the tide floods, water will spread across the intertidal areas from the subtidal channels towards the high water mark. As the water deepens across the intertidal area, flows are likely to align more with offshore streams which run parallel to the coast.

There are three tidal diamonds adjacent to Maplin Sands, from which tidal stream information is summarised in Table IX.2. Their locations are shown in Figure IX.1. These confirm the pattern of offshore tidal circulation described above, and also provide an indication of tidal excursion. There is some asymmetry at Diamond A, probably due to differing paths followed by the peak ebb and flood streams in this particular area. At Diamonds B and C, estimated tidal excursions were about 17 and 15 km on spring tides, and 11 and 9 km on neap tides. Tidal streams will be considerably slower across intertidal areas due to the effects of friction.

The ebb plume from the Crouch estuary will generally be confined to the subtidal channel, particularly at lower states of the tide when contamination within it is likely to be most concentrated. Impacts from this estuary are therefore only anticipated along the northern edge of Foulness Sands. The secondary connection between the Roach estuary and Maplin Sands only forms from mid flood through to mid ebb. When the connection is formed, the water level is higher over Maplin Sands due to a lag within the estuary, so water flows into the estuary through Havengore Creek when the tide is flooding. The reverse occurs on the ebb, until the connection is broken about halfway through the tide (Cefas, 2012a). The plume from the Roach estuary will therefore drain onto Maplin Sands during the first half of the ebb tide only, and will travel in an easterly direction.

Table IX.2: Tidal stream predictions for the Maplin Sands area, summarised from Admiralty Charts 1185 and 1975

Time before /after High Water	Station A		
	Direction (°)	Rate (m/s)	
		Spring	Neap
HW-6	-	0.0	0.0
HW-5	264	0.4	0.3
HW-4	276	0.8	0.5
HW-3	276	1.3	0.8
HW-2	276	1.3	0.8
HW-1	276	0.7	0.5
HW	-	0.0	0.0
HW+1	84	1.0	0.6
HW+2	96	1.4	0.9
HW+3	96	1.5	0.9
HW+4	96	1.3	0.8
HW+5	96	0.9	0.5
HW+6	96	0.5	0.3
Flood excursion (km)		16.1	10.0
Flood direction		W	
Ebb excursion (km)		23. 9	14.6
Ebb direction		E	

Time before /after High Water	Station B		
	Direction (°)	Rate (m/s)	
		Spring	Neap
HW-6	223	0.3	0.2
HW-5	252	0.9	0.6
HW-4	230	1.2	0.8
HW-3	234	0.9	0.6
HW-2	235	0.8	0.5
HW-1	146	0.6	0.4
HW	265	0.1	0.1
HW+1	62	0.6	0.4
HW+2	55	1.4	0.9
HW+3	59	1.3	0.9
HW+4	62	0.9	0.6
HW+5	46	0.6	0.4
HW+6	180	0.1	0.1
Flood excursion (km)		17.2	11.5
Flood direction		SW	
Excursion (ebb)		17.6	11.5
Ebb direction		ENE	

Time before /after High Water	Station C		
	Direction (°)	Rate (m/s)	
		Spring	Neap
HW-6	231	0.2	0.1
HW-5	252	0.8	0.5
HW-4	250	1.0	0.6
HW-3	250	0.9	0.6
HW-2	253	0.7	0.5
HW-1	255	0.4	0.3
HW	39	0.2	0.2
HW+1	70	0.8	0.5
HW+2	74	1.0	0.7
HW+3	74	0.9	0.6
HW+4	75	0.7	0.5
HW+5	79	0.4	0.3
HW+6	158	0.1	0.1
Flood excursion (km)		14.4	9.1
Flood direction		WSW	
Ebb excursion (km)		14.8	9.6
Ebb direction		ENE	

Freshwater inputs may modify circulation in coastal waters through density effects. Given the open coastal location of Maplin Sands, and the low volumes of freshwater inputs, such effects are unlikely to occur within the survey area. Figure IX.2 presents boxplots of salinity measurements made at the shellfish water and bathing water monitoring points.

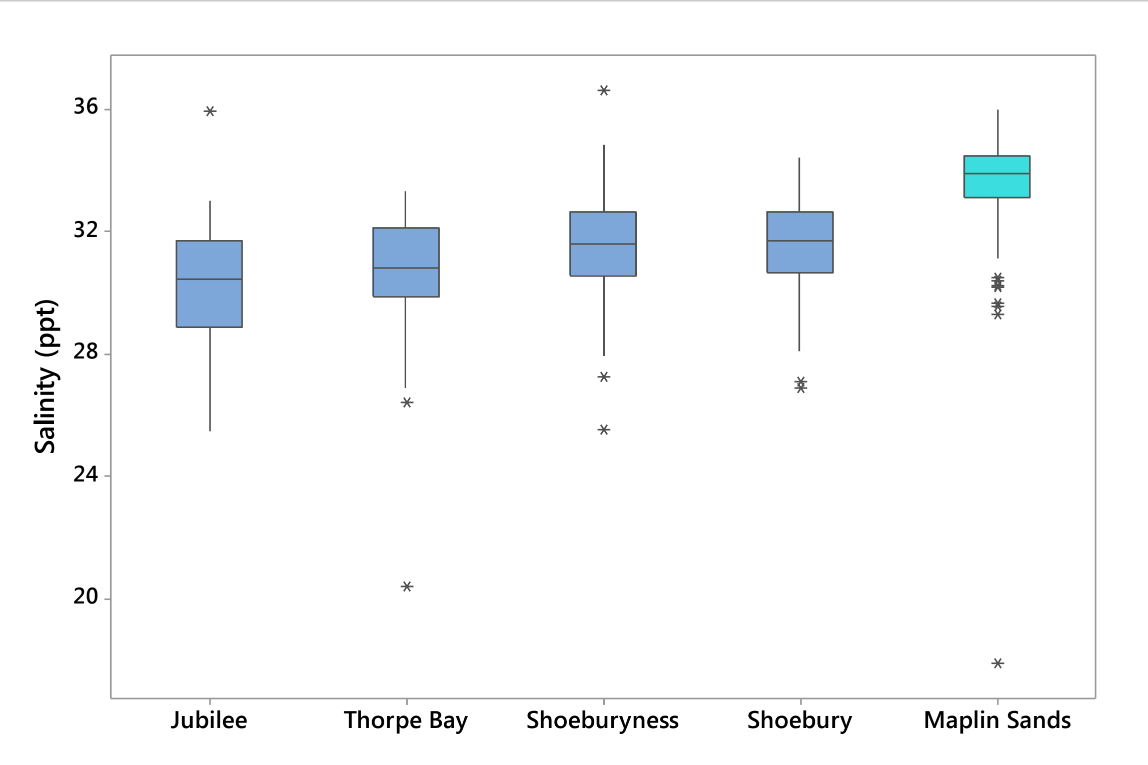

Figure IX.2: Boxplot of salinity records at bathing water (dark blue) and shellfish water (light blue) monitoring points.

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Average salinity exceeded 30 ppt at all monitoring points indicating that freshwater influence was low, and that stratification of the water column and density driven circulation are unlikely to be of significance. A slight gradient of increasing average salinity from west to east is apparent, suggesting that the western end of the survey area may be subject to higher levels of contamination delivered via land runoff. It must be noted that the bathing waters are only monitored from May to September, whereas the shellfish water is monitored all year round.

A density effect of potential relevance is that plumes from subtidal sewage outfalls such as the Southend STW, being less saline and often warmer than the receiving water, tend to float to the surface. This will limit its impact on benthic shellfish stocks in the vicinity of the outfall, but will render its plume susceptible to advection by wind driven currents.

Strong winds will modify surface currents. Maplin Sands is most exposed to winds from the east and south. Winds typically drive surface water currents at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m s^{-1}) would drive a surface water current of about 1 knot or 0.5 m s^{-1}. These surface currents create return currents which may flow at depth or along sheltered margins. 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. Winds with a southerly element will push surface water from offshore towards the foreshore, which will convey the plume from the Southend STW outfall towards the intertidal shellfish beds when the tide is ebbing. Onshore winds will also create wave action. This may resuspend any contamination held within the sediments of the intertidal zone, temporarily increasing levels of contamination within the water column until it is carried away by the tides. It is therefore concluded that shellfish beds at Maplin Sands may be subject to higher levels of contamination during southerly and south easterly winds, although targeting such conditions in the sampling plan is unlikely to be practical.

Appendix X. Microbiological Data: Seawater

X.1. Bathing Waters

There are 8 bathing waters of relevance to the survey area, designated under the Directive 76/160/EEC (Council of the European Communities, 1975), the locations of which are shown in Figure X.1.

