EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Roach and Crouch

2012

Cover photo: Brandy Hole Reach, upper Crouch estuary.

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STATEMENT OF USE: This report provides information from a study of the information available relevant to perform a sanitary survey of bivalve mollusc classification zones in the Roach and Crouch. Its primary purpose is to demonstrate compliance with the requirements for classification of bivalve mollusc production areas, determined in EC Regulation 854/2004 laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption. The Centre for Environment, Fisheries & Aquaculture Science (Cefas) undertook this work on behalf of the Food Standards Agency (FSA).

CONSULTATION:

Consultee	Consultation Date	Response Date
Environment Agency	03/08/2012	16/10/2012
London Port Health Authority	03/08/2012	27/09/2012
Maldon District Council	03/08/2012	Ongoing to 27/11/2012
IFCA	03/08/2012	13/08/2012
Anglian Water	03/08/2012	Ongoing to 12/12/2012

DISSEMINATION: Food Standards Agency, Environment Agency, London Port Health Authority, Maldon District Council, Kent and Essex Inshore Fisheries and Conservation Authority.

The Final Report will also be available via the FSA and Cefas web sites.

RECOMMENDED BIBLIOGRAPHIC REFERENCE: Cefas, 2012. Sanitary survey of the Roach and Crouch. Cefas report on behalf of the Food Standards Agency, to demonstrate compliance with the requirements for classification of bivalve mollusc production areas in England and Wales under of EC Regulation No. 854/2004.

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1. INTRODUCTION

1.1 LEGISLATIVE REQUIREMENT

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

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

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

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

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

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

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

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

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

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

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

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

This report documents the information relevant to undertake a sanitary survey for Pacific oysters (*Crassostrea gigas*), native oysters (*Ostrea edulis*), mussels (*Mytilus* spp.) and American hard clams (*Mercenaria mercenaria*) harvested in the Roach and Crouch estuaries.

1.2 Site Description

Roach and Crouch estuaries

The survey area consists of a relatively large estuary complex draining to the very outer reaches of the Thames estuary. It is mainly surrounded by reclaimed marshes and is constrained throughout by flood defences. As a consequence it is characterised by relatively deep, narrow channels and flanked by limited intertidal areas. The intertidal areas are mainly mud with narrow fringes of saltmarsh. The Crouch is a linear estuary about 24km long, whereas the Roach is shorter (14km) and has numerous tributary creeks and a secondary connection to the outer Thames estuary. Both the Roach and Crouch have supported native oyster fisheries dating back many hundreds of years, but these suffered major declines during the 20th century.

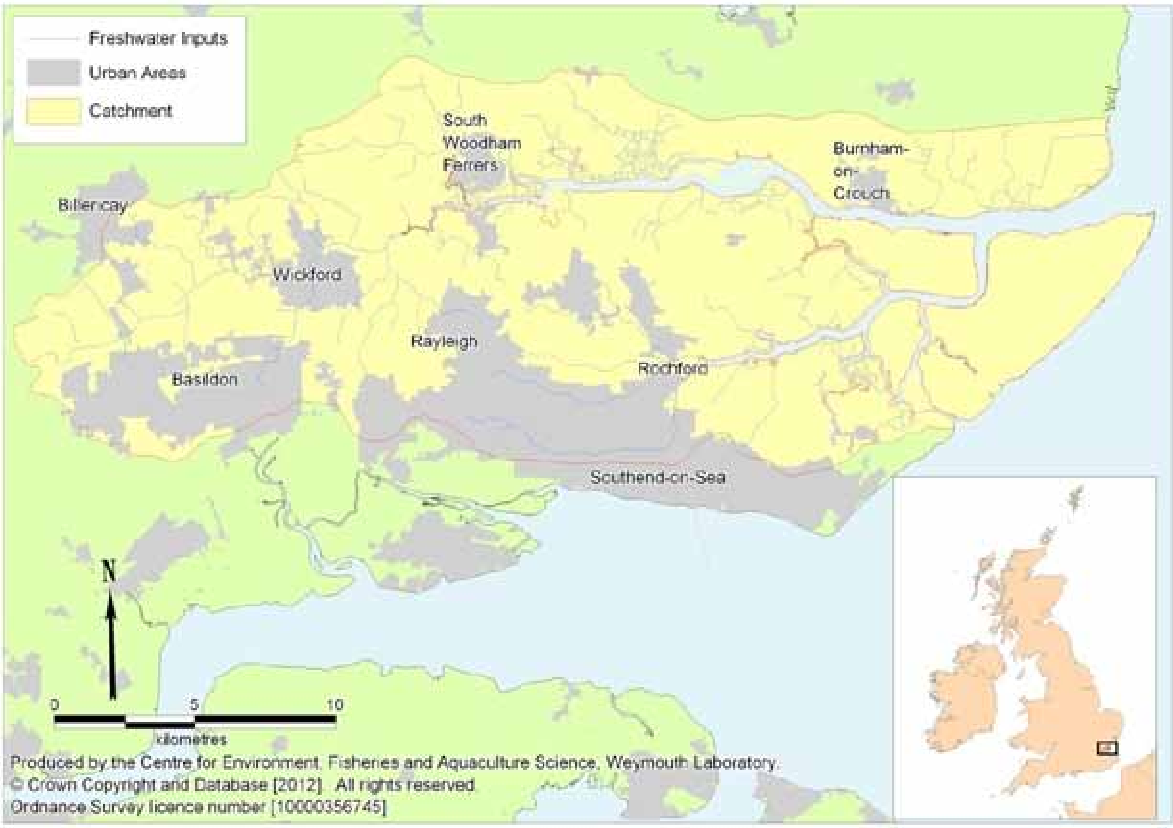

Figure 1.1 Overview of the Roach and Crouch estuary complex.

Catchment

The catchment area draining directly to the estuaries covers about 383km^2 and is predominantly a mixture of farmland (mostly arable with some pasture) and developed areas. Most of the urban areas lie in the south west of the catchment. Towns lie at the head of both estuaries, and their outer reaches are mainly flanked by reclaimed farmland, with the exception of the town of Burnham on the north shore of the Crouch. Soils in south Essex are mainly London Clay (Environment Agency, 2009a) which is relatively impermeable so high rainfall runoff rates are anticipated.

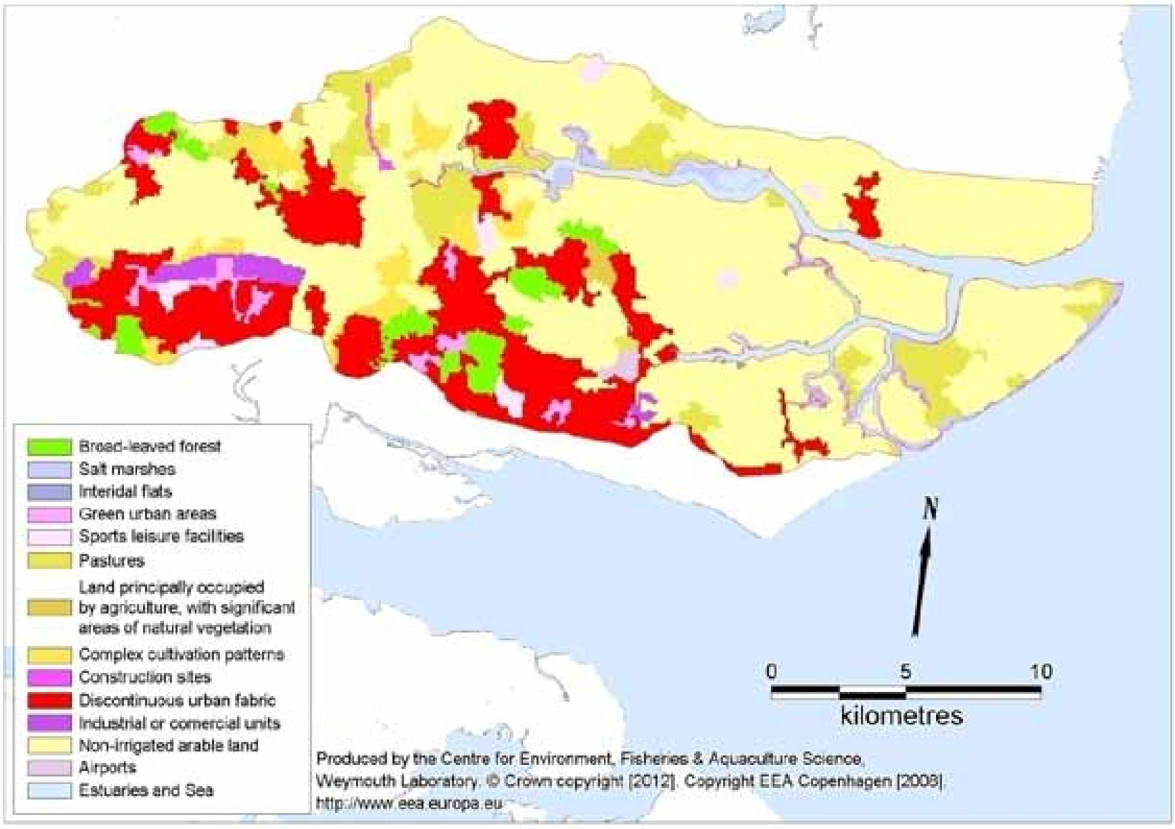

Figure 1.2 Land cover within the Roach and Crouch catchments.

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

2 RECOMMENDATIONS

2.1 The following 11 zones are proposed to reflect broad areas of differing water quality and hydrology throughout the large area requiring classification (Figure 3.1 and 3.2). Table 3.1 identifies RMPs which are required for ongoing classification of the current fisheries. Table 3.2 shows RMPs which may be required on industry request at some point in the future, and these should not be sampled unless classification is formally requested. RMPs are generally located where peak levels of contamination are anticipated within these zones. For two RMPs, the LEA has considered that sampling the point where peak levels of contamination are anticipated by this assessment to be impractical. In these cases, the LEA and competent authority are to note that the RMP sampled may not be best protective of public health. The location of both the RMP preferred on hygiene grounds and the RMP preferred by the LEA for practical purposes are show on Figure 3.1.

- Brandy Hole. Deteriorating water quality is anticipated towards the upper reaches of this zone given the upstream location of significant sewage discharges and freshwater inputs. There are also some intermittent discharges to the south shore within 1km upstream of the area requiring classification. Moorings are also potentially of significance and are present throughout this zone. The zone should not extend as far as the monitoring point which yielded a prohibited result during the bacteriological survey, and the area upstream of this zone should remain unclassified. The RMP should be located on the south shore as close as is practical to the up-estuary boundary of this zone. Although classification has been requested to the upstream boundary indicated in Figure 3.1 (suggesting stock is present) the LEA has indicated that it is only practical for them to sample at TQ 8295 9581, about 580m down from the upstream boundary. This location will be used in the sampling plan, but does not represent the location best protective of public health within this zone. The LEA has indicated the only species available for sampling here is Pacific oysters, so the classification for this zone will be for Pacific oysters only, the only species for which classification has been specifically requested.
- Fambridge. Some deterioration in water quality is anticipated towards the upper reaches of this zone as described for Brandy Hole. The marina at Stow Creek should be excluded. There is a freshwater input to the head of Clementsgreen Creek. Moorings at North Fambridge may also be an influence. An RMP located at the south shore of the mouth of Clementsgreen Creek should capture contamination from up estuary sources which are likely to be the main contaminating influence. Within this zone the LEA intends to sample hard clams and Manila clams, so the ongoing classification for this zone will be for these species only. Classifications for native oysters, pacific oysters and mussels within this zone will lapse in due course.
- Easter Reach. There is little in the way of sources of contamination within this zone, which is likely to be primarily under the influence of up-estuary and down-estuary sources. As the highest individual result was recorded at the up-estuary end of this zone during the bacteriological survey, the RMP should be located here. Within this zone the LEA intends to sample hard clams and Manila clams, so the ongoing classification for this zone will be for these

species only. Classifications for native oysters, pacific oysters and mussels within this zone will lapse in due course

- Althorne. This zone is likely to be similar throughout as there is little in terms of contaminating influences discharging directly to it and it is a sufficient distance from the head of the estuary to be largely outside of the contaminating influences from sources here. Contamination from the Burnham STW and boat traffic here may be an increasing influence in the lower reaches of this zone. The marina at Bridgmarsh should be excluded. There may be a slight elevation in levels of contamination within Bridgmarsh Creek due to its more enclosed shallower nature. On balance it is recommended that the RMP be set within this creek at Althorne to capture contamination from the marina and private sewage discharges to the field drains here. The LEA has indicated that bagged mussels can be sampled here, which will maintain the existing classification for mussels, Pacific and native oysters and hard clams.
- Burnham. The main contaminating influence within this zone is the Burnham STW outfall. Boat moorings are an almost continuous presence throughout this zone and represent a more diffuse source of contamination as well as preventing shellfish dredging. The two main marinas should be excluded from this zone in accordance with Good Practice Guide recommendations. An RMP located at the Burnham STW outfall would capture peak levels of contamination. This zone has not been historically classified, and no applications for classification of any of it have been received. There is therefore little point in the LEA sampling and classifying this zone unless a specific request is made, which is considered unlikely due to the difficulties of dredging within the moorings.
- Outer Crouch. The main contaminating influence is the Burnham STW discharge, although its influence will be much less than in the Burnham zone. Overboard discharges from boats off Burnham may be an additional influence in this zone. The RMP should be set on the up estuary boundary of the zone in such a position to best capture the plume from this discharge (due east of the outfall). However, a trial dredge did not recover any live shellfish here. Although classification has been requested to the upstream as the boundary indicated in Figure 3.1 for hard clams, the LEA has indicated that it is preferable for them to sample native oysters at TR 0010 9540, about 3.3km down from the upstream boundary. This location and species will be used in the sampling plan, but will not represent the location best protective of public health within this zone. It will also result in the preliminary classification for hard clams here lapsing in due course.
- Outer Roach. Within this zone there are small sewage discharges (Paglesham and Foulness STWs) although it is uncertain the exact route that the effluent from the latter takes through the field drains and into the estuary. There are also some moorings off Paglesham, and a possible minor influence from up estuary sources (e.g. inputs to the head of the estuary, Rochford STW). The RMP should therefore be located at Paglesham. The LEA has indicated that bagged mussels can be sampled here, which will allow the classification of mussels, Pacific and native oysters and hard clams.
- Paglesham Pool. This is a side-arm of the Roach channel within which oysters are cultured. There is little in the way of contaminating influences

within this zone, aside from some minor freshwater input at the head. The RMP should therefore be located at the up estuary end of the oyster lay here to best capture contamination from this source. The LEA has indicated the only species available for sampling here is Pacific oysters, so the classification for this zone will be for Pacific oysters only.

- Inner Roach. This is subject to contamination from sources to the head of the estuary (Rayleigh East STW, various intermittent discharges, significant watercourses primarily draining urban areas) as well as the Rochford STW outfall. Effluent from these two sewage works generally carries low concentrations of bacterial indicators, and bacteriological sampling results indicate a major deterioration in water quality in the very upper reaches. Is it therefore recommended that the RMP be located at the up-estuary end of this zone. The LEA has indicated that shellfish stocks do not extend west of Bartonhall Creek, so the upstream boundary of the zone should be located there. The LEA has indicated that bagged mussels can be sampled here, which will allow the classification of mussels, Pacific and native oysters and hard clams.
- Middleway. There is little in the way of contamination sources entering Middleway, Narrow Gut and Potton Creek, which are parallel creeks running between Havengore and the main Roach channel. Shelford Creek branches off the Middleway and receives no significant contaminating sources so can be included in this zone. The marina at the southern end of Potton Creek (which should be excluded from the zone) and the intermittent discharge at Havengore are sources which may create an area of decreased water quality. It is therefore recommended that the RMP be located at the confluence of Potton Creek and the Middleway. The LEA has indicated that bagged mussels can be sampled here, which will allow the classification of mussels, Pacific and native oysters and hard clams.
- Barlinghall Creek. This is a side-arm of Potton Creek within which oysters are cultured. Within this zone there is an area of moorings at Barling Hall and some minor freshwater inputs to the head of this creek. An RMP located within these moorings, and just upstream of the oyster lay here should capture contamination from both these sources. The LEA has indicated that bagged mussels can be sampled here, which will allow the classification of mussels, Pacific and native oysters and hard clams.

2.2. Use of bagged mussels. Native oysters, Pacific oysters, mussels and hard clams may all be classified based on mussel sampling results. Cockles and Manila clams accumulate *E. coli* to higher levels and so cannot be classified on the basis of mussel sampling results. Bagged mussels will be needed in the absence of accessible mussel stocks at the RMP locations. These must be of market size and allowed to equilibrate *in situ* for at least 2 weeks before sampling. They should be deployed on the river bed to best represent the location of shellfish stocks throughout the estuary. Stock should be of a market size. A tolerance of Sampling should be undertaken on a monthly basis to maintain a year round classification. A tolerance of 10m around the RMP locations is recommended.

2.3 Sampling of wild species. Native oysters, Pacific oysters and hard clams will all need sampling within each zone where they need classification, unless mussels are sampled. If mussels are not sampled within a zone and a classification request for this species is received they will also require sampling (but may be used as a surrogate for some other species, see 2.2). Cockles and Manila clams require sampling if they are to be classified. Where wild species are sampled, a tolerance of 100m should be applied, and the sample collection method should be the same as the harvest method. Stock should be of a market size. Sampling should be on a monthly basis. It is recognised that it may not be possible to sample the exact locations identified as stock may not be present. Should this situation arise samples should be taken as close as possible to the recommended locations. The location sampled should be recorded by GPS to 10m accuracy and this location should be recorded on the sample submission form and communicated to the classification team at CEFAS.

3. SAMPLING PLAN

General Information

Location Reference

Production Area	Roach and Crouch
Cefas Main Site Reference	M073 and M015
Cefas Area Reference	Roach and Crouch
Ordnance survey 1:25,000 map	Explorer 176
Admiralty Chart	3750

Shellfishery

Species/culture	Native oysters (*Ostrea edulis*)	Wild & cultured
	Pacific oysters (*Crassostrea gigas*)	Wild & cultured
	Hard clams (*Mercenaria mercenaria*)	Wild & cultured
	Mussels (*Mytilus* spp.)	Wild & cultured
	Manila clams (*Tapes philippinarum*)	Wild
	Cockles (*Cerastoderma edule*)	Wild
Seasonality of harvest	Closed season from 1st May to 31st August (native oysters only) although this fishery is currently closed for stock preservation reasons.	

Local Enforcement Authorities

Name	London Port Health Authority, Thamesport & Lower River Division Quarantine Station, Denton, Nr. Gravesend, Kent DA12 2QE
Environmental Health Officer	Keith Wilson
Telephone number (	01474 363033
Fax number Ê	01474 353354
E-mail š	Keith.Wilson@cityoflondon.gov.uk
Area covered	Roach Estuary
Name	Maldon District Council Princes Road Maldon Essex CM9 5DL
Environmental Health Officer	Malcolm Sach
Telephone number (	01621 875830
Fax number Ê	01621 875899
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Area covered	Crouch Estuary

REQUIREMENT FOR REVIEW

The Guide to Good Practice for the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2010) indicates that sanitary assessments should be fully reviewed every 6 years, so this assessment is due a formal review in 2018. 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 within the Roach and Crouch estuary for ongoing/immediate classification.

Classification zone	RMP code	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Sampling method	Tolerance	Frequency	Comment
Brandy Hole	B015T	Brandy Hole	TQ 8295 9581	51° 37.881' N 00° 38.522' E	Pacific oysters	Dredge or Hand (Maldon DC)	100m	Monthly	Represents Pacific oysters only.
Fambridge	B015U	Clementsgreen Creek	TQ 8326 9644	51° 38.214' N 00° 38.810' E	Hard clams	Dredge (Maldon DC)	100m	Monthly	Represents hard clams only
Fambridge	B015V	Clementsgreen Creek	TQ 8326 9644	51° 38.214' N 00° 38.810' E	Manila clams	Dredge (Maldon DC)	100m	Monthly	Represents Manila clams only
Easter Reach	B015W	Purleigh Shawl	TQ 8645 9657	51° 38.222' N 00° 41.577' E	Hard clams	Dredge (Maldon DC)	100m	Monthly	Represents hard clams only
Easter Reach	B015X	Purleigh Shawl	TQ 8645 9657	51° 38.222' N 00° 41.577' E	Manila clams	Dredge (Maldon DC)	100m	Monthly	Represents Manila clams only
Bridgmarsh	B015Y	Althorne	TQ 9042 9738	51° 38.578' N 00° 45.041' E	Mussels	Hand (bagged) (Maldon DC)	10m	Monthly	Represents mussels, hard clams, Pacific and native oysters
Burnham	TBA*	Burnham STW outfall	TQ 9581 9528	51° 37.336' N 00° 49.639' E	Any required	Various	100m for dredge samples, 10m if bagged mussels used	Monthly	If classification is required for this area, the species sampled is to be the species harvested. Alternatively bagged mussels may be used to represent mussels, Pacific oysters, native oysters and hard clams.
Outer Crouch	B015B	Outer Crouch	TR 0010 9540	51° 37.310' N 00° 53.356' E	Native oysters	Dredge	100m	Monthly	Represents native oysters only in Outer Crouch
Outer Roach	B73AA	Paglesham	TQ 9490 9207	51° 35.625' N 00° 48.743' E	Mussels	Hand (bagged) (London PH)	10m	Monthly	Represents mussels, hard clams, Pacific and native oysters

Classification zone	RMP code*	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Sampling method	Tolerance	Frequency	Comment
Inner Roach	B73AB	Barton Hall	TQ 9140 9057	51° 34.889' N 00° 45.667' E	Mussels	Hand (bagged) (London PH)	10m	Monthly	Represents mussels, hard clams, Pacific and native oysters
Paglesham Pool	B73AC	Paglesham Pool	TQ 9418 9381	51° 36.578' N 00° 48.179' E	Pacific oysters	Hand (London PH)	10m	Monthly	Represents Pacific oysters only
Barlinghall Creek	B73AD	Barling Hall	TQ 9375 8991	51° 34.485' N 00° 47.678' E	Mussels	Hand (bagged) (London PH)	10m	Monthly	Represents mussels, hard clams, Pacific and native oysters
Middleway	B73AE	Rushey Island	TQ 9589 8888	51° 33.886' N 00° 49.494' E	Mussels	Hand (bagged) (London PH)	10m	Monthly	Represents mussels, hard clams, Pacific and native oysters

*RMP code will not be generated on the database until required.

Table 3.2 Number and location of representative monitoring points (RMPs) and frequency of sampling for classification zones within the Roach and Crouch estuary for any unclassified species, to be applied on request only.

Classification zone	RMP code*	RMP name	NGR	Latitude & Longitude (WGS84)	Additional species potentially required	Sampling method	Tolerance	Frequency	Comment
Brandy Hole	TBA	Recommended Brandy Hole	TQ 8238 9582	51° 37.897' N 00° 38.028' E	Mussels, native oysters, hard clams, Manila clams, cockles	As per harvest method	100m	Monthly	-
Fambridge	TBA	Clementsgreen Creek	TQ 8326 9644	51° 38.214' N 00° 38.810' E	Mussels, native oysters, Pacific oysters, cockles	As per harvest method	100m	Monthly	-
Easter Reach	TBA	Purleigh Shawl	TQ 8645 9657	51° 38.222' N 00° 41.577' E	Mussels, native oysters, Pacific oysters, cockles	As per harvest method	100m	Monthly	-
Bridgmarsh	TBA	Althorne	TQ 9042 9738	51° 38.578' N 00° 45.041' E	Manila clams, cockles	As per harvest method	100m	Monthly	-
Burnham	TBA	Burnham STW outfall	TQ 9581 9528	51° 37.336' N 00° 49.639' E	Mussels, native oysters, Pacific oysters, hard clams, Manila clams, cockles	As per harvest method	100m	Monthly	Unlikely that classification will be required for any species within this zone - dredging impractical due to moorings.
Outer Crouch	TBA	Recommended Outer Crouch	TQ 9690 9527	51° 37.308' N 00° 50.582' E	Mussels, Pacific oysters, hard clams, Manila clams, cockles	As per harvest method	100m	Monthly	-
Outer Roach	TBA	Paglesham	TQ 9490 9207	51° 35.625' N 00° 48.743' E	Manila clams, cockles	As per harvest method	100m	Monthly	-
Inner Roach	TBA	Barton Hall	TQ 9140 9057	51° 34.889' N 00° 45.667' E	Manila clams, cockles	As per harvest method	100m	Monthly	-

Classification zone	RMP code*	RMP name	NGR	Latitude & Longitude (WGS84)	Additional species potentially required	Sampling method	Tolerance	Frequency	Comment
Paglesham Pool	TBA	Paglesham Pool	TQ 9418 9381	51° 36.578’ N 00° 48.179’ E	Mussels, native oysters, hard clams, Manila clams, cockles	As per harvest method	100m	Monthly	-
Barlinghall Creek	TBA	Barling Hall	TQ 9375 8991	51° 34.485’ N 00° 47.678’ E	Manila clams, cockles	As per harvest method	100m	Monthly	-
Middleway	TBA	Rushey Island	TQ 9589 8888	51° 33.886’ N 00° 49.494’ E	Manila clams, cockles	As per harvest method	100m	Monthly	-

*RMP code will not be generated on the database until required.

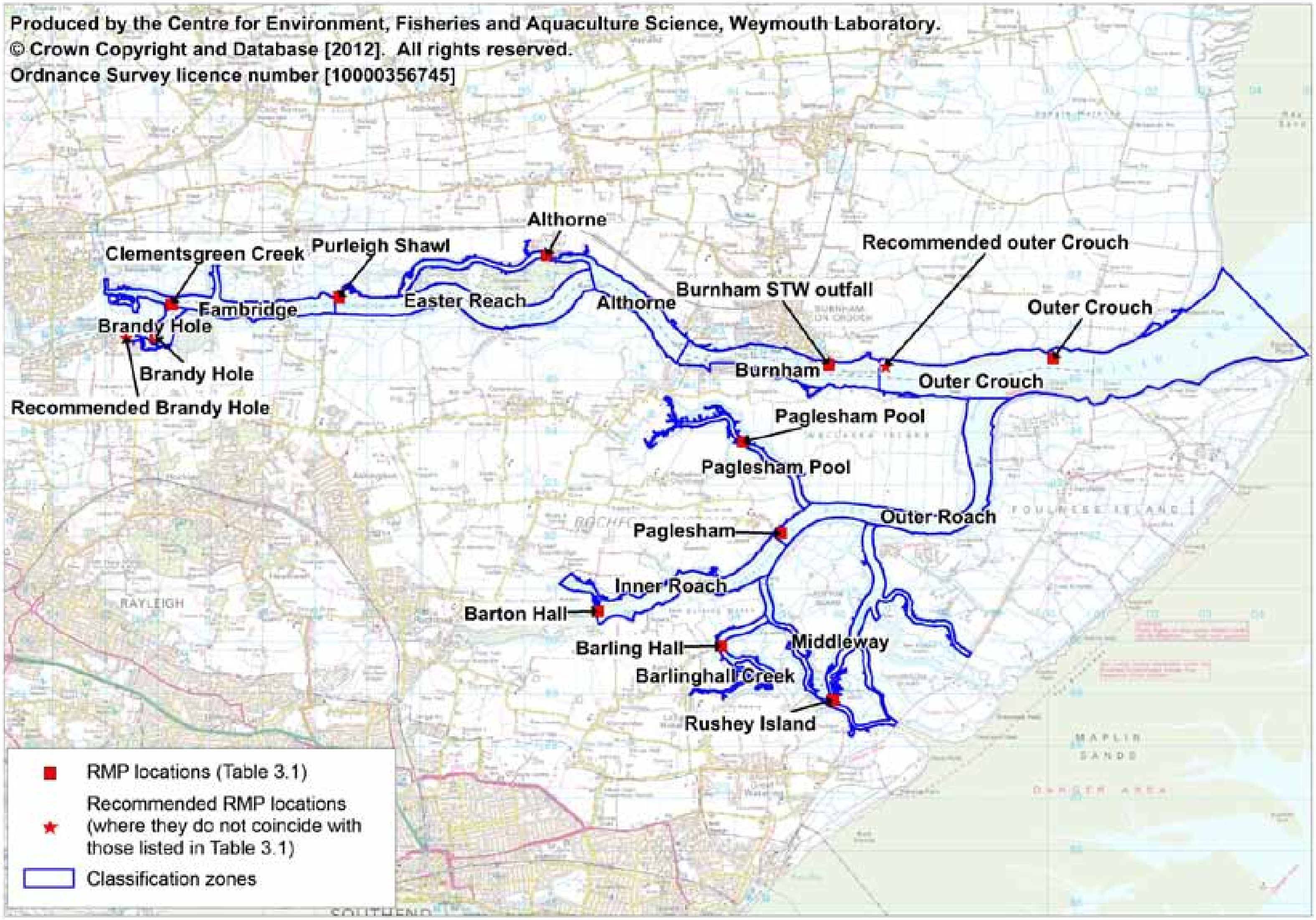


Figure 3.1 Recommended classification zone boundaries and RMP locations for all species.

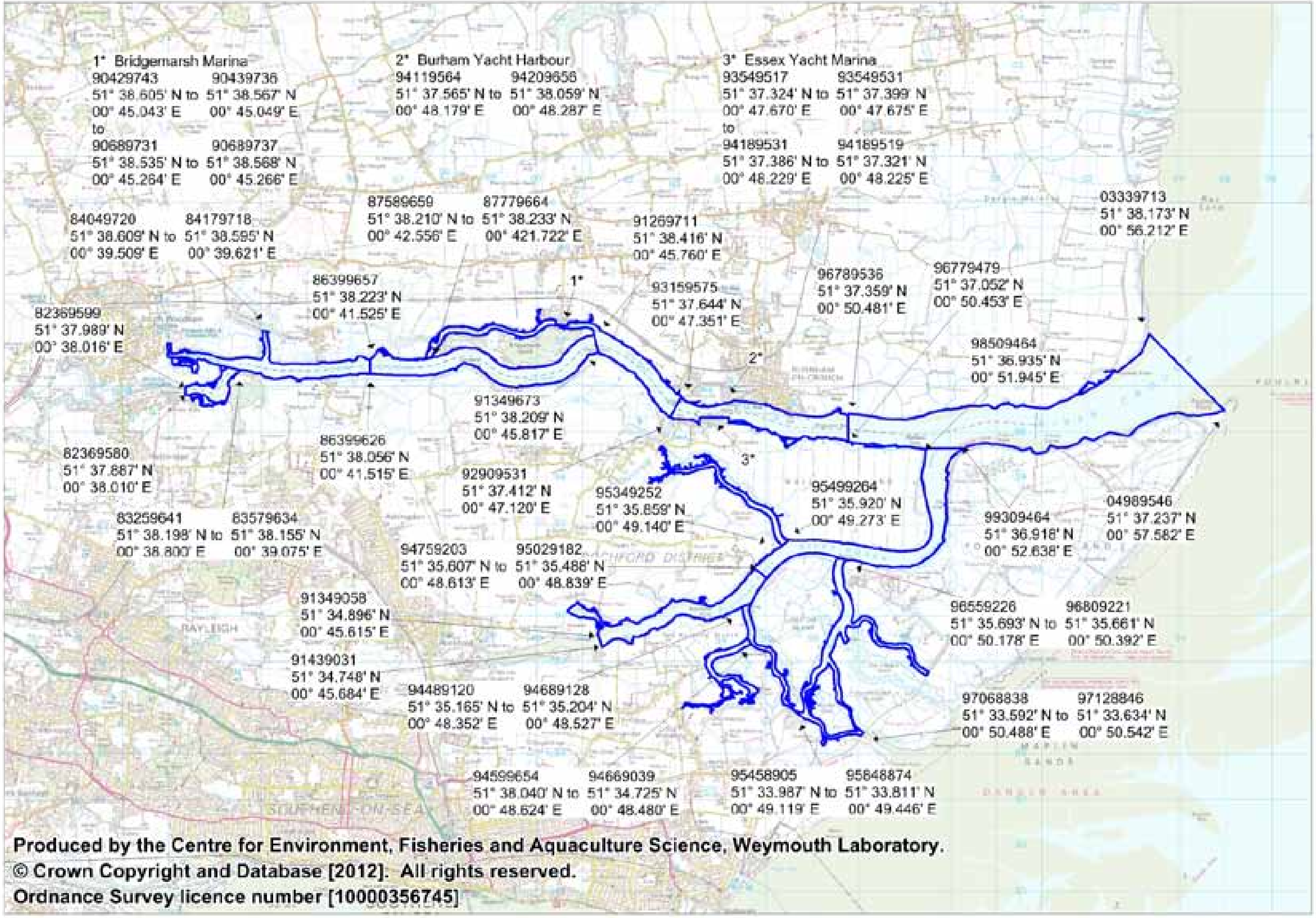


Figure 3.2 Recommended classification zone boundaries and coordinates for all species.

4. SHELLFISHERIES

4.1 SPECIES, LOCATION AND EXTENT

This sanitary survey was prompted by applications for classification of hard clams in the Roach, and subsequently for hard clams, Pacific and native oysters at various locations within the Crouch. Other stocks of current commercial interest include mussels in the Crouch and Roach, and Pacific and native oysters in the Roach. Most stocks are naturally occurring, but some mussels are relaid stocks and there are some places where one or both species of oysters are cultured. The information presented here has been primarily obtained from shellfish bed locations held at Cefas, discussions with the Kent and Essex Inshore Fisheries and Conservation Authority (K&E IFCA) and some anecdotal information from local fishermen.

NATIVE OYSTERS

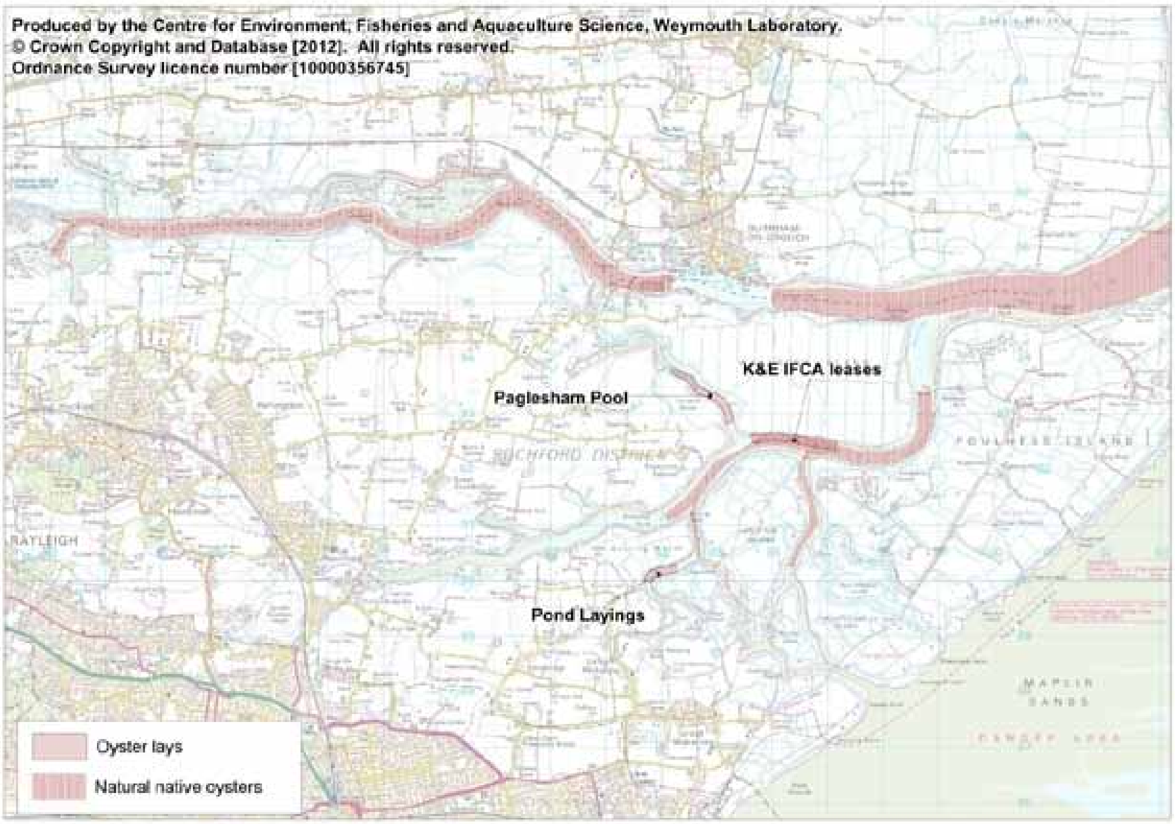


Figure 4.1 Native oyster fisheries

Wild stocks of native oysters are present throughout the subtidal areas of the Roach and Crouch. Stock levels declined significantly during the mid 20th century, and numbers are so low now that commercial fishing of these is generally considered unviable. They have been subject to an occasional dredge fishery in recent years, but this has recently been closed for at least a year to aid stock recovery. The Roach has been renowned for good spatfalls of this species as the pattern of tidal circulation tends to trap spat within this estuary. Native oysters are also ongrown at culture sites within the Roach. There are a series of lays (a mixture of trestles and ground lays) on the south shore of Wallasea Island which are leased by the Kent &

Essex IFCA to several harvesters where native oysters are ongrown. Within Barling Creek there is another oyster lay (Pond Layings). A section of the Paglesham Pool is leased to a harvester by Wallasea Farm and although native oysters are not currently cultured here, a sampling plan should be provided to cover this area in case it is required in the future. Finally, native oysters are thought to have been laid fairly recently on private grounds somewhere in the upper Roach between The Violet and Bartonhall Creek although the exact location is unclear so it is not shown on Figure 4.1. Applications have been received to extend the classification of this species throughout areas of the upper Crouch. Due to their wide distribution and the possibility of ongrowing this species on any of the private grounds dotted throughout it is concluded that classification of this species should be extended to encompass the entire estuary complex.

