Cefas

EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Milford Haven

2012

Cover photo: Intertidal area near Picton Point.

CONTACTS:

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

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

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

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

Jayne Griffiths
Tim Polisi Bwyd/Food Policy Team
Asiantaeth Safonau Bwyd/Food Standards Agency
Llawr 10, Ty Southgate/10th Floor, Southgate House
Wood Street
Caerdydd/Cardiff CF10 1EW

☎ +44 (0) 029 2067 8908
shellfish_hygiene@foodstandards.gsi.gov

STATEMENT OF USE: This report provides a study of the information available relevant to perform a sanitary survey of bivalve mollusc classification zones in Milford Haven. 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	Date of consultation	Date of response
Environment Agency	18/10/2012	07/12/2012
Local Enforcement Authority	18/10/2012	05/12/2012
Welsh Government Fisheries	07/12/2012	18/12/2012
Dŵr Cymru - Welsh Water	18/10/2012	-

DISSEMINATION: Food Standards Agency, Milford Haven Port Health Authority, Welsh Government Fisheries, Environment Agency.

RECOMMENDED BIBLIOGRAPHIC REFERENCE: Cefas, 2012. Sanitary survey of Milford Haven. 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.

CONTENTS

1. INTRODUCTION

1.1 LEGISLATIVE REQUIREMENT

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

When consumed raw or lightly cooked, bivalves contaminated with pathogenic microorganisms may cause infectious diseases (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 the information relevant to undertake a sanitary survey for carpet shell clams (*Venerupis pullastra*), native oysters (*Ostrea edulis*), Pacific oysters (*Crassostrea gigas*), cockles (*Cerastoderma edule*), mussels (*Mytilus* spp.) and razors (*Ensis* spp.) within Milford Haven.

1.2 Site Description

The Estuary

Milford Haven is located in south west Wales and is the largest ria (drowned river valley) type estuary in the UK. It measures about 32km from its mouth to its head and covers an area of about 55km^2 of which about 30% is intertidal. It hosts the largest deepwater port in Wales within its outer reaches. The bulk of shipping traffic is associated with the hydrocarbon industry, with some cargo and fishing vessels and a twice daily ferry to Rosslare. The towns of Milford Haven and Pembroke Dock and Neyland lie on the shore of the outer estuary, and the town of Haverfordwest lies at the head of its' upper western reach. Its large area and diversity of intertidal and subtidal habitats support a range of shellfisheries.

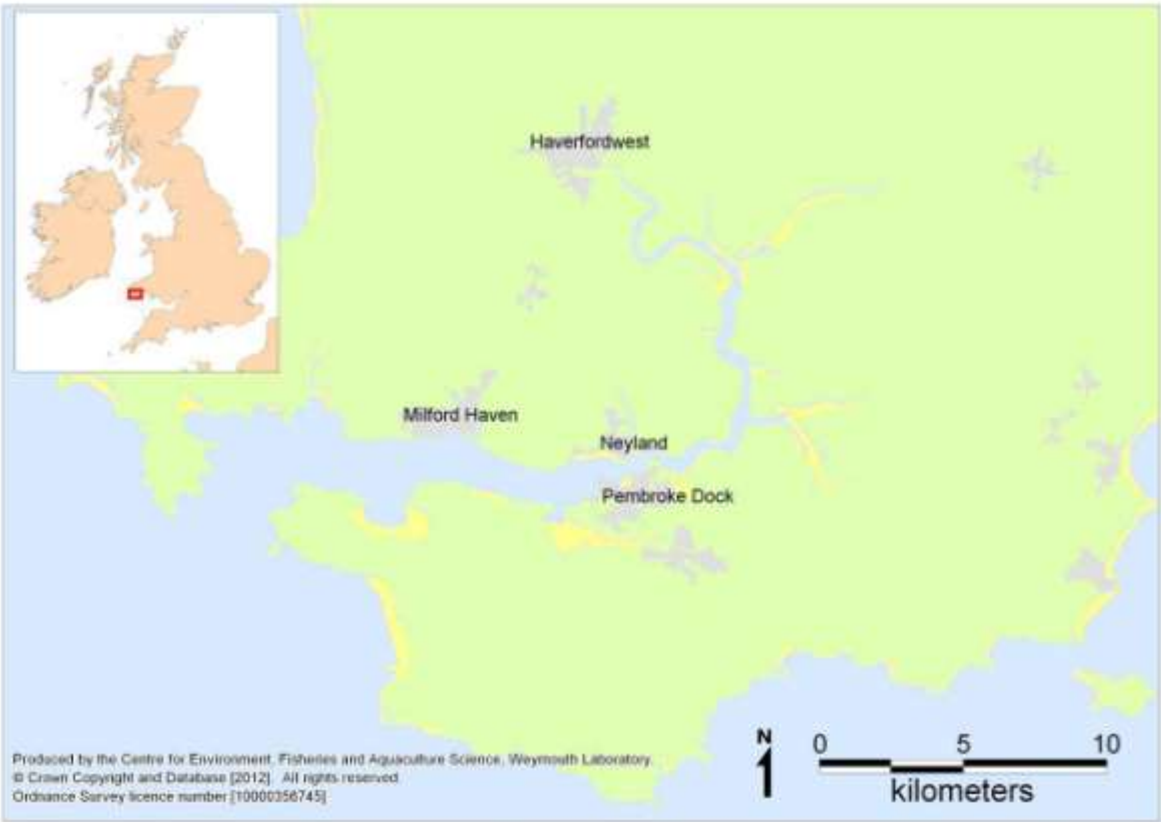


Figure 1.1 Location of Milford Haven.

Catchment

Milford Haven has a catchment area of about 820km^2 in total. The two main freshwater inputs are the East and West Cleddau, which form a confluence in the upper reaches of the estuary. There are also several other significant watercourses joining the estuary in various locations. The catchment is mainly low lying, although it does rise to an elevation of 535m in the upper reaches of the Eastern Cleddau catchment. Figure 1.2 shows land cover within the catchment area.

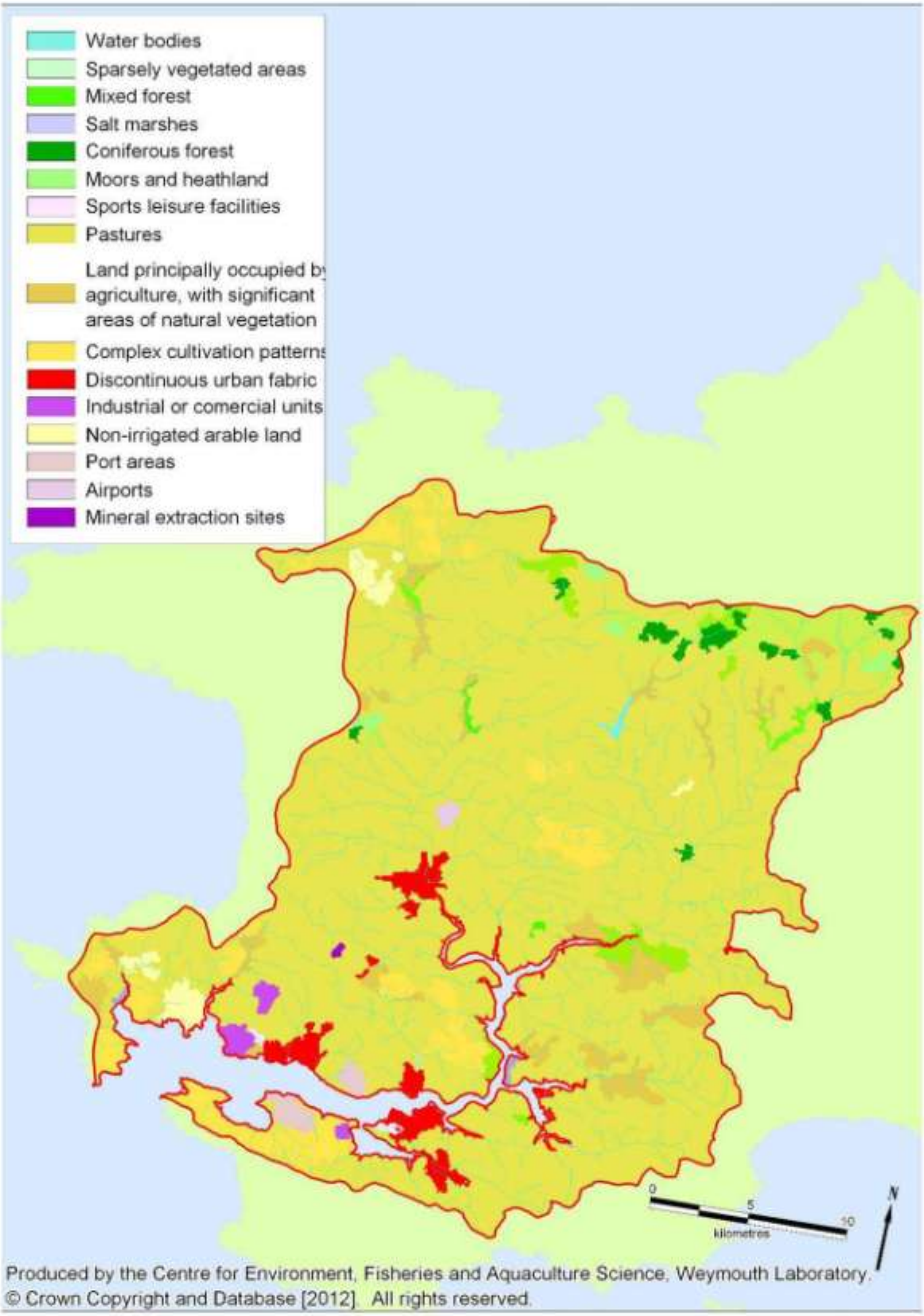


Figure 1.2 Land cover within the Milford Haven catchment.

The majority of the land within this area is pasture so agricultural runoff is likely to be of significance to Milford Haven. The main urban areas are on the shores of the estuary. Different land cover types will generate differing levels of contamination in surface runoff. Highest faecal coliform contributions arise from developed areas, with intermediate contributions from the improved pastures and lower contributions from the other land cover types (Kay *et al*. 2008a). The contributions from all land cover types would be expected to increase significantly after marked rainfall events, particularly for improved grassland which may increase up to 100 fold.

2. SHELLFISHERIES

2.1 SPECIES, LOCATION AND EXTENT

This sanitary survey was prompted by an application for classification of three areas (one at Milford Shelf, one by Pwllcrochan Flats, and a much smaller one at Wear Point) for carpet shell clams. An application was also received at the same time to extend the native oyster classification to cover the Milford Shelf. A further application was received after the shoreline survey was completed for classification of razors at Dale Flats. In addition to these new fisheries, there are existing classified fisheries for mussels and native oysters. Historically, wild cockles and cultured Pacific oysters have been classified for harvest within the survey area, but these fisheries are not currently in operation.

NATIVE OYSTERS

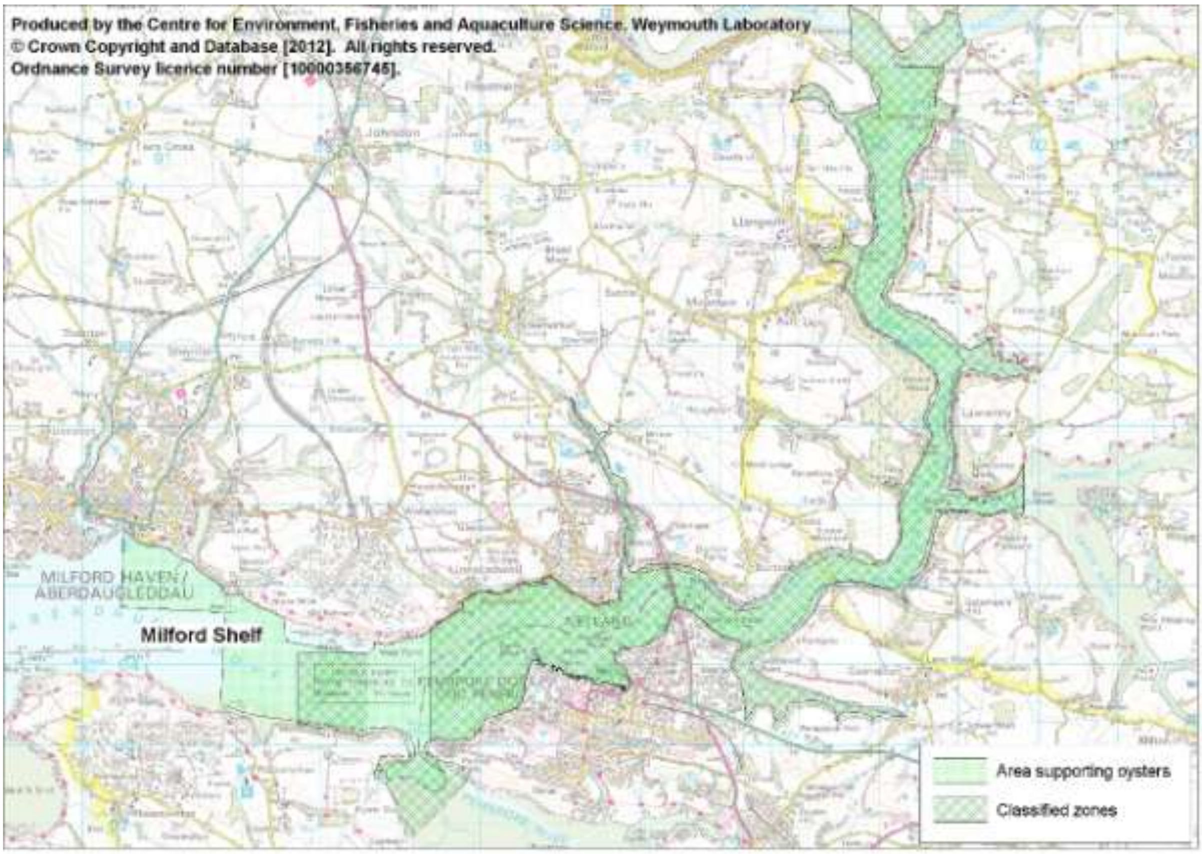


Figure 2.1. Native oyster distribution and classification zones within Milford Haven

Native oysters are widespread throughout the area with stocks present from Milford Haven Town up to Picton Point. It is possible that some stocks are present further west as far as Thorne Island, but dredging here is largely impractical or not permitted for various reasons including rocky substrates, oil terminal jetties, the volume of shipping traffic, and the presence of moorings and crab pots (Milford Haven Port Health, personal communication). Therefore the area requiring classification includes Milford Shelf, and from the Pier at Newton Noyes up to Picton Point. During the shoreline survey specimens were seen on mussel beds just downstream from Picton Point, under the Cleddau Bridge and in a dredge catch from Pennar Gut. A diver survey undertaken in 2002 counted oysters within seven areas of 80-100m^2 from Pennar Gut to Garron Pill, and found that although native oysters were present at every transect, densities were generally low ranging from 0.09 to 1.49 oysters per m^2 (Emu Ltd., 2003). The highest density was observed in Pennar Gut.

