EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

St Ives Bay

2011

Cover photo: St. Ives Bay viewed from St. Ives.

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

CONSULTATION:

Consultee	Consultation Date	Response Date
Environment Agency	16/7/2012	31/08/2012
Local Enforcement Authority	16/7/2012	11/09/2012
Cornwall Inshore Fisheries and Conservation Authority	16/7/2012	14/08/2012
South West Water (discharges sections)	16/7/2012	23/08/2012

DISSEMINATION: Food Standards Agency, Cornwall Port Health Authority, Environment Agency, Cornwall IFCA.

RECOMMENDED BIBLIOGRAPHIC REFERENCE: Cefas, 2011. Sanitary survey of St Ives 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 of EC Regulation No. 854/2004.

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1. INTRODUCTION

1.1 LEGISLATIVE REQUIREMENT

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

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

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

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

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

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

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

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

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

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

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

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

This report documents information relevant to undertake a sanitary survey for wild razors (*Ensis* spp.) and mussels (*Mytilus* spp.) within St. Ives Bay.

1.2 SITE DESCRIPTION

ST IVES BAY

St. Ives Bay is situated on the north coast of Cornwall, in the south west of England (Figure 1.1).

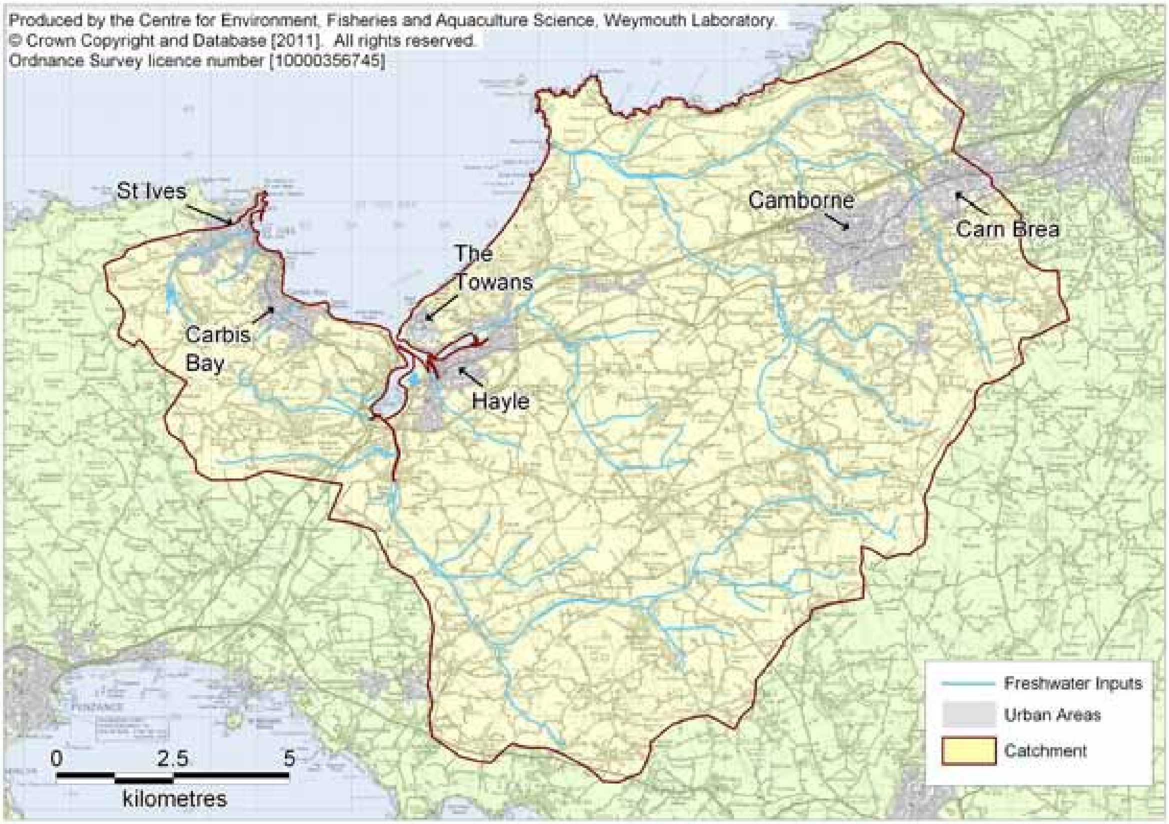


Figure 1.1 Location of St. Ives Bay and its river catchments

This bay is approximately 6.3km wide and recessed by 3.0km and covers an area of about 16km^2. The towns of St. Ives and Carbis Bay border its western end. The Hayle estuary, and the town of Hayle, border the south of the bay. Just to the east of the Hayle estuary is a small settlement called The Towans, The eastern shore of the bay is flanked by dune systems, with some holiday chalets. The bathymetry is uncomplicated, gradually sloping to a depth of about 22m below chart datum in the outer bay

CATCHMENT

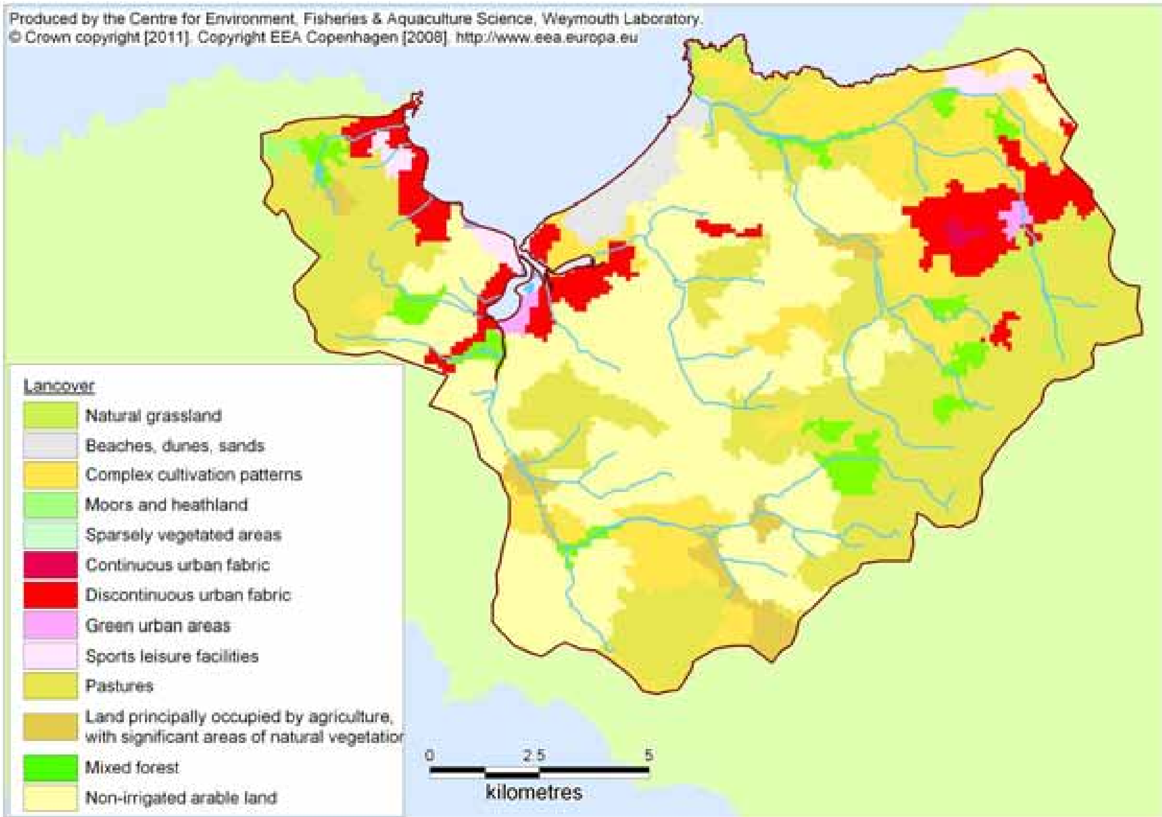


Figure 1.2 Land cover in catchments bordering St. Ives Bay.

The overall catchment area of St. Ives Bay is relatively small at 170km^2, and is drained by several watercourses. The Red River discharges to the eastern end of the bay and drains an area of about 65km^2, a large proportion of which is pasture, with some arable land and natural areas as well as the town of Camborne. The Hayle estuary, at the head of St Ives Bay receives freshwater inputs from an area of about 95km^2. Land use in this catchment area is mainly arable farming, interspersed with pastures and natural areas. The town of Hayle borders the estuary. Three small streams drain into the western end of the bay, and have a combined catchment area of about 10km^2, and drain mainly pasture in their upper reaches, before flowing through the coastal towns of St Ives and Carbis Bay. There are several soil types within these catchment areas, but all are reported to be permeable and freely draining (National Soil Resources Institute, 2010). It must be noted however that whilst underlying soils may be permeable, higher levels of runoff are expected from urban areas due to extensive areas of hard standing.

2. SHELLFISHERIES

This sanitary survey of St. Ives Bay was prompted by an application for the classification of parts of St. Ives Bay for the harvest and possibly the relaying of razors (*Ensis* spp.). From 1999 two parts of the bay were classified B for the harvest of mussels (areas at Carbis Bay and Godrevy), but classification lapsed in 2004.

2.1 SPECIES, LOCATION AND EXTENT

The fishery requiring classification is for razor clams (*Ensis* spp.). A specimen collected during the survey was subsequently identified as *Ensis siliqua* (pod razor), although other *Ensis* species are likely to be present. In terms of depth, highest concentrations of animals are generally found along the 7.5m below chart datum contour. In water shallower than this, animals are less numerous but generally larger, and in water deeper than this animals are less numerous and smaller. Higher densities are found in the west side of the bay (up to 40 animals m^{-2} in places) compared to the east side (up to 5-8 animals m^{-2} in places), and as the seabed slopes away more gently on the west side of the bay there are larger areas around the optimum depth (Karma Waters pers. com.). On commencement of the bacteriological survey (Appendix XIII) it was discovered that there is little or no stock present to the north west of Bessack Rock, the part of the bay where wave action is generally most energetic.

Mussels are present on rocky substrates, with the main concentrations around Godrevy, and in some places within the western half of the bay. *Mytilus edulis*, *Mytilus galloprovencialis* and hybrids of the two species are present in St. Ives Bay. Commercial exploitation of mussel stocks within St. Ives Bay ceased several years ago, although hand gathering for personal consumption continues (Cornwall Inshore Fisheries and Conservation Authority [CIFCA] ex. Sea Fisheries Committee, personal communication). Classification sampling recommendations for this species will nevertheless be included in this report, in the event the LEA deems a classification necessary, for example if commercial interest is rekindled.

Hand gathering of winkles (*Littorina* spp.) is also reported to occur within St. Ives Bay (Cornwall Sea Fisheries Committee, personal communication) but gastropods no longer require classification under EC Regulation 854/2004 (EU, 2010) so will not be considered further in this report.

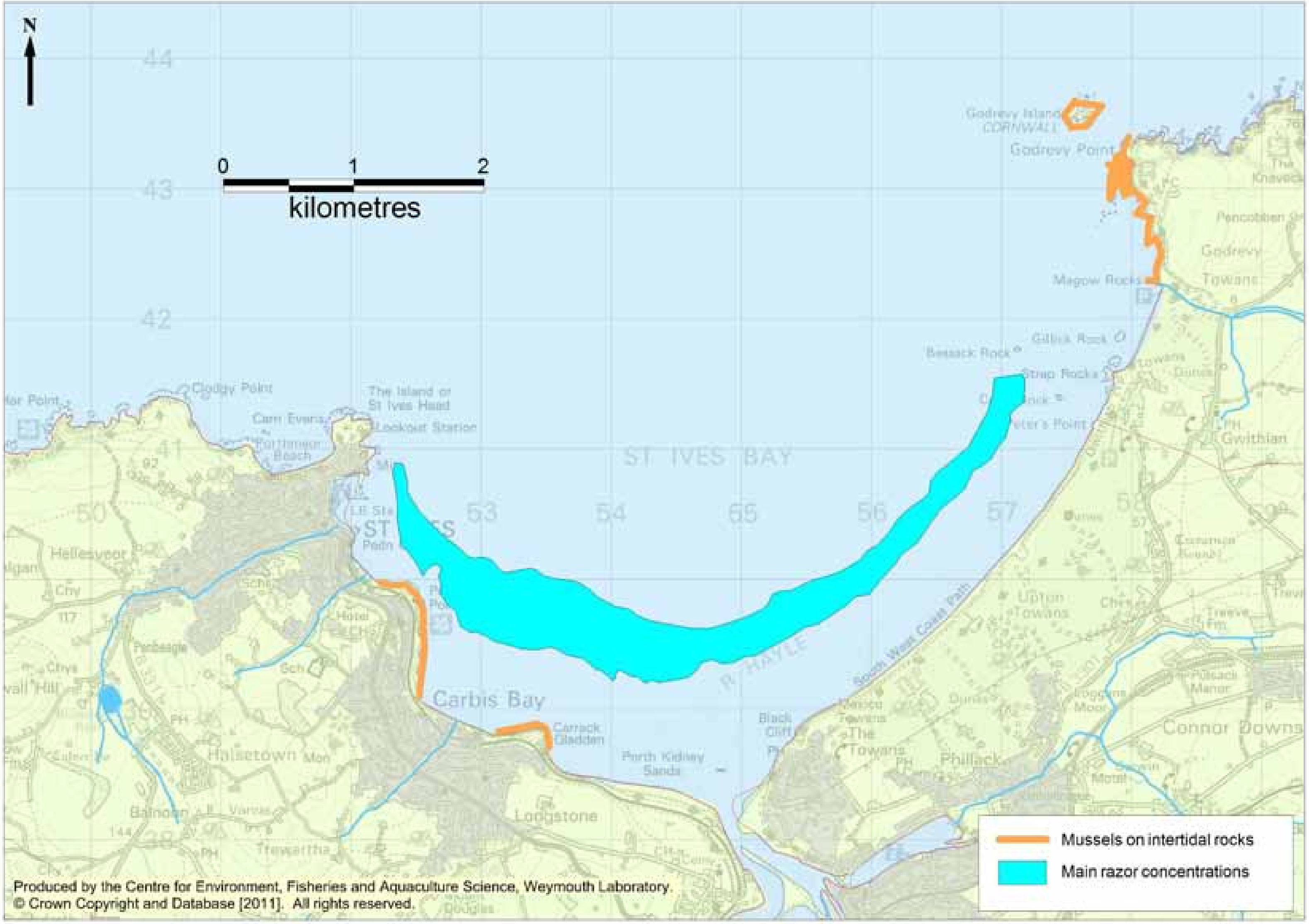


Figure 2.1 Location of fisheries within St Ives Bay.

2.2 GROWING METHODS AND HARVESTING TECHNIQUES

The razor stocks are wild. Burrows are inundated with saturated salt solution by divers and animals are collected as they emerge. There is the possibility that at some time in the future the harvester may apply to use a part of the outer bay as a relay area, but at present there are no firm plans to pursue this. Depuration facilities are available locally.

Mussels are hand gathered from rocks in the intertidal zone.

2.3 SEASONALITY OF HARVEST, CONSERVATION CONTROLS AND DEVELOPMENT POTENTIAL

The razor fishery will be operated year round, but tides and sea conditions will constrain operating windows. Poor underwater visibility is likely to prevent successful gathering at times. Access to and from Hayle harbour, where the boat is based is not possible around low water. In practise divers using SCUBA and breathing a normal air mixture are constrained to a maximum depth of 15-20m. The deeper the dive, the shorter the time which can be safely spent underwater without decompression stops, so some of the deeper areas are effectively inaccessible at high water.

The stocks of both mussels and razors are open to exploitation by anyone. There are no specific byelaws which apply to either fishery, although there are byelaws restricting the configuration of dredging gear within the district which prohibit the use of dredges capable of capturing razors. Marine electrical fishing of any form is considered banned under EC 850/98, Article 31 (EC, 1998) unless granted a specific derogation. A derogation has been awarded for a study in Wales to investigate the impacts of an electrified razor dredge on seabed communities (Woolmer *et al*, 2011). The results of this may support a case for permitting the more widespread use of certain types of electrofishing gear for razors at some point in the future. At present however, the only appropriate method of exploitation for razors within St. Ives Bay is hand gathering by divers. A statutory minimum landing size of 100mm applies to razors, although in practice only the larger (150mm plus) animals are likely to be marketable.

3. OVERALL ASSESSMENT

AIM

This section presents an overall assessment of the impacts of pollution sources on the microbiological contamination of the mussel sites within St Ives Bay as a result of a sanitary survey undertaken by Cefas on behalf of the Food Standards Agency. Its main purpose is to inform the sampling plan for the microbiological monitoring and classification of this area.

SHELLFISHERIES

The fishery is for diver caught razor clams (*Ensis* spp.), with main concentrations located between the 5 and 10m depth contours, although they are found outside of this depth band. Highest densities are present in the more sheltered western half of the bay, with no stock present to the north east of the Bessack Rock. Therefore, the area requiring classification will be inshore of a line drawn from the Bessack Rock across to St. Ives Head, and extend to mean low water springs. As the LEA is not equipped to collect samples of these species, the assistance of the applicant will be required. Industry sampling may be permitted as long as it is carried out under LEA supervision. Although the fishery is open to anyone, the only method by which these species can legally be gathered at present according to local byelaws and EU law is hand capture by divers. This will prevent the use of more destructive methods likely to rapidly deplete stocks.

Mussels are present on intertidal rocks in various places around the bay. Commercial exploitation of these stocks ceased several years ago, although hand gathering for personal consumption continues. Classification sampling recommendations for this species will be included for this species in this report, which can be applied in the future should commercial gathering resume of if the LEA otherwise decides a classification necessary. The area within St Ives Bay potentially requiring classification extends from the Red River to Godrevy Point and Godrevy Island, where the main concentrations are located, and around Carrick Gladden and Porthminster Point on the western side of the bay.

POLLUTION SOURCES

FRESHWATER INPUTS

The catchment area of St. Ives Bay (about 170 km^2) is not particularly large. The majority of this area is drained by two minor rivers (The Red River and The Hayle River), with additional small streams draining to the western end of the bay. These watercourses represent the hydrological connection between terrestrial sources of contamination and coastal waters. For both the Red River and the Hayle River there are marked seasonal variations in discharge volumes, with highest discharge on average during the winter and lowest on average during the summer, although high flow events have been recorded throughout most of the year. A similar pattern is likely to apply to the smaller watercourses within the St. Ives Bay catchment.

The Red River discharges direct to St. Ives Bay across the beach at Godrevy and has a catchment area of about 65km^2, a large proportion of which is pasture, with some arable land and natural areas as well as the town of Camborne. It receives sewage effluent from two minor secondary treatment works with consented dry weather flows totalling 290 m^3/day, as well as from 9 small private septic tank or package plant treated discharges and 8 intermittent water company discharges. Press reports indicate that significant spills of untreated sewage from intermittent water company discharges to the Red River occur on a regular basis, but the Environment Agency was unable to supply more specific information. Water samples taken by the agency from this watercourse during the bathing season generally contained moderate levels of faecal coliforms (geometric mean 690 cfu/100ml) although some very high counts of up to 210,000 cfu/100ml were recorded. Increased concentrations of faecal coliforms were associated with increased rainfall. It is therefore concluded that the Red River is a significant pathway by which contamination is carried into St. Ives Bay, and its impacts will generally be greater following high rainfall events.

The Hayle estuary drains an area of about 95km^2. Land use in this catchment is mainly arable farming, interspersed with pastures and natural areas. The town of Hayle borders the estuary. It receives the effluent from two minor secondary sewage treatment works with a combined dry weather flow of 67.4m^3/day, as well as 29 small private septic tank or package plant treated discharges and 9 intermittent water company discharges. The incidence of spills from these intermittent discharges is unknown. Therefore, the Hayle estuary catchment has a similar profile of inputs to the Red River, but drains a slightly larger area and is more urbanised at its estuary. Contamination from these inputs will be subject to dilution within the estuary before the ebbing tide carries it into St. Ives Bay. No bacteriological surveys have been carried out at the Hayle estuary or watercourses draining to it. A surface seawater sample taken during the shoreline survey from the outer channel of the estuary towards low water contained 870 *E. coli* cfu/100ml, indicating that levels of contamination within this estuary were considerably higher than those encountered in the open waters of St. Ives Bay (range of 12-56 *E. coli* cfu/100ml) at the time, so the ebb plume from this estuary should be considered as a significant source of contamination.

There are three small streams (Stennack River, Primrose Valley Stream, and Carbis Bay Stream) which discharge across the beaches at the western end of St. Ives Bay. The catchments of these are steep, and urbanised in their lower reaches, so may be expected to carry high levels of contamination following significant rainfall. The Stennack River outfall receives effluent from an intermittent water company discharge. Two of these watercourses were sampled on multiple occasions as part of Environment Agency investigations (Stennack River and Primrose Stream) and both were found to carry high average (geometric means of 6,120 and 6,690 cfu/100ml respectively) and peak (1,000,000 and 100,000 cfu/100ml respectively) levels of faecal coliforms. The shoreline survey identified that the Primrose Valley stream was minor in terms of discharge volume relative to the other two, and water samples taken from the Stennack River and the Carbis Bay Stream contained high levels of *E. coli* (80,000 and 16,000 cfu/100ml respectively). Therefore, the Stennack River and the Carbis Bay Stream may be expected to cause localised 'hotspots' of contamination at times of high rainfall, whilst the Primrose Valley Stream may be too small to be of significance outside of its immediate vicinity.

AGRICULTURE

There are relatively high densities of cattle and significant numbers of sheep within the St. Ives Bay catchment area, but it is difficult to be precise about their distribution throughout the area as the livestock census data was not available at sufficiently high resolution. Pastures are most concentrated inland from St. Ives and Carbis Bay, throughout the Red River catchment, and in the upper Hayle catchment, so highest densities of grazing animals may be expected in these areas. Arable land is most concentrated in the lower Hayle catchment and manures, slurries and sewage sludge may be spread in these areas. Therefore, all significant watercourses draining to St. Ives Bay are likely to be impacted by contamination of agricultural origin in some way. The magnitude of flux of contamination from livestock sources to coastal waters will be highly dependent on rainfall. To best capture their impacts representative monitoring points should be set in a position which most exposes them to plumes originating from watercourses draining to the bay.

As well as being influenced by rainfall, it is anticipated that there will be seasonality in impacts from livestock. Greater numbers of animals will be present on pastures during the summer and autumn, so overall impacts may be greatest at these times of year. Highest impact from grazing animals on pastures may therefore be expected in the 'first flush' following high rainfall events in the summer preceded by a dry period. Manures tend to be spread on fields mainly during the late winter and spring, and should heavy rain follow a spreading, significant but more localised impacts may be anticipated.

