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EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Porlock Bay

March 2015

Food Standards Agency

Cover photo: Porlock Bay

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Statement of use

This report provides a sanitary survey relevant to the bivalve mollusc farm in Porlock 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).

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Revision history

Version	Details	Approved by	Approval date
1	Draft for internal review	Fiona Vogt	25/02/2015
2	Draft for external review	Simon Kershaw	27/02/2015
Final	Final report post consultation	Simon Kershaw	28/05/2015

Consultation

Consultee	Date of consultation	Date of response
West Somerset Council	05/03/2015	10/04/2015
Devon & Severn IFCA	05/03/2015	None
Environment Agency	05/03/2015	09/03/2015
Wessex Water	05/03/2015	None
Porlock Futures Group	05/03/2015	18/03/2015
Natural England	05/03/2015	17/04/2015

Dissemination

Food Standards Agency, West Somerset Council. The report is available publicly via the Cefas website.

Recommended Bibliographic Reference

Cefas, 2015. Sanitary survey of Porlock. 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 Pacific oysters (*Crassostrea gigas*) and mussels (*Mytilus* spp.) at Porlock Bay. The area was prioritised for survey as it is a new area.

1.2. Area description

Porlock is a small coastal village situated in the outer Bristol Channel on the Somerset coast. The oyster and mussel fishery is located on the sandy intertidal area of Porlock Bay.

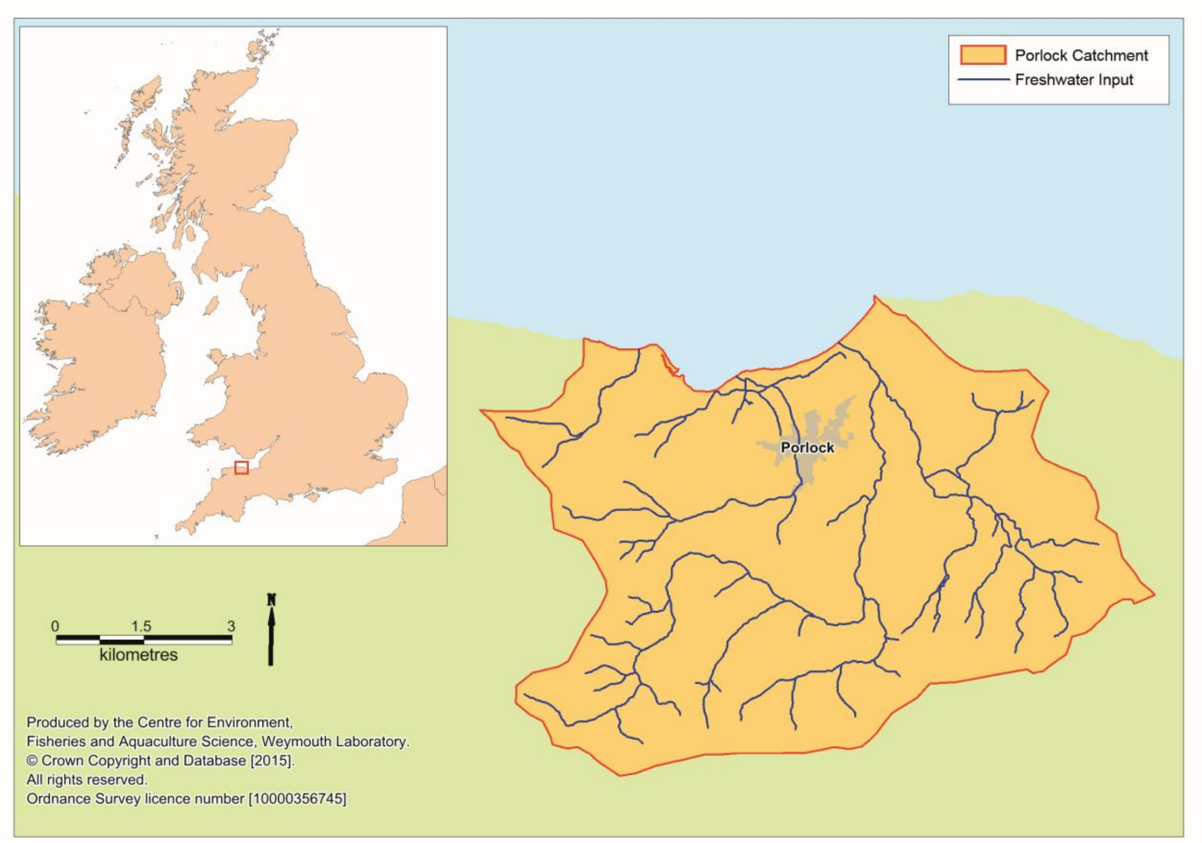

Figure 1.1: Location of Porlock

The survey catchment is sparsely populated, with a population of less than 4,000. It falls within the Exmoor National Park, and tourism is important to the local economy. The area historically supported a native oyster fishery, but harvesting ceased over a century ago (BBC News, 2014). The Porlock Futures Group was set up in 2013 to create a sustainable oyster and mussel farm for the local community to increase revenue to the area.

1.3. Catchment

The hydrological catchment draining to Porlock Bay, as estimated from topographical maps, covers an area of approximately 57 km^2.

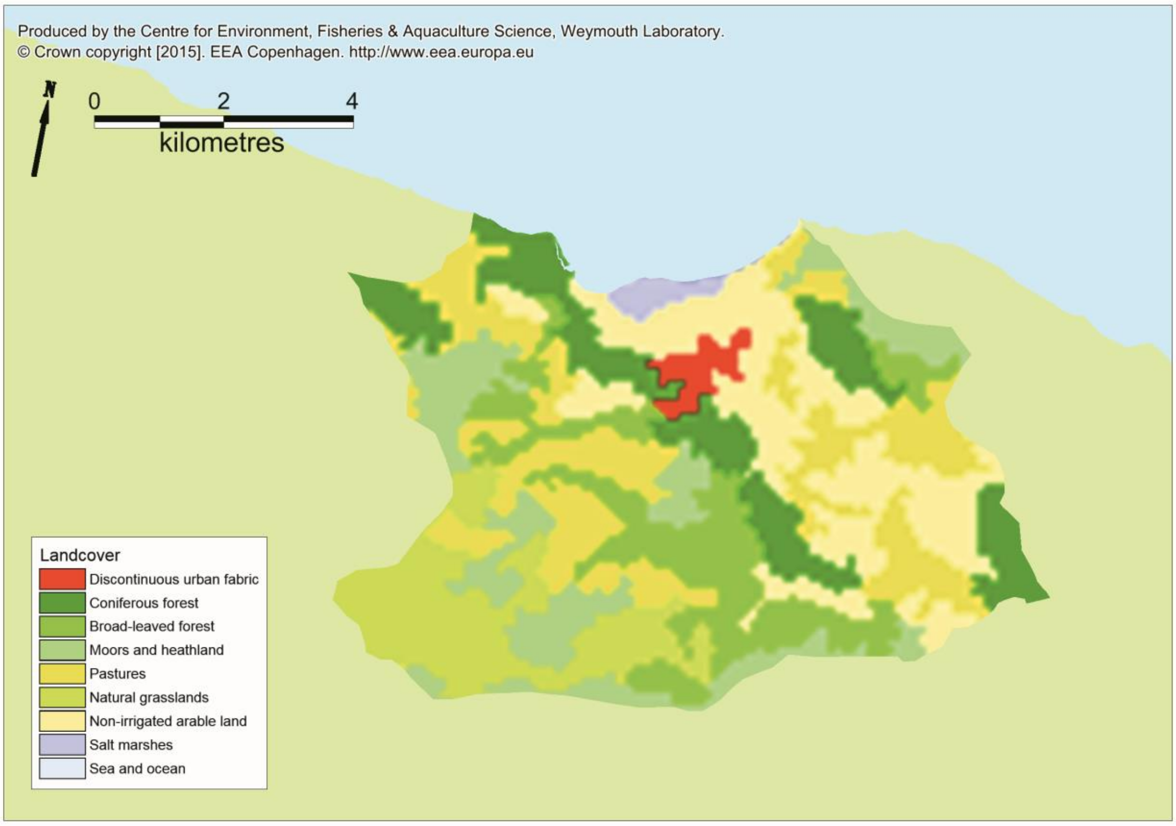

Figure 1.2 Land cover in the Porlock catchment

The catchment is predominantly rural, with a mixture of pasture and moorland in the west and a mixture of pasture and arable land in the east, interspersed with woodland. Less than 5% of the catchment is urbanised, and the built up areas largely fall within in the low lying area just inland from Porlock Bay. The catchment is drained by two main watercourses (Hawkcombe Stream and Horner Water).

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 515 m in its upper reaches. The underlying hydrogeology is reported to be of low permeability (NERC, 2012). Therefore it is assumed that the catchment will respond quickly to rainfall, which will predominantly reach watercourses via surface run-off.

2. Recommendations

The main sewage input is the Porlock STW, which discharges to the lower intertidal about 1 km to the east of the area requiring classification. It provides effective membrane filtration treatment so the bacterial loading it generates is very small and unlikely to be a significant influence. The Hawkcombe stream is a minor watercourse which discharges via a tidal lagoon about 400 m east of the fishery. It receives effluent from two intermittent discharges in its lower reaches, one of which has hardly spilled at all from 2012-14, the other of which was active for 18.1% of this period. Horner Water is a slightly larger stream which discharges about 2 km to the east of the fishery. There is also an intermittent discharge to the shore 2 km east of the fishery (Bossington PS) which was active for 6.7% of the period 2012-14. There may also be minor and diffuse impacts on the fishery from birds and boat traffic. It is concluded that the ebb plume from the tidal lagoon to which the Hawkcombe Stream drains is likely to be of most significance to the shellfishery. It is therefore recommended that the RMP is located on the eastern-most extremity of the trestles on the lower intertidal due southwest of where the lagoon drains to the bay to best capture its impacts while allowing reasonable access on foot by the sampling officer. If the extent of these trestles is expanded then the RMP should remain on the eastern-most extremity. This may require the RMP to be moved following such an expansion.

Following unsuccessful attempts to grow mussels in this area, only Pacific oysters are grown currently grown here. It is therefore recommended that only Pacific oysters are sampled. However, if mussels are grown successfully in the future, then both species will require sampling. Samples should be taken by hand and should consist of animals of a market size. Sampling should be undertaken on a monthly, year round basis. A tolerance of 10 m applies. Should native oysters be introduced to the site, they can be assigned a classification based on Pacific oyster results without the need for additional sampling of this species.

3. Sampling Plan

3.1. General Information

Location Reference

Production Area	Porlock Bay
Cefas Main Site Reference	M094
Ordnance survey 1:25,000 map	Explorer OL9
Admiralty Chart	1165

Shellfishery

Species/culture	Pacific oysters	Trestle culture
Seasonality of harvest	Year round	

Local Enforcement Authority

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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	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comment
Porlock	B094C	Porlock East	SS 8714 4784	51°13.113'N 03°37.046'W	Pacific oysters	Trestle culture	Hand	Hand	10 m	Monthly	May also be used to represent native oysters if required.

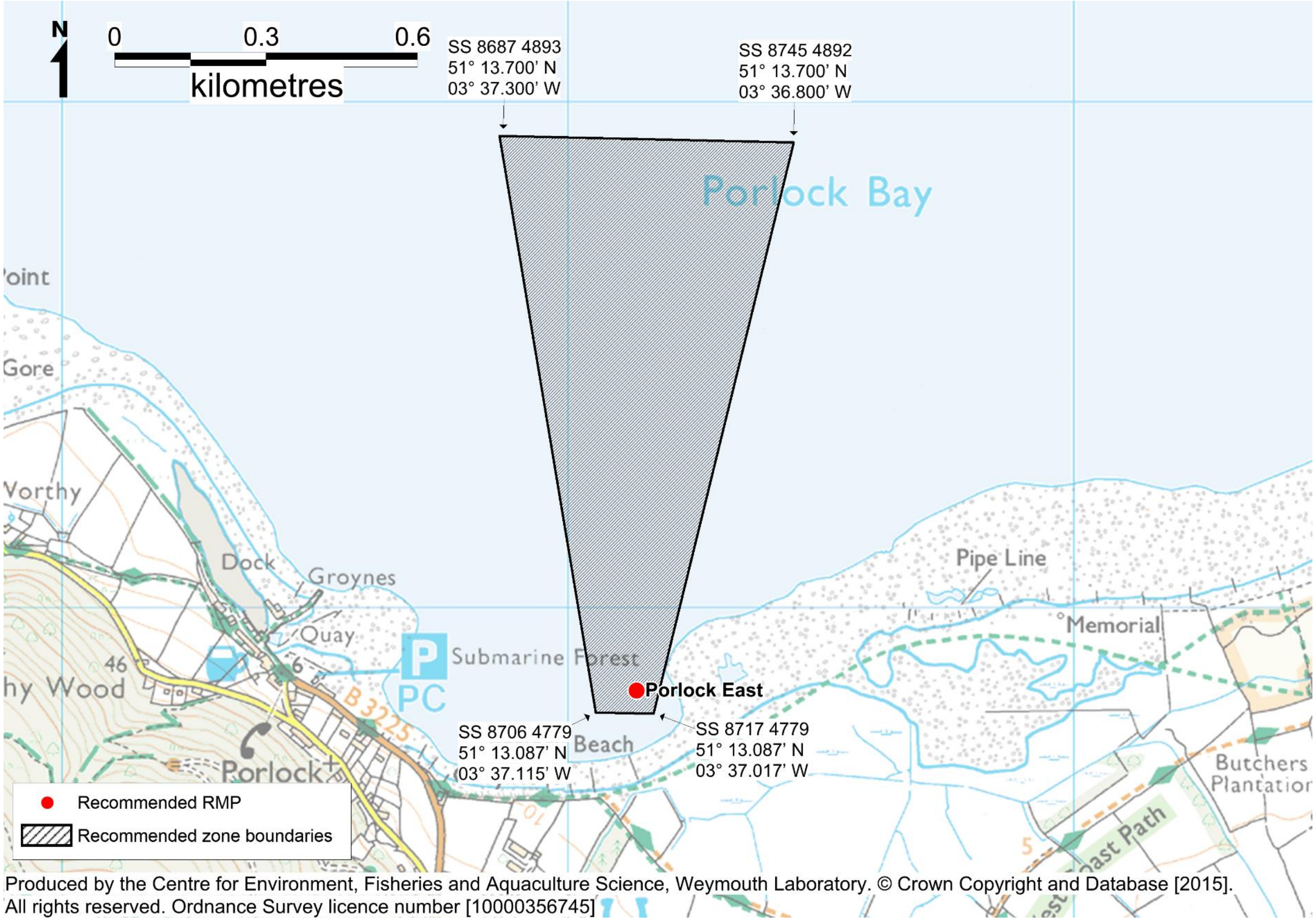

Figure 3.1: Recommended zoning and monitoring arrangements (Pacific oysters)

Figure 3.2: Locations of current and recommended RMPs

4. Shellfisheries

4.1. Description of fishery

The fishery which is the subject of this survey is in an early stage of development. The species to be cultured commercially here are Pacific oysters and mussels, and possibly native oysters at some point in the future. The fishery is unusual in that it is a community project, initiated and managed by the Porlock Futures Group, a Community Interest Company, with the intention of boosting employment opportunities in the area in a sustainable manner.