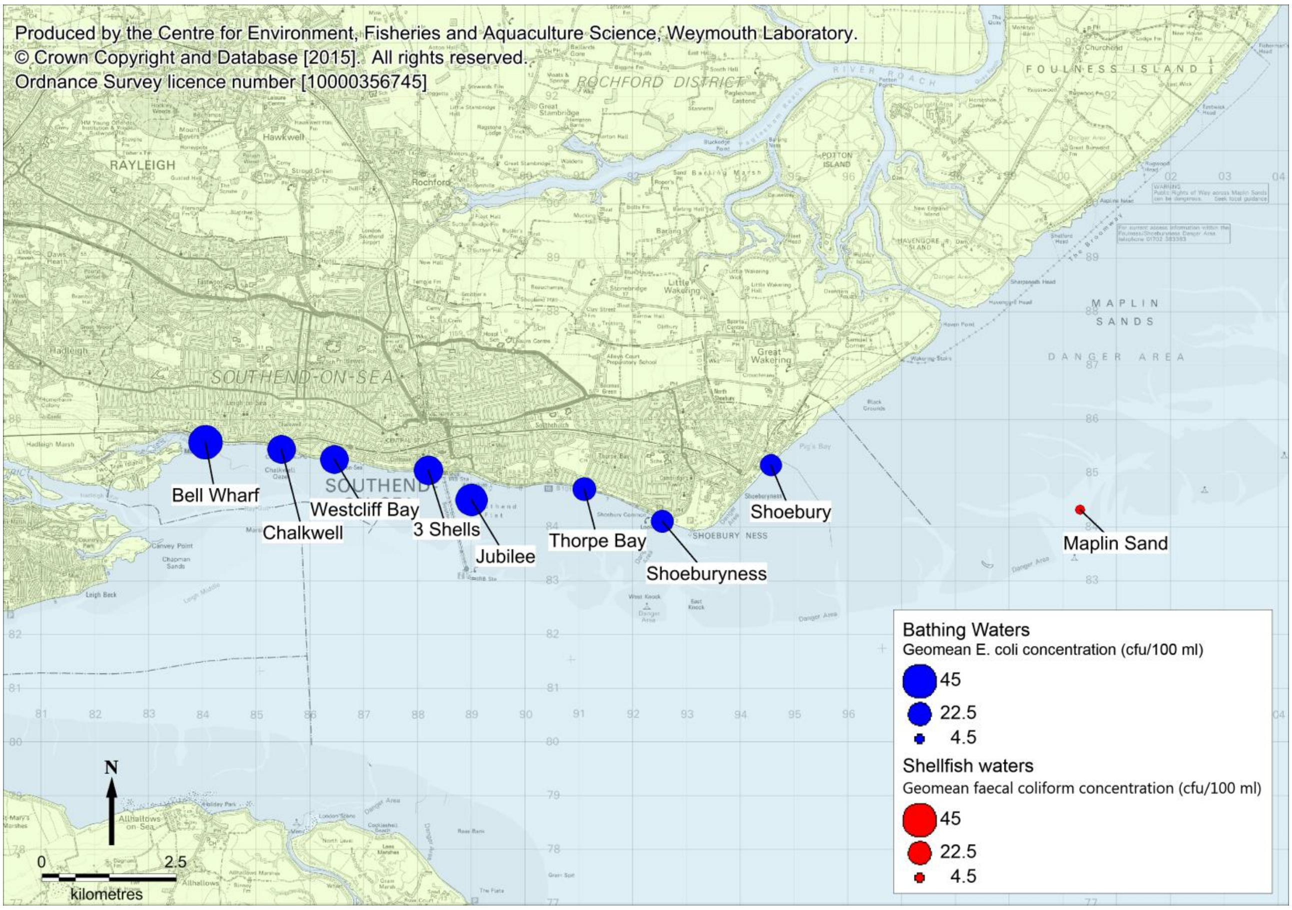

Figure X.1: Location of designated bathing and shellfish waters monitoring points in the survey area
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Around twenty water samples were taken from each of the bathing water sites during each bathing season, which runs from the 15th May to the 30th September. Due to a change in analysis method from faecal coliforms to *E. coli* in 2011, results from 2012-2014 only were considered in this report. *E. coli* were enumerated in all of these samples. Summary statistics of all results by bathing water are presented in

Table X.1, and Figure X.2 presents box plots of these data.

Table X.1: Summary statistics for bathing waters *E. coli* results, 2012-2014 (cfu/100 ml).

Sampling Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1,000	% over 10,000
Bell Wharf	63	08/05/2012	26/09/2014	40.1	<10	2,700	23.0	1.6	0.0
Chalkwell	63	08/05/2012	26/09/2014	27.2	<10	450	14.8	0.0	0.0
Westcliff Bay	61	08/05/2012	26/09/2014	26.6	<10	420	16.7	0.0	0.0
3 Shells	63	08/05/2012	26/09/2014	29.1	<10	640	21.3	0.0	0.0
Jubilee	65	08/05/2012	26/09/2014	34.2	<10	>10,000	27.4	3.2	1.6
Thorpe Bay	63	08/05/2012	26/09/2014	17.3	<10	520	9.8	0.0	0.0
Shoeburyness	61	08/05/2012	26/09/2014	16.0	<10	390	6.7	0.0	0.0
Shoebury	61	08/05/2012	26/09/2014	13.8	<10	520	10.0	0.0	0.0

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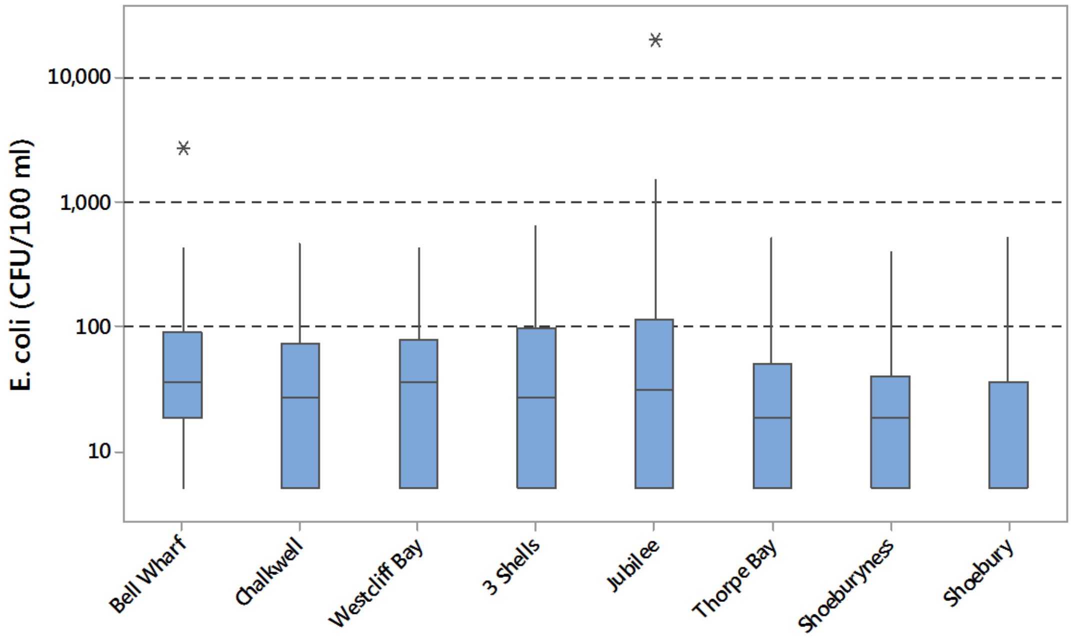

Figure X.2: Box-and-whisker plots of all *E. coli* results by site
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Bell Wharf sampling site had the highest geometric mean and Jubilee had the maximum *E. coli* concentration, while Shoebury had the lowest geometric mean *E. coli* concentration. A one-way ANOVA test showed that there were significant differences in *E. coli* concentrations between sites ($p<0.001$). Post ANOVA Tukey tests showed that Bell Wharf had significantly higher *E. coli* concentrations than Thorpe Bay, Shoeburyness and Shoebury. Additionally Jubilee had significantly higher *E. coli* concentrations than Shoebury. This suggests a general decrease in levels of contamination from west to east, with a local elevation in the vicinity of Jubilee.

Correlations (Pearson's) were run between samples at the sites that shared sampling dates, and therefore environmental conditions, on at least 20 occasions. All sites correlated significantly ($r=0.301$-0.554, $p=<0.001$-0.020) indicating that all sites are likely to share similar contamination sources.

Overall temporal pattern in results

The overall temporal variation in *E. coli* levels found at bathing water sites is shown in Figure X.3.

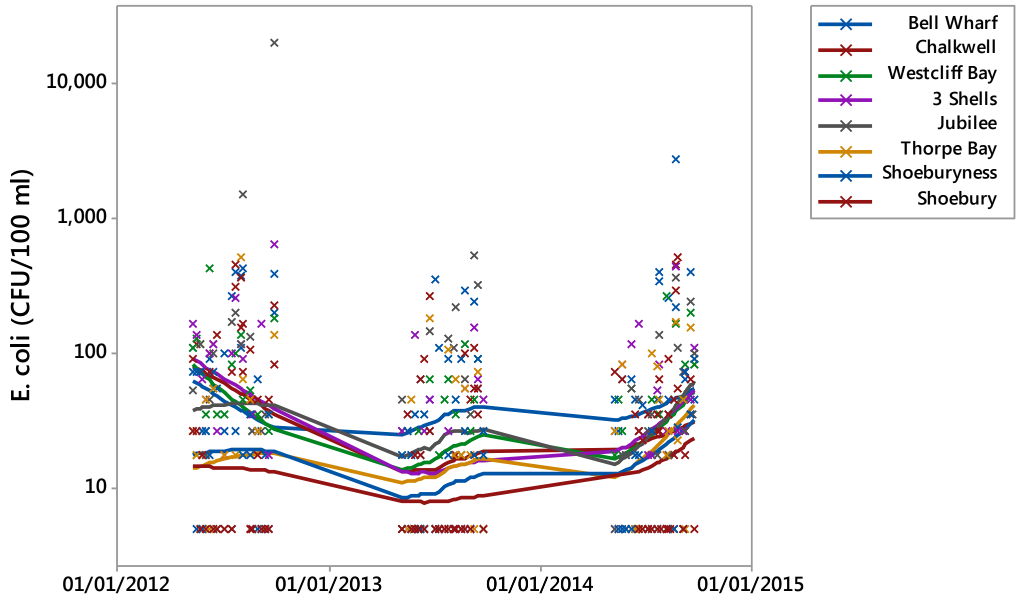

Figure X.3: Scatterplot of *E. coli* results for bathing waters in the survey area overlaid with loess lines.
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E. coli levels have remained fairly constant on average through the three year period considered.

Influence of tides

To investigate the effects of tidal state on *E. coli* results, circular-linear correlations were carried out against both the high/low and spring/neap tidal cycles for each of the bathing waters sampling points. Correlation coefficients are presented in Table X.2, where significant correlations are highlighted in yellow.