HUMAN POPULATION

Total resident population within the St. Ives Bay catchment area was about 69,000 at the time of last census (2001). The population is mainly concentrated in the towns of St Ives, Hayle and Camborne. Impacts from sewage generated by this population will depend on the nature and locations of treatment works and their associated discharges.

St Ives Bay is a popular holiday destination, and its population increases significantly during the main summer holiday season. Therefore volumes of waste water received by sewage treatment works in the area are likely to peak during the summer.

SEWAGE DISCHARGES

The main sewage treatment works serving the area is the Hayle STW, with a consented dry weather flow of 19,704 m^3/day. This provides secondary treatment to waste water from St. Ives and Hayle, which is subsequently discharged outside the bay via a long sea outfall to a depth of 16m at chart datum about 500m outside a line drawn between Godrevy Point and St. Ives Head.

Another significant sewage treatment works serves the towns of Camborne, Redruth and Pool which is consented to discharge a dry weather flow of 17,698 m^3/day of secondary treated effluent. It discharges to the north Cornwall coast, just below the low water mark, about 4km east of Godrevy Point.

Four minor sewage treatment works discharge to watercourses draining to St. Ives Bay, two within the River Hayle catchment and two within the Red River catchment. All provide secondary treatment. In total, their consented dry weather flows to the River Hayle and the Red River are 67.4 and 480 m^3/day respectively, so whilst they will contribute to levels of contamination within these watercourses, their impacts within St. Ives Bay are expected to be minor.

Associated with the water company sewerage network are a series of intermittent discharges, STW storm tank overflows, combined (foul and surface water) sewer and pumping station overflows and emergency overflows. Some discharge direct to St. Ives Bay, and others discharge to either the Hayle estuary or watercourses within the St. Ives Bay catchment area. Information on spill frequency and/or spill volumes were requested from the Environment Agency, but were not available at the time of writing. Therefore it is difficult to assess the potential impacts of any of these aside from noting their location and their potential to cause localised hotspots of contamination at times and an increased likelihood of this occurring after heavy rain. Press reports suggest that regular discharges of untreated sewage are made to the Red River from overflow discharges associated with the Camborne sewerage network, resulting in sewage related debris arriving at Godrevy Beach.

In summary, the largest continuous discharge is from Hayle STW, but this discharges offshore from St. Ives Bay, so whether it impacts on water quality within the bay will depend on patterns of water circulation. The smaller Camborne STW discharge is located about 4km east along the coast from St. Ives Bay, and so may have some impacts, primarily towards the eastern end of the bay. Other continuous minor water company and private discharges in the area discharge to watercourses or the Hayle estuary, and are likely to make some contribution to the bacterial loading carried into St. Ives Bay. Intermittent water company discharges have the potential to cause significant impacts, specifically at St. Ives/Carbis Bay, within the Hayle estuary and to the Red River. The Red River is reported to be regularly affected by these, but no detailed information on spill frequency was available for any of these intermittent discharges.

BOATS

Hayle is the main harbour in St. Ives Bay, but there is also a drying harbour at St. Ives. The harbour at Hayle is not generally used by visiting yachts, but hosts about 50 small fishing boats and cabin cruisers. Development of Hayle Harbour may occur at some point in the next few years, and this would include the construction of a marina. Should this development occur, increased numbers of the larger live aboard yachts may be expected in the bay. Within St. Ives Harbour about 90 small boats were recorded on drying moorings were recorded during the shoreline survey, but none of these were large enough to have onboard toilets. Just off from St. Ives 9 boats were recorded on moorings, of which possibly two may have had on board toilets. About 150 overnight yacht visits are made to these moorings during the summer time. Therefore it is concluded that there may be some inputs to St. Ives Bay from fishing boats *en route* to and from Hayle Harbour, and from visiting yachts just off St. Ives. These will however be relatively minor and unpredictable, and so have no real bearing on the sampling plan.

Wildlife

Wildlife populations which may contribute to contamination within St. Ives Bay include up to 18,000 wildfowl overwintering in the Hayle estuary, resident and breeding populations of about 1,500 seagulls spread throughout the area, and a colony of up to about 60 grey seals at Godrevy Point. Contamination from wildfowl will be carried into the bay via the Hayle estuary, and will be mainly confined to the winter months. It would be captured by an RMP located to reflect contamination within the Hayle estuary plume. Contamination from resident and breeding seagulls is likely to be widely spread around the bay, so does not influence the location of any RMPs. Contamination from seals may be most concentrated at their haul out sites at Godrevy Point, impacts from this species, if any, would be strongest towards the north east corner of the bay.

Domestic animals

The beaches in St. Ives Bay are popular for dog walking, although dogs are banned from some of the more popular beaches in the western half of the bay from Easter to the 1st October and dog owners are encourage to clean up after their pets. Therefore, dog faeces present a potential source of diffuse contamination to nearshore shellfish beds and are likely to be distributed widely around the bay, although not in the western half during the summer months.

Summary of Pollution Sources

The two largest identified sources of contamination within St. Ives Bay are the Red River and the ebb plume from the Hayle estuary, both of which receive sewage and agricultural inputs. There are also some smaller streams and sewage overflows in the St Ives/Carbis Bay area, and diffuse inputs from wildlife and dogs may be felt throughout the area. The Hayle STW discharges just outside the bay at depth so would not be expected to impact significantly within the bay (apart from at Godrevy Island) except under strong northerly winds and neap tides.

Table 3.1 Qualitative assessment of changes in pollution load.

Pollution source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sewage treatment works												
Intermittent discharges												
Agriculture												
Waterbirds, seals & dogs												
Peak human population												

Red - high risk; orange - moderate risk.

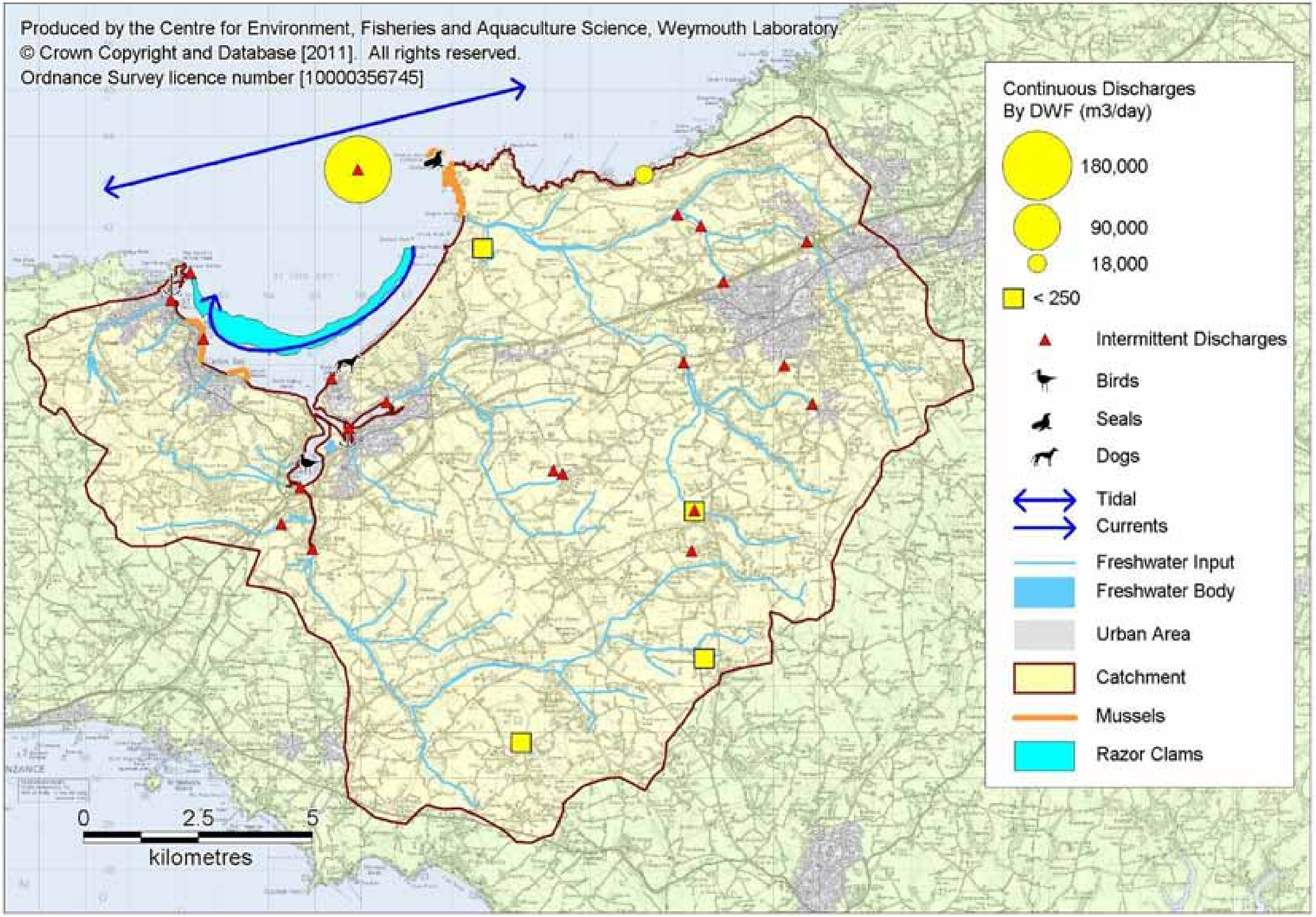


Figure 3.1 Significant sources of microbiological pollution to St Ives Bay.

WATER CIRCULATION PATTERNS

Tidal streams along the north coast of Cornwall run parallel to the coast, flooding in a north easterly direction and ebbing in a south westerly direction. St. Ives Bay is recessed into this coast, and for the majority of the tidal cycle there is reported to be a clockwise circulation within the bay. At the head of the bay lies the Hayle estuary, a partially enclosed body of tidal waters which receives freshwater inputs from the Hayle catchment. Freshwater inputs to the bay are not large, so in St. Ives Bay, outside of the Hayle estuary, density effects are not anticipated to modify tidally driven flows. Wind effects may modify circulation patterns within the bay at times, driving surface currents and creating return currents lower down the water column. Onshore winds will also increase wave action, which may increase mixing within the bay as well as potentially resuspending any contamination within the sediment.

The generally clockwise circulation within the bay suggests contamination from shoreline sources such as watercourses may be expected to impact most heavily close to the shore to their immediate west, and it is possible that their cumulative effects will result in higher general levels of contamination at the western end of the bay. Contamination arising from sources discharging to the Hayle estuary will be carried into St. Ives Bay via the ebb tide. During its passage through the estuary it will be subject to dilution, so whilst remaining a significant source, it will not create such an intense hotspot of contamination as would be anticipated from a more direct, concentrated source.

The largest identified contamination source in the survey area is the Hayle STW long sea outfall, which discharges outside the bay. The majority of contamination from this source becomes entrained in the main tidal stream running along the north Cornwall coast rather than being carried into the bay under most conditions. Generally impacts from this discharge on shellfish, are therefore only anticipated on the mussels at Godrevy Island. However, under strong onshore winds and neap tides, the plume from this discharge, which is likely to be buoyant and float to the surface, may be driven into the bay which could result in a significant decrease in water quality. Under these circumstances the greatest impacts are likely to arise in the eastern half of the bay, but the exact pattern of impact will depend on the precise (but unpredictable) interaction of wind and tide. Effluent from the Camborne STW discharge, which is located on the coast about 4km east of Godrevy Head, may be carried as far as the eastern end of St. Ives Bay on an ebb spring tide, although by the time it reaches there it is likely to be highly diluted.

SUMMARY OF EXISTING MICROBIOLOGICAL DATA

The most comprehensive microbiological dataset for St. Ives Bay derives from the Bathing Waters monitoring programme, under which about 20 water samples are taken between May and September every year from 6 sites around the bay. The sample sites ranked Porthminster>Godrevy>Station Beach>Porthgwidden>Porth Kidney>Hayle (Table XI.1) in terms of geometric mean faecal coliforms results. Therefore, contamination levels were highest on average at Porthminster and Godrevy, and lowest at the beaches either side of the Hayle Channel. At all these sites higher results were correlated with increased recent rainfall, with the strongest correlations generally found at the sites with higher overall geometric mean levels of faecal coliform results. This implies that rainfall dependent sources of contamination are of significance within St. Ives Bay. The two sites either side of the Hayle estuary (Porth Kidney and Hayle) showed the weakest correlations between faecal coliforms and rainfall despite their proximity to the estuary mouth. An influence of the spring neap tidal cycle was found at all sites. This was weakest at the western end of the bay, and strongest at the eastern end of the bay. Increased levels of contamination generally arose as tide size increased from neaps to springs, but this pattern was only strongly apparent at the western end of the bay. This implies that contamination deposited towards the high water mark (e.g. dog / bird / seal faeces) may be of significance or may be due to more remote sources impacting as a result of increased tidal excursion over spring tides. An influence of the high low tidal cycle was only found at the two sites either side of the Hayle estuary, where levels of faecal coliforms were consistently higher around low water. This implies that the more contaminated water ebbing from this estuary is a significant influence of water quality in the centre of the bay.

Under the shellfish hygiene classification programme mussel samples from 5 sites were taken for *E. coli* analysis on varying occasions between 1998 and 2004. Overall, results were similar throughout the bay and were highest on average at Gillick Rock, and lowest on average at Porthminster A. A comparison of paired samples taken from Godrevy and Wacky's Cave, on either side of the bay showed not only similar levels of contamination, but similar temporal fluctuations in contamination suggesting they were impacted by similar sources. However, results from Wacky's Cave showed a statistically significant influence from rainfall and the spring neap tidal cycle, whereas Godrevy did not.

As the bathing waters samples and mussel hygiene classification samples were all taken from the intertidal zone, and the razor beds are located a small distance offshore the spatial profile in levels of contamination within the razor beds may not align with the patterns observed with intertidal samples. It is likely that any ‘hotspots’ created by shoreline sources discharging to the beach are less acute at the razor beds as they will be subject to some dilution before reaching the razor beds. The ebb flows from the Hayle estuary, which are relatively large in volume but more lightly contaminated than for example freshwater streams draining directly across the beaches may be of more relative impact to the razor beds.

After undertaking a shoreline survey, a bacteriological survey of the area was requested. This involved sampling from three points within the razor bed (St. Ives East / St. Ives Central / St Ives West) to capture contamination from identified sources of contamination (Hayle STW & Red River / Hayle Estuary / assorted shoreline sources in the vicinity of St Ives). On the first sampling attempt, it was found that there was no stock present at St. Ives East. Results were similar at the two other monitoring points, with results highest on average at St. Ives Central, but the only result exceeding 4600 *E. coli* MPN/100g arose at St. Ives West. Based on this one high result, the St. Ives West monitoring point should be adopted for routine monitoring. However, the geometric mean result was higher at St. Ives Central, and the sanitary assessment has identified the ebb plume from the Hayle estuary as the largest source of contamination to this part of the bay, so on balance the adoption of the St. Ives Central RMP to monitor the central and western areas of the bay is preferable. This report has identified that the eastern part of the bay may be subject to contamination from the Red River, and possibly Hayle STW outfall under certain conditions, so extending any classification derived from St. Ives Central throughout the eastern part of the bay should not be recommended without additional monitoring, preferably targeting specific conditions likely to be associated with increased bacterial loadings from the Red River (i.e. heavy rainfall).

4. RECOMMENDATIONS

4.1 On the basis of an analysis of sources of contamination, the St. Ives Central Representative Monitoring Point (RMP) (SW 5432 3928) should be sufficient to effectively monitor the central and western parts of the razor bed as it is well located to capture any contamination from the ebb plume of the Hayle estuary, and on average bacteriological survey results were higher here than at St. Ives Bay West.

4.2 The eastern part of the razor bed extends towards a significant shoreline source of contamination (the Red River) which is believed to receive regular inputs of untreated sewage, as well as inputs from agricultural sources and small sewage treatment works. It is also likely that this part of the bay is most prone to any potential impacts from the main Hayle STW discharge. It is therefore recommended that 10 monthly samples should be taken from SW 5715 4153 in parallel with the St. Ives Central RMP before the classified area is extended to encompass the entire extent of the bed. Following this period of parallel monitoring, assuming the classification derived from these two points is the same, the entire area could be monitored using the RMP which yielded the highest individual result. The area classified on the basis of results from the St. Ives Central RMP, within which the majority of the razor stocks lie, should provide the harvester with sufficient classified resource to exploit in the meantime.

4.3 Mussel stocks within St. Ives Bay do not currently require classification, so classification sampling arrangements described below should not be implemented unless the LEA identifies a specific need for classification of these stocks. Monitoring may be undertaken on either a monthly or weekly basis towards a full or provisional classification depending on the urgency with which classification is required.

4.3 For mussel stocks in the eastern half of the bay, an RMP located on Magow Rocks, which lie immediately adjacent to the Red River (SW 5812 4229), and would be best placed to capture contamination from this source, which is the most significant shoreline source to the area.

4.4 If the classified area for mussels in the eastern half of the bay is to include Godrevy Island, it is recommended that an additional RMP at SW 5773

4340 is used to classify stocks around this island, which are likely to be subject to contamination from the main Hayle STW discharge entrained in the along shore tidal streams running along this stretch of coast rather than any shoreline sources within the bay. Should parallel monitoring at Godrevy Island and Magow Rocks result in the same classification after 10 sampling events, the two zones should be combined and monitored thereafter from whichever RMP yielded the highest individual result.

4.5 For mussel stocks in the western half of the bay, the most significant source likely to impact on them is the ebb plume from the Hayle estuary. It is therefore recommended that the RMP for mussels in this half of the bay is located at Carrick Gladden (SW 5352 3874), which is the closest point within this area where stocks are believed to be present.

4.6 All razor RMPs should be assigned a tolerance of 100m to ensure there is sufficient stock for repeated sampling. Mussel RMPs should be assigned a tolerance of 10m. Should there be insufficient stock for repeated sampling at any of the recommended RMPs, the LEA are to consult CEFAS regarding their relocation, or the possible use of bagged shellfish in the case of mussels.

4.7 This report should be reviewed in 6 years time, or in the event that any further information of significance comes to light in the meantime. Specifically, the assessment may require modification should information become available on any Hayle STW outfall dispersion assessments, spill information from intermittent discharges, or field level information on the application of sewage sludge and manures especially in the lower catchment and land immediately bordering the Bay and its principal watercourses.

5. SAMPLING PLAN

GENERAL INFORMATION

Location Reference

Production Area	St. Ives Bay
Cefas Main Site Reference	M070
Cefas Area Reference	FDR 3529
Ordnance survey 1:25,000 map	OS Explorer 105 (Falmouth & Mevagissey)
Admiralty Chart	Admiralty 148 (Dodman Point to Looe Bay) Admiralty 442 (Lizard Point to Barry Head)

Shellfishery

Species/culture	Razors (*Ensis* spp.) Mussels (*Mytilus* spp.)	Wild
Seasonality of harvest	Year round	

Local Enforcement Authority

Name	Cornwall Port Health Authority The Docks Falmouth TR11 4NR
Environmental Health Officer	Terry Stanley
Telephone number (	01326 211581
Fax number	01326: 211548
E-mail š	t.stanley@cieh.org.uk

REQUIREMENT FOR REVIEW

The need for this sampling plan to be reviewed will be assessed by the competent authority within six years or in light of any obvious known changes in sources of pollution of human (e.g. improvements in sewage treatment works) or animal origin likely to be a source of contamination.

Table 5.1 Number and location of representative monitoring points (RMPs) and frequency of sampling for classification zones in St. Ives Bay

Classification zone	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
St Ives West and Central	B088G	St Ives Central	SW 5432 3928	50°12.15N 5°26.65W	*Ensis* spp.	Wild	Hand (salting by diver)	Hand (salting by diver)	100m	Monthly	May be combined with St Ives East zone if following 10 parallel samples both zones achieve the same classification. Combined zone to be monitored at whichever RMP yields the highest individual result. Otherwise, separate monitoring and classification to continue.
St Ives East	TBA	St Ives East	SW 5715 4153	50°13.43N 5°24.36W	*Ensis* spp.	Wild	Hand (salting by diver)	Hand (salting by diver)	100m	Monthly	As for St. Ives West and Central.
Red River to Godrevy Point	TBA	Magow Rocks	SW 5812 4229	50°13.86N 5°23.58W	*Mytilus* spp.	Wild	Hand	Hand	10m	Monthly (or 10 samples not less then 1 week apart if greater urgency)	Monitoring only to be initiated if need for classification identified by LEA. May be combined with Godrevy Island zone if following 10 parallel samples both zones achieve the same classification. Combined zone to be monitored at whichever RMP yields the highest individual result.
Godrevy Island	TBA	Godrevy Island	SW 5773 4340	50°14.45N 5°23.95W	*Mytilus* spp.	Wild	Hand	Hand	10m	As previous	As for Red River to Godrevy Point.
St Ives West	TBA	Carrick Gladden	SW 5352 3874	50°11.83N 5°27.30W	*Mytilus* spp.	Wild	Hand	Hand	10m	As previous	Monitoring only to be initiated if need for classification identified by LEA.