PACIFIC OYSTERS

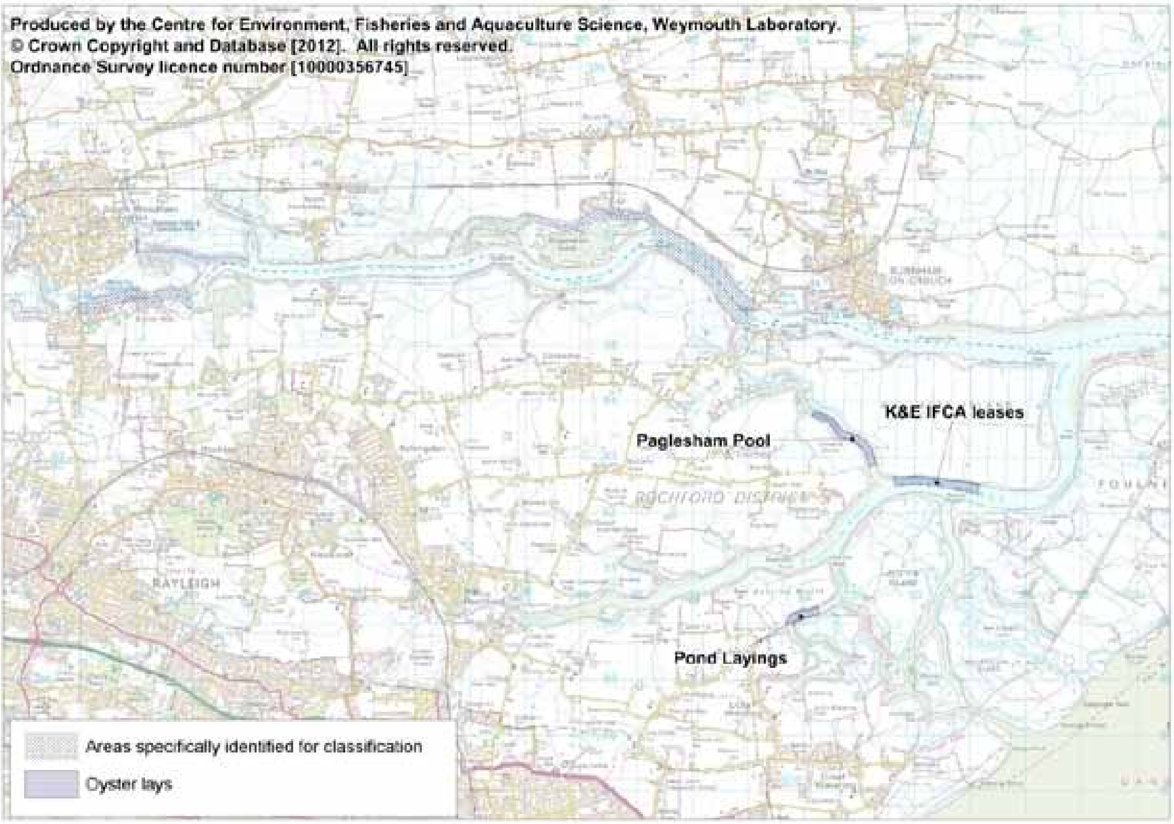


Figure 4.2 Pacific oyster fisheries

Pacific oysters are cultured within the Roach estuary, but not the Crouch. They are grown alongside native oysters on the Kent and Essex IFCA lays on the south shore of Wallasea Island and in Paglesham Pool, but not at Barlinghall Creek (Pond Layings). A sampling plan should perhaps be provided for the latter in case a classification is required in the future.

Naturally occurring Pacific oysters have become more frequent in the outer Thames estuary and within Essex estuaries in recent years, to the extent that reef formation has occurred (e.g. Natural England, 2009). The temperature regime within the Crouch (and presumably the Roach) is thought to be sufficiently warm for successful spatfalls to occur on an annual basis (Syvret *et al*, 2008). The exact distribution of naturally occurring stock is uncertain as they have not been subject to a recent stock survey, although it is known that hand gatherers are interested in intertidal stocks within the Brandy Hole Reach in the upper Crouch (London Port Health Authority, pers comm.). Kent and Essex IFCA report that this species has been found in dredge catches from the subtidal within the main Roach channel. Specific applications to classify this species within the Crouch have been received from Cliff Reach through to Clementsgreen Creek so most commercial interest appears to be focussed on the upper Crouch. Spatfalls of Pacific oysters have been reported at the Wallasea Island managed realignment site on the south shore of the Crouch just to the east of Burnham (Scott, 2011). It is likely that they are present throughout the estuary where there are suitable substrates for settlement although this is likely to be limited somewhat by the predominance of soft mud substrates in the intertidal zone at least. It is likely that they will be caught as bycatch in the dredge fisheries, so it is concluded that Pacific oysters should be classified throughout the entire estuary complex.

MUSSELS

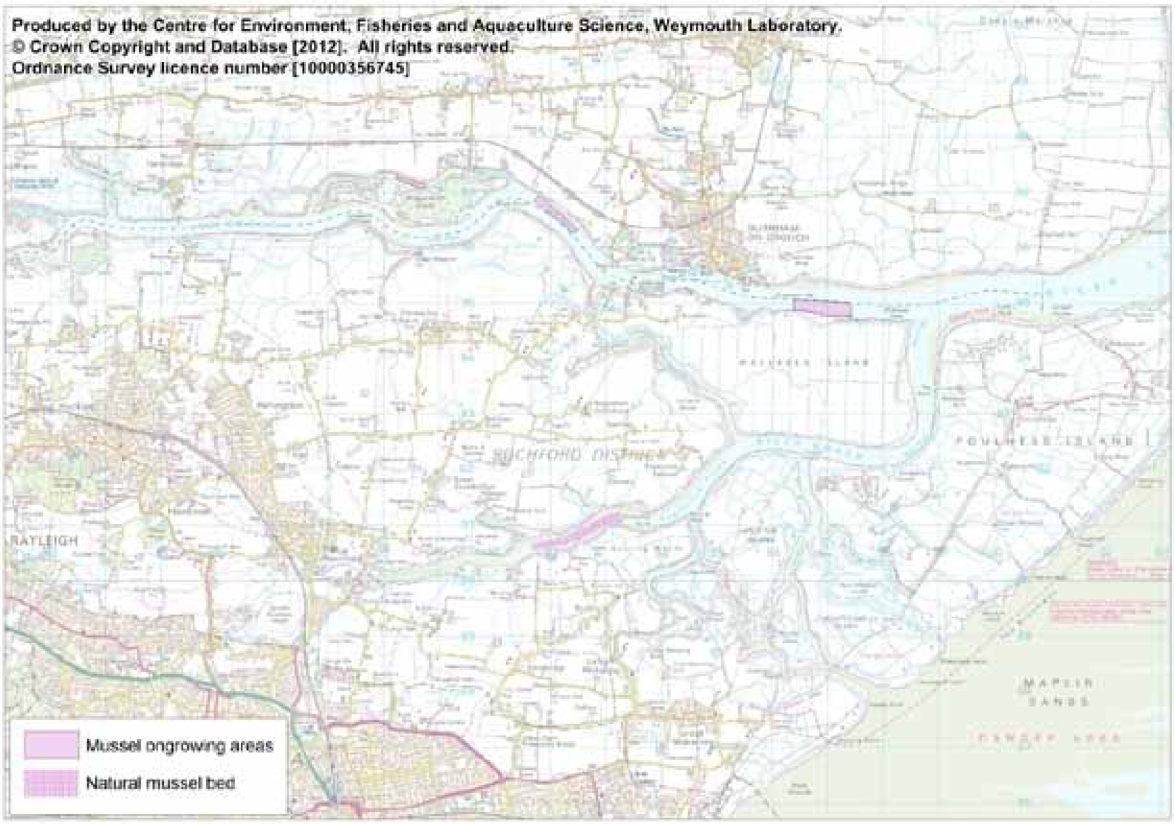


Figure 4.3 Mussel fisheries

There are wild stocks of mussels between Blackledge Point and Bartonhall Creek, but these are of low marketability and are not of specific commercial interest at present, although interest may be renewed in the future. Relaid mussels have historically been ongrown in three areas within the Crouch, one of which (just north of Wallasea Island) is not currently classified. The status of these sites at present is uncertain but it is not thought that any seed has been deposited in recent years. It is likely that there are other patches of naturally occurring mussels in suitable areas. For example, mussel settlement was reported at the Wallasea Island managed realignment site (Scott, 2011).

HARD CLAMS

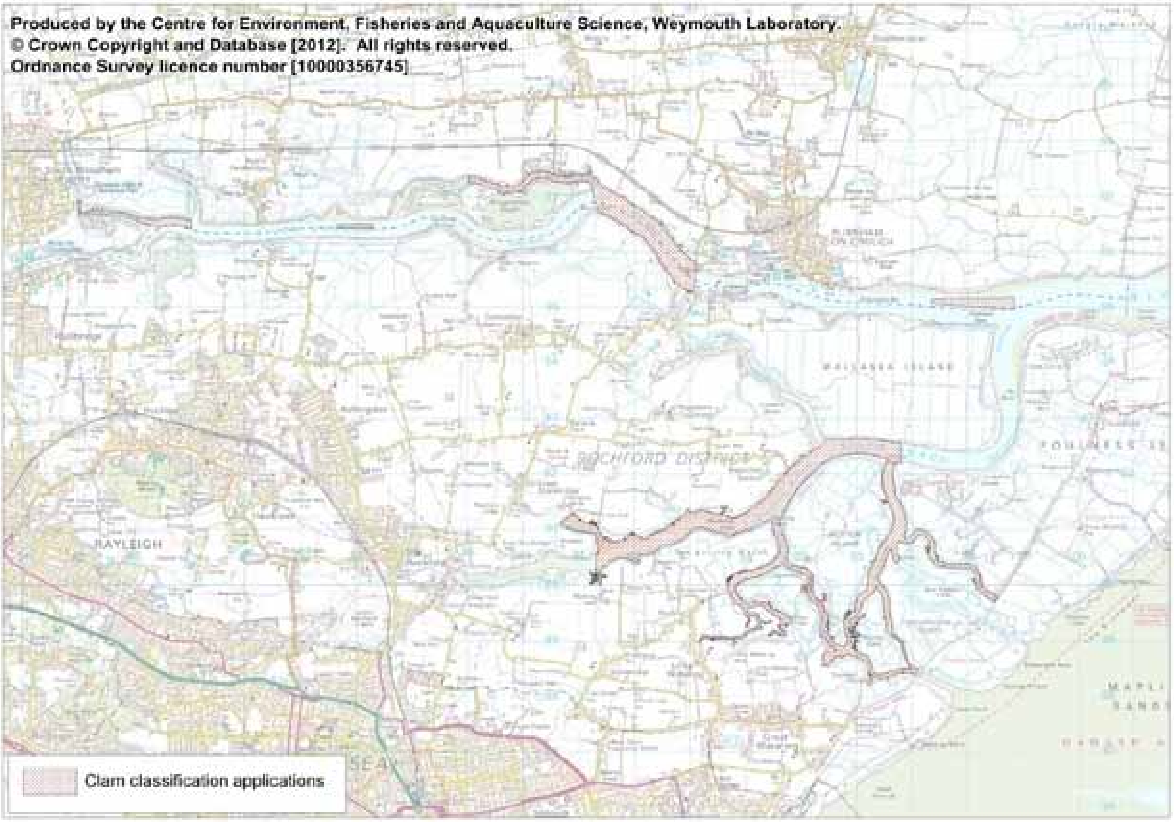


Figure 4.4 Specific areas where hard clam classification applications have been received

Hard clams were introduced to the Crouch and Roach estuary complex through the relocation of specimens from Southampton Water some decades ago (Purleigh Shawl Shellfish, pers comm.). They appear to have proliferated relatively unnoticed until recently but now there is considerable commercial interest mainly driven by a lucrative export market. They burrow up to 10cm into the substrate in subtidal and intertidal areas and are subject to a dredge fishery, but can also be hand dug from the intertidal zone. Before the dredge fishery emerged, a fishery for this species was established at the Pond Layings site in Barlinghall Creek, which was first classified in 2000. Total stock biomass is uncertain but may be quite large, possibly in the order of hundreds of tonnes.

Applications for classification of this species have been received for areas throughout the Crouch and for most of the Roach. Further expressions of interest and applications for undefined areas for this species in the upper Crouch have also been made. The geographical extent and size of stocks is uncertain but they are thought to be present throughout almost the entire estuary complex. Therefore the sampling plan for this species should cover the same geographic area as those for Pacific and native oysters.

Manila clams

Manila clams are thought to be present throughout the estuary, and have been observed amongst dredge catches of hard clams at the Kent and Essex IFCA lays on the south shore of Wallasea Island, Purleigh Shawl, and in the vicinity of Burnham. They were less frequent than hard clams but still caught in potentially marketable numbers (Kent and Essex IFCA, pers comm.). Although no interest in the classification of this species has been expressed by either fishermen or the LEAs, such a classification would allow bycatch of this species to be marketed.

Cockles

Cockles are thought to be present in some areas of the estuary, and have also been observed amongst dredge catches of hard clams, but their occurrence is thought to be more patchy (Kent and Essex IFCA, pers comm.). Some interest was expressed to London Port Health in harvesting a patch of cockles on private grounds in the vicinity of Blackledge in February 2012, but this was not followed up with an application for classification or a map showing the exact location.

4.2 Growing methods and harvesting techniques

Wild native oysters were subject to a dredge fishery, but this is now temporarily closed. They are also ongrown on trestles and on ground lays in some areas within the Roach. Pacific oysters are cultured alongside native oysters at some of these culture sites, and are also of interest to hand gatherers where there are intertidal stocks present. It is likely that they are also taken as bycatch in the dredge fishery. Mussels are ongrown from seed stocks relaid on the substrate within a few defined subtidal areas in the Crouch. Wild stocks have also been subject to a dredge fishery at Blackledge. Naturally occurring hard clams are subject to a dredge fishery which requires a toothed dredge to extract them due to their burrowing habits. They may also be collected by hand digging in the intertidal. Naturally occurring Manila clams and cockles feature as bycatch in the hard clam dredge fishery, but are not thought to be subject to a specific targeted fishery at present.

4.3 Seasonality of harvest, conservation controls and development potential

Native oysters

There is a closed season for native oysters which runs from May to August inclusive. A minimum landing size of 70mm applies to this species. A maximum width of dredge (or dredges) of 4m applies. Oyster dredging within the estuary complex has recently been closed for at least one year to aid stock recovery. When the fishery is re-opened it will likely be subject to additional management measures to help sustain any recovery. Major changes in the spatial distribution of these stocks are not anticipated in the immediate future. Whilst the removal of fishing pressure may result in some recovery of these stocks, the spread of the Pacific oyster is viewed as a threat.

Pacific oysters

There are no specific conservation controls applying to Pacific oysters such as a closed season or minimum landing size. Harvesting may occur at any time of the year. Pacific oyster stocks have become more numerous and widespread in recent years in the south east of England, and it is likely that their expansion will continue on the whole, although some areas may be cleared through exploitation. There is increased demand for such oysters for relaying and ongrowing in France, where juvenile oysters have suffered high levels of mortalities due to oyster herpes virus. It is therefore likely that the volume of naturally occurring Pacific oysters harvested from the estuary complex will increase on the whole.

MUSSELS

There is no closed season for mussels. There is a maximum dredge front opening size of 2m for vessels fishing for mussels. A maximum of 13.6 m^3 of mussels may be retained per vessel per day. No more than 10% by weight of a representative sample of the catch can pass through a space 18mm in width. Any fishing for seed mussels requires prior written authorisation from the Kent and Essex IFCA.

Currently there is no commercial interest in wild mussel stocks within the Roach and Crouch, although it is possible that beds of commercial interest may be discovered at any time. It is thought that no seed has been deposited in recent years on the private grounds where they have been previously ongrown, although this is difficult to confirm. It is likely that there is some remnant stock within these areas and quite probable that fresh deposits of seed will be made at some point.

HARD CLAMS

There is no closed season for this species, but a minimum size of 5cm applies within the district. At present hard clam stocks appear to be sufficient to support a lucrative fishery. An increase in the area classified for this species is likely to result in increased levels of exploitation. Aside from a marked commercial interest suggesting fishing of this species is very viable, there is no solid information on the status of these stocks. Therefore the biomass, stock structure, recruitment dynamics and hence the levels of fishing effort it can withstand are unknown. Southampton Water supported a very productive fishery for hard clams in the late 1970s and early 1980s, but a combination of poor recruitment and overfishing has left the stock much reduced and it is now only occasionally exploited (Walmsley and Pawson, 2007). It is quite possible a similar situation could arise within the Roach and Crouch, which may result in a renewed interest in culturing this species in the future.

MANILA CLAMS

There is no closed season or minimum size for this species. There is little solid information on the status of Manila clam stocks within the estuary complex, so it is difficult to predict how this fishery may or may not develop in the future. It is likely that they will continue to feature as bycatch in the hard clam fishery, in some areas at least.

COCKLES

K&E IFCA Byelaws apply to cockle fishing on any public grounds within the estuary complex. These indicate a maximum vessel size (14m) and specify permissible dredge configurations, including a minimum bar spacing of 16mm. The fishery is open to any suitable boats but a permit and prior approval of the vessel and gear via an annual inspection is required. A maximum of 13.6 m^3 of cockles may be retained per vessel per day. Hand gatherers using rakes also require a permit. No more than 10% by weight of a representative sample of the catch can pass through a space 16mm in width. The fishery is only opened at the discretion of the K&E IFCA, based on stock status and other considerations. It was not opened in either 2010 or 2011 to prevent boats from other areas affected by unexplained cockle mortalities from fishing the area and potentially importing diseases. When the fishery does open, it is within the June to November (inclusive) window at which point meat yields are best, most typically during the latter half of this period. These restrictions do not apply to private grounds so from these areas harvesting may occur at any time of the year. There is little information on the status of cockle stocks within the estuary, although there are believed to be several patches where they occur. They are reported to feature as bycatch in the hard clam fishery although not in great numbers. It is possible that cockles may be specifically targeted in some places in the future.

4.4 Ownership of the river bed and fishing rights

The river bed has various owners and leasers. The Crouch Harbour Authority owns much of the Crouch and a few small areas of Roach. Other areas are owned by the Crown Estate and by private landowners. In turn, various parts are leased out by their owners (Crouch and Roach Estuary Project, 2005). No comprehensive register of fishing rights is available, and it is beyond the scope of the sanitary survey to attempt to map out current ownership of fishing rights. No marker buoys delineating private areas were seen during the shoreline surveys.

4.5 HYGIENE CLASSIFICATION

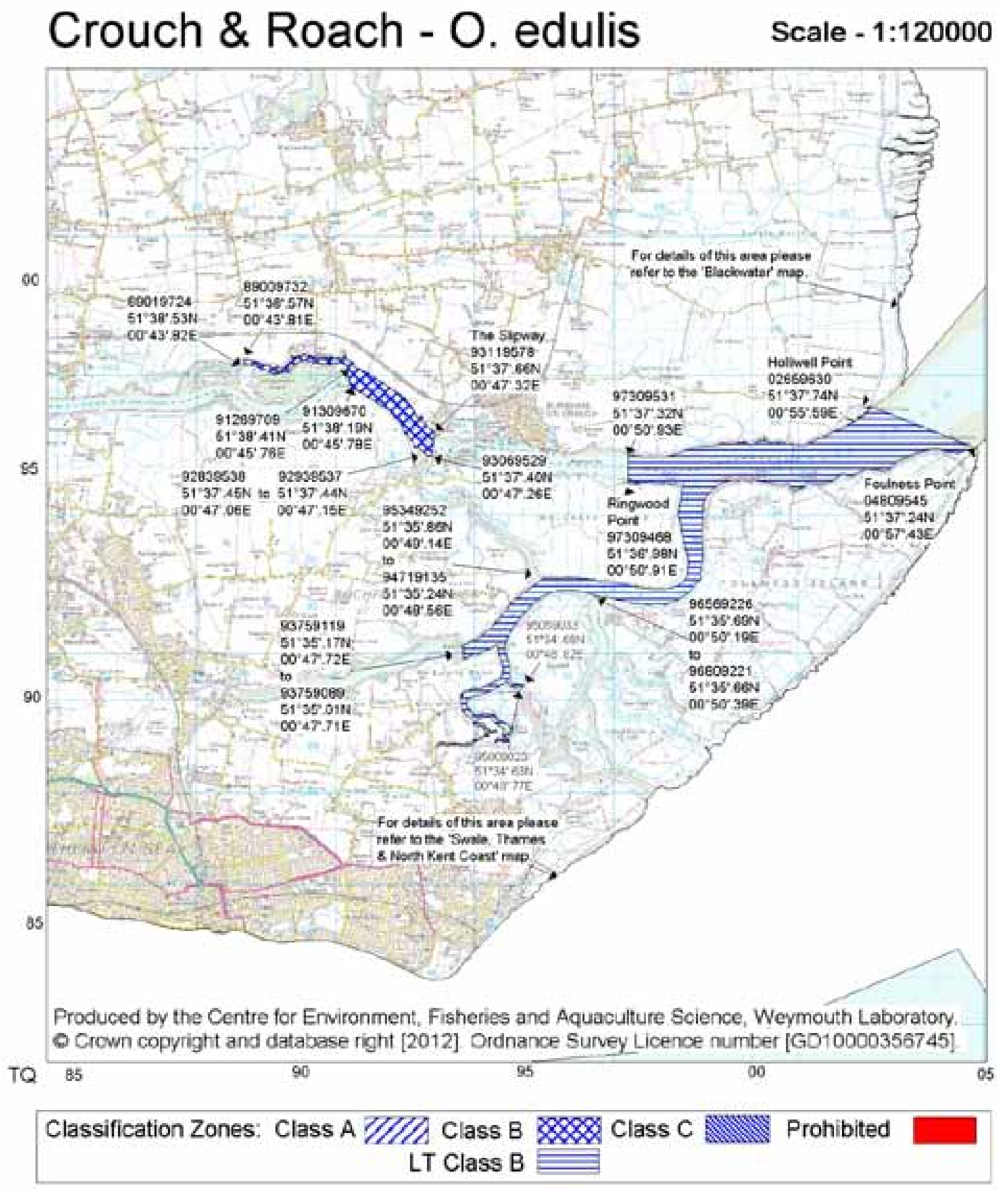
Table 4.1 lists all classifications within the survey area from 2004 onwards.

Table 4.1 Classification history for the Roach and Crouch 2004 onwards

River	Area	Species	2004	2005	2006	2007	2008	2009	2010	2011
Crouch	Althorne Creek	N. oyster	B	-	-	-	-	-	-	-
	Purleigh Shawl	N. oyster	B	-	-	-	-	-	-	-
	Outer Crouch[1]	N. oyster	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
	Cliff Reach[2]	Mussel	-	B	B	B	B	B	B-LT	B-LT
	Althorne Creek[2]	Mussel	-	B	B	B	B	B	B-LT	B-LT
Roach	Paglesham Pool	P. oyster	A	A	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
	Paglesham Pool	Manila clam	B	B-LT	B-LT	-	-	-	-	-
	Paglesham Reach	N. oyster	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
	Paglesham Reach	P. oyster	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
	Middleway	P. oyster	B	-	-	-	-	-	-	-
	Dunhopes	N. oyster	B	-	-	-	-	-	-	-
	Dunhopes	Mussels	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
	Blackledge	Mussels	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
	Blackledge	Hard clam	-	-	-	-	-	-	-	B(P)
	Pond Lays	N. oyster	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
	Pond Lays	Hard clam	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT

LT denotes long term classification
P denotes preliminary classification
[1] Preliminary classification also awarded for part of this zone (Winkle Bay) for hard clams in January 2012
[2] Preliminary classification also awarded for this zone for hard clams and Pacific oysters in January 2012

All classifications within the Roach and Crouch are B at present, although in 2004 and 2005 Paglesham Pool was classified as an A. Current classification zone boundaries for native oysters, Pacific oysters, mussels, and hard clams are shown in Figures 4.5 to 4.8 respectively. Manila clams are no longer cultured at Paglesham Pool and the classification for this species lapsed in 2007. Preliminary classifications were recently awarded at Blackledge (hard clams), Cliff Reach and Althorne Creek (Pacific oysters and hard clams) and at Winkle Bay, part of the Outer Crouch zone (Hard clams) on the basis of existing monitoring results from suitably representative RMPs. Although preliminary classifications for hard clams were requested for areas further upstream of the currently classified areas it was not possible to issue these due to a lack of suitably representative recent shellfish flesh monitoring data. There have been no cockle classifications in recent years.



Classification of Bivalve Mollusc Production Areas: Effective from 17 January 2012

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

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

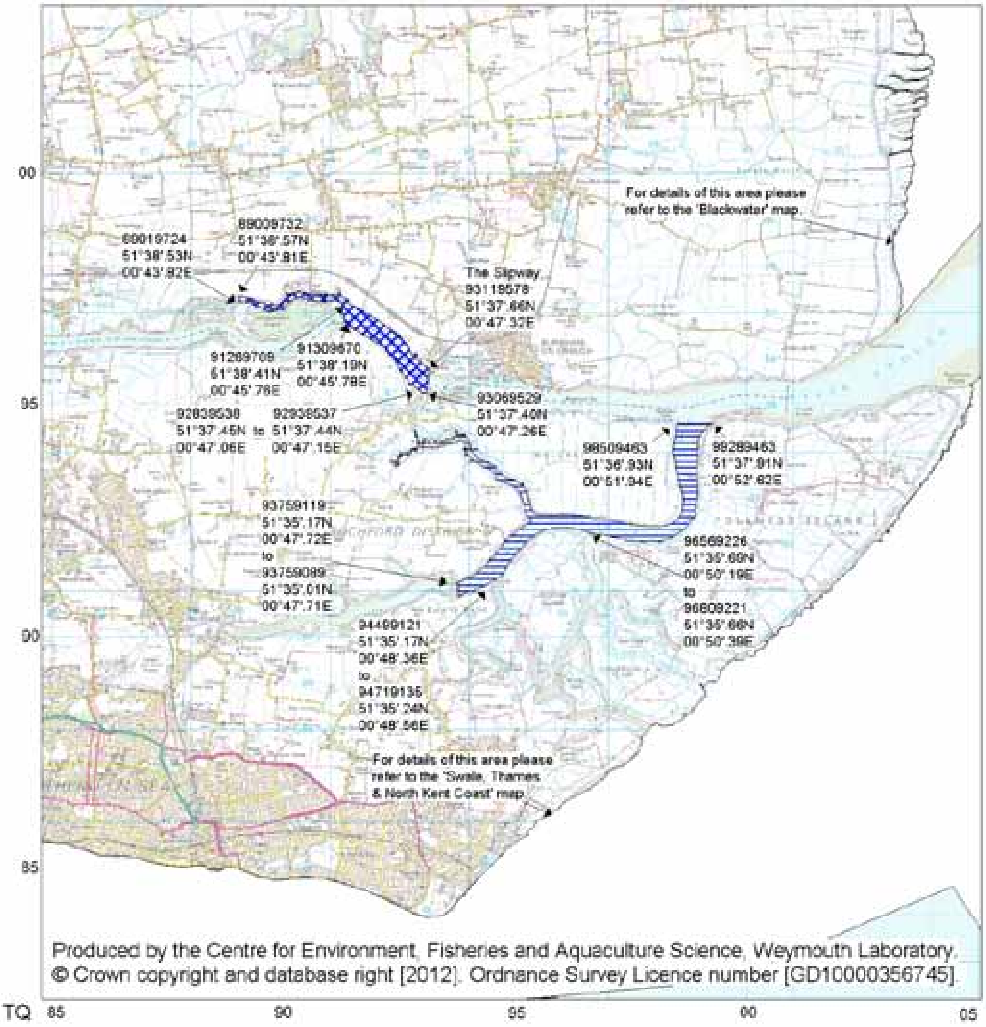
NB. 1) Lat/Longs quoted are WGS84
2) Separate maps available for C. gigas, Clams (M. mercenaria) and Mytilus spp. at Crouch & Roach

Food Authority: London Port Health Authority
Maldon District Council

Figure 4.5 Current native oyster classifications

Crouch & Roach - C. gigas

Scale - 1:120000



Classification Zones: Class A ▨ Class B ▩ Class C ▦ Prohibited ■ LT Class B ▤

Classification of Bivalve Mollusc Production Areas: Effective from 17 January 2012

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

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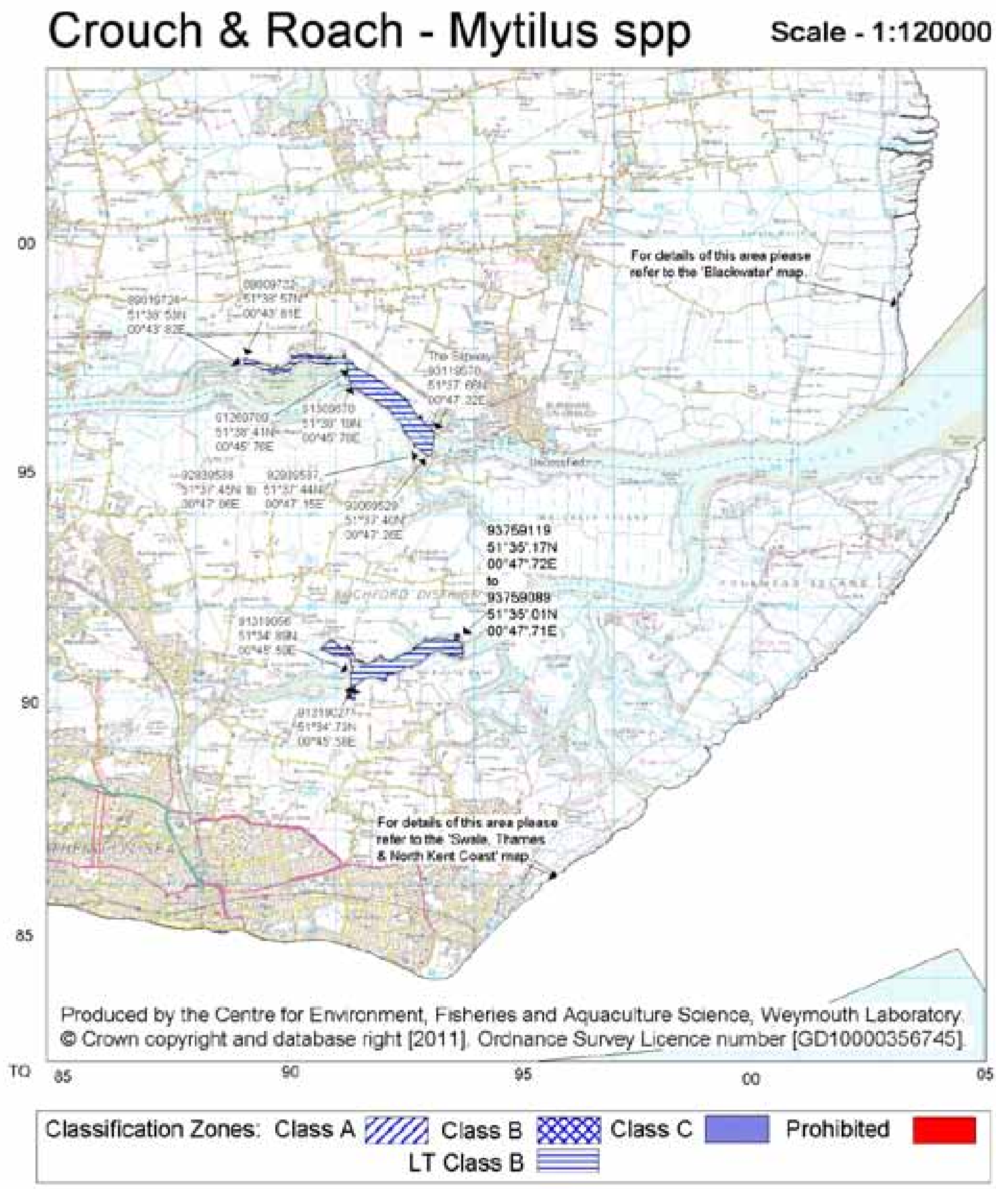
(Tel: 01305 206600 Fax: 01305 206601)

NB. 1) Lat/Longs quoted are WGS84
2) Separate maps available for Clams (M. mercenaria), Mytilus spp. and O. edulis at Crouch & Roach

Food Authority: London Port Health Authority
Maldon District Council

Figure 4.6 Current Pacific oyster classifications



Classification of Bivalve Mollusc Production Areas: Effective from 1 September 2011

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

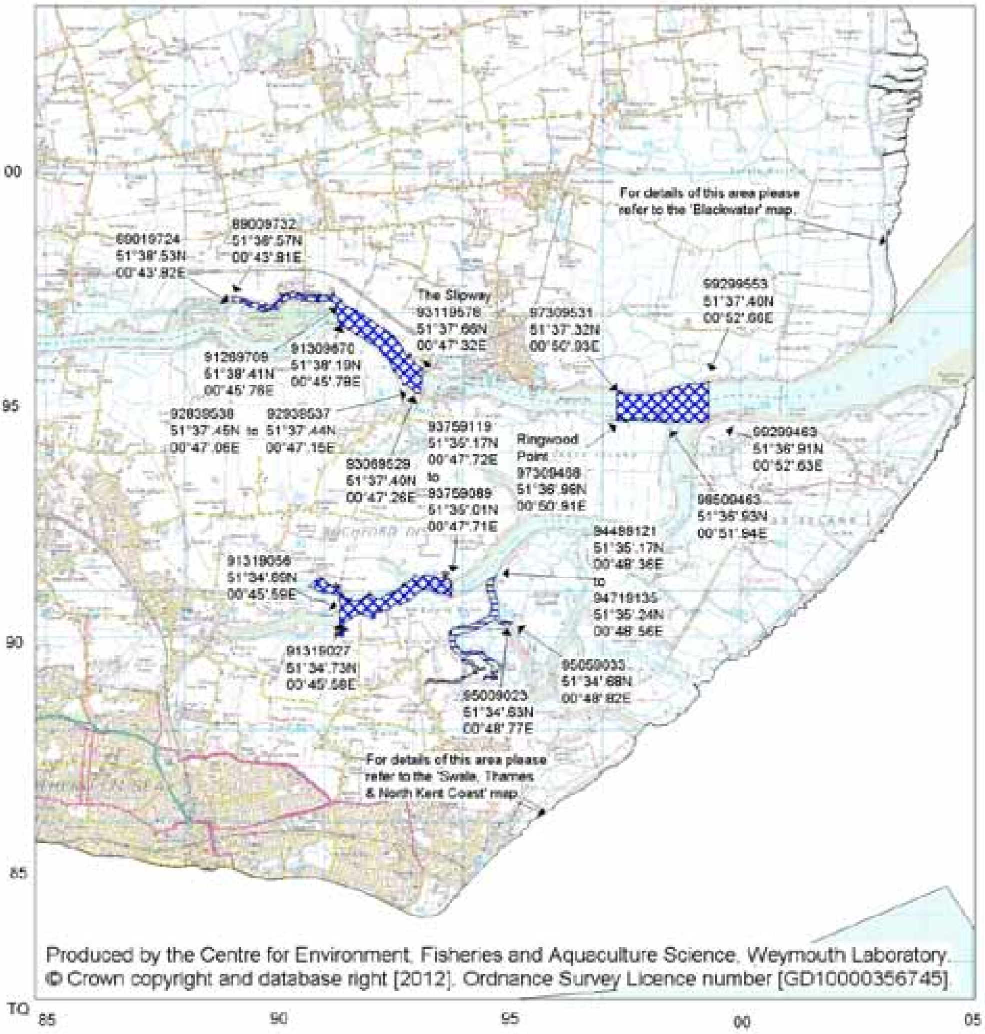
Further details on the classified species and the areas may be obtained from the responsible Food Authority. Enquiries regarding the maps should be directed to: Shellfish Microbiology, CEFAS Weymouth Laboratory, Barrack Road, The Nothe, Weymouth, Dorset DT4 8UB. (Tel: 01305 206600 Fax: 01305 206601)

NB. 1) Lat/Longs quoted are WGS84
2) Separate maps available for C. gigas, Clams (M. mercenaria) and O. edulis at Crouch & Roach

Food Authority: London Port Health Authority
Maldon District Council

Figure 4.7 Current mussel classifications

Crouch & Roach - (M. mercenaria) Scale - 1:120000



Classification Zones: Class A ▨ Class B ▩ Class C ▧ Prohibited ■ LT Class B ▤

Classification of Bivalve Mollusc Production Areas: Effective from 17 January 2012

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

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

N.B 1) Lat/Longs quoted are WGS84
2) Separate maps available for C. gigas, Mytilus spp. and O. edulis at Crouch & Roach

Food Authority: London Port Health Authority
Maldon District Council

Figure 4.8 Current clam 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

AIM

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

SHELLFISHERIES

The estuary complex has a patchwork of various owners and leasers, and it is beyond the scope of this survey to establish the ownership of fishing rights throughout. Shellfish stocks may therefore potentially be ongrown in any part of the estuary, quite probably without the LEA or the K&E IFCA being aware. Therefore a general principle of classifying the entire estuary complex for the four main species of interest (native oysters, Pacific oysters, mussels and hard clams) should be applied where possible.