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

	High/low tides		Spring/neap tides	
Site Name	**r**	**p**	**r**	**p**
Bell Wharf	0.159	0.233	0.119	0.442
Chalkwell	0.328	0.002	0.149	0.277
Westcliff Bay	0.156	0.250	0.236	0.041
3 Shells	0.060	0.810	0.198	0.102
Jubilee	0.337	0.001	0.029	0.951
Thorpe Bay	0.049	0.869	0.169	0.189
Shoeburyness	0.218	0.066	0.184	0.146
Shoebury	0.108	0.515	0.136	0.347

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Figure X.4 presents polar plots of $\log_{10}$ *E. coli* results against tidal states on the high/low cycle for the correlations indicating a statistically significant effect. High water at Southend is at 0° and low water is at 180°. Results of 100 *E. coli* cfu/100 ml or less are plotted in green, those from 101 to 1,000 are plotted in yellow, and those exceeding 1,000 are plotted in red.

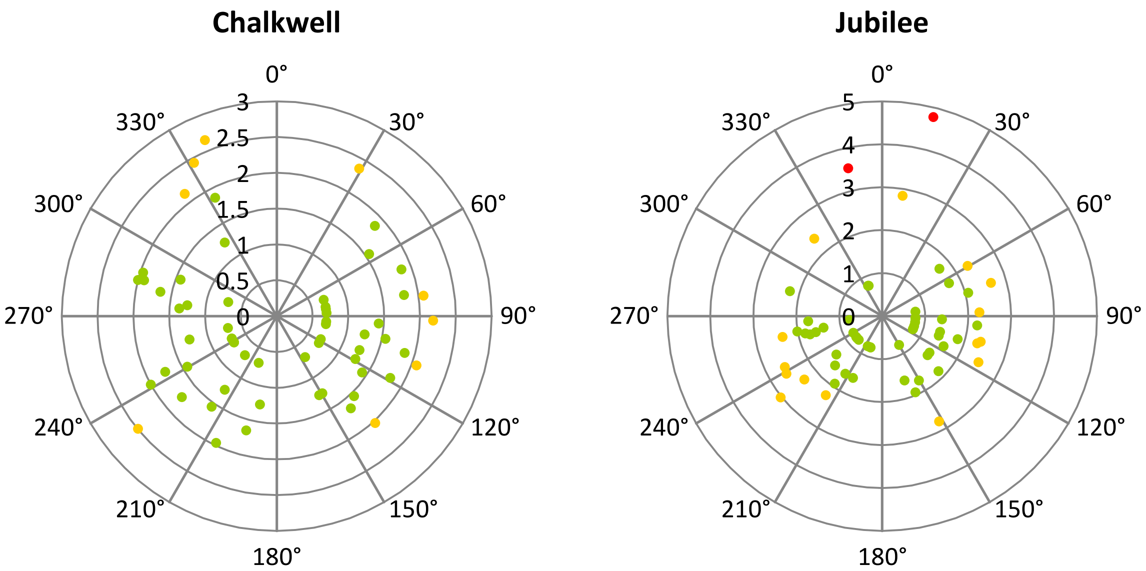

Figure X.4: Polar plots of $\log_{10}$ *E. coli* results (cfu/100 ml) against high/low tidal state.
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At both Chalkwell and Jubilee, highest *E. coli* concentrations tended to arise around high water. The reasons for this are unclear.

Figure XI.5 present a polar plot of $\log_{10}$ *E. coli* results against the spring/neap tidal cycle for Westcliff Bay. 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 100 *E. coli* cfu/100 ml or less are plotted in green, those from 101 to 1,000 are plotted in yellow, and those exceeding 1,000 are plotted in red.

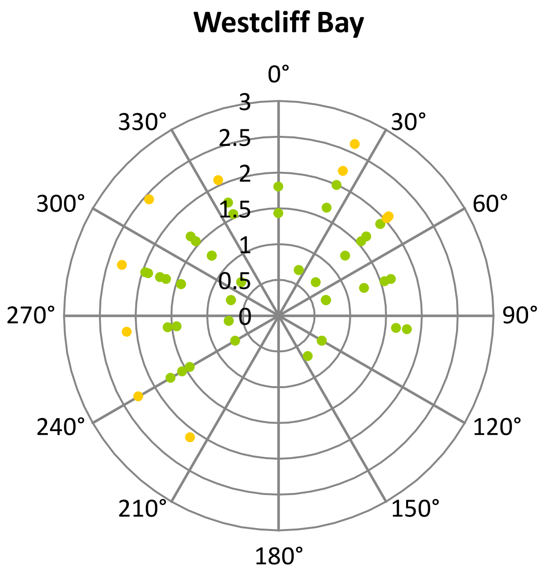

Figure X.5: Polar plot of $\log_{10}$ *E. coli* results (cfu/100 ml) against spring/neap tidal state

While a significant correlation was found between the spring/neap tidal state and *E. coli* concentrations at Westcliff Bay, no pattern is evident in Figure X.5.

Influence of Rainfall

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 Southchurch Park weather station (Appendix VI for details) over various periods running up to sample collection and *E. coli* results. These are presented in Table X.3 and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table X.3: Spearmans Rank correlation coefficients for *E. coli* results against recent rainfall

	Site	Bell Wharf	Chalkwell	Westcliff Bay	3 Shells	Jubilee	Thorpe Bay	Shoeburyness	Shoebury
	n	40	40	40	40	40	40	40	40
24 hour periods prior to sampling	1 day	0.086	0.248	0.163	0.296	0.291	0.297	0.288	0.145
	2 days	0.055	0.454	0.224	0.320	0.308	0.441	0.388	0.363
	3 days	0.314	0.513	0.532	0.481	0.467	0.161	0.328	0.364
	4 days	0.208	0.327	0.154	0.057	0.129	-0.070	0.205	0.191
	5 days	-0.154	-0.055	-0.127	-0.178	0.089	0.044	0.296	0.047
	6 days	-0.009	0.217	0.200	0.174	0.272	0.049	0.148	-0.008
	7 days	-0.070	0.093	0.150	0.295	0.016	0.146	0.231	0.200
Total prior to sampling over	2 days	0.137	0.434	0.240	0.402	0.379	0.420	0.382	0.264
	3 days	0.210	0.542	0.404	0.472	0.460	0.256	0.310	0.217
	4 days	0.273	0.498	0.332	0.450	0.445	0.090	0.228	0.278
	5 days	0.244	0.442	0.273	0.357	0.421	0.075	0.253	0.283
	6 days	0.133	0.359	0.252	0.318	0.476	0.084	0.265	0.192
	7 days	0.151	0.404	0.254	0.376	0.445	0.106	0.221	0.240

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Rainfall affected *E. coli* levels at all sites to varying degrees. Rainfall had the greatest effect at Chalkwell, 3 Shells and Jubilee where accumulative rainfall affected *E. coli* levels from 1 day up to 1 week. Shoeburyness and Shoebury were affected by rainfall that had fallen within 1 day, but at Bell Wharf, Westcliff Bay and Jubilee it took 3 days for rainfall to have a significant effect on *E. coli* levels.

Salinity

Salinity was recorded on most sampling occasions. Pearson's correlations were run to determine the effect of salinity on *E. coli* at the bathing waters site. Figure X.6 shows scatter-plots between *E. coli* and salinity where significant correlations were found.

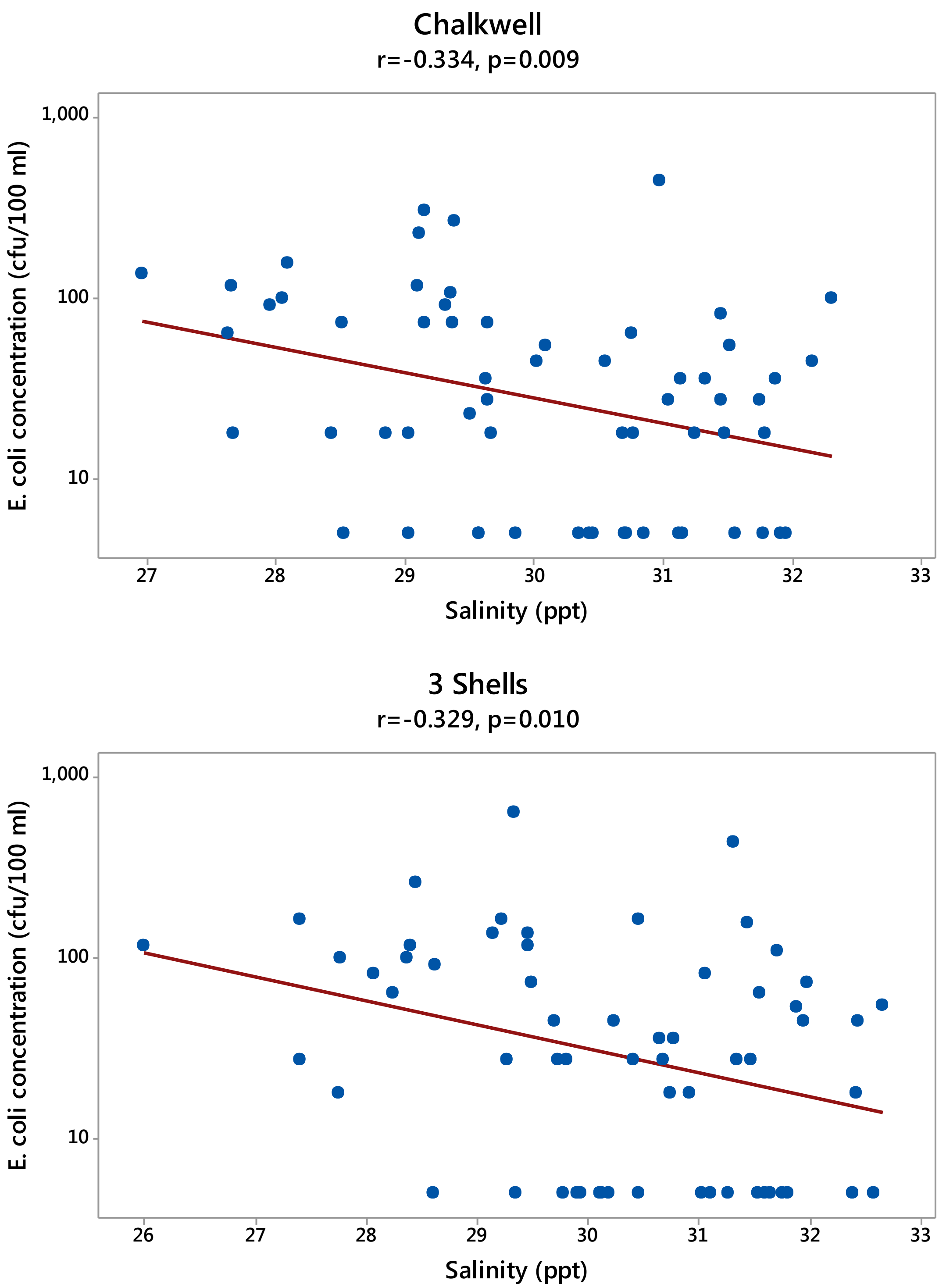

Figure X.6: Scatter-plots of salinity against *E. coli* concentration.
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E. coli levels at Chalkwell and 3 Shells correlated significantly with salinity. This indicates that freshwater inputs have a significant effect on contamination levels at these sites.

