EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT
Colne

2013

Cover photo: Pacific oyster reef at Brightlingsea

CONTACTS:

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

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

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

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

Beverley Küster
Hygiene Delivery Branch
Enforcement and Delivery Division
Food Standards Agency
Aviation House
125 Kingsway
London
WC2B 6NH

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

STATEMENT OF USE: This report provides a sanitary survey relevant to bivalve mollusc beds within the Colne estuary, as required under EC Regulation 854/2004 which lays down specific rules for official controls on products of animal origin intended for human consumption. It provides an appropriate hygiene classification zoning and monitoring plan based on the best available information with detailed supporting evidence. The Centre for Environment, Fisheries & Aquaculture Science (Cefas) undertook this work on behalf of the Food Standards Agency (FSA).

CONSULTATION:

Consultee	Date of consultation	Date of response
Environment Agency	25/02/13	16/04/13
Tendring DC	25/02/13	09/04/13
Colchester BC	25/02/13	08/04/13
Kent & Essex IFCA	25/03/13	-
Anglian Water	25/03/13	16/04/13

DISSEMINATION: Food Standards Agency, Colchester Borough Council, Tendering District Council, Environment Agency, Kent and Essex IFCA.

RECOMMENDED BIBLIOGRAPHIC REFERENCE: Cefas, 2013. Sanitary survey of the Colne estuary. Cefas report on behalf of the Food Standards Agency, to demonstrate compliance with the requirements for classification of bivalve mollusc production areas in England and Wales under of EC Regulation No. 854/2004.

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1. INTRODUCTION

1.1 LEGISLATIVE REQUIREMENT

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

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

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

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

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

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

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

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

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

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

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

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

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

1.2 AREA DESCRIPTION

SITE DESCRIPTION

The Colne is a macro tidal estuary situated on the Essex coast, in the east of England. It drains into the Southern North Sea at Colne Point, and lies adjacent to the West Mersea bivalve production area to the west. The estuary is narrow, relatively short and has several branching arms. The River Colne is the main freshwater input into the estuary.

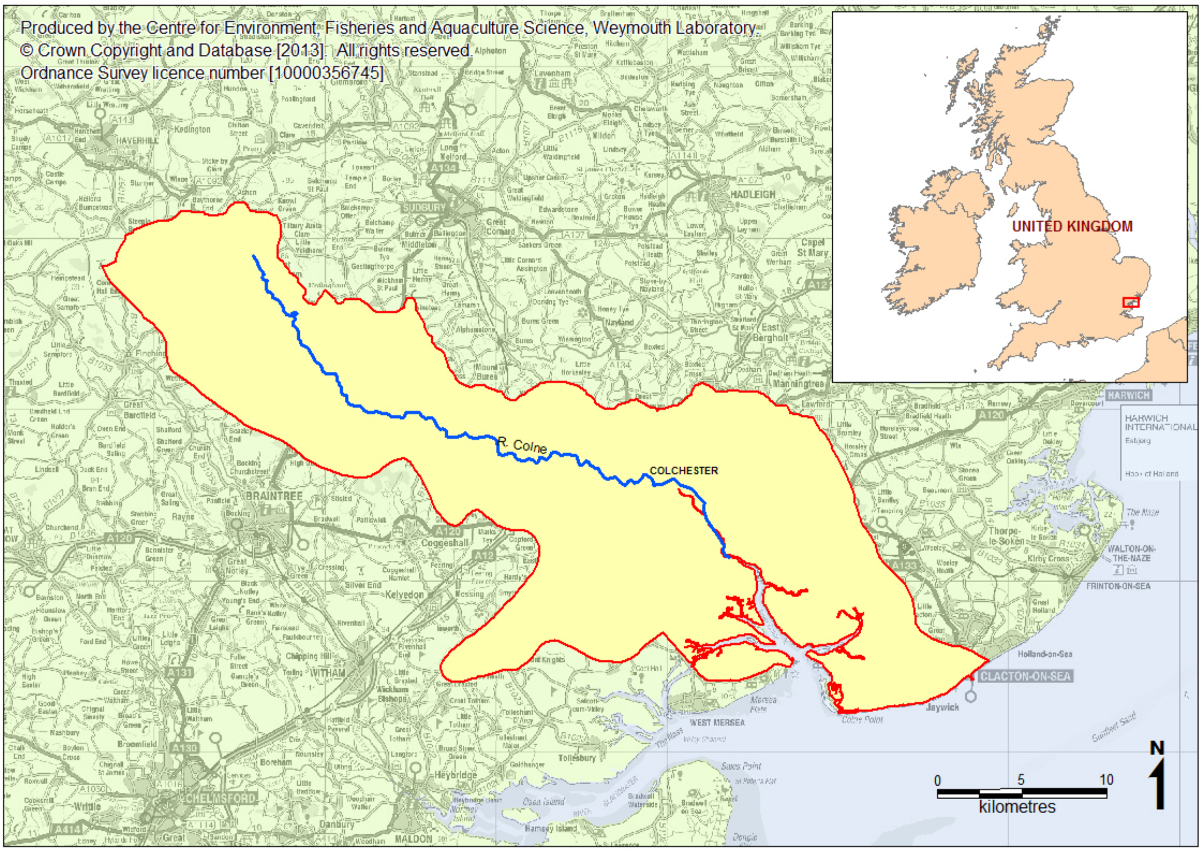


Figure 1.1 Location of the Colne Estuary

The Colne estuary encompasses a rich variety of estuarine habitats including areas of intertidal mudflats, saltmarsh in the upper reaches, shingle banks, sandflats and small islands. It is because of these habitats and the wildlife that the estuary has been protected through several national and international designations: the Essex Estuaries SAC, SSSI, SPA, NNR, and Wetland Ramsar sites. Large numbers of internationally and nationally important flocks of wading and migratory birds frequent the saltmarsh and mudflats. The catchment is relatively low lying and prone to flooding consequently the coastline is protected by seawalls, polder schemes and a tidal barrier, located at Wivenhoe, protecting Colchester from tidal surges.

Recreational boating activities take place on the Colne these include yachting, dinghy sailing, windsurfing and canoeing. A small number of commercial fishermen and charter fishing boats operate from Brightlingsea. Commercial shipping associated with the aggregate trade and the maintenance of Gunfleets Sands

Offshore Windfarm takes place in the Colne at Olivers Wharf, Ballast Quay and Brightlingsea harbour.

The estuary supports a large variety of bivalves and marine invertebrates; a source of food for the birds that frequent the mudflats and providing oysters and other bivalve species for human consumption. The harvesting of native oysters (*Ostrea edulis*) in the Colne Estuary, has taken place since Roman time (Essex County Council, 2012).

CATCHMENT

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

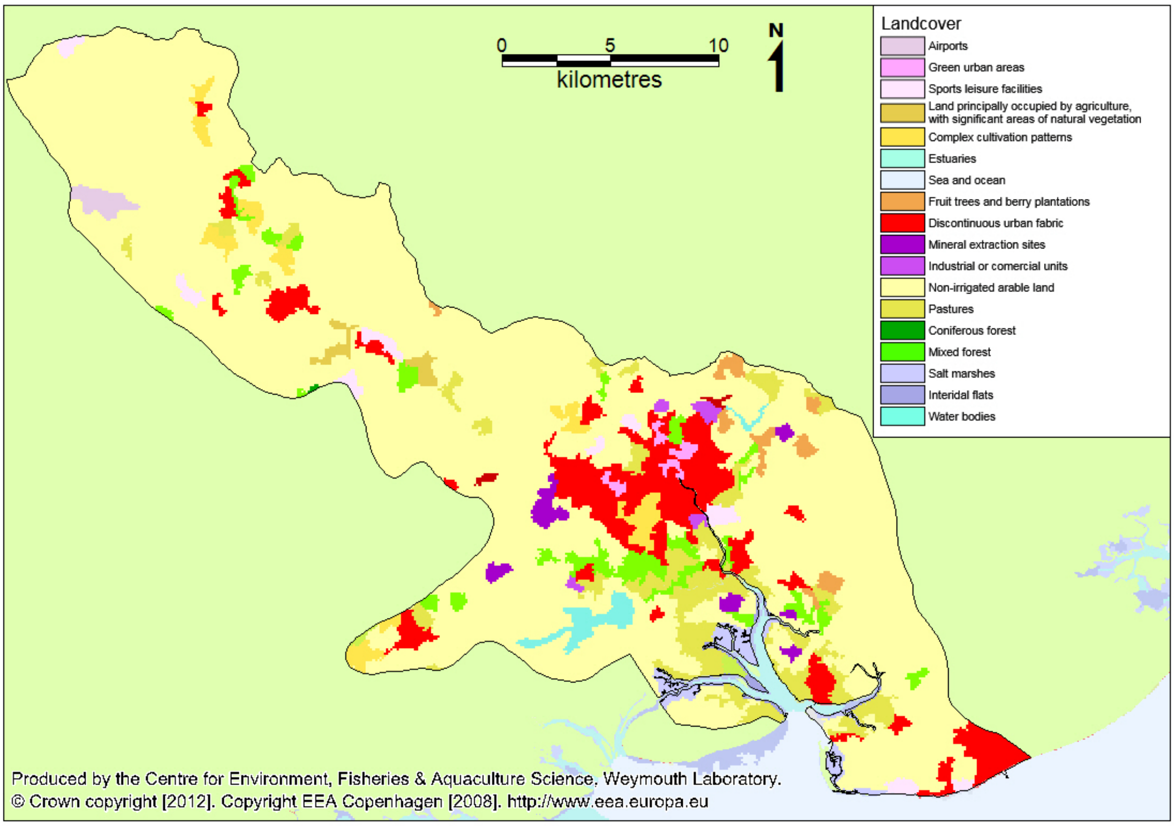


Figure 1.2 Land Cover in the Colne catchment

The Colne's 556km² hydrological catchment is covered by various different land uses. The predominant land cover is arable with significant clusters of mixed forest, pasture and complex cultivation. The main urbanised regions, represent the towns of Colchester, Brightlingsea and part of Clacton on Sea. There are smaller clusters of sports and leisure facilities and industrial and mineral extraction sites close to the outskirts of the urban areas. Adjacent to the estuary the principal land use is pasture. The estuary receives sewage discharges from a population of approximately 300,000.

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

The majority of the catchment characterises low permeability bedrocks such as London clay and the upper reaches of the catchment highly permeable chalk bedrock (Environment Agency, 2009b).

2. RECOMMENDATIONS

The eight zones described below are proposed for the various species requiring or potentially requiring classification. Should a species not specifically identified in the sampling plan require classification within any of these zones, the sampling plan may be applied to this species (or a suitable surrogate).

Main Channel Inner. This zone encompasses the main channel from the flood barrier down to Aldboro Point. The main contaminating influence here is likely to be up-estuary and catchment sources and a gradient of generally decreasing levels of contamination is expected from north to south (going seawards) as a consequence. There may be some more localised areas of increased contamination associated with the mouth of Alresford Creek and the Fingringhoe STW which discharges to the west bank just upstream of the flood barrier via a short watercourse. It is therefore proposed that the RMP should be located on the west side of the channel between the flood barrier and Ballast Quay (TM 0419 2217).

The only species currently present in this zone in commercial concentrations is hard clams, although Colchester Oyster Fishery does not require these to be classified here at present. Manila clams may also be of commercial interest here if a major spatfall occurs. There may be occasional Pacific and native oysters also present but probably not in sufficient concentrations to merit a classification. It is concluded that at present no species require sampling for classification within this zone, but Colchester Oyster Fishery may request a classification for the two species of clams at some point in the future.

These two clam species accumulate *E. coli* to different levels so hard clams should be sampled to classify hard clams and Manila clams should be sampled to classify Manila clams. Sampling can be via dredge or hand digging, either of which should collect both species simultaneously if they are both present. Alternatively, bagged shellfish may be used. A tolerance of 100m applies to dredge or hand dug samples, whereas a tolerance of 10m would apply to bagged samples. Sampled stock should be of a harvestable size. If bagged shellfish are used they should be allowed to equilibrate *in situ* for at least two weeks prior to sampling. It may be prudent to use separate bags for the two species as they are similar in appearance. Sampling frequency should be monthly, unless classification is required more rapidly, in which case a provisional classification can be issued following the submission of 10 samples collected not less than a week apart.

Main Channel Central. This zone encompasses the main estuary channel between Aldboro Point and Mersea Stone. There will be a significant contaminating influence from up-estuary and catchment sources so a gradient of generally decreasing levels of contamination is expected across the north south plane as a consequence. Superimposed on this there is likely to be a hotspot of contamination arising from the Brightlingsea STW outfall on the east shore in the middle reaches of this zone. There may also be some influence from the ebb plumes from Brightlingsea Creek and possibly Geedon Creek and Pyefleet Channel. On balance it is recommended that the RMP be located at the Brightlingsea Outfall in its drainage channel across the intertidal (TM 0625 1751) as this will probably represent the most concentrated source discharging directly to this zone.

Species present within this zone of current commercial interest are Pacific oysters and hard clams. A sampling plan will also be required for Manila clams if a major spatfall occurs, and for native oysters if Colchester Oyster Company decides there has been sufficient recovery to start harvesting again.

Monitoring of Pacific oysters could be used to represent Pacific oysters, native oysters and hard clams. If Manila clams require classification they will also need to be sampled. Sampling can be via dredge or hand digging. Alternatively, bagged shellfish may be used. A tolerance of 100m applies to dredged or hand dug samples, whereas a tolerance of 10m would apply to bagged samples. Sampled stock should be of a harvestable size. If bagged shellfish are used they should be allowed to equilibrate *in situ* for at least two weeks prior to sampling. Sampling frequency should be monthly, unless classification is required more rapidly for an unclassified species, in which case a provisional classification can be issued following the submission of 10 samples collected not less than a week apart.

<u>Main Channel Outer.</u> This zone encompasses the outer reaches of the Colchester Oyster Company Fishery, from Mersea Stone out to the Colne Fishery Buoy, but does not include the public fishery in Point Clear Bay. No point sources discharging directly to this zone have been identified. Multiple sources within the Colne and Brightlingsea Creek are likely to be the main contaminating influences, although they will have been subject to significant dilution before reaching this zone. There may also be some influence from a sewage discharge to Ray Creek. On balance the RMP should be located on the lower intertidal by Point Clear (TM 0810 1560) to capture the ebb plume from both the main channel and Brightlingsea Creek.

This zone requires continued classification for Pacific and native oysters only. Pacific oysters, the main commercial species, would be suitably representative of both. Sampling can be via dredge or hand digging. Alternatively, bagged shellfish may be used. A tolerance of 100m applies to dredge or hand dug samples, whereas a tolerance of 10m would apply to bagged samples. Sampled stock should be of a harvestable size. If bagged shellfish are used they should be allowed to equilibrate *in situ* for at least two weeks prior to sampling. Sampling frequency should be monthly.

<u>Geedon Creek.</u> This zone encompasses the whole of this side channel. There is little in the way of contamination sources direct to this zone. There are a few minor surface water outfalls from the adjacent grazing marsh, and a colony of about 2300 pairs of black headed gulls on Rat Island. The creek will fill with water from down-estuary as the tide floods, and there are no significant contamination sources to the west bank of the estuary downstream of the mouth of this creek. This pattern of circulation makes it less vulnerable to the sewage and catchment sources discharging further up the main channel. Access to the upper reaches of the creek is constrained by the presence of a firing range. An RMP located adjacent to Rat Island at the boundary of the firing range (TM 0543 1734) should adequately capture contamination from the gull colony and surface water outfalls.

This zone requires continued classification for Pacific and native oysters only. Pacific oysters, the main commercial species, would be suitable representative of both. Sampling can be via dredge or hand digging. Alternatively, bagged shellfish may be used. A tolerance of 100m applies to dredge or hand dug samples, whereas a tolerance of 10m would apply to bagged samples. Sampled stock should be of a harvestable size. If bagged shellfish are used they should be allowed to equilibrate *in situ* for at least two weeks prior to sampling. Sampling frequency should be monthly.

Pyefleet Creek. This zone encompasses the whole of this side channel. There is little in the way of contamination sources direct to this zone, only a few minor surface water outfalls from the adjacent grazing marsh. The creek will fill with water from down-estuary as the tide floods, and there are no significant contamination sources to the west bank of the estuary downstream of the mouth of this creek. This pattern of circulation makes it less vulnerable to the sewage and catchment sources discharging further up the main channel. The existing RMP located just down from where the creek splits in two (TM 0266 1604) should be suitably representative of this zone.

The species requiring classification within this creek are Pacific oysters, native oysters and cockles. Current practice is to sample bagged Pacific oysters here to represent both oyster species and bagged mussels to represent cockles. The former is widely established as acceptable, but there is some uncertainty about how representative mussels are of cockles. The preferred option would be for cockles to be sampled directly and it is recommended that the LEA try to pursue such a strategy. It is however recognised that this is likely to present the LEA with practical difficulties, so the use of mussels to represent cockles may have to continue in agreement with the Competent Authority.

If cockles can be sampled directly then dredge or hand raking may be used, and a tolerance of 100m would apply. Otherwise the existing arrangement of using bagged mussels should continue with a tolerance of 10m. A tolerance of 10m should also apply to the use of bagged Pacific oysters. Sampled stock should be of a harvestable size. If bagged shellfish are used they should be allowed to equilibrate *in situ* for at least two weeks prior to sampling. Sampling frequency should be monthly for Pacific oysters. For cockle classification, whichever species are sampled, sampling may remain quarterly to maintain the temporarily declassified status until a classification is required, at which point sampling should revert to monthly.

Brightlingsea Creek Inner. This zone encompasses the upper reaches of Brightlingsea Creek from the St Osyth Creek confluence up to where Brightlingsea Creek splits into two arms. The main sources discharging to this zone are watercourses and a private sewage discharge from a country park, all of which discharge to the very upper reaches. It is therefore recommended that the RMP should be located at the upstream end of this zone (TM 1134 1767). However, the LEA has advised that the nearest point from which it is possible to sample is towards the downstream end of the zone (TM 1025 1653) where the contaminating influence of these sources is likely to be slightly weaker. At present, there is not thought to be any active harvesting upstream from TM 1025 1653.

Species for which classifications have been requested here are Pacific oysters and hard clams. Pacific oysters should be suitably representative of both. Sampling can be via dredge or hand gathering. Alternatively, bagged shellfish may be used. A tolerance of 100m applies to dredge or hand gathered samples, whereas a tolerance of 10m would apply to bagged samples. Sampled stock should be of a harvestable size. If bagged shellfish are used they should be allowed to equilibrate *in situ* for at least two weeks prior to sampling. Sampling frequency should be monthly, unless classification is required more rapidly, in which case a provisional classification can be issued following the submission of 10 samples collected not less than a week apart.

<u>Brightlingsea Creek Outer.</u> This zone encompasses the lower reaches of Brightlingsea Creek and St Osyth Creek. Sources from Brightlingsea Creek Inner may be of some significance to the lower reaches of Brightlingsea Creek, but will not have much impact on St Osyth Creek as water will ebb from both at the same time. Sources direct to this zone include a watercourse discharging to the head of St Osyth Creek, and extensive area of boat moorings to the south of Cindery Island, and two very small sewage discharges to the Brightlingsea seafront. An RMP located at the mouth of St Osyth Creek (TM 0974 1606) would represent a compromise between capturing contamination from the large area of moorings in the south channel, freshwater inputs to St Osyth Creek and the up channel sources described for Brightlingsea Creek Inner.

Species for which classifications have been requested here are Pacific oysters and hard clams. Pacific oysters would be suitably representative of both. Sampling can be via dredge or hand gathering. Alternatively, bagged shellfish may be used. A tolerance of 100m applies to dredge or hand gathered samples, whereas a tolerance of 10m would apply to bagged samples. Sampled stock should be of a harvestable size. If bagged shellfish are used they should be allowed to equilibrate *in situ* for at least two weeks prior to sampling. Sampling frequency should be monthly, unless classification is required more rapidly, in which case a provisional classification can be issued following the submission of 10 samples collected not less than a week apart.

<u>Point Clear Bay.</u> This encompasses the mainly intertidal area in Point Clear Bay immediately east of the Colchester Oyster Fishery boundary and the very lower reaches of Ray Creek. This zone may be influenced to some extent by the ebb plume from the Colne estuary and Brightlingsea Creek. The main contaminating influence is likely to be St Osyth STW which discharges to the very upper reaches of Ray Creek. It is therefore recommended that the RMP be located adjacent to the Ray Creek channel, as far up channel as it is possible to sample (TM 0915 1455).

Species requiring classification within this area are Pacific oysters and mussels. Mussels would be suitably representative of both. Sampling can be via dredge or hand gathering. Alternatively, bagged shellfish may be used. A tolerance of 100m applies to dredge or hand dug samples, whereas a tolerance of 10m would apply to bagged samples. Sampled stock should be of a harvestable size. If bagged shellfish are used they should be allowed to equilibrate *in situ* for at least two weeks prior to sampling. Sampling frequency should be monthly, unless classification is required more rapidly, in which case a provisional classification can be issued following the submission of 10 samples collected not less than a week apart.

3. SAMPLING PLAN

General Information

Location Reference

Production Area	Colne
Cefas Main Site Reference	M012
Ordnance survey 1:25,000 map	Explorer 184
Admiralty Chart	1975

Shellfishery

Species/culture	Native oysters (*Ostrea edulis*) Pacific oysters (*Crassostrea gigas*) Hard clams (*Mercenaria mercenaria*) Manila clams (*Tapes philippinarum*) Mussels (*Mytilus* spp.) Cockles (*Cerastoderma edule*)	Wild & cultured Wild & cultured Wild Wild Wild Wild
Seasonality of harvest	September to April (native oysters) Year round (all other species)	

Local Enforcement Authority

Name	Planning and Protection Department Colchester Borough Council PO Box 889 Town Hall Colchester CO1 1FL
Environmental Health Officer	Tim Nice
Telephone number ☎	01206 282588
Fax number	01206 282598
E-mail	Tim.Nice@colchester.gov.uk
Name	Environmental & Technical Services Tendring District Council Council Offices Weeley Essex CO16 9AJ
Environmental Health Officer	Ed King
Telephone number ☎	01255 686752
Fax number	-
E-mail	edking@tendringdc.gov.uk

Requirement for Review

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

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

Classification zone	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species Sampled	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Main Channel Inner	B12AE	Ballast Quay	TM 0419 2117	51° 51.11' N 00° 57.80' E	Hard clams	Wild	Dredge/ hand	Bagged / handpicked / dredge	10m / 100m / 100m	Monthly	Represents hard clams. Not currently required.
	B12AF	Ballast Quay	TM 0419 2117	51° 51.11' N 00° 57.80' E	Manila clams	Wild	Dredge/ hand	Bagged / handpicked / dredge	10m / 100m / 100m	Monthly	Represents Manila clams. Not currently required.
Main Channel Central	B12AG	Brightlingsea Outfall	TM 0625 1751	51° 49.09' N 00° 59.46' E	Pacific oysters	Wild/ culture	Dredge/ hand	Bagged / handpicked / dredge	10m / 100m / 100m	Monthly	Represents Pacific oysters, native oysters and hard clams
	B12AH	Brightlingsea Outfall	TM 0625 1751	51° 49.09' N 00° 59.46' E	Manila clams	Wild	Dredge/ hand	Bagged / handpicked / dredge	10m / 100m / 100m	Monthly	Represents Manila clams. Not currently required.
Main Channel Outer	B12AI	Point Clear	TM 0810 1560	51° 48.02' N 01° 01.00' E	Pacific oysters	Wild/ culture	Dredge/ hand	Bagged / handpicked / dredge	10m / 100m / 100m	Monthly	Represents Pacific oysters and native oysters
Geedon Creek	B12AJ	Rat Island	TM 0543 1734	51° 49.01' N 00° 58.74' E	Pacific oysters	Wild/ culture	Dredge/ hand	Bagged / handpicked / dredge	10m / 100m / 100m	Monthly	Represents Pacific oysters and native oysters.
Pyefleet Creek	B12AK	Pyefleet Channel	TM 0266 1604	51° 48.38' N 00° 56.29' E	Pacific oysters	Wild/ culture	Dredge/ hand	Bagged / handpicked / dredge	10m / 100m / 100m	Monthly	Represents Pacific oysters and native oysters
	B12AL	Pyefleet Channel	TM 0266 1604	51° 48.38' N 00° 56.29' E	Cockles	Wild	Dredge/ hand	Handpicked / dredge	100m	Monthly	Preferred choice for cockle classification. Currently sampled quarterly as temporarily declassified.
	B12AM	Pyefleet Channel	TM 0266 1604	51° 48.38' N 00° 56.29' E	Mussels	N/A	Hand	Bagged	10m	Monthly	Second choice to represent cockles should cockle sampling prove impractical.

Classification zone	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species Sampled	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Brightlingsea Creek Inner	B12AD	Flag Creek	TM 1134 1767	51° 49.06' N 01° 03.89' E	Pacific oysters	Wild/ culture	Dredge/ hand	Bagged	10m	Monthly (or 10 samples at least 1 week apart for preliminary classification)	Represents Pacific oysters and hard clams. The LEA has advised that the closest sampleable location is TM 1025 1653 (51° 49.47' N 01° 02.90' E)
Brightlingsea Creek outer	B12AC	South Creek	TM 0974 1606	51° 48.23' N 01° 02.44' E	Pacific oysters	Wild/ culture	Dredge/ hand	Bagged	10m	Monthly (or 10 samples at least 1 week apart for preliminary classification)	Represents Pacific oysters and hard clams
Point Clear Bay	B12AN	Ray Creek	TM 0915 1455	51° 47.43' N 01° 01.88' E	Mussels	Wild/ culture	Dredge/ hand	Bagged / handpicked / dredge	10m / 100m / 100m	Monthly (or 10 samples at least 1 week apart for preliminary classification)	Represents Pacific oysters and mussels

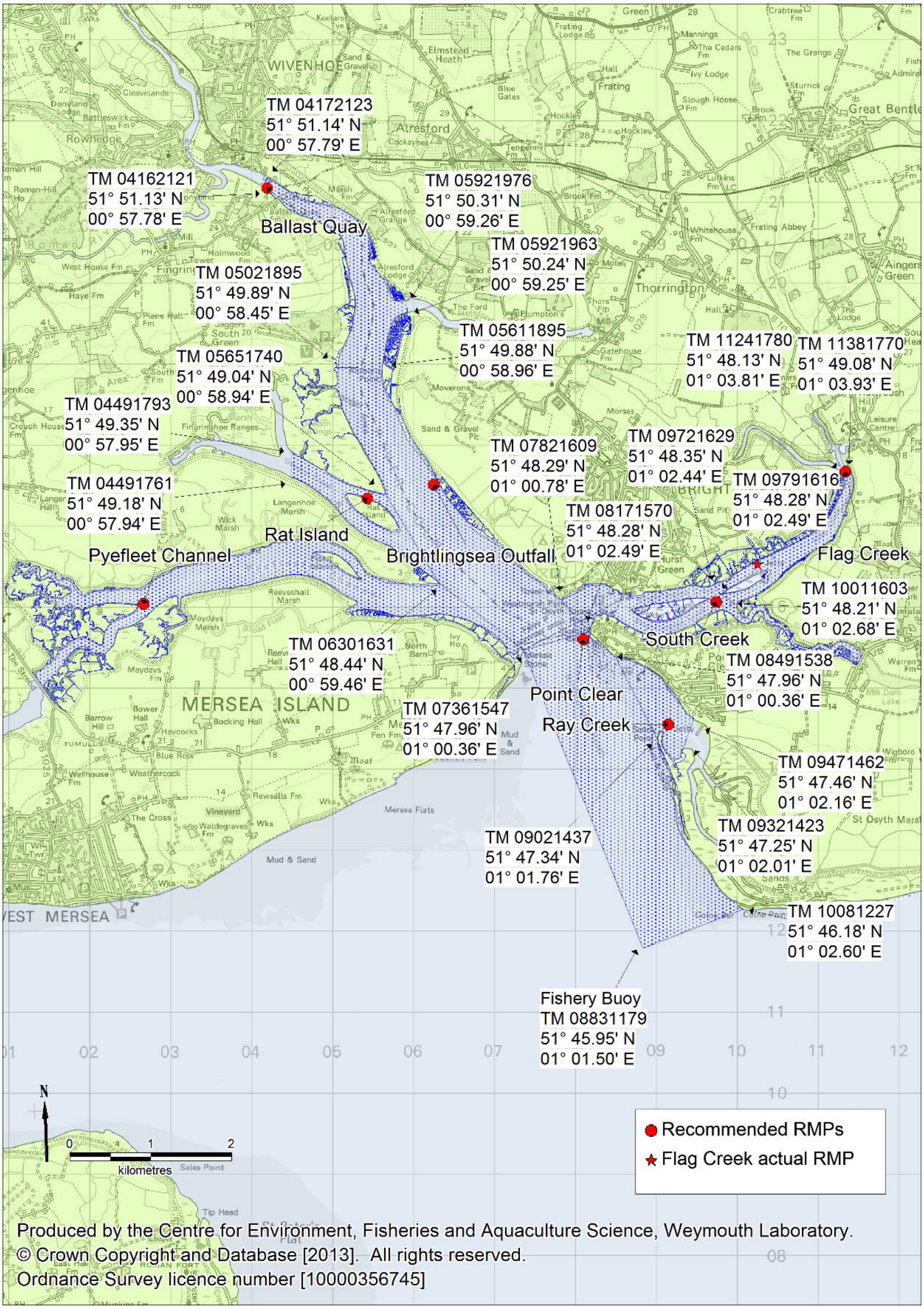


Figure 3.1 Recommended classification zone boundaries and RMP locations (all species)

4. SHELLFISHERIES

SPECIES, LOCATION AND EXTENT

The Colne estuary is largely a private fishery, the rights to which were awarded to the town of Colchester in 1189. Colchester Council leases these rights to Colchester Oyster Fishery Ltd, which was established in 1966. This lease conveys the rights to manage and harvest all bivalve species within the area indicated in Figure 4.1. Species which have been harvested in recent years within this area are native oysters, Pacific oysters, American hard clams and cockles.