Wild native oyster stocks are present throughout the subtidal zone of the entire estuary complex, but generally at such low levels that commercial fishing for them is considered unviable. The area has recently been closed (May 2012) to the harvesting of this species for at least a year on conservation grounds. It is quite likely that this fishery will be reopened, although it will probably be subject to additional management measures aimed at assisting stock recovery. Any declassification of this fishery should therefore be temporary, with sampling decreased to quarterly rather than stopped altogether so that the area can be reclassified instantly when monthly monitoring is restarted. Native oysters are ongrown at various lays within the River Roach, so these areas will require continued classification. There is a closed season for native oysters which runs from May to August inclusive, so classification at these times is not required for this species.

Naturally occurring Pacific oysters are also present throughout the estuary, both in subtidal areas where native oysters are found and in some more localised intertidal areas where suitable (non-mud) substrates are present, such as at Brandy Hole. They will therefore be encountered as bycatch in any dredge fishery, and will also be subject to hand gathering from some parts of the intertidal zone. This species is also cultured at some of the oyster lays in the Roach. There is no closed season for Pacific oysters, and their increasing abundance in recent years is seen as a threat to the recovery of native oyster stocks so from a conservation point of view their exploitation should perhaps be encouraged. It is therefore concluded that classification of this species should also be extended to cover the entire estuary complex if possible, and such classifications should be year round.

There is one recognised natural mussel bed at Blackledge in the Roach but this is not currently of commercial interest. It is likely that there are further small patches of mussels, and possibly more extensive beds within the complex which may become of commercial interest at some point. There are three areas of private grounds in the middle reaches of the Crouch which have been used for ongrowing of seed mussels, although it is uncertain whether these are active at present. It is however possible that mussels may be being ongrown at these and possibly other private grounds about which the LEAs and IFCA may be unaware. Therefore, continued classification, at least of the currently classified areas is required for this species. As there is no closed season the classification should be year round.

A significant population of naturally occurring hard clams has become established throughout the estuary complex in both the subtidal and intertidal zones. These have recently become the subject of a relatively lucrative dredge fishery. Classification of the entire area is required as far as possible, and as there is no closed season for this species such classification should be year round.

Manila clams and cockles are also present in the estuary complex and they feature in the bycatch of the dredge fishery for hard clams. Their geographical distribution the fishery prospects for these species are uncertain but ideally they should be classified throughout the entire estuary to allow bycatch from the hard clam dredge fishery to be marketed. A closed season applies to cockles on public grounds, but not on private grounds, and there is no closed season for Manila clams. Both species will require a year round classification.

SURROGATE SPECIES

An investigation into the relative levels of *E. coli* accumulation in different bivalve species was recently carried out by Cefas on behalf of the FSA (Younger & Reese, 2011). Comparisons of paired sample results supported the use of mussels as a surrogate for Pacific and native oysters as well as hard clams. Mussels were not found to be a suitable surrogate for Manila clams and cockles however. Formal guidelines for the use of surrogate species are however yet to be developed, although such an approach was endorsed by the competent authority (the FSA) in the case of the bacteriological survey of the upper Crouch.

The use of bagged mussels to classify the four the main species harvested from the Roach and Crouch offers significant logistical and cost advantages. These include guaranteed availability of sampleable stock in the desired RMP locations, no requirement for the use of a dredge or to take the more valuable species for laboratory analysis, and reduced laboratory costs and sampling officer time. As the acceptable surrogate species generally accumulate *E. coli* to similar or slightly higher levels, their use for classification of areas where borderline classification compliance is anticipated should not be adopted to avoid potentially disadvantaging the industry. Historically, classifications in the area have been comfortably within the B thresholds for all species. The bacteriological survey of the upper Crouch did return two sets of results where levels of *E. coli* exceeded the B classification threshold in mussels at most locations. As these results generally exceeded the threshold by a large margin their use to derive a provisional classification for the upper Crouch should be acceptable, as should the continued use of such a strategy throughout the area.

As mussels are not a suitable surrogate for either Manila clams or cockles, both these species will have to be monitored separately if their classification is required.

POLLUTION SOURCES

FRESHWATER INPUTS

The catchment area draining directly to the Roach and Crouch estuary is 383km^2. Rainfall in Essex is relatively low and a high proportion of this is likely to be lost to evaporation and transpiration. As a consequence the volumes of runoff entering the estuary are quite low as reflected by estimates of mean and maximum runoff rates into the estuary complex of 0.39 and 18.4m^3/sec. River flow gauging records from the River Crouch and the Eastwood Brook indicate that flows are usually low, but on occasion very high flows in relation to base flow are experienced. Flows were highest on average from November through to February, and the highest flow events tended to arise during this period, although some quite high flow events were recorded in most months of the year. Impacts associated with land runoff are likely to be minor for most of the time, but from time to time they will increase significantly. Such impacts may be generally higher in winter, although other factors such as the seasonal profile of pasture grazing will also influence this. Some relationship between river discharge and levels of faecal indicator bacteria was found at most water and shellfish flesh bacteriological sampling sites.

Around half of the catchment is drained by watercourses that discharge to the head of the estuaries so their upper reaches are likely to be impacted most heavily by land runoff. The watercourses discharging to the upper estuaries, particularly those joining the Roach are modified and have heavily urbanised catchments so are likely to respond rapidly to rainfall and are likely to carry relatively high levels of contamination. There are also numerous smaller watercourses joining the estuary at various points which may cause localised increases in bacterial indicator concentrations. These generally have more rural catchments, which are low lying and drained via a network of ditches and dykes which discharge to the estuary through sluices at regular intervals. These may cause minor and localised decreases in water quality, particularly those discharging to the head of enclosed creeks rather than direct to the main estuaries. A general principle of locating RMPs towards the head of the estuaries and any creeks receiving freshwater inputs should therefore be assumed on this basis.

HUMAN POPULATION

The area is quite heavily populated in places, supporting a total resident human population within the Roach and Crouch catchment of 412,662 at the time of the last published census (2001 as the 2011 census data was not available at the time of writing). There are population centres at the head of both estuaries and throughout the south west part of the catchment. The land surrounding the lower reaches of the estuary complex is generally sparsely populated, with the exception of the town of Burnham-on-Crouch. Therefore the majority of the population is within the catchments of watercourses draining to the upper parts of the estuaries, so the spatial profile of impacts associated with sewage discharges and urban runoff may be expected to reflect this.

The main visitor town in the area is Burnham, where the majority of tourism is associated with boating activities. The northern part of Southend, a major tourist town lies within the Roach catchment area. Therefore a slight increase in population may arise in some parts of the catchment during the summer months, primarily at Burnham and Southend, and the volumes of sewage received by sewage works serving these areas will increase correspondingly.

SEWAGE DISCHARGES

There are nine water company sewage treatment works within the Roach/Crouch catchment. Of these, two discharge to the upper reaches of the Crouch estuary (Rayleigh West and Woodham Ferrers STWs) above all the fisheries and two discharge to the River Crouch upstream of its tidal limit (Wickford and Billericay STWs). Burnham-on-Crouch STW discharges to the Crouch at Burnham, Rochford discharges to the Roach at Blackledge, and Rayleigh East STW discharges to Rayleigh East Brook, which in turn drains to the head of the Roach estuary. Two much smaller treatment works (Paglesham and Foulness STWs) discharge to watercourses draining to the middle and outer reaches of the main Roach estuary channel, although the path effluent from the latter follows into the estuary is uncertain. All provide secondary treatment, with additional reedbeds at Rayleigh East STW and final effluent lagoons at Rayleigh West and Rochford STWs.

Estimates of the bacterial loading each works generates were made based on dry weather flows and the geometric mean concentrations of faecal coliforms in a series of samples of final effluents. Reference values of average faecal coliform concentrations from the literature were used in the case of Billericay, Paglesham and Foulness STWs as no effluent testing data was available for these, so these estimates should be treated with caution. Burnham STW, which had consistently high concentrations of bacteria in its effluent, was estimated to be responsible for about 50% of the combined loading of all these works. A further 45% was generated by the two works discharging to the River Crouch above its tidal limit, although there is some uncertainty about the impacts of the Billericay STW as no final effluent testing data was available and this works discharges about 12km upstream of the tidal limit. Peak levels of contamination are therefore anticipated within the plume emanating from the Burnham STW outfall, so the area affected should either not be classified or monitored and classified separately. The upper reaches of the Crouch at Brandy Hole are also likely to be subject to elevated levels of contamination, but effluent from upstream sewage discharges will be subject to dilution and mixing before arriving at the shellfish beds here. The other continuous water company discharges will have lesser impacts but may nonetheless be of local significance.

There are a large number of intermittent overflow discharges associated with the water company sewer networks. There is a large cluster of these around the very upper reaches of the Crouch estuary. At Burnham, there are only two intermittent discharges, and it is likely that most spills from this network are made via the main STW outfall. There are a few intermittent discharges which may impact on the Roach, mainly in its very upper reaches due to a cluster around Rochford. Intermittent sewage discharges can deliver large volumes of untreated storm sewage to coastal waters. Data from selected monitored outfalls identified a higher frequency of potential spills (high water levels alarms) at two discharges located in the very upper reaches of the Crouch, and less frequent potential spills from other locations. It is not however possible to estimate the volumes discharges or event to tell whether these events were actual spills. For the other intermittent outfalls it is difficult to make any meaningful assessment of their relative significance aside from noting their locations and their potential to deliver large bacterial loadings. Their geographic distribution suggests that the upper areas of the Crouch and to a lesser extent the upper Roach may be most affected. Spills will mainly be associated with wet weather events, particularly within the sewerage networks which collect larger amounts of surface water, and some catchments and individual outfalls may have a greater tendency to spill than others.

Most of the Roach/Crouch catchment is connected to mains sewers but some properties, generally in the more rural areas, are not. These are served by small private discharges, which are generally treated by septic tank or package plant, and most of which are to watercourses. Most watercourses draining to the estuary receive some inputs from such discharges. The cumulative bacterial loadings generated by these will however be very minor in relation to those from water company discharges. One cluster of private discharges at a caravan park at Althorne Creek has been identified as discharging raw sewage to the adjacent drainage ditches by the LEA. This may have some localised effects within Althorne Creek.

AGRICULTURE

The agricultural land within the Roach and Crouch catchment is mainly arable, with some small pockets of pasture. Numbers of grazing animals are low at 4667 cattle and just over 1848 sheep, so associated impacts are likely to be relatively minor. The highest densities of both cattle and sheep were recorded in the land adjacent to the upper half of the Crouch estuary so watercourses draining this area may be more susceptible to contamination from grazers. As well as cattle and sheep, there are some poultry and pig rearing units in the area.

Grazing animals will deposit directly on pastures whilst outdoors. Cattle are likely to be transferred indoors during the winter and their manure will be collected and applied to farmland. Manure from pig and poultry operations is typically stored and then spread strategically on nearby farm land. Therefore, periodic applications of manures to the arable farmland which dominates the catchment are anticipated, although the temporal and spatial profile of these applications is uncertain. It is also likely that treated sewage sludges are spread on arable land, but no information on local practices was available at the time of writing.

The primary mechanism for mobilisation of faecal matter deposited on agricultural land into watercourses is via land runoff, so fluxes of agricultural related contamination into the estuary will be highly rainfall dependent. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the ‘first flush’). It is likely that most watercourses are subject to contamination from agricultural sources to some extent. Runoff from about half the catchment area enters the upper reaches of the estuaries, so on this basis higher impacts may be anticipated towards the up-estuary ends of the shellfish beds.

There is likely to be seasonality in levels of contamination of agricultural origin. Numbers of sheep and cattle will increase significantly in the spring, with the birth of lambs and calves, and decrease in the autumn when animals are sent to market. Manure from cattle housed indoors may be stored for significant periods, although farms without large storage capacities are likely to spread during the winter and spring. Applications of manure from pig and poultry operations may take place at any time of the year depending on crop cycles. Therefore peak levels of contamination from grazing animals may arise following high rainfall events in the summer, particularly if these have been preceded by a dry period which would allow a build up of faecal material on pastures. Contamination events may occur on a more localised basis if wet weather follows a manure/slurry/sludge application which may occur at any time of the year.

Boats

The Crouch is renowned as a centre for sailing and hosts a small commercial port, four major marinas at North Fambridge, Bridgmarsh, and two just to the west of Burnham (Essex Marina and Burnham Yacht Harbour). There is also significant boat traffic within the Roach. There are extensive areas of moorings off Burnham and at Brandy Hole as well as a smaller area of moorings off North Fambridge. A few houseboats were seen during the shoreline survey at Burnham and North Fambridge. The commercial port at Baltic Wharf receives small volumes of shipping traffic. Within the Roach, there are marinas at Rochford and the southern end of Potton Creek, and moorings in Barling Creek and at Paglesham. The Good Practice Guide (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2010) indicates that areas within active marinas should not be classified for the harvest of bivalves so classification zone boundaries should be set accordingly.

There is considerable uncertainty about the extent to which these discharges occur and whether they will impact significantly on shellfish hygiene. Merchant shipping are not permitted to make overboard discharges within 3 nautical miles of land so vessels associated with the commercial port should be of no impact. Smaller private craft such as yachts, cabin cruisers and fishing vessels may make overboard discharges despite the discouragement of such practices. Those in marinas may be less inclined to make overboard discharges as it is somewhat antisocial and onshore facilities are easily accessed. Those in occupation on moorings, or those in transit through the estuary may be more likely to discharge. Houseboats in occupation are likely to make regular discharges. On this basis, stocks in the vicinity of Burnham in particular, as well as Brandy Hole, North Fambridge, Paglesham and Barling Creek are perhaps most at risk from such discharges, and RMPs should be set accordingly. Peak pleasure craft activity is anticipated during the summer, particularly during the Burnham regatta week held annually in August, so associated impacts are likely to follow this seasonal pattern.

Wildlife

Within the survey area there are saltmarshes and intertidal mudflats which provide bird foraging habitat. These attract large numbers of overwintering waterbirds (wildfowl and waders) with an average total count of 32,394 over the five winters up to 2009/10. The majority of these migrate elsewhere to breed, but some will remain on a year round basis and other species such as gulls will be present throughout the year, albeit at much lower numbers. Birds may impact on the shellfisheries via direct deposition on the intertidal or via runoff or tidal inundation of areas of saltmarsh and wetland. Due to the diffuse and spatially unpredictable nature of contamination from wading birds it is difficult to select specific RMP locations to best capture this, although they may well be a significant influence during the winter months. Other overwintering species such as grazing ducks and geese will mainly frequent the saltmarsh, where their faeces will be carried into coastal waters via runoff into tidal creeks or through tidal inundation. Therefore RMPs within or near to the creeks draining saltmarsh areas will be best located to capture contamination from these species.

The Roach and Crouch estuary complex is frequented by a small population of seals. During the shoreline survey of the Roach a total of 14 seals were seen, 10 of which were in the Middleway, and 4 were in the main Roach channel between Horseshoe Corner and Blackledge Point. No seals were recorded within the Crouch, and although shoreline observations tentatively suggest they favour the creeks extending south from the Roach as haul-out areas it is likely they forage widely throughout both estuaries. As a diffuse input they will have little bearing on the sampling plan. No other wildlife species of potential influence to the sampling plans have been identified.

Domestic animals

Dogs are exercised by the estuaries, and represent a potential source of diffuse contamination to the near shore zone, although the soft muds may discourage them from accessing much of the intertidal area. It is likely that the intensity of this is greatest at town parks and seafronts, and their impacts may be felt through land runoff from such areas. Dogs are however likely to be of minor importance relative to some other sources.

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 changes in pollution load within the Roach and Crouch.

Pollution source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Continuous sewage discharges												
Intermittent sewage discharges												
Boat traffic												
Land runoff												
Waterbirds												

Red - high risk; orange - moderate risk.

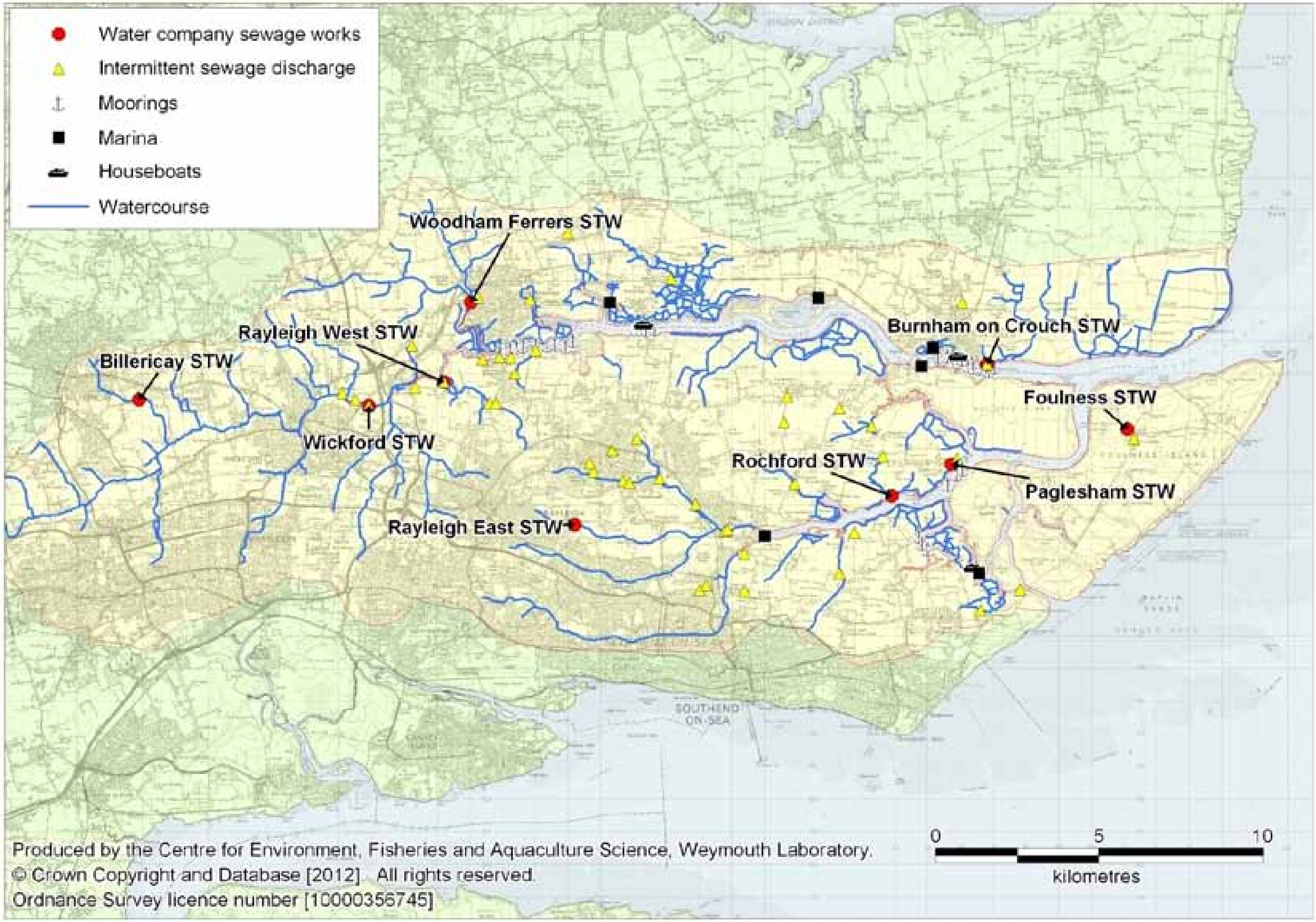


Figure 5.1 Significant sources of microbiological pollution to the Roach and Crouch.

HYDRODYNAMICS

The Roach and Crouch form a branching estuary complex surrounded by reclaimed land and flanked throughout by flood defence walls. The sea defences confine the estuary to relatively narrow channels and generally limit the intertidal areas to a narrow strip of mud fringed by saltmarsh. The Crouch is more linear than the Roach, with a few small creeks and side channels in its upper reaches. The Roach is more complicated in shape, with branching creeks surrounding small islands and a secondary connection to the sea at Havengore that dries during the lower half of the tidal cycle. Depth decreases progressively towards the head of the estuaries, and the proportion of intertidal area also increases. The creeks and side-channels are shallower than the main channels. The potential for dilution is therefore lower in the upper reaches and within the side-channels.

The tidal range in the Roach and Crouch estuaries is relatively large at about 5m on springtides and 3m on neap tides, and this drives extensive water movements. Within the Crouch tidal streams move up the estuary on the flood and back down on the ebb. The situation within the Roach is more complicated in some parts due to the secondary connection to the North Sea at Havengore. The tide enters the Roach through the Crouch during the first half of the flood tide, and there is a lag as it propagates through the estuary. When the tide reaches a sufficient height to open the connection at Havengore, water levels are higher in the open sea and over this connection so the tide reverses and flows north through the creeks around the islands to the south of the main Roach channel. Flows therefore move up the main Roach channel and Paglesham Pool on the flood, and back down on the ebb, but move south then north along the creeks between Havengore and the main channel on the flood, then south then north on the ebb. Throughout the estuary shoreline sources will therefore impact either side of their location, with the magnitude of these impacts decreasing with distance as the plume disperses. Within the creeks between Havengore and the main Roach channel impacts will be more spatially limited but more acute, and there will be less tidal flushing within the Roach as a whole.

Very limited data indicates that peak tidal current velocity is around 1m/s in the Crouch opposite Burnham, which translates to a tidal excursion in the very approximate order of 10-15km on spring tides. Therefore, the influence from major sources may potentially be felt across such distances.

The volume of freshwater entering the estuary is very low in relation to the volume of water exchanged each tidal cycle. As a consequence the estuary complex is well mixed and density driven currents are very unlikely to alter the tidal flow regime. One density effect of potential relevance is the tendency for sewage effluents to be buoyant and rise to the surface, which will tend to keep the sewage separate from benthic shellfish stocks if they are located in the deeper areas. This will only really apply to the Burnham STW outfall, and only towards high water as it is located around the low water mark.

The shape of the estuary and the location of the freshwater inputs suggests salinity may decrease slightly towards the upper reaches, particularly at times of high freshwater input. The salinity reflects the degree of freshwater influence, and where land runoff is an important contaminating influence decreasing salinity is usually associated with increasing levels of faecal indicator bacteria. Measurements taken during the shoreline survey (dry conditions) showed salinity within the Crouch was approaching that of full strength seawater throughout, although it did drop very slightly but steadily towards the head of the estuary. Within the Roach, salinity was noticeably lower than in the Crouch, although the minimum was 28.6ppt indicating a limited freshwater influence. This may be due to its smaller volume and decreased flushing.

Strong winds can modify tidal streams by driving surface water currents. These currents in turn drive return currents which may travel lower in the water column or along sheltered margins. Winds aligning with the estuary channels will have the greatest effect, by either increasing or retarding tidal streams at the surface. Winds may cause considerable variation in the dispersal of buoyant plumes arising from sewage outfalls at times. 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. Strong winds can also generate wave action which may resuspend contamination in intertidal sediments. Energetic wave action is unlikely to be a significant feature in this narrow and enclosed estuary complex. It is concluded that wind related effects have little bearing on the sampling plans due to their dynamic and unpredictable nature, although they may be a consideration when investigating the causes of high results.

SUMMARY OF EXISTING MICROBIOLOGICAL DATA

A large amount of bacteriological sampling has been undertaken on the Roach and Crouch under both the shellfish waters and the hygiene classification monitoring programmes. Results from 2004 onwards only were considered in this assessment as the most recent significant STW upgrade within the area occurred in 2003 and bacteriological sampling results indicate an improvement in water quality in 2002 and 2003. Figure 5.2 shows the locations sampled.

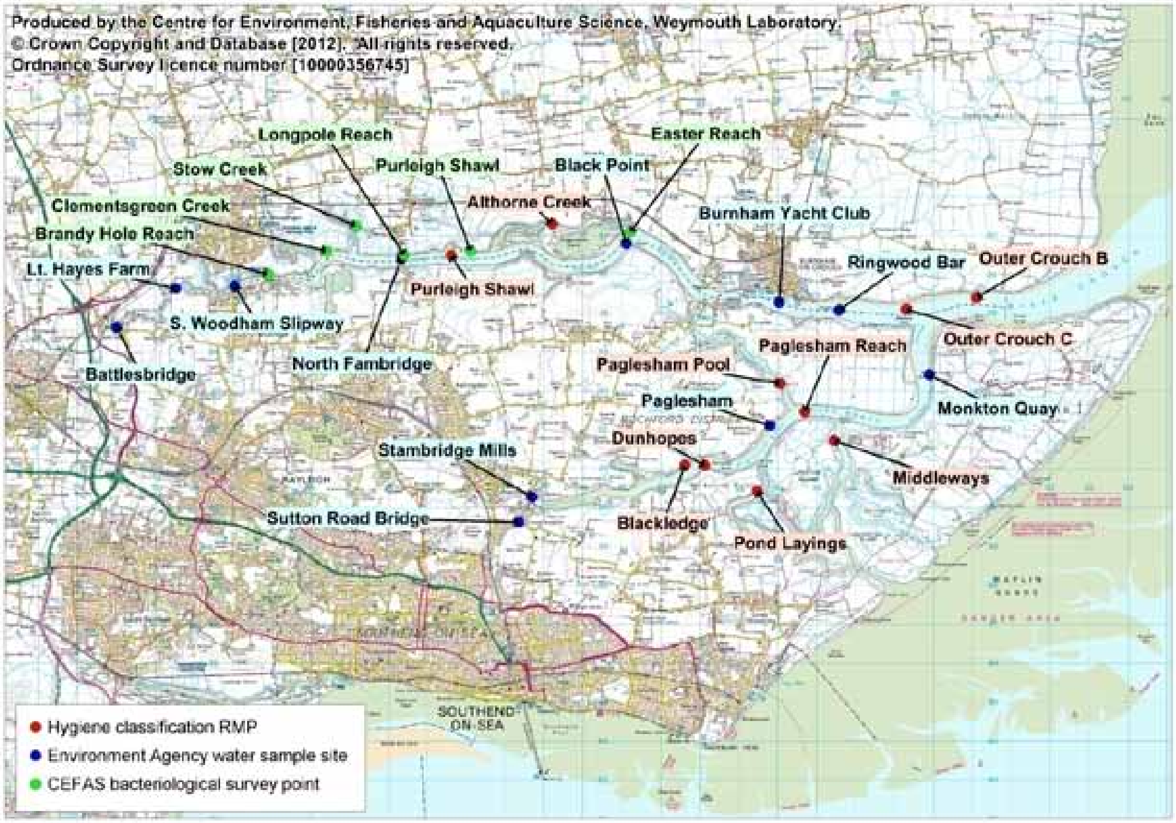


Figure 5.2 Bacteriological sampling points from 2004 onwards

Under the shellfish waters programme, the Environment Agency collect water samples on a quarterly basis from North Fambridge, Paglesham and Monkton Quay and enumerate faecal coliforms within them. Smaller numbers of investigative samples (9-16) were taken from the other water sampling sites over a more limited timescale (June 2008 to October 2009).

Within the Crouch, results were similar on average from North Fambridge through to Ringwood Bar (geometric mean of 10.1 to 13.6 faecal coliforms/100ml) with the exception of Burnham Yacht Club where there was a slight elevation (geometric mean of 28.5 faecal coliforms/100ml). A progressive elevation in levels of contamination was observed from S. Woodham Slipway (geometric mean of 168 faecal coliforms/100ml) through to the tidal limit at Battlesbridge (geometric mean of 9813 faecal coliforms/100ml). A similar pattern was observed in the Roach, with relatively low results at Monkton Quay and Paglesham (geometric mean of 5.7 and 9.6 faecal coliforms/100ml) and much higher results at Sutton Road Bridge and Stambridge Mills (geometric mean of 1521 and 2307 faecal coliforms/100ml).

The three sites monitored on a quarterly basis were sampled between 44 and 46 times so a more detailed analysis of these was undertaken. Comparisons of sample results from the 37 occasions when all three were sampled on the same day revealed mean results were significantly higher on average at Paglesham compared to Monkton Quay. Strong correlations were found between results for all site pairings suggesting that levels of contamination throughout the estuary complex, although subject to some geographical variation, respond in a similar manner to environmental variables such as rainfall.

Statistically significant seasonal variation was found at these three sites, with a consistent winter peak apparent for all. Weak correlations between faecal coliform concentrations and the state of the tide on the high/low tidal cycle were found at North Fambridge and Paglesham. For North Fambridge no clear pattern in results was apparent when the data was plotted, whereas at Paglesham a slight tendency for higher results on the flood tide was found suggesting sources to the east are of significance here. Correlations between faecal coliform concentrations and the spring/neap tidal cycle were found at Paglesham and Monkton Quay. At Paglesham there was a tendency for lower results during neap tides implying that important sources are some distance away. A slight tendency for lower results on neap tides was also apparent at Monkton Quay. An influence of rainfall was detected at all three locations. Rainfall three days prior to sampling was most consistently associated with elevated levels of indicator bacteria, although a more rapid response was seen at the two sites in the Roach. A strong and consistent influence of river discharge on levels of indicator bacteria was found at all three of these sites indicating that periods of increased land runoff are associated with higher levels of contamination. The response becomes less marked three days after a high flow event, and correlations were generally slightly stronger within the Roach.

Flesh samples have been taken from 13 RMPs for classification monitoring purposes since the start of 2004. Of these two were only sampled on four or fewer occasions so results from these were not analysed in detail (Pacific oysters at Purleigh Shawl and Middleways). In general results were broadly similar across all the hygiene RMPs and were well within the B classification compliance threshold.

Across the four native oyster RMPs results were significantly higher at those within the Crouch (Outer Crouch C and Outer Crouch B) compared to the two within the Roach (Pond Layings and Paglesham Reach). Paired (same day) sample results showed no difference in average result at Outer Crouch B and Outer Crouch C, and also found that results were strongly correlated on a sample by sample basis. The same was found when the results of paired samples from Pond Layings and Paglesham Reach were compared. It was not possible to undertake other paired comparisons between native oyster RMPs on the Roach and Crouch as they were generally sampled on different days.

Across the three mussel RMPs (Blackledge, Dunhopes and Althorne Creek) there was no significant difference in results. Paired (same day) sample comparisons between Blackledge and Dunhopes revealed no significant difference in mean result and a strong sample by sample correlation.

For Pacific oysters the only geographic comparison possible was between Paglesham Pool and Paglesham Reach. No significant difference in mean result was found but sample numbers from Paglesham Reach were low. No paired comparisons were possible as these two RMPs were generally sampled on different days. Hard clams and Manila clams were only sampled from one RMP each so no geographic comparisons were possible for these.

From 2004 to 2012, hygiene monitoring results fluctuated slightly with time as may be expected, but no strong overall trends are apparent across the estuary complex.

Within the Crouch all three RMPs (native oysters at Outer Crouch B and Outer Crouch C, and mussels at Althorne Creek) showed similar seasonal variations with highest results in the winter and lowest results in the spring. Within the Roach, the native oyster RMPs (Pond Laying and Paglesham Reach) showed a different pattern of seasonal variation to that observed in the Crouch, with higher levels of contamination during the summer and autumn. However, mussels within the Roach (Blackledge and Dunhopes) showed highest results in the winter and lowest results in the spring. Both species sampled at Pond Layings (native oysters and hard clams) showed similar seasonal peaks through the summer and autumn. Both species sampled at Paglesham Pool (Pacific oyster and Manila clams) showed a similar seasonal pattern with highest results on average during the winter but a tendency for fewer low results during the summer and autumn. The differences in seasonal variation through the system suggests differing profiles of sources within the system, and were perhaps also influenced by differing feeding physiology of the various species sampled.

A weak correlation was found between *E. coli* results and tidal state on the high/low cycle for Pacific oysters at Paglesham Pool only, but no pattern was apparent when this data was plotted. Correlations between *E. coli* results and the spring/neap tidal cycle were found for native oysters at Outer Crouch C and for mussels at Dunhopes and Blackledge. No pattern was apparent for the weak correlation at Outer Crouch C. At Blackledge and Dunhopes, which are two nearby mussels sites in the main Roach channel, the correlations were stronger and a tendency for higher results on average during the larger spring tides was apparent. This may suggest that some sources influencing at such a distance from this RMP that they impact more during the larger spring tides.

Some influence of recent rainfall was detected at all sites apart from for Pacific oysters at Paglesham Pool. Influence was generally stronger at the RMPs which lie in the main channels (Outer Crouch B, Paglesham Reach and Blackledge) with the notable exception of mussels at Dunhopes. Overall this may suggest that the main river channels are more susceptible to runoff related contamination, but the reasons why rainfall was a much stronger influence at Blackledge compared to Dunhopes is unclear. This may suggest, alternatively, that land runoff from nearby watercourses may be of more localised importance at the various RMPs. River discharge had no significant influence on levels of *E. coli* at Pond Layings (both species) and for Manila clam (but not Pacific oysters) at Pagelsham Pool. The strongest and most consistent influences were found at Outer Crouch B, Althorne Creek and Blackledge. Again, Dunhopes responded to a much lesser degree than Blackledge. Also, Outer Crouch C did not respond to the same extent as the nearby Outer Crouch B, although the former was sampled on much fewer occasions.

In order to assess the spatial variation in levels of contamination in the upper Crouch, a bacteriological survey was carried out, where bagged mussels were sampled at six locations through the upper estuary, from the eastern end of Bridgmarsh Island up to Brandy Hole. Nine sets of samples had been submitted at the time of writing. An overall increase in levels of contamination was observed towards the up-estuary end of this area. Heavy rainfall was recorded in the days before the sampling on the two occasions when greatly elevated results were recorded, with results exceeding 4600 *E. coli* MPN/100g extending as far down as

North Fambridge on one occasion and Purleigh Shawl on the other. This is perhaps indicative of the tidally driven extent of influence of sources located at the head of the estuary. Results to date suggest that a C/B classification boundary would lie somewhere in between Longpole Reach and Purleigh Shawl. A result exceeding 46000 *E. coli* MPN/100g was recorded on one of these occasions at Brandy Hole, the uppermost site, implying that the estuary should not be classified from here upstream. The geometric mean and proportion of results exceeding 230 *E. coli* MPN/100g was lowest at Purleigh Shawl. Fewer low results were recorded at Easter Reach, suggesting an increase in levels of contamination under dry conditions at the downstream end of this stretch although results to date are consistent with a B classification at both Purleigh Shawl and Easter Reach.

APPENDICES

APPENDIX I
HUMAN POPULATION

The distribution of resident human population by Super Output Area Boundary totally or partially included within the Roach and Crouch catchment area is shown in Figure I.1. Total resident human population in the area shown was 412,662 at the time of the last published census (2001). Results of the 2011 census were not available at the time of writing.

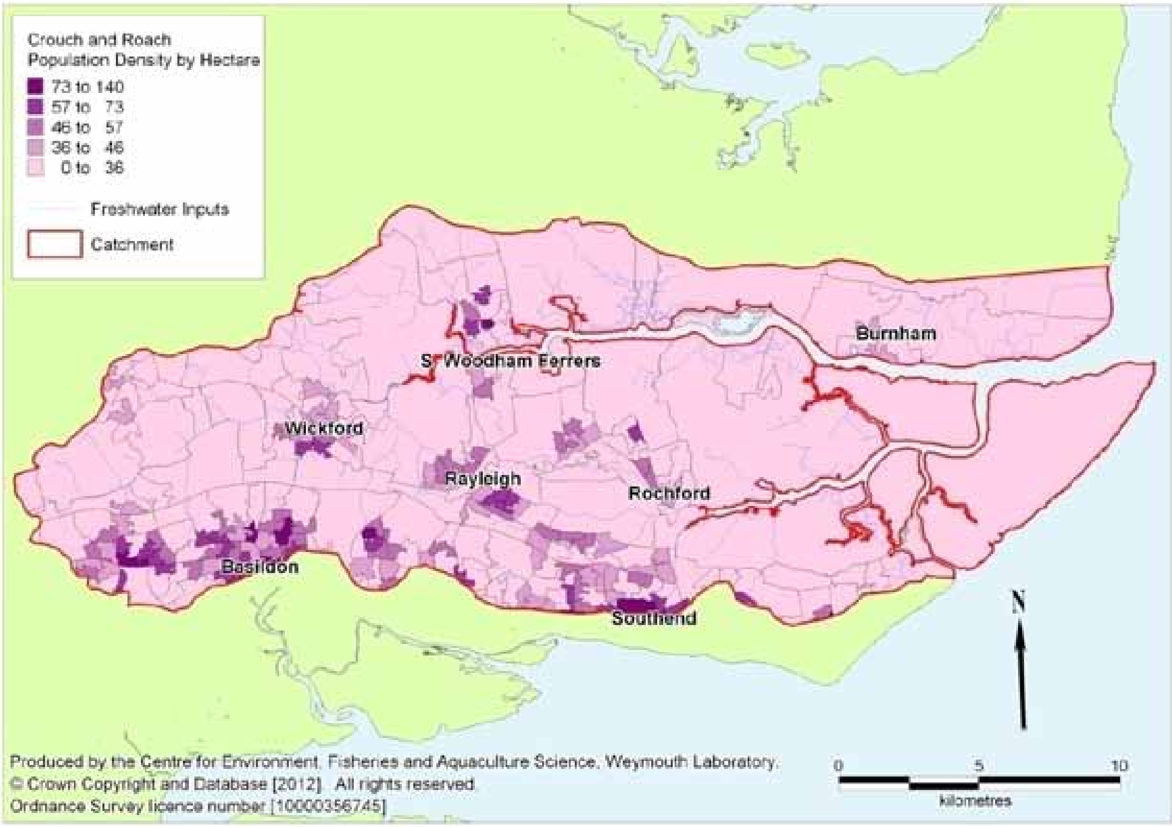


Figure I.1 Human population density in the Roach and Crouch catchment.
Source: ONS, Super Output Area Boundaries (Lower layer). Crown copyright 2004. Crown copyright material is reproduced with the permission of the Controller of HMSO.