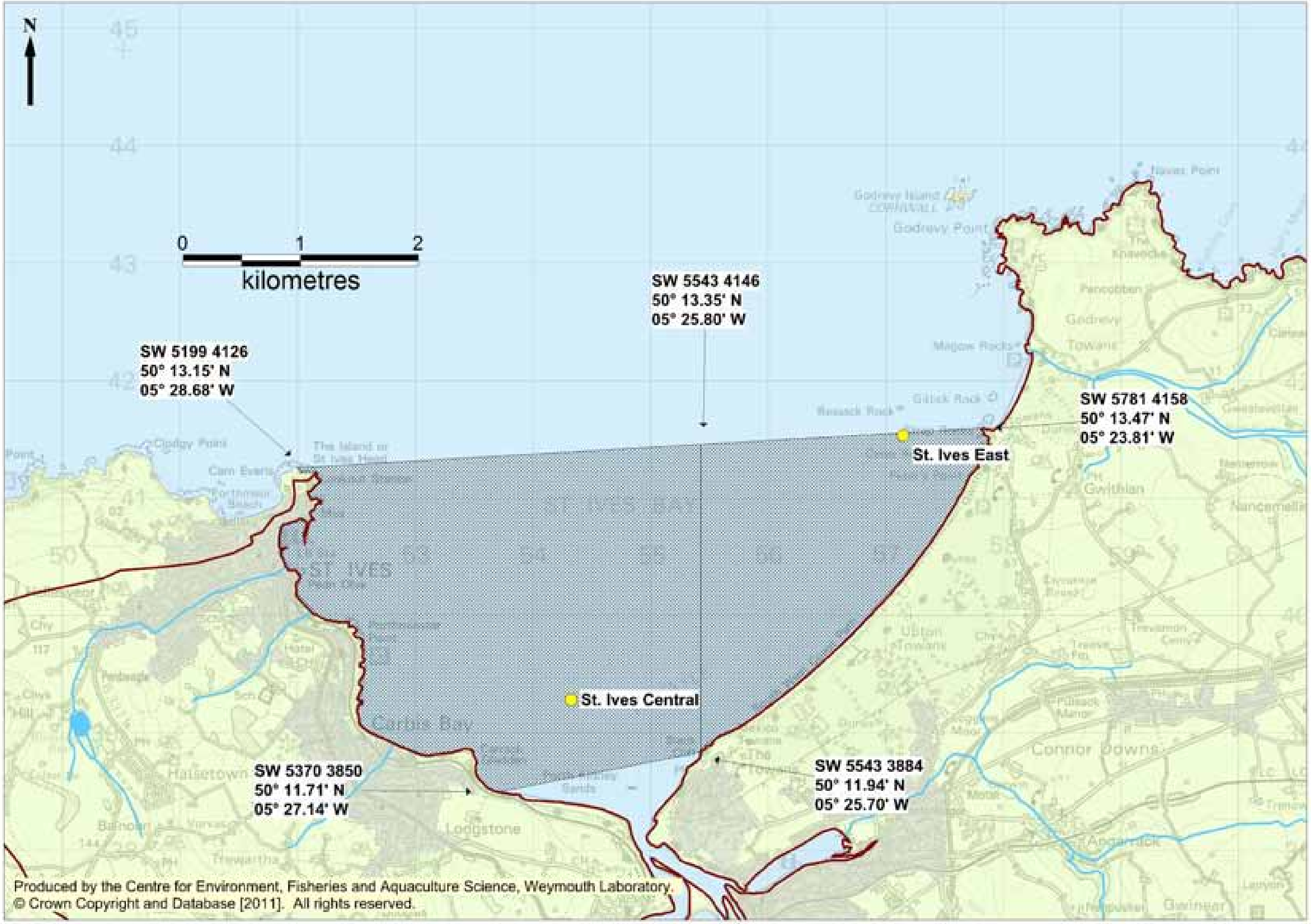


Figure 5.1 Recommended classification zone boundaries and RMP locations for razors in St Ives Bay.

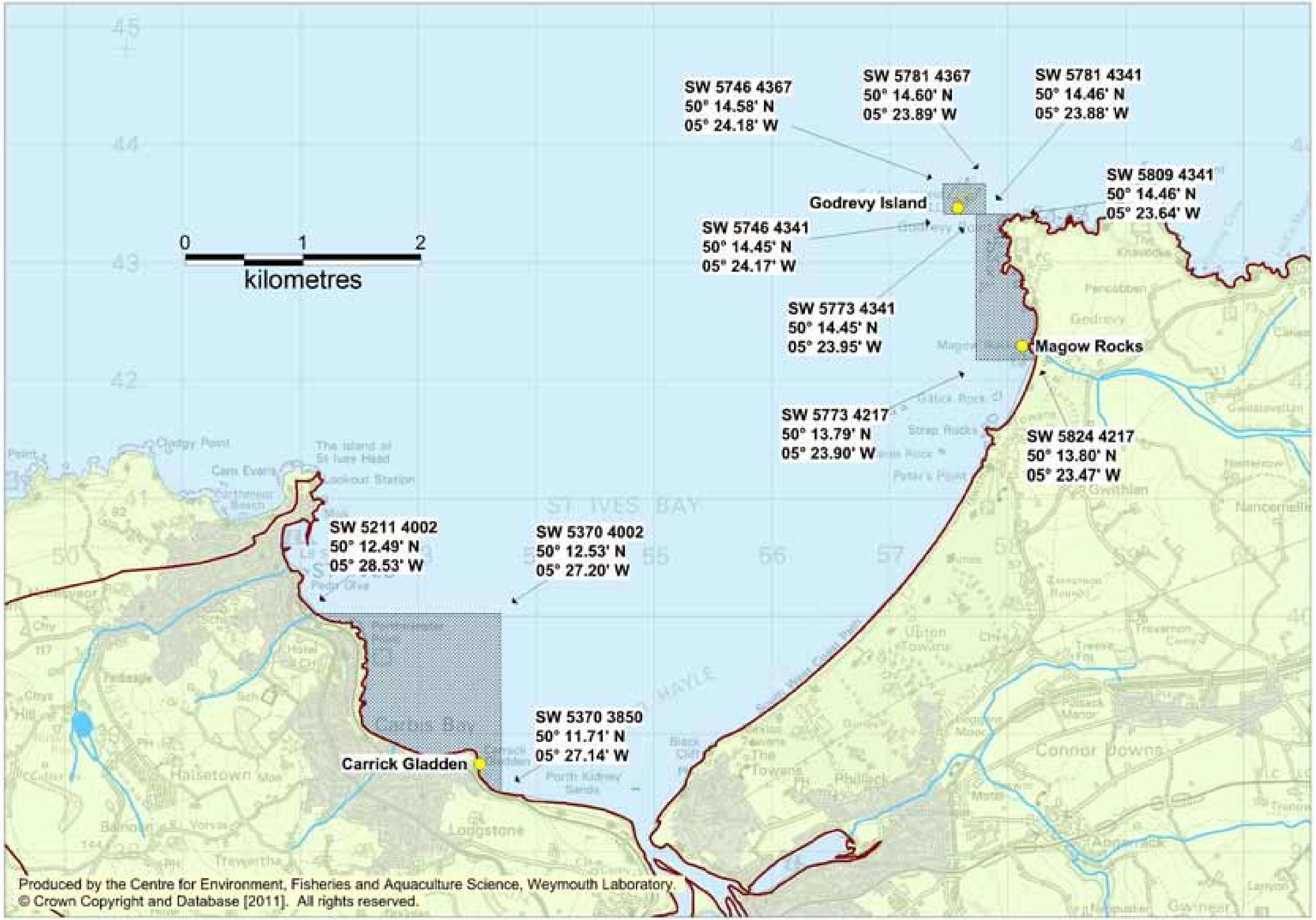


Figure 5.2 Recommended classification zone boundaries and RMP locations for mussels in St Ives Bay.

APPENDICES

APPENDIX I
HUMAN POPULATION

Figure I.1 shows population densities in census output areas within or partially within the St. Ives Bay catchment, derived from data collected at the time of last census (2001).

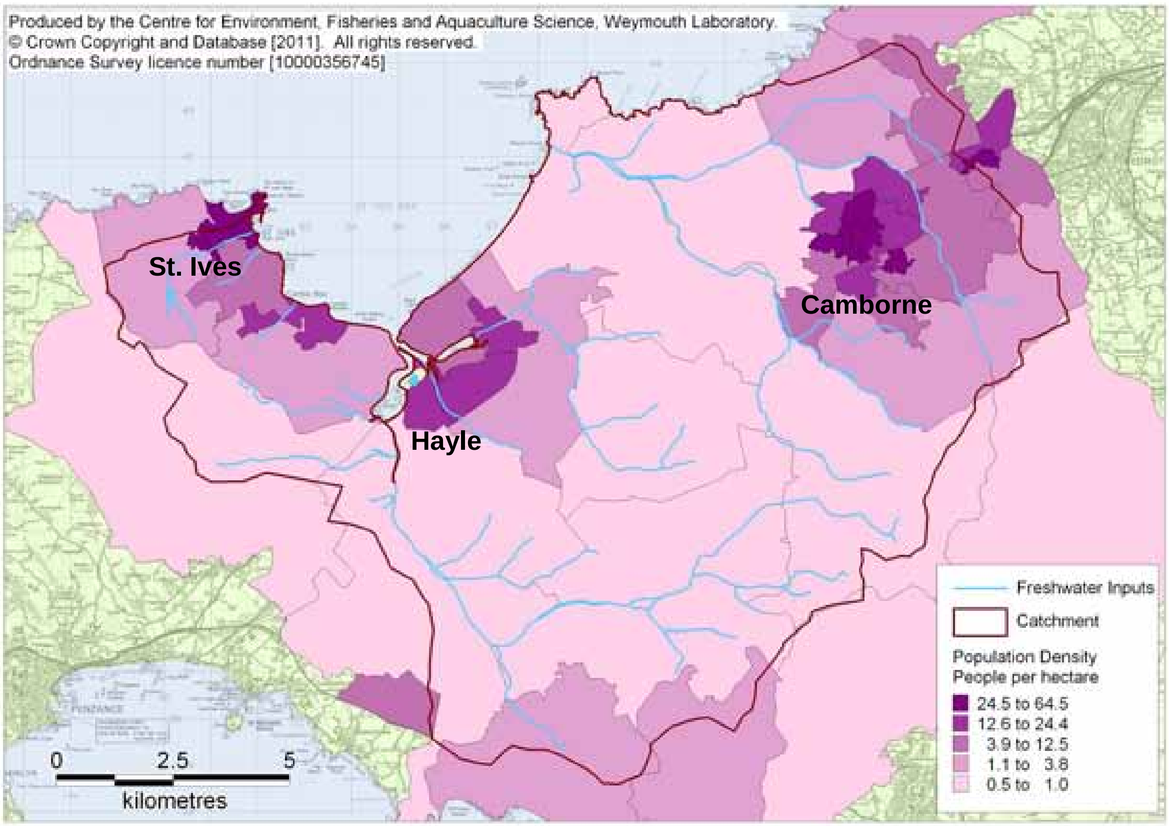


Figure I.1 Human population density in Census Areas bordering St. Ives Bay.

Total resident population was about 69,000 at the time of last census. Figure I.1 indicates that population densities are highest at the towns of St Ives, Hayle and Camborne. Therefore, the western part of the bay may be more prone to contamination from urban runoff, although runoff from urban areas at Camborne will be conveyed into the eastern end of the Bay via the Red River. Impacts from sewage will depend on the nature and locations of discharges associated with these settlements and are discussed in detail in Appendix VII.

St Ives Bay is bordered by attractive sandy beaches and the towns of St. Ives and Carbis Bay are popular tourist destinations in themselves. There are many other attractions in the area such as the Eden Project and Land's End. Cornwall online listed 41 B&Bs/Hotels and just over 100 establishments offering self catering accommodation in the vicinity of St. Ives Bay. A large proportion of private houses in the area are second (holiday) homes, and Penwith District council reported that over 20% of all residences in St. Ives were second homes in 2007 (BBC, 2008). Occupancy survey statistics for tourist accommodation in Cornwall in 2006 indicate lowest occupancy rates in January (31% in hotels/B&Bs, 13% in self catering) steadily increasing to a peak in August (85%

in hotels/B&Bs, 99% in self catering) steadily declining to December for hotels (37%), and steadily declining to November for self catering (20%) but with a small upturn to 33% in December (Cornwall County Council, 2006). Therefore it can be concluded that there will be highly significant seasonal variation in population levels in the catchment of St. Ives Bay, and that population will be highest in summer and lowest in winter, and bacterial loadings from sewage treatment works serving the area will fluctuate accordingly.

APPENDIX II
HYDROMETRIC DATA: RAINFALL

The southwest of England is one of the wettest regions in the UK. Annual precipitation totals in the district have been increasing in recent years to nearly 1,300mm (Perry, 2006). The pattern is heavily influenced by the topography, which forces the moisture-laden air to precipitate high levels of rainfall over higher ground, although the elevation only rises to just over 200m within the St. Ives Bay catchment. Figure II.1 presents box and whisker plots of daily rainfall values at the Hayle weather station (Figure III.1 for location) recorded between 2000 and 2010.

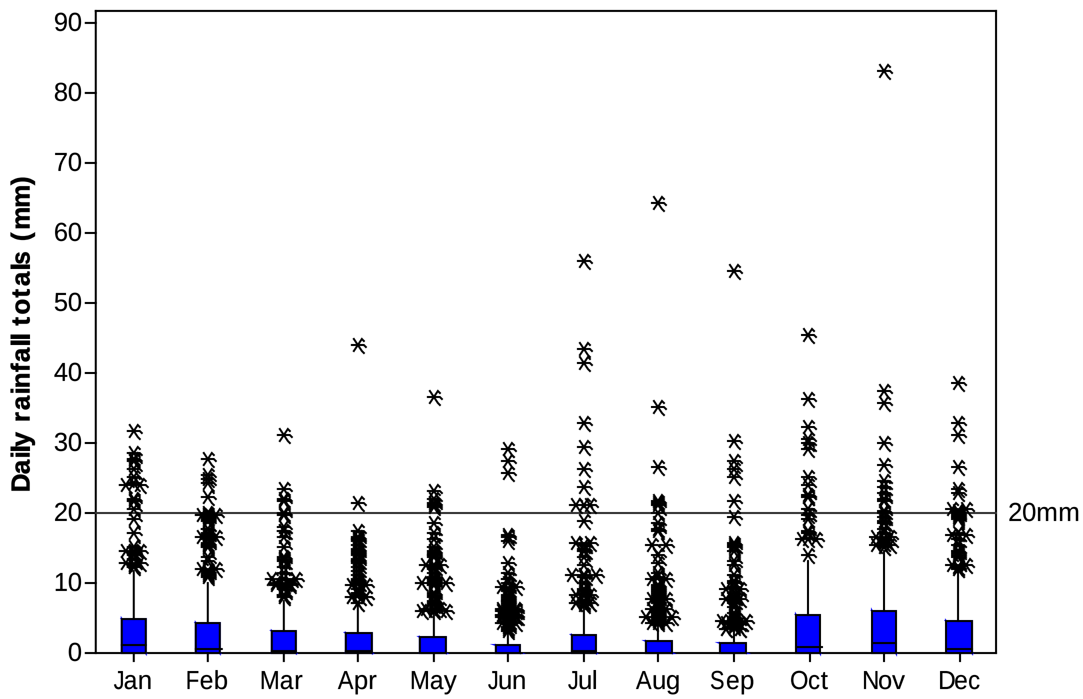


Figure II.1. Box and whisker plot of total daily rainfall values (Jan 2000 to May 2010) by month at Hayle.
Data from the Environment Agency (2010).

Rainfall is generally highest from October through to February, and lowest from June to September. Therefore, river discharge and volumes of runoff from pastures are likely to be highest from October to February. High rainfall events of over 20mm in a day were recorded in every month of the year, and so sewer overflows may happen at any time of the year. High rainfall events following a period of dry weather may generate a ‘first flush’ of more contaminated runoff from pastures.

An examination of the relationship between levels of faecal coliforms in designated bathing waters in the vicinity of St. Ives Bay and recent rainfall is given in Appendix XI, and similar evaluations of shellfish hygiene flesh monitoring data and Environment Agency bacteriological monitoring of streams in the area are presented in Appendix XII and XIII respectively.

APPENDIX III
HYDROMETRIC DATA: FRESHWATER INPUTS

Figure III.1 shows the most significant freshwater inputs to St. Ives Bay.

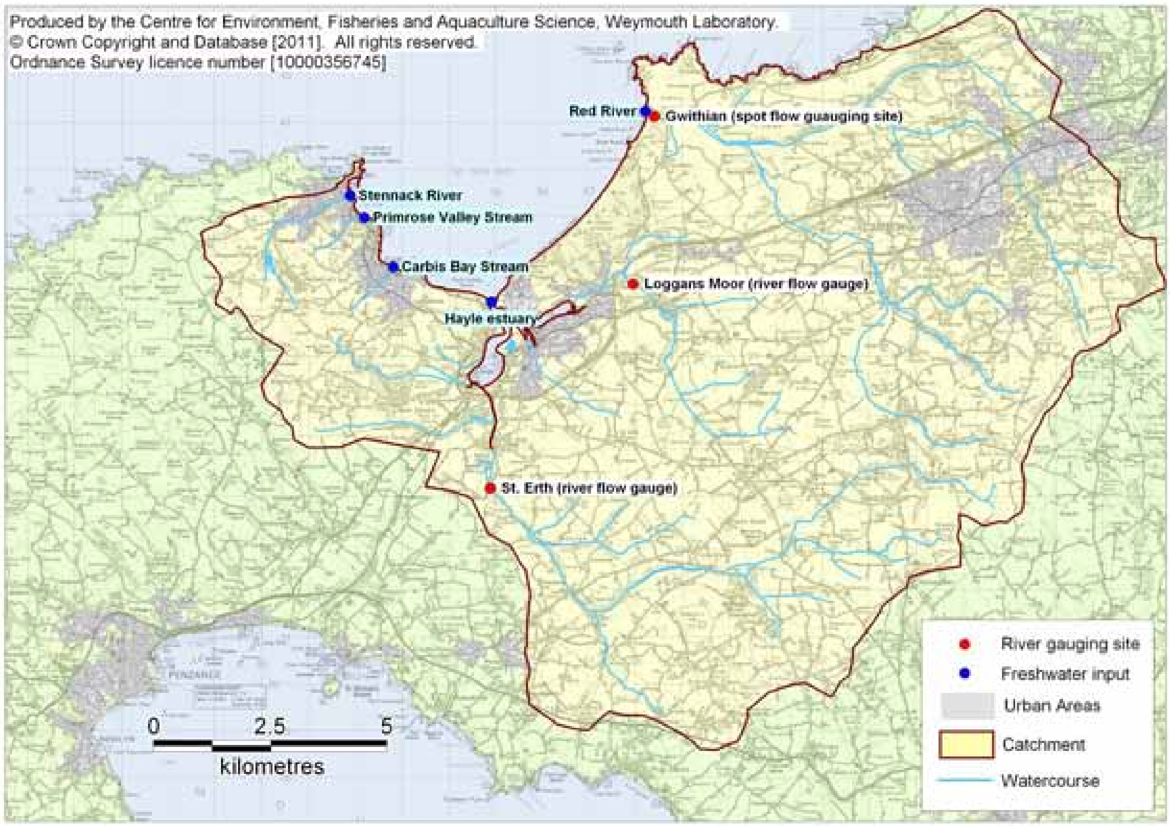
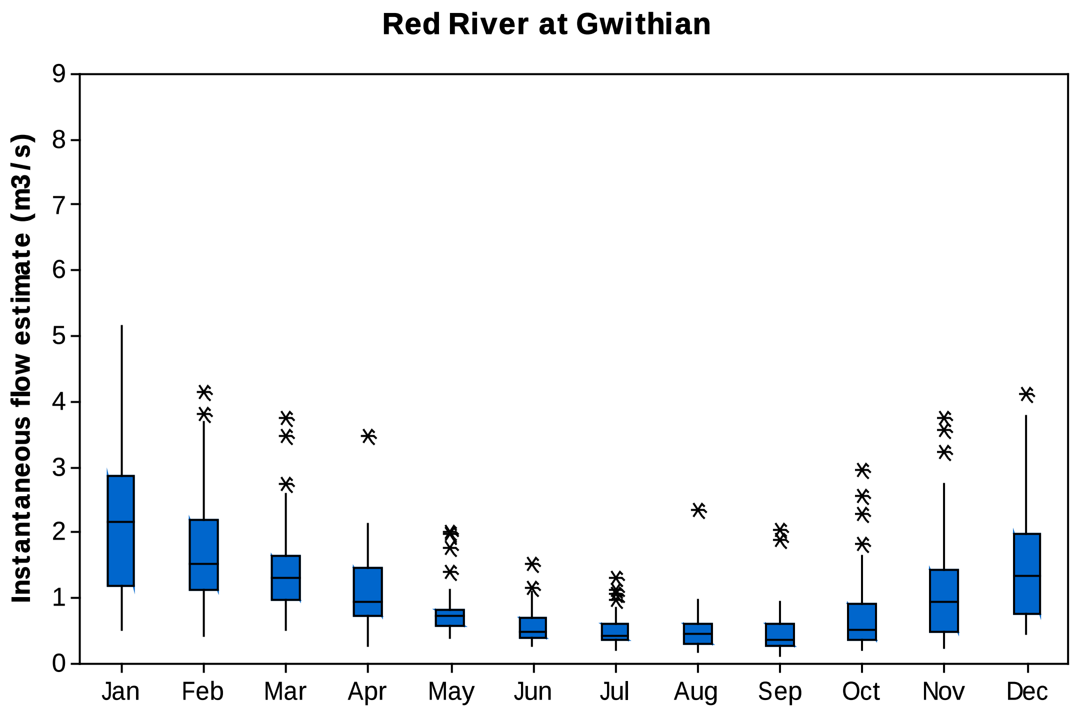


Figure III.1 Freshwater inputs to St. Ives Bay and location of gauging sites

The two main freshwater inputs to St. Ives Bay are the Red River, which discharges direct to the bay at Gwithian, and the Hayle, which discharges near the centre of the bay via the Hayle estuary, to which a number of smaller watercourses also discharge. Three much smaller watercourses discharge at St Ives and at Carbis Bay. Land within the St. Ives Bay catchment is a mixture of pasture, arable land, natural areas and urban areas. Flow gauging records were available for three sites within the St. Ives Bay catchment. At Gwithian, on the Red River, instantaneous flow measurements were made on a total of 621 occasions from 1972 to present. At St. Erth on the River Hayle, records of mean daily flow from 2000 to 2010 were available. Flow gauging records for these two stations are presented as boxplots in Figure III.2. At Loggans Moor on the Angarrack Stream flow estimates made at 15 minute intervals were available for only a small part of 2008. These are not presented in Figure III.2, but for comparison, the average flow recorded here during this period was 0.3 m^3/s, whereas it was 0.58 m^3/s at St. Erth.

Discharge of the Hayle and the Red River are generally lowest from May to September and are highest on average during December and January, although elevated flow events do occasionally occur during the summer.