Outside of this lease there are two further areas of commercial interest which require a sampling plan. There are large amounts of naturally occurring Pacific oysters within Brightlingsea Creek which local fishermen are interested in exploiting and managing. One fisherman has established a lease area within Brightlingsea Creek where juvenile Pacific oysters will be grown to marketable size. Within Point Clear Bay there is a relatively small scale Pacific oyster fishery. The harvester here would like to expand classification of this area into the lower reaches of Ray Creek and would also like the classification to include mussels which also occur naturally here.

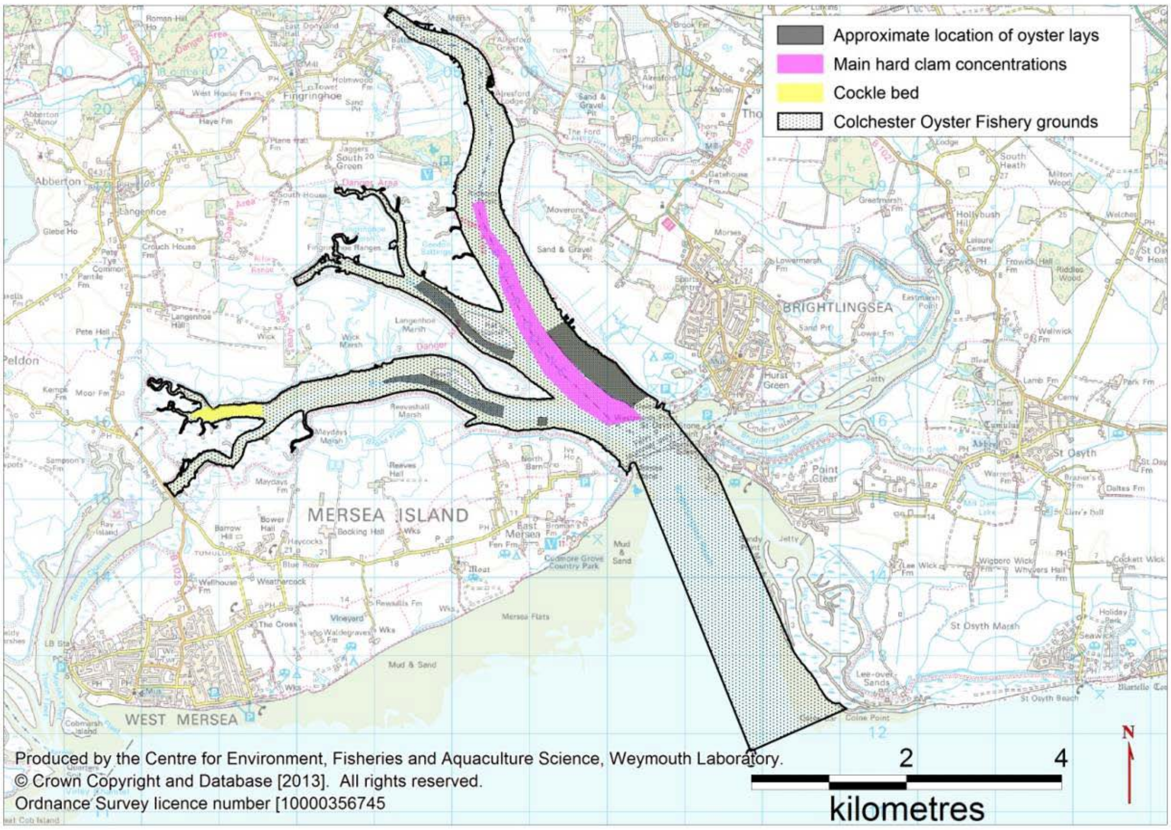


Figure 4.1 Colne fisheries

Pacific oysters occur naturally within the area, primarily in the less muddy intertidal areas and form the mainstay of the fishery. This species has proliferated in the outer Thames estuary and within Essex estuaries in recent years, to the extent that reef formation has occurred in some places (e.g. Natural England, 2009 and cover photograph of this report). The temperature regime within the area is thought to be sufficiently warm for successful spatfalls to occur on an annual basis (Syvret *et al*, 2008). Within the Colchester Oyster Fishery, stocks of this species are only found in exploitable concentrations as far upstream as the number 19 buoy. The fishery is managed to maximise the productivity and marketability of these stocks. There are lays in Pyefleet Creek, Geedon Creek and at the Binnaker (Brightlingsea Harbour to number 17 buoy). Stocks are also held on trestles by the Colchester Oyster Fishery offices at the eastern end of Mersea Island. The current upper classification boundaries within the Pyefleet Channel and Geedon Creek are in line with the upper limit of Pacific oyster stocks within these water bodies. Within Brightlingsea Creek, the upper boundary need not extend past where the creek spits in two in its very upper reaches. At Brightlingsea there are pontoons and moorings throughout the channel to the south of Cindery Island which will not be possible for dredgers to fish routinely. There are however considerable stocks present within this area. It is quite likely that Brightlingsea Harbour will arrange for fishermen to clear stocks from here to remove any oyster reefs which have formed as they may constitute a hazard to craft, so the area around the pontoons will also require classification. Within Point Clear Bay the classification need not extend more than about 200m into Ray Creek.

Native oysters occur primarily in the sub tidal areas, but stocks are currently at very low levels. The majority of stocks are likely to be within the Colchester Oyster Fishery, but there are likely to be a few present in Point Clear Bay and Brightlingsea Creek. Their harvest from public grounds has been temporarily closed by the Kent and Essex IFCA to aid their recovery. The Colchester Oyster Fishery is not exploiting native oysters within their grounds at present. They advise that they are monitoring the situation, there are some reproducing stocks left in certain areas, and spatfalls do occur annually. It is therefore possible that recovery may occur in the future and commercial exploitation of these stocks may continue.

American hard clams are present throughout the estuary. The main concentrations lie in the sub tidal area between the Batemans Tower and the number 19 buoy. The Colchester Oyster Fishery advise that there is no need to classify clams outside of this area at present, although it is possible that in the future they may wish to harvest upstream of this, as far as the barrier. Clams are unlikely to ever occur in commercial quantities downstream of the Batemans Tower. As well as American hard clams, occasional specimens of Manila clams are found in dredge catches, but not in marketable quantities at present. Should a heavy spatfall of Manila clams occur then this species would also require classification for the same areas as for hard clams. Classification has been requested for hard clams in Brightlingsea Creek within the same boundaries as for Pacific oysters.

Cockles have been harvested most years from the upper reaches of the Pyefleet Channel. These are predominantly found in the north channel up from where the creek splits, and the location of this bed is fairly stable from year to year. In 2012 these stocks were not harvested due to low numbers and quality, but it is highly likely that a classification will be required in future years.

The distribution of mussels within the area is uncertain, but they are not particularly widespread within the estuaries and creeks. Brightlingsea Harbour has been classified for this species in the past. The only area where a commercial interest in this species has been expressed is within Point Clear Bay.

4.2 GROWING METHODS AND HARVESTING TECHNIQUES

Wild populations of Pacific oysters are subject to exploitation both via dredge and hand gathering. They are also grown on lays within the Colchester Oyster Fishery Grounds which are managed to maximise productivity and marketability. At least one lay is planned within Brightlingsea Creek. Wild stocks of native oysters were subject to a sub tidal dredge fishery, but this is not currently in operation in either the public or private grounds. They were also grown on the managed lays alongside Pacific oysters. Wild clam stocks are harvested by dredge from the sub tidal areas indicated on Figure 4.1. They may also be dredged or hand dug from Brightlingsea Creek once this area has been classified. Cockle stocks are harvested sporadically (typically once a year) by a visiting dredger when stock status merits the effort. Within Point Clear Bay Pacific oyster and mussels will be harvested by hand.

4.3 SEASONALITY OF HARVEST, CONSERVATION CONTROLS AND DEVELOPMENT POTENTIAL

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

There is a closed season for native oysters which runs from May to August inclusive, and applies to both the public and private grounds. A minimum landing size of 70mm applies to this species. A maximum width of dredge (or dredges) of 4m applies. Native oyster fishing on the public grounds was closed by the Kent and Essex IFCA in May 2012 for at least one year to aid stock recovery, although this only applies to public grounds. If the public fishery is re-opened it may be subject to additional management measures to help sustain any recovery. Harvesting has also stopped within the Colchester oyster fishery for the time being. It remains uncertain whether a significant recovery will occur over the next few years.

There is no closed season for hard clams, but a minimum size of 5cm applies within the district. The stocks presently support a limited commercial fishery within the Colchester Oyster Fishery grounds. There is no closed season or minimum size for Manila clams, occasional specimens of which are caught in the hard clam fishery. It is possible that there may be significant increases in stocks of this species in the future, should a major spatfall occur, in which case the Colchester Oyster Fishery would want these classified so they can be marketed.

There are no conservation controls for cockles on the private grounds. It is likely that the current pattern of harvesting once a year when stocks permit will continue.

There is no closed season for mussels. Within the district, no more than 10% by weight of a representative sample of the catch can pass through a space 18mm in width. The intended mussel fishery in Point Clear Bay is on a relatively small scale and it is uncertain how it may develop.

4.5 HYGIENE CLASSIFICATION

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

Table 4.1 Classification history for the Colne, 2004 onwards

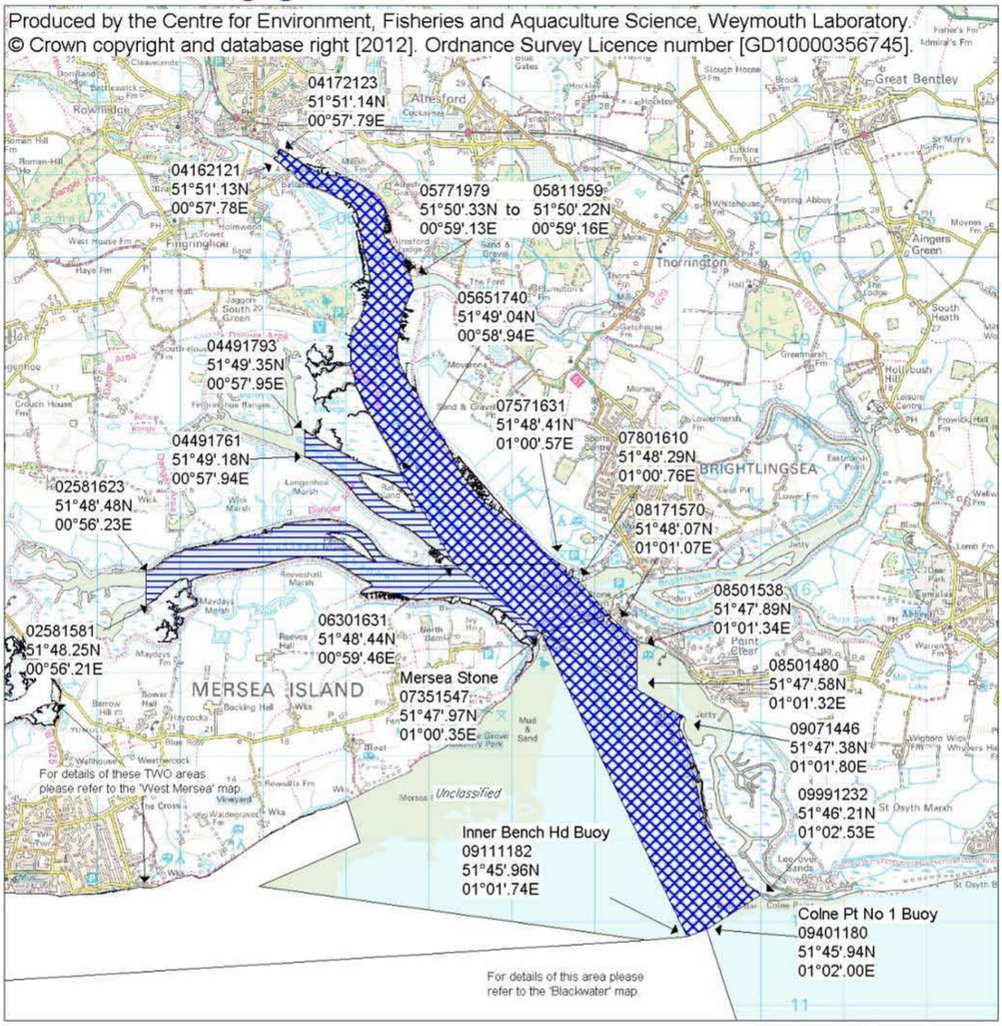
Area	Species	2004	2005	2006	2007	2008	2009	2010	2011	2012
Brightlingsea Harbour	Mussels	B	B	B	B	B	-	-	-	-
Brightlingsea Harbour	P. oyster	B	B	B	B	B	-	-	-	-
Central Colne Channel	P. oyster	-	-	-	C	C	C	B	B	C
Central Colne Channel	N. oyster	-	-	-	-	C	C	B	B	C
Central Colne Channel North	Hard clams	-	-	-	-	B	B	B-LT	B-LT	-
Central Colne Channel South	Hard clams	-	-	-	-	B	-	B	B	B
Pyefleet Channel	N. oyster	-	-	-	B	B	B	B-LT	B-LT	B-LT
Pyefleet Channel	P. oyster	-	-	-	B	B	B	B-LT	B-LT	B-LT
Pyefleet Channel	Cockles	C	C	B	-	-	-	-	-	-
Pyefleet Channel North	Cockles	-	-	-	B	B	B	B-LT	-	-
Pyefleet Channel South	Cockles	-	-	-	-	C	C	B	-	-
Pyefleet Spit	P. oyster	B	A	A	B	B	B	B-LT	B-LT	-
South Geedon	P. oyster	-	-	B	B	B	B	B-LT	B-LT	B-LT
The Ranges	P. oyster	-	-	B	B	B	B	B-LT	B-LT	B-LT
Point Clear North	P. oyster	-	-	-	-	-	-	-	-	B
Brightlingsea Reach	P. oyster	-	-	-	-	-	-	-	-	B

LT denotes long term classification
P denotes preliminary classification

Since the 2012 annual classification review, classifications for Pacific and native oysters in the Central Colne Channel have been upgraded from C to B based on a re-evaluation of monitoring results. Since 2004, C classifications have arisen within the main Colne channel and the Pyefleet Channel for the two oyster species. All other species/zones have held B classifications when classified, except for the Pyefleet spit where Pacific oysters held an A classification in 2005 and 2006. Figures 4.2 to 4.4 show the current classification maps for the Colne. The cockle beds in Pyefleet Channel are temporarily declassified at present.

Colne - C. gigas

Scale - 1:70000



TM

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

Classification of Bivalve Mollusc Production Areas: Effective from 31 October 2012

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

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

N.B. Lat/Longs quoted are WGS84
Separate maps available for M. mercenaria and O. edulis at Colne

Food Authority: Colchester Borough Council

Figure 4.2 Current Pacific oyster classifications

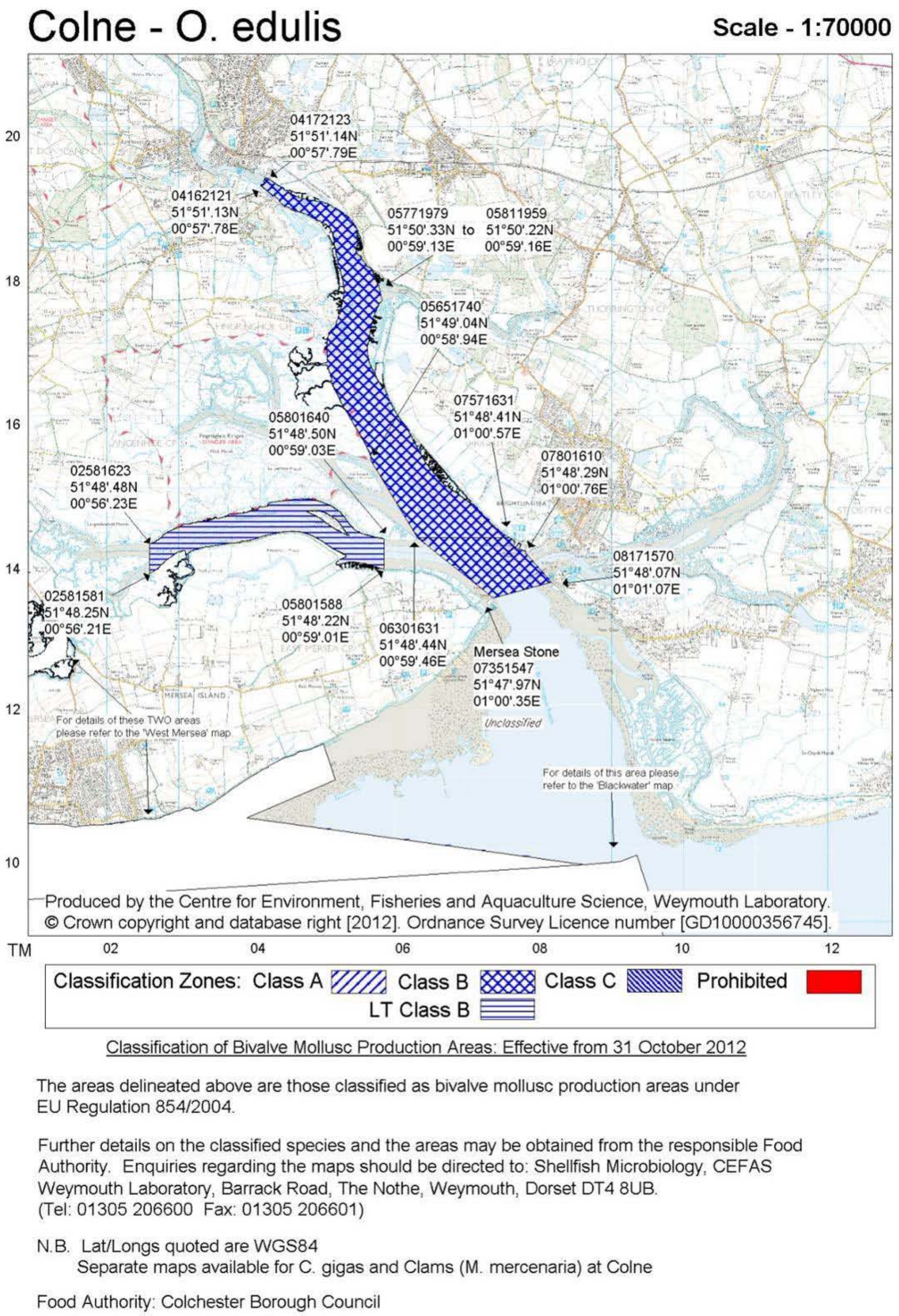
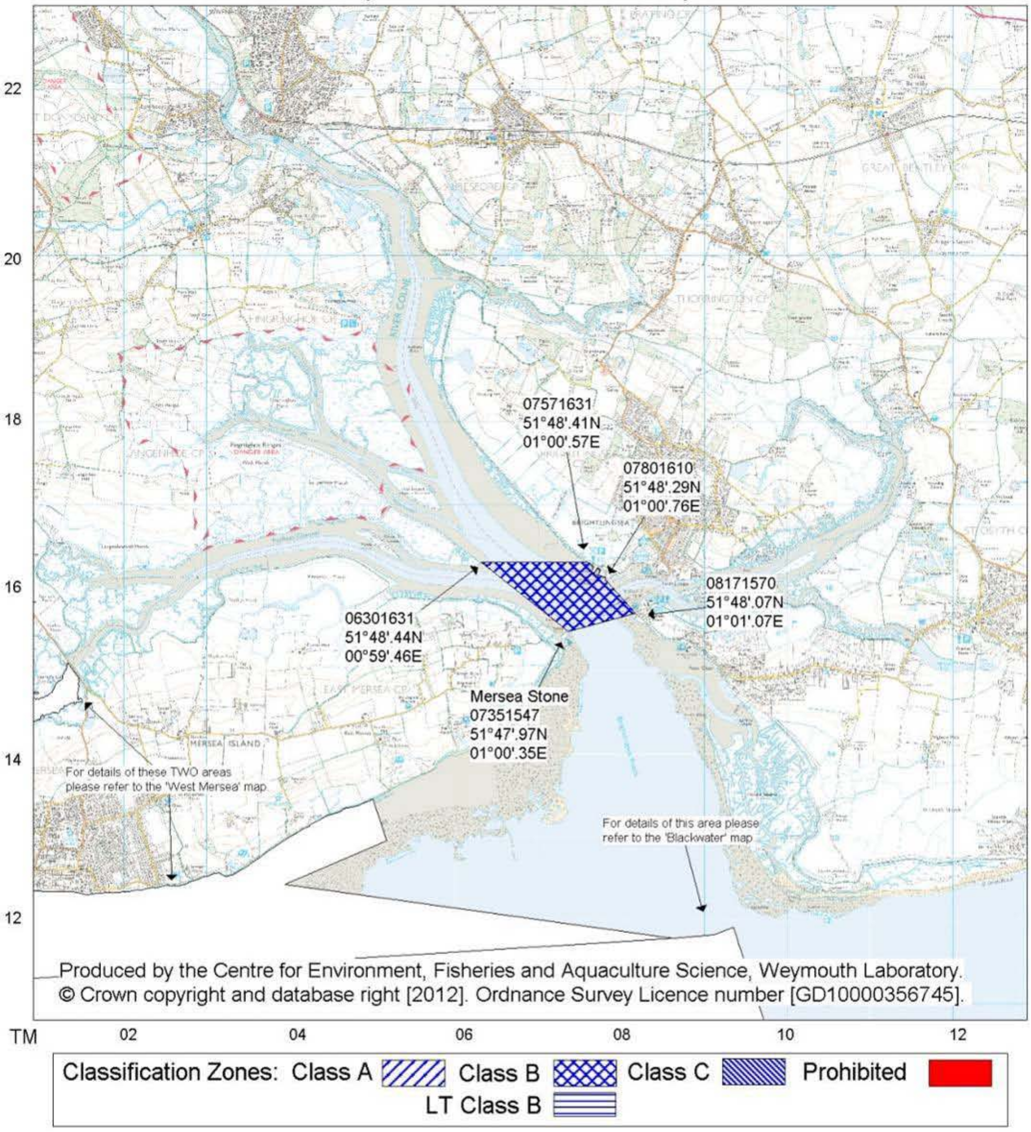


Figure 4.3 Current native oyster classifications

Colne - Clams (M. mercenaria) Scale - 1:70000



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

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

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

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

Food Authority: Colchester Borough Council

Figure 4.4 Current hard 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*/100 g Flesh and Intravalvular Liquid (FIL)	None
B[3]	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution MPN test of 4,600 *E. coli*/100 g FIL in more than 10% of samples. No sample may exceed an upper limit of 46,000 *E. coli*/100 g FIL	Purification, relaying or cooking by an approved method
C[4]	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution Most Probable Number (MPN) test of 46,000 *E. coli*/100 g FIL	Relaying for at least two months in an approved relaying area or cooking by an approved method
Prohibited[6]	>46,000 *E. coli*/100 g FIL[5]	Harvesting not permitted

[1] The reference method is given as ISO 16649-3.
[2] By cross-reference from EC Regulation 854/2004, via EC Regulation 853/2004, to EC Regulation 2073/2005.
[3] From EC Regulation 1021/2008.
[4] From EC Regulation 854/2004.
[5] This level is not specifically given in the Regulation but does not comply with classes A, B or C. The competent authority has the power to prohibit any production and harvesting of bivalve molluscs in areas considered unsuitable for health reasons.
[6] Areas which are not classified and therefore commercial harvesting of LBMs cannot take place. This also includes areas which are unfit for commercial harvesting for health reasons e.g. areas consistently returning prohibited level results in routine monitoring and these are included in the FSA list of designated prohibited beds

5. OVERALL ASSESSMENT

AIM

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

SHELLFISHERIES

COLCHESTER OYSTER FISHERY

The majority of the area considered in this report is a private fishery, the rights to which are owned by Colchester Council and leased to the Colchester Oyster Fishery. The fishery includes the rights to all bivalve species (not just oysters) and extends from the Fishery Buoy outside the mouth of the Colne up to the flood barrier at Wivenhoe. It does not include Brightlingsea Creek or Point Clear Bay, but does include Geedon and Pyefleet Creeks. Species exploited within this area include native oysters, Pacific oysters, American hard clams and cockles.

Pacific oysters are present throughout the area, primarily in the intertidal and stocks within the fishery area are managed to maximise productivity and marketability. They occur naturally throughout the lease area as far upstream as the No. 19 buoy. There are lays in Pyefleet Creek, Geedon Creek and at the Binnaker, and trestles by the Colchester Oyster Fishery offices at the eastern end of Mersea Island. Harvesting occurs on a year round basis.

Native oysters occur primarily in the sub tidal areas, but stocks are currently at very low levels. Harvest of these has stopped within the lease area for the time being to aid their recovery. There are some remaining stocks in certain areas and spatfalls still occur annually. Colchester Oyster Fishery is monitoring the situation and may start harvesting again should stock status merit. A closed season from May to August inclusive applies to this species.

American hard clams are present throughout the estuary, with the main concentrations in the sub tidal area between the Batemans Tower and the number 19 buoy. This is the only area requiring continued classification at present, although a sampling plan should be provided for the section above this up as far as the flood barrier. It is thought unlikely they will ever occur in commercial quantities downstream of the Batemans Tower. Manila clams are also caught in clam dredges, but not in marketable quantities. However, if a large spatfall of Manila clams was to occur this species would require classification over the same areas as for hard clams, so a sampling plan for such an eventuality should be provided. Harvesting of clams may occur at any time of the year.

Commercial cockle beds are present in the upper reaches of the Pyefleet channel. These are generally harvested once a year via visiting suction dredger when stock status merits. No closed season applies to these stocks.

BRIGHTLINGSEA CREEK

Within Brightlingsea Creek there are large amounts of Pacific oysters which are currently unclassified. In some areas oyster reefs have formed. Several harvesters are interested in these stocks. The classified area should include areas of moorings and pontoons, which although they may not be regularly harvested it is likely that the harbour authorities will want the reefs cleared as they represent a hazard to shipping. The fishery may be pursued via dredging or hand gathering. At least one lease area where Pacific oysters will be ongrown and harvested is in the process of being established. Classification has also been requested for hard clams in the same area, although less is known about the status of these stocks. No closed season applies to either of these species.

POINT CLEAR BAY

Point Clear Bay is subject to a relatively small scale Pacific oyster fishery operated on a part time basis by one fisherman. He has requested that the area also be classified for the harvest of mussels which occur naturally there. The classification should include the whole of Point Clear Bay and the very outer reaches of Ray Creek. Harvest of both these species may occur at any time of the year.

SAMPLING PRACTICALITIES

Pacific oysters are currently used to represent native oysters and hard clams in some areas within the Colne, as agreed by the LEA and the competent authority. There is no evidence to suggest that this practice should not continue. Mussels are currently monitored on a quarterly basis to maintain the 'temporarily declassified' status for cockles at the head of the Pyefleet Channel. This is perhaps a less robust practice as whilst the two species accumulate *E. coli* to similar levels in statistical terms, a tendency for cockles to return more extreme high results has been noted (Younger & Reese, 2011). No parallel monitoring of the two species has been undertaken in the Pyefleet Channel. Younger & Reese (2011) also identified that mussels are a suitable surrogate for both Pacific and native oysters.

Most of the current RMPs in the Colne use bagged shellfish. It is desirable that this practice should continue as it allows more precision in the location of the RMPs compared to dredging and hand gathering. It also allows RMPs to be located independently of the distribution of stocks, allowing a larger and more stable area to be classified than would otherwise be the case if wild stocks or existing aquaculture sites are sampled. Most involve the use of bagged Pacific oysters, but one of these RMPs uses bagged hard clams. Clams are a burrowing species so there is some uncertainty how well they survive, feed and grow in such situations, but it appears to be a satisfactory practice in this location.