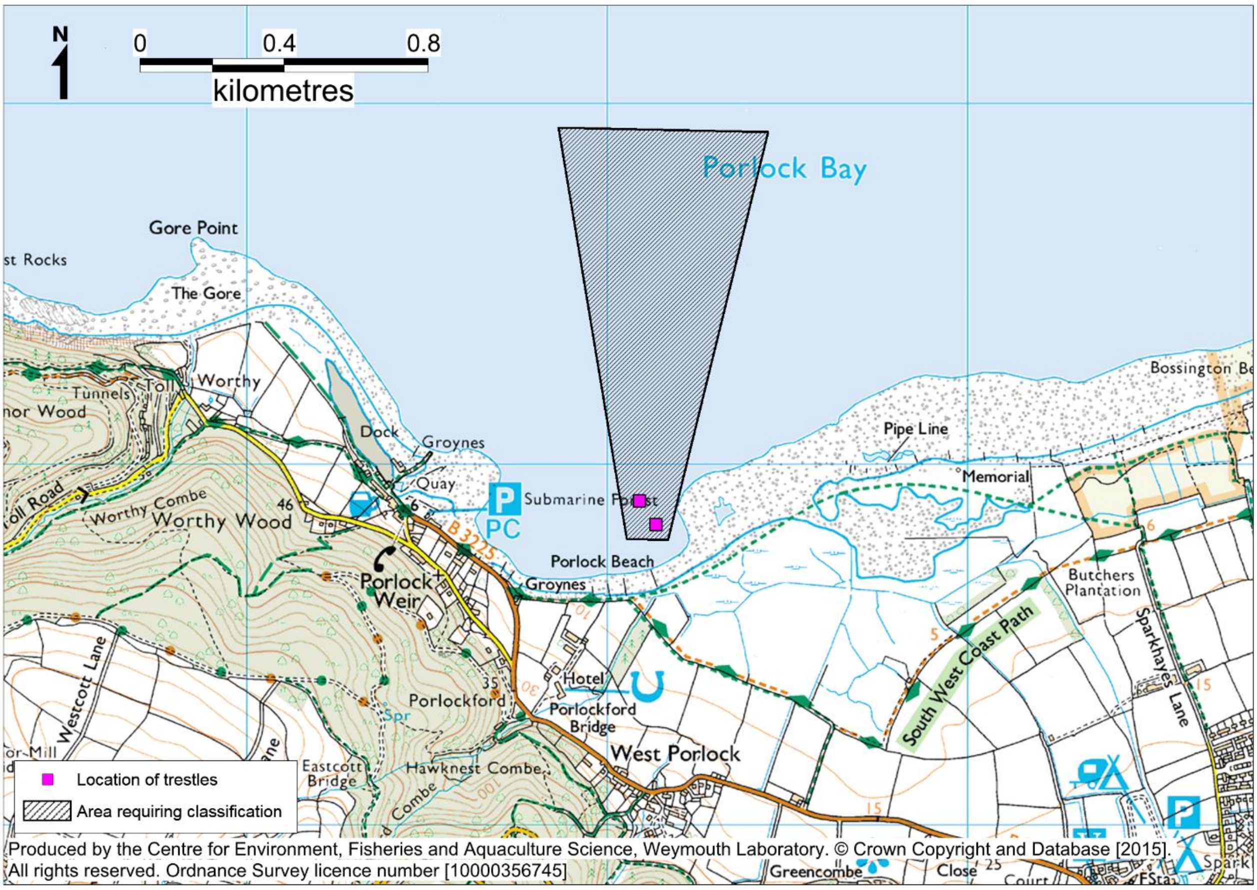

Figure 4.1: Location of fishery

At present, the fishery consists of a pilot trial of Pacific oyster culture, over eight trestles on in two discrete blocks on the lower intertidal. Triploid and diploid stock of a variety of ages was sourced from Seasalter Walney and introduced to the site in spring 2014. Suitable growth and survival has been observed to date. Ultimately, it is planned that the intertidal area will be used for trestle culture (where oysters will be hardened off before going to market), and oyster cages will be used in the subtidal, which constitutes most of the area for which classification has been requested. At some point in the future, the same methods may be applied to the culture of native oysters. Husbandry and harvesting will be undertaken by hand.

Several bouchot poles have also been deployed in close proximity to the trestles to which seeded mussel ropes were attached in the summer of 2014. Following high levels opf bir predation, the culture of mussels has been abandoned. However, alternative methods of mussel culture such as longlines are under consideration for future trials.

Permissions to establish the site have been issued by all necessary parties, including the landowner (Porlock Manor Estate) and the Crown Estate. Assuming the trials continue successfully, rapid expansion is planned, with projected production of 25 tonnes of Pacific oysters in 2018 and further increases expected subsequently. The establishment of a local depuration and equipment storage facility is planned when the development of the operation reaches an appropriate stage. As it is a culture fishery, no conservation controls such as closed seasons or minimum landing sizes apply. Due to the problems encountered with the mussel culture on bouchot poles, the future prospects for this species are uncertain at present.

4.2. Hygiene Classification

The site has yet to be classified, but at the time of writing eight samples of both Pacific oysters and mussels had been submitted, so it is likely that a classification will be issued in spring 2015. Early indications are the mussels are likely to comply solidly with a B classification, and Pacific oysters may obtain an A classification, as no result exceeding 230 *E. coli* MPN/100 g has been returned for this species.

Table 4.1: Criteria for classification of bivalve mollusc production areas.

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

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

5. Overall Assessment

5.1. Aim

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

5.2. Shellfisheries

The subject of this survey is a Pacific oyster trestle farm at an early stage of its development. Trestles were installed and the site was stocked with oysters of a range of sizes in the spring of 2014. Good growth and survival has been observed to date. Significant expansion is planned, with projected production of 25 tonnes of Pacific oysters in 2018 and further increases expected subsequently. As well as trestles on the lower intertidal, it is intended that oysters will also be cultured in subtidal cages as the fishery develops. Harvest will be by hand, and no minimum landing sizes or closed season apply. At some point in the future native oysters may also be introduced to the site. As these are known to accumulate *E. coli* to similar levels as Pacific oysters (Younger & Reese, 2013) they may be assigned a classification based on Pacific oyster results without the need for additional sampling.

Culture of mussels on bouchot poles has also been piloted in the area. However, mussel culture has been abandoned due to to bird predation. Alternative methods of production are under consideration, and mussel culture may be resumed if suitable alternatives are found.

5.3. Pollution Sources

Freshwater Inputs

The catchment draining to Porlock bay is small (57 km^2). Land cover is a mixture of pasture and moors in the west of the catchment and a mixture of pasture and arable land in the east, interspersed with woodland, with some minor urban areas near the coast. The topography is hilly, reaching a maximum elevation of 515 m. There is a small area of low lying land with saltmarsh and pasture between the village of Porlock and the coast. The underlying geology is of low permeability. It is therefore expected that watercourses within catchment will respond quickly to rainfall and a high proportion of rainfall will run off.

There are two main watercourses which drain to the bay. Horner Water is the largest, and discharges to the bay through the shingle beach about 2 km east of the fishery. There is a flow gauging station on this watercourse, through which about 50% of the catchment of this watercourse drains. Flows were higher on average during the colder months (November through to February). High flow events were recorded in most months of the year, but there tended to be a greater number of higher magnitude events during the autumn and winter. Mean discharge here were 0.5 m^3/sec, with extreme events occasionally exceeding 10 m^3/sec recorded. During the shoreline survey, the discharge rate was 0.555 m^3/sec, and it was carrying a bacterial loading of $5.19x10^{10}$ *E. coli*/day.

The Hawkcombe Stream drains to a tidal lagoon about 400 m east of the fishery, so runoff from this watercourse will only enter the bay whilst the tide is ebbing, and will be mixed with seawater beforehand. Flow gauging and water sampling undertaken during the shoreline survey indicate the combined discharge and bacterial loading (Hawkcombe Stream and tributaries) draining to this lagoon was 0.254 m^3/sec and $1.2x10^{10}$ *E. coli*/day respectively. There is no fixed gauging station on this watercourse, but it is likely that the day to day and seasonal variation in flow is similar to that observed for Horner Water.

As well as the two main watercourses, there is a smaller unnamed stream discharging to the shore about 1.3 km west of the fishery. This was not sampled or measured during the shoreline survey, and no alternative flow gauging or bacteriological testing results are available for it. Also, during the shoreline survey a spring was observed on the beach, the water from which drains across the beach and through the fishery site. A water sample taken from this contained <10 *E. coli* cfu/100 ml.

It is therefore concluded that of the freshwater inputs, Hawkcombe Stream is of most potential significance to the fishery, particularly given that the ebb tide would carry runoff from it towards the fishery. Horner Water may be a minor influence. The spring draining to the foreshore at the fishery site appears to be uncontaminated, although the only evidence to support this is a single water sample from the shoreline survey. The unnamed stream to the west is probably too small and remote to be of influence. There is likely to be significant day to day variation in the bacterial loading these watercourses deliver. Whilst there is some seasonal variation in discharge volumes, it is uncertain whether this results in a corresponding variation in bacterial loadings.

Human Population

Total resident population within census areas contained within or partially within the catchment area was approximately 3,900 at the time of the last census (2011). However, this is a significant overestimate as the two census areas considered cover an area of almost three times that of the catchment. Population densities were low in both census areas. The area supports caravan sites, campsites as well as several bed and breakfasts and hotels so there will be increases in population within the summer holiday period, at which times the sewage works serving the area will receive increased volumes of effluent.

Sewage Discharges

There is one continuous water company owned sewage works discharging within the survey area (Porlock STW). It provides membrane treatment for a consented dry weather flow of 668 m^3/day, and discharges to the low water mark about 1 km to the east of the fishery. Bacteriological testing of the final effluent indicates that the membrane plant is consistently effective at removing bacteria from the effluent, so the estimated average bacterial loading generated by this sewage works is very low (4.3×10^8 faecal coliforms/day). This discharge will be of little, if any, influence on the shellfishery providing the membrane plant continues to perform as effectively as it has in recent years.

There are four permitted intermittent (overflow) discharges associated with the local sewerage network. One of these (Porlock Weir PS) is currently sealed, and is likely to remain so for the foreseeable future. Until it is reinstated, it will be of no impact on Porlock Bay. The other three are in use, and are subject to spill monitoring, records of which were available from 2012-2014. Two discharge to the Hawkcombe Stream at the same location, a short distance upstream of where it drains to the tidal lagoon (Porlock CSO and Porlock STW). The former hardly spilled at all (<0.1% of the time) so will be of negligible influence. The latter was much more active, spilling for 18.1% of the time. During the winter, it was active for almost half of the time, whereas during the summer it hardly spilled at all. Contamination from this discharge is likely to be a significant influence during the colder months of the year, and an RMP positioned to capture the ebb plume from the saline lagoon would be most effective at capturing its impacts. The fourth intermittent discharge (Bossington PS) is to the intertidal area about 2 km east of the fishery. It spilled for 6.7% of the period considered, and was also most active in the winter, and did not spill once during the summer months. Given its more remote location from the shellfishery, and its lower spill frequency it will be much less of an influence than the Porlock STW overflow.

Although the majority of properties within the survey area are served by water company sewerage infrastructure, there are also 8 permitted private discharges. These are all small, serving one or a small number of properties, and provide treatment via septic tank or small secondary treatment plants. Five of these discharge to soakaway so should be of no impact on coastal waters assuming they are functioning correctly. Of the remaining three, two discharge to watercourses within the Horner Water catchment, and one discharges to the Hawkcombe Stream. They will make a minor contribution to the bacterial loadings delivered to coastal waters by these watercourses.

Agriculture

Agricultural land within the catchment comprises mainly of pastures in the western part of the catchment, and of arable land in the eastern part of the catchment. Agricultural census data (2013) indicates that there are 24,891 sheep and 790 cattle held at farms located within the catchment. Around 200 sheep were observed on the low lying grassland by the saline lagoon during the shoreline survey. Significant impacts from grazing livestock are therefore anticipated given their high numbers and densities. The numbers of holdings rearing pigs and poultry were too small for census results for these species to be disclosed without potentially revealing data on individual holdings.

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'). Both of the main watercourses will be affected to some extent. This will occur through direct deposition on farmland and subsequent wash off into watercourses. Other organic fertilizers (manures, slurry, sewage sludge) may also be applied to both arable fields and pastures, but no firm information on local practices was available at the time of writing.

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. Other organic fertilisers (e.g. 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, or on a more localised basis if wet weather follows a slurry/manure application which may be more likely in winter or spring.

Boats

The discharge of sewage from boats is a potential source of bacterial contamination of shellfisheries within Porlock Bay. There is a small drying harbour at Porlock Weir which is only accessible to smaller vessels around high water, and does not have sewage pump-out facilities. The bay is sometimes used as an anchoring area by yachts. No fishing vessels are listed as having their home port as Porlock Weir, but it is likely that vessels from other ports operate in the bay from time to time.

It is therefore concluded that boat traffic in the area is limited to small numbers of fishing vessels and recreational craft such as yachts, so any impacts are likely to be minor and sporadic. Private vessels such as yachts, motor cruisers and fishing vessels 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

Porlock Bay includes a large shingle ridge which stretches approximately 4 km north of Porlock village, and a saltmarsh and coastal grassland habitat is present inshore of this ridge. These and other features support some wildlife populations, although there are no large aggregations of any particular species. It is likely that some overwintering waterbirds (wildfowl and waders) use the saltmarsh, grassland and intertidal areas during the winter months. The area is not an important site for overwintering waterbirds, so is not subject to routine bird counts under the wetland bird surveys co-ordinated by the British Trust for Ornithology. There are also resident seabird populations within the area. A survey in the early summer of 1999 recorded 10 pairs of gulls north of Hurlstone Point. It is therefore concluded that there may be some diffuse impacts from birds, and these may increase during the winter months. The tidal lagoon and surrounding saltmarsh is likely to represent the area most heavily impacted by waterbirds, so an RMP located to catch the ebb plume from the lagoon would best capture their impacts.

There are no resident seal colonies in Porlock Bay, the closest being at Carmarthen Bay and Lundy Island, although they are periodically sighted in the area. Their presence will be unpredictable both spatially and temporally, so whilst they may potentially be an occasional minor influence it will not be possible to define an RMP location which will reliably capture their impacts. Dolphins and harbour porpoises are also often sighted in small numbers within the survey area but again, whilst they may potentially be a minor and sporadic influence, it will not be possible to define an RMP location which will reliably capture their impacts.

Domestic animals

Dog walking takes place on coastal paths and beaches around Porlock Bay and is therefore likely to represent a potential source of diffuse contamination to the near shore zone. As a diffuse source, it will have little influence on the location of RMPs.

Summary of Pollution Sources

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

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.

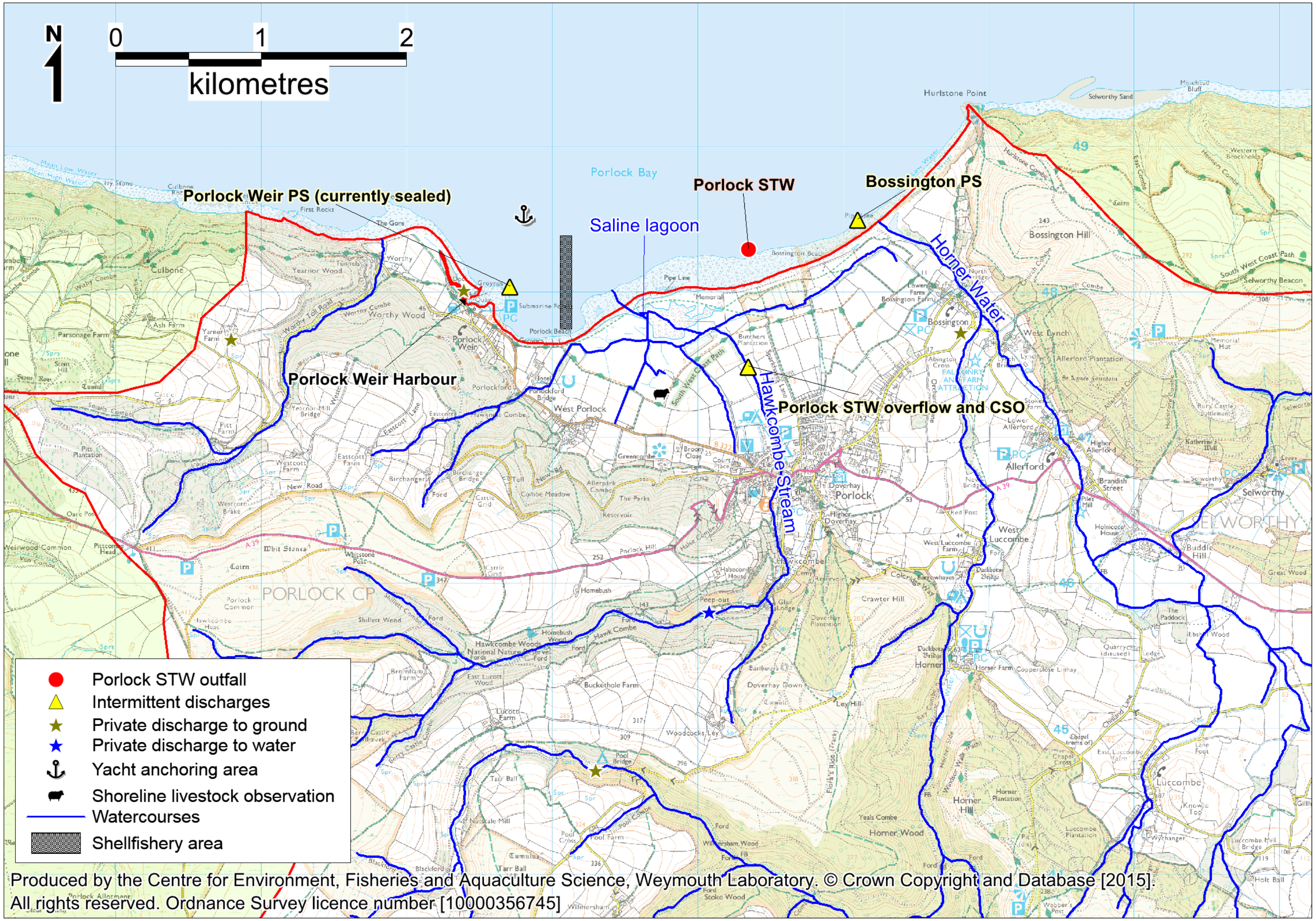

Figure 5.1: Summary of main contaminating influences

Hydrography

Porlock Bay is a small, open embayment located in the outer reaches of the Bristol Channel. The bathymetry is relatively uncomplicated, sloping gently away to a maximum depth of 14 m relative to chart datum in the outer bay. The open coastal location will offer high potential for dilution and water exchange. There are small headlands at Gore Point and Hurlstone, around which there are likely to be increases in current speed relative to those within the bay. A coarse shingle barrier beach spans the full length of the bay between. This was breached in 1996 about 1 km east of Porlock Weir, and the breach is now backed by a small intertidal lagoon into which the Hawkcombe Stream discharges. Contamination delivered by this stream will therefore mainly be carried into Porlock Bay during the ebb tide. The other main freshwater input (Horner Water) seeps through the shingle bar, and will drain to the bay throughout the tidal cycle.