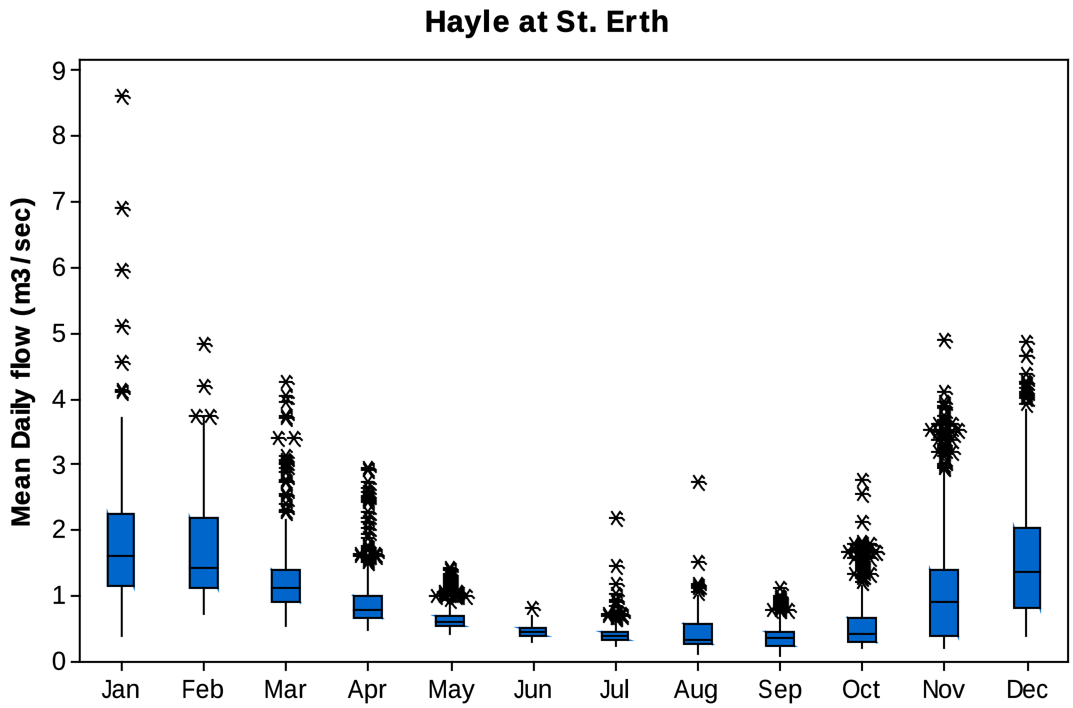


Figure III.2. Box and whisker plot of flows recorded on the Hayle and the Red River.
Data from the Environment Agency (2010).

The Stennack River and the Red River were both sampled on multiple occasions for faecal coliforms by the Environment Agency as part of an investigation into bathing water quality (Appendix XIII). The results of these indicate that the Stennack River carried higher average and peak levels of contamination, but the latter was also highly contaminated at times, and due to its larger catchment area would be expected have a considerably higher discharge. For both these watercourses, the concentration of faecal coliforms tended to increase with increasing recent rainfall. Greater volumes will be discharged under wet conditions further increasing their importance as a source of contamination. It is likely that other watercourses discharging to St. Ives Bay would also respond in a similar manner to rainfall, although the very minor stream (Primrose Valley Stream) discharging across Porthminster Beach did not show this relationship (Appendix XIII).

Kay *et al*. (2008a) investigated catchment export coefficients for faecal indicator bacteria (cfu km^{-2} hr^{-1}) in a range of river catchments in the UK under a range of conditions, and found that these increased by roughly 2 orders of magnitude from base to high flow conditions in both summer and winter. Whilst catchment export coefficients were not significantly different at base flow conditions between summer and winter, at high flow conditions they were significantly higher in summer than in winter. This seasonal difference was attributed to lower faecal input to pasture land and more frequent flushing under the generally wetter conditions experienced during winter.

APPENDIX IV
HYDROGRAPHIC DATA: BATHYMETRY

St Ives Bay is an open, north facing bay with an uncomplicated bathymetry (Figure IV.1) recessed into the north Cornwall coast. The bottom gently slopes down to about 20m below chart datum in the centre of the bay. About 1km offshore from Godrevy Island, at the north east extremity of the bay there is a reef known as The Stones, which may affect the pattern of flows along the coast. Between Godrevy Island and The Stones, there is a deeper channel known as The Sound.

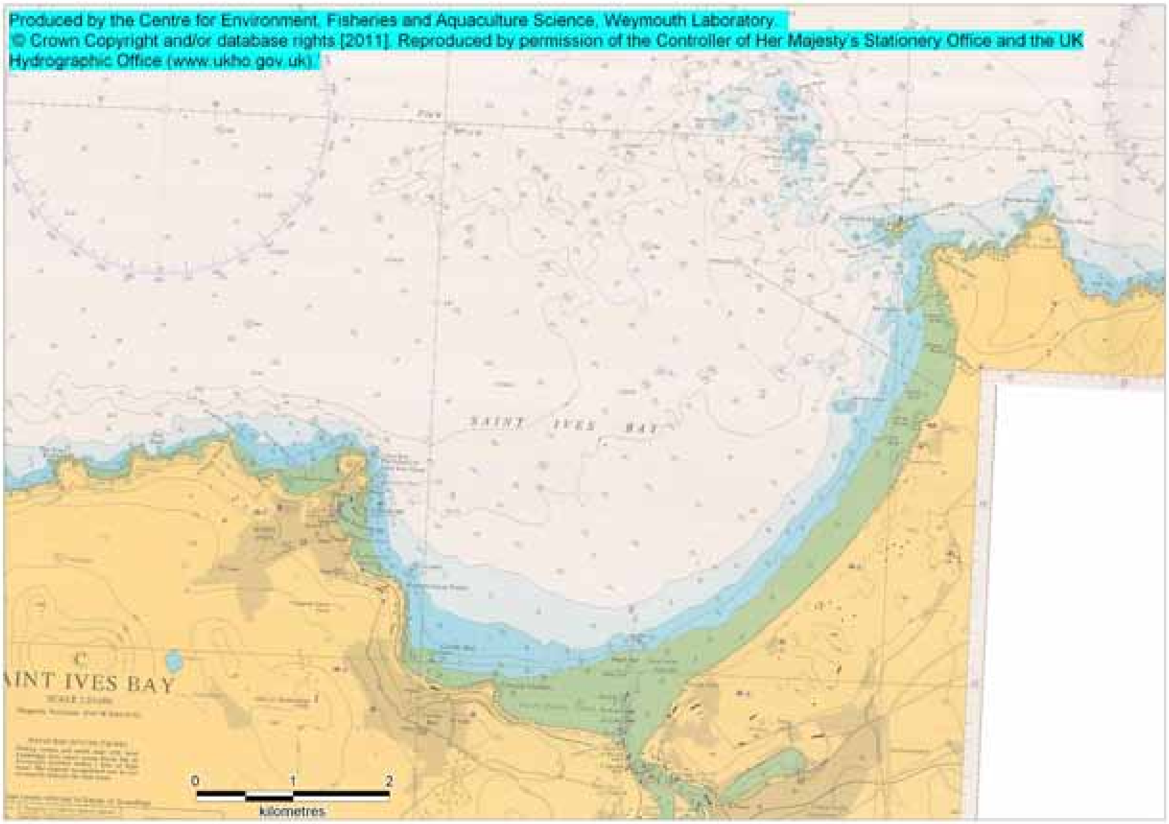


Figure IV.1 Bathymetry of St. Ives Bay.

The focus of the razor fishery will be between the 5 and 10m depth contours as far to the east as Bessack Rock. This covers an area of approximately 2km^2, is widest at Carbis Bay, and lies between 100m and 1.2km out from MLWS.

APPENDIX V
HYDRODYNAMIC DATA: WATER CIRCULATION PATTERNS

TIDALLY DRIVEN CIRCULATION

Mean high and low water levels and the spring and neap tidal range are shown for the nearest port to the proposed new harvesting area in St. Ives Bay in Table V.1.

Table V.1 Tide levels and ranges in St Ives Bay.

	Height (m) above Chart Datum				Range (m)	
Port	MHWS	MHWN	MLWN	MLWS	Spring	Neap
St. Ives	6.60	4.90	2.40	0.80	5.80	2.50

Predictions are based on Milford Haven.
Data from Proudman Oceanographic Laboratory (2010).

Tidal streams along the north coast of Cornwall are generally bi-directional, running parallel to the coast. The nearest tidal diamond is off from Perranporth, about 25km to the north west, and here peak spring currents are 0.46 m/s and peak neap currents are 0.21 m/s on both the ebb and the flood. Based on this tidal diamond, tidal excursion along this stretch of coast is expected to range from about 3km on neap tides to 6km on neap tides. St. Ives Bay is recessed into the coast, and an underwater reef extends from Godrevy Head, and these will complicate flow patterns in comparison to the tidal streams described above. Tidal currents are likely to speed up off Godrevy Head, and increased mixing due to turbulence may occur here. Within St. Ives Bay tidal streams are likely to be weaker than offshore, and eddies may form on various scales. A search of peer reviewed literature and internet sources did not reveal any published information on hydrographic observations or modelling within St. Ives Bay of suitable detail to be of relevance to this assessment.

Informed local sources (the harvester and the St. Ives Harbourmaster) advise that for the majority of the tidal cycle there is a clockwise circulation within the bay. On this basis, shoreline sources within the bay will tend to have the greatest impacts just to the west of where they discharge, and there may be a slight increase from east to west as the effects of these shoreline sources accumulate.

The Hayle STW long sea outfall lies about 500m outside a line drawn between Godrevy Point and St. Ives Head. Therefore, it might be anticipated that the majority of the contamination from this source would become entrained within the offshore bi-directional tidal streams along the north Cornwall coast rather than impacting within the bay. Before this outfall was constructed South West Water carried out investigations into the plume dispersal from this point. The study included drogue tracking, releases of dye and bacterial spores, deployment of current meters and some modelling (South West Water, 1990). This confirmed that for the vast majority of the time effluent from the outfall would not enter St. Ives Bay, although under neap tides and strong northerly winds the plume may be pushed into the bay in part at least. It also confirmed the presence of a clockwise rotation in the eastern half of the bay due to the formation of a gyre on the flood tide.

Effluent from Camborne STW discharge, which is located on the coast about 4km east of Godrevy Head, will be carried up and down the north Cornwall coast by the tidal streams. Although tidal excursions offshore within this tidal stream are in the order of 3km during neaps to 6km during springs, it is likely that in they are retarded by friction in the immediate vicinity of the shore. Therefore it is unlikely that effluent from this discharge is carried as far as Godrevy Head during a single ebb tide apart from on the largest spring tides, and by the time it reaches there it is likely to be subject to significant dilution.

Contamination arising from sources discharging to the Hayle estuary will be carried into St. Ives Bay via the ebb tide. During its passage through the estuary it will be subject to significant dilution, so the profile of impacts within St. Ives Bay from this source are likely to be more diffuse than that for point sources and watercourses discharging directly to the shore of the bay (i.e. the plume will consist of a large volume of lightly contaminated water as opposed to a small volume of more heavily contaminated water).

Density Effects

In general terms, both warmer water and less saline water will originate at/near the shore from either freshwater inputs or the heating of shallow waters. As they are more buoyant they will form a seaward moving surface layer, in turn driving return flows in the opposite direction towards the bottom of the water column. Any thermal stratification is more likely to occur during summer, whereas salinity stratification may be expected more during the winter when freshwater inputs are generally higher. The relatively low freshwater input to the bay would suggest any salinity stratification would be highly localised and minimal in relation to wind and tide effects. One consequence of density effects of possible significance is that the effluent from the Hayle STW outfall will tend to float to the surface.

Wind Effects

Strong winds may significantly modify patterns of water circulation within St. Ives Bay. Winds typically drive surface water currents at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2m s^{-1}) would drive a surface water current of about 1 knot or 0.5m s^{-1}. These in turn will drive return currents lower in the water column, so wind driven surface currents may actually be flowing in an entirely different direction to those lower in the water column at the razor beds. The bay is most exposed to the north west, and winds from this direction would drive surface currents in an onshore direction, but towards the bottom water may be flowing in the opposite direction, carrying contamination from the nearshore region towards the razor beds. Associated wave action is likely to disrupt this somewhat through mixing, particularly in the eastern half of the bay, which is most exposed to the prevailing westerly winds and swells. Northerly winds may push any contamination from the Hayle STW long sea outfall which has risen to the surface due to its lower density than the receiving seawater into the bay.

Summary and conclusions

Tidal streams off the north Cornwall coast are bi-directional and run parallel to the coast. The main (Hayle STW, Appendix VII) sewage discharge to the area is located about 500m offshore from the mouth of St Ives Bay, and so the majority of contamination from here is entrained within the offshore tidal stream and does not enter the bay. Within St Ives Bay, tidally driven circulation is weaker, and generally clockwise throughout the eastern half of the bay irrespective of tidal state. Therefore, contamination from shoreline sources such as watercourses may be expected to impact most heavily close to the shore, mainly to their immediate west, and it is possible that their cumulative effects will result in higher general levels of contamination at the western end of the bay across the depth contours in which the main concentration of razor stocks are located. Given the relatively minor nature of freshwater inputs, density driven circulation is not expected to significantly modify circulation patterns within the bay. Density effects will however cause the effluent from the Hayle STW outfall to float to the surface, and under northerly winds this plume may be driven into the bay, where it is likely to become mixed into the water column to some extent by wave induced mixing. Therefore this discharge may impact within St. Ives Bay at times, although the geographic profile and intensity of its impacts is likely to be unpredictable and highly dependent on the dynamic interaction of wind and tide.

APPENDIX VI
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. The frequency and strength of depressions is greatest in the winter half of the year and this is when mean speeds and gusts are strongest (Met Office, 2007). Another seasonal pattern noted was the increased prevalence of winds from the north east during spring.

Wind data for the period January 1992–December 1998 from Culdrose meteorological station, about 20km to the south east of St Ives Bay is presented in Figure VI.1.

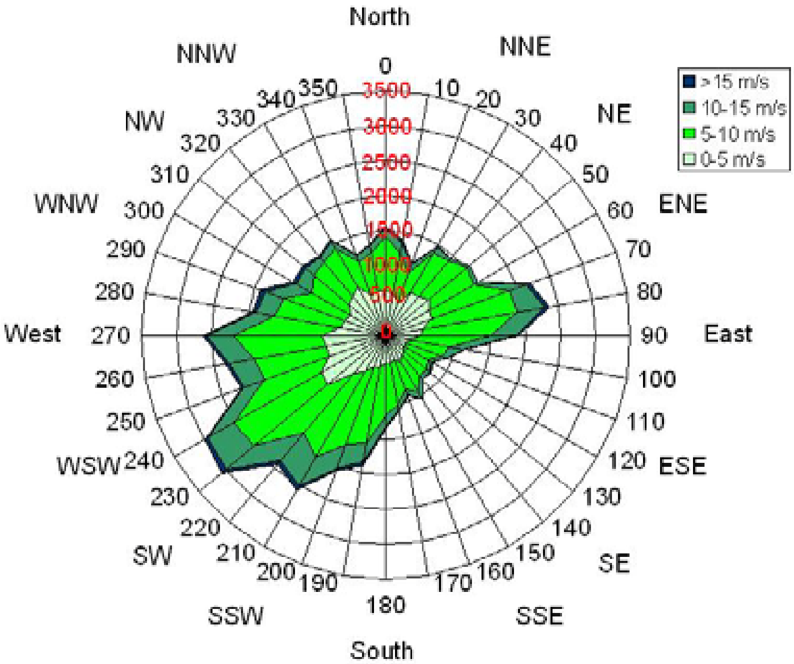


Figure VI.1 Wind rose showing mean wind speed direction and by hourly count over the period 1 January 1992–31 December 1998.
Derived from Culdrose meteorological station.
Data provided by the Environment Agency.

Figure VI.1 indicates that the prevailing wind direction at Culdrose is from the south west. St. Ives Bay is most exposed to the north west, so winds from this direction have the greatest potential to affect water circulation within the bay. Onshore winds will also create wave action, may resuspend any contamination settled within the sediment. The eastern half of the bay is likely to be subject to more frequent and more energetic wave action.

APPENDIX VII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: SEWAGE DISCHARGES

The St Ives Bay catchment area is served by 5 water company sewage treatment works of varying sizes, all of which provide secondary treatment, so their associated bacterial loadings will be roughly in proportion to their dry weather flow (DWF). Associated with these works are assorted intermittent discharges. Details of water company discharges are presented in Tables VII.1 and VII.3, and their locations are show in Figure VII.1. In addition to this, a number of properties are served by small private discharges. Their locations are shown in Figure VII.1, but individual details are not presented as all are minor, serving either one or a small number of properties.

Table VII.1 Continuous sewage discharges to St Ives Bay.

Name	Treatment	DWF (m^3/day)	NGR of outfall	Discharges to
Hayle STW	Secondary (Trickling filter)	19,704	SW 5593 4326	Sea
Camborne STW	Secondary (Activated sludge)	17,698	SW 6217 4315	Sea
Gwithian Churchtown STW	Secondary (Trickling filter)	91	SW 5878 4169	Red River catchment
Praze and Beeble STW	Secondary (Trickling filter)	389.6	SW 6327 3584	Red River catchment
Nancegollan STW	Secondary (Trickling filter)	60	SW 6349 3262	Hayle catchment
Trewithen Terrace STW	Secondary (Trickling filter)	7.4	SW 5950 3080	Hayle catchment

The most significant of these is the secondary discharge from Hayle STW, which discharges at depth just outside St. Ives Bay. The secondary treated effluent has a consented dry weather flow of 19,704 m^3/day and is discharged to the bay through a 2.5km pipe with a diffuser head to a depth of 16m relative to Chart Datum just offshore of St. Ives Bay. This treatment works serves the towns of Hayle and St. Ives, so will receive effluent from a significantly larger population during the summer tourist season (Appendix I). The scheme was commissioned in 1995. Whilst this discharge is likely to have some impacts on levels of contamination within St. Ives Bay, the geographical profile and extent of these impacts will depend on circulation patterns within the area.

The Camborne STW discharges to the shore outside of St. Ives Bay, about 4km east of Godrevy Head. This may also have some impact on water quality within St. Ives Bay, more so in the eastern parts of the bay, although given its distance from St. Ives Bay its impacts are likely to be minor at most.

Four minor sewage treatment works discharge to watercourses draining to St. Ives Bay, two within the River Hayle catchment and two within the Red River catchment. All these provide secondary treatment. In total, their consented dry weather flows to the River Hayle and the Red River are 67.4 and 480 m^3/day respectively, so whilst they will contribute to levels of contamination within these watercourses, their impacts within St. Ives Bay are likely to be very minor and localised relative to the main Hayle STW discharge.

Of the private discharges, 2 discharge direct to the Hayle estuary, 38 discharge to watercourses within either the River Hayle or Red River catchments, and 30 discharge to soakaway. The average consented dry weather flow for these is about 1.6 m^3/day, and they are treated by either septic tank or package plant.

Those discharging to soakaway are unlikely to have any impact on water quality within St. Ives Bay, whereas the spatial profile of impacts from those discharging to watercourses is likely to be similar to that of the four minor water company discharges, but more limited on the basis of the volumes involved. Reference concentrations of faecal coliforms in sewage discharges, subject to differing degrees of treatment, under low and high flow conditions are given in Table VII.2.

Table VII.2 Summary of reference faecal coliform levels for different sewage treatment levels under different flow conditions.

Treatment Level	Flow			
	Base-flow		High-flow	
	n	Geometric mean	n	Geometric mean
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 STW sampled.

Intermittent sewage discharges can deliver highly contaminated water to coastal areas resulting from the rapid flushing of stored contaminants during storm conditions and/or the overloading during periods of heavy rainfall (Lee and Morgan, 2003). Contaminant microorganisms in these discharges can be rapidly accumulated by bivalves and deteriorate the microbiological quality of BMPAs (Younger *et al.*, 2003). Intermittent sewage discharges direct to St. Ives Bay and to watercourses draining to the bay are listed in Table VII.3.

Figure VII.1 Locations of sewage discharges to St Ives Bay.

Table VII.3 Intermittent sewage discharges to St Ives Bay.

Name	Location	Receiving water
Bamaluz Point CSO/EO	SW 52280 41020	St. Ives Bay
Hayle STW SO	SW 55930 43260	St. Ives Bay
Porthminster Point 1 EO	SW 52580 39570	St. Ives Bay
Towans PSEO	SW 55356 38713	St. Ives Bay
Westcots Quay CSO	SW 51855 40416	St. Ives Bay (via Stennack River outfall)
East Quay PSEO	SW 55750 37630	Hayle Harbour
Hayle STW SO	SW 54680 36340	Hayle Harbour
Lelant PSEO	SW 54700 36940	Hayle Harbour
Phillack CSO	SW 56557 38196	Hayle Harbour
Hayle (Reawla Lane) PS	SW 60200 36700	Watercourse (Hayle catchment)
Holiday Village PSEO	SW 63210 34940	Watercourse (Hayle catchment)
Playing Fields SO	SW 54940 35000	Watercourse (Hayle catchment)
Relistian PSCSO/EO	SW 60400 36626	Watercourse (Hayle catchment)
Treloweth PSEO	SW 54270 35540	Watercourse (Hayle catchment)
Coombe PS	SW 62890 42280	Watercourse (Red River catchment)
Knave-go-bye CSO	SW 65230 38990	Watercourse (Red River catchment)
Mill Road PSCSO/EO	SW 63037 39062	Watercourse (Red River catchment)
Praze-an-Beeble STW SO	SW 63270 35840	Watercourse (Red River catchment)
Reskadinnick PS	SW 63410 42030	Watercourse (Red River catchment)
St Martin's Crescent CSO	SW 63894 40814	Watercourse (Red River catchment)
Tolvaddon Downs CSO	SW 65710 41690	Watercourse (Red River catchment)
Troon Farm CSO	SW 65836 38150	Watercourse (Red River catchment)

PS - pumping station
CSO - combined storm overflow
SO - storm overflow
EO - emergency overflow
STW - sewage treatment works.

Information on spill frequency and/or spill volumes were requested from the Environment Agency, but were not available at the time of writing. Therefore it is difficult to assess the potential impacts of any of these aside from noting their location and their potential to cause localised hotspots of contamination at times and an increased likelihood of this occurring after heavy rain. Very high levels of faecal coliforms have been recorded in the Stennack River and the Red River (Appendix XIII) suggesting they may receive significant inputs from intermittent discharges at times. The presence of untreated sewage at Godrevy, a popular beach with surfers, originating from intermittent overflow discharges to the Red River has been reported in the press on numerous occasions (e.g. This is Cornwall, 22 July 2010; The Sunday Times, 3 August 2008).

Overall, the most significant sewage discharge to the area is the Hayle STW discharge, although this lies outside the bay and its impacts on the shellfish beds will depend on water circulation patterns. There will be some contamination from small sewage works and private discharges carried into St. Ives Bay via the Hayle and the Red River. Intermittent discharges to the Red River, the Hayle, and to the shore at the Towns, St. Ives and Carbis Bay may also be of significance at times of high rainfall.

APPENDIX VIII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: AGRICULTURE

Livestock production is one of the main activities taking place in catchments bordering St. Ives Bay. Table VIII.2 shows the numbers of farmed animals by species and catchment area (Figure VII.1) from the June 2009 agricultural survey undertaken by Defra. It must be noted that each farm is allocated to a single point, whereas in practice an individual farm may span two or more catchments. Nevertheless, the information in Table VIII.2 will give a broad overview of livestock farming in the area.