POLLUTION SOURCES

FRESHWATER INPUTS

All freshwater inputs will carry some contamination from land runoff and so will require consideration in this assessment. The area considered in this survey is the estuary of a major lowland river. Its catchment is largely used for arable farming but there are significant urban areas including the city of Colchester at its tidal limit. About 75% of the catchment is drained by watercourses discharging to the estuary upstream of the fisheries, so a general pattern of increasing levels of runoff-borne contamination towards the up-estuary ends of the fisheries in the main channel is anticipated. There however are some significant freshwater inputs to the lower estuary in the vicinity of the fisheries. Brightlingsea creek receives two significant freshwater inputs (Bentley Brook and St Osyth Brook). They are of similar sizes, and one discharges to the head of Brightlingsea Creek, and the other discharges to the south shore via St. Osyth Creek, in the middle of the area requiring classification. St Osyth Brook passes through the Mill Dam Lake immediately before it discharges to St Osyth Creek, which will reduce the variability in flow rates and offer some opportunity for bacterial die-off during retention. Alresford Creek also receives two significant freshwater inputs (Sixpenny Brook and Tenpenny Brook) so there may be a hotspot of contamination in the fisheries around the mouth of this creek. There are no major freshwater inputs direct to the Pyefleet Channel, Geedon Creek or Ray Creek. There are numerous minor surface water outfalls from urban areas and reclaimed land such as that surrounding Geedon and Pyefleet Creeks but these are too small to be a significant consideration in the sampling plan.

Flows gauging records from the main rivers draining to these estuaries showed higher discharge volumes on average during the winter months, although flows varied considerably on a day to day basis in response to rainfall. Increased levels of runoff are likely to result in an increased bacterial loading carried into coastal waters, particularly as river levels rise when heavy rain occurs following a dry period (the ‘first flush’).

HUMAN POPULATION

Total resident population within the Colne catchment area was 297,909 at the time of the last census for which data was available. The catchment area is predominantly rural/arable land although there are several major conurbations in the area. The largest is Colchester, at the head of the estuary. Other towns adjacent to the estuary are Wivenhoe, which lies up-estuary of the shellfisheries, and Brightlingsea which is situated on the north shore of Brightlingsea Creek.

The Essex coast is a popular holiday destination consequently the population within coastal towns is likely to increase during the summer months. Colchester attracts significant numbers of tourists as do seaside resorts such as Mersea Island, Brightlingsea and Point Clear. There is a large caravan park adjacent to Point Clear Bay for example. Increased population numbers will result in increased volumes of sewage being treated by sewage works so there may be some seasonality in the bacterial loadings generated by these.

SEWAGE DISCHARGES

The majority of sewage inputs in terms of volumes are discharged (~80% in terms of volume) is discharged to the estuary upstream of the shellfishery, or to watercourses which drain to the estuary upstream of the fishery areas. Although significant bacterial die-off is likely to occur during transit from those discharges higher up in the Colne catchment, higher levels of sewage derived contamination are expected towards the head of the estuary on this basis.

The largest discharge within the catchment by a considerable margin is the Colchester STW, which discharges direct to the very upper reaches of the estuary. It has a consented dry weather flow of 29,284m^3/day but has just had UV disinfection installed (March 2013). An estimate of the bacterial loading it now generates is relatively minor at $8.2x10^{10}$ faecal coliforms per day, based on dry weather flow and average bacterial concentrations for this treatment type from the scientific literature, although this is likely to fluctuate. No final effluent testing data was available at the time of writing.

There are several other continuous sewage discharges to the estuary which are likely to cause localised elevations in concentrations of faecal indicator bacteria. Fingringhoe STW discharges just above the flood barrier at Wivenhoe and provides secondary treatment for a consented dry weather flow of 403 m^3/day. The final effluent here has not been subject to bacteriological testing but an estimate of the loading it generates, based on average values from scientific literature, is $1.3x10^{12}$ faecal coliform cfu/day.

Alresford Creek receives the effluent from two continuous sewage discharges (Thorrington and Great Bromley STWs) which provide secondary treatment for a combined dry weather flow of 2765 m^3/day. No final effluent testing data was available for either, but an estimate of their combined bacterial loading is $9.1x10^{12}$ faecal coliform cfu/day. Some dilution and bacterial die-off is anticipated during transit through the watercourses and Alresford Creek before it reaches the main Colne Channel where the shellfish resources are located.

Brightlingsea STW provides treatment for a dry weather flow of 2726 m^3/day and discharges via an outfall opposite the mouth of Geedon Creek, about 350m up-estuary from an area used as an oyster lay. It was fitted with UV disinfection around the same time as Colchester STW. An estimate of the bacterial loading it generates is $7.6x10^9$ cfu/day although this is likely to fluctuate. No final effluent testing data was available at the time of writing.

St Osyth STW discharges to the head of Ray Creek (via a borrow dyke) and provides secondary treatment for a dry weather flow of 1600 m^3/day. No final effluent testing data was available, but an estimate of the bacterial loading it generates is $5.3x10^{12}$ faecal coliform cfu/day. This will be a highly significant contaminating influence to Ray Creek and Point Clear Bay. No improvements are planned for this works.

Outside of the estuary, there are two mid-sized sewage discharges to the North Sea within a few km. The UV treated discharge at West Mersea consistently contains very low concentrations of faecal indicator bacteria and is unlikely to be of any significance to the Colne estuary. Jaywick STW provides secondary treatment for a dry weather flow of 6199 m^3/day and effluent from this will be carried towards the mouth of the Colne estuary on a flooding tide.

In addition to the continuous sewage discharges, there are a large number of intermittent water company discharges associated with the sewerage networks. The main cluster of intermittent discharges is in the Colchester area, with smaller aggregations at Wivenhoe and Brightlingsea. There is also one at the head of St Osyth Creek, and one to Ray Creek from the St Osyth STW. Most are therefore located up-estuary of the fisheries, the spatial pattern of their influences is likely to be broadly similar to that of the water company continuous discharges. Those in the Brightlingsea and St Osyth area discharge in closest proximity to the shellfish beds and so spills from these will have the greatest potential impacts. No spill records from these discharges were available at the time of writing, so it is difficult to assess their significance aside from noting their location and their potential to discharge large volumes of untreated sewage. Such events may occur either under storm conditions when the sewers are inundated with runoff which may happen after intense rainfall events, or in the event of an emergency such as a pump failure or blockage which may occur at any time. Typically, spills are too infrequent for their impacts to be captured reliably under monthly classification sampling.

In addition to the water company owned discharges, there are 74 consented discharges within about 2km of the estuary. These are generally small and serve one or a handful of properties and provide treatment via package plant or septic tank. Of potential significance, one of these is from a country park which discharges at the head of Brightlingsea Creek and is consented to discharge a maximum of 50m^3/day.

AGRICULTURE

The majority of agricultural land within the Colne catchment is used for arable farming, although there are some pockets of pasture. There are relatively low overall numbers and densities of grazing animals (cattle and sheep) within the catchment. A large proportion of the pastures lie adjacent to the estuary, including the land surrounding Pyefleet and Geedon Creeks so the watercourses and field drains draining these areas are likely to carry some contamination of livestock origin. There are also significant numbers of poultry and a few pigs in the catchment, the manure from which is typically collected and applied tactically to nearby farmland. Sewage sludge may also be used as fertilizer, but no information on local practices was available at the time of writing.

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

The seasonal pattern of application of manures and slurries is uncertain. Cattle may be housed indoors in winter so applications of slurry to pastures in these farms may be more likely during the winter and spring.

BOATS

Overboard discharges made by boats may be a significant source of contamination to the survey area at times. The main boating centre is Brightlingsea, where there are about 500 moorings and pontoon berths used by yachts, cabin cruisers, wind farm maintenance vessels and fishing boats. Most of these moorings/berths are in the south channel of Brightlingsea Creek adjacent to Cindery Island. In addition to this there are a few moorings near the tidal barrier at Wivenhoe sailing club, and a few in the mouth of Alresford Creek. There is some limited merchant shipping traffic in the Colne, to Olivers Wharf in Brightlingsea Creek and Ballast Quay situated just south of Wivenhoe tidal barrier. The area is also used for watersports such as windsurfing, dinghy sailing and power boating. A houseboat was seen at Brightlingsea during the shoreline survey.

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

WILDLIFE

Overwintering waterbirds (wildfowl and waders) represent the largest aggregations of wildlife which may impact on shellfish hygiene in the area. Over the five winters up until 2010 an average total count of 22,652 overwintering and wildfowl were recorded in the Colne estuary. The shoreline survey confirmed a significant presence of overwintering waterbirds. Some species such as waders will forage (and defecate) directly on the shellfish beds across a wide area. They may tend to aggregate in certain areas holding the highest densities of invertebrates of their preferred size and species, but this will change from year to year. Although they may contribute significant amounts of faecal indicator organisms, as a diffuse input they will have no influence on RMP locations. Other species, such as geese will graze on saltmarshes and pastures so their faeces will be carried into coastal waters via land runoff from these areas in the same manner as that originating from livestock.

Whilst most of the overwintering population migrate elsewhere in the summer, a much smaller but nevertheless potentially significant population of resident and breeding birds will remain. A survey of breeding seabirds (gulls, terns etc) recorded a breeding colony of about 2,300 pairs of black headed gulls on Rat Island in Geedon Creek. These are likely to forage widely throughout the area, therefore faecal inputs could be generally considered as diffuse. Impacts are likely to be more concentrated in the immediate vicinity of the colony, both in the form of an increased concentration of droppings on the adjacent intertidal and via runoff from this island. The presence of this colony may influence the location of any RMPs within Geedon Creek.

The Essex estuaries support a combined population of about 100 harbour seals. They are present year round but numbers tend to peak in the late summer and in mid winter. They will forage widely and have been sighted within the Colne estuary. Given their small numbers and the large area they are likely to forage over impacts are likely to be minor, and unpredictable in spatial terms so will not be an influence on the sampling plan. No other wildlife species which have a potentially significant influence on levels of contamination within shellfish within the survey area have been identified.

DOMESTIC ANIMALS

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

SUMMARY OF POLLUTION SOURCES

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

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

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

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

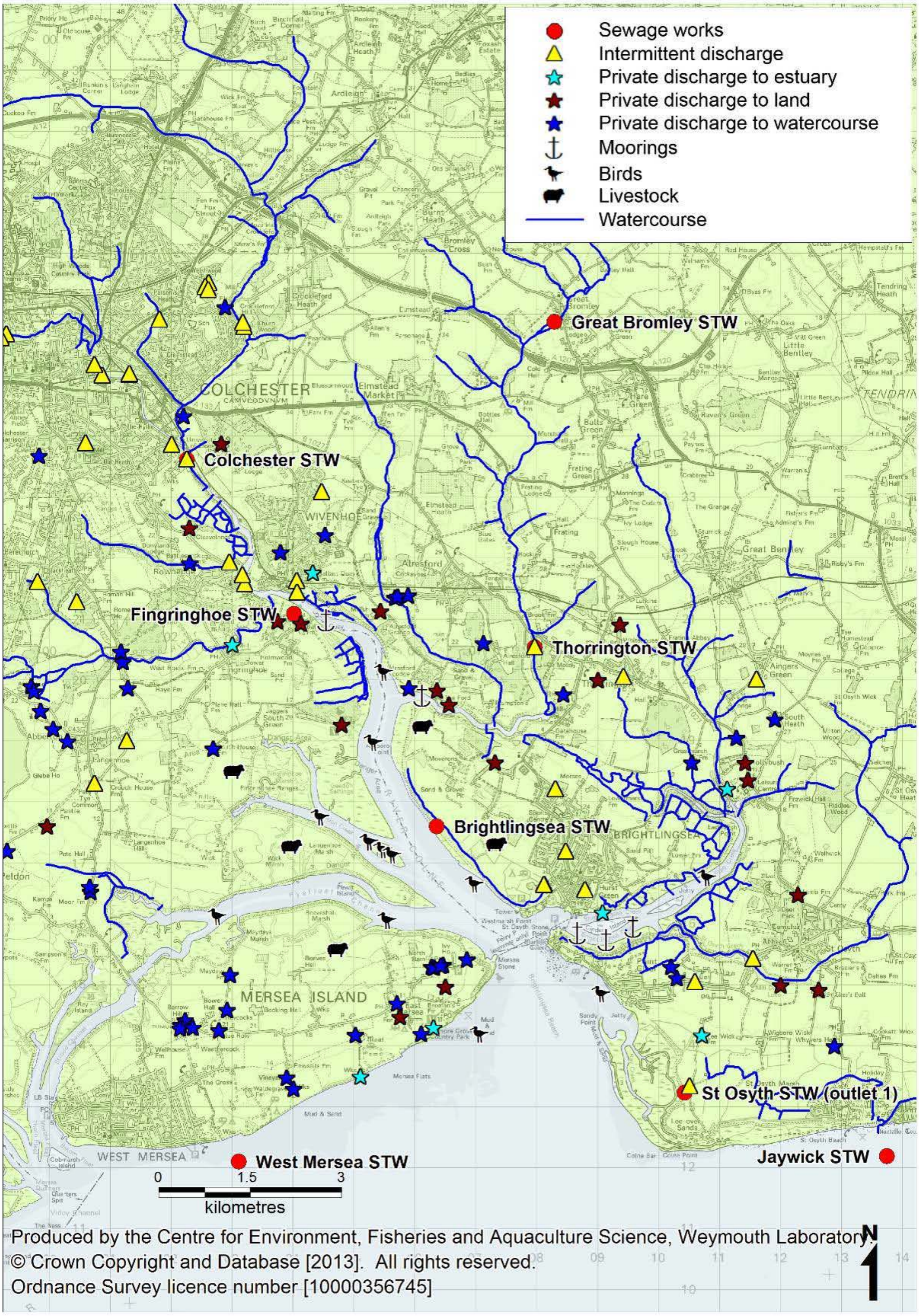


Figure 5.1 Significant sources of microbiological pollution to the Colne estuary

HYDROGRAPHY

The Colne is a branching estuary approximately 7km in length from its tidal limit at Colchester to its mouth. Most of the estuary is intertidal with extensive mudflats that are fringed with saltmarsh in places. Therefore, a large proportion of the water within the estuary is exchanged on each tide, but dilution potential is quite low away from the main channels. The main channel has a northwest to southeast orientation with slight meanders. It becomes progressively narrower and shallower towards the upper reaches so dilution potential will decrease significantly towards the head.

There are four major side arms off the main channel between its mouth and the flood barrier at Wivenhoe. Brightlingsea Creek extends in an easterly direction just inside the estuary mouth and splits into two channels around two saltmarsh islands. The two channels merge again in its upper reaches. St Osyth Creek, a smaller creek joins the south channel of Brightlingsea Creek between the two saltmarsh islands. The Pyefleet channel originates north of Mersea Island and extends in a westerly direction. It splits into two separate channels in its upper reaches. The southern channel has a tidal causeway at its head, on the other side of which lies the head of the Strood Channel. At high water on spring tides the causeway is submerged, so there is some very limited water exchange between the two at these times. Geedon Creek also extends in a westerly direction from the main channel, just up-estuary from the Pyefleet channel. It splits into two channels around Rat Island, then the channels rejoin, and the split again into two separate channels at its head. Alresford Creek extends in an easterly direction from the main channel about 4km up-estuary from Brightlingsea Creek. It is narrower and shallower than the creeks further down-estuary, and does not contain any significant shellfish resources.

Seawards of the mouth is Point Clear Bay, which consists of intertidal mudflats which gently slope gradient west into the subtidal region and into the Colne deepwater channel. Ray Creek is a subtidal channel that meanders through Point Clear Bay in a south easterly direction and is then surrounded by an extensive area of saltmarsh at its head.

The tidal amplitude here is large and is the main force driving water movements in the area. Offshore tidal streams flood down the Essex coast towards the Thames Estuary in a south westerly direction, and reverse on the ebb. The indentation to the coast at the Colne and Blackwater estuaries cause the flood streams to be diverted in a north westerly direction into the Colne estuary. Within the estuary and the adjoining creeks there is a bi-directional pattern of tidal circulation, with water moving up the estuary and creeks on the flood tide and reversing on the ebb. Shoreline sources of contamination will therefore primarily impact up and downstream of their locations along the bank to which they discharge. This pattern of circulation also means that the creeks will be mainly under the influence of down-estuary sources and sources discharging directly to them, as sources further up the main channel will not be carried directly into them on a flooding tide. The two parallel channels present in the lower reaches of Brightlingsea Creek and Geedon Creek will further constrain the impacts of shoreline sources to the banks to which they discharge.

An estimate of tidal excursion based on a tidal diamond in the mouth of the estuary is about 8.5km on spring tides and about 5.5km on neap tides. This would suggest the Jaywick STW may impact on Point Clear Bay to some extent, but should not reach the mouth of the Colne even on the larger tides. It also suggests that sources discharging to the head of the estuary will impact throughout most of its length, although it should be noted that the tidal diamond only applies to its specific location and current speeds are likely to vary throughout the estuary.

Freshwater inputs may significantly modify the circulation of water around estuaries via density effects. Freshwater inputs to the Colne are very low in relation to tidal exchange in the estuary as a whole suggesting it should be well mixed and that density driven circulation is unimportant. Salinity measurements taken at two sites in the outer estuary (Colne mouth and Pyefleet Creek) indicate that salinity is approaching that of full strength seawater at both these locations for most of the time. Further up-estuary salinity is reported to become lower and more variable, in the range of 20-32ppt at the Alresford Creek confluence and 2-17ppt at Colchester. There are also likely to be more limited salinity gradients in Alresford Creek and Brightlingsea Creek as both receive significant freshwater inputs to their upper reaches. The Pyefleet Channel and Geedon Creek receive little in terms of freshwater inputs.

There may therefore be some stratification in the upper reaches of the estuary, which would result in a net seaward flow in the upper layers and a net landward flow at depth. Decreasing salinity is likely to be associated with higher levels of faecal indicator organisms from land runoff, so gradients of decreasing salinity are likely to be accompanied by gradients of increasing contamination. A significant correlation was found between salinity and concentrations of faecal coliforms recorded at the estuary mouth even though there was little variation in either at this location. No such correlation was found at the site in Pyefleet Creek, which would be consistent with the patterns of circulation and impacts of land runoff suggested by this assessment.

Tidal currents may also be modified by the effects of wind. Strong winds drive surface water currents, which in turn create return currents which may travel at depth or along sheltered margins. Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great range of scenarios may arise. The estuary is not particularly exposed to the prevailing south westerly winds, apart from the very outer reaches between the estuary mouth and the fishery buoy. Winds from a south easterly direction will tend to push surface water up the estuary. As well as driving surface currents, onshore winds will create wave action which may resuspend any contamination held within sediments. Energetic wave action will arise in Point Clear Bay when there are strong winds from the prevailing south-west quadrant. Significant wave action is not generally anticipated within the estuary and its associated side arms as they are enclosed and more sheltered.

SUMMARY OF EXISTING MICROBIOLOGICAL DATA

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

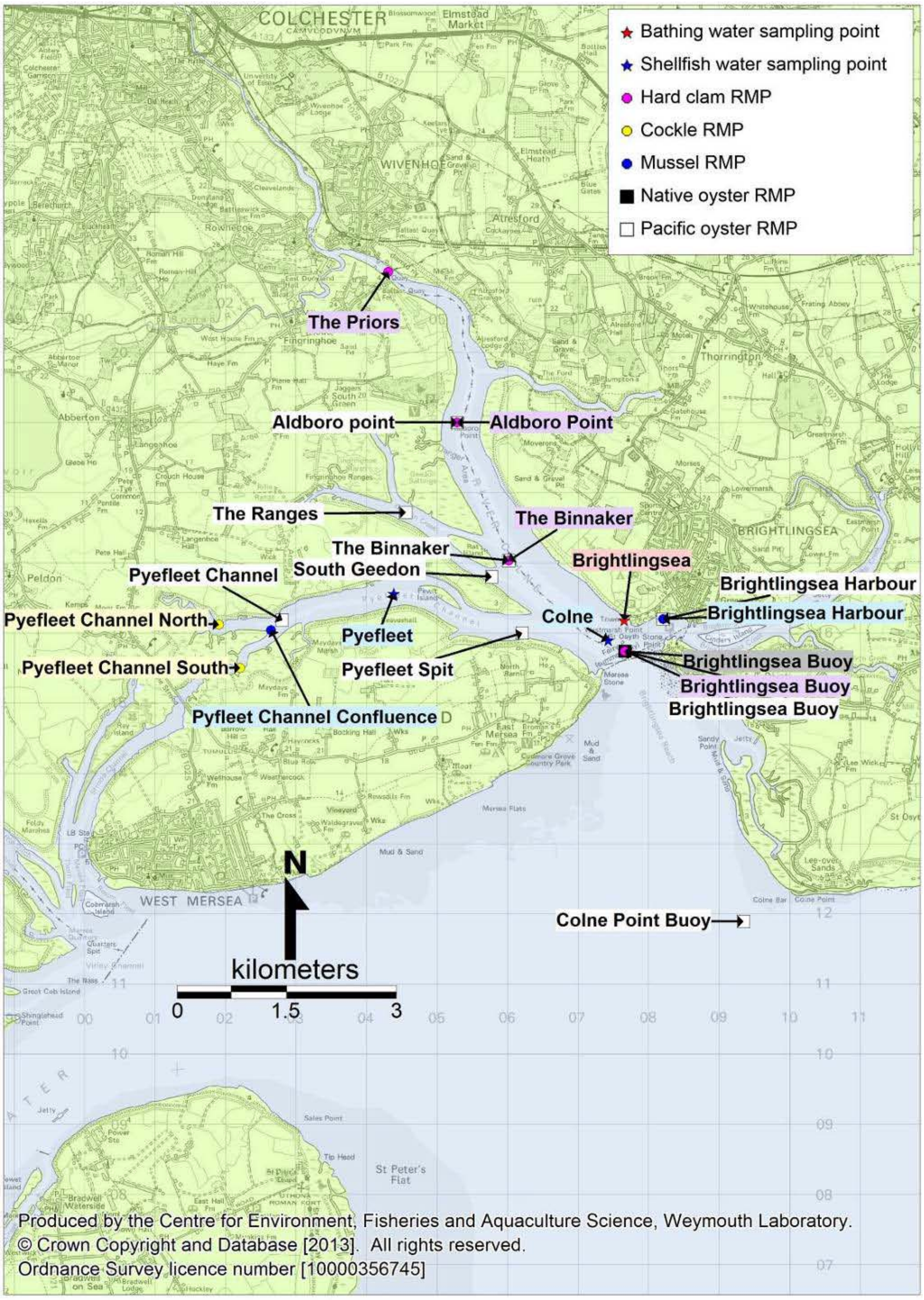


Figure 5.2 Location of microbiological sampling points referred to in this assessment.

WATER SAMPLES

Only one site at Brightlingsea Beach was sampled under the Bathing Waters monitoring programme, where around 20 water samples were taken each bathing season (May-September) and tested for faecal coliforms. Levels of faecal coliforms at the bathing waters site were generally low, averaging 10.2 cfu/100ml and were stable over recent years. No correlations between levels of faecal coliforms and tidal state on either the spring/neap or high/low tidal cycles were found here. Significant positive correlations were found between faecal coliform levels and rainfall between two and four days prior to sampling.

Water samples were taken on a quarterly basis and tested for faecal coliforms from two locations under the Shellfish Waters monitoring programme (Colne and Pyefleet). Levels of faecal coliforms were low at both these sites, averaging 6.9 and 9.1 cfu/100ml respectively. Significant seasonal variation was found at both, with higher results occurring during the winter at both. Both sites did show some significant correlations between faecal coliforms and recent rainfall, but these were stronger and more consistent at Colne than at Pyefleet. Similarly, a significant negative correlation between salinity and levels of faecal coliforms was found at Colne but not at Pyefleet.

SHELLFISH FLESH SAMPLES

Over the last decade, four hard clam RMPs, two cockle RMPs, two mussel RMPs, one native oyster RMP and nine Pacific oyster RMPs have been sampled and tested for *E. coli* under the classification monitoring programme. Of these, two hard clam RMPs, one mussel RMP and one Pacific oyster RMP were sampled on six or fewer occasions so could not be included in any detailed analyses.

Across the two main clam RMPs, results were significantly higher at the up estuary RMP (The Priors, geometric mean of 617 *E. coli* MPN/100g) compared to the one at the estuary mouth (Brightlingsea Buoy, geometric mean of 94 *E. coli* MPN/100g). At the former, 8% of samples exceeded 4600 *E. coli* MPN/100g with a maximum of 16,000, whilst at the latter the highest result was 1700 *E. coli* MPN/100g. This suggests increasing levels of contamination towards the upper reaches of the main estuary channel. A paired comparison of samples taken on the same day and hence under the same environmental conditions showed results were not correlated on a sample by sample basis suggesting these two RMPs are under differing contaminating influences.

Results were very similar at the two cockle RMPs (Pyefleet Channel North and Pyefleet Channel South) both in terms of geometric mean result (430 and 653 *E. coli* MPN/100g) and proportion of results exceeding 4600 (3% and 5%). Paired (same day) sample results were strongly correlated. This suggests separate monitoring of cockle beds in the north and south channels at the head of Pyefleet Creek is not necessary, particularly given their close proximity.

Only one mussel RMP and only one native oyster RMP were sampled on more than six occasions so geographical comparisons of results for these species were not possible.

Nine Pacific oyster RMPs were sampled on more than six occasions. In terms of geometric mean *E. coli* result the RMPs were ranked as follows: Aldboro Point (1067) > The Ranges (359) > The Binnaker (353) > South Geedon (319) > Brightlingsea Buoy (317) > Brightlingsea Harbour (281) > Pyefleet Channel (121) > Pyefleet Spit (68). This suggests an overall pattern of increasing levels of contamination towards the head of the main channel. It also indicates higher levels of contamination in Geedon Creek compared to Pyefleet Creek, and that within these two channels results were slightly higher on average at the up-channel RMPs. Statistical testing revealed that oysters collected from Aldboro point had significantly higher average levels of *E. coli* than at all other sites except The Binnaker (although the latter was only sampled on 12 occasions). The two Pyefleet RMPs did not differ significantly from each other, but Pyefleet Spit had significantly lower *E. coli* levels than all the other RMPs. The Binnaker and Brightlingsea Buoy were the only other sites that did not differ significantly from Pyefleet channel. Results of samples taken on the same day were correlated between most site pairings with the exception of Aldboro Point and Pyefleet Spit, and Pyefleet Spit and South Geedon. This suggests that most RMPs are under broadly similar influences with the possible exception of Pyefleet Spit.

Results have been quite stable at all RMPs regularly sampled over the course of two years or more. Some seasonality was detected at some RMPs but the pattern varied with location and with species sampled. At the two hard clam RMPs results were highest on average in the autumn and lowest on average in the winter, although this was more marked and statistically significant only at The Priors. The two cockle RMPs results were lowest on average in the spring and highest on average in the winter, although this variation was statistically significant only at Pyefleet Channel North. No seasonal variation was apparent at the mussel RMP at Brightlingsea Harbour or at the native oyster RMP at Brightlingsea Buoy. Little seasonal variation was observed across the six Pacific oyster RMPs with sufficient sample numbers, with the exception of Pyefleet Channel where *E. coli* levels were significantly lower in the spring than in the autumn.

Correlations were found between *E. coli* results and the high/low tidal cycle for Pacific oysters at Aldboro Point and Pyefleet Channel, but no pattern was apparent when this data was plotted. Correlations between *E. coli* results and the spring/neap tidal cycle were found for cockles at Pyefleet Channel North, and Pacific oysters at Brightlingsea Harbour, The Ranges, Aldboro Point and Pyefleet Channel. Tentatively, higher results appeared to occur during spring tides at Aldboro Point and Pyefleet Channel, and on tides of decreasing size at Brightlingsea Harbour. No pattern could be seen for the Ranges.

Correlations were undertaken between rainfall in various periods running up to sample collection and *E. coli* results. No significant effect of rainfall was detected at either of the hard clam RMPs. A minor influence of rainfall was detected at the two cockle RMPs. A strong and consistent influence of recent rainfall was found at the mussel RMP at Brightlingsea. A minor influence of rainfall was found for native oysters at Brightlingsea Buoy. Weak influences of rainfall were detected at all Pacific oyster RMPs except the Binnaker and Brightlingsea Buoy which were sampled on fewer occasions than the others. Overall, the influence of rainfall is quite weak. It is likely that differences in physiology (e.g. their response to changes in salinity) are responsible in part for the differences observed between the species.