Both estuaries have towns at their head, and the town of Burnham lies on the north shore of the Crouch about 7km west from its mouth. Aside from Burnham South Woodham Ferrers and Rochford, populations adjacent to the estuary are relatively sparse. Most of the population centres lie within the catchments of watercourses draining to the heads of the two estuaries. Therefore impacts from urban runoff will be most acute at the head of the estuaries. Impacts from sewage discharges may follow a similar spatial pattern, but this will be dependent on the configuration of the sewerage networks serving these towns.

The main visitor town in the area is Burnham, where the majority of tourism is associated with boating activities. The northern part of Southend, a major tourist town lies within the Roach catchment area. Therefore a slight increase in population may arise in some parts of the catchment during the summer months, primarily at Burnham and Southend, and the volumes of sewage received by sewage works serving these areas will increase correspondingly.

APPENDIX II
HYDROMETRIC DATA: RAINFALL

Due to its sheltered location relative to rain-bearing weather systems feeding in off the Atlantic, the Roach and Crouch lie within one of the drier areas of the UK, receiving an average of 475mm a year at Burnham, 2002-2011. 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 II.1 presents a boxplot of daily rainfall records by month at Burnham.

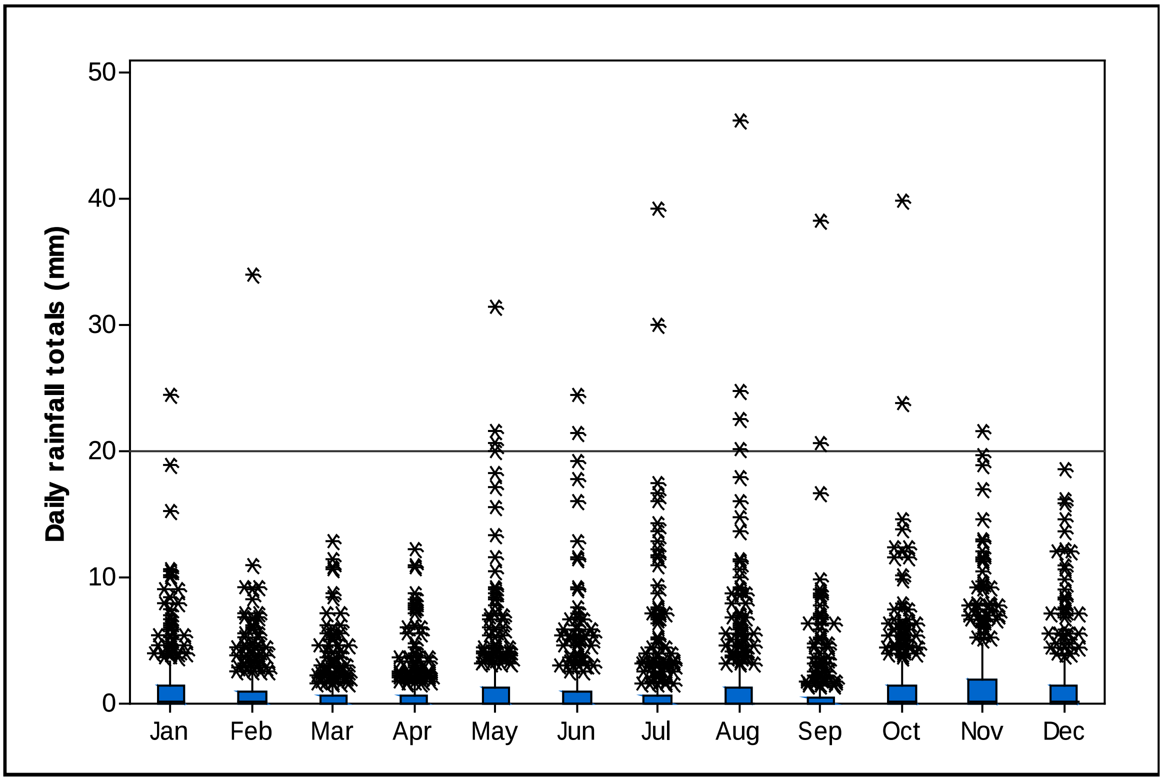


Figure II.1 Boxplot of daily rainfall totals at Burnham, January 2002 to February 2012.
Data from the Environment Agency

Rainfall records from Burnham, which is representative of conditions in the vicinity of the shellfish beds indicate relatively low seasonal variation in average rainfall. Rainfall was lowest on average in March and April and highest on average in November and August. Daily totals of over 20mm were recorded on 0.5% of days and 53.6% of days were dry. High rainfall events, whilst relatively rare, tended to occur most during the summer and autumn but events of over 20mm were recorded in all months apart from March, April and 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 (pages 74 and 81).

APPENDIX III
HYDROMETRIC DATA: FRESHWATER INPUTS

The catchment area draining directly to the survey area as estimated by local topography is 383km^2. Rainfall is relatively low (Appendix II, page 51) and of this a high proportion is likely to be lost to evaporation and transpiration mainly during the summer months. As a consequence freshwater inputs direct to the survey area are usually quite low relative to the size of the estuaries especially during the summer. Figure III.1 shows the location of the main watercourses draining the area.

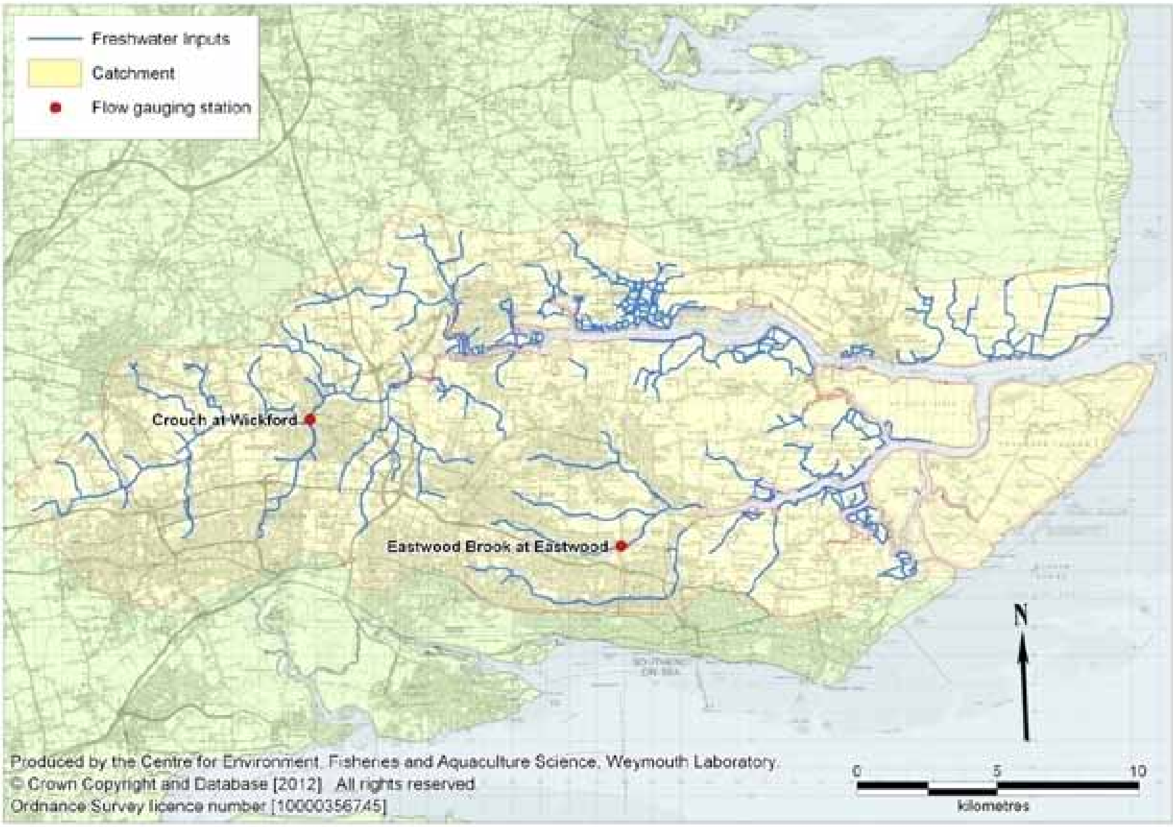


Figure III.1 Main watercourses within the survey catchment area.

Figure III.1 shows that roughly half of the catchment is drained by watercourses that discharge to the head of the estuaries so their upper reaches are likely to be impacted most heavily by land runoff. The watercourses discharging to the upper estuaries, particularly those joining the Roach are modified and have heavily urbanised catchments so are likely to respond rapidly to rainfall and carry relatively high levels of contamination.

There are also numerous smaller watercourses joining the estuary at various points which may cause localised increases in bacterial indicator concentrations. These generally have more rural catchments, which are low lying and drained via a network of ditches and dykes which discharge to the estuary through sluices at regular intervals. These may cause minor and localised decreases in water quality, particularly those discharging to the head of enclosed creeks rather than direct to the main estuaries.

There are two river gauging stations within the Roach and Crouch catchment area, one on the Crouch and one on the Eastwood Brook. Figure III.2 presents boxplots of mean daily flow records by month.

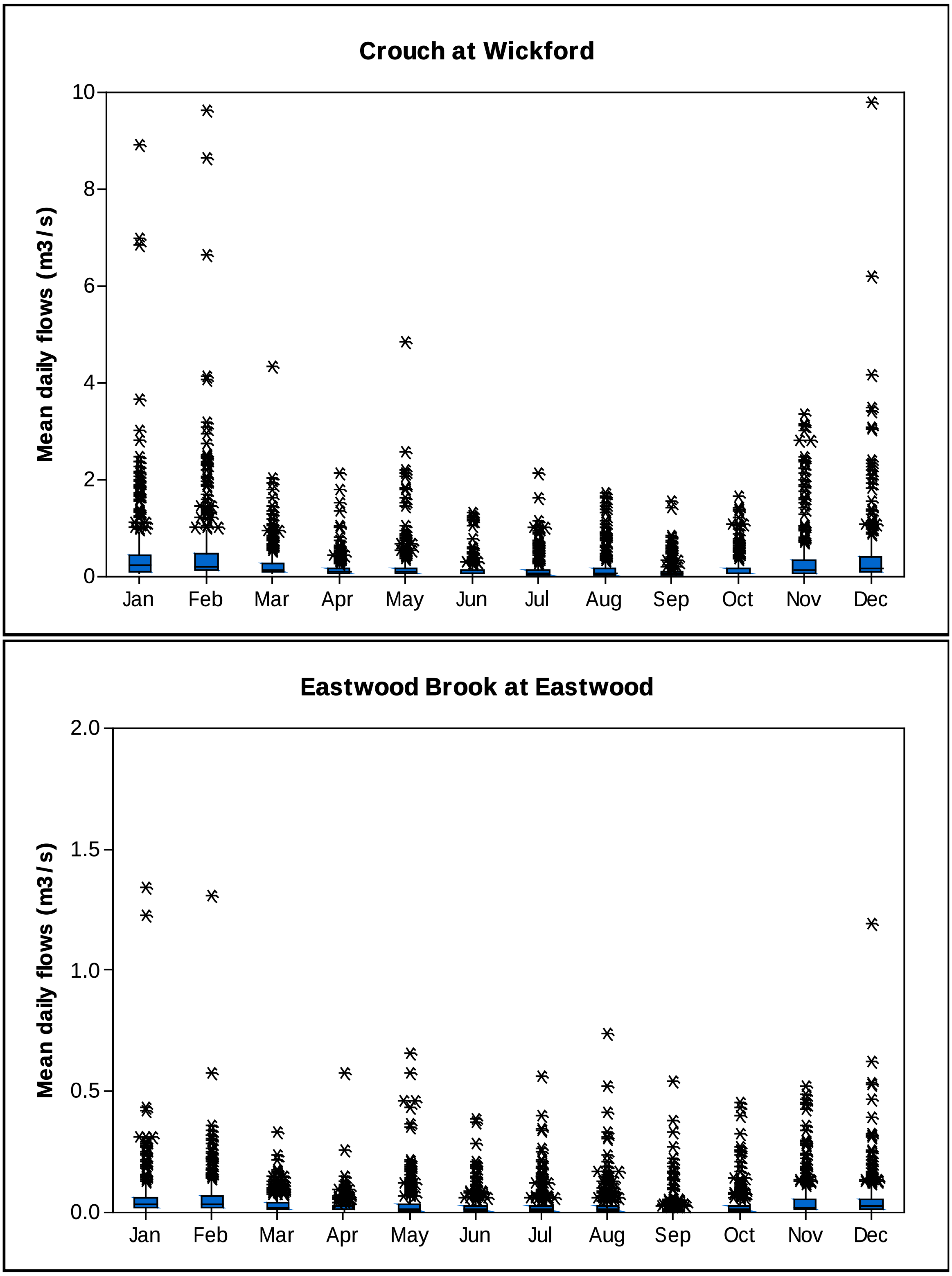


Figure III.2 Boxplot of mean daily flows for the Crouch at Wickford and Eastwood Brook at Eastwood, Jan 2002 to Feb 2012. *Data from the Environment Agency.*
NB three outlying records of daily flows for the Crouch of between 15.9 and 22.3 m^3/s in January, February and December have been omitted for clarity

Mean flows on these watercourses are low at 0.29m^3/sec for the Crouch and 0.042m^3/sec for Eastwood Brook for the period presented. Futurecoast (2002) estimated the mean and maximum freshwater inputs to the system at 0.39 and 18.4m^3/sec respectively. The shape of the boxplots indicate that flows are generally low, but on occasion very high flows in relation to base flow are experienced. Therefore impacts from land runoff will vary considerably, but will generally be quite low. Flows were highest on average from November through to February, and the highest flow events tended to arise during this period, although some quite high flow events were recorded in most months of the year. Relationships between levels of faecal indicator bacteria in shellfish and water samples and recent river discharge are examined in detail in Appendices XI and XII (pages 74 and 81).

APPENDIX IV
HYDROGRAPHIC DATA: BATHYMETRY

The Roach and Crouch form a large branching estuary complex which is largely surrounded by reclaimed land and flanked throughout by flood defence walls. The Crouch is more linear than the Roach, with a few small creeks and side channels in its upper reaches. The Roach is more complicated in shape, with branching creeks surrounding small islands and a secondary connection to the sea at Havengore. A causeway across Maplin Sands (the Broomway) dries out during the lower half of the tidal cycle thereby limiting exchange through Havengore Creek to the upper half of the tidal cycle.

The sea defences confine the estuary to relatively narrow channels and limit the intertidal areas to a narrow strip of mud fringed by saltmarsh. In a few areas adjacent to the Crouch, sea defences have been breached and there are larger areas of saltmarsh. The depth decreases progressively towards the head of the estuaries from a maximum of 13m in the outer Crouch, and the proportion of intertidal area also increases. The creeks and side channels are shallower than the main channels. Therefore, the dilution potential decreases in the upper reaches of the estuaries and within the side channels. There is no hydrological connection between the head of Paglesham Pool and the Crouch at Creeksea (Figure IV.1).

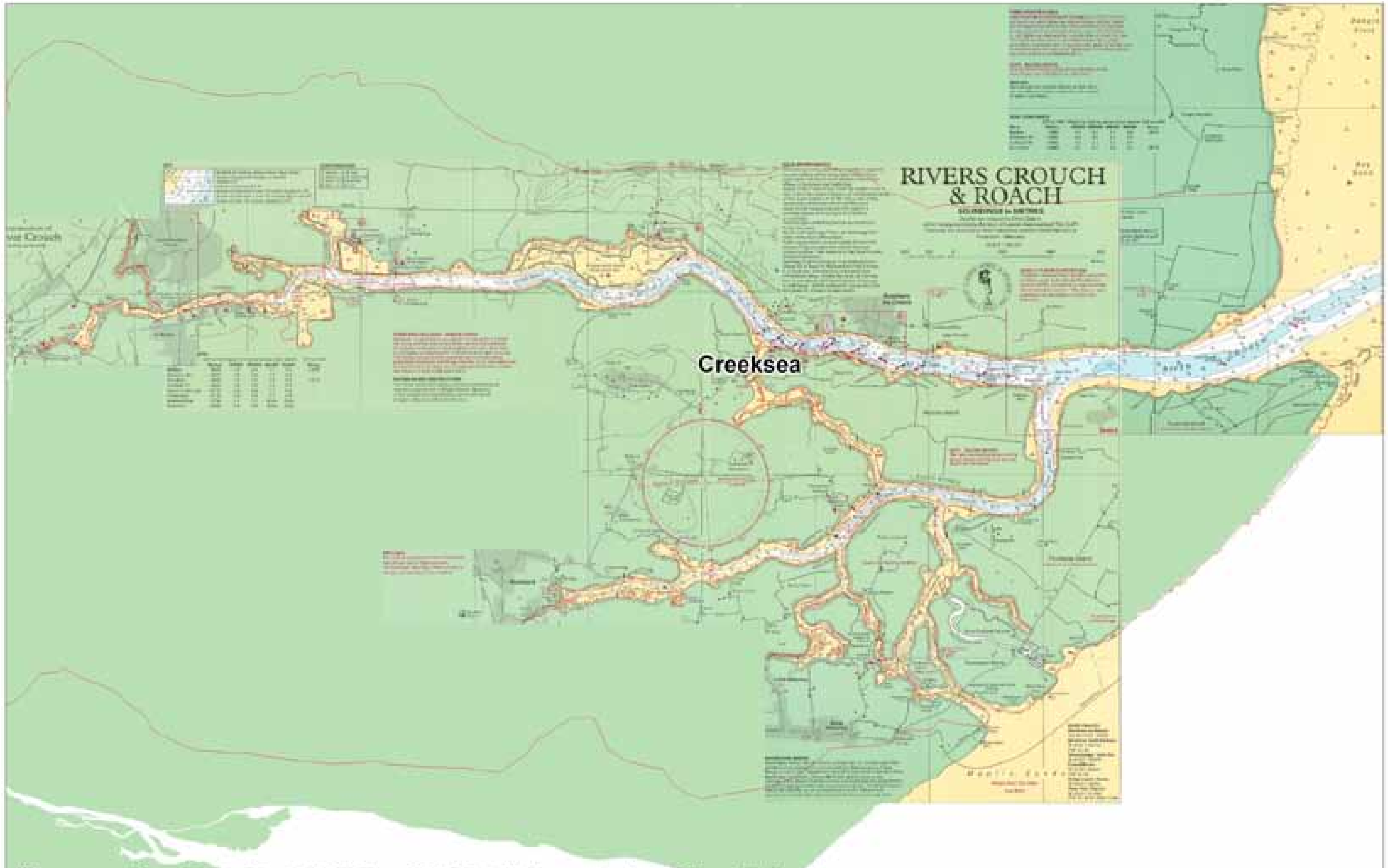


Figure IV.1 Bathymetric chart of the Roach and Crouch

APPENDIX V
HYDRODYNAMIC DATA: TIDES AND CURRENTS

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. Tidal range in the Roach and Crouch estuaries is relatively large, and this drives extensive water movements throughout the complex. Table V.1 shows tidal range at various locations.

Table V.1 Tide levels and ranges within the Roach and Crouch.

Port	Height (m) above Chart Datum				Range (m)		Lag in HW time relative to Burnham
	MHWS	MHWN	MLWN	MLWS	Springs	Neaps	
Burnham-on-Crouch	4.90	3.85	1.15	0.10	4.80	2.70	-
North Fambridge	5.30	4.20	1.10	0.30	5.00	3.10	~20 mins
Hullbridge	5.30	4.20	1.10	0.30	5.00	3.10	~20 mins
Battlesbridge	2.40	1.40	-	-	-	-	~ 25 mins
Rochford	3.40	2.30	-	-	-	-	~0 mins

Data from the Proudman Oceanographic Office

There are no tidal diamonds within the Roach and Crouch on the nautical charts to provide information on the directions and speeds of tidal streams. Within the Crouch patterns of tidal flows are relatively straightforward, moving up the estuary on the flood and back down on the ebb. The more complicated shape and secondary connection to the sea make precise predictions more difficult for the Roach. Its main connection to the sea is through the River Crouch, and this is via a relatively deep subtidal channel. The secondary connection to the sea is via Havengore Creek, but water can only pass through here from about half tide upwards as the sandbanks and a causeway on Maplin Sands dry out during the lower part of the tidal cycle. The depth through this connection at high water is reported to be 2.2m during spring tides and 1.2m on neap tides (Crouch Harbour Authority, 2012) so this connection exists for just under half of the tidal cycle. As a consequence the tide enters the Roach through the Crouch during the first half of the flood tide. There is a lag as the tide propagates through the estuary from the main estuary mouth round to the Roach. This means that when the tide reaches a sufficient height to open the connection at Havengore, water levels are higher in the open sea and over this connection so the tide reverses and flows north through Havengore Creek, the Middleway and Potton Creek and into the main Roach channel. The opposite occurs on the ebb. Although there is no solid evidence to verify this, the reversing of tidal streams was described during the shoreline survey by a local fisherman. The impacts from shoreline sources will differ somewhat from that within the Crouch in that they will be more limited spatially but with less dispersion and flushing. Within the upper Roach and Paglesham Pool tidal streams will move up estuary on the flood and down estuary on the ebb.

Some measurements of tidal current velocity within the Roach and Crouch were reported by Cea-Gomez, 2005. In this study, current speed and water depth were measured at 15 minute intervals over a period of 5 days at Holliwell and Fambridge on the Crouch and at Wallasea and Paglesham on the Roach. Currents at all these stations were bi-directional, moving up-estuary on the flood and down-estuary on the ebb. Maximum current speeds recorded were 0.9 m/s at Holliwell and Wallasea, 0.8 m/s at Paglesham, and 0.6m/s at Fambridge. As it was not stated whether these were spring or neap tides, this information is of limited relevance, although it does suggest that there is no mid-tide reversal of tidal flows in the main Roach channel. Measured tidal current velocities north of Wallasea Island are reported to reach 0.9m/s on the ebb and 1m/s on the flood (ABPmer, 2004) which translates to a tidal excursion very approximate order of 10-15km. The pattern of tidal flows within the Crouch mean that shoreline sources will impact to either side of their location, with the associated plumes becoming less concentrated with distance travelled. Contamination may potentially be carried 10-15km along the estuary on spring tides so major sources may impact on distant shellfish beds.

Superimposed on tidally driven currents are the effects of freshwater inputs and wind. The flow ratio (freshwater input: tidal exchange) is very low and the system is well mixed (Futurecoast, 2002), so density driven circulation is unlikely to be of importance. One density effect of potential relevance is the tendency for sewage effluents to be buoyant and rise to the surface, which will tend to keep the sewage separate from benthic shellfish stocks if they are located in the deeper areas.

Given the shape of the estuary and the location of the freshwater inputs, salinity may decrease slightly towards the upper reaches, particularly at times of high freshwater input. The salinity reflects the degree of freshwater influence, and where land runoff is an important contaminating influence decreasing salinity is usually associated with increasing levels of faecal indicator bacteria. A series of salinity measurements were taken during the shoreline survey (Figure V.1) which was undertaken in dry conditions.

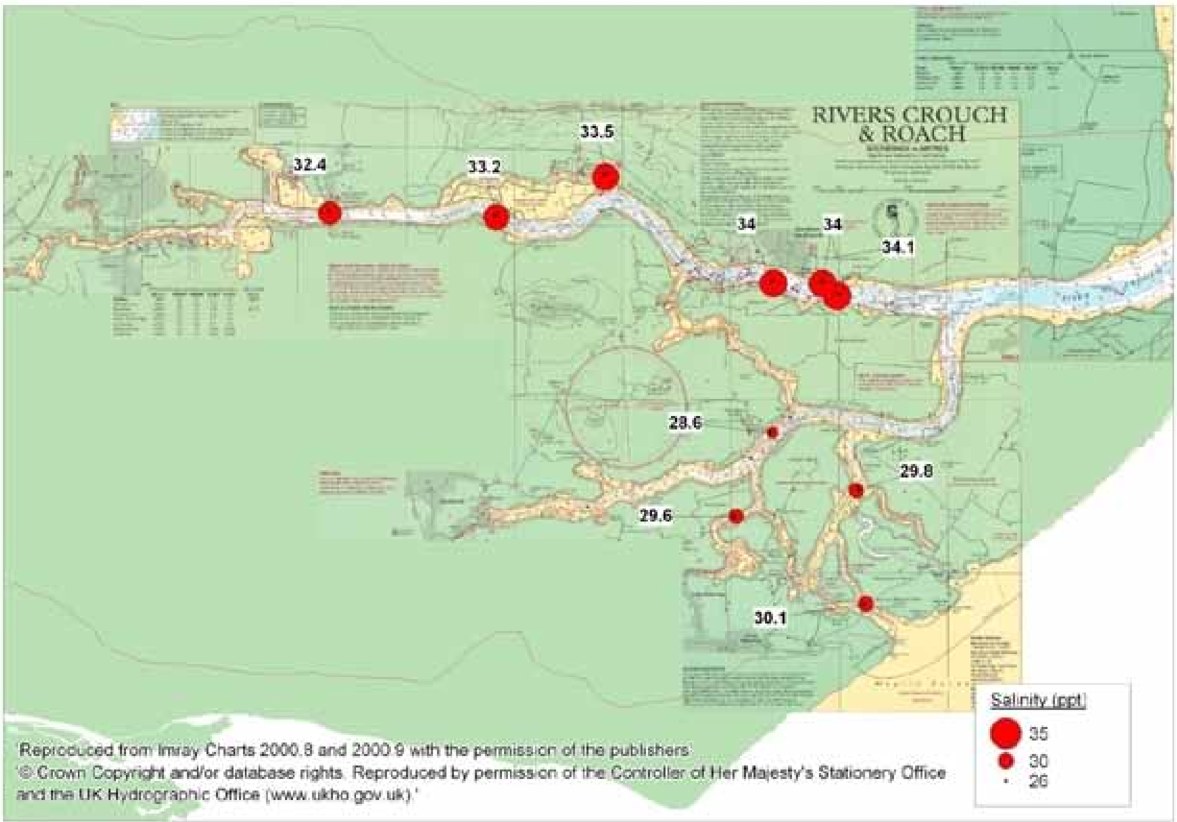


Figure V.1 Thematic map of salinity measurements taken during the shoreline survey.

Within the Crouch, salinity was approaching that of full strength seawater throughout, although it did drop very slightly but steadily towards the head of the estuary. At sites sampled within the Roach, salinity was noticeably lower than in the Crouch, although the minimum was 28.6ppt indicating a limited freshwater influence. Lower salinities within the Roach may be due to the decreased flushing arising from the tidal flipping and/or the smaller volume of this estuary reducing the dilution of freshwater inputs by seawater. A slightly higher contaminating influence of freshwater inputs (and other sources) may be anticipated within the Roach on this basis. Samples of water were tested for faecal coliforms alongside the salinity measurements for the Crouch only, and all these contained <10 *E. coli* cfu/100ml so it is not possible to draw any conclusions on whether the lower salinities were associated with higher levels of contamination.

Strong winds will modify surface currents. Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m s^{-1}) would drive a surface water current of about 1 knot or 0.5 m s^{-1}. These currents in turn drive return currents which may travel lower in the water column or along sheltered margins. Winds aligning with the estuary channels will have the greatest effect, by either increasing or retarding tidal streams at the surface. For the Crouch, winds aligning with its east-west orientation are likely to have the most effect on water circulation. The more complex shape of the Roach means that winds will affect water circulation in different ways throughout the different reaches. Winds may cause considerable variation in the dispersal of buoyant plumes arising from sewage outfalls such as that from Burnham STW at times. Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great range of scenarios may arise. Where strong winds blow across a sufficient distance of water they may create wave action, and where these waves break contamination held in intertidal sediments may be resuspended, although given the enclosed nature of the estuary complex strong wave action is not generally anticipated.

APPENDIX VI
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 VI.1). The frequency of gales is relatively low.

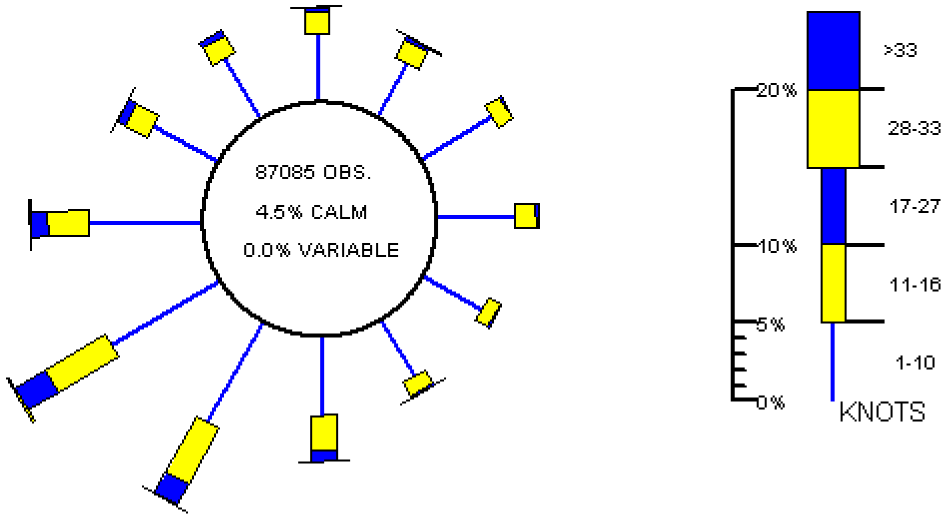


Figure VI.1 Wind rose for Coltishall, Norfolk.
Period of data: January 1995–December 2004.
Produced by the Meteorological Office. Contains public sector information licensed under the Open Government Licence v1.0.

The Roach and Crouch are most exposed to easterly winds blowing in from the sea, but the low lying nature of the surrounding land generally affords little shelter from wind from any direction. Strong winds drive surface currents and so may potentially have a significant effect on water movements. For the Crouch, winds aligning with its east-west orientation are likely to have the most effect on water circulation. The more complex shape of the Roach means that winds will affect water circulation in different ways throughout the different reaches. Where strong winds blow across a sufficient distance of water they may create wave action, and where these waves break contamination held in intertidal sediments may be resuspended. The potential impacts of wind on the circulation of water and contaminants within the estuary complex are discussed in more detail in Appendix V (page 58).

APPENDIX VII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: SEWAGE DISCHARGES

Details of all consented discharges were taken from the Environment Agency's national discharge database (January 2012). There are a total of nine water company sewage treatment works within the Roach/Crouch catchment (Figure VII.1 and Table VII.1). Of these, two discharge to the upper reaches of the Crouch estuary (Rayleigh West and Woodham Ferrers STWs) above all the fisheries and two discharge to the River Crouch upstream of its tidal limit (Wickford and Billericay STWs). Burnham-on-Crouch STW discharges to the Crouch at Burnham, Rochford discharges to the Roach at Blackledge, and Rayleigh East STW discharges to Rayleigh East Brook, which in turn drains to the head of the Roach estuary. A further two much smaller treatment works (Paglesham and Foulness STWs) discharge to small watercourses draining to the middle and outer reaches of the main Roach estuary channel. The path taken by effluent from the Foulness STW through the network of field drains and into the estuary is uncertain.

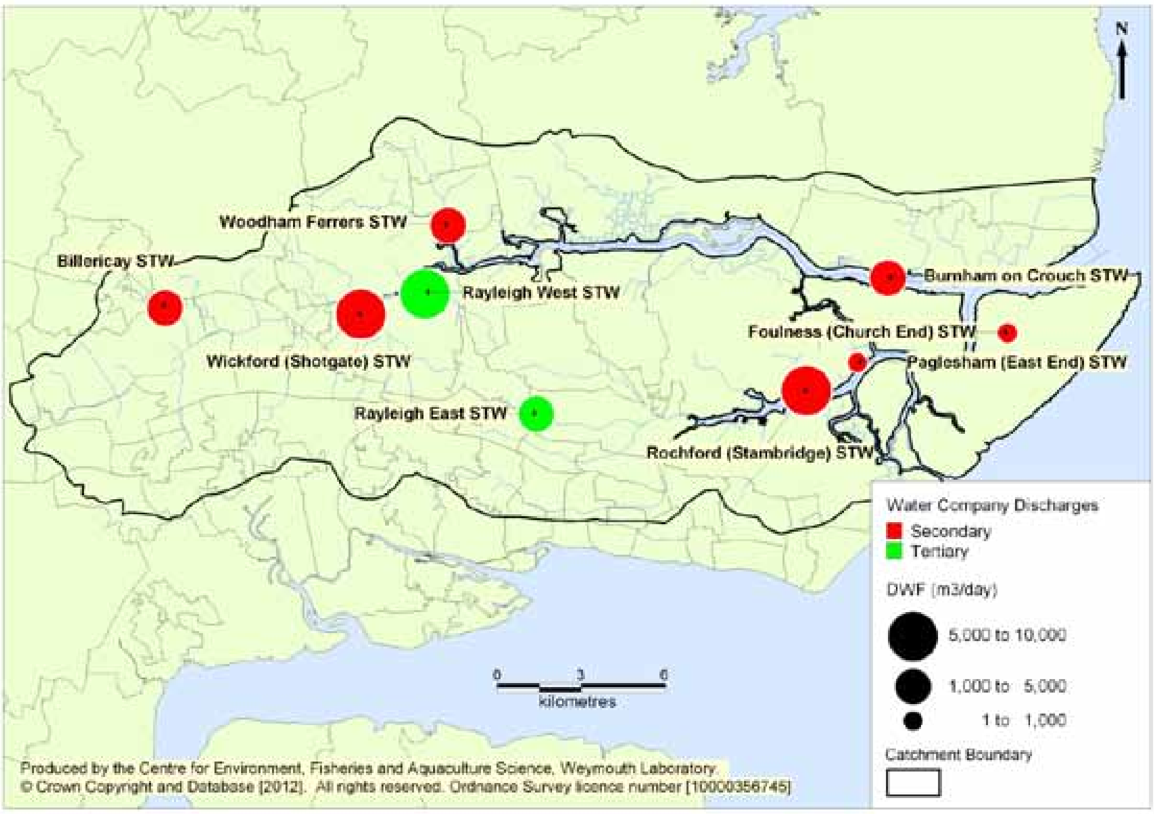


Figure VII.1. Locations and size of major continuous water company sewage discharges

Both Rayleigh East STW and Rayleigh West STW employ tertiary treatment methods consisting of reed beds and final lagoons respectively to produce a higher quality final effluent. Effluent from the Rochford STW also passes through a lagoon before it is discharged to the estuary, which has a retention time of 10 days at dry weather flows (Environment Agency, 2009b). All other works provide secondary treatment, although Rayleigh East, Burnham-on-Crouch, and Wickford are due to have UV treatment added by March 2013. Table VII.2 presents summary statistics for a series of final effluent samples taken from the main six sewage works influencing the Roach and Crouch.

Table VII.1 Details of major continuous water company sewage discharges to the area

Name	Location	DWF (m^3/day)	Treatment Level	Estimated bacterial loading (faecal coliforms/day)	Receiving Water
Billericay STW	TQ6989094200	1417	Secondary & lagoon	$4.7x10^{12}$ [a]	Trib of River Crouch
Wickford (Shotgate) STW	TQ7691094010	8214	Secondary & 50% of flow through lagoon	$6.3x10^{12}$ [b]	River Crouch
Rayleigh West STW	TQ7921094740	5827	Secondary & lagoon	$7.9x10^{10}$ [b]	River Crouch
Woodham Ferrers STW	TQ8004097170	3900	Secondary & lagoon	$3.0x10^{11}$ [b]	Fenn Creek
Rayleigh East STW	TQ8321090390	4600	Secondary & reedbeds	$3.7x10^{11}$ [b]	Rayleigh East Brook
Rochford (Stambridge) STW	TQ9290091260	8630	Secondary & lagoon	$1.4x10^{11}$ [b]	River Roach
Paglesham (East End) STW	TQ9472092230	27	Secondary	$8.9x10^{10}$ [a]	Trib of River Roach
Burnham on Crouch STW	TQ9581095280	2200	Secondary	$1.1x10^{13}$ [b]	Tidal River Crouch
Foulness (Church End) STW	TR0010093300	20	Secondary	$6.6x10^{10}$ [a]	Trib of River Roach

[a] Based on base flow average from a range of UK STWs (Table VII.4). These estimates are intended for comparative purposes only and bacterial loadings generated by each STW are likely to fluctuate significantly.
[b] Based on geometric mean faecal coliforms in a series of final effluent samples (Table VII.3).

Table VII.2 Summary of final effluent testing results, June 2008 to October 2009.