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

	Total number				Density (animals/km^2)			
Catchment	Cattle	Pigs	Sheep	Poultry	Cattle	Pigs	Sheep	Poultry
Hayle (C049022B)	3,300	195	393	58,138	25	1	3	432
Hayle Tidal (C049022A)	12,852	514	1,519	3,054	216	9	26	51
Red River (C048023A)	12,552	1,417	9,967	25,484	63	7	50	128
Total	28,704	2,126	11,879	86,676	73	5	30	221

The catchments for which this data is presented do not actually align to true hydrological catchments, so will not give an accurate indication of numbers within the area drained by each watercourse discharging into St. Ives Bay. Pastures are most concentrated inland from St. Ives and Carbis Bay, throughout the Red River catchment, and in the upper Hayle catchment, so highest densities of grazing animals may be expected in these areas. Arable land is most concentrated in the lower Hayle catchment (see Figure 1.2), and manures, slurries and sewage sludge may be spread in these areas. Therefore, all significant watercourses draining to St. Ives Bay are likely to be impacted by contamination of agricultural origin in some way.

Table VIII.2 indicates that cattle are present at relatively high densities, and that there are also significant numbers of sheep. The overall density of grazers is 103 animals/km^2, which is under half the overall human population density for the area covered in Appendix I (233 persons/km^2). In addition, there are some pigs and poultry reared in the area. No livestock was recorded in the immediate vicinity of the shore of St. Ives Bay during the shoreline survey.

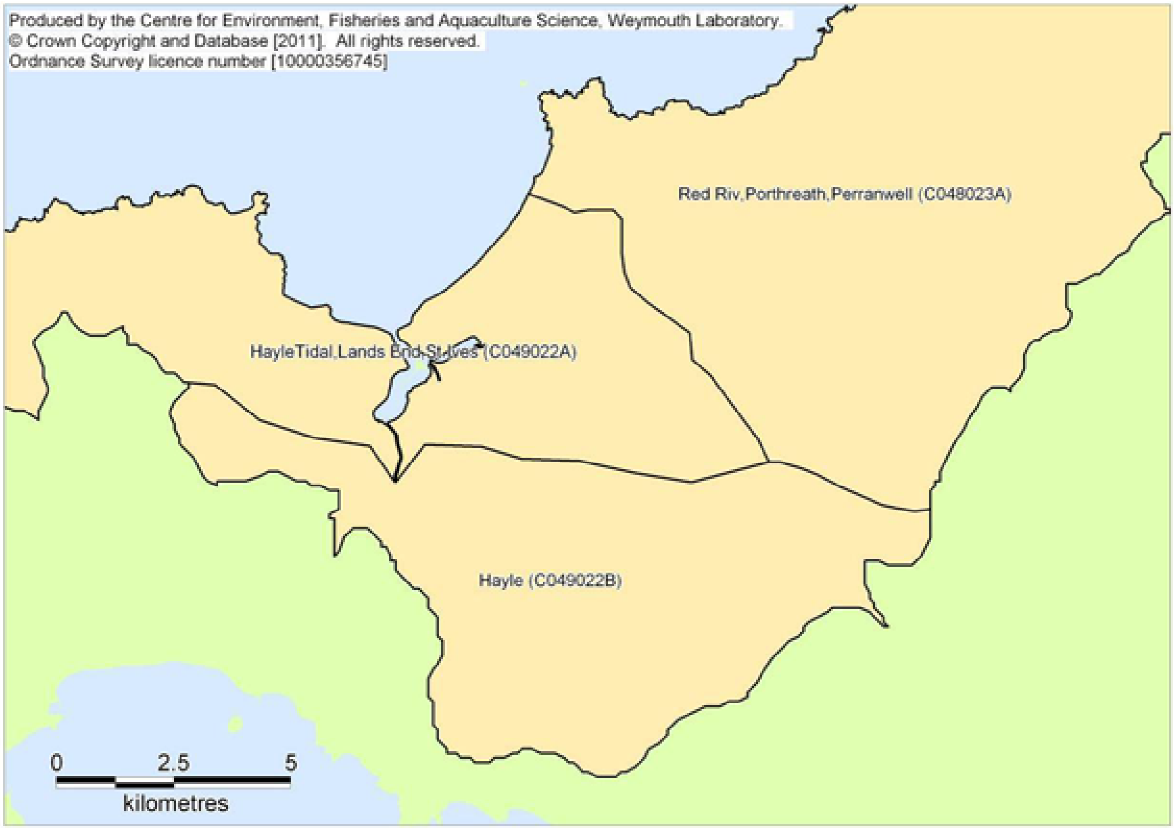


Figure VII.1 Location of catchments for agricultural survey data

Grazing animals (sheep and cattle) will directly deposit faeces on pastures, although during the winter cattle may be housed indoors and at these times slurry is collected and stored for later application to fields. Timing of slurry applications is uncertain, although farms without large storage capacities are likely to spread during the winter and spring. Many farms in Cornwall do not have long-term storage capacity for slurries and manure and, therefore, maintain these as a pile in fields (Roderick and Burke, 2004; Lizbe Pilbeam, Natural England, pers. comm.). For this reason, most farmers frequently apply manure and slurries during the winter, throughout the spring (February–March) for spring growth and some are applied in the autumn for winter cereals. Winter spreading is usually more frequent as farmers try to avoid over-topping their slurry stores. Lesser quantities are retained for the late spring and summer for second and third cut silage applications. Numbers of grazing animals are expected to peak following the birth of lambs and calves in the spring, then decline in the autumn as these animals are sent to market. Therefore it is likely that peak levels of contamination from cattle and sheep may arise in the bay 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 at a more localised level if wet weather occurs following a slurry application, and this is most likely in the winter or spring.

Manure/slurry from pig and poultry operations is typically collected and subsequently spread on nearby farmland (Defra, 2009) and this may occur at any time of the year. Sewage sludge is usually applied to land in February–March and in September (Lizbe Pilbeam, Natural England, pers. comm.), although it is not known whether this practice occurs within the St. Ives Bay catchment area.

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

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

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

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

In conclusion, all significant watercourses draining to St. Ives Bay are likely to be impacted by contamination from agricultural sources at times as all have significant numbers of grazing animals, and significant areas of pastures and arable land onto which manures and slurries may be spread within their catchments. The Red River and two streams discharging at St. Ives and Carbis Bay have higher proportions of pasture within their catchments compared to the Hayle, which has the highest proportion of arable land. Contamination from agricultural sources will be carried into coastal waters via rivers and streams and the magnitude of this flux is likely to be highly dependent on rainfall. Some seasonality is expected, possibly with greatest overall inputs to the bay following summer storms when numbers of animals on pastures are the highest, or on a more localised level in wet weather in the winter and spring from fields where slurry or manure has been recently applied.

APPENDIX IX
SOURCES AND VARIATION AND MICROBIOLOGICAL POLLUTION: BOATS

Boating activities in St. Ives Bay are represented in Figure IX.1. Hayle is the main harbour in St. Ives Bay, but there is also a drying harbour at St. Ives. The harbour at Hayle is not generally used by visiting yachts as it can be difficult to navigate. A number of small fishing boats and small cabin cruiser type pleasure boats operate from here. Around 50 of these small vessels were seen during the shoreline survey, of which none appeared likely to have on board toilets.

Significant development is planned for Hayle Harbour, which is likely to involve development of harbourside flats and shops, and at some point the development of a marina and the removal of a sandbank from the mouth of the estuary to improve its navigability. If and when these developments occur, increased numbers of the larger cruising yachts may be expected in the bay, and increased inputs from these may be expected.

Within St. Ives Harbour about 90 small boats were recorded on drying moorings, but none appeared to have on board toilets. Just off from St Ives 9 boats were recorded on moorings, of which possibly two may have had on board toilets. The Harbourmaster at St. Ives advised that there are about 150 overnight yacht visits to these moorings during the summer time. Surfing and windsurfing activities are mainly undertaken along the east shore between The Towans to Godrevy Point.

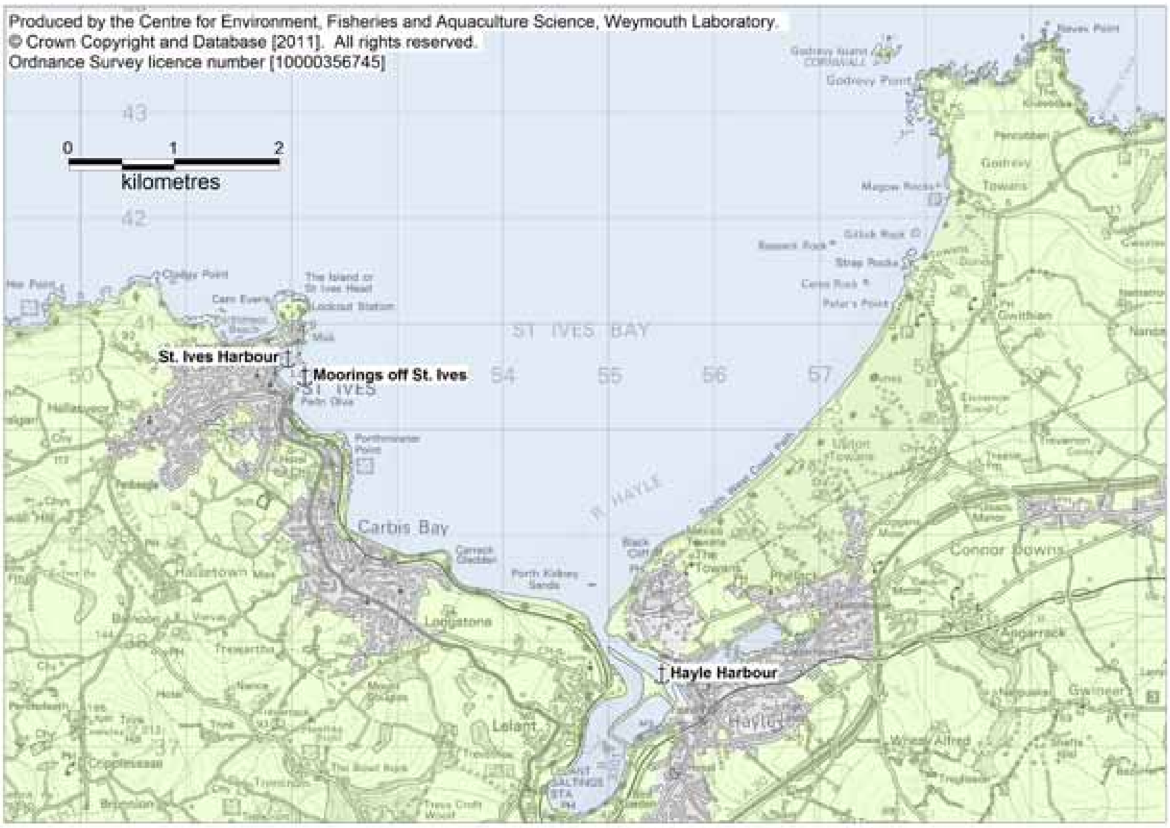


Figure IX.1 Boating activities in St. Ives Bay.

The boats most likely to make overboard discharges are yachts in overnight occupation at the moorings just off St. Ives. However, the numbers of overnight stays here are low, and limited to the summer months, so anticipated impacts are relatively minor, seasonal, and localised. If the development of a marina in Hayle Harbour goes ahead, there may be increased inputs to the bay from yachts making overboard discharges within the Hayle estuary, and whilst on passage through the bay.

APPENDIX X
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: WILDLIFE

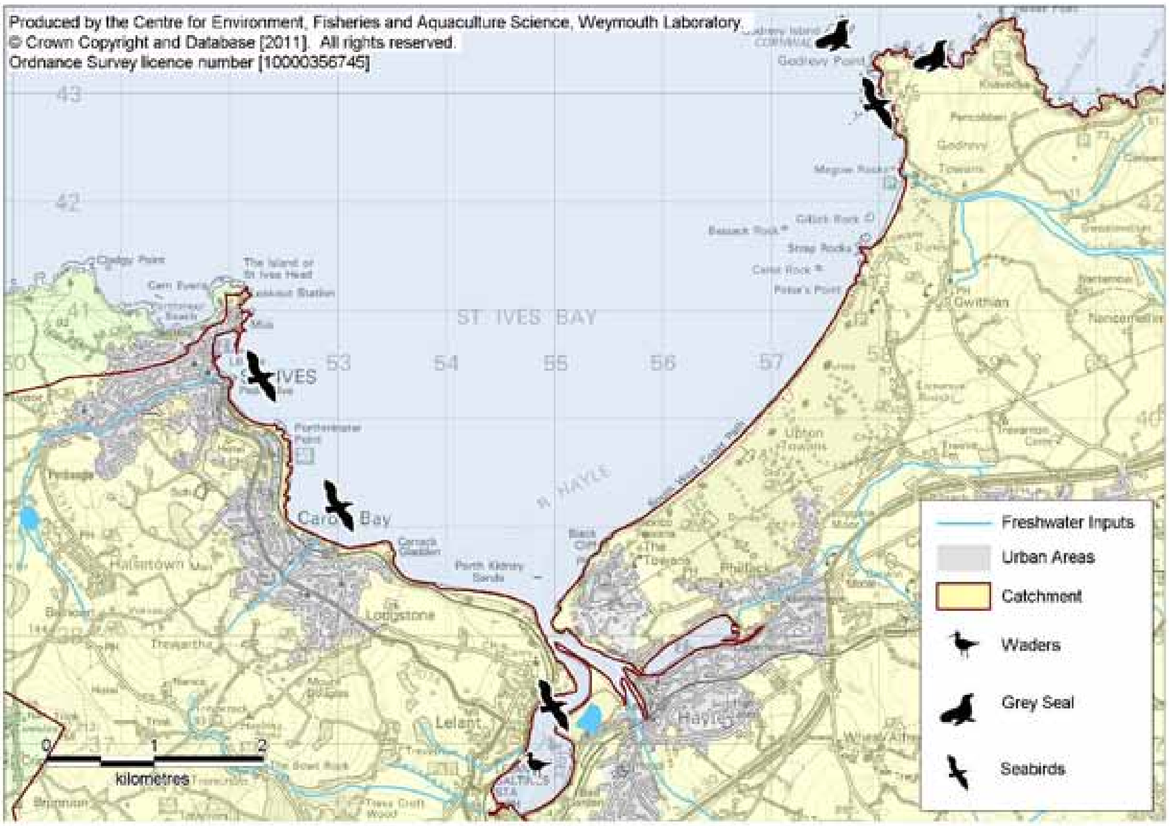


Figure X.1 Wildlife populations in St. Ives Bay

Most of the Hayle estuary is managed as a reserve by the RSPB, and supports up to 18,000 overwintering waterbirds (waders and wildfowl) according to its SSSI citation (Natural England, 2011). Numbers are likely to be higher in colder winters as the climate is mild here relative to the rest of the UK. Any impacts from these would tend to be carried into St. Ives Bay via ebb flows from this estuary, and would peak during the winter months.

The Seabird 2000 survey carried out counts of breeding seabirds during the early summer of 2000 (Mitchell *et al*, 2004), This identified significant colonies of breeding seabirds (about 750 gulls, cormorants etc) in the vicinity of Godrevy Point. Breeding seabirds were also recorded around the Hayle estuary (about 250 gulls) and at St. Ives and Carbis Bay (about 500 gulls). These 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. These species of seabirds are likely to be present in the area all year round. An aggregation of about 50 seagulls was observed on the beach at St. Ives during the shoreline survey (September).

There is a grey seal colony in the area, which uses haul out sites on Godrevy Island and at Mutton Cove, which is the cove immediately to the east of Godrevy Point. Average numbers are about 31 animals, although more than twice this amount was observed on occasions. They are present all year round, but numbers tend to peak in March. (Godrevy Seal Group, 2005). Any contamination deposited at the haul out sites will have greatest impacts in the immediate vicinity. They are likely to forage over a very wide area, so away from their haul out sites impacts will be minor and spatially unpredictable.

No other wildlife populations which may have a potentially significant influence on levels of contamination within shellfish in St. Ives Bay have been identified.

The beaches in St. Ives Bay are popular for dog walking, although dogs are banned from some of the more popular beaches in the western half of the bay from Easter to the 1st October and dog owners are encourage to clean up after their pets. Four dog walkers were recorded on the shore by The Towans during the shoreline survey. Dog faeces therefore present a potential source of contamination to nearshore shellfish beds.

APPENDIX XI
MICROBIOLOGICAL DATA: WATER

BATHING WATERS

There are six bathing waters sites within St. Ives Bay, designated under the Directive 2006/7/EC (European Communities, 2006) (Figure XI.1).

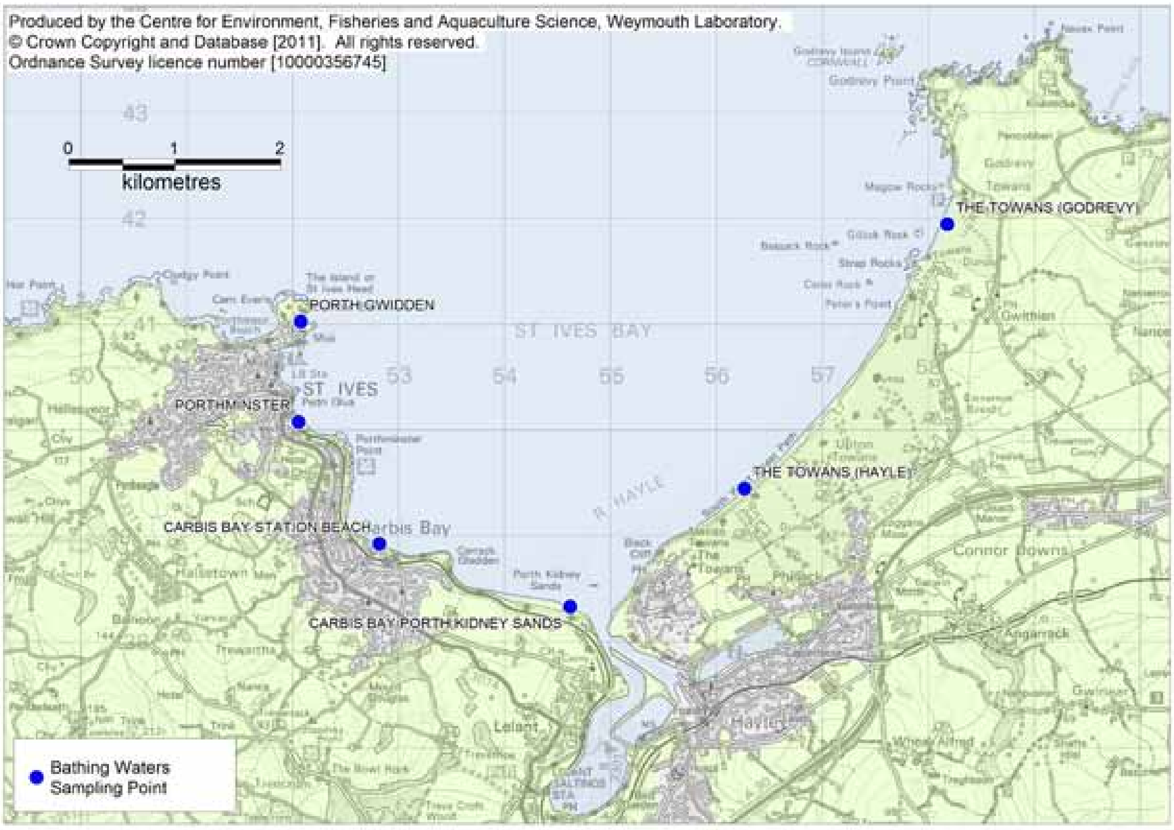


Figure XI.1 Location of bathing waters monitoring points

Under this programme, around 20 surface water samples are taken from each site every bathing season (15th May to 30th September) for faecal coliform enumeration. Table XI.1 presents summary statistics for all bathing waters sample faecal coliform results from these sites from 2000 to the time of writing, and Figure XI.2 presents a boxplot of these results by site.

Table XI.1 Summary statistics for bathing waters faecal coliforms results (cfu/100ml) within St. Ives Bay (from west to east)

Site	Date of first sample	Date of last sample	No.	Min.	Max.	Median	Geometric mean
Porthgwidden	05 May 2000	08 Sep 2010	221	2	2,450	10	7.4
Porthminster	05 May 2000	08 Sep 2010	226	2	1,700	10	13.0
Station Beach	05 May 2000	08 Sep 2010	222	2	2,800	10	9.1
Porth Kidney	05 May 2000	08 Sep 2010	222	1	20,000	6	6.4
The Towans (Hayle)	05 May 2000	08 Sep 2010	222	2	2,360	4	5.3
The Towans (Godrevy)	05 May 2000	08 Sep 2010	224	2	62,100	10	10.3

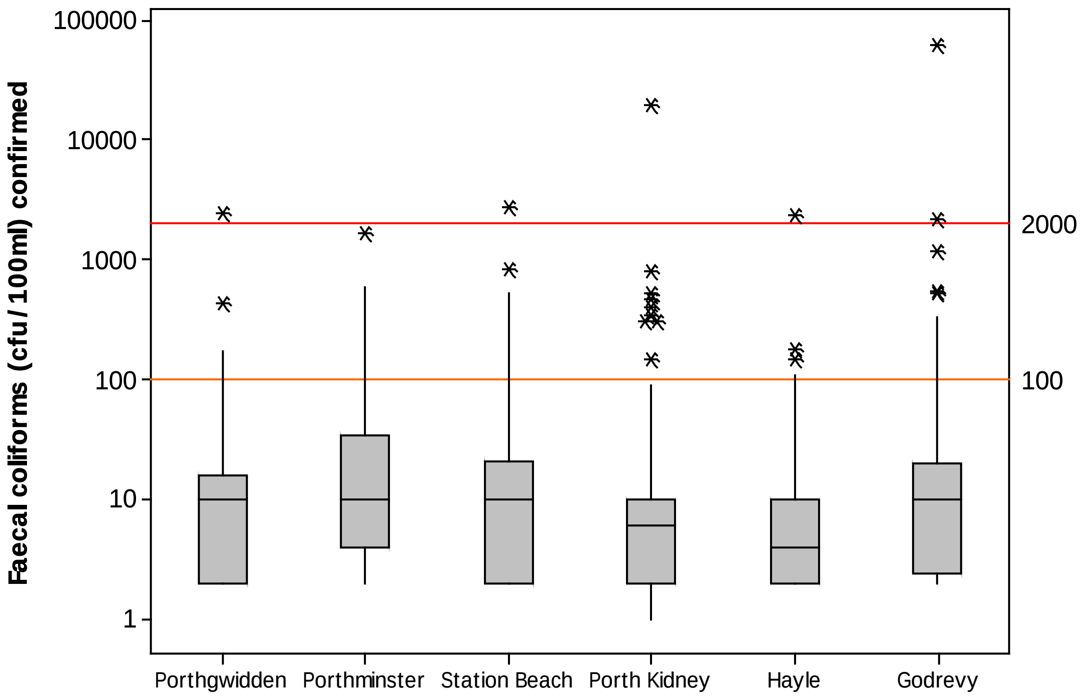


Figure XI.2 Box plot of bathing waters faecal coliform results by site (from west to east)

An EU working group report (European Commission 1996) suggests that 1 bacteria/100ml is required to achieve an A classification, whereas 100 bacteria/100ml is required to achieve a B classification. Therefore, levels of contamination observed at the bathing waters sites within St. Ives Bay were generally consistent with a B classification. Defra is currently undertaking further investigations into relationships between levels of bacteria in water and shellfish flesh.