APPENDICES

APPENDIX I
HUMAN POPULATION

Figure I.1 shows population densities in census output areas within or partially within the hydrological catchment, derived from data collected at the time of last census (2001). The equivalent data from the 2011 census was not yet published at the time of writing.

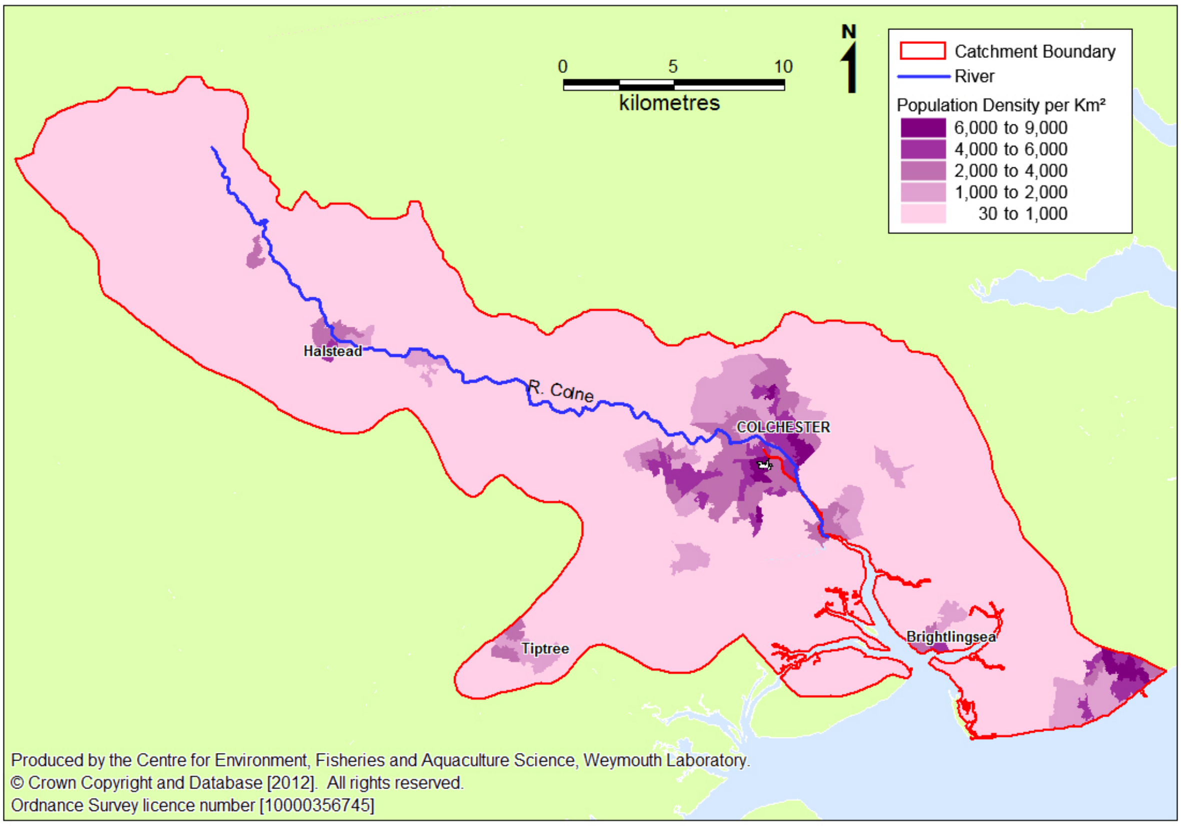


Figure I.1 Population densities in the Colne catchment area

Total resident population within the Colne catchment area was 297,909 at the time of the 2001 census. Figure I.1 indicates that the highest population densities are found within the main town of Colchester. Brightlingsea a small seaside town is populated by approximately 8,400 (Brightlingsea Town Plan Steering Committee, 2011). The survey area is predominantly rural/arable land, represented by the relatively low population densities throughout the catchment, a large proportion between 30 and 1,000 persons per km². The pattern of impacts on the fisheries associated with sewage will largely depend on the nature of the sewerage infrastructure serving the area. Urban runoff is likely to make a significant contribution to levels of faecal indicator bacteria, particularly at Colchester.

Colchester, the oldest recorded town in Britain attracts an abundance of visitors each year, approximately 4.5 million (Visit Colchester, 2012) are drawn to the town's rich history, culture and heritage, as well as outdoor pursuits. Tourism plays an important part in Colchester's economy contributing to expenditure of £200 million plus to the region and supporting over 6,000 jobs each year (Colchester Borough Council, 2012). Brightlingsea is an attractive seaside town popular amongst tourists, offering a variety of activities including attractive coastal walks, fishing trips and watersports. Visitors to the area tend to stay in the various hotels, guesthouses, B&B's, caravan and camping sites. For example there is a large caravan park adjacent to Point Clear Bay. Although accurate tourism figures are not known for the majority of the catchment it is likely that numbers are increased during the summer months, particularly within the seaside towns. During the summer months when tourism is at its highest the total population will be higher and bacterial loadings from sewage treatment works serving the area will increase accordingly. Deterioration in the microbiological quality of water and bivalve molluscs is frequently detected in coastal areas that are impacted by pollution sources associated with tourism activities, possibly due to increased loads from sewage treatment plants (Younger et al., 2003).

APPENDIX II
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: SEWAGE DISCHARGES

Details of all consented discharges within the Colne estuary hydrological catchment and nearby coastal waters were taken from the Environment Agency's national discharge database (July 2012). The locations of the water company owned sewage treatment works are shown in Figure II.1. Further details of these treatment works are presented in Table II.1. For works consented for a population equivalent rather than a dry weather flow a water usage of 160 l/head/day was assumed.

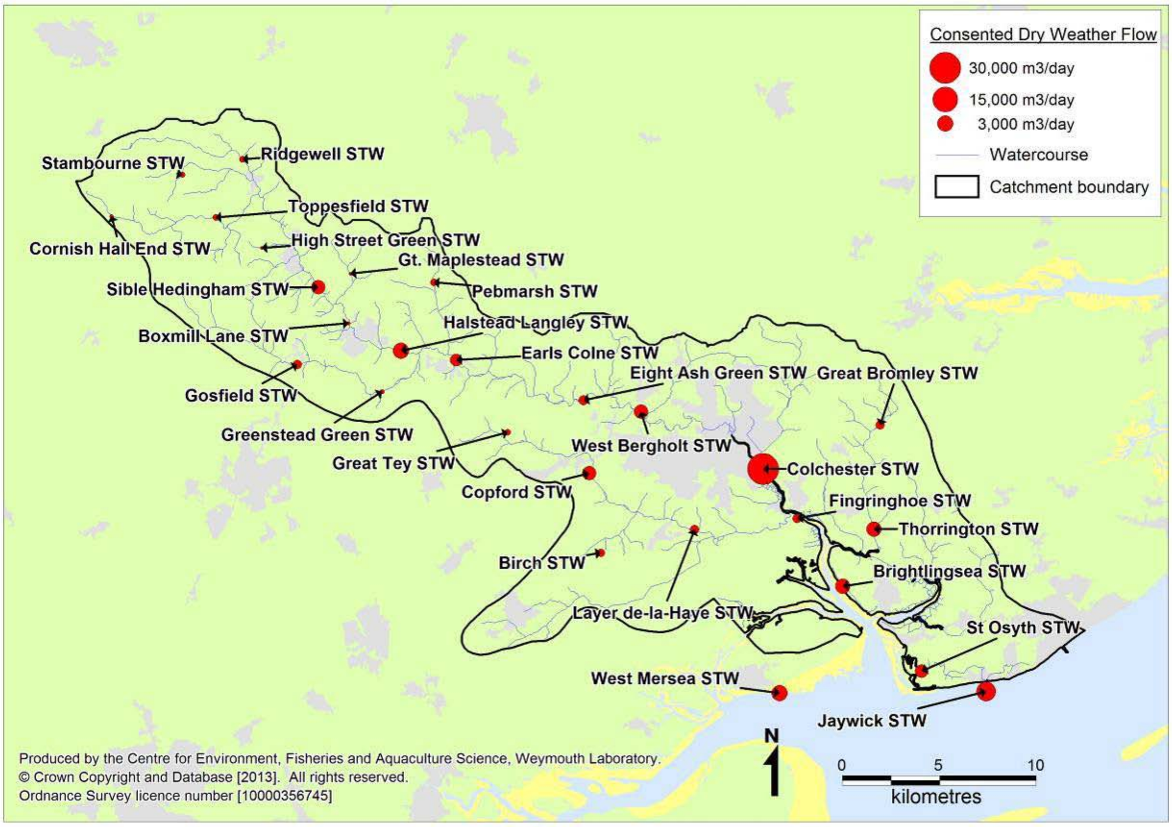


Figure II.1 Water company sewage treatment works discharging within the Colne estuary catchment and to nearby coastal waters. *Data from the Environment Agency*

For four of these sewage works (Colchester, Brightlingsea, West Mersea and Jaywick) some bacteriological testing of final effluents had been undertaken. However, since this testing was undertaken two have had UV treatment added (Colchester and Brightlingsea) so the results are no longer relevant. Results for Jaywick and West Mersea are presented in Table II.2 and Figure II.2. For all the other sewage works, estimates of their bacterial loading were made based on their consented dry weather flow and the geometric mean base flow concentrations of faecal coliforms from a range of UK STWs providing secondary treatment (Table II.3). Some of these works provide additional treatment for nutrient removal, which is likely to further reduce levels of faecal indicators so such estimates may be higher than actual loadings. The estimates are intended for broad comparative purposes only, and bacterial concentrations in effluents are likely to vary significantly between different treatment works, and with time at individual treatment works. Although levels of *E. coli* are usually correlated to faecal coliforms levels at a ratio approaching roughly 1:1, the ratio depends on a number of factors, such as environmental conditions and the source of contamination so caution should be exercised when comparing the two.

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

Name	Location	DWF (m^3/day)	Treatment Level	Estimated bacterial loading	Receiving Water
Birch STW	TL 93900 19300	300	Tertiary (Biological)	$9.9x10^{11}$*	Birchwood Brook
Boxmill Lane STW	TL 80900 31100	24	Secondary	$7.9x10^{10}$*	River Colne
Brightlingsea STW	TM 06350 17600	2726	Tertiary (UV) from Apr 2013	$7.6x10^{9}$*	Colne Estuary
Colchester STW	TM 02250 23610	29284	Tertiary (UV) from Apr 2013	$8.2x10^{10}$*	Colne estuary
Copford STW	TL 93300 23400	1893	Tertiary (Biological)	$6.2x10^{12}$*	Roman River
Cornish Hall End STW	TL 68700 36600	13.44	Secondary	$4.4x10^{10}$*	Toppesfield Brook
Earls Colne STW	TL 86440 29220	1267	Secondary + reed bed	$4.2x10^{12}$*	River Colne
Eight Ash Green STW	TL 93000 27150	650	Secondary	$2.1x10^{12}$*	River Colne
Fingringhoe STW	TM 04010 21080	403	Secondary	$1.3x10^{12}$*	Tributary of Colne Estuary
Gosfield STW	TL 78260 28980	466	Tertiary (Biological)	$1.5x10^{12}$*	Bourne Brook
Great Bromley STW	TM 08280 25870	365	Secondary	$1.2x10^{12}$*	Bromley Brook
Great Tey STW	TL 89100 25500	142	Secondary	$4.7x10^{11}$*	Roman River
Greenstead Green STW	TL 82630 27600	48	Secondary	$1.6x10^{11}$*	Bourne Brook
Gt. Maplestead STW	TL 81000 33650	6.4	Secondary	$2.1x10^{10}$*	Hepworth Hall Brook
Halstead Langley STW	TL 83600 29700	2900	Secondary + phosphate stripping	$9.6x10^{12}$*	River Colne
High Street Green STW	TL 76430 34980	11.2	Secondary	$3.7x10^{10}$*	Graves Hall Brook
Jaywick STW	TM 13740 12190	6199	Secondary	$5.0x10^{12}$**	North Sea
Layer de-la-Haye STW	TL 98720 20510	451	Secondary	$1.5x10^{12}$*	Roman River
Pebmarsh STW	TL 85300 33200	183	Secondary	$6.0x10^{11}$*	Pebmarsh Brook
Ridgewell STW	TL 75450 39530	102	Secondary	$3.4x10^{11}$*	River Colne
Sible Hedingham STW	TL 79340 32970	2145	Tertiary (Biological)	$7.1x10^{12}$*	River Colne
St Osyth STW	TM 10420 13230 & TM 10380 13260	1600	Secondary	$5.3x10^{12}$*	Borrow Ditch & Ray Creek
Stambourne STW	TL 72350 38740	70	Secondary	$2.3x10^{11}$*	Stambourne Brook tributary
Thorrington STW	TM 07960 20530	2400	Secondary	$7.9x10^{12}$*	Ten Penny Brook
Toppesfield STW	TL 74060 36540	102	Secondary	$3.4x10^{11}$*	Toppesfield Brook
West Bergholt STW	TL 95960 26570	1877	Secondary	$6.2x10^{12}$*	River Colne
West Mersea STW	TM 03100 12100	2900	Tertiary (UV)	$7.8x10^{8}$***	North Sea

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

Data from the Environment Agency

Table VII.2 Summary statistics for final effluent testing data

Sewage works	No.	Date of first sample	Date of last sample	Parameter measured	Geometric mean result (cfu/100ml)	Minimum	Maximum
Jaywick STW	3	08/09/2009	08/09/2009	Faecal coliforms (presumptive)	80,928	53,000	100,000
West Mersea STW	64	07/01/2008	11/12/2010	*E. coli*	27	1	9,800

Data from the Environment Agency

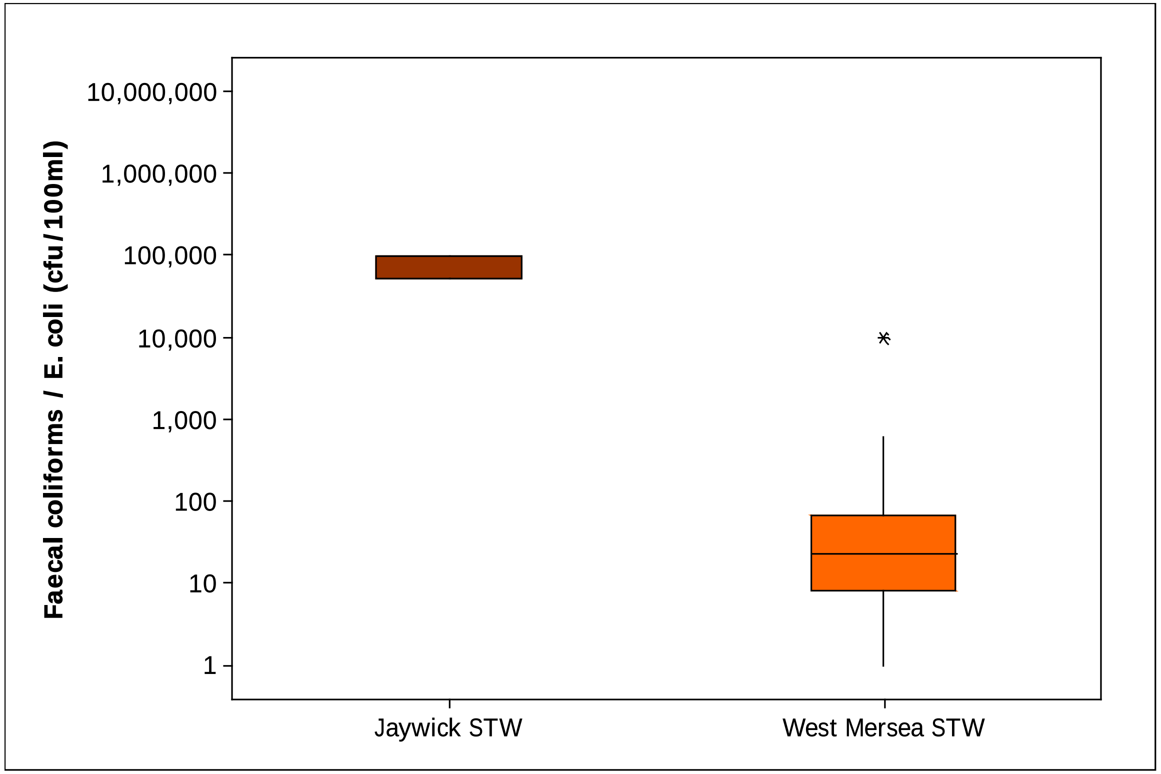


Figure II.2. Boxplot of bacterial concentrations measured in final effluent samples. Those in orange are faecal coliforms (presumptive) and those in brown are* E. coli*.
Data from the Environment Agency

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

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

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

The majority of sewage (~80% in terms of volume) is discharged to the estuary upstream of the shellfishery, or to watercourses which drain to the estuary upstream of the currently classified areas. Although significant bacterial die-off is likely to occur during transit from those discharges higher up in the Colne catchment, higher levels of sewage derived contamination are expected towards the head of the estuary on this basis.

Both Brightlingsea and Colchester STWs were fitted with UV disinfection in March 2013. The bacterial loading they now generate should be two or three orders of magnitude lower than was the case previously, although no final effluent testing data was available at the time of writing to confirm this. It must be noted that UV disinfection is less effective at eliminating viruses than bacteria (e.g. Tree *et al*, 1997). Viral contamination originating from these discharges, which are the principle sewage discharges impacting on the fishery may therefore be more significant than bacterial indicators would suggest.

The discharge from Brightlingsea STW is may generate a small hotspot of contamination in the vicinity of its outfall, which is within some shellfish beds. Satellite images show the drainage channel from this outfall cuts across the intertidal perpendicular to the shore. The St Osyth STW is likely to cause a hotspot of contamination on the eastern shore of the estuary mouth. The UV treated discharge at West Mersea consistently contains very low concentrations of faecal indicator bacteria and is unlikely to be of any significance to the Colne estuary. Jaywick STW provides secondary treatment and has the potential to impact primarily around the estuary mouth, but the extent of this will depend on water circulation patterns.

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

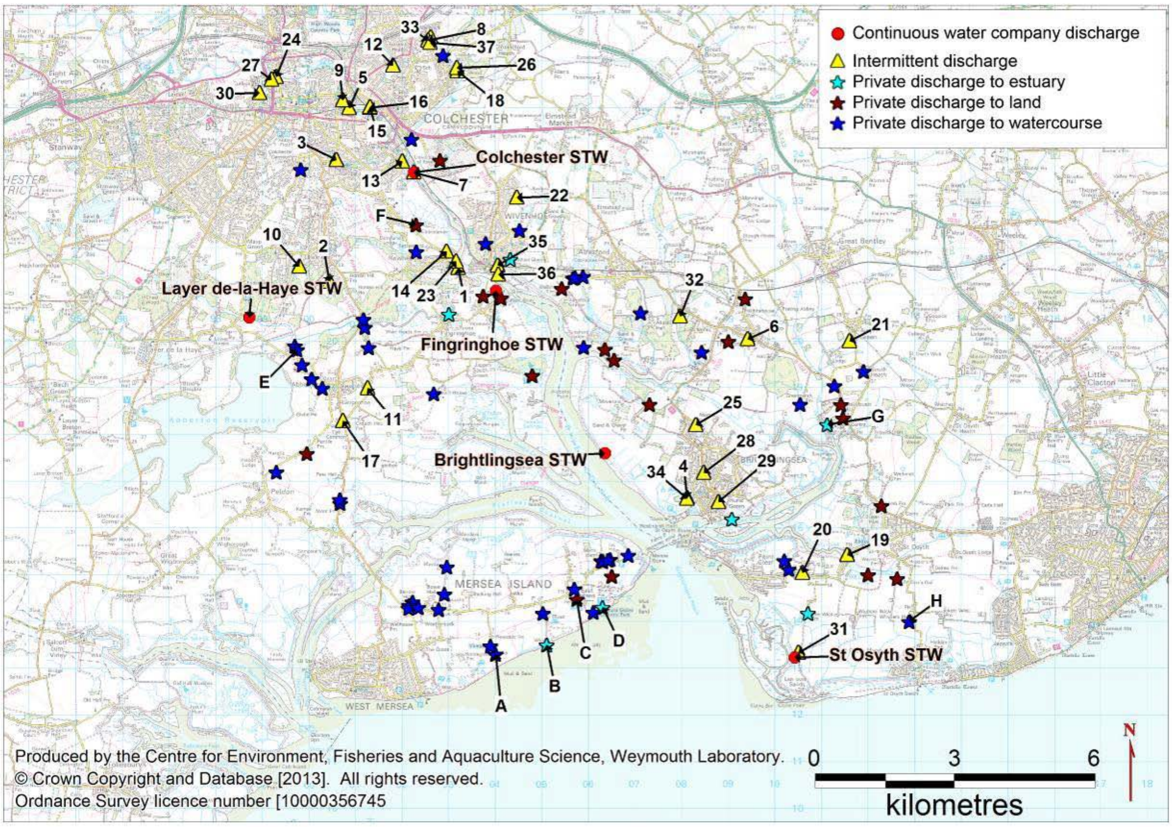


Figure II.3 Intermittent and private discharges within 2km of the Colne estuary

Table II.4. Intermittent discharges within 2km of the Colne estuary

No.	Name	Location	Receiving water	Type
1	Albion Street CSO	TM0320021570	Colne estuary	Storm overflow
2	Blackheath-Holt Drive SPS	TM0044021270	Roman River trib.	Storm overflow
3	Bourne Mill	TM0059023880	Bourne Brook	Pumping station
4	Brightlingsea Overflow	TM0812016640	West Dyke	Storm tank overflow
5	Challenge Way CSO	TM0086024990	Colne estuary	Storm overflow
6	Clacton Road PS	TM0941520044	River Colne trib.	Pumping station
7	Colchester (Haven) STW	TM0225023610	Colne estuary	Storm tank overflow
8	Deben Road PS	TM0255026440	Salary Brook trib.	Pumping station
9	East Mill CSO	TM0073025160	Colne estuary	Storm tank overflow
10	Friday Wood Green SPS	TL9979621598	Roman River trib.	Pumping station
11	Hams Green PS	TM0126018990	River Colne trib.	Pumping station
12	Harwich Road/Hazelton Road	TM0180025900	Porter's Brook	Storm overflow
13	Haven Road	TM0200023850	Colne estuary	Storm overflow
14	High Street PS	TM0295021920	Birch Brook	Storm overflow
15	Hunting Lane CSO	TM0131025010	Colne estuary	Storm overflow
16	Hythe Bridge	TM0130025000	Colne estuary	Storm tank overflow
17	Langenhoe School PS	TM0073018290	Pete Tye Hall Ditch trib.	Pumping station
18	Longridge Par	TM0319025780	Salary Brook	Pumping station
19	No. 2 PS-St Osyth Mill	TM1154515422	St. Osyth Creek	Pumping station
20	Outlet at Point Clear Road	TM1059015040	St. Osyth Creek trib.	Storm tank overflow
21	Plough Road SPS	TM1160020000	Bentley Brook trib.	Storm overflow
22	PS at Broadfields Est.	TM0446123073	River Colne trib.	Pumping station
23	Regent Court CSO	TM0316021710	River Colne	Storm overflow
24	Royal London Middleborough PS	TL9929025660	River Colne trib.	Pumping station
25	Sampson Road SPS	TM0830018200	Brightlingsea Brook trib.	Storm overflow
26	Shearwater Mews CSO	TM0317025850	Salary Brook	Pumping station
27	Sheepen Road	TL9920025600	Sheepen Road Ditch	Storm overflow
28	Spring Road CSO	TM0847017180	West Dyke	Storm tank overflow

29	SSO Lime Street	TM0878816551	Unnamed watercourse	Storm tank overflow
30	St Albans Road CSO	TL9894025310	River Colne trib.	Storm overflow
31	St Osyth STW	TM1050013330	Borrow ditch	Storm tank overflow
32	Thorrington STW	TM0796020530	Ten Penny Brook	Storm tank overflow
33	Welshwood Park Res. Dev.	TM0260926505	Salary Brook trib.	Pumping station
34	West Dyke TPS CSO/EO	TM0811016630	West Dyke	Storm tank overflow
35	Wivenhoe-Phillip Road CSO	TM0405021620	Colne estuary	Storm overflow
36	Wivenhoe-The-Folly Ov.	TM0406021430	Colne estuary	Pumping station
37	Woodlands PS	TM0260026390	Salary Brook trib.	Pumping station

Data from the Environment Agency

The main cluster of intermittent discharges is in the Colchester area, with smaller aggregations at Wivenhoe and Brightlingsea. Most are therefore located up-estuary of the fisheries the spatial pattern of their influences is likely to be broadly similar to that for the water company continuous discharges. Those in the Brightlingsea area discharge in closest proximity to the shellfish beds and so spills from these will have the greatest potential impacts. No spill records from these discharges was available at the time of writing, so it is difficult to assess their significance aside from noting their location and their potential to discharge large volumes of untreated sewage. Such events may occur either under storm conditions when the sewers are inundated with runoff which may happen after intense rainfall events, or in the event of an emergency such as a pump failure or blockage which may occur at any time. Typically, spills are too infrequent for their impacts to be captured reliably under monthly classification sampling.

In addition to the water company owned discharges, there are 74 consented discharges within about 2km of the estuary. Where specified, these are generally treated by either septic tank or small treatment works such as package plants. The vast majority of these are small, serving one or a small number of properties. There are eight discharging direct to the estuary, 19 discharging to soakaway and 47 discharging to various watercourses. Those discharging to watercourses may make a contribution to levels of *E. coli* carried by them but overall impacts from these are anticipated to be minor. It is not anticipated that those draining to soakaway will have a significant contaminating effect on coastal waters. Only eight have consented maximum flows of over 10m^3/day (Table II.5).

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

Ref.	Property served	Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
A	Youth Camp	TM0400013300	Unspecified	27.3	Unnamed watercourse
B	Holiday Park	TM0510013500	Unspecified	114	North Sea via borrow dyke
C	Campsite	TM0575014480	Septic tank	11.5	Groundwaters
D	Caravan Park	TM0630014300	Unspecified	14	North Sea
E	Nursing Home	TL9974019820	Biodisc	18	Roman River trib.
F	Nursing Home	TM0229422495	Package plant	20	Groundwaters
G	Country Park	TM1112118217	Unspecified	50	Thorrington Creek
H	Public House	TM1288014000	Biological filtration	14	Unnamed watercourse

Data from the Environment Agency

Of these larger private discharges, two discharge to soakaway (C and F) so are unlikely to be of significance. The three discharging to water on the south shore of Mersea Island (A, B and D) are likely to result in increased levels of contamination in their immediate vicinity. The Country Park (G) discharges to the head of Brightlingsea Creek, and is likely to have some influence on levels of contamination here.

APPENDIX III
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: AGRICULTURE

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

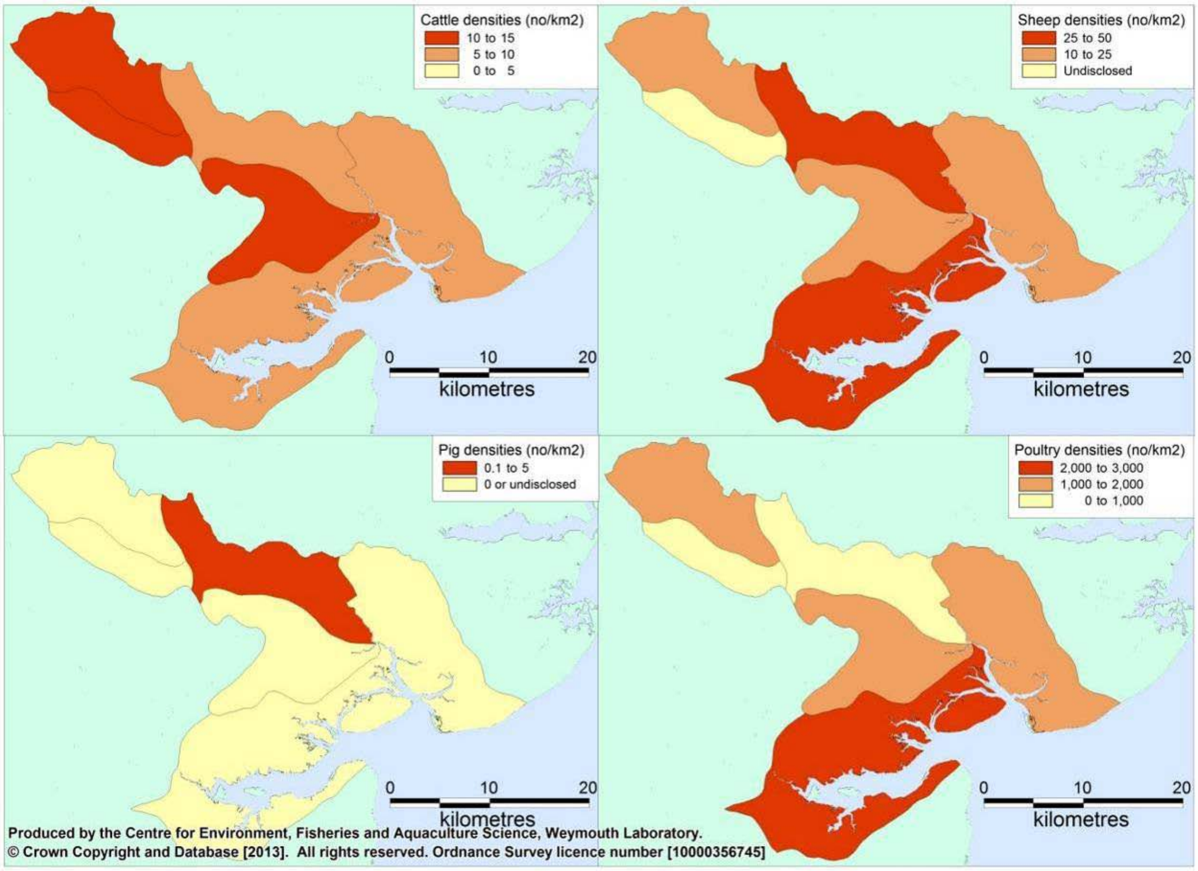


Figure VIII.1. Livestock densities within the Colne catchment.

