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EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Chichester Harbour

November 2013

Food Standards Agency

Cover photo: Fishing boat navigating Chichester Harbour

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Statement of use

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

Report prepared by

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Revision history

Version	Details	Approved by	Approval date
1	Draft for internal review	Simon Kershaw	12/07/2013
2	Draft for external review	Simon Kershaw	08/08/2013
Final	Final report post consultation	Simon Kershaw	05/11/2013

Consultation

Consultee	Date of consultation	Date of response
Chichester DC	08/082013	None
Havant BC	08/082013	None
Environment Agency	08/082013	04/09/2013
Southern Water	08/082013	None
Sussex IFCA	08/082013	16/09/2013
Southern IFCA	08/082013	None
Shellfish Association of Great Britain	08/082013	None

Dissemination

Food Standards Agency, Chichester DC, Havant BC. The report is available publicly via the Cefas website.

Recommended Bibliographic Reference

Cefas, 2013. Sanitary survey of Chichester Harbour. Cefas report on behalf of the Food Standards Agency, to demonstrate compliance with the requirements for classification of bivalve mollusc production areas in England and Wales under EC regulation No. 854/2004.

Contents

1. Introduction

1.1. Legislative Requirement

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

When consumed raw or lightly cooked, bivalves contaminated with pathogenic microorganisms may cause infectious diseases in humans (e.g. Norovirus-associated gastroenteritis, Hepatitis A and Salmonellosis). 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 anticipated 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 native oysters (*Ostrea edulis*), clams (*Tapes* spp. and *Mercenaria Mercenaria*) and cockles (*C. edule*) within Chichester Harbour. The area was prioritised for survey in 2013-14 by a shellfish hygiene risk ranking exercise of existing classified areas.

1.2. Area description

Chichester Harbour is situated on the south coast of England to the east of Portsmouth and Langstone Harbours; its location is shown in Figure 1.1. It covers a total area of 29.5 km², 79% of which is intertidal (Futurecoast, 2002). A narrow mouth in the south connects it to the Solent, and a smaller channel in the northwest corner connects Chichester Harbour with Langstone Harbour.

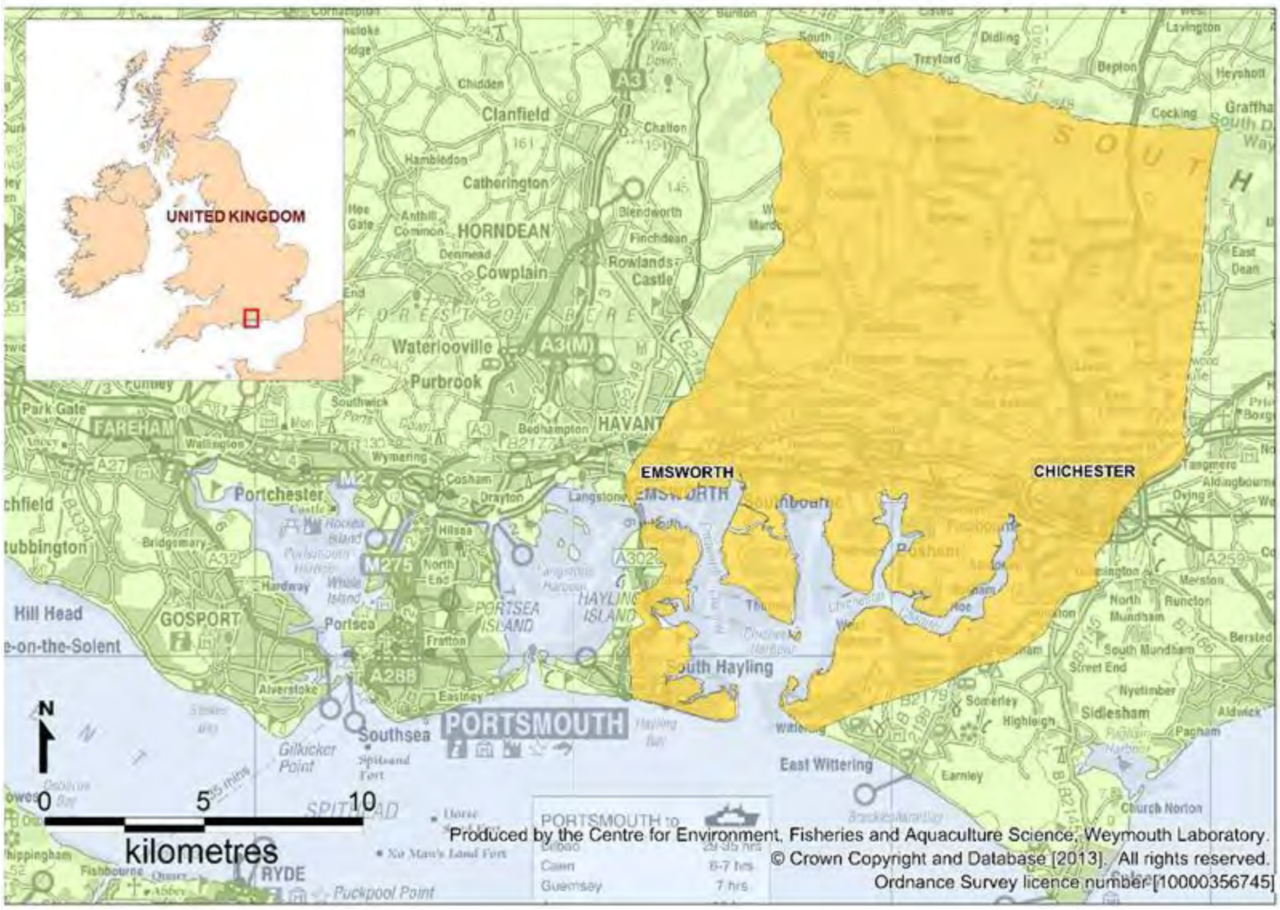


Figure 1.1: Location of Chichester Harbour

Chichester Harbour has been recognised as an important area for its estuarine habitats and wildlife. It comprises of large areas of intertidal mudflats and smaller areas of sand and shingle beds, with saltmarsh and eel grass beds in some places. These features attract significant populations of internationally and nationally important birds and an abundance of other wildlife. Consequently, the harbour has been designated under several international and national conservation statuses including Area of Natural Beauty (AONB), RAMSAR wetland, Site of Special Scientific Interest (SSSI) and Special Protection Area (SPA), it also falls within the Solent Special Area of Conservation (SAC) and encloses three Local Nature Reserves; Nutbourne Marshes, Pilsey Island and Thorney Deeps.

Boating is an important pastime within Chichester Harbour, with many recreational activities taking place such as yachting, dinghy sailing, windsurfing and canoeing. A commercial fishing fleet also operates from the harbour. The harvesting of oysters in Emsworth (formerly the main port in Chichester Harbour) has been recorded since the late 16th century. At its peak in the late 19th century, around 400 people were employed in the Emsworth oyster trade (The Emsworth Heritage Project, 2008). Presently, stocks are at low levels and although this fishery still continues it is much less prolific than it was historically.

1.3. Catchment

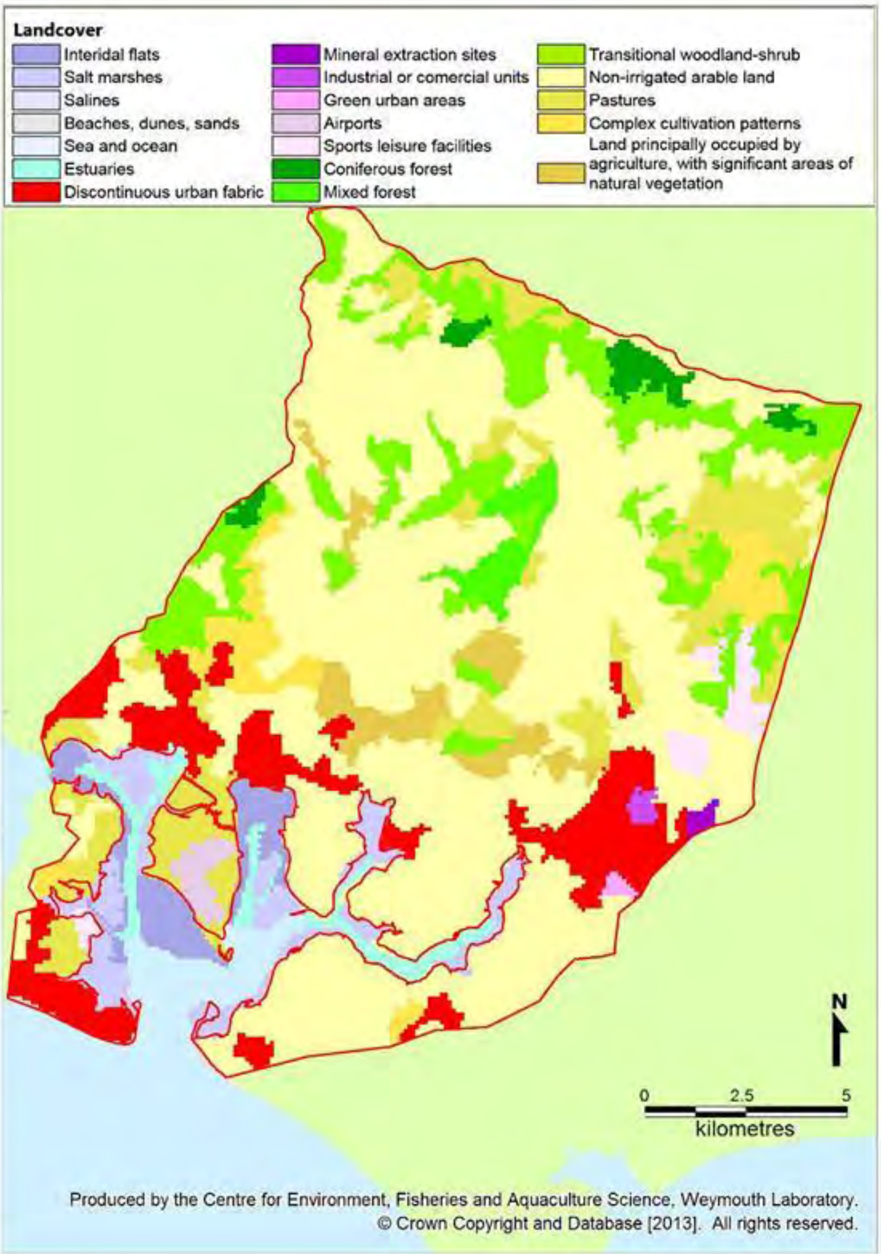


Figure 1.2: Landcover in Chichester Harbour catchment area

Figure 1.2 illustrates land cover within the Chichester Harbour catchment area which covers an area of approximately 242 km². There is a marked division of land use between the upper and lower catchment. The lower catchment is significantly more urbanised than the upper catchment which lies within the South Downs National Park and comprises of arable land with areas of mixed woodland, coniferous forest and woodland shrub. Smaller areas of agriculture and complex cultivation also exist within the upper catchment.

Urbanised areas are limited to the lower catchment, close to the shore representing the towns of Chichester, Southbourne, Emsworth and part of Havant. The urban areas are interspersed with mainly arable land with some pastures and some woodland. The northern division of Hayling Island is predominantly pasture, cultivated land and arable land, with the most urbanised areas being located in the south. Thorney Island situated centrally in Chichester Harbour comprises of pasture land with a military base in the south.

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

There is a marked difference in the geology between the upper catchment and the lower catchment, and this is likely to result in differing hydrological regimes. The upper reaches are underlain with chalk so there will be significant flows of groundwater here, whereas the lower reaches are underlain with bands of Reading and London clay and Bracklesham sands, which are much less permeable (West, 2007).

2. Recommendations

2.1. Native oysters

2.1.1 Native oysters (*O. edulis*) are widely distributed throughout the harbour but confined to the subtidal channels. RMP locations are therefore located within the subtidal channels.

2.1.2 It is recommended that the native oyster fishery is divided into the following five classification zones (Figure 3.1). The zoning is largely driven by the hydrographic separation of the main channels and the differing profile of pollution sources they receive. Their respective RMPs are located to best capture contamination from the principal identified sources impacting upon them.

<u>Upper Chichester Channel</u>. This zone is subject to several of the most significant sources of contamination including Chichester STW and its storm tanks, the River Lavant, and two significant private discharges by the Chichester Marina. There are also a number of private discharges and Bosham STW discharging to Furzefield Creek, and a particularly high concentration of moorings in the lower reaches of this zone. The Chichester STW storm tanks are likely to be the main influence when active. They have spilled for 19.2% of the time in recent years, and when active appear to be associated with significantly increased levels of contamination. It is therefore recommended that the RMP be located at the upstream end of this zone (Dell Quay) by the eastern bank to reflect this. This location should also be effective at capturing contamination delivered by the River Lavant. The very upper reaches of the Chichester Channel and the small embayment by Chichester Marina should be excluded from this zone on the basis of lack of stock and the relatively high levels of contamination observed through microbiological testing. There is not thought to be significant stock in Furzefield Creek, which should also be excluded from this zone due to its enclosed nature and the sewage discharges it receives.

<u>Lower Chichester Channel.</u> There is little in the way of contamination sources discharging directly to this zone aside from possible bird concentrations to the south of Cobnor Point and at Pilsey Island, and some minor freshwater inputs. It is likely to be primarily influenced by the upstream sources impacting on the Upper Chichester Channel zone. Sources to the Bosham and Thorney Channels are also likely to have a secondary albeit lesser influence. It is therefore recommended that the RMP be located at Cobnor, to best capture the influence of upstream sources.

<u>Bosham Channel.</u> Two watercourses discharge to the head of this channel, one of which was carrying a relatively high *E. coli* loading at the time of shoreline survey. Other sources include a small cluster of private discharges at Chidham and two

small streams in the vicinity of Bosham. None of the sources discharging to this channel are particularly large in themselves. It is therefore recommended that the RMP be located where the creek by Bosham joins the main channel, a compromise which should be reasonably effective at capturing contamination from all these sources. The small embayment at Chidham should be excluded on the basis of lack of stock and the sewage discharges it receives.

Thorney Channel. This receives contamination from a watercourse discharging to its head (Ham Brook) and from the Thornham STW via the Great Deep. Limited bacteriological testing suggests that the latter is a more significant influence. It is therefore recommended that the existing Thorney Outfall RMP be retained as it is best positioned to capture contamination from this source.

Emsworth Channel. This is a relatively large zone. Contaminating influences include the River Ems and other smaller watercourses discharging to its head and high concentrations of moorings in its uppermost and lowermost reaches. Within a creek at Eastoke some evidence of sewage contamination of surface water drains was observed during the shoreline survey. There is a connection with Langstone Harbour at the top of the channel, but water movements are primarily in a westerly direction through here so sources in Langstone Harbour should be of little influence. It is recommended that the RMP be located as far up the Emsworth Channel as possible to best capture contamination from the River Ems.

2.1.3 The following sampling criteria should apply for all native oyster RMPs:

- The species sampled should be market size native oysters.
- If the sampling method is dredge, a tolerance of 100m applies. This may need to be extended to 250m in some places where stocks are particularly sparse.
- If the oysters are sampled from a deployment bag they should be allowed to equilibrate *in situ* for at least two weeks, and a tolerance of only 10m applies.
- Regular monthly monitoring is required to maintain a full classification.

2.2. Clams and cockles.

2.2.1 Clams [American hard clams (*Mercenaria mercenaria*), Manila clams and native clams the latter also known as palourdes (*Tapes* spp.) and cockles (*C. edule*)] are thought to be widespread throughout the harbour. The LEAs have indicated that they do not have the resources required to establish and maintain a classification throughout the entire harbour. Sampling plans are provided only for two relatively small areas, one of which has been subject to a formal request for classification, the other of which there have been reports of clam digging activity within.

2.2.2 Two discrete zones are recommended for the mixed clam and cockle hand digging fishery. Their respective RMPs are located to best capture contamination from the principal identified sources impacting upon them.

Northney. This zone has been subject to a formal request for classification. Aside from the Northney Marina and some moorings in the Sweare Deep there are no significant identified sources of contamination impacting directly to this zone. There is a connection with Langstone Harbour at the top of the channel, but water movements are primarily in a westerly direction through here so contamination from any sources in Langstone Harbour should be of little influence. An RMP located by the entrance to the Northney Marina should be adequately representative of this zone, and would be best located to capture any contamination originating from within Northney Marina.

Prinstead. This zone has not been subject to a formal request for classification, although some clam gathering has been observed there. As such, this zone does not require classification unless it is subject to a formal request, or if the LEA otherwise identifies such a requirement. The main source impacting directly on this zone is a stream at Nutbourne (Ham Brook). Contamination from the Great Deep outfall will be carried into this zone, but only during the early stages of the flood tide. It is therefore recommended that the RMP should be located immediately adjacent to the drainage channel that Ham Brook cuts across the intertidal area.

2.2.3 The following sampling criteria should apply at clam/cockle RMPs:

- *C. edulis* may be sampled to represent cockles, *Tapes*. Spp. and *M. mercenaria.* The species sampled should be of a market size. If only clams (*Tapes* spp. and *M. mercenaria*) are to be harvested then *Tapes spp*. may be sampled instead of *C. edulis.*

- Alternatively after a period of sampling both species in parallel, and review of the data by Cefas/FSA, *Tapes* spp. may or may not be also deemed representative of both cockles and the aforementioned clam species in these locations.

- Sampling should be via hand digging, and a tolerance of 100m applies to allow repeated sampling of wild stocks.

- The sampling frequency should be monthly and on a year round basis. If a more rapid classification is required in the first instance, a provisional classification can be awarded on the basis of 10 samples taken not less than one week apart.

- Should employing a local gatherer prove the best practical option, the LEA should consult with the FSA to ensure that sample collection method meets all the appropriate requirements.[1]

[1] Should such a strategy be pursued, the LEA should contact the FSA to agree alternative options. Proposals must comply with the appropriate sampling protocols, ensure adequate training and supervision is provided and is to be documented accordingly.

3. Sampling Plan

3.1. General Information

Location Reference

Production Area	Chichester Harbour
Cefas Main Site Reference	M018
Ordnance survey 1:25,000 map	Explorer 120
Admiralty Chart	3418

Shellfishery

Species/culture	Native oysters (*Ostrea edulis*)	Wild
	Hard clams (*Mercenaria mercenaria*)	Wild
	Manila & native clams (*Tapes* spp.)	Wild
	Cockles (*C. edule*)	Wild
Seasonality of harvest	Closed season for native oysters (March-October inclusive). Additional temporary closures apply in specified areas of the Harbour during 2013/14.	

Local Enforcement Authority

Name	Environmental Health Department Chichester District Council
Address	East Pallant House East Palant Chichester PO19 1TY
Environmental Health Officer	Adrian Cook
Telephone number ☎	01243 785166 ext 2116
Fax number	01243 776766
E-mail	environmentalhealth@chichester.gov.uk
Name	Environmental Health Department Havant Borough Council
Address	Civic Offices Centre Road Havant PO9 2AX
Environmental Health Officer	Nick Harvey
Telephone number ☎	02392 446654
Fax number	02392 446659
E-mail	Nick.Harvey@havant.gov.uk

3.2. Requirement for Review

The Guide to Good Practice for the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 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 in sources of contamination come to light, such as the upgrading or relocation of any major discharges.

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

Classification zone	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Upper Chichester Channel	B018J	Dell Quay	SU 8342 0280	50º49.12'N 0º49.03'W	*O. edulis* (Native oysters)	Wild	Dredge	Dredge / deployment bag	100m / 10m	Monthly	Sampling may be via dredge or from a deployment bag.
Lower Chichester Channel	B018K	Cobnor	SU 7911 0173	50º48.58'N 0º52.71'W		Wild	Dredge	Dredge / deployment bag	100m / 10m	Monthly	
Bosham Channel	B018L	Bosham	SU 8016 0356	50º49.56'N 0º51.80'W		Wild	Dredge	Dredge / deployment bag	100m / 10m	Monthly	
Thorney Channel	B018H	Thorney Outfall	SU 7710 0360	50º49.61'N 0º54.40'W		Wild	Dredge	Dredge / deployment bag	100m / 10m	Monthly	
Emsworth Channel	B018M	Emsworth	SU 7469 0448	50º50.10'N 0º56.44'W		Wild	Dredge	Dredge / deployment bag	100m / 10m	Monthly	
Northney	B018N*	Northney Marina	SU 7299 0439	50º50.07'N 0º57.09'W	*C. edule* (cockles)*	Wild	Hand digging	Hand digging	100m	Monthly (or 10 samples not less than one week apart for provisional classification)	New zone for which classification has been formally requested. Represents *Tapes* spp., hard clams (*M. mercenaria*) and cockles (*C. edule*).

Classification zone	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Prinstead	B018O*	Ham Brook	SU 7776 0479	50º50.25’N 0º53.82’W	*C. edule* (cockles)*	Wild	Hand digging	Hand digging	100m	Monthly (or 10 samples not less than one week apart for provisional classification)	New zone. Will not require sampling or classification unless requested by the industry or otherwise identified by LEA as requiring classification. Represents *Tapes* spp., hard clams (*M. mercenaria*) and cockles (*C. edule*).

†*Seagrass protection areas implemented under IFCA byelaws should be excluded from these zones.*
** Separate RMP codes for clam species will be generated if required.*

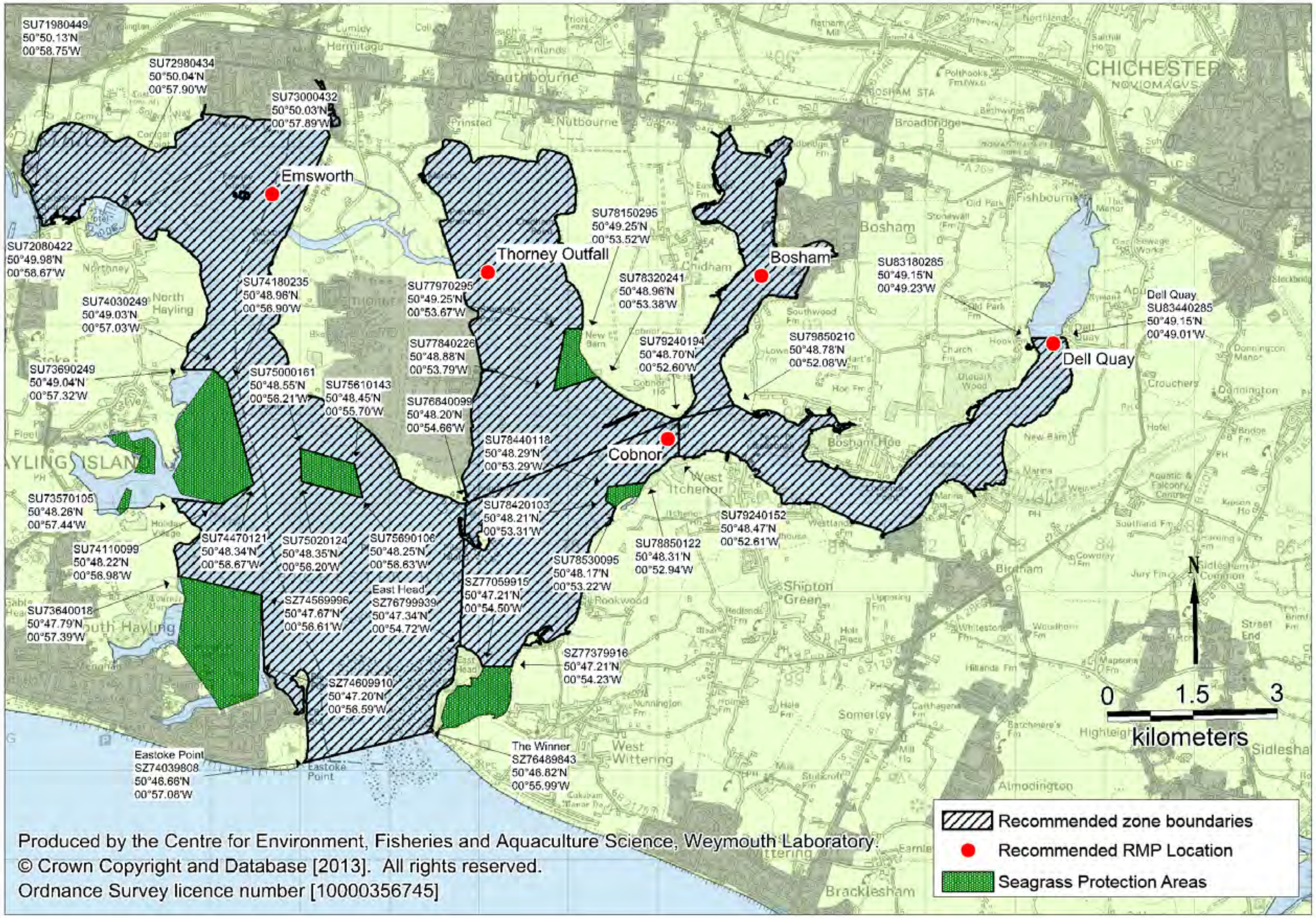


Figure 3.1: Recommended zoning and monitoring arrangements (native oysters)

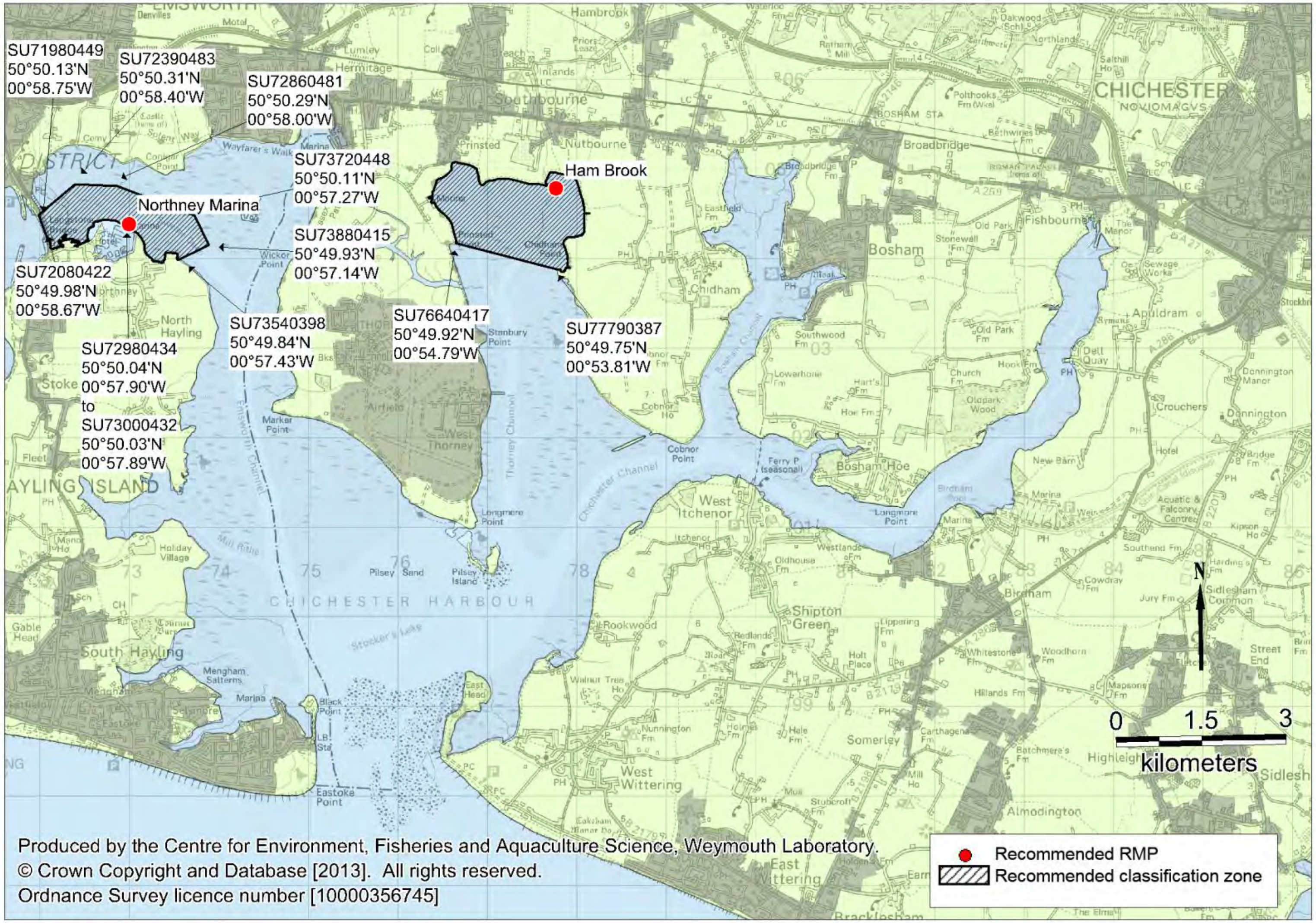


Figure 3.2: Recommended zoning and monitoring arrangements (clams and cockles)

4. Shellfisheries

4.1. Species, location and extent

Only native oysters (*Ostrea edulis*) are commercially exploited in Chichester Harbour at present, although there is also interest in harvesting Manila clams (*Tapes philippinarum*), American hard clams (*Mercenaria mercenaria*), native clams (*Tapes decussatus*) and cockles (*C. edule*). Oysters occur throughout the main subtidal channels, whereas the clams and cockles occur in the intertidal areas.

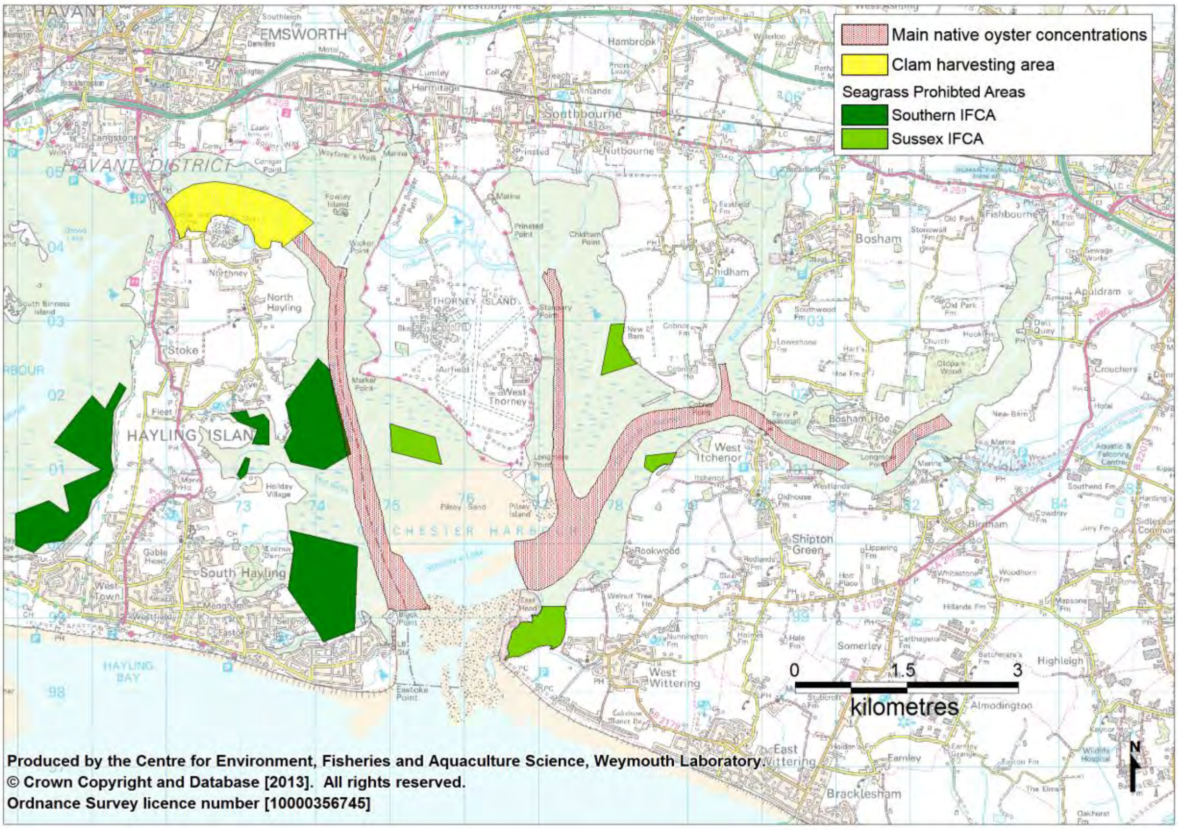


Figure 4.1: Overview of shellfisheries and seagrass protected areas within Chichester Harbour

The oyster dredge fishery is supported by a natural population of this species, which are taken from the main channels using dredges. Catches are generally exported to France for ongrowing. Populations of native oysters in Chichester Harbour and the wider Solent area have declined significantly in recent years, following a series of recruitment failures, the causes for which are as yet undetermined (Vause, 2010).

The precise distribution of clams and cockles within the harbour is uncertain, but they are thought to be widely distributed throughout the intertidal. An application to classify most of Chichester Harbour for hand gathering of these species was received in December 2012. Due to the large extent of the area and number of species, the cost of sampling to obtain these classifications was considered too high by the LEAs. In January 2013 a compromise solution was identified, whereby a recommended sampling plan was issued for an area off Northney, supporting relatively high densities of clams. Sampling towards classification for this area is ongoing. Some clam digging has been observed in the upper reaches of the Thorney Channel, recommendations are therefore provided for zoning and sampling of this area.

Under the current system for classification, data from official monitoring of oysters can, in certain circumstances, be used to assign a preliminary classification for clams. However, as Manila clams are the main species present in Chichester Harbour this would not be appropriate, as this species has been shown to accumulate *E. coli* to a higher level than oysters. Furthermore clams occur on intertidal mudflats whereas oysters occur in the subtidal channels and therefore may be subject to differing sources or influences of pollution.

4.2. Growing Methods and Harvesting Techniques

All stocks of clams and oysters are wild. The commercial harvesting technique for oysters is via dredge. Any clam or cockle harvesting would be via hand digging.

4.3. Seasonality of Harvest, Conservation Controls and Development Potential

Chichester Harbour falls under the management of two Inshore Fisheries and Conservation Authorities (IFCAs). The Hampshire/Sussex county line, which runs through the centre of the Emsworth Channel represents the dividing line between the two IFCAs.

Seagrass beds

Four areas on the west side of the Emsworth Channel adjacent to Hayling Island are subject to a voluntary dredging ban to protect seagrass beds (Jury, 2013). As this voluntary ban has not been universally adhered to within the Solent area, Southern IFCA are also likely to prohibit all towed gear within these areas. Southern IFCA also intends to prohibit other activities likely to damage seagrass, including hand digging of shellfish within these areas. Both these byelaws are likely to be in force by the end of 2013. These will prevent any possible exploitation within the Hayling Island creeks, including the one at Eastoke. The seagrass beds infringe the oyster fishery but may hold significant stock of clams.

Within the Sussex IFCA District harvesting will be prohibited in the areas of seagrass following implementation a new Sussex IFCA byelaw in the near future. These areas are shown in Figure 4.1 above,

Oysters

Around 40 boats, a higher number than usual, operated in this fishery at the beginning of the 2012/13 season. In the past effort was highest in the first week or two of November when the season opened. After the initial rush, catch rates of sizeable oysters tend to drop significantly, and the level of effort drops to nothing within a week. During the oyster fishing season of 2012/13 200 tonnes of oysters were harvested from Chichester Harbour with a value of approximately £600,000 (Chichester Harbour Conservancy, 2013). Native oysters are subject to a minimum landing size of 70mm. The maximum dredge opening is 1.5m and only two can be towed.

Stocks of this species have declined significantly within Chichester Harbour and the wider Solent area in recent years, and as a consequence catches have fallen. In the western part of the Harbour which lies in the Southern IFCA District there is a closed season from March to October inclusive. Under an 'Emergency Temporary Closure of Shellfish Fisheries Byelaw' Sussex IFCA is implementing temporary spatial closures in their District, these are being introduced in two stages: 'Stage one: Closure from 1 November 2013 (start of season) to 31 October 2014 (both days inclusive) in the specified areas. Stage two: To introduce a closure for the remaining area of the harbour (within Sussex IFCA District) at a time when a predetermined harvest control threshold has been reached. The threshold will be derived from catch per unit effort data obtained from samples on active fishing vessels. The methodology for the sampling is defined separately and reflects the relationship between dredge efficiency and seabed oyster density.'

Nevertheless a sampling plan is provided for oysters across the whole harbour in anticipation of areas re-opening in the future.

The Chichester Harbour Oyster Partnership Initiative, which aims to restore stocks, was started in 2010. Under this, broodstock from the Solent have been laid at suitably high densities for successful breeding in limited areas within the harbour where a voluntary dredging ban has been agreed (Vause, 2010). Additionally, a study is underway (the Solent Oyster Group Initiative) which aims to investigate the causes of oyster decline over the wider Solent area over the next few years.

Cockles & clams

The harvest of cockles is closed from February to April inclusive within the Southern IFCA district. There are no closed seasons for clams within either district. Minimum landing sizes apply to Manila clams (35mm), hard clams (63mm), palourdes (40mm) and cockles (23.8mm) within the Southern IFCA district, but none are specified within the Sussex IFCA district. Clam dredging is not allowed anywhere within the harbour. There is some uncertainty about the levels of clam and cockle stocks present and the level of exploitation they can withstand, but it is likely that they represent a major and as yet largely untapped resource.