Significant differences were found between geometric mean result by site (One-way ANOVA, p=0.000, Tukeys comparison). Specifically, results for Porthminster were significantly higher than those for Porth Kidney, Hayle and Porthgwidden, results for Godrevy were significantly higher than those for Porth Kidney and Hayle, and results for Station Beach were significantly higher than those for Hayle. This indicates that there is some spatial variation in levels of contamination along the shores of St. Ives Bay, with highest levels on average at Porthminster and Godrevy, and lowest levels at the beaches either side of the Hayle Channel.

To investigate the effects of rainfall in levels of faecal coliforms in bathing waters samples, Spearman's rank correlations were carried out with rainfall recorded at the Hayle weather station over various periods running up to sample collection. These are presented in table XI.2, where statistically significant correlations (p<0.05) are highlighted in yellow.

Table XI.2 Spearman's rank correlations between rainfall recorded at Hayle and bathing waters faecal coliform results

		Porthgwidden	Porthminster	Station Beach	Porth Kidney Sands	The Towans (Hayle)	The Towans (Godrevy)
	n	206	211	207	207	207	209
24 hour periods prior to sampling	Day of sampling	0.252	0.323	0.299	0.162	0.118	0.263
	1 day	0.164	0.332	0.206	0.177	0.175	0.287
	2 days	0.074	0.088	0.042	-0.015	-0.034	0.111
	3 days	0.054	0.013	0.117	0.017	0.062	0.078
	4 days	0.047	0.005	0.081	-0.027	0.011	0.043
	5 days	-0.001	0.050	0.086	0.063	-0.003	0.008
	6 days	0.012	0.098	0.039	0.011	0.032	0.041
	7 days	-0.100	-0.028	0.034	0.021	0.040	-0.024
Total prior to sampling over	2 days	0.275	0.419	0.302	0.206	0.178	0.344
	3 days	0.236	0.372	0.218	0.150	0.096	0.309
	4 days	0.206	0.323	0.193	0.143	0.107	0.298
	5 days	0.215	0.278	0.226	0.114	0.116	0.287
	6 days	0.196	0.259	0.222	0.119	0.111	0.266
	7 days	0.193	0.238	0.192	0.113	0.105	0.243

All sites showed some correlation between recent rainfall and levels of contamination. The strength of these correlations broadly align with the geometric mean results for each site (i.e. stronger relationships with rainfall are apparent at the more heavily contaminated sites). Perhaps surprisingly, the weakest influence of rainfall was observed at the two sites either side of the mouth of the Hayle estuary.

When the larger (spring) tides occur every two weeks, circulation of water and particle transport distances will increase, and more of the shoreline will be covered at high water, potentially washing more faecal contamination deposited on the shore into the water. Figure XI.3 presents polar plots of $\log_{10}$ *E. coli* results on the lunar spring/neap tidal cycle at the six bathing waters sites within St. Ives Bay. Individual results are shown as black diamonds, and the red line indicates the geometric mean result by days post full/new moon. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account.

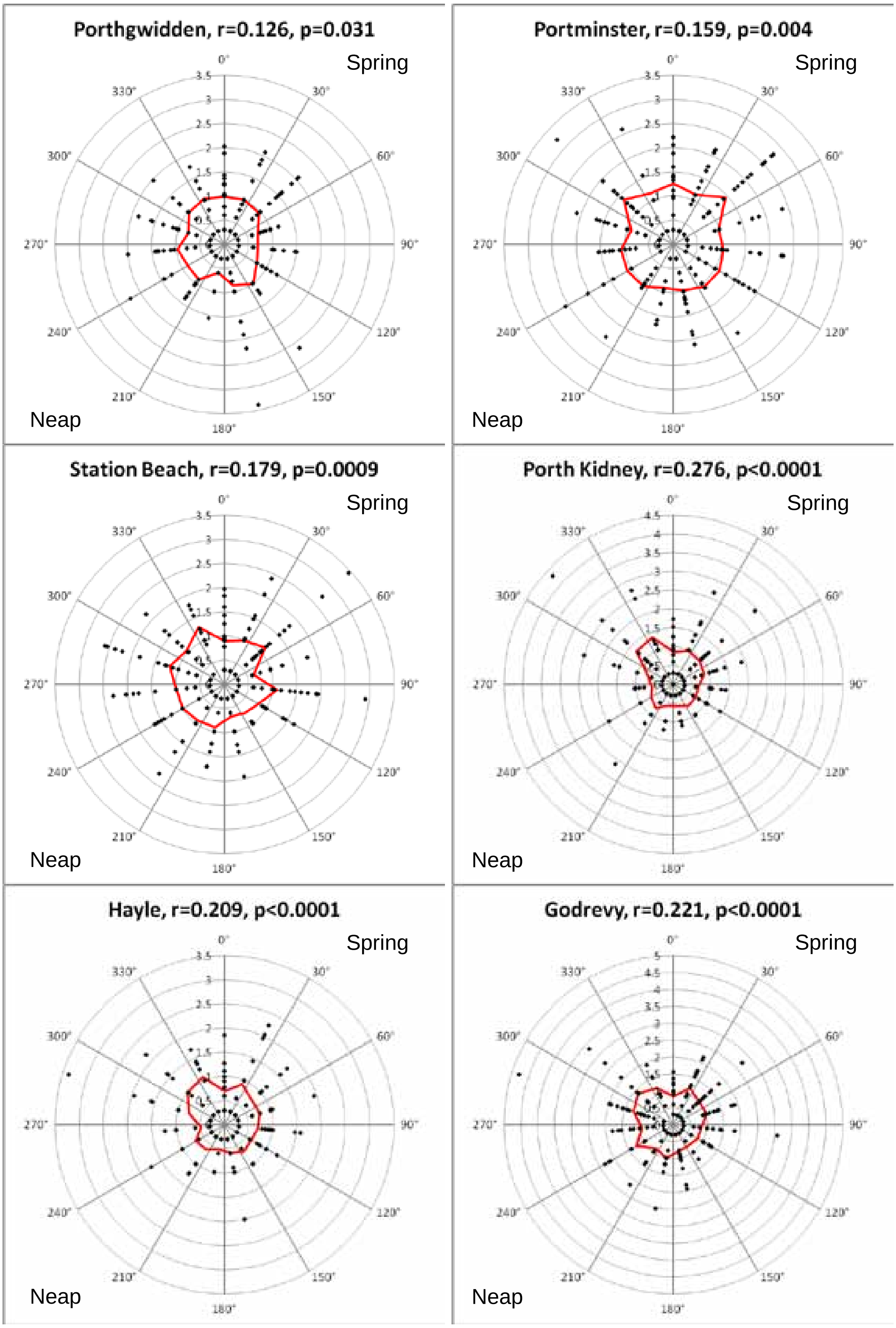


Figure XI.3 Polar plots of individual $\log_{10}$ Faecal coliforms results (cfu/100ml) against tidal state on the spring neap tidal cycle

An influence of the spring neap tidal cycle was found at all sites. The correlations were weakest at the western end of the bay, and strongest at the eastern end of the bay. A similar pattern in tidal influence can be seen throughout the bay, with increased levels of contamination generally arising as tide size increased from neaps to springs, but this pattern was only strongly apparent at the western end of the bay. As the tide sizes increase greater impacts from contamination deposited in the intertidal zone towards the high water mark, such as that originating from dogs and waterbirds may be anticipated, so these findings imply that contamination from such sources are of significance at the eastern end of the bay.

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality during this cycle. Figure XI.4 presents polar plots of $\log_{10}$ faecal coliform results on the twice daily high/low tidal cycle at the six bathing waters sites within St. Ives Bay. Individual results are shown as black diamonds, and the red line indicates the geometric mean result by each 30º subdivision. High water occurs at 0º, the tide ebbs down to low water from 0º to 180 º, and the flood tide runs from 180º back to high water at 0º. It should be noted that local meteorological conditions such as barometric pressure, wind strength and direction can influence tidal levels and streams and this is not taken into account.

No correlations were found between faecal coliform results and predicted tidal state on the high/low cycle for Porthgwidden or Godrevy. Very weak correlations were found at Porthminster and Station Beach, but no strong pattern in levels of contamination is apparent in Figure XI.4 for either of these sites. Strong correlations were found at Porth Kidney and Hayle, and in both cases results were consistently higher towards low water. As these latter two sites are the sample points in closest proximity to the Hayle estuary, this implies that more contaminated water ebbing from this estuary is a significant influence of water quality in the centre of the bay, to both sides of the estuary mouth, and that its influence is of lesser relative significance towards the outer parts of the bay.

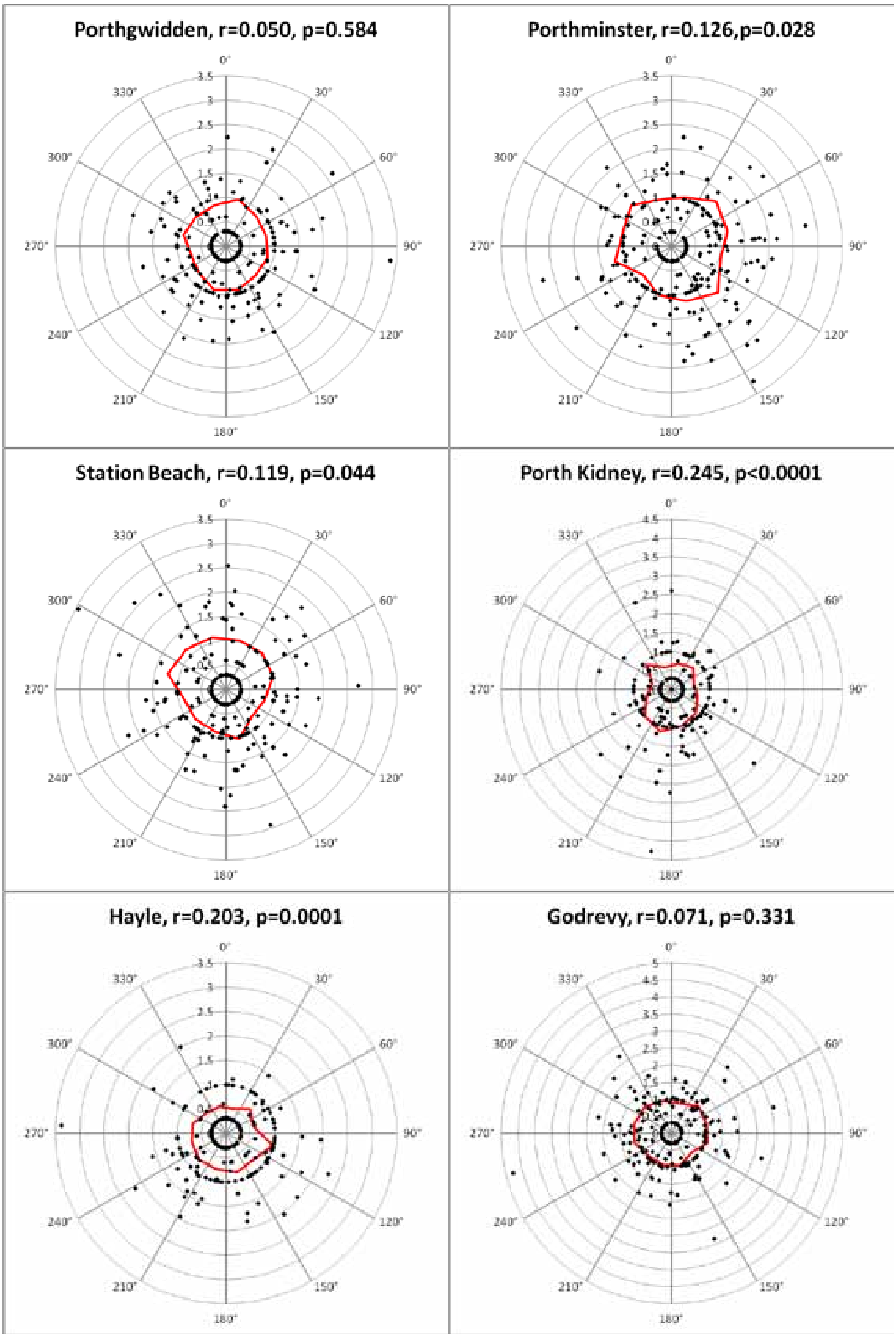


Figure XI.4 Polar plots of individual $\log_{10}$ Faecal coliforms results (cfu/100ml) against tidal state on the high low tidal cycle

Shellfish Waters

St. Ives Bay does not coincide with any Shellfish Growing Waters designated under the Shellfish Water Directive.

APPENDIX XII
MICROBIOLOGICAL DATA: SHELLFISH FLESH

From 1998 to 2004, mussel samples from 5 sites were taken for *E. coli* analysis under the shellfish hygiene classification programme. As these are the only shellfish flesh testing results for this area, and there have been no major changes to the sewerage network in the area since the installation of the Hayle long sea outfall in 1995, an examination of this data was carried out. Any conclusions must be treated with some caution however, as they may not accurately reflect the current situation. The locations of the sampling points are shown in Figure XII.1, summary statistics are presented in Table XII.1, and a boxplot of all results is presented by site in Figure XII.2.

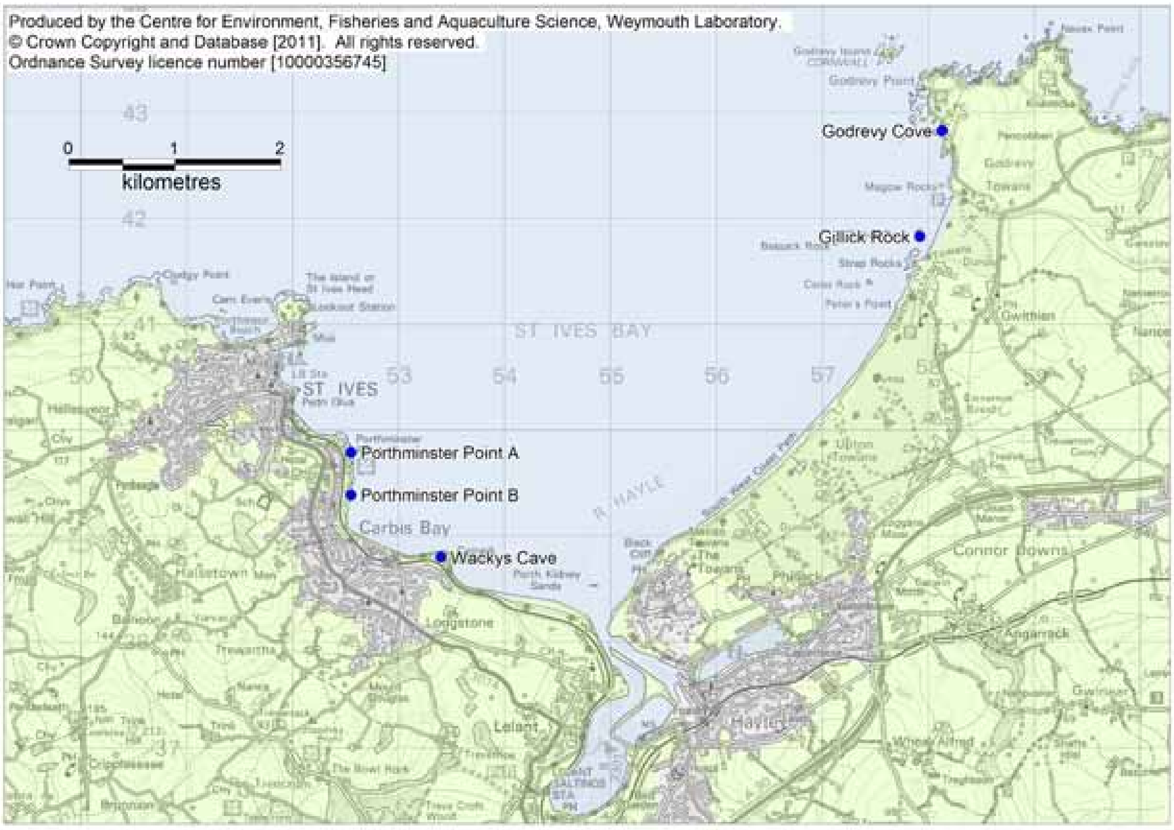


Figure XII.1 Location of mussel flesh sampling points

Table XII.1 Summary statistics for mussel flesh samples taken from St. Ives Bay

RMP ID	RMP name	Date of first sample	Date of last sample	No.	*E. coli* results (MPN/100g) Geometric mean	Median	Minimum	Maximum
B088C	Porthminster A	02/03/1999	08/02/2000	18	115	125	20	16,000
B088D	Porthminster B	02/03/1999	08/02/2000	18	159	150	10	16,000
B088E	Wacky's Cave	17/05/1999	08/06/2004	58	152	160	10	2,400
B088A	Gillick Rock	12/05/1998	08/02/2000	24	213	220	10	2,400
B088B	Godrevy Cove	12/05/1998	08/06/2004	64	148	110	10	5,400

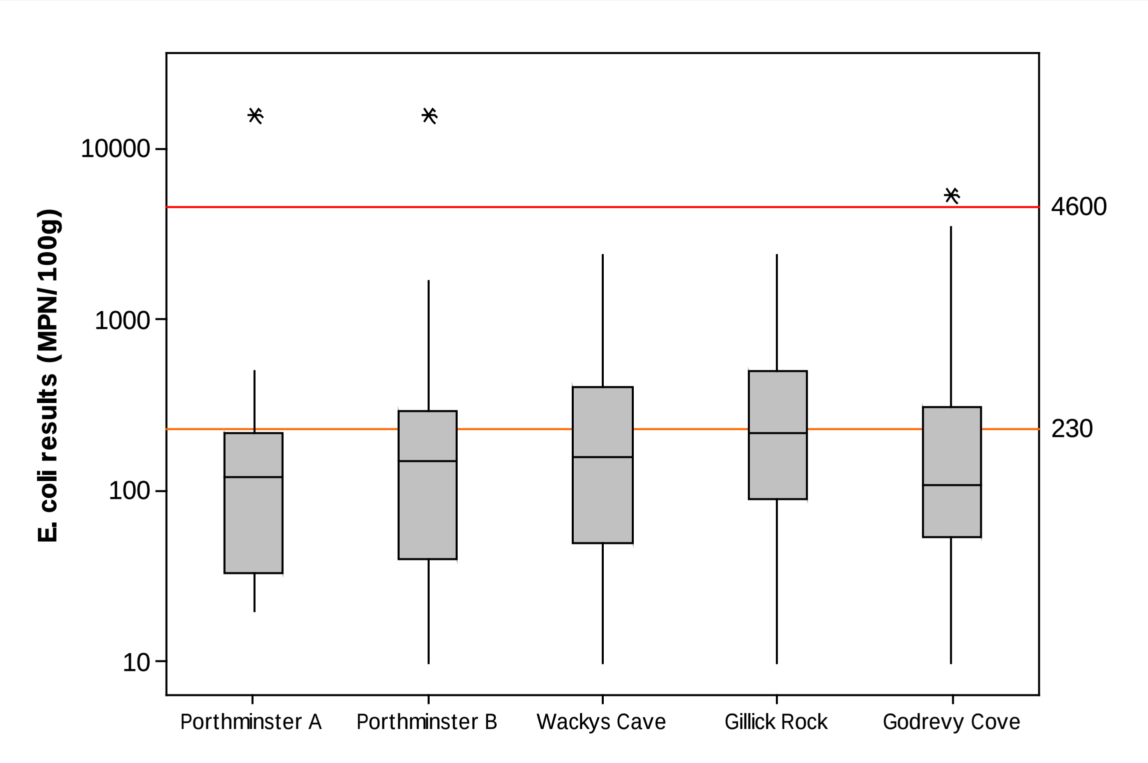


Figure XII.2 Boxplot of mussel E. coli results by site.

SPATIAL PATTERNS IN LEVELS OF CONTAMINATION

Overall, levels of contamination were similar at all sites sampled. Results were highest on average at Gillick Rock, and lowest on average at Porthminster A, but a comparison of all results revealed no significant difference between the sampling locations (One-way ANOVA, p=0.743). It must however be noted that the different sites were often sampled on different days and hence under different environmental conditions. Only three results of over 4,600 *E. coli* MPN were recorded. The two highest results (both of 16,000 *E. coli* MPN/100g) were recorded at the two Porthminster sites on the same day. None of the other sites were sampled on the same day, so it is not possible to assess whether contamination rose to similar high levels on the other side of the bay at this time or whether this was a localised peak.

More robust spatial comparisons are possible when sites are sampled on the same day, and hence under the same environmental conditions. All five sites were sampled on the same day on only four occasions, so a direct comparison of all sites was not possible. A comparison of the 45 paired (same day) samples from Godrevy Cove and Wacky's Cave showed similar levels of contamination (geometric mean *E. coli* results of 146 and 130 MPN/100g respectively). The levels of contamination found at each of these sites on any given sampling day were closely correlated (Pearson correlation, r=0.420, p=0.004) suggesting that they were subject to contamination from similar sources. A comparison of the 23 paired (same day) samples from Godrevy Cove and Gillick Rock also showed similar overall levels of contamination (geometric mean *E. coli* results of 208 and 195 MPN/100g respectively). The levels of contamination found at each of these sites on any given sampling day were not correlated (Pearson correlation, r=0.256, p=0.239) suggesting that they may be subject to contamination from differing sources. A comparison of the 18 paired samples from Porthminster A and Porthminster B showed slightly higher levels of contamination at Porthminster B (geometric mean *E. coli* results of 106 and 160 MPN/100g respectively). The levels of contamination found at each of these sites on any given sampling day were closely correlated (Pearson correlation, r=0.705, p=0.002) suggesting that they were subject to contamination from similar sources. No other site pairings were sampled on the same day on 10 or more occasions, so no further same day sample site pairings were investigated.