Table VIII.1 Summary statistics from 2010 livestock census

	Numbers				Density (animals/km^2)			
Catchment name	Cattle	Sheep	Pigs	Poultry	Cattle	Sheep	Pigs	Poultry
Blackwater Estuary[1]	1,282	5,970	**	470,807	5.8	27.0	**	2,132
Bourne Brook	604	**	0	193	12.8	**	0.0	4
Colne (Lower)	1,037	5,380	373	88,712	9.0	46.6	3.2	768
Colne (Upper)	1,405	1,989	**	130,699	13.4	18.9	**	1,243
Roman River	1,185	2,368	**	124,758	10.6	21.1	**	1,113
TOTAL	6592	>17,793	>373	995,568	8.8	>23.6	>0.5	1321

[1] Not all of this catchment drains directly into the Colne estuary
**Data suppressed to prevent disclosure of information about individual holdings

The concentration of faecal coliforms excreted in the faeces of animal and human and corresponding loads per day are summarised in Table VIII.2.

Table VIII.2 Levels of faecal coliforms and corresponding loads excreted in the faeces of warm-blooded animals.

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

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

There are relatively low numbers and densities of grazing animals (cattle and sheep) within the area, which deposit faeces directly on pastures. Their impacts are likely to be relatively minor overall, although they may be of local significance for example where there is an area of grazing marsh immediately adjacent to a shellfishery. As well as direct deposition by livestock, slurry is also collected from livestock sheds when cattle are housed indoors and subsequently applied to fields as fertilizer. Large numbers of poultry and a few pigs are also raised within the catchment. Manure from pig and poultry operations is typically collected, stored and spread on nearby farm land (Defra, 2009). Sewage sludge may also be used as fertilizer, but no information on local practices was available at the time of writing.

The primary mechanism for mobilisation of faecal matter deposited or spread on farmland to coastal waters is via land runoff, so fluxes of livestock related contamination into the estuary will be highly rainfall dependent. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the ‘first flush’). Most of the major watercourse will be impacted to some extent by agriculture, but the smaller watercourses draining areas of pasture marsh adjacent to the estuary may be of most impact on the shellfisheries. No direct observations of grazing livestock were made during the shoreline survey, but this was undertaken from a boat which restricted the ability to view adjacent land over the sea defences.

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

APPENDIX IV
SOURCES AND VARIATION AND MICROBIOLOGICAL POLLUTION: BOATS

The discharge of sewage from boats is potentially a significant source of bacterial contamination of shellfisheries within the Colne estuary. There is significant boat traffic within the estuary, it hosts two commercial quays, a small fishing fleet and is used by pleasure craft. Figure IX.1 presents an overview of boating activity derived from the shoreline survey, satellite images and various internet sources.

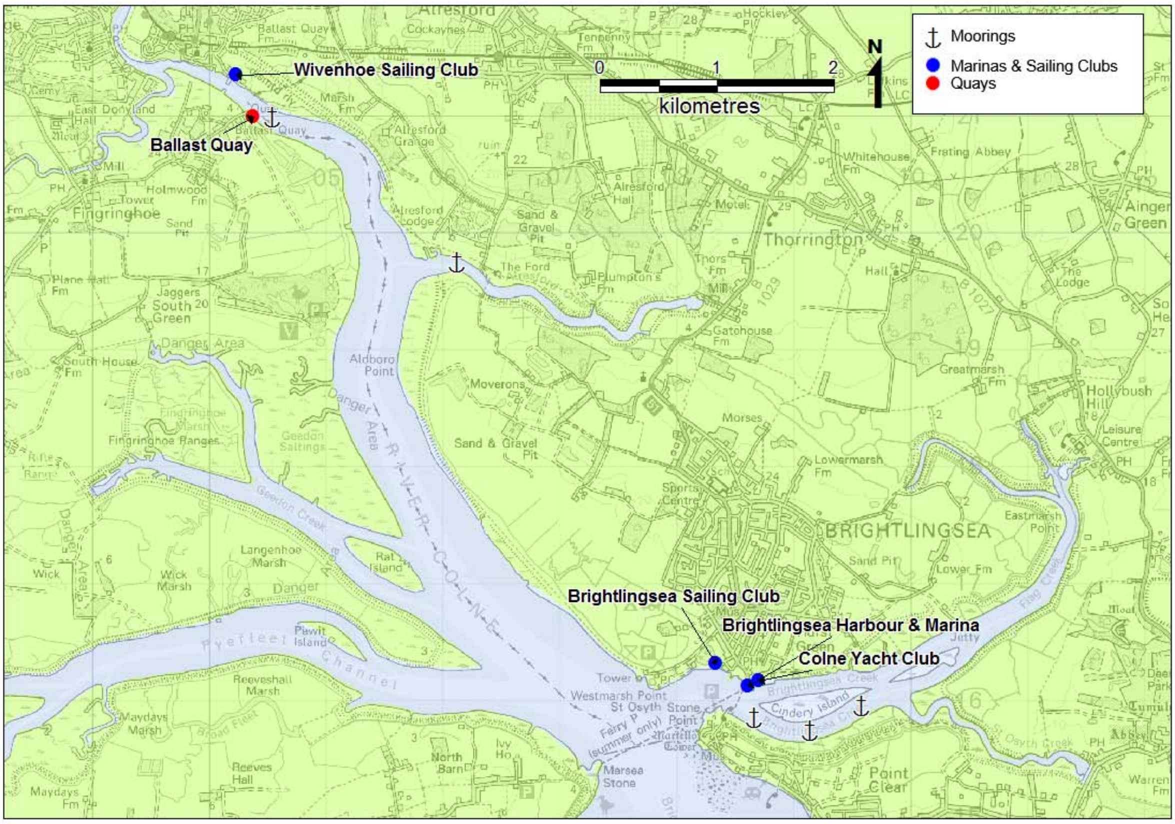


Figure IX.1 Location of mooring areas and sailing clubs in the Colne Estuary

Since the closure of Colchester Port in 2000 there has been a significant decline in commercial traffic, however there are still commercial movement's within the Colne. Ballast Quay situated just south of Wivenhoe tidal barrier, a working aggregates industry imports sand and gravel to London on large barges. Seven barges work between the Colne, Thames and Medway rivers (JJ Priors, 2012). Two ships, approximately 90m in length manoeuvre in the lower region of the Colne and offload roadstone, at Olivers wharf in Brightlingsea Harbour. Wheelers Export Ltd also operate from this wharf exporting scrap metal and wood chippings Maintenance vessels for Gunfleets Sands wind farm located 7km offshore from Clacton regularly use Brightlingsea as a land base and fuelling station, this has lead to annual dredging of the channel into the harbour.

Recreational watersports activities are popular within the waters of the Colne estuary. Several sailing club and watersports centres operate from the Colne offering a variety of dinghy sailing, powerboat courses, windsurfing and kitesurfing courses. However, these recreational boats are not large enough to contain onboard toilet facilities and therefore are very unlikely to make any discharges. This is also true of the Brightlingsea Ferry which transports people between Brightlingsea, Point Clear, West Mersea and Colchester.

Brightlingsea Harbour can hold up to 500 boats on a combination of dry and wet moorings and pontoon moorings, for boats varying in length from about 14 to 40 feet and located within Brightlingsea Creek (Mackintosh, 2012). Sewage pumpout facilities are available at Brightlingsea (Reeds, 2011). In addition to this there are a few wet and drying moorings located close to the tidal barrier just offshore from Wivenhoe sailing club. Increased boating traffic within the summer months is from visiting yachtsmen and boats that giving wildlife and history tours. On the shoreline survey, east of Brightlingsea harbour one houseboat was recorded.

A small fleet of commercial fishing boats, under 10 metres in length, and three charter fishing boats operate from the Colne estuary (Charter Boats UK, 2012), they catch a variety of fish and shellfish, including sea bass, mackerel and oysters.

Merchant shipping vessels are not permitted to make overboard discharges within three nautical miles of land[1] so vessels associated with the commercial ports should have no impact. Small 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 pontoon berths not connected to the shore may be more likely to make overboard discharges. It is also likely that overboard discharges are made by vessels on passage from time to time. Occupied yachts within the marina may be less likely to make overboard discharges as this is somewhat antisocial in the crowded marina setting, and on land facilities are more easily accessible. Peak pleasure craft activity is anticipated during the summer and it is probable that more moorings will be occupied at this time so associated impacts are likely to follow this seasonal pattern.

The areas that are at highest risk from microbiological pollution are the main navigation routes in the deeper waters, and amongst moorings, most of which are in Brightlingsea Creek. Peak pleasure craft activity is anticipated during the summer, 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 V
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: WILDLIFE

The Colne estuary contains a variety of different habitats; mudflats and salt marsh cover the majority of the estuary at low tide and smaller areas of sea grass and sandy shingle shores. A large proportion of the estuary is protected by national and international conservation designations including: SSSI, Ramsar site, SPA, SAC and NNR. These encompass all or some of the following habitats: the intertidal mudflats, salt marsh, Abberton freshwater reservoir, freshwater marshes and tidal channels. It is of particular importance as a site for overwintering waders and wildfowl, which are the main wildlife aggregation of potential significance to shellfish hygiene.

Studies in the UK have found significant concentrations of microbiological contaminants (thermophilic campylobacters, salmonellae, faecal coliforms and faecal streptococci) from intertidal sediment samples supporting large communities of birds (Obiri-Danso and Jones, 2000). Over the five winters up until 2010 an average total count of 22,652 overwintering and wildfowl were recorded (Holt *et al*, 2011) within the Colne, including the following species Dark-bellied Brent Goose and Black Tailed-Godwit. Waders forage for food (and defecate) on the intertidal mudflats, across a wide area and therefore potentially, directly onto shellfish beds. Contamination via direct deposition may be quite patchy, with some shellfish containing quite high levels of *E. coli* with others a short distance away unaffected. Due to the diffuse and spatially unpredictable nature of contamination from wading birds it is difficult to select specific RMP locations to best capture this, although they may well be a significant contributor to the levels of *E. coli* found within shellfish during the winter months.

Small numbers of waders will remain in the area to breed in the summer, but the majority migrate elsewhere to breed. Breeding seabirds (gulls, terns etc) were subject to a survey in the early summer of 2000 (Mitchell *et al*, 2004). The vast majority of birds recorded were black headed gulls using Rat Island in Geedon Creek as a breeding site (2,300 pairs). Twenty pairs of terns were also recorded at Colne Point during this survey. Seabirds are likely to forage widely throughout the area, therefore faecal inputs could be considered as diffuse. It is expected to be most marked in the immediate vicinity of the gull breeding colony at Rat Island, both in the form of an increased concentration of droppings on the adjacent intertidal or via runoff from this island.

There is a population of about 100 harbour seals within the Essex estuaries, and they have been sighted within the Colne estuary (Marine Management Organisation, 2011). One was seen near Mersea Stone during the shoreline survey. Given the large area they are likely to forage over and their relatively small numbers, impacts are likely to be minor, and unpredictable in spatial terms.

A small number of otters have been recorded in the upper reaches of the Colne tributaries, however exact numbers are not known (Tansley, 2009). Otters generally tend to favour the more secluded areas with access to watercourses. However, given their likely wide distribution and small numbers they have no material bearing on the sampling plan.

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

APPENDIX VI
METEOROLOGICAL DATA: RAINFALL

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

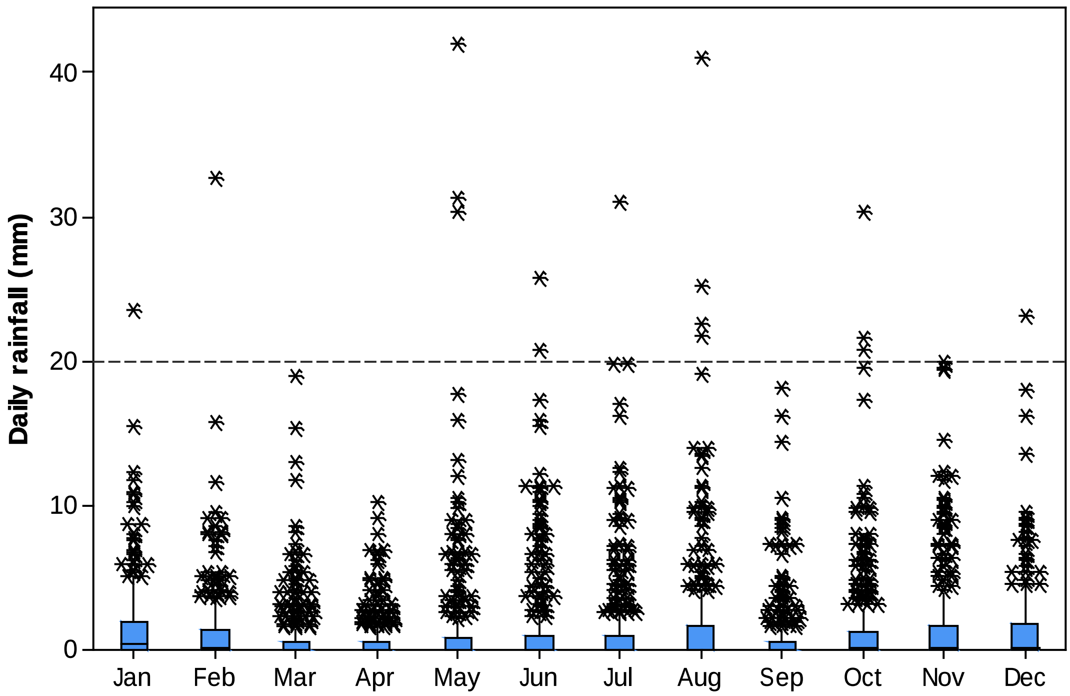


Figure 1 Boxplot of daily rainfall totals at Mersea, January 2003 to August 2012.
Data from the Environment Agency

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

Rainfall may lead to the discharge of raw or partially treated sewage from combined sewer overflows (CSO) and other intermittent discharges as well as runoff from faecally contaminated land (Younger *et al.*, 2003). Representative monitoring points located in parts of shellfish beds closest to rainfall dependent discharges and freshwater inputs will reflect the combined effect of rainfall on the contribution of individual pollution sources. Relationships between levels of *E. coli* and faecal coliforms in shellfish and water samples and recent rainfall are investigated in detail in Appendices XI and XII.

APPENDIX VII
METEOROLOGICAL DATA: WIND

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

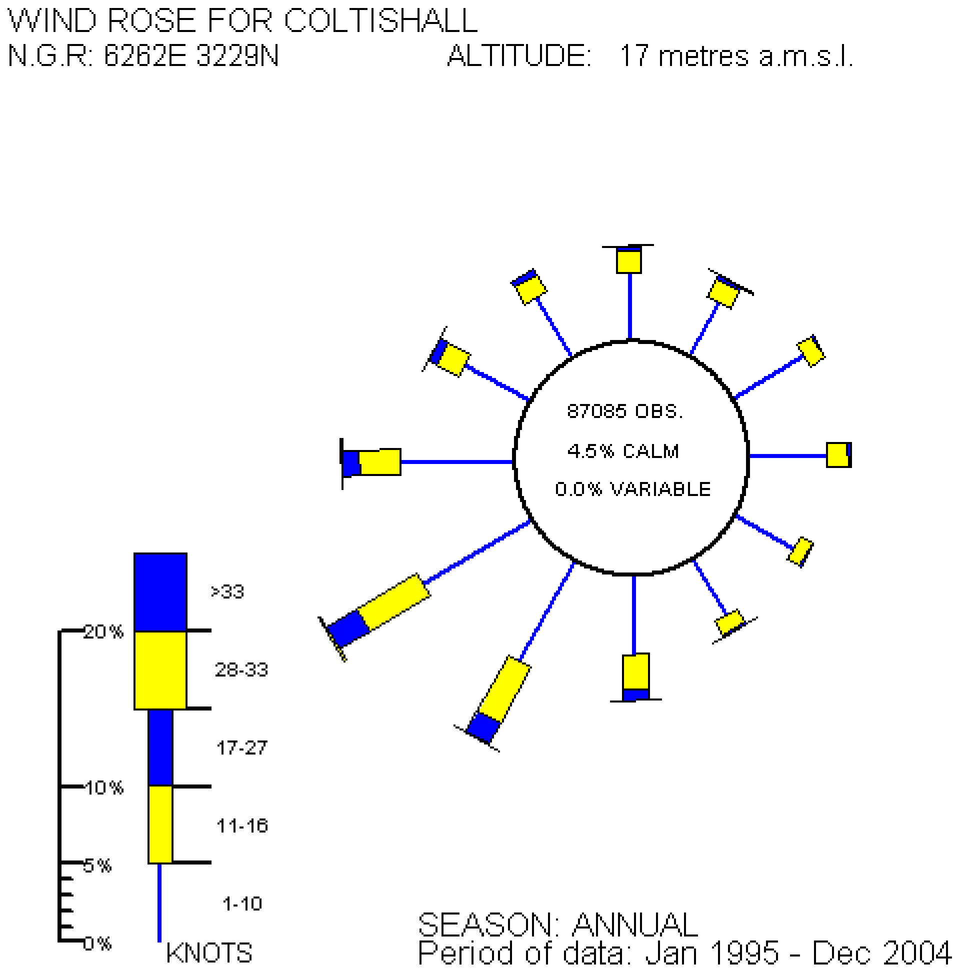


Figure VII.1 Wind rose for Coltishall

Produced by the Meteorological Office. Contains public sector information licensed under the Open Government Licence v1.0

The wind rose for Coltishall, typical of open, level locations across the region. There is a prevailing south-westerly wind direction throughout the year. During spring there is also a high frequency north-easterly wind's due to a build up of high pressure over Scandinavia (Met Office, 2012). Periods of very light or calm winds are more prevalent inland, with coastal areas having similar wind directions to inland locations but higher wind speeds. The Colne estuary has a north west to south east orientation and is surrounded by land between approximately 10-40m above sea level, consequently it is relatively sheltered from the prevailing winds and from the winds from the north east in the spring months.

APPENDIX VIII
HYDROMETRIC DATA: FRESHWATER INPUTS

The catchment area draining into the Colne estuary is around 596 km^2 and is illustrated in Figure VIII.1. The main freshwater input to the Colne estuary is the River Colne whose catchment occupies approximately 55% of the catchment. In addition to the River Colne some smaller watercourses also drain into the Colne estuary at various locations. Rivers in this catchment flow through both rural and urban areas, with most of the rural areas being used for arable crop production. The majority of the catchment overlays low permeability bedrocks such as London clay, and only the northern most reaches of the catchment overlie highly permeable chalk bedrock. The low permeability of much of the catchment's bedrock means that there are relatively high rainfall runoff rates (Environment Agency, 2009b).

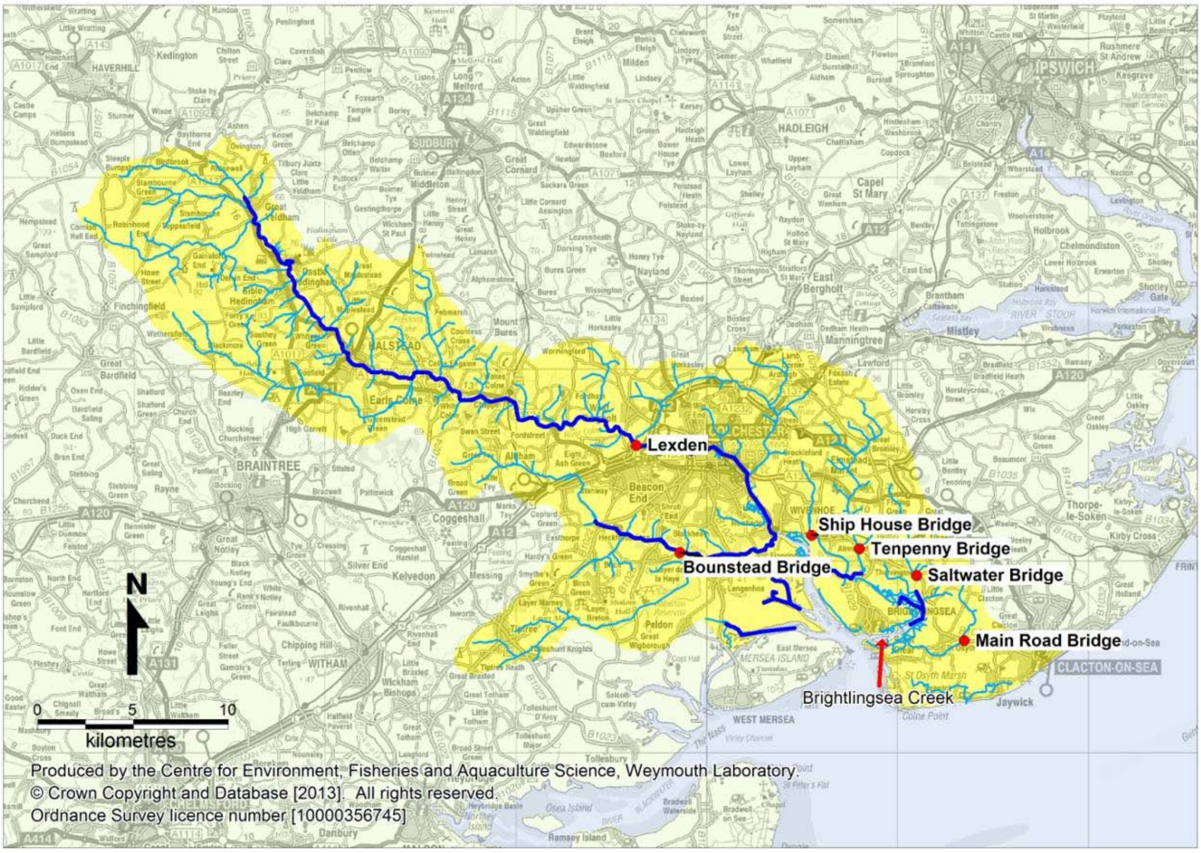


Figure VIII.1: Watercourses within the survey catchment area

These rivers will receive microbiological pollution from multiple point and diffuse sources such as sewage discharges and urban and agricultural runoff. They are therefore potentially a significant source of microbiological contamination for the shellfisheries in the estuary. About 75% of the whole catchment drains through watercourses discharging to the estuary upstream of the flood barrier at Wivenhoe. It is likely that there will be a gradient of increasing runoff related contamination towards the up-estuary ends of shellfish beds within the main channel. Brightlingsea creek receives two significant freshwater inputs (Bentley Brook and St Osyth Brook). They are of similar sizes, and one discharges to the head of Brightlingsea Creek, and the other discharges to the south shore via St. Osyth Creek in the middle of the area requiring classification. St Osyth Brook passes through the Mill Dam Lake immediately before it discharges to St Osyth Creek. This will likely reduce the variability in flow rates and offer some opportunity for bacterial die-off during retention. Alresford Creek also receives two significant freshwater inputs (Sixpenny Brook and Tenpenny Brook) but there is little in the way of freshwater inputs direct to the Pyefleet Channel, Geedon Creek or Ray Creek. Summary statistics for flow gauges on the larger watercourses are presented in Table VIII.1. Water is abstracted from R. Colne throughout much of the year for public water supply. The abstraction point is below the gauging station so the gauged flows do not accurately reflect the freshwater entering the estuary.

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

Watercourse	Station name	Catchment area (km^2)	Mean annual rainfall 1961-90 (mm)	Mean flow (m^3s^{-1})	Q95[1] (m^3s^{-1})	Q10[2] (m^3s^{-1})
Bentley Brook	Saltwater Bridge	12.1	550	0.034	0.003	0.076
Colne	Lexden	238.2	566	1.065	0.202	2.197
Roman	Bounstead Bridge	52.6	560	0.340	0.066	0.641
Sixpenny Brook	Ship House Bridge	5.1	554	0.025	0.003	0.059
St Osyth Brook	Main Road Bridge	8.0	544	0.032	0.000	0.085
Tenpenny Brook	Tenpenny Bridge	29.0	556	0.085	0.011	0.212

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

A boxplot of mean daily flow record by month at the Lexden gauging station (above the abstraction point) is presented in Figure VIII.2.

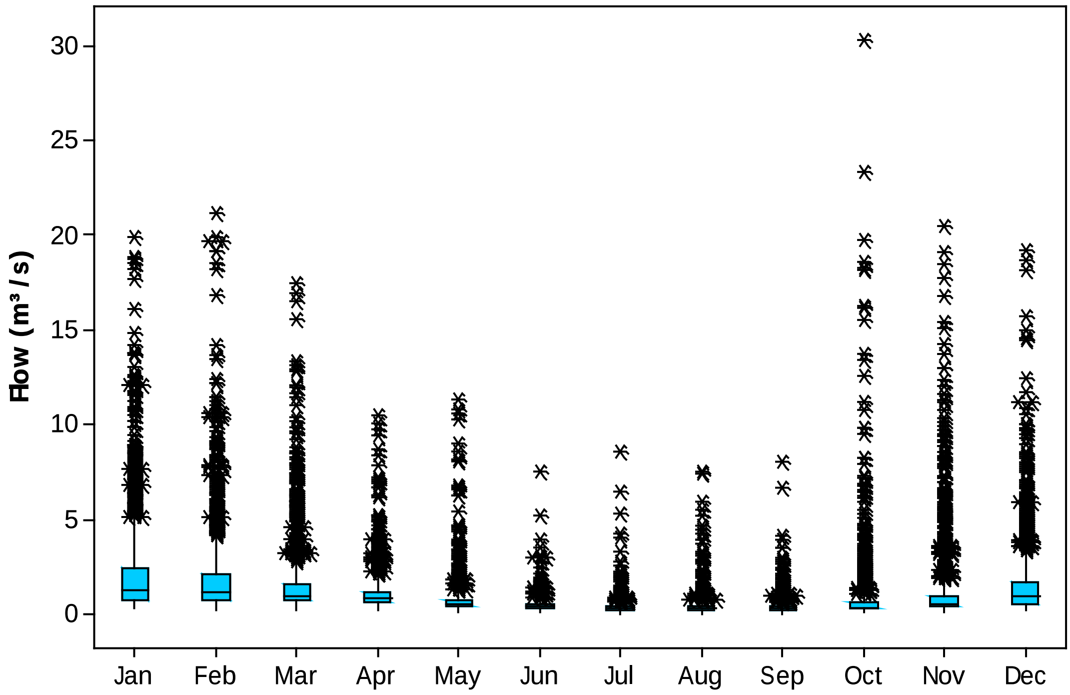


Figure VIII.2: Boxplots of mean daily flow records from the Lexden gauging station on the River Colne from 1959-2010

Flows were highest in the colder months and flows of greater than 10 m^3/s only occurred between October and May. The seasonal pattern of flows is not entirely dependent on rainfall as during the colder months there is less evaporation and transpiration, leading to a higher water table. This in turn leads to a greater level of runoff immediately after rainfall. Increased levels of runoff are likely to result in an increase in the amount of microorganisms carried into coastal waters. Additionally, higher runoff will decrease residence time in rivers, allowing contamination from more distant sources to have an increased impact during high flow events.

APPENDIX IX
HYDROGRAPHY

BATHYMETRY

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

Figure IX.1 Bathymetry chart of the Colne Estuary

The Colne estuary is a south facing, funnel shaped, double spit enclosed estuary (Futurecoast, 2002). The estuary is predominantly intertidal (90%) with extensive mudflats fringed with saltmarsh in places, the majority of which dries completely at low water (Futurecoast, 2002). Consequently a large proportion of water will be exchanged on each tide, but the dilution potential will be quite low away from the main channels.