X.2. Shellfish Waters

Summary statistics and geographical variation

There is one shellfish waters monitoring site designated under Directive 2006/113/EC (European Communities, 2006) relevant to the survey area. Figure X.1 shows the location of this site. Table X.4 presents summary statistics for bacteriological monitoring results and Figure X.7 presents a boxplot of faecal coliform levels from the monitoring point.

Table X.4: Summary statistics for shellfish waters faecal coliform results, 2004 to 2013 (cfu/100 ml).

Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100
Maplin Sand	38	16/04/2004	10/07/2013	2.7	<2	61	0.0

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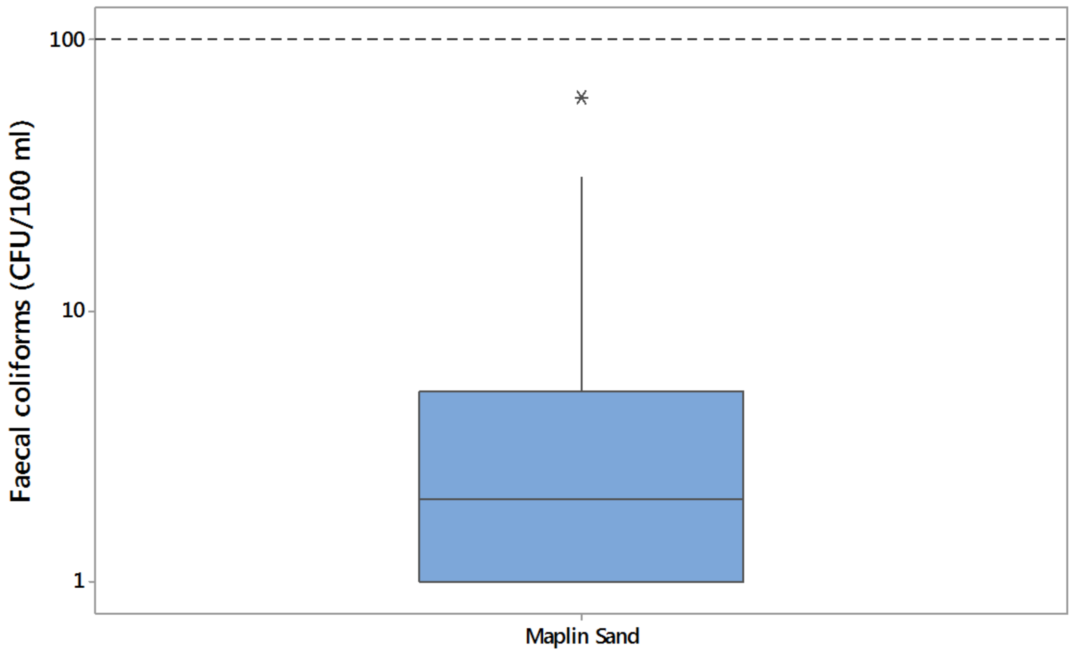

Figure X.7: Box-and-whisker plots of all faecal coliforms results
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Faecal coliform concentrations at Maplin Sand have not exceeded 100 cfu/100 ml in any samples since 2004.

Overall temporal pattern in results

The overall variation in faecal coliform levels found at shellfish water sites over time is shown in Figure X.8.

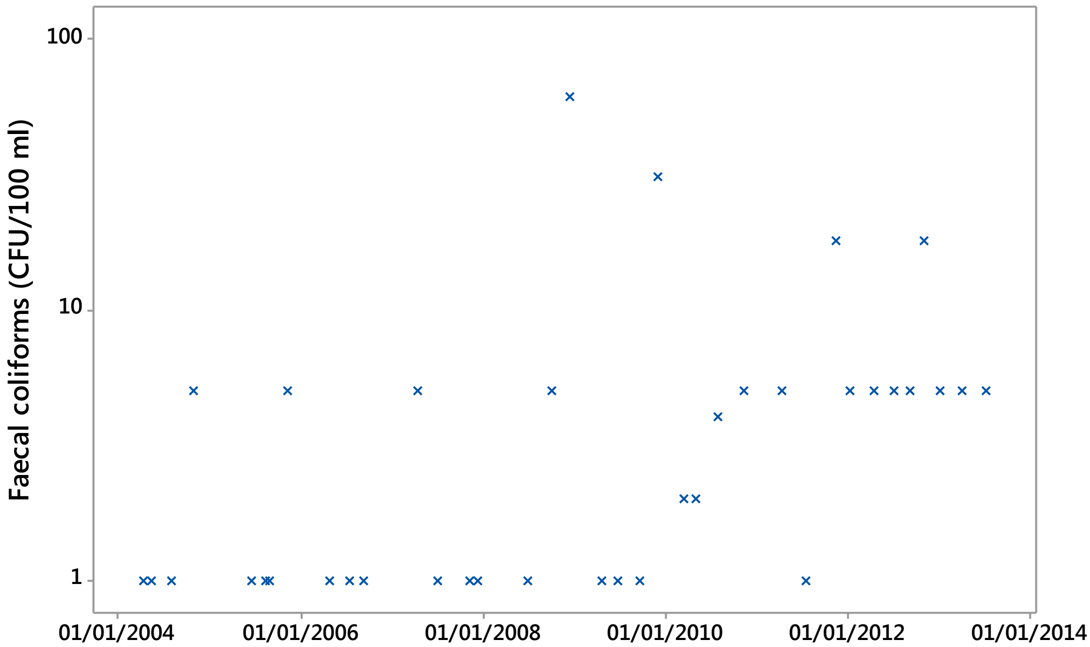

Figure X.8: Scatterplot of faecal coliform results by date.
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Faecal coliform concentrations have remained fairly stable since 2004. The lower limit of detection of faecal coliforms was increased in 2012.

Seasonal patterns of results

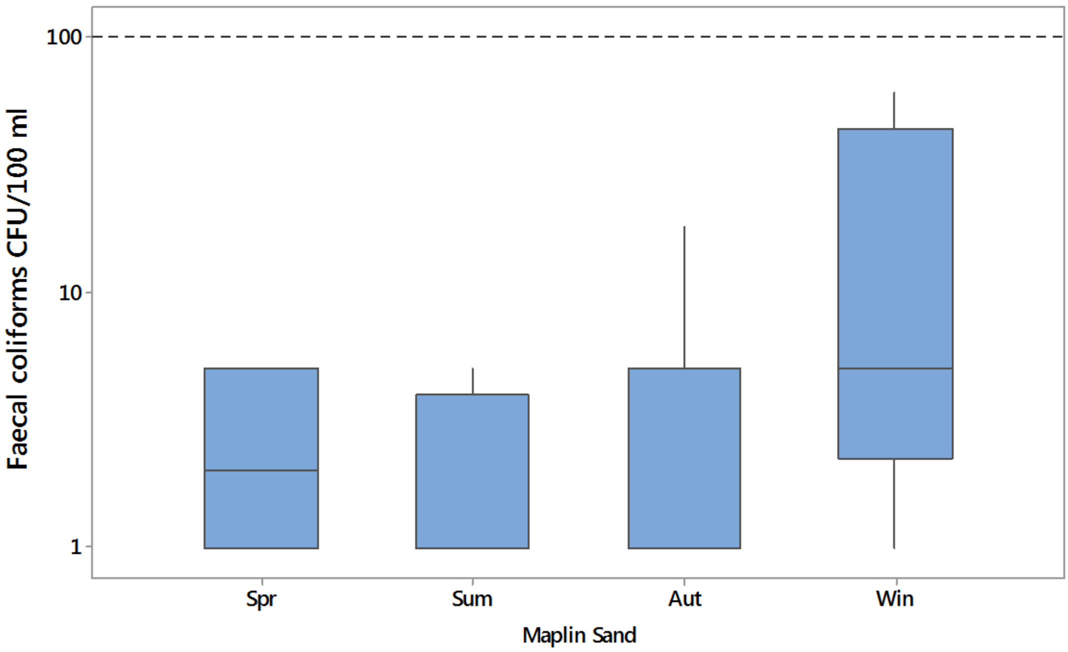

Figure X.9: Boxplot of faecal coliform results by season
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One-way ANOVA tests showed that there were significant variations in faecal coliform concentrations between seasons ($p=0.019$). Post-hoc Tukey tests showed that faecal coliform levels were significantly higher in winter than in summer.

Influence of tide

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 for each of these shellfish waters sampling points. Correlation coefficients are presented in Table X.5. There were no significant correlations between faecal coliform levels and tidal state at Maplin Sand.