		Faecal coliforms results (cfu/100ml)			
STW	No.	Geomean	Minimum	Maximum	95%ile
Wickford STW	15	76,913	10,000	369,000	289,572
Rayleigh West STW	15	1,349	88	112,000	21,166
Woodham Ferrers STW	15	7,656	2,000	59,400	44,405
Rayleigh East STW	15	7,998	793	196,000	108,311
Rochford STW	15	1,618	38	16,727	10,762
Burnham STW	15	505,825	33,000	2,700,000	2,249,331

Date from the Environment Agency

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

Treatment Level	Flow			
	Base-flow		High-flow	
	n	Geometric mean	n	Geometric mean
Storm sewage overflows (53)			200	$2.5x10^6$
Primary (12)	127	$1.0x10^7$	14	$4.6x10^6$
Secondary (67)	864	$3.3x10^5$	184	$5.0x10^5$
Tertiary - Reed bed/grass plot (6)	71	$1.3x10^4$	2	$1.5x10^4$

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

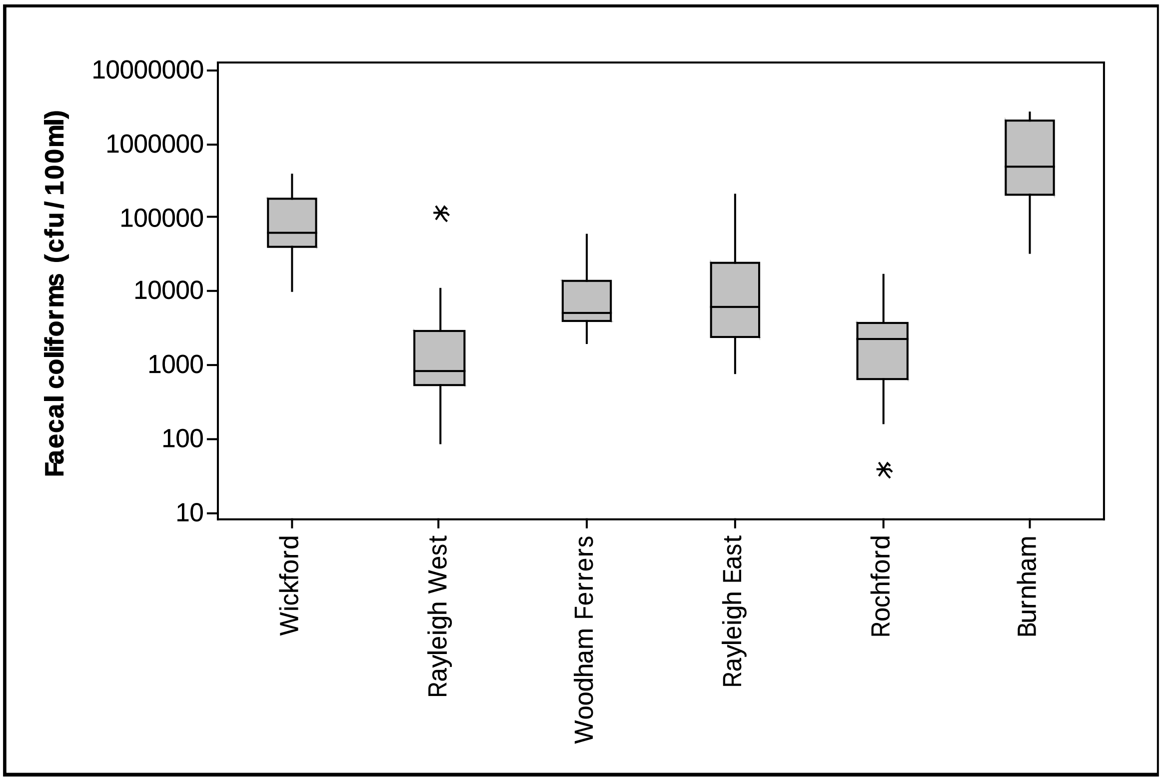


Figure VII.2 Boxplots of faecal coliform concentrations in final effluents, June 2008 to October 2009.

Table VII.2 and Figure VII.2 indicate considerable variation in average concentrations of bacterial indicators in final effluents both across and to a lesser extent within these six treatment works. Burnham and Wickford STWs are the least effective at reducing faecal coliform concentrations, and Rayleigh West and Rochford are the most effective. This has a considerable influence on the estimates of the average bacterial loading they generate presented in Table VII.1.

These should be treated with some caution as both flows and bacterial concentrations can vary significantly with time, and three of these estimates are based on published values of bacterial concentrations from a range of secondary works. Nevertheless, they give a rough comparison of the importance of the various works, and indicate that the Burnham STW generates perhaps 50% of the combined loadings from all these continuous discharges. Significant loadings are also generated by Wickford (~25% of total) and possibly Billericay (~20% of total) STWs. The loadings generated by the other works are likely to be relatively small (~5% of total). On this basis the most acute influences from continuous water company discharges are likely to arise in the very upper reaches of the Crouch estuary, and within the plume generated by the Burnham STW outfall just off Burnham on Crouch. The Burnham outfall discharges at about the low water mark just off the eastern end of Burnham and is uncovered at low water on spring tides (Figure XIII.4, page 104 for shoreline survey photograph). The influences of the other continuous discharges will be minor in comparison and localised.

In addition to the continuous sewage discharges, there are a large number of intermittent water company discharges within the area associated with the sewerage networks. Figure VII.2 shows the locations of these as well as private discharges directly to or within close proximity to the estuary. There are additional intermittent and private discharges distributed within the catchment further inland that are not shown on the map.

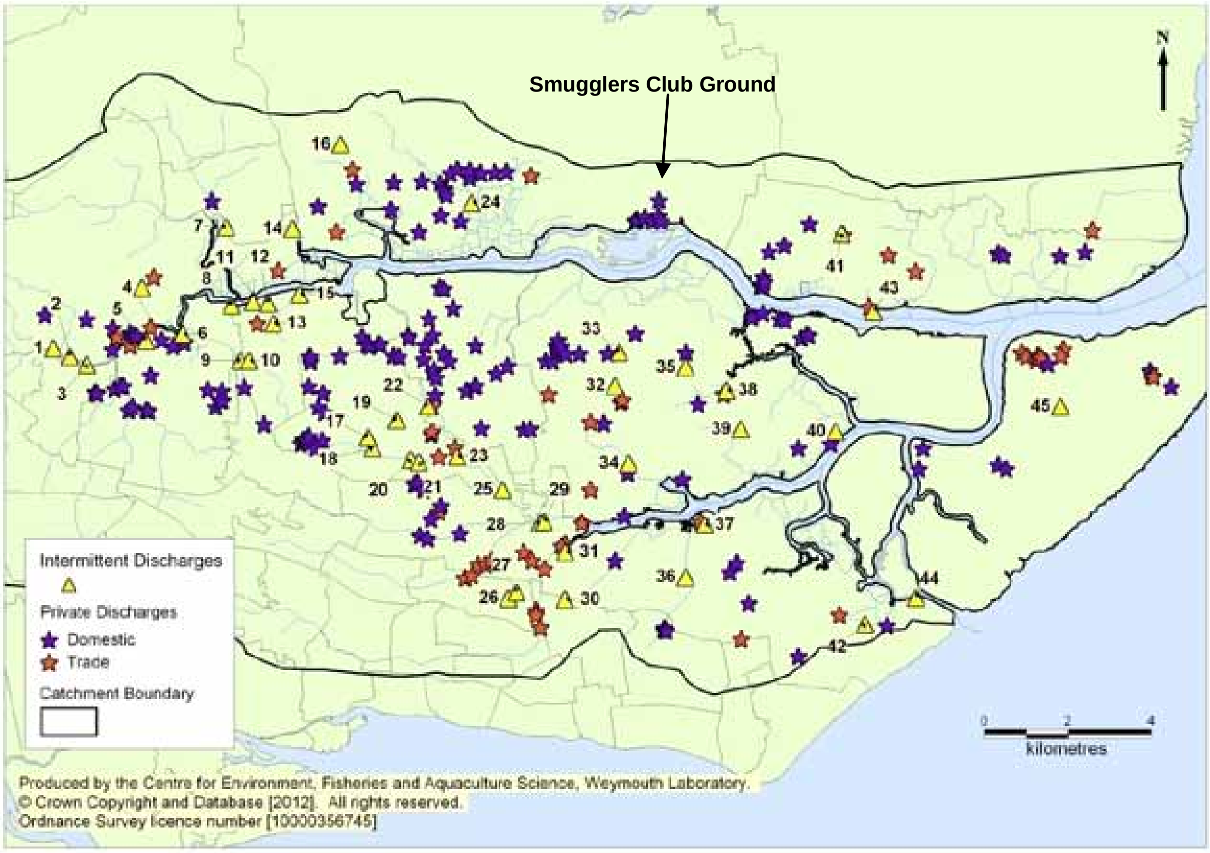


Figure VII.3. Locations of intermittent and private discharges within the catchment

Table VII.4 Details of intermittent discharges situated within the catchment.

ID	Name	Location	Type
1	Runwell PS	TQ7610094400	Storm & Emergency
2	Southlands Farm PS	TQ7650094200	Storm & Emergency
3	Wickford (Shotgate) STW	TQ7691094010	Storm
4	PS at Woodham Road	TQ7822895854	Storm & Emergency
5	Beeches Rd & Church Rd PS	TQ7833294580	Emergency
6	Rayleigh West STW	TQ7960094200	Storm & Emergency
7	Ferrers Road PS	TQ8024997321	Storm & Emergency
8	The Esplanade PS	TQ8039095430	Emergency
9	Whitepost Bridge Corner	TQ8060094100	Storm
10	West Side of Ferry Road	TQ8080094100	Storm
11	Ferry Road SPS	TQ8090095510	Storm & Emergency
12	Crouch Caravan Park*	TQ8125795480	Storm
13	Keswick Avenue/Burnham Rd	TQ8139095000	Storm
14	Clements Green Lane PS	TQ8184497273	Emergency
15	PS at Pooles Lane	TQ8202095700	Emergency
16	Stow Maries SPS	TQ8300099300	Storm & Emergency
17	Hawkwell & Hockley SPS	TQ8366092260	Storm & Emergency
18	Woodlands Road PS	TQ8377892000	Storm & Emergency
19	Hawkwell Rd	TQ8435292670	Storm
20	Tudor Way	TQ8469091720	Storm
21	Hawkwell Rd	TQ8488891662	Storm
22	Hawkwell Rd	TQ8511193009	Storm
23	Rectory Rd	TQ8580091800	Storm

ID	Name	Location	Type
24	Franklin Rd PS	TQ8615197898	Storm & Emergency
25	Road Construction Serving Res. Dev.	TQ8690091000	Storm
26	Outlet at Rochford Rd	TQ8703088390	Storm
27	Bell PH/Prince Avenue CSO	TQ8723088530	Storm
28	Council Depot	TQ8780090200	Storm
29	Rochford PS	TQ8789390232	Storm & Emergency
30	Temple Farm SPS	TQ8839088361	Storm & Emergency
31	PS at Sutton Rd	TQ8840089500	Emergency
32	Scotts Hall Road	TQ8960093500	Storm
33	PS at Canewdon Village	TQ8970094300	Storm & Emergency
34	Stambridge SPS	TQ8993091630	Storm & Emergency
35	PS at Loftmans Corner	TQ9129793946	Storm & Emergency
36	Stonebridge TPS	TQ9130088900	Storm & Emergency
37	Outlet at Barling Magna	TQ9175190158	Emergency
38	Pagelsham Church End SPS	TQ9228093390	Storm & Emergency
39	Paglesham SPS	TQ9262092460	Storm & Emergency
40	Paglesham East	TQ9490092400	Storm
41	Romans Farm SPS	TQ9504997158	Storm & Emergency
42	Great Wakering SPS	TQ9561187767	Storm & Emergency
43	Burnham on Crouch STW	TQ9581095280	Storm
44	Wakering Common TPS	TQ9683088400	Storm & Emergency
45	Foulness (Church End) PS	TR0030093000	Storm & Emergency

* Privately owned (not an Anglian Water asset)
Yellow - spill data requested and provided by Anglian Water.
Blue - spill data requested but not available (no logging).

There is a large cluster of intermittent discharges around the upper reaches of the Crouch estuary. At Burnham, there are only two intermittent discharges, and it is likely that most spills from this network are made via the main STW outfall as this is at a lower elevation. There are a few intermittent discharges which may impact on the Roach. Rochford PS has been identified by the Environment Agency as having the potential to influence the Shellfish Water (Environment Agency 2009b). Intermittent sewage discharges can deliver large volumes of storm sewage to coastal waters.

Information on the spill frequencies from selected outfalls was provided by Anglian Water for 2010 and 2011 (Table VII.5). For spill counting purposes, a spill of 24 hours or less is counted as 1 spill, and if a spill continues for longer than 24 hours, each subsequent 24 hours counts as a further spill. If several spills occur within a 24 hour period, they are counted as 1 spill. The events reported as a spill are actually water levels alarms, which indicate high water levels in the wet well but do not necessarily mean that a spill has occurred. Therefore, each recorded spill indicates that a spill (or spills) of 24 hours or less may potentially have occurred, but does not give any indication of spill volume nor actual date of occurrence.

Table VII.5 Recorded spills from selected intermittent outfalls with event logging

ID	Name	Potential spills 2010	Potential spills 2011	Total
5	Church Rd PS	22	34	56
8	The Esplanade PS	18	38	56
11	Ferry Road SPS	3	13	16
14	Clements Green Lane PS	1	0	1
15	PS at Pooles Lane	8	13	21
29	Rochford PS	0	11	11
31	PS at Sutton Rd	2	0	2
38	Pagelsham Church End SPS	10	11	21
39	Paglesham SPS	2	10	12
40	Paglesham East	3	4	7

The two outfalls which recorded the most potential spill events during this period are both located in the upper Crouch, upstream of the fisheries. Potential spills from other monitored outfalls did occur from time to time but occurred less than once a month on average. With no confirmation whether these events were actually spills or indication of volumes discharged, it is difficult to draw meaningful conclusions from this data. For other unmonitored outfalls, it is difficult to make an assessment of their significance aside from noting their locations and their potential to deliver large bacterial loadings. Spills will mainly be associated with wet weather events, particularly within the sewerage networks that collect larger amounts of surface water. Occasionally spills may be associated with mechanical failures or blockages which may occur at any time. Their geographic distribution and available spill data suggests that the upper areas of the Crouch may be most affected.

Although the majority of properties in the Roach/Crouch catchment are connected to mains sewers, there are a significant number of small private discharges to the area, some of which discharge to soakaway and others to watercourses. Only those closest to the fishery are shown in Figure VII.3. Of the 293 private discharges within the entire catchment which contain sewage (i.e. excluding discharges such as cooling water or surface water), the majority (218) discharge to freshwater watercourses, with 58 discharging to land/soakaway, 15 direct to the estuary and 2 to enclosed waterbodies (ponds/lakes). The cumulative bacterial loadings generated by these private discharges will be very minor in relation to those from water company discharges. A cluster of private discharges at the Smugglers Club Caravan Park, on the north shore of Althorne Creek are reported to discharge raw sewage to adjacent land drains (Maldon DC, pers comm.). When these drains are flowing, this is likely to have some impacts within Althorne Creek.

In summary, under normal (dry) conditions, the majority of bacterial loadings from sewage discharges entering the Roach and Crouch are generated by Burnham STW and two works discharging to the River Crouch upstream of its tidal limit (Billericay and Wickford STWs). There is some uncertainty about the impacts of the Billericay STW as this discharges about 12km upstream of the tidal limit. Also, its bacterial loading was estimated from published reference values of faecal coliform concentrations in sewage effluent rather than actual testing results. The Burnham STW is due to have UV disinfection fitted in early 2013, so its impacts should greatly reduce in the near future. Two other sewage works discharge to the upper reaches of the tidal Crouch (Rayleigh West and Woodham Ferrers STWs) but these appear to generate a much lower bacterial loading. A further four sewage works discharge to the Roach or tributaries thereof. The Rochford STW discharges at Blackledge and the Rayleigh East STW discharges to a tributary of the River Roach, but both of these only generate small bacterial loadings due to lagoon and reedbed treatment respectively. Two minor treatment works discharge to the estuary at Paglesham (Paglesham STW) and to drainage ditches on Foulness Island (Foulness STW). There are intermittent discharges associated with these sewerage networks, mainly clustered around the head of the Crouch estuary and to a lesser extent the Roach estuary. Of the selected outfalls for which telemetry data was available, high level alarms were recorded most frequently at two outfalls in the very upper reaches of the Crouch, although this does not mean that a spill actually occurred. For the other intermittent discharged it is difficult to assess their impacts aside from noting their location and their potential to spill primarily during wet weather events. Many of the watercourses draining to the estuary complex receive small amounts of effluent from private discharges, the cumulative effects of which will be minor in relation to the water company discharges. A cluster of poorly performing private discharges at the Smugglers Club Grounds may have some localised effects within Althorne Creek.

APPENDIX VIII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: AGRICULTURE

Diffuse contamination from livestock or slurry applications will be carried into the estuary via watercourses draining areas of pastures or arable land. The extent of this will depend not only on the numbers and distribution and type of livestock and patterns of slurry application, but also rainfall patterns, soil permeability, slope, and the degree of separation between livestock and watercourses. To capture contamination of livestock origin RMPs should be set in a position which most exposes them to plumes originating from these watercourses. The concentration of faecal coliforms excreted in the faeces of animal and human and corresponding loads per day are summarised in Table VIII.1.

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

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

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

There are significant areas of arable land as well as some pockets of pasture within the area draining to the Roach and Crouch estuaries (Figure 1.2). Livestock census data from the 2010 census was provided by Defra for this area and is presented in Figure VIII.1 and Table VIII.2. It must be noted that each farm is allocated to a single point, whereas in practice an individual farm may span two or more catchments. Nevertheless, this information will give a broad overview of livestock farming in the area.

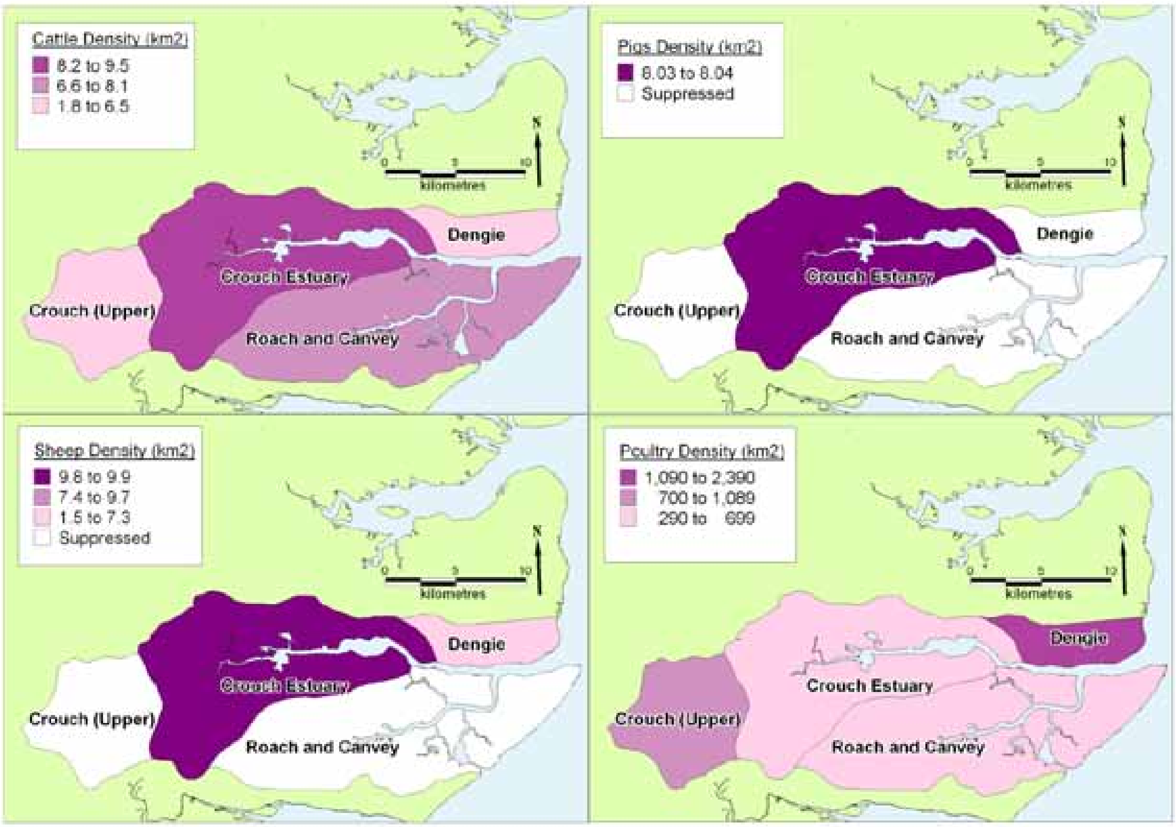


Figure VIII.1 Livestock densities within the Roach and Crouch catchment.

Table VIII.2 Total numbers and densities of livestock by catchment

	Total number				Density (animals/km^2)			
Catchment	Cattle	Pigs	Sheep	Poultry	Cattle	Pigs	Sheep	Poultry
Crouch (Upper)	121	**	**	69,103	2	**	**	1087
Crouch Estuary	1,938	1,162	1,423	112,197	13	8	10	776
Roach and Canvey	1,934	**	**	107,013	10	**	**	531
Dengie	675	**	425	243,979	7	**	4	2385
Total	4,667	>1,162	>1,848	532,292	9	>2	>4	1,039

** Data withheld for confidentiality reasons as it relates to less than 5 holdings

Grazing animals are present throughout the catchment with highest numbers and densities within the Crouch Estuary sub catchment. Numbers are very low relative to the human population (412,662). The land cover map (Figure 1.2, page 8) indicates pockets of pasture dotted throughout the Roach and Crouch catchment including areas adjacent to the estuaries around South Woodham Ferrers, North Fambridge and Foulness Island. Watercourses draining these areas are likely to be subject to contamination of livestock origin. There is likely to be some seasonality in levels of contamination originating from grazing livestock. Numbers of cattle and sheep will increase significantly in the spring, with the birth of calves and lambs, and decrease in the autumn when animals are sent to market. During winter cattle may be transferred from pastures to indoor sheds and at these times slurry will be collected and stored for later application to fields. Timing of these applications is uncertain, although farms without large storage capacities are likely to spread during the winter and spring. Therefore peak levels of contamination from grazers may arise following high rainfall events in the summer, particularly if these have been preceded by a dry period which would allow a build up of faecal material on pastures, or on a more localised basis if wet weather follows a slurry application which may be more likely in winter or spring.

Manure from poultry and pig operations is stored and then strategically applied to local arable land (Defra, 2009). Therefore, periodic applications of manures to the arable farmland which dominates the catchment is anticipated, although the temporal and spatial profiles of these applications is uncertain. It is also likely that treated sewage sludges are spread on arable land, but no information on local practices was available at the time of writing.

In conclusion, the number of grazing animals in the catchment is low relative to the human population, but some impacts are likely to arise through runoff from areas of pasture. Land cover maps indicate that there are pastures adjacent to the estuary around South Woodham Ferrers, North Fambridge and Foulness Island so watercourses draining these areas may be more at risk. Higher volumes of faecal matter are likely to be deposited on pastures from spring through to autumn. Slurries, manures and sewage sludge may be sporadically spread on the arable land which is found throughout the catchment, possibly with a winter/spring peak associated with the indoor housing of cattle. Contamination of agricultural origin is primarily carried into coastal waters via land runoff, so the magnitude of such fluxes is highly rainfall dependent.

APPENDIX IX
SOURCES AND VARIATION AND MICROBIOLOGICAL POLLUTION: BOATS

The discharge of sewage from boats is potentially a significant source of bacterial contamination of shellfisheries within the Roach and Crouch. The Crouch is renowned as a centre for sailing and hosts a small commercial port, and there is significant boat traffic within the Roach. Figure IX.1 presents an overview of boating activity derived from the shoreline survey, satellite images and various internet sources.

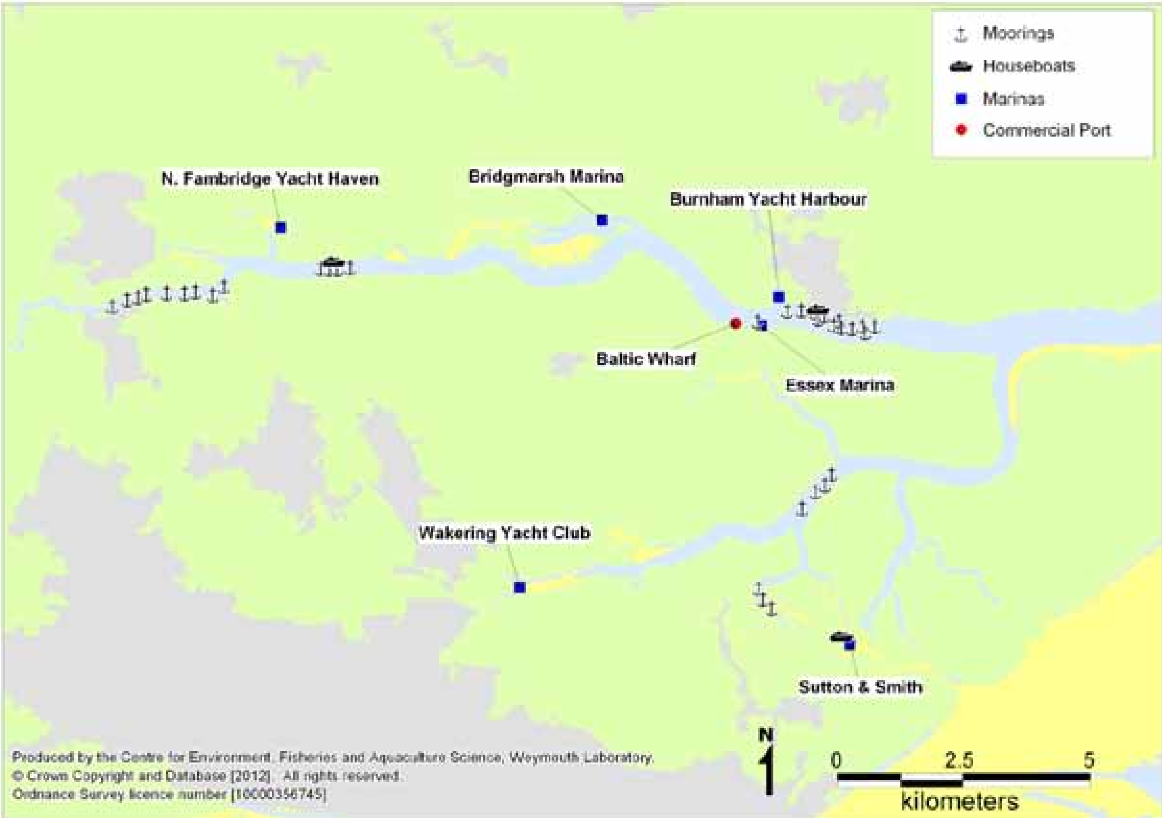


Figure IX.1 Locations of moorings, marinas and houseboats.

The majority of marinas and moorings and the only commercial port are on the Crouch. At Brandy Hole there are around 120 moorings associated with the Brandy Hole Yacht Station. North Fambridge Yacht Haven has about 180 pontoon berths within Stow Creek and about 120 moorings in the main river. Bridgmarsh Marina is located in Bridgmarsh Creek and has about 120 pontoon berths. Essex Marina has about 400 berths/moorings opposite Burnham. Burnham Yacht Harbour has around 350 berths (Reeds, 2012). The area just of Burnham is filled with several hundred moorings under various ownership. Houseboats were observed at Burnham on Crouch and at North Fambridge. There is a minor commercial port at Baltic Wharf which receives small volumes of shipping traffic generally associated with the wood trade.

Within the Roach there are a small number of berths at Wakering Yacht club and at Sutton & Smith Boatyard. Areas of moorings are located at Paglesham and within

Barling Creek. Some probable houseboats were also seen at Sutton and Smith Boatyard.

Merchant shipping vessels are not permitted to make overboard discharges within 3 nautical miles of land[1] so vessels associated with the commercial port should produce little or no impact. Smaller private vessels such as yachts, cabin cruisers and fishing vessels are likely to make overboard discharges from time to time. Those in overnight occupation on moorings or at anchor may be more likely to make overboard discharges. Occupied yachts on pontoon berths may be less likely to make overboard discharges as this is somewhat antisocial in the crowded marina setting, and facilities on land are easy to access. Houseboats in occupation are likely to make regular discharges. The greatest potential for impacts from boats is probably in the vicinity of Burnham, although impacts may be felt in other areas where moorings and marinas and houseboats are present, and it is quite likely that some overboard discharges are made by boats on passage. Peak pleasure craft activity is anticipated during the summer, particularly during the Burnham regatta week during August, so associated impacts are likely to follow this seasonal pattern. 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 X
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: WILDLIFE

Within the survey area there are areas of saltmarsh and intertidal mud which provide bird foraging habitat. Studies in the UK have found significant concentrations of microbiological contaminants (thermophilic campylobacters, salmonellae, faecal coliforms and faecal streptococci) from intertidal sediment samples supporting large communities of birds (Obiri-Danso and Jones, 2000). The Roach and Crouch estuary complex supports large numbers of overwintering waterbirds (wildfowl and waders) with an average total count of 32,394 over the five winters up to 2009/10 (Holt et al, 2011). Numbers will peak in the winter and birds may impact on the shellfisheries via direct deposition on the intertidal or via runoff or tidal inundation of areas of saltmarsh and wetland. Contamination via direct deposition may be quite patchy, with some shellfish containing quite high levels of *E. coli* with others a short distance away unaffected.

Of these birds, some species may remain in the area to breed in the summer, but the majority migrate elsewhere to breed. Several small aggregations of gulls and waders were recorded on intertidal areas during the shoreline survey of the Roach and lower Crouch which took place in June. The seabird 2000 survey carried out counts of breeding seabirds (gulls, cormorants etc) during the early summer of 2000 (Mitchell *at al*, 2004). This identified only one pair of terns at Paglesham, and three pairs of terns on Foulness Island, although the exact areas surveyed are not known.

The Roach and Crouch estuary complex is frequented by a small population of seals. During the shoreline survey of the Roach a total of 14 seals were seen, 10 of which were in the Middleway, and 4 were seen within the main Roach channel between Horseshoe Corner and Blackledge Point. No seals were recorded within the Crouch, and although shoreline observations suggest they favour the creeks extending south from the Roach as haul-out areas it is likely they forage widely throughout both estuaries. The Sea Mammal Research Unit reported a total count of 299 harbour seals in Essex, Suffolk and Kent (SMRU, 2009) so the maximum number of seals in the Roach and Crouch is likely to be a small fraction of this.

No other wildlife species of potential influence to the sampling plans have been identified. Although not wildlife, dogs exercised adjacent to the estuaries may be a source of contamination, although the soft intertidal muds generally present may deter them from accessing intertidal areas. Intensity of dog walking is likely to be highest on town parks and seafronts.

In conclusion, the most significant wildlife impacts are likely to derive from the large populations of overwintering waterbirds, and to a much lesser extent breeding birds during the summer. As they will forage widely their impacts are considered diffuse and so will have no bearing on the location of RMPs. Seals may also be a contaminating influence, perhaps more so in the Roach, but again they will range widely and their impacts may be considered diffuse. No firm information was available on preferred bird roosting sites and seal haul-out sites which may be associated with higher impacts from these species. Contamination from dogs is likely to be associated with runoff from urban seafronts and parks.

APPENDIX XI
MICROBIOLOGICAL DATA: WATER

Microbiological sampling results from 2004 onwards were considered in this report as the most recent significant STW upgrade within the area occurred in 2003 and bacteriological sampling results indicate and improvement in water quality in 2002 and 2003 (Environment Agency, 2009b&c&d). There are no bathing waters within the survey area designated under the Directive 76/160/EEC (Council of the European Communities, 1975). The majority of the Roach and Crouch estuary complex has been designated under Directive 2006/113/EC as Shellfish Waters since 1999 (European Communities, 2006). The designated areas and bacteriological monitoring points are shown in Figure XI.1.

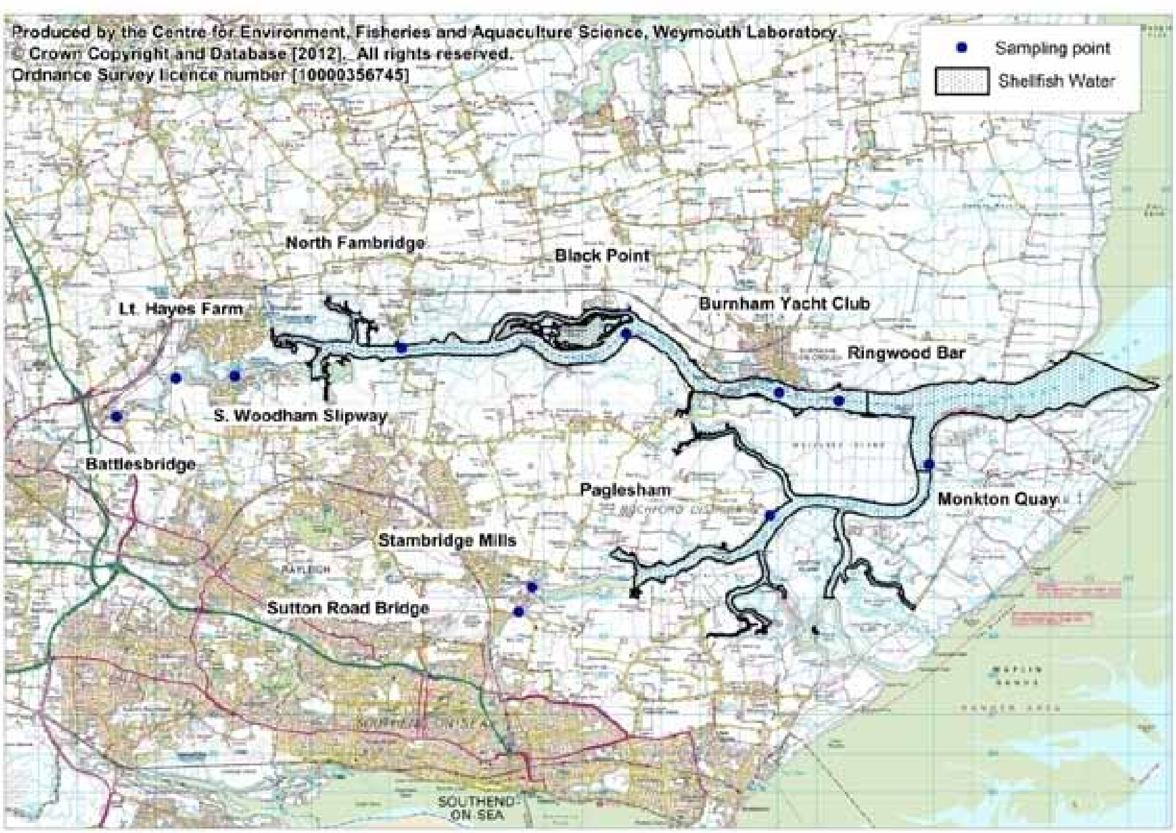


Figure XI.1 Location of shellfish waters bacteriological sampling points.

SUMMARY STATISTICS AND GEOGRAPHICAL VARIATION

Table XI.1 presents summary statistics and Figure XI.2 presents a boxplot of bacteriological monitoring results from Roach and Crouch.