TEMPORAL PATTERNS IN LEVELS OF CONTAMINATION

Figure XII.3 presents a scatterplot of all *E. coli* results by date and by site, overlaid with lowess trend lines for each sampling site.

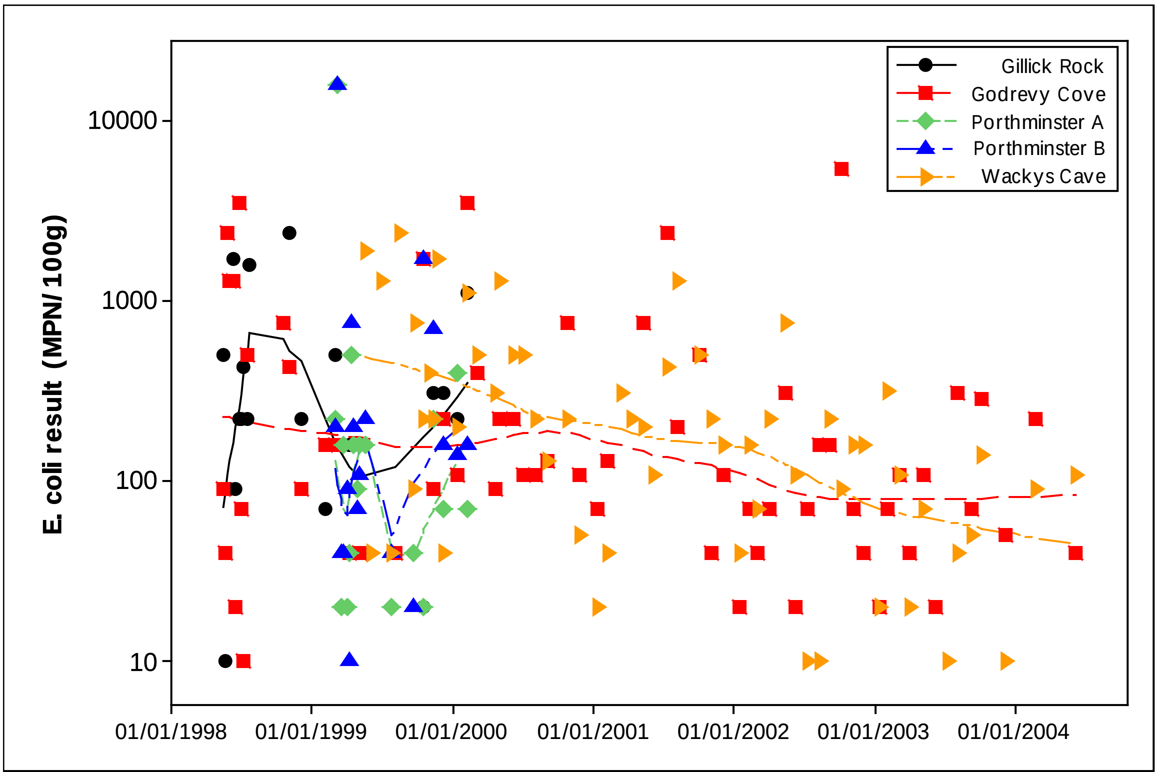


Figure XII.3 Scatterplot of* E. coli *results by site and by date

For the two sites which were sampled throughout this period (Godrevy Cove and Wacky's Cave) results appear to have gradually improved.

SEASONAL PATTERNS IN LEVELS OF CONTAMINATION

Season influences not only weather patterns and water temperature, but patterns of human occupation, and the distribution of livestock and wildlife. All of these can affect levels of microbial contamination, and cause seasonal variation in results. Figure XII.4 presents a boxplot of *E. coli* results by season for the two sites for which sufficient samples were taken to highlight any seasonal patterns.

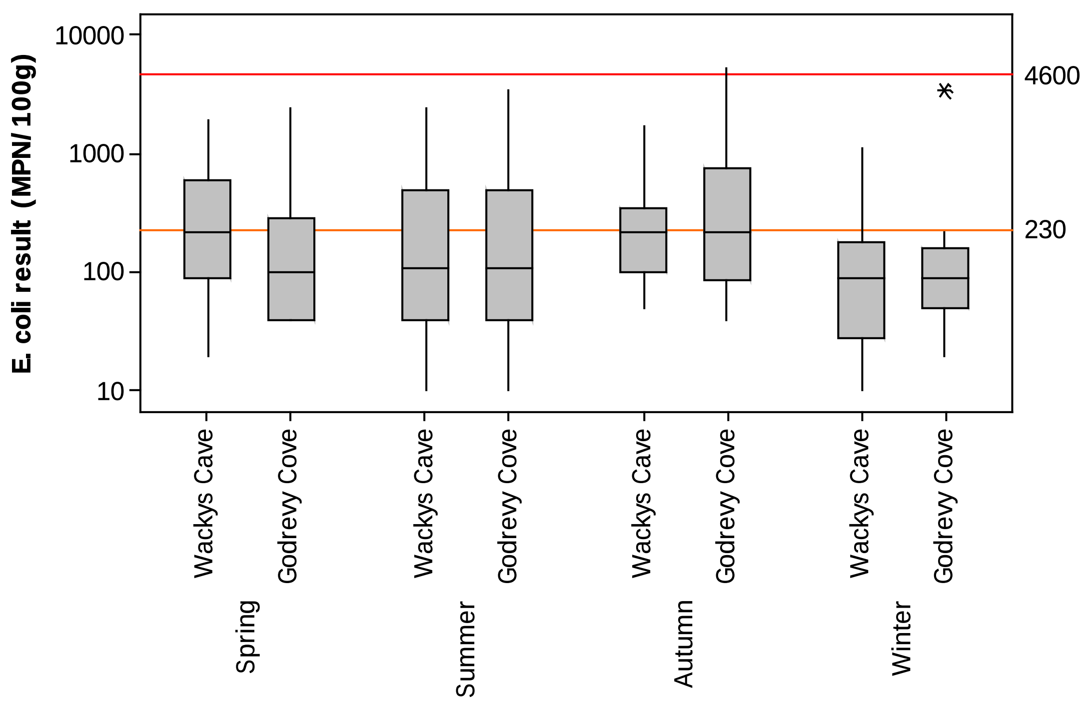


Figure XII.4 Boxplot of* E. coli *result by season (Wacky's Cave and Godrevy Cove)

For both Wacky's Cave and Godrevy Cove results were lowest on average during the winter months. The seasonal pattern was not particularly strong, and was not statistically significant in either case (One-Way ANOVA, p=0.180 and 0.284 respectively).

INFLUENCE OF RAINFALL

To investigate the effects of rainfall on levels of *E. coli* in shellfish flesh, Spearman's rank correlations were carried out with rainfall recorded at the Hayle weather station over various periods running up to sample collection. These are presented in Table XII.2, where statistically significant correlations ($p<0.05$) are highlighted in yellow. Rainfall records were only available from 2000 onwards, so relationships between rainfall and *E. coli* levels were only carried out for Godrevy and Wacky's Cave.

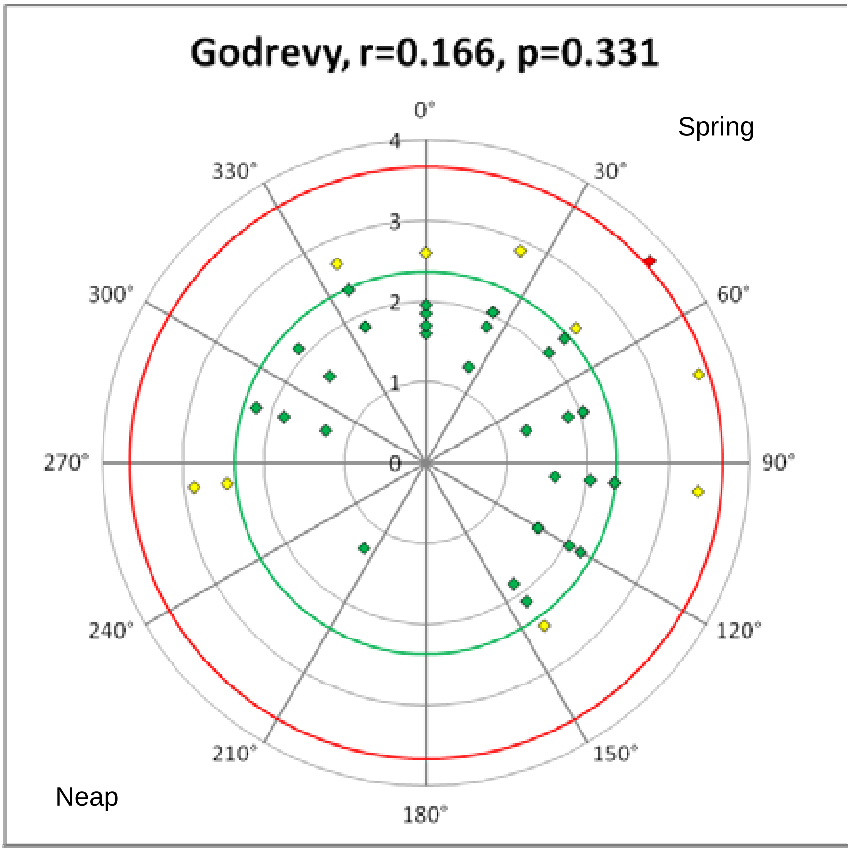
Table XII.2 Spearman's rank correlations between recent rainfall and mussel* E. coli *results. Significant correlations are highlighted in yellow.

		Wacky's Cave	Godrevy Cove
	No. samples	46	43
	Day of sampling	-0.129	-0.187
24 hour periods prior to sampling	1 day	0.361	0.171
	2 days	0.130	-0.128
	3 days	-0.041	-0.033
	4 days	0.047	-0.060
	5 days	0.011	-0.036
	6 days	-0.159	-0.023
	7 days	0.147	0.034
Average prior to sampling over	2 days	0.121	0.058
	3 days	0.128	0.027
	4 days	0.110	0.015
	5 days	0.094	0.047
	6 days	0.034	0.025
	7 days	-0.035	-0.031

No correlations between recent rainfall and *E. coli* result were found at Godrevy Cove. A relatively weak correlation was found between *E. coli* results and rainfall on the day before sampling at Wacky's Cave.

INFLUENCE OF TIDE

Figure XII.5 presents polar plots of $\log_{10}$ *E. coli* results on the lunar spring/neap tidal cycle at the two sites for which sufficient *E. coli* results were available (Godrevy and Wacky's Cave). Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of under 230 *E. coli* MPN/100g are plotted in green, those between 230 and 4,600 *E. coli* MPN/100g are plotted in yellow, and those over 4,600 *E. coli* MPN/100g are plotted in red. The red annuli depict the B/C threshold (4,600) and the green annuli depict the A/B threshold (230). It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account.



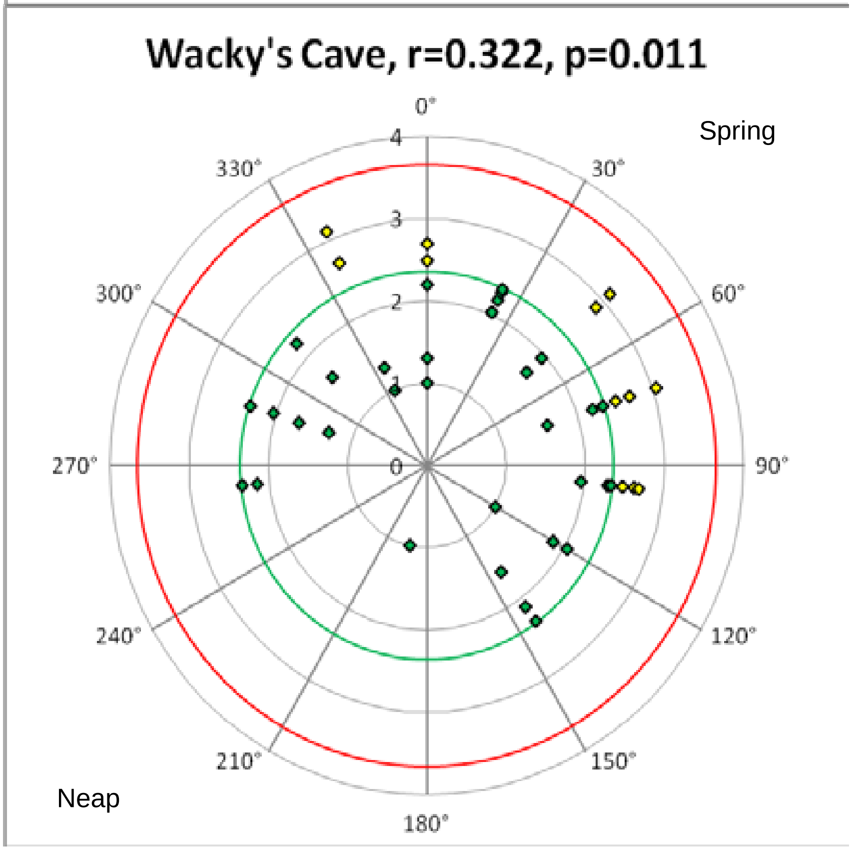


Figure XII.5 Polar plots of log$_{10}$* E. coli *results (MPN/100g) against tidal state on the spring neap tidal cycle.

No correlation was found between the spring neap tidal cycle and *E. coli* results at Godrevy Cove. A very weak correlation was found for Wacky's Cave, where higher results tended to occur on larger tides.

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality during this cycle. However, sampling was targeted towards low water, so it was not possible to investigate variation in levels of contamination through this tidal cycle.

APPENDIX XIII
MICROBIOLOGICAL DATA: BACTERIOLOGICAL SURVEYS

INVESTIGATIONS UNDERTAKEN BY THE ENVIRONMENT AGENCY – BACTERIOLOGICAL SURVEY OF WATERCOURSES DISCHARGING TO ST IVES BAY

From 2000 to the time of writing, the Environment Agency had taken multiple water samples from three watercourses draining into St. Ives Bay. These were taken alongside the bathing waters samples reported in Appendix XI (i.e. from May to September) and tested for faecal coliforms (presumptive only). As faecal coliforms were not confirmed by the testing laboratory these results are not directly comparable with the bathing waters results.

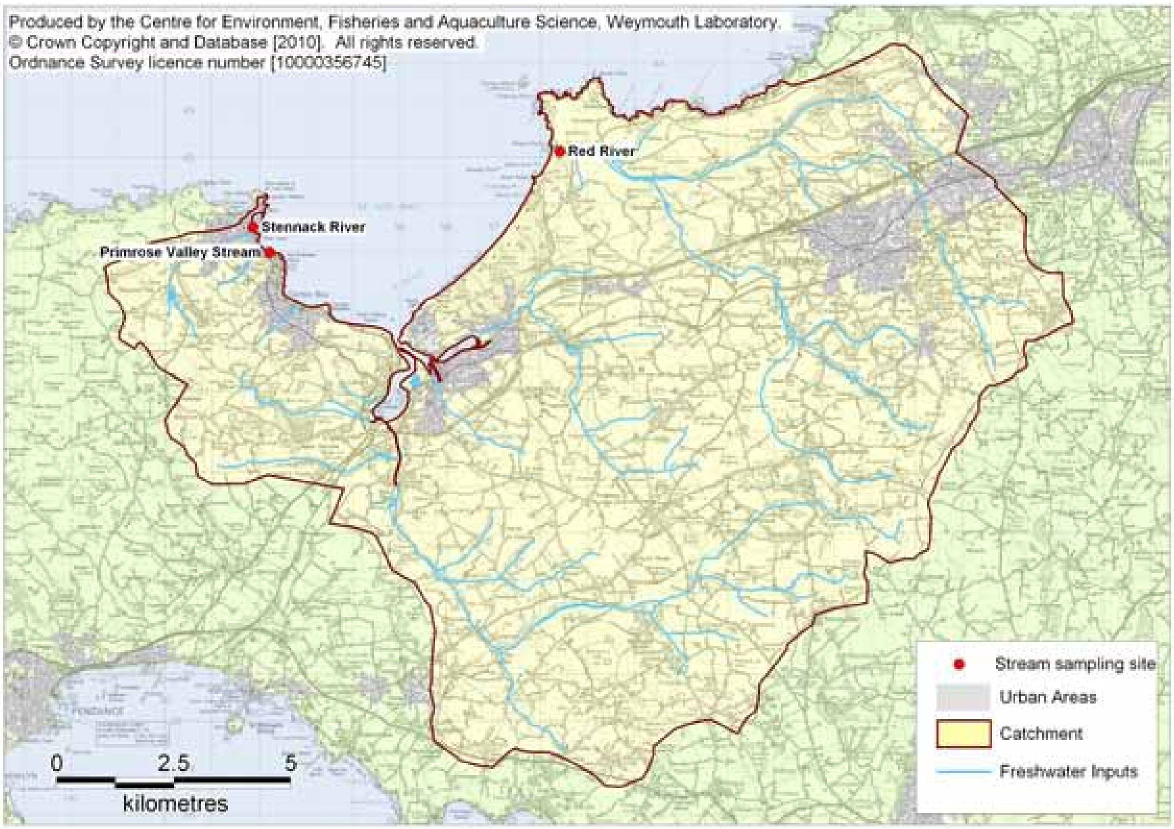


Figure XIII.1 Location of stream sites tested for Faecal coliforms alongside the bathing waters monitoring programme

Summary statistics are presented in Table XIII.1 and all results are presented in boxplots in Figure XIII.2

Table XIII.1 Summary statistics for stream sites tested for Faecal coliforms alongside the bathing waters monitoring programme

				Faecal coliforms presumptive (cfu/100ml)		
Site	Date of first sample	Date of last sample	No.	Min.	Max.	Geometric mean
Stennack River	06/05/2001	08/09/2010	183	96	1,000,000	6,120
Primrose Valley Stream	06/05/2003	08/09/2010	117	115	100,000	6,690
Red River	05/05/2000	08/09/2010	225	18	210,000	690

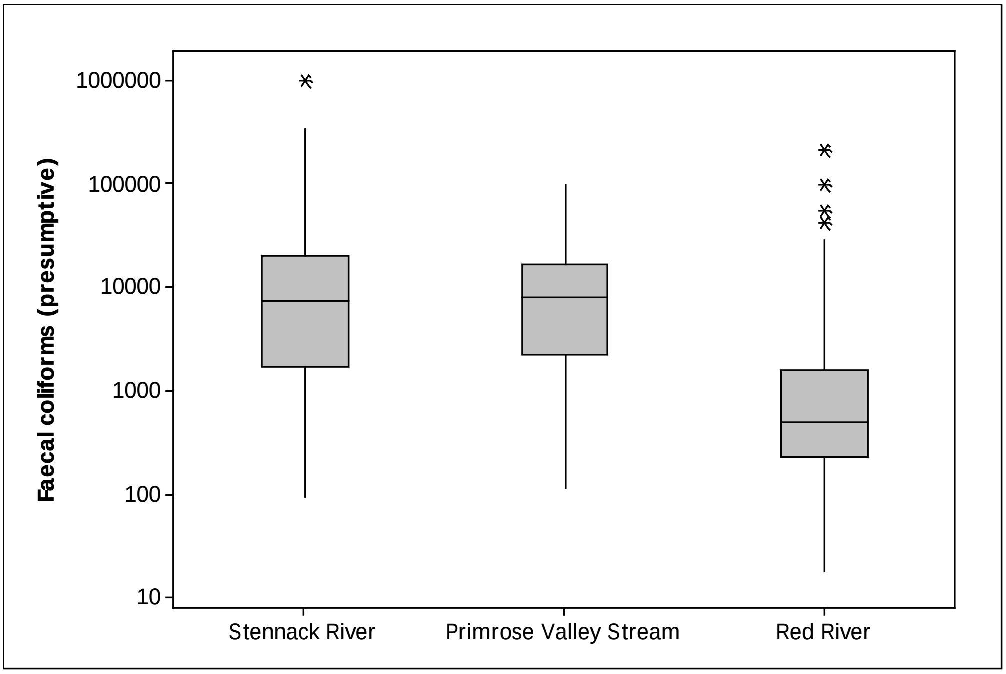


Figure XIII.2 Boxplot of Faecal coliforms for stream sites tested alongside the bathing waters monitoring programme

The two small streams at St. Ives carried concentrations of faecal coliforms which were on average about an order of magnitude higher than carried by the Red River. As the former drain urban areas, whereas the latter drains mainly rural areas this is not surprising. Some high levels of faecal coliforms were recorded within the Red River on occasion however.

To investigate the effects of recent rainfall on the concentration of faecal coliforms in these watercourses Spearman's rank correlations were carried out between these results and rainfall recorded at the St. Erth weather station over various periods running up to sample collection. Statistically significant correlations ($p<0.05$) are highlighted in yellow in table XIII.2.

Table XIII.2 Spearman's Rank correlations between rainfall recorded at the St. Erth weather station and water sample results from three streams draining to St Ives Bay

	Watercourse	Stennack River	Primrose Valley	Red River
	No. samples	169	103	210
24 hour periods prior to sampling	Day of sampling	0.339	0.082	0.250
	1 day	0.255	0.155	0.487
	2 days	0.169	0.090	0.165
	3 days	0.104	-0.090	0.050
	4 days	0.040	-0.114	0.070
	5 days	0.053	-0.044	0.001
	6 days	0.062	0.056	0.027
	7 days	-0.056	-0.104	0.031
Average prior to sampling over	2 days	0.387	0.130	0.408
	3 days	0.369	0.094	0.400
	4 days	0.344	0.047	0.377
	5 days	0.306	-0.008	0.393
	6 days	0.270	-0.024	0.367
	7 days	0.269	0.014	0.356

Significant correlations were observed between recent rainfall up to 2 days prior to sampling and levels of faecal coliforms in the Stennack River and the Red River, but no correlations were found for the Primrose Valley Stream. Discharge will also increase following rain, further increasing the amount of contamination conveyed into the bay.

BACTERIOLOGICAL SURVEY RECOMMENDED BY CEFAS

After an initial review of information compiled for the desk study and a shoreline survey, the location of three potential representative monitoring points within the wild razor fishery were identified. It was recommended that these points should be sampled on 10 occasions not less than a week apart, and unless the final sanitary assessment identified otherwise, the results of these could form part of the preliminary monitoring towards classification of this area.