All gathering of wild stocks is limited to the hours from 08:00 to 16:00. The IFCAs may close any wild fishery at any time for reasons of stock preservation.

4.4. Hygiene Classification

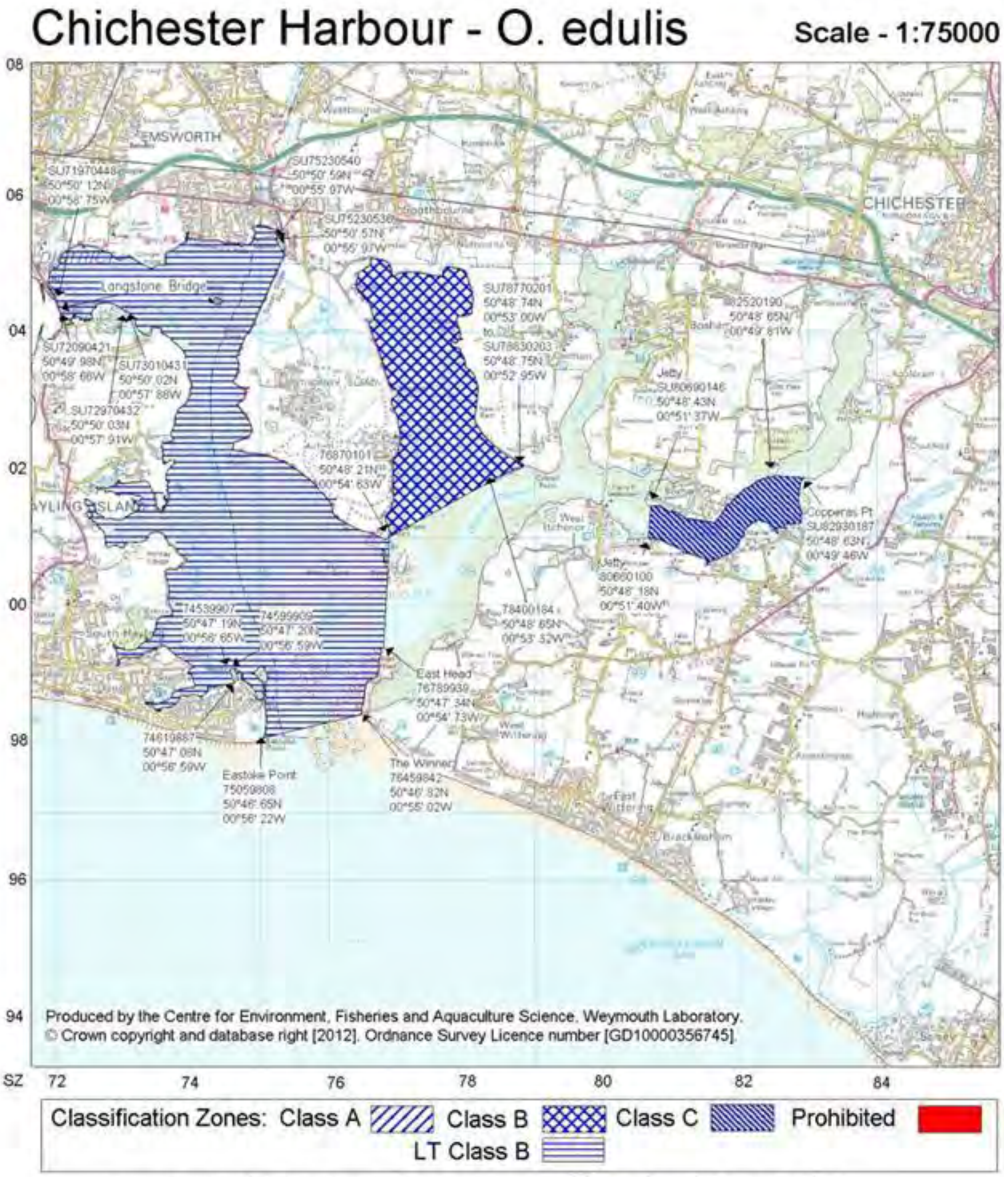
Table 4.1 lists all classifications within Chichester Harbour from 2004 onwards.

Table 4.1: Classification history for Chichester Harbour, 2004 onwards

Area	Species	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Birdham Spit	Native oyster	C	B	B	C	C	B	B	B	B	C
Chichester Channel	Native oyster	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	-
Mill Rythe	Native oyster	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Sweare Deep	Native oyster	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Thorney	Native oyster	B	B-LT	B	C	C	C	B	B	B	B

P denotes Prohibited.
LT denotes long term classification

In recent years C classifications have arisen at Birdham Spit and Thorney, with the former recently downgraded from B to C. Due to low stock levels and a lack of commercial activity the area covered by the Chichester Channel RMP has been temporarily declassified and is currently sampled on a quarterly basis to maintain this status.



Classification of Bivalve Mollusc Production Areas: Effective from 22 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

Food Authorities: Havant Borough Council
Chichester District Council

Figure 4.2: Current native oyster classifications

Table 4.2: Criteria for classification of bivalve mollusc production areas.

Class	Microbiological standard[1]	Post-harvest treatment required
A[2]	Live bivalve molluscs from these areas must not exceed 230 Most Probable Number (MPN) of *E. coli* 100g-1 Fluid and Intravalvular Liquid (FIL)	None
B[3]	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution MPN test of 4,600 *E. coli* 100g-1 FIL in more than 10% of samples. No sample may exceed an upper limit of 46,000 *E. coli* 100g-1 FIL	Purification, relaying or cooking by an approved method
C[4]	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution Most Probable Number (MPN) test of 46,000 *E. coli* 100g-1 FIL	Relaying for, at least, two months in an approved relaying area or cooking by an approved method
Prohibited[6]	>46,000 *E. coli* 100g-1 FIL[5]	Harvesting not permitted

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

5. Overall Assessment

5.1. Aim

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

5.2. Shellfisheries

Chichester Harbour supports wild stocks of native oysters, which are present throughout the main subtidal channels. Oyster stocks in the harbour and in the wider Solent area have declined significantly in recent years. Despite the stock status a significant seasonal dredge fishery continues to target them and their continued classification is required throughout the harbour. It is a public fishery which is managed via local byelaws. There is a closed season that runs from 1st March to the 31st October. It is possible that the IFCA will further restrict the open season further. The typical seasonal pattern is intensive harvesting for the first week or two of November, after which catches decline and harvesting activity is greatly decreased. Around 40 boats participated on the opening of the season in 2012, landing about 200 tonnes between them. The majority of the catch is sent to France for ongrowing. The current stock status has made the collection of samples increasingly difficult at some RMPs. The most extreme case is the lower Chichester Channel and the Bosham Channel, which are currently temporarily declassified due to sampling difficulties for the RMP representing this area. The use of deployment bags[2] may therefore represent a more efficient approach, and would also allow more precise positioning of the RMP. However, the dredge sampling is also used for stock assessment purposes so the LEAs and IFCAs may consider it a better overall use of resources to continue with dredge sampling. Monthly sampling should be continued but the first two months of the closed season (March and April) need not be sampled assuming a full set of 10 samples are taken throughout the remaining months. The preferred option from a public health perspective however would be for monthly sampling to continue throughout the year.

[2] Shellfish deployed in a suitable bag fixed to a buoy/anchor to guarantee stock is available in the desired sampling location.

An area by Northney has been subject to an application for the harvest of clams (Manila clams, native clams and American hard clams) and cockles via hand gathering. Additionally, some clam gathering has been reported in the upper reaches of the Thorney Channel, although this area is not classified for commercial harvesting of these species. A sampling plan should be provided for both these areas, and the sampling plan for the latter area should only be applied if a classification is formally requested. Manila clams and native clams are treated as the same species (referred to as *Tapes* spp.) for classification purposes as they are closely related and difficult to distinguish. There is no closed season for these species so sampling should be monthly and year round. There is evidence to suggest that some of these species accumulate *E. coli* to different levels than others (Younger & Reese, 2011) so should ideally be monitored separately. However, it is a mixed fishery and sampling resources must be used carefully, so, with the agreement of the harvester, it will be acceptable to sample just one of these species. Cockles and *Tapes* spp. appear to accumulate *E. coli* to similar levels, and to higher levels than Amercian hard clams. Therefore either cockles or *Tapes* spp. should be monitored to be suitably protective of public health.

There are four areas of seagrass within the Emsworth Channel in which the IFCA are likely to ban both dredging and shellfish digging via new byelaws. It is envisaged that these byelaws will be in place by the end of 2013. If and when these byelaws come into force it may be prudent to exclude these areas from any classified zones to avoid any potential confusion regarding the legality of harvesting shellfish within them. They slightly overlap the subtidal oyster beds. They are likely to hold significant stocks of clams, but do not coincide with any of the areas for which clam/cockle sampling plans will be provided in this report.

5.3. Pollution Sources

Freshwater Inputs

All rivers and streams will carry some bacteriological contamination and so will require consideration in this assessment. Chichester Harbour drains a catchment area of only 242km^2 so receives relatively little freshwater input. Flows of water through the upper catchment are via aquifers rather than surface watercourses. Microbiological contamination from the upper catchment (e.g. from agricultural sources) is therefore unlikely to arrive at the harbour in a viable state due to the lengthy transit times. In the lower catchment the geology is more impermeable and there are several significant surface streams.

The larger watercourses generally discharge to the upper reaches of the various channels. The two largest watercourses are the River Ems and the River Lavant, which discharge to the head of the Emsworth Channel and near the head of the

Chichester channel respectively. The heads of the Thorney and Bosham channels receive freshwater inputs from smaller but nevertheless potentially significant streams. There are also significant streams discharging to the Chichester Marina and at West Wittering. There are also many smaller watercourses and surface water drains discharging at various locations around the harbour. Many of these watercourses drain low lying land via sluices or flap gates that are covered at high water. As such these will discharge only at lower states of the tide. This includes the Great Deep, which drains part of Thorney Island and receives sewage effluent from Thornham STW and discharges to the east shore of the Thorney Channel.

In order to assess the relative significance of these watercourses, records from gauging stations, spot flow measurements, and results of bacteriological samples taken from the various watercourses were considered. The most information was available for the Lavant, which has a gauging station and has been regularly sampled for faecal coliforms in recent years. It has a mean discharge rate of 0.638 m^3/sec, and contained a mean concentration of 631 faecal coliforms/100ml, and based on this it delivers a mean loading of 3.5×10^{11} faecal coliforms/day to Chichester Harbour. Strong seasonality was observed in both discharge rate and faecal coliform concentrations. Flows were highest in the colder months at both stations peaking in January, whereas the concentration of faecal coliforms it carries shows almost the opposite seasonal pattern, with higher concentrations observed in the summer and autumn months. As a result, the bacterial loading it delivers is similar across the seasons on average, but will vary significantly with rainfall on a day to day basis. The Lavant was not sampled or measured during the shoreline survey as its outfall was covered by the tide at the time. The Ems also has a fixed gauging station, and its mean flow (0.533 m^3/sec) is slightly lower than that of the Lavant. The seasonal pattern of discharge was similar, peaking slightly later (February).

During the shoreline survey spot flow gauging was undertaken and samples taken for bacteriological analysis from all flowing watercourses. This did not include the Lavant or the Great Deep as their outfalls were covered by the tide, or the stream draining to the Chichester Marina, which could not be accessed. The largest measured watercourses in terms of volumes were the River Ems and the Bosham Stream, two watercourses discharging to the head of the Chichester Channel, and a stream at West Wittering. None of these carried high levels of *E. coli*, so none was delivering a particularly high *E. coli* loading. An estimate of the bacterial loading delivered by the Ems, including two separately measured side channels, is about 1.8×10^{11} *E. coli*/day. The highest measured loading (9.5×10^{11}) was actually delivered by a small culverted watercourse at the southern end of Hayling Island, where very high concentrations of *E. coli* were found (9.3×10^5 cfu/100ml). This suggests it was receiving some sanitary input at the time. Only two other streams, one to the west of Emsworth and one at the head of the Bosham Channel were also delivering *E. coli* loadings exceeding 10^{11} cfu/day at the time of survey.

In summary, the largest freshwater inputs in terms of volumes are generally to the heads of the four main channels. The largest are the Lavant and the Ems which discharge to Chichester Channel and the Emsworth Channel. The watercourses discharging to the head of the Thorney and Bosham channels are relatively minor. There are also relatively large watercourses discharging to the harbour at West Wittering, and via the impounded Chichester Marina. The Great Deep is also likely to be of significance as it receives effluent from Thornham STW. The Great Deep is low lying and is connected to the harbour through a sluice and so will only discharge at lower states of the tide. Flow gauging records and repeated bacteriological sampling of the Lavant reveal that there were differing seasonal fluctuations in both which lead to a similar bacterial loading delivered throughout the year on average. Whether this applies to the Ems or other watercourses is uncertain. The bacterial loading delivered by watercourses is likely to vary significantly from day to day depending on rainfall. Their combined inputs are likely to be of significance to the harbour as a whole, and the individual watercourses may generate a localised ‘hotspot’ of contamination. Their individual impacts will be greatest where they enter the harbour, and within or immediately adjacent to any drainage channels they follow across the intertidal area, and RMPs should be located accordingly.

Human Population

Total resident population within the Chichester Harbour estuary catchment was about 106,000 at the time of last census. Population densities are highest on the north and west shores of the harbour around Hayling Island, Emsworth and the city of Chichester, with Chichester representing the largest settlement. The more inland part of the catchment forms part of the South Downs, where population densities are much lower.

The area is a popular tourist destination due to its seaside location and various attractions. The harbour itself is heavily used for watersports and sailing during the summer months. There are several holiday parks on Hayling Island, and a relatively high proportion of properties are second homes. Significant population increases are therefore anticipated during the summer months. Increased population numbers will result in increased volumes of sewage treated by the sewage works so there may be some seasonality in the bacteriological loadings generated by these.

Sewage Discharges

There are eight water company owned sewage treatment works discharging to the survey area. Of these, two discharge directly to Chichester Harbour, both of which provide UV disinfection of the final effluent. The largest is Chichester STW which discharges towards the head of the Chichester Channel and has a consented dry weather flow of 13,524 m^3/day. Bacteriological testing of the final effluent indicates that the UV treatment at Chichester is generally effective and an estimate of the average bacterial loading it generates is only $1.1x10^{10}$ faecal coliforms/day. As such its' impacts should be minor and localised. The maximum concentration of faecal coliforms recorded is however over two orders of magnitude higher than the average so this loading is likely to be significantly higher at times. Bosham STW, which discharges to Furzefield Creek, is much smaller (consented dry weather flow of 1,221 m^3/day) and final effluent testing data from here also shows that the UV treatment applied is generally very effective. An estimate of average bacterial loading generated by this discharge is around $6.0x10^8$ faecal coliforms/day, but again the maximum concentration of faecal coliforms recorded in its effluent is over two orders of magnitude higher than the average. It must be noted that UV disinfection is less effective at eliminating viruses than bacteria, so the associated risks of norovirus contamination may be greater than their bacterial loadings may suggest.

Another discharge of significance is Thornham STW, which provides secondary treatment for a consented dry weather flow of 6,565 m^3/day and generates an estimated bacterial loading of $2.2x10^{13}$ faecal coliforms/day. This is considerably higher than the two UV treated works. It discharges to a freshwater body on Thorney Island (Great Deep) which subsequently discharges into the harbour in the upper reaches of Thornham Creek. Great Deep is a lake rather than a stream, and effectively provides additional lagoon treatment which should significantly reduce faecal coliform load received by the harbour. The extent to which this occurs will be dependent on the retention time. Four samples were taken from the Great Deep by the sluice outfall during late autumn 2009 and these contained an average of 16,749 faecal coliforms (presumptive)/100ml. This limited data suggests Thornham STW is a significant contaminating influence during the colder wetter months at least. A sample taken during the shoreline survey (late May) contained 730 *E. coli*/100ml.

The remaining five water company sewage works (West Marden, West Stoke, Hillside Cottages, Maudlin and Lavant STWs) are relatively minor and discharge inland. The first three discharge to soakaway, so should have no impact on coastal waters assuming they are functioning correctly. The latter two discharge to the River Lavant or a tributary thereof so will contribute to the bacterial loading carried by this watercourse, although some bacterial die-off is anticipated during passage to the harbour. Lavant STW provides secondary treatment for a consented dry weather flow of 1,696 m^3/day so will generate a bacterial loading in the order of $5.6x10^{12}$ faecal coliforms/day. The treatment type and consented discharge volumes are not known for Maudlin STW.

There are a series of 18 intermittent (storm and/or emergency) discharges associated with the water company sewer networks within the Chichester Harbour catchment. Of these, five have spill monitoring, and four of these monitored outfalls hardly spilled at all (<0.5% of the period January 2008 to March 2012). The monitored intermittent outfall from Chichester STW storm tanks however spilled for

19.2% of this period so is likely to be a significant contaminating influence. The Chichester sewer network receives significant groundwater infiltration, and the vast majority of these spills occurred during the autumn and winter months when the water table is high. Bacteriological testing of water from this storm tank indicates it consistently contains high concentrations of faecal coliforms (geometric mean of 1.7×10^6 cfu/100ml). It is therefore likely to be a very significant influence during the autumn and winter within the Chichester Channel and quite probably beyond. The high spill frequency indicates that its impacts are likely to be captured twice on average over the course of a years' month monitoring. The Environment Agency commented that Chichester storm tank discharge is not due for completion until spring 2014 at the earliest. This should reduce the concentrations of bacterial indicators within the effluent. How effective this will be for the relatively turbid storm sewage is uncertain. For unmonitored outfalls it is difficult to assess their potential impacts aside from noting their location and potential to spill untreated sewage.

Intermittent discharges create issues in management of shellfish hygiene however infrequently they spill. Their impacts' are not usually captured during a year's worth of monthly monitoring from which the classification is derived as they only operate occasionally. Thus when they do have a significant spill, heavily contaminated shellfish may be harvested under a better classification than the levels of E. coli within them may merit. A reactive system alerting relevant parties to spill events in real time may therefore convey better public health protection. LEAs and harvesters should be aware that notifications of discharges from the monitored outfalls are provided by Southern Water and displayed on the Chichester Council website. The LEAs may wish to consider issuing alerts to harvesters via the local action group emailing list when spills occur.

Although the majority of properties within the survey area are connected to mains sewerage, there are a significant number of privately owned sewage discharges. Most are small treatment works such as package plants or septic tanks serving one or a small number of properties. There are two relatively large private discharges which discharge just outside the entrance to Chichester Marina. Both Birdham Canal Houseboats and Chichester Yacht Basin are served by what appeared to be secondary treatment and have consented flows of 55 and 18 m^3/day respectively. These may create a small 'hotspot' of contamination within the small embayment to which they discharge.

There is a cluster of private (domestic) discharges around Furzefield Creek, all but one of which discharge to the creek or to ditches draining to the creek. Some of these were seen on the shoreline survey, and not all appeared to be in recent use. There is a smaller cluster of private discharges feeding to a surface water drain at Chidham. There is also a cluster at Shipton Green (including a caravan park consented to discharge up to 40 m^3/day) which may significantly add to the bacterial loadings carried by watercourses draining this area. Most of the larger watercourses draining to the heads of the various branches of the harbour also receive inputs from private discharges. Therefore, impacts from private discharges may primarily be felt within Furzefield Creek, Chidham Creek, and in the runoff carried into the harbour by the stream discharging at West Wittering. Some evidence of sewage contamination of surface drains was observed during the shoreline survey along the south shore of the creek at Eastoke, southern Hayling Island, although there are no consented discharges in the vicinity.

Agriculture

The majority of agricultural land within the hydrological catchment of Chichester Harbour is used for arable farming. There are also some pockets of pasture, the most extensive areas of which are on Thorney Island and Hayling Island. The Chichester Harbour hydrological catchment supports relatively low numbers of livestock (4,307 cattle, 6,342 sheep, 4,012 pigs and 11,356 poultry in the 2010 census). Major impacts from agriculture are therefore not anticipated, although some impacts are likely to occur in places. During the shoreline survey grazing livestock were recorded on fields adjacent to the harbour at the northern end of Hayling Island, west of Emsworth, at Southbourne, on Thorney Island, and by the head of the Chichester Channel. No areas of grazed saltmarsh were observed.

Faecal matter from grazing livestock is either deposited directly on pastures, or collected from livestock sheds if animals are housed indoors during the colder months and then applied to agricultural lands as a fertilizer. Manure from pigs and poultry is typically stored and applied tactically to nearby farmland. Treated sewage sludge may also be applied to some crops. These will then be washed into watercourses with field runoff, so fluxes of agricultural contamination into coastal waters are highly rainfall dependent. The areas most susceptible to agricultural contamination are by streams and surface water outfalls draining adjacent areas of pasture (Hayling Island, west of Emsworth, Southbourne, Thorney Island, and the head of the Chichester Channel). Sporadic, more localised impacts may arise in most of the other larger watercourses as well as some smaller field drains as a result of the application of organic fertilisers to arable lands. In the upper catchment, flows of water are through chalk aquifers, which are very slow so little microbiological contamination is likely to survive the passage.

There is likely to be some seasonality in the amount of agricultural contamination washed into Chichester Harbour. 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. Slurry generated from the indoor housing of cattle in the winter is likely to be spread in the late winter and spring, depending on the storage capacities of each farm. The seasonal pattern of application of pig and poultry manures and sewage sludge to agricultural land is uncertain. Rainfall and river flows are generally higher during the winter months, although 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').

Boats

Chichester Harbour is very busy in terms of boat traffic, which principally consists of leisure craft such as yachts and cabin cruisers. Almost 12,000 boats are registered to the harbour, and there are 2,250 marina berths and numerous yacht moorings spread throughout it. There are six main marinas and at least 12 sailing clubs, with sewage pumpout facilities only available at two of the marinas. A small commercial fishing fleet also operates from the harbour, and watersports such as kayaking and dinghy sailing are also popular. The discharge of sewage from boats is therefore potentially a significant source of bacterial contamination of shellfisheries within Chichester Harbour.

It is likely that the larger of the private vessels (yachts, cabin cruisers, fishing vessels) which have onboard toilets make overboard discharges from time to time. Boats in marinas may be less inclined to make overboard discharges as it is antisocial and onshore facilities are easily accessed. Those in occupation on moorings, or those in transit through the estuary may be more likely to discharge. Moorings and anchorages are an almost continuous presence in Chichester Harbour, with most located in the subtidal channels. As such, almost anywhere in the harbour may be impacted by overboard discharges and such inputs are considered as diffuse. The greatest concentrations of moorings are in the upper and lower reaches of the Emsworth Channel and associated creeks, and in the Chichester Channel between Itchenor and Birdham. There are also large numbers of moorings in the middle and upper reaches of the Thorney Channel, throughout the Bosham Channel, and at Dell Quay. Pleasure craft activity is much higher during the summer, so associated impacts are likely to follow this seasonal pattern.

It is difficult to be more specific without any firm information about the locations, timings and volumes of such discharges. Overboard discharges made by vessels on passage may occur almost anywhere and at any time so will not influence the sampling plan. Those made by moored boats may be best captured by locating RMPs within the densest mooring areas.

Wildlife

Chichester Harbour encompasses a variety of habitats including large areas of tidal inlets and creeks, saltmarsh in the upper reaches, intertidal mudflats, eelgrass beds and sand and shingle beds. These features attract significant populations of birds and other wildlife. The most significant wildlife aggregation in terms of shellfish hygiene is likely to be overwintering waterbirds (waders and wildfowl). An average total count of 51,071 waterbirds (waders and wildfowl) was reported over five winters up to 2010/11 for Chichester Harbour. Some species of waders feed on intertidal invertebrates so will forage (and defecate) directly on the shellfish beds across a wide area. They may tend to aggregate in certain areas holding the highest densities of their preferred size and species of prey, but this may vary from year to year. They will therefore represent a diffuse input and whilst they may be a significant contaminating influence at times, they will not influence the positioning of any RMPs. Other overwintering waterbirds such as ducks and geese will mainly frequent the saltmarsh and coastal grasslands, where their faeces will be carried into coastal waters via runoff into tidal creeks or through tidal inundation. RMPs positioned in or by creeks and channels draining from such areas would be best positioned to capture contamination from these.

Although the majority of waterbirds migrate elsewhere to breed, other species such as gulls and terns are present during the summer months. Relatively small numbers of such birds use Chichester Harbour. They are likely to forage around the harbour so represent a minor source of diffuse contamination, but this will not influence the sampling plan.

There is a colony of around 25 harbour seals which frequent the harbour on a daily basis. They haul out on the intertidal mudflats, but the more precise locations of their preferred haulout sites, where heaviest impacts are anticipated, are not known. They forage widely so outside of their haulout sites their impacts are likely to be minor, and diffuse, and unpredictable in spatial terms. During the moulting and pupping season (June to August for harbour seals) they tend to spend more time on haulouts in the harbour so there may be increased impacts during these times.

Domestic animals

Dog walking takes place along the coastal path that runs adjacent to much of the shoreline of the harbour, and represents a potential source of diffuse contamination to the near shore zone. Coast paths by the more heavily populated areas are likely to see a greater intensity of dog walking. However, 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	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Continuous sewage discharges	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange
Intermittent sewage discharges	Red	Red	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Red	Red	Red
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	Red	Red	Red	Red	Red	Yellow	Yellow	Yellow

Red - high risk; orange - moderate risk; yellow - lower risk; white - little or no risk.

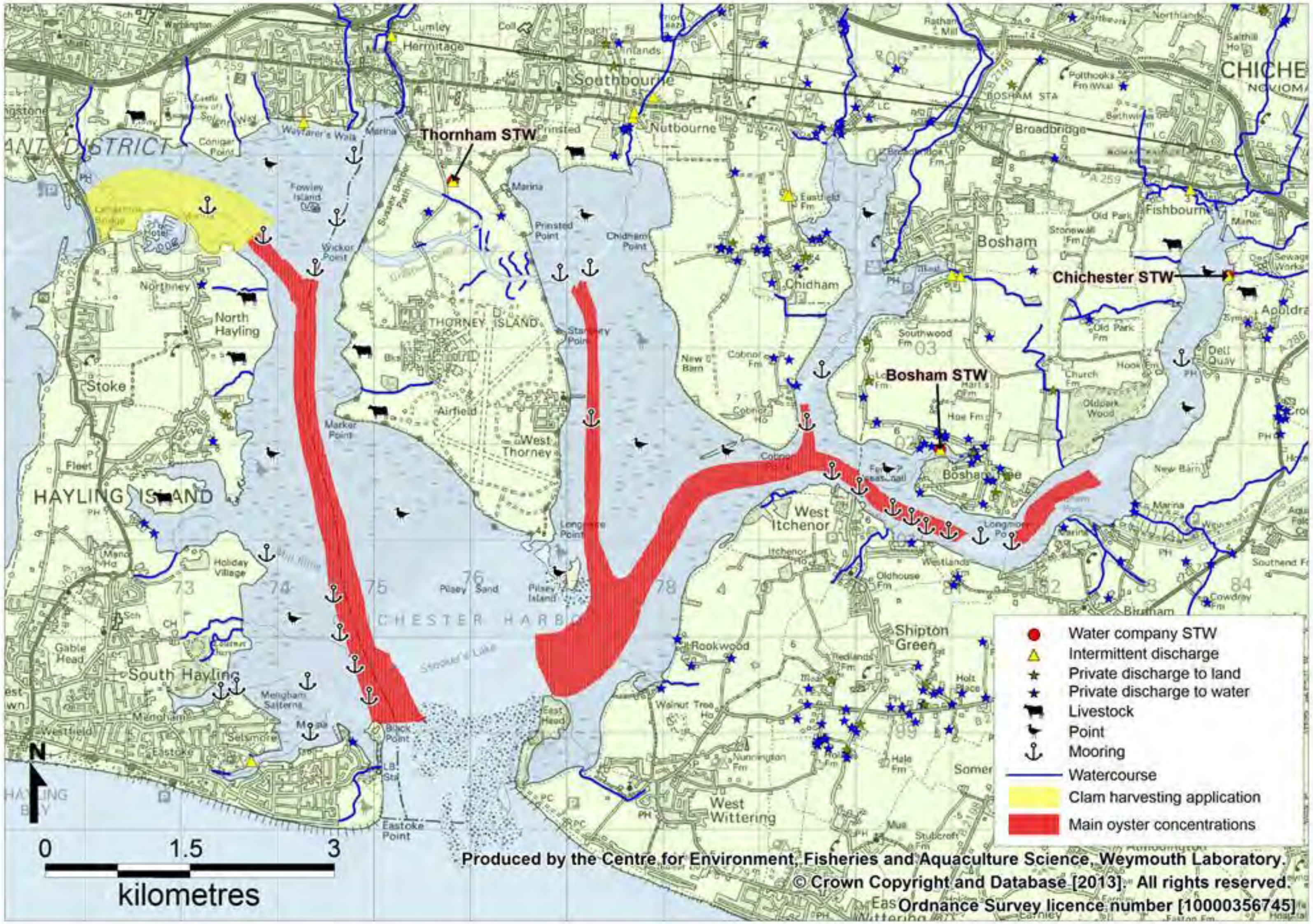


Figure 5.1: Summary of main contaminating influences

5.4. Hydrography

Chichester Harbour is a shallow semi-enclosed branching tidal inlet with four main channels (the Chichester Channel, the Emsworth Channel, the Thorney Channel, and the Bosham Channel). The main Chichester channel is about 13 km in length and meanders in a north easterly direction from the entrance, from which the other three channels emanate in a northerly direction. The harbour faces south and is connected to the eastern Solent via a relatively narrow, deep mouth. There is also a secondary connection to the neighbouring Langstone Harbour at the top of the Emsworth Channel which dries at low water. Intertidal areas form a large proportion of the harbour (78%) with the subtidal channels occupying the rest. The channels become shallower in their upper reaches, where muddier sediments are more prevalent, and some areas are flanked by saltmarsh.

The tidal range is up to 4.4 m on spring tides and 2.1 m on neap tides, and this drives extensive water movements throughout the harbour. Tidal streams are bi-directional, with relatively clean water from the English Channel entering and moving up the harbour on the flood tide, and with the ebb tide carrying contamination from shoreline sources out through the harbour. The main flows align with the subtidal channels, although the complicated shape of the harbour may result in eddy currents forming in some places at times. Tidal streams are strongest in the entrance (up to 3.3 m/s on spring tides), but decrease inside the harbour to peak flows in the main channels of around 0.5 to 1 m/s. They are weaker in the upper reaches of the channels. Peak neap tide current velocities are just under half those on spring tides. Tidal excursion along the subtidal channels is likely to be in the approximate order of between 5 and 10km on spring tides and about 2 to 5 km on neap tides.

The four main channels will be primarily influenced by sources of contamination discharging directly to them. There is the potential for some impacts from major sources in other channels carried back up the harbour on the subsequent flood tide, although they will be subject to dilution and mixing during travel. The potential for such exchanges is greatest between adjacent channels. Although the vast majority of water exchange occurs via the mouth there is some limited exchange of water through the secondary connection to Langstone Harbour. The net movement of water through here is out of Chichester Harbour, so sources of contamination to north east Langstone Harbour should be of little impact.

Over the intertidal areas away from the main subtidal channels tidal current velocities are much lower. In places at some states of the tide the currents will run parallel to the shore, so impacts from shoreline sources will arise to either side, and the magnitude of their impacts will decrease with distance as the plume spreads and becomes more diluted. In other places, where there are drainage channels or where creeks cut across the intertidal area, these have a more perpendicular orientation to the main channels. Relatively high concentrations of faecal indicator bacteria may arise at lower states of the tide in the intertidal channels and creeks which receive inputs from shoreline sources such as watercourses. Either way, contamination from shoreline sources will initially remain on the same side of the subtidal channel to which they discharge.

The volumes of freshwater inputs to the harbour are very low in relation to volumes exchanged by the tides. Therefore the harbour can be considered well mixed and stratification and associated density driven circulation is highly unlikely to be of any significance. Salinity measurements from twelve points within the harbour indicate average salinities approaching that of full strength seawater throughout. Slightly lower average salinities indicative of more significant freshwater influences were recorded at the sites in the Chichester Channel. Despite the relatively low variation in salinity, salinity was negatively correlated with levels of faecal coliforms in surface water samples at the main three shellfish water monitoring points (Emsworth Channel, Thonham Channel and Chichester Channel). This suggests that freshwater borne contamination (i.e. land runoff) is a major influence at times.

Strong winds may modify tidal circulation at times by driving surface currents. These in turn create return currents at depth or along sheltered margins. Chichester Harbour is most exposed to the south, whereas the prevailing wind is from the south west. The prevailing winds will tend to push surface water in a north easterly direction, or up the Chichester channel. 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. As well as driving surface currents, onshore winds create wave action. This may resuspend any contamination held within the sediments of the intertidal zone, temporarily increasing levels of contamination within the water column until it is carried away by the tides. Given the enclosed nature of the harbour strong wave action is not generally anticipated. The intertidal area to the south of Thorney Island is most exposed, so is likely to experience more energetic wave action than other parts of the harbour. Within the inner reaches of the harbour channels, strong onshore winds may create waves large enough to disturb the finer sediments present here despite the limited fetch.

5.5. Summary of Existing Microbiological Data

Chichester harbour has been subject to considerable microbiological monitoring over recent years, deriving from the monitoring of recreational water quality by Chichester DC and Chichester Harbour Conservancy, the Shellfish Waters monitoring programme, and shellfish flesh monitoring for hygiene classification purposes. Figure 5.2 shows the locations of the monitoring points referred to in this assessment. Only the results of samples since April 2008 were considered as major upgrades to the local sewerage systems were completed at this time.

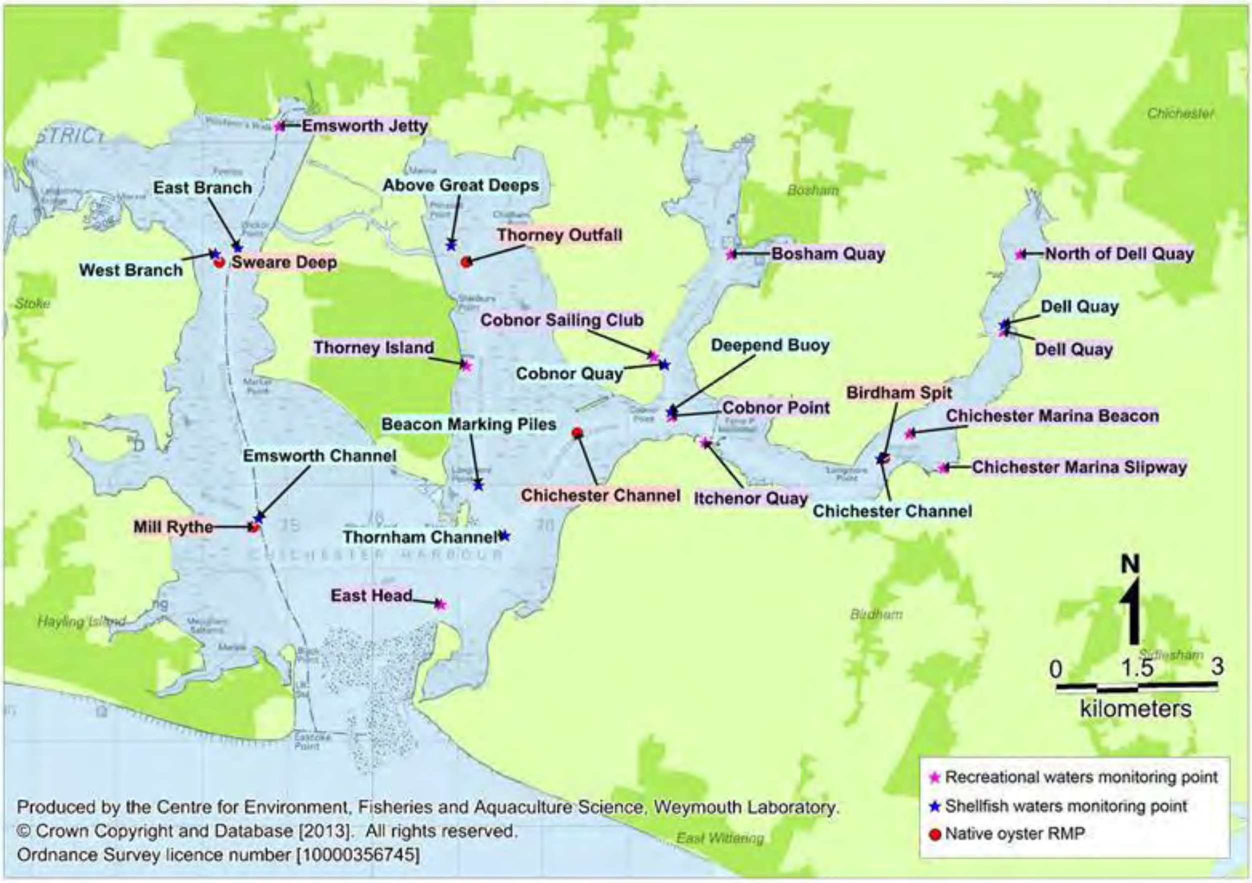


Figure 5.2: Location of microbiological sampling sites.