Currents in coastal waters are largely driven by a combination of tides, winds and density effects. The tidal range in the area is large (9.3 m on spring tides and 3.9 m on neap tides) and this will drive extensive water movements. Tides within the Bristol Channel flood in an easterly direction and ebb in a westerly direction. The admiralty chart reports peak tidal current of 2.6 m/s in the outer central part of Porlock Bay, with bidirectional streams orientated parallel to the coast. Tidal streams are likely to be slower over shallower and intertidal areas due to the effects of friction. Contamination from shoreline sources will therefore travel parallel to the coast, impacting either side of their locations, and the magnitude of their impacts will decrease with distance as the plume spreads and becomes more diluted. Contamination from shoreline sources will be carried several km along the shore during the course of a flood or ebb tide, so impacts may potentially be felt a considerable distance away. The ebb plume from the tidal lagoon to which the Hawkcombe Stream discharges will be carried in a westerly direction, towards the shellfishery.

Superimposed on tidally driven currents are the effects of freshwater inputs and wind. Freshwater inputs are minor, and the survey area is in an open coastal location, so it is unlikely that freshwater related stratification of the water column will occur. Salinity measurements taken at the Porlock Weir bathing water averaged 31.8 ppt and rarely dropped below 30 ppt, confirming that there is little freshwater influence.

Strong winds can modify surface currents by driving surface water currents, which in turn create return currents at depth or along sheltered margins. The bay is afforded shelter from winds with a southerly element by the adjacent land, but is exposed to winds and waves from the north. Exact effects of wind are dependent on its speed and direction as well as state of the tide and other environmental variables so a great number of scenarios may arise. Where strong winds blow across a sufficient distance of water they may create wave action. Where these waves break contamination held in intertidal sediments may be re-suspended. Strong northerly winds will result in significant onshore wave action at Porlock Bay.

5.4. Summary of Microbiological Data

The survey area has been subject to limited microbiological monitoring, deriving from the Bathing Water monitoring programme, and shellfish flesh monitoring for hygiene classification purposes. Figure 5.2 shows the locations of the monitoring points referred to in this assessment.

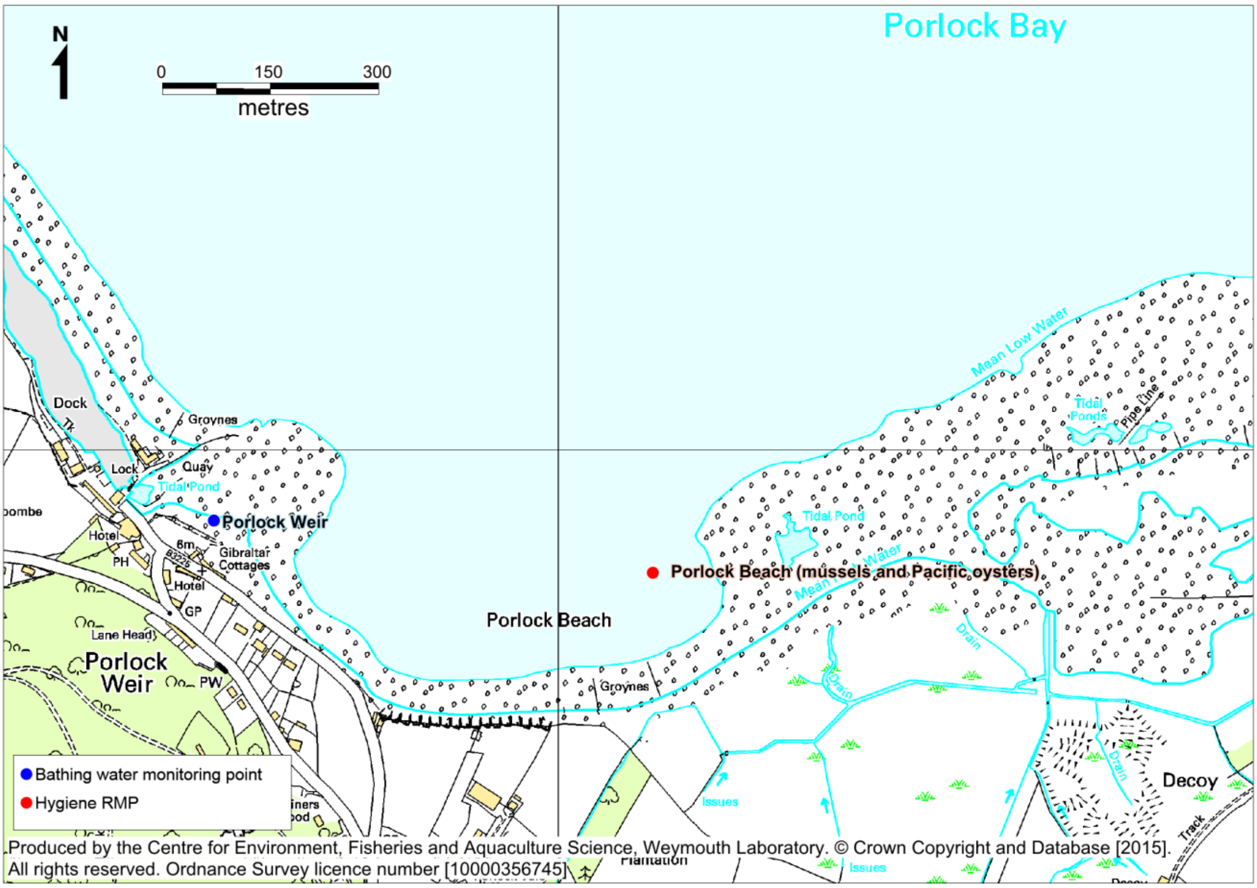

Figure 5.2: Location of microbiological sampling sites.

Bathing Waters

There is one bathing water within the survey area (Porlock Weir) where around 20 water samples are taken each bathing season (May to September) and enumerated for faecal indicator bacteria. As the test employed changed from faecal coliforms to *E. coli* at the start of the 2012 bathing season, and the two are not directly comparable, only results for 2012 to 2014 were considered. The vast majority (93%) of samples contained <10 *E. coli* cfu/100 ml, with a maximum result of 136 *E. coli* cfu/100 ml. This indicates that levels of contamination here are low. Results did not vary on average throughout the period considered. Whilst a significant correlation was detected between *E. coli* levels and tidal state across the spring/neap tidal cycle, all samples were taken around high water and no pattern was apparent when the data was plotted. No significant influence of either antecedent rainfall or salinity at the time of sampling were found, suggesting that land runoff is not a major contaminating influence. It must however be noted that as most results were below the limit of quantification, the majority of variation in results has been masked.

Shellfish Hygiene monitoring

Eight samples of mussels and Pacific oysters were taken from one location within the survey area since September 2014 and enumerated for *E. coli* for hygiene classification purposes. The geometric mean result for Pacific oyster samples was 43.1 *E. coli* MPN/100 g, and no results exceeded 230 *E. coli* MPN/100 g. The geometric mean result for mussels was 157 *E. coli* MPN/100 g, with two results exceeding 230 *E. coli* MPN/10 0g and a maximum result of 1,300 *E. coli* MPN/100 g. The difference in average result between the species was statistically significant, indicating that the two species should be monitored separately at this location. It was not possible to take further more detailed analyses of these results due to the small number of samples taken.

Bacteriological survey

Whilst additional information on the spatial variation in levels of contamination within Porlock Bay may have been beneficial, it was not practical to undertake a bacteriological survey due to the limited amount of stock present and the small footprint of the site in its current state.

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.

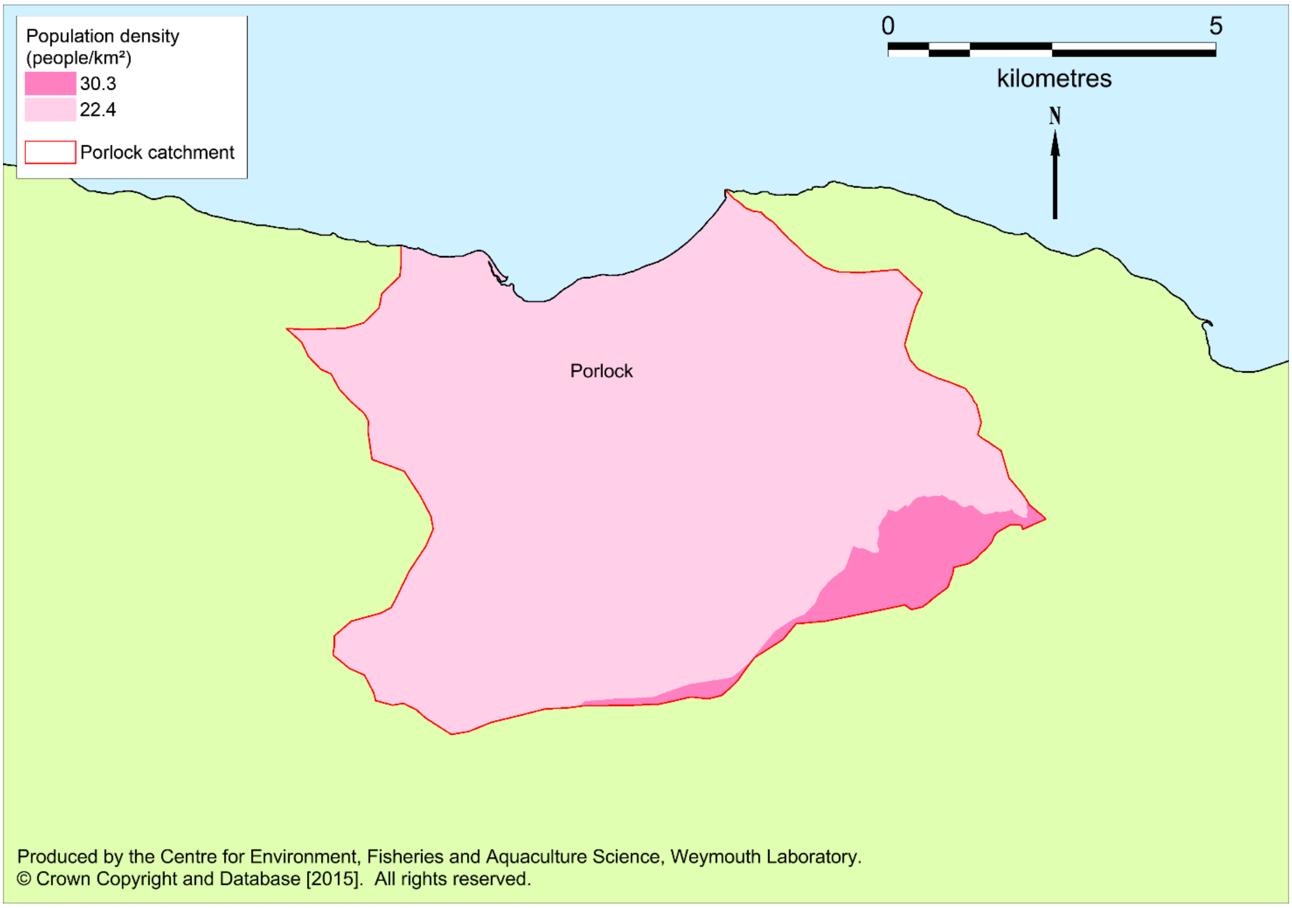

Figure I.1: Human population density in census areas in the survey catchment.

Total resident population within census areas contained within or partially within the catchment area was approximately 3,900 at the time of the last census (2011). However, the two census areas considered have a combined area of 157 km^2, whereas the catchment is only 57 km^2, so the population within the catchment is considerably smaller. Population densities were low in both census areas.

No tourism statistics are available for the Porlock area. However, there are caravan sites and campsites within the catchment area as well as several bed and breakfasts and hotels. The entire Porlock catchment is within the Exmoor national park and so is likely to attract tourists throughout the summer months.

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

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

Table II.1: Details of the continuous water company sewage works in the Porlock catchment

Name	**NGR**	**Treatment**	**DWF (m^3/day)**	**Estimated bacterial loading (cfu/day)***	**Receiving environment**
Porlock STW	SS 48300 88350	Membrane Filtration	668	4.3×10^8	Porlock Bay Hawkcombe Stream

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*Faecal coliforms (cfu/day) based on geometric mean of final effluent monitoring data

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.

Porlock STW provides treatment via membrane, and so the bacteriological quality of the effluent is tested on a regular basis.

Table II.3: Summary statistics for final effluent monitoring data from membrane disinfected effluent from Porlock STW

Name	**Date of first sample**	**Date of last sample**	**No.**	**Geometric mean result (cfu/100 ml)**	**Minimum**	**Maximum**
Porlock STW	30/01/08	09/12/14	52	64.3	<10	3,500

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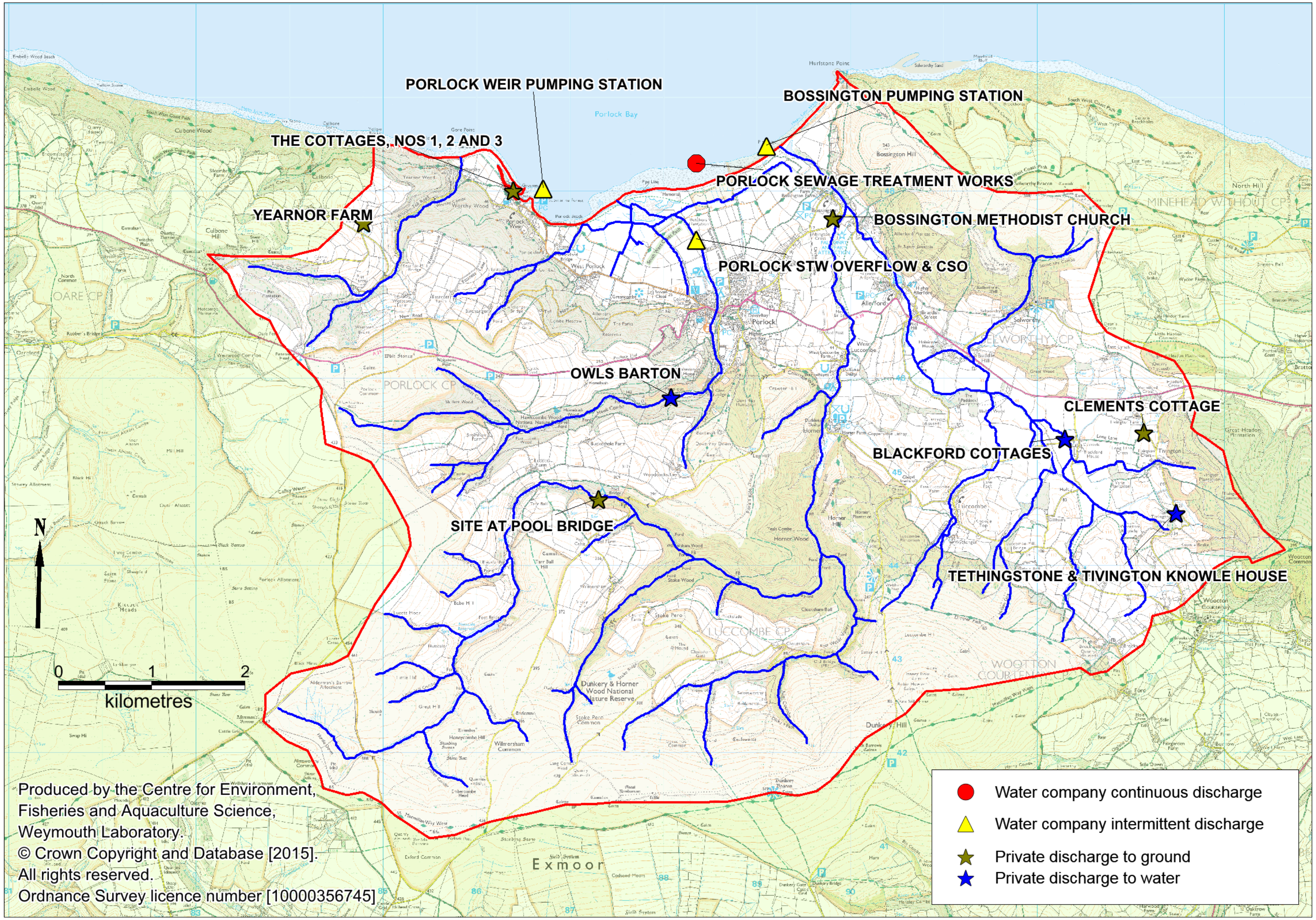