Table X.5: Circular linear correlation coefficients (r) and associated p values for faecal coliform results against the high/low and spring/neap tidal cycles

	High/low tides		Spring/neap tides	
Site Name	**r**	**p**	**r**	**p**
Maplin Sand	0.206	0.237	0.183	0.322

Influence of rainfall

To investigate the effects of rainfall on levels of contamination at the water quality monitoring sites Spearman's rank correlations were carried out between rainfall recorded at the Southchurch Park weather station (Appendix VI for details) over various periods running up to sample collection and faecal coliform results. These are presented in Table X.6 and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table X.6: Spearman's Rank correlation coefficients for faecal coliform results against recent rainfall

	Site	Maplin Sand
	n	37
24 hour periods prior to sampling	1 day	0.407
	2 days	0.057
	3 days	0.239
	4 days	0.137
	5 days	0.226
	6 days	-0.043
	7 days	0.025
Total prior to sampling over	2 days	0.252
	3 days	0.195
	4 days	0.140
	5 days	0.179
	6 days	0.076
	7 days	0.016

Rainfall had a slight effect on faecal coliforms, but this effect did not last longer than one day after rainfall.

Influence of salinity

Salinity was recorded on most sampling occasions. Figure X.10 shows scatter-plots between faecal coliforms and salinity. Pearson's correlations were run to determine the effect of salinity on faecal coliforms.

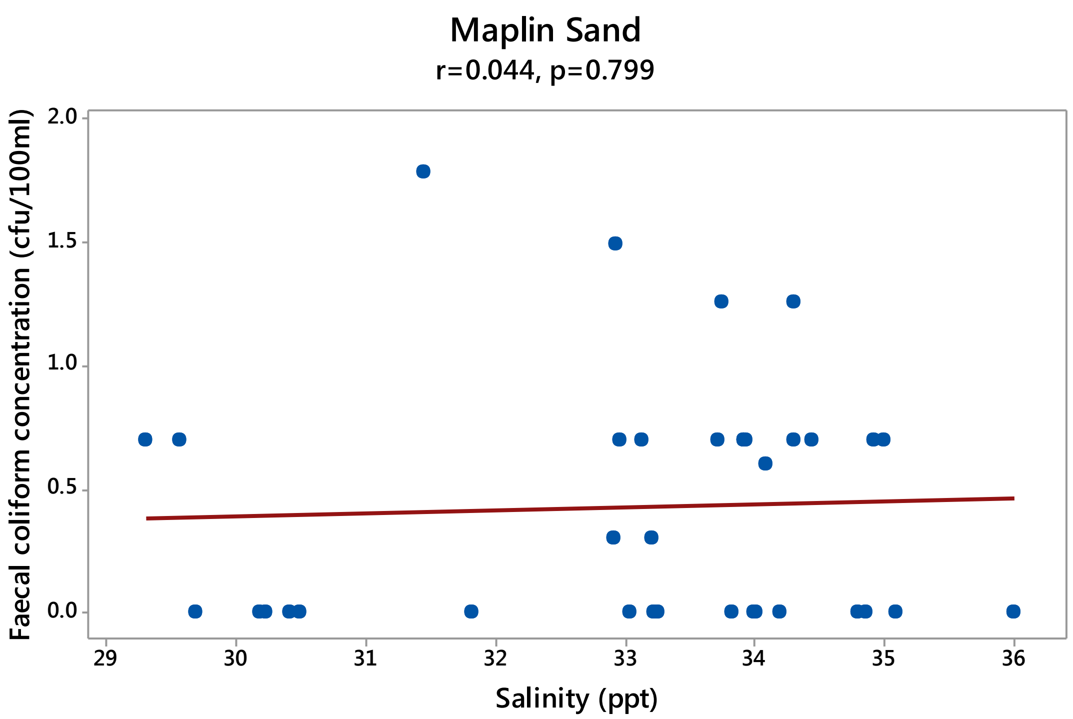

Figure X.10: Scatter-plot of salinity against faecal coliform concentration.

There was no significant correlation between salinity and faecal coliform concentrations at Maplin Sand suggesting that land runoff is not a major contaminating influence.

Appendix XI. Microbiological Data: Shellfish Flesh Hygiene

XI.1. Summary statistics and geographical variation

There are a total of six RMPs in the survey area that have been sampled between 2005 and 2014. The geometric mean results of shellfish flesh monitoring from all RMPs sampled from 2005 onwards are presented in Figure XI.1. Summary statistics are presented in Table XI.1 and boxplots of results by RMP are show in Figure XI.2. One of the RMPs (East Shoebury Island) was only sampled on one occasion and so could not be included in the analyses.

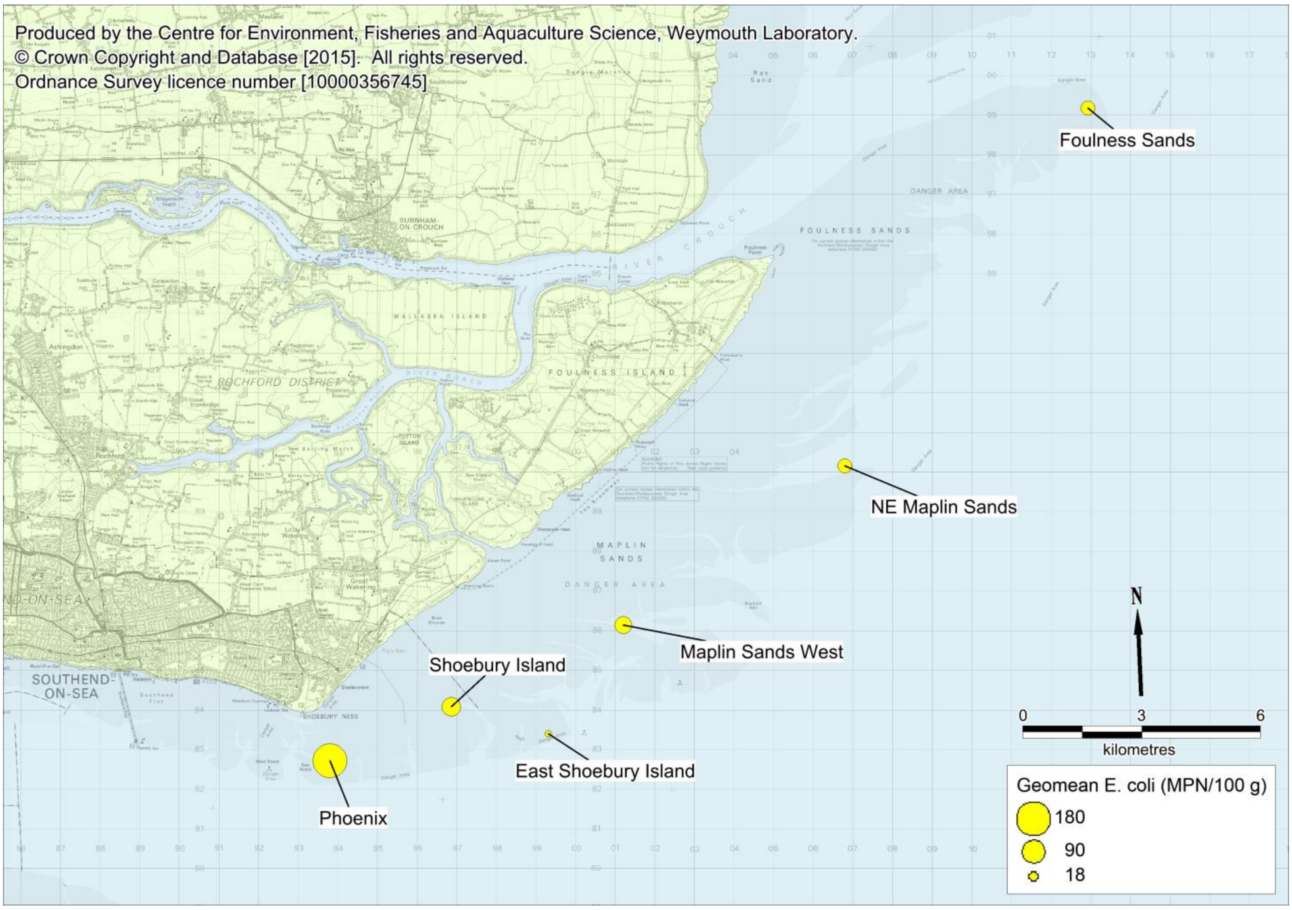

Figure XI.1: Bivalve RMPs active since 2005.

Table XI.1: Summary statistics of *E. coli* results (MPN/100 g) from RMPs sampled from 2005 onwards.