It is a complex branching estuary approximately 7km in length from its tidal limit at Colchester to its mouth (Futurecoast, 2002). The main River Colne channel has a northwest to southeast orientation with slight meanders. It becomes progressively shallower and narrower towards its head. Land surrounding the Colne is low lying and prone to flooding, consequently sea walls protect the majority of the perimeter. A tidal barrier situated at Wivenhoe prevents flooding to Colchester, as tidal and storm surges are common within the Colne. Annual dredging occurs within Brightlingsea Creek and in the main navigational channels of the Colne. In the past considerable reclamation of salt marshes has taken place within the Colne estuary and there is pressure for more reclamation in the future (Futurecoast, 2002) potentially altering the bathymetry.

There are four major side arms off the main channel between its mouth and the flood barrier at Wivenhoe, three of which contain commercially exploitable shellfish. Brightlingsea Creek extends in an easterly direction just inside the estuary mouth and splits into two channels around two saltmarsh islands. The two channels merge again in its upper reaches, which are flanked with intertidal mudflats and saltmarsh. St Osyth Creek, a smaller creek joins the south channel of Brightlingsea Creek between the two saltmarsh islands.

Pyefleet channel originates north of Mersea Island and extends in a westerly direction. It splits into two separate channels in its upper reaches, which are flanked by saltmarsh. The southern channel has a tidal causeway at its head, on the other side of which lies the head of the Strood Channel. At high water on spring tides the causeway is submerged, so there is some very limited water exchange between the two at these times.

Geedon Creek also extends in a westerly direction from the main channel, just up-estuary from the Pyefleet channel. It splits into two channels around Rat Island and then the channels rejoin, this channel splits once again into two separate saltmarsh fringed channels at its head.

Alresford Creek extends in an easterly direction from the main channel about 4km up-estuary from Brightlingsea Creek. It is narrower and shallower than the creeks further down-estuary, and does not contain any significant shellfish resources.

Seawards of the mouth, is Point Clear Bay, which consists of intertidal mudflats which gently slope gradient west into the subtidal region and into the Colne deepwater channel. Ray Creek is a subtidal channel that meanders through Point Clear Bay in a south easterly direction and is then surrounded by an extensive area of saltmarsh at its head.

WATER CIRCULATION PATTERNS

Currents in coastal waters are predominantly driven by a combination of tide, wind and density effects. Tidal amplitude is large (Table IX.1) and will drive extensive water movements throughout the area.

Table IX.1 Tide levels and ranges within the Colne estuary

	Height (m) above Chart Datum				Range (m)	
Port	MHWS	MHWN	MLWN	MLWS	Springs	Neaps
Brightlingsea	5.0	3.8	1.2	0.4	4.6	2.6
Olivers Wharf	4.2	3.1	-	-	-	-
Rowhedge & Wivenhoe Wharfs	4.2	3.1	-	-	-	-
Colchester	4.2	3.1	river water only at low water			

Data from the Proudman Oceanographic Laboratory

The flood tide will convey relatively clean water originating from the open North Sea into the estuary and up the creeks, whereas the ebb tide will carry contamination from shoreline sources back out to sea. Offshore tidal streams flood down the Essex coast towards the Thames Estuary in a south westerly direction, and reverse on the ebb. The indentation to the coast at the Colne and Blackwater estuaries cause the flood streams to be diverted in a north-westerly direction into the Colne estuary. There is one tidal diamond within the area shown in Figure IX.1. Tidal stream information from this tidal diamond is shown in Table IX.2.

Table IX.2. Tidal stream information from Colne estuary mouth.

	B (51° 47.9'N 1° 00.7'E) Colne estuary mouth		
	Direction (°)	Spring rate (m/s)	Neap rate (m/s)
HW-6		0.00	0.00
HW-5	0	0.21	0.15
HW-4	12	0.41	0.26
HW-3	10	0.46	0.31
HW-2	2	0.57	0.36
HW-1	358	0.46	0.31
HW	353	0.31	0.21
HW+1	180	0.26	0.15
HW+2	183	0.62	0.41
HW+3	190	0.67	0.41
HW+4	187	0.51	0.36
HW+5	180	0.21	0.15
HW+6	180	0.10	0.05

The tidal diamond confirms that the tidal stream follows the channel into and up the estuary, with the reverse occurring on the ebb. Peak current speeds in the estuary mouth are almost 0.7m/s on spring tides. Neap current speeds are about 65% of that experienced on springs. Based on this tidal diamond, an estimate of tidal excursion (the distance a suspended particle will travel during the course of a flood or an ebb tide) is about 8.5km on spring tides and about 5.5km on neap tides.

Within the side arms there will also be a bi-directional pattern of tidal circulation, with water travelling up on the flood and back down on the ebb. Shoreline sources of contamination will therefore primarily impact up and downstream of their locations along the bank to which they discharge. The two parallel channels present in the lower reaches of Brightlingsea Creek and Geedon Creek will further constrain the impacts of shoreline sources to the banks to which they discharge.

Freshwater inputs may significantly modify the circulation of water around estuaries via density effects. The Colne estuary has a low flow ratio, indicating that freshwater inputs are very low in relation to tidal exchange in the estuary as a whole (Futurecoast, 2012). This suggests it should be well mixed and that density driven circulation is unimportant. Salinity measurements taken at two sites in the outer estuary are presented in Figure IX.2, and sampling locations are shown in Figure IX.1.

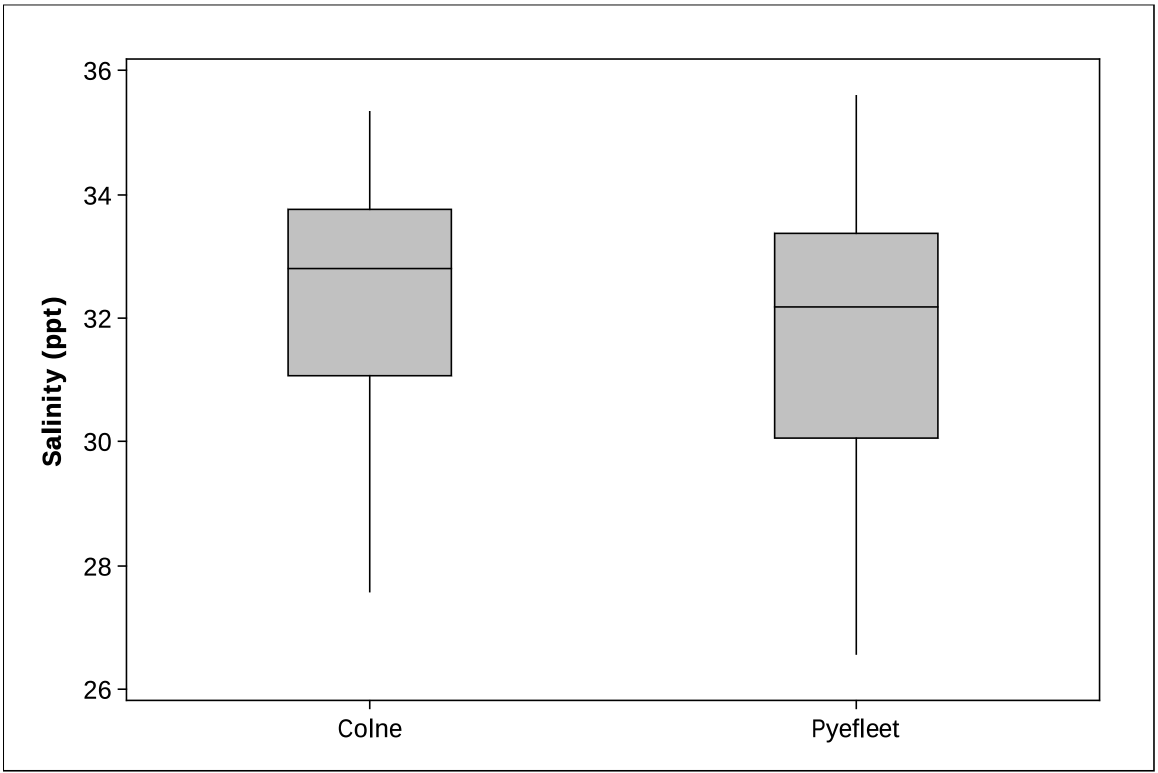


Figure IX.2. Boxplot of salinity measurements taken under the Shellfish Waters monitoring programme. *Data from the Environment Agency*

These salinity measurements confirm that salinity is approaching that of full strength seawater (35ppt) at both these locations for most of the time, although occasionally salinities under 30ppt were recorded. Slightly more variation in salinity is apparent within the Pyefleet Channel. Both these locations are within the outer reaches of the estuary. Given the decreasing depth and width in the upper reaches of the estuary, and the location of the main freshwater input at its head, salinity is expected to decrease on average and become more variable towards the upper reaches. Salinity measurements taken by Dong *et al* (2000) indicate variable and low salinity at Colchester STW (2-17ppt), variable but higher salinities where Alresford Creek joins the main channel (20-32ppt) and more stable higher salinities at the mouth of Geedon Creek and in Point Clear Bay (28-34ppt). It is therefore possible that there are some density driven effects in the upper reaches of the estuary. Any stratification will result in a shear in currents down the water column, with a net seaward flow in the upper layers and a net landward flow at depth. Perhaps more important in terms of contamination of shellfish, stratification will tend to entrain freshwater borne contamination in the surface layers meaning stocks at lower elevations may be more separated from such contamination. Any such effects however will be limited to the upper reaches of the estuary, upstream of the fisheries.

Salinity within the mid and upper reaches of the estuary will fluctuate significantly with tidal state as well as river discharge. Much smaller corresponding fluctuations may be felt in the outer reaches of the estuary. Decreasing salinity is likely to be associated with higher levels of faecal indicator organisms from land runoff. There are significant freshwater inputs to the head of Brightlingsea Creek and Alresford Creek so a similar gradient of decreasing salinity and increasing contamination is likely to be present within these water bodies. The creeks on the west side of the estuary (Pyefleet Channel and Geedon Creek) receive relatively little in the way of land runoff.

Tidally driven currents may also be modified by the effects of wind. Strong winds will typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s. These currents in turn create return currents, which may travel at depth or along sheltered margins. Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great range of scenarios may arise. The estuary is not particularly exposed to the prevailing south westerly winds, apart from the very outer reaches between the estuary mouth and the fishery buoy. Winds from a south easterly direction will tend to push surface water up the estuary. As well as driving surface currents, onshore winds will create wave action. Waves may resuspend any contamination held within the sediments of the intertidal zone, temporarily increasing levels of contamination within the water column until it is carried away by the tides. Energetic wave action will arise in Point Clear Bay when there are strong winds from the prevailing south-west quadrant. Significant wave action is not generally anticipated within the estuary and associated side arms as they are enclosed and more sheltered.

APPENDIX X
MICROBIOLOGICAL DATA: SEAWATER

BATHING WATERS

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

Figure X.1 Location of bathing and shellfish waters monitoring points in the Colne estuary.

Twenty water samples were taken from the bathing waters site during each bathing season, which runs from the 15th May to the 30th September. Faecal coliforms (confirmed) were enumerated in all these samples. Summary statistics of all results from 2003 to 2011 by bathing water are presented in Table X.1. Figure X.2 presents box plots of all results from the Brightlingsea bathing water site by year from 2003 to 2011.

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

N	Geo-mean	Min.	Max.	% exceeding 100 cfu/100ml	% exceeding 1000 cfu/100ml
180	10.2	<2	1760	6.7	0.6

Data from the Environment Agency

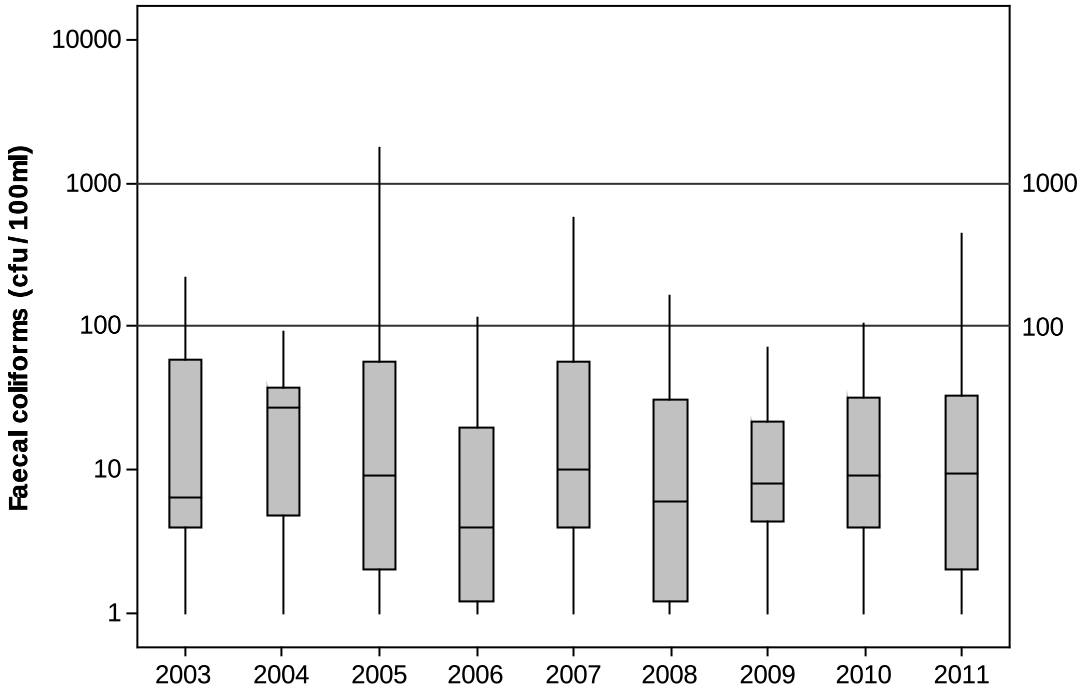


Figure X.2 Box-and-whisker plots of all faecal coliforms results by year
Data from the Environment Agency

Levels of faecal coliforms at the bathing waters site were generally low, averaging 10.2 cfu/100ml. Comparisons of the results found no significant difference by year (One-way ANOVA, p=0.656). This indicates that the level of faecal coliforms found in these bathing waters has been stable in recent years.

To investigate the effects of tidal state on faecal coliform results, circular-linear correlations were carried out against both the high/low and spring/neap tidal cycles for the Brightlingsea bathing waters sampling points. No correlations were found between either tidal cycle and levels of faecal coliforms here (circular-linear correlation, r=0.130 or less, p=0.051 or greater).

To investigate the effects of rainfall on levels of contamination at the Brightlingsea bathing waters site, Spearman's rank correlations were carried out between rainfall recorded at the Mersea weather station (Appendix II for details) over various periods running up to sample collection and faecal coliforms results. These are presented in Table X.3 and statistically significant correlations (p<0.05) are highlighted in yellow.

Table X.3 Spearman's Rank correlation coefficients for faecal coliforms results against recent rainfall

	n	180
24 hour periods prior to sampling	1 day	0.133
	2 days	0.234
	3 days	0.260
	4 days	0.201
	5 days	0.100
	6 days	0.017
	7 days	0.034
Total prior to sampling over	2 days	0.212
	3 days	0.298
	4 days	0.324
	5 days	0.295
	6 days	0.277
	7 days	0.308

Data from the Environment Agency

Table X.3 shows that rainfall is associated with a significant elevation in faecal coliform levels at Brightlingsea from two days to four days after a rainfall event.

SHELLFISH WATERS

Figure X.1 shows the location of the Colne shellfish water monitoring points, designated under Directive 2006/113/EC (European Communities, 2006). Table X.4 presents summary statistics for bacteriological monitoring results from these points. Only water sampling results are presented as flesh results from the shellfish hygiene monitoring programme are used to assess compliance with bacteriological standards in shellfish flesh.

Table X.4 Summary statistics for shellfish waters faecal coliforms results (cfu/100ml), 2003-2012.

Site	No.	Geometric mean	Minimum	Maximum	% exceeding 100 cfu/100ml	% exceeding 1000 cfu/100ml
Colne	71	6.9	<2	955	7.0	0.0
Pyefleet	55	9.1	<2	982	10.9	0.0

Data from the Environment Agency

Levels of faecal coliforms were low at both these sites. Comparisons between the two showed that there were no significant differences in faecal coliform levels between sites (T-test, p=0.343).

Figure X.3 indicates that there is some seasonality in levels of contamination in the Colne, with highest results in the winter. Statistically significant differences were found between seasons at both sites (One-way ANOVA, p<0.001 in both cases). Post ANOVA tests (Tukey) showed that at both sites winter levels of faecal coliforms were significantly greater than the other seasons. However at the Pyefleet site, summer faecal coliform levels were also significantly lower than in the autumn.

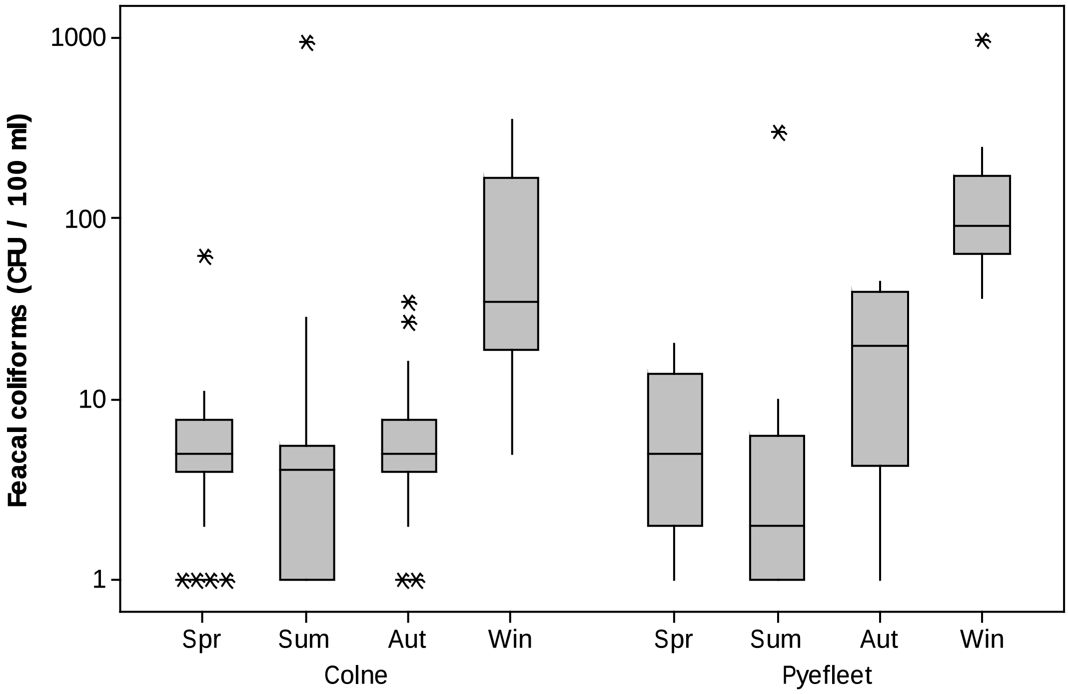


Figure X.3 Boxplot of shellfish growing waters faecal coliforms results by season
Data from the Environment Agency

No significant correlations were found between faecal coliform levels and either the high/low or spring/neap tidal cycles at either of these sites.

To investigate the effects of rainfall on levels of contamination at the bathing waters sites Spearman's rank correlations were carried out between rainfall recorded at the Mersea weather station over various periods running up to sample collection and faecal coliforms results. These are presented in Table X.5 and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table X.5 Spearmans Rank correlation coefficients for faecal coliform results against recent rainfall

		Colne	Pyefleet
	n	**71**	**55**
24 hour periods prior to sampling	1 day	0.145	0.251
	2 days	0.304	0.110
	3 days	0.319	0.267
	4 days	0.364	0.209
	5 days	0.214	0.209
	6 days	0.310	0.195
	7 days	0.252	0.293
Total prior to sampling over	2 days	0.303	0.283
	3 days	0.383	0.320
	4 days	0.409	0.285
	5 days	0.430	0.253
	6 days	0.464	0.248
	7 days	0.444	0.256

Data from the Environment Agency

Both sites did show some influence of recent rainfall, but this was much stronger at the Colne than at Pyefleet.

Salinity was recorded on most sampling occasions. Figure X.4 presents scatterplots of faecal coliforms against salinity for the two sites.

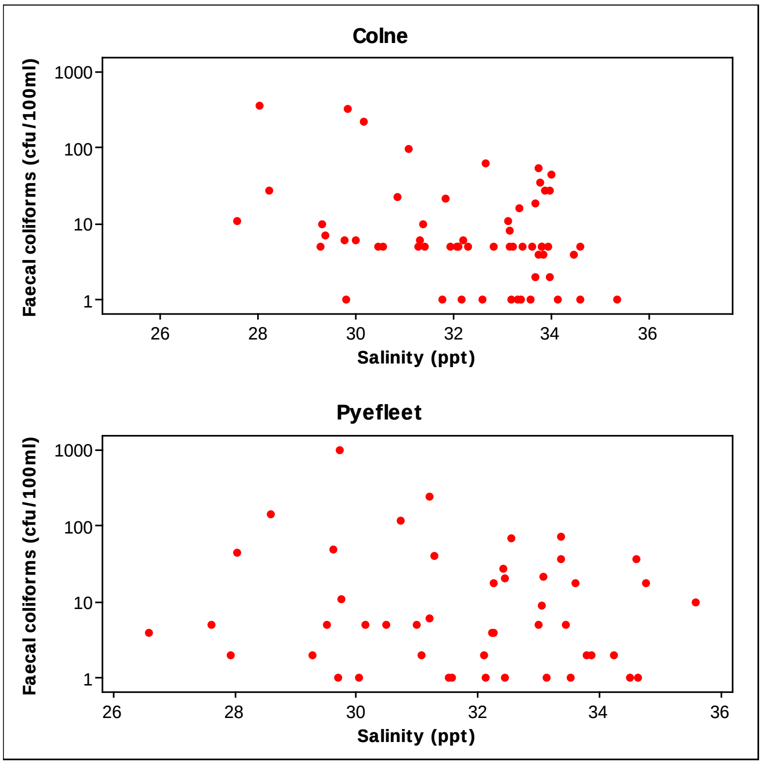


Figure X.4. Scatterplots of faecal coliforms against salinities at the shellfish waters monitoring points. *Data from the Environment Agency.*

A significant negative correlation between salinity and levels of faecal coliforms was found at Colne (Pearsons correlation, r=-0.352, p=0.006) but not at Pyefleet (Pearsons correlation, r=-0.121, p=0.414).

APPENDIX XI
MICROBIOLOGICAL DATA: SHELLFISH FLESH

SUMMARY STATISTICS AND GEOGRAPHICAL VARIATION

The geometric mean results of shellfish flesh monitoring from all RMPs sampled from 2003 onwards are presented in Figure XI.1 to Figure XI.5. Summary statistics are presented in Table XI.1 and boxplots for sites sampled on 10 or more occasions are shown in Figure XI.6 to Figure XI.8.

Figure XI.1: Hard clam RMPs active since 2003

Figure XI.2: Cockle RMPs active since 2003

Figure XI.3: Mussel RMPs active since 2003

Figure XI.4: Native oyster RMPs active since 2003

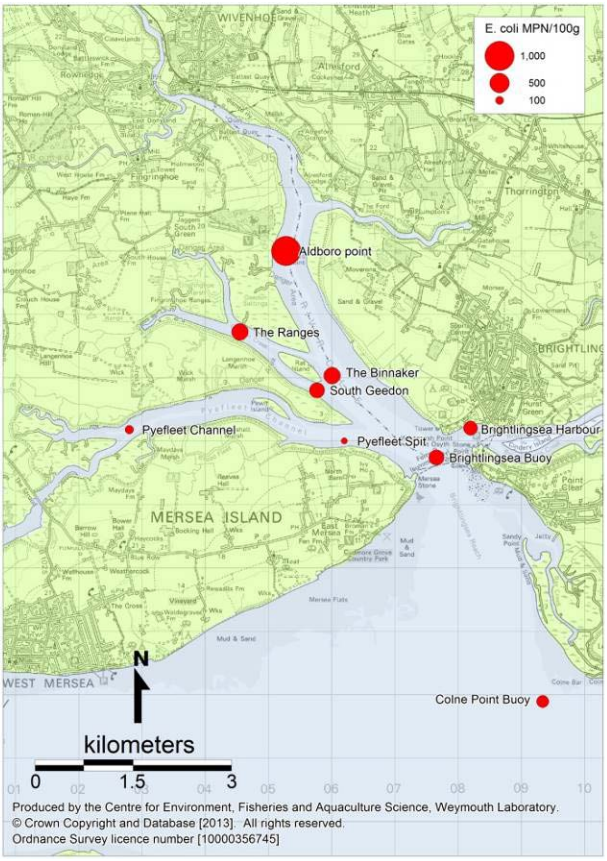


Figure XI.5: Pacific oyster RMPs active since 2003

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

RMP	Species	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 230	% over 4600
Aldboro Point	Hard clam	4	16/06/2004	19/02/2007	291.0	40	16000	25.0	25.0
The Binnaker	Hard clam	3	16/06/2004	15/05/2006	115.7	<20	500	66.7	0.0
Brightlingsea Buoy	Hard clam	36	07/11/2006	07/12/2010	94.0	<20	1700	22.2	0.0
The Priors	Hard clam	51	07/11/2006	14/08/2012	617.4	20	16000	72.5	7.8
Pyefleet Channel North	Cockle	72	23/01/2003	07/12/2010	429.5	<20	>18000	68.1	2.8
Pyefleet Channel South	Cockle	37	05/09/2006	30/06/2010	652.8	40	5400	73.0	5.4
Brightlingsea Harbour	Mussel	66	22/01/2003	05/09/2008	409.1	20	5400	59.1	1.5
Pyefleet Channel Confluence	Mussel	6	21/03/2011	04/09/2012	209.5	20	1400	50.0	0.0
Brightlingsea Buoy	Native oyster	35	21/11/2006	21/10/2010	432.1	40	16000	62.9	5.7
Pyefleet Spit	Pacific oyster	87	23/01/2003	07/12/2010	68.0	<20	5400	24.1	1.1
Brightlingsea Harbour	Pacific oyster	38	22/01/2003	02/03/2006	280.6	20	3500	44.7	0.0
The Ranges	Pacific oyster	73	30/06/2003	10/11/2010	358.9	<20	9200	58.9	2.7
South Geedon	Pacific oyster	92	17/03/2003	04/09/2012	318.8	<20	9100	55.4	4.3
Aldboro point	Pacific oyster	78	30/11/2004	04/09/2012	1067.1	40	>18000	88.5	15.4
The Binnaker	Pacific oyster	12	30/11/2004	21/08/2006	353.4	40	9100	66.7	8.3
Pyefleet Channel	Pacific oyster	75	18/10/2005	04/09/2012	120.9	<20	2400	29.3	0.0
Brightlingsea Buoy	Pacific oyster	19	21/02/2011	04/09/2012	317.2	20	9200	52.6	5.3
Colne Point Buoy	Pacific oyster	1	14/08/2012	14/08/2012	220.0	220	220	0.0	0.0

Of these RMPs, four were sampled on less than 10 occasions so will not be considered in detail in the following analyses (hard clams at Aldboro Point & The Binnaker, mussels at Pyefleet Channel Confluence, Pacific oysters at Colne Point Buoy).

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

Of the two hard clam RMPs, the level of *E. coli* only exceeded 4,600 MPN/100g at The Priors. Comparisons of the sites showed that The Priors had significantly higher levels of *E. coli* than Brightlingsea buoy (One way ANOVA, p=0.000).

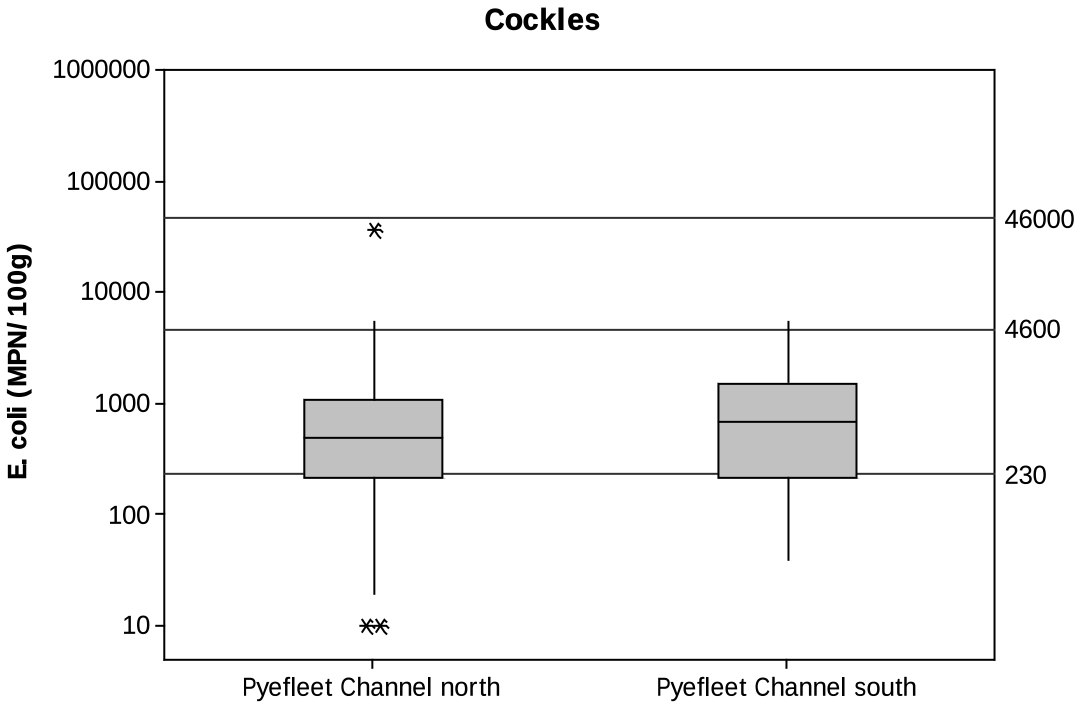


Figure XI.7: Boxplots of* E. coli *results from cockle RMPs sampled on 10 or more occasions from 2003 onwards.