Figure II.1: All permitted sewage discharges to the Porlock catchment
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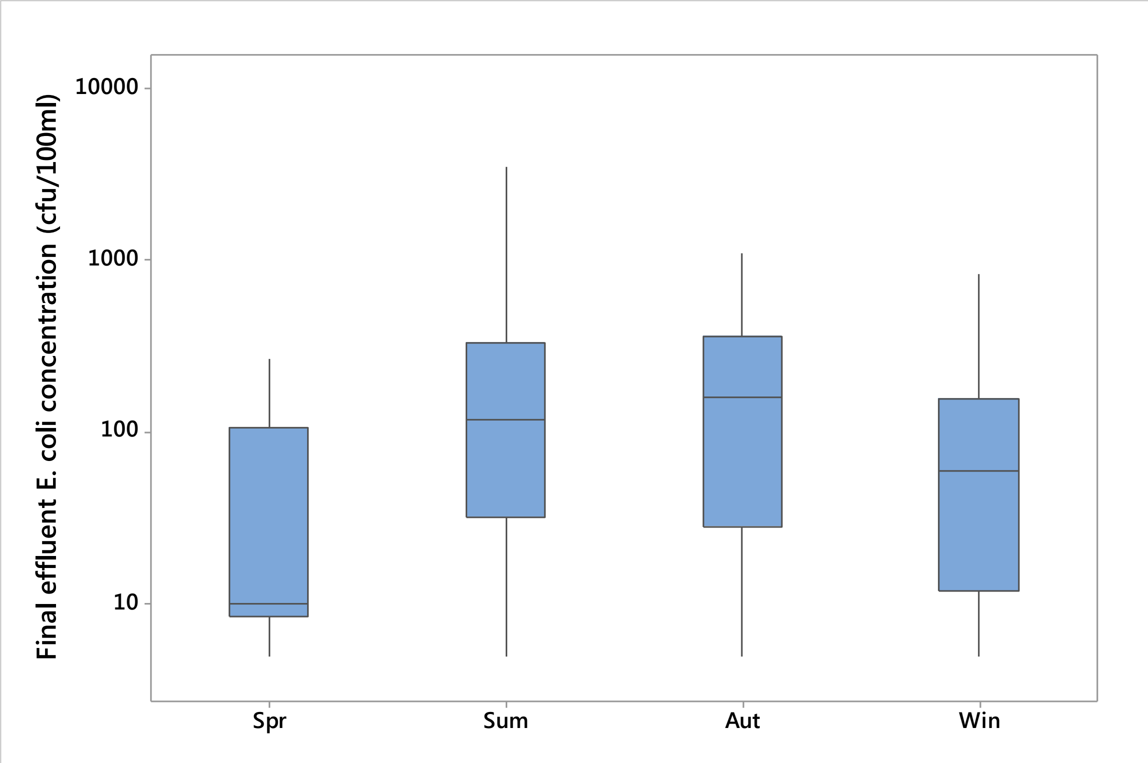

Figure II.2: Boxplot of faecal coliform concentrations in final effluent by season at Porlock STW
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The summary statistics in Table II.2: Summary of reference faecal coliform levels (cfu/100 ml) for different sewage treatment levels under different flow 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
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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.

Porlock STW provides treatment via membrane, and so the bacteriological quality of the effluent is tested on a regular basis.

Table II.3 and the boxplots in Figure II.2 show that the quality of effluent from Porlock STW is generally good. There is no statistically significant seasonal variation, although the data set was limited and the boxplots indicate that faecal coliform concentrations in the effluent are generally higher in summer and autumn. This discharge is located just over a kilometre to the east of the shellfisheries and should be of limited impact given the low bacterial loading it delivers and the open coastal location to which it discharges.

In addition to the continuous sewage discharge, there are 4 permitted intermittent water company discharges associated with the sewer networks, details of which are shown in Table II.4.

Table II.4: Intermittent discharges in the Porlock catchment

Name	Grid reference	Receiving water	Discharge type
Bossington PS	SS 89100 48500	Porlock Bay	Pumping Station
Porlock CSO	SS 88350 47490	Hawkcombe Stream	Storm Overflow
Porlock STW	SS 88350 47490	Hawkcombe Stream	Storm Overflow/ Storm Tank
Porlock Weir PS	SS 86636 48060	Porlock Bay	Pumping Station

The nearest overflow to the shellfisheries, Porlock Weir PS, is currently sealed in order to prevent ingress of seawater back into the sewer during high tides (Wessex Water, *pers comm.),* and any sewage build up in the pumping station chamber is tankered away as required. This is a temporary measure whilst a more permanent solution is investigated, but it is likely this arrangement will be maintained for some time. It is therefore concluded that although this outfall is located in close proximity to the shellfishery, it will be of no impact as long as the current arrangements continue.

The remaining three intermittent discharges are all subject to spill monitoring, although only event durations are recorded rather than spill volumes. Records from the Bossington PS are not subject to the same level of validation as those from the two Porlock overflows as Wessex Water are not required to provide performance reports to the Environment Agency from this pumping station. Summary spill statistics for 2012 to 2014 are presented in Table II.5.

Two of these discharge to the Hawkcombe Stream at the same location, about 1 km inland. Of these, the Porlock CSO hardly spilled at all (<0.1% of the period considered) so will be of negligible influence. The Porlock STW storm tanks were much more active, spilling for 18.1% of the period considered. It is therefore likely to be active on one sampling occasion in every five. During the winter, it was active for almost half of the time, whereas during the summer it hardly spilled at all. The Bossington PS discharges to the shore towards the eastern end of the survey area, and spilled for 6.7% of the period considered. It was also most active in the winter, and did not spill once during the summer months.

Table II.5: Summary of spill records from intermittent discharges, January 2012 to December 2014

	Spring			Summer			Autumn			Winter			Total		
Spiller	No. events	Total duration (days)	% time active	No. events	Total duration (days)	% time active	No. events	Total duration (days)	% time active	No. events	Total duration (days)	% time active	No. events	Total duration (days)	% time active
Bossington PS	11	4.0	1.5%	0	0.0	0%	26	22.6	8.3%	39	47.2	17.4%	76	73.9	6.7%
Porlock CSO	3	0.1	<0.1%	3	0.1	<0.1%	3	0.05	<0.1%	14	0.4	0.1%	23	0.5	<0.1%
Porlock STW	102	20.9	7.6%	17	0.8	0.3%	179	49.8	18.2%	28	126.6	46.7%	326	198.0	18.1%

Data provided by Wessex Water

Although the majority of properties within the survey area are served by water company sewerage infrastructure, there are also 8 permitted private discharges, details of which are presented in Table II.6.

Table II.6: Details of consented private sewage discharges in the Porlock catchment

Name	Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
Blackford Cottages	SS9229045370	Biological Filtration	1.6	Horner Water trib.
Bossington Methodist Church	SS8981047730	Septic Tank	1	Soakaway
Clements Cottage	SS9313345436	Septic Tank	1.2	Soakaway
Owls Barton	SS8808045810	Biological Filtration	1	Hawkcombe Stream
Site At Pool Bridge	SS8730044720	Septic Tank	3	Soakaway
Tethingstone & Tivington Knowle Hse	SS9348044570	Biological Filtration	2	Horner Water trib.
The Cottages, Nos 1, 2 And 3	SS8639048020	Biological Filtration	3	Soakaway
Yearnor Farm	SS8479047680	Septic Tank	Unspecified	Soakaway

The majority of private discharges are small, serving one or a small number of properties. They provide treatment by either small septic tanks or package plants. Five discharge to soakaway so should be of no impact on the shellfisheries, assuming they are functioning correctly. The remaining three discharge to various watercourses inland with two discharging to watercourses within the Horner Water catchment and one discharging to the Hawkcombe Stream. They will make very minor contributions to bacterial loadings in their receiving waters. Given the very small volumes, that the effluents undergo secondary treatment, and that they are located at least 3 km inland, these discharges will be of little consequence to microbiological water quality in the coastal waters. In addition, some bacterial die off will take place during transit to coastal waters.

Appendix III. Sources and Variation of Microbiological Pollution: Agriculture

Agricultural land within the catchment comprises mainly of pastures in the western part of the catchment, and of arable land in the eastern part of the catchment (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 individual farms may span the catchment boundary. Given the small catchment considered in this report, Table III.1 may not accurately reflect the true numbers of animals held within the catchment.

Table III.1: Livestock census data for the Porlock 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)
790	13.9	24,891	537.6	*	*	*	*

Data from Defra

*Data suppressed for confidentiality reasons

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

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

Large numbers of sheep are present within the catchment at high densities. Much smaller numbers of cattle are also present. Around 200 sheep were observed on the low lying grassland by the saline lagoon during the shoreline survey. Significant impacts from grazing livestock are therefore anticipated. The numbers of holdings rearing pigs and poultry were too small to be presented without potentially revealing data on individual holdings.

Diffuse inputs associated with grazing livestock may occur through direct deposition on pastures and subsequent wash off into watercourses. Slurry may also 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 any streams draining farmland 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. Other organic fertilisers (e.g. 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/manure 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 Porlock Bay. Boat traffic in this area is limited to small numbers of recreational craft such as yachts and small fishing vessels. Figure IV.1 presents an overview of boating activity derived from the shoreline survey, satellite images and various internet sources.

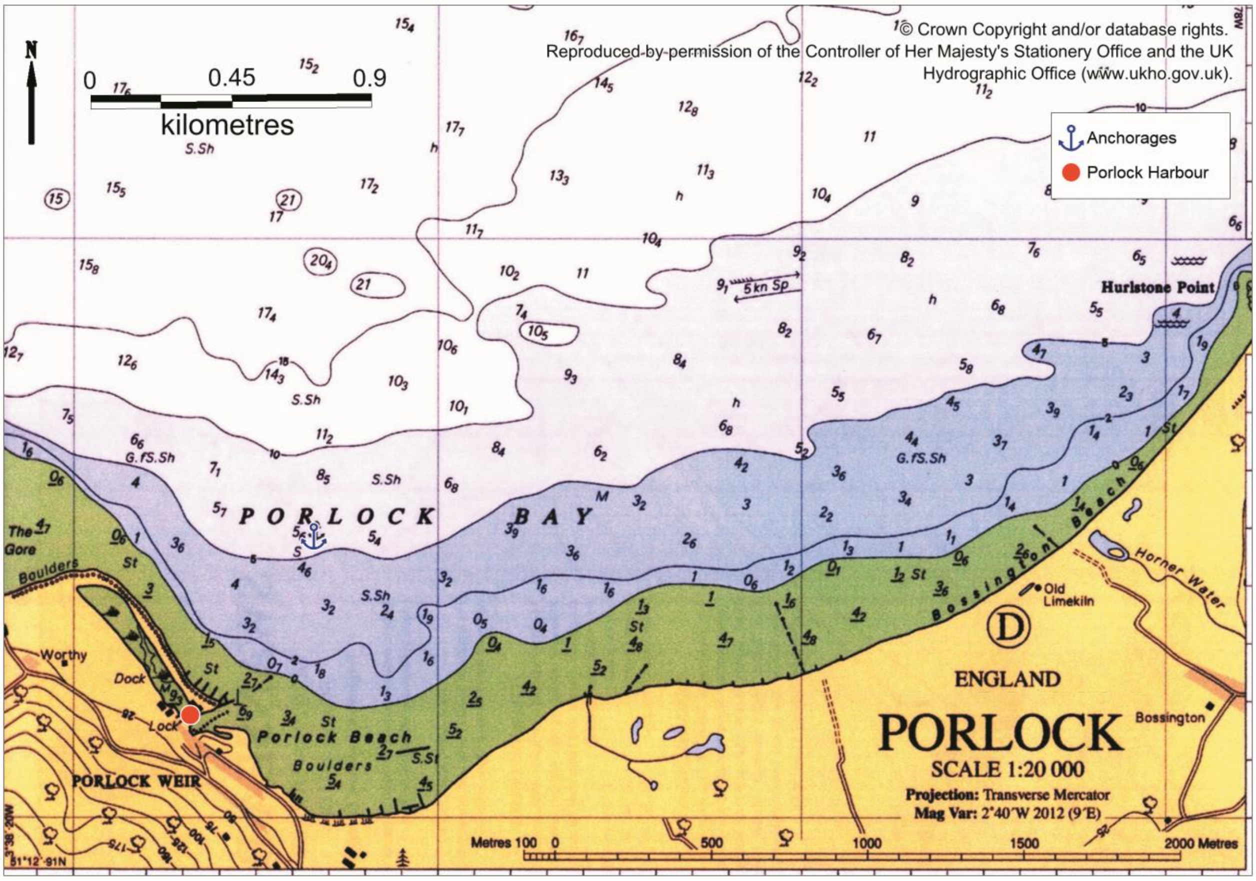

Figure IV.1 Boating activity in the Porlock survey area

There are no marinas or facilities within the area but there is a small drying harbour at Porlock Weir which is accessible for an hour either side of high water. Moorings are available here for small fishing vessels and pleasure craft. In addition to this, Porlock Bay offers a place for visiting pleasure craft to anchor, providing shelter from the prevailing south westerly winds. The closest sewage pump out facilities are situated in Swansea approximately 50 km across the Bristol Channel (The Green Blue, 2010). On the shoreline survey one houseboat that appeared to be in residence was observed in the upper reaches of Porlock harbour. This could represent a source of microbiological contamination.

No fishing vessels were registered within the survey area. However, it is possible that fishing vessels registered locally to Minehead and elsewhere in the Bristol Channel will fish the waters around Porlock Bay. Two fishing vessels ≥10 metres in length had Minehead as their home port in the February 2015 UK Vessel Lists (MMO, 2015). Their fishing patterns are uncertain but are unlikely to cause significant microbiological pollution given their small numbers.

It is therefore concluded that boat traffic in the area is limited to small numbers of pleasure craft, and fishing vessels so the impacts from boat traffic are likely to be minor. Private vessels such as yachts, motor cruisers and fishing vessels 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

Porlock Bay includes a large shingle ridge which stretches approximately 4 km north of Porlock village, and a saltmarsh habitat is present inshore of this ridge. These features attract birds and other wildlife, and as a consequence the area has been designated as a Special Site of Scientific Interest (SSSI). It also falls within Exmoor National Park.

There are no sites within the survey area where the British Trust for Ornithology undertakes counts of overwintering waterbirds (waders and wildfowl) (Austin et. al, 2014). However, the saltmarsh area is likely to provide a source of food for small numbers of overwintering waterbirds. They are therefore likely to represent a minor source of diffuse contamination to saltmarsh areas during the winter months.

There are also resident seabird populations within the area. A survey in the early summer of 1999 recorded 10 pairs of European Herring Gulls north of Hurlstone Point (Mitchell et al, 2004). Seabirds are likely to forage widely throughout the area so inputs could be considered as diffuse, but are likely to be most concentrated in the immediate vicinity of the nest sites. As the nesting colonies are not in the immediate vicinity of the fishery, their presence will have no influence on the sampling plan.

There are no resident seal colonies in Porlock Bay, with the closest significant colonies in Carmarthen Bay and Lundy Island (ABPmer 2014). Seals are sighted periodically off Hurlstone Point, on the eastern extremity of the survey area (Somerset Wildlife Trust, 2015). Their presence will be unpredictable both spatially and temporally, so whilst they may potentially be an occasional minor influence it will not be possible to define an RMP location which will reliably capture their impacts. Dolphins and harbour porpoises are also often sighted in small numbers within the survey area (Somerset Wildlife Trust, 2015) but again, whilst they may potentially be a minor and sporadic influence, it will not be possible to define an RMP location which will reliably capture their impacts.