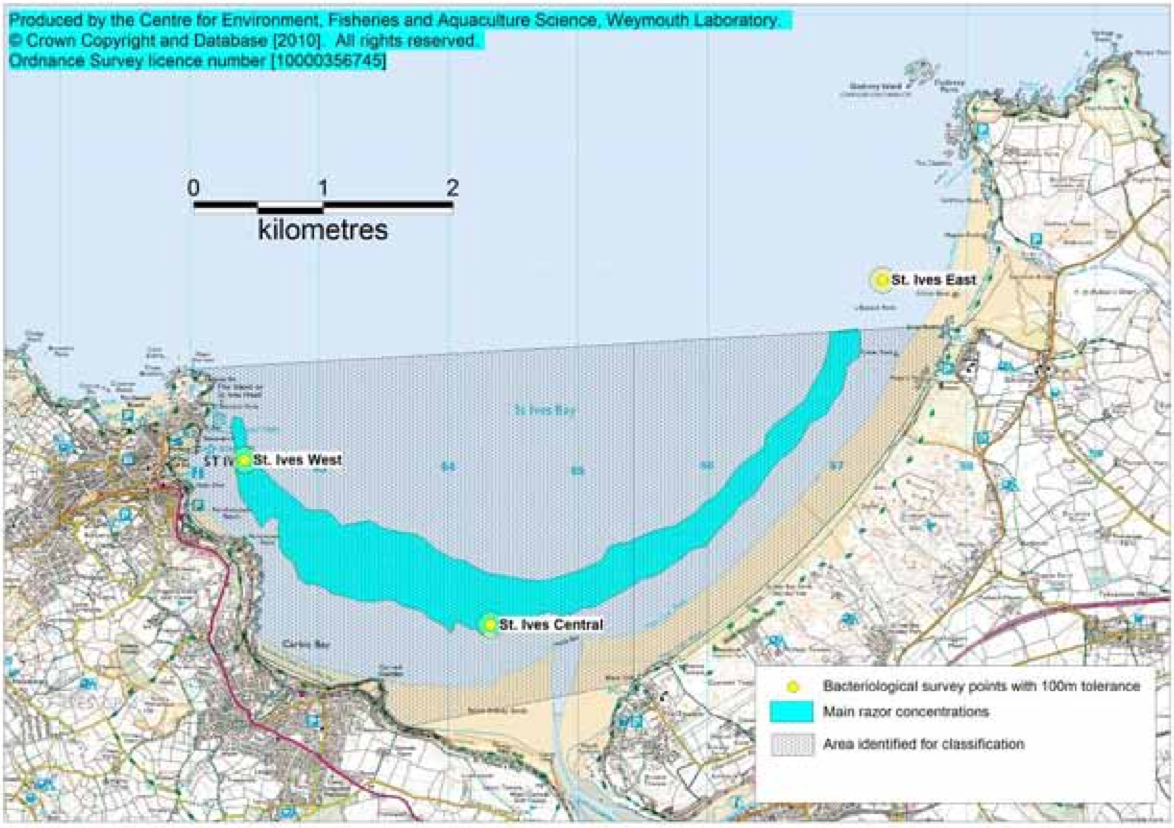


Figure XIII.3 Recommended bacteriological survey points (wild razor fishery)

During the course off the bacteriological survey it became apparent that there was insufficient stock present at St. Ives East, so samples were only collected from St. Ives Central and St. Ives West. Results to date are presented in Table XIII.3 and Figure XII.4.

Table XIII.3 Bacteriological survey results to date

	E. coli result (MPN/100g)	
Date	St Ives West	St Ives Central
25/01/2011	20	80
31/01/2011	50	130
08/02/2011	50	2,400
15/02/2011	330	230
22/02/2011	490	490
07/03/2011	140	80
14/03/2011	<20	20
22/03/2011	330	330
28/03/2011	310	790
04/04/2011	9,200	1,300
Geometric mean	159	262

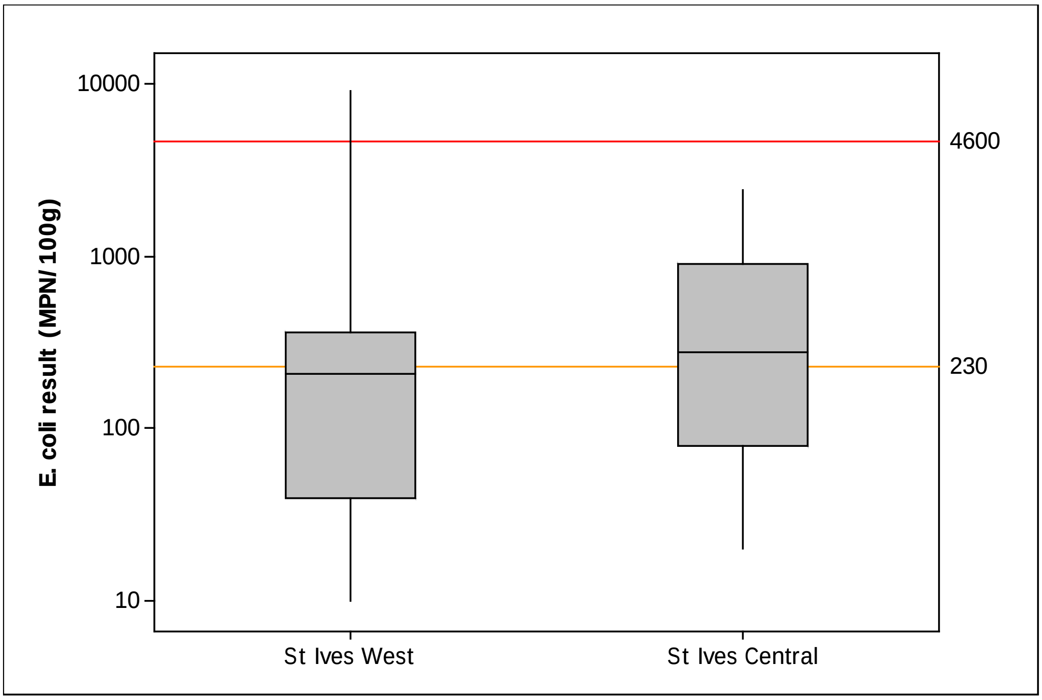


Figure XIII.4 Box plot of bacteriological survey results by sampling location

Results were similar across these two sampling locations. On average they were higher at St. Ives Central, but this difference was not statistically significant (Paired T-test, T=-1.03, p=0.331) and St. Ives West yielded the only result over 4,600 *E. coli* MPN/100g.

APPENDIX XIIV
SHORELINE SURVEY

Date (time): 6 September 2010 (09:45−15:45 BST)
Applicant: Mr P. Easterbrook (Karma Waters)
Cefas Officers: Simon Kershaw, Alastair Cook
Local Enforcement Authority Officer: Terry Stanley (Cornwall Port Health Authority).
Area surveyed: St Ives Bay (Figure XIV.1).
Weather: Winds southerly force 4, 18°C, heavy showers at times.
Tidal predictions (St Ives) for 6th September 2010: High Water (5.8m) at 04:01 BST, Low water (1.4m) at 10:28 BST, High Water (6.2m) at 16:22 BST.

Objectives: (a) establish the geographical extent of the fishery and its *modus operandus*; (b) obtain samples of shellfish, seawater and freshwater inputs to the bay for bacteriological testing; and (c) identify any additional sources of contamination in the area. A full list of recorded observations is presented in Table XIV.1 and the locations of these observations are mapped in Figure XIV.1. Photographs referenced in the text and tables are presented in Figures XIV.3-9.

Description of Fishery

The fishery is for diver caught razor clams (*Ensis* sp.). Burrows are inundated with saturated salt solution and animals are collected as they emerge. A specimen collected during the survey was subsequently identified as *Ensis siliqua* (pod razor, Figure XIV.3). In terms of depth, highest concentrations of animals are generally found along the 7.5m below chart datum contour. In shallower water, animals are less numerous but generally larger, and in deeper water animals are less numerous and smaller. Higher densities are found in the west side of the bay (up to 40 animals m^{-2}) compared to the east side (around 5-8 animals m^{-2}), and as the seabed slopes away more gently on the west side of the bay there are larger areas around the optimum depth.

The area falling between the 5 and 10m contours on the bathymetric chart is approximately $2km^2$. If razors are present throughout this area at a density of around 10 animals m^{-2} and weigh 50g on average, the standing stock biomass within this area is in the very approximate order of 1000 tonnes.

The harvester indicated that it would be preferable for the entire of the bay to be classified. The fishery will be operated year round, but tides and sea conditions will constrain operating windows. Poor underwater visibility is likely to prevent successful gathering at times. Access to and from Hayle harbour, where the diving boat is based is not possible around low water. As divers are constrained to a maximum depth of 15-20m, and the deeper the dive, the shorter the time which can be safely spent underwater so some of the deeper areas are effectively inaccessible at high water.

In addition to directly exploiting the area, the harvester plans to use a small area in the deeper water in the western part of the bay as a relay area. Razors would be potentially collected from various locations around the north Cornish coast, transported to the bay, and deposited in a specially constructed cage dug into the seabed. These other areas would require classification before shellfish could be relaid within St Ives Bay as without classification it cannot be confirmed that these areas may be of prohibited hygiene status. The cage would be divided and labelled so individual batches could be held separately for the minimum relaying period of 2 months.

Sources of contamination

Insufficient time was available to permit a full verification of the location of sewage discharges to St. Ives Bay. It was observed that the area was popular with holidaymakers, with many seen in St. Ives and holiday park accommodation noted between The Towans and Godrevy (Figure XIV.4), so large seasonal fluctuations in sewage loadings may be expected in the area.

Within St. Ives Harbour about 90 small boats were recorded on drying moorings, but none appeared to have on board toilets. Just off from St Ives 9 boats were recorded on moorings, of which possibly two may have had on board toilets. The Harbourmaster at St. Ives advised that there are about 150 overnight yacht visits to these moorings during the summer time. The harbour at Hayle is not generally used by visiting yachts as it can be difficult to navigate. A number of small fishing boats and small cabin cruiser type pleasure boats operate from here. Around 50 of these small vessels were seen, of which none appeared likely to have on board toilets. Surfing and windsurfing activities are mainly undertaken along the east shore between The Towans to Godrevy Point.

No livestock were recorded in the areas visited during the shoreline survey, although it is probable that there are livestock farmed within the St Ives Bay catchment area.

An aggregation of about 50 seagulls was observed on the intertidal area by St Ives harbour. Four dog walkers were recorded on the shore by The Towans.

Sample results

A full list of sample results is presented in Table XIV.2 and the locations of these observations are mapped in Figure XIV.2. One razor sample was collected from a point just offshore of Carbis Bay and contained 1300 *E. coli* MPN/100g. Attempts to gather further samples of razors from other locations were unsuccessful due to poor underwater visibility. Seawater samples were taken from the top and the bottom of the water column at three offshore points, and levels of *E. coli* were higher at the bottom on all three occasions, and quite consistent geographically. Levels of *E. coli* present were consistent with those generally expected in B classified areas.

A surface seawater sample was taken at the end of the ebb tide from the Hayle Channel, and this contained levels of *E. coli* of more than an order of magnitude higher than those found offshore. Freshwater samples were taken from three streams representing the largest freshwater inputs into the bay (excepting those entering Hayle Harbour), and these contained levels of *E. coli* ranging from 2500 to 80,000 cfu/100ml, with the two higher results originating from the streams draining more urban areas at St. Ives and Carbis Bay. All were turbid and flowing strongly at the time of sampling and given the intense rainfall on the day of survey levels of contamination carried via runoff would likely have been approaching the worst case scenario. Another very small stream was seen but not sampled at Porthminster Beach (Primrose Valley Stream, Figure XII.8) which issued from under the promenade and drained into the sand.

Other observations

Both the harbourmaster at St. Ives and the harvester advised that for most of the time there is a clockwise circulation of water within the bay.

In addition to the razor fishery, the Harbourmaster at Hayle identified in a brief meeting that there were some areas within Hayle Harbour supporting substantial mussel stocks, and requested advice on how to assess whether the food safety status of these stocks would permit them to be harvested in the future.

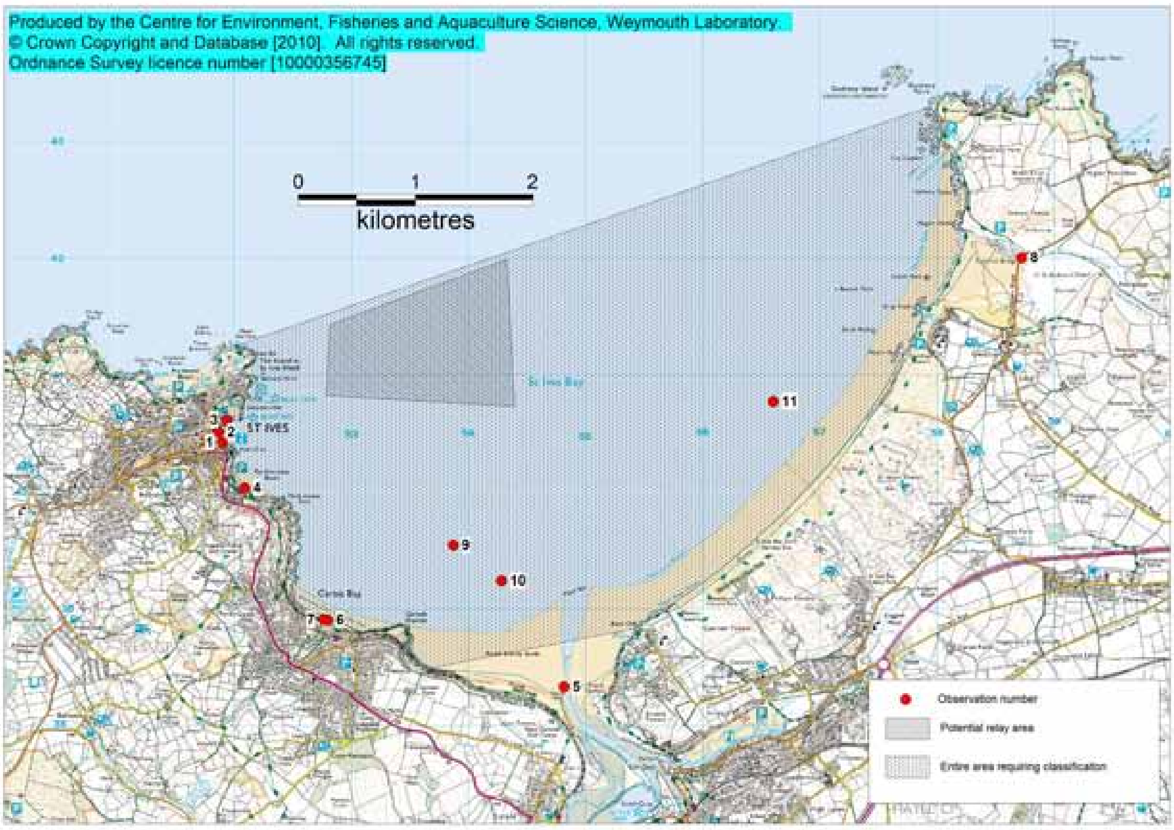


Figure XIV.1. Locations of shoreline observations

Table XIV.1. Details of shoreline observations

No.	Date and Time	Position	Observation
1	06-SEP-10 9:55:39AM	SW 51897 40423	Surface drain, flowing.
2	06-SEP-10 9:59:10AM	SW 51866 40512	Stream (Figure XIV.5), water sample 1, turbid and slight sewage odour, estimated dimensions 40cm x3cm x1.5m/s. 9 boats on moorings in bay, perhaps about 2 may have onboard toilet.
3	06-SEP-10 10:04:36AM	SW 51933 40615	St Ives harbour. Dries out. 90 powered boats on sand probably none of which have onboard toilets. 50 seagulls in flock on sand.
4	06-SEP-10 10:46:01AM	SW 52086 40035	Small stream which disappears into beach. Water clear.
5	06-SEP-10 11:15:36AM	SW 54813 38334	Water sample 2 from Hayle channel (Figure XIV.6), water clear, flowing seawards (very end of ebb tide).
6	06-SEP-10 11:41:11AM	SW 52795 38904	Stream (Figure XIV.7), water sample 3, turbid, estimated dimensions 230cmx5cmx0.5m/s.
7	06-SEP-10 11:48:27AM	SW 52761 38909	South West Water sewage pumping station
8	06-SEP-10 12:19:04PM	SW 58722 42003	Stream, estimated 4m wide very turbid, water sample 4.
9	06-SEP-10 1:35:43PM	SW 53869 39544	Seawater sample 5 (bottom) seawater sample 6 (top) razor sample 7. 12.1m deep, 13.7 C.
10	06-SEP-10 2:28:21PM	SW 54280 39239	Seawater sample 8 (bottom) and 9 (top), 12.3m deep, 13.7 C. Unable to gather razors due to poor visibility
11	06-SEP-10 2:47:43PM	SW 56602 40771	Seawater sample 11 (bottom) and 12 (top). 18.9m deep, 12.3C. Unable to sample razors due to poor visibility.

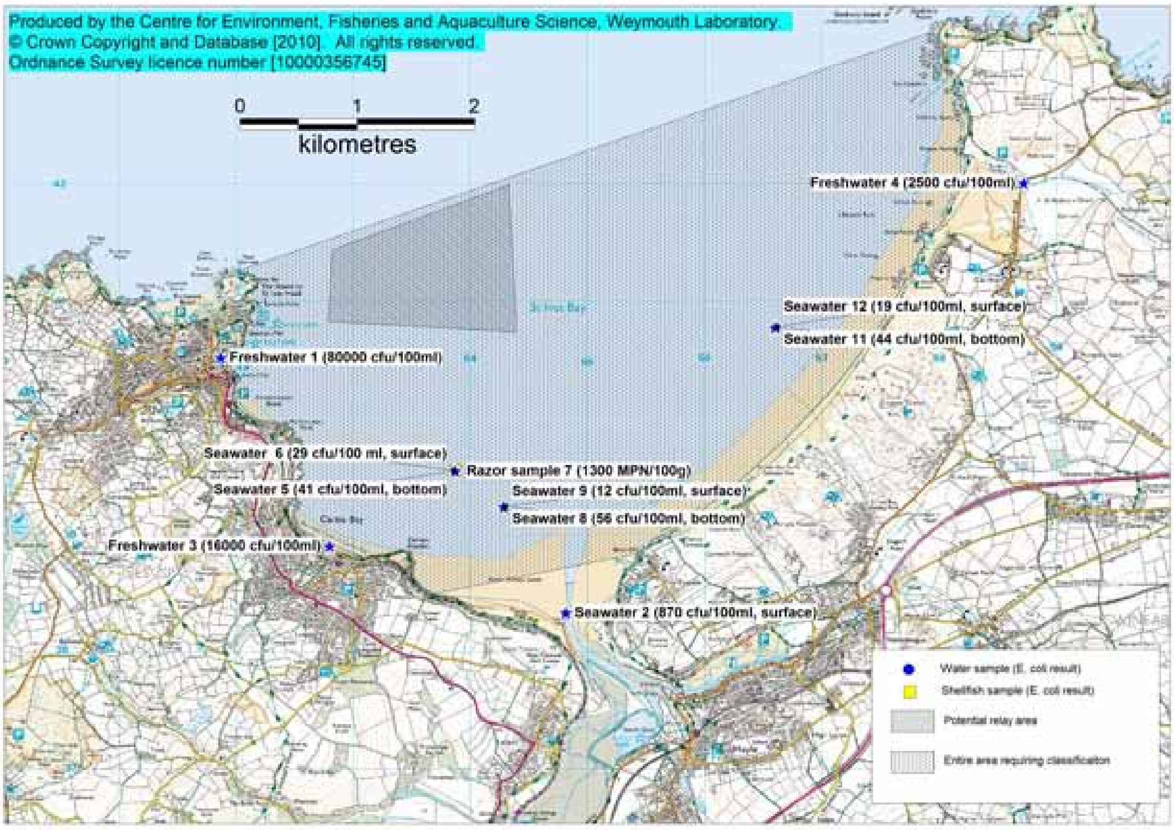


Figure XIV.2. Locations of samples taken

Table XIV.2. Details of samples taken

Sample reference	Date and time	Position	Type	*E. coli* result*
Water sample 1	06-SEP-10 9:59:10AM	SW 51866 40512	Freshwater	80000
Water sample 2	06-SEP-10 11:15:36AM	SW 54813 38334	Seawater	870
Water sample 3	06-SEP-10 11:41:11AM	SW 52795 38904	Freshwater	16000
Water sample 4.	06-SEP-10 12:19:04PM	SW 58722 42003	Freshwater	2500
Water sample 5 (bottom)	06-SEP-10 1:35:43PM	SW 53869 39544	Seawater	41
Water sample 6 (top)	06-SEP-10 1:35:43PM	SW 53869 39544	Seawater	29
Razor sample 7	06-SEP-10 1:35:43PM	SW 53869 39544	Shellfish	1300
Water sample 8 (bottom)	06-SEP-10 2:28:21PM	SW 54280 39239	Seawater	56
Water sample 9 (top)	06-SEP-10 2:28:21PM	SW 54280 39239	Seawater	12
Water sample 11 (bottom)	06-SEP-10 2:47:43PM	SW 56602 40771	Seawater	44
Seawater sample 12 (top)	06-SEP-10 2:47:43PM	SW 56602 40771	Seawater	19

*Water sample results are reported in cfu/100ml and shellfish sample results are reported in MPN/100g.

***Figure XIV.3. Shell of* Ensis siliqua**

Figure XIV.4 Holiday park on east shore

Figure XIV.5 Stream at St. Ives beach

Figure XIV.6 Hayle Channel

Figure XIV.7 Stream at Carbis Bay

Figure XII.8 Stream at Porthminster Beach

Figure XIV.9 Harvesting boat

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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
CIFCA	Cornwall Inshore Fisheries and Conservation Authority
CZ	Classification Zone
Defra	Department for Environment, Food and Rural Affairs
DWF	Dry Weather Flow
EA	Environment Agency
E. coli	*Escherichia coli*
EC	European Community
EEC	European Economic Community
EO	Emergency Overflow
FIL	Fluid and Intravalvular Liquid
FSA	Food Standards Agency
GM	Geometric Mean
ISO	International Organization for Standardization
km	Kilometre
LEA (LFA)	Local Enforcement Authority formerly Local Food Authority
M	Million
m	Metres
ml	Millilitres
mm	Millimetres
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MPN	Most Probable Number
OSGB36	Ordnance Survey Great Britain 1936
mtDNA	Mitochondrial DNA
PS	Pumping Station
RMP	Representative Monitoring Point
SAC	Special Area of Conservation
SCUBA	Self Contained Underwater Breathing Apparatus
SSSI	Site of Special Scientific Interest
UV	Ultraviolet
WGS84	World Geodetic System 1984

Glossary

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

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

Terry Stanley (Cornwall Port Health Authority), Samantha Davies (Cornwall Sea Fisheries Committee), Phil Easterbrook (Karma Waters).