E. coli levels exceeded 4600 *E. coli* MPN/100g at both sites on 2 occasions (but in less than 10% of all of the samples). Comparisons of the sites showed that there was no significant variation between sites (One-way ANOVA, p=0.142).

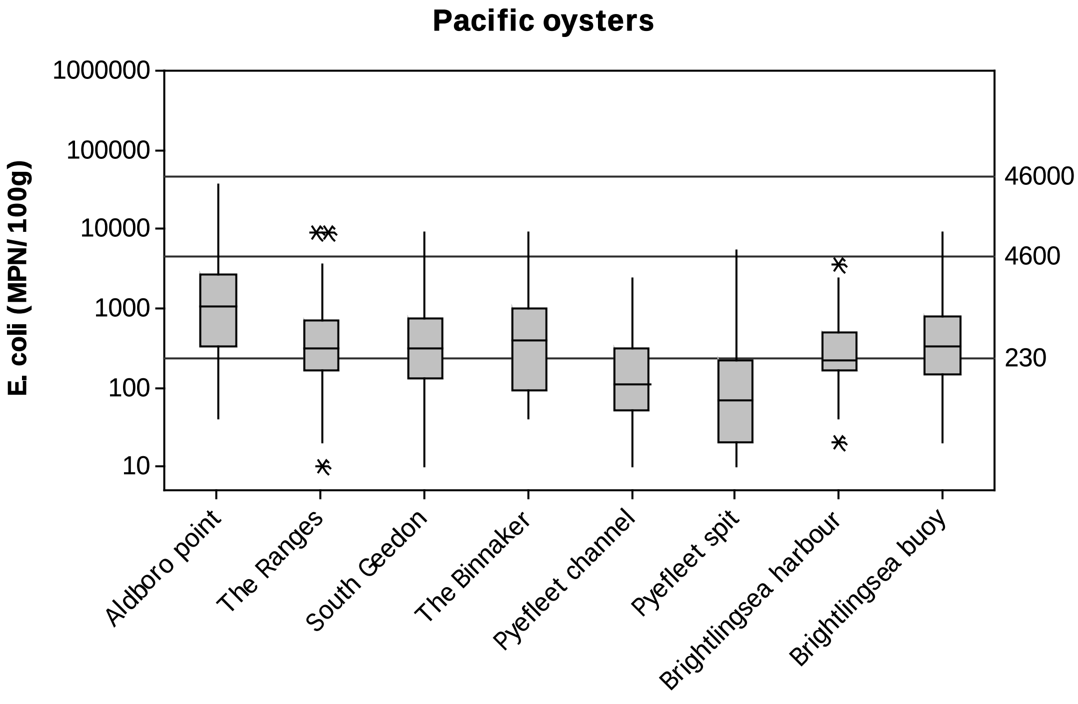


Figure XI.8: Boxplots of* E. coli *results from Pacific oyster RMPs sampled on 10 or more occasions from 2003 onwards.

E. coli levels in Pacific oysters appeared to decline slightly towards the mouth of the Colne estuary. Comparisons of the sites showed that there was significant variation in *E. coli* levels within Pacific oysters (One-way ANOVA, p<0.001). Post ANOVA testing (Tukeys comparison) revealed that oysters collected from Aldboro point had significantly greater levels of *E. coli* than at all other sites except The Binnaker. Out of all the Pacific oyster RMPs, Aldboro point is the furthest upstream in the main Colne channel. The two Pyefleet RMPs did not differ significantly from each other, but Pyefleet spit had significantly lower *E. coli* levels than all other RMPs. The Binnaker and Brightlingsea buoy were the only other sites that did not differ significantly from Pyefleet channel.

More robust comparisons of RMPs were carried out on a pair-wise basis by running correlations (Pearson's) between sites that shared sampling dates, and therefore environmental conditions, on at least 20 occasions. Table XI.2 shows the results of these correlations.

A significant correlation was found between all sites tested except at Brightlingsea buoy vs. The Priors (hard clam), Aldboro Point vs. Pyefleet Spit (Pacific oyster) and Pyefleet Spit vs. South Geedon (Pacific oyster). The significant correlations between sites suggest that the sites compared are influenced to a similar extent by environmental conditions. It was not possible to undertake meaningful paired comparisons between mussel RMPs as fewer than 20 same day samples were taken for each of these pairings.

Table XI.2: Correlations between RMPs that shared sampling dates on at least 20 occasions. Significant results are shaded in grey.

Comparison	Species	r	p
Brightlingsea Buoy vs The Priors	Hard clam	0.231	0.212
Pyefleet channel north vs Pyefleet channel south	Cockle	0.721	<0.001
Aldboro Point vs Pyefleet Channel	Pacific oyster	0.303	0.016
Aldboro Point vs Pyefleet Spit	Pacific oyster	0.220	0.107
Aldboro Point vs South Geedon	Pacific oyster	0.318	0.007
Aldboro Point vs The Ranges	Pacific oyster	0.414	0.001
Pyefleet Channel vs Pyefleet Spit	Pacific oyster	0.484	0.001
Pyefleet Channel vs The Ranges	Pacific oyster	0.496	0.000
Pyefleet Spit vs South Geedon	Pacific oyster	0.175	0.162
Pyefleet Spit vs The Ranges	Pacific oyster	0.348	0.004
South Geedon vs The Ranges	Pacific oyster	0.394	0.001

OVERALL TEMPORAL PATTERN IN RESULTS

The overall variation in levels of *E. coli* found in bivalves is shown in Figure XI.9 to Figure XI.13, which show fairly consistent levels over the last decade for all bivalves. Only RMPs with data for more than two years were included.

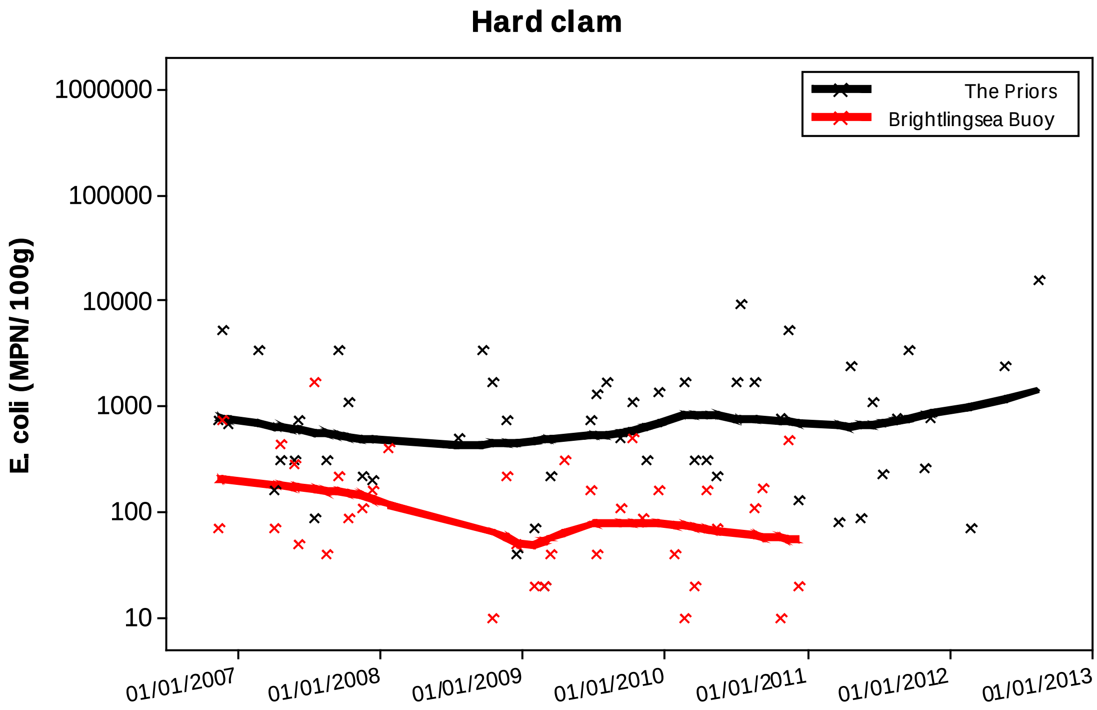


Figure XI.9: Scatterplot of* E. coli *results for hard clams overlaid with loess lines.

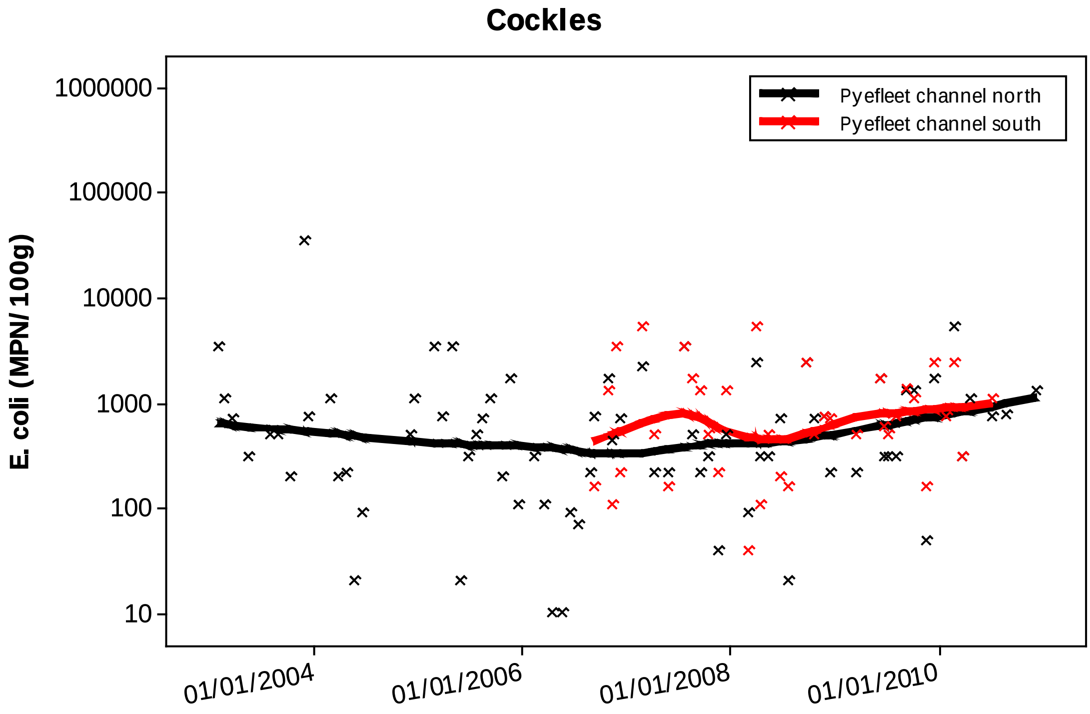


Figure XI.10: Scatterplot of* E. coli *results for cockles overlaid with loess lines.

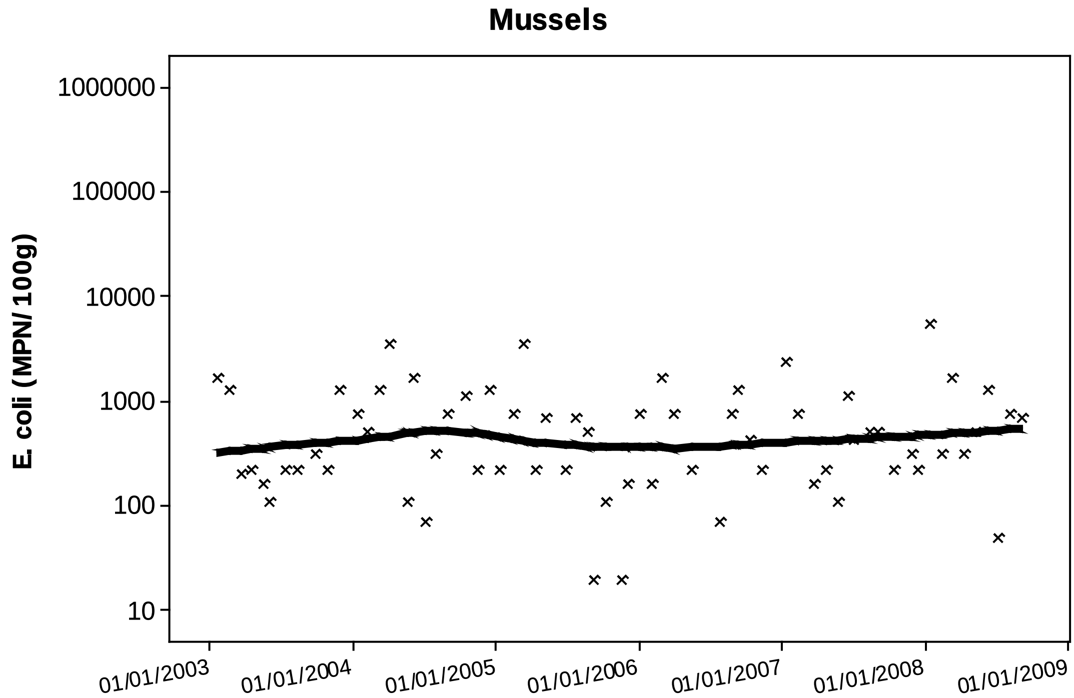


Figure XI.11: Scatterplot of* E. coli *results for mussels at Brightlingsea Harbour, overlaid with loess lines.

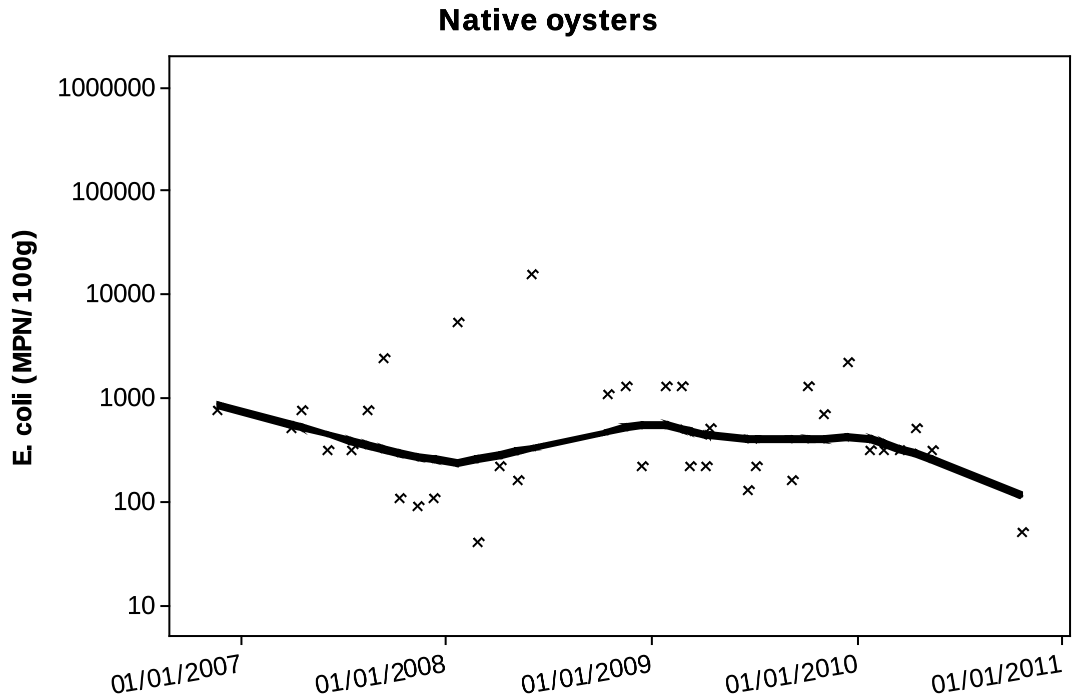


Figure XI.12: Scatterplot of* E. coli *results for native oysters at Brightlingsea Buoy, overlaid with loess lines.

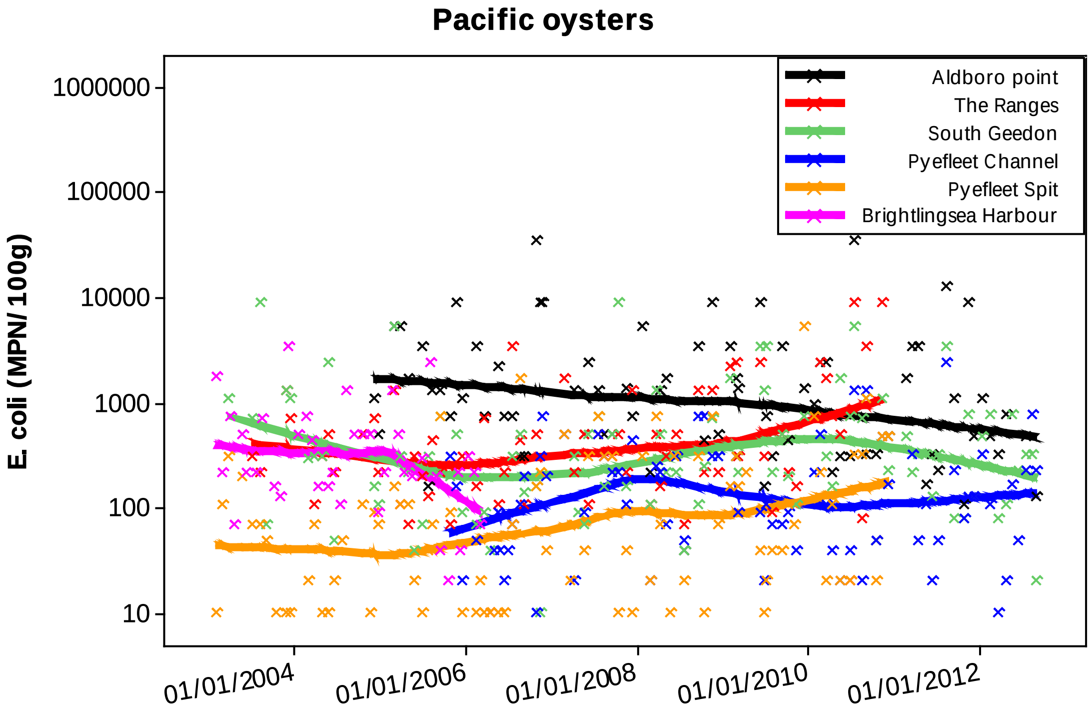


Figure XI.13: Scatterplot of* E. coli *results for Pacific oysters overlaid with loess lines.

SEASONAL PATTERNS OF RESULTS

The seasonal patterns of results from 2003 onwards were investigated by RMP for all RMPs where at least 30 samples had been taken.

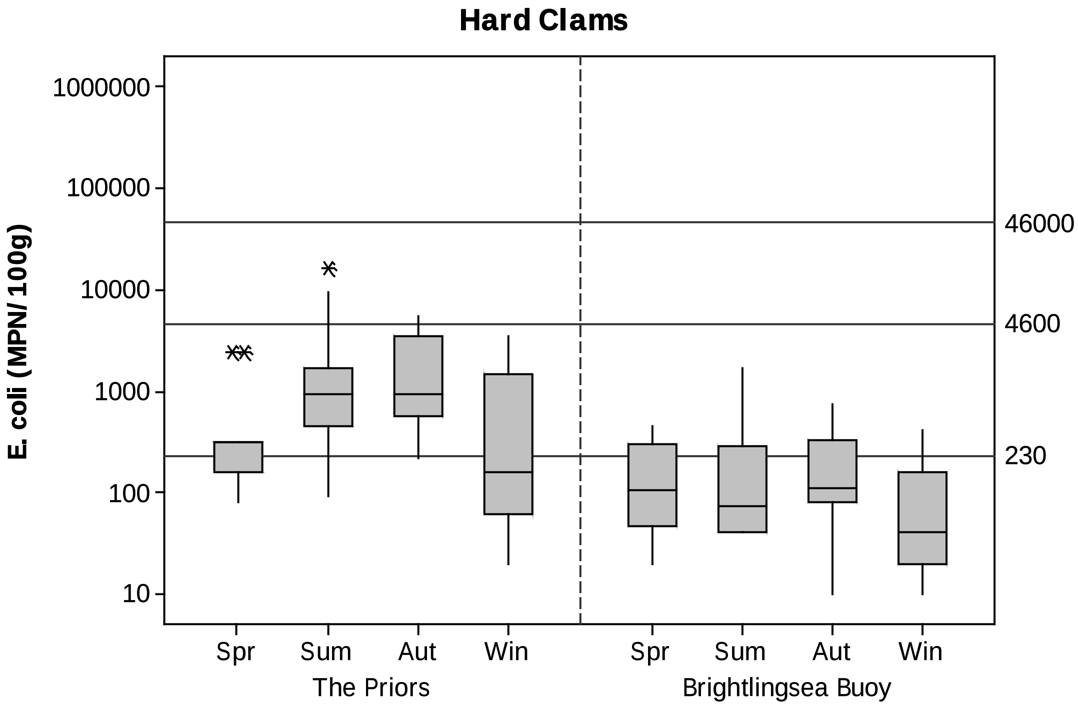


Figure XI.14: Boxplot of hard clam* E. coli *results by RMP and season

There was significant seasonal variation at The Priors, but not at Brightlingsea Buoy (One-way ANOVA, p=0.007 and 0.391 respectively). Post ANOVA tests (Tukeys) showed that at The Priors, there were significantly greater levels of *E. coli* in the summer and autumn than during the winter.

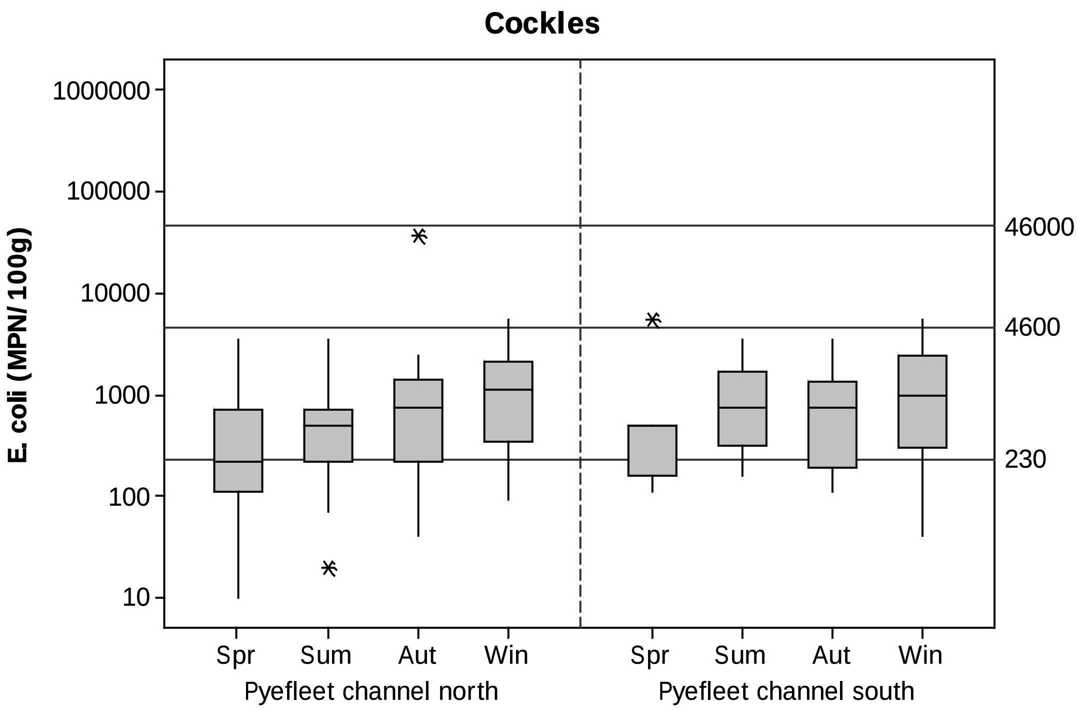


Figure XI.15: Boxplot of cockle* E. coli *results by RMP and season

There was significant seasonal variation at Pyefleet Channel north, but not at Pyefleet Channel south (One-way ANOVA, p=0.021 and 0.791 respectively), although the seasonal pattern appears similar. Post ANOVA tests (Tukeys) showed that at Pyefleet Channel north, there were significantly higher levels of *E. coli* in the winter than in the spring.

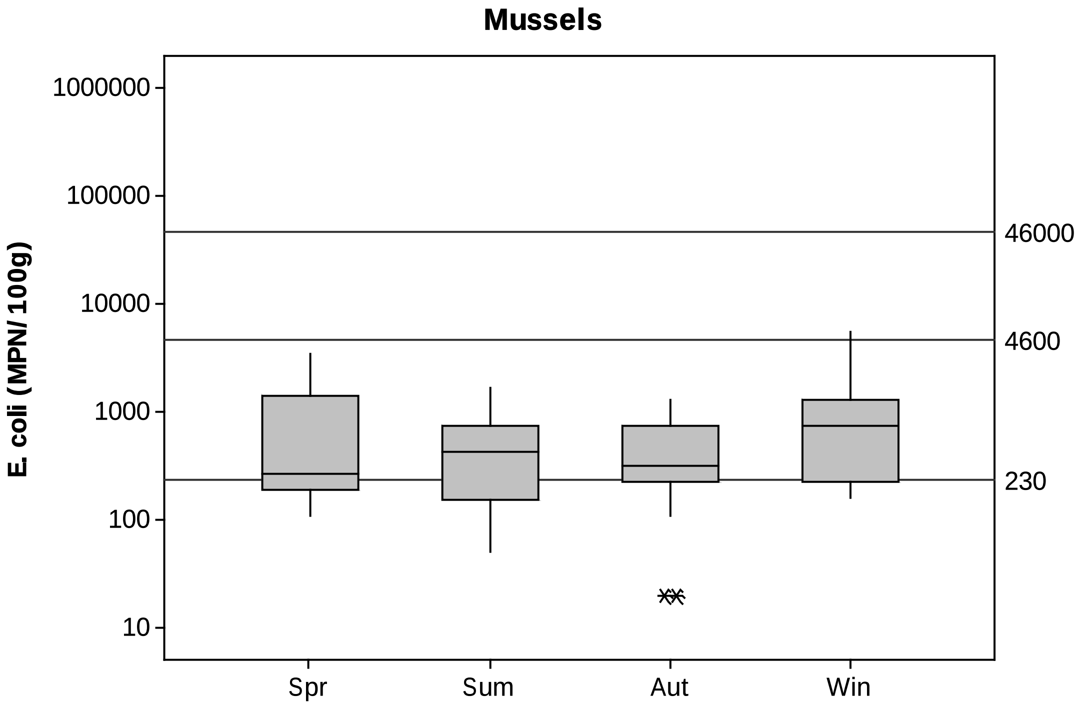


Figure XI.16: Boxplot of mussel* E. coli *results at Brightlingsea harbour by RMP and season

There were no significant variations in *E. coli* levels in mussels between seasons (One-way ANOVA, p=0.791).