Table XI.1 Summary statistics for shellfish waters faecal coliforms results (cfu/100ml), 2002-2011. *Data from the Environment Agency*

Site	Date of 1st sample	Date of last sample	No.	Geometric mean	Min.	Max.	% exceeding 100 cfu/100ml	% exceeding 1000 cfu/100ml
Battlesbridge	06/08/2008	15/10/2009	14	9813.0	3000	34200	100%	100%
Lt Hayes Farm	06/08/2008	15/10/2009	14	829.9	18	11200	86%	43%
S Woodham Slipway	06/08/2008	15/10/2009	14	168.3	25	2448	50%	14%
North Fambridge	13/04/2004	05/01/2012	44	10.6	1	4410	20%	7%
Black Point	25/06/2008	18/09/2009	16	10.1	1	156	13%	0%
Burnham Yacht Club	25/06/2008	18/09/2009	16	28.5	1	338	38%	0%
Ringwood Bar	25/06/2008	18/09/2009	16	13.6	1	2760	19%	6%
Sutton Road Bridge	06/08/2008	01/05/2009	9	1520.5	127	9800	100%	56%
Stambridge Mills	06/08/2008	15/10/2009	14	2306.7	144	33000	100%	79%
Paglesham	13/04/2004	25/01/2012	45	9.6	1	486	11%	0%
Monkton Quay	12/04/2004	25/01/2012	46	5.7	1	94	0%	0%

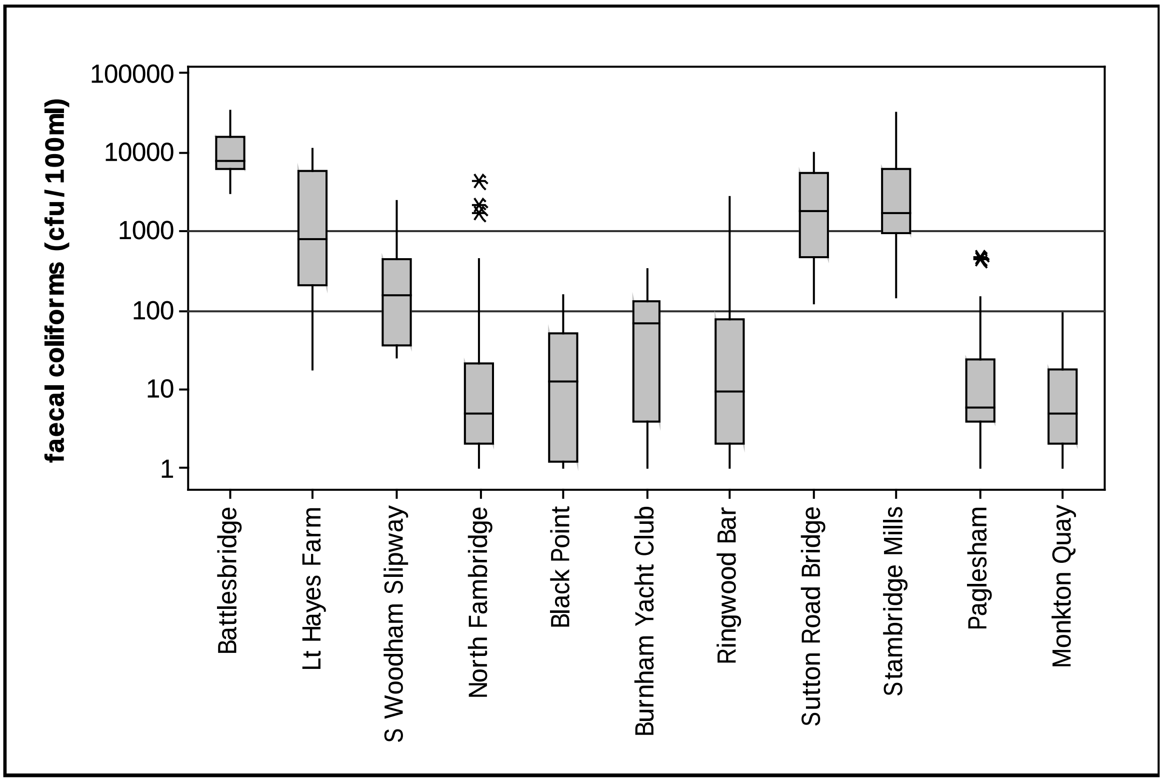


Figure XI.2 Boxplot of shellfish growing waters faecal coliforms results by site
Data from the Environment Agency

These results clearly indicate that the levels of contamination increase within the upper reaches of both the Roach and Crouch. Within the Crouch, levels of contamination appear to increase somewhere between North Fambridge and S. Woodham Slipway. From north Fambridge through to the Ringwood Bar results were similar, with a slight peak in average result at Burnham Yacht Club. A comparison of mean results indicated significant differences between the sites (One way ANOVA, p=0.000). Post ANOVA testing (Tukeys comparison) indicated that results at Battlebridge were significantly higher than all other sites on the Crouch, results at Lt. Hayes Farm were significantly higher than at North Fambridge to Ringwood Bar inclusive. Results for S. Woodham Slipway were significantly higher than at North Fambridge, Black Point and Ringwood Bar, but not Burnham Yacht Club.

Within the Roach, the two sites at the head of the estuary showed much higher levels of contamination than the two lower sites. Significant differences in average results were found (One way ANOVA, p=0.000) and post ANOVA testing (Tukeys comparison) indicated that results at Sutton Road Bridge and Stambridge Mills were significantly higher than at Paglesham and Monkton Quay.

The three sites sampled most frequently (North Fambridge, Paglesham and Monkton Quay) were sampled on the same day and hence under the same environmental conditions on 37 occasions. Comparisons of these paired samples revealed mean results were significantly higher at Paglesham compared to Monkton Quay (paired T-test, p=0.001) but no other significant differences were found. Strong correlations were found between all site pairings (Pearsons correlation, r=0.626 or greater, p=0.000) suggesting that levels of contamination throughout the estuary complex, although variable geographically, respond in a similar manner to environmental variables such as rainfall.

SEASONAL VARIATION

The seasonal pattern in results for the three sites sampled on a sufficient number of occasions to permit an analysis of seasonality is presented in Figure XI.3.

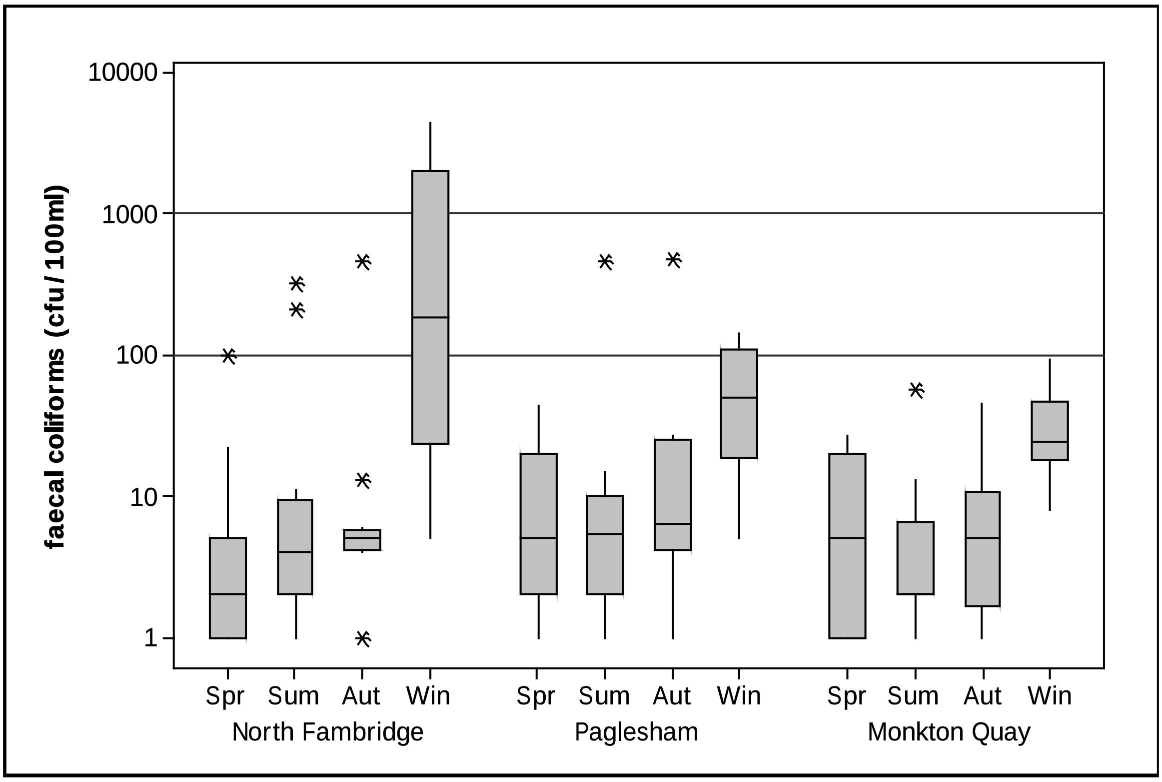


Figure XI.3 Boxplot of results by season at North Fambridge, Paglesham and Monkton Quay. *Data from the Environment Agency.*

A similar seasonal pattern of highest results in the winter is apparent at all three sites, and the seasonal pattern was statistically significant in all three cases (One way ANOVA, p=0.000, 0.014 and 0.002 respectively). Post ANOVA testing (Tukeys comparison) found that at North Fambridge and Monkton Quay results for the winter were significantly higher than all other seasons, and at Paglesham results for the winter were significantly higher than for the spring and summer.

INFLUENCE OF TIDE

To investigate the influence of tide on sample results, circular-linear correlations of tidal state on both the high/low and spring/neap tidal cycles against faecal coliforms results were carried out for the three main sites. The correlation coefficients and associated p-values are shown in Table XI.2, where significant correlations are highlighted in yellow.

Table XI.2. Circular-linear correlation coefficients and associated p values for faecal coliforms against tidal state on the high/low and spring/neap tidal cycles

		High/low cycle		Spring/neap cycle	
Site	n	r	p	r	p
North Fambridge	44	0.301	0.024	0.247	0.083
Paglesham	45	0.297	0.025	0.313	0.016
Monkton Quay	46	0.233	0.097	0.352	0.005

Data from the Environment Agency

Some relatively weak correlations were found. Figure XI.4 presents a polar plots of $\log_{10}$ faecal coliforms results against tidal states where statistically significant correlations were found. For plots of the high/low cycle high water at Burnham is at 0° and low water is at 180°. For plots of the spring neap tidal cycle 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 faecal coliforms/100ml or less are plotted in green, and those from 101 to 1000 are plotted in yellow.

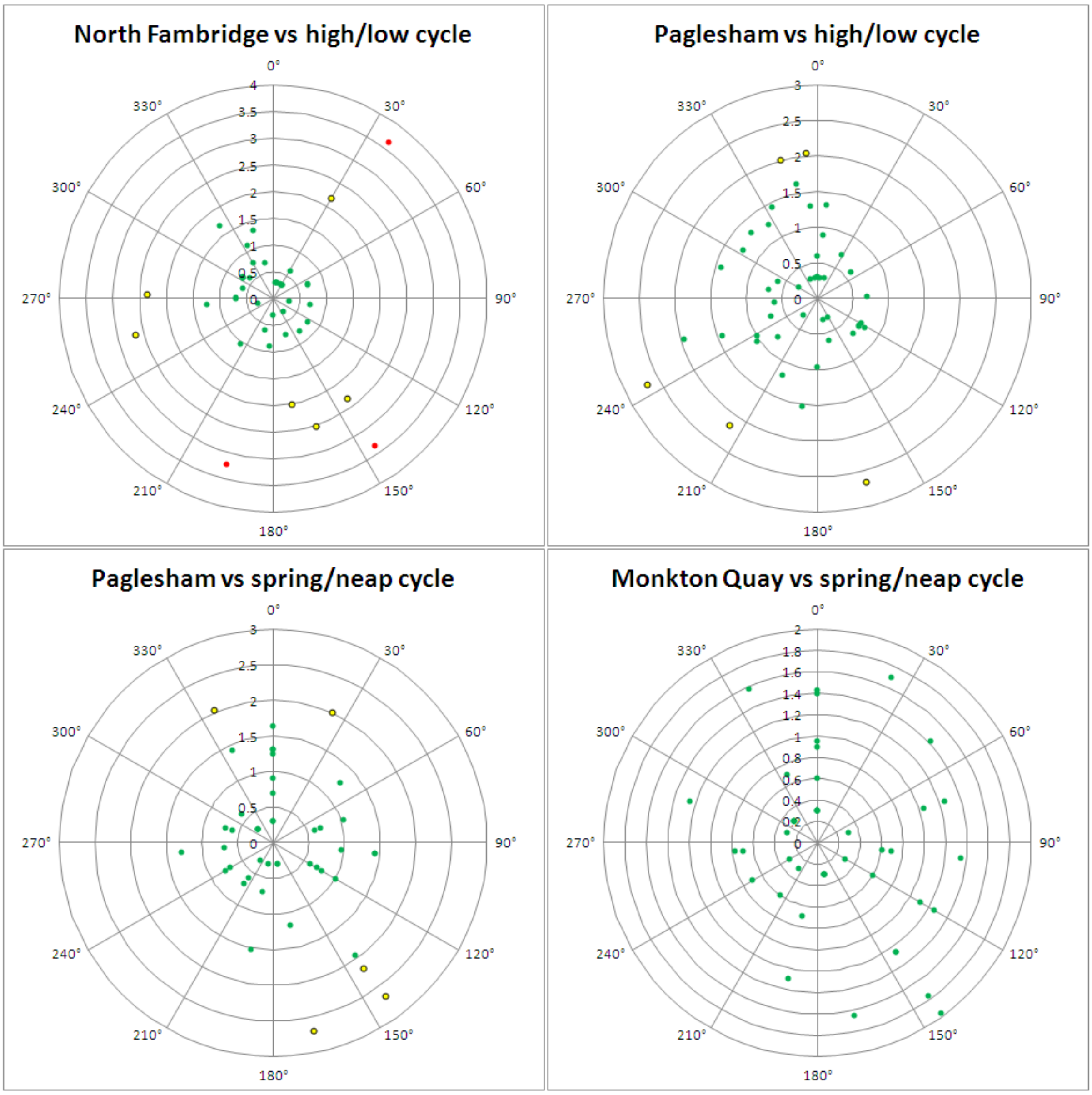


Figure XI.4. Polar plots of log_{10} faecal coliforms from the main shellfish waters sites against tidal state *Data from the Environment Agency*

For North Fambridge no clear pattern in results with respect to the high/low tidal cycle is apparent in Figure XI.4 despite the weak correlation. At Paglesham there appears to be a tendency for higher results on the flood tide suggesting sources to the east are of significance here. There also appears to be a slight tendency for lower results during neap tides implying that important sources are some distance away. A slight tendency for lower results on neap tides is also apparent at Monkton Quay.

INFLUENCE OF RAINFALL

To investigate the effects of rainfall on levels of contamination at the shellfish waters sites Spearman's rank correlations were carried out between rainfall recorded at the Burnham rain gauge (Appendix II, page 51 for details) over various periods running up to sample collection and faecal coliforms results. These were only undertaken for

RMPs with valid recent rainfall data for over 20 samples. The results are presented in Table XI.3 where statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table XI.3. Spearmans rank correlations (r) between faecal coliforms results and recent rainfall totals in various periods before sampling

	Site	Fambridge	Paglesham	Monkton
	No.	28	29	29
24 hour periods prior to sampling	1 day	0.234	0.445	0.354
	2 days	0.354	0.408	0.593
	3 days	0.587	0.549	0.473
	4 days	0.052	0.101	0.038
	5 days	-0.175	-0.060	-0.236
	6 days	-0.039	-0.042	-0.088
	7 days	-0.018	-0.100	-0.008
Total prior to sampling over	2 days	0.420	0.504	0.476
	3 days	0.520	0.627	0.567
	4 days	0.380	0.524	0.396
	5 days	0.295	0.411	0.281
	6 days	0.274	0.362	0.245
	7 days	0.273	0.346	0.248

Data from the Environment Agency

An influence of rainfall was detected at all three locations. Rainfall three days prior to sampling was most consistently associated with elevated levels of indicator bacteria, although a more rapid response was seen at the two sites in the Roach.

INFLUENCE OF RIVER LEVELS

To investigate the effects of river discharge on levels of contamination at the shellfish waters sites Spearman's rank correlations were carried out between recent mean daily flows recorded on the Crouch at Wickford (for the site on the Crouch) and Eastwood Brook at Eastwood (for the sites on the Roach) and faecal coliforms results.

Table XI.3. Spearmans rank correlations (r) between faecal coliforms results and recent river discharge in various periods before sampling

	Site	Fambridge	Paglesham	Monkton
	Gauging station	Wickford	Eastwood	Eastwood
	Number	43	44	44
24 hour periods prior to sampling	1 day	0.463	0.545	0.525
	2 days	0.428	0.543	0.609
	3 days	0.353	0.511	0.518
	4 days	0.212	0.261	0.208
	5 days	0.149	0.273	0.301
	6 days	0.166	0.321	0.392
	7 days	0.110	0.182	0.223
Total prior to sampling over	2 days	0.478	0.553	0.557
	3 days	0.478	0.571	0.554
	4 days	0.445	0.516	0.451
	5 days	0.412	0.502	0.450
	6 days	0.435	0.502	0.466
	7 days	0.392	0.480	0.446

Data from the Environment Agency

A strong and consistent influence of river discharge on levels of indicator bacteria was found indicating that periods of increased land runoff are associated with higher levels of contamination. The response becomes less marked three days after a high flow event, and correlations were generally slightly stronger within the Roach.

APPENDIX XII
MICROBIOLOGICAL DATA: SHELLFISH FLESH

Microbiological sampling results from 2004 onwards were considered in this report as the most recent significant STW upgrade within the area occurred in 2003 and bacteriological sampling results indicate and improvement in water quality in 2002 and 2003 (Environment Agency, 2009b&c&d).

SUMMARY STATISTICS

Since the start of 2004, samples of native and Pacific oysters, mussels, hard clams and Manila clams have been taken from the area and tested for *E. coli* for classification monitoring. The results are summarised by RMP in Table XII.1, plotted in Figure XII.2, and the locations sampled are shown in Figure XII.1.

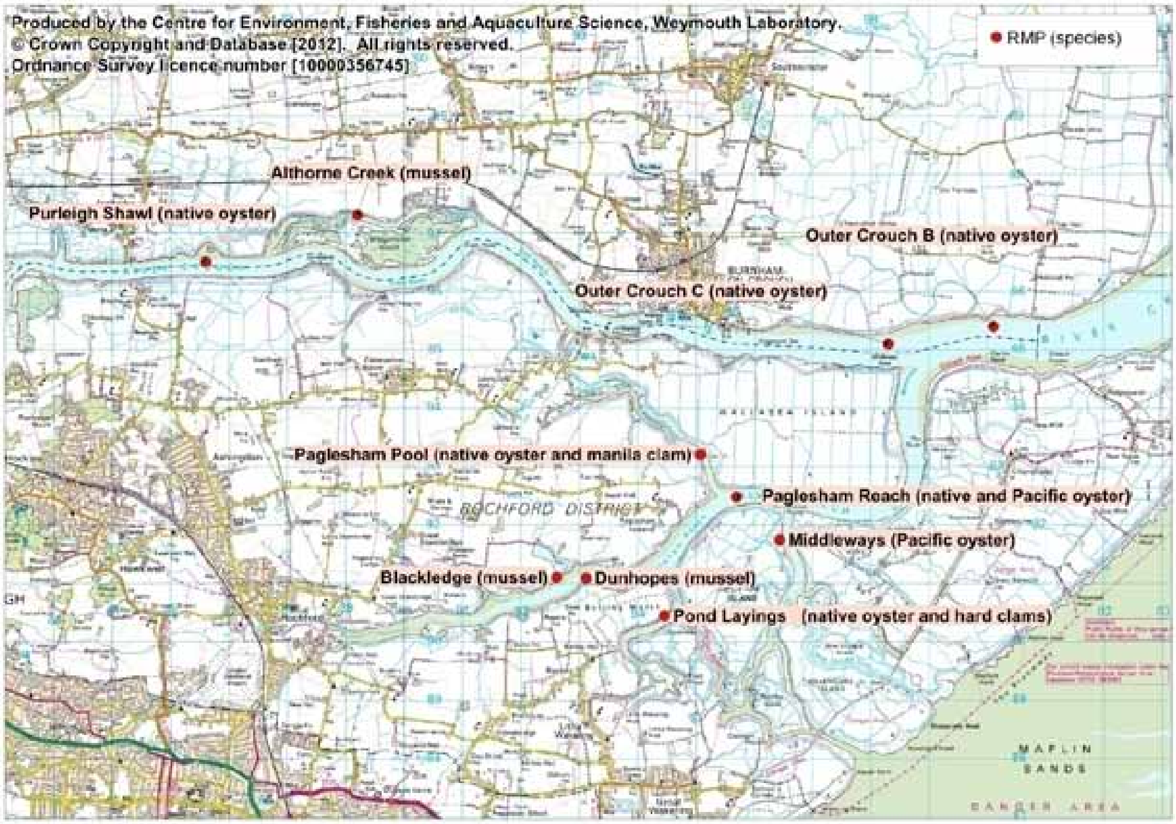


Figure XII.1 Hygiene monitoring RMPs active since 2004

Table XII.1 Summary statistics of* E. coli *results (MPN/100g) from RMPs sampled from 2004 onwards

RMP	Species	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 230	% over 4600
Purleigh Shawl	Native oyster	1	20/01/2004	20/01/2004	310	310	310	100%	0%
Outer Crouch C	Native oyster	31	15/01/2004	21/11/2006	244	40	3500	48%	0%
Outer Crouch B	Native oyster	88	15/01/2004	06/03/2012	176	<20	3500	40%	0%
Pond Layings	Native oyster	102	20/01/2004	19/03/2012	96.1	<20	16000	24%	1%
Paglesham Reach	Native oyster	101	19/01/2004	19/03/2012	90.4	<20	16000	21%	1%
Paglesham Pool	Pacific oyster	93	12/01/2004	20/03/2012	62.2	<20	750	20%	0%
Paglesham Reach	Pacific oyster	12	19/01/2004	07/08/2006	120	<20	3500	33%	0%
Middleways	Pacific oyster	4	19/01/2004	05/04/2004	147	20	950	25%	0%
Althorne Creek	Mussel	87	20/01/2004	28/03/2012	258	<20	>18000	49%	2%
Blackledge	Mussel	101	20/01/2004	19/03/2012	310	<20	16000	53%	6%
Dunhopes	Mussel	74	20/01/2004	26/01/2010	305	20	>18000	53%	5%
Pond Layings	Hard clam	100	20/01/2004	19/03/2012	52.7	<20	2800	14%	0%
Paglesham Pool	Manila clam	27	23/02/2004	09/10/2006	146	<20	9100	37%	4%

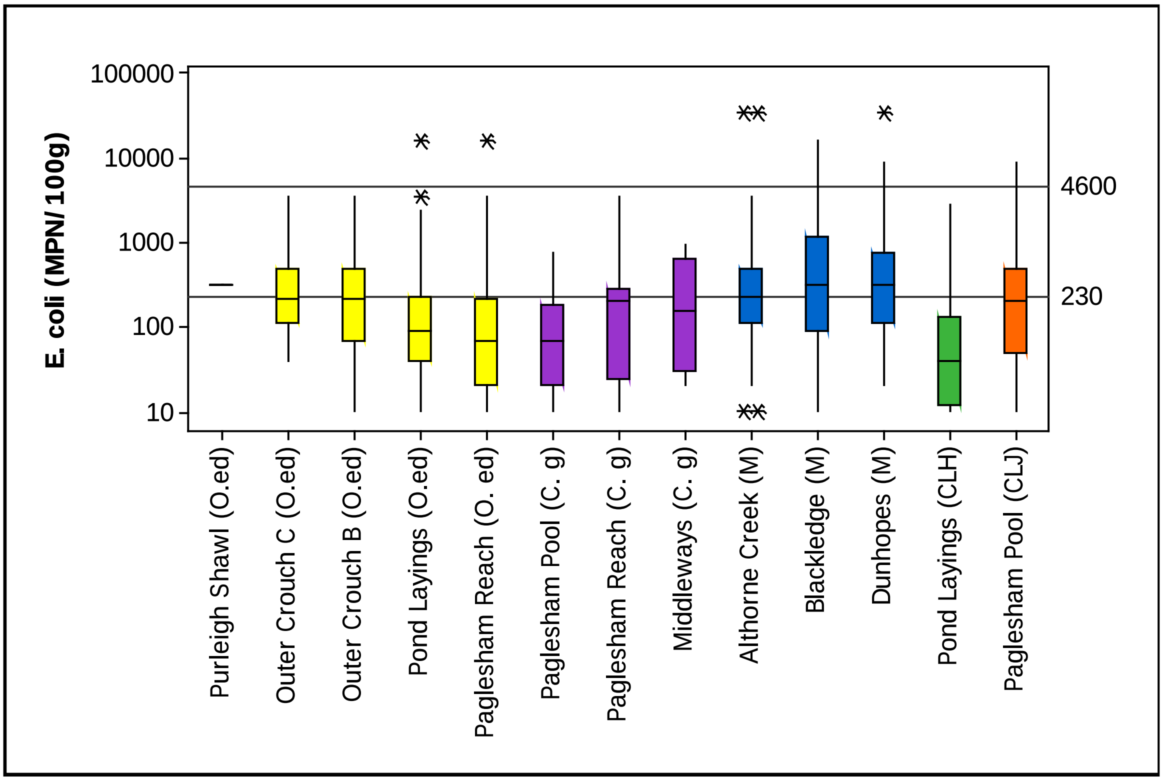


Figure XII.2 Boxplot of* E. coli *results by RMP

Results ranged from <20 to >18000 *E. coli* MPN/100g indicating significant geographical, temporal and between species variation. As different species accumulate *E. coli* to different levels assessments of geographical variation within the system can only be made separately by species.

GEOGRAPHICAL VARIATION

Four RMPs were sampled for native oysters on multiple occasions (Outer Crouch C, Outer Crouch B, Pond Layings and Paglesham Reach). A comparison of all these results revealed a significant difference in mean results (One way ANOVA, p=0.000). Post ANOVA testing (Tukeys comparison) indicated that results for the two RMPs on the Crouch were significantly higher on average for the two RMPs on the Roach. When the proportions of results exceeding 230 *E. coli* MPN/100g (the A/B classification threshold) were examined a significant difference was found (Chi-square, p=0.002) with higher proportions of results exceeding 230 at the two RMPs in the Crouch.

Within the Crouch, samples were taken from the two sites on the same day and hence under the same conditions on 31 occasions, allowing a more robust comparison of paired samples. There was no significant difference in mean result (paired T-test, p=0.931) and results were strongly correlated on a sample by sample basis (Pearsons correlation, r=0.622, p=0.000) indicating these two RMPs are subject to similar sources and levels of contamination. Paired samples of native oysters were taken from Pond Layings and Paglesham Reach on 98 occasions, and there was no significant difference in results (paired T-test, p=0.617) and a very strong correlation between paired sample results (Pearsons correlation, r=0.613, p=0.000). It was not possible to undertake other paired comparisons between RMPs on the Roach and Crouch as they were generally sampled on different days.

For Pacific oysters the only geographic comparison possible was between Paglesham Pool and Paglesham Reach. No significant difference in mean result was found (one way ANOVA, p=0.121) but sample numbers from Paglesham Reach were low. No paired comparisons were possible as the two RMPs were generally sampled on different days.

For mussels, a comparison of all samples from the three RMPs revealed no significant difference in average results (one way ANOVA, p=0.681) nor in the proportion of results exceeding 230 *E. coli* MPN/100g (Chi-square, p=0.847). The only paired (same day samples) comparison which could be undertaken was between Blackledge and Dunhopes, and this revealed no significant difference in mean result (paired T-test, p=0.243) and a strong sample by sample correlation (Pearsons correlation, r=0.778, p=0.000).

Each of the two clam species sampled were taken from only one RMP so no geographic comparisons were possible for these.

OVERALL TEMPORAL PATTERNS IN RESULTS

Figure XII.3 presents a scatterplot of results by date for the seven sites sampled throughout the period 2004-2012, overlaid with a lowess smoother line to highlight any overall trends.

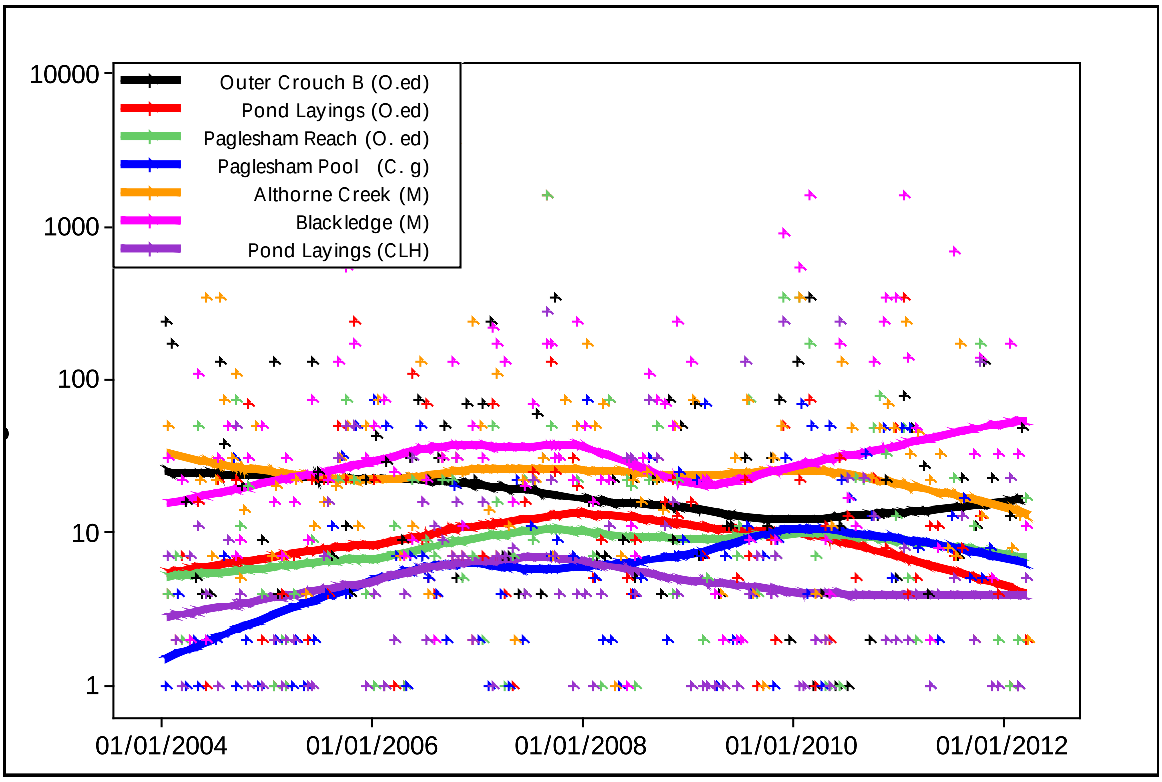


Figure XII.3 Scatterplot of* E. coli *results by RMP and date, overlaid with lowess lines for each RMP

Results varied slightly with time as may be expected, but no strong overall trends are apparent across the estuary complex. Results for Pond layings, Paglesham Reach and Paglesham Pool appear to have varied in a broadly similar manner throughout the period.

SEASONAL PATTERNS OF RESULTS

For native oysters, four RMPs were sampled on a sufficient number of occasions to evaluate seasonal variations in levels of *E. coli*.

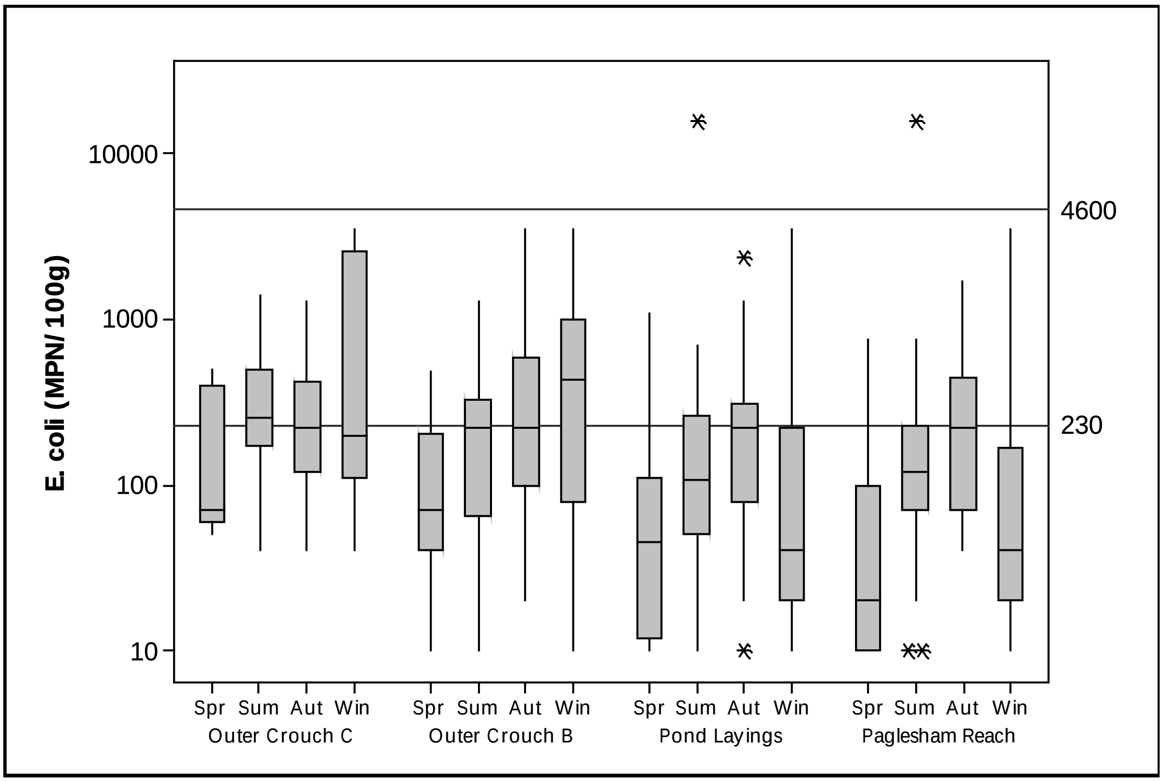


Figure XII.4 Boxplot of* E. coli *results by RMP and season for native oysters

Differing seasonal trends are apparent between the Crouch RMPs and the Roach RMPs implying that sources of a different nature are impacting on the two. Both outer Crouch C and Outer Crouch B showed highest average levels of contamination in the winter and lowest levels in the spring. No statistically significant seasonal variation was found at Outer Crouch C (one way ANOVA, p=0.556). Seasonal variation was statistically significant at Outer Crouch B (one way ANOVA, p=0.010) where results were significantly higher in the winter compared to the spring (Tukeys comparison). The latter was sampled on more occasions than the former.

For both RMPs in the Roach (Pond Layings and Paglesham Reach) a statistically significant seasonal pattern was found (one way ANOVA, 0=0.007 and 0.001 respectively). Post ANOVA testing (Tukeys comparisons) indicated that at Pond Layings results for the summer and autumn were significantly higher than the spring, and at Paglesham Reach results for the summer and autumn were significantly higher than the spring and results for the autumn were significantly higher than the winter.

The only Pacific oyster RMP for which sufficient samples were taken to permit a seasonal analysis was Paglesham Pool.

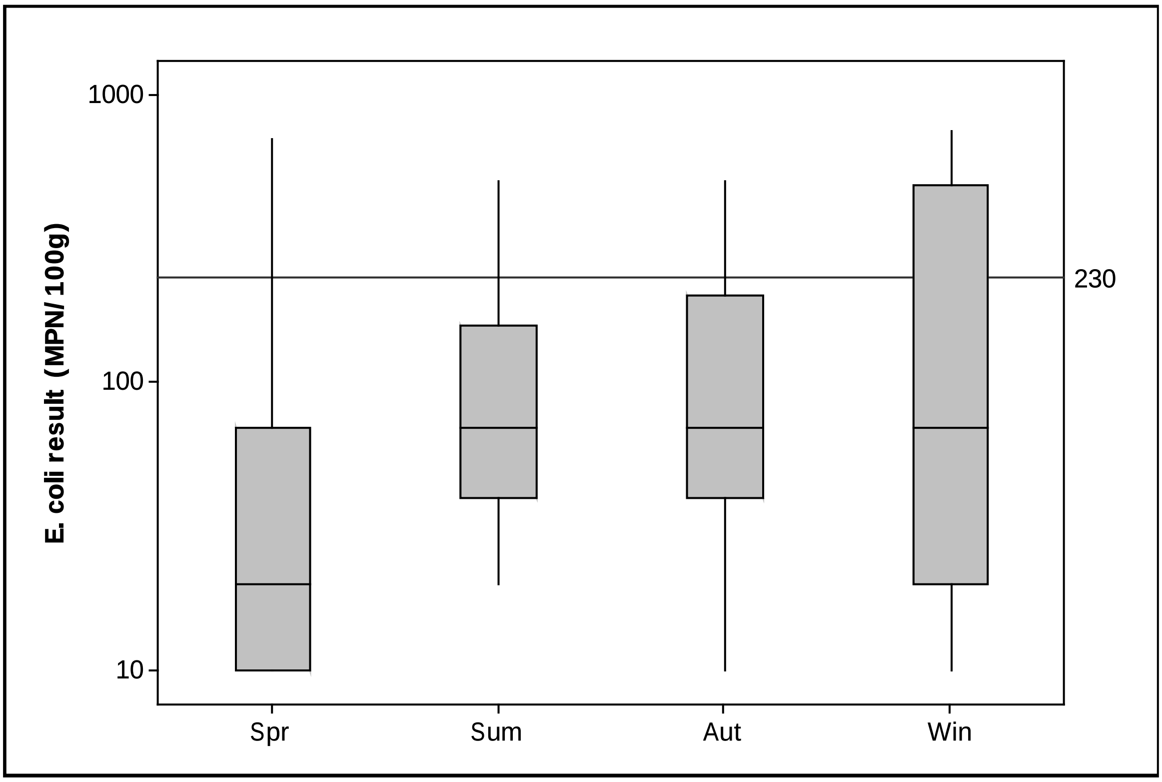


Figure XII.5 Boxplot of* E. coli *results by season for Pacific oysters at Paglesham Pool

The seasonal pattern observed at Paglesham Pool shows not only highest average results in the winter but also a tendency for fewer low results in summer and autumn. There was a significant difference between the seasons (one way ANOVA, p=0.036) and results for the winter were significantly higher than for the spring (Tukeys comparison).

All three mussel RMPs were sampled on a sufficient number of occasions to permit seasonal analyses.

