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EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Start Bay

March 2015

Food Standards Agency

Cover photo: Start Bay

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Statement of use

This report provides a sanitary survey relevant to the bivalve mollusc farm at Start Bay, 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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Final	Final report post consultation	Simon Kershaw	08/06/2015

Consultation

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Food Standards Agency, South Hams District Council. The report is available publicly via the Cefas website.

Recommended Bibliographic Reference

Cefas, 2015. Sanitary survey of Start Bay. 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). 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 Bivalve Mollusc Production Areas (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 surf clams (*Spisula solida,* also referred to as thick trough shells) within Start Bay. The area was prioritised for survey in 2014-15 via a risk ranking exercise.

1.2. Area description

Start Bay is an east facing embayment situated in the south west of England, between Start Point and Combe Point, at the mouth of the Dart Estuary.

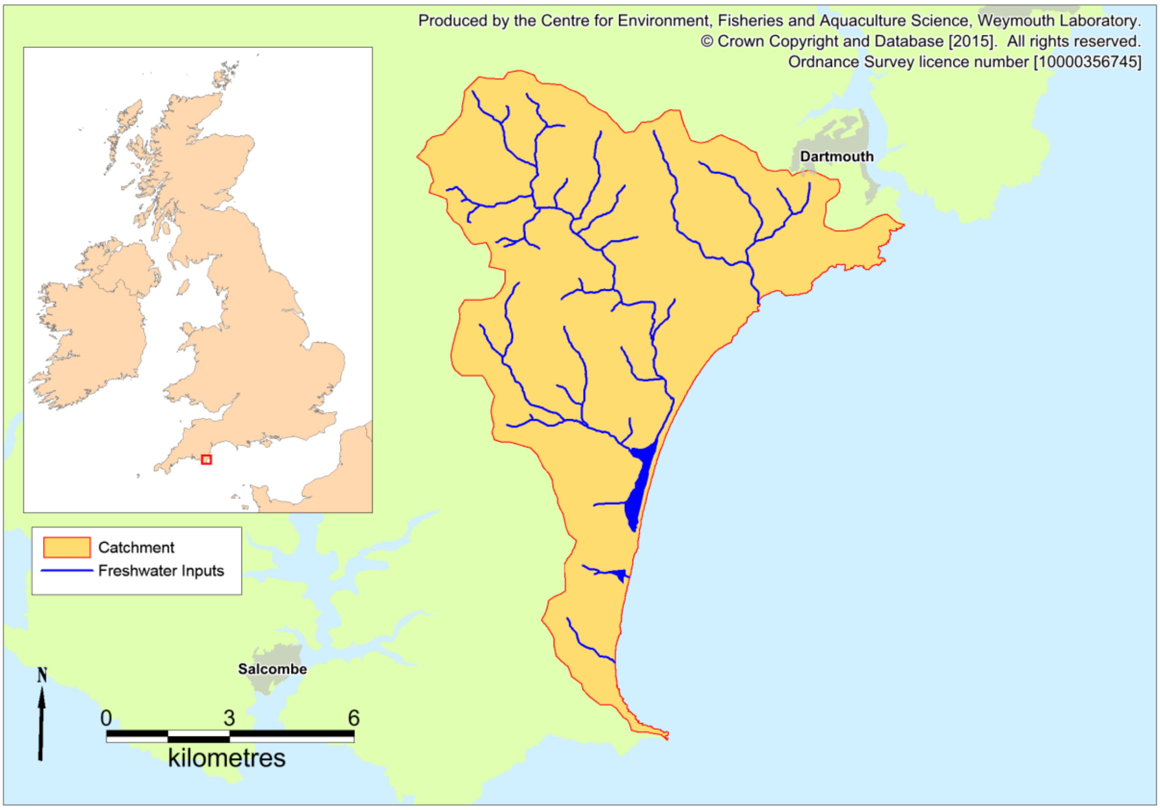

Figure 1.1: Location of Start Bay

The bay is shallow, with a maximum depth of about 16 m relative to chart datum. It is flanked by cliffs at its northern and southern ends, whilst the central portion is backed by a barrier beach of fine gravel. There are several villages by the shoreline, and agriculture and tourism is important to the local economy. There is significant boat traffic in the area, including yachts and fishing vessels. The subject of this survey are naturally occurring surf clam beds which are present in the shallow subtidal throughout much of the bay.

1.3. Catchment

The hydrological catchment, as estimated from topographical maps, covers an area of approximately 71 km^2.

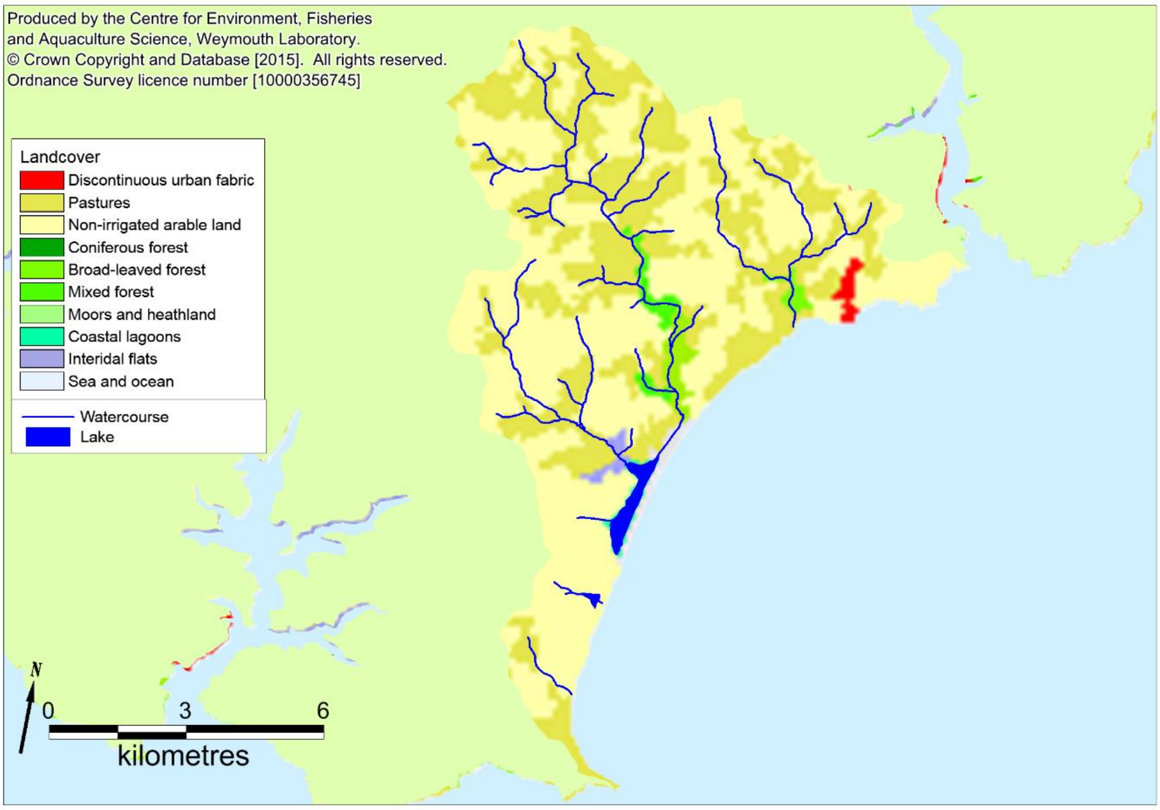

Figure 1.2: Land cover in the Start Bay catchment

The catchment is predominantly rural, mainly arable farmland interspersed with pasture and smaller areas of woodland, tidal flats and heathland. Less than 5% of the catchment is urbanised. It is drained by several watercourses which discharge to the coast at intervals, the largest of which is the Gara River.

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

The catchment is fairly hilly with elevations rising to around 215 m in inland areas. The underlying hydrogeology is reported to contain low permeability bedrock (NERC, 2012). It is therefore concluded that watercourses draining the catchment will respond quickly to rainfall and surface water flows will predominate.

2. Recommendations

The following three zones are proposed for surf clams within Start Bay:

Blackpool

The main sources of contamination direct to this zone are the Stoke Fleming STW and several intermittent discharges. Additionally the ebb plume from the River Dart will have some influence here. It is recommended that the RMP is located next to the Stoke Fleming STW discharge.

Strete

The main source of contamination direct to this zone is the Strete STW, which has both an intermittent and continuous discharge. To the north of this zone, sources of contamination include the Blackpool Stream, Stoke Fleming STW and some boat anchorage areas. The ebb plume from the Dart Estuary, about 6 km to the north east, may also be an influence. It is therefore recommended that the RMP is located just to the north of the Strete STW outfall, as far inshore as stocks extend.

Slapton

The main contaminating influences to this zone are clustered around its southern extremity. These include the Slapton STW outfall, the Torcross PS (which was active for about 27% of the time in recent years) and the Slapton Ley outfall at Torcross. Runoff from Slapton Ley will also percolate through the beach along the length of this lake, but may be considered more as a diffuse input. It is therefore recommended that the RMP is located at the southern end of the zone, off Torcross, as far inshore as stocks extend.

Sampling requirements

Sampling should be undertaken on a monthly, year round basis. Sample collection should be via dredge or hand-picked by diver (depending on the RMP), and should be fully supervised by an officer from South Hams DC. Animals sampled should be of a harvestable size (>2.5 cm). A tolerance of 100 m applied to allow for repeated sampling.

3. Sampling Plan

3.1. General Information

Location Reference

Production Area	Start Bay
Cefas Main Site Reference	M087
Ordnance survey 1:25,000 map	Explorer OL20
Admiralty Chart	1613

Shellfishery

Species/culture	Surf clams (or thick trough shells)	Wild
Seasonality of harvest	Year round	

Local Enforcement Authority

Name & Address	Environmental Health South Hams District Council Follaton House Plymouth Road Totnes Devon TQ9 5NE
Environmental Health Officer	Dan Blackley
Telephone number	01803 861234
Fax number	01803 861294
E-mail	Dan.Blackley@southhams.gov.uk

3.2. Requirement for Review

The Guide to Good Practice for the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2014) indicates that sanitary assessments should be fully reviewed every 6 years, so this assessment is due a formal review in 2021. The assessment may require review in the interim should any significant changes in sources of contamination come to light, such as the upgrading or relocation of any major discharges.

Table 3.1: Number and location of representative monitoring points (RMPs) and frequency of sampling

Classification zone	Blackpool	Strete	Slapton
RMP	B087H	B087I	B087J
RMP name	Off Stoke Fleming	Off Strete	Off Torcross
NGR	SX 8664 4819	SX 8472 4671	SX 8250 4197
Latitude & Longitude (WGS84)	50° 19.363'N 03° 35.630'W	50° 18.542’ N 03° 37.218’ W	50° 15.959’ N 03° 38.999’ W
Species	Surf clams (*S.solida*)	Surf clams (*S.solida*)	Surf clams (*S.solida*)
Growing method	Wild	Wild	Wild
Harvesting technique	Hand picked	Dredge	Dredge
Sampling method	By diver	Dredge	Dredge
Tolerance	100 m	100 m	100 m
Frequency	Monthly	Monthly	Monthly
Comments	Sample collection should be fully supervised by a sampling officer from South Hams DC.		
	Monthly (for one year) for full classification.		
	If a more rapid provisional classification is required, this may be issued on the basis of results from 10 samples taken not less than one week apart. Following this monthly monitoring will be required to maintain the classification	-	-

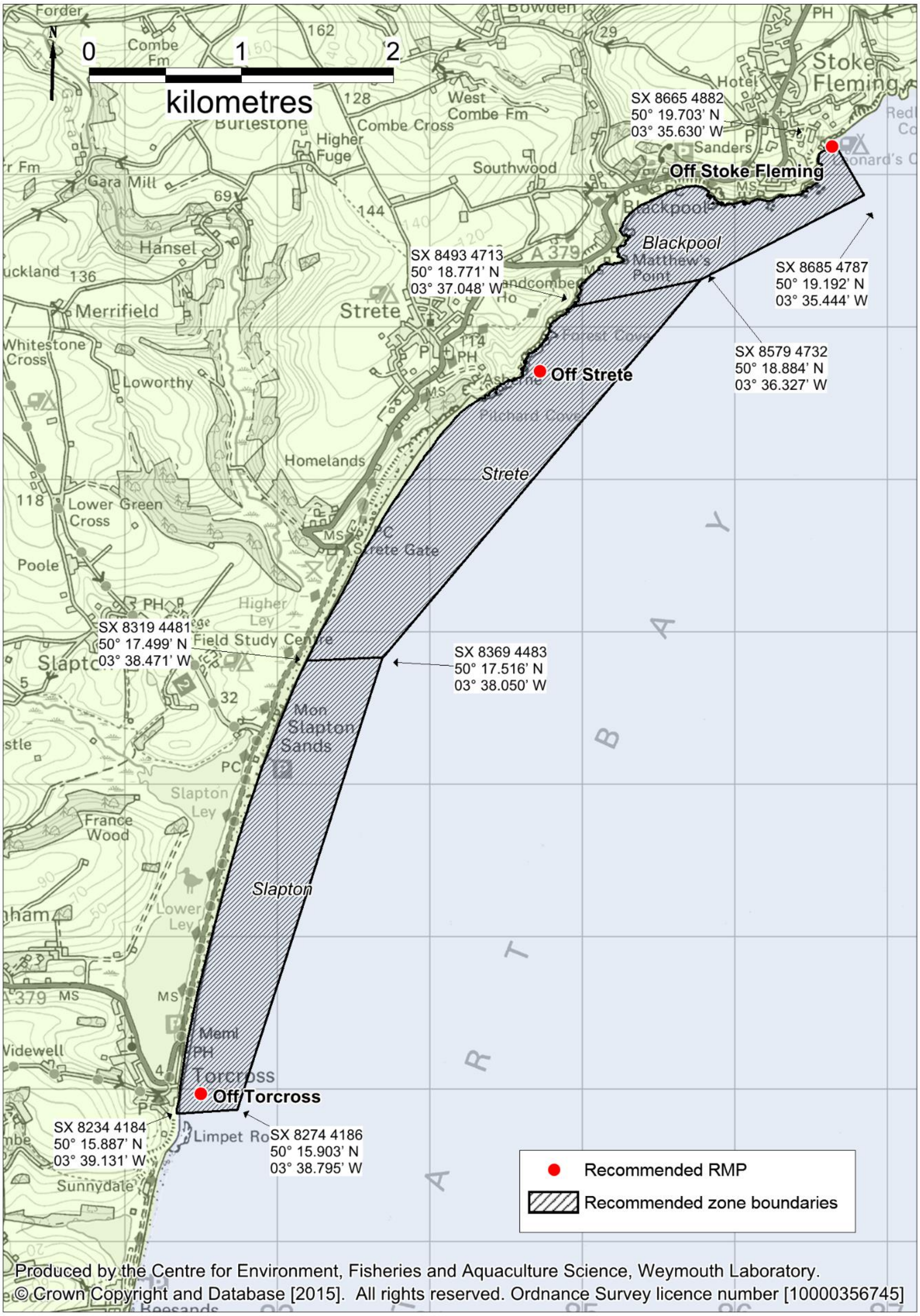

Figure 3.1: Recommended zoning and monitoring arrangements

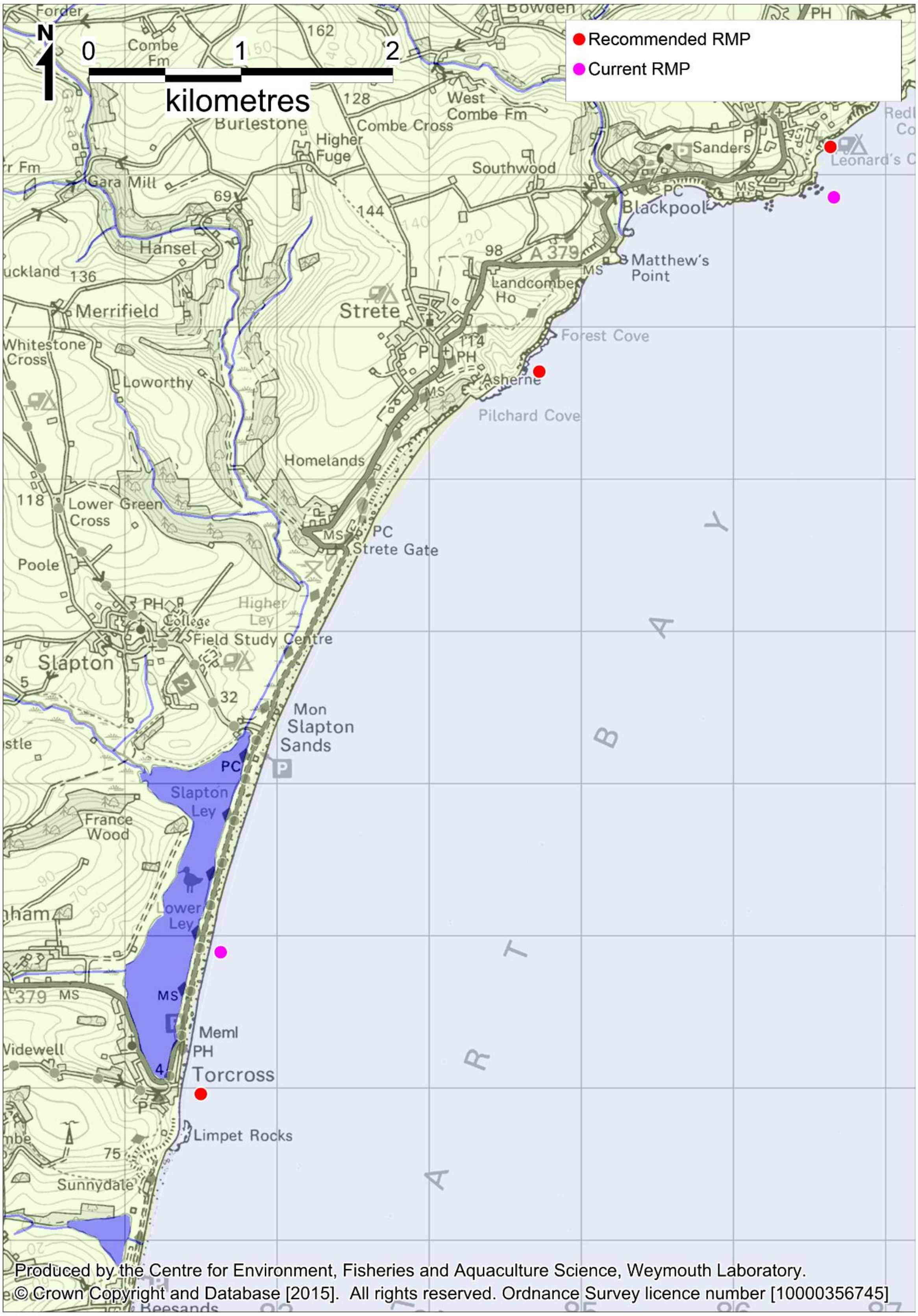

Figure 3.2: Locations of current and recommended RMPs

4. Shellfisheries

4.1. Description of fishery

The subject of this survey is a surf clam dredge fishery.

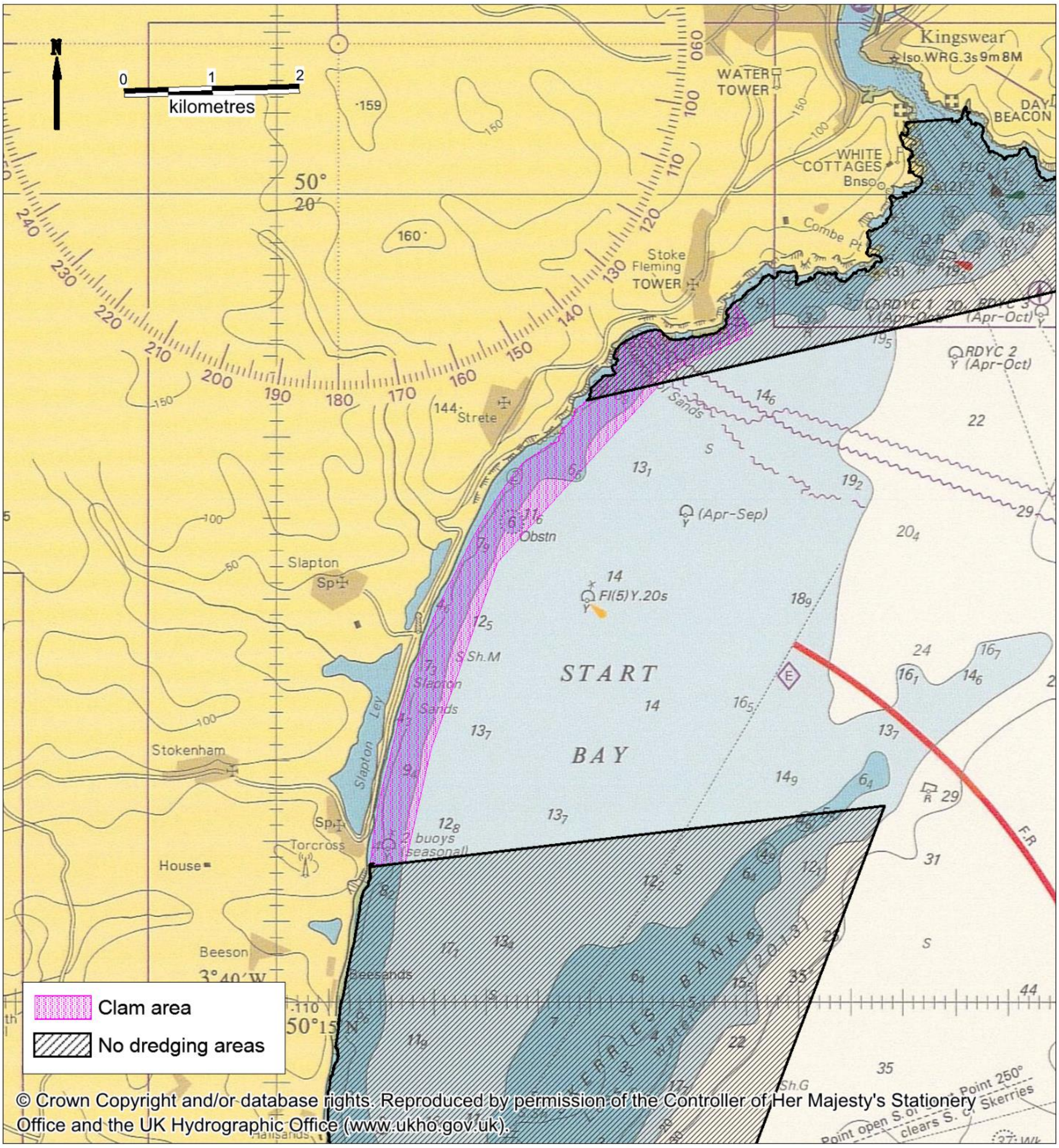

Figure 4.1: Approximate extent of surf clam stocks

Naturally occurring stocks of surf clams are present along a narrow subtidal strip within the area show in Figure 4.1, between the 5 and 10 m depth bands. The IFCA have not undertaken surveys of these stocks, so there is no firm information on their exact distribution and densities. They are harvested by dredge by one operator on a part time, year round basis. The harvester only takes clams which are four years or older (growth annuli are clearly visible on the exterior of the shells) and rotates harvesting areas over a four year cycle to ensure the fishery is sustainable in the long term.

A minimum size of 2.5 cm applies to surf clams within the district. There is no closed season for this species. The use of mobile demersal fishing gear is prohibited in the southern half of Start Bay and around the mouth of the Dart Estuary. This will prevent fishing within the northern part of the currently classified area, and preclude the expansion of the fishery in a southerly direction.

4.2. Hygiene Classification

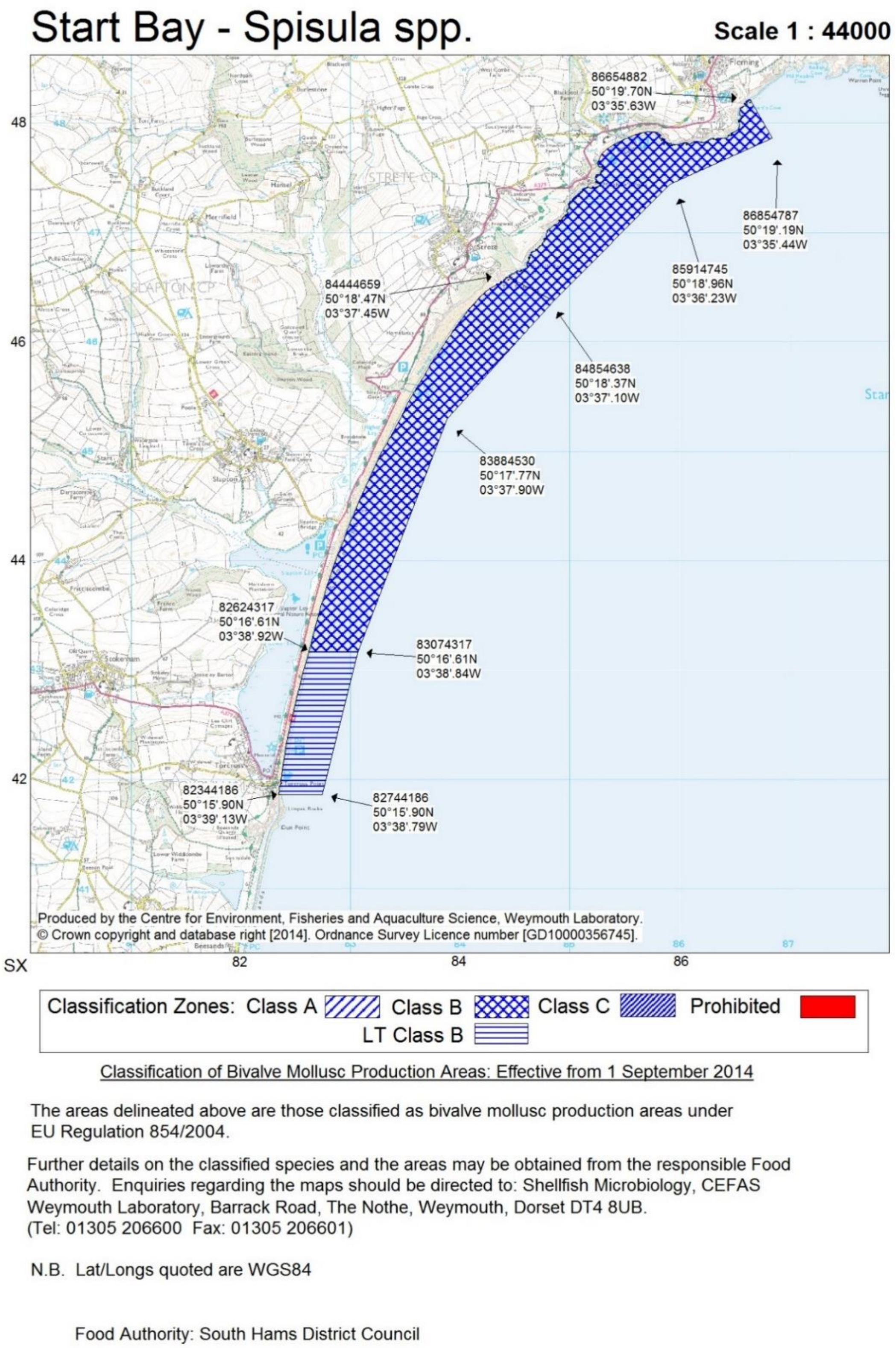

Figure 4.1: Current classification zones (Start Bay)

Table 4.1: Historical hygiene classifications, 2005 to present

Bed name	Species	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15
Torcross	*S. solida*	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Slapton Ley to Pilchard Cove	*S. solida*	-	-	-	-	-	-	B	B	B	B
Forest Cove and Blackpool	*S. solida*	-	-	-	-	-	-	B	B	B	B

The area has been classified B throughout its history. It was expanded considerably in 2011/12.

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

Class	Microbiological standard[1]	Post-harvest treatment required
A[2]	Live bivalve molluscs from these areas must not exceed 230 Most Probable Number (MPN) of *E. coli* 100 g^{-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* 100 g^{-1} FIL in more than 10% of samples. No sample may exceed an upper limit of 46,000 *E. coli* 100 g^{-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* 100 g^{-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* 100 g^{-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 fishery.

5.2. Shellfisheries

The shellfishery considered in this survey is a dredge fishery for naturally occurring surf clams. These stocks are present along a narrow band in the shallow subtidal, between the 5 and 10 m depth contours. These stocks are exploited by one harvester on a part time basis. The areas fished are rotated on a four year cycle and only animals of four years or older are retained to ensure that the fishery is sustainable over the years. The use of mobile demersal gear is not permitted in southern half of Start Bay and the northern end around the mouth of the Dart Estuary, thereby limiting any further expansion of the dredge fishery. The northern boundary of the classified area currently extends into the closed area around the mouth of the Dart Estuary into the restricted area. Although this are cannot be harvested by dredge, it can be harvested by diver/hand-picking and so the current northern classification zone should be split to taken this into account. There is no closed season for this species so continued year round classification is required. A minimum landing size of 2.5 cm applies within the district so samples should be of animals exceeding this size. Sample collection requires the use of the harvester's boat and dredge, and should be supervised by the Local Enforcement Authority (LEA), with a sampling officer present throughout each sampling run.

5.3. Pollution Sources

Freshwater Inputs

The Start Bay survey area has a small hydrological catchment of 71 km^2. It is drained by a series of streams, some of which flow through lakes in their lower reaches. Land cover is mainly arable farmland, interspersed with areas of pasture, heathland and woodland and few built up areas. The catchment is quite hilly throughout reaching a maximum elevation of 215 m in the west, and the hydrogeology is described as impermeable. It is therefore anticipated that watercourses within the catchment will respond quickly to rainfall, a high proportion of which will run off.

There are two freshwater inputs direct to the foreshore adjacent to the clam beds, the Slapton Ley outfall at Torcross and the Blackpool stream at Blackpool. The Slapton Ley outfall is from a lake to which several streams drain, the largest of which is the River Gara. In total about 66% of the catchment drains to Slapton Ley. It has an average retention time of 19 days so the majority of bacterial contamination it receives will die off during passage through it. At times of high flows the retention time may decrease to as little as one day, so the potential for die off at such times is greatly reduced. The outfall was sampled and measured during the shoreline survey, which was undertaken in wet conditions in January 2015. Its bacterial loading at the time was $1x10^{10}$ *E. coli*/day, and the bacterial concentration within it was low (20 *E. coli* cfu/100 ml). Much of the water within Slapton Ley actually percolates through the beach at intervals rather than through the main outfall, so the nearshore region along the entire length of the lake can be considered subject to more diffuse inputs of runoff borne contamination. The Blackpool Stream drains about 24% of the Start Bay catchment, and was carrying a bacterial loading of $6.5x10^{10}$ *E. coli*/day at the time of the shoreline survey. It has a small pond in its lower reaches, and drains directly across the beach.

To the south of the fishery area, there are two small unnamed streams which discharge to the bay. Each drains about 5% of the Start Bay catchment. The more northerly of the two flows through a small lake (Widdicombe Ley) so some additional bacterial dieoff is likely to occur on passage through the lake. The stream to the south drains directly across the beach. Both were sampled and measured during the shoreline survey (January 2015), at which time their respective bacterial loadings were $5.8x10^9$ and $7.9x10^9$ *E. coli*/day.

None of these streams have fixed flow gauging stations on them, so it was not possible to investigate in detail the degree of day to day and seasonal variation in discharge rates. Given the physical characteristics of the catchment, discharge rates are likely to respond rapidly to rainfall so significant day to day variation is likely, although this will be buffered to some extent where watercourses pass through lakes. Rainfall in the area tends to be higher from October to January, and during the colder months there will be less transpiration and evaporation. Discharge from freshwater inputs is therefore likely to be higher on average during the colder months of the year, although whether this translates to increased fluxes of faecal indicator organisms is uncertain.

The much larger Dart catchment (470 km^2) drains via the Dart Estuary, the mouth of which lies about 6 km to the north west of the clam harvesting area. This drains via a large estuary, so will only drain to Start Bay whilst the tide is ebbing, and the plume it generates will mainly consist of seawater with a limited amount of runoff mixed in. Its spatial pattern of impacts will depend largely on tidal circulation patterns.

Human Population

Total resident population within census areas contained within or partially within the catchment area was approximately 12,700 at the time of the last census (2011). However, the census areas considered cover an area of over twice the catchment area, so the population within the actual catchment is considerably smaller. It is concentrated to the north around Dartmouth, with lower population densities throughout the rest of the catchment. Tourism is important to the local economy, so the population in the catchment area will increase significantly during the summer, and this will be reflected by an increased sewage output. The population within the Slapton STW catchment for example is reported to treble during the peak summer holiday period.

Sewage Discharges

There are eight continuous water company discharges within the survey area. The three likely to be of most significance to the fishery are Slapton STW, Strete STW and Stoke Fleming STW. Slapton STW provides secondary treatment for a consented dry weather flow of 777 m^3/day, and generates an estimated bacterial loading of $2.6x10^{12}$ faecal coliforms/day. It discharges to the subtidal area about 70 m offshore and 150 m to the south of the fishery. Strete STW is a smaller secondary works (consented dry weather flow of 122 m^3/day) which generates an estimated bacterial loading of $4.x10^{11}$ faecal coliforms/day. It discharges to the lower intertidal directly to the northern end of the fishery. Stoke Fleming STW only provides primary treatment and discharges to the lower reaches of a short watercourse which drains to the shore about 2 km northeast of the edge of the area where dredging is prohibited around the mouth of the Dart Estuary. It has a consented dry weather flow of 260 m^3/day, and generates an estimated bacterial loading of $2.6x10^{13}$ faecal coliforms/day.

The Blackawton STW provides secondary treatment for a dry weather flow of 104 m^3/day and generates an estimated bacterial loading of $3.4x10^{11}$ faecal coliforms/day. It discharges to the River Gara some distance inland, so significant bacterial dieoff is anticipated on passage to the coast, particularly given that this watercourse drains through Slapton Ley. There are two small sewage works close to the coast to the south of Torcross (Beeson STW and Beesands STW). No discharge volumes are specified on their consents. Beeson STW provides secondary treatment and discharges to a small watercourse which subsequently passes through Willicombe Ley before draining to the coast. The treatment type and receiving environment were not specified for Beesands STW. The remaining two water company treatment works are small septic tanks which discharge to soakaway (Silver Cloud Septic Tank and Bickerton STW) so should be of no impact on coastal waters.

In addition to the continuous sewage discharges, there are 13 intermittent water company discharges associated with the sewerage networks. There are four of these at Stoke Fleming, two at Torcross, and one at Strete. The remainder discharge to watercourses which subsequently drain to Slapton Ley. Spill records were only available for one of these intermittent discharges (Torcross PS) which uses the same outfall as the Slapton STW. It was active for about 27% of the period October 2012 – March 2014, so on average it would be spilling on one in four of the monthly hygiene sampling runs. As such, it will require consideration in the sampling plan. It is difficult to assess the significance of the other intermittent discharges, aside from noting their location and their potential to spill untreated sewage.

Although the majority of properties within the survey area are served by water company sewerage infrastructure, there are also 120 permitted private discharges within the survey catchment. Most of these are small, serving one or two properties, and provide treatment by septic tank or package plant. The majority (90) discharge to soakaway so should be of no impact on coastal waters. Of those discharging to water most discharge either to the Blackpool Stream or to watercourses draining to Slapton Ley, so will make a contribution to the bacterial loading carried by these watercourses. Several of the larger private discharges have UV disinfection, which should greatly reduce the bacterial loading they generate. None discharge directly to coastal waters in the vicinity of the fishery.

Agriculture

The majority of land within the catchment considered in this report is used for agriculture. It comprises primarily of arable farmland, with significant amounts of pasture also. Agricultural census data indicates that there were 12,294 cattle and 12,490 sheep held within the catchments in 2013. The census also recorded about 12,561 poultry and 147 pigs. All significant watercourses draining to Start Bay are therefore likely to be impacted by diffuse contamination of agricultural origin.

Faecal matter from grazing livestock may be deposited directly into watercourse where fencing does not prevent their access. Faecal matter is also deposited on pastures, or collected from livestock sheds if animals are housed indoors, then applied to agricultural lands as a fertilizer. Manure from pigs and poultry operations is typically stored and applied as required to nearby farmland. Sewage sludge may also be applied. The primary mechanism for mobilisation of faecal matter from agricultural land in the wider catchment is via land runoff, so fluxes of livestock related contamination into the estuary will be highly rainfall dependent. Peak fluxes of contamination from grazing livestock are likely to arise following high rainfall events, 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.

There is likely to be some seasonality in fluxes of agricultural contamination to coastal waters. Rainfall and river flows are generally higher during the winter months, although high rainfall events may occur at any time of the year. 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 the warmer months, livestock are likely to access watercourses more frequently to drink and cool off. Cattle may be housed indoors during the winter, so slurry collected from such operations 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 other organic fertilizers (e.g. poultry manure or sewage sludge) is uncertain.

It is therefore concluded that RMPs positioned to capture the impacts of land runoff will best capture agricultural contamination, fluxes of which will vary significantly on a day to day basis in response to rainfall, and possibly on a seasonal basis in response to farming practices. Some attenuation of bacterial loadings will occur for those watercourses which drain through lakes in their lower reaches.

Boats

The main boating centre in the vicinity of the shellfishery is the Dart Estuary, where there are three large marinas and several hundred moorings used by recreational craft such as yachts and cabin cruisers. Within Start Bay itself there are no harbours, marinas or ports, but there are anchorages used by recreational craft in the more sheltered areas in the north and south of the bay. Fishing fleets operate from Dartmouth and Salcombe, which between them have 47 resident fishing vessels ≥10 m in length and 15 >10 m in length.

It is therefore concluded that boat traffic in the area consists of potentially large numbers of pleasure craft on transit to and from the Dart Estuary, and smaller numbers on the anchorages at the northern and southern ends of Start Bay. Fishing vessels will also work the area. Those of a sufficient size are likely to make overboard discharges from time to time. This may either occur when the boats are at anchor, particularly if they are in overnight occupation, or while they are navigating through the area. Therefore, whilst overboard discharges may be made anywhere within the survey area, it is likely that the anchorages and the main navigation routes through the area are most at risk of contamination from this source. 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.

Wildlife

Start Bay encompasses a variety of habitats including sea cliffs, shingle beaches, marshland, reed beds and a fresh water lake (Slapton Ley). These features attract populations of birds and other wildlife. The most significant wildlife population of relevance to shellfish hygiene is likely to be seabirds such as gulls and terns, which are widespread throughout the area and present all year round. A survey in the early summer of 1999 along the coastline between Start Point and Blackstone Point recorded 878 pairs of breeding seabirds. The main breeding site is around Hallsands, where over 700 pairs were recorded nesting. During the shoreline survey large numbers of gulls were observed on the beach seawards of Slapton Ley (~500). 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 or roost sites. As the main nest site lies about 3 km south of the fishery, seabirds can therefore be considered a diffuse input and whilst they may be a contaminating influence, will have no bearing upon the sampling plan.

Counts of overwintering waterbirds (wildfowl and waders) are undertaken annually at Slapton Ley. An average peak count of 1,096 was recorded over the five winters up until 2012/2013. These birds are likely to contribute to the loadings of faecal indicator organisms delivered to coastal waters via the weir and/or freshwater percolation through the shingle barrier. Numbers are not particularly large so their impacts are likely to be minor.

There are no major seal colonies in Start Bay, with the closest significant colony in the Solent. Whilst they may forage in the vicinity of the shellfish beds from time to time, they are unlikely to be a significant source of contamination to the shellfishery as their presence will be both unpredictable spatially and temporally. Several species of dolphin and porpoise are regularly sighted in Lyme Bay so will frequent Start Bay from time to time. As with the seals their presence will be unpredictable spatially and temporally, so whilst they may potentially be an influence it will not be possible to define an RMP location which will reliably capture their impacts. No other wildlife species which may influence the sampling plan have been identified.

Domestic animals

Dog walking takes place on coastal paths and beaches around Start Bay and is therefore likely to represent a potential source of diffuse contamination to the near shore zone. 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.

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												
Urban runoff												
Continuous sewage discharges												
Intermittent sewage discharges												
Birds												
Boats												

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

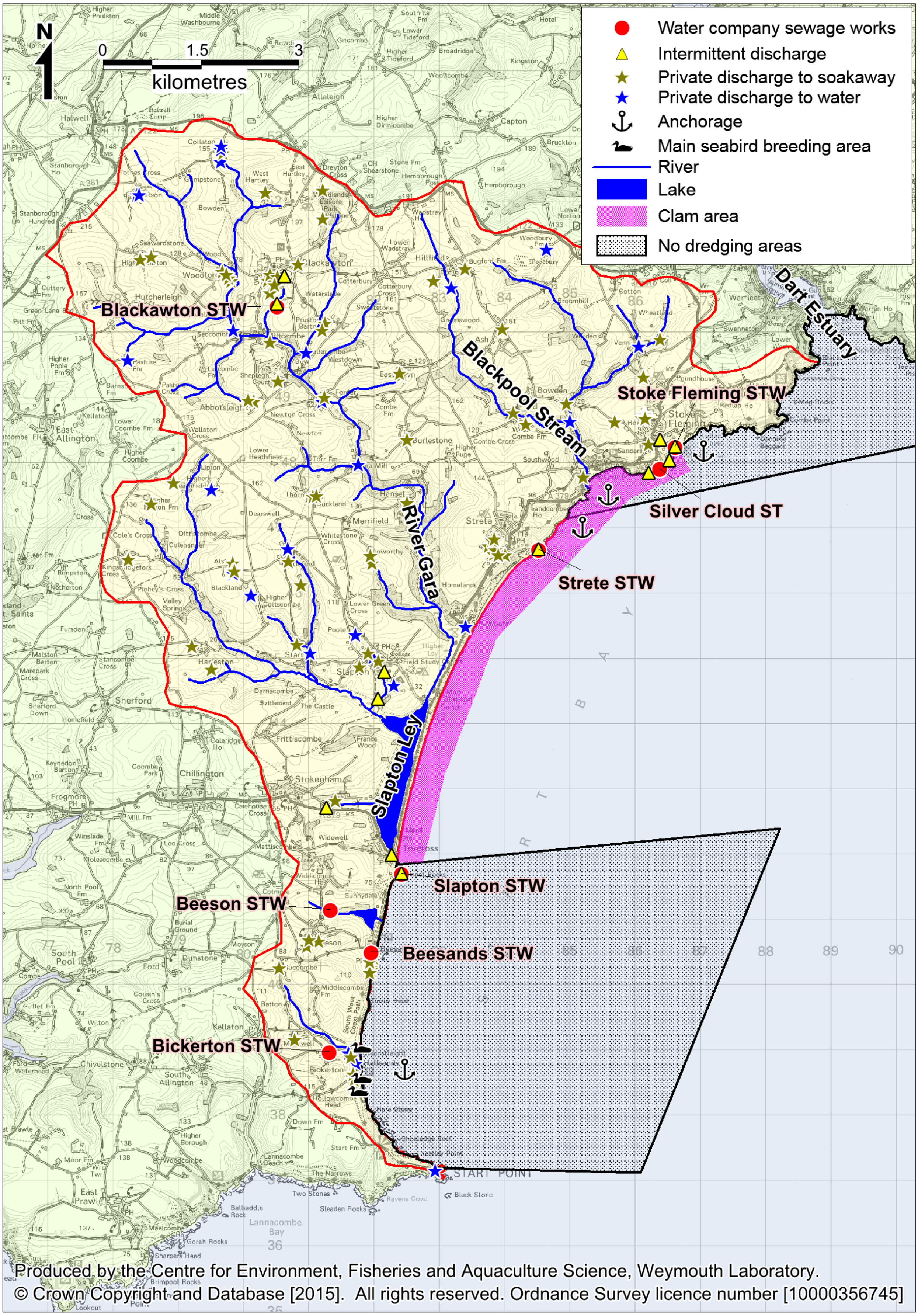

Figure 5.1: Summary of main contaminating influences

Hydrography

Start Bay is a large, open, east facing embayment on the western English Channel at the western extremity of the larger Lyme Bay. The open coastal location will offer high potential for dilution and dispersion of contamination. It stretches around 16 km from Start Point to Combe Point, by the mouth of the Dart Estuary, and is backed by a shingle barrier beach throughout most of its length, with cliffs at the northern and southern ends. Its bathymetry is relatively uncomplicated, sloping gently away from the coast to a depth of about 20 m relative to chart datum in the outer reaches of the Bay. Initially, the depth drops to around 10 m within a km of the shore, then the bathymetry levels out to between 10 m and 19 m in the majority of the bay. The clam beds are located between the 5 and 10 m depth contours. A notable feature is the Skerries Bank, an offshore sandbank which extends 8 km in a north easterly direction from Start Point. Its crest rises to about 2 m below chart datum. Freshwater inputs direct to the survey area are limited to a few minor watercourses which drain directly over/through the beach. The Dart Estuary, at the northern end of the bay receives runoff from a much larger catchment. Its enclosed nature means that contamination it receives will only drain to Start Bay whilst the tide is ebbing.

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. Tidal amplitude is large, at 4.4 m on spring tides and 1.9 m on neap tides. Tidal streams are therefore likely to dominate patterns of water circulation in the bay under most conditions. Tidal diamonds located off Start Point and in the offshore central part of the bay show a bidirectional pattern of circulation, aligning along the north east – south west plane, roughly parallel to the coast. The northeast going stream starts between 2 and 3 hours before high water, then continues until between 3 and 5 hours after high water, at which point it reverses and travels in a south westerly direction. An eddy forms to the north of Start Point when the tidal stream is moving in a north easterly direction, but this does not extend as far as the clam fishery. Contamination from shoreline sources in the vicinity of the fishery will therefore travel parallel to the coast, impacting on either side of their locations, with their plumes becoming progressively diluted as they travel. The ebb plume from the Dart will only be carried in the direction of the fishery during the latter part of the ebb, although at this time contamination within it is likely to be most concentrated. Estimates of tidal excursions based on the tidal diamond in the central outer part of the bay are about 9 km on spring tides and about half that on neap tides. Tidal streams are likely to be weaker in shallower near shore areas due to the effects of friction. Contamination from shoreline sources will be carried several km before the tide reverses, and any ebb plume from the Dart Estuary will only impact on the northern end of the fishery. Current velocities and estimated tidal excursions at the diamond off Start Point are more than double that at the other diamond, confirming that there is a significant local acceleration of tidal streams around the headland. Some turbulent mixing of the water column is likely to occur here.

Superimposed on tidally driven currents are the effects of freshwater inputs and wind. The main source of freshwater is the Dart Estuary, to the north of the survey area. The average and maximum flow ratios (river input/tidal exchange) for this estuary are 0.021 and 0.439. This indicates that the plume from this estuary will be usually be well mixed and land runoff will generally be diluted with large amounts of seawater, but at peak river flows the salinity of the plume will be lower. As such, some localised density driven circulation may arise at the mouth of this estuary at high river flows. The plume of low salinity water emanating from the estuary will be less dense than the more saline seawater and so will have a tendency to spread out and to float on the surface, with a corresponding return of more saline water at depth. Away from the Dart Estuary, freshwater inputs direct to the bay are minor, and the survey area is in an open coastal location, so it is unlikely that significant modification of tidal streams by density effects will occur. Repeated salinity measurements taken as part of the bathing water monitoring programme confirm that salinity is generally approaching that of full strength seawater, with very occasional readings under 30 ppt recorded. There was no evidence of a significant influence of the Dart Estuary at the northern most site at Blackpool Beach.

Winds may have a significant effect on water circulation within the bay. Strong winds drive surface water currents, which in turn create return currents which may travel lower in the water column or along sheltered margins. Start Bay is sheltered from the prevailing south westerly winds by the adjacent land. It is most exposed to the east and south. Winds from these directions would tend to push surface water currents towards the shore. 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. Strong winds will also induce wave action, which will lead to increased mixing of the water column in offshore areas, and the re-suspension of sediment entrained contamination in intertidal areas. Southerly and easterly winds and swells are likely to be most effective in generating energetic wave action in the vicinity of the clam beds. It is likely that the Skerries Bank attenuates swells to some extent as they pass over it, so the northern half of the bay may be more exposed to wave action.

5.4. Summary of Microbiological Data

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

Figure 5.2: Location of microbiological sampling sites.

Bathing Waters

There are three bathing waters in Start Bay, where around 20 water samples were taken each bathing season (May to September) and enumerated for faecal indicator bacteria. The analysis method changed from faecal coliforms to *E. coli* at the beginning of the 2012 bathing season. The more limited *E. coli* dataset gave similar low average results at all three sites (5.8 to 8.2 *E. coli* cfu/100 ml) and most samples were below the limit of quantification of the test (10 *E. coli* cfu/100 ml). The larger faecal coliform dataset (2004 to 2011) also gave a low average result (2.2 to 2.7 faecal coliforms cfu/100 ml) and a lower limit of quantification was used (2 faecal coliforms cfu/100 ml). The more extensive faecal coliform data was therefore used for detailed analysis.

There was no statistically significant difference in average faecal coliform concentration between the three sites. The results of paired (same day) samples were found to correlate significantly between all site pairings, suggesting they share similar sources of contamination. Faecal coliform concentrations remained stable on average at all three sites from 2004-2011. It was not possible to investigate seasonality as sampling was only undertaken from May to September. The only significant correlation between results and tidal cycles was found for Monument across the spring/neap cycle. Here, results tended to be lower on average on the smaller (neap) tides. Positive correlations between faecal coliform concentrations and antecedent rainfall were found for all three sites in the 2-3 days following a rainfall event. The correlations were strongest at Blackpool Sands. Faecal coliforms levels at Blackpool Sands correlated significantly with salinity, but not at Monument or Torcross. It is therefore concluded that land runoff is more of an influence Blackpool Sands than the other two bathing waters, possibly as a consequence of the nearby Blackpool Stream.

Shellfish Waters

There is one shellfish water monitoring point within the survey area, where water samples were taken at quarterly intervals and enumerated for faecal coliforms. Data from 2004 to 2014 were considered in the following analyses.

The geometric mean result here (3.9 faecal coliforms cfu/100 ml) was similar to that from the bathing water monitoring points. Results were fairly stable on average throughout the period evaluated. Some seasonality was apparent, with higher average faecal coliform concentrations in the autumn and winter. This effect was not statistically significant however. Results were found to correlate significantly with both the high/low and spring/neap tidal cycles. Plots of the data against these tidal cycles indicated a tendency for higher results whilst the tide was ebbing, but no obvious pattern was apparent across the spring/neap tidal cycle. Faecal coliform levels at Start Bay were significantly affected by rainfall shortly after rainfall events and continued to be so for several days. No correlation was found between faecal coliform concentrations and salinity however.

Shellfish Hygiene monitoring

There are five RMPs in the Start Bay production area where surf clams have been sampled between 2005 and 2014. Only two samples were taken at one of these (Slapton Sands 1) so results from here were not considered in the detailed analyses. Across the other four RMPs results were similar, with the geometric means ranging from 116 to 247 *E. coli* MPN/100 g. There appeared to be a slight tendency for higher results towards the northern end of the shellfishery, but there was no statistically significant difference in average result between them. The only result exceeding 4,600 *E. coli* MPN/100 g was from Leonards Cove Point, the most northerly RMP. Comparisons of paired (same day) samples could only be made between Slapton Sands 2 and Leonards Cove Point, and results for these two RMPs did not quite correlate significantly at the 0.05 level.

E. coli levels have remained stable on average at Slapton Sands 2 since 2005. There was no statistically significant seasonal variation in *E. coli* levels here. A significant correlation between *E. coli* result and tidal state across the spring/neap cycle was found for Slapton Sands 2 where a tendency for fewer low results during spring tides was found. There was no correlation here between *E. coli* results and the high/low tidal cycle. The other RMPs were monitored over shorter periods (< 2 years) so there was insufficient data to investigate the influence of tides, season, and the overall temporal pattern of results.

No statistically significant influence of antecedent rainfall was detected at three of the four main RMPs. A single significant correlation was observed at Matthews Point, but this is likely to be an artefact as an apparently significant correlation will arise by chance alone 5% of the time.

Bacteriological survey

Due to the extensive microbiological monitoring history there was little to be gained from undertaking a bacteriological survey, which would require the use of a boat with a suitable dredge.

Appendices

Appendix I. Human Population

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

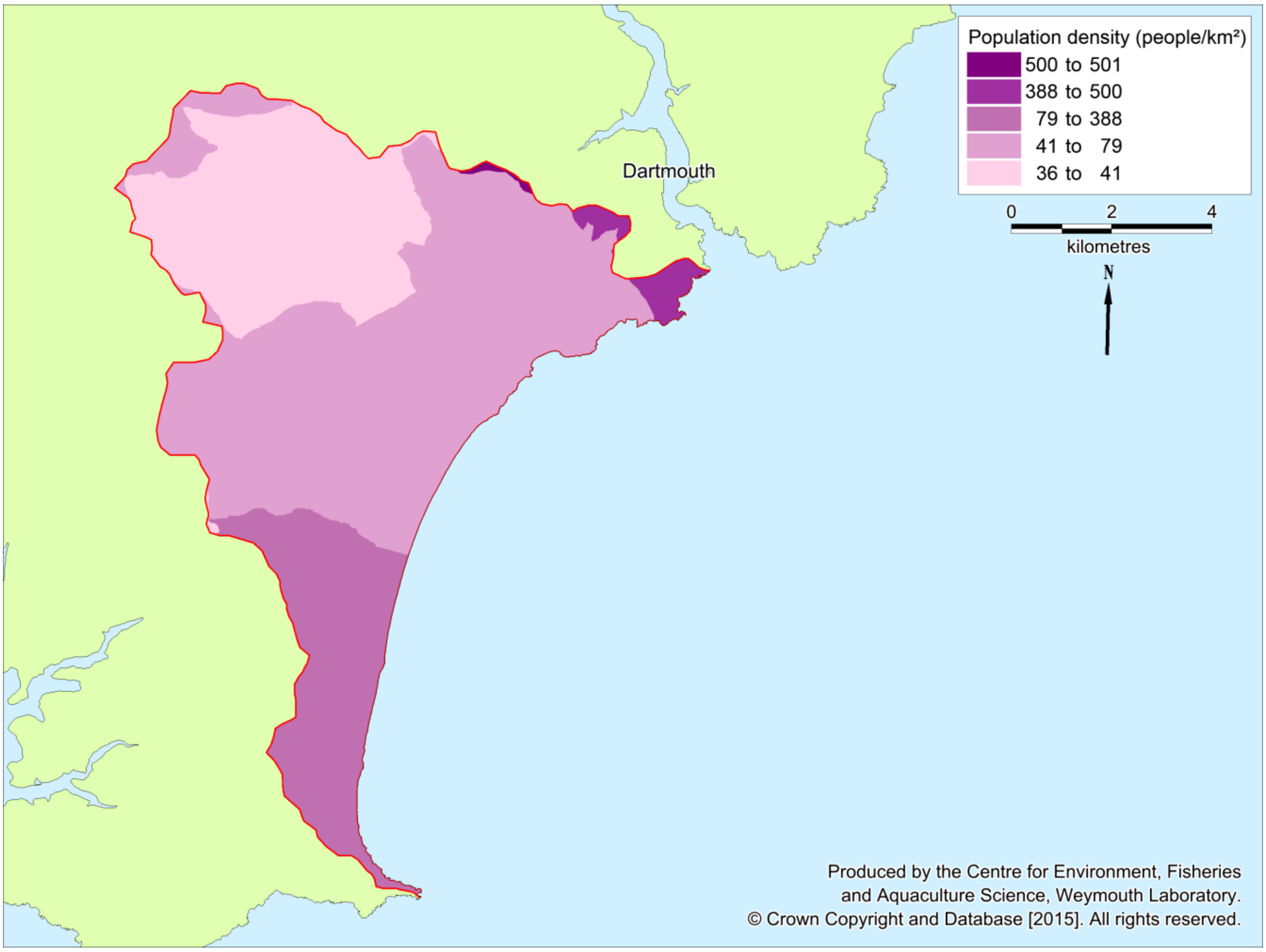

Figure I.1: Human population density in census areas in the survey catchment.

Total resident population within census areas contained within or partially within the catchment area was approximately 12,700 at the time of the last census. However, the census areas considered have a combined area of 219 km^2, whereas the catchment is only 71 km^2, so the population within the actual catchment is considerably smaller. The population is concentrated to the north around Dartmouth, with lower population densities throughout the rest of the catchment.

While no tourism statistics specific to Start Bay could be found, information was available for the South Hams district. South Hams received 633,000 staying visitors and 2,384,000 day visitors in 2007, and it is noted that tourism is a key industry for the Start Bay area (Slapton Line Partnership, 2009). It is therefore likely that the population in the catchment area will increase significantly during the summer, and this will be reflected by an increased sewage output.

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

Details of all consented sewage discharges within the Start Bay hydrological catchment were taken from the most recent update of the Environment Agency national permit database (October 2014). These are mapped in Figure II.1.

Figure II.1: All permitted sewage discharges to the Start Bay catchment
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Table II.1: Details of continuous water company sewage works to the Start Bay catchment

Name	NGR	Treatment	DWF (m^3/day)	Estimated bacterial loading (cfu/day)**	Receiving environment
Beesands STW	SX8195040500	Unspecified	Unspecified	Unknown	Unspecified
Beeson STW	SX8132041150	Biological Filtration	Unspecified	Unknown	Beeson Stream
Bickerton STW	SX8130438968	Septic Tank	4.6	4.6×10^{11}	Soakaway
Blackawton STW	SX8050050400	Biological Filtration	104	3.4×10^{11}	Blackawton Stream
Silver Cloud ST	SX8637047910	Septic Tank	4*	4.0×10^{11}	Soakaway
Slapton STW	SX8241041700	Biological Filtration	777	2.6×10^{12}	Start Bay
Stoke Fleming STW	SX8661048240	Primary Settlement	260	2.6×10^{13}	Leonards Cove Stream
Strete STW	SX8451046670	Biological Filtration	122	4.0×10^{11}	Start Bay

*Maximum flows per day (DWF not available)
**Faecal coliforms (cfu/day) based on geometric base flow averages from a range of UK STWs (Table II.2)

Table II.2: Summary of reference faecal coliform levels (cfu/100 ml) for different sewage treatment levels under different flow conditions.

Treatment Level	Flow			
	Base-flow		High-flow	
	n	Geometric mean	n	Geometric mean
Storm overflow (53)	-	-	200	7.2×10^6
Primary (12)	127	1.0×10^7	14	4.6×10^6
Secondary (67)	864	3.3×10^5	184	5.0×10^5
Tertiary (UV) (8)	108	2.8×10^2	6	3.6×10^2

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

There are eight continuous water company discharges within the catchment. Most of these discharges are directly to or in close proximity of the coast. The largest of these is Slapton STW, the effluent from which undergoes secondary biological treatment and has a consented dry weather flow of 777 m^3/day. The population in the holiday season is said to increase locally by three-fold from the baseline (resident) population (Dawe, *et al*, 2005). Effluent volumes will therefore increase considerably during the peak summer holiday period. Slapton STW discharges just south of the shellfishery but given its large volume proximity is likely to be an influence. Stoke Fleming STW and Strete STW also located near the coast, at the northern end of the survey area. Stoke Fleming STW is located just north of the fishery and has a dry weather flow of 260 m^3/day but only provides primary settlement and screening. As such, it will produce a relatively high bacterial loading and may impact on the shellfisheries to the south of it. Strete STW discharges directly to the shore adjacent to the shellfishery. It has a dry weather flow of 122 m^3/day, and undergoes secondary biological filtration. There is one other coastal discharge in the north of the survey area, Silver Cloud Septic Tank, but as this discharges to soakaway this should have no impact on water quality provided it is functioning correctly.

There are three water company continuous discharges to the south of the survey area, Beeson STW, Beesands STW and Bickerton STW. Limited information on the discharge volumes and treatment types for the first two of these discharge was available and as such the extent of impacts is uncertain. Bickerton STW discharges to groundwater so should have no impact in Start Bay, if functioning correctly, and effluent from the Beeson STW passes through a small lake before draining to the shore. The Blackawton STW discharge discharges to the upper reaches of the River Gara and so will make a contribution to the bacterial loading delivered to coastal waters by this watercourse.

In addition to the continuous sewage discharges, there are 13 intermittent water company discharges associated with the sewerage networks, details of which are shown in Table II.3. Those discharges for which storm overflow data was available are highlighted in yellow.

Table II.3: Intermittent discharges to the Start Bay catchment

No.	Name	Grid reference	Receiving water	Discharge type
1	Blackawton STW	SX8050550435	Blackawton Stream	Storm overflow/ Storm tank
2	Field Adj Council Houses CSO	SX8061850855	Stream	Storm overflow
3	Kimberley Nurseries CSO	SX8214744788	Stream	Storm overflow
4	Leonards Cove PS	SX8661048240	Leonards Cove Stream	Storm overflow
5	Overseas Estate East PS	SX8652048030	Start Bay	Pumping station
6	Overseas Estate West PS	SX8620047840	Start Bay	Pumping station
7	Slapton STW	SX8205044380	Slapton Ley	Storm overflow/ Storm tank
8	Stoke Fleming PS	SX8638048350	Leonards Cove Stream	Pumping station
9	Stokenham Caravan Park CSO	SX8126242705	Slapton Ley	Storm overflow
10	Strete STW	SX8451046670	Start Bay	Storm overflow/ Storm tank
11	The Anchorage CSO	SX8061850855	Stream	Storm overflow
12	Torcross PS	SX8241041700	Start Bay	Storm overflow
13	Torcross PS	SX8226041980	Start Bay	Emergency overflow

Table II.4: Summary of spill records for Torcross PS storm overflow, October 2011 to March 2014

2011 (Oct-Dec)			2012			2013			2014 (Jan-Mar)		
No of spills	Total duration (hrs)	% time spilling	No of spills	Total duration (hrs)	% time spilling	No of spills	Total duration (hrs)	% time spilling	No of spills	Total duration (hrs)	% time spilling
6	600.9	27.8%	35	2844.0	32.4%	9	2308.0	26.3%	2	85.3	4.0%

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Spill data was only available for one intermittent storm discharge (Torcross PS) from October 2011 to March 2014. This discharge is made via the Slapton STW outfall. It was active for a high proportion of the period considered, and would be active on average at about one in four hygiene sampling occasions (based on monthly monitoring). It will therefore require consideration in the sampling plan. The remaining coastal intermittent discharges are mainly located to the north end of the survey area, associated with Strete STW, and around Stoke Fleming. Without further information on spill records it is difficult to assess their impacts apart from noting their location and their potential to discharge untreated sewage. These coastal discharges may potentially be of significance at times as they spill untreated sewage when in operation. Those located inland all discharge to watercourses draining to Slapton Ley, so will be of much less significant due to their distance from the shellfisheries and the potential for bacterial die off during transit to coastal waters.

Although the majority of properties within the survey area are served by water company sewerage infrastructure, there are also 120 permitted private discharges. Table II.5 present details of those consented to discharge 5 m^3/day.

Table II.5: Details of private sewage discharges >5 m^3/day within the Start Bay catchment

Ref.	Name	Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
A	1-7 Coleridge House And The Hayloft	SX7950044850	Package Plant	5	Soakaway
B	8 Dwellings At Beeson Farm	SX8115040680	Septic Tank	10	Soakaway
C	8 Properties At West Hartley Barns	SX8033052160	Package Plant	7	Soakaway
D	Blackland Farm Barns	SX8010945989	Package Plant	20	Slapton Stream
E	Buckland Court	SX8106047500	Not specified	5	Soakaway
F	Fordsworth Cottages, Taffrail	SX8160038970	UV Disinfection	15	Kellaton Stream
G	Green Banks (Land Adjc)	SX8177044890	Septic Tank	8	Soakaway
H	Hillfield Cottages & Country House	SX8318050700	UV Disinfection	92	Blackpool Stream
I	Plots 1-6	SX8172038810	UV Disinfection	7	Natural Reedbed Area
J	Poole Farm	SX8171145379	Package Plant	5	South Grounds Stream
K	Prospect House	SX8169038559	Package Plant	13	Soakaway
L	STP Serving Gara Mill Lodges	SX8175647986	Package Treatment Plant	13	The Gara

Ref.	Name	Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
M	STP Serving The Cricket Inn	SX8192940367	UV disinfection	12	Soakaway

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The majority of private discharges are small, serving one or two properties. Where specified, these are generally treated by small septic tanks or package plants. Of the 120 discharges, 90 discharge to soakaway so should be of no impact on the waters of Start Bay, assuming they are functioning correctly. The majority of those discharging to water discharge either to the Blackpool Stream or to watercourses draining to Slapton Ley, so will make a contribution to the bacterial loading carried by these watercourses. Several of the larger private discharges have UV disinfection, which should greatly reduce the bacterial loading they generate.

Appendix III. Sources and Variation of Microbiological Pollution: Agriculture

The majority of land within the hydrological catchment of Start Bay is devoted to agriculture. There is more arable farmland than pasture, but pastures tend to be located along the banks of the main watercourses (Figure 1.2). Table III.1 presents livestock numbers and densities within the survey area. This data was provided by Defra and is based on the 2013 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. It should nevertheless give a reasonable indication of livestock numbers and densities.

Table III.1: Livestock census data for the Start Bay Catchment

Cattle		Sheep		Pigs		Poultry	
No.	Density (no/km^2)	No.	Density (no/km^2)	No.	Density (no/km^2)	No.	Density (no/km^2)
12,294	172.6	12,490	175.3	147	2.1	12,561	176.3

Data from Defra

The concentration of faecal coliforms excreted in the faeces of animal and humans 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).

There are a large number of grazing livestock within the catchment, as well as relatively small numbers of pigs and poultry. Diffuse inputs associated with grazing livestock may occur through direct deposition in watercourses to which livestock have access or on pastures and subsequent wash off into watercourses. Slurry may also be collected from livestock sheds when cattle are housed indoors and subsequently applied to fields as fertilizer. Manure from pig and poultry operations is typically collected, stored and spread on nearby farm land (Defra, 2009). Sewage sludge may also be used as fertilizer, but no information on local practices was available at the time of writing.

The primary mechanism for mobilisation of faecal matter deposited or spread on farmland to coastal waters is via land runoff, so fluxes of livestock related contamination into the bay will be highly rainfall dependent. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the 'first flush'). It is likely that all of the main watercourses will be impacted to some extent by agriculture.

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/pig manure and sewage sludge may be spread at any time of the year. Therefore peak levels of contamination from sheep and cattle may arise following high rainfall events in the summer, particularly if these have been preceded by a dry period which would allow a build-up of faecal material on pastures, or on a more localised basis if wet weather follows a slurry application which may be more likely in winter or spring.

Appendix IV. Sources and Variation of Microbiological Pollution: Boats

The discharge of sewage from boats is a potential source of bacterial contamination of shellfisheries within Start Bay. Boat traffic in this area is limited to small numbers of recreational craft such as yachts and a few fishing vessels. Figure IV.1 presents an overview of boating activity derived from the shoreline survey, satellite images and various internet sources.

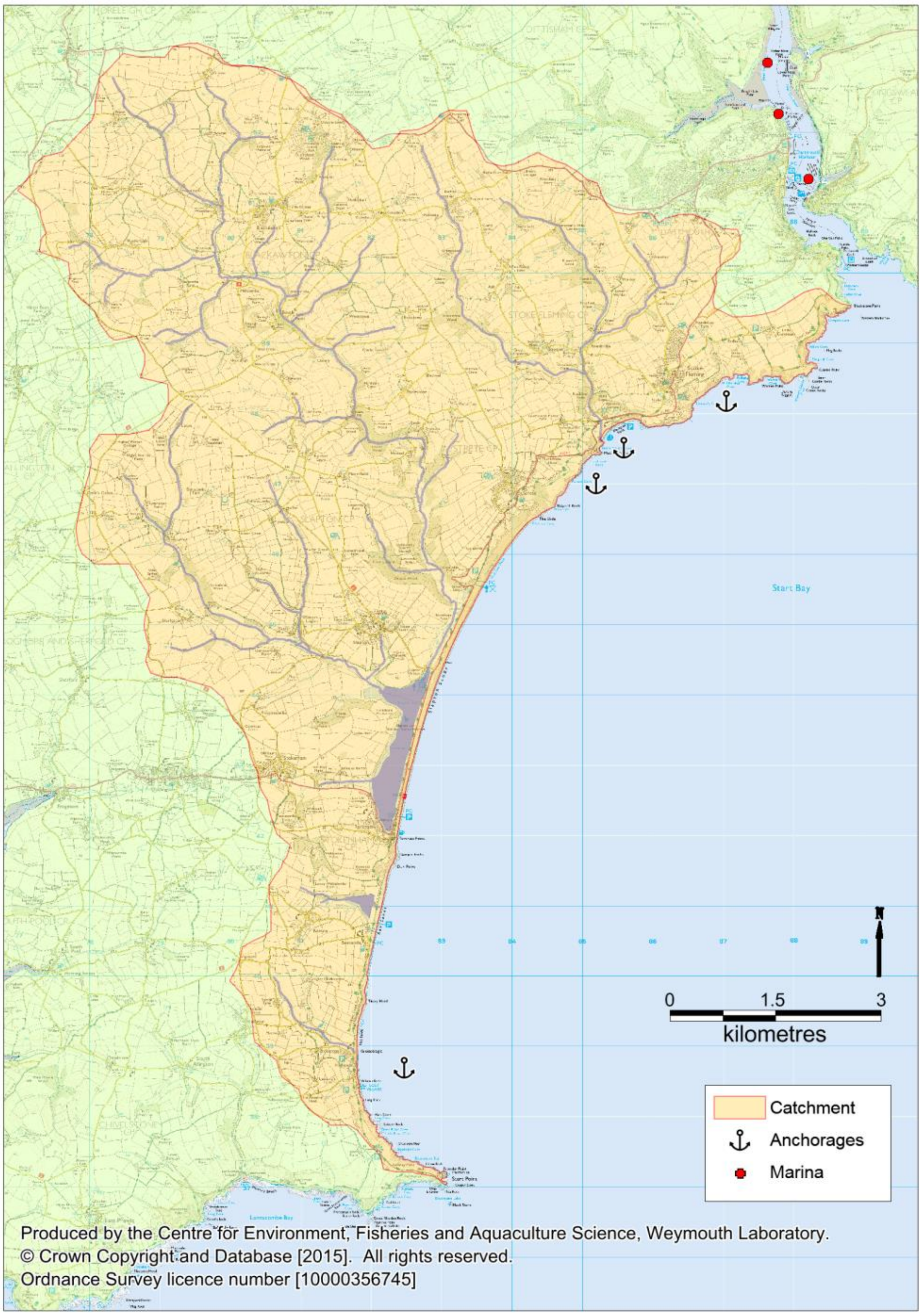

Figure IV.1 Boating activity in the Start Bay survey area

There are no marinas or commercial ports within Start Bay. The Dart Estuary, which is situated just to the north of the survey area has three marinas which collectively have berths for up to 560 boats. In addition to this there are hundreds of moorings available for pleasure craft within the Dart Estuary. The closest sewage pump out facilities are situated in Salcombe, about 10 km west of Start Point (The Green Blue, 2010). The coastline along Start Bay survey area offers anchorages for pleasure craft in the more sheltered areas in the north and south of the bay.

No fishing vessels were registered within the survey area. However, it is likely that fishing vessels registered to surrounding ports such as Dartmouth and Salcombe will fish the waters around Start Bay. Collectively 47 fishing vessels ≥10 m in length and 15 >10 m in length had either Dartmouth or Salcombe as their home port in the January 2015 UK Vessel Lists (MMO, 2015). Their fishing patterns are uncertain but it is likely that some vessels regularly work within Start Bay.

It is therefore concluded that boat traffic in the area consists of potentially large numbers of pleasure craft on transit to and from the Dart Estuary, and smaller numbers on the anchorages at the northern and southern ends of Start Bay. Fishing vessels will also work the area. Those of a sufficient size are likely to make overboard discharges from time to time. This may either occur when the boats are at anchor, particularly if they are in overnight occupation, or while they are navigating through the area. Therefore, whilst overboard discharges may be made anywhere within the survey area, it is likely that the anchorages and the main navigation routes through the area are most at risk of contamination from this source. 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

Start Bay encompasses a variety of habitats including sea cliffs, shingle beaches, marshland, reed beds and a large fresh water lake (Slapton Ley). These features attract significant populations of birds and other wildlife. Consequently Start Bay falls within several national and international conservation designations. These include a National Nature Reserve (NNR), a Site of Special Scientific Interest (SSSI), a Marine Conservation Zone (MCZ), and the Lyme Bay Marine Protected Area (MPA).

The most significant wildlife population of relevance to shellfish hygiene is likely to be seabirds such as gulls and terns, which are widespread throughout the area and present all year round. A survey in the early summer of 1999 along the coastline between Start Point and Blackstone Point recorded 878 pairs of breeding seabirds including European Herring Gull, Northern Fulmar, Black-legged Kittiwake, Great Black-backed Gull and European Shag (Mitchell *et al*, 2004). The largest aggregation of seabirds were observed nesting to the south of the fishery around Hallsands (>700 pairs). During the shoreline survey large numbers of gulls were observed on the beach by Slapton Ley (~500 individuals). 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 or roost sites. Their faeces will be carried into coastal waters via runoff from their nesting sites or via direct deposition to the adjacent intertidal.

Counts of overwintering waterbirds (wildfowl and waders) are undertaken at Slapton Ley. An average peak count of 1,096 was recorded over the five winters up until 2012/2013 (Austin *et. al*, 2014). These birds are likely to contribute to the loadings of faecal indicator organisms delivered to coastal waters via the weir and/or freshwater percolation through the shingle barrier. It is concluded that whilst there is likely to be an influx during the winter months, the survey area does not attract these birds in large concentrations. These are likely to represent a minor source of diffuse contamination to the shellfishery.

There are no major seal colonies in Start Bay, with the closest significant colony in the Solent (SCOS, 2013). Whilst they may forage in the vicinity of the shellfish beds from time to time, they are unlikely to be a significant source of contamination to the shellfishery as their presence will be both unpredictable spatially and temporally. Several species of dolphin and porpoise are regularly sighted in Lyme Bay (Brereton *et al*, 2010) so will frequent Start Bay from time to time. As with the seals their presence will be unpredictable spatially and temporally, so whilst they may potentially be an influence it will not be possible to define an RMP location which will reliably capture their impacts. No other wildlife species which may influence the sampling plan have been identified.

Appendix VI. Meteorological Data: Rainfall

The monthly rainfall data for the Slapton Ley weather station is shown in Figure VI.1.

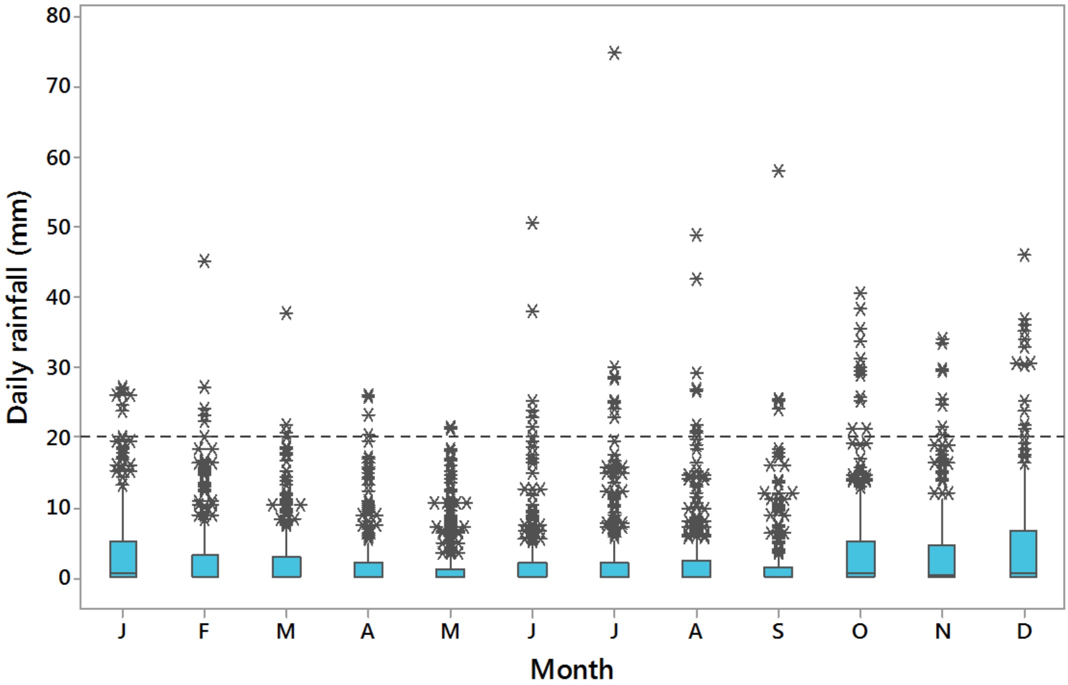

Figure VI.1: Boxplot of daily rainfall totals at Slapton Ley, January 2004 to December 2013.
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The Slapton Ley weather station received an average of 1,069 mm per year between 2004 and 2014. Rainfall was higher on average from October through to January. December had the highest average rainfall, while September had the lowest. Daily totals of over 20 mm were recorded on 2.4% of days and no rainfall was recorded on 44% of days between 2004 and 2014. High rainfall events (>20 mm per day) were recorded in every month of the year but were least frequent during the spring.

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

The southwest is one of the more exposed areas of the UK. The strongest winds are associated with the passage of deep depressions, and the frequency and strength of depressions is greatest in the winter so mean wind and maximum gust speeds are strongest at this time of year. As Atlantic depressions pass the UK, the wind typically starts to blow from the south or southwest, but later comes from the west or northwest as the depression moves away (Met Office, 2012). Another seasonal pattern noted was the increased prevalence of winds from the north east during spring. The annual wind rose for Plymouth Mount Batten is presented in Figure VII.1.

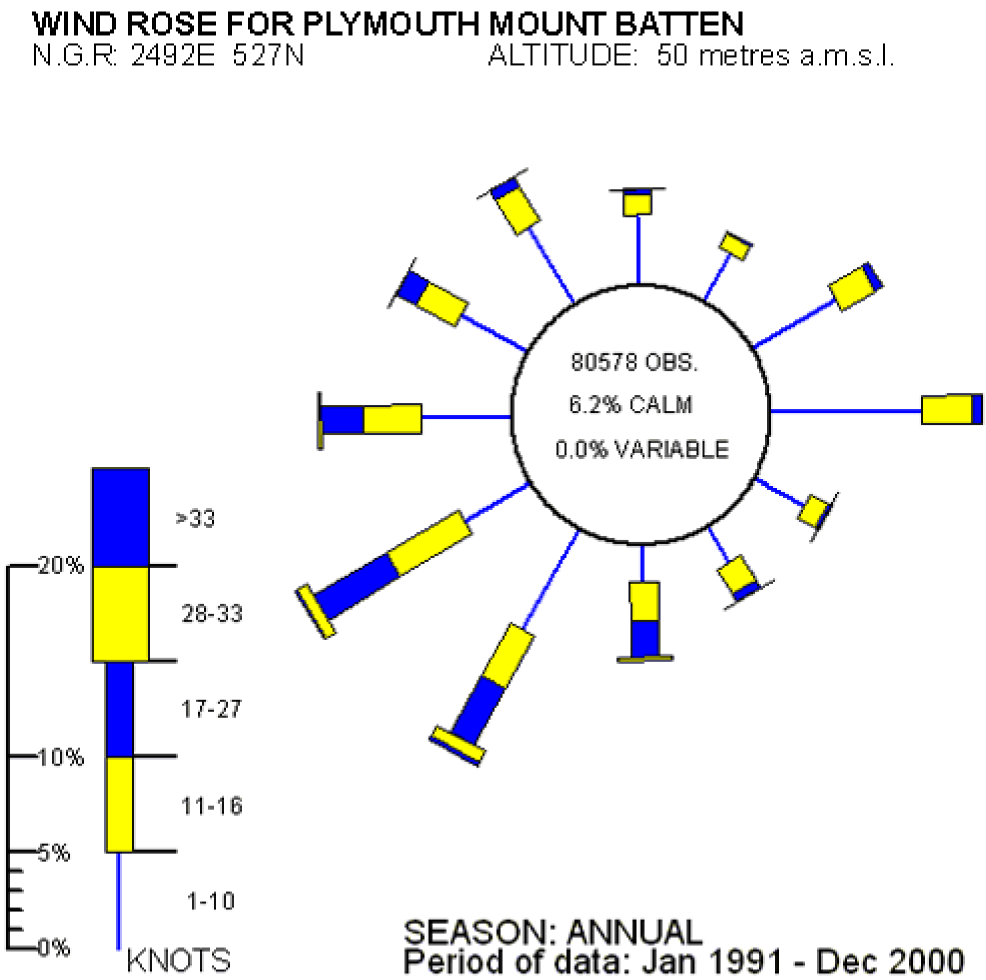

Figure VII.1 Windrose for Plymouth Mount Batten

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Figure VII.1 indicates that the prevailing wind direction at Mount Batten is from the south west. Start Bay is located on the western extremity of Lyme Bay and faces south east. Due to its aspect it is sheltered from the prevailing winds, but is exposed to winds from the east and south. Strong winds from this direction in particular are likely to modify water circulation and generate significant wave action in the vicinity of the fishery.

Appendix VIII. Hydrometric Data: Freshwater Inputs

Start Bay survey area has a hydrological catchment of 71 km², as estimated from topography maps. Figure VIII.1 shows the main watercourses draining the survey catchment.

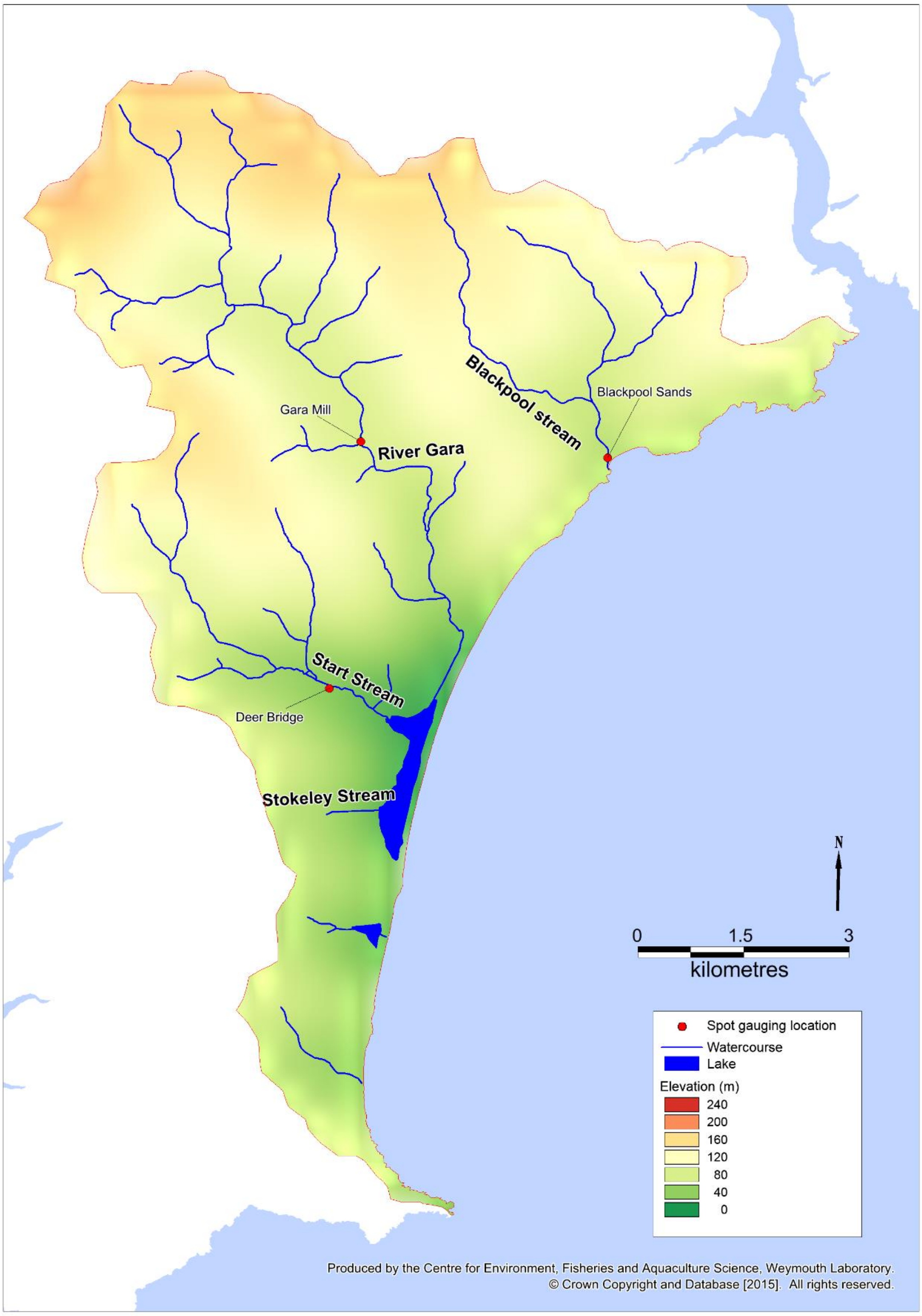

Figure VIII.1: Freshwater inputs to Start Bay

Arable land covers most of the catchment, interspersed with smaller areas of pasture, woodland and heathland. A small proportion of the land is urbanised. The catchment is quite hilly throughout reaching a maximum elevation of 215 m in the west. A small area of low lying marsh surrounds Slapton Ley. The geology comprises of low permeability Devonian slates, sandstones, volcanic rocks and schists (Devon County Council, 2015). Due to the hilly nature of this catchment and it's the low permeability of the underlying geology it is anticipated that watercourses within the catchment will respond quickly to rainfall a high proportion of which will run off.

Three watercourses drain the central catchment (River Gara, Start Stream and Stokeley Stream) and flow into Slapton Ley, a natural freshwater lake. Slapton Ley then discharges to the beach at Torcross via a sluice gate. Blackpool Stream drains the north of the catchment and two smaller unnamed streams drain to the shore in the south of the survey area, one of which discharges to Widdicombe Ley. The average retention time of Slapton Ley is 19 days so the majority of bacterial contamination it receives will die off during passage through it. However, at times of high flows the retention time may decrease to as little as one day (Johnes & Wilson, 1996). Additional bacterial dieoff will also occur for the stream which drains through Widdicombe Ley, and the Blackpool Stream, which flows through a smaller pond in its lower reaches.

There are no daily flow gauging stations within the catchment so detailed information on average discharge rates and day to day and seasonal variations therein could not be made. There are three spot gauging stations situated on the River Gara, Blackpool Stream and Start Stream for the period 1972 – 2004. Summary statistics for these stations are presented in Table VIII.1, where mean and maximum discharges are presented.

Table VIII.1: Summary flow statistics for spot gauging stations on watercourses draining into Start Bay survey area

Site	Watercourse	Number of samples	Mean flow (m^3/s)	Maximum flow (m^3/s)
Deer Bridge	Start stream	11	0.055	0.094
Gara Mill	River Gara	4	0.074	0.220
Blackpool Sands	Blackpool stream	4	0.038	0.062

Mean flows at all three watercourses is low (< 0.080 m^3/s), the highest mean discharge was recorded on the River Gara, the largest watercourse within the catchment. However due to the low the number of samples taken at each site they will not be fully representative of the discharge rates on each river.

Stream discharge will vary significantly from day to day in response to rainfall. It will also vary on average with season, as rainfall is higher on average during the autumn and winter, and during the colder months of the year there is much less evaporation and transpiration. Increased levels of runoff in response to rainfall events are likely to result in an increase in the amount of microorganisms carried into coastal waters. Whether higher average discharge rates during colder months translate to higher average fluxes of faecal indicator organisms is uncertain. Higher runoff rates will decrease residence time in rivers, allowing contamination from more distant sources to have an increased impact during high flow events.

During the shoreline survey, which was conducted under wet conditions, watercourses which could be safely accessed were sampled for *E. coli* and spot flow measurements were taken. The results are presented in Table VIII.2 and Figure VIII.2.

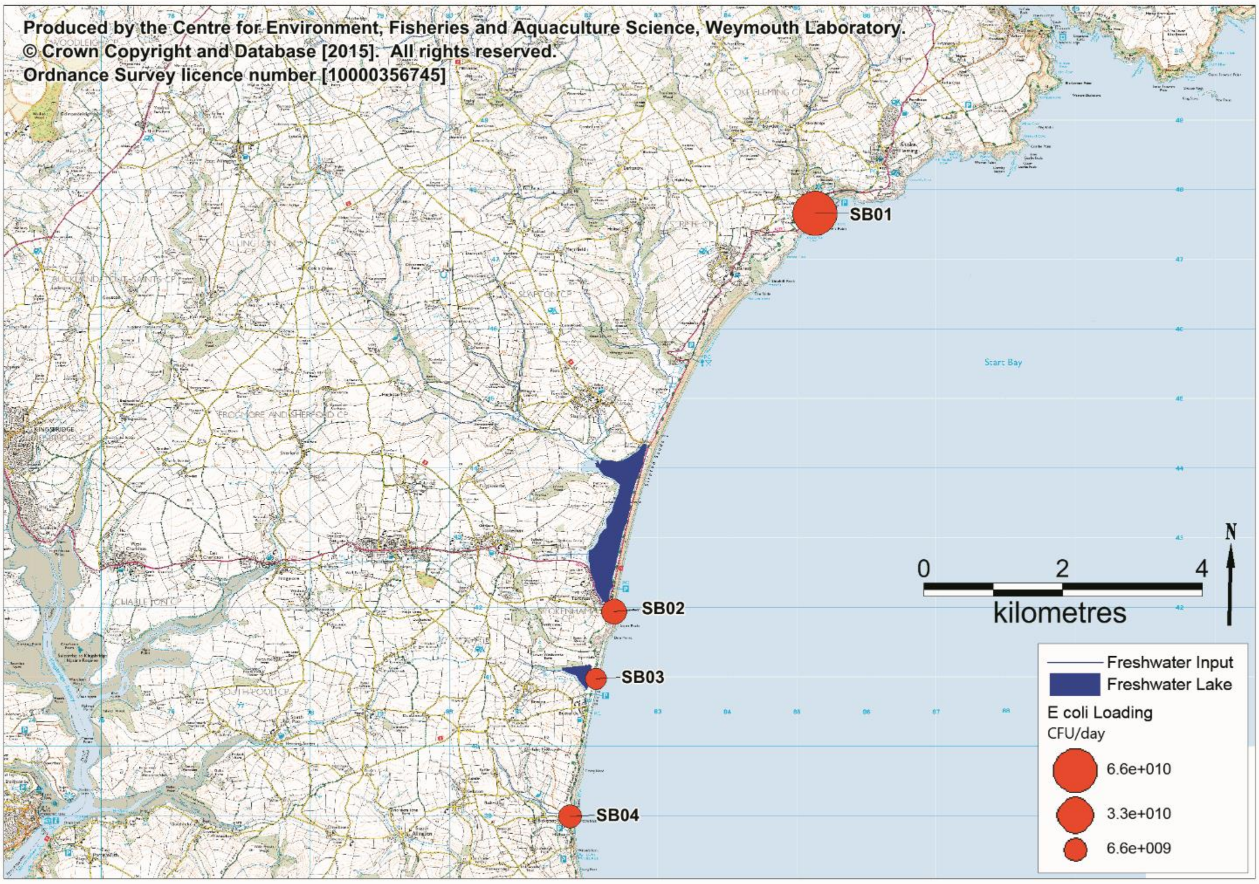

Figure VIII.2: Locations of shoreline survey observations and *E. coli* loadings

Table VIII.2: Details of freshwater inputs observed on the shoreline survey

Sample ID	Observation	*E.* coli (cfu/100 ml)	Flow (m³/s)	*E.* coli Loading cfu/day
SB01	Blackpool Stream	120	0.631	6.54×10^{10}
SB02	Slapton Ley Weir	20	0.598	1.03×10^{10}
SB03	Stream	80	0.083	5.76×10^{9}
SB04	Stream	80	0.114	7.90×10^{9}

All watercourses contained low *E. coli* concentrations, ranging from 20 to 120 cfu/100 ml. As a consequence the *E. coli* loadings they were delivering to Start Bay at the time were not particularly large, although they are likely to be of localised significance. Freshwater seepage from Slapton Ley was observed all along the barrier beach adjacent to the lake, so the Torcross outfall only carries a proportion of the runoff from the streams draining to the Ley.

Appendix IX. Hydrography

IX.1. Bathymetry

Start Bay is a large, open, east facing embayment on the western English Channel at the western extremity to the larger Lyme Bay. It stretches around 16 km from Start Point to Combe Point, by the mouth of the Dart Estuary. Figure IX.1 shows the bathymetry of the survey area, taken from Admiralty Chart 1613.

Figure IX.1: Bathymetry of Start Bay

Start Bay is mainly backed by a barrier beach of fine gravel, although the northern and southern ends are flanked by cliffs. Its bathymetry is relatively uncomplicated, sloping gently away from the coast to a depth of about 20 m relative to chart datum in the outer reaches of the Bay. Initially, the depth drops to around 10 m within a kilometre of the shore, then the bathymetry levels out to between 10 m and 19 m in the majority of the bay. The surf clams are found within a strip running parallel to the shore, just inside the 10 m depth band. An 8 km long sand bank (the Skerries Bank) extends north eastwards from Start Point. Its crest rises to about 2 m below chart datum. Freshwater inputs direct to the survey area are limited to a few minor watercourses which drain directly over/through the beach. The Dart Estuary, at the northern end of the bay receives runoff from a much larger catchment of 470 km^2. Its enclosed nature means that contamination it receives will only drain to Start Bay whilst the tide is ebbing.

The open coastal location will offer high potential for dilution and dispersion of contamination. Tidal streams are likely to accelerate significantly around the prominent headland at Start Point, where some turbulent mixing of the water column is likely to occur, and eddies may form at certain states of the tide.

IX.2. Tides and Currents

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. Tidal amplitude is large, and tidal streams are likely to dominate patterns of water circulation in the bay under most conditions. Table IX.1 shows the tidal ranges at Dartmouth and Start Point, at either end of the bay.

Table IX.1: Tide levels and ranges at Dartmouth and Start Point

Port	Height (m) above Chart Datum				Range (m)	
	MHWS	MHWN	MLWN	MLWS	Springs	Neaps
Dartmouth	4.9	3.8	2.0	0.6	4.3	1.8
Start Point	5.4	4.2	2.3	1.0	4.4	1.9

Data from Admiralty TotalTide©

There are two tidal diamonds within the area shown in Figure IX.1. Both are offshore from the fishery, but they will nevertheless give an indication of the pattern of tidal streams within the bay.

Table IX.3: Tidal stream predictions for Start Point summarised from Admiralty Chart 1613

Time before /after High Water (Plymouth)	Station D		
	Direction (°)	Rate (m/s)	
		Spring	Neap
HW-6	203	1.13	0.57
HW-5	203	1.08	0.57
HW-4	192	0.77	0.41
HW-3	137	0.36	0.21
HW-2	57	1.49	0.72
HW-1	43	1.54	0.77
HW	46	1.29	0.62
HW+1	49	1.13	0.57
HW+2	61	0.72	0.36
HW+3	137	0.36	0.21
HW+4	186	0.77	0.41
HW+5	200	1.08	0.51
HW+6	202	1.13	0.57
Excursion (SW flowing)		21.5 km	10.9 km
Excursion (NE flowing)		24.8 km	12.4 km

Time before /after High Water (Plymouth)	Station E		
	Direction (°)	Rate (m/s)	
		Spring	Neap
HW-6	206	0.51	0.26
HW-5	208	0.62	0.31
HW-4	213	0.51	0.26
HW-3	235	0.26	0.15
HW-2	72	0.15	0.10
HW-1	44	0.36	0.15
HW	39	0.62	0.31
HW+1	31	0.57	0.26
HW+2	35	0.41	0.21
HW+3	44	0.26	0.10
HW+4	46	0.05	0.05
HW+5	214	0.26	0.10
HW+6	209	0.41	0.21
Excursion (SW flowing)		9.3 km	4.6 km
Excursion (NE flowing)		8.7 km	4.3 km

The diamonds indicate a bidirectional pattern of tidal streams which travel along the northeast-southwest plane, roughly parallel to the coast. A similar pattern of circulation is likely to occur in the inshore part of the northern half of the bay, where the fishery is located. Contamination from shoreline sources in this part of the bay will travel parallel to the coast, impacting on either side of their locations, with their plumes becoming progressively diluted as they travel.

The northeast going stream starts between 2 and 3 hours before high water at Plymouth, then continues until between 3 and 5 hours after high water, at which point it reverses and travels in a south westerly direction. High water arrives at Dartmouth about 30 minutes after it arrives at Plymouth, so the ebb plume from the Dart Estuary will only be carried towards the clam fishery for the last two hours of the ebb. This will limit the impacts of the Dart ebb plume, although it will be carried towards the fishery at the end of the ebb tide when faecal indicator bacteria concentrations within it are likely to be highest.

Tidal streams were much stronger at diamond D than at diamond E, due to a local acceleration caused by Start Point. The offshore tidal diamond in central Start Bay indicates tidal excursions of about 9 km on spring tides and 4.5 km on neap tides. They will be slower in shallower inshore areas due to the effects of friction. The ebb plume from the Dart Estuary will only therefore impact on the northern end of the fishery.

The southern half of the bay has been subject to several hydrographic studies investigating the nature of the Skerries Bank. These indicate that when the tide is flowing in a north easterly direction, an eddy current forms between the bank and the shore (e.g. Dyer & Huntley, 1999). The eddy does not extend as far north as the shellfishery.

Superimposed on tidally driven currents are the effects of freshwater inputs and wind. The main source of freshwater is the Dart Estuary, to the north of the survey area. The average and maximum flow ratios (river input/tidal exchange) for this estuary are 0.021 and 0.439. This indicates that the plume from this estuary will be usually be well mixed and land runoff will generally be diluted with large amounts of seawater, but at peak river flows the salinity of the plume will be lower. As such, some localised density driven circulation may arise at the mouth of this estuary at high river flows. The plume of low salinity water emanating from the estuary will be less dense than the more saline seawater and so will have a tendency to spread out and to float on the surface, with a corresponding return of more saline water at depth. Away from the Dart Estuary, freshwater inputs direct to the bay are minor, and the survey area is in an open coastal location, so it is unlikely that significant modification of tidal streams by density effects will occur. Repeated salinity measurements taken as part of the bathing water and shellfish water monitoring programmes are presented in Figure IX.2.

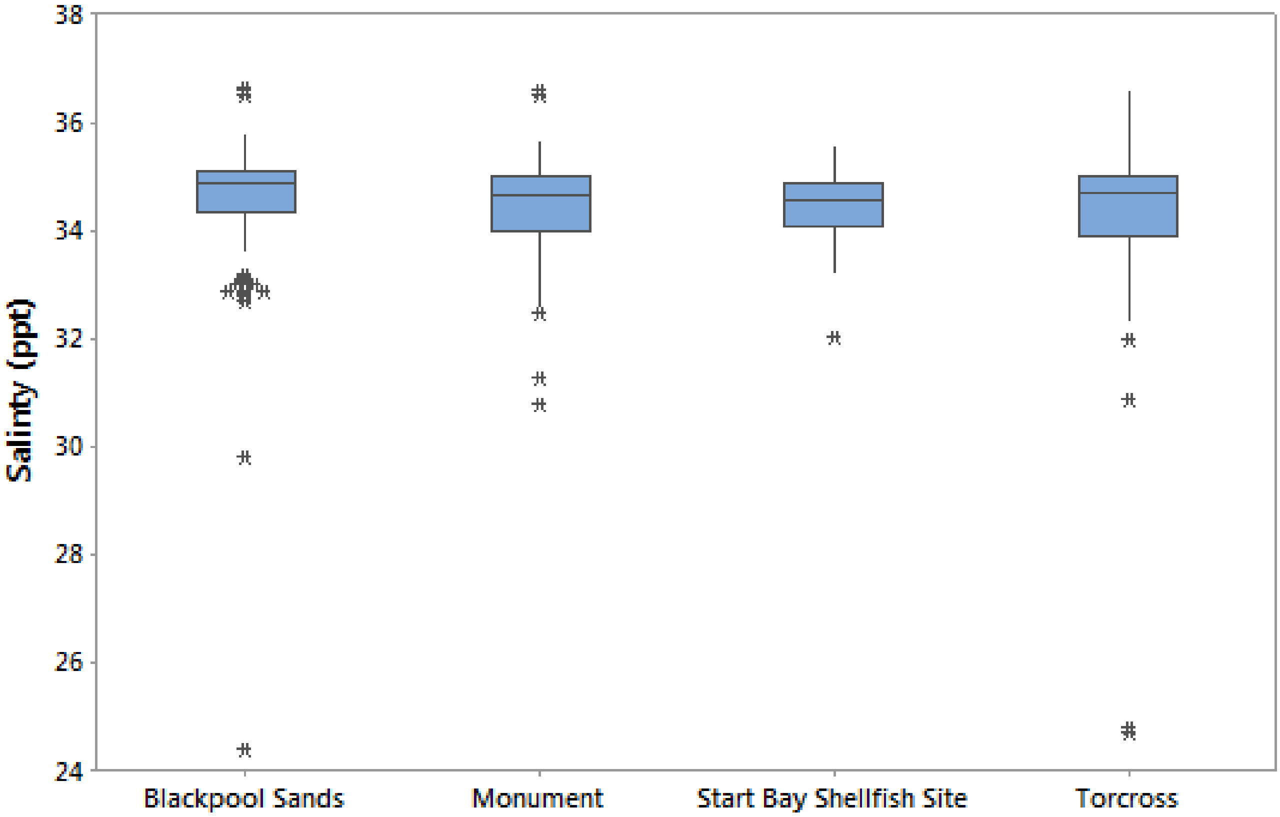

Figure IX.2: Box-and-whisker plots of levels of salinity readings taken from bathing water and shellfish water sampling locations (for the period 2004 - 2013).

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Salinity at all four locations predominantly gave salinity results of full strength seawater. Salinities at the beaches were typically approaching that of full strength seawater, although at most locations salinities of less than 30 ppt were occasionally recorded. This indicates that freshwater influence within the bay is generally minor, although at times of high freshwater inputs reductions in nearshore salinity are observed. The boxplot for Blackpool Sands has a very similar profile to those for the other sites. This suggests that the Dart Estuary does not have a major influence along the near shore region at the northern end of the fishery area.

Winds may have a significant effect on water circulation within the bay. 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 a current of about 0.5 m/s. These surface currents drive return currents which may travel lower in the water column or along sheltered margins. Start Bay is sheltered from the prevailing south westerly winds by the adjacent land. It is most exposed to the east and south. Winds from these directions would tend to push surface water currents towards the shore. 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. Strong winds will also induce wave action, which will lead to increased mixing of the water column in offshore areas, and the re-suspension of sediment entrained contamination in intertidal areas. Southerly and easterly winds and swells are likely to be most effective in generating energetic wave action in the vicinity of the clam beds. It is likely that the Skerries Bank attenuates swells to some extent as the pass over it, so the northern half of the bay may be more exposed to wave action.

Appendix X. Microbiological Data: Seawater

X.1. Bathing Waters

Due to changes in the analyses of bathing water quality by the Environment Agency from 2012, only data produced up to the end of 2011 were available for faecal coliform concentrations. The available *E. coli* data are summarised in Table X.1. *E. coli* data for bathing waters were only available for 2012 and 2013, so further analyses used faecal coliform data up to 2011 as this represents a much larger dataset. There are three bathing waters in Start Bay designated under the Directive 76/160/EEC (Council of the European Communities, 1975), the locations of which are shown in Figure X.1.

Table X.1: Summary statistics for bathing waters *E. coli* results, 2012-2013 (cfu/100 ml).

Sampling Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1,000
Blackpool Sands	40	14/05/2012	17/09/2013	8.2	<10	209	2.5	0.0
Monument	40	14/05/2012	17/09/2013	5.8	<10	55	0.0	0.0
Torcross	40	14/05/2012	17/09/2013	7.1	<10	470	7.5	0.0

The majority of results at all sites were below the limit of quantification for the test (10 *E. coli* cfu/100 ml) and the geometric mean result was similar at all three.

Figure X.1: Location of designated bathing and shellfish waters monitoring points in Start Bay
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Summary statistics of all faecal coliform results by bathing water from 2004-2011 are presented in Table X.2, and Figure X.2 presents box plots of these data. The limit of quantification of the faecal coliform test was lower (2 cfu/100 ml) than that used for subsequent *E. coli* testing (10 cfu/100 ml) allowing more robust statistical analyses.

Table X.2: Summary statistics for bathing waters faecal coliforms results, 2004-2011 (cfu/100 ml).

Sampling Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1,000
Blackpool Sands	160	01/05/2004	22/09/2011	2.6	<2	2,000	1.3	0.6
Monument	160	01/05/2004	22/09/2011	2.2	<2	160	0.6	0.0
Torcross	160	01/05/2004	22/09/2011	2.7	<2	577	2.5	0.0

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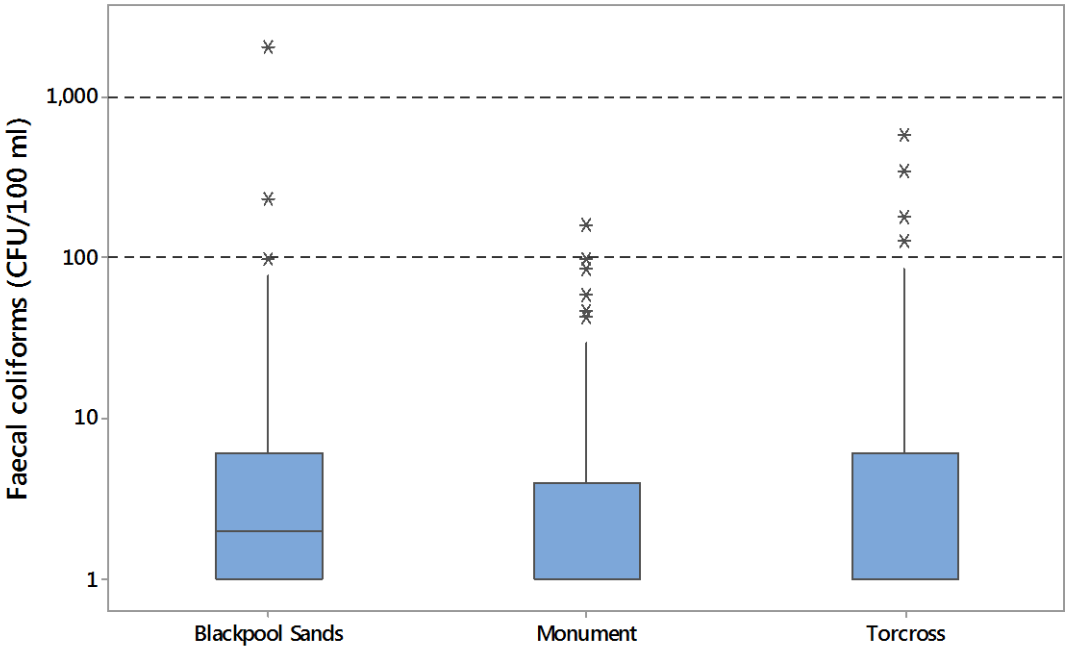

Figure X.2: Box-and-whisker plots of all faecal coliforms results by site
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Results were low on average at all three locations. Torcross had the highest geometric mean faecal coliform concentrations and Blackpool Sands had the maximum faecal coliform concentrations. A one-way ANOVA test showed that there were no significant differences in faecal coliforms concentrations between sites (p=0.220).

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

Overall temporal pattern in results

The overall temporal variation in faecal coliforms levels found at bathing water sites is shown in Figure X.3.

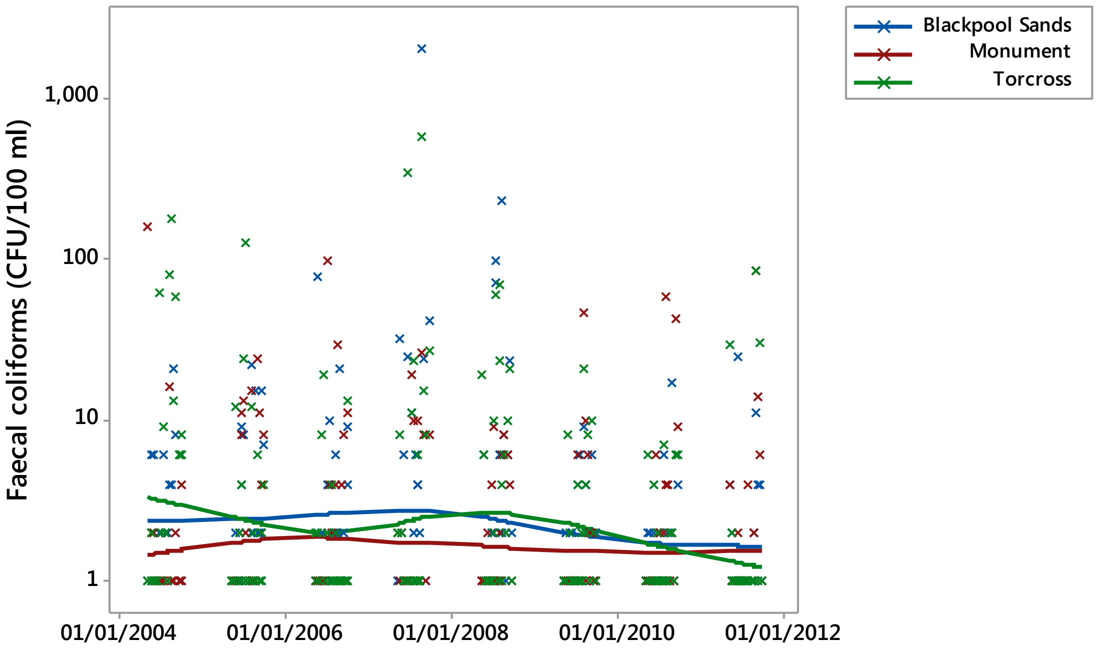

Figure X.3: Scatterplot of faecal coliforms results for bathing waters in the Start Bay overlaid with loess lines.

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Faecal coliform concentrations have remained fairly stable on average since 2004.

Influence of tides

To investigate the effects of tidal state on faecal coliforms results, circular-linear correlations were carried out against both the high/low and spring/neap tidal cycles for each of the bathing waters sampling points. Correlation coefficients are presented in Table X.3, with statistically significant correlations highlighted in yellow.

Table X.3: Circular linear correlation coefficients (r) and associated p values for faecal coliforms results against the high/low and spring/neap tidal cycles

	High/low tides		Spring/neap tides	
Site Name	**r**	**p**	**r**	**p**
Blackpool Sands	0.087	0.302	0.034	0.832
Monument	0.120	0.103	0.212	0.001
Torcross	0.107	0.163	0.117	0.115

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Figure X.4 presents a polar plot of $\log_{10}$ faecal coliforms results against the spring/neap tidal cycle for Monument, the only monitoring point for which a significant correlation was detected. Full/new moons occur at 0º, and half moons occur at 180º, and the largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 100 faecal coliforms cfu/100 ml or less are plotted in green, and those exceeding 100 cfu/100 ml are plotted in yellow.

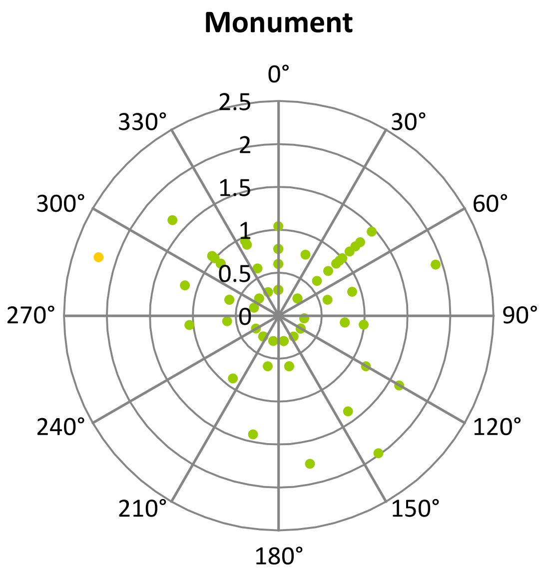

Figure X.4: Polar plots of log_{10} faecal coliforms results (cfu/100 ml) against the spring/neap tidal cycle.

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At Monument, there tended to be lower faecal coliform concentrations on the smaller (neap) tides.

Influence of Rainfall

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

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

	Site	Blackpool Sands	Monument	Torcross
	n	160	160	160
24 hour periods prior to sampling	1 day	0.396	0.189	0.287
	2 days	0.404	0.170	0.217
	3 days	0.280	0.050	0.066
	4 days	0.155	0.145	0.065
	5 days	0.079	0.128	0.070
	6 days	0.018	0.060	-0.032
	7 days	0.022	0.039	0.063
Total prior to sampling over	2 days	0.453	0.208	0.310
	3 days	0.435	0.162	0.288
	4 days	0.410	0.172	0.253
	5 days	0.369	0.183	0.221
	6 days	0.353	0.170	0.217
	7 days	0.362	0.184	0.233

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At all three sites, rainfall had rapid influence on faecal coliform levels and continued to do so for two to three days following a rainfall event. The correlations were strongest at Blackpool Sands.

Salinity

Salinity was recorded on most sampling occasions. Figure X.5 shows scatter-plots between faecal coliforms and salinity. Pearson's correlations were run to determine the effect of salinity on faecal coliforms at the bathing waters site.

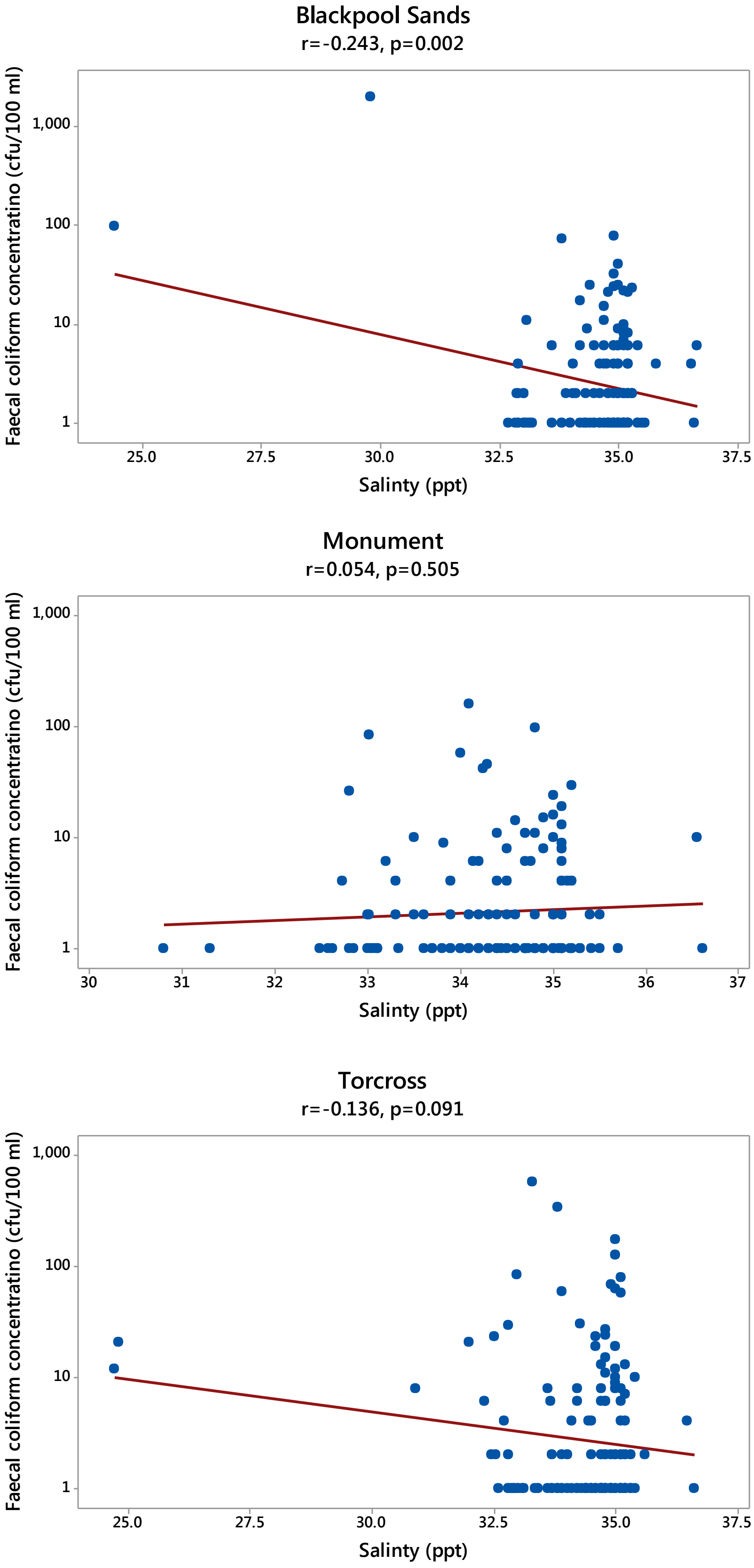

Figure X.5: Scatter-plots of salinity against faecal coliforms concentration.
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Faecal coliforms levels at Blackpool Sands correlated significantly with salinity, but not at Monument or Torcross. This suggests that land runoff is more of an influence Blackpool Sands.

X.2. Shellfish Waters

Summary statistics and geographical variation

There is one shellfish water monitoring site originally designated for the purposes of Directive 2006/113/EC (European Communities, 2006) relevant to the Start Bay production area. Figure X.1 shows the location of this site. Table X.5 presents summary statistics for bacteriological monitoring results and Figure X.6 presents a boxplot of faecal coliform levels from the monitoring point.

Table X.5: Summary statistics for shellfish waters faecal coliform results, 2004 to 2013 (cfu/100 ml).

Sampling Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100
Start Bay	40	15/09/2004	26/06/2013	3.9	<2	37	0.0

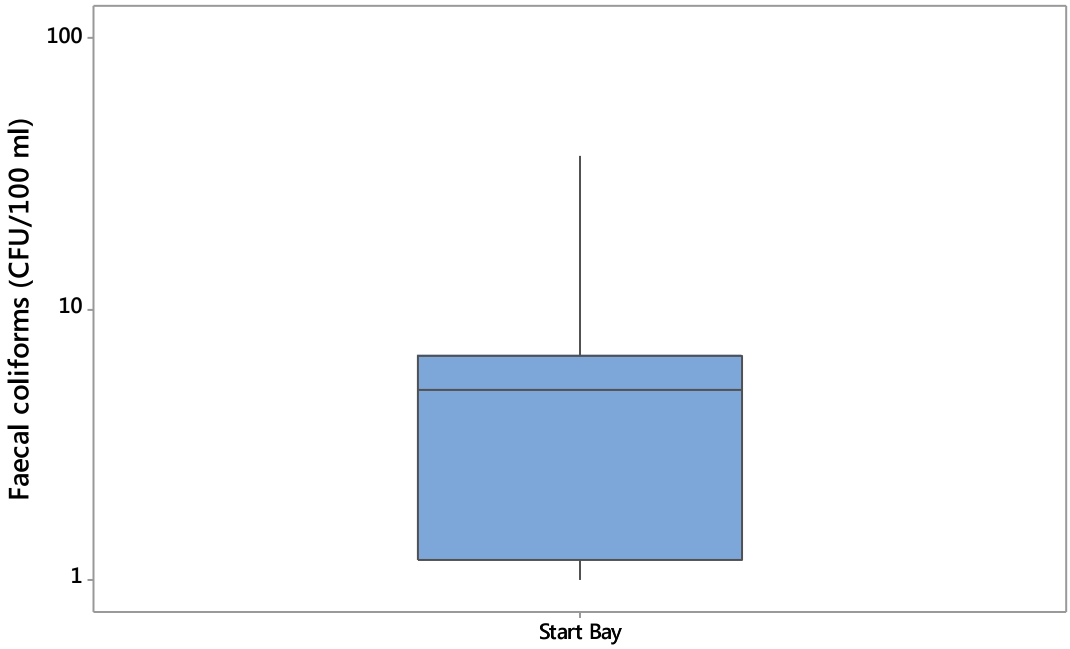

Figure X.6: Box-and-whisker plot of all faecal coliforms results

Results were low on average and no samples had a faecal coliform concentration exceeding 100 cfu/100 ml.

Overall temporal pattern in results

The overall variation in faecal coliform levels found at shellfish water sites over time is shown in Figure X.7.

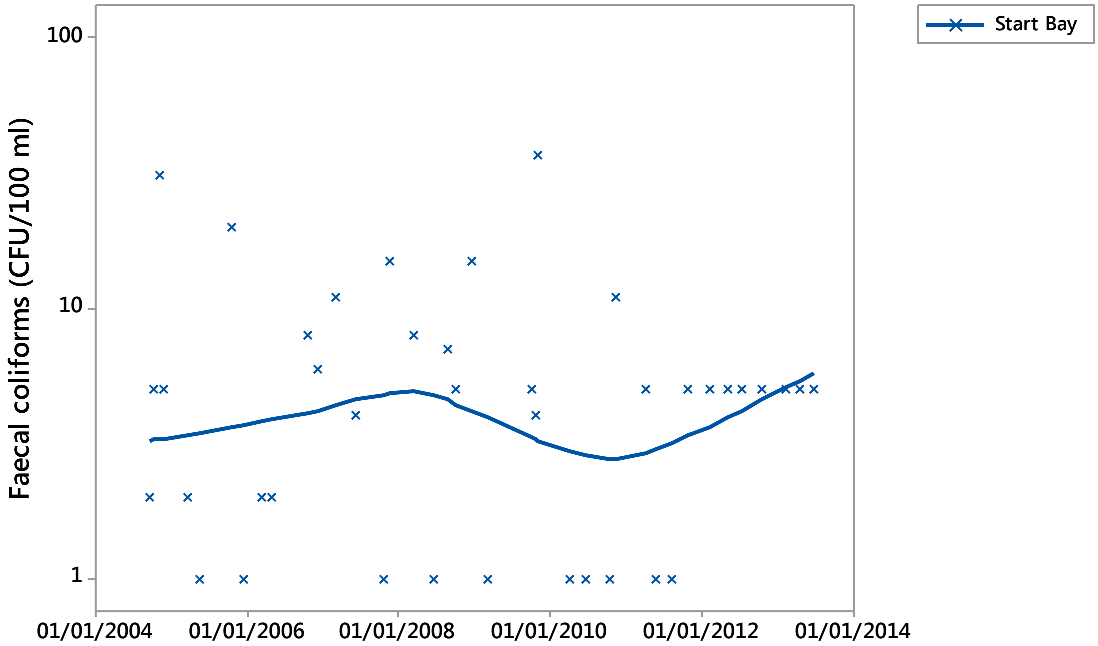

Figure X.7: Scatterplot of faecal coliform results by date, overlaid with loess lines
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Faecal coliform levels have remained fairly stable on average since 2004.

Seasonal patterns of results

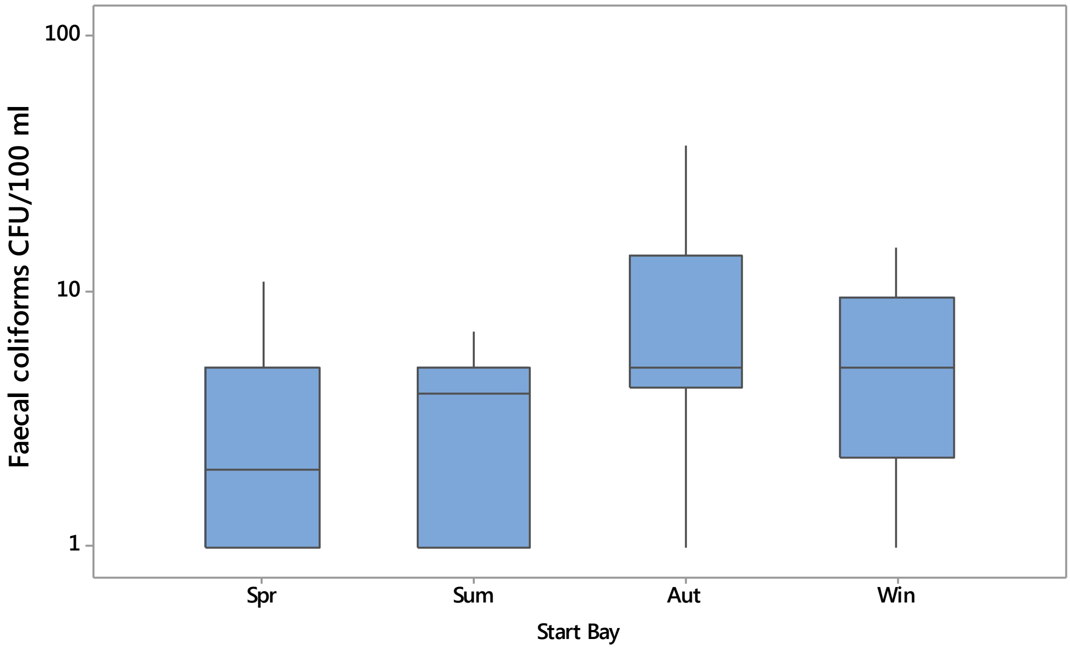

Figure X.8: Boxplot of faecal coliform results by site and season
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While faecal coliform concentrations were higher on average in the autumn and winter (Figure X.8), one-way ANOVA tests revealed there were no statistically significant differences between seasons (p=0.086).

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. Correlation coefficients are presented in Table X.6, with statistically significant correlations highlighted in yellow.

Table X.6: 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**
Start Bay	0.322	0.021	0.404	0.002

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Figure X.9 presents a polar plot of $\log_{10}$ faecal coliform results against tidal state on the high/low cycle. High water at Start Point is at 0° and low water is at 180°.

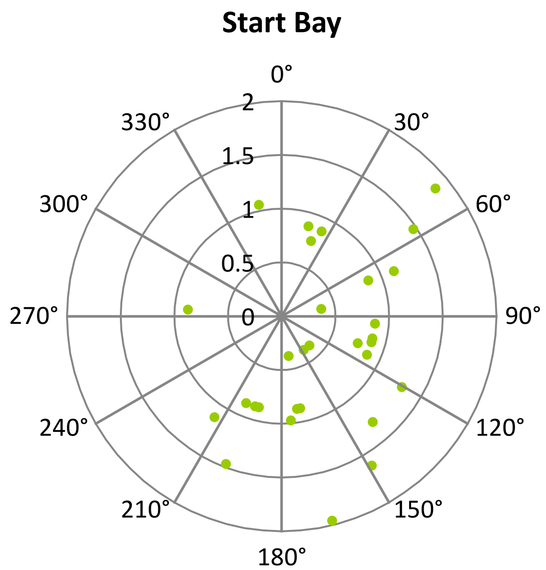

Figure X.9: Polar plots of log_{10} faecal coliforms against tidal state on the high/low tidal cycle for the shellfish water monitoring point.
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Higher results tended to occur during the ebb tide at Start Bay.

Figure X.10 presents a polar plot of log_{10} faecal coliforms results against the spring/neap tidal cycle. Full/new moons occur at 0º, and half moons occur at 180º, and the largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides.

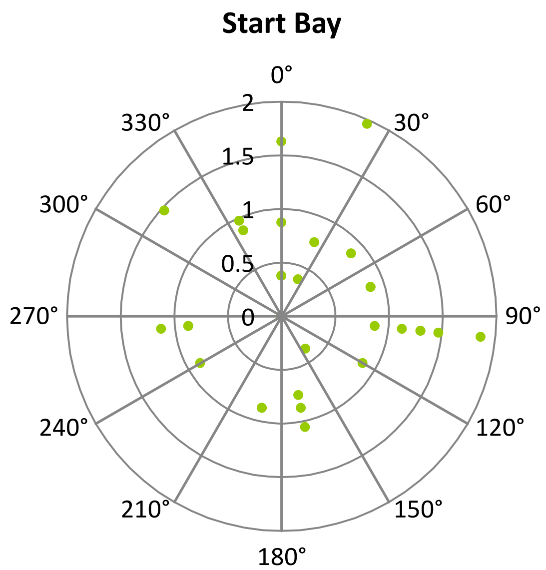

Figure X.10: Polar plot of log_{10} faecal coliforms against tidal state on the spring/neap tidal cycle for the shellfish water monitoring point.
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While a significant correlation was found between faecal coliform concentrations and spring/neap tidal state, no obvious pattern is evident in Figure X.10.

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 Slapton Ley weather station (Appendix VI for details) over various periods running up to sample collection and faecal coliform results. These are presented in Table X.7 and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table X.7: Spearman's Rank correlation coefficients for faecal coliform results against recent rainfall

	Site	Start Bay
	n	40
24 hour periods prior to sampling	1 day	0.363
	2 days	0.245
	3 days	0.543
	4 days	0.590
	5 days	0.523
	6 days	0.304
	7 days	0.154
Total prior to sampling over	2 days	0.352
	3 days	0.486
	4 days	0.551
	5 days	0.649
	6 days	0.649
	7 days	0.625

Faecal coliform levels at Start Bay were significantly affected by rainfall shortly after rainfall and continued to be so for several days.

Salinity

Salinity was recorded on most sampling occasions. Figure X.11 shows scatter-plots between faecal coliforms and salinity. Pearson's correlations were run to determine the effect of salinity on faecal coliforms at the bathing waters site.

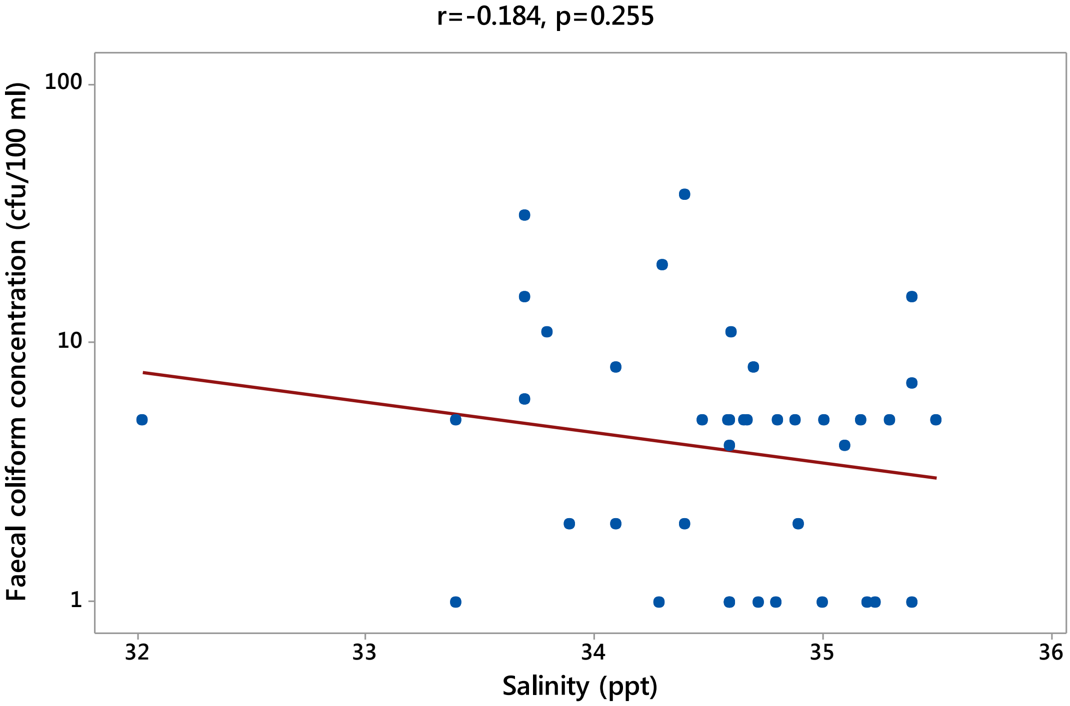

Figure X.11: Scatter-plot of salinity against faecal coliform concentration.
Contains Environment Agency information © Environment Agency and database right

Faecal coliform levels at Start Bay did not correlate significantly with salinity.

Appendix XI. Microbiological Data: Shellfish Flesh

XI.1. Summary statistics and geographical variation

There are five RMPs in the Start Bay production area that have been sampled between 2005 and 2014. The geometric mean results of shellfish flesh monitoring from all RMPs sampled from 2005 onwards are presented in Figure XI.1. Summary statistics are presented in Table XI.1 and boxplots for sites are show in Figure XI.2. The Slapton Sands 1 RMP was sampled on fewer than 10 occasions and so will not be included in more detailed analyses.

Figure XI.1: RMPs active since 2005.

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

Site	Species	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 230	% over 4,600
Slapton Sands 1	Surf clams (or thick trough shells)	2	21/02/2006	27/02/2006	293.3	200	430	50.0	0.0
Slapton Sands 2		95	22/02/2005	30/06/2014	116.0	<20	3,500	29.5	0.0
Forest Cove Point		12	10/07/2012	18/04/2013	173.7	20	3,500	50.0	0.0
Matthews Point		12	10/07/2012	18/04/2013	247.0	50	1,700	58.3	0.0
Leonards Cove Point		26	10/07/2012	30/06/2014	169.2	<20	9,200	53.8	3.8

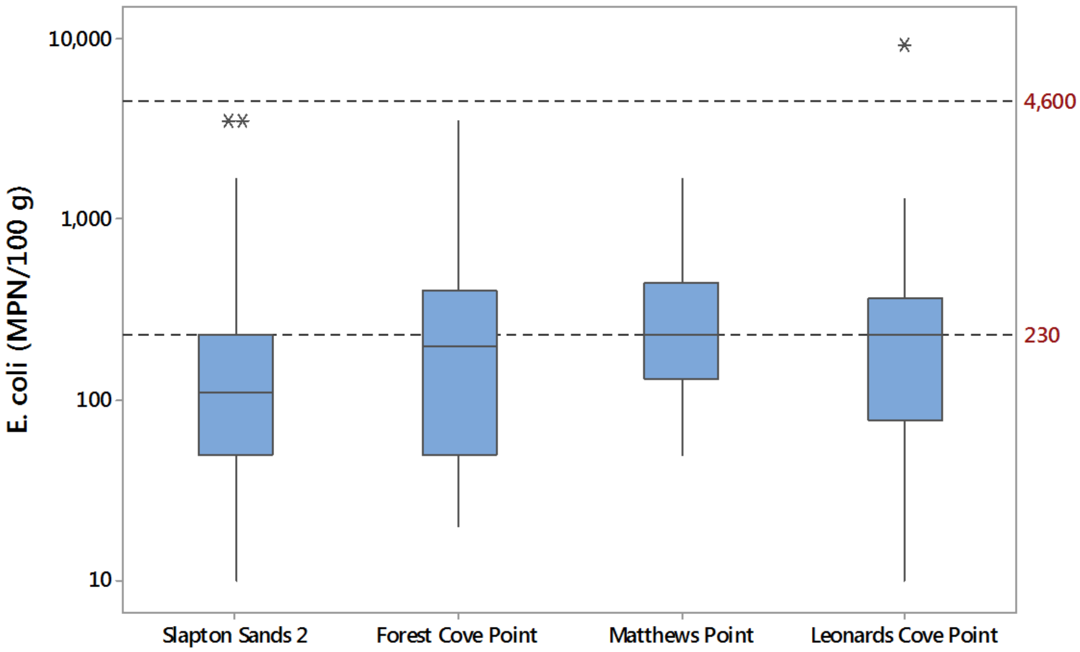

Figure XI.2: Boxplots of *E. coli* results from RMPs sampled from 2005 onwards.

At RMPs sampled on 10 or more occasions, *E. coli* levels exceeded 230 MPN/100 g for at least 29.5% of samples at all sites but only exceeded 4,600 MPN/100 g at one site (Leonards Cove Point) on one occasion. A one-way ANOVA test showed that there were no significant differences in average *E. coli* levels between sites (p=0.202).

Comparisons of RMPs were carried out on a pair-wise basis by running correlations (Pearson's) between sites that shared at least 20 sampling dates, and therefore environmental conditions. Only one comparison could be made (Slapton Sands 2/Leonards Cove Point) and this was not quite statistically significant at the 0.05 level (r=0.419, p=0.057).

XI.2. Overall temporal pattern in results

There were less than two years' worth of data at Forest Cove Point, Matthews Point and Leonards Cove Point and so temporal analyses were not possible for these sites. The overall variation in *E. coli* levels found in thick trough shells at Slapton Sands 2 is shown in Figure XI.3.

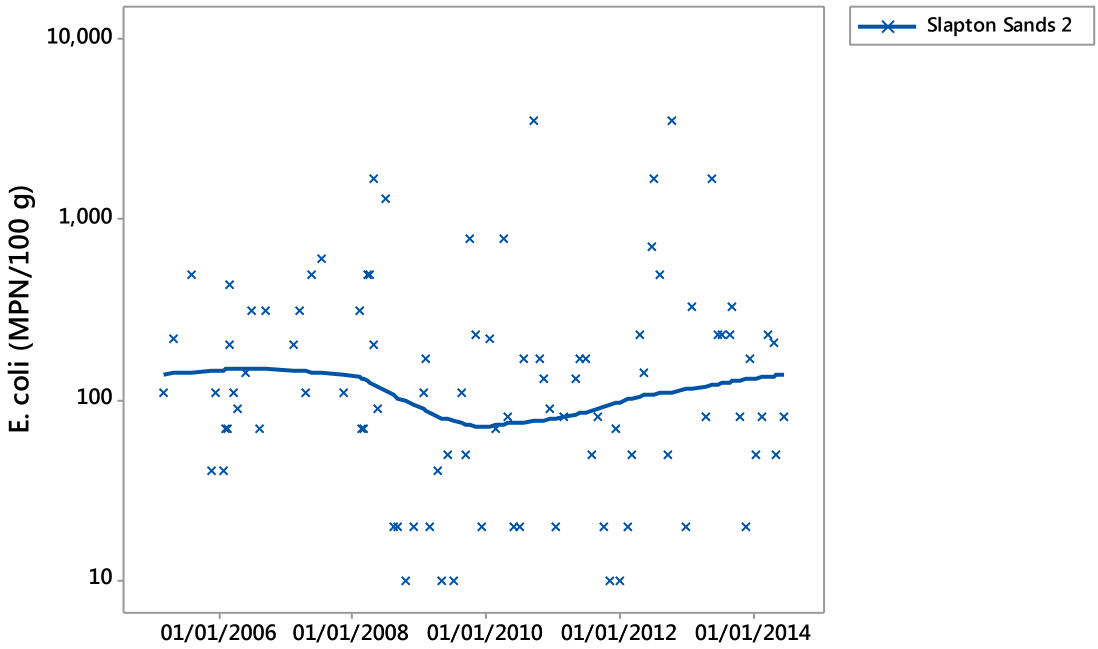

Figure XI.3: Scatterplot of *E. coli* results for Slapton Sands 2 overlaid with loess line.

E. coli levels have remained stable on average at Slapton Sands 2 since 2005.

XI.3. Seasonal patterns of results

There were less than two years' worth of data at Forest Cove Point, Matthews Point and Leonards Cove Point and so seasonal analyses were not possible for these sites. The seasonal patterns of results at Slapton Sands 2 were investigated. Figure XI.4 shows box plots of *E. coli* levels by season.

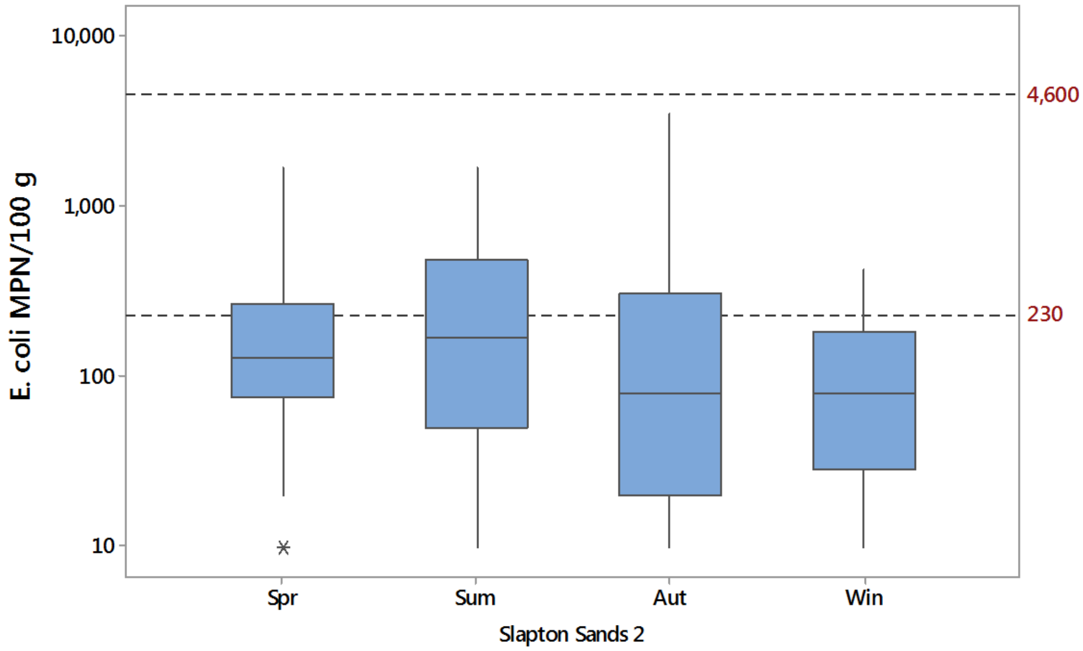

Figure XI.4: Boxplot of *E. coli* results for Slapton Sands 2 by season

One-way ANOVAs showed that there were no significant differences in *E. coli* levels between seasons at Slapton Sands 2 (p=0.267).

XI.4. Influence of tide

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

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

	High/low tides		Spring/neap tides	
Site Name	**r**	**p**	**r**	**p**
Slapton Sands 2	0.166	0.080	0.196	0.029

Figure XI.5 presents polar plots of $\log_{10}$ *E. coli* results against the spring neap tidal cycle for Slapton Sands 2. Full/new moons occur at 0º, and half moons occur at 180º, and the largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 230 *E. coli* MPN/100 g or less are plotted in green, those from 231 to 4600 are plotted in yellow, and those exceeding 4,600 are plotted in red.

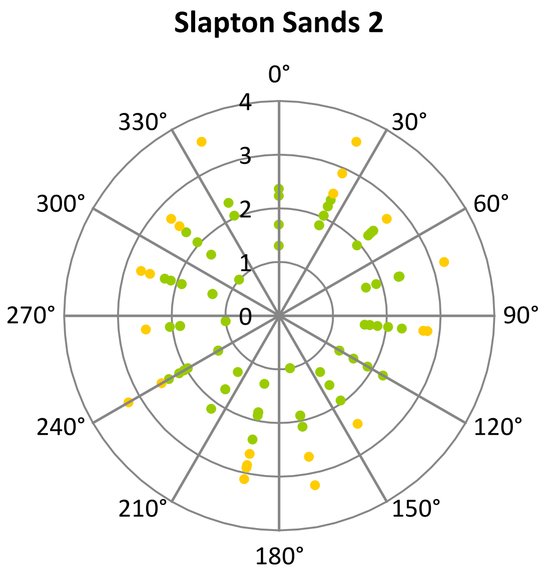

Figure XI.5: Polar plot of log_{10} *E. coli* results (MPN/100 g) at Slapton Sands 2 against spring/neap tidal state

There appeared to be a trend of fewer low *E. coli* results during the spring tides at Slapton Sands 2.

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 Slapton Ley 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 Slapton Ley and shellfish hygiene results

	Site	Slapton Sands 2	Forest Cove Point	Matthews Point	Leonards Cove Point
	n	89	12	12	20
24 hour periods prior to sampling	1 day	-0.034	-0.436	0.035	0.021
	2 days	0.099	-0.200	-0.361	-0.315
	3 days	0.028	-0.195	-0.401	-0.279
	4 days	-0.020	-0.091	-0.172	-0.257
	5 days	0.050	0.286	0.671	0.347
	6 days	-0.006	-0.086	0.036	-0.131
	7 days	0.124	0.278	-0.099	0.044
Total prior to sampling over	2 days	0.014	-0.260	-0.023	-0.084
	3 days	0.024	-0.452	-0.160	-0.113
	4 days	0.021	-0.380	-0.067	-0.061
	5 days	0.081	0.167	0.503	0.159
	6 days	0.074	-0.039	0.394	0.072
	7 days	0.112	0.075	0.351	0.043

No correlations between *E. coli* levels and antecedent rainfall were found for three of the four sites. A single significant correlation was observed at Matthews Point, but this is likely to be an artefact as many of the other correlation coefficients were negative and on average an apparently significant correlation will arise by chance alone 5% of the time.

Appendix XII. Shoreline Survey Report

Date (time):
20/01/2015 (09:00-13:30)

Cefas Officers:
Rachel Parks

Local Enforcement Authority Officers:
Dan Blackley (South Hams District Council)

Observers:
Beverley Kuster (Food Standards Agency)
Nathan Phillipo (Food Standards Agency)

Area surveyed:
Blackpool Sands and the shoreline between Strete Gate and Hallsands.

Weather:
20th January – Overcast with showers 4.6°C, wind bearing 45° at 8 km/h

Tides:
Admiralty TotalTide© predictions for Dartmouth. All times in this report are GMT.

20/01/2015	
High 05:41	4.9 m
High 18:10	4.8 m
Low 11:38	0.6 m

XII.1. Objectives:

The shoreline survey aims to obtain samples of freshwater inputs to the area for bacteriological testing; confirm the location of previously identified sources of potential contamination; locate other potential sources of contamination that were previously unknown and find out more information about the fishery. A full list of recorded observations is presented in Table XII.1 and the locations of these observations are shown in Figure **XII**.**1**. The shoreline survey was undertaken over 1 day on foot.

XII.2. Description of Fishery

The wild surf clam fishery covers the shoreline between Leonards Cove and Torcross. The clams are harvested by one fisherman all year round by boat.

XII.3. Sources of contamination

Sewage discharges

Observation 8 is assumed to be the submerged discharge pipe for Slapton Sewage Treatment Works continuous discharge and Torcross Pumping Station intermittent discharge. No other sewage discharges were identified on the survey.

Freshwater inputs

Two unnamed streams were observed on the survey both of which were flowing at the time of survey (Observations 2 and 13) both gave low *E. coli* loadings of 6.54×10^{10} and 7.90×10^{9} cfu/day respectively.

Slapton Ley weir discharges to the beach at Torcross (observation 7, Figure XII.7) and gave an *E. coli* loading of 1.03×10^{10} cfu/day.

A sample was taken from a pipe at Beesands (observation 9, Figure XII.9) and gave an *E. coli* loading of 5.76×10^{9} cfu/day. The pipe carries freshwater from Widdicombe Ley which is located further inshore. An unnamed stream carrying the discharge from the Beeson STW continuous discharge drains to Widdicombe Ley.

A drainage pipe was observed at Beesands (observation 10) but was not flowing at the time of survey.

Freshwater drainage from Slapton Ley was observed to percolate through the shingle beach at various points along Slapton Sands. It was not possible to measure these seeps as flows were slow and spread over a large area.

Livestock

Sheep were observed in the fields north of Hallsands in flocks of around 50 and 100 (observation 10 & 11) respectively. No other livestock were observed during the shoreline survey.

Wildlife

Aggregations of birds (between 40 and 300) were observed at three locations along the coastline (observations 3, 4 and 6).

Dog walking was evident on Blackpool Sands and on the coastal path close to Torcross.

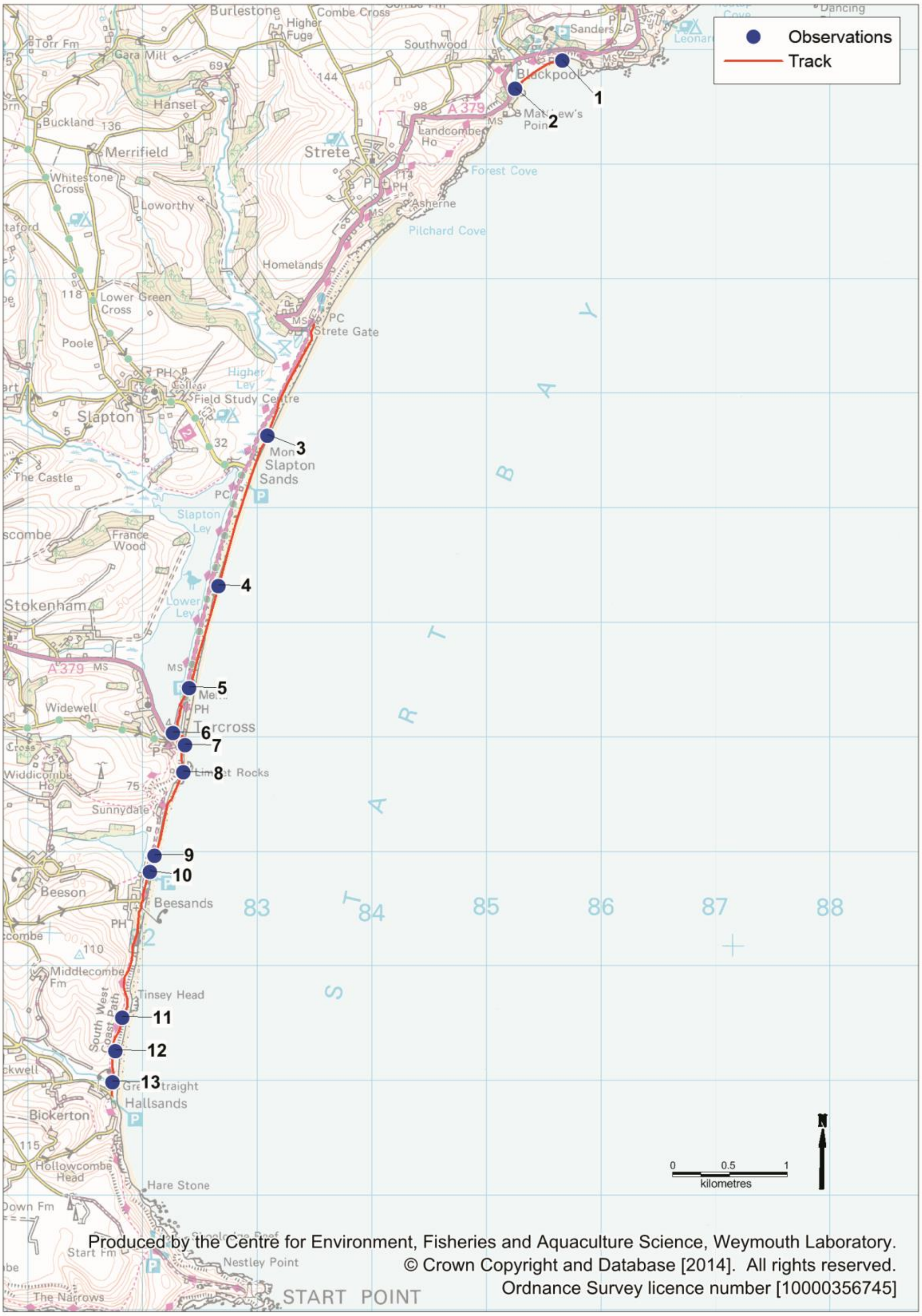

Figure XII.1: Locations of Shoreline Observations (Table XII.2 for details)

Table XII.1: Details of Shoreline Observations

Observation no	NGR	Date	Time	Description	Photo
1	SX8566547910	20/01/2015	09:03	Dog walkers	-
2	SX8524947664	20/01/2015	09:12	Stream flowing across Blackpool Sands, SB01	Figure XII.3
3	SX8308644637	20/01/2015	10:08	~200 gulls on beach	Figure XII.4
4	SX8266243325	20/01/2015	10:36	~300 gulls on beach	-
5	SX8240642435	20/01/2015	10:58	Concrete structure with wooden board covering a possible pipe	Figure XII.5
6	SX8226242042	20/01/2015	11:09	Gridded water outlet from Slapton Ley & ~40 ducks and geese	Figure XII.6
7	SX8236641938	20/01/2015	11:19	Slapton Ley Weir, SB02, dog walkers	Figure XII.7
8	SX8235241701	20/01/2015	11:41	Submerged pipes. Assumed to be Slapton STW continuous discharge and Torcross PS intermittent discharge	Figure XII.8
9	SX8210340973	20/01/2015	11:55	Pipe – flowing, SB03	Figure XII.9
10	SX8205940832	20/01/2015	12:03	Drainage pipe - not flowing	Figure XII.10
11	SX8181939558	20/01/2015	12:32	~50 sheep in field	-
12	SX8175939267	20/01/2015	12:37	~100 sheep in field	-
13	SX8173338995	20/01/2015	12:42	Stream flowing across beach, SB04	Figure XII.11

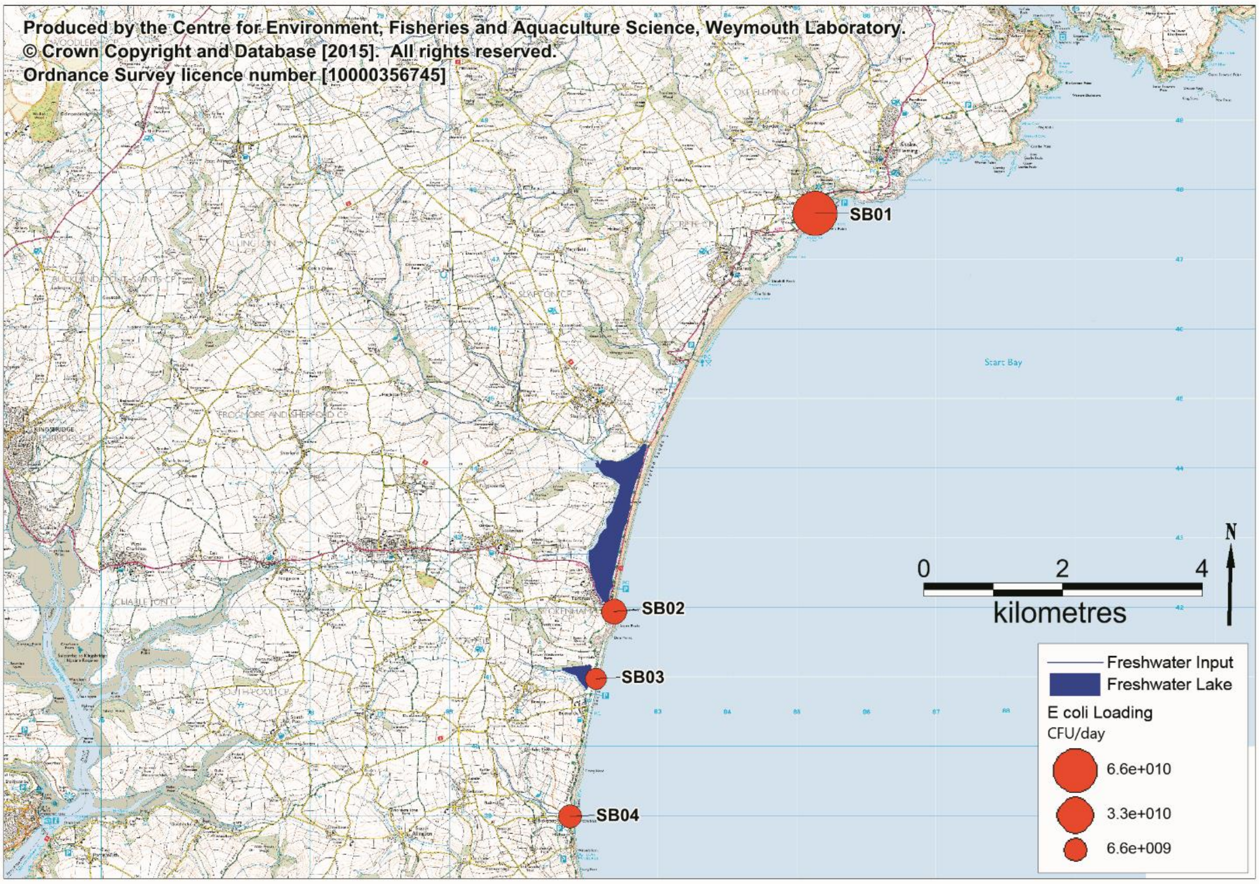

Figure XII.2: Water sample results (Table XII.2 for details)

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

Sample ID	Observation number	Date and Time	Description	*E. coli* concentration (cfu/100 ml)	Flow (m^3/s)	*E. coli* loading (cfu/day)	NGR
SB01	2	20/01/2015 09:12	Stream	120	0.631	$6.54x10^{10}$	SX8524947664
SB02	7	20/01/2015 11:19	Slapton Ley Weir	20	0.598	$1.03x10^{10}$	SX8236641938
SB03	9	20/01/2015 11:55	Pipe from Widdicombe Ley	80	0.083	$5.76x10^{9}$	SX8210340973
SB04	13	20/01/2015 12:42	Stream	80	0.114	$7.90x10^{9}$	SX8173338995

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

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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
OSGB36	Ordnance Survey Great Britain 1936
mtDNA	Mitochondrial DNA
ppt	Parts per thousand
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.
Loess	Locally Weighted Scatterplot Smoothing, more descriptively known as locally weighted polynomial regression. At each point of a given dataset, a low-degree polynomial is fitted to a subset of the data, with explanatory variable values near the point whose response is being estimated. The polynomial is fitted using weighted least squares, giving more weight to points near the point whose response is being estimated and less weight to points further away. The value of the regression function for the point is then obtained by evaluating the local polynomial using the explanatory variable values for that data point. The LOWESS fit is complete after regression function values have been computed for each of the n data points. LOWESS fit enhances the visual information on a scatterplot.
Telemetry	A means of collecting information by unmanned monitoring stations (often rainfall or river flows) using a computer that is connected to the public telephone system.
Secondary Treatment	Treatment to applied to breakdown and reduce the amount of solids by helping bacteria and other microorganisms consume the organic material in the sewage or further treatment of settled sewage, generally by biological oxidation.
Sewage	Sewage can be defined as liquid, of whatever quality that is or has been in a sewer. It consists of waterborne waste from domestic, trade and industrial sources together with rainfall from subsoil and surface water.
Sewage Treatment Works (STW)	Facility for treating the waste water from predominantly domestic and trade premises.
Sewer	A pipe for the transport of sewage.
Sewerage	A system of connected sewers, often incorporating inter-stage pumping stations and overflows.
Storm Water	Rainfall which runs off roofs, roads, gulleys, etc. In some areas, storm water is collected and discharged to separate sewers, whilst in combined sewers it forms a diluted sewage.
Waste water	Any waste water but see also “sewage”.

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