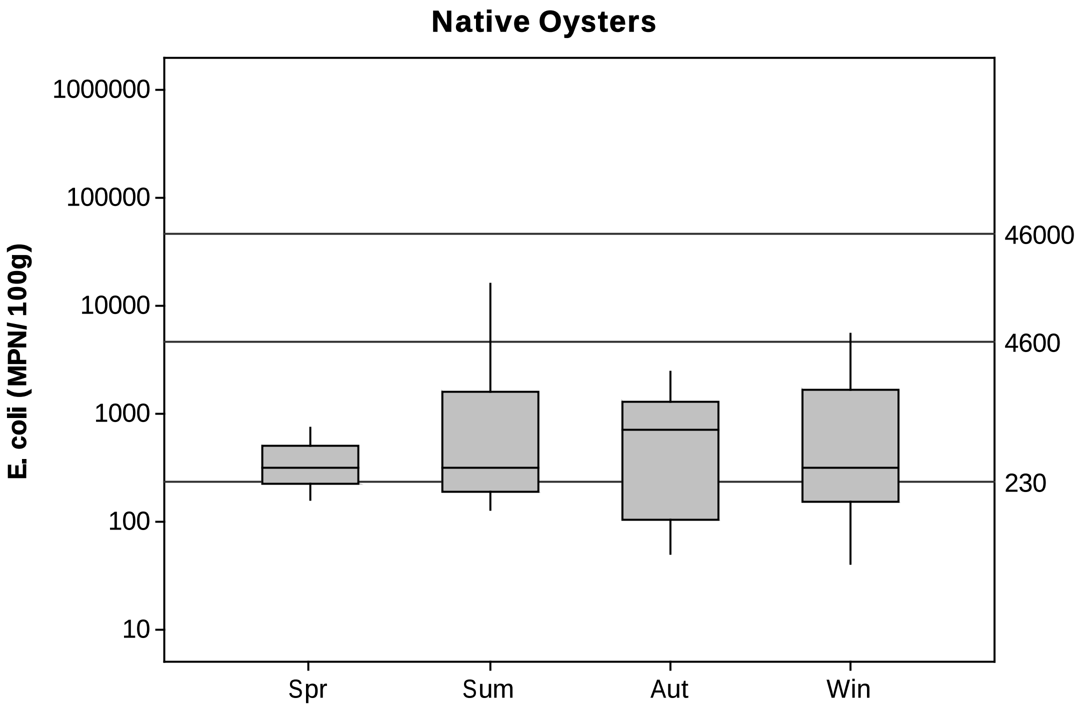


Figure XI.17: Boxplot of native oyster* E. coli *results at Brightlingsea buoy by RMP and season

There were no significant variations in *E. coli* levels in native oysters between seasons (One-way ANOVA, p=0.853).

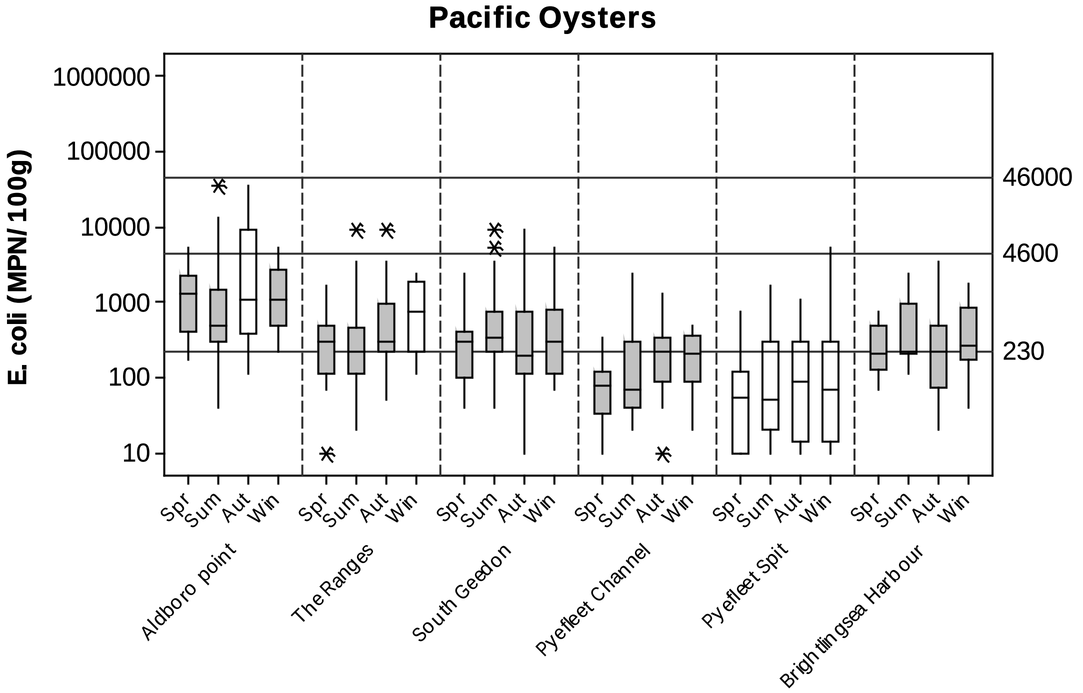


Figure XI.18: Boxplot of Pacific oyster* E. coli *results by RMP and season

Significant variation in *E. coli* levels by season in Pacific oysters was only found at Pyefleet channel (p=0.038). Post ANOVA testing (Tukeys comparison) showed that at Pyefleet channel, there was significantly lower *E. coli* levels in the spring than in the autumn.

INFLUENCE OF TIDE

To investigate the effects of tidal state on *E. coli* results, circular-linear correlations were carried out against the spring/neap tidal cycle for each RMP where at least 30 samples had been taken since 2003. Results of these correlations are summarised in Table XI.3, and significant results are highlighted in yellow.

Table XI.3: Circular linear correlation coefficients (r) and associated p values for* E. coli *results against the high/low and spring/neap tidal cycles

			High low		Spring neap	
Site	Species	n	r	p	r	p
Brightlingsea Buoy	Hard clam	36	0.276	0.081	0.223	0.194
The Priors	Hard clam	51	0.227	0.085	0.087	0.698
Pyefleet Channel North	Cockle	72	0.197	0.068	0.267	0.007
Pyefleet Channel South	Cockle	37	0.188	0.300	0.246	0.128
Brightlingsea Harbour	Mussel	66	0.199	0.083	0.107	0.486
Brightlingsea Buoy	Native oyster	35	0.273	0.091	0.260	0.114
Pyefleet Spit	Pacific oyster	87	0.180	0.065	0.080	0.580
Brightlingsea Harbour	Pacific oyster	38	0.137	0.520	0.338	0.018
The Ranges	Pacific oyster	73	0.194	0.072	0.26	0.009
South Geedon	Pacific oyster	92	0.109	0.346	0.164	0.091
Aldboro point	Pacific oyster	78	0.373	<0.001	0.307	<0.001
Pyefleet Channel	Pacific oyster	75	0.234	0.019	0.320	<0.001

Data from the Environment Agency

Figure XI.19 presents polar plots of $\log_{10}$ *E. coli* results against tidal states on the high/low cycle for the correlations indicating a statistically significant effect. High water at Brightlingsea is at 0° and low water is at 180°. Results of 230 *E. coli* MPN/100g or less are plotted in green, those from 231 to 4600 are plotted in yellow, and those exceeding 4600 are plotted in red.

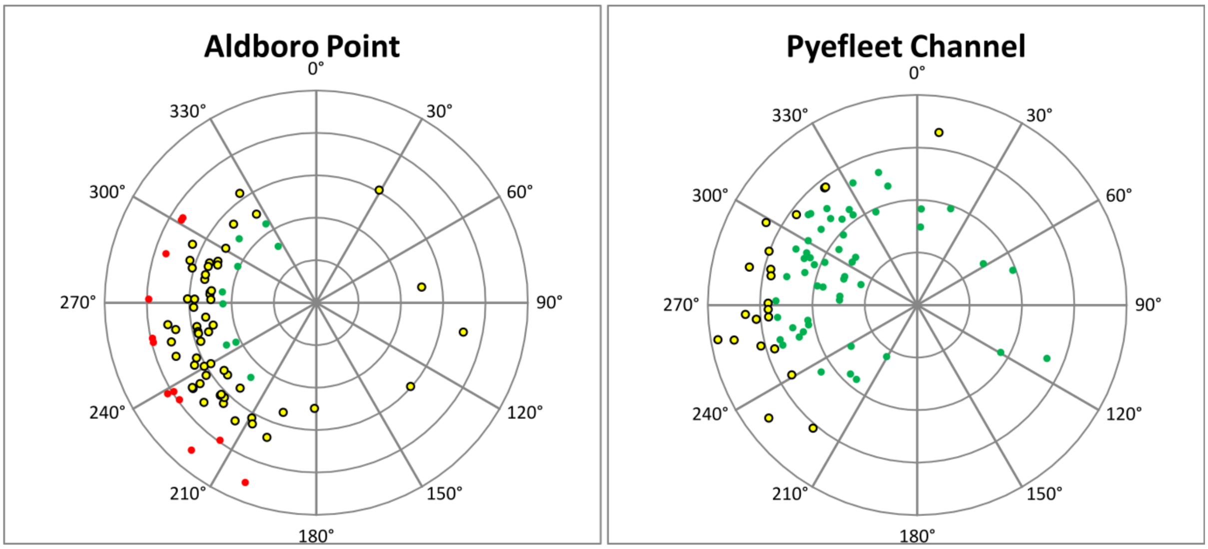


Figure XI.19: Polar plots of log10* E. coli *results (MPN/100g) in against high/low tidal state for Pacific oysters RMPs

At both Aldboro Point and Pyefleet Channel, the majority of samples were taken during the ebbing tide, so it is difficult to determine precisely any relationships between *E. coli* levels in Pacific oysters with the high/low tidal cycle. As the tide changes from high to low (180° to 0°) there are no obvious patterns that emerge.

Figure XI.22 and Figure XI.23 present polar plots of log10 *E. coli* results against the spring neap tidal cycle for each RMP where a significant correlation was observed. Full/new moons occur at 0º, and half moons occur at 180º, and the largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 230 *E. coli* MPN/100g or less are plotted in green, those from 231 to 4600 are plotted in yellow, and those exceeding 4600 are plotted in red.

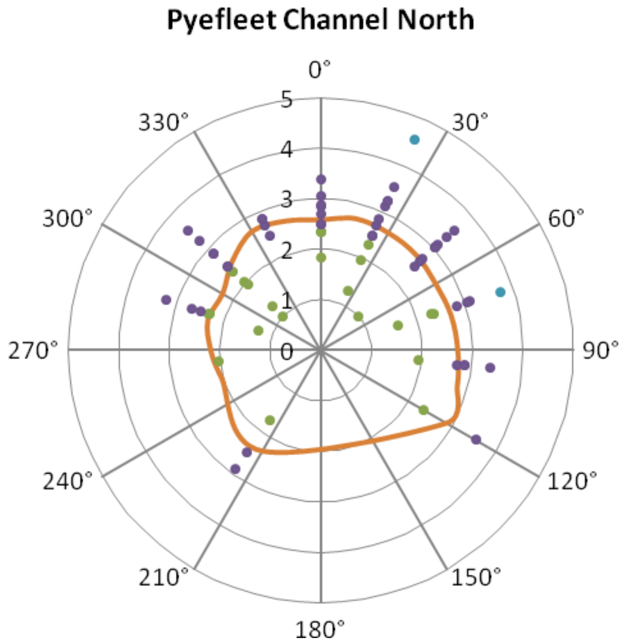


Figure XI.20: Polar plot of log10* E. coli *results (MPN/100g) against spring/neap tidal state for cockle RMPs

At Pyefleet Channel north, only 2 samples had greater than 4600 *E. coli* MPN/100g. Both of these were sampled around the spring tide. However, while significant correlations were found between the spring/neap tidal cycle and *E. coli* levels in cockles at Pyefleet Channel north, no obvious patterns can be seen in Figure XI.20.

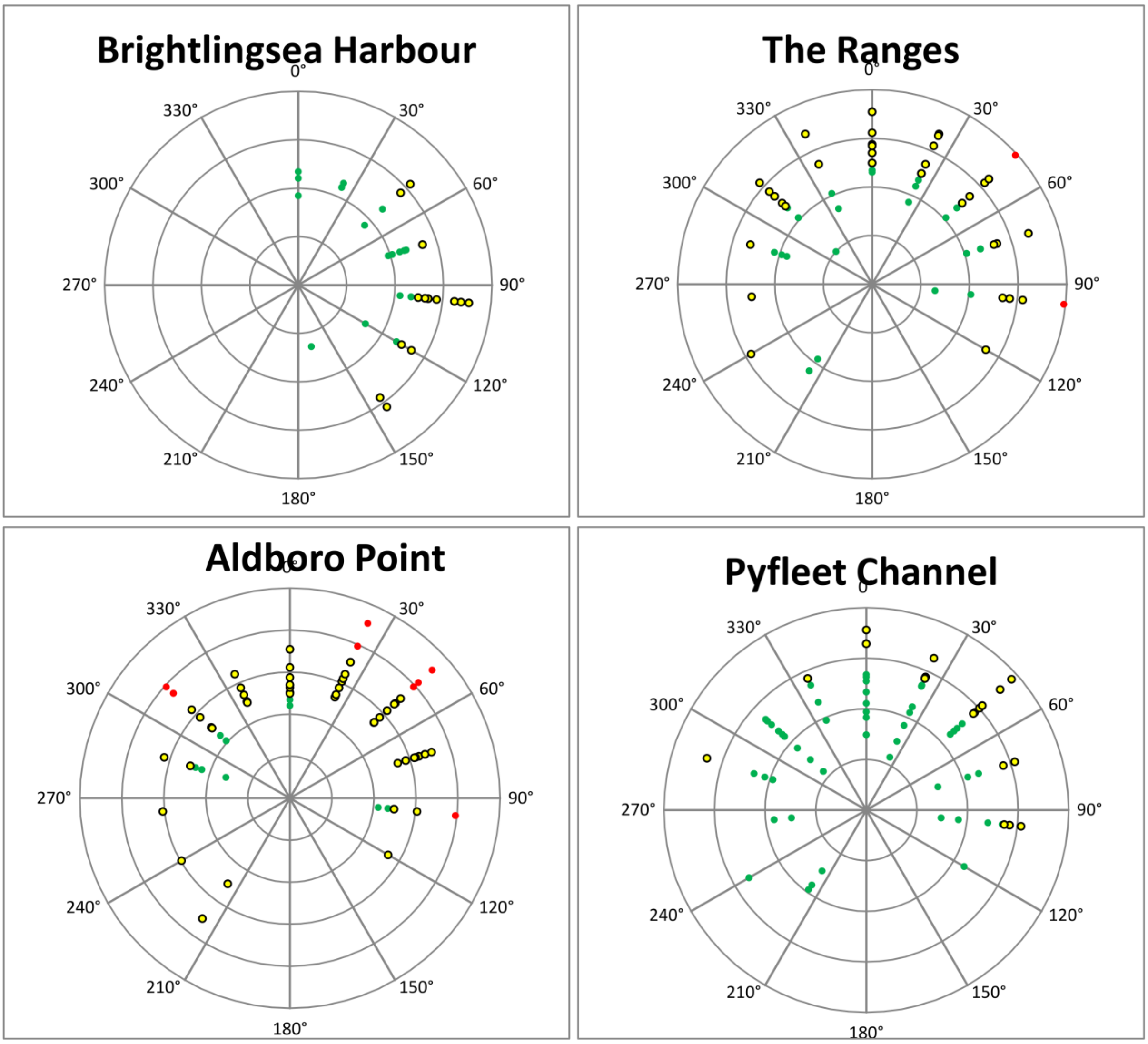


Figure XI.21: Polar plot of log10* E. coli *results (MPN/100g) against spring/neap tidal state for Pacific oyster RMPs

At Brightlingsea harbour, all of the Pacific oyster samples were taken between the full/new moon (0°) and the half moon (180°). The occurrence of *E. coli* levels of greater than 230 MPN/100g appeared to be greater after the spring tide, but low sample numbers make the certainty of this pattern questionable. At Aldboro Point and Pyefleet Channel there appears to be a slight tendency for higher results at spring tides. No pattern is apparent at The Ranges.

INFLUENCE OF RAINFALL

To investigate the effects of rainfall on levels of contamination within shellfish samples Spearman's rank correlations were carried out between *E. coli* results and rainfall recorded at the Mersea weather station (Appendix VI for details) over various periods running up to sample collection. These are presented in Table XI.4, and statistically significant positive correlations ($p<0.05$) are highlighted in yellow.

Table XI.4 Spearman's Rank correlations between rainfall recorded at Mersea and shellfish hygiene results

Site		Brightlingsea Buoy	The Priors	Pyefleet Channel North	Pyefleet Channel South	Brightlingsea Harbour	Brightlingsea Buoy	Pyefleet Spit	Brightlingsea Harbour	The Ranges	South Geedon	Aldboro point	The Binnaker	Pyefleet Channel	Brightlingsea Buoy
Species		Hard clam		Cockle		Mussel	Native oyster	Pacific oyster							
n		36	51	72	37	66	35	87	38	73	92	78	12	75	19
24 hour periods prior to sampling	1 day	-0.002	0.016	-0.029	0.098	0.207	0.262	0.142	0.189	0.102	0.17	0.264	-0.206	0.005	0.305
	2 days	0.071	0.139	0.216	0.088	0.252	-0.036	0.153	0.281	0.178	0.214	0.247	0.438	0.135	-0.046
	3 days	0.187	0.106	-0.040	0.289	0.236	0.052	0.075	-0.071	0.248	0.243	0.155	-0.443	0.182	0.305
	4 days	-0.334	-0.297	0.105	-0.178	0.364	0.000	-0.094	-0.034	0.122	-0.037	0.098	0.498	0.059	0.337
	5 days	-0.090	0.033	0.013	0.027	0.235	0.339	0.033	0.186	0.004	-0.061	0.080	-0.046	-0.015	-0.047
	6 days	0.042	-0.065	0.031	0.178	0.248	0.105	0.037	0.259	0.276	0.055	0.057	-0.123	0.010	-0.118
	7 days	-0.208	0.133	0.125	0.135	0.144	0.145	-0.012	0.251	0.131	0.003	0.066	0.314	0.134	-0.186
Total prior to sampling over	2 days	0.109	0.097	0.125	0.188	0.289	0.164	0.203	0.266	0.207	0.282	0.311	-0.106	0.123	0.176
	3 days	0.120	0.127	0.102	0.282	0.289	0.121	0.207	0.154	0.246	0.322	0.231	-0.275	0.119	0.289
	4 days	-0.037	0.010	0.160	0.316	0.332	0.072	0.220	0.135	0.302	0.288	0.226	-0.253	0.212	0.355
	5 days	0.010	0.049	0.109	0.244	0.335	0.071	0.181	0.231	0.257	0.259	0.222	-0.306	0.133	0.307
	6 days	0.047	0.033	0.130	0.300	0.361	0.028	0.158	0.270	0.360	0.264	0.205	-0.176	0.094	0.301
	7 days	0.016	0.115	0.159	0.277	0.355	0.048	0.182	0.290	0.312	0.251	0.132	-0.164	0.079	0.111

No significant effect of rainfall was detected at either of the hard clam RMPs. A minor influence of rainfall was detected at the two cockle RMPs. A strong and consisted influence of recent rainfall was found at the mussel RMP at Brightlingsea. A minor influence of rainfall was found for native oysters at Brightlingsea Buoy. Weak influences of rainfall were detected at all of the Pacific oyster RMPs except the Binnaker and Brightlingsea Buoy which were sampled on fewer occasions than the others. It should be noted that if significance is assumed at a p-value of 0.05 or less, then an apparent correlation will arise by chance on average for 5% of them.

APPENDIX XII
SHORELINE SURVEY REPORT

Date (time): 4 December 2012 (09:30–13:00)
5 December 2012 (12:00–14:30)

Cefas Officers: Simon Kershaw, Rachel Parks (04/12/2012 & 05/12/2012), Alastair Cook (05/12/2012 only).

Local Enforcement Authority Officers:
Tim Nice (Colchester Council, 04/12/2012 only)

Area surveyed: Brightlingsea Creek, Brightlingsea Reach, Pyefleet Channel, River Colne. It was not possible to enter the firing range at Geedon Creek.

Weather: 4 December 2012 - Wind 330° 5 km/h, 5°C, overcast
5 December 2012 - Wind 340° 1 km/h, 2°C, snow

Tidal predictions:

Admiralty TotalTide - 0126 Brightlingsea 51°48'N 1°00'E. Times GMT+0000.

04/12/2012			05/12/2012		
High	02:09	4.6 m	High	03:29	4.4 m
High	14:36	4.6 m	High	16:04	4.4 m
Low	08:30	0.7 m	Low	09:44	0.8 m
Low	20:31	1.0 m	Low	21:46	1.1 m

Objectives:

The shoreline survey aims to obtain samples of freshwater inputs to the area for bacteriological testing; confirm the location of previously identified sources of potential contamination; locate other potential sources of contamination that were previously unknown; find out more information about the fishery. A full list of recorded observations is presented in Table XII.1 and the locations of these observations are mapped in Figure XII.1. Photographs referenced in Table XII.1 are presented in Figure XII.3-Figure XII.10.

Description of Fishery

Most of the survey area is a private fishery, leased to the Colchester Oyster Company by Colchester Council. Pacific oysters, native oysters, cockles and American hard clams are the commercially exploited species. Point Clear Bay and Brightlingsea Creek fall outside of the private grounds. At present there are large volumes of Pacific oysters in Brightlingsea Creek, to the extent that reefs have formed in places. Brightlingsea Creek up as far as Lower Farm requires classification for this species. This includes the Brightlingsea Harbour area as they represent a hazard to shipping here and the harbour authorities will probably liaise with local fishermen to get them cleared. Pacific oysters are exploited in Point Clear Bay on a small scale by one local fisherman who has a small depuration plant. This fisherman would also like mussels in Point Clear Bay classified so he can harvest and market these alongside the oysters.

Sources of contamination

Sewage discharges

The location of the Pioneer Sailing Trust and Brightlingsea Pools discharges (observations 4 and 8 respectively) were confirmed. Observations 6, 9, 20 and 23 were of pipes or outfalls of unknown origin.

Water samples taken from Brightlingsea Creek showed relatively high levels of *E. coli* contamination close to the Brightlingsea pontoons (water sample BS2), but much of this had dispersed upstream in the Creek (water sample BS1). The cause of this high result is uncertain.

Freshwater inputs

Usually, the locations of all significant freshwater inputs would be recorded, and they would be sampled and measured to gain an appreciation of the bacterial loadings they generate. However, during this survey it was not possible to run the boat ashore to carry out such measurements.

Boats and Shipping

There are some marinas and house boats within the estuary which may be potential sources of contamination for the shellfisheries. Boat traffic is mainly centred around Brightlingsea, where there is commercial traffic associated with the wind farm and a large area of moorings/pontoon berths in the south channel of Brightlingsea Creek. House boats in occupation are likely to make regular sewage discharges, and one was observed at Brightlingsea (observation 3).

Wildlife

Small numbers of birds (<50) were seen in various locations throughout the estuary confirming a significant presence of overwintering waterbirds.

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

Table XII.1: Details of shoreline observations

No.	Date and time	NGR	Photograph	Observation
1	04-Dec-12 09:47	TM 09529 16164		Birds x 30. Seawater Sample. Water sample BS1
2	04-Dec-12 09:56	TM 09399 16159	Figure XII.3	Oyster Beds
3	04-Dec-12 09:59	TM 09192 16140		Houseboat
4	04-Dec-12 10:01	TM 09095 16137		Pipes x 2 - 1 flowing 1 not flowing (Pioneer Sailing Trust discharge). Fuel Pumping Station
5	04-Dec-12 10:04	TM 08872 16115		Sample. Water sample BS2
6	04-Dec-12 10:09	TM 08609 16057	Figure XII.4	Pipes x 2 - not flowing
7	04-Dec-12 10:23	TM 08381 16074		Gulls
8	04-Dec-12 10:25	TM 08170 16099	Figure XII.5	Pipes x3 - not flowing - sailing lake behind. Gulls x20, Oyster Beds visible
9	04-Dec-12 10:30	TM 08041 16031	Figure XII.6	Pipes x2 not flowing
10	04-Dec-12 11:11	TM 07413 14469		Birds x 30
11	04-Dec-12 11:25	TM 07651 15106		Seal
12	04-Dec-12 11:29	TM 07643 15099		Sample taken close to Port marker buoy. Water sample BS3
13	04-Dec-12 11:52	TM 06350 16041	Figure XII.7	Colchester Oyster Fisheries Slipway
14	04-Dec-12 11:55	TM 06385 16105		Water sample BS4
15	04-Dec-12 12:15	TM 03888 16496	Figure XII.8	Blue barrels – floating enclosure
16	04-Dec-12 12:20	TM 03457 16351		Wading birds on North Bank
17	04-Dec-12 12:23	TM 03120 16264	Figure XII.9	North Creek
18	04-Dec-12 12:39	TM 02574 15919		Seal
19	04-Dec-12 12:41	TM 02771 16087		Cockles (collected sporadically)
20	05-Dec-12 12:35	TM 07423 16229		Outfall - submerged
21	05-Dec-12 12:52	TM 05969 17430		Birds x 30
22	05-Dec-12 12:59	TM 05674 18229		Birds sighted along the coast
23	05-Dec-12 13:23	TM 03639 21460	Figure XII.10	Pipe capped
24	05-Dec-12 13:30	TM 03488 21402		Seawater Sample. Water sample BS5
25	05-Dec-12 13:56	TM 05435 20130		Seawater Sample. Water sample BS6
26	05-Dec-12 14:08	TM 05699 18094		Seawater Sample. Water sample BS7
27	05-Dec-12 14:25	TM 07310 16139		Seawater Sample. Water sample BS8

Sample results

A series of seawater samples were taken during the course of the survey (Table XII.2 and Figure XII.2).

Table XII.2: Water sample E. coli results

Sample No.	Date and Time	Position	*E. coli* (cfu/100ml)
BS1	04-Dec-12 09:47	TM 09529 16164	1800
BS2	04-Dec-12 10:04	TM 08872 16115	20000
BS3	04-Dec-12 11:29	TM 07643 15099	820
BS4	04-Dec-12 11:55	TM 06385 16105	220
BS5	05-Dec-12 13:30	TM 03488 21402	20000
BS6	05-Dec-12 13:56	TM 05435 20130	3000
BS7	05-Dec-12 14:08	TM 05699 18094	84
BS8	05-Dec-12 14:25	TM 07310 16139	200

These indicate increasing levels of contamination up the main channel, with a very high result at Wivenhoe, presumably related to increasing influence of land runoff and sewage discharges. A very high result was also recorded at Brightlingsea, but the reasons for this are unclear.

Figure XII.2: Water sampling locations and bacterial concentrations

Figure XII.3

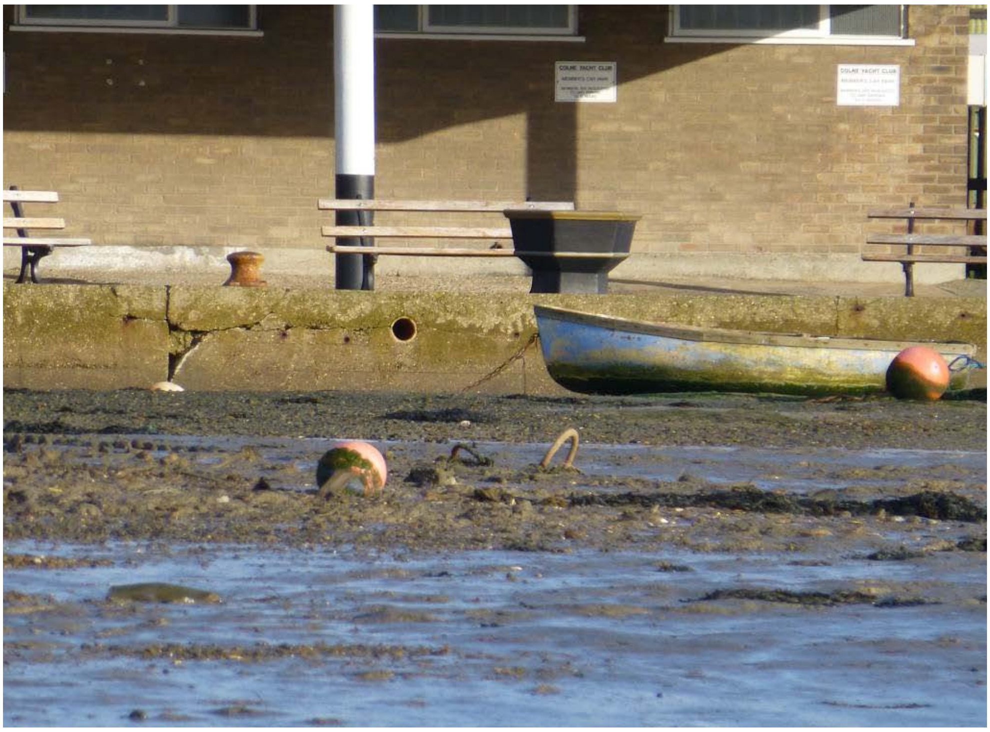


Figure XII.4

Figure XII.5

Figure XII.6

Figure XII.7

Figure XII.8

Figure XII.9

Figure XII.10

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List of Abbreviations

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

Glossary

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

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

Acknowledgements

Cefas would like to thank Richard Haward (West Mersea Oysters), Jennifer Tickner (Defra), Tim Nice (Colchester Council), Ed King (Tendring Council), Graham Larkin (Colchester Oyster Fishery).