Sampling Site	Species	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 230	% over 4,600
Phoenix	Cockle	108	25/01/2005	11/08/2014	176.1	<20	3,500	45.4	0.0
Shoebury Island	Cockle	108	25/01/2005	11/08/2014	65.5	<20	2,400	14.8	0.0
East Shoebury Island	Cockle	1	28/06/2006	28/06/2006	10.0	<20	<20	0.0	0.0
Maplin Sands West	Cockle	108	25/01/2005	11/08/2014	52.4	<20	2,400	13.9	0.0
NE Maplin Sands	Cockle	105	25/01/2005	11/08/2014	38.4	<20	1,300	10.5	0.0
Foulness Sands	Cockle	106	25/01/2005	11/08/2014	38.9	<20	1,300	6.6	0.0

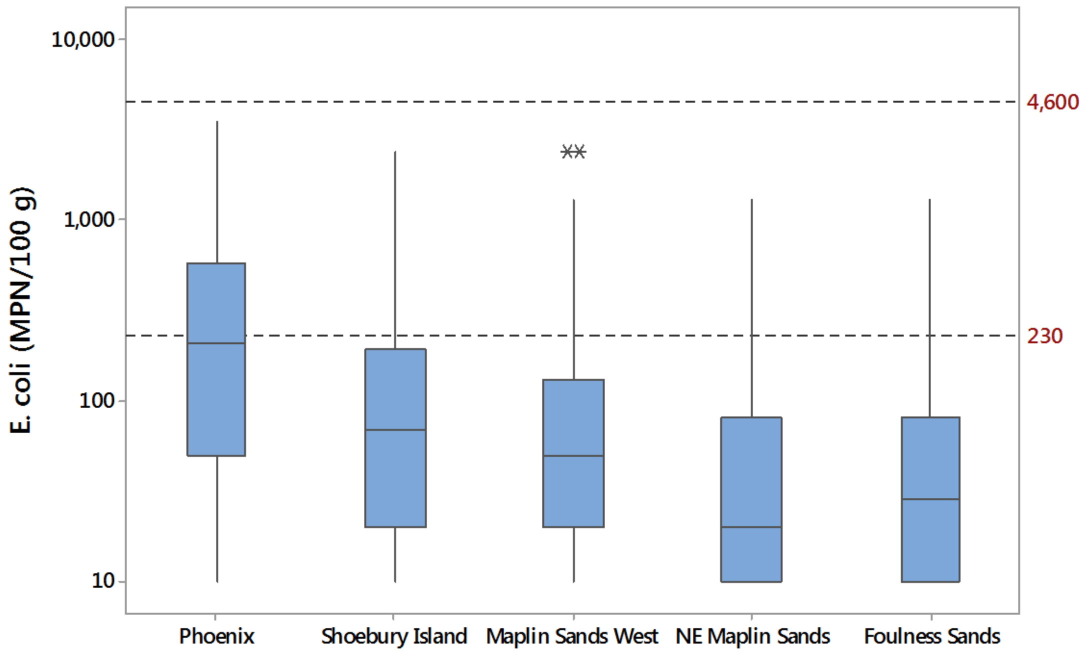

Figure XI.2: Boxplots of *E. coli* results from cockle RMPs from 2005 onwards.

E. coli levels did not exceed 4,600 MPN/100 g in any samples. Phoenix had the greatest geometric mean and maximum *E. coli* results, while NE Maplin Sands had the lowest geometric mean and maximum *E. coli* levels (excluding East Shoebury Island). One-way ANOVA tests showed that there were significant differences in *E. coli* levels between sites ($p<0.001$). Post ANOVA Tukey tests showed that Phoenix had significantly higher *E. coli* levels than all other sites, and Shoebury Island had significantly higher *E. coli* levels than NE Maplin Sands and Foulness Sands. It is therefore concluded that there is a gradient of decreasing levels of contamination from Phoenix through to NE Maplin Sands.

Comparisons of RMPs were carried out on a pair-wise basis by running correlations (Pearson's) between sites that shared at least 20 sampling dates, and therefore environmental conditions. All sites correlated significantly with all other sites ($p<0.001$ in all cases). This indicates that the sites share similar contamination sources.

XI.2. Overall temporal pattern in results

The overall temporal variation in *E. coli* levels found in cockles is shown in Figure XI.3.

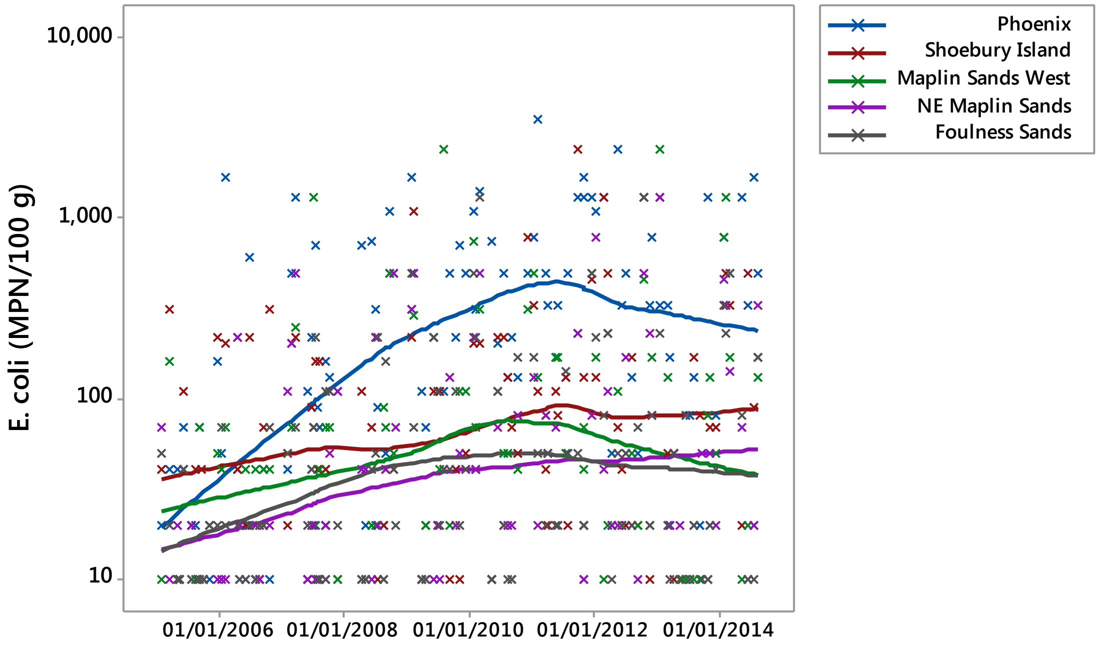

Figure XI.3: Scatterplot of *E. coli* results for cockles overlaid with loess line.

Overall since 2005, *E. coli* levels have increased in cockles. This trend is most obvious at Phoenix where *E. coli* levels rose considerably between 2005 and 2011.

XI.3. Seasonal patterns of results

The seasonal patterns of results from 2005 to 2014 were investigated by RMP. Figure XI.4 shows box plots of *E. coli* levels at each cockle site by season.

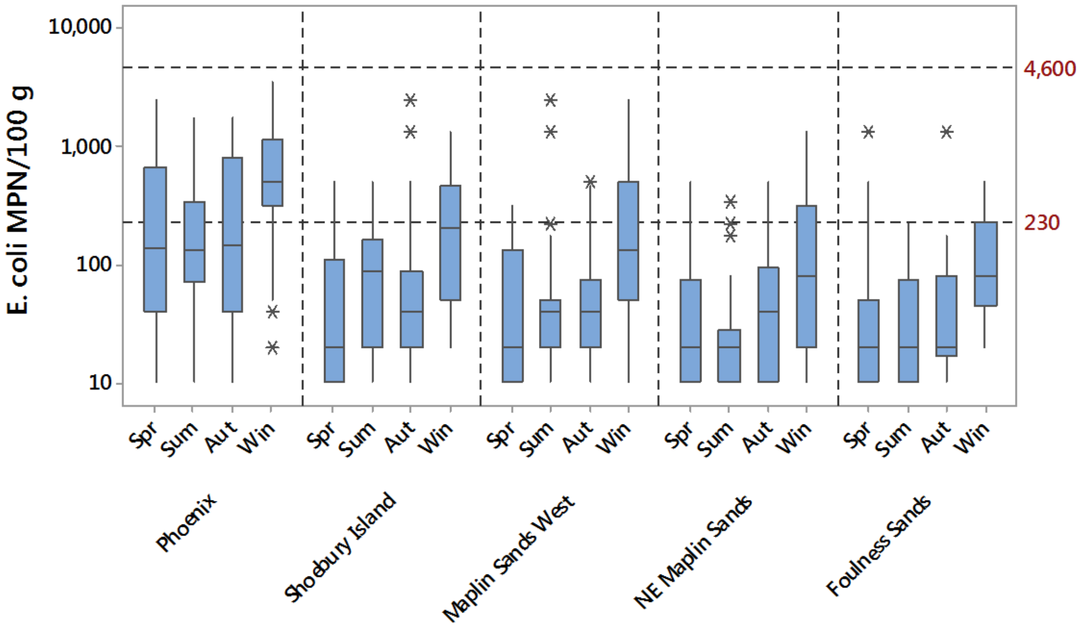

Figure XI.4: Boxplot of *E. coli* results for cockles by RMP and season

One-way ANOVA tests showed that there were significant differences in *E. coli* levels between seasons at all sites (Phoenix, p=0.018; Shoebury Island, p<0.001; Maplin Sands West p<0.001; NE Maplin Sands p=0.002; Foulness Sands, p=0.001). At Shoebury Island, Maplin Sands West and Foulness Sands, *E. coli* levels were significantly higher in winter than all other seasons. At Phoenix and NE Maplin Sands, *E. coli* levels were significantly higher in winter than in summer.

XI.4. Influence of tide

To investigate the effects of tidal state on *E. coli* results, circular-linear correlations were carried out against the high/low tides at Southend and spring/neap tidal cycles for each RMP where more than 30 samples had been taken. Results of these correlations are summarised in Table XI.2, and significant results are highlighted in yellow.

Table XI.2: Circular linear correlation coefficients (r) and associated p values for *E. coli* results against the high/low and spring/neap tidal cycles

		High/low tides		Spring/neap tides	
Site Name	**Species**	**r**	**p**	**r**	**p**
Phoenix	Cockle	0.174	0.042	0.121	0.216
Shoebury Island	Cockle	0.147	0.103	0.214	0.008
Maplin Sands West	Cockle	0.099	0.355	0.192	0.021
NE Maplin Sands	Cockle	0.152	0.095	0.160	0.073
Foulness Sands	Cockle	0.177	0.039	0.107	0.310

Figure XI.5 presents polar plots of $\log_{10}$ *E. coli* results against tidal states on the high/low cycle for the correlations indicating a statistically significant effect. High water at Southend is at 0° and low water is at 180°. Results of 230 *E. coli* MPN/100 g or less are plotted in green, those from 231 to 4,600 are plotted in yellow, and those exceeding 4,600 are plotted in red.