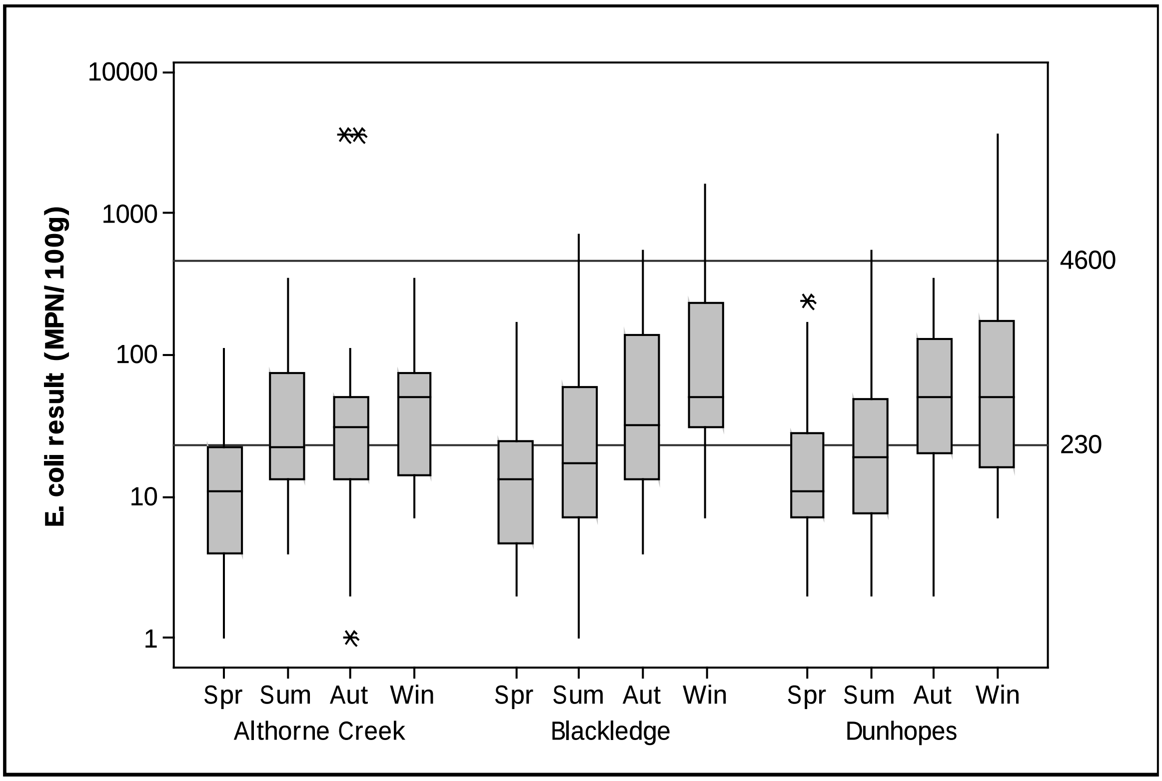


Figure XII.6 Boxplot of* E. coli *results by RMP and season for mussels

The pattern of seasonal variation in mussels is similar for all RMPs, and statistically significant seasonal variations in mean result were found at all (One way ANOVA, p=0.009, 0.000 and 0.016 respectively). Post ANOVA testing (Tukeys comparison) indicated that results were significantly higher in autumn and winter compared to spring at Althorne Creek. Results were significantly higher in autumn and winter compared to spring and in winter compared to summer at Blackledge. Results were significantly higher in winter compared to spring at Dunhopes.

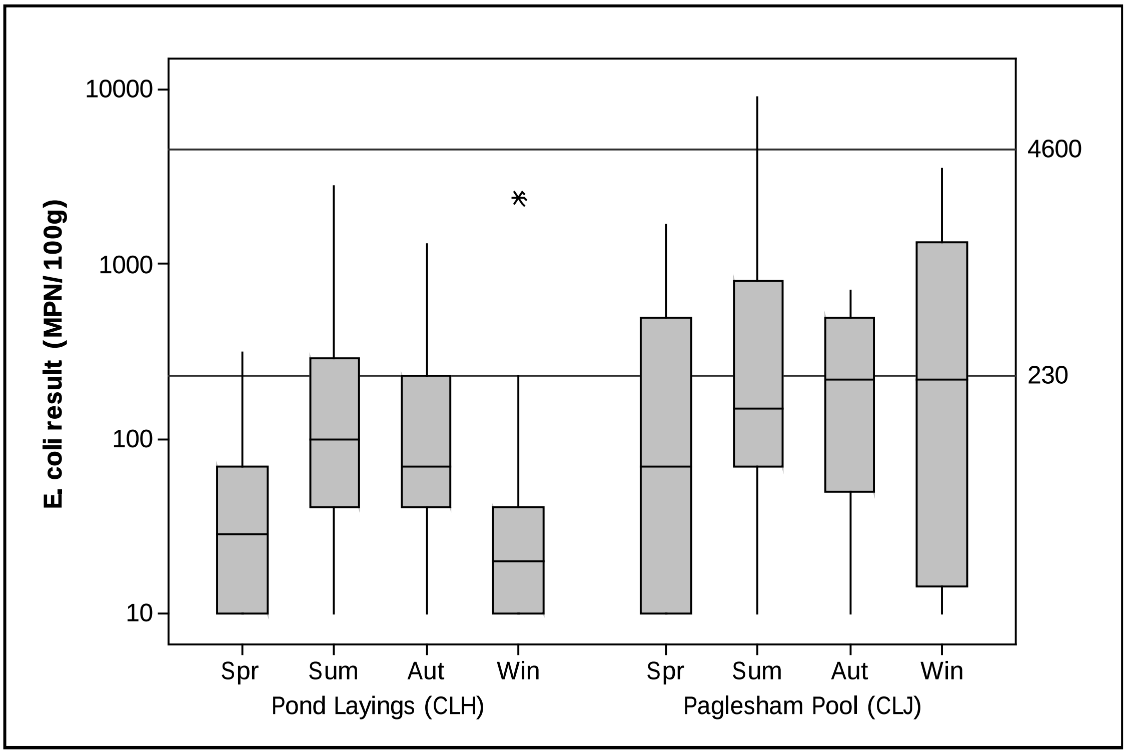


Figure XII.7 Boxplot of* E. coli *results by RMP and season for hard clams and Pond Layings and Manila clams at Paglesham Pool

A statistically significant seasonal pattern was found for Pond Layings (one way ANOVA, p=0.000) where results for the summer and autumn were significantly higher than those for the winter and spring. This is a similar pattern to that observed in native oysters at the same location. No significant seasonal variation was found for Paglesham Pool (one way ANOVA, p=0.872) but the seasonal pattern was broadly similar to that observed within Pacific oysters at the same location.

INFLUENCE OF TIDE

To investigate the effects of tidal state on *E. coli* results, circular-linear correlations were carried out against the spring/neap and high/low tidal cycles for each RMP where at least 20 samples had been taken since 2004. Table XII.2 presents the results of these correlations, and statistically significant correlations are highlighted in yellow.

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

			High/low		Spring/neap	
Site	**Species**	**No.**	**r**	**p**	**r**	**p**
Outer Crouch C	Native oyster	31	0.252	0.169	0.349	0.032
Outer Crouch B	Native oyster	88	0.087	0.525	0.131	0.234
Pond Layings	Native oyster	102	0.066	0.647	0.015	0.977
Paglesham Reach	Native oyster	101	0.041	0.851	0.026	0.937
Paglesham Pool	Pacific oyster	93	0.206	0.022	0.082	0.547
Althorne Creek	Mussel	87	0.074	0.633	0.078	0.601
Blackledge	Mussel	101	0.086	0.488	0.233	0.005
Dunhopes	Mussel	74	0.200	0.058	0.398	0.000
Pond Layings	Hard clam	100	0.050	0.784	0.120	0.248
Paglesham Pool	Manila clam	27	0.154	0.567	0.150	0.582

To describe the pattern of results in relation to the tidal cycles, Figure XII.6 presents polar plots of $\log_{10}$ *E. coli* results against the respective tidal cycle where a significant correlation was found. For plots of the spring/neap cycle, 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. For plots of the high/low cycles, high water is at 0° and low water is at 180°. Results of 230 *E. coli* MPN/100g less are plotted in green, those from 231 to 4600 are plotted in yellow, and those exceeding 4600 are plotted in red.

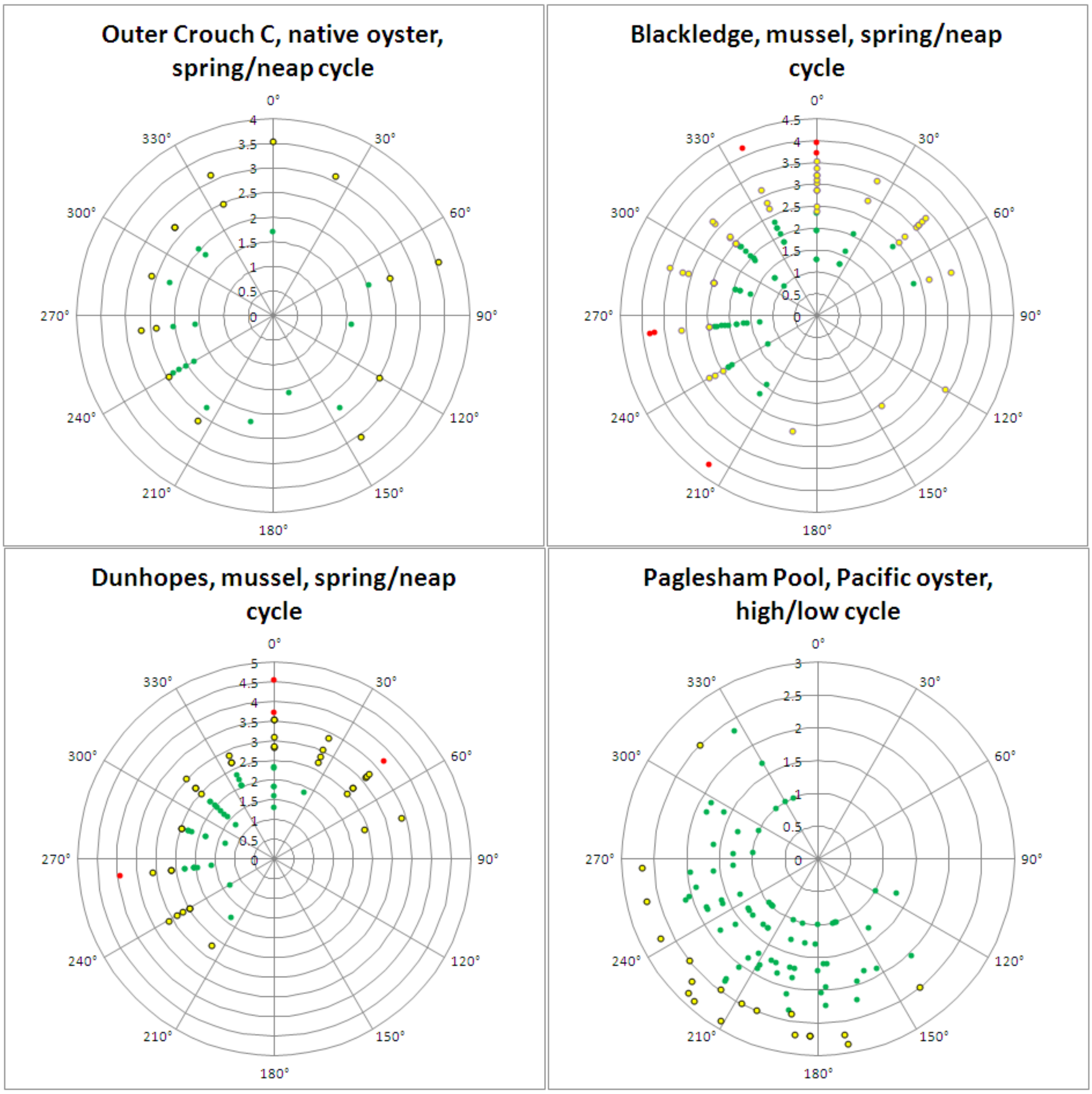


Figure XII.8 Polar plots of $\log_{10}$ E. coli against tidal state where significant correlations found.

At outer Crouch C and Paglesham Pool the correlations were weak and no clear pattern is apparent in Figure XII.8. At Blackledge and Dunhopes, which are two nearby mussels sites in the main Roach channel, the correlations were stronger and there appear to be fewer low results around and just before spring tides. This may suggest that some sources influencing at such a distance from this RMP that they impact more during the larger spring tides.

INFLUENCE OF RAINFALL

To investigate the effects of rainfall on levels of contamination Spearman's rank correlations were carried out between rainfall recorded at the Burnham rain gauge (Appendix II for details) over various periods running up to sample collection and *E. coli* results. These were only undertaken for RMPs with valid recent rainfall data for over 20 samples. The results are presented in Table XII.3 where statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table XII.3 Spearmans rank correlations (r) between* E. coli *results and recent rainfall totals in various periods before sampling

	Site	Outer Crouch B	Pond Layings	Paglesham Reach	Paglesham Pool	Althorne Creek	Blackledge	Dunhopes	Pond Layings
	Species	Native oyster	Native oyster	Native oyster	Pacific oyster	Mussel	Mussel	Mussel	Hard clam
	Number	59	68	69	59	62	69	45	67
24 hour periods prior to sampling	1 day	0.251	0.148	0.115	0.121	0.059	0.278	0.225	0.126
	2 days	0.277	0.200	0.180	0.078	0.362	0.295	0.137	0.133
	3 days	0.226	0.141	0.263	-0.068	0.050	0.191	0.072	0.116
	4 days	0.248	-0.007	-0.021	0.123	0.126	0.087	-0.050	0.045
	5 days	0.258	0.049	0.197	-0.044	0.048	0.263	0.202	0.071
	6 days	0.084	0.147	0.359	0.088	0.222	0.276	0.210	0.140
	7 days	0.335	0.229	0.262	0.041	0.247	0.277	0.292	0.012
Total prior to sampling over	2 days	0.312	0.291	0.265	0.079	0.212	0.365	0.260	0.22
	3 days	0.237	0.305	0.385	0.089	0.168	0.417	0.313	0.291
	4 days	0.287	0.278	0.355	0.188	0.142	0.378	0.134	0.317
	5 days	0.335	0.261	0.401	0.175	0.158	0.471	0.182	0.318
	6 days	0.299	0.267	0.465	0.177	0.209	0.482	0.192	0.361
	7 days	0.323	0.351	0.512	0.206	0.229	0.484	0.302	0.274

Some influence of recent rainfall was detected at all sites apart from for Pacific oysters at Paglesham Pool. Influence was generally stronger at the RMPs which lie in the main channels (Outer Crouch B, Paglesham Reach and Blackledge) with the notable exception of Dunhopes. Overall this may suggest that the main river channels are more susceptible to runoff related contamination, but the reasons why rainfall was a much stronger influence at Blackledge compared to Dunhopes is unclear. This may suggest, alternatively, that land runoff from nearby watercourses may be of more localised importance at the various RMPs.

INFLUENCE OF RIVER LEVELS

To investigate the effects of river discharge on levels of contamination at the shellfish waters sites Spearman's rank correlations were carried out between recent mean daily flows recorded on the Crouch at Wickford (for RMPs on the Crouch) and Eastwood Brook at Eastwood (for RMPs on the Roach) and *E. coli* results. The results are presented in Table XII.4 where statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table XI.4 Spearmans rank correlations (r) between* E. coli *results and river discharge in various periods before sampling

	Site	Outer Crouch C	Outer Crouch B	Pond Layings	Paglesham Reach	Paglesham Pool	Althorne Creek	Blackledge	Dunhopes	Pond Layings	Paglesham Pool
	River	Crouch	Crouch	Roach	Roach	Roach	Crouch	Roach	Roach	Roach	Roach
	Species	Native oyster	Native oyster	Native oyster	Native oyster	Pacific oyster	Mussel	Mussel	Mussel	Hard clam	Manila clam
	Number	30	86	101	100	92	83	100	74	99	27
24 hour periods prior to sampling	1 day	0.261	0.325	0.115	0.107	0.131	0.377	0.351	0.155	0.103	0.139
	2 days	0.160	0.339	0.165	0.122	0.140	0.32	0.372	0.160	0.092	0.059
	3 days	0.207	0.246	0.126	0.154	0.291	0.303	0.441	0.225	0.073	0.147
	4 days	0.389	0.302	0.012	0.068	0.174	0.283	0.355	0.150	-0.023	-0.203
	5 days	0.431	0.352	0.041	0.153	0.174	0.263	0.393	0.203	-0.003	-0.104
	6 days	0.186	0.213	0.079	0.241	0.134	0.250	0.263	0.136	-0.005	-0.230
	7 days	0.045	0.145	0.058	0.060	0.051	0.123	0.342	0.207	-0.049	0.000
Total prior to sampling over	2 days	0.223	0.356	0.166	0.162	0.109	0.398	0.364	0.175	0.163	0.118
	3 days	0.207	0.346	0.188	0.229	0.204	0.381	0.428	0.238	0.187	0.154
	4 days	0.176	0.348	0.170	0.214	0.231	0.379	0.415	0.187	0.184	0.118
	5 days	0.263	0.389	0.163	0.244	0.266	0.402	0.471	0.204	0.171	0.066
	6 days	0.299	0.377	0.179	0.291	0.268	0.422	0.469	0.239	0.167	0.039
	7 days	0.279	0.373	0.188	0.295	0.260	0.416	0.463	0.258	0.134	0.003

River discharge had no significant influence on levels of *E. coli* at Pond Layings (both species) and for Manila clam (but not Pacific oysters) at Pagelsham Pool. The strongest and most consistent influences were found at Outer Crouch B, Althorne Creek and Blackledge. Again, Dunhopes responded to a much lesser degree than Blackledge. Also, Outer Crouch C did not respond to the same extent as the nearby Outer Crouch B, although the former was sampled on much fewer occasions.

BACTERIOLOGICAL SURVEY

In order to assess the spatial variation in levels of contamination in the upper Crouch, a bacteriological survey was initiated following the shoreline survey of this area. Bagged mussels were deployed at six locations (Figure XII.9) and allowed to equilibrate for two weeks before sampling commenced. It was agreed with the competent authority (the FSA) that the results of these samples could be used for the classification of mussels, hard clams and Pacific and native oysters throughout this reach.

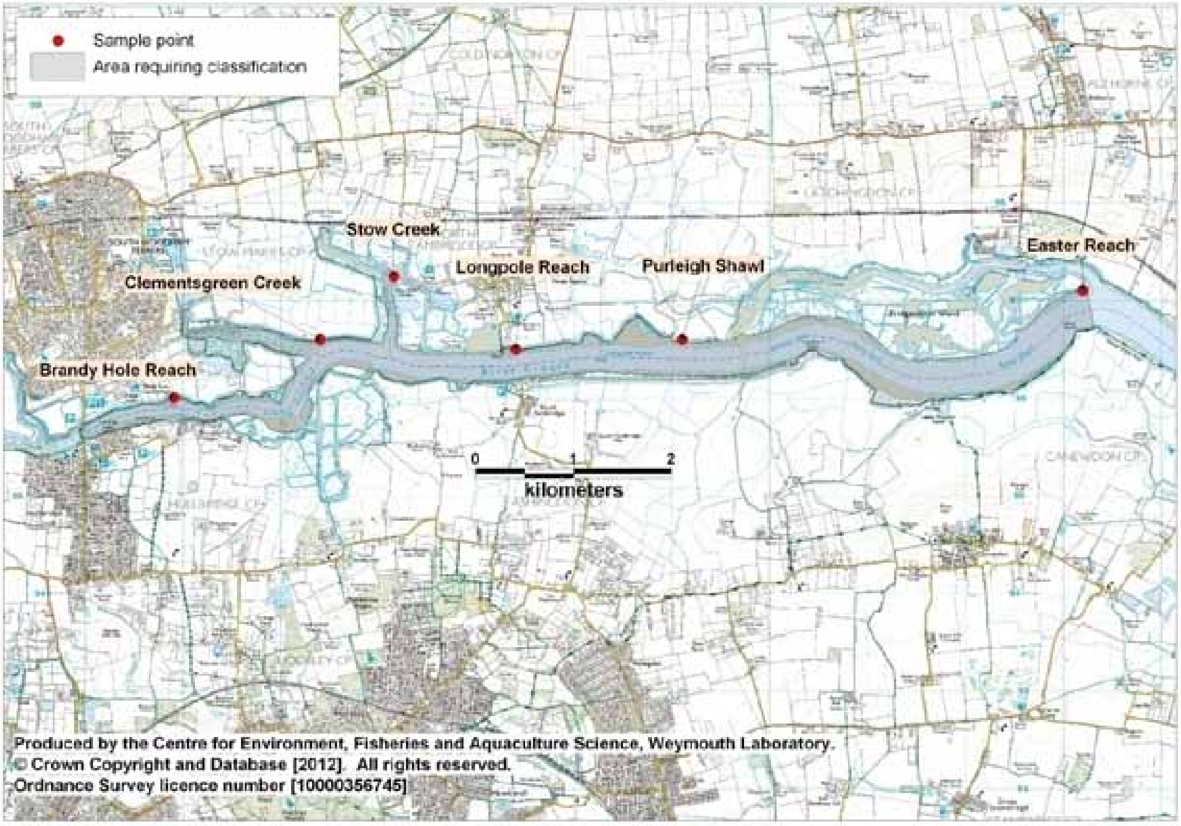


Figure XII.9 Bacteriological survey points

The results to date are presented in full in Table XII.5, and are summarised graphically in Figure XII.10.

Table XII.5. Bacteriological survey results (**E. coli*** ***MPN/100g)***

Date	Brandy Hole Reach	Clementsgreen Creek	Stow Creek	Longpole Reach	Purleigh Shawl	Easter Reach
29/03/2012	490	50	70	40	<20	790
10/04/2012	330	80	80	110	80	230
18/04/2012	330	130	490	130	130	490
26/04/2012	17000	17000	5400	35000	9200	220
03/05/2012	54000	28000	11000	5400	3500	1300
14/05/2012	490	1300	230	330	230	330
22/05/2012	490	130	130	130	170	1100
30/05/2012	20	80	210	3500	80	130
07/06/2012	490	790	330	490	330	130
Geometric mean	787	517	411	584	247	378
% > 230	89%	44%	44%	56%	33%	56%
% > 4600	22%	22%	22%	22%	11%	0%
% > 46000	11%	0%	0%	0%	0%	0%
Maximum	54000	28000	11000	35000	9200	1300

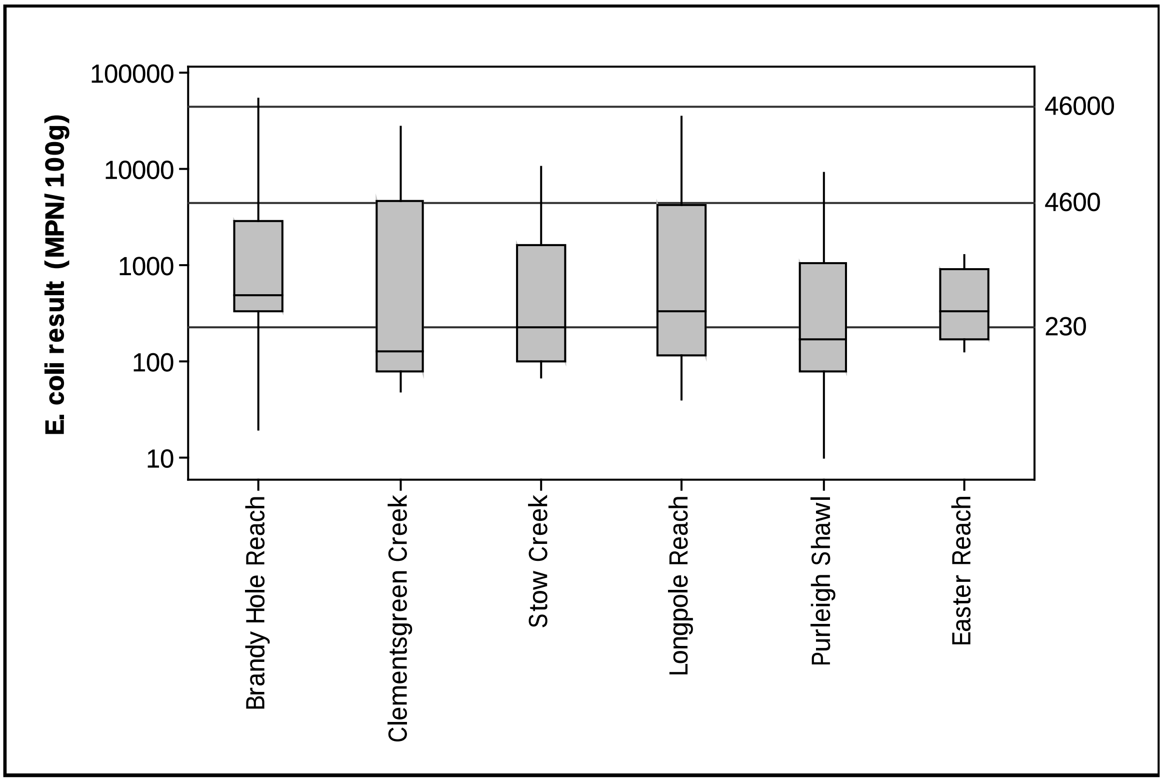


Figure XII.10 Boxplot of E. coli result by sampling location

An overall increase in levels of contamination was observed towards the up-estuary end of this area. Of particular note, heavy rainfall was recorded in the days before the sampling on the 26/04/2012 and 03/05/2012 (Figure XII.11). This will have resulted in greatly increased volumes of land runoff and quite likely caused many of the intermittent discharges in the area to spill storm sewage. Levels of contamination during this event were generally higher up-estuary, with the highest individual result arising at Brandy Hole. Significant elevations in *E. coli* levels were felt down as far as Purleigh Shawl, but did not manifest at Easter Reach, which is perhaps indicative of the tidally driven extent of influence of sources located at the head of the estuary.

Although this rainfall event could probably be classed as exceptional, it nevertheless indicates the potential for high levels of contamination within this stretch.

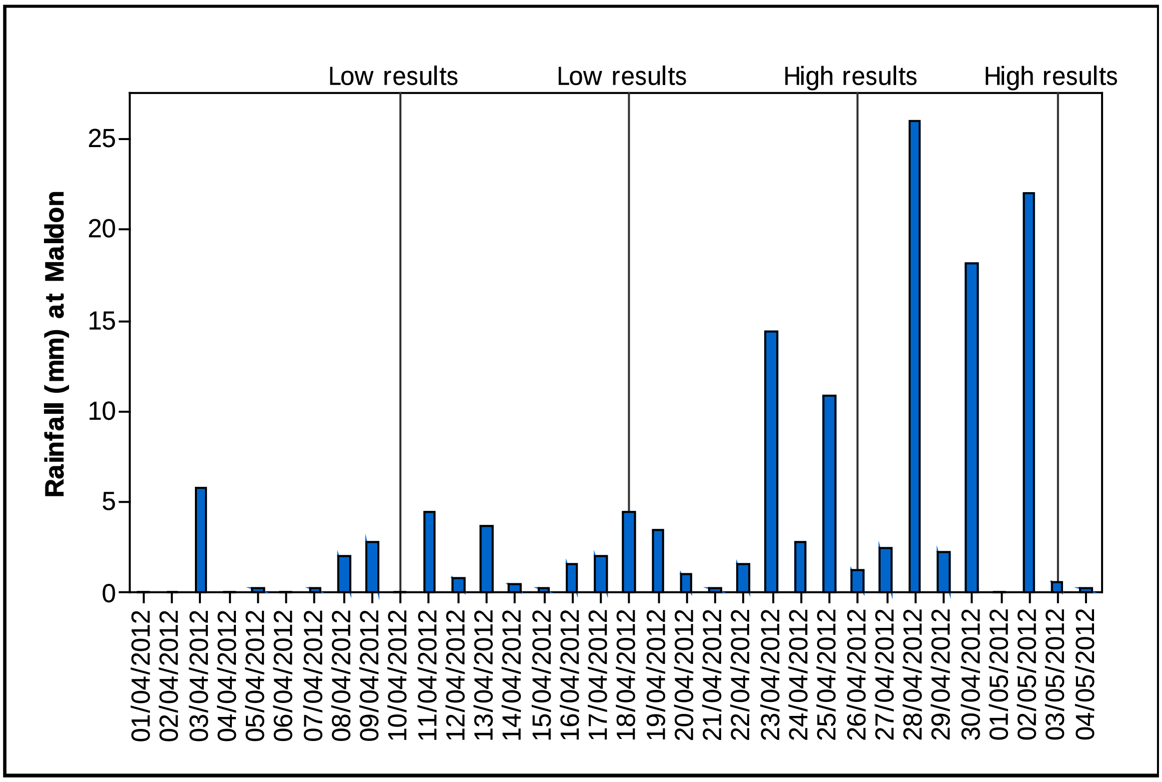


Figure XII.11 Rainfall at Maldon in relation to the high sample results
Data from the Environment Agency

Results to date suggest that a C/B classification boundary would lie somewhere in between Longpole Reach and Purleigh Shawl. The geometric mean and proportion of results exceeding 230 *E. coli* MPN/100g was lowest at Purleigh Shawl, although one result exceeding 4600 *E. coli* MPN/100g was recorded here. Fewer low results were recorded at Easter Reach, suggesting an increase in levels of contamination under dry conditions at the downstream end of this stretch although results to date are consistent with a B classification at both Purleigh Shawl and Easter Reach.

APPENDIX XIII
SHORELINE SURVEY (LOWER CROUCH AND ROACH)

Date (time): 14 July 2011 (12:00-15:00 BST) and 15 July 2011 (07:00-12:000 BST)

Cefas Officers: Alastair Cook, Simon Kershaw

Local Enforcement Authority Officers: Keith Wilson, London Port Health Authority

Area surveyed: Selected parts of the Roach and Crouch estuaries.

Weather:
14 July – winds NW force 4, 18°C, cloudy
15 July – winds W force 2, 16°C, sunny

Tidal predictions (Burnham on Crouch):
Admiralty TotalTide – Burnham on Crouch 51°37'N 0°48'E England. Times in BST (GMT+0100).

14/7/2011			15/7/2011		
High	00:05	4.8m	High	00:59	5.0m
Low	06:34	0.4m	Low	07:23	0.3m
High	12:29	4.8m	High	13:19	4.9m
Low	19:06	0.2m	Low	19:56	0.0m

Predicted heights are in metres above Chart Datum.

Objectives: (a) confirm the location of previously identified sources of contamination; (b) obtain samples of seawater for bacteriological testing; (c) identify any additional sources of contamination in the area and (d) obtain information on the fisheries. A full list of recorded observations is presented in Table XIII.1 and the locations of these observations are mapped in Figure XIII.2. Photographs referenced in Table XIII.1 are shown in Figures XIII.3-9.

Description of Fishery

The survey was prompted by an application to classify hard clams (*Mercenaria mercenaria*) within the Roach estuary. They burrow up to 10cm into the substrate in subtidal and intertidal areas and are present in commercially exploitable densities. This species has a widespread distribution within the Roach, and classification was requested for the majority of the estuary. They are subject to a dredge fishery, with some hand gathering in the intertidal zone also occurring. A local fisherman advised that these stocks extend slightly further than indicated in the application, up to Horseshoe corner. Another fisherman advised that the large concentrations were present in the middle reaches of the Middleway. Two boats were seen dredging for clams in the upper Roach in the vicinity of Bartonhall Creek. A preliminary classification was awarded for the Blackledge area on the basis of mussel monitoring results, although this only includes part of the area for which a classification is required (Figure XIII.1). Within the Crouch there is a population of this species, extending from Bridgemarsh up to Brandy Hole. No interest in classifying these stocks within the Crouch has been expressed to date.

Wild stocks of native oysters are present throughout the subtidal areas of the Roach and Crouch. These are subject to a seasonal dredge fishery (September to April). The Roach is renowned for good spatfalls of this species as tidal streams tend to trap spat within this estuary. Native oysters are also ongrown at culture sites within the Roach. There are a series of lays (a mixture of trestles and ground lays) on the south shore of Wallasea Island which are leased by the Kent & Essex IFCA to several harvesters where native oysters are ongrown. A section of the Paglesham Pool is leased to a harvester by Wallasea Farm. This lease has recently changed hands and is undergoing renovation. Within Barling Creek there is another oyster lay. Within the Crouch, classification was requested after the shoreline survey for an area of farmed native oysters at Purleigh Shawl, as well as for naturally occurring hard clams within the same boundaries.

Pacific oysters are cultured within the Roach estuary, but not the Crouch. They are grown alongside the native oysters on the lays on the south shore of Wallasea Island and in Paglesham Pool, but not at Barling Creek. Subsequent to the shoreline survey an area of naturally occurring Pacific oysters has been identified within the Crouch, just upstream of Brandy Hole, although classification has not been requested for this.

There are wild stocks of mussels between Blackledge Point and Bartonhall Creek, but these are not of commercial interest. Relaid mussels are being ongrown in three areas within the Crouch.

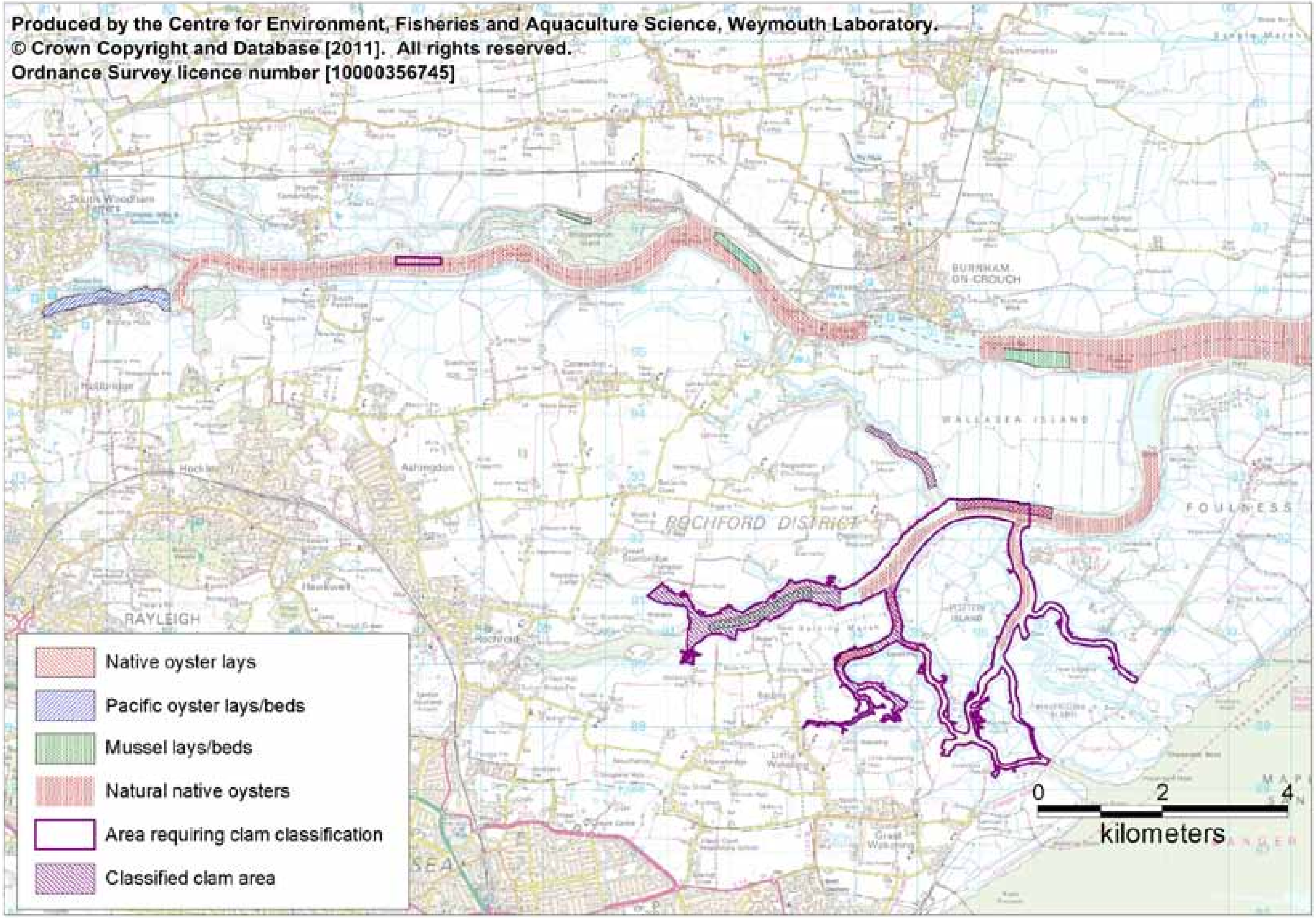


Figure XIII.1. Location of shellfish of commercial interest within the Roach/Crouch complex at the time of shoreline survey

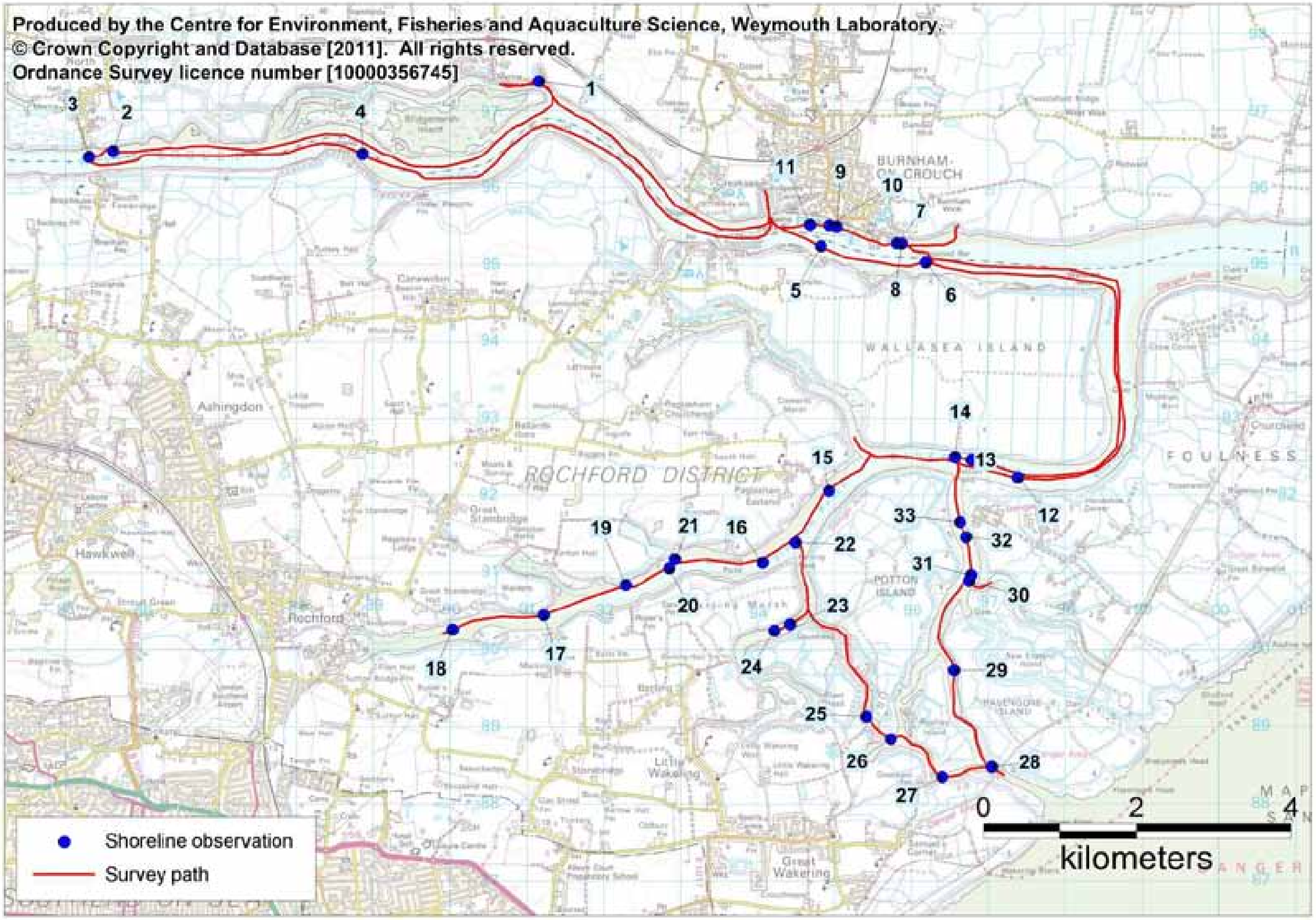


Figure XIII.2. Shoreline survey path and locations of shoreline survey observations

Sources of contamination

The locations of the main Burnham discharge (observation 7) and the Rochford discharge (observation 21) were confirmed. The latter appeared to pass through a stillwater pond before entering the estuary via a sluice. No other sewage discharges were seen during the shoreline survey.