Appendix VI. Meteorological Data: Rainfall

The monthly rainfall data for the Birchanger weather station, which is located about 2 km west of Porlock village, is shown in Figure VI.1.

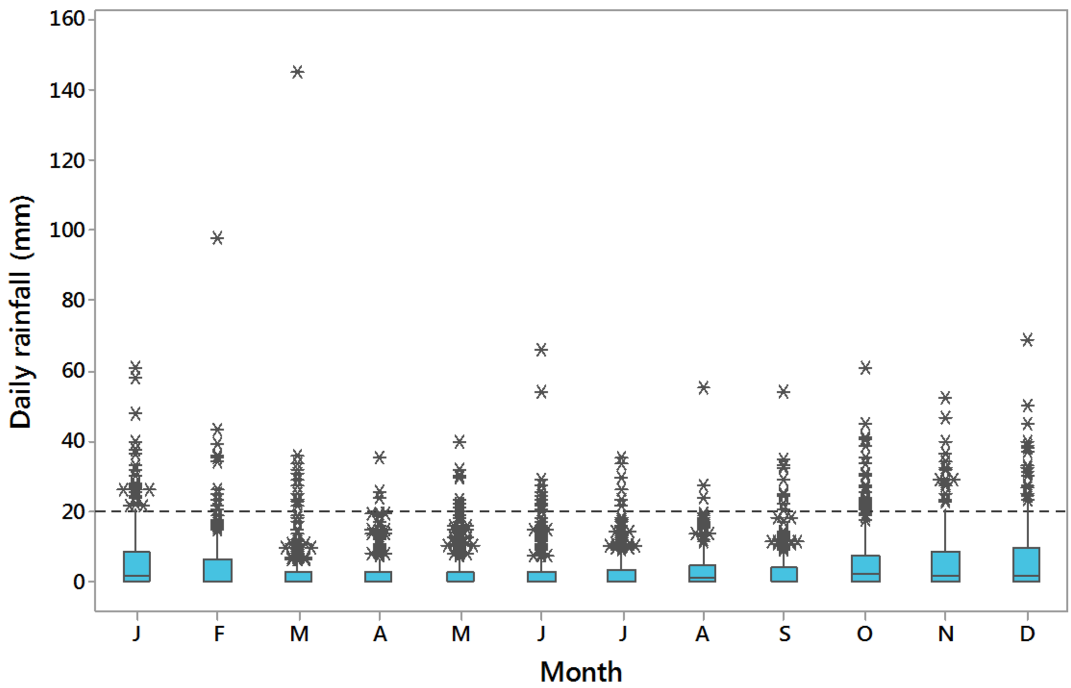

Figure VI.1: Boxplot of daily rainfall totals at Birchanger, January 2004 to July 2014.
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The Birchanger weather station received an average of 1,467 mm per year between January 2004 and July 2014. The autumn and winter months (October to February inclusive) had the highest average rainfall, and late spring and summer (April to July inclusive) had the lowest rainfall. Daily totals of over 20 mm were recorded on 4.4% of days, and were recorded in all months of the year. No rainfall was recorded on 50% of days.

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

South-west England is one of the more exposed areas of the UK. The strongest winds are associated with the passage of deep areas of low pressure close to or across the UK. The frequency and strength of these depressions is greatest in the winter half of the year, especially from November to March and this is when mean speeds and gusts are strongest. During December and January gusts can reach over 80 knots (Met Office, 2012).

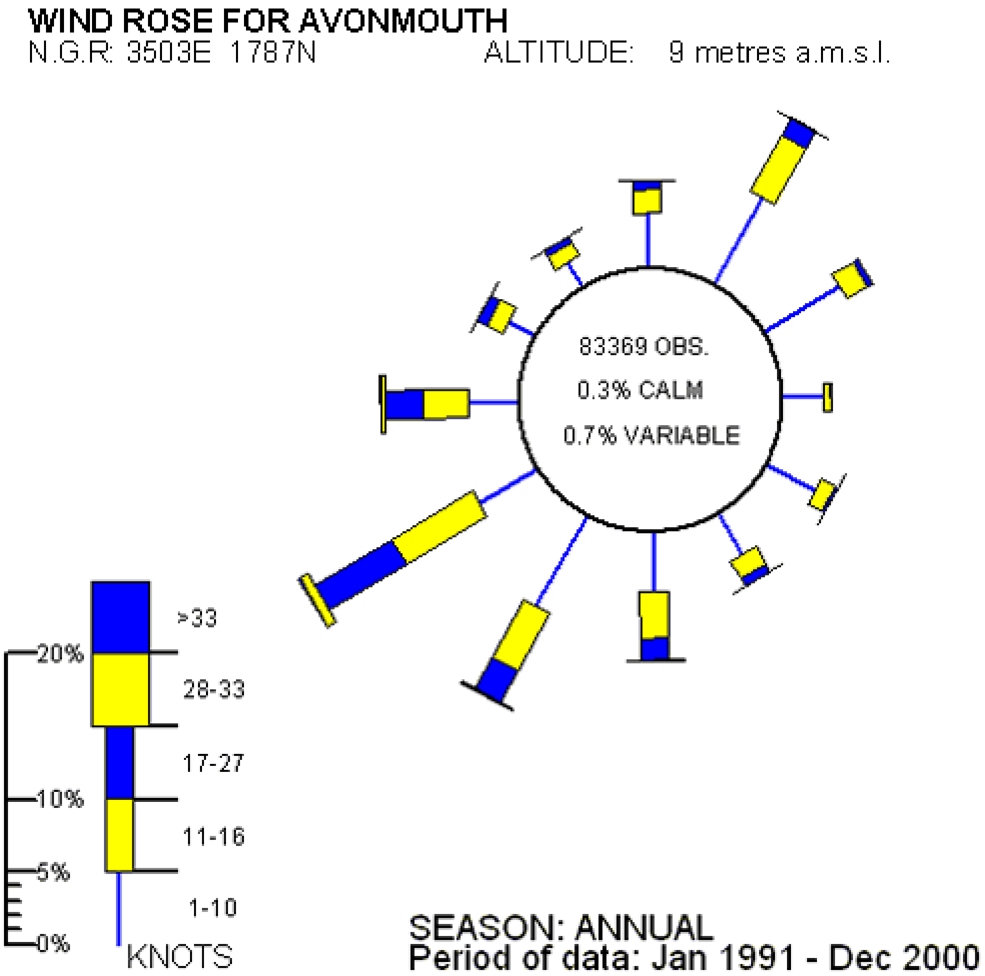

Figure VII.1: Wind rose for Avonmouth.
Produced by the Meteorological Office. Contains public sector information licensed under the Open Government Licence v1.0

The wind rose for Avonmouth is typical of a coastal location in the Bristol Channel. The predominant wind direction is from the south west and the strongest winds usually blow from this direction (Met Office, 2012). Porlock is located on a relatively open stretch of coastline and faces north, so is more exposed to northerly winds. The land adjacent to Porlock Bay is hilly and will offer shelter from all winds from a southerly direction.

Appendix VIII. Hydrometric Data: Freshwater Inputs

The survey area has a hydrological catchment of 57 km², as estimated from topography maps. There are two main watercourses which drain to the bay, the Hawkcombe Stream and Horner Water. There is also a smaller stream which drains to the shore west of Porlock Weir.

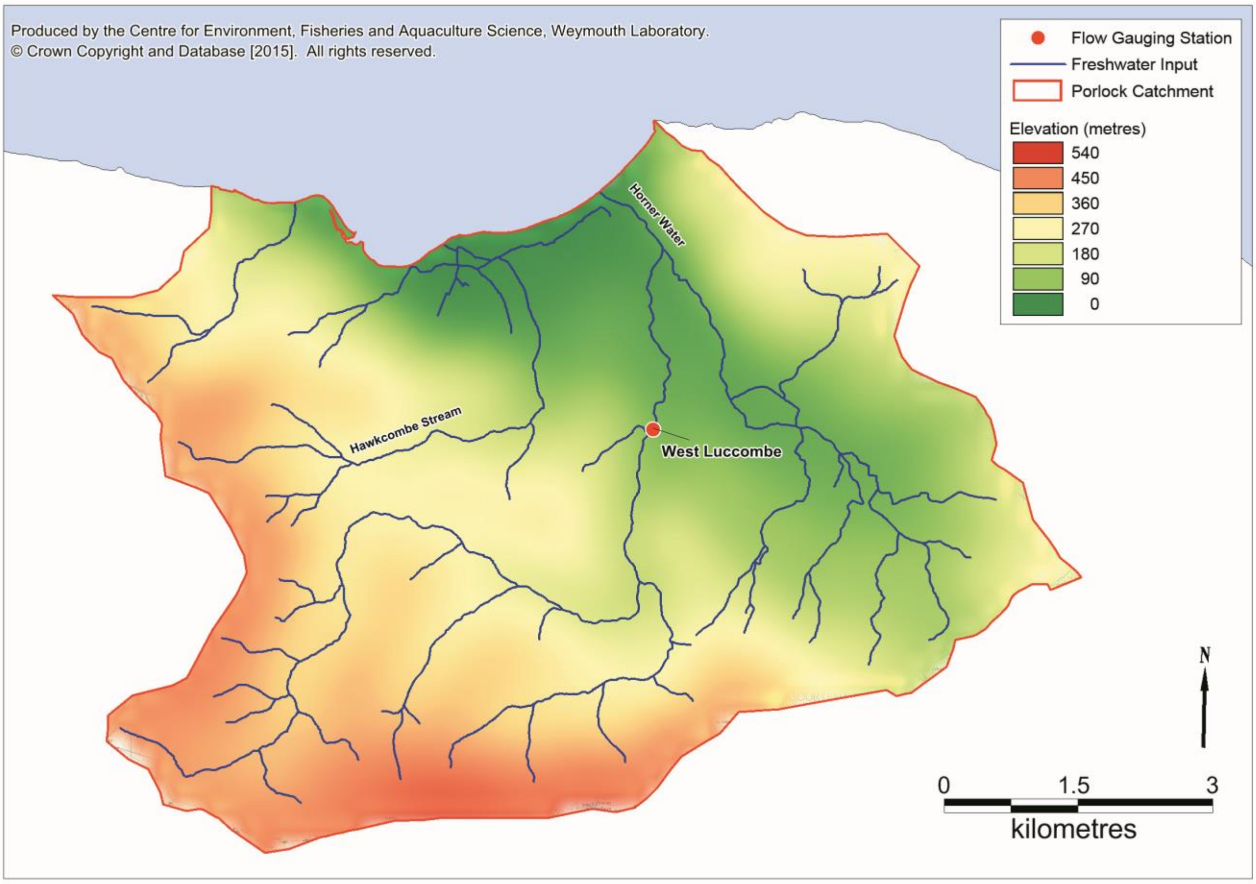

Figure VIII.1 Freshwater inputs flowing into Porlock survey area

Land cover is a mixture of pasture and moors in the west of the catchment and a mixture of pasture and arable land in the east, interspersed with woodland. A small proportion of land is urbanised close to the coast, most of which falls within the village of Porlock. The catchment is quite hilly reaching a maximum elevation of 515 m at Dunkery Hill in the south east of the catchment. There is a small area of low lying land with saltmarsh and pasture between the village of Porlock and the coast. The underlying geology comprises of low permeability Mid Devonian Grits and Lower Devonian Old Red Sandstone (NERC, 2012). Due to the hilly nature of this catchment and its low permeability it is expected that watercourses within catchment will respond quickly to rainfall and a high proportion of rainfall will run off.

There is a flow gauging station on the Horner Water. Table VIII.1 presents summary statistics, and Figure VIII.2 presents boxplots of mean daily flows by month.

Table VIII.1 Summary of flow statistics for four gauging stations draining into the Porlock survey area

Watercourse	Station Name	Catchment Area (Km²)	Mean Annual Rainfall 1961-1990 (mm)	Mean Flow (m³s-1)	Q95[1] (m³s-1)	Q10[2] (m³s-1)
Horner Water	West Luccombe	20.8	1,480	0.50	0.08	1.07

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

Data from NERC, 2012 and contains Environment Agency information © Environment Agency and database right

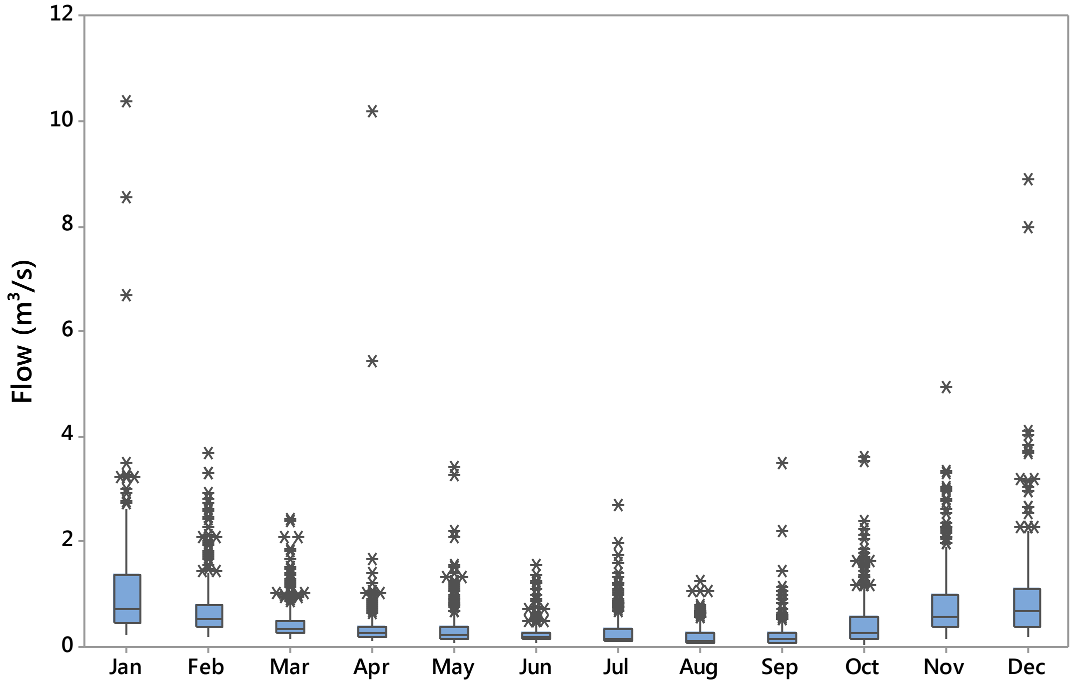

Figure VIII.2 Boxplots of mean daily flow records from the West Luccombe gauging station on the Horner Water watercourse (2004 – 2014)

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Flows were higher on average during the colder months (November through to February). High flow events were recorded in most months of the year, but there tended to be a greater number of higher magnitude events during the autumn and winter. Flow rates peaked to extremely high levels (10.2 and 10.4 m³/s) in April 2012 and January 2013, after extended periods of heavy precipitation. The seasonal pattern of flows is not entirely dependent on rainfall as during the colder months there is less evaporation and transpiration, leading to a higher water table. This in turn leads to a greater level of runoff immediately after rainfall. Increased levels of runoff are likely to result in an increase in the amount of microorganisms carried into coastal waters. Additionally, higher runoff will decrease residence time in rivers, allowing contamination from more distant sources to have an increased impact during high flow events.

During the shoreline survey, which was conducted under dry conditions, watercourses which could be safely accessed were sampled for *E. coli* and spot flow measurements were taken. The results and locations are presented in Table VIII.2 and Figure VIII.3.