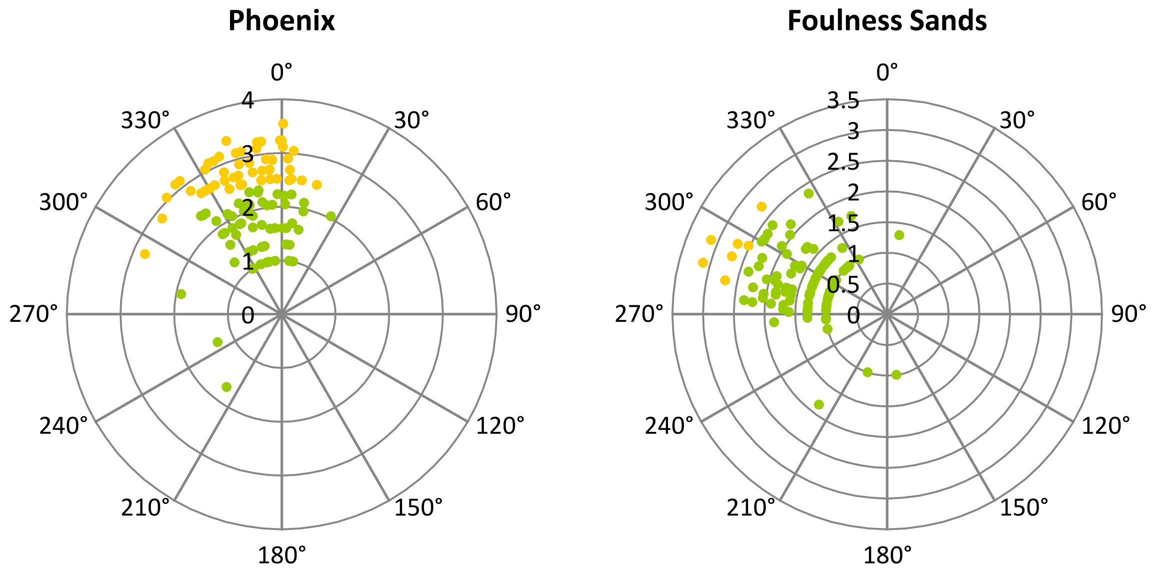

Figure XI.5: Polar plot of $\log_{10}$ *E. coli* results (MPN/100 g) at cockle RMPs against high/low tidal state

Most samples at Phoenix were taken just before high water, and at Foulness Sands, most samples were taken early in the second half of the flooding tide. At Phoenix, those samples taken earlier in the flood tide had lower *E. coli* levels, but low sample numbers mean that it is not possible to determine whether this is a real effect.

Figure XI.6 presents polar plots of $\log_{10}$ *E. coli* results against the spring/neap tidal cycle for each RMP where significant correlations were 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/100 g or less are plotted in green, those from 231 to 4,600 are plotted in yellow, and those exceeding 4,600 are plotted in red.

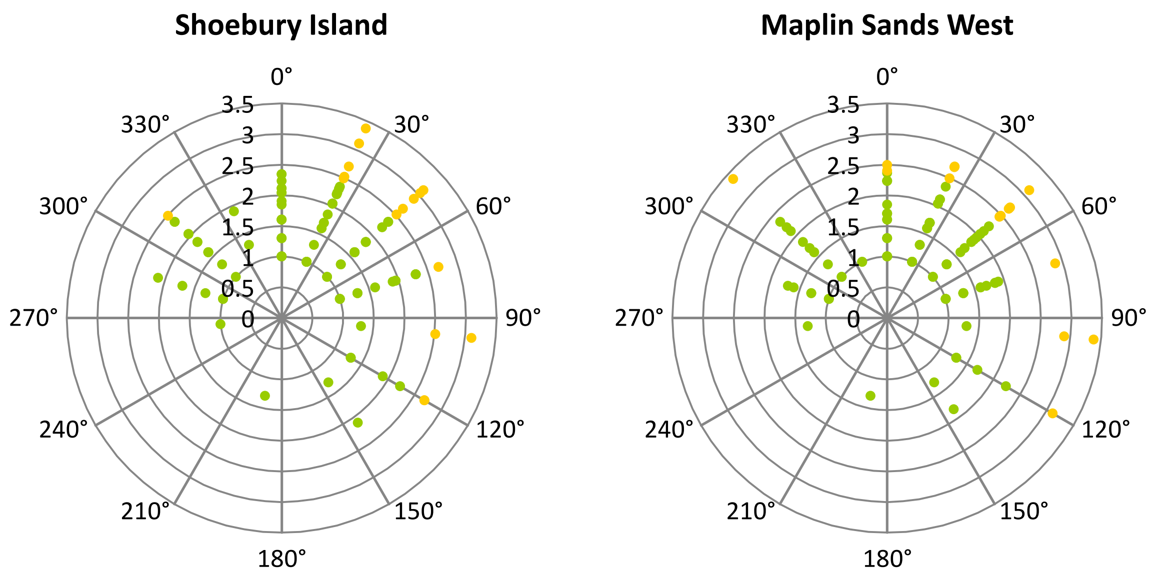

Figure XI.6: Polar plot of $\log_{10}$ *E. coli* results (MPN/100 g) at cockle RMPs against spring/neap tidal state

At Shoebury Island and Maplin Sands West, the majority of samples were taken when the tidal range was higher. At both sites, the few samples that were taken during the smaller tides tended to have lower *E. coli* results, and higher *E. coli* results tended to occur during the larger tides. This suggests that the main contamination sources may be remote from these RMPs.

XI.5. 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 Southchurch Park weather station (Appendix VI for details) over various periods running up to sample collection. These are presented in Table XI.3 and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table XI.3: Spearman's Rank correlations between rainfall recorded at Southchurch Park and shellfish hygiene results

	Site	Phoenix	Shoebury Island	Maplin Sands West	NE Maplin Sands	Foulness Sands
	n	101	101	101	98	99
24 hour periods prior to sampling	1 day	0.050	-0.106	-0.019	-0.001	-0.072
	2 days	0.160	0.099	0.267	-0.018	0.143
	3 days	0.053	0.157	0.232	0.083	-0.034
	4 days	0.086	-0.040	0.039	-0.120	-0.073
	5 days	0.101	0.044	0.045	0.104	0.104
	6 days	0.043	-0.043	-0.005	0.114	0.157
	7 days	-0.079	0.005	-0.075	-0.066	-0.035
Total prior to sampling over	2 days	0.096	-0.012	0.128	-0.105	0.005
	3 days	0.039	0.053	0.165	-0.069	-0.043
	4 days	0.044	0.017	0.122	-0.128	-0.100
	5 days	0.046	0.027	0.104	-0.078	-0.072
	6 days	0.039	-0.025	0.043	0.009	-0.012
	7 days	0.015	-0.048	0.007	-0.038	-0.044

Rainfall had no effect on *E. coli* levels in cockles at any RMP except for Maplin Sands West, where an influence was detected 2-3 days after a rainfall event.

Appendix XII. Shoreline Survey Report

Date (time):
05/12/2014, 09:00 – 14:00
06/12/2014, 08:00 – 12:00

Cefas Officers: David Walker

Survey Partners: Jacqueline Ingram (London Port Health Authority), Emma England (QinetiQ)

Area surveyed:
Shoeburyness Boom to coastguard lookout station. Havengore Creek to Shoeburyness Boom. Havengore creek to Fisherman's Head (Foulness Island).

Weather:
05/12/2014 – Clear, 5°C, no wind.
06/12/2014 – Clear, 5°C, no wind.

Tides:
Admiralty TotalTide© predictions for Southend-on-Sea 51°31'N 0°43'E. All times in this report are GMT.

05/12/2014		
High	11:20	5.7 m
High	23:50	5.7 m
Low	05:20	0.8 m
Low	17:46	0.7 m

06/12/2014		
High	12:04	5.8 m
Low	06:13	0.7 m
Low	18:29	0.8 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 shown in Figure XII.1.

Much of this survey was carried out on the MoD range and Shoeburyness and Foulness, which is managed by QinetiQ. Access to this area is restricted and permission must be obtained before any work can be carried out here.

XII.1. Fishery

It was not possible to meet with the harvesters on this survey. No additional shellfishery information was obtained.

XII.2. Sources of contamination

Sewage discharges

The location of the White City sewage works was confirmed (observation 14). While it was not possible to gain access to the works, a water sample (T05) was taken from a ditch into which the works discharge and had an *E. coli* concentration of 7,400 cfu/100 ml.

Freshwater inputs

Much of Shoeburyness and Foulness is below sea level and the area is mostly made up of drained marshland which is maintained by an extensive network of drainage channels and sluices. During this survey, samples were taken next to two inlets and one outlet sluices (observations 4, 5, 7, 9 & 11). However, none of the sluices were flowing and all samples (T01-T04) had *E. coli* concentrations of 10 or fewer cfu/100 ml.

Livestock

Much of Foulness Island is used for agriculture. During this survey, sheep were seen in one field (observation 6). Due to the sea wall and fences, the livestock on the Island do not have direct access to the shoreline, however runoff from fields used for grazing may enter the sea via sluices.

Wildlife

Many large flocks of birds were seen across the Shoeburyness and Foulness area, with the exception for the short stretch outside of the restricted area (Shoeburyness Boom to coastguard lookout station).