The fishery is operated on a part time basis by 3-5 boats. Total annual catch is relatively small at less than 10 tonnes. The catch is sent to various depuration centres both within England and Wales and in Europe.

MUSSELS

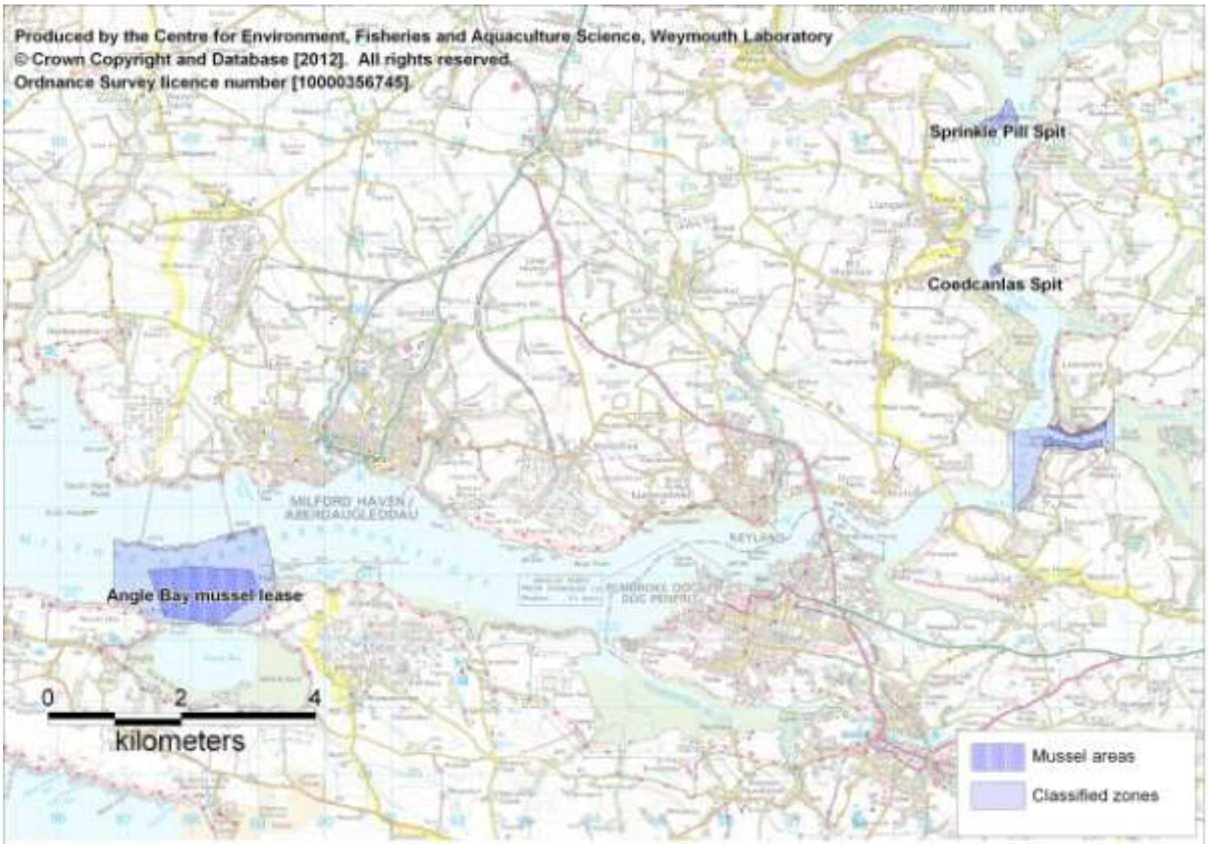


Figure 2.2. Mussel areas and classification zones within Milford Haven

Wild stocks of mussels are present in patches throughout Milford Haven, either on raised beds or on rocks. The main raised beds are found between the Cleddau Bridge and Picton Point at Lawrenny Quay, Coedcanlas and Sprinkle Pill. Most of these are of no commercial interest due to heavy barnacle coverings. The only area which has been fished commercially in recent years is at Lawrenny Quay, where mussels were hand picked at low tide.

A mussel farm is planned just outside the mouth of Angle Bay. A several order has been proposed and construction is yet to start (Welsh Government Fisheries, pers. comm.). CCW have identified conservation related issues of concern (impacts to the seabed in the vicinity of the farm, and increased mussel spatfalls due to the farm). A small scale trial of both bed and suspended culture with an assessment of ecological impacts is planned in the first instance before the site can be fully developed.

COCKLES

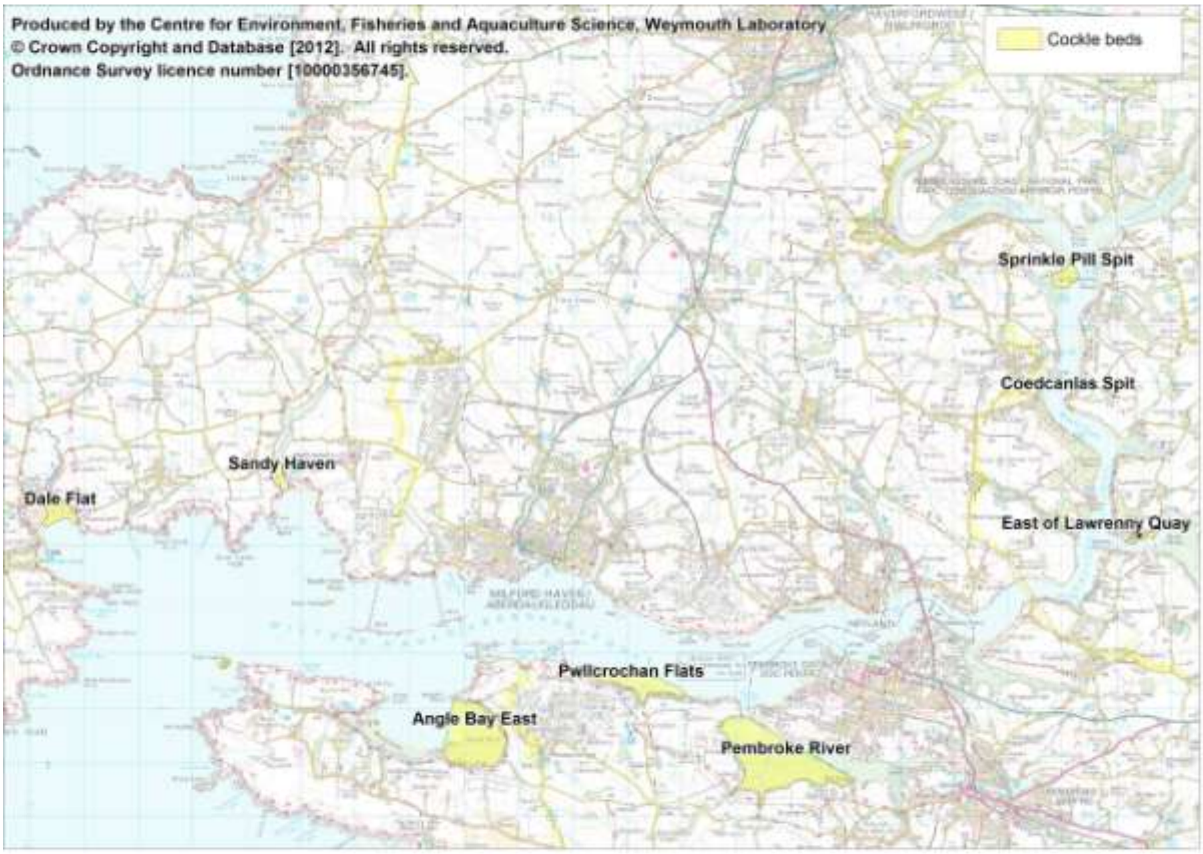


Figure 2.3. Cockle beds within Milford Haven

Cockles are present in some areas where there is suitable intertidal habitat. Stock status is very variable between years, with commercial densities generally arising in the various beds every five to ten years or so but not at predictable intervals. None are currently classified as there has been no commercial interest in recent years. Mortalities of a similar nature to those experienced in Burry Inlet have been reported during late spring at Angle Bay in recent years and it is possible that this may occur at other beds.

The main two beds of former commercial interest are the eastern half of Angle Bay, and the intertidal area just south of the Pembroke River Channel. Angle Bay is no longer classified as stocks have been low for some years, but a sampling plan will nevertheless be provided in case stocks recover. Should these beds reopen it is likely that CCW via Welsh Government Fisheries will impose some restrictions to access points and the fishable area aimed at protecting areas of seagrass found just inshore of these beds. The Pembroke River bed has been closed to cockle harvesters on safety grounds and this situation is not thought likely to change in the near future (Milford Port Health, personal communication). Sample collection from the Pembroke River is difficult due to the soft nature of the substrate. As with Angle Bay, should this bed reopen, restrictions aimed at protecting areas of seagrass inshore of these beds are likely to be imposed. In spite of the relatively low likelihood of this bed reopening, a sampling plan will also be provided for Pembroke River.

In addition to the two main cockle beds, smaller areas supporting (or historically supporting) some cockles are located at Sprinkle Pill, Coedcanlas Spit, East of Lawrenny Quay, Pwllcrochran Flats, Sandy Haven, and Dale Flat. Milford Port Health advise that these beds are of no commercial interest due to low stock levels at present. Welsh Government Fisheries advise that stocks have been present in the past but their occurrence at commercial densities is rare at these locations. Nevertheless, sampling plans should be provided for all these beds in case commercial interest is revived.

CARPET SHELL CLAMS

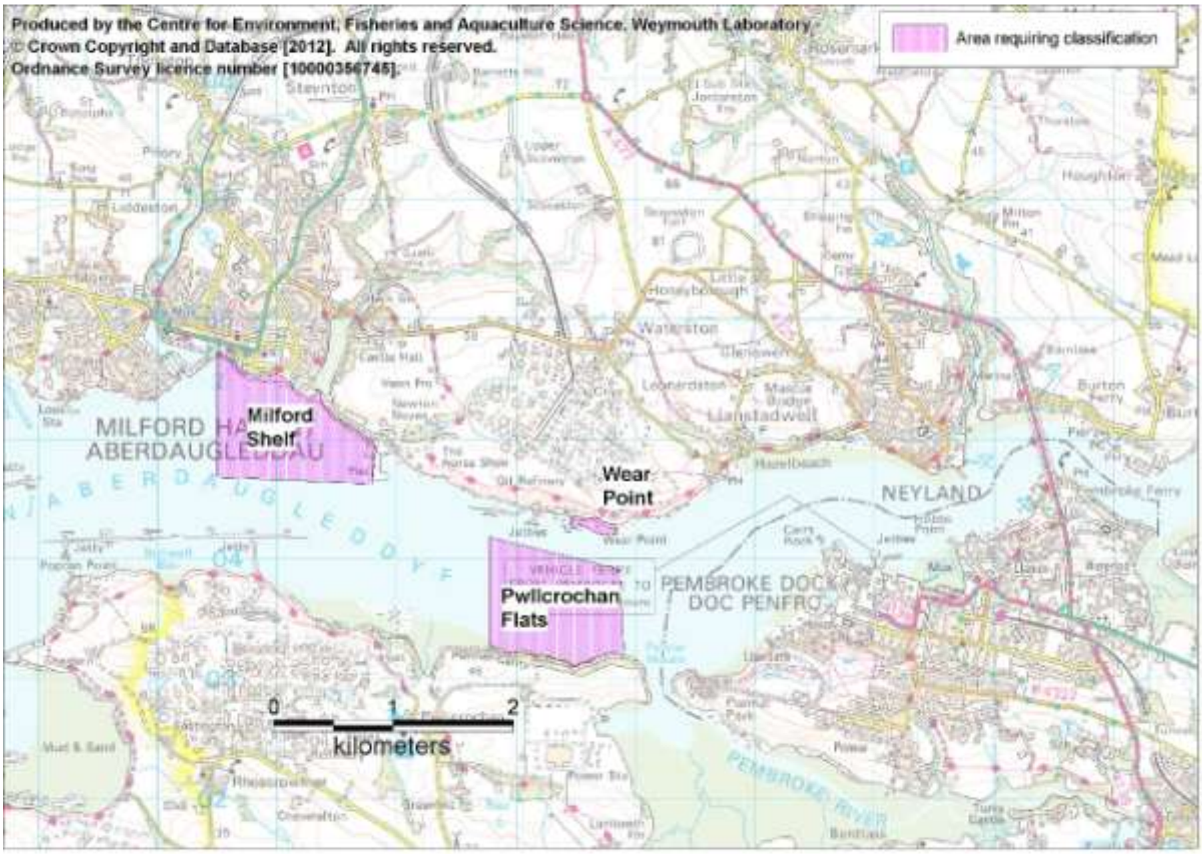


Figure 2.4. Areas requiring classification for carpet shell clams within Milford Haven

Classification was requested for carpet shell clams (*Venerupis pullastra*) within the three areas shown in Figure 2.4. It is likely that they are distributed much more widely within Milford Haven where suitable sand, gravel or mud substrates are present. The applicant suggested that stocks may extend up as far as Carr Rocks and beyond, but no stock surveys or other firm information are available to indicate their wider distribution. The applicant indicated that the three areas in Figure 2.4, which cover a total area of 1.93km^2, contain sufficient stock to meet his individual needs for several years. Therefore, in the absence of further information on stock distribution only these specific areas for which classification has been requested will be considered in the sampling plan.

RAZORS

An application to classify razors (*Ensis* spp.) at Dale Flats was received in February 2012. The area for which classification was requested is shown in Figure 2.5.

Figure 2.5 Area for which razor classification has been requested

The area requiring classification covers about 0.36km^2 and lies in the outer reaches of Milford Haven in an embayment sheltered from wind and waves from most directions. It lies on a gently sloping sandy area below the mean low water mark. The exact extent of the razor beds and the amount of stock present within this area is not known, nor is any information available on whether there are further areas supporting exploitable razor beds within Milford Haven. The applicant has indicated that the beds can only be accessed on the largest (equinoctial) spring tides, so sampling on a monthly basis may prove problematic.

PACIFIC OYSTERS

Pacific oysters (*Crassostrea gigas*) were formerly cultured on trestles within the Cresswell/Carew Rivers, but this operation ended about a decade ago. The applicant reported that small numbers of naturally occurring specimens of this species are now found in the estuary, mainly within the Cresswell/Carew side channel and adjacent reaches of the main Cleddau channel up to Carron Pill. Syvret *et al* (2008) report that although the temperature regime within Milford Haven is likely to result in conditioning and spawning, it is not sufficiently warm for consistent recruitment of this species. It is nevertheless possible that successful recruitment may occur in warmer years, and that such events may become more frequent in the future given a warming climate and increased inputs of power station cooling water to Milford Haven. Therefore this species should be classified within the areas dredged for native oysters to allow any specimens caught in this fishery to be landed and marketed.

2.2 Growing methods and harvesting techniques

All stocks considered in this report are wild, with the future exception of the mussel farm planned at Angle Shelf. The intertidal fisheries for cockles and mussels are harvested via hand gathering. Native oysters are naturally occurring and are fished commercially on a part time basis by 3-5 licensed dredgers. Bycatch of this dredge fishery may include occasional Pacific oysters. Carpet shell clams will also be fished by dredge, should such a fishery be permitted. Razors will be captured by hand salting during the largest spring tides when the beds are exposed.

The culture methods to be used at the Angle Shelf mussel farm are yet to be decided. A pilot trial of both bed and suspended culture is due to start shortly. Once the relative success and environmental impacts of these techniques have been assessed the layout of the farm will be determined.

2.3 Seasonality of harvest, conservation controls and development potential

The native oyster dredge fishery upstream of the Cleddau Bridge is only open from the 1st October to 31st January, but is open to hand gathering all year. Downstream of the bridge the dredge fishery is open year round. No closed seasons apply to any other species within Milford Haven, although cockle fishing is only permitted during the daytime. Any shellfishery may be closed at any time by Welsh Government Fisheries for stock preservation reasons. Current minimum landing sizes which apply are: native oysters (70mm); cockles (19mm); mussels (51mm); razors (100mm) and carpet shell clams (38mm). The minimum sizes may be reduced by Welsh Government Fisheries for cockles to thin beds or for mussels to be used as seed stock.

Gear limitations (hand gathering only) apply to the intertidal fisheries (cockles and mussels). Any vessel engaging in dredging requires a permit from the Welsh Government Fisheries, and where there may be potential conservation issues CCW are consulted. Dredge configurations authorised within the district do include toothed dredges but these are not to exceed 4 inches (10cm) digging depth. It is yet to be determined by CCW and Welsh Government Fisheries whether toothed dredges will be authorised for collecting carpet shell clams from Milford Haven and the timescale for such a decision is unclear at present. Milford Port Health may therefore wish to consider delaying the implementation of this sampling plan until they receive written confirmation from the Welsh Government and CCW that these permissions issues are satisfactorily resolved. No dredging is permitted within 100m of any oil terminal jetty, or any vessels docked there.

The wild native oyster and mussel fisheries are unlikely to change much in the near future. The planned Angle Bay mussel farm is within a lease area of just over 1km^2, so, if fully developed, production levels could be high. Interest in the cockle fisheries will continue to fluctuate with stock levels, ranging from negligible in many years to considerable in good years. As the full distribution and densities of clams are not known it is difficult to say what the potential of the fishery is. The harvester indicated that within the ~2km^2 for which he requested classification there were sufficient stocks to meet his individual needs for several years, and that stocks are probably much more widespread, so there may be potential to develop a large and lucrative fishery. The razor fishery at Dale is only accessible on the very largest tides (i.e. only a handful of short intervals per year) and gathering is via hand so it is unlikely that a significant commercial fishery will be developed on this basis. If the stocks of Pacific oysters increase they may potentially overtake the significance of the native oyster fishery, as has happened in some other areas. At present, and probably for the foreseeable future, this species is only of incidental interest.

2.4 HYGIENE CLASSIFICATION

Table 2.1 Classification history for the Milford Haven, 2001 onwards

Area	Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
All beds: Cleddau Bridge (exc. Angle Bay and Pembroke River)	All species					P						
Cleddau River: All beds below Cleddau Bridge	All species			P	P							
All beds: Cleddau Bridge to Pennar Point	All species						P	P	P	P	P	P*
Carew River (Area 1)	Pacific oysters	B	B									
Carew River (Area 2)	Pacific oysters	B	B									
Carew River (Area 3)	Pacific oysters	B	B									
Angle Bay	Cockles					B	B	B	B			
Angle Bay East	Cockles									B		
Pembroke River	Cockles					B	B	B	B	B		
All other beds	Mussels		C									
Cleddau Bridge to Coedcanlas	mussels		B									
Cleddau Bridge to Jenkins Point	Mussels	B										
Cleddau River - Jenkins Point to Picton Point	Mussels	C										
Jenkins Point	Mussels			B	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Mount Pleasant	Mussels			B	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Neyland Marina	Mussels	C										
Popton Point	Mussels							B	B	B	B-LT	B-LT
Sprinkle Pill Spit	Mussels			B								
Cleddau River: all beds	Native oysters	B	B									
Cleddau River: All beds above Cleddau Bridge	Native oysters				B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT
Cleddau River: All beds above Cleddau Bridge (Exc. Sprinkle Pill)	Native oysters			B								
Pennar	Native oysters						B	B	B	B	B-LT	B-LT
Pennar Gut	Native oysters						B	B	B	B	B-LT	B-LT

*Reclassified as C for Pacific oysters only in April 2012
Classifications shown as at the annual review (September) in each year

Current classification maps are shown for native oysters in Figure 2.5 and mussels in Figure 2.6.

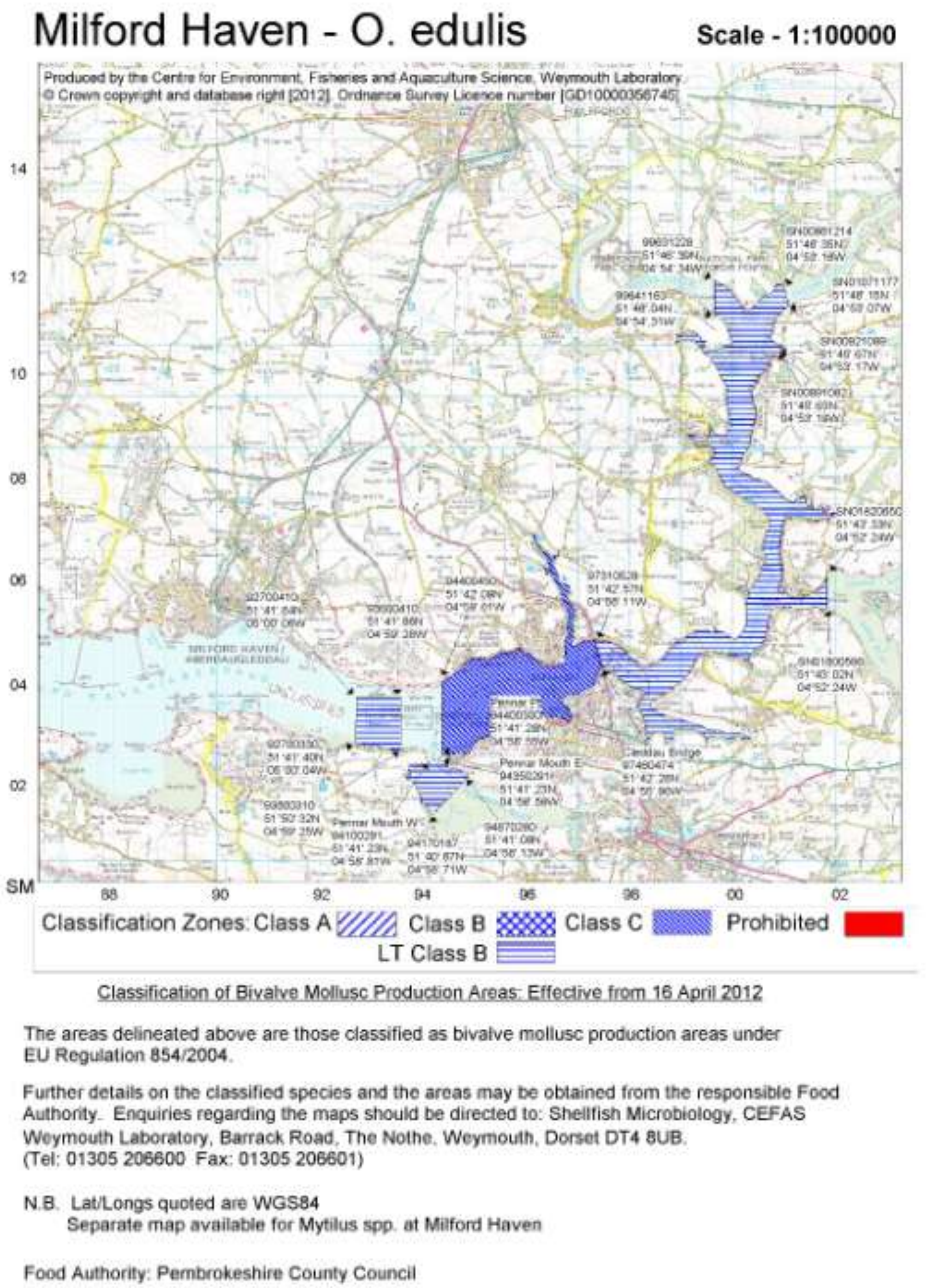
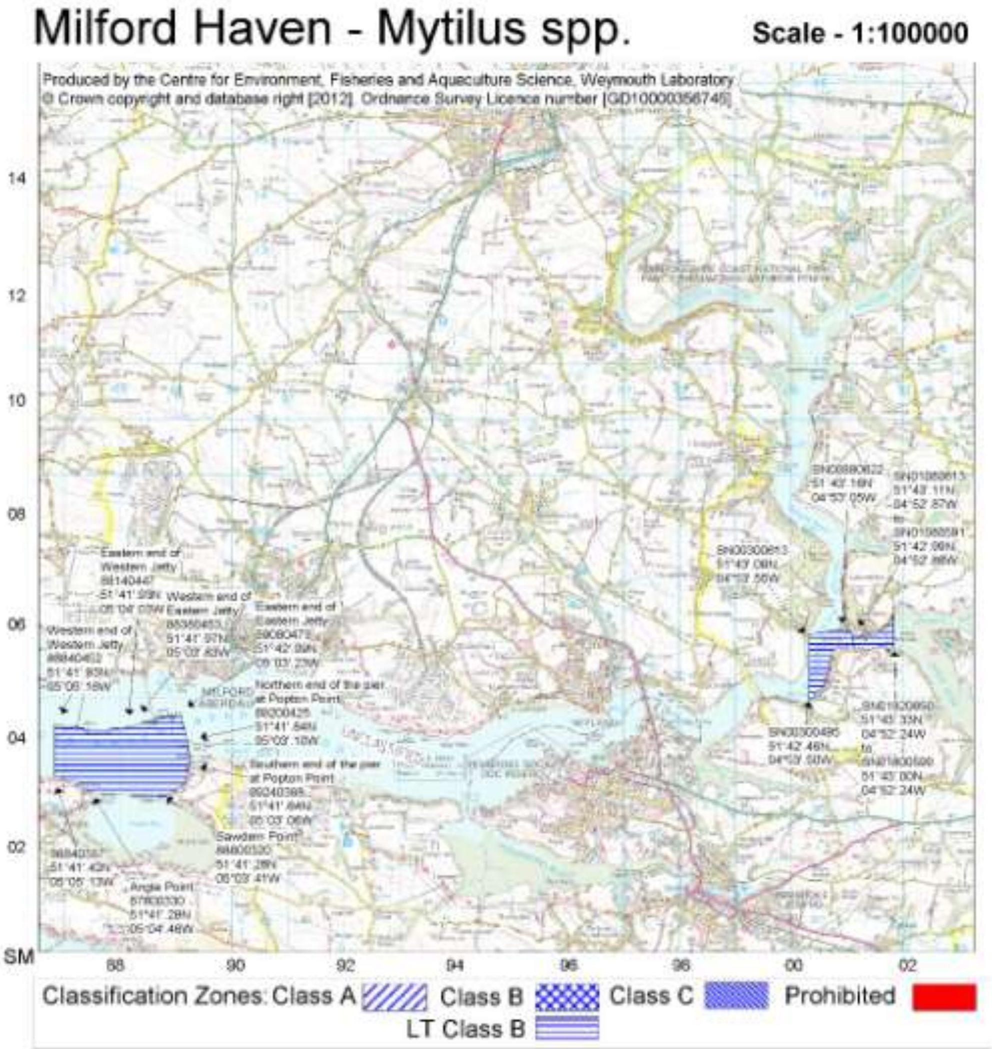


Figure 2.5 Current classifications for native oysters.



Classification of Bivalve Mollusc Production Areas: Effective from 16 April 2012

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

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

N.B. Lat/Longs quoted are WGS84
Separate map available for O. edulis at Milford Haven

Food Authority: Pembrokeshire County Council

Figure 2.6 Current classification for mussels

The area between Neyland and Pembroke Dock (where there are two major sewage outfalls) was assigned prohibited status until April 2012, when it was classified as C for native oysters. Outside of this, all classified areas are currently long term B. The vast majority of historic classifications have been B, but C classifications have arisen in mussels in the upper reaches towards Picton Point and within the Marina at Neyland. Table 2.2 summarises the post-harvest treatment required before bivalve molluscs can be sold for human consumption.

Table 2.2 Criteria for classification of bivalve mollusc production areas.

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

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

3. OVERALL ASSESSMENT

AIM

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

SHELLFISHERIES

Although the actual volumes of shellfish harvested from Milford Haven are not particularly large, there are many parts of the estuary requiring or potentially requiring classification. This includes six species within numerous shellfish beds located from Dale Flats near the estuary mouth up as far as Picton Point at the confluence of the East and West Cleddau. Several of these beds are small, often devoid of stock and only occasionally the subject of commercial interest. A sampling plan for each will nonetheless be provided in case it is needed.

NATIVE OYSTERS

Wild native oysters are widely distributed through the estuary but at low densities. The fishery is operated on a part time basis by 3-5 boats. Total annual catch is relatively small at less than 10 tonnes. The area requiring classification includes Milford Shelf, and from the Pier at Newton Noyes up to Picton Point. The fishery is active throughout the currently classified area. Upstream of the Cleddau Bridge the dredge fishery is only open from the 1st October to 31st January but is open to hand gathering all year round. Downstream of the bridge the fishery is open year round.

MUSSELS

Wild stocks of mussels are present in fairly small patches throughout Milford Haven, either on raised beds or on rocks. The main raised beds are found between the Cleddau Bridge and Picton Point at Lawrenny Quay, Coedcanlas and Sprinkle Pill. Most of these are of no commercial interest due to heavy barnacle coverings. The only area which has been fished commercially in recent years is at Lawrenny Quay, where mussels were hand picked at low tide.

A mussel farm is planned just outside the mouth of Angle Bay and continued classification of the area for which a Several Order has been proposed, although a mussel farm has not yet been established. CCW require a small scale trial of both bed and suspended culture with an assessment of ecological impacts before the site can be fully developed. As there is no closed season for mussels year round classifications are required for both wild and cultured stocks.

COCKLES

Cockles are present in exploitable densities at times and have been subject to commercial hand gathering. Stock status is very variable between years, with commercial densities generally arising every five to ten years or so but not at predictable intervals. No areas have been classified or harvested since 2009. The main concentrations have arisen in recent years within the eastern half of Angle Bay, and in the intertidal area just south of the Pembroke River Channel. The Pembroke River bed has been closed on safety grounds and this situation is unlikely to change in the immediate future. Should the Angle Bay bed reopen, CCW are likely to seek to impose restrictions on the fishable area to protect adjacent seagrass beds.

Smaller areas which have historically supported some cockles are located at Sprinkle Pill, Coedcanlas Spit, East of Lawrenny Quay, Pwllcrochran Flats, Sandy Haven and Dale Flat. Their occurrence at exploitable densities in these areas is a rare event, and none have been classified within the last decade. There is no closed season for cockles so if classifications are required for any area they should be year round.

CARPET SHELL CLAMS

Classification was requested for carpet shell clams at Pennar Cant, Wear Point and Milford Shelf, a combined area of 1.93km^2. The applicant indicated that there are sufficient stocks to meet his individual needs for several years within these areas. It is likely that they are more widespread within the outer reaches of Milford Haven although there is no solid information available on their distribution. Therefore a sampling plan will only be provided for the requested areas.

It is yet to be determined by CCW and Welsh Government Fisheries whether the use of the toothed dredges required to extract this species will be permitted and the timescale for such a decision is unclear at present. Until permission has been agreed the fishery cannot be opened, nor will it be possible to collect samples for classification purposes. There is no closed season for carpet shell clams so any classifications should be year round.

RAZORS

An application to classify razors (*Ensis* spp.) within a 0.36km^2 area at Dale Flats was received while this report was in preparation. The collection method is via hand salting. The bed can only be accessed on the largest (equinoctial) spring tides, so sampling on a monthly basis is likely to prove problematic unless there are some stocks at higher elevations or Milford Port Health can arrange diver collection. As the stocks are only accessible during a short window within a handful of tides each year, and the collection method is relatively labour intensive it is questionable whether this fishery would operate on a significant commercial scale. There is no closed season for razors so any classifications should be year round.

PACIFIC OYSTERS

Pacific oysters were formerly cultured on trestles within the Cresswell/Carew Rivers. Small numbers of naturally occurring specimens of this species are now reported within the estuary, mainly within the Cresswell/Carew side channel and adjacent reaches of the main Cleddau channel up to Carron Pill. The temperature regime within Milford Haven is not sufficiently warm for consistent recruitment of this species, but successful recruitment may occur in warmer years. Therefore this species should be classified within the areas dredged for native oysters to allow any specimens caught in this fishery to be landed and marketed. There is no closed season for this species, but the native oyster dredge fishery upstream of the Cleddau Bridge is only open from the 1st October to 31st January.

SURROGATE SPECIES

An investigation into the relative levels of *E. coli* accumulation in different bivalve species was recently carried out by Cefas on behalf of the FSA (Younger & Reese, 2011). Comparisons of paired sample results supported the use of mussels as a surrogate for Pacific and native oysters, and the use of Pacific or native oysters to represent each other. Although cockles accumulated *E. coli* at broadly similar levels to mussels, they appeared to show a tendency for more extreme high results than mussels. Therefore mussels should not generally be used to represent cockles or clams without a period of parallel monitoring to ascertain whether this would be appropriate on a site specific basis. Neither carpet shell clams nor razors were considered in this study.

Formal guidelines for the use of surrogate species are however yet to be developed although they may be used in some cases. As the acceptable surrogate species generally accumulate *E. coli* to similar or slightly higher levels, the use of surrogate species for classification of areas where class B compliance is borderline should not be adopted to avoid potentially disadvantaging the industry.

Mussels may potentially be used to classify native (and Pacific) oysters, thereby reducing laboratory costs as well as ensuring that the higher value species can be retained for marketing rather than sent for testing. Very limited microbiological testing results indicate that mussel sample results at Sprinkle Pill Spit may align with a C classification, whereas a B classification has been derived from native oyster sampling results here in recent years. Therefore mussels may not be an appropriate surrogate within the upper reaches of the estuary. Also the differing distributions of the two species in the estuary further limits the scope for using mussels as a surrogate.

As Pacific oysters are deemed representative of native oysters and the same area should be classified for the two to allow Pacific oyster bycatch from the native oyster fishery to be marketed, either species may be used to classify both.

Cockle classifications may potentially be derived from mussel sampling, but only after a period of parallel monitoring. This is unlikely to be practical given the differing distributions of the two species and the highly variable nature of cockle stocks.

REDUCED SAMPLING EFFORT FOR SEASONAL CLASSIFICATIONS/CLOSURES

The native oyster fishery upstream of the Cleddau Bridge is only open from the 1st October to 31st January and so does not require classification outside of this time. Current classification protocols (Cefas, 2011) indicate that a minimum of 10 samples per year are generally required for classification, but do not indicate that further reductions in sampling effort may be made to reflect seasonally inactive fisheries. Therefore the only potential reduction in sampling will arise at any RMPs representing native oysters upstream of the Cleddau Bridge, where it will not be necessary to take samples during February and March.

POLLUTION SOURCES

FRESHWATER INPUTS

The catchment area for Milford Haven totals 820km^2, the majority of which is pasture, although there are a few significant urban areas on the shores of Milford Haven. Watercourses will carry contamination derived from a variety of sources into the estuary. The main freshwater inputs are the East and West Cleddau which drain about 65% of the catchment and discharge to the head of the estuary. A general presumption of higher levels of freshwater borne contamination towards the head of the estuary therefore applies, and RMPs should be sited accordingly. There are numerous smaller watercourses of various sizes discharging to the middle and lower estuary which will have a more localised influence but may be of great significance to some shellfish beds. Several of the larger ones discharge to shallow embayments or side arms of the main estuary within which their influence will be most marked. Inside these side arms freshwater influence will be highest where the watercourses enter them and along the drainage channels they follow at low tide so RMPs should be sited accordingly. Table 3.1 summarises relevant available information on some of the larger watercourses draining to Milford Haven.

Table 3.1. Summary information on the larger watercourses draining to Milford Haven

Watercourse name	Median discharge (m^3/sec) [1]	Geometric mean faecal coliforms/100ml (n) [1]	Comments
West Cleddau	5.7	1260 (144)	Together with the East Cleddau contributes the majority of freshwater input and river borne bacterial loading. Likely to generate a noticeable gradient of increasing contamination perhaps towards the head of the estuary. An estimate of their combined loading based on median discharge and geometric mean concentrations of faecal coliforms is 8x10^{12} cfu/day. This may increase by an order of magnitude or more during spate conditions.
East Cleddau	4.5	417 (144)	See above
Cresswell	1	1601 (48)	Together with the Carew this will be a major influence on the mussel fishery within the Carew/Cresswell side channel and possibly beyond.
Carew	0.6	Not sampled	See above
Pembroke River	0.6	1380 (4)	Will be a significant influence on any cockle fishery within the Pembroke River side channel.
Neyland River	0.4	369 (48)	Discharges to the estuary via Neyland Marina within which it is likely to be a significant influence.
River at Dale	0.4	Not sampled	Of local influence to the cockle and possibly

			razor beds within the bay at Dale
Sandy Haven Pill	0.4	Not sampled	Of local influence to the cockle bed at Sandy Haven
Milford Haven River	0.3	Not sampled	Discharges to the estuary via Milford Haven docks within which it is likely to be a significant influence.
Mill Bay River	0.1	Not sampled	Probably only of minor localised influence
Llangwm River	0.1	Not sampled	Probably only of minor localised influence

[1] Discharge estimates and faecal coliforms results from METOC, 2008.

River discharge varies significantly in response to rainfall, and average discharge varies considerably with season. During high flow events increased bacterial loadings are carried into coastal waters as both river discharge and concentrations of faecal indicators will be elevated. At the Canaston Bridge gauging station, on the East Cleddau, flows were markedly higher on average from October to February, and generally lower from April to September. High flow events were most common during the autumn and winter, but were recorded in most months of the year.

In conclusion, the majority of land runoff enters the estuary upstream of the Cleddau confluence and hence upstream of the fisheries. Freshwater borne contamination would therefore be expected to have the greatest influence towards the head of the main estuary. A significant freshwater influence is also anticipated within the Carew/Cresswell side channel as two minor rivers discharge here. Increased freshwater influence is also likely to be felt within other embayments or small side channels to which significant watercourses drain. These include the Garron Pill, Cocheston Pill, Pembroke River, Sandy Haven and Dale. Those watercourses which have been sampled generally carried moderate and occasionally high concentrations of faecal coliforms. Volumes of runoff vary with season, and are highest on average from October to February, although high flow events may occur at any time of the year.

Human Population

The total resident human population in census areas within or partially within the Milford Haven catchment area was 93,807 at the last census in 2001. Most of this was concentrated in Milford Haven Town and Pembroke Dock on the north and south shore of the outer estuary, and Haverford West at the tidal limit of the West Cleddau. The rest of the catchment is more sparsely populated and rural in character with the population here mainly residing in a number of villages.

Pembrokeshire is a tourist destination and receives influxes of visitors primarily during the summer months. Milford Haven itself is a popular area for water sports such as dinghy sailing, windsurfing, powerboating, canoeing, waterskiing and kayaking. These visitors will generate increased volumes of sewage for treatment by the sewage works in the Milford Haven area during the summer months.

Sewage Discharges

There are 45 water company owned sewage treatment works of various sizes within the Milford Haven catchment area. Of these, 24 discharge direct to or to watercourses draining to the estuary upstream of Picton Point, so on this basis

RMPs for the upper estuary should be set towards the upstream ends of the shellfisheries. The largest of these (Merlin's Bridge STW) receives UV treatment which should greatly reduce the bacterial loading it generates.

Tentative estimates suggest the combined loadings generated by these 24 discharges is lower than that for either of the two large secondary treatment works discharging to the middle reaches of Milford Haven. These two large treatment works (Pembroke Dock and Milford Haven STWs) are therefore likely to create an area of decreased water quality in their vicinities. Neyland STW also generates a considerable bacterial loading and discharges within 700m of the Pembroke Dock discharge. Both Pembroke Dock and Neyland STW outfalls lie within an area requiring continued classification for native oysters, but the Milford Haven STW outfall lies over 500m from the nearest area requiring classification. There are likely to be areas of significantly decreased water quality in the immediate vicinity of these outfalls, and this should be reflected in the classification zoning.

There are numerous other small sewage works which may be of localised significance to some shellfish beds. Three small sewage works discharge to the main estuary channel from Picton Point through to the Cleddau Bridge (Hook, Llangwm and Burton Ferry STWs). Most of the side channels and embayments receive sewage effluent from small water company treatment works, notably the Carew/Cresswell side channel, Coheston Pill, Pembroke River, Angle Bay, Sandy Haven and Dale Bay. These are likely to be of importance within these embayments, and RMPs set in such a location where they receive the greatest exposure to the plumes emanating from these outfalls would best capture contamination from them.

In addition to the continuous sewage discharges, there are a large number of intermittent water company discharges within the areas associated with the various sewerage networks. Modelled spill predictions were available for most of the main sewerage catchments discharging directly to the estuary, although some which are in close proximity to certain shellfish beds (e.g. Dale, Angle) were not included. The modelling indicated that the largest single spiller was the Picton PS/Picton Fields CSO at Haverfordwest. Although it only spilled for a small proportion of the time (1.4%) it is tentatively predicted to generate a bacterial loading about 16 times that generated by the Pembroke Dock STW continuous discharge. These predictions were made using the modelled spill information and reference values for concentrations of faecal coliforms in various effluent types rather than real data from the actual outfalls so should be treated with great caution.

Intermittent discharges from the Milford Haven STW sewerage network were also only predicted to be active for a small fraction of the time, but when active may increase the output from this sewage catchment by about 20 fold. The main spillers here were the Milford Haven SWO and Milford Haven Rath SWO. Predicted spill volumes from the Pembroke Dock STW sewerage network were much lower, and again the intermittent outfalls were found to be active only a small proportion of the time. Nevertheless, when active the bacterial loading from this network may increase by about 4 fold. The majority of spills occurred at the main Pembroke Dock STW outfall. Although caution should be applied when using such estimates, they do suggest that, whilst spill events from these outfalls are likely to be relatively rare, they will generate huge bacterial loadings when active, quite possibly greater than any other individual source. Lesser but nonetheless possibly significant spills were predicted to arise from intermittent outfalls within the Hook and Neyland STW catchments from time to time. Spills from the Llangwm and Burton Ferry catchments were predicted to be smaller in volume and so are likely to be of more localised impact. Any spills will be associated with high rainfall events which result in the networks receiving more effluent than can be treated. Therefore, the various networks will tend to spill at the same time, particularly during exceptionally wet weather.

Measured data on actual spills from the sewerage networks would aid further assessment of the impact from intermittent discharges. This data is not available at the time of writing but should be evaluated if available at the next review.

Although the majority of properties in the Milford Haven catchment are connected to mains sewers, there are a significant number of private discharges to the area, some of which discharge to soakaway and others to watercourses. Most are small, serving only one or a handful of properties. An exception is the Bluestones campsite discharge which serves a holiday park and discharges to an East Cleddau tributary. Nevertheless their combined bacterial loading is likely to be very minor in relation to those from water company sewage works.

AGRICULTURE

The agricultural land within the Milford Haven catchment is almost all pasture with some small pockets used for arable farming. There are substantial populations of grazing animals recorded within this area (126,000 sheep and 117,000 cattle). Significant diffuse inputs associated with grazing livestock are therefore anticipated. Well over half of grazers are within areas draining to the estuary upstream of the Cleddau confluence, and they are less numerous in the area bordering the north shore of the outer estuary. There are also some poultry rearing operations, mainly in the catchment area bordering the north shore of the outer estuary as well as very small numbers of pigs throughout.

Grazing animals will deposit directly on pastures whilst outdoors. Cattle are likely to be transferred indoors during the winter and their manure will be collected and applied to pastures. Manure from pig and poultry operations is typically stored and spread periodically on nearby farm land. No field level information on the spreading of manures was available and such information would aid further assessment. Records held by the Environment Agency indicate that no sewage sludge has been spread in the Cleddau catchment from 2009 to 2012.

The primary mechanism for mobilisation of faecal matter deposited on agricultural land into watercourses is via land runoff, so fluxes of livestock related contamination into the estuary will be highly rainfall dependent. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the ‘first flush’). Runoff from the majority of the catchment area enters the estuary upstream of the fishery, so in general higher impacts may be anticipated towards the up-estuary ends of the shellfish beds.

There is likely to be seasonality in levels of contamination originating from livestock. Numbers of sheep and cattle will increase significantly in the spring, with the birth of lambs and calves, and decrease in the autumn when animals are sent to market. Manure from cattle housed indoors may be stored for significant periods, although farms without large storage capacities are likely to spread during the winter and spring. Applications of manure from pig and poultry operations may take place at any time of the year. Therefore peak levels of contamination from sheep and cattle may arise following high rainfall events in the summer, particularly if these have been preceded by a dry period which would allow a build up of faecal material on pastures. Contamination events may occur on a more localised basis if wet weather follows a manure/slurry application which is perhaps more likely in winter or spring.

BOATS

Milford Haven is a major deepwater port mainly serving the hydrocarbon industry, but also handling smaller volumes of other cargoes, and a twice daily Ireland ferry. As merchant shipping is prohibited from making overboard discharges to inshore waters, these are not considered further in this assessment, although the competent authority (the FSA) may wish to consider further the possibility of chemical contamination of shellfish from industrial sources.

Milford Haven is also extensively used by recreational craft such as yachts and cabin cruisers, as well as a few commercial fishing vessels. All of these may make overboard discharges despite the discouragement of such practices. There is considerable uncertainty about the extent to which these discharges occur and whether they will impact significantly on shellfish hygiene. There are marinas at Neyland and at Milford town which have a combined total of almost 750 berths. There are several hundred moorings throughout Milford Haven, the main areas of which are at Dale, the Milford Shelf, several areas around Neyland, Pembroke Dock and the Cleddau Bridge, at Lawrenny Yacht station and at Black Tar Point. Boats in marinas may be less inclined to make overboard discharges as it is somewhat antisocial and onshore facilities are easily accessed. Those in occupation on moorings, or those in transit through the estuary may be more likely to discharge. On this basis, stocks in the vicinity of Dale, Milford Shelf, Neyland, the Cleddau Bridge, Lawrenny and Coedcanlas may be most affected. Volumes of small boat traffic will peak during the summer, as will levels of overnight occupancy, so any impacts would be greatest at these times.

WILDLIFE

Milford Haven contains a large diversity of habitats including intertidal mud/sandflats and saltmarsh, and attracts large numbers of overwintering waterbirds (23,422 average over the five winters up to 2009/10). Most of these migrate elsewhere to breed. Smaller numbers of seabirds (gulls etc) are present in the area throughout the year. Therefore some impacts from birds may be anticipated, mainly during the winter months. These may be through direct deposition on intertidal areas or via land runoff. No particular favoured bird foraging areas have been identified, and their inputs may be considered as diffuse, so whilst they may cause increases of indicator organisms within shellfish birds do not directly influence the sampling plan.

There are significant grey seal colonies in south Wales, the closest of which is at Skomer island about 10 km from the mouth of Milford Haven, where a peak count of 354 seals was recorded in 2010. Seals forage over a wide area and have been recorded in Milford Haven upstream of the Cleddau Bridge, and are reported to haul out on Stack Rock. Some minor and geographically widespread impacts from seals may be anticipated, perhaps more so in the vicinity of rocky islands in the outer haven which may be used as haulout sites. As there are no shellfish beds in close proximity to the possible haulout sites seals will have no bearing on the sampling plan. Otters are also present in small numbers but associated impacts will be very minor and diffuse so their presence has no influence on the sampling plan either. No other wildlife species which have a potential influence have been identified.

Domestic Animals

Dogs are exercised along the shores of Milford Haven, and represent a potential source of diffuse contamination to the near shore zone. It is likely that the intensity of this is greatest on areas of foreshore adjacent to urban areas, so RMPs set adjacent to urban areas would be best placed to capture contamination of canine origin. Dogs are likely to be of minor importance relative to some other sources.

Summary of Pollution Sources

An overview of sources of pollution likely to affect the levels of microbiological contamination to the shellfish beds is shown in Table 3.2 and Figure 3.1.

Table 3.2 Qualitative assessment of seasonality of important sources of contamination

Pollution source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Continuous sewage discharges	red	red	red	red	red	red	red	red	red	red	red	red
Land runoff	red	red	red	red	red	red	red	red	red	red	red	red
Intermittent sewage discharges	red	red	red	red	red	red	red	red	red	red	red	red
Waterbirds	orange	orange	orange							orange	orange	orange
Boat traffic						orange	orange	orange	orange			

Red - high risk; orange - moderate risk.

Figure 3.1 Significant sources of microbiological pollution to Milford Haven.

HYDRODYNAMICS

Milford Haven is a large branching drowned river valley of about 32km in length with a fairly complex bathymetry. The outer reaches have an east west orientation, are up to 3km wide, and have a central channel up to 30m deep flanked by extensive shallower subtidal areas. It gradually narrows and intertidal areas tend to increase in size through its middle reaches, then bends round to a north south orientation in its upper reaches. The main channel here is 200-500m wide and the maximum depth decreases from 20m down to less than 3m at Picton Point where it spits into the tidal East and West Cleddau channels. Its bathymetry therefore indicates a decreasing dilution potential towards the head of the estuary into which important river and sewage sources discharge. An underlying gradient of increasing levels of contamination towards the head of the estuary may be anticipated on this basis. There is a shallow bar extending across the main channel just up-estuary from the Carew/Cresswell confluence where tidal streams are likely to accelerate and some mixing may occur.

There are several side channels and embayments at various locations throughout the estuary which are generally shallow with large intertidal areas and the mouths of some are quite constricted. As a consequence they will tend to form hydrographic zones distinct from the main body of the estuary and so should generally be assigned separate classification zones. Those containing shellfish resources for which a sampling plan may be required are the Carew/Cresswell, Cocheston Pill, Pembroke River and Angle Bay, all of which form distinct side arms, as well as Sandy Haven and Dale Flats, which are more open embayments in the outer estuary. Within these the various local sources are likely to be largely responsible for any noticeable spatial variations in levels of contamination. Their relatively shallow nature will reduce dilution potential but enhance tidal exchange.

Milford Haven has a large tidal range of between 6 and 6.5m on spring tides and this drives extensive water movements through the estuary. Cleaner water from the open ocean enters and travels up the estuary on the flood, with the reverse occurring on the ebb. Contamination from shoreline sources will therefore generally travel parallel to the shore, impacting either side with the magnitude of their influence dropping away with distance as the plume spreads. Sources discharging to deeper waters such as the Pembroke Dock STW will also generally create a plume aligning with the orientation of the estuary. In certain localised areas such as off Neyland this may be complicated by the formation of eddy currents at some states of the tide. The tidal excursion is estimated at 7-15km on spring tides and about half of that on neaps so the maximum tidal excursion is about half the length of the estuary so major sources could impact over a considerable area.

Within the side channels flood tides will carry contamination from any down-estuary sources into them. At Angle Bay, the Angle STW at its mouth may cause higher levels of contamination in water flooding into the western half of the bay. In the other side channels with shellfish resources there are no major sources immediately down-estuary so the incoming water should be relatively homogeneous. Sources discharging directly inside these are likely to result in the most acute ‘hotspots’ and account for most of the spatial variation in contamination, and will therefore be the most important consideration for the sampling plan. For those with defined channels, such as the Pembroke River and Carew/Cresswell, the main flows will be along these and tidal currents over the intertidal areas will be slower. Contamination from shoreline sources will tend to be most concentrated within such channels towards low water so RMPs should be located accordingly.

Freshwater inputs can modify circulation patterns through density effects. Volumes of freshwater entering Milford Haven are low in relation to volumes of water exchanged by tides so the estuary as a whole is considered well mixed. The majority of freshwater enters the estuary upstream of Picton Point, with additional small to medium sized watercourses entering at various other locations throughout the estuary, often via the partially enclosed channels. Although some stratification and vertical difference in flows is reported to occur in the upper reaches upstream of Mill Bay tidally driven circulation processes will dominate over density effects throughout. Vertical salinity profiles taken during the shoreline survey in the outer estuary up as far as Burton Ferry showed very little in the way of stratification.

One density effect of potential importance to the assessment is the tendency for sewage effluent to float to the surface which may tend to keep it away from benthic shellfish particularly for discharges to deeper water. ‘Boils’ of effluent rising to the surface were observed at the Pembroke Dock and Milford Haven STW outfalls during the shoreline survey. Of the main three sewage outfalls in the middle to lower estuary, Milford Haven STW discharges to the subtidal at about 2m below chart datum on a fairly flat subtidal shelf. The Pembroke Dock STW discharges to Carr Spit at a depth of about 0m relative to chart datum. East and west (i.e. uptide and downtide) of this discharge depth drops off fairly rapidly to over 5m within 300m. The Neyland STW discharges at about 1m above chart datum to a relatively even intertidal area off Neyland. Therefore the least potential for dilution and density driven separation of the plume away from benthic shellfish stocks is for Neyland STW, and the greatest potential for these effects is for the Pembroke Dock STW.

The bathymetry of the estuary and the location and size of the various freshwater inputs create a gradient of decreasing salinity towards the head of the estuary. Surface salinity measurements taken during the shoreline survey indicate a steady increase in salinities from between 9 and 10ppt at Picton Point to 32.7ppt off Angle Bay. Other studies indicate there is little freshwater influence downstream of Neyland, whereas within the upper reaches salinity decreases towards Picton Point and fluctuates significantly across the high/low tidal cycle. The salinity profile of the estuary is of relevance to this assessment as much of the contamination entering the estuary is entrained within land runoff so lower salinity waters will tend to be associated with higher levels of faecal indicator organisms. Strong negative correlations between faecal coliforms and salinity were found in repeated water samples taken for shellfish waters monitoring purposes at the Cleddau Bridge and Carew. A gradient of decreasing levels of *E. coli* and increasing salinity from Picton Point down to off Angle Bay was observed during the shoreline survey. On this basis, RMPs should be set at the up-estuary ends of the shellfish beds to best capture runoff borne contamination in the upper reaches of the main estuary and within side arms such as the Carew/Cresswell and the Pembroke River.

Strong winds may modify tidal circulation at times by driving surface currents. These in turn create return currents at depth or along sheltered margins. The mouth of the estuary is exposed to the prevailing winds from the southwest, the outer and middle reaches are orientated on the east-west plane and so are most exposed to winds from these directions, and the upper estuary has a north-south orientation. The local topography will tend to funnel winds up or down the estuary. South west winds will tend to push surface water up-estuary. Perhaps of most significance to the contamination of shellfish is the advection of the buoyant plumes from the major sewage discharges by wind driven currents. The spatial profile of impacts from these discharges are therefore expected to vary significantly with wind conditions. Exact effects of wind on water circulation are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great range of scenarios may arise. As well as driving surface currents, strong winds will create wave action which may re-suspend any contamination held within the sediments of the intertidal zone. The cockle bed at Sandy Haven is the only shellfish bed which is likely to be exposed to incoming swells. It is however concluded that wind related effects have little bearing on the sampling plans due to their dynamic nature, although they may be a consideration when investigating the causes of high results.

SUMMARY OF EXISTING MICROBIOLOGICAL DATA

Milford Haven has a wealth of bacteriological data from recent years deriving from the Bathing Waters, Shellfish Waters and hygiene classification monitoring programmes. The last major sewerage upgrade occurred in 2005, so only results from 2006 onwards are considered here. Figure 3.3 shows the locations of all sampling points referred to in this assessment.

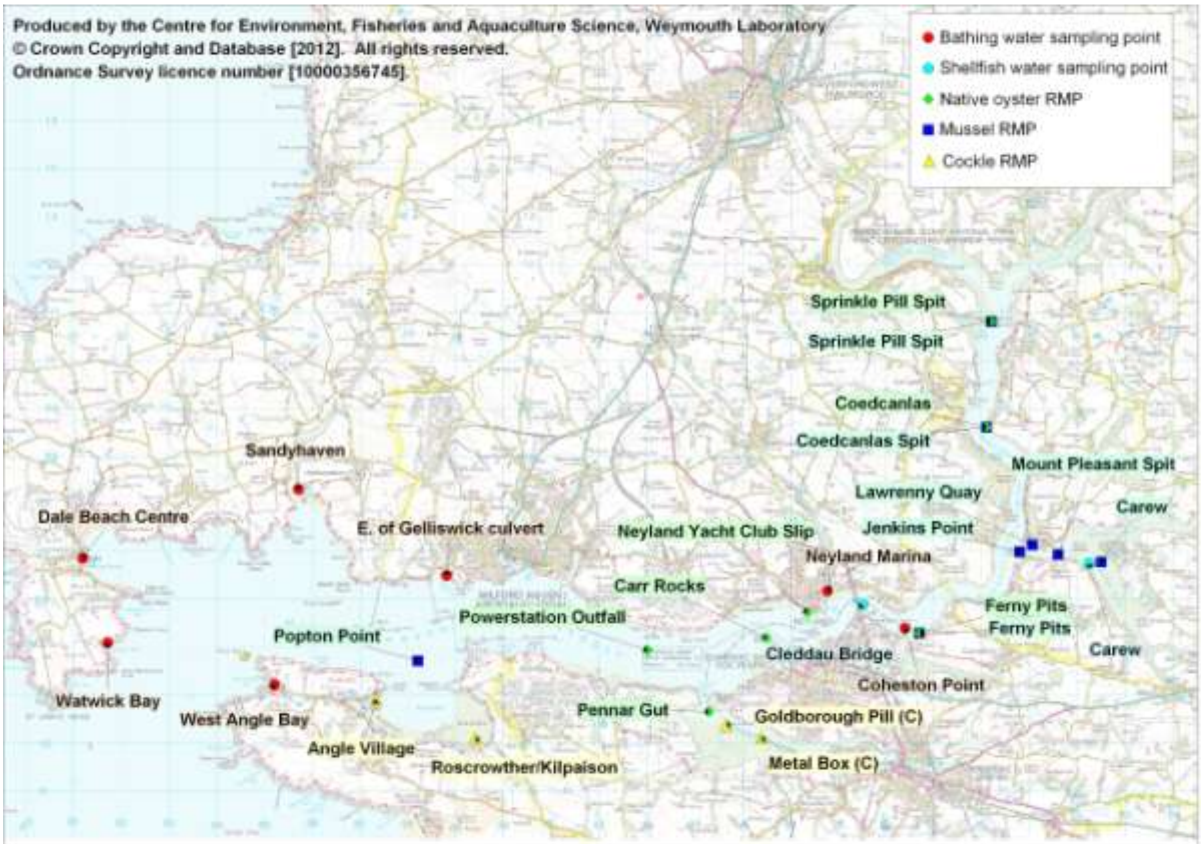


Figure 3.3 Bacteriological sampling locations, 2006 onwards

Faecal coliforms were monitored at seven beaches during summer bathing seasons. Results from this programme indicated an increase in faecal coliforms concentrations with distance from the estuary mouth, increasing from a geometric mean of 3.7 faecal coliforms/100ml at Watwick Bay to 59.6 faecal coliforms/100ml at Neyland Marina. Results for Sandyhaven, E. of Gelliswick Culvert, Neyland Marina and Coheston Point were significantly higher than those for Dale Beach Centre, Watwick Bay and West Angle Bay. Results for Neyland Marina were also significantly higher than for Sandyhaven.

Correlations were found between levels of faecal coliforms and state of the tide on the high/low cycle at five sites. When this data was plotted and a pattern could be discerned (Dale Beach Centre, Sandyhaven, Gelliswick and Neyland Marina) results tended to be higher during the ebb tide, suggesting that up-estuary sources were of some importance at these sites. At Dale higher results tended to arise later during the ebb than at the other sites. Taken together this tentatively suggests that sources at Milford Haven Town are of significance from Gelliswick through to Dale Beach.

Strong correlations were found between the spring neap tidal cycle and faecal coliforms results at Sandyhaven and Gelliswick. At Sandyhaven results were generally lower during the phase when tide size decreased from spring to neap compared to the rest of the tidal cycle, whereas at Gelliswick results tended to be higher during spring tides. The implications of these are uncertain but may relate to a reduced advection of bacteria from more ‘remote’ sources onto shellfish beds with reduced tidal range and excursion. Weak correlations were found between the spring neap tidal cycle and faecal coliforms results at West Angle Bay and Neyland Marina but no pattern could be seen when this data was plotted.

Correlations were found between recent rainfall and levels of faecal coliforms at all bathing waters sites apart from Watwick Bay, which lies in the mouth of the estuary and does not receive any significant freshwater input. This indicates that there is a widespread influence of rainfall dependent sources even within the outer estuary at places such as West Angle.

Seawater samples were taken on a quarterly basis for shellfish waters monitoring at two sites, one within the Carew side channel and the other at the Cleddau Bridge. Results were higher on average at Carew, but the difference in mean result was not statistically significant. When the results of paired (same day) samples were compared there was a strong correlation in levels of faecal coliforms between these two sites suggesting that they are subject to contamination from similar sources or sources that respond to environmental variables in a similar manner. Similar seasonal patterns were observed at both sites with results increasing on average from spring through to winter, although this seasonal effect was not statistically significant in either case. No correlations between tidal state on both the high/low and spring/neap tidal cycles were found at either. Strong negative correlations between faecal coliforms and salinity were found at both indicating that the amount of land runoff entering the system is a strong influence on levels of contamination. Correlations between amount of recent rainfall and levels of faecal coliforms were detected at both sites. Unsurprisingly this was stronger at Carew than at Cleddau Bridge.

A total of 19 RMPs from Angle Bay through to Sprinkle Pill Spit were sampled and tested for *E. coli* under the shellfish hygiene flesh monitoring programme since the beginning of 2006.

Across the seven native oyster RMPs, results were similar at most RMPs in terms of average results and the proportion of results exceeding the classification thresholds, and no increase in levels of contamination was seen towards the head of the estuary. At the RMPs at Carr Rocks and Neyland Slip, which lie within the formerly prohibited zone, results were much higher to the extent that they were consistent with a C rather than a B classification indicating significantly lowered water quality in this area presumably as a result of the Pembroke Dock and Neyland STWs. A comparison of paired (same day) results from the three RMPs upstream of the Cleddau Bridge (Ferny Pits, Coeacanlas, Sprinkle Pill Spit) indicated that levels of contamination were very similar throughout this reach, and varied in a similar manner temporally. Similar conclusions were reached when results from paired samples at the two main RMPs in the lower estuary were compared (Pennar Gut and Powerstation Outfall). Low sample numbers precluded meaningful analysis of results from Carr Rock and Neyland Slip. The geometric mean result was higher at the latter, and the lowest result recorded here was 940 *E. coli* MPN/100g, indicating that this latter site was more consistently subject to high levels of contamination.

Of the eight mussel RMPs, only four were sampled on more than five occasions (Lawrenny Quay, Mount Pleasant Spit, Jenkins Point and Popton Point) so detailed analyses were limited to these, although the highest geometric mean result was recorded at Sprinkle Pill Spit. A comparison of all results from the main four RMPs indicated that they were significantly lower on average at Popton Point, in the outer estuary, compared to the three sites at the Carew/Cresswell. A comparison of paired (same day) samples from Mount Pleasant Spit and Lawrenny Quay showed that results were significantly higher on average at Mount Pleasant Spit and that results at the two RMPs were strongly correlated on a sample by sample basis. A comparison of paired samples from Jenkins Point and Mount Pleasant Spit showed results were significantly higher at Mount Pleasant Spit and results at these two RMPs were also strongly correlated. This indicates that the three RMPs at the Carew/Cresswell side channel are subject to similar contaminating influences and these influences were stronger at the RMP further upstream in the side channel (Mount Pleasant Spit).

Four cockle RMPs were each sampled on more than 30 occasions in the period considered. Two of these were in Angle Bay (Angle Village and Roscrowther/Kilpaison) and two were in the Pembroke River side channel (Goldborough Pill and Metal Box). Results, although slightly higher on average in the Pembroke River side channel, were very similar throughout both in terms of average result and proportions exceeding classification thresholds. A strong correlation between paired (same day) samples results was found for the two sites within Pembroke River suggesting they are under similar contaminating influences. A similar comparison of paired sample results within Angle Bay revealed no correlation on a sample by sample basis suggesting that, although levels of contamination are similar, a different profile of sources may be involved.

The overall temporal trends observed in levels of *E. coli* at the various RMPs since 2006 suggest a possible slight increase across the native oyster fishery, no particular trend across the mussel RMPs, and a more noticeable deterioration in results for cockles within the Pembroke River side channel, and to a lesser extent within Angle Bay. The reasons for this are unclear.

Statistically significant seasonal variation was found at the three native oyster RMPs upstream of the Cleddau Bridge, where the general pattern was for highest results in the summer and autumn and much lower results in the winter and spring. This was slightly less marked at the furthest downstream of these three sites (Ferny Pits) than at Sprinkle Pill Spit and Coedcanlas. No statistically significant seasonal variation was apparent for native oysters at Pennar Gut and Powerstation Outfall. This suggests that the upper and lower estuary are under the influence of a different profile of sources, possibly an agriculture related summer/autumn peak in the upper estuary and a more year round sewage related influence in the lower estuary. Seasonal patterns for Pacific oysters at Neyland Yacht Club and Carr rocks were not examined due to low sample numbers. No statistically significant seasonal variation was found at any of the four main mussel RMPs or at the four cockle RMPs.

Of the 13 RMPs sampled on more than 30 occasions, correlations between levels of *E. coli* and the tidal state on the high/low tidal cycle were only found for native oysters at Powerstation Outfall and mussels at Lawrenny Quay. For Powerstation outfall more lower results were seen towards high water compared to earlier in the flood tide suggesting that contamination clears as the cleaner water flows in on the flood tide. No pattern was discernable for Lawrenny Quay and sampling here was strongly targeted towards low water. Correlations between *E. coli* levels and tidal state on the spring/neap tidal cycle were only found for native oysters at Coedcanlas and cockles at Roscrowther/Kilpaison. At Coedcanlas there appeared to be a slight tendency for higher results around spring tides perhaps suggesting that increased tidal flows result in greater exposure to contamination from more distant sources. No obvious pattern was apparent for Roscrowther/Kilpaison when the data was plotted.

Correlations between recent rainfall and levels of *E. coli* were found at all the native oyster RMPs. These were strongest at the two RMPs closest to the head of the estuary (Sprinkle Pill Spit and Coedcanlas). Similar but slightly weaker correlations were found at Ferny Pits, just upstream from the Cleddau Bridge. The pattern was different at the two sites in the lower estuary, where correlations only arose for less recent rainfall, suggesting that there is a lag of several days following rainfall events before the effects are felt here. These observations are consistent with the locations of the main freshwater inputs and the bathymetry and hydrography of the area. Correlations were found across all four mussel sites including Popton Point for most rainfall totals. Rainfall was not generally an influence across the cockle beds in Angle Bay and Pembroke River apart from at Metal Box, the more upstream site in Pembroke River, where some limited influence was detected.

4. RECOMMENDATIONS

4.1 Native and Pacific oysters

4.1.1 Zoning arrangements and RMP locations

The following five main zones are proposed to reflect broad areas of differing water quality and hydrography throughout the large area requiring classification (Figures 5.1 and 5.2). Additionally, two much smaller classification zones are proposed around the Pembroke Dock and Neyland STW outfalls to reflect the much higher levels of contamination anticipated here relative to the wider area. Proposed RMPs (Figures 5.1 and 5.2, Table 5.1) are located where peak levels of contamination are anticipated.

- Upper Cleddau, from Picton Point down to the Carew Cresswell confluence. This zone is mainly influenced by catchment and up estuary sources, on top of which there are a few small watercourses and sewage discharges, and some areas of moorings which may create more localised hotspots of relatively limited impact on subtidal stocks. An RMP by the Sprinkle Pill channel across the intertidal at Sprinkle Pill Spit (SM 9985 1071) should not only capture peak levels of contamination from up-estuary and wider catchment sources but also any hotspot associated with the Sprinkle Pill and sewage inputs to it.
- Lower Cleddau, from the Carew/Cresswell confluence down to the Cleddau Bridge. This includes the lower 1km of the Carew/Cresswell. Influence from upper and catchment sources decreases through this zone with increasing distance from the head of the estuary and increasing channel size. Overlaid on this are potential hotspots deriving from the Carew/Cresswell, Mill Bay River, Coheston and Burton Ferry STWs. As exploitable stocks are not present within the Coheston Pill side channel, and higher levels of contamination may arise within here through freshwater and sewage inputs and its enclosed nature, this side channel should be excluded. An RMP located immediately south of the Carew/Cresswell confluence on the east shore (SN 0072 0596) should reliably capture contamination from up-estuary and catchment sources as well as that originating from within the Carew/Cresswell.
- Pembroke Dock, from the Cleddau Bridge to Pennar Mouth. The Neyland Marina should not be included within the classified area in accordance with Good Practice Guide recommendations. There are two major continuous sewage discharges within this zone, Pembroke Dock and Neyland STW. Considerably higher levels of contamination are anticipated in the immediate vicinity of these outfalls relative to the wider area, so it is recommended that small classification zones are established around each of these (Pembroke STW and Neyland STW). For these two smaller zones, RMPs should be set at the outfall locations (SM 9545 0425 and SM 9583 0483) where bagged oysters should be sampled. The LEA is to decide whether sampling and classification of these two smaller zones is worthwhile given their small area, likely poor classification and possible practical difficulties in deploying sample bags in the required locations. The RMP location which would capture peak

levels of contamination within the main Pembroke and Neyland zone is difficult to determine. The Pembroke Dock STW discharge is larger and spills larger volumes of storm sewage compared to the Neyland STW outfall. However, water is deeper in the vicinity of the Pembroke Dock STW outfall than around the Neyland STW outfall, so there is greater dilution potential and the buoyant plume from Pembroke Dock will be more separated from benthic shellfish stocks. Limited monitoring results show higher average levels of contamination at Neyland slipway than at Carr Rocks, although the latter is only 70m from the Pembroke Dock STW outfall. Patterns of tidal flows suggest that the RMP at Neyland Slipway is more exposed to the Neyland STW plume than the RMP at Carr Rocks is exposed to the Pembroke Dock STW plume which would perhaps suggest a further reason why results were higher at Neyland Slipway. There are likely to be practical difficulties establishing an RMP at the uptide edge of the smaller classification zone around Pembroke Dock STW as this would lie off the dock area where there is likely to be significant shipping traffic. Therefore, on balance it is recommended that an RMP (bagged oysters) be established in the lower intertidal on the eastern edge of the smaller classification zone around the Neyland STW outfall (SM 9618 0478) where exposure of benthic stocks to the sewage plume is likely to be greatest.

- Pennar Gut, at the mouth of the Pembroke River. This area is thought to host the greatest concentration of native oysters. The main contaminating influences are likely to be the Pembroke River and the Hundleton STW. An RMP set at the point where the Pembroke River drainage channel meets the oyster bed (SM 9451 0267) should capture peak levels of contamination.
- Milford Outer, from Pennar Mouth to Newton Noyes pier, and the Milford Shelf. The two main contaminating influences here are likely to be the Milford Haven STW outfall, 700m to the west of the zone, and the Pembroke Dock STW, about 1.1km to the east of the zone. The Milford Haven STW is closer to the zone, and the plume from this will reach the edge of the zone in shallower water than the plume from Pembroke Dock STW. Also, spills of storm sewage are likely to occur more frequently from the Milford Haven STW outfalls. Contamination from land runoff will impact locally mainly via the Pembroke River and the Milford Haven river. Therefore, the RMP should be located in the western edge of this zone, on the Milford Shelf in such a position which tidal flows would most consistently direct the plume towards (SM 9053 0512). This should also capture variations associated with river discharge.

4.1.2 Species sampled.

The species sampled should be native oysters, as this is the main target species. Any classification awarded on this basis would also apply to Pacific oysters, so any bycatch of this species caught during dredging operations may be marketed. Sampled stock should be of a harvestable size. The sampling of either bagged or dredged oysters is acceptable. Any bagged samples should be allowed to acclimate *in situ* for at least two weeks prior to sampling.

4.1.3 Sampling frequency

For the zones located downstream of the Cleddau Bridge, monthly monitoring is required to maintain a year round classification. Upstream of the Cleddau Bridge, where the fishery is only open from October to January, sampling will not be necessary during February and March, but samples will be required from all of the other 10 months of the year to maintain the classification.

4.1.4 RMP tolerances.

Bagged oysters have been sampled historically in the upper three zones, and dredged samples have been taken from Pennar Gut and Milford Outer. For dredged samples a tolerance of 100m around the RMP location should be sufficient to allow repeated sampling. A tolerance of 10m should be applied for bagged samples.

4.2 Mussels

4.2.1 Zoning arrangements and RMP locations

The following three zones are proposed to reflect the various limited areas potentially requiring classification for this species (Figure 5.3). Proposed RMPs are located where peak levels of contamination are anticipated within these (Figure 5.3 and Table 5.1).

- Upper Cleddau, from Picton Point down to Coedcanlas. There are two recognised mussel beds within this zone, one at Sprinkle Pill Spit and the other at Coedcanlas. Neither is currently classified or of commercial interest. This zone is mainly influenced by catchment and up estuary sources, on top of which there are a few small watercourses and sewage discharges, and some areas of moorings which may create more localised hotspots of relatively limited impact on subtidal stocks. An RMP by the Sprinkle Pill channel across the intertidal at Sprinkle Pill Spit (SM 9985 1071) should not only capture peak levels of contamination from up estuary and wider catchment sources but also any hotspot associated with the Sprinkle Pill and sewage inputs to it.
- Carew/Cresswell, covering the outer reaches of the Carew/Cresswell side channel where currently classified mussel beds are located. The main influences here are catchment and sewage sources discharging to these two rivers. The Cresswell is the larger of the two rivers and receives higher volumes of sewage effluents, mainly from the Langdon STW. The upstream ends of the mussel beds are likely to show higher levels of contamination on average. Therefore the RMP should be located at the up estuary end of the mussel bed on the north shore (SN 0168 0622) where the influence of the Cresswell will be strongest.
- Angle Shelf, within the Angle Shelf Several Order. The Angle STW outfall may create a small hotspot of contamination in its immediate vicinity. Water ebbing from Angle Bay is likely to be more contaminated than that flooding in from the outer haven as there are a few small shoreline sources within Angle Bay and the potential for dilution is lower. An RMP set at Angle Point (SM

8761 0327) would capture contamination from both these sources. Bagged mussels will be required in the absence of naturally occurring stocks here.

4.2.2 Species sampled.

The species sampled should be mussels. Sampled stock should be of a harvestable size. The sampling of either bagged or naturally occurring mussels is acceptable. Any bagged samples should be allowed to acclimate *in situ* for at least two weeks prior to sampling.

4.2.3 Sampling frequency

To maintain a year round classification within the Carew/Cresswell and at Angle Shelf, the sampling frequency should be monthly. To classify the upper Cleddau beds, 10 samples taken not less than 1 week apart will allow a provisional classification to be awarded, or alternatively a full classification may be awarded following one year of monthly monitoring.

Should any classified zones become inactive and a classification is no longer required the LEA has two options to consider. If sampling frequency is reduced to quarterly, the zone may be maintained as 'temporarily declassified', and can be reclassified as soon as monthly sampling is reinstated. If sampling within a zone is stopped completely then the zone will be fully declassified at the subsequent annual classification review.

4.2.4 RMP tolerances.

A standard tolerance of 10m should be applied around these RMPs.

4.3 Cockles

4.3.1 Zoning arrangements and RMP locations

The following six zones are proposed to reflect the various limited areas potentially requiring classification for this species (Figure 5.4). Proposed RMPs are located where peak levels of contamination are anticipated within these (Figure 5.4 and Table 5.1).

- Upper Cleddau, from Picton Point down to Coedcanlas. There are two recognised areas where cockles occur within this zone, one at Sprinkle Pill Spit and the other at Coedcanlas. Neither is currently classified or holds stocks of commercial interest. This zone is mainly influenced by catchment and up estuary sources, on top of which there are a few small watercourses and sewage discharges, and some areas of moorings which may create more localised hotspots of relatively limited impact on subtidal stocks. An RMP by the Sprinkle Pill channel across the intertidal at Sprinkle Pill Spit (SM 9985 1071) should not only capture peak levels of contamination from up-estuary and wider catchment sources but also any hotspot associated with the Sprinkle Pill and sewage inputs to it.

- Cresswell, covering the outer reaches of the Cresswell side channel where currently classified mussel beds are located. This is not currently classified and does not hold stocks of commercial interest. The main influences here are catchment and sewage sources discharging to the Cresswell. The upstream ends of the cockle are likely to show higher levels of contamination on average. Therefore the RMP should be located at SN 0168 0622 or as far upstream on the north shore as stocks extent, where the influence of the Cresswell will be strongest.
- Pembroke River, encompassing the intertidal area lying to the south of the main channel within the Pembroke River side arm. Harvesting of this bed is currently not permitted on safety grounds and it is likely that this situation will continue. The main sources are the Hundleton STW outfall and the Pembroke River. In the unlikely event that a classification is required for this bed, an RMP located at the upstream end of the bed close to the main channel off Bentlass (SM 9600 0173) should best capture contamination from both these sources.
- Pwllcrochan Flats, encompassing the intertidal area of Pwllcrochan. This bed has not been of commercial interest in recent years. The only source of contamination which may cause a small hotspot over and above background levels originating from distant or diffuse sources is a small stream which discharges across the bed. Therefore, an RMP situated in the path of this stream towards the inshore part of the bed (SM 9226 0320) should represent peak levels of contamination within this bed.
- Angle Bay East. Within Angle Bay the cockle concentrations lie in the eastern half. The main sources of contamination at Angle Bay are Angle STW at Angle Point, and three small streams discharging to the eastern part of the bay, one of which receives effluent from Rhoscrowther STW. An RMP situated in the path of this stream towards the inshore part of the bed (SM 8965 0226) should represent peak levels of contamination within the eastern half of Angle Bay.
- Sandyhaven. This is a small bed which has not been of commercial interest in recent years. The main source influencing levels of contamination across this bed is the Sandyhaven Pill which flows through the middle of the bed. Herbrandston STW also discharges within the bay, but over 500m from the outer edge of the bed. An RMP situated in the path of Sandyhaven Pill at the inshore part of the bed (SM 8558 0747) should represent peak levels of contamination within it.
- Dale. This is a small bed which has not been of commercial interest in recent years. The main source influencing levels of contamination across this bed is the Dale River which flows across the bed and receives sewage effluent from Marloes STW. An RMP situated in the path of the Dale River at the inshore part of the bed (SM 8128 0684) should represent peak levels of contamination within it.

4.3.2 Species sampled.

The species sampled should be cockles raked by hand. Sampled stock should be of a harvestable size.

4.3.3 Sampling frequency

To classify any of these areas, 10 samples taken not less than 1 week apart will allow a provisional classification to be awarded, or alternatively a full classification may be awarded following one year of monthly monitoring.

Should any classified zones become inactive and a classification is no longer required the LEA has two options to consider. If sampling frequency is reduced to quarterly, the zone may be maintained as 'temporarily declassified', and can be reclassified as soon as monthly sampling is reinstated. If sampling within a zone is stopped completely then the zone will be fully declassified at the subsequent annual classification review.

4.3.4 RMP tolerances.

A tolerance of 100m should be applied around these RMPs to allow repeated sampling of wild stocks.

4.4 Carpet shell clams

Permission to use toothed dredges will be required from CCW and Welsh Government Fisheries before these stocks can be sampled, classified or harvested.

4.4.1 Zoning arrangements and RMP locations

One zone is proposed which includes all areas for which classification was requested, aside from some small areas within 100m of the oil terminal jetties where dredging is not permitted (Figure 5.5). The RMP is located where peak levels of contamination are anticipated (Figure 5.5 and Table 5.1).

- Milford Outer, from Pennar Mouth to Newton Noyes pier, and the Milford Shelf. The two main contaminating influences here are likely to be the Milford Haven STW outfall, 700m to the west of the zone, and the Pembroke Dock STW, about 1.1km to the east of the zone. The Milford Haven STW is closer to the zone, and the plume from this will reach the edge of the zone in shallower water than the plume from Pembroke Dock STW. Also, spills of storm sewage are likely to occur more frequently from the Milford Haven STW outfalls. Contamination from land runoff will impact locally mainly via the Pembroke River and the Milford Haven river. Therefore, the RMP should be located in the western edge of this zone, on the Milford Shelf in such a position which tidal flows would most consistently direct the plume towards (SM 9053 0512). This should also capture variations associated with river discharge.

4.4.2 Species sampled.

The species sampled should be carpet shell clams caught by dredge. Sampled stock should be of a market size.

4.4.3 Sampling frequency

To classify this area, 10 samples taken not less than 1 week apart will allow a provisional classification to be awarded. Alternatively a full classification may be awarded following one year of monthly monitoring. Following this monthly monitoring is required for continued classification.

4.4.4 RMP tolerances.

A tolerance of 100m should be applied around these RMPs to allow repeated sampling of wild stocks by dredge.

4.5 Razors

4.5.1 Zoning arrangements and RMP locations

One zone is proposed in the outer reaches of Dale Bay which encompasses the area for which classification has been requested (Figure 5.6). The RMP is located where peak levels of contamination are anticipated (Figure 5.6 and Table 5.1).

- Dale flats, encompassing the subtidal areas in outer Dale Bay for which classification has been requested. Shoreline sources which may influence levels of contamination are the Dale STW outfall and a small spring fed stream both discharging to the shore at the western edge of the bed, moorings which are spread throughout the area requiring classification, and the Dale River, which receives sewage effluent from Marloes STW. The Dale River discharges to the head of the Bay over 500m from the northern edge of the razor bed, so is not anticipated to create a particular hotspot but may cause a slight elevation in levels of contamination towards its northern edge. The small spring fed stream is unlikely to generate a large bacterial loading. The Dale STW is UV treated so should generate a negligible bacterial loading assuming it is working effectively, although it does also carry an overflow discharge about which no spill information was available. The moorings may be considered as a diffuse input. On balance the greatest potential for a hotspot of contamination is probably at the Dale STW outfall. The LEA advise the closest spot to this which can be easily sampled is at SM 8147 0576.

4.5.2 Species sampled.

The species sampled should be razors caught by hand salting. This may be problematic as stocks can only be accessed on the very largest tides. However, bagged razors are unlikely to feed normally or survive for prolonged periods, and no suitably representative surrogate species have been identified. The use of hand salting by divers may represent a possible means of obtaining samples outside of the equinoctial spring tides. Sampled stock should be of a market size.

4.5.3 Sampling frequency

To classify this area, 10 samples taken not less than 1 week apart will allow a provisional classification to be awarded. Alternatively a full classification may be awarded following one year of monthly monitoring. Following this monthly monitoring is required for continued classification.

4.5.4 RMP tolerances.

A tolerance of 100m should be applied around this RMP to allow repeated sampling of wild stocks.

4.6 Chemical Contamination

Although it is beyond the formal scope of this report to consider chemical contamination of shellfish, chemical spills associated with the hydrocarbon industry may occur from time to time. As a consequence, contamination of shellfish from such incidences is a potential public health issue which the competent authority (the FSA) may wish to consider further for this area.

5. SAMPLING PLAN

GENERAL INFORMATION

Location Reference

Production Area	Milford Haven
Cefas Main Site Reference	M039
Cefas Area Reference	Milford Haven
Ordnance survey 1:25,000 map	OS Explorer 36
Admiralty Charts	3274 and 3275

Shellfishery

Species/culture	Native oysters (*Ostrea edulis*)	Wild
	Mussels (*Mytilus* spp.)	Wild/ cultured
	Cockles (*Cerastoderma edule*)	Wild
	Carpet shell clams (*Venerupis pullastra*)	Wild
	Pacific oysters (*Crassostrea gigas*)	Wild
	Razors (*Ensis* spp.)	Wild
Seasonality of harvest	Closed season for dredged native oysters upstream of the Cleddau Bridge from February to September. Otherwise year round, including hand picked native oysters upstream of the Cleddau Bridge.	

Local Enforcement Authority

Name	Milford Port Health Authority Pembrokeshire County Council County Hall Haverfordwest Pembrokeshire SA61 1TP
Environmental Health Officer	Carwyn Thomas
Telephone number ☎	01437 776390
Fax number 📠	01437 776391
E-mail	Carwyn.Thomas@pembrokeshire.gov.uk

REQUIREMENT FOR REVIEW

The Guide to Good Practice for the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2010) indicates that sanitary assessments should be fully reviewed every 6 years, so this assessment is due a formal review in 2018. The assessment may require review in the interim should any significant changes in sources of contamination come to light, such as the upgrading or relocation of any major discharges.

Table 5.1 Number and location of representative monitoring points (RMPs) and frequency of sampling for classification zones within Milford Haven.

Classification zone	RMP code*	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Upper Cleddau		Sprinkle Pill	SM 9985 1071	51° 45.553' N 04° 54.094' W	Native oyster	Wild	Dredge	Bagged	10m	Monthly (excluding February and March)	Represents native and Pacific oysters
Lower Cleddau		Jenkins Point	SN 0720 0596	51° 43.148' N 04° 47.554' W	Native oyster	Wild	Dredge	Bagged	10m	Monthly (excluding February and March)	Represents native and Pacific oysters
Pembroke & Neyland		Off Neyland	SM 9618 0478	51° 42.279' N 04° 57.072' W	Native oyster	Wild	Dredge	Bagged	10m	Monthly	Represents native and Pacific oysters
Pennar Gut		Pennar Gut	SM 9451 0267	51° 41.105' N 04° 58.445' W	Native oyster	Wild	Dredge	Dredge	100m	Monthly	Represents native and Pacific oysters
Milford Outer		Milford Shelf	SM 9053 0512	51° 42.337' N 05° 01.983' W	Native oyster	Wild	Dredge	Dredge	100m	Monthly	Represents native and Pacific oysters
Pembroke STW	TBA*	Pembroke STW	SM 9545 0425	51° 41.977' N 04° 57.686' W	Native oyster	Wild	Dredge	Bagged	10m	Monthly	Represents native and Pacific oysters. LEA to decide if classification is worthwhile.
Neyland STW	TBA*	Neyland STW	SM 9583 0483	51° 42.298' N 04° 57.377' W	Native oyster	Wild	Dredge	Bagged	10m	Monthly	Represents native and Pacific oysters. LEA to decide if classification is worthwhile.

Classification zone	RMP code*	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Upper Cleddau	TBA*	Sprinkle Pill	SM 9985 1071	51° 45.553' N 04° 54.094' W	Mussel	Wild	Hand	Hand picked	10m	Monthly (weekly if provisional classification required quickly)	Not currently classified. Only sample if a classification is required.
Carew/ Cresswell		Lawrenny	SN 0168 0622	51° 43.173' N 04° 52.351' W	Mussel	Wild	Hand	Hand picked	10m	Monthly	
Angle Shelf		Angle Point	SM 8761 0327	51° 41.274' N 05° 04.447' W	Mussel	Cultured	Hand	Bagged	10m	Monthly	
Upper Cleddau	TBA*	Sprinkle Pill	SM 9985 1071	51° 45.553' N 04° 54.094' W	Cockles	Wild	Hand (rake)	Hand (rake)	100m	Monthly (weekly if provisional classification required quickly)	Not currently classified. Only sample if a classification is required.
Cresswell	TBA*	Lawrenny	SN 0168 0622	51° 43.173' N 04° 52.351' W	Cockles	Wild	Hand (rake)	Hand (rake)	100m	Monthly (weekly if provisional classification required quickly)	Not currently classified. Only sample if a classification is required.
Pembroke River	TBA*	Bentlass	SM 9600 0173	51° 40.632' N 04° 57.121' W	Cockles	Wild	Hand (rake)	Hand (rake)	100m	Monthly (weekly if provisional classification required quickly)	Not currently classified. Only sample if a classification is required.

Classification zone	RMP code	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Pwllcrochan Flats	TBA*	Pwllcrochan Flats	SM 9226 0320	51° 41.341' N 05° 00.414' W	Cockles	Wild	Hand (rake)	Hand (rake)	100m	Monthly (weekly if provisional classification required quickly)	Not currently classified. Only sample if a classification is required.
Angle Bay East	TBA*	Rhoscrowther	SM 8965 0226	51° 40.776' N 05° 02.642' W	Cockles	Wild	Hand (rake)	Hand (rake)	100m	Monthly (weekly if provisional classification required quickly)	Not currently classified. Only sample if a classification is required.
Sandyhaven	TBA*	Sandyhaven	SM 8558 0747	51° 43.491' N 05° 06.361' W	Cockles	Wild	Hand (rake)	Hand (rake)	100m	Monthly (weekly if provisional classification required quickly)	Not currently classified. Only sample if a classification is required.
Dale	TBA*	Dale inner	SM 8128 0684	51° 43.052' N 05° 10.067' W	Cockles	Wild	Hand (rake)	Hand (rake)	100m	Monthly (weekly if provisional classification required quickly)	Not currently classified. Only sample if a classification is required.

Classification zone	RMP code	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Milford Outer	TBA*	Milford Shelf	SM 9053 0512	51° 42.337’ N 05° 01.983’ W	Carpet shell clams	Wild	Dredge	Dredged	100m	Monthly (weekly if provisional classification required quickly)	Not currently classified. Classification requested. Permission to use dredge required before sampling can start
Dale Flats	B39CQ	Dale Flats	SM 8147 0576	51° 42.474’ N 05° 09.862’ W	Razors	Wild	Hand (salting)	Hand (salting)	100m	Monthly (weekly if provisional classification required quickly)	Not currently classified. Classification requested.

*RMP codes will only be generated on the SHS database on request of Milford Port Health Authority.

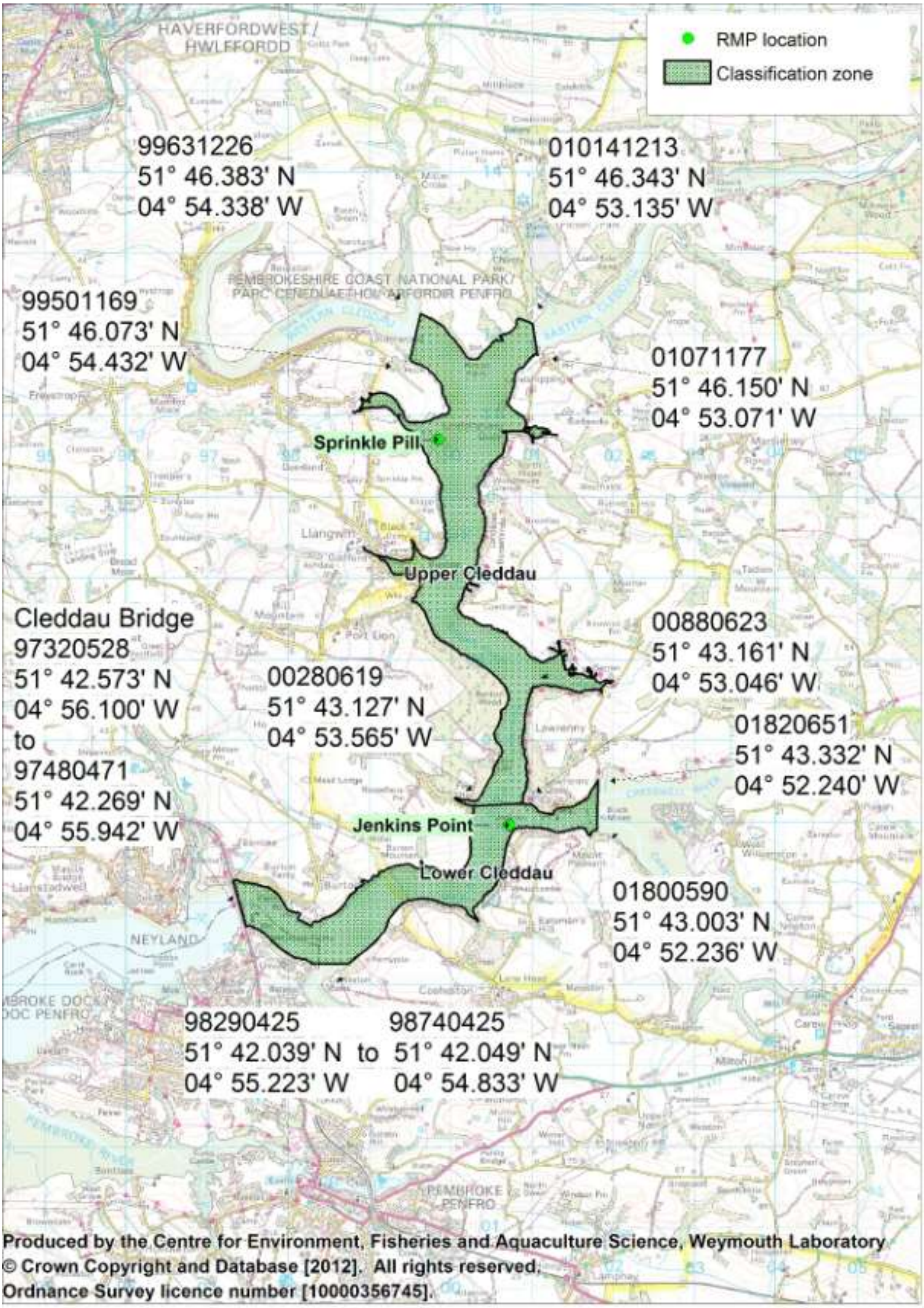


Figure 5.1 Recommended classification zone boundaries and RMP locations for native and Pacific oysters upstream of Cleddau Bridge

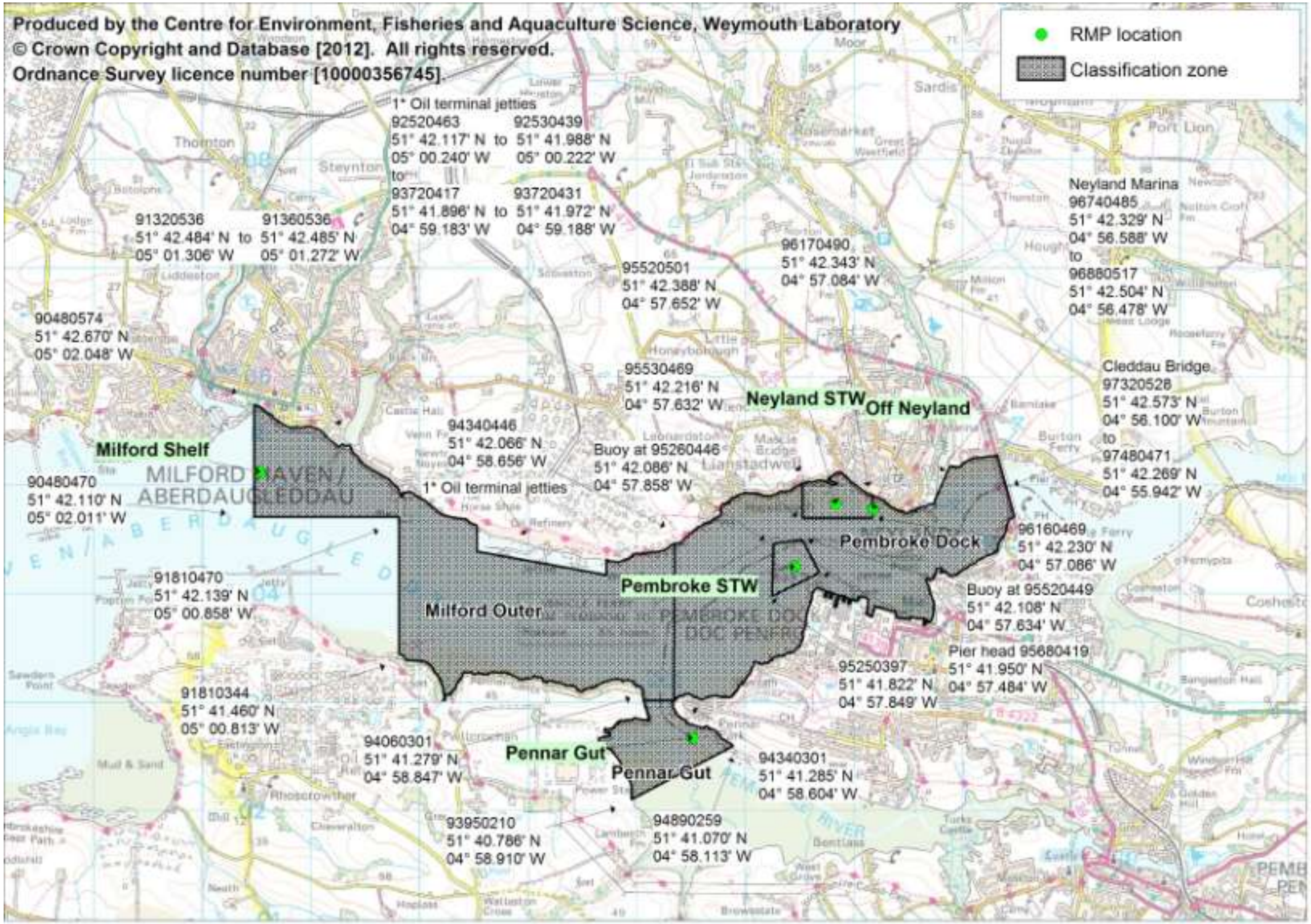


Figure 5.2 Recommended classification zone boundaries and RMP locations for native and Pacific oysters downstream of Cleddau Bridge