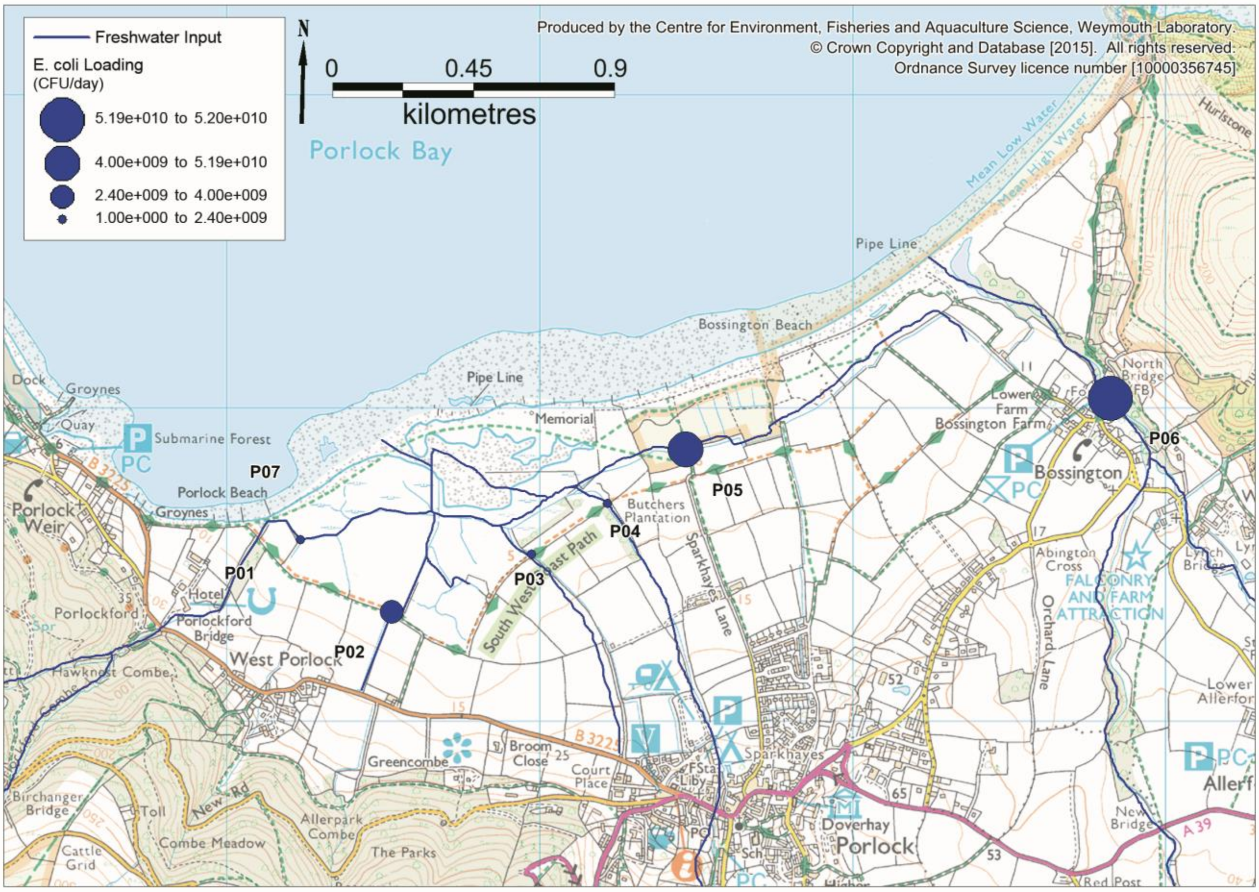

Figure VIII.3: Locations of shoreline survey observations

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

Sample ID	Observation	*E.* coli (cfu/100 ml)	Flow (m^3/s)	*E.* coli Loading cfu/day
P01	Unnamed stream	150	0.016	2.02×10^{9}
P02	Unnamed stream	130	0.028	3.14×10^{9}
P03	Unnamed stream	340	0.002	6.16×10^{7}
P04	Hawkcombe Stream	30	0.092	2.37×10^{9}
P05	Unnamed stream	40	0.116	4.01×10^{9}
P06	Horner Water	130	0.554	5.19×10^{10}
P07	Spring on beach	<10	Flow too dispersed and shallow to measure	

All watercourses contained low *E. coli* concentrations, ranging from <10 to 340 cfu/100 ml. The Hawkcombe Stream and several other small watercourses drain to the tidal lagoon which has formed behind the breach in the shingle bar. The combined bacterial loading from these measurements (P01 to P05) was 1.2×10^{10} *E. coli*/day. It drains to the shore about 400 m east of the fishery, through a tidal lagoon, so contamination originating from this watercourse will mainly enter the bay during the ebb tide. Horner Water was delivering a bacterial loading just over 4 times that of the streams draining to the lagoon, but discharges over 2 km to the east of the fishery. It flows through the shingle bar, so will discharge to the bay throughout the tidal cycle, although flows are likely to be more rapid at lower states of the tide when the level difference is greater. A spring which emerges on Porlock beach (P07) close to the shellfish trestles was not flow gauged as its discharge was too diffuse and shallow to accurately measure. Although it is a potential source of contamination to the shellfish due to its close proximity, the *E. coli* concentration within it was lower than the limit of quantification of the test employed (10 cfu/100 ml). The small stream located about 1.2 km west of the fishery was not sampled or measured, but given its small catchment and relatively remote location its impacts on the fishery are unlikely to be of significance.

Appendix IX. Hydrography

IX.1. Bathymetry

Porlock Bay is a small, open embayment located in the outer reaches of the Bristol Channel. Figure IX.1 illustrates the bathymetry within and surrounding the survey area.

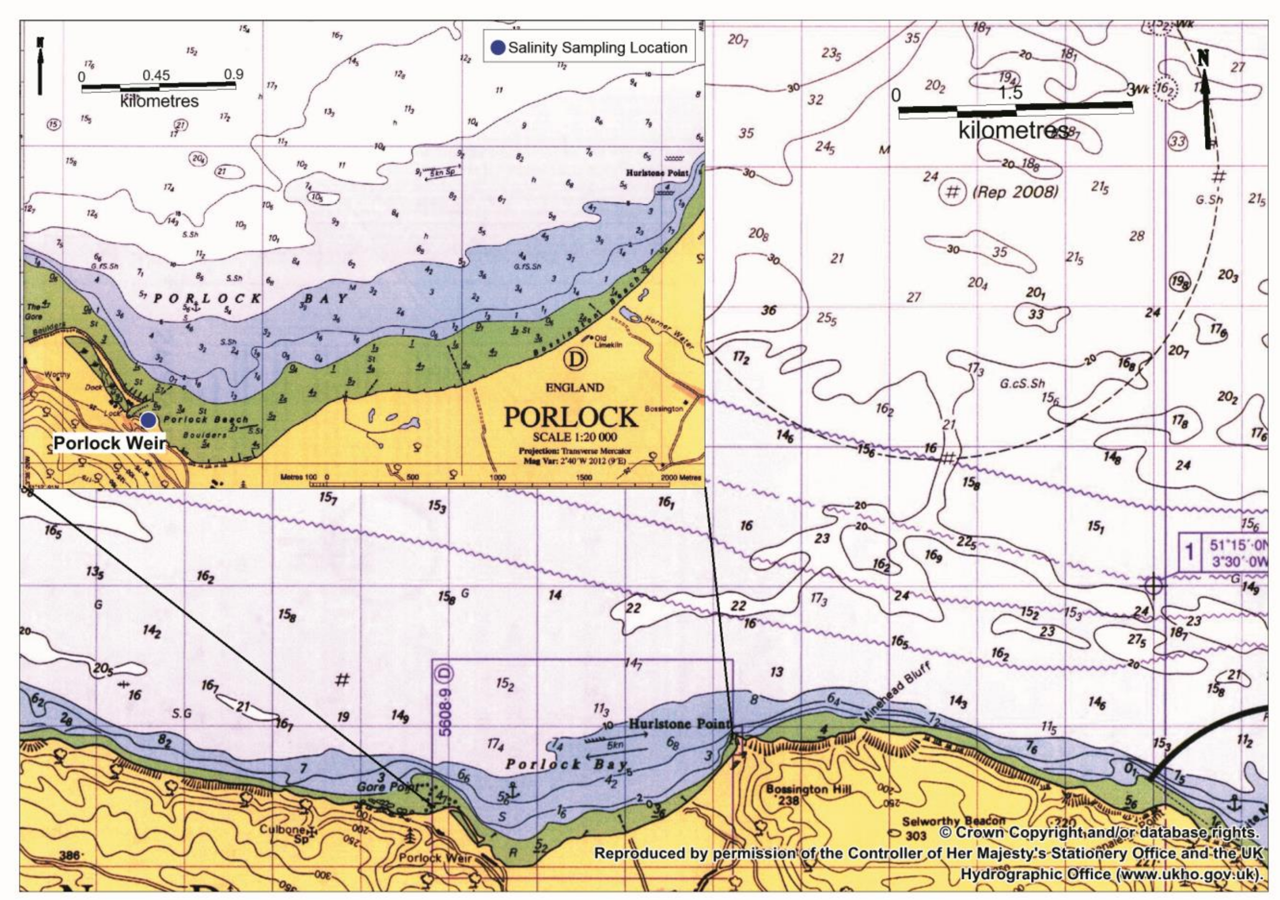

Figure IX.1 Bathymetry of Porlock Bay

The bathymetry within Porlock Bay is relatively uncomplicated and comprises of a shallow, gently sloping embayment reaching a maximum depth of 14 m relative to chart datum in the outer bay. A coarse shingle barrier beach runs the full length of the bay between Gore Point and Hurlstone. This was breached during a storm in 1996 about 1 km east of Porlock Weir (Bray and Duane, 2001). The breach is backed by a small intertidal lagoon and saltmarsh into which the Hawkcombe Stream discharges. Contamination delivered by this stream will therefore mainly be carried into Porlock Bay during the ebb tide. The other main freshwater input (Horner Water) seeps through the shingle bar, and will drain to the bay throughout the tidal cycle. Flows may increase at lower states of the tide when the water level difference is greater.

There are small headlands at Gore Point and Hurlstone, around which there are likely to be increases in current speed relative to those within the bay. The open coastal location will offer high potential for dilution and water exchange.

IX.2. Tides and Currents

Currents in coastal waters are largely driven by a combination of tides, winds and density effects. The tidal range in the area is large (9.3 m on spring tides) and this will drive extensive water movements.

Table IX.1 Tide levels and ranges at Porlock Bay

	Height (m) above Chart Datum				Range (m)	
Port	MHWS	MHWN	MLWN	MLWS	Springs	Neaps
Porlock Bay	10.2	7.6	3.7	0.9	9.3	3.9

Data from Admiralty TotalTide©

Tides within the Bristol Channel flood in an easterly direction and ebb in a westerly direction. The admiralty chart reports peak tidal current of 5 knots (2.6 m/s) in the outer central part of Porlock Bay, with bidirectional streams orientated parallel to the coast. Tidal streams are likely to be slower over shallower and intertidal areas due to the effects of friction. Contamination from shoreline sources will therefore travel parallel to the coast, impacting either side of their locations, and the magnitude of their impacts will decrease with distance as the plume spreads and becomes more diluted. Contamination from shoreline sources will be carried several km along the shore during the course of a flood or ebb tide, so impacts may potentially be felt a considerable distance away. The ebb plume from the tidal lagoon to which the Hawkcombe Stream discharges will be carried towards the shellfishery by tidal streams.

Superimposed on tidally driven currents are the effects of freshwater inputs and wind. Freshwater inputs are minor, and the survey area is in an open coastal location, so it is unlikely that freshwater related stratification of the water column will occur. Repeated salinity measurements taken as part of the bathing water monitoring programme are presented in Figure IX.2.

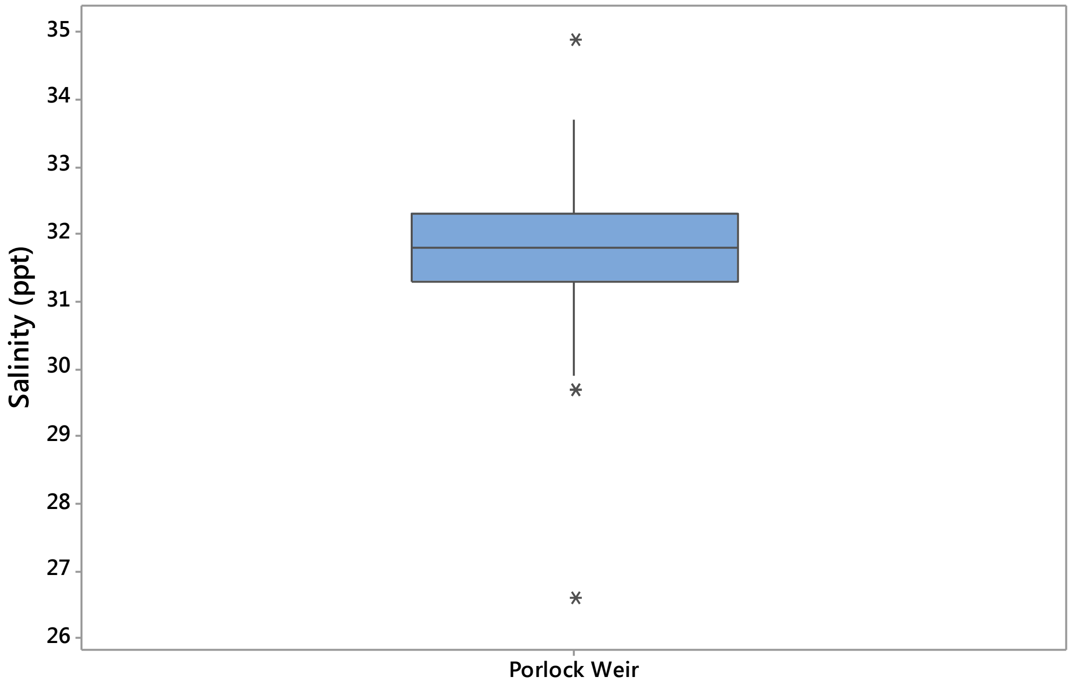

Figure IX.2: Boxplot of salinities recorded at Porlock Weir bathing water monitoring point (2004-2014)
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These indicate salinity at Porlock Weir averaged 31.8 ppt and rarely dropped below 30 ppt. Although these measurements were all made during the warmer months of the year, it can nevertheless be concluded that freshwater influence here is minimal.

Strong winds will modify surface currents within the survey area. Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive surface water currents of about 0.5 m/s. These create return currents which may travel lower in the water column or along sheltered margins. The bay is afforded shelter from winds with a southerly element by the adjacent land, but is exposed to winds and waves from the north. Exact effects of wind are dependent on its speed and direction as well as state of the tide and other environmental variables so a great number of scenarios may arise. Where strong winds blow across a sufficient distance of water they may create wave action. Where these waves break contamination held in intertidal sediments may be re-suspended. Strong northerly winds will result in significant onshore wave action at Porlock Bay.

Appendix X. Microbiological Data: Seawater

There is one bathing water in the survey area designated under the Directive 76/160/EEC (Council of the European Communities, 1975), the location of which is shown in Figure X.1.

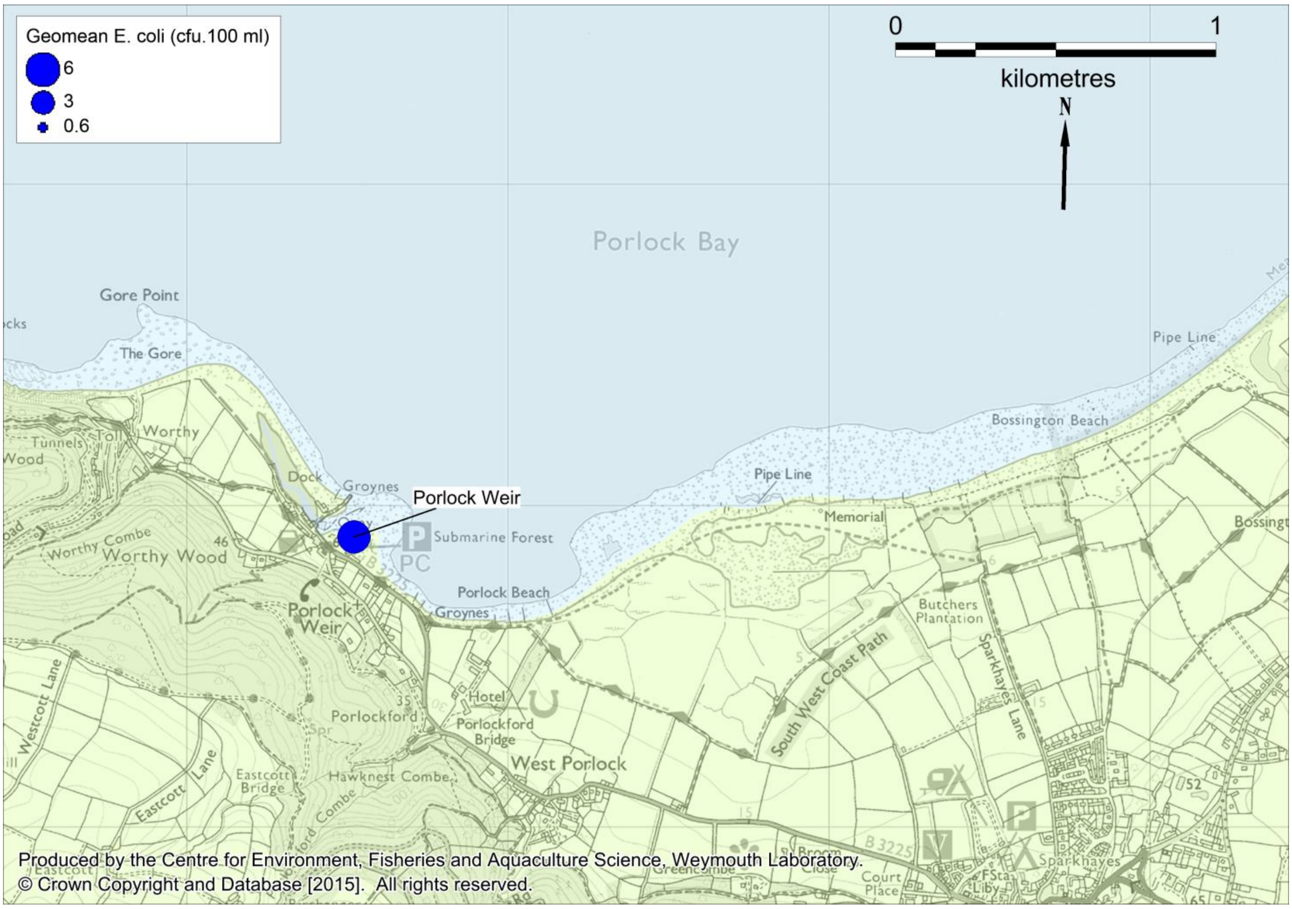

Figure X.1: Location of designated bathing and shellfish waters monitoring points in the survey area

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Around twenty water samples were taken from the bathing waters site during each bathing season, which runs from the 15th May to the 30th September. *E. coli* were enumerated in all of these samples. Before 2012, faecal coliforms were enumerated so only data from 2012 onwards is considered as the two are not directly comparable. Summary statistics of all results by bathing water are presented in Table X.1, and Figure X.2 presents box plots of these data.