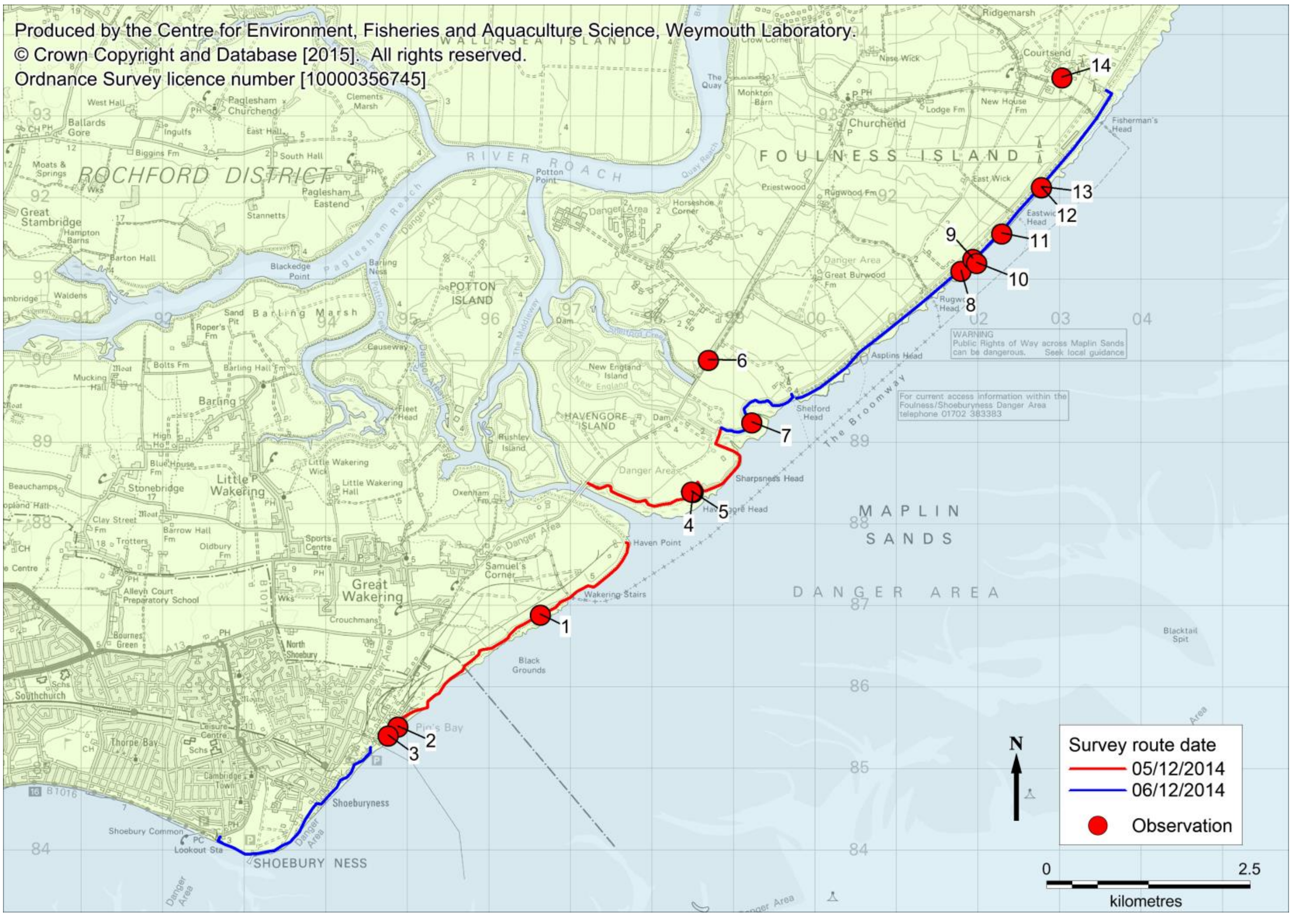

Figure XII.1: Locations of shoreline observations (Table XII.1 for details).

Table XII.1: Details of Shoreline Observations

Observation no.	NGR	Date and time	Description	Photo
1	TQ9663286893	05/12/2014 10:10	~100 birds (waders) on shore, ~500 birds in the air.	Figure XII.3
2	TQ9488385520	05/12/2014 10:56	~400 birds (waders) on shore and rocky outcrops.	Figure XII.4
3	TQ9476285407	05/12/2014 11:02	~200 birds (waders) on shore.	Figure XII.5
4	TQ9850288396	05/12/2014 12:29	Inlet sluice (seaward end). Not flowing (T01).	Figure XII.6
5	TQ9848488402	05/12/2014 12:35	Inlet sluice (landward end). Not flowing (T02).	Figure XII.7
6	TQ9869190018	06/12/2014 08:39	~100 sheep and 20 geese in field seaward of road.	
7	TQ9922389251	06/12/2014 09:03	Inlet sluice (landward end). Not flowing - seaward side is mud (T03).	Figure XII.8 & Figure XII.9
8	TR0179091113	06/12/2014 09:45	~50 geese landward of drainage ditch.	
9	TR0193791258	06/12/2014 09:47	Sluice (landward side). 80 cm diameter. Not flowing (T04).	Figure XII.10
10	TR0198291209	06/12/2014 09:55	Oysters, cockles, clams.	Figure XII.11
11	TR0229191571	06/12/2014 10:02	Sluice (seaward side of 51). Valved. Not flowing.	Figure XII.12
12	TR0277992137	06/12/2014 10:08	~200 birds on intertidal.	
13	TR0278092138	06/12/2014 10:08	~1000 birds on intertidal, 500 m forward on shore.	
14	TR0303093483	06/12/2014 10:27	White City Sewage works. Nearby ditch with sulphurous smell and sewage fungus. Sample taken from ditch (T05).	Figure XII.13 & Figure XII.14

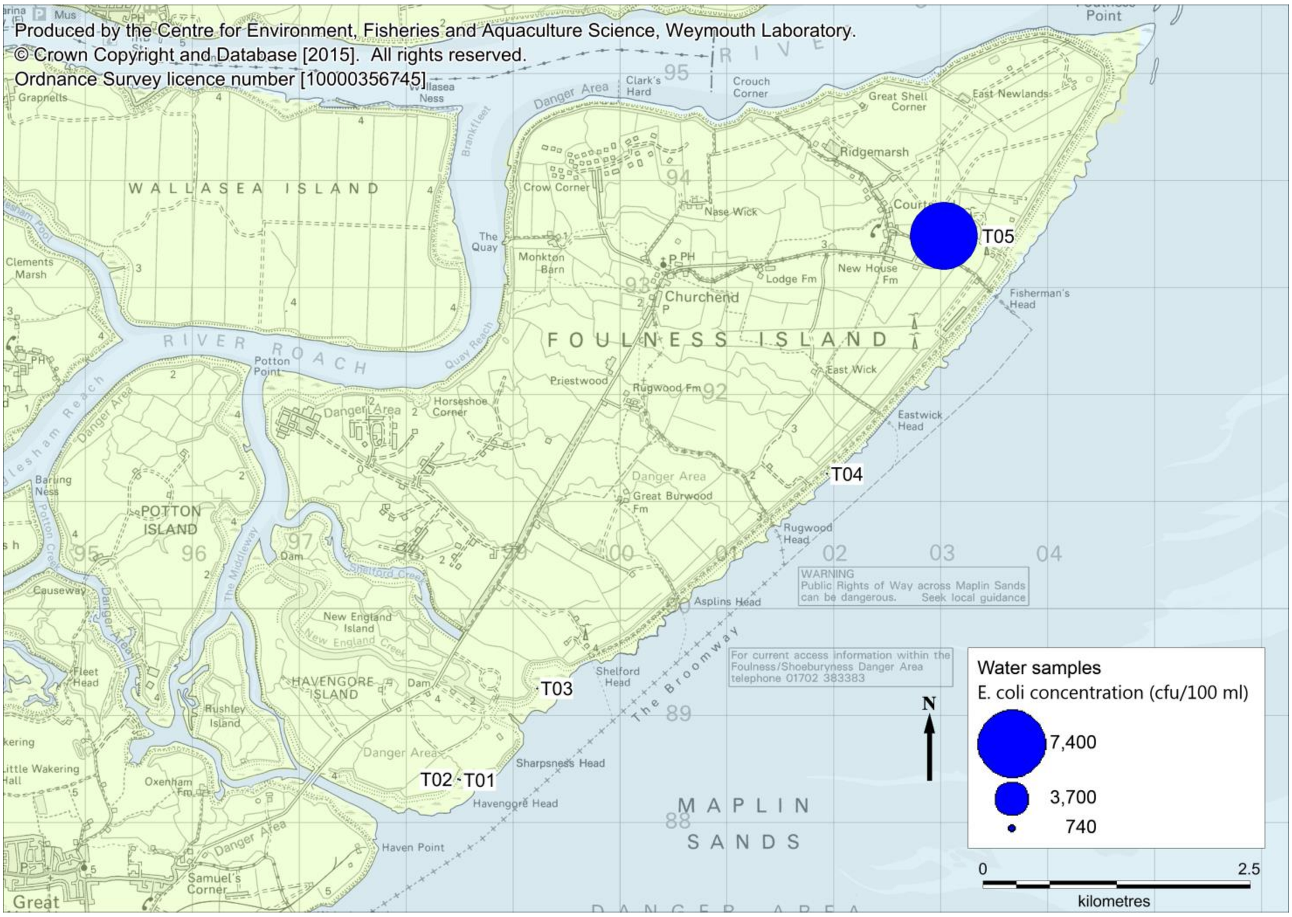

Figure XII.2: Water sample results (Table XII.2 for details).

Table XII.2: Water sample *E. coli* results.

Sample ID	Observation number	Date and time	Description	*E. coli* concentration (cfu/100 ml)	NGR
T01	4	18/08/2014 08:24	Inlet sluice	<10	TQ9850288396
T02	5	18/08/2014 08:44	Inlet sluice	<10	TQ9848488402
T03	7	18/08/2014 09:17	Inlet sluice	10	TQ9922389251
T04	9	18/08/2014 10:20	Sluice	<10	TR0193791258
T05	14	20/08/2014 11:43	Ditch near sewage works	7,400	TR0303093483

Figure XII.3

Figure XII.4

Figure XII.5

Figure XII.6

Figure XII.7

Figure XII.8

Figure XII.9

Figure XII.10

Figure XII.11

Figure XII.12

Figure XII.13

Figure XII.14

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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 Nth 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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