The Crouch, and to a lesser extent, the Roach are heavily used by pleasure boats such as yachts and cabin cruisers, with numerous boatyards and areas of moorings throughout both. Within the Crouch, marinas and/or significant areas of moorings were recorded at North Fambridge, Bridgemarsh Creek, Burnham Yacht Haven, with moorings present all along the shore at Burnham. Within the Roach, moorings and/or berths were seen at Paglesham Boatyard and Potton Creek. A few houseboats were seen at Burnham and at Potton Creek.

Both estuaries receive freshwater inputs from a minor river draining to their head, and a series of small watercourses/drains from the bordering land. Those watercourses seen appeared to drain via sluices. No watercourses were sampled or measured during the shoreline survey.

No livestock were recorded during the shoreline survey, although a large proportion of the adjacent land was obscured from view by flood defence dykes.

Several seals were seen within the Roach, the largest aggregation of which was recorded in the Middleway (10 animals). Several small aggregations of seagulls and waders were also seen within the Roach.

Sample results

A list of seawater sample results is presented in Table XIII.2. Seawater samples taken from the Crouch, from Burnham through to Fambridge all contained <10 *E. coli* cfu/100ml, including one taken about 50m downtide of the Burnham STW outfall. No water samples were taken from the Roach as this area was surveyed on a Friday and the testing laboratory was unable to receive samples for testing late on Fridays or at weekends. Salinity often correlates with *E. coli* levels in estuaries, and salinities recorded within the Roach complex (28.6-30.1ppt) were slightly lower than those recorded within the Crouch (32.4-34.0ppt) suggesting a higher freshwater influence and possibly higher levels of *E. coli* within the Roach.

Table XIII.1. Details of shoreline observations

No.	Date & Time	Position	Photograph	Details
1	14/07/2011 12:26	TQ 91158 97380		Water sample 1 33.5ppt. Marina up creek many large yachts
2	14/07/2011 13:02	TQ 85618 96477		Area of moorings, large yachts
3	14/07/2011 13:04	TQ 85298 96399		Water sample 2 32.4ppt
4	14/07/2011 13:18	TQ 88857 96437		Water sample 3 33.2ppt
5	14/07/2011 13:52	TQ 94826 95240	Figure XIII.3	Water sample 4 34.0ppt. Many yachts on moorings off Burnham
6	14/07/2011 13:59	TQ 96193 95031		Water sample 5 34.1ppt
7	14/07/2011 14:19	TQ 95810 95280	Figure XIII.4	STW outfall
8	14/07/2011 14:24	TQ 95875 95274		Water sample 6 34.0ppt (d/s outfall)
9	14/07/2011 14:32	TQ 95032 95489		4 houseboats
10	14/07/2011 14:33	TQ 94932 95509		2 houseboats
11	14/07/2011 14:35	TQ 94686 95521	Figure XIII.5	5 houseboats
12	15/07/2011 07:46	TQ 97387 92235		3 seals
13	15/07/2011 07:52	TQ 96785 92468		Start of line of trestles along low water mark
14	15/07/2011 07:53	TQ 96566 92504	Figure XIII.6	End of line of trestles along low water mark
15	15/07/2011 08:17	TQ 94929 92060	Figure XIII.7	Paglesham, 6 houseboats/barges. 28.6ppt surface salinity
16	15/07/2011 09:25	TQ 94071 91130	Figure XIII.8	Seal in water. Dredger working nearby
17	15/07/2011 09:41	TQ 91215 90451		Dry sluice
18	15/07/2011 09:49	TQ 90029 90260		About 50-100 waders on mud. Surface salinity 26.0ppt
19	15/07/2011 10:00	TQ 92285 90838		Fincham No 1 outfall
20	15/07/2011 10:10	TQ 92854 91058		About 100 seagulls on intertidal
21	15/07/2011 10:11	TQ 92928 91178	Figure XIII.9	Rochford STW outfall
22	15/07/2011 10:19	TQ 94496 91391		About 100 seagulls on intertidal
23	15/07/2011 10:25	TQ 94425 90331		Over 100 seagulls on intertidal
24	15/07/2011 10:28	TQ 94221 90244		Surface salinity 29.6ppt
25	15/07/2011 10:40	TQ 95417 89129		2 houseboats, marina/boatyard, several yachts on pontoon
26	15/07/2011 10:43	TQ 95735 88836		3 houseboats up creek
27	15/07/2011 10:51	TQ 96403 88349		Sluice
28	15/07/2011 10:56	TQ 97053 88479		Surface salinity 30.1ppt
29	15/07/2011 11:07	TQ 96558 89735		Sluice on right
30	15/07/2011 11:12	TQ 96754 90888		5 seals. Surface salinity 29.8ppt
31	15/07/2011 11:17	TQ 96782 90969		About 100 seagulls on intertidal, another 4 seals in water
32	15/07/2011 11:19	TQ 96710 91463		10 seals hauled out on left bank, sluice on right bank
33	15/07/2011 11:20	TQ 96635 91656		About 100 seagulls on intertidal

Table XIII.2. Details of seawater samples taken

Sample	Date & Time	Position	*E. coli* (cfu/100ml)
1	14/07/2011 12:26	TQ 91158 97380	<10
2	14/07/2011 13:04	TQ 85298 96399	<10
3	14/07/2011 13:18	TQ 88857 96437	<10
4	14/07/2011 13:52	TQ 94826 95240	<10
5	14/07/2011 13:59	TQ 96193 95031	<10
6	14/07/2011 14:24	TQ 95875 95274	<10

Other information

Tidal streams within the Crouch are uncomplicated, with water moving up estuary on the flood and back down on the ebb, reaching speeds of up to 4 knots off Burnham on spring tides. The Roach is connected to the North Sea via both the Crouch and Havengore Creek. For the first half of the flood tide, water enters the Roach via its connection with the Crouch, but cannot enter via Havengore Creek as a sandbar just off the creek entrance is uncovered. Once this sandbar is covered, about three hours into the flood, tidal streams reverse and water enters the Roach complex via Havengore Creek. The reverse happens on the ebb. The nature of these tidal streams limits the exchange of water to some extent, and creates 'dead spots' in some places. It is also thought to encourage the settlement of oyster spat within the Roach complex.

Photographs

Figure XIII.3 *- Yachts on moorings off Burnham-on-Crouch*

Figure XIII.4 - *Burnham-on-Crouch STW outfall*

Figure XIII.5 *- Houseboats at Burnham-on-Crouch*

Figure XIII.6 *- End of line of trestles along low water mark, Wallasea Island shore, R. Roach*

Figure XIII.7 *- Paglesham, R. Roach*

Figure XIII.8 *- Dredger off Blackedge Point, R. Roach*

Figure XIII.9 *- Rochford STW outfall*

APPENDIX XIV
SHORELINE SURVEY (UPPER CROUCH)

SHORELINE SURVEY

Date (time): 23 February 2012 (09:30-14:00 GMT)

Cefas Officers: Simon Kershaw, Alastair Cook

Local Enforcement Authority Officers: Malcolm Sachs, Maldon District Council

Area surveyed: Upper River Crouch.

Weather: 23 February – winds W force 3, 14°C, sunny spells

Tidal predictions (Burnham on Crouch):
Admiralty TotalTide – North Fambridge 51°38'N 0°41'E England. Times in GMT.

23/02/2012

High	01:16	5.0m
Low	07:40	0.0m
High	13:38	5.1m
Low	19:45	0.4m

Predicted heights are in metres above Chart Datum.

Objectives: (a) confirm the location of previously identified sources of contamination; (b) obtain samples of seawater for bacteriological testing; (c) identify any additional sources of contamination in the area and (d) obtain information on the fisheries. A full list of recorded observations is presented in Table XIV.1 and the locations of these observations are mapped in Figure XIV.2. Photographs referenced in Table XIV.1 are shown in Figures XIV.4-8.

Description of Fishery

The survey was prompted by applications to classify hard clams, Pacific, and native oysters within the Crouch estuary. These species are present throughout the estuary in suitable habitats, so the entire area requires classification up as far as the Anchor Pub at Hullbridge, and should include Clementsgreen Creek and Stow Creek.

The river bed has various owners and leasers. The Crouch Harbour Authority owns much of the Crouch and a few small areas of Roach. Other areas are owned by the Crown Estate and by private landowners. In turn, various parts are leased out by their owners. It will probably be beyond the scope of the sanitary survey to map out current ownership of fishing rights, and no marker buoys delineating these areas were seen during the survey.

Representatives of Purleigh Shawl Shellfish Ltd. indicated that the hard clams became established in the area through the relocation of specimens from Southampton Water some decades ago. It appears that they remained unnoticed and unexploited until recently, but now commercial interest is considerable and there is a large and lucrative export market for them. The clams are burrowers which are harvested using toothed dredges, and several dredge passes over an area are required before they are close enough to the surface of the substrate to be caught. Representatives of Purleigh Shawl Shellfish indicated a business critical requirement for classification of the upper reaches of the Crouch for this species as soon as possible. A preliminary C classification would allow them to market the clams for relay on the continent. Illegal harvesting from unclassified areas and/or areas where the fishing rights are privately owned has been reported to the various enforcement authorities in recent months.

Pacific oysters occur naturally within the Crouch. These may be exploited via hand gathering or by dredge. Their exact distribution is uncertain, but they are thought to be present from Cliff Reach through to Hullbridge. Their status downstream of this area is uncertain.

There are some stocks of wild native oysters within the estuary. These are exploited by dredge. Their exact distribution is uncertain, but stock size is believed to be low at present relative to historical levels.

There are some areas used for long term relaying of mussels within the Crouch, but these lie downstream of the area surveyed on this visit. The LEA indicated that it should be possible to obtain mussels locally which could be bagged and deployed for subsequent sampling during the bacteriological survey.

Sources of contamination

The location Rayleigh West STW discharge was confirmed. Effluent from this work passes through a lagoon before being released to the upper reaches of the Crouch. The locations of two intermittent discharge outfalls direct to the Crouch at Brandy Hole were also confirmed. The Woodham Ferrers and Wickford STW outfalls were not visited due to their distance upstream.

The Crouch is heavily used by recreational craft, with numerous boatyards and areas of moorings throughout. Within the survey area, a pontoon and moorings were observed at North Fambridge, where several boats were present including a few (up to 5) possible houseboats. There is a marina at the top of Stow Creek with Pontoon Berths for about 150 yachts and a wide range of facilities, but no sewage pumpout capability. Further upstream, moorings are scattered throughout the reach from Brandy Hole through to Hullbridge, and there is a yacht club at Brandy Hole and several small pontoons and slipways. Within Clementsgreen Creek several small buoys were seen, which may possibly have been moorings but were more likely waterskiing marker buoys which had been moved to this location for the winter.

No livestock were recorded during the shoreline survey, although a large proportion of the adjacent land was obscured from view by flood defence dykes. Significant numbers of waterbirds were present throughout the area surveyed. The largest aggregations were of wading birds foraging on areas of intertidal mud. Flocks of seagulls were also seen throughout the area and a group of swans was present around Hullbridge.

The surrounding land is low lying and drained via a series of sluice gates. None of these appeared to be open or flowing at the time of survey, possibly as a consequence of prolonged dry weather in the region. A series of surface water drainage pipes were seen at the urban areas on the south shore at Hullbridge and Brandy Hole, but again none was in operation at the time.

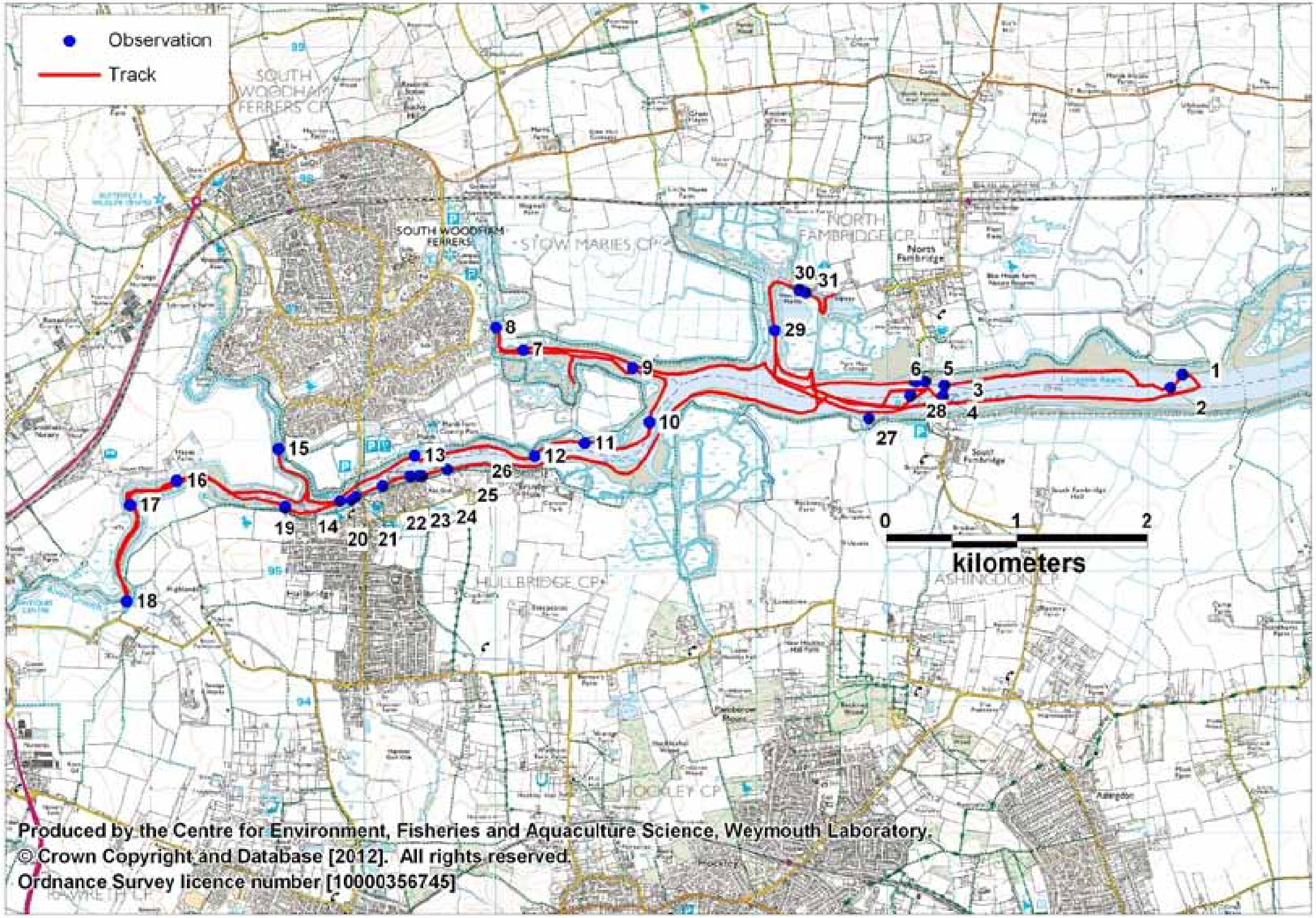


Figure XIV.1. Shoreline survey path and locations of shoreline survey observations

Table XIV.1. Details of shoreline observations

No.	Date & Time	Position	Photograph	Details
1	23/02/2012 10:10	TQ 87260 96497		Water sample 1
2	23/02/2012 10:13	TQ 87166 96399		Salinity profile 1
3	23/02/2012 10:31	TQ 85434 96416		Water sample 2, Salinity profile 2
4	23/02/2012 10:33	TQ 85425 96331		Salinity profile 3
5	23/02/2012 10:35	TQ 85283 96445		Small number of possible houseboats moored by jetty
6	23/02/2012 10:36	TQ 85216 96447		Sluice in bay up by cottages
7	23/02/2012 11:33	TQ 82209 96686		Water sample 3
8	23/02/2012 11:37	TQ 82001 96858	Figure XIV.4	Water sample 4, Salinity profile 4, sluice at top of Creek
9	23/02/2012 11:46	TQ 83046 96547		Waterskiing marker buoys?
10	23/02/2012 11:49	TQ 83175 96131		Water sample 5, Salinity profiles 5 and 6
11	23/02/2012 11:54	TQ 82681 95973		Moorings all along south side
12	23/02/2012 11:55	TQ 82297 95874		Water sample 6, Salinity profile 7
13	23/02/2012 12:01	TQ 81377 95879		Sluice on north bank
14	23/02/2012 12:04	TQ 80806 95532		Water sample 7, Salinity profile 8
15	23/02/2012 12:09	TQ 80337 95928		Water sample 8, Salinity profile 9
16	23/02/2012 12:18	TQ 79556 95686		Caravan and chalet park on north shore
17	23/02/2012 12:20	TQ 79200 95501		Water sample 9, Salinity profile 10
18	23/02/2012 12:26	TQ 79175 94765	Figure XIV.5	Outfall from Rayleigh West STW via lagoons. Flowing. Water sample 10 from flow
19	23/02/2012 12:39	TQ 80385 95486	Figure XIV.6	Intermittent sewage outfall marker post, outfall submerged
20	23/02/2012 12:43	TQ 80892 95537	Figure XIV.7	Outfall with flap valve, not flowing
21	23/02/2012 12:44	TQ 80928 95565	Figure XIV.8	Grey concrete pipe, not flowing
22	23/02/2012 12:47	TQ 81131 95646		Small surface water outfall pipe not flowing
23	23/02/2012 12:48	TQ 81347 95716		Plastic pipe and flap valve, neither flowing
24	23/02/2012 12:50	TQ 81417 95721		Drainage pipe
25	23/02/2012 12:50	TQ 81433 95721		No observation
26	23/02/2012 12:51	TQ 81629 95772		Flap valve outlet and smaller outlet
27	23/02/2012 13:13	TQ 84855 96161		Sluice
28	23/02/2012 13:17	TQ 85174 96336		Salinity profile 11
29	23/02/2012 13:24	TQ 84137 96835		Water sample 11, salinity profile 12
30	23/02/2012 13:31	TQ 84324 97144		Water sample 12
31	23/02/2012 13:32	TQ 84372 97122		Salinity profile 13

It has not yet been possible to extract the salinity profiles from the CTD machine, which salinity, temperature and depth, so unfortunately salinity measurements taken during this survey were unavailable at the time of writing.

Sample results

Table XIV.2. Details of seawater samples taken

Sample	Date & Time	Time relative to High Water*	Position	*E. coli* (cfu/100ml)
1	23/02/2012 10:10	HW-3:28	TQ 87260 96497	5
2	23/02/2012 10:31	HW-3:07	TQ 85434 96416	8
3	23/02/2012 11:33	HW-2:05	TQ 82209 96686	8
4	23/02/2012 11:37	HW-2:01	TQ 82001 96858	180
5	23/02/2012 11:49	HW-1:49	TQ 83175 96131	6
6	23/02/2012 11:55	HW-1:43	TQ 82297 95874	8
7	23/02/2012 12:04	HW-1:34	TQ 80806 95532	36
8	23/02/2012 12:09	HW-1:29	TQ 80337 95928	60
9	23/02/2012 12:20	HW-1:18	TQ 79200 95501	480
10	23/02/2012 12:26	HW-1:12	TQ 79175 94765	4200
11	23/02/2012 13:24	HW-0:14	TQ 84137 96835	4
12	23/02/2012 13:31	HW-0:07	TQ 84324 97144	25

**times relative to high water at North Fambridge (13:38 GMT)*

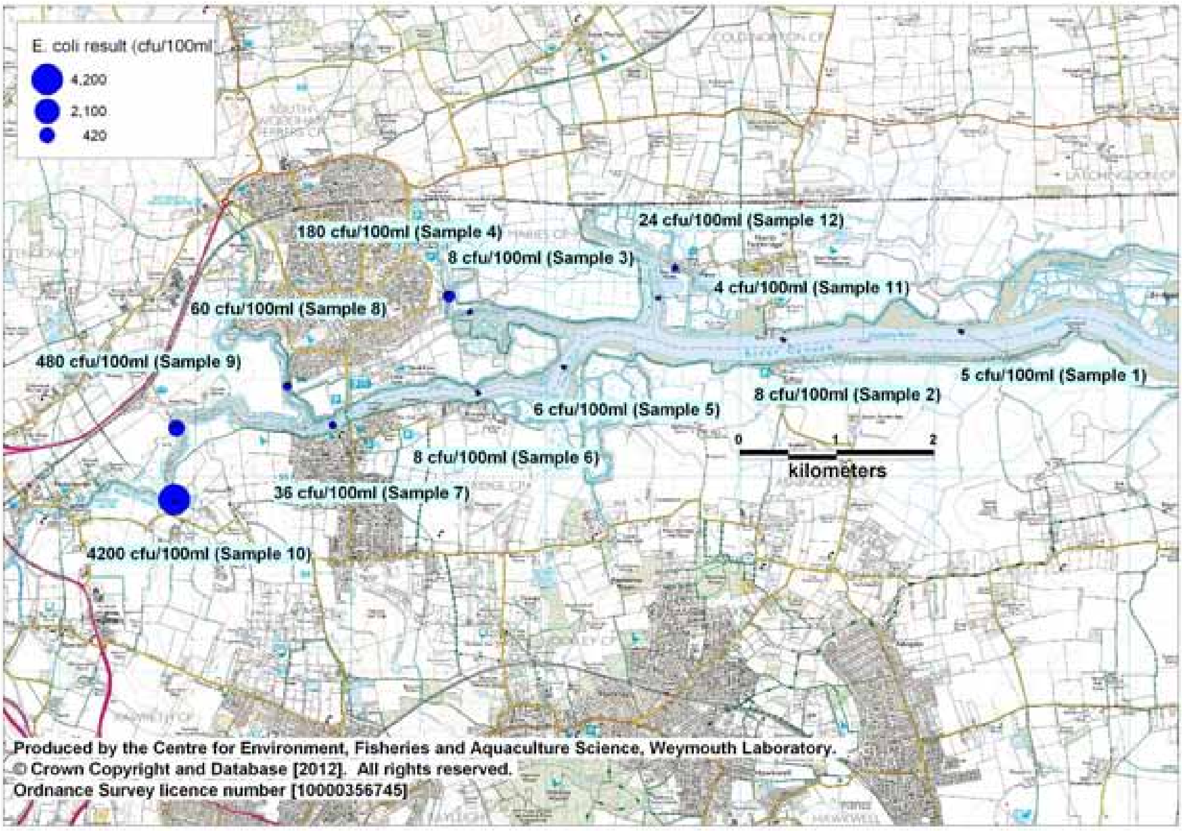


Figure XIV.2. Seawater sampling locations

Low levels of contamination (<10 *E. coli* cfu/100ml) were found throughout the main river channel from Purleigh Shawl up as far as Brandy Hole. Above Brandy Hole levels increased up to a maximum of 4200 *E. coli* cfu/100ml in the immediate vicinity of the Rayleigh West STW outfall. Smaller increases in contamination were also found towards the head of Stow Creek and Clementsgreen Creek. These samples were taken following a prolonged dry spell and a deterioration in water quality may be anticipated under wet conditions.

Other information

Tidal streams within the Crouch are generally uncomplicated, with water moving up estuary on the flood and back down on the ebb. The water is turbid which is likely to slow down the rate of bacterial die off.

Further downstream from the area surveyed, there is a caravan park by Althorne Creek (Smugglers Club Ground) that discharges untreated sewage to nearby land drains. This is likely to have some localised impacts when the drainage sluices here are open. Maldon DC is currently taking action against this practice and an appropriate sewage treatment system will need to be installed. This location was not visited during the survey.

Purleigh Shawl Shellfish Ltd. have taken two sets of shellfish samples from the upper Crouch estuary that were subsequently tested for *E. coli* by AquaProva. The results of these are shown in Table XIV.3, and the locations sampled are shown in Figure XIV.3.

Table 3. Harvesters testing results

Date sampled	Location	Species	*E. coli* result (MPN/100g)
09/01/2012	Purleigh Shawl	Hard clam	<20
09/01/2012	Purleigh Shawl	Pacific oyster	330
09/01/2012	Bed 2	Not specified	80
09/01/2012	Bed 3	Not specified	110
16/01/2012	Purleigh Shawl	Not specified	<20
16/01/2012	Purleigh Shawl	Not specified	490
16/01/2012	Bed 2	Not specified	<20
16/01/2012	Bed 3	Not specified	20

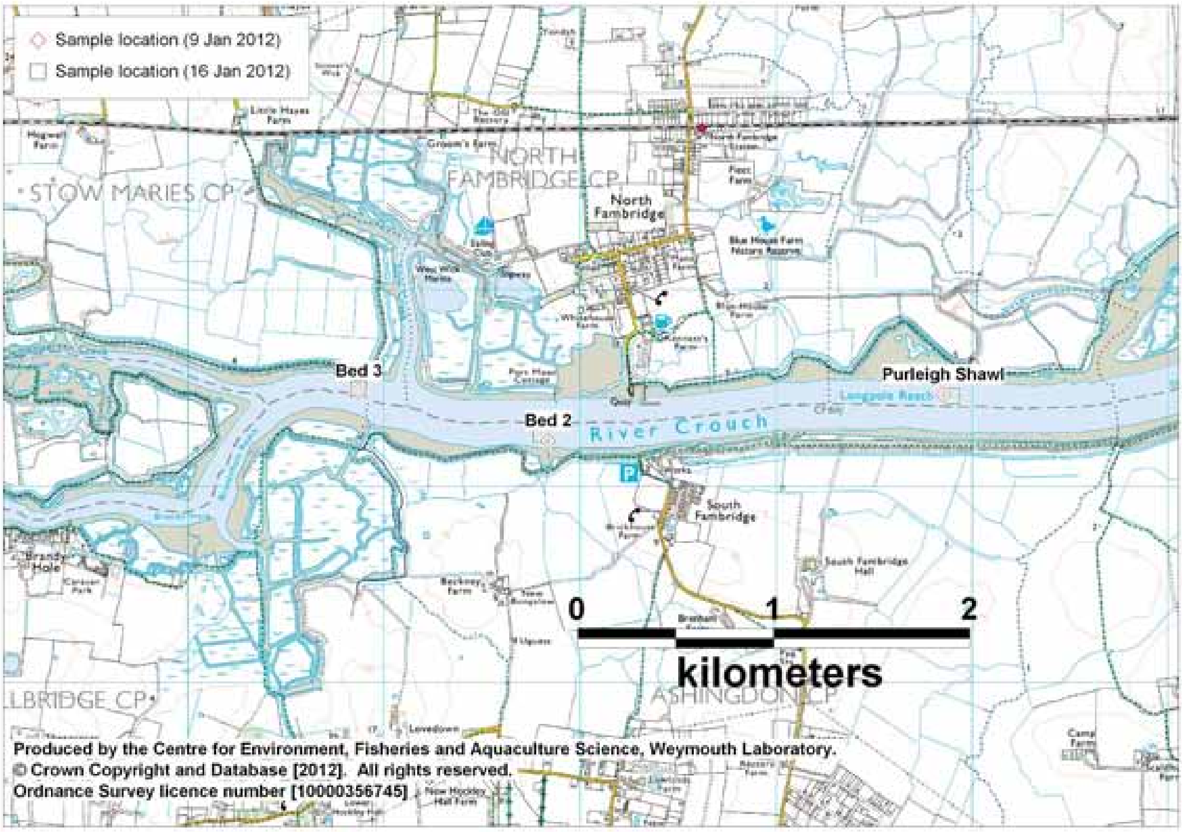


Figure XIV.3. Harvester sampling locations

The two samples yielding results of over 230 *E. coli* MPN/100g both originated from Purleigh Shawl, and the rest yielded results of less than 230 *E. coli* MPN/100g. Whilst these results are indicative of relatively low levels of contamination in this area, they must be treated with some caution as the samples from the first batch were not analysed within 24 hours of collection, the time between collection and analysis was uncertain for the second batch, and sample handling and transport conditions are uncertain. As such, they cannot be used for classification purposes.

Photographs

Figure XIV.4 *Sluice at head of Clementsgreen Creek*

Figure XIV.5 *Rayleigh West STW outfall*

Figure XIV.6 *Intermittent sewage outfall marker post*

Figure XIV.7 *Flap valve, Brandy Hole Reach*

Figure XIV.8 *Concrete pipe, Brandy Hole Reach*

References

ABPMER, 2004. Wallasea Island north bank realignment. Environmental statement. Report number R1114.

ASHBOLT J. N., GRABOW, O. K., SNOZZI, M, 2001. Indicators of microbial water quality. *In* Fewtrell, L. and Bartram, J. (Eds). Water quality: guidelines, standards and health. IWA Publishing, London. pp. 289−315.

BROWN J., 1991. The final voyage of the Rapaiti. A measure of surface drift velocity in relation to the surface wind. *Marine Pollution Bulletin* 22: 37-40.

CALBRADE, N., HOLT, C., AUSTIN, G., MELLAN, H., HEARN, R., STROUD, D., WOTTON S., MUSGROVE, A. (2010) Waterbirds in the UK 2008/09. The Wetland Bird Survey. BTO/WWF/RSPB/JNCC, Thetford.

CEA GOMEZ, L., 2005. An unstructured finite volume model for unsteady turbulent shallow water flow with wet-dry fronts: Numerical solver and experimental validation. Chapter 6: Tidal flow in the Crouch estuary. Doctoral Thesis, University of Seville.

CEFAS, 2010. Sanitary survey of the North Wirral coast. Cefas report on behalf of the Food Standards Agency, to demonstrate compliance with the requirements for classification of bivalve mollusc production areas in England and Wales under of EC Regulation No. 854/2004.

COUNCIL OF THE EUROPEAN COMMUNITIES, 1975. Council Directive 76/160/EEC of 8 December 1975 concerning the quality of bathing water. *Official Journal* L031: 0001-0007.

CROUCH AND ROACH ESTUARY PROJECT, 2005. The Crouch and Roach Estuary Management Plan. http://www.rochford.gov.uk/PDF/planning_crouch_roach_estuary_management_plan.pdf

CROUCH HARBOUR AUTHORITY, 2012. Pilotage instructions for Foulness and Havengore. http://crouchharbour.org.uk/navigation/crouch-and-roach-pilotage/foulness-and-havengore/

DEFRA, 2009. Pigs and Poultry Farm Practices Survey 2009 – England. http://www.defra.gov.uk/evidence/statistics/foodfarm/enviro/farmpractice/documents/FPS2009-pigspoultry.pdf. Accessed 25 October 2010.

ENVIRONMENT AGENCY, 2009a. Directive (2006/113/EC) on the quality required of shellfish waters. Article 5 Programme, Upper Roach.

ENVIRONMENT AGENCY, 2009b. Directive (2006/113/EC) on the quality required of shellfish waters. Article 5 Programme, Upper Crouch.

ENVIRONMENT AGENCY, 2009c. Directive (2006/113/EC) on the quality required of shellfish waters. Article 5 Programme, Roach and lower Crouch.

ENVIRONMENT AGENCY, 2009d. South Essex Catchment Flood Management Plan. http://publications.environment-agency.gov.uk/PDF/GEAN0909BPCB-E-E.pdf

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

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

EU WORKING GROUP ON THE MICROBIOLOGICAL MONITORING OF BIVALVE HARVEST AREAS (2010). Microbiological Monitoring of Bivalve Harvest Areas. Guide to Good Practice: Technical Application. Issue 4, August 2010.

FUTURECOAST, 2002. Department of Environment, Food and Rural Affairs (Defra), Halcrow Group Ltd 3 CD set.

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

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

KAY, D, CROWTHER, J., STAPLETON, C.M., WYLER, M.D., FEWTRELL, L., ANTHONY, S.G., BRADFORD, M., EDWARDS, A., FRANCIS, C.A., HOPKINS, M. KAY, C., MCDONALD, A.T., WATKINS, J., WILKINSON, J., 2008a. Faecal indicator organism concentrations and catchment export coefficients in the UK. Water Research 42, 442-454.

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

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

MET OFFICE, 2012. Regional Climates. Available at: http://www.metoffice.gov.uk/climate/regional/ Accessed February 2012.

MITCHELL, P. IAN, S. F. NEWTON, N. RATCLIFFE & T. E. DUNN, 2004. Seabird Populations of Britain and Ireland, Results of the Seabird 2000 Census (1998-2002). T&AD Poyser, London.

NATURAL ENGLAND, 2009. Pacific Oyster survey of the North East Kent European marine sites. Natural England Commissioned Report NECR016

NERC, 2011. UK guaging station network. Available at: http://www.ceh.ac.uk/data/nrfa/uk_gauging_station_network.html

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

REEDS, 2011. Reeds Nautical Almanac 2012.

SCOTT, C., 2011. Shellfish culture in a managed realignment site at Wallasea Island. Shellfish News 31, Spring/Summer 2011, 4-7.

SMRU, 2009. Scientific Advice on Matters Related to the Management of Seal Populations: 2009. http://www.smru.st-andrews.ac.uk/documents/341.pdf

SYVRET, M., FITZGERALD, A., HOARE, P., 2008. Development of a Pacific oyster aquaculture protocol for the UK – Technical report to the Sea Fish Industry Authority, Project No. 07/Eng/46/04.

WALMSLEY, S. A., PAWSON M. G. (2007). The Coastal Fisheries of England and Wales Part V: A Review of their Status, 2005-2006. Science Series Technical Report Number 140. Cefas, Lowestoft.

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

YOUNGER, A.D., REESE, R.A.R.,. 2011. *E. coli* accumulation compared between mollusc species across harvesting sites in England and Wales. Cefas/FSA internal report.

List of Abbreviations

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

Glossary

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

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

Summary of consultations on draft report

Consultee	Comment	CEFAS response
Kent and Essex IFCA	Havengore STW may still be in operation	There is now a pumping station there which transfers the sewage elsewhere for treatment
	Advised that commercial interest in the mussel fishery in Roach may be renewed at some point	Noted, no change required
	Advised cockles and Manila clams are present throughout the estuary and may also require classification	Sampling plans adjusted to include these species should such classifications be required
	Advised that mussels may still be ongrown on private grounds	Report adjusted accordingly.
Anglian Water	Some minor inaccuracies in list of intermittent discharges	List corrected
	Provided summary spill data for selected intermittent discharges	Data added to report and interpretation of data checked and agreed with Anglian Water.
London Port Health	Suggested some minor adjustments to sampling plan for reasons of practicality and stock availability.	Sampling plan adjusted to accommodate these
Maldon District Council	Suggested some adjustments to sampling plan for reasons of practicality and stock availability	Sampling plan adjusted to accommodate these, and recommendations adjusted to highlight where these adjustments were not in agreement with the rationale behind the hygiene assessment.
Environment Agency	STWs at Burnham-on-Crouch, Rayleigh East & Wickford will have all year round UV disinfection by March 2013.	Information added to report.

Acknowledgements

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