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

Sampling Site	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 100	% over 1,000
Porlock Weir	61	10/05/2012	26/09/2014	5.7	<10	136	1.6	0.0

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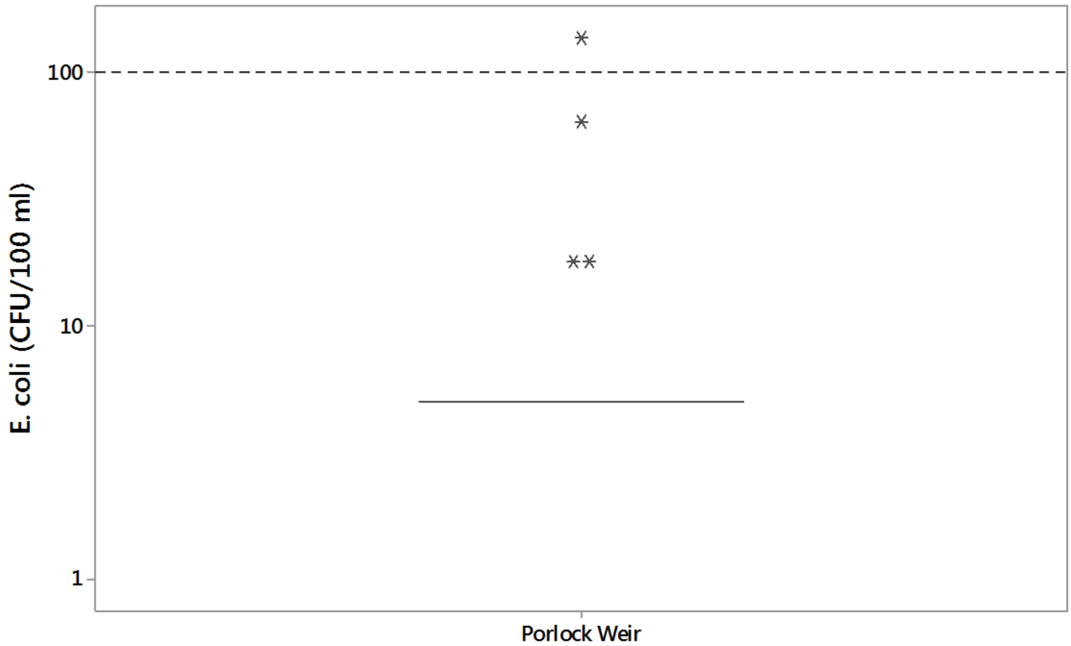

Figure X.2: Box-and-whisker plots of all *E. coli* results
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The vast majority (93%) of samples contained <10 *E. coli* cfu/100 ml, with a maximum result of 136 *E. coli* cfu/100 ml. This indicates that levels of contamination here are low, and the lack of variability makes it unlikely that statistical analyses will reveal any significant environmental influences.

Overall temporal pattern in results

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

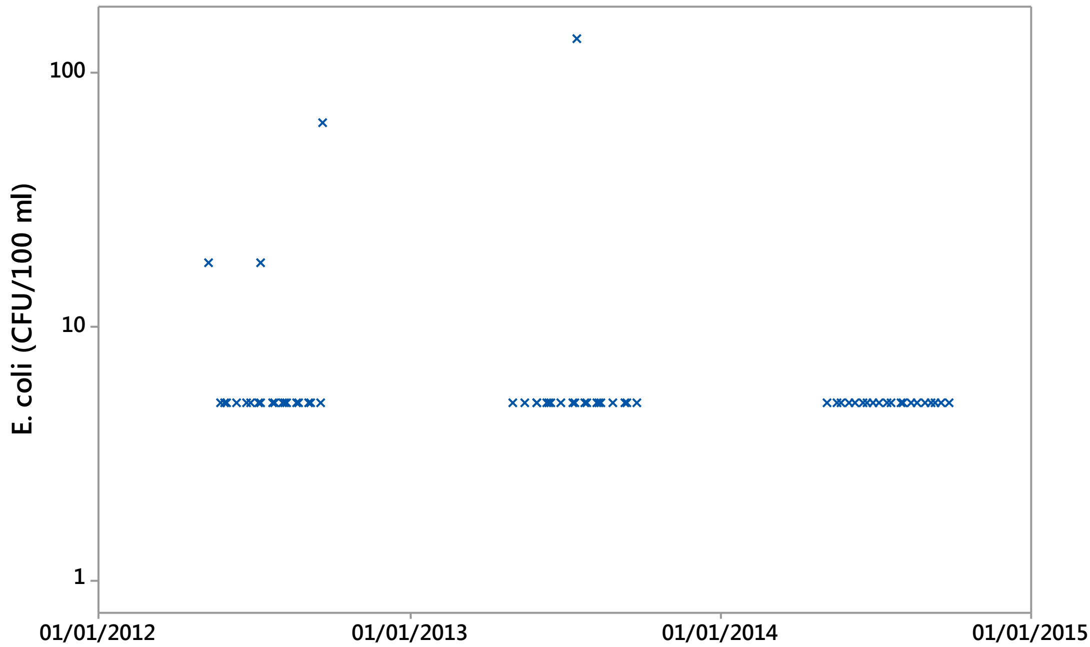

Figure X.3: Scatterplot of *E. coli* results for bathing waters in the survey area.
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E. coli concentrations have remained low on average throughout the period considered, with only occasional results higher than the limit of quantification for the method used.

Influence of tides

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

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

	High/low tides		Spring/neap tides	
Site Name	**r**	**p**	**r**	**p**
Porlock Weir	0.240	0.035	0.054	0.845

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

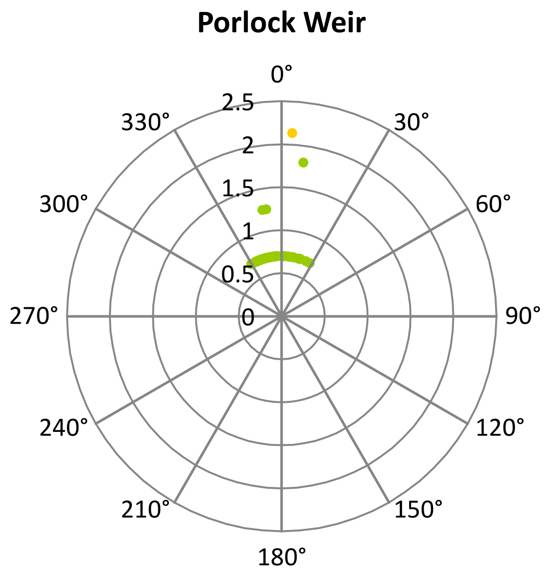

Figure X.4: Polar plots of log10 *E. coli* results (cfu/100 ml) against high/low tidal state.
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All samples at Porlock Weir were taken around high water. While the analyses showed a significant correlation with tidal state, no pattern can be seen in the polar plot.

Influence of Rainfall

To investigate the effects of rainfall on levels of contamination at the bathing water site, Spearman's rank correlations were carried out between rainfall recorded at the Birchanger weather station (Appendix VI for details) over various periods running up to sample collection, and *E. coli* results. These are presented in Table X.3.

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

	Site	Porlock Weir
	n	53
24 hour periods prior to sampling	1 day	-0.014
	2 days	0.099
	3 days	0.062
	4 days	0.207
	5 days	0.015
	6 days	0.008
	7 days	-0.017
Total prior to sampling over	2 days	0.056
	3 days	0.053
	4 days	0.096
	5 days	0.055
	6 days	0.039
	7 days	<0.001

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No influence of antecedent rainfall on *E. coli* concentrations was detected.

Salinity

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

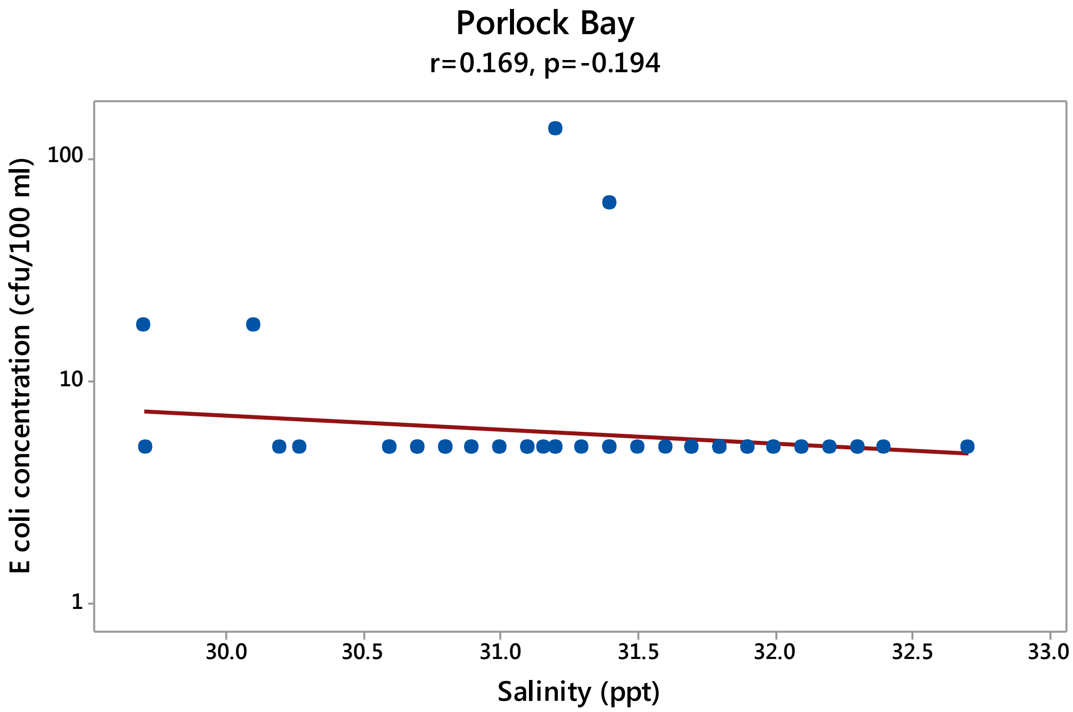

Figure X.5: Scatter-plots of salinity against *E. coli* concentration.
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There was little variation in both salinity and *E. coli* concentrations, and no significant correlation between the two.

Appendix XI. Microbiological Data: Shellfish Flesh

Eight samples of mussels and Pacific oysters have been taken from one location within the survey area and enumerated for *E. coli* for hygiene classification purposes.

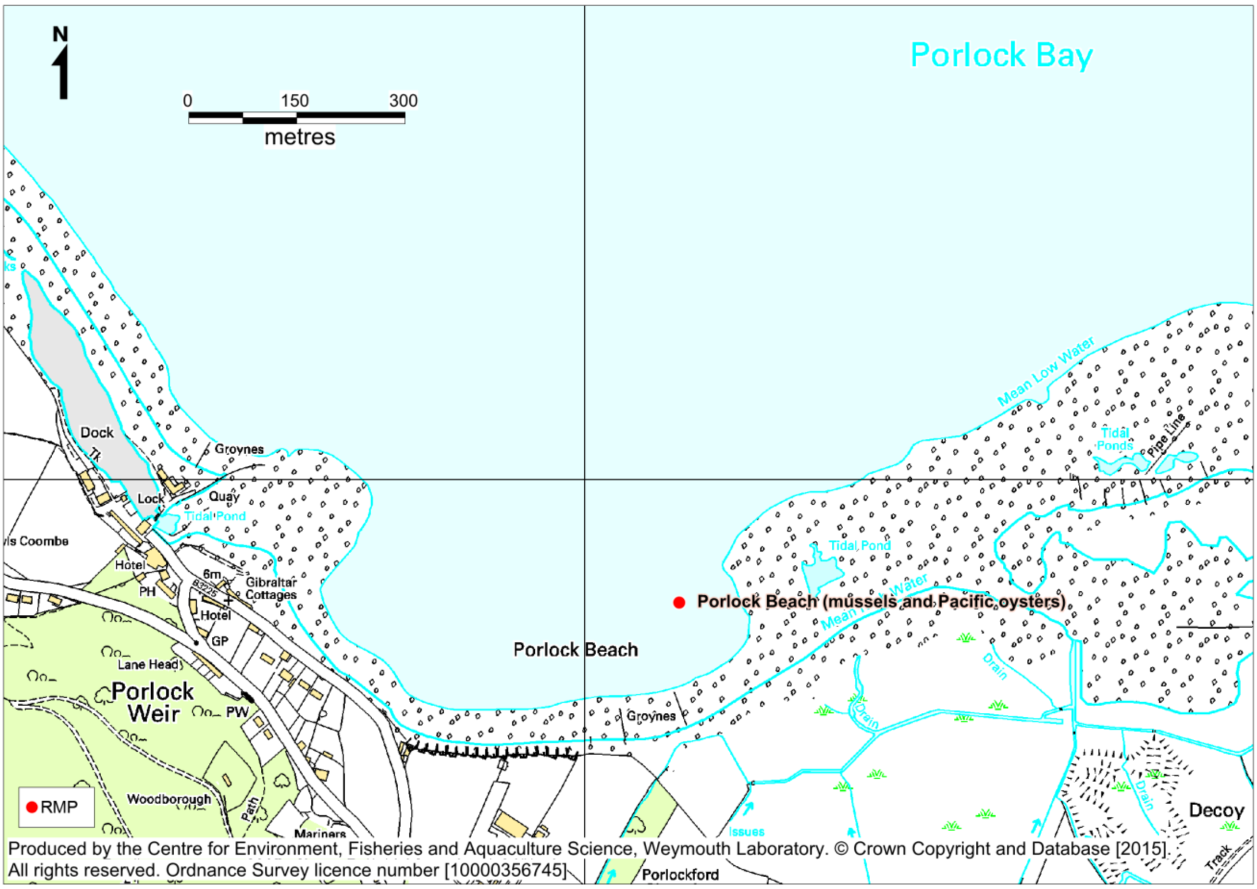

Figure XI.1: Location of RMP

Table XI.1: Summary Statistics for *E. coli* results

Species	No.	Date of first sample	Date of last sample	*E. coli* results (MPN/100g)				
				Geometric mean	Min.	Max.	% exceeding 230	% exceeding 4600
Mussels	8	10/09/2014	19/01/2015	157.0	40	1,300	25%	0%
Pacific oysters	8	10/09/2014	19/01/2015	43.1	<18	230	0%	0%