Chichester District Council and the Chichester Harbour Conservancy have tested water samples for *E. coli* levels from 11 sites across the harbour at regular intervals on a year round basis. Generally, all of these sites were sampled on each sampling occasion. Of these sites the highest average and peak levels were recorded in the upper reaches of the Chichester Channel (Dell Quay and North of Dell Quay). Results were also relatively high on average within the small embayment by Chichester Marina (Chichester Marina Slipway) but not in the main channel on the opposite bank (Chichester Marina Beacon) suggesting that there are some significant local inputs to this embayment. Relatively high average levels of contamination were also recorded at the head of the Emsworth Channel (Emsworth Jetty) in close proximity to the River Ems outfalls. When paired (same-day) sample results were compared, significant correlations in levels of *E. coli* were found between all sites tested except Emsworth Jetty. This is perhaps unsurprising given that Emsworth Jetty is relatively remote from the other sites and is located near to the mouth of the River Ems. From 2008 to 2013, results have been reasonably stable at all sites with no evidence of any major improvements or declines in water quality. A seasonal pattern of highest average results in the winter was observed at all sites apart from Emsworth Jetty, where no pattern was apparent. This pattern of highest results in the winter was statistically significant in all cases apart from Chichester Marina Slipway, suggesting that this site may be under slightly different contaminating influences from the rest of the Chichester Channel. The absence of a summer peak tentatively suggests that inputs from boats are not a great influence.

A significant influence of tidal state was found at some sites. Across the high/low tidal cycle higher results occurred at Emsworth Jetty during the flood tide. The reasons for this are uncertain. At East Head and North of Dell Quay, higher results tended to occur during the ebb suggesting upstream sources are of significance. At Chichester Marina Slipway there was a tendency for greater numbers of lower results during the early stages of the ebb tide, for which there is no obvious explanation. Across the spring/neap tidal cycle, there appeared to be a slight tendency for lower results on spring tides at Chichester Marina Beacon and Chichester Marina Slipway. At Dell Quay results were higher on average as the tide size decreased from spring to neap, whereas at North of Dell Quay the opposite pattern can be seen. Again, no obvious explanation can be offered for these findings. *E. coli* levels at all sites across the harbour were influenced by rainfall to a similar extent, with rainfall between two and four days prior to sampling being of greatest influence. This is consistent with the relatively rapid runoff associated with a small catchment area.

Differences between the *E. coli* results recorded when the Chichester STW storm tanks had and had not recorded a spill in various intervals prior to sampling were investigated. Significant differences between samples taken when there were and were not recent spills were detected at all sites apart from Bosham Quay, Cobnor Sailing club and Chichester Marina Slipway, although t-tests suggested that the effect was nearly significant at the 0.05 level at Chichester Marina Slipway for 24 and 48 hours. This would suggest that spills from Chichester STW have wide ranging effects. However, such conclusions should be treated with caution as conditions associated with spills (wet weather when the water table is high) will also be associated with increased inputs of indicator bacteria from other sources such as rivers. An effect was detected at Emsworth Jetty for example when a 72 hour interval between the spill event and sampling was considered. The delay is consistent with its location relative to the discharge, although it would perhaps seem unlikely that a detectable influence would extend this far.

There are three shellfish water sites in Chichester Harbour; Emsworth Channel, Thornham Channel and Chichester Channel. These sites are sampled for faecal coliforms in water on a quarterly basis. Additionally a further seven locations were sampled on 6-8 occasions in 2008/09. Across the main three sites there was no significant difference in average results, and the numerical distribution of results was similar across them all. Chichester Channel had higher results on average and in terms of the number of samples exceeding 100 and 1000 faecal coliforms/100ml. Paired (same day) sample comparisons across these sites showed that results were significantly correlated on a sample by sample basis for all site pairings. This suggests that all three are under broadly similar contaminating influences. Of the seven sites sampled on a more limited basis the average results at all sites were very similar and low, with the exception of Dell Quay, where the average result was notably higher. A scatterplot of sample results by date collected suggested an increase in levels of faecal coliforms since 2011 at all three of the main sites. Again, results were highest on average during the winter at all three main sites. This effect was much more pronounced at Emsworth Channel and Chichester Channel than at Thornham Channel. No significant influence of tidal state, either across the high/low or spring/neap cycle was observed at these three sites. Faecal coliform levels at all sites across the harbour were influenced by rainfall to some extent. This influence was strongest at Thornham Channel. Significant negative correlations between salinity and levels of faecal coliforms were found for all three sites. The relationship was strongest at Chichester Channel, where variation in both parameters was greatest. This suggests that freshwater borne contamination (i.e. land runoff) is a major influence throughout the harbour at times. In the case of Chichester Channel, spills from the Chichester STW storm tanks are more likely to occur when freshwater inputs are higher, so it is difficult to categorically separate these two influences. Insufficient data was available to undertake a meaningful investigation into the effects of spills from the Chichester storm tanks on bathing waters faecal coliform results.

Under the hygiene classification sampling programme, there are five RMPs where native oysters are sampled and tested for *E. coli* most months (Birdham Spit, Chichester Channel, Thorney Outfall, Sweare Deep and Mill Rythe). Results were markedly higher at Birdham Spit and Thorney Outfall both in terms of geometric mean result (501 and 445 *E. coli* MPN/100g) and the proportion of samples exceeding 4600 *E. coli* MPN/100g (11.7% and 10.2%). Thorney Outfall is located where it is likely to be influenced by sewage discharged via the Great Deep. Birdham Spit may be influenced by the Chichester STW, private STWs by Chichester Marina, and the River Lavant. Geometric mean levels of *E. coli* at all other RMPs were less than 300 MPN/100g, and less than 4% of their results exceeded 4600 *E. coli* MPN/100g. Since 2008, results at most sites appear to have been relatively stable. At Birdham Spit however, results appear to have deteriorated since 2011.

The seasonal pattern observed with water sampling of higher levels of bacterial contamination during the winter was not apparent at any of the oyster RMPs. In fact the opposite pattern was observed at four of the five RMPs, with levels of contamination peaking in the summer and autumn. This is probably mainly due to increased metabolic rates in oysters during the warmer months of the year resulting in increased uptake of indicator bacteria. Almost no seasonal variation was seen at Birdham Spit, suggesting it may be subject to a different profile of contaminating sources than most other areas of the harbour.

Correlations between levels of *E. coli* and tidal state on the spring/neap tidal cycle were detected at three of the RMPs. At Mill Rythe and Sweare Deep *E. coli* levels tended to be higher on average just after low water, possibly suggesting a build up of contamination on the later stages of the ebb tide. At Thorney Outfall, *E. coli* levels were highest towards the end of the ebb tide, possibly relating to the release of water from the Great Deep outfall. An effect of tidal state across the spring/neap tidal cycle was detected at two of the RMPs. At both Mill Rythe and Sweare Deep, higher *E. coli* results tended to occur around the spring tide. This may suggest that more distant sources are of significance at these RMPs. A significant influence of recent rainfall on levels of *E. coli* was found at all RMPs. This was weaker at Birdham Spit and Mill Rythe compared to the other three RMPs.

Differences between the *E. coli* results recorded when Chichester STW storm tanks had and had not recorded a spill in various intervals prior to sampling were investigated. No statistically significant effect was found for any of the RMPs, although sample numbers were perhaps slightly too low for a robust analysis in most cases. When the data was plotted, a noticeable influence at Birdham Spit, and possibly at Chichester Channel was observed. All sites had higher average results and a lesser frequency of low results following recent spills. Again, this illustrates the difficulty of separating the impacts of spills from the impacts of increased freshwater inputs, both of which will tend to occur under similar conditions. The more marked increases observed following spills at Birdham Spit, and to a lesser extent Chichester Channel do however fit with the anticipated geographical patterns of impacts from this discharge.

Appendices

Appendix I. Human Population

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

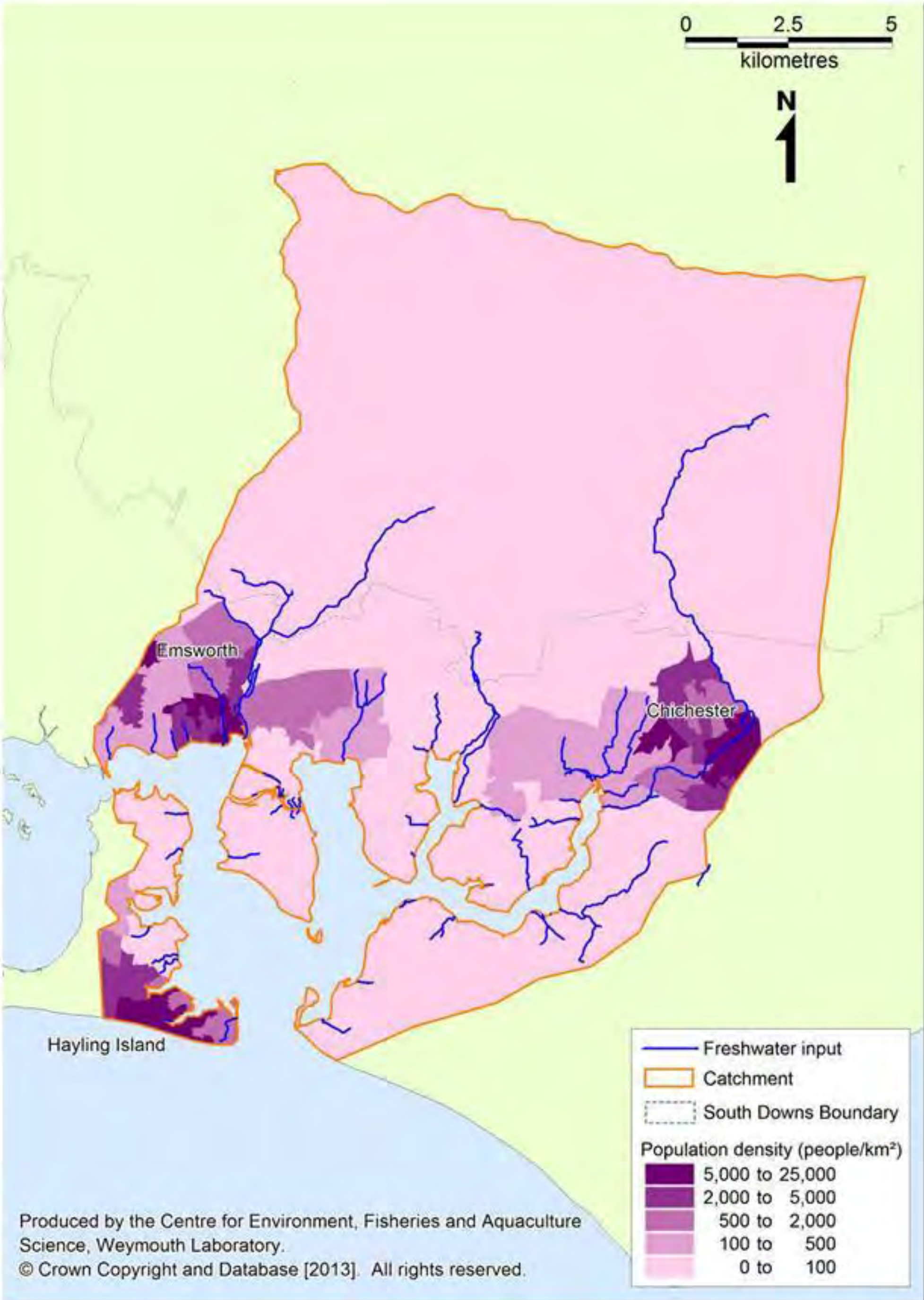


Figure I.1: Human population density in census areas in the Chichester Harbour catchment.

Total resident population within the Chichester Harbour catchment area was approximately 106,000 at the time of the last census. Figure I.1 indicates that population densities are highest on the north and west sides of the harbour around Hayling Island, Emsworth and Chichester. All of these areas exceed 5,000 people/km², but Chichester has the highest density with parts exceeding 16,600 people/km². Most of the population in the catchment is located at the northern end of the channels where rivers meet the harbour. These areas are therefore at the most risk from contaminated urban runoff. Impacts from sewage will depend on the nature and locations of discharges associated with these settlements and are discussed in detail in Appendix VII.

Approximately 55% of the catchment is covered by South Downs National Park; its boundary running north of Emsworth and Chichester. Population densities here are relatively low, not exceeding 100 persons per km^2. However this number is likely to increase during the summer months when tourists visit the South Downs for its rich English history and to take part in outdoor activities such as walking or cycling. Hayling Island attracts tourists to its long stretches of unspoilt Blue flag beaches, watersports and close proximity to Portsmouth.

With its historic city centre and cathedral, several music and art festivals and easy access to the South Downs, Chichester Harbour and Goodwood racecourse, the District of Chichester receives approximately 5.7 million tourists per year (Chichester District Council, 2010).

Chichester Harbour itself is designated as an Area of Outstanding Natural Beauty (AONB) and attracts around 1.3 million tourists annually. Much of the population increase in summer months in the AONB is due to around 14% of the homes being second homes (Chichester Harbour Conservancy, 2009). There are several large holiday parks adjacent to the harbour on Hayling Island.

Although accurate tourism figures are not known for the majority of the catchment it is likely that the numbers are relatively high in the summer months due to it being situated with a national park in the north, seaside resorts in the south (Hayling Island) and in close proximity to both Portsmouth and Chichester. Therefore it can be assumed that there will be a significant seasonal variation of population levels in the catchment and the volumes of sewage received by the various sewage treatment works serving the area would be expected to fluctuate accordingly.

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

Details of all consented discharges in the Chichester Harbour Hydrological catchment were taken from the most recent update of the Environment Agency national permit database (December 2012). These are mapped in Figure II.1.

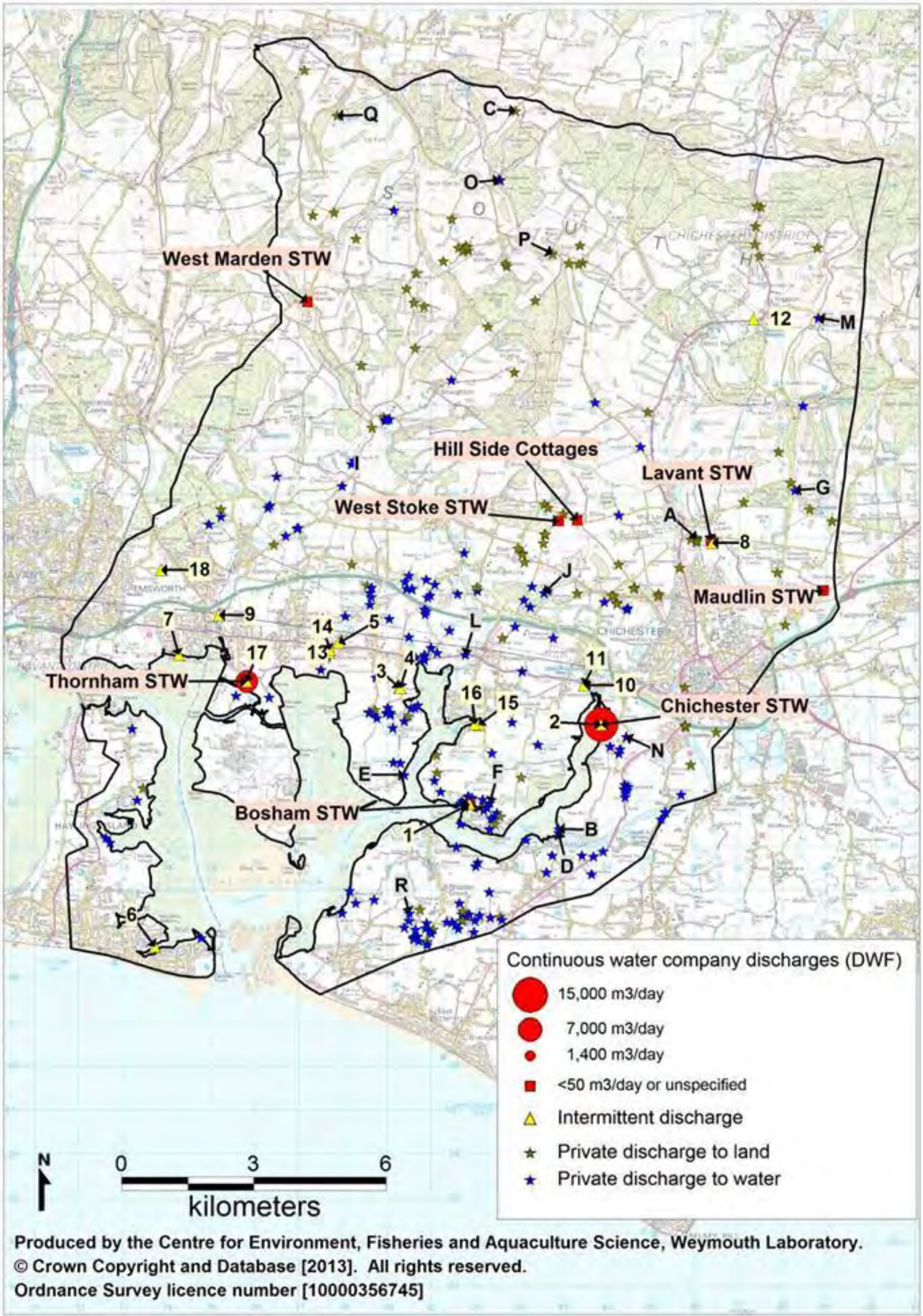


Figure II.1: Sewage discharges to the Chichester Harbour catchment

There are eight continuous water company discharges to the area, details of which are presented in Table II.1.

Table II.1: Details of continuous water company sewage works

Name	NGR	Treatment	Dry weather flow (m^3/day)	Estimated bacterial loading (cfu/day)	Receiving environment
Bosham STW	SU8088001940	UV disinfection	1221	$5.97x10^{8}$**	Chichester Harbour
Chichester STW	SU8387003750	UV disinfection	13524	$1.13x10^{10}$**	Chichester Harbour
Hill Side Cottages	SU8332008400	Unspecified	(Max flow) 4		Soakaway
Lavant STW	SU8637007930	Secondary	1696	$5.60x10^{12}$*	River Lavant
Maudlin STW	SU8892006800	Unspecified	Unspecified		Unnamed watercourse
Thornham STW	SU7582004730	Secondary	6565	$2.17x10^{13}$*	Little Deep
West Marden STW	SU7719013360	Secondary	40		Soakaway
West Stoke STW	SU8290008380	Unspecified	Unspecified		Soakaway

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

Table II.2 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.

Two of these discharge directly to Chichester Harbour (Bosham STW and Chichester STW). Both of these provide UV disinfection. Table II.3 and Figure II.2 summarise the results of bacteriological testing of the final effluents.

Table II.3 Summary statistics for final effluent testing data from UV treated works, July 2008 to June 2011

Sewage works	No.	Geometric mean result (cfu/100ml)	Minimum	Maximum
Bosham STW	70	48.9	0	24,200
Chichester STW	73	83.8	0	24,200

Data from the Environment Agency

Bacteriological testing results for the final effluent from both indicate that disinfection is consistently effective. The estimated (average) bacterial loading they generate is therefore very small, although the maximum concentration of faecal coliforms recorded is over two orders of magnitude higher than the average. It must be noted that UV disinfection is less effective at eliminating viruses than bacteria (e.g. Tree *et al*, 1997).

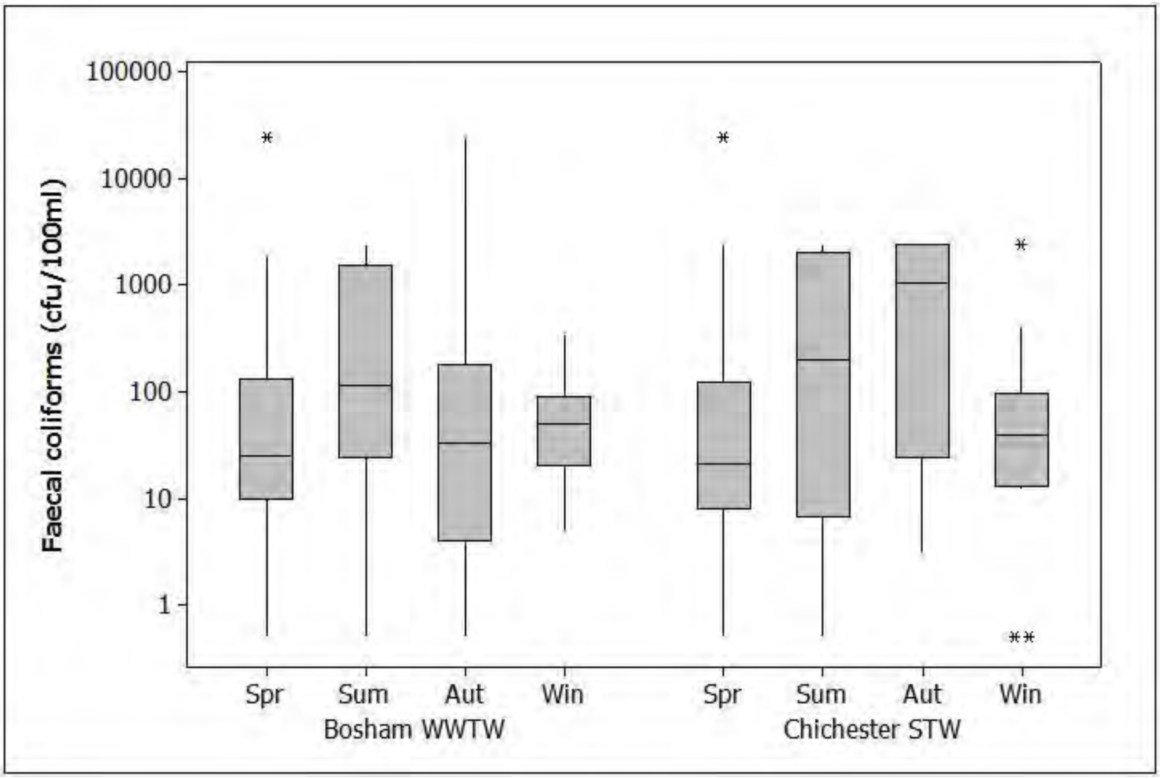


Figure II.2: Boxplot of faecal coliform concentrations in STW final effluent by season.
Data from the Environment Agency.

Some seasonality in faecal coliform concentrations was observed at both STWs, with higher average results in the summer at Bosham and in the summer and autumn at Chichester.

Another discharge of significance is the Thornham STW, which discharges to a drain which subsequently empties into the harbour in the upper reaches of Thornham Creek. This effectively provides additional lagoon treatment, which should significantly reduce faecal coliform loads received by the harbour. The extent to which this occurs will be largely dependent on the retention time. During the autumn of 2009 a series of samples were taken from four locations and tested for faecal coliforms (presumptive) to investigate the impacts of this sewage works. Between four and seven samples were taken from each location. Figure II.3 shows the sample locations and Figure II.4 shows boxplots of the results.

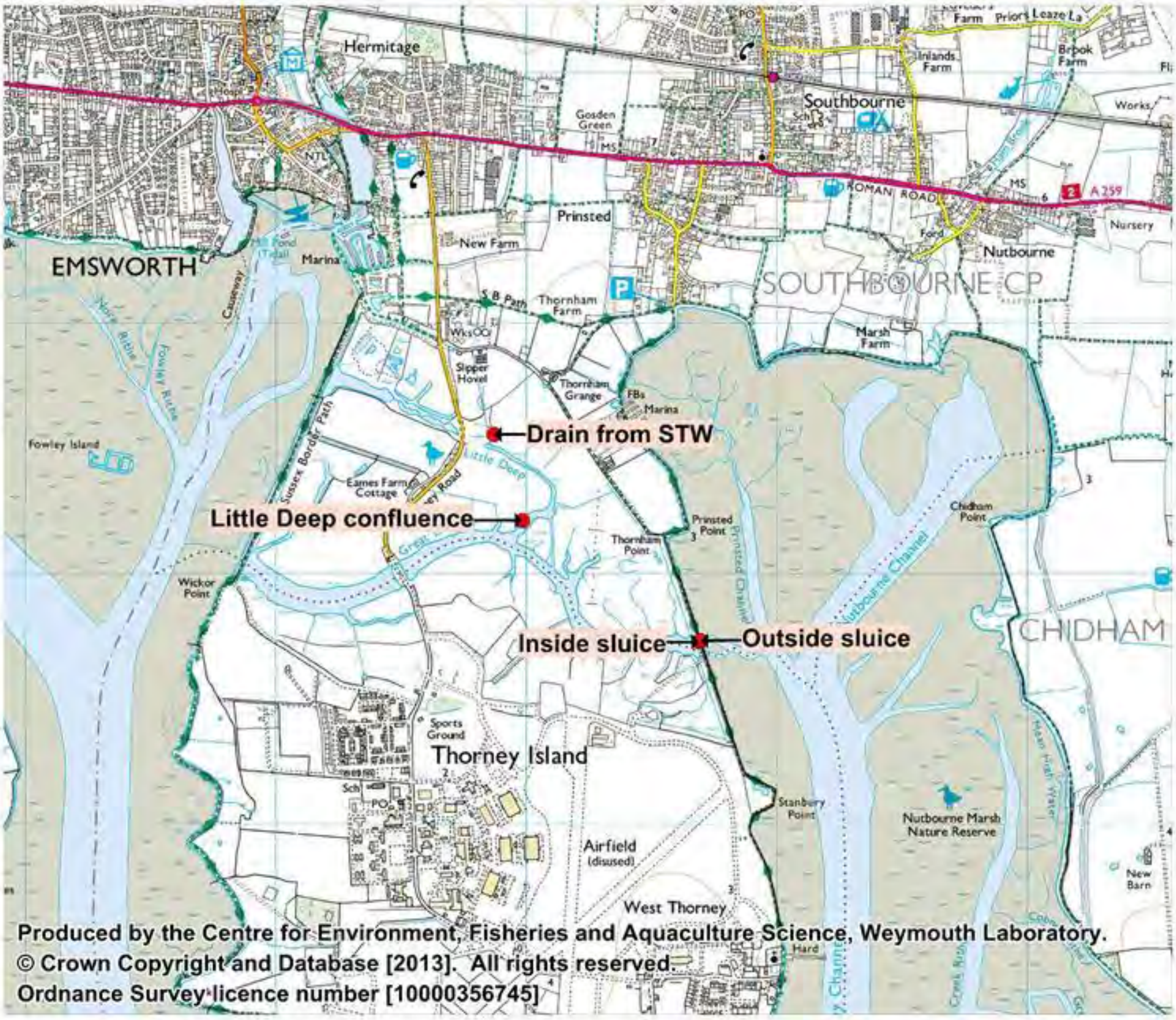


Figure II.3: Sampling locations within Great Deep

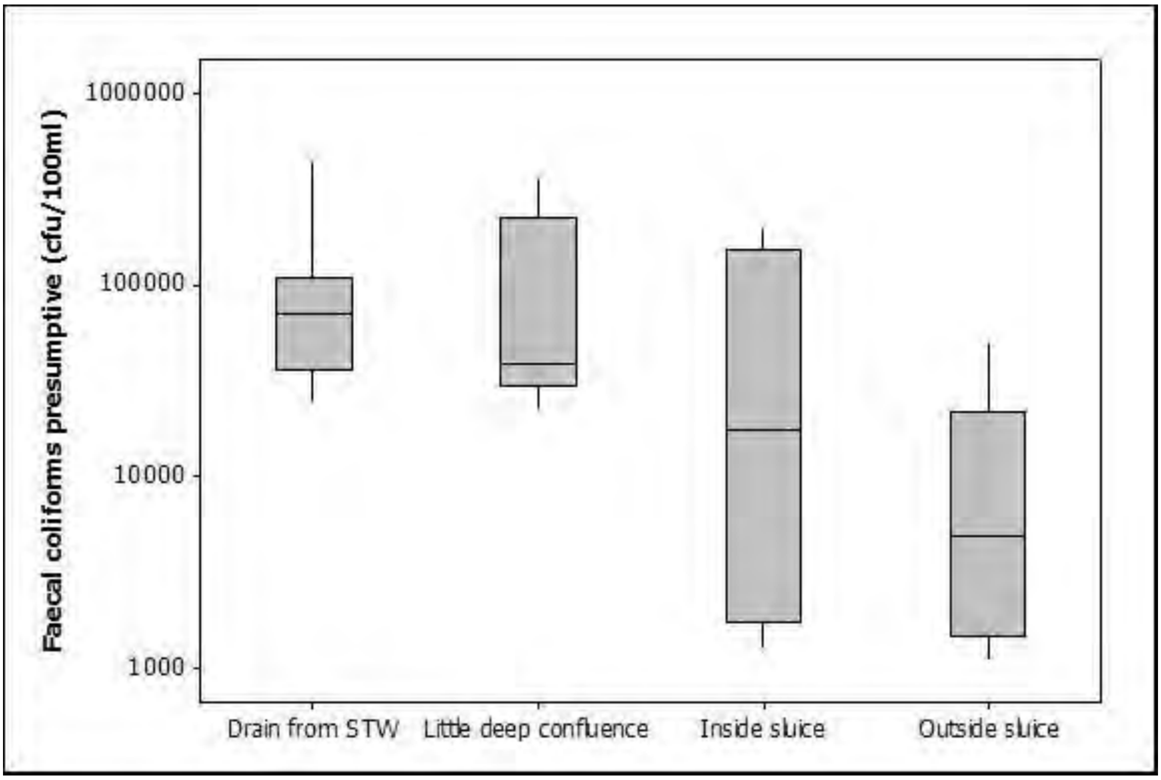


Figure II.4: Boxplot of sample results from Great Deep

A decrease in levels of faecal coliforms can be seen from the Little Deep confluence through to the sluice. High average levels of faecal coliforms were however still present within Great Deep just inside the sluice outfall (16,749 cfu/100ml). These samples were taken in late autumn when environmental conditions will be less favourable for bacterial dieoff. A sample taken just inside the sluice during the shoreline survey (late May) contained 730 *E. coli* cfu/100ml.

There are five inland discharges. The largest of these is the Lavant STW which provides secondary treatment and discharges to the River Lavant about 7.5km from its tidal limit. This is likely to add significantly to the bacterial loading carried by this watercourse. Three are very small works discharging to groundwaters (Hill Side Cottages, West Marden and West Stoke STWs) and as such should have no influence on water quality in Chichester Harbour. The final one (Maudlin STW) discharges to an unnamed watercourse, and treatment type and discharge volumes are both unspecified on the permit database.

In addition to the continuous sewage discharges, there are several intermittent water company discharges associated with the sewerage networks also shown on Figure II.1. Details of these are shown in Table II.4, where discharges highlighted in yellow have spill event monitoring.

Table II.4: Intermittent discharges within the Chichester Harbour catchment

No.	Name	Grid reference	Receiving water	Type
1	Bosham STW	SU8088001940	Chichester Harbour	Storm Tank
2	Chichester STW	SU8387003750	Chichester Harbour	Storm Tank
3	Chidham Lane PS	SU7928004590	Unnamed watercourse	Pumping Station
4	Chidham Lane SPS Chidham	SU7931004580	Unnamed watercourse	Pumping Station
5	CSO Breakers Yard Nutbourne	SU7790005610	Ham Brook	Storm overflow
6	Fishery Lane PS	SZ7373098710	Chichester Harbour	Pumping Station
7	Kings Road Emsworth CSO	SU7427105341	Chichester Harbour	Storm overflow
8	Lavant STW	SU8639007880	River Lavant	Storm Tank
9	Lumley Road PS	SU7518006240	River Ems	Storm overflow
10	Main Road Fishbourne PS	SU8347704643	Unnamed watercourse	Storm overflow
11	Mill Lane WPS	SU8347704643	Unnamed watercourse	Pumping Station
12	Pumping Station in field number	SU8733012970	River Lavant	Storm overflow
13	School Lane PS	SU7769005390	Ham Brook	Storm overflow
14	School Lane Sewage PS	SU7770005450	Ham Brook	Pumping Station
15	Sewage Pumping Station Bosham	SU8109003750	Unnamed watercourse	Pumping Station
16	Taylors Lane Bosham WWPS	SU8100003760	Chichester Harbour	Pumping Station
17	Thornham STW	SU7582004730	Little Deep	Storm Tank
18	Woodbine Cottage	SU7387007270	Unnamed watercourse	Storm overflow

Data from the Environment Agency

For those without event monitoring it is difficult to assess their potential impacts aside from noting their location and potential to spill untreated sewage. For those with event monitoring some spill summary statistics covering the period January 2008 to March 2012 are shown in Table II.5, and a bubble plot of spills over time is shown in Figure II.5.

Table II.5 Summary of spill records, January 2008 to March 2012.

Discharge Name	No. events recorded	Mean event duration (hrs)	% of period active
Bosham STW	94	1.82	0.5%
Chichester STW	111	64.40	19.2%
School Lane PS	1	1.98	<0.1%
Taylors Lane Bosham WWPS	145	0.97	0.4%
Thornham STW	5	14.34	0.2%

Data from the Environment Agency

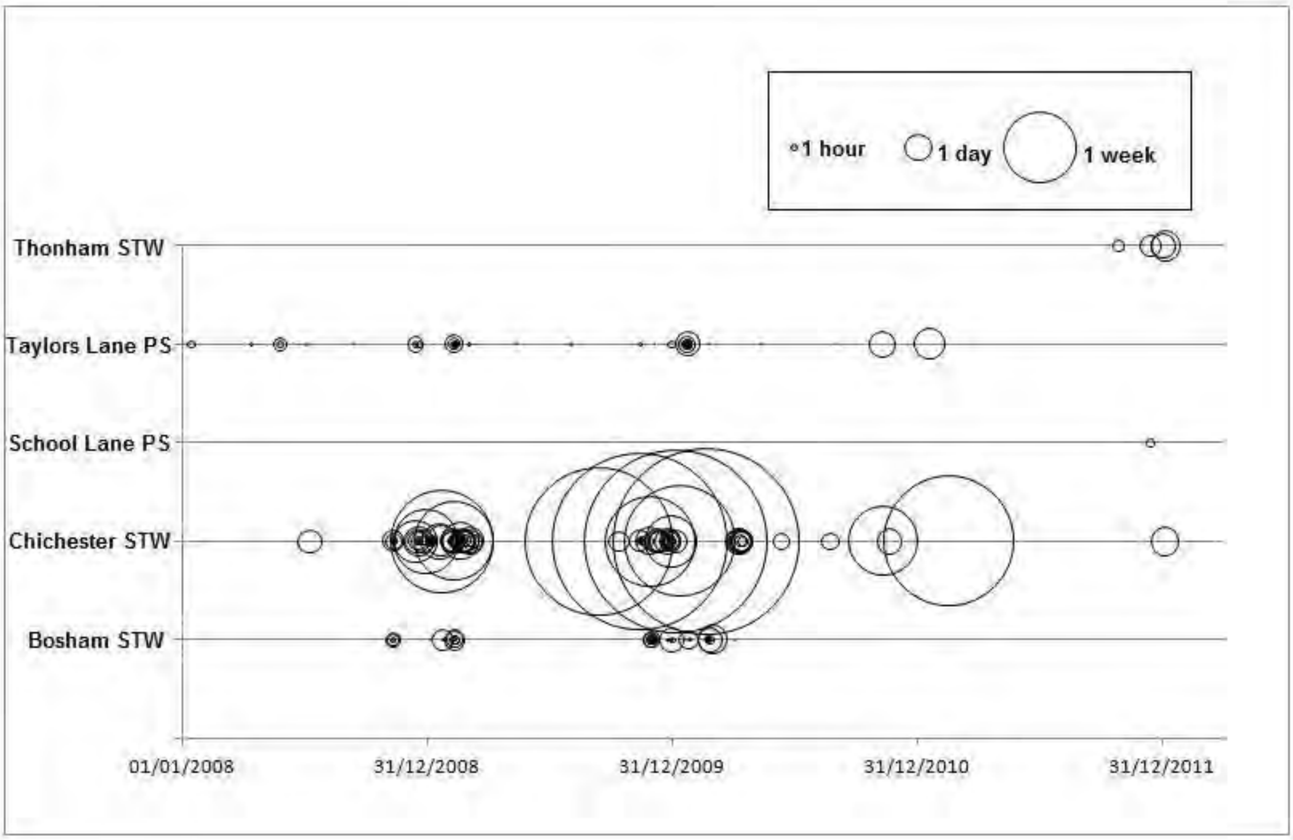


Figure II.5: Bubble plot of recorded spills
Data from the Environment Agency

Of these five discharges, the most active by far was the Chichester STW discharge, which spilled for almost 20% of the period assessed. This discharge is therefore likely to be a significant influence, and should be captured during the course of a year's monthly monitoring. Marked seasonality was observed, with the discharge operational for much higher proportions of the time in autumn and winter (26.1 and 46.2% of the time respectively) compared to spring and summer (1.7 and 0.4% of the time respectively). This is unsurprising as the sewer network here is old and subject to significant infiltration when the water table is high. Only one spill event was recorded here during the dry winter of 2011/12. A series of 27 samples have been taken from the storm tanks by the Environment Agency since 2011. The geometric mean concentration of faecal coliforms (confirmed) within these samples was 1.7×10^6/100ml, with a maximum and minimum of

$1.6x10^5$ and $9.0x10^6$ cfu/100ml. This indicates that effluent from this discharge consistently carries high levels of bacterial contamination. It is due to be fitted with UV disinfection by the end of 2013, which should reduce bacterial concentrations but may not be particularly effective if the effluent is turbid, and again will not be so effective for viruses as for bacteria.

The other monitored intermittent discharges spill much less frequently and so whilst they may be of occasional influence their impacts are very unlikely to be captured during monthly shellfish monitoring. Notifications of discharges from the monitored outfalls are provided by Southern Water and displayed on the Chichester Council website (http://www.conservancy.co.uk/page/water-quality/339/): this is a useful innovation which harvesters and LEAs should be aware of.

Although the vast majority of the survey area is served by water company sewerage infrastructure, there are also a number of private sewage discharges in the area. Where specified, these are generally treated by small treatment works such as package plants. The majority of these are small, serving one or two properties. Details of the larger private discharges (>5m^3/day maximum permitted flow) are presented in Table II.6.

Table II.6: Details of private sewage discharges of over 5m^3/day

Ref.	Property served	Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
A	Raughmere Barns	SU8602007990	Unspecified	5	Soakaway
B	Birdham Canal Houseboats	SU8290001380	Unspecified	55*	Chichester Harbour
C	Buriton Farm	SU8192017700	Package plant	5	Soakaway
D	Chichester Yacht Basin	SU8289001300	Unspecified	18	Chichester Harbour
E	Cobnor Activity Centre	SU7939002610	Unspecified	10	Chichester Harbour
F	Corner Cottage	SU8134001980	Package plant	5	Unnamed watercourse
G	Goodwood House	SU8827009080	Unspecified	15	Unnamed watercourse
H	Goodwood Park	SU8860008650	Unspecified	92	Soakaway
I	Lordington Park	SU7819009680	Package plant	6	River Ems
J	Oakwood School	SU8257006750	Package plant	10	Bosham Stream trib.
K	Oakwood School	SU8265006800	Package plant	10	Bosham Stream trib.
L	Sailaway Rest Home	SU8078005350	Unspecified	5	Unnamed watercourse
M	Saltham House	SU8880013000	Package plant	5	River Lavant
N	Apuldram Centre	SU8443603480	Package plant	5	River Lavant trib.
O	Royal Oka	SU8155016140	Unspecified	5	Unnamed watercourse
P	White Horse	SU8276014460	Unspecified	13	Soakaway
Q	Uppark House	SU7787017600	Unspecified	20	Soakaway
R	Wicks Farm Cravan Site	SZ7951099470	Unspecified	40	Unnamed watercourse

* Dry weather flow rather than maximum flow.
Data from the Environment Agency.

Of significance to the fishery, there are two relatively large private discharges (Birdham Canal Houseboats and Chichester Yacht Basin) by the entrance to Chichester Marina. Although treatment is unspecified in the database, both appear to provide secondary treatment (shoreline survey, Figure XII.27 and Figure XII.28). There is a cluster of 18 private discharges around Furzefield Creek (including Corner Cottage) all but one of which discharge to the creek or to ditches draining to the creek. There is a smaller cluster of private discharges feeding to a surface water drain at Chidham. There is also a cluster at Shipton Green (including the Wicks Farm Caravan Park discharge) which may significantly add to the bacterial loadings carried by watercourses draining this area. Most of the larger watercourses draining to the heads of the various branches of the harbour also receive inputs from private discharges.

Appendix III. Sources and Variation of Microbiological Pollution: Agriculture

The majority of agricultural land within the hydrological catchment of Chichester Harbour is used for arable farming, but there are some small pockets of pasture. A significant proportion of this is on the east shore of Hayling Island and on Thorney Island (Figure 1.2). Table III.1 presents livestock numbers and densities for the catchment. These data were provided by Defra and are derived from the June 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, Table III.1 should give a reasonable indication of the numbers and types of livestock within the catchment.

Table III.1: Summary statistics from 2010 livestock census for the areas draining to Chichester Harbour

Cattle		Sheep		Pigs		Poultry	
No.	Density (no/km^2)	No.	Density (no/km^2)	No.	Density (no/km^2)	No.	Density (no/km^2)
4,307	17.8	6342	26.2	4012	16.6	11356	46.8

Data from Defra

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

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

Farm Animal	Faecal coliforms (No./g wet weight)	Excretion rate (g/day wet weight)	Faecal coliform load (No./day)
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).

Contamination of livestock origin will either be deposited directly on pastures by grazing animals, or collected from operations such as cattle sheds and poultry houses and spread on both arable land and pasture. This in turn will enter watercourses which will carry it to coastal waters. As the primary mechanism for mobilisation of faecal matter deposited on pastures into watercourses is via land runoff, fluxes of agricultural contamination into coastal waters 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'). Flows of water through the upper catchment are via chalk aquifers, and only re-emerge as surface streams in the lower catchment where the geology changes. The flow of groundwater through aquifers is typically very slow, from 1 m/year to 1 m/day (Environment Agency, 2011) and such lengthy travel times suggest little microbial contamination would survive passage. 50 days are deemed sufficient to remove microbial contamination from groundwater flows.

There are small numbers of grazing animals (both sheep and cattle) within the catchment, as well as some poultry. Given the small numbers the overall impact of livestock farming is likely to be relatively small. The larger watercourses are likely to carry some limited contamination of agricultural origin at times, although there is little in the way of pasture in their catchments. Smaller watercourses draining areas of pasture adjacent to the harbour such as Thorney Island and parts of Hayling Island may carry higher concentrations of agricultural contamination into the harbour. During the shoreline survey, livestock were observed in several locations adjacent to the harbour; the northern end of Hayling Island, west of Emsworth, at Southbourne, on Thorney Island, and by the head of the Chichester Channel. Numbers were not particularly high in any of these places.

The spatial pattern of application of organic fertilisers (manures, slurries and sewage sludge) to arable crops is uncertain, but arable land is widespread throughout the upper catchment areas. Contamination of chalk aquifers through the use of organic fertilisers in the South Downs is reported to be only of limited local importance compared to inorganic fertilisers (Jones and Robins, 1999).

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. 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 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 of Microbiological Pollution: Boats

The discharge of sewage from boats is potentially a significant source of bacterial contamination of shellfisheries within Chichester Harbour. There is significant boat traffic within the sheltered waters of Chichester Harbour. It hosts several marinas and is popular for both commercial fishing and pleasure boating; which are important for the local economy (Natural England, 2013). Figure IV.1 presents an overview of boating activity derived from the shoreline survey, satellite images and various internet sources.

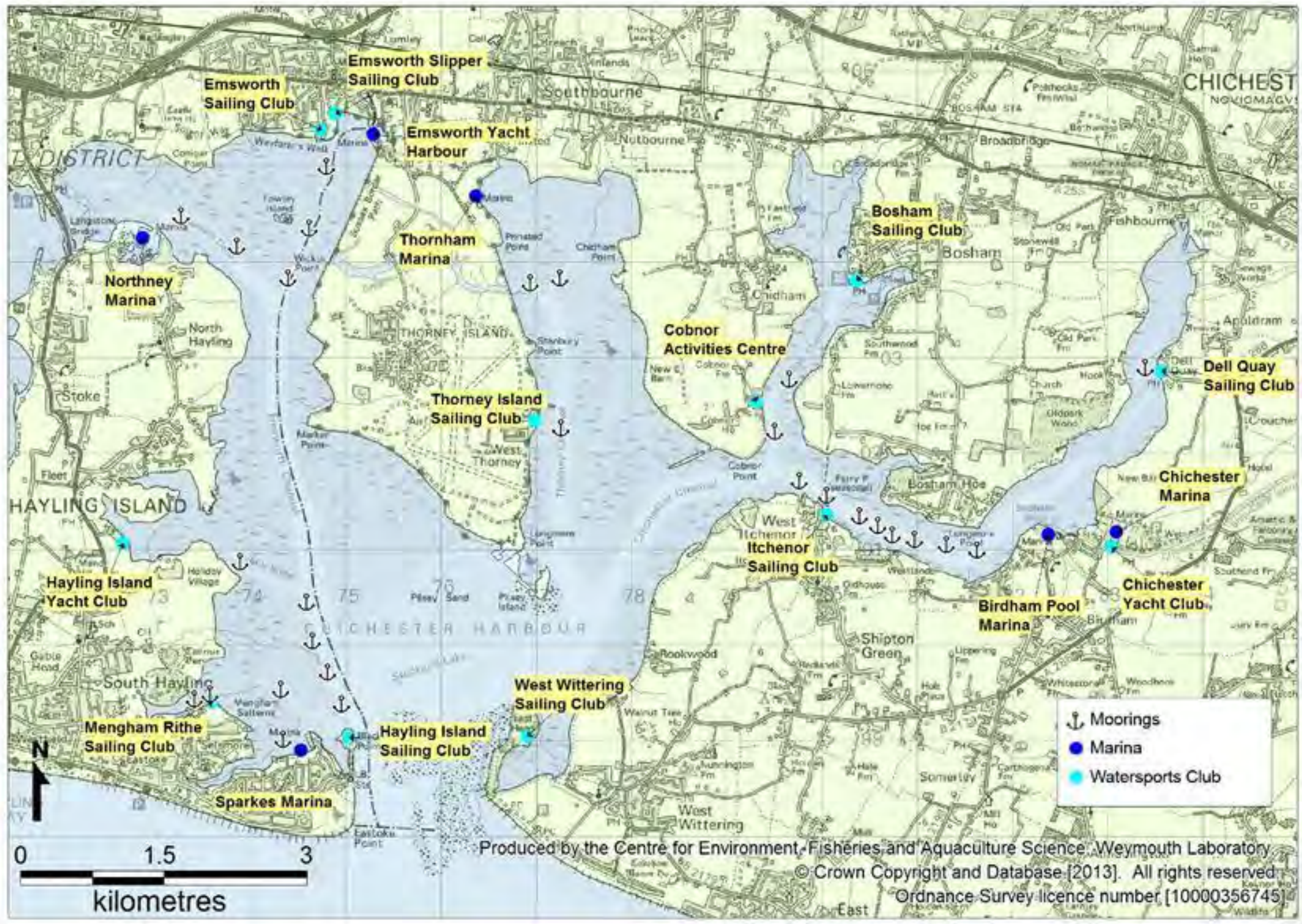


Figure IV.1: Boating activity in Chichester Harbour

Recreational boat traffic is extremely heavy within Chichester Harbour. There are six marinas with over 2,250 berths for pleasure craft such as yachts and cabin cruisers (Reeds, 2012) and numerous moorings throughout the harbour (Figure IV.1). A large number of vessels are registered to the harbour (approximately 11,830), representing around 28% of overall numbers of vessels registered within the Solent (Chichester Harbour Conservancy, 2013). Sewage pumpout facilities are only available at Itchenor and Chichester Marina (Chichester Harbour Conservancy, 2010).

A commercial fishing fleet operates from the harbour, with around 17 vessels registered in 2009. During autumn and winter months, there is often an increase in the number of fishing boats within Chichester Harbour, as commercial lobster and crab boats from Selsey Bill seek shelter in poor weather (Chichester Harbour Conservancy, 2009). The first week of the oyster season, which starts in November, attracted around 40 oyster dredgers in 2012.

There are numerous watersports clubs that surround Chichester Harbour. The majority are sailing clubs which provide racing and training sessions for both the smaller dinghies and the larger sailing yachts (Natural England, 2013). It is one of the most popular locations on the south coast for sailing and attracts 25,000 visitors each year for fishing, cruising and racing (Natural England, 2013). Other watersports such as windsurfing, kayaking, canoeing and paddle boarding also take place within the harbour. However, the smaller recreational boats are not large enough to contain onboard toilet facilities and therefore are therefore unlikely to make overboard discharges.

There are no commercial ports within Chichester Harbour therefore merchant shipping vessels are unlikely to come into the harbour and do not pose a threat in terms of microbiological contamination. In addition to this, merchant shipping vessels are not permitted to make overboard discharges within 3 nautical miles of land so vessels associated with the commercial port, cruise port and ferry terminals should be of no impact. Ferries run between Chichester Harbour, Itchenor and Emsworth; these are small and so are unlikely to make overboard discharges.

The more sizeable private vessels such as yachts, cabin cruisers and fishing vessels are likely to make overboard discharges from time to time. There are a very large number of these in use in the harbour at times, so their impacts may be of significance. Those in overnight occupation on moorings or at anchor may be more likely to make overboard discharges, so higher impacts may be anticipated within moorings or anchorages. Occupied yachts on pontoon berths may be less likely to make overboard discharges as this is somewhat antisocial in the crowded marina setting, and facilities on land are easier to access. Boats may also make overboard discharges whilst underway, so the main navigation channels may also be more susceptible to impacts from boat traffic. 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.

Appendix V. Sources and Variation of Microbiological Pollution: Wildlife

Chichester Harbour encompasses a variety of habitats including large areas of tidal inlets and creeks, saltmarsh in the upper reaches, intertidal mudflats, eelgrass beds and sand and shingle beds. These features attract significant populations of birds and other wildlife. Consequently large areas have been designated as conservation areas, Chichester Harbour is designated as an Area of Outstanding Natural Beauty (AONB), RAMSAR wetland, Site of Special Scientific Interest (SSSI) and Special Protection Area (SPA) for overwintering, migratory and seabird populations. It also falls within the Solent Special Area of Conservation (SAC). Three Local Nature Reserves, Nutbourne Marshes, Pilsey Island and Thorney Deeps are situated on Thorney Island and within Thorney Channel (Chichester Harbour Conservancy, 2013).

The most significant wildlife aggregation in terms of shellfish hygiene is likely to be overwintering waterbirds (waders and wildfowl). Studies in the UK have found significant concentrations of microbiological contaminants (thermophilic Campylobacter, salmonellae, faecal coliforms and faecal streptococci) from intertidal sediment samples supporting large communities of birds (Obiri-Danso and Jones, 2000). The harbour supports internationally important numbers of five species of wildfowl and a minimum of eight nationally important species (Wild Travel, 2008) including Dunlin, Dark-bellied Brent Geese, two species of Godwit's and Curlew. An average total count of 51,071 waterbirds (wildfowl and waders) was reported over five winters up to 2010/11 for Chichester Harbour (Holt *et al*., 2012). Studies undertaken in the winter of 2010/2011 revealed that Dark-bellied Brent Geese are widely distributed throughout Chichester Harbour, with higher densities in the upper reaches of the Bosham Channel and Emsworth Channel. Knots tend to favour the large intertidal mudflats located to the south of Thorney Island.

Geese and ducks will mainly frequent the grassland and saltmarsh, where their faeces will be carried into coastal waters via runoff into tidal creeks or through tidal inundation. Therefore RMPs within or near to the drainage channels from saltmarsh areas will be best located to capture contamination from this source. Waders, such as dunlin and oystercatchers forage upon shellfish and so will forage (and defecate) directly on any shellfish beds on the intertidal. They may tend to aggregate in certain areas holding the highest densities of bivalves of their preferred size and species, but this will probably vary from year to year. Contamination via direct deposition may be patchy, with some shellfish containing high levels of *E. coli* while others a short distance away are unaffected. At high tide waders are likely to frequent the saltmarsh and the perimeter of the estuary. Due to the diffuse and spatially unpredictable nature of contamination from wading birds it is difficult to select specific RMP locations to best capture this, although they may well be a significant influence during the winter months.

Birds such as gulls and terns and relatively small numbers of waders remain in the area to breed in the summer, but the majority migrate elsewhere outside of the winter months.

Bird numbers and potential impacts on the hygiene status of the fisheries are therefore much lower during the summer. The JNCC Seabird 2000 census recorded 9 pairs of European Herring Gull, 1 pair of Little Terns, and 1 pair of Common Terns (Mitchell et al, 2004). On the shoreline survey an aggregation of approximately 200 gulls were recorded on an offshore shingle bank in the Thorney Channel. Seabirds are likely to forage widely throughout the area so inputs could be considered as diffuse, but are likely to be most concentrated in the immediate vicinity of the nest sites. Their faeces will be carried into coastal waters via runoff from their nesting sites or via direct deposition to the adjacent intertidal. There are no major colonies in the immediate vicinity of the fisheries therefore they are not considered a significant microbiological source to the shellfish.

There is a small colony of seals, between 23 and 25 harbour seals and a couple of grey seals that frequent Chichester Harbour on a daily basis (The Wildlife Trusts' South East Marine Programme, 2010). The intertidal mudflats form the principal haulout site for these seals. During the moulting and pupping season (June to August for harbour seals) they tend to spend more time on haulouts in the harbour. In spatial terms, contamination is likely to be heaviest in the immediate vicinity of their haulout site. However, given the large area they are likely to forage over, impacts are likely to be minor, and unpredictable in spatial terms, but will peak during the summer, and be lowest during the autumn.

Appendix VI. Meteorological Data: Rainfall

The Fishbourne weather station, received an average of 682 mm per year between 2003 and 2012. Figure VI.1 presents a boxplot of daily rainfall records by month at Fishbourne.

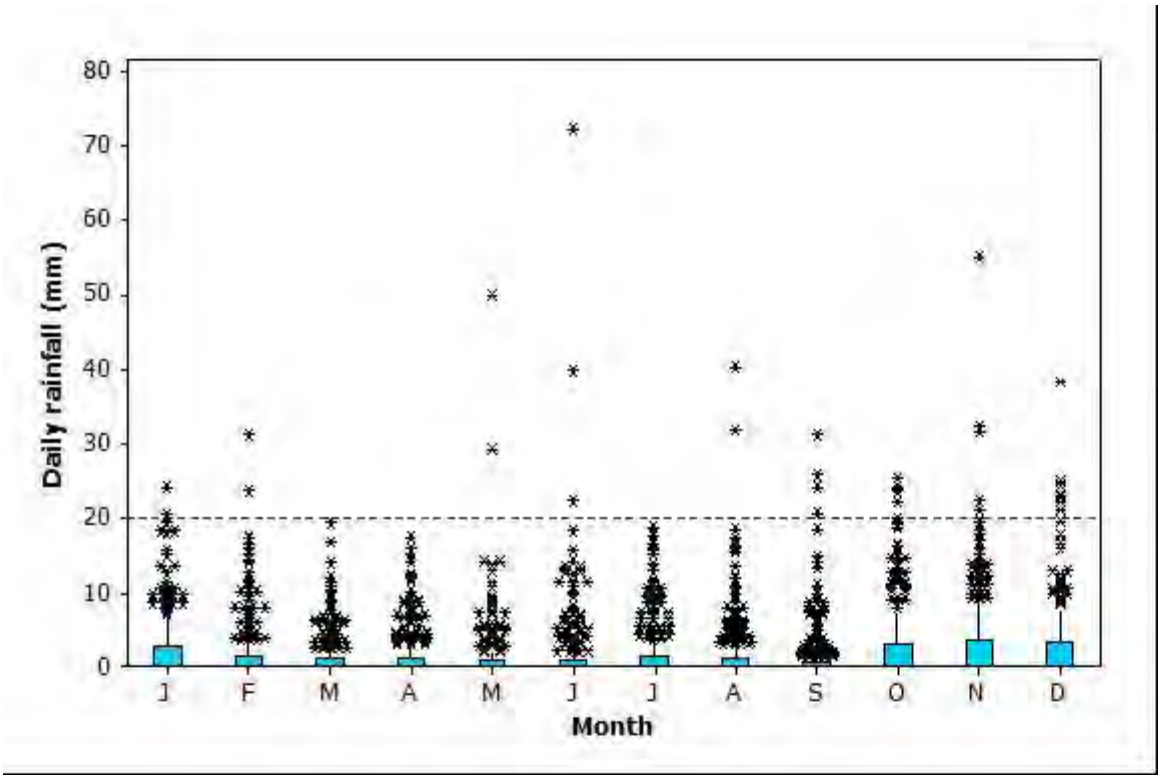


Figure VI.1: Boxplot of daily rainfall totals at Fishbourne, January 2003 to December 2012.
Data from the Environment Agency

Rainfall records from Fishbourne, which is representative of conditions in the vicinity of the shellfish beds, indicate relatively low seasonal variation in average rainfall. Rainfall was lowest on average in March and highest on average in November. Daily totals of over 20mm were recorded on 0.8% of days and 53% of days were dry. High rainfall events were recorded in all months except March, April and July.

Rainfall may lead to the discharge of raw or partially treated sewage from combined sewer overflows (CSOs) 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

Southern England is one of the more sheltered parts of the UK. The strongest winds are associated with the passage of deep areas of low pressure close to or across the UK. The frequency and strength of these depressions is greatest in the winter from December to February, and this is when mean speeds and gusts are strongest (Met Office, 2012).

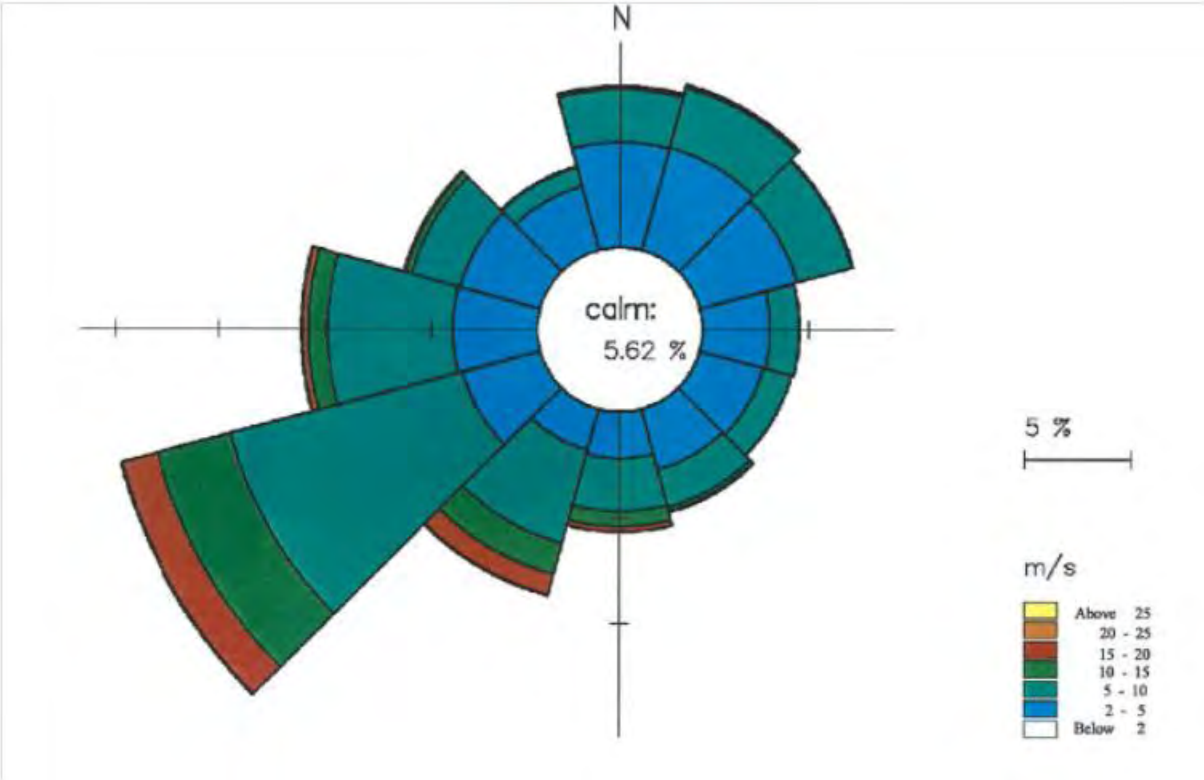


Figure VII.1: Wind Rose for Southampton Water Produced by ABPmer, 2007.

The prevailing wind direction is from the south west and the strongest winds usually blow from this direction (Figure VII.1). A higher frequency of north easterly winds occurs during spring.

Chichester Harbour is a partially enclosed inlet with a narrow mouth that faces south. It is relatively sheltered from the prevailing winds however; it is exposed to gales from the south (ABPmer, 2001).

Appendix VIII. Hydrometric Data: Freshwater Inputs

The catchment area draining directly into Chichester Harbour, as estimated by topography, is approximately 240 km². The northern reaches of the catchment are underlain by the chalk of the South Downs, where water flows underground via chalk aquifers rather than along the surface in watercourses (Jones and Robins, 1999). Groundwater flow through aquifers is typically very slow between 1m/year to 1m/day (Environment Agency, 2011) and the retention time of 50 days is deemed sufficient in the removal of microbial contamination from groundwaters. It is therefore unlikely that microbiological contamination of water originating from aquifers poses a significant threat to the shellfish beds in Chichester Harbour. The lower catchment is characterised by more impermeable geology (West, 2007) which causes groundwaters to re-emerge and flow across the surface.

The two largest watercourses are the River Ems and the River Lavant (Figure VIII.1). The River Ems flows through the west of the catchment and discharges at the head of the Emsworth channel, and the Lavant flows through the east side of the catchment and discharges near the head of Chichester Channel. Both flow through both rural land in the upper catchment and urbanised areas in the lower catchment. The heads of Thorney and Bosham channels receive freshwater inputs from smaller but nevertheless potentially significant streams. There are also significant watercourses discharging to Chichester Marina and at West Wittering, where the actual size of the watercourse is larger than indicated on the map. There are also many smaller watercourses and surface water drains discharging at various locations around the harbour. Many of these watercourses (for example the Great Deep, a lagoon/drain on Thorney Island) drain low lying land via sluices or flap gates that are covered at high water. As such these will discharge only at lower states of the tide.

All watercourses will carry some faecal indicator bacteria, potentially deriving from a range of point and diffuse sources such as STW discharges and urban and agricultural runoff. They are therefore likely to be an important source of microbiological contamination to shellfisheries within the harbour, although the extent of the impacts of each watercourse will depend both on its discharge rate and the concentrations of *E. coli* it carries.

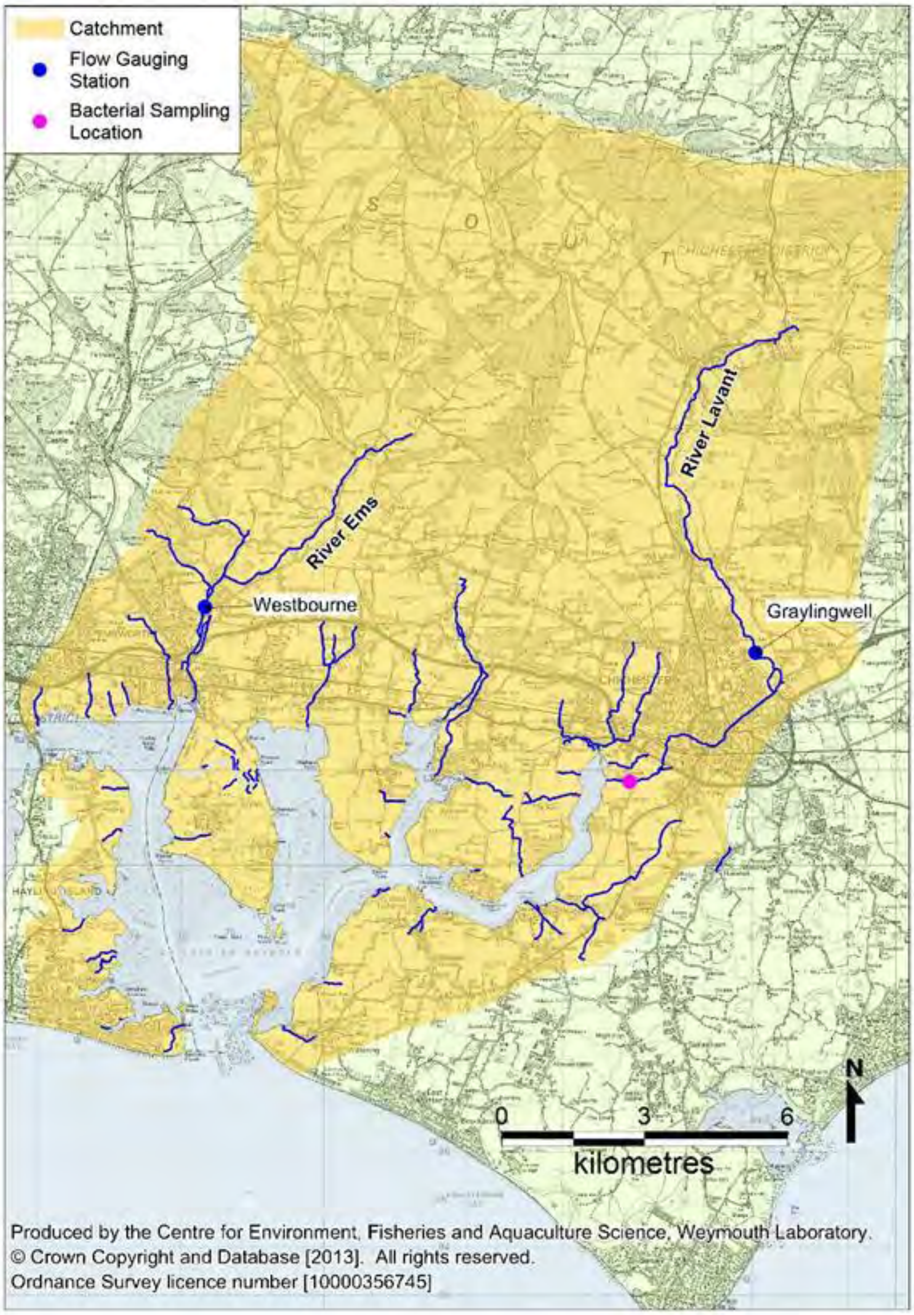


Figure VIII.1: Main watercourses within the catchment

The two larger rivers have automatic flow gauging stations in their lower reaches. Summary statistics for these flow gauges are presented in Table VIII.1 for the period 2003 to 2013.

Table VIII.1: Summary flow statistics for flow gauge stations on watercourses draining into Chichester Harbour, 2003-2013

Watercourse	Station name	Catchment area (km²)	Mean annual rainfall 1961-1990 (mm)	Mean flow (m^3s-1)	Q951 (m^3s-1)	Q10[2] (m^3s-1)
Ems	Westbourne	58.3	897	0.533	0.016	1.511
Lavant	Graylingwell	87.2	922	0.638	0.001	1.565

Q95[1] is the flow that is exceeded 95% of the time (i.e. low flow).
Q10[2] is the flow that is exceeded 10% of the time (i.e. high flow).
Data from the Environment Agency and Centre for Ecology and Hydrology

The Lavant exhibits a higher flow rate on average than the Ems most likely due to its larger catchment size. Base flow rates for both are very low. Boxplots of mean daily flow record by month at Westbourne and Graylingwell gauging stations are presented in Figure VIII.2 and Figure VIII.3. A considerable variation in discharge rates can be seen throughout the year at both. Flows were highest in the colder months at both stations peaking in February in the Ems and January in the Lavant. Water is abstracted from aquifers supplying the River Ems and to a smaller extent from the River Ems itself. Abstractors are required to augment the river with 0.016 m^3s^{-1} when flows of less than 0.032 m^3s^{-1} are recorded at the Westbourne gauging station. However it has been reported that during periods of low flow the augmented flows do not reach Westbourne (Holmes, 2007). During floods, water from the Lavant, downstream of the gauging station may be diverted through a flood relief channel to Pagham Rife to prevent flooding in Chichester (Environment Agency, 2013). Therefore, during major floods, not all of the flows recorded at Graylingwell will continue towards Chichester Harbour.

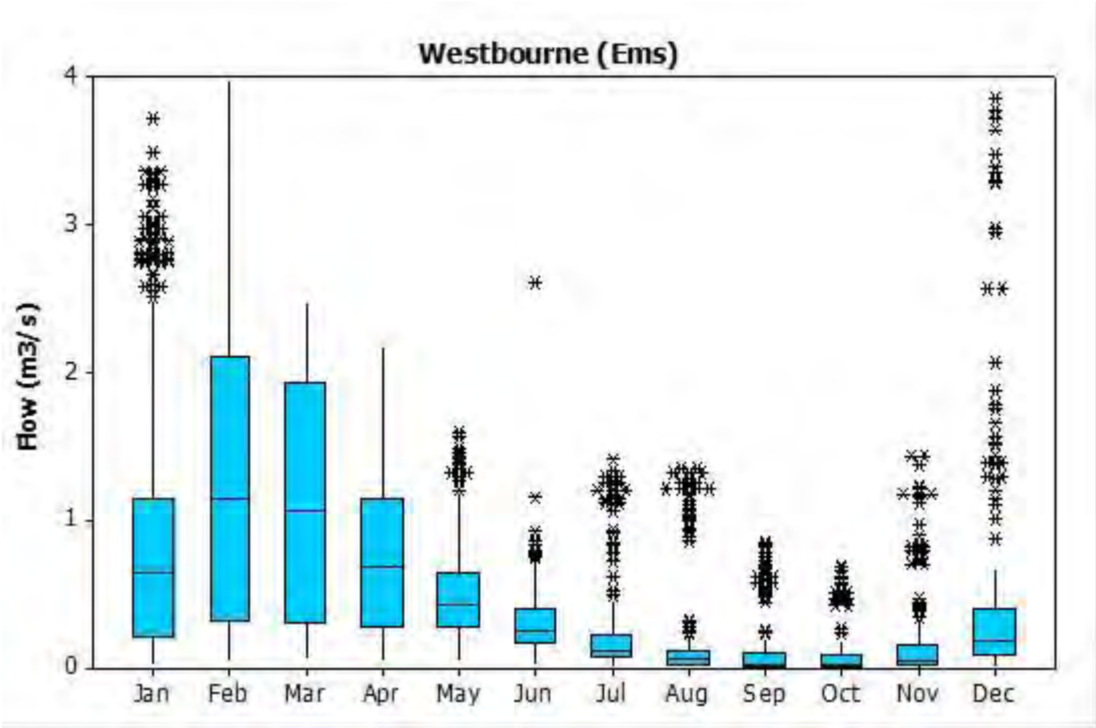


Figure VIII.2: Boxplots of mean daily flow records from the Westbourne gauging station on the Ems river from 2003 – 2013

Data from the Environment Agency

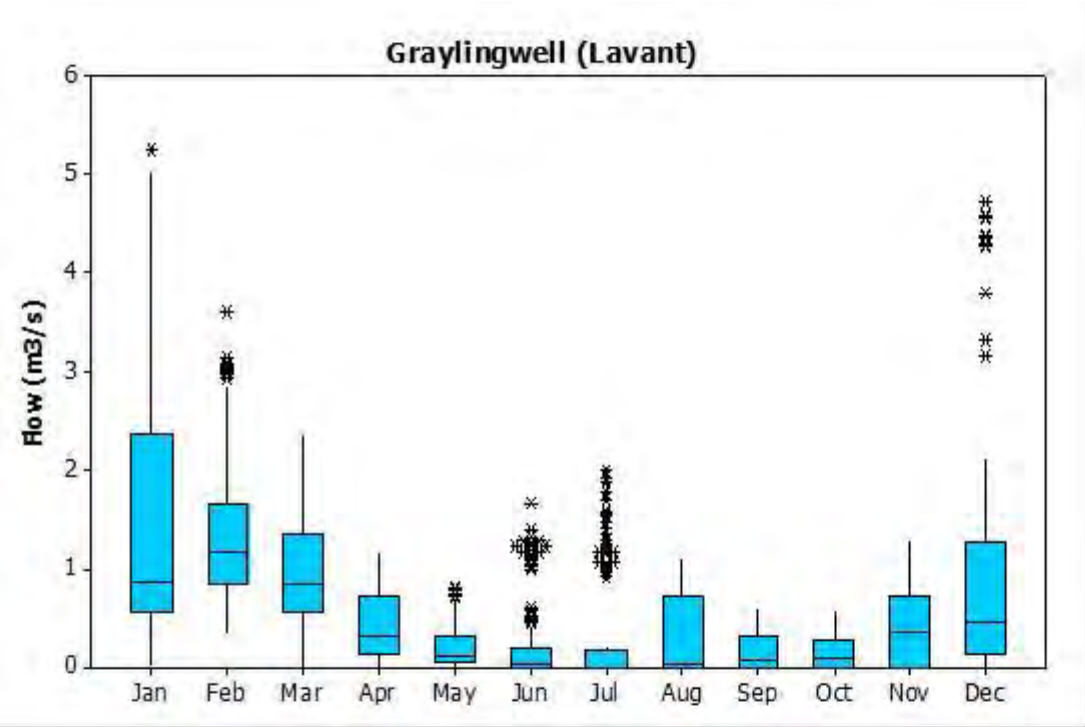


Figure VIII.3: Boxplots of mean daily flow records from the Gralingwell gauging station on the Lavant river from 2003 – 2013
Data from the Environment Agency

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

Table VIII.2 presents maximum and mean spot flow gauging results at 10 sampling locations within Chichester Harbour, locations of which are illustrated in Figure VIII.4. The highest mean flows are found at Fishbourne Reedbeds Main and Brookmeadow. Surprisingly low flow rates were recorded at the River Lavant (Fishbourne Apuldram Lane).

Table VIII.2: Summary flow statistics for spot flow gauging stations on watercourses draining into Chichester Harbour, 2006-2011

Site	Number of measurements	Mean flow (m^3s-1)	Maximum flow (m^3s-1)
Emsworth Harbour	27	0.009	0.039
Walderton Bridge	34	0.110	0.830
Brookmeadow	42	0.185	0.582
Nutbourne	40	0.060	0.242
Bosham Old Bridge	40	0.082	0.201
Fishbourne Apuldram Lane	16	0.091	0.387
Bosham	31	0.065	0.260
Fishbourne Meadows	25	0.136	0.468

Site	Number of measurements	Mean flow (m^3s^{-1})	Maximum flow (m^3s^{-1})
Fishbourne Reedbeds Side	18	0.004	0.007
Fishbourne Reedbeds Main	24	0.171	0.439

Data from the Environment Agency

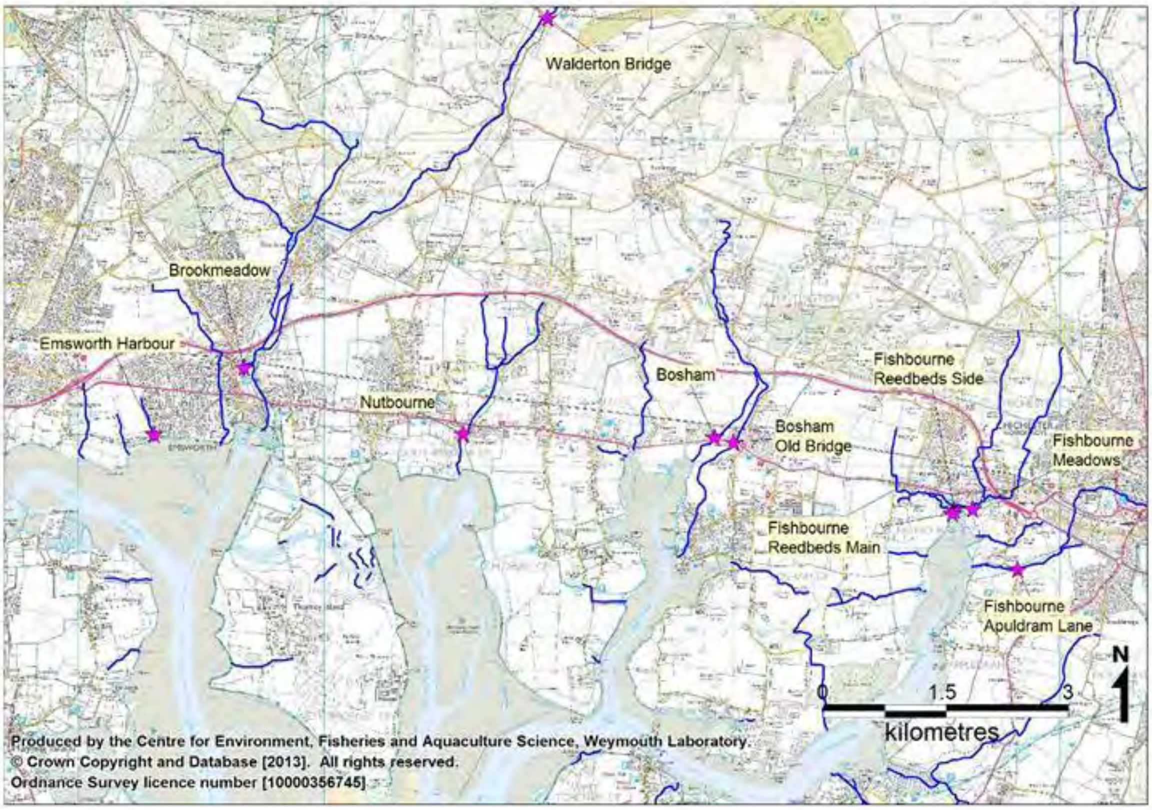


Figure VIII.4: Location of spot gauging stations

The River Lavant has been subject to repeated bacteriological sampling by the Environment Agency since 2010. The geometric mean level of faecal coliforms within this watercourse was 631 faecal coliforms/100ml over 56 sampling occasions. The majority of the time concentrations were <2000 faecal coliforms/100ml, although one exceptionally high result of 24,300 faecal coliforms/100ml was reported. Using the average measured discharge at the gauging station, and the average faecal coliform result, an estimate of the average bacterial loading carried by this watercourse is about $3.5\text{x}10^{11}$ faecal coliforms/day. Such an estimate should be treated with some caution however, not least because the gauging station is some distance upstream from the bacteriological sampling site.

Figure VIII.5 indicates that there is marked seasonality in levels of faecal coliforms levels in the Lavant. Comparisons of the results between seasons found a significant difference in levels of faecal coliforms (one way ANOVA, p=0.003). Post ANOVA tests (Tukeys comparison) showed that there were significantly higher levels of faecal coliforms in the summer and autumn months than in the spring. This is almost the opposite seasonal pattern to that observed for discharge volumes for this watercourse.

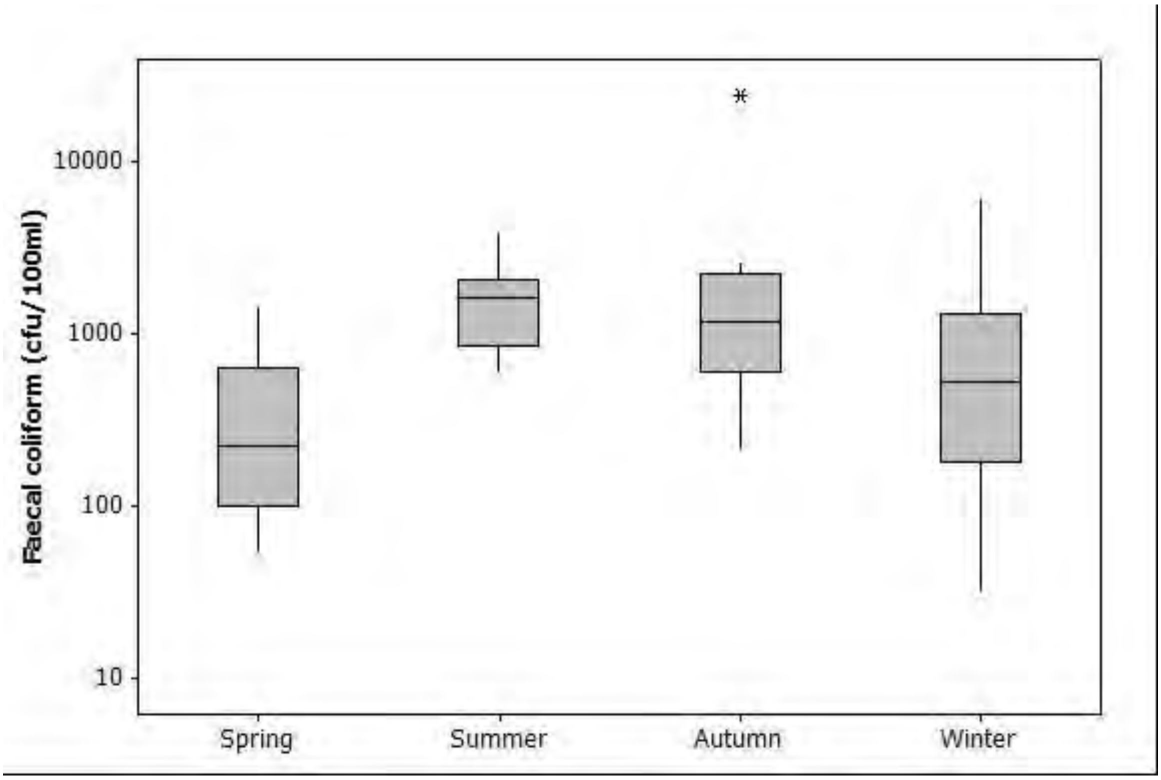


Figure VIII.5: Boxplot of Faecal coliform results from the Lavant stream, December 2010 – April 2013
Data from the Environment Agency

During the shoreline survey, all running watercourses were sampled and measured. Figure VIII.6 and Table VIII.3 show the *E.* coli loadings measured during the shoreline survey.

Table VIII.3: Estimated stream loadings

Sample No.	Date and Time	Position	*E. Coli* (cfu/100ml)	Flow (m^3/day)	*E. coli* (cfu/day)*
1	13/05/2013 09:31	SZ 74963 98661	2300	302	6.96×10^{9}
2	13/05/2013 09:54	SZ 74165 98726	930000	102	9.50×10^{11}
3	13/05/2013 10:24	SZ 73345 98585	230	105	2.42×10^{8}
4	13/05/2013 11:26	SZ 73348 99527	770	218	1.68×10^{9}
5	13/05/2013 12:29	SU 72415 01555	550	69	3.80×10^{8}
6	14/05/2013 09:17	SU 75172 05756	480	8771	4.21×10^{10}
7	14/05/2013 09:22	SU 75243 05735	320	28305	9.06×10^{10}
8	14/05/2013 09:31	SU 75344 05491	280	16692	4.67×10^{10}
9	14/05/2013 09:48	SU 74904 05504	10	434	4.34×10^{7}
10	14/05/2013 10:13	SU 73915 05384	460	862	3.96×10^{9}
11	14/05/2013 10:23	SU 73624 05115	420	978	4.11×10^{9}
12	14/05/2013 10:36	SU 73054 05094	400	2838	1.14×10^{10}
13	14/05/2013 10:58	SU 71978 04944	910	11916	1.08×10^{11}
14	20/05/2013 09:14	SU 76676 03742	710		
15	22/05/2013 08:34	SU 79810 05229	4500	12040	5.42×10^{11}
16	22/05/2013 08:42	SU 79690 05115	2600	21	5.53×10^{8}
17	22/05/2013 09:06	SU 79489 04136	410		
18	22/05/2013 12:19	SU 77936 05654	90	5655	5.09×10^{9}
19	04/06/2013 09:07	SU 80481 05095	150	29190	4.38×10^{10}
20	04/06/2013 09:25	SU 80314 04198	90	95	8.57×10^{7}
21	04/06/2013 09:28	SU 80310 04173	430	231	9.95×10^{8}
22	04/06/2013 09:32	SU 80306 04074	910	2495	2.27×10^{10}

Sample No.	Date and Time	Position	*E. Coli* (cfu/100ml)	Flow (m^3/day)	*E. coli* (cfu/day)*
23	04/06/2013 09:43	SU 80396 03812	360	2561	$9.22x10^9$
24	04/06/2013 13:26	SU 83338 03441	300	45	$1.36x10^8$
25	04/06/2013 13:37	SU 83366 03905	120	1200	$1.44x10^9$
26	04/06/2013 13:51	SU 83678 04414	60	25319	$1.52x10^{10}$
26	04/06/2013 13:58	SU 83731 04468	60	2376	$1.43x10^9$
27	04/06/2013 14:02	SU 83761 04506	50	3062	$1.53x10^9$
28	05/06/2013 09:03	SU 83920 04450	170	22696	$3.86x10^{10}$
29	05/06/2013 09:11	SU 84052 04127	230	1051	$2.42x10^9$
30	05/06/2013 12:11	SU 78510 00797	Not detected	48	0
31	05/06/2013 13:05	SZ 77270 98648	Not detected	23092	0

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

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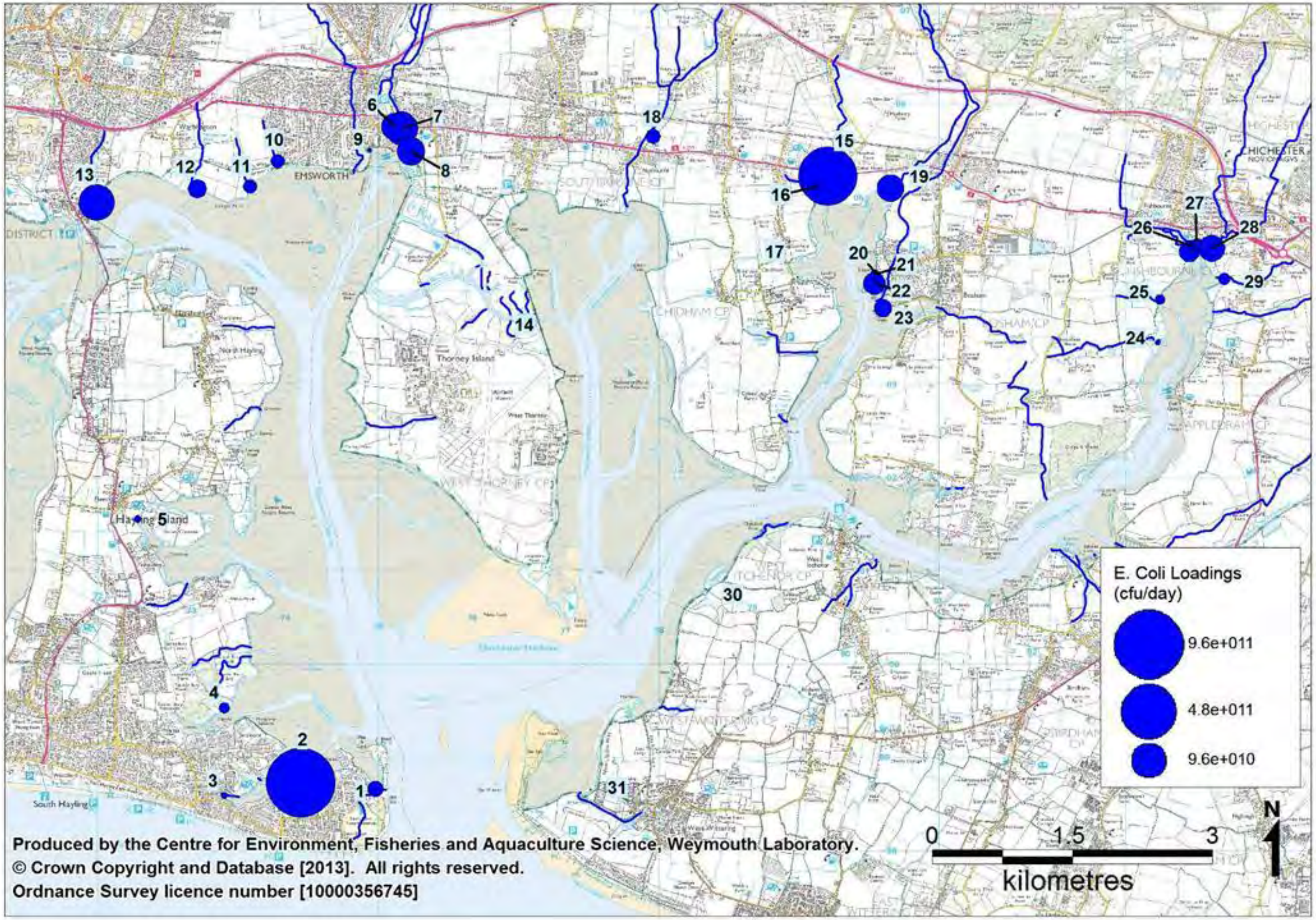


Figure VIII.6: Measured stream loadings from shoreline survey

It was not possible to sample and measure the River Lavant or the Great Deep as their outfalls were covered by the tide at the time, or the stream discharging to Chichester Marina as this was not accessible. Chichester Marina is impounded, and lies behind lock gates which may be opened for access at any state of the tide, and are sometimes left open over high water (Chichester Marina website, 2013).

The largest measured watercourses in terms of volumes were the main River Ems (7) the Bosham Stream (19), two watercourses discharging to the head of the Chichester Channel (26 and 28) and a stream at West Wittering (31). None of these carried high levels of *E. coli*, so none was delivering a particularly high *E. coli* loading (all <10^{11} cfu/day) at the time of survey. The highest measured loading ($9.5x10^{11}$) was actually delivered by a small culverted watercourse at the southern end of Hayling Island (2). It is likely that this was receiving some sanitary input at the time. Only two other streams, one to the west of Emsworth (13) and one at the head of the Bosham Channel (15) were also delivering *E. coli* loadings exceeding 10^{11} cfu/day at the time of survey. The combined bacterial loading of the main River Ems (7) and its two smaller side channels (6 & 8) was $1.8x10^{11}$ *E. coli*/day.

Appendix IX. Hydrography

Chichester Harbour is a shallow semi-enclosed tidal inlet with four main channels. It faces south and drains into the eastern Solent. It covers an area of about 29.5km, of which 78% is intertidal (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.

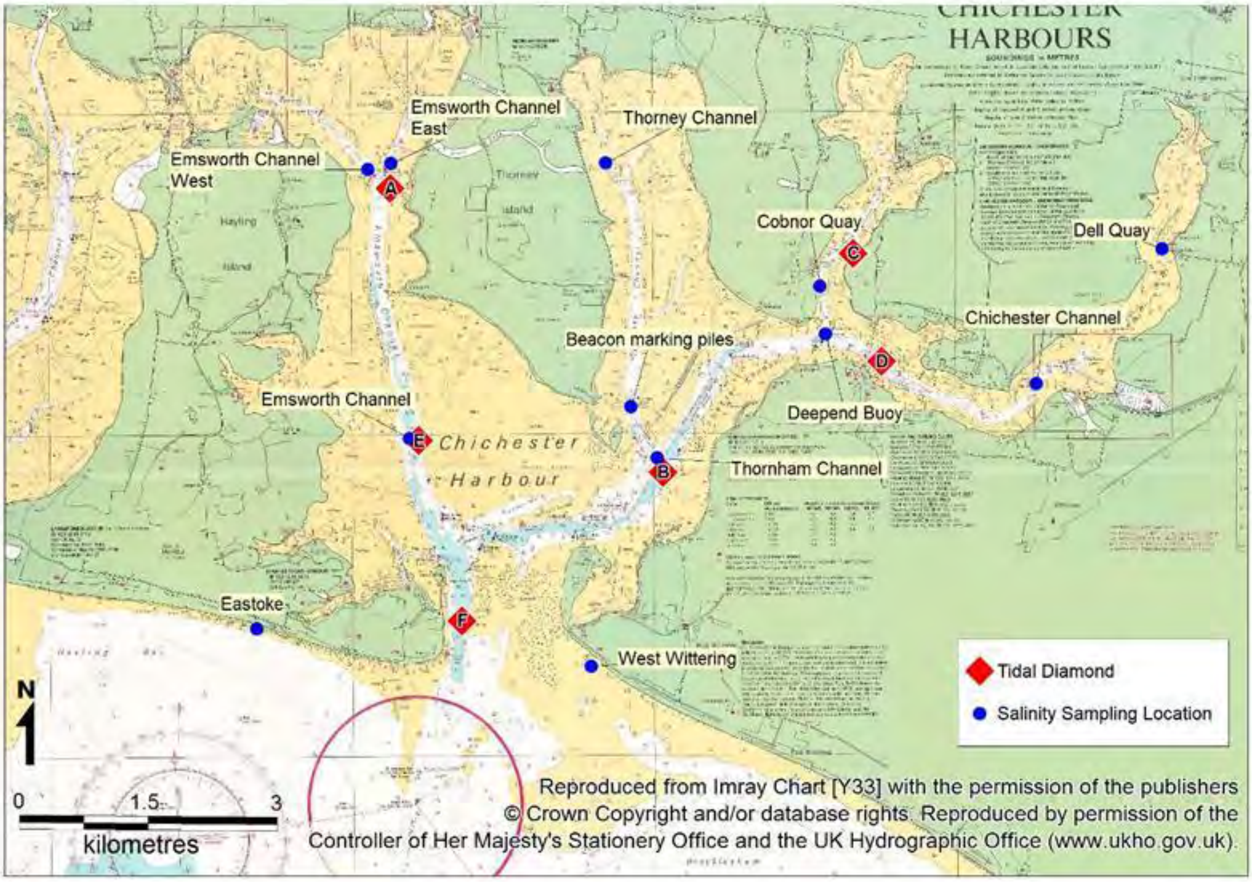


Figure IX.1: Bathymetry of Chichester Harbour

It has a narrow and relatively deep mouth (13 m below CD) flanked with sand/gravel spits on either side. The main Chichester channel is about 13km in length and meanders in a north easterly direction from the entrance. There are three side channels which branch off from the main Chichester Channel; Emsworth Channel, Thorney Channel, and Bosham Channel, all of which have a north-south orientation. Numerous smaller drainage channels of varying sizes drain into these deeper channels.

The channels become shallower in their upper reaches, where muddier sediments are more prevalent, and some areas are flanked by saltmarsh. Emsworth and Thorney channels are considerably wider than Bosham Channel and the upper reaches of the Chichester Channel. At high water Chichester Harbour is connected to Langstone Harbour by a narrow shallow passage in the northwest corner of Emsworth Channel. Consequently, there is potential for water exchange with Langstone Harbour. The intertidal areas at the mouth of the Thorney Channel are at a relatively high elevation, constricting its entrance somewhat.

Dredging of gravel for the aggregate trade occurs at the ebb tidal delta seaward of its mouth (Futurecoast, 2002) and Chichester Sand Bar, to the west of its mouth, is dredged to maintain a depth of 2m at spring low water (Harbour Guides, 2013). A series of sea walls, boulders and gabions protect the majority of Chichester Harbour, and groynes protect the southern beaches and spits of Hayling Island and West Wittering.

IX.1. Tides and Currents

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. Chichester Harbour is meso-tidal and expresses a semi diurnal cycle with an average tidal range on spring tides of 4.2m. The highest tidal range is observed at Northney, situated in the north east of the harbour, 4.4m on spring tides and 2.1m on neap tides (Table IX.1).

Table IX.1: Tide Levels and ranges within Chichester Harbour

	Height above chart datum (m)				Range (m)	
Port	MHWS	MHWN	MLWN	MLWS	Spring	Neap
Chichester Harbour (Entrance)	4.9	4.0	1.9	0.9	4.0	2.1
Northney	4.9	3.8	1.7	0.5	4.4	2.1
Itchenor	4.8	3.8	1.7	0.6	4.2	2.1
Bosham	4.9	-	3.9	-	-	-
Dell Quay	4.9	-	3.9	-	-	-

Data from the Admiralty Total Tide

Table IX.2 presents the maximum rate of tidal streams at four stations on spring and neap tides. The locations of these stations are shown in Figure IX.1.

Table IX.2: Tidal Rate Predictions for Chichester Harbour

	Maximum Rate (m/s)							
	Station C (Bosham Channel)		Station D (Itchenor Reach)		Station E (Lower Emsworth Channel)		Station F (Mouth)	
	Spring	Neap	Spring	Neap	Spring	Neap	Spring	Neap
Flood	0.5	-	0.5	0.3	1.0	0.3	1.4	0.5
Ebb	0.8	-	1.2	0.5	0.6	0.4	3.3	0.6

Data from Admiralty Chart SC 5600.20 (Chichester Harbour)

Table IX.3 presents the direction and rate of tidal streams at two stations in Chichester Harbour on spring and neap tides and at hourly intervals before and after high water.

Table IX.3: Tidal direction and rates at Chichester Harbour

Time before /after High Water	Station A (Upper Emsworth Channel)			Station B (south east of Thorney Island)		
	Direction (°)	Rate (m/s)		Direction (°)	Rate (m/s)	
		Spring	Neap		Spring	Neap
HW-6	010	0.1	0.1	023	0.2	0.1
HW-5	020	0.1	0.1	023	0.2	0.1
HW-4	-	0.0	0.0	-	0.0	0.0
HW-3	010	0.3	0.1	025	0.4	0.2
HW-2	015	0.4	0.2	023	0.6	0.3
HW-1	010	0.4	0.2	022	0.8	0.4
HW	009	0.2	0.1	009	0.4	0.2
HW+1	200	0.1	0.1	226	0.4	0.2
HW+2	187	0.1	0.1	223	0.3	0.1
HW+3	187	0.6	0.3	217	0.9	0.4
HW+4	199	0.4	0.2	220	0.8	0.4
HW+5	215	0.1	0.1	223	0.5	0.3
HW+6	-	0.0	0.0	005	0.1	0.1
Excursion Km (flood)		5.00	2.41		9.62	4.63
Excursion Km (ebb)		4.26	2.04		9.99	5.00

Data from Admiralty Chart SC 5600.20 (Chichester Harbour)

The tidal diamonds, stations A and B, indicate that tidal streams move into the harbour and up the channels on the flood, with the reverse occurring on the ebb. Currents are strongest in the mouth of the harbour (Station F), at 3.3 m/s on ebb spring tides. The peak current velocity in the upper Emsworth Channel (Station A) is 0.6 m/s also on ebb spring tides. Current velocities are about half of this on neap tides. In general, the current speeds are faster in the Chichester Channel than in the Emsworth Channel and decrease towards the heads of the channels.

Tides are asymmetrical, with a shorter duration and faster moving ebb tide in the outer harbour. The tidal curve shows a slight stand on the early flood. The tidal excursion (the distance water travels during the course of a flood or ebb tide) is greatest in the main Chichester channel where the currents are strongest; around 10km is experienced on spring tides and 5km on neap tides. In the upper estuary, in the Emsworth Channel the tidal excursion is smaller with around 5 km experienced on the spring tide and 2 km experienced on the ebb tide.

Advection of pollutants by tidal currents is likely to be the main mode of contaminant transport in Chichester Harbour. The flood tide will convey relatively clean water originating from the English Channel into the estuary, whereas the ebb tide will carry contamination from shoreline sources out through the estuary. On a flood tide the principal tidal stream flows in a northerly direction into Chichester Harbour and progresses up the main channels with the opposite occurring on the ebb. As these channels fill, the tidal flow will fill the creeks and spread over the extensive mudflats. Current velocities will be considerably lower in these shallower areas. Shoreline sources of contamination will therefore primarily impact up and downtide of their locations along the bank to which they discharge. Their impacts will decrease with distance travelled, as the plume becomes progressively more diluted. At lower states of the tide contamination from some shoreline sources such as watercourses will be carried through the intertidal drainage channels where the dilution potential is low. Relatively high concentrations of indicator bacteria may arise in these channels at such times. Given the complex shape of the harbour, it is likely that eddies form in some places at certain states of the tide.

The four main channels will be primarily influenced by sources of contamination discharging directly to them. There is the potential for some impacts from major sources in other channels carried back up the harbour on the subsequent flood tide, although they will be subject to significant dilution during travel. Although the vast majority of water exchange occurs via the mouth, some exchange of water through the secondary connection to Langstone Harbour has been documented. These exchanges are in an overall westerly direction (Portsmouth Polytechnic, 1976) so sources of contamination to discharging to the north east corner of Langstone Harbour should not be a major influence on the Emsworth Channel.

In addition to tidally driven currents, are the effects of freshwater inputs and wind. The flow ratio (freshwater input:tidal exchange) is very low and the system is well mixed (Futurecoast, 2002), so density driven circulation is unlikely to modify tidal circulation. Salinity measurements taken between 2003 and 2013 at twelve points within the harbour indicate average salinities approaching that of full strength seawater throughout (Figure IX.2). Low salinities indicative of more significant freshwater influences were recorded in Dell Quay in the upper Chichester Channel in April/May 2013.

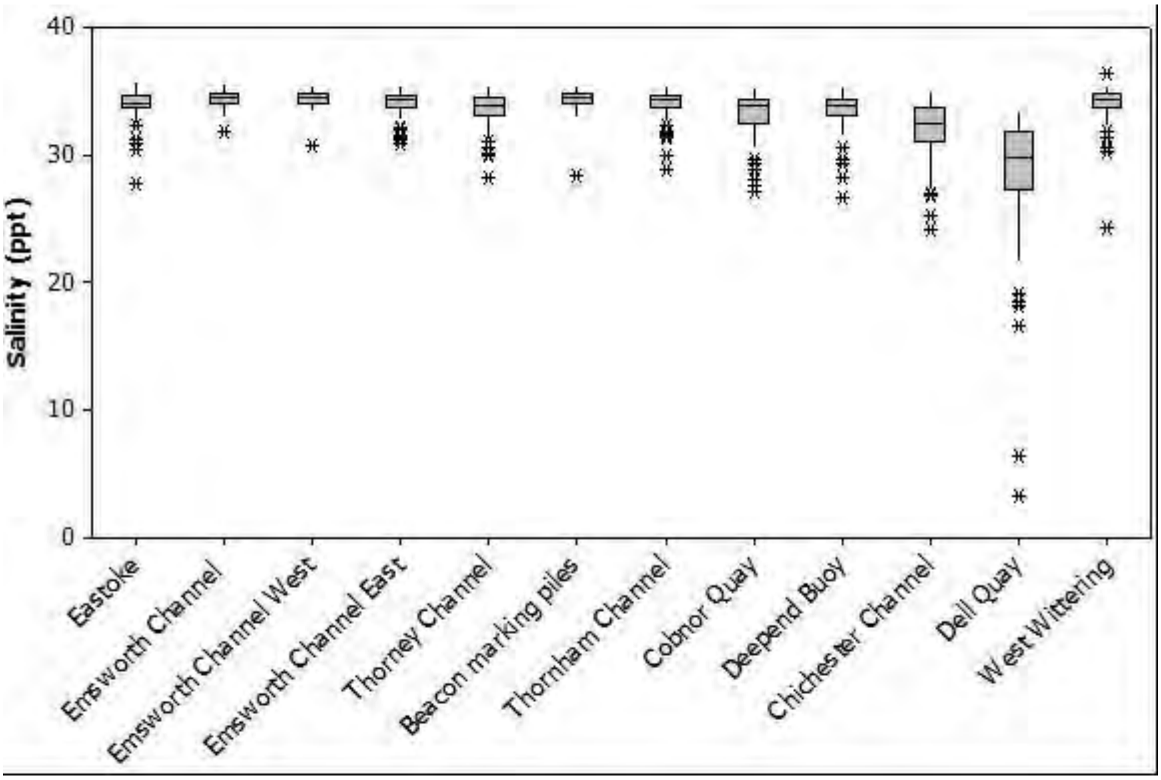


Figure IX.2: Boxplot of salinity readings taken in Chichester Harbour 2003 – 2013
Data from the Environment Agency

Strong winds will modify surface currents. Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so gale force wind (34 knots or 17.2 m/s) would drive surface water currents which may travel lower in the water column or along sheltered margins. The prevailing south westerly winds will tend to push surface water in a north easterly direction. Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great number of scenarios may arise. Where strong winds blow across a sufficient distance of water they may create wave action. Where these waves break contamination held in intertidal sediments may be resuspended, although given the enclosed nature of the harbour strong wave action is not generally anticipated. The intertidal area to the south of Thorney Island is relatively exposed to winds. Winds blowing up the channels may result in sufficient wave action at their heads to disturb the finer sediments present in these areas.

Appendix X. Microbiological Data: Seawater

Chichester Harbour has an extensive history of microbiological monitoring of seawater. There is an independent water quality monitoring programme undertaken by Chichester DC and Chichester Harbour Conservancy, due to the large number of recreational users. Water quality within the harbour is also monitored by the Environment Agency under the shellfish waters monitoring programme. There are no designated bathing waters sites within Chichester Harbour. Due to major improvements at two of the water treatment works that discharge into the harbour, data are only presented from April 2008 onwards.

X.1. Chichester District Council and Chichester Harbour Conservancy monitoring results

Summary statistics and geographical variation

Chichester DC and the Chichester Harbour Conservancy have collected water quality data at 11 sites across the harbour for several years. Figure X.1 shows the locations of the monitoring sites and their geometric mean *E. coli* levels from April 2008 onwards. Summary statistics of results for each site are presented in Table X.1 and Figure X.2 presents box plots of these data.

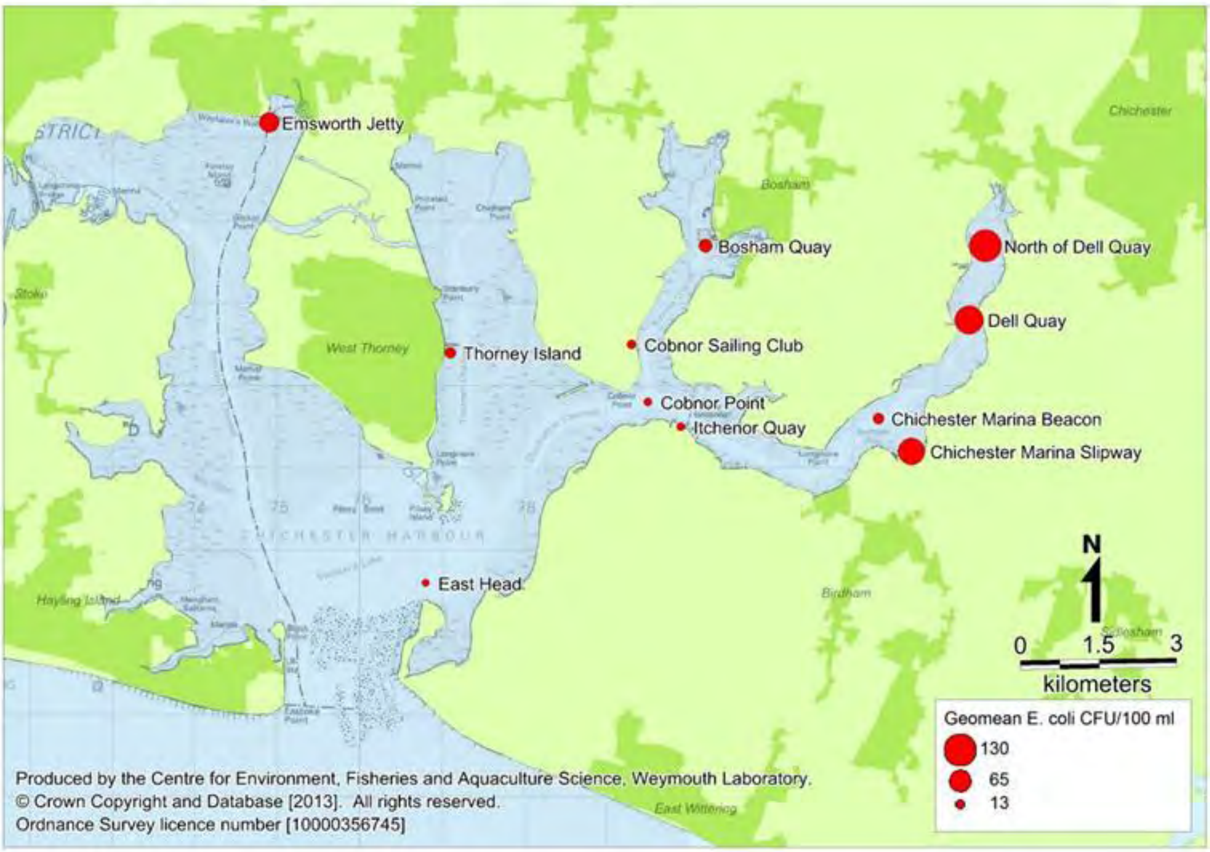


Figure X.1: Location of recreational waters monitoring points in Chichester Harbour
Data from Chichester District Council and Chichester Harbour Conservancy

Table X.1: Summary statistics for recreational waters *E. coli* (cfu/100ml).results, April 2008 to June 2013

Site name	No.	Geometric mean	Min.	Max.	% over 100	% over 1000
Emsworth Jetty	100	56.6	<10	7300	39.0	9.0
East Head	105	9.0	<10	840	1.9	0.0
Thorney Island	106	17.9	<10	740	17.0	0.0
Bosham Quay	106	27.2	<10	1100	22.6	0.9
Cobnor Sailing Club	106	13.4	<10	910	5.7	0.0
Cobnor Point	105	11.1	<10	1000	6.7	1.0
Itchenor Quay	106	11.8	<10	1800	8.5	1.9
Chichester Marina Beacon	105	19.1	<10	2500	17.1	3.8
Chichester Marina Slipway	106	96.6	<10	4300	50.9	11.3
Dell Quay	106	105.5	<10	360000	44.3	15.1
North of Dell Quay	88	129.3	<10	700000	42.0	21.6

Data from Chichester District Council and Chichester Harbour Conservancy

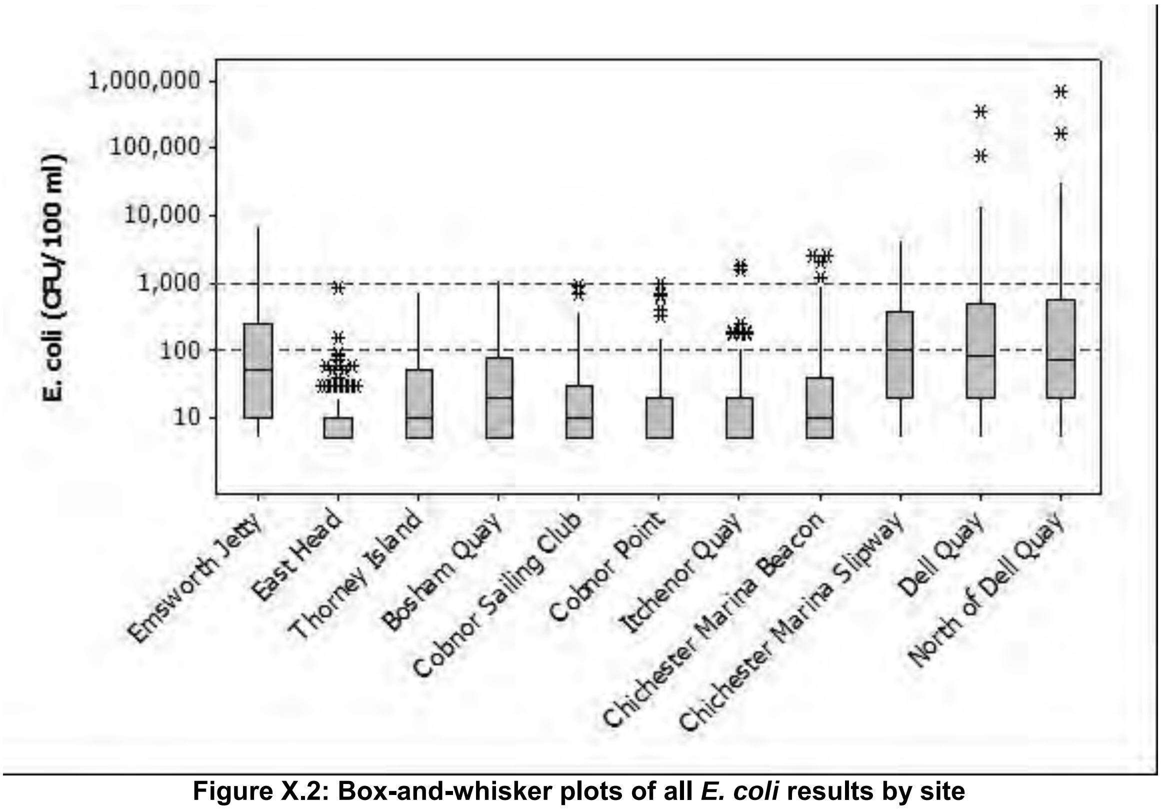


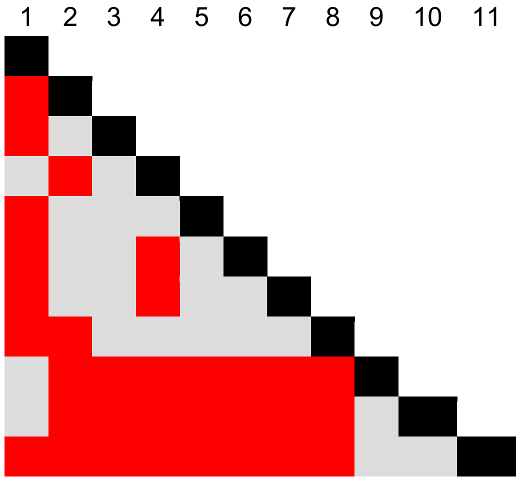
Figure X.2: Box-and-whisker plots of all *E. coli* results by site
Data from Chichester District Council and Chichester Harbour Conservancy

Highest average and peak levels were recorded in the two sites in the upper reaches of the Chichester Channel (Dell Quay and North of Dell Quay). Results were also relatively high on average within the small embayment by Chichester Marina (Chichester Marina Slipway) but not in the main channel on the opposite bank (Chichester Marina Beacon). This suggests there are some significant local inputs to this embayment. Relatively high average levels of contamination were also recorded at the head of the Emsworth Channel (Emsworth Jetty).

All sites had results exceeding 100 *E. coli*/100 ml and seven of the 11 sites had results exceeding 1,000 *E. coli*/100 ml. One-way ANOVA testing showed there to be a significant difference in *E. coli* levels between sites (p <0.001). Table X.2 shows the results of post-ANOVA pairwise Tukey tests. Grey boxes indicate there was no significant difference between sites (p >0.05), and red boxes indicate that the site listed vertically had greater *E. coli* levels than the site listed horizontally.

Table X.2: Post-ANOVA Tukey test results for water quality data in Chichester Harbour

1	Emsworth Jetty
2	East Head
3	Thorney Island
4	Bosham Quay
5	Cobnor Sailing Club
6	Cobnor Point
7	Itchenor Quay
8	Chichester Marina Beacon
9	Chichester Marina Slipway
10	Dell Quay
11	North of Dell Quay



Data from Chichester District Council and Chichester Harbour Conservancy

More robust comparisons of sites were carried out on a pair-wise basis by running correlations (Pearson's) between sites that shared sampling dates, and were therefore taken under the same environmental conditions, on at least 20 occasions. Pairwise comparisons between all sites except Emsworth Jetty were significant, indicating that all sites except Emsworth Jetty were affected by the same or similar sources. This is perhaps unsurprising given that Emsworth Jetty is relatively remote from the other sites and is located near to the mouth of the River Ems.

Overall temporal pattern in results

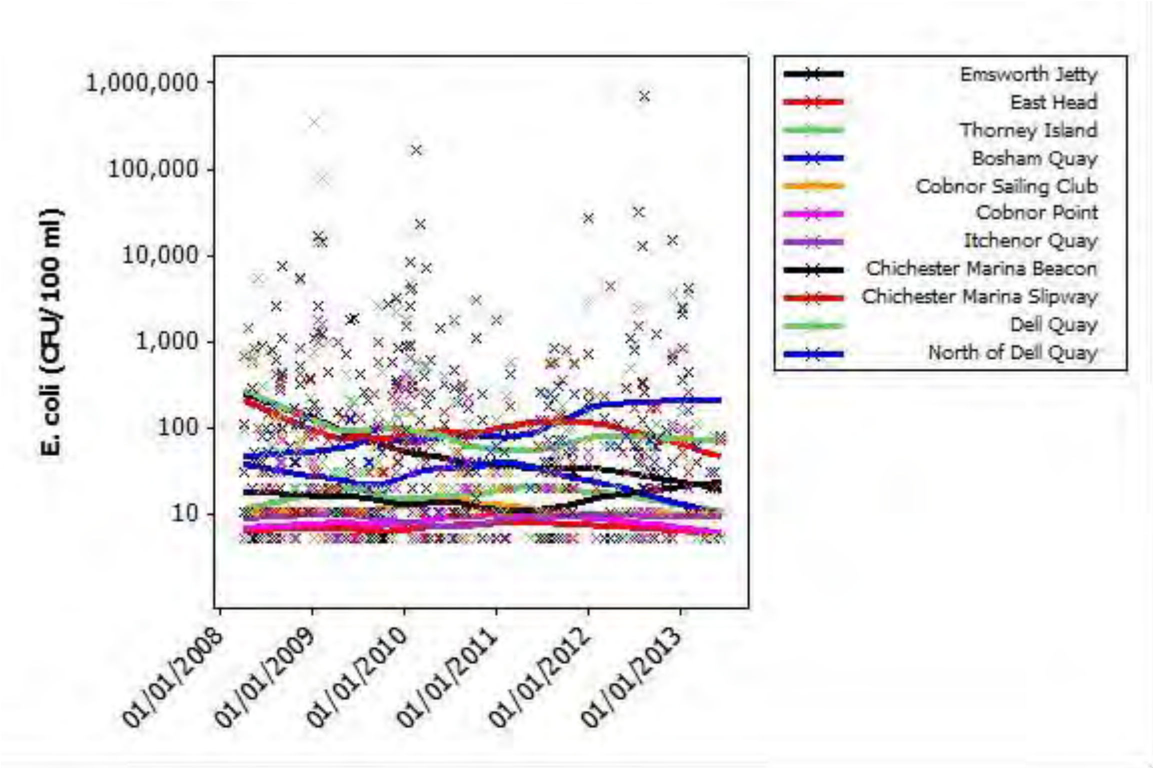


Figure X.3: Scatterplot of *E. coli* results by RMP and date, overlaid with lowess lines
Data from Chichester District Council and Chichester Harbour Conservancy

Figure X.3 shows some fluctuations over the years, but there is no consistent pattern apparent across the harbour as a whole.

Seasonal patterns of results

The seasonal patterns of results from April 2008 onwards were investigated by site (Figure X.4). One-way ANOVA tests showed that there were significant differences ($p \leq 0.005$) between seasons at all sites except Emsworth Jetty and Chichester Marina Slipway ($p = 0.802$ and 0.121 respectively). In all cases, there were significantly higher levels of *E. coli* in the winter than in the spring. At East Head, Thorney Island and Bosham Quay, there were higher levels of *E. coli* in the autumn than in spring. At all other sites, there were significantly higher levels of *E. coli* during the winter than during any other season.

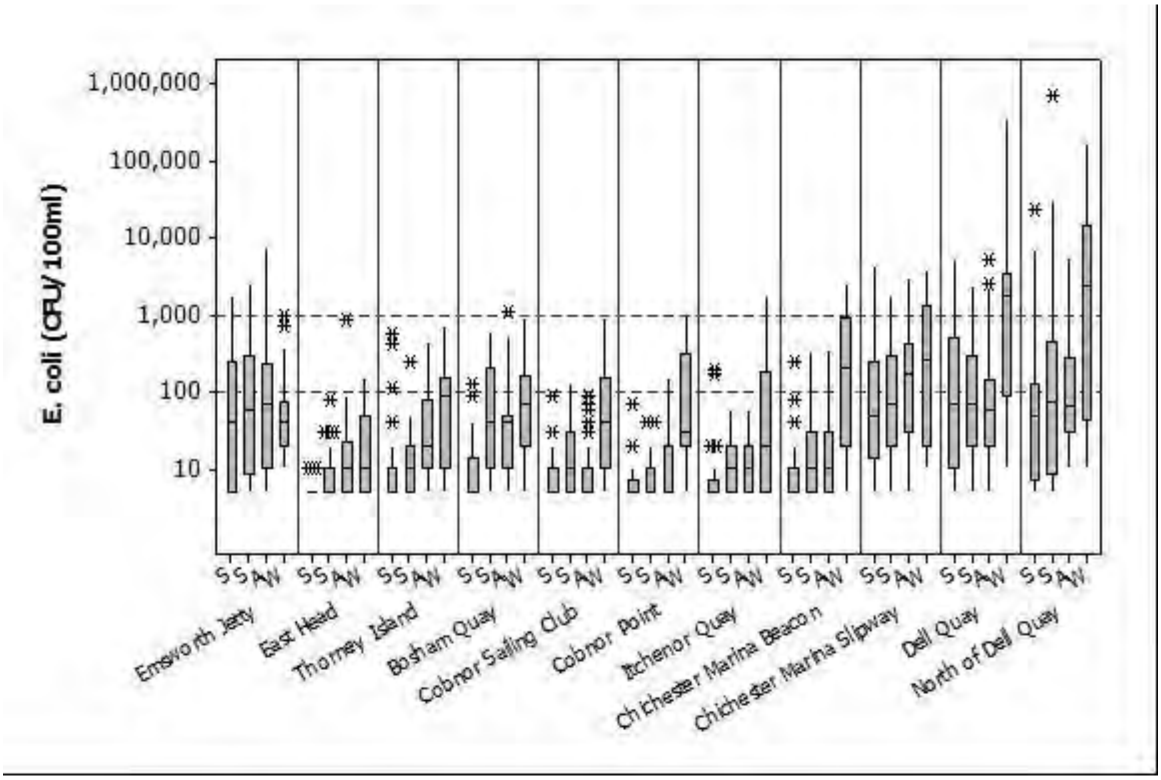


Figure X.4: Boxplot of *E. coli* results by RMP and season
Data from Chichester District Council and Chichester Harbour Conservancy

Influence of tide

To investigate the effects of tidal state on *E. coli* results, circular-linear correlations were carried out against both the high/low and spring/neap tidal cycles for each of the water quality sampling sites. Correlation coefficients are presented in Table X.3, with statistically significant correlations highlighted in yellow.

Table X.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 tides		Spring/neap tides	
Site Name	r	p	r	p
Emsworth Jetty	0.196	0.024	0.144	0.133
East Head	0.201	0.016	0.069	0.618
Thorney Island	0.086	0.463	0.034	0.890
Bosham Quay	0.092	0.422	0.086	0.464
Cobnor Sailing Club	0.118	0.237	0.183	0.032
Cobnor Point	0.138	0.143	0.067	0.629
Itchenor Quay	0.111	0.284	0.044	0.819
Chichester Marina Beacon	0.129	0.184	0.187	0.028
Chichester Marina Slipway	0.240	0.003	0.260	0.001
Dell Quay	0.123	0.208	0.255	0.001
North of Dell Quay	0.257	0.004	0.214	0.020

Data from Chichester District Council and Chichester Harbour Conservancy

Figure X.5 presents polar plots of $\log_{10}$ faecal coliform results against tidal states on the high/low cycle for the correlations indicating a statistically significant effect. High water at Chichester Harbour is at 0° and low water is at 180°. Results of 100 faecal coliforms/100ml or less are plotted in green, those from 101 to 1,000 are plotted in yellow, and those exceeding 1,000 are plotted in red.

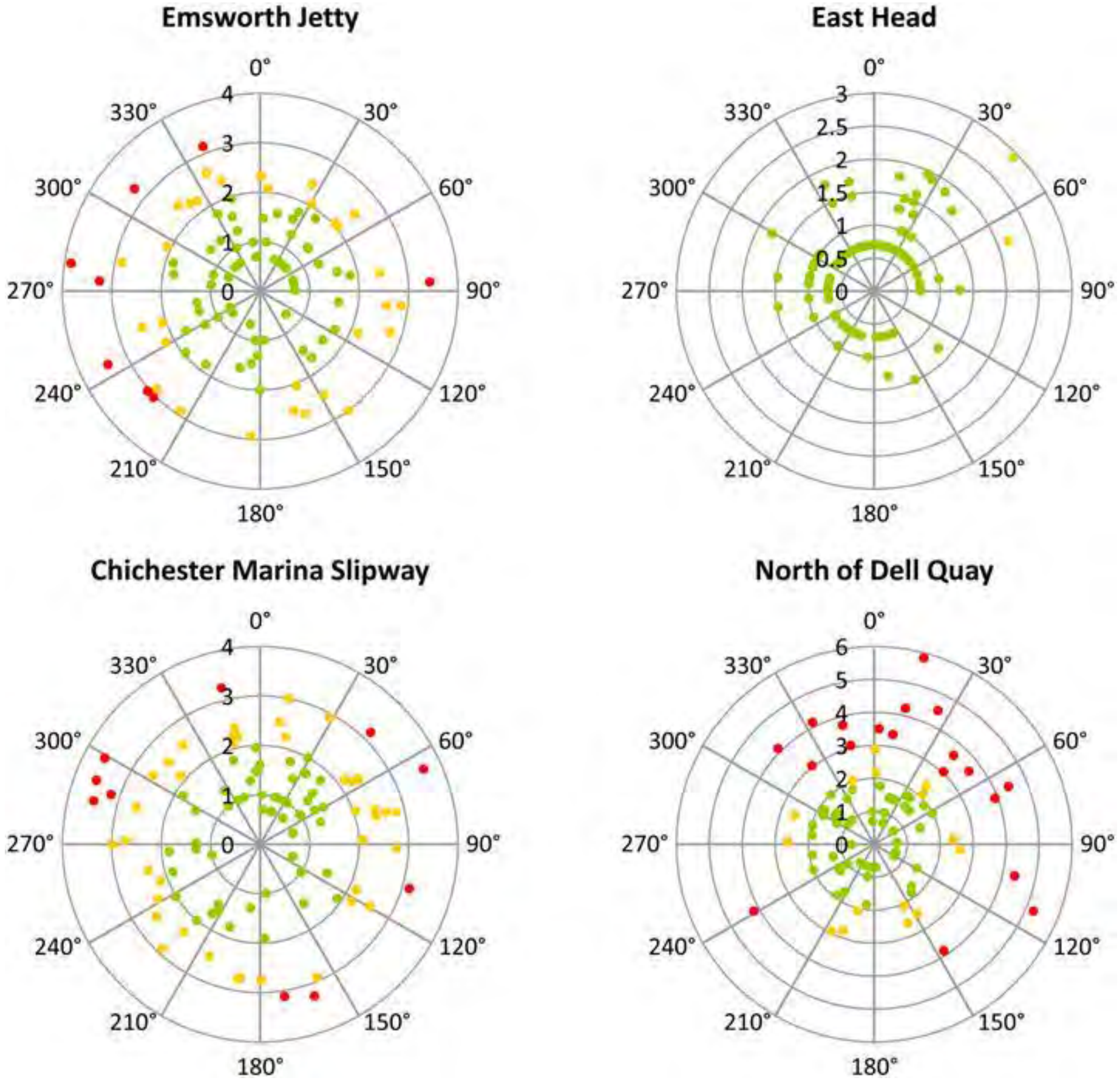


Figure X.5: Polar plots of log10 faecal coliforms against tidal state on the high/low tidal cycle for water quality monitoring points with significant correlations
Data from Chichester District Council and Chichester Harbour Conservancy

At Emsworth Jetty higher results occurred during the flood tide, while at East Head and North of Dell quay, higher results tended to occur from just before high tide to just before low tide. At Chichester Marina Slipway there was a tendency for more lower results during the early stages of the ebb tide.

Figure X.6 presents polar plots of *E. coli* results against the lunar spring/neap cycle, where a statistically significant correlation was found. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 100 *E. coli* /100ml or less are plotted in green, those from 101 to 1,000 are plotted in yellow, and those exceeding 1,000 are plotted in red.

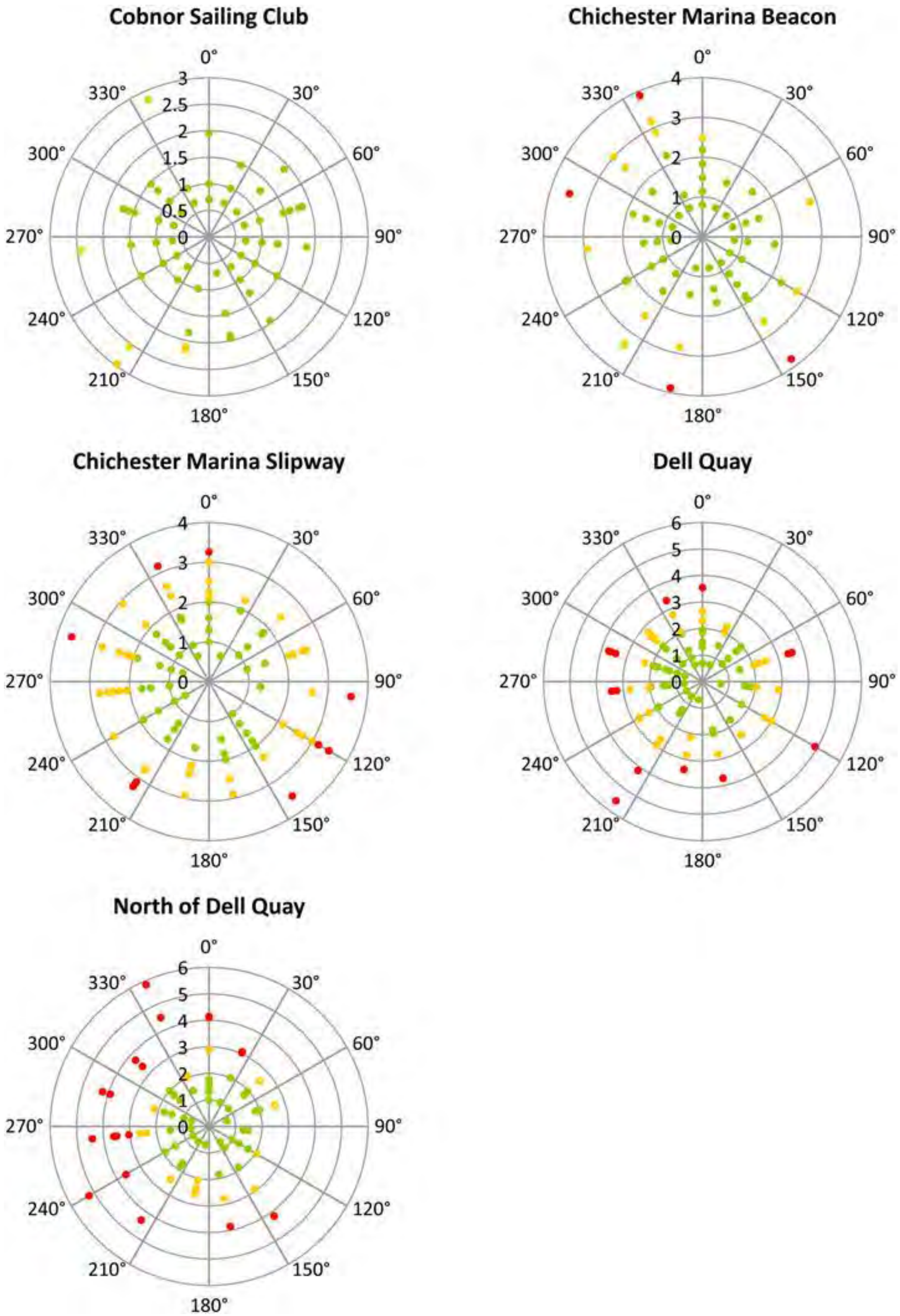


Figure X.6: Polar plots of log10 faecal coliforms against tidal state on the spring/neap tidal cycle for bathing waters monitoring points with significant correlations

Data from Chichester District Council and Chichester Harbour Conservancy

No obvious patterns in relation to the spring/neap tidal cycle are apparent at Cobnor Sailing club. At Chichester Marina Beacon and Chichester Marina Slipway there appears to be a slight tendency for lower results on spring tides. At Dell Quay results were higher on average as the tide size decreased from spring to neap, whereas at North of Dell Quay the opposite pattern can be seen.

Influence of rainfall

To investigate the effects of rainfall on levels of contamination at the water quality monitoring sites Spearman's rank correlations were carried out between rainfall recorded at the Fishbourne weather station (Appendix II for details) over various periods running up to sample collection and *E. coli* results. These are presented in Table X.4 and statistically significant correlations ($p<0.05$) are highlighted in yellow.

E. coli levels at all sites across the harbour were influenced by rainfall to a similar extent. Rainfall between two and four days prior to sampling was of greatest influence at all sites.

Table X.4: Spearmans Rank correlation coefficients for *E. coli* results against recent rainfall

Site		Emsworth Jetty	East Head	Thorney Island	Bosham Quay	Cobnor Sailing Club	Cobnor Point	Itchenor Quay	Chichester Marina Beacon	Chichester Marina Slipway	Dell Quay	North of Dell Quay
n		97	102	103	103	103	102	103	102	103	103	85
24 hour periods prior to sampling	1 day	0.260	0.093	0.130	0.118	0.125	0.140	0.214	0.244	0.102	0.291	0.241
	2 days	0.335	0.345	0.154	0.350	0.124	0.335	0.434	0.234	0.257	0.433	0.407
	3 days	0.234	0.207	0.327	0.279	0.243	0.345	0.437	0.322	0.255	0.325	0.296
	4 days	0.204	0.264	0.281	0.200	0.228	0.241	0.186	0.321	0.184	0.247	0.185
	5 days	-0.002	-0.027	0.000	0.135	0.027	0.120	0.069	0.095	-0.016	0.042	0.052
	6 days	0.114	0.020	0.128	0.115	0.125	0.169	-0.030	0.099	0.042	-0.038	0.161
	7 days	-0.100	0.176	0.077	0.225	0.252	0.304	0.096	0.165	0.204	0.082	0.151
Total prior to sampling over	2 days	0.330	0.222	0.163	0.254	0.132	0.241	0.349	0.283	0.200	0.410	0.368
	3 days	0.306	0.226	0.187	0.266	0.156	0.295	0.427	0.322	0.287	0.454	0.419
	4 days	0.287	0.222	0.275	0.323	0.243	0.351	0.402	0.407	0.290	0.472	0.410
	5 days	0.262	0.145	0.223	0.317	0.204	0.332	0.355	0.360	0.192	0.411	0.341
	6 days	0.260	0.130	0.203	0.311	0.239	0.362	0.305	0.334	0.185	0.324	0.339
	7 days	0.210	0.148	0.183	0.299	0.222	0.353	0.280	0.319	0.177	0.295	0.306

Data from Chichester District Council, Chichester Harbour Conservancy and the Environment Agency

Influence of sewage spills

To investigate the impact of sewage spills on the level of *E. coli* found in water samples, spill records for the Chichester STW were compared with *E. coli* results. Figure X.7 shows boxplots to compare data from those samples taken when a spill had or had not occurred within 48 hours prior to sampling. Table X.5 shows the results of 2 sample t-tests comparing the level of *E. coli* in water when a spill had or had not occurred within time periods from 24 hours to 72 hours.

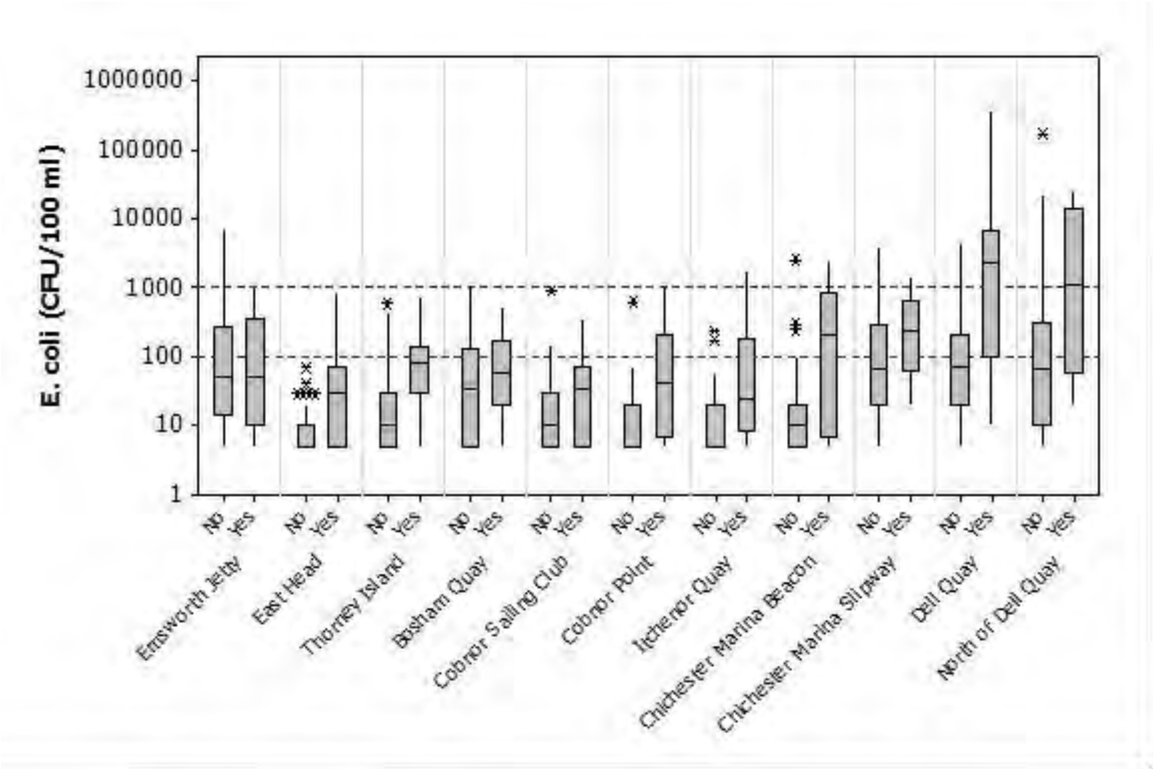


Figure X.7: Boxplots to show the effect spillages from Chichester STW on E. coli levels in water samples within 48 of a spillage event.

Data from Chichester District Council, Chichester Harbour Conservancy and the Environment Agency

Table X.5: Results of t-tests between *E. coli* results of samples that had or had not been taken within a specified period after a spillage event. Significant ($p < 0.05$) results are highlighted in yellow. Numbers in brackets are degrees of freedom.

	Number of hours prior to sampling where spillage occurred		
Site	24	48	72
Emsworth Jetty	0.989 (12)	0.743 (14)	0.009 (8)
East Head	0.043 (9)	0.022 (10)	0.795 (5)
Thorney Island	0.004 (13)	0.021 (15)	0.452 (6)
Bosham Quay	0.204 (16)	0.236 (16)	0.597 (8)
Cobnor Sailing Club	0.215 (12)	0.088 (13)	0.903 (6)
Cobnor Point	0.026 (10)	0.029 (10)	0.626 (5)
Itchenor Quay	0.065 (10)	0.035 (11)	0.481 (6)

Site	Number of hours prior to sampling where spillage occurred 24	48	72
Chichester Marina Beacon	0.013 (10)	0.016 (11)	0.600 (5)
Chichester Marina Slipway	0.068 (16)	0.061 (17)	0.821 (7)
Dell Quay	0.005 (11)	0.009 (13)	0.348 (6)
North of Dell Quay	0.032 (10)	0.046 (10)	0.911 (4)

Data from Chichester District Council, Chichester Harbour Conservancy and the Environment Agency

Some influence was detected at all sites aside from Bosham Quay, Cobnor Sailing club and Chichester Marina Slipway, although t-tests suggested that the effect was nearly significant at the 0.05 level at Chichester Marina Slipway for 24 and 48 hours. This would suggest that spills from Chichester STW have wide ranging effects. However, such conclusions should be treated with great caution as conditions associated with spills (wet weather when the water table is high) will also be associated with increased inputs of indicator bacteria from other sources such as rivers. An effect was found at Emsworth Jetty for example, although it would seem unlikely that a detectable influence would extend this far.

X.2. Shellfish waters monitoring results

Summary statistics and geographical variation

There are three shellfish waters sites designated under Directive 2006/113/EC (European Communities, 2006) in Chichester Harbour: Emsworth Channel, Thornham Channel and Chichester Channel. Figure X.8 shows the location of the three Chichester Harbour shellfish water monitoring points as well as seven other sites from which occasional samples have been taken. Table X.6 presents summary statistics for bacteriological monitoring results from the Chichester Harbour shellfish water monitoring points. Only water sampling results are presented here, as flesh results from the shellfish hygiene monitoring programme (Appendix XII) are used to assess compliance with bacteriological standards in shellfish flesh under this programme.

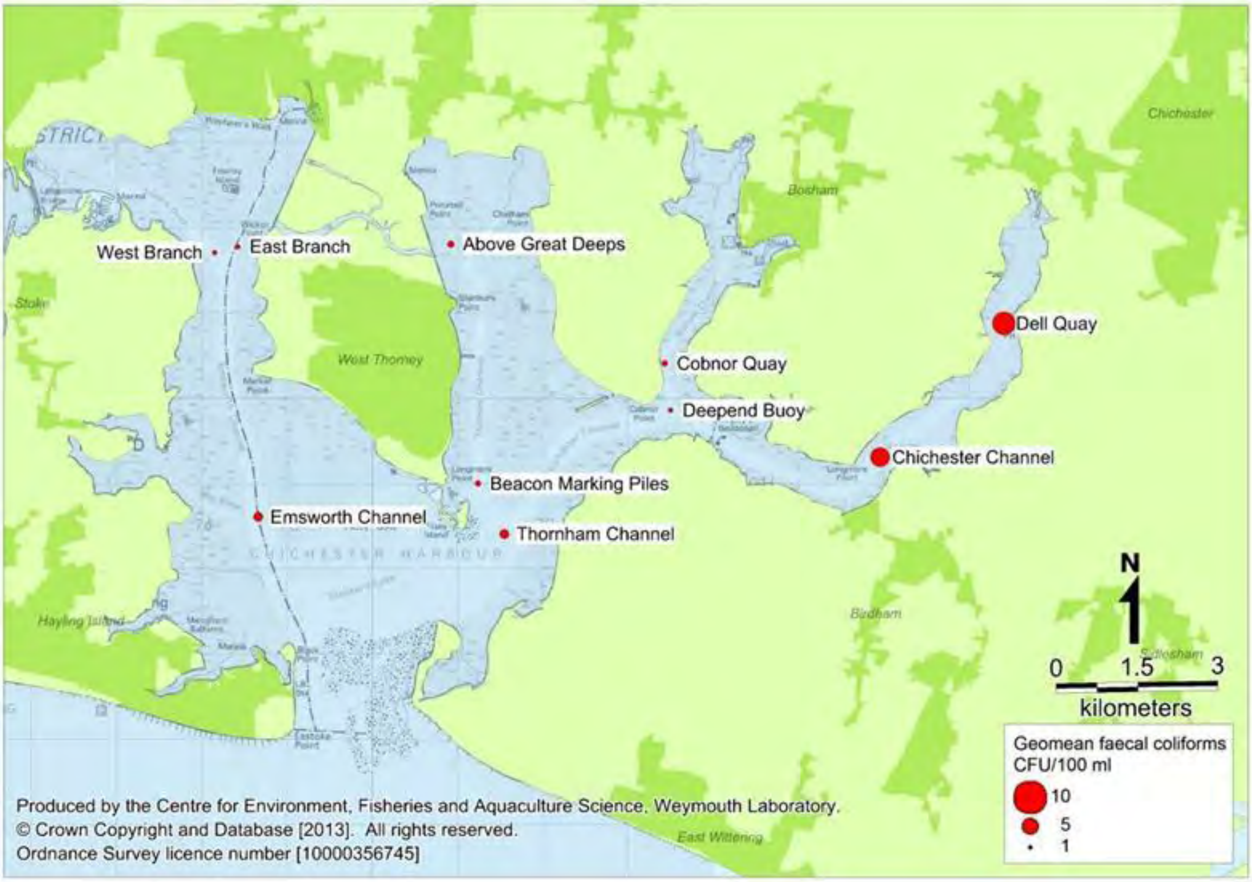


Figure X.8: Location of designated bathing waters monitoring points in Chichester Harbour
Data from the Environment Agency

Table X.6: Summary statistics for bathing waters faecal coliform results, April 2008 to 2013 (cfu/100ml).

Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1000
West Branch	6	25/02/2009	01/10/2009	1.3	<2	5	0.0	0.0
East Branch	6	25/02/2009	01/10/2009	1.3	<2	5	0.0	0.0
Emsworth Channel	34	21/05/2008	11/04/2013	2.8	<2	338	2.9	0.0
Thornham Channel	34	21/05/2008	11/04/2013	2.7	<2	116	2.9	0.0
Beacon Marking Piles	6	25/02/2009	01/10/2009	1.6	<2	5	0.0	0.0
Above Great Deeps	6	25/02/2009	01/10/2009	1.8	<2	5	0.0	0.0
Cobnor Quay	8	21/05/2008	01/10/2009	1.8	<2	11	0.0	0.0
Deepend Buoy	8	21/05/2008	01/10/2009	1.3	<2	5	0.0	0.0
Chichester Channel	34	21/05/2008	11/04/2013	5.7	<2	3690	11.8	5.9
Dell Quay	8	21/05/2008	01/10/2009	6.9	2	72	0.0	0.0

Data from the Environment Agency

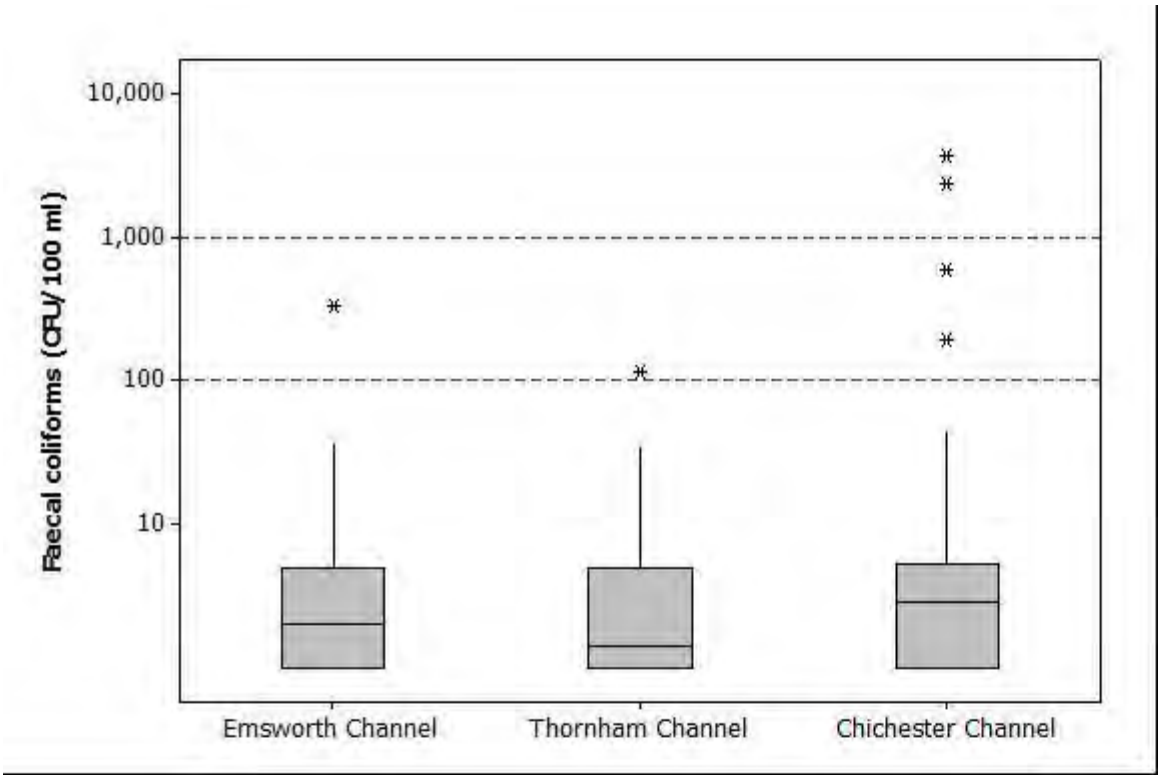


Figure X.9: Box-and-whisker plots of all faecal coliforms results by site
Data from the Environment Agency

The distribution of results was similar across these three sites (Figure X.9), although Chichester Channel had distinctly higher results on average and in terms of the number of samples exceeding 100 and 1000 faecal coliforms/100ml. One-way ANOVA testing showed there to be no significant differences in faecal coliform levels between sites ($p = 0.111$).

More robust comparisons of sites 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. These tests revealed significant correlations between all three of the main sites, suggesting that they are influenced by similar sources of contamination.

Overall temporal pattern in results

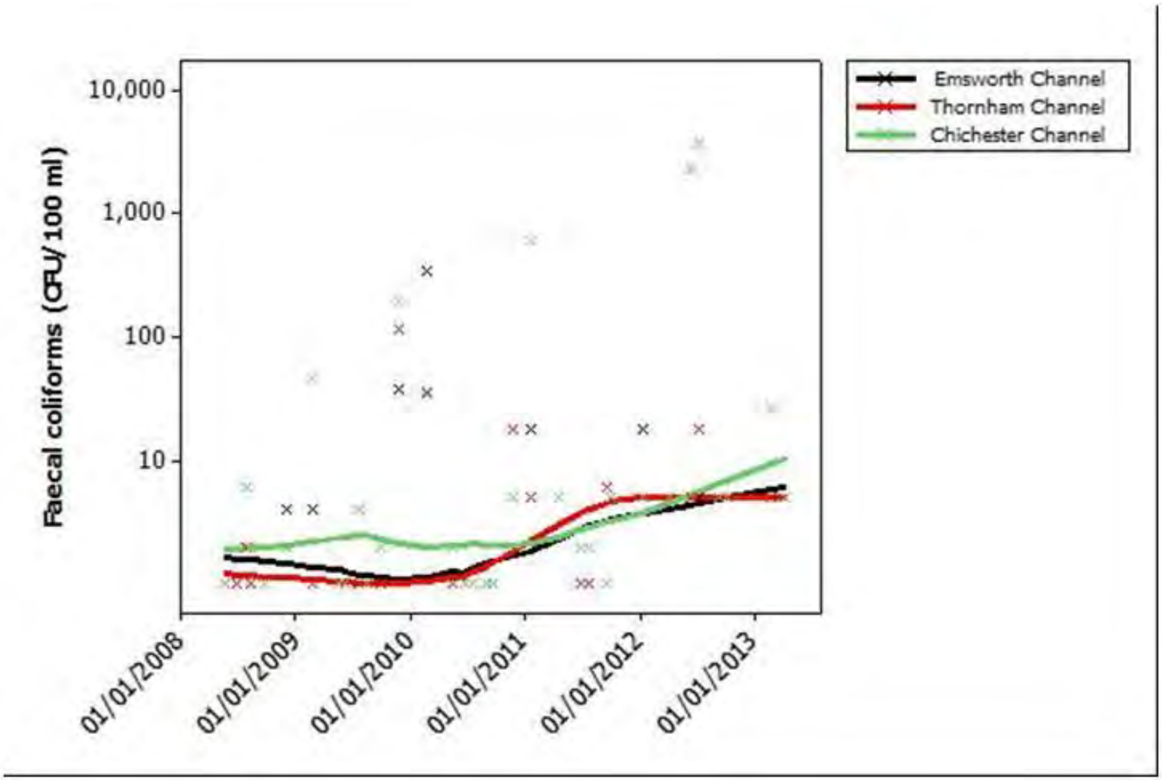


Figure X.10: Scatterplot of faecal coliform results by site and date, overlaid with lowess lines
Data from the Environment Agency

Figure X.10 shows that faecal coliform levels have increased on average at all three sites during the period examined.

Seasonal patterns of results

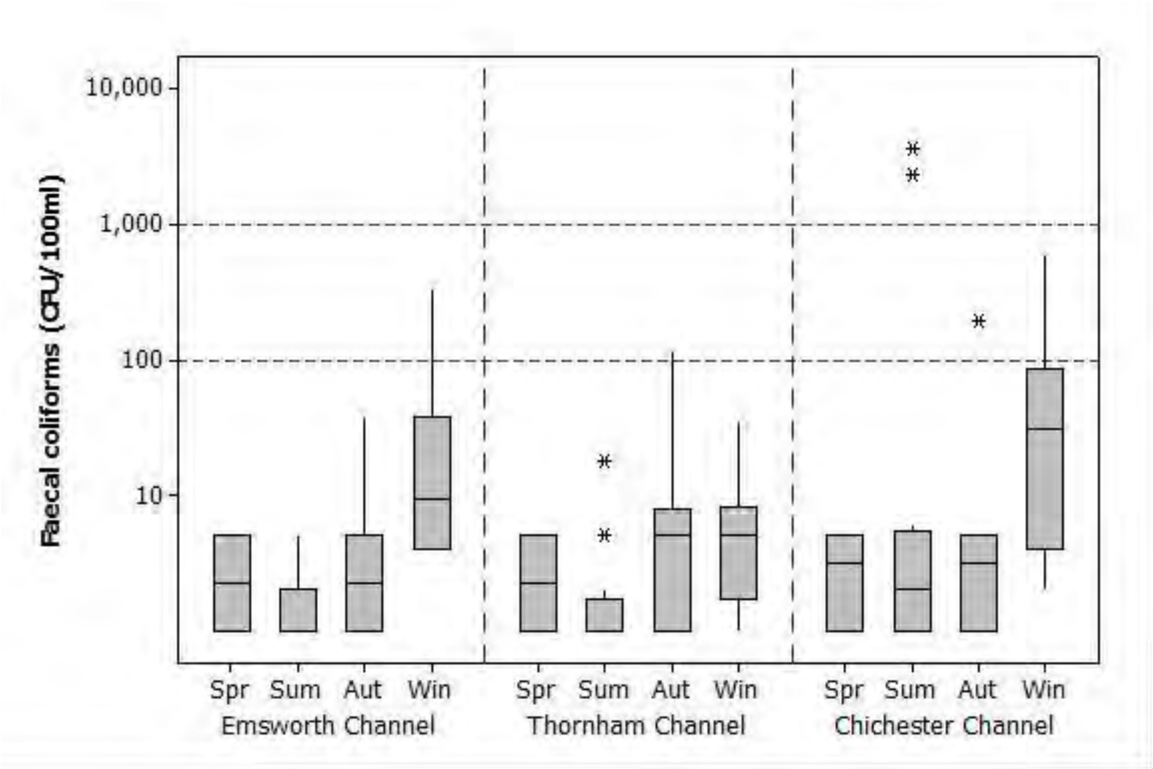


Figure X.11: Boxplot of faecal coliform results by site and season
Data from the Environment Agency

Results were highest on average during winter at all three sites, although the pattern was much less marked at Thornham Channel, the outermost site (Figure X.11). Comparisons (One-way ANOVA) of faecal coliform levels at each site between seasons revealed that there were no significant differences between seasons at Thornham channel and Chichester Channel ($p = 0.171$ and 0.255 respectively), but there was a significant difference between seasons at Emsworth Channel ($p = 0.003$). Post-ANOVA tests (Tukey) showed that there were significantly higher levels of faecal coliforms in the winter than any other season at Emsworth Channel.

Influence of tide

To investigate the effects of tidal state on faecal coliform results, circular-linear correlations were carried out against both the high/low and spring/neap tidal cycles for each of the water quality sampling sites. No significant correlations ($p < 0.05$) were found between any site and tidal state (Table X.7).

Table X.7: Circular linear correlation coefficients (r) and associated p values for faecal coliform results against the high low and spring/neap tidal cycles

	High/low tides		Spring/neap tides	
Site Name	r	p	r	p
Emsworth Channel	0.290	0.073	0.193	0.315
Thornham Channel	0.182	0.357	0.216	0.234
Chichester Channel	0.054	0.913	0.060	0.894

Data from the Environment Agency

Influence of rainfall

To investigate the effects of rainfall on levels of contamination at the water quality monitoring sites Spearman's rank correlations were carried out between rainfall recorded at the Fishbourne weather station (Appendix II for details) over various periods running up to sample collection and faecal coliform results. These are presented in Table X.8 and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table X.8: Spearmans Rank correlation coefficients for faecal coliform results against recent rainfall

Site		Emsworth Channel	Thornham Channel	Chichester Channel
n		34	34	34
24 hour periods prior to sampling	1 day	0.298	0.458	0.298
	2 days	0.346	0.351	0.405
	3 days	0.209	0.407	0.193
	4 days	0.291	0.395	0.184
	5 days	0.206	0.194	0.354
	6 days	-0.053	-0.052	0.024
	7 days	0.100	-0.078	0.134
Total prior to sampling over	2 days	0.280	0.417	0.333
	3 days	0.237	0.403	0.317
	4 days	0.354	0.472	0.389
	5 days	0.246	0.372	0.326
	6 days	0.204	0.294	0.262
	7 days	0.143	0.185	0.224

Data from the Environment Agency

Faecal coliform levels at all sites across the harbour were influenced by rainfall to some extent. This influence was strongest at Thornham Channel.

Influence of salinity

Salinity was recorded on most sampling occasions. Figure X.12 presents scatterplots of salinity against faecal coliforms for the three main sites.

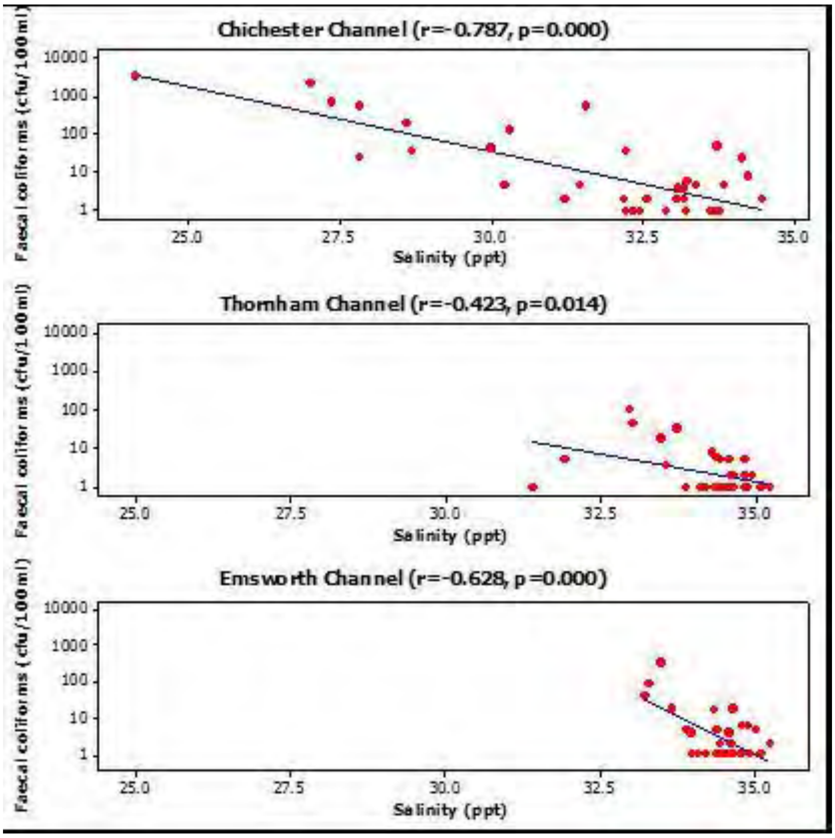


Figure X.12: Scatterplots of salinity against faecal coliforms.

Significant negative correlations between salinity and levels of faecal coliforms were found for all three sites. The relationship was strongest at Chichester Channel, where variation in both parameters was greatest.

Influence of sewage spills

Insufficient data was available to undertake a meaningful investigation into the effects of spills on bathing waters faecal coliform results.

Appendix XI. Microbiological Data: Shellfish Flesh

XI.1. Summary statistics and geographical variation

In March 2008, the Bosham and Chichester STW discharges were fitted with UV treatment. Therefore the following analyses used data from April 2008 onwards.

The geometric mean results of shellfish flesh monitoring from all RMPs are presented in Figure XI.1. Summary statistics are presented in Table XI.1 and boxplots summarising *E. coli* levels at the RMPs are presented in Figure XI.2.

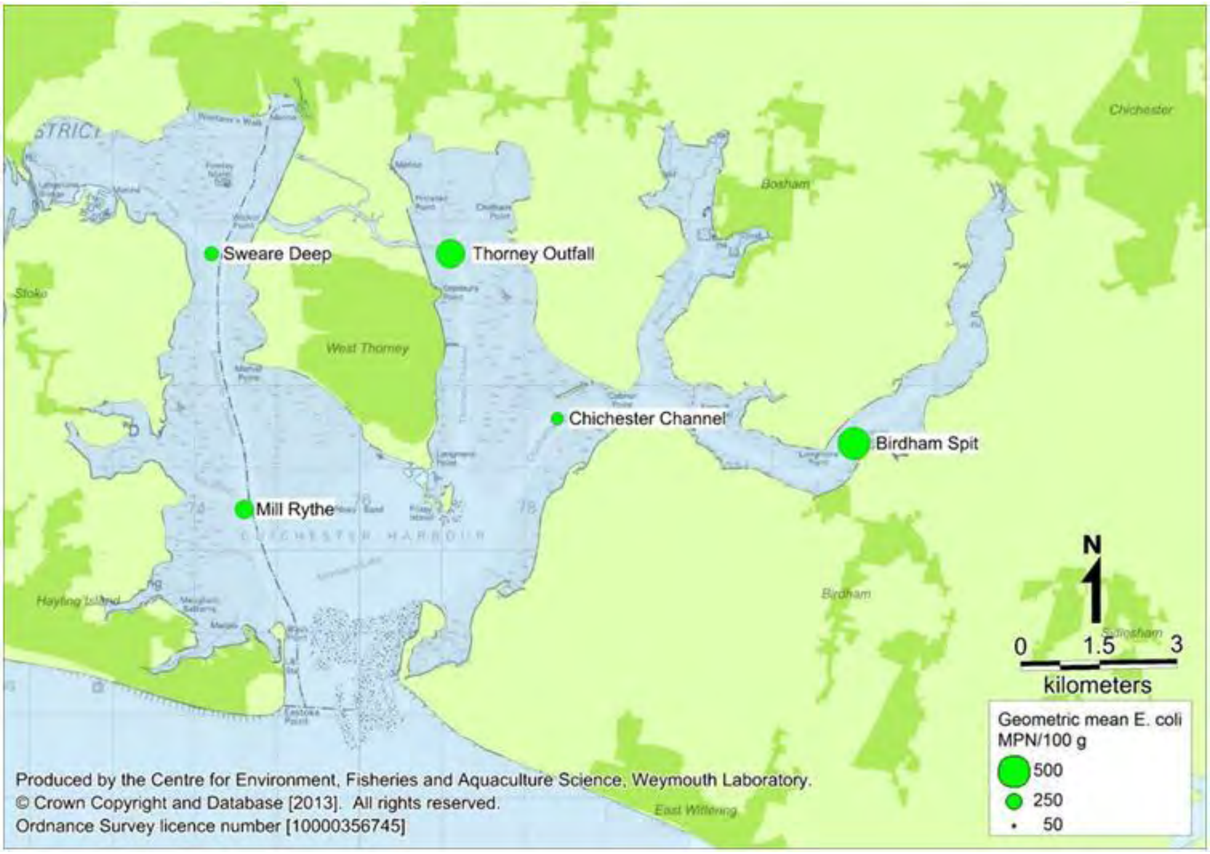


Figure XI.1: Geometric mean *E. coli* (MPN/100g) results of shellfish flesh monitoring from RMPs in Chichester Harbour

Table XI.1: Summary statistics of *E. coli* results (MPN/100g) from native oyster RMPs sampled from April 2008 to 2013

RMP	n	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 230	% over 4600
Sweare Deep	61	06/04/2008	13/03/2013	228.1	<20	24000	47.5	1.6
Mill Rythe	59	06/04/2008	13/03/2013	291.3	<20	5400	62.7	3.4
Thorney Outfall	59	06/04/2008	13/03/2013	445.0	<20	11000	71.2	10.2
Chichester Channel	53	06/04/2008	13/03/2013	193.7	<20	5400	49.1	1.9
Birdham Spit	60	06/04/2008	13/03/2013	501.0	<20	35000	71.7	11.7

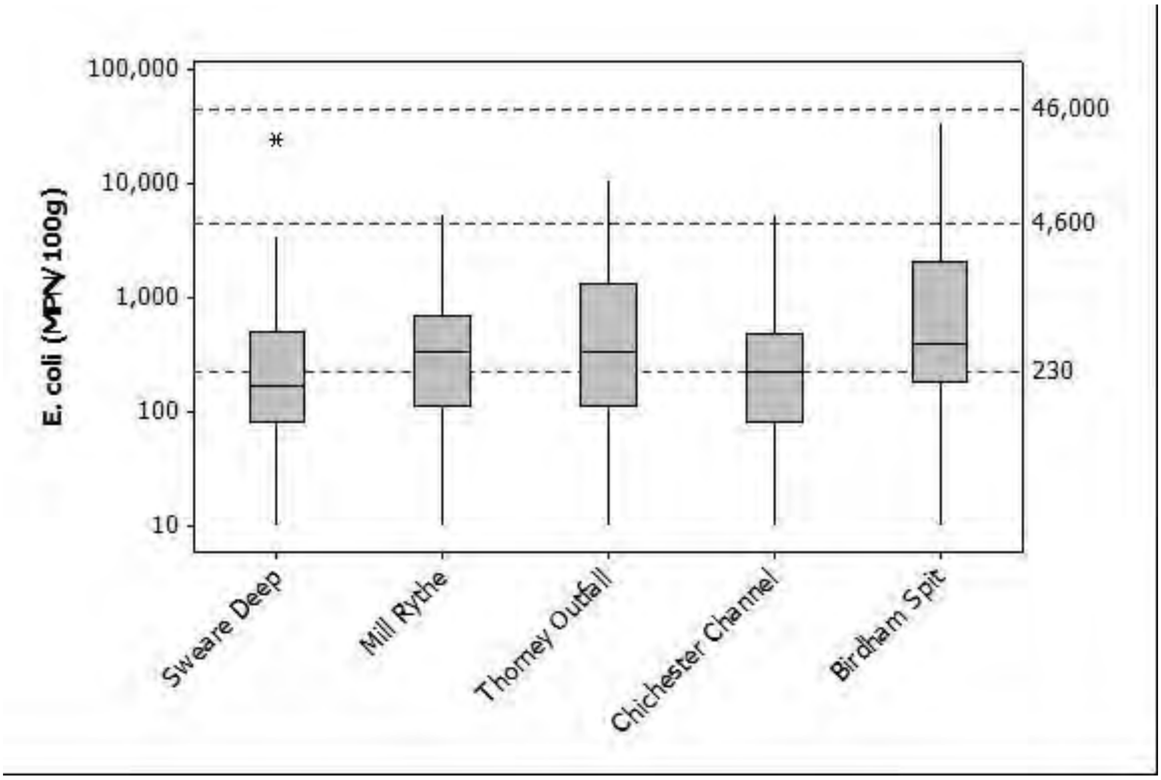


Figure XI.2: Boxplots of *E. coli* results from RMPs sampled from April 2008 onwards

Comparisons of the sites (One-way ANOVA, p = 0.002) showed that there were significant differences between RMPs. Post ANOVA tests (Tukey) revealed that Birdham Spit had significantly greater levels of *E. coli* contamination than Sweare Deep and Chichester Channel. Additionally, Chichester Channel had significantly lower *E. coli* contamination than Thorney Outfall. All sites had maximum levels above 4,600 cfu/100 g, but none exceeded 46,000. Just over 10% of samples returned results of over 4600 at both Thorney Outfall and Birdham Spit suggesting that results from these RMPs are more likely to align with a C classification. The spread of results from the other three RMPs were consistent with B classifications.

XI.2. Overall temporal pattern in results

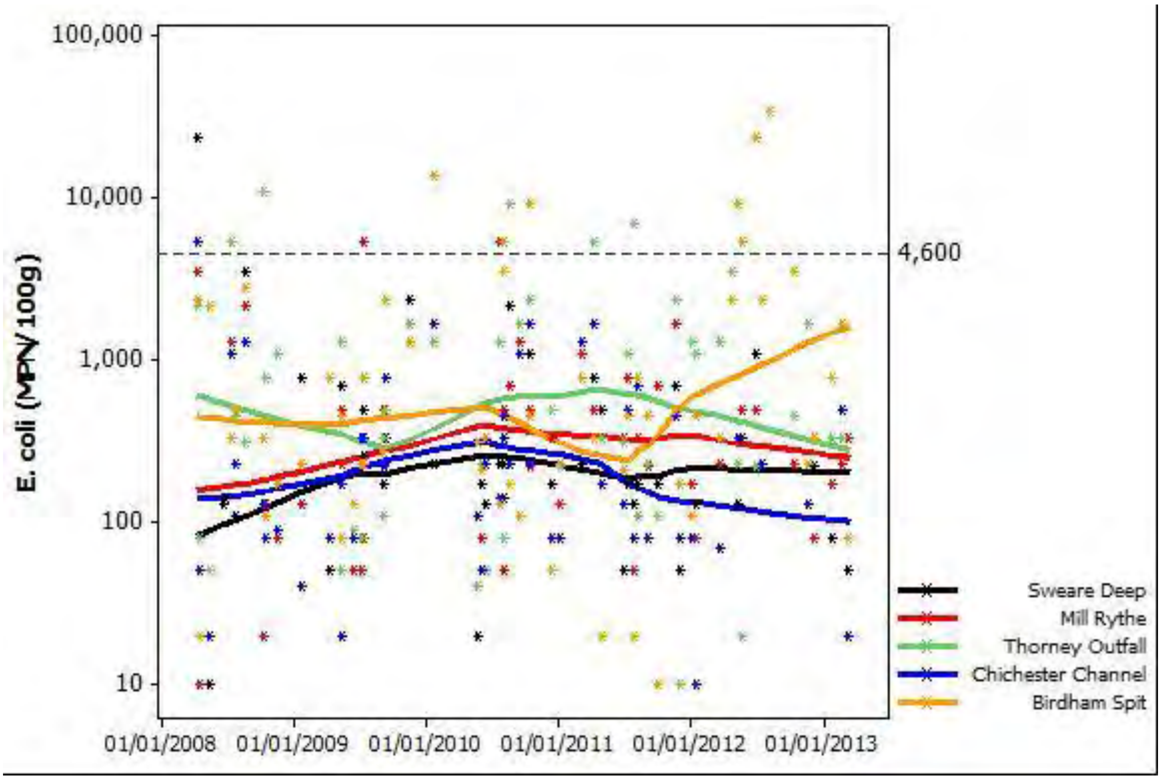


Figure XI.3: Scatterplot of *E. coli* results by RMP and date, overlaid with lowess lines

Figure XI.3 shows some fluctuations over the years, but there is no consistent pattern apparent across the harbour as a whole. However, *E. coli* levels at Birdham Spit appear to have increased on average from mid 2011 to present.

XI.3. Seasonal patterns of results

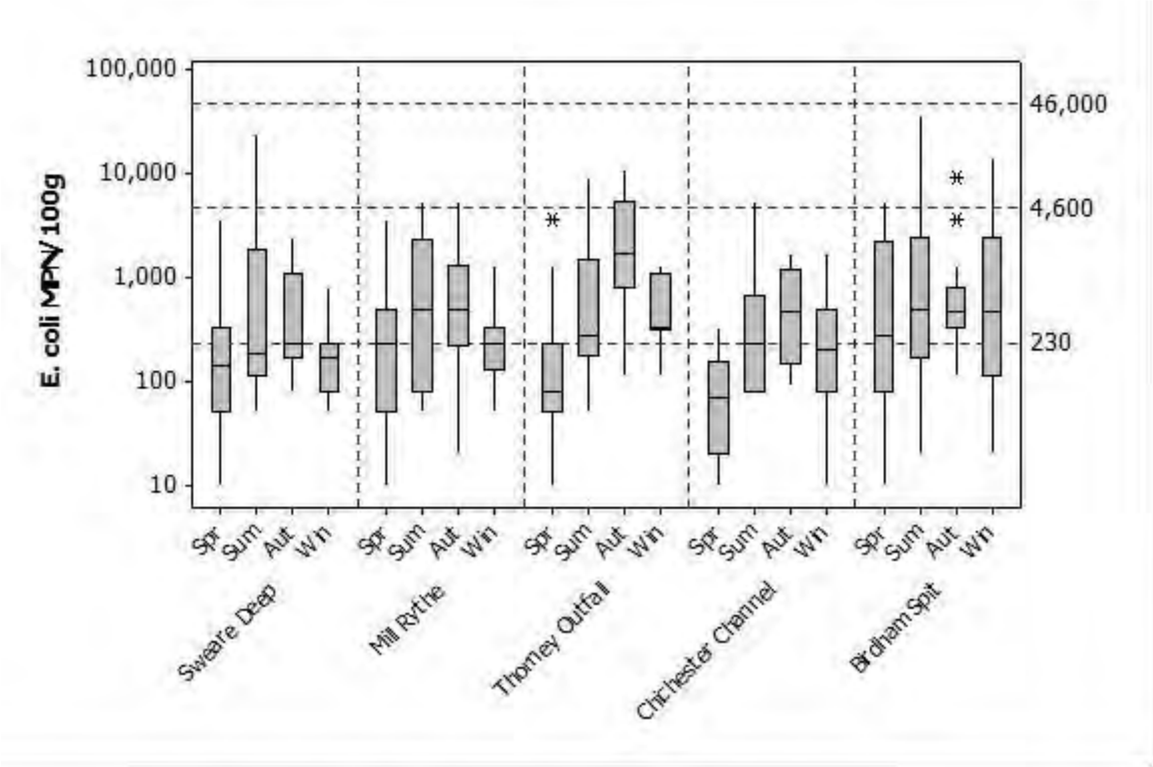


Figure XI.4: Boxplot of *E. coli* results by RMP and season

One-way ANOVA tests showed that there was no significant seasonal variation at Sweare Deep, Mill Rythe or Birdham Spit (p = 0.064 to 0.627). However there were significant differences in *E. coli* levels between seasons at both Thorney Outfall (p < 0.001) and Chichester Channel (p = 0.001). At both sites, autumn and summer had higher *E. coli* levels than spring. At Chichester Channel, winter *E. coli* levels did not differ significantly from spring levels, but at Thorney outfall spring *E. coli* levels were significantly higher than in winter.

XI.4. Influence of tide

To investigate the effects of tidal state on *E. coli* results, circular-linear correlations were carried out against the high/low and spring/neap tidal cycles for each RMP. The results of these correlations are summarised in Table XI.2, with significant results highlighted in yellow.

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

		High/low tides		Spring/neap tides	
Site Name	Species	r	p	r	p
Sweare Deep	Native oyster	0.260	0.020	0.284	0.009
Mill Rythe	Native oyster	0.342	0.001	0.424	<0.001
Thorney Outfall	Native oyster	0.241	0.038	0.067	0.779
Chichester Channel	Native oyster	0.104	0.585	0.160	0.278
Birdham Spit	Native oyster	0.112	0.490	0.206	0.089

Figure XI.5 presents polar plots of log_{10} *E. coli* results against tidal states on the high/low cycle for the correlations indicating a statistically significant effect. High water at Chichester Harbour 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 4,600 are plotted in yellow, and those exceeding 4,600 are plotted in red.

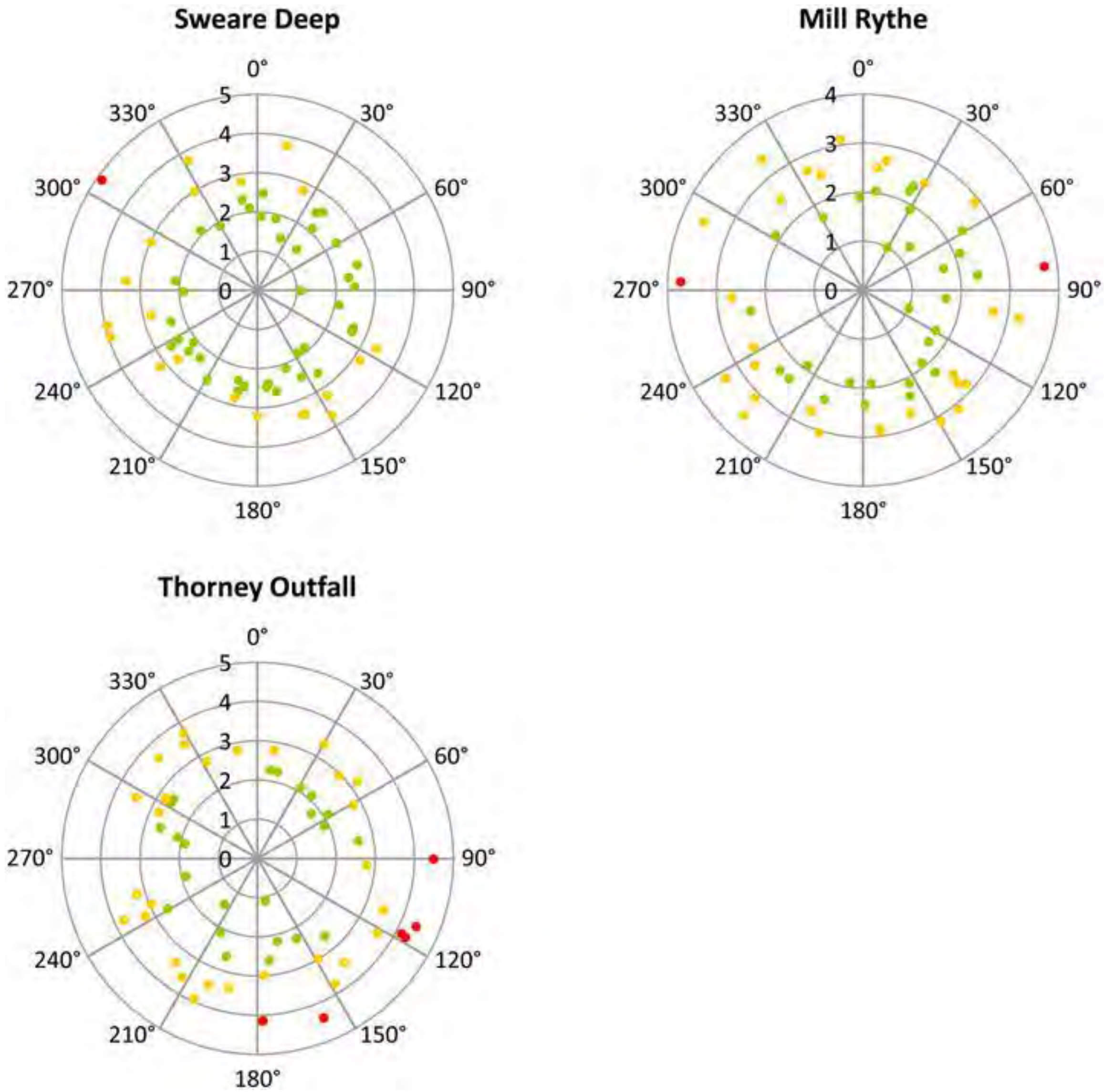


Figure XI.5: Polar plots of log10 *E. coli* results (MPN/100g) against tidal state on the high/low tidal cycle for sampling points with significant correlations

At Mill Rythe and Sweare Deep *E. coli* levels tended to be higher on average just after low water, possibly suggesting a build-up of contamination on the later stages of the ebb tide. At Thorney Outfall, *E. coli* levels were highest towards the end of the ebb tide, possibly relating to the influence of the Great Deep outfall.

Figure XI.6 presents polar plots of log_{10} *E. coli* results against the spring/neap tidal cycle for those RMPs that showed a significant correlation. 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 less are plotted in green, those from 231 to 4,600 are plotted in yellow, and those exceeding 4600 are plotted in red.

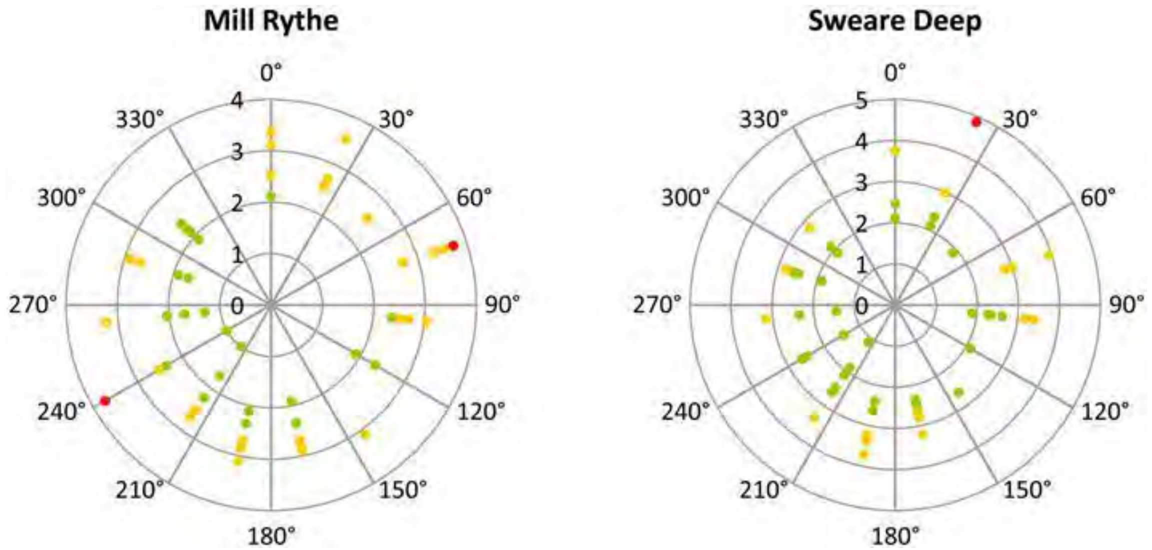


Figure XI.6: Polar plots of log_{10} *E. coli* results (MPN/100g) against tidal state on the spring/neap tidal cycle for sampling points with significant correlations

At both Mill Rythe and Sweare Deep, higher *E. coli* results tended to occur around the spring tide. This may be because the increased tidal range allowed contamination from distant sources to reach these sites.

XI.5. Influence of rainfall

To investigate the effects of rainfall on levels of contamination within shellfish samples Spearman's rank correlations were carried out between *E. coli* results and rainfall recorded at the Fishbourne weather station (Appendix II for details) over various periods running up to sample collection. These are presented in Table XI.3, and statistically significant correlations (p<0.05) are highlighted in yellow.

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

Site		Sweare Deep	Mill Rythe	Thorney Outfall	Chichester Channel	Birdham Spit
n		61	59	59	53	60
24 hour periods prior to sampling	1 day	0.179	0.185	0.141	0.350	0.217
	2 days	0.309	0.176	0.350	0.251	0.209
	3 days	0.347	0.282	0.294	0.363	0.196
	4 days	0.274	0.118	-0.003	0.200	0.245
	5 days	0.284	0.120	0.183	0.116	0.081
	6 days	0.096	0.080	0.094	0.099	0.241
	7 days	0.150	0.092	-0.025	-0.006	0.094
Total prior to sampling over	2 days	0.238	0.158	0.297	0.324	0.195
	3 days	0.338	0.258	0.341	0.442	0.253
	4 days	0.346	0.232	0.251	0.349	0.207
	5 days	0.396	0.232	0.306	0.287	0.167
	6 days	0.420	0.239	0.290	0.271	0.235
	7 days	0.409	0.243	0.192	0.261	0.234

Levels of *E. coli* appear to be influenced to some extent by the level of rainfall. Mill Rythe is the site furthest away from land and it is not significantly affected by rainfall until 3 days after a rainfall event. Birdham Spit is the site least affected by rainfall, with no clear pattern in the number of days after rainfall.

XI.6. Influence of storm sewage spills

To investigate the impact of storm overflow events on the level of *E. coli* found in shellfish flesh, storm spill data for Chichester STW were compared with *E. coli data*. Figure XI.7 shows boxplots to compare hygiene data from those samples taken when a spill had or had not occurred within 48 hours prior to sampling. Table XI.4 shows the results of 2 sample t-tests comparing the level of *E. coli* in flesh when a spill had or had not occurred within time periods from 24 hours to 72 hours.

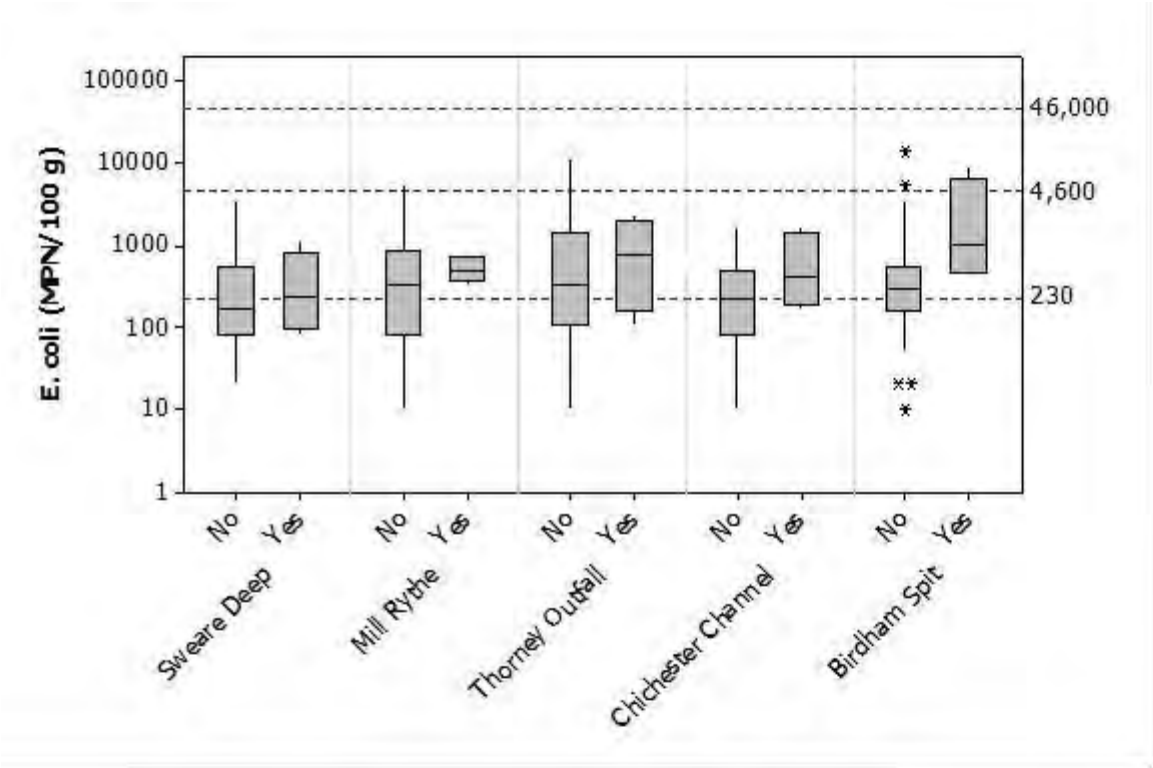


Figure XI.7: Boxplots to show the effect of storm overflow events from Chichester STW on *E. coli* levels in shellfish samples within 48 hours of an event.

The boxplots suggest a noticeable influence of storm overflow events at Birdham Spit, and possibly at Chichester Channel. It is interesting to note that following recent spills there were fewer low results and average results were higher at all sites. This again illustrates the difficulty of separating the impacts of spills from the impacts of increased freshwater inputs, both of which will tend to occur under similar conditions.

Table XI.4: Results of t-tests between *E. coli* results of samples that had or had not been taken within a specified period after a spillage event. Significant ($p < 0.05$) results are highlighted in yellow. Numbers in brackets are degrees of freedom.

	Number of hours prior to sampling where spillage occurred		
Site	24	48	72
Sweare Deep	0.868 (4)	0.775 (3)	0.633 (3)
Mill Rythe	0.698 (5)	0.080 (18)	0.066 (7)
Thorney Outfall	0.601 (4)	0.693 (4)	0.769 (4)
Chichester Channel	0.778 (3)	0.241 (3)	0.222 (4)
Birdham Spit	0.370 (4)	0.129 (3)	0.081 (5)

None of the comparisons revealed a statistically significant increase in *E. coli* results in the three days following a spill from Chichester storm tanks. This is perhaps largely due to the low sample numbers considered in the analyses.

Appendix XII. Shoreline Survey Report

Date (time): 13th May 2013 (0830-16:30)

14th May 2013 (0830-12:30)

20th May 2013 (08:30-13:00)

22nd May 2013 (0800-13:30)

4th June 2013 (09:00-14:00)

5th June 2013 (09:00-14:00)

Cefas Officers: Alastair Cook (all dates) & David Walker (4th and 5th June)

Local Enforcement Authority Officers: Nick Harvey (Havant Council, 13th and 14th May), Clif Davis (Chichester Council, 20th May), Adrian Cook (Chichester Council, 22nd May).

Area surveyed: Perimeter of Chichester Harbour (Figure XII.1).

Weather: 13th May 2013, dry, overcast, 12°C, wind WSW force 3.

14th May 2013, dry, overcast, 11°C, wind W force 3.

20th May 2013, dry, overcast, 16°C, wind N force 3.

22nd May 2013, dry, overcast, 13°C, wind N force 2.

4th June 2013, dry, sunny, 18°C, wind E force 2.

5th June 2013, dry, sunny, 20°C, wind SE force 1.

Tides:

Admiralty Totaltide predictions for Chichester Harbour (50°47'N 0°56'W). All times in this report are BST.

13/05/2013	14/05/2013	20/05/2013
High 02:05 4.5 m High 14:34 4.5 m Low 07:24 1.0 m Low 19:40 1.3 m	High 02:37 4.4 m High 15:08 4.4 m Low 07:57 1.2 m Low 20:14 1.4 m	High 07:34 3.9 m High 20:16 4.2 m Low 00:57 1.8 m Low 13:19 1.6 m
22/05/2013 High 09:47 4.3 m High 22:13 4.6 m Low 02:49 1.3 m Low 15:07 1.2 m	04/06/2013 High 09:20 4.0 m High 21:48 4.2 m Low 02:08 1.6 m Low 14:31 1.5 m	05/06/2013 High 10:24 4.1 m High 22:36 4.3 m Low 03:05 1.5 m Low 15:26 1.5 m

Objectives:

The shoreline survey aims to obtain samples of freshwater inputs to the area for bacteriological testing; confirm the location of previously identified sources of potential contamination; locate other potential sources of contamination that were previously unknown and find out more information about the fishery. A full list of recorded observations is presented in Table XII.1 and the locations of these observations are mapped in Figure XII.1. Photographs are presented in Figure XII.3 – Figure XII.32. The shoreline survey was carried out over several visits. Every effort was made to ensure the entire shoreline was surveyed, although there were some short stretches where the shoreline was privately owned and could not be accessed.

XII.1. Description of Fishery

There is a native oyster fishery within the harbour, which received a high level of effort (40 boats) in 2013, but only for the first few days of the season in early November. This has been the typical pattern of activity in recent years. Most of the catch is sent to France for ongrowing. Stocks are quite sparse, and sampling some RMPs via dredge requires a considerable effort. The possibility of using deployment bags instead was suggested to the local authorities.

A recent application to harvest clams (*Tapes* spp. and American hard clams) and cockles via hand digging was also discussed with the local authorities. The application had requested classification of the whole harbour for these species meaning that the interim sampling plan was too costly and intensive for the local authorities to support. It was suggested that the applicant could select one or two smaller areas where stocks are plentiful, the water quality suitable, and there are no conservation restrictions. Such a compromise may provide the applicant with sufficient stocks to meet his needs whilst keeping monitoring costs realistic. Some clam digging activity has been reported in the upper reaches of Thorney Channel, although this area is not classified for commercial harvesting. The use of clam dredges is prohibited within Chichester Harbour so exploitation will be limited to hand digging.

Dead shells of American hard clams, Manila clams and/or native clams, cockles and occasionally native oysters were observed on intertidal areas. The cockle shells were mainly of a small size, whereas some of the clam shells were relatively large for the species.

XII.2. Sources of contamination

Sewage discharges

Two water company owned sewage works discharge direct to the harbour. The boil from the Chichester STW outfall was seen (observation 127). A marker post which presumably marks the Bosham STW outfall was also noted (observation 109). Thornham STW discharges to a natural freshwater lagoon (Great Deep) which in turn discharges to the Thorney Channel via a sluice (observation 48). Although the retention time of this lagoon is uncertain, it is likely that there is considerable bacterial dieoff before the diluted effluent reaches tidal waters. At the time of the visit the tide was higher than the level of Great Deep so it was not discharging. A water sample from the Great Deep contained 710 *E. coli* cfu/100ml.

The Fishery Lane pumping station outfall (observation 11) and the Kings Road CSO outfall (observation 38) were seen and neither showed signs of recent discharge. Inspection covers associated with the Breakers Yard PS were seen (observation 85) but the outfall to Ham Brook was not. Neither of the two pumping stations at Bosham were visible, but it is presumed they discharge via a stream/drain (observation 95). A pumping station was observed by Sandy Point (observation 2) but this is not listed as a sewage pumping station on the permit database. Similarly, three apparent pumping stations were observed in the vicinity of Westbourne (observations 133-135) none of which was listed on the permit database. It is therefore assumed that these do not make storm or emergency discharges of sewage.

Several private discharges were observed. The largest of these were at Birdham Pool (observations 130 and 132) and it is presumed these serve the Birdham Canal houseboats and the Chichester Yacht Basin. A cluster of private discharges was observed feeding into a small surface water drain at Chidham (observations 69 to 75). The cluster of private discharges around Furzefield Creek was not fully investigated as staff could not access the entire (private) foreshore here. Some were seen but the majority did not appear to be in regular use (observations 102-110). A local resident advised that the majority of properties by Furzefield Creek had connected to mains sewerage about 5 years ago. A few other small private sewage discharges were observed at various locations (observations 52, 78, 115, 141). In a few places oozes of grey water with sewage fungus were seen suggesting minor sewage inputs (observations 6, 12, 112). A small freshwater input at the southern end of Hayling Island carried a very high concentration of *E. coli*, suggestive of some sewage inputs (observation 5). Old cotton buds were commonly sighted in the tideline, but less persistent sewage related debris (rag) was only observed in one location (observation 18).

Freshwater inputs

All significant surface water inputs to shorelines adjacent to any shellfisheries were sampled and measured (Table XII.2). Some significant freshwater outfalls, including the River Lavant were covered by the tide when encountered and so were not discharging. Generally, the larger watercourses discharge to the heads of the four main channels.

Boats and Shipping

Large numbers of recreational craft, including yachts and cabin cruisers were moored throughout the harbour. There are numerous marinas and sailing clubs. Pleasure craft traffic is very heavy in the summer months. A few houseboats were observed in various locations (observations 9, 23, 47, 77, 129). These may make regular discharges when in occupation.

Livestock

Livestock were observed in several locations around the harbour, but not in particularly great numbers. The greatest concentrations were towards the northern end of Hayling Island (observations 21, 24-25, 27-28, 30-33). Some were also observed to the west of Emsworth (observations 42 and 43), at Southbourne (observations 46, 82-83), on Thorney Island (observations 61 and 63) and by the head of Chichester Channel (observations 120 and 128).

Wildlife

Seagulls, wading birds and wildfowl were commonly sighted all around the harbour. A high tide roost was seen at the southern tip of Chidham peninsula (observation 79) and a large aggregation of swans was seen on two consecutive days around the Chichester STW outfall (observation 127). Dog walkers and dog excrement were frequently observed along the coastal paths.

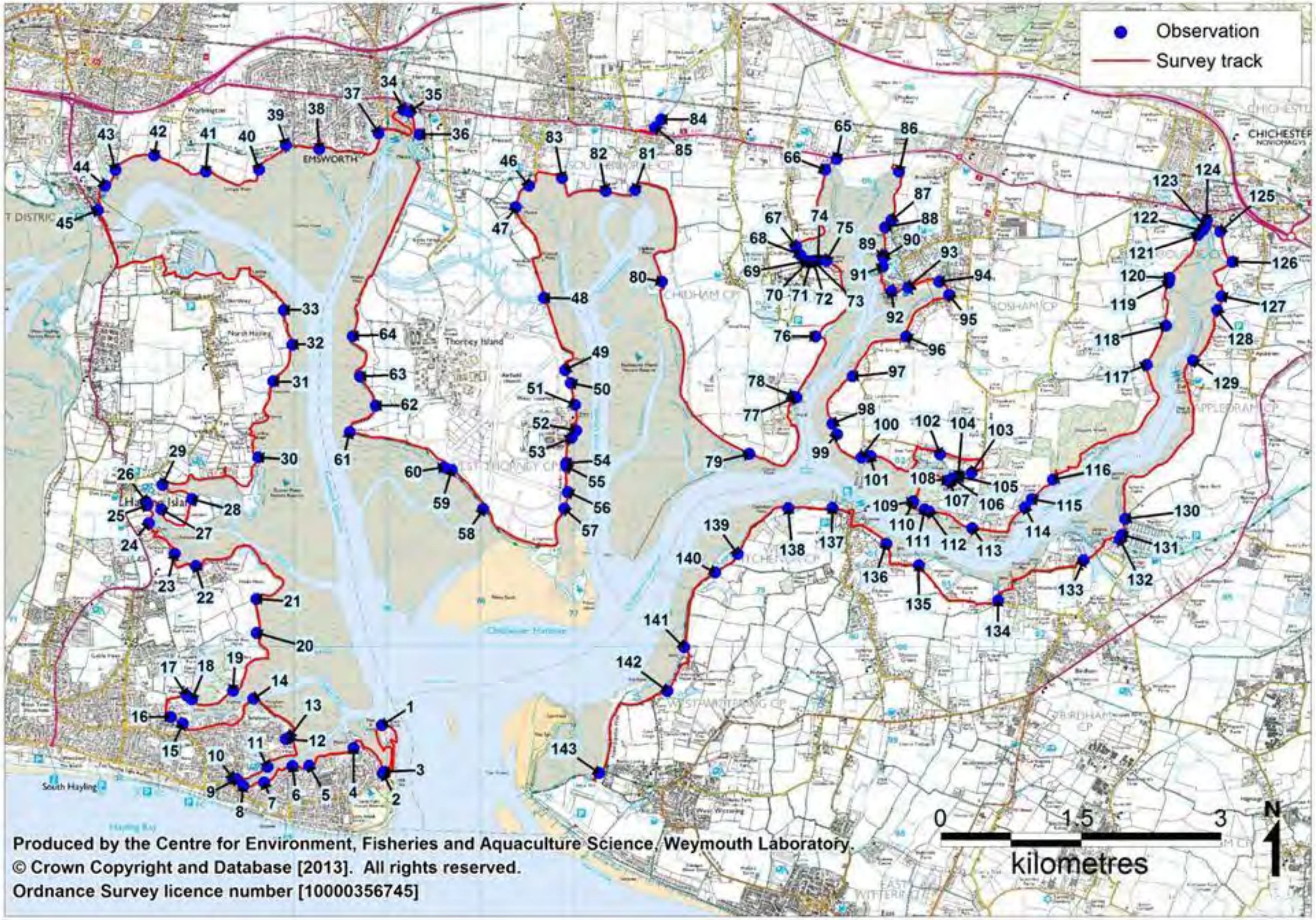


Figure XII.1: Locations of shoreline observations (see Table XII.1 for details)

Table XII.1: Details of Shoreline Observations

No	Time and Date	NGR	Photograph	Observation
1	13/05/2013 09:18	SZ 74944 99158		50 boats on moorings
2	13/05/2013 09:30	SZ 74953 98635	Figure XII.3	Pumping station (not a sewage discharge according to permit database).
3	13/05/2013 09:31	SZ 74963 98661	Figure XII.3	Stream 70cmx4cmx0.125m/s. Water sample 1
4	13/05/2013 09:46	SZ 74640 98914		Flap valve, trickling
5	13/05/2013 09:54	SZ 74165 98726	Figure XII.4	Stream 55cmx5cmx0.043m/s. Water sample 2.
6	13/05/2013 09:59	SZ 73984 98719	Figure XII.5	Culverted stream, not flowing sufficiently to measure. Odour and lots of sewage fungus.
7	13/05/2013 10:12	SZ 73678 98544		Dry flap valve
8	13/05/2013 10:20	SZ 73459 98509		Dry flap valve
9	13/05/2013 10:22	SZ 73388 98580		Houseboat, window open.
10	13/05/2013 10:24	SZ 73345 98585		Stream 20cmx3cmx0.203m/s. Water sample 3.
11	13/05/2013 10:34	SZ 73716 98713	Figure XII.6	Fishery Lane PS outfall, not flowing, no signs of recent discharges.
12	13/05/2013 10:43	SZ 73915 99006		Small trickle of surface water
13	13/05/2013 10:45	SZ 73952 99034		Small trickle of surface water
14	13/05/2013 10:54	SZ 73566 99443		Small trickle of surface water
15	13/05/2013 11:08	SZ 72810 99176		5 horses
16	13/05/2013 11:10	SZ 72679 99246		Pig enclosure
17	13/05/2013 11:16	SZ 72845 99479		Dry stream
18	13/05/2013 11:18	SZ 72910 99438		Sanitary debris (rag)
19	13/05/2013 11:26	SZ 73348 99527		Stream 18cmx6cmx0.234m/s. Water sample 4
20	13/05/2013 11:43	SU 73602 00150		Surface water outfall not flowing. 2 horses.
21	13/05/2013 11:48	SU 73596 00514		25 cattle
22	13/05/2013 12:10	SU 72950 00864		Surface water pumping station.
23	13/05/2013 12:16	SU 72725 00998		2 houseboats in marina
24	13/05/2013 12:25	SU 72444 01325		2 horses
25	13/05/2013 12:28	SU 72424 01515		9 horses
26	13/05/2013 12:29	SU 72415 01555		Stream 40cmx1cmx0.200m/s. Water sample 5.
27	13/05/2013 12:36	SU 72579 01471		2 horses
28	13/05/2013 12:45	SU 72908 01582		5 horses
29	13/05/2013 12:51	SU 72593 01734		Dry stream
30	13/05/2013 13:19	SU 73616 02029		2 horses

No	Time and Date	NGR	Photograph	Observation
31	13/05/2013 13:50	SU 73778 02845		20 cattle
32	13/05/2013 13:57	SU 73983 03236		12 cattle
33	13/05/2013 14:03	SU 73891 03609		10 cattle
34	14/05/2013 09:17	SU 75172 05756		Stream 180cmx10cmx0.564m/s. Water sample 6.
35	14/05/2013 09:22	SU 75243 05735		Stream 300cmx30cmx0.364m/s. Water sample 7.
36	14/05/2013 09:31	SU 75344 05491		Duck pond outfall, 300cmx10cmx0.644m/s. Water sample 8.
37	14/05/2013 09:48	SU 74904 05504		Stream 180cmx3cmx0.093m/s. Water sample 9.
38	14/05/2013 10:03	SU 74270 05338	Figure XII.7	Kings Road CSO outfall, inspection cover labelled 'EA sampling point' on road behind. No signs of recent discharge.
39	14/05/2013 10:13	SU 73915 05384		Stream 70cmx15cmx0.095m/s. Water sample 10.
40	14/05/2013 10:23	SU 73624 05115		Stream 155cmx5cmx0.385m/s. Water sample 11. Evidence of cattle walking in stream in field behind although no animals present at time of survey.
41	14/05/2013 10:36	SU 73054 05094		Stream 150cmx15cmx0.146m/s. Water sample 12.
42	14/05/2013 10:46	SU 72500 05269		35 cattle.
43	14/05/2013 10:52	SU 72088 05110		3 horses.
44	14/05/2013 10:58	SU 71978 04944		Stream 160cmx20cmx0.431m/s. Water sample 13.
45	14/05/2013 11:07	SU 71897 04681	Figure XII.8	Ooze of odorous grey water with sewage fungus from bottom of seawall. Insufficient flow to measure. Suggests a leaking sewer pipe.
46	20/05/2013 08:51	SU 76517 04945		2 horses
47	20/05/2013 08:56	SU 76375 04712		Possible houseboat at boatyard
48	20/05/2013 09:14	SU 76676 03742	Figure XII.9	Water sample 14 (from Little Deep, not discharging due to height of tide).
49	20/05/2013 09:32	SU 76904 02966		Surface water outfall not flowing.
50	20/05/2013 09:35	SU 76966 02828		Surface water outfall not flowing.
51	20/05/2013 09:39	SU 77009 02593		Surface water outfall not flowing.
52	20/05/2013 09:46	SU 77021 02319	Figure XII.10	Sewer pipe from sailing club, appears redundant.
53	20/05/2013 09:50	SU 76971 02239		Surface water outfall not flowing.
54	20/05/2013 09:54	SU 76914 01968		Surface water outfall not flowing.
55	20/05/2013 09:57	SU 76919 01934		Surface water outfall not flowing. Cotton buds
56	20/05/2013 10:02	SU 76930 01656		Surface water outfall not flowing.
57	20/05/2013 10:05	SU 76893 01483		Surface water outfall not flowing.

No	Time and Date	NGR	Photograph	Observation
58	20/05/2013 10:28	SU 76027 01475		Concrete clad outfall pipe not flowing
59	20/05/2013 10:39	SU 75691 01895		Surface water outfall not flowing.
60	20/05/2013 10:42	SU 75609 01925		Surface water outfall not flowing.
61	20/05/2013 11:00	SU 74600 02303		13 cattle
62	20/05/2013 11:08	SU 74876 02583		Surface water outfall not flowing.
63	20/05/2013 11:15	SU 74707 02897		17 cattle
64	20/05/2013 11:23	SU 74629 03330		Surface water outfall not flowing.
65	22/05/2013 08:34	SU 79810 05229		Stream 415cmx23cmx0.146. Water sample 15. Blue flap valve next to stream.
66	22/05/2013 08:42	SU 79690 05115		Stream 10cmx2cmx0.123m/s. Water sample 16.
67	22/05/2013 08:59	SU 79376 04290		Flap valve from duck pond, covered by tide.
68	22/05/2013 09:02	SU 79421 04199		Flap valve from duck pond, covered by tide.
69	22/05/2013 09:06	SU 79489 04136	Figure XII.11	Flap valve from ditch. Not flowing. Apparent human (or possibly dog) excrement. Water sample 17 from pooled water.
70	22/05/2013 09:09	SU 79510 04131	Figure XII.12 and Figure XII.13	Septic tank to ditch
71	22/05/2013 09:10	SU 79537 04132	Figure XII.14	Package plant to ditch
72	22/05/2013 09:11	SU 79557 04133		Septic tank to ditch
73	22/05/2013 09:12	SU 79567 04131	Figure XII.15	Septic tank to ditch
74	22/05/2013 09:13	SU 79615 04139		Septic tank to ditch
75	22/05/2013 09:16	SU 79704 04138	Figure XII.16	Possible septic tank outfall pipe but probably not as only 5cm diameter.
76	22/05/2013 09:32	SU 79585 03325		Surface water outfall, covered by tide.
77	22/05/2013 09:45	SU 79382 02676	Figure XII.17	Floating clubhouse. Black outfall pipe.
78	22/05/2013 09:49	SU 79351 02682		Likely package plant behind hedge. Unable to access sailing club to confirm.
79	22/05/2013 10:07	SU 78875 02068	Figure XII.18	Gull colony on shingle bar just offshore. ~200 birds.
80	22/05/2013 10:45	SU 77940 03913		Surface water outfall, covered by tide.
81	22/05/2013 11:13	SU 77655 04896		Ham Brook outfall, covered by tide
82	22/05/2013 11:21	SU 77336 04886		6 horses
83	22/05/2013 11:32	SU 76869 05026		5 horses
84	22/05/2013 12:19	SU 77936 05654		Ham Brook, 170cmx22cmx0.175m/s. Water sample 18.

No	Time and Date	NGR	Photograph	Observation
85	22/05/2013 12:24	SU 77866 05565	Figure XII.19	Breakers Yard CSO inspection covers, presumably discharges to Ham Brook.
86	04/06/2013 09:07	SU 80481 05095		Stream 145cmx20cmx1.165m/s. Water sample 19.
87	04/06/2013 09:19	SU 80396 04574		Surface water flap valve outfall, not flowing.
88	04/06/2013 09:21	SU 80334 04495		Surface water outfall pipe not flowing
89	04/06/2013 09:25	SU 80314 04198		Surface water outfall 35cmx3cmx0.105m/s. Water sample 20
90	04/06/2013 09:28	SU 80310 04173		Surface water outfall 35cmx3cmx0.255m/s. Water sample 21
91	04/06/2013 09:32	SU 80306 04074		Stream 110cmx15cmx0.175m/s. Water sample 22
92	04/06/2013 09:43	SU 80396 03812		Stream 305cmx4cmx0.243m/s. Water sample 23.
93	04/06/2013 09:47	SU 80577 03851		Surface water pipe, trickle.
94	04/06/2013 09:52	SU 80912 03915		Dry Stream.
95	04/06/2013 09:56	SU 81019 03774	Figure XII.20	Stream/drain, not flowing. No obvious CSO outfall seen here.
96	04/06/2013 10:07	SU 80557 03325		Surface water outfall, trickling.
97	04/06/2013 10:18	SU 79983 02899		Surface water outfall, not flowing.
98	04/06/2013 10:27	SU 79765 02390		Dry stream
99	04/06/2013 10:29	SU 79815 02275		Dry stream
100	04/06/2013 10:36	SU 80078 02029		Dry stream
101	04/06/2013 10:39	SU 80175 02044		Dry stream
102	04/06/2013 11:04	SU 80919 02063	Figure XII.21	Stream, trickling, package plant in back garden, no outfall from it visible.
103	04/06/2013 11:17	SU 81258 01865		3 old sewer pipes. Do not seem in use.
104	04/06/2013 11:20	SU 81116 01825		1 possible sewer pipe from private discharge. No sign of recent use
105	04/06/2013 11:20	SU 81113 01824		1 possible sewer pipe from private discharge. No sign of recent use
106	04/06/2013 11:22	SU 81052 01800	Figure XII.22	1 possible sewer pipe from private discharge. May have been in recent use
107	04/06/2013 11:23	SU 81026 01770		1 possible sewer pipe from private discharge. No sign of recent use
108	04/06/2013 11:24	SU 81002 01781	Figure XII.23	1 possible sewer pipe from private discharge. Some signs of use.
109	04/06/2013 11:34	SU 80631 01559	Figure XII.24	Bosham STW outfall pipe marker in channel.
110	04/06/2013 11:35	SU 80633 01547		1 possible sewer pipe from private discharge. No sign of recent use
111	04/06/2013 11:39	SU 80756 01474		Flap valve in wall.
112	04/06/2013 11:40	SU 80806 01447		Small pool of standing grey water.
113	04/06/2013 11:52	SU 81262 01270		Dry concrete pipe
114	04/06/2013 12:06	SU 81830 01494		Houseboat.

No	Time and Date	NGR	Photograph	Observation
115	04/06/2013 12:08	SU 81905 01584	Figure XII.25	2 probable septic tank outfalls immediately next to each other. One dripping.
116	04/06/2013 12:24	SU 82129 01793		Almost dry stream
117	04/06/2013 13:15	SU 83134 03023		Almost dry stream
118	04/06/2013 13:26	SU 83338 03441		Stream 35cmx2cmx0.075m/s. Water sample 24.
119	04/06/2013 13:37	SU 83366 03905		Stream 70cmx16cmx0.124m/s. Water sample 25.
120	04/06/2013 13:41	SU 83377 03956		13 cattle
121	04/06/2013 13:51	SU 83678 04414		Stream 450cmx16cmx0.407m/s. Water sample 26.
122	04/06/2013 13:58	SU 83731 04468		Stream 120cmx12cmx0.191m/s. Same water as sample 26 (braided stream)
123	04/06/2013 14:02	SU 83761 04506		Stream 100cmx8cmx0.443m/s. Water sample 27.
124	04/06/2013 14:05	SU 83776 04572		Southern Water enclosure.
125	05/06/2013 09:03	SU 83920 04450		Stream 270x23cmx0.423m/s. Water sample 28.
126	05/06/2013 09:11	SU 84052 04127		Stream 260cmx6cmx0.078m/s. Water sample 29
127	05/06/2013 09:22	SU 83935 03758	Figure XII.26	Watercourse/drain, not flowing, outfall covered by tide. Boil visible just offshore from Chichester STW. 50-100 swans in area.
128	05/06/2013 09:26	SU 83890 03609		30 cattle.
129	05/06/2013 09:37	SU 83630 03067		2 possible houseboats.
130	05/06/2013 10:12	SU 82906 01371	Figure XII.27	Private STW. Marker post offshore. Outfall not visible.
131	05/06/2013 10:31	SU 82871 01203		Inspection covers and vents.
132	05/06/2013 10:34	SU 82843 01155	Figure XII.28	Private STW. Marker post offshore. Outfall not visible.
133	05/06/2013 10:43	SU 82459 00929	Figure XII.29	Southern water cabinet and inspection covers.
134	05/06/2013 11:02	SU 81543 00495	Figure XII.30	Pumping station.
135	05/06/2013 11:19	SU 80695 00875	Figure XII.31	Pumping station.
136	05/06/2013 11:27	SU 80346 01103		Sluice outfall, covered by tide.
137	05/06/2013 11:43	SU 79766 01491		Flap valve not flowing.
138	05/06/2013 11:50	SU 79296 01485		Surface water outfall not flowing.
139	05/06/2013 12:04	SU 78755 00995		Small stream, trickle.
140	05/06/2013 12:11	SU 78510 00797		Pond outfall 25cmx3cmx0.074m/s. Water sample 30.
141	05/06/2013 12:34	SZ 78178 99996	Figure XII.32	Septic tank with pipe to shore.
142	05/06/2013 12:44	SZ 78000 99525		Surface water outfall not flowing.
143	05/06/2013 13:05	SZ 77270 98648		Stream 480cmx12cmx0.464m/s. Water sample 31.

Sample results

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

Table XII.2: Water sample *E. coli* results, spot flow gauging results and estimated stream loadings

Sample No.	Date and Time	Position	*E. Coli* (cfu/100ml)	Flow (m3/day)	*E. coli* (cfu/day)*
1	13/05/2013 09:31	SZ 74963 98661	2300	302	$6.96x10^{9}$
2	13/05/2013 09:54	SZ 74165 98726	930000	102	$9.50x10^{11}$
3	13/05/2013 10:24	SZ 73345 98585	230	105	$2.42x10^{8}$
4	13/05/2013 11:26	SZ 73348 99527	770	218	$1.68x10^{9}$
5	13/05/2013 12:29	SU 72415 01555	550	69	$3.80x10^{8}$
6	14/05/2013 09:17	SU 75172 05756	480	8771	$4.21x10^{10}$
7	14/05/2013 09:22	SU 75243 05735	320	28305	$9.06x10^{10}$
8	14/05/2013 09:31	SU 75344 05491	280	16692	$4.67x10^{10}$
9	14/05/2013 09:48	SU 74904 05504	10	434	$4.34x10^{7}$
10	14/05/2013 10:13	SU 73915 05384	460	862	$3.96x10^{9}$
11	14/05/2013 10:23	SU 73624 05115	420	978	$4.11x10^{9}$
12	14/05/2013 10:36	SU 73054 05094	400	2838	$1.14x10^{10}$
13	14/05/2013 10:58	SU 71978 04944	910	11916	$1.08x10^{11}$
14	20/05/2013 09:14	SU 76676 03742	710		
15	22/05/2013 08:34	SU 79810 05229	4500	12040	$5.42x10^{11}$
16	22/05/2013 08:42	SU 79690 05115	2600	21	$5.53x10^{8}$
17	22/05/2013 09:06	SU 79489 04136	410		
18	22/05/2013 12:19	SU 77936 05654	90	5655	$5.09x10^{9}$
19	04/06/2013 09:07	SU 80481 05095	150	29190	$4.38x10^{10}$
20	04/06/2013 09:25	SU 80314 04198	90	95	$8.57x10^{7}$
21	04/06/2013 09:28	SU 80310 04173	430	231	$9.95x10^{8}$
22	04/06/2013 09:32	SU 80306 04074	910	2495	$2.27x10^{10}$
23	04/06/2013 09:43	SU 80396 03812	360	2561	$9.22x10^{9}$
24	04/06/2013 13:26	SU 83338 03441	300	45	$1.36x10^{8}$
25	04/06/2013 13:37	SU 83366 03905	120	1200	$1.44x10^{9}$
26	04/06/2013 13:51	SU 83678 04414	60	25319	$1.52x10^{10}$
26	04/06/2013 13:58	SU 83731 04468	60	2376	$1.43x10^{9}$
27	04/06/2013 14:02	SU 83761 04506	50	3062	$1.53x10^{9}$
28	05/06/2013 09:03	SU 83920 04450	170	22696	$3.86x10^{10}$
29	05/06/2013 09:11	SU 84052 04127	230	1051	$2.42x10^{9}$
30	05/06/2013 12:11	SU 78510 00797	Not detected	48	0
31	05/06/2013 13:05	SZ 77270 98648	Not detected	23092	0

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

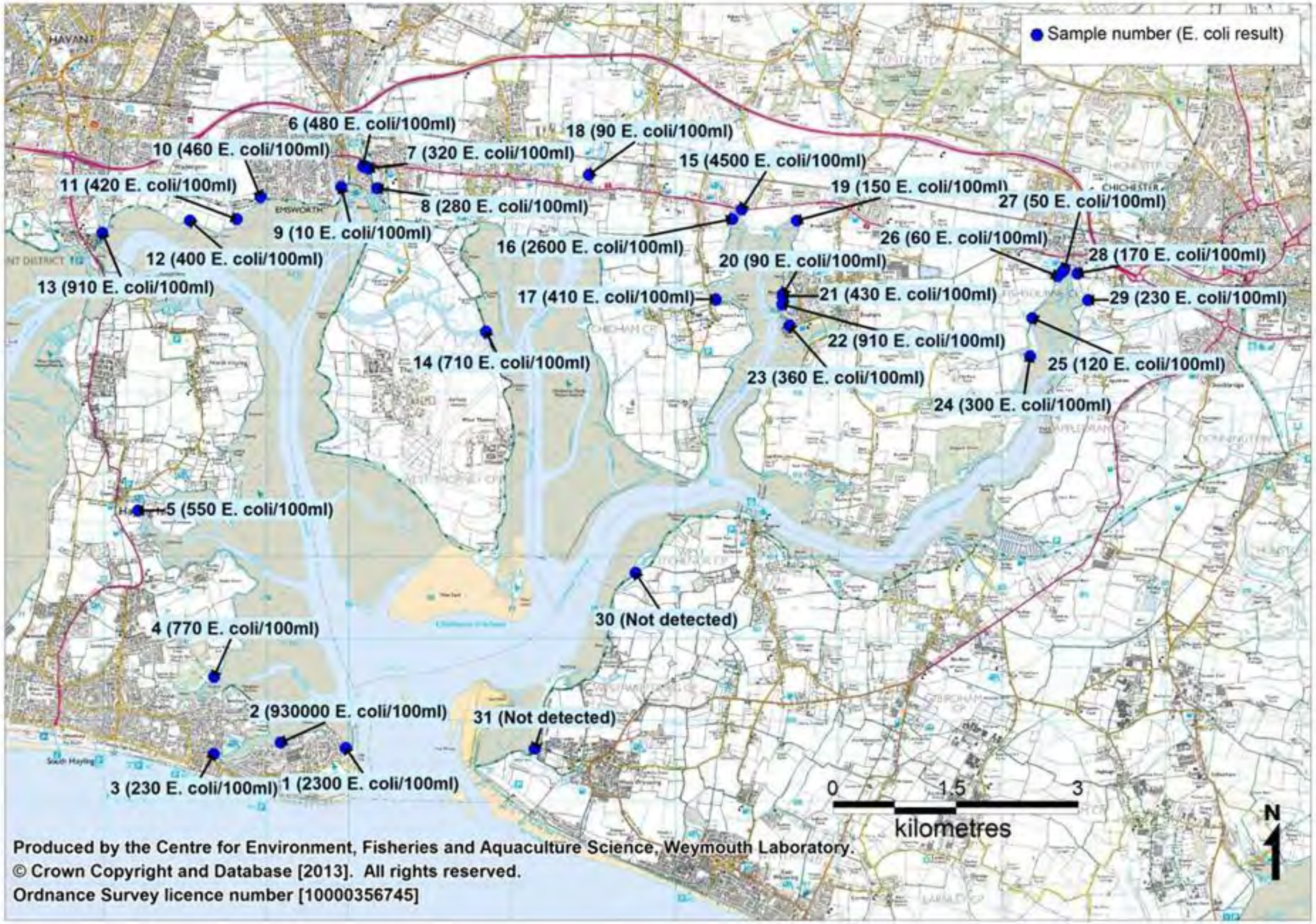


Figure XII.2: Water sample results

Figure XII.3

Figure XII.4

Figure XII.5

Figure XII.6


Figure XII.7


Figure XII.8

Figure XII.9

Figure XII.10

Figure XII.11

Figure XII.12

Figure XII.13

Figure XII.14

Figure XII.15

Figure XII.16

Figure XII.17

Figure XII.18


Figure XII.19


Figure XII.20

Figure XII.21

Figure XII.22

Figure XII.23

Figure XII.24

Figure XII.25

Figure XII.26

Figure XII.27

Figure XII.28

Figure XII.29

Figure XII.30

Figure XII.31

Figure XII.32

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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

Nick Harvey (Havant BC), Adrian Cook and Clif Davis (Chichester DC), Jennifer Tickner (Defra).