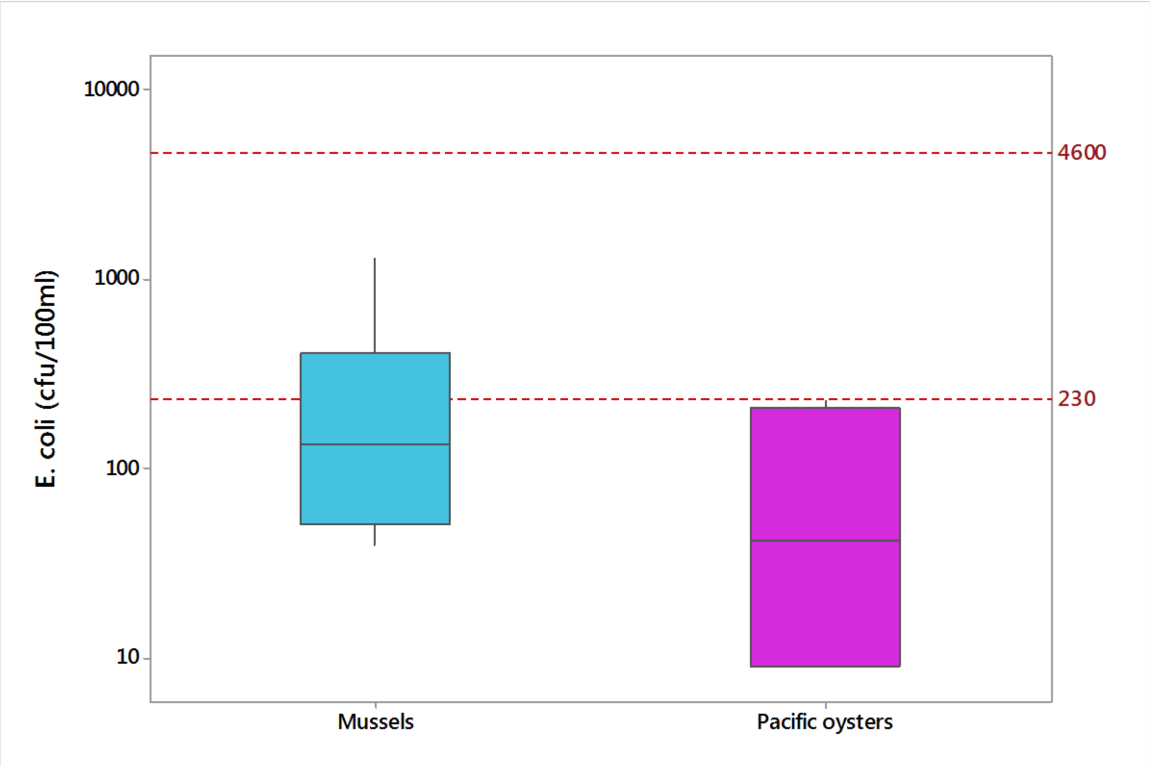

Figure XI.2: Boxplot of *E. coli* results by species

Results for both species were low. No results exceeded 230 *E. coli* MPN in Pacific oysters, whereas 2 results exceeded this classification threshold for mussels. There was a statistically significant difference in average result between the two species (paired T-test, p=0.015) suggesting that the two species should be monitored separately in this location. It was not possible to take further more detailed analyses of these results due to the small number of samples taken.

Appendix XII. Shoreline Survey Report

Date (time):
09/12/2014 (09:00 – 15:00)

Cefas Officers:
Rachel Parks
Lesley Bickerstaff

Local Enforcement Authority Officers:
Nicola Sambells (West Somerset Council)
Roger Hall (Porlock Shellfish Group)

Area surveyed:
Porlock Weir to Bossington

Weather:
09th December – Overcast 7.9°C, wind bearing 258° at 11.3 km/h

Tides:
Admiralty Totaltide predictions for Porlock Bay. All times in this report are GMT.

09/12/2014	
High 07:47	10.0 m
High 20:10	9.7 m
Low 01:03	1.4 m
Low 13:30	1.8 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 one day by foot.

XII.2. Description of Fishery

Currently there are eight trestles in two discrete blocks. Only the block nearer to the shore could be seen at the time of the visit. These trestles have been stocked with Pacific oysters of a variety of sizes from Seasalter, Morecambe Bay, the growth and survival of which is being assessed. As the operation develops and expands into the subtidal area, oyster cages will be used and husbandry and harvest will largely be undertaken from a boat. At some point native oysters may also be introduced to the site. The culture of mussels on bouchot poles was also trialled in close proximity to the trestles, but this was not successful due to bird predation. A bag of mussels (from Loch Fyne) is maintained on the inner block of trestles for classification sampling purposes, and other mussel culture methods such as longlines are under consideration.

The Porlock Futures Group indicated a desire to increase the size of the zone for which classification is required from that originally requested. A representative of the group indicated that it should extend a further 400 m offshore (north) and 100 m further inshore (south).

XII.3. Sources of contamination

Sewage discharges

Porlock Weir PS intermittent was observed on the shoreline survey, however it was submerged by the tide. There was no evidence of Bossington PS intermittent and Porlock STW continuous discharges. It is likely that these were submerged by the sea and the pipes hidden beneath the boulder beach.

An occupied houseboat was observed moored in the upper reaches of Porlock Weir Harbour and could be a source of microbiological contamination to the shellfish beds.

Freshwater inputs

Six streams and a spring emerging on the beach were observed, all of which were flowing at the time of survey (Observations 1, 2, 4, 5, 6, 9 and 13). Their details are shown in Table XII.2. Water samples were taken from all and flow measurements taken at all except the spring emerging on Porlock Beach, (observation 13). The discharge from this spring formed several shallow channels making it impossible to obtain accurate measurements. *E. coli* concentrations in all watercourses were low, the maximum being 340 cfu/100 ml (see Table XII.2 for details).

One pipe was observed on the survey, running through the marsh land (observation 7). A couple of pipe outlets with grids were observed on the northern quay at Porlock Weir, neither of which were flowing at the time of survey (observation 10).

Livestock

Livestock were observed in fenced fields along the shoreline (observations 3, 7, 8, & 12). The largest aggregation, ~200 sheep were seen in fields adjacent to the marsh land at West Porlock (observation 3).

Wildlife

No aggregations of birds were observed on the survey. Dog walking was observed along the coastal path and along the shingle beach close to Porlock Weir and Bossington.

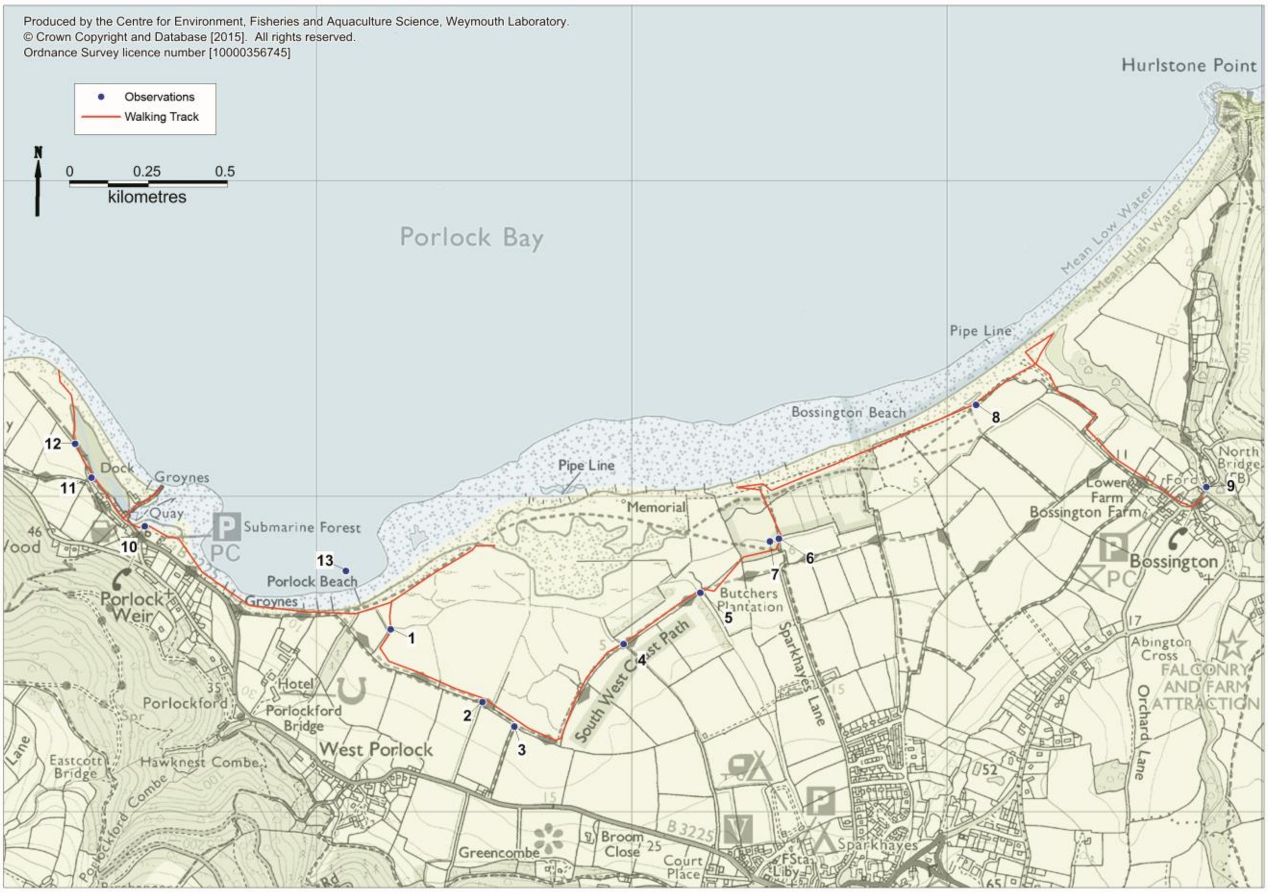

Figure XII.1: Locations of Shoreline Observations (Table XII.1 for details)

Table XII.1: Details of Shoreline Observations

Observation no	NGR	Date	Time	Description	Photo
1	SS8723647580	09/12/2014	09:36	Stream flowing (0.85m x0.09m x 0.204 m/s). Sample P01	Figure XII.4
2	SS8752747349	09/12/2014	09:51	Stream flowing through farmland (0.79 x 0.08m x 0.442 m/s). Sample P02	Figure XII.5
3	SS8762847271	09/12/2014	10:02	~200 sheep on field adjacent to marsh	Figure XII.6
4	SS8797447533	09/12/2014	10:12	Stream flowing (0.5m x 0.05m x 0.095 m/s). Sample P03	
5	SS8821747696	09/12/2014	10:22	Stream flowing (2.6m x 0.1m x 0.352 m/s). Sample P04	Figure XII.7
6	SS8846747867	09/12/2014	10:34	Stream flowing (6.0m x 0.09 m x 0.215 m/s). Sample P05	Figure XII.8
7	SS8843947859	09/12/2014	10:39	Pipe running through marsh. ~80 Sheep in field & horses	Figure XII.9
8	SS8909248292	09/12/2014	11:05	5 horses in field	
9	SS8982348031	09/12/2014	11:39	Stream running through Bossington (8.0m x 0.15m x 0.462m/s). Sample P06	Figure XII.10
10	SS8645547906	09/12/2014	12:25	Manhole cover and 2 pipes with grids on other side of the harbour wall (not flowing)	Figure XII.11
11	SS8628648061	09/12/2014	12:30	Houseboat (occupied)	Figure XII.12
12	SS8623548168	09/12/2014	12:32	~60 Sheep in field	
13	SS8709447765	09/12/2014	13:48	Spring flowing across the beach under trestles. Sample P07	

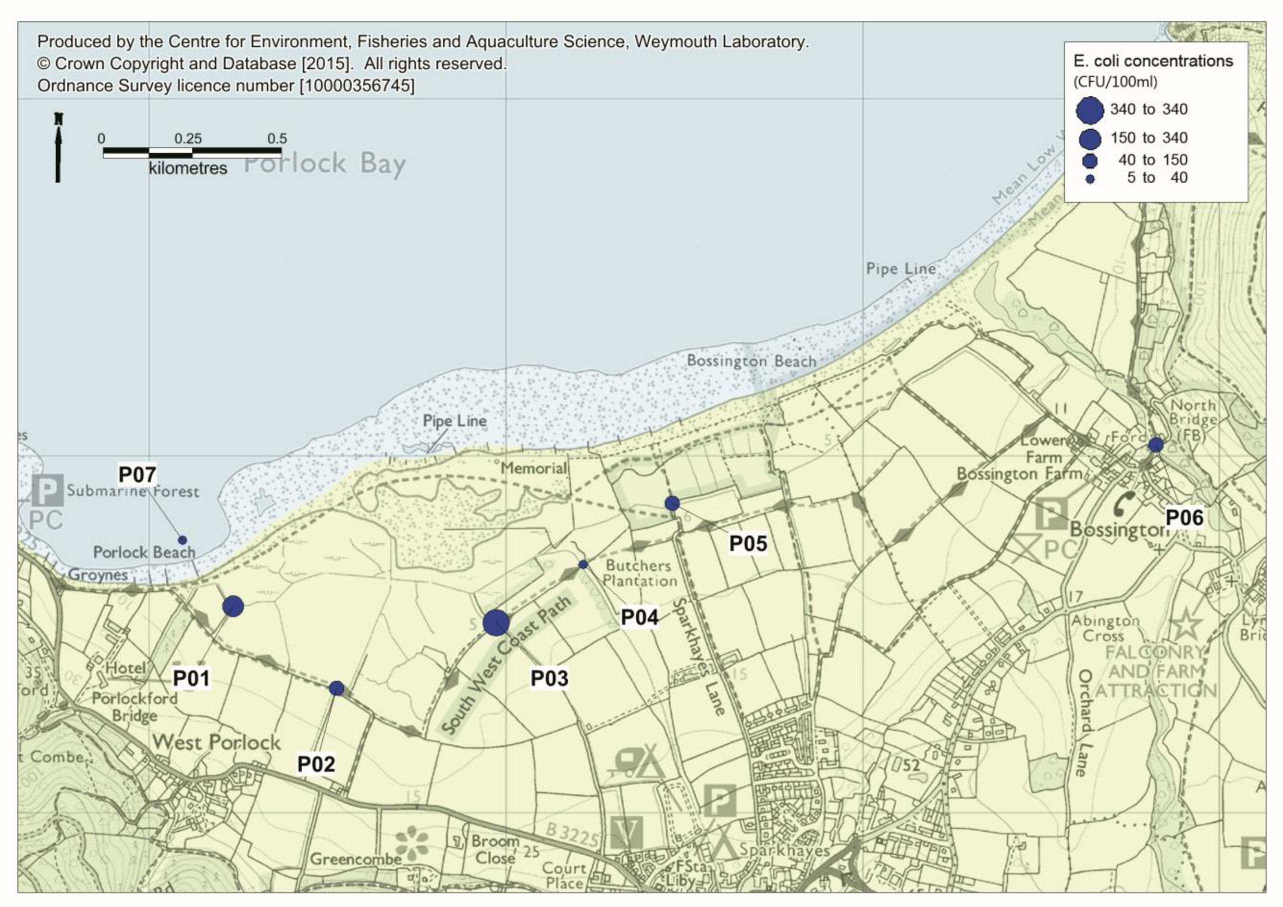

Figure XII.2: Water sample results (Table XII.2 for details)

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

Sample ID	Observation number	Description	*E. coli* concentration (cfu/100 ml)	Flow (m³/s)	*E. coli* loading (cfu/day)	NGR
P01	1	Stream	150	0.016	$2.02x10^9$	SS8723647580
P02	2	Stream	130	0.028	$3.14x10^9$	SS8752747349
P03	4	Stream	340	0.002	$6.16x10^7$	SS8797447533
P04	5	Stream	30	0.092	$2.37x10^9$	SS8821747696
P05	6	Stream	40	0.116	$4.01x10^9$	SS8846747867
P06	9	Stream	130	0.554	$5.19x10^{10}$	SS8982348031
P07	13	Spring	<10	Not measured		SS8709447765

Figure XII.3

Figure XII.4

Figure XII.5

Figure XII.6

Figure XII.7

Figure XII.8

Figure XII.9

Figure XII.10

Figure XII.11

Figure XII.12


Figure XII.13

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List of Abbreviations

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

Glossary

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

Geometric mean	The geometric mean of a series of N numbers is the Nth root of the product of those numbers. It is more usually calculated by obtaining the mean of the logarithms of the numbers and then taking the anti-log of that mean. It is often used to describe the typical values of skewed data such as those following a log-normal distribution.
Hydrodynamics	Scientific discipline concerned with the mechanical properties of liquids.
Hydrography	The study, surveying, and mapping of the oceans, seas, and rivers.
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”.

Acknowledgements

Andy Mears and Adrian Stoodley (Wessex Water), Nicola Sambells (West Somerset Council), Roger Hall (Porlock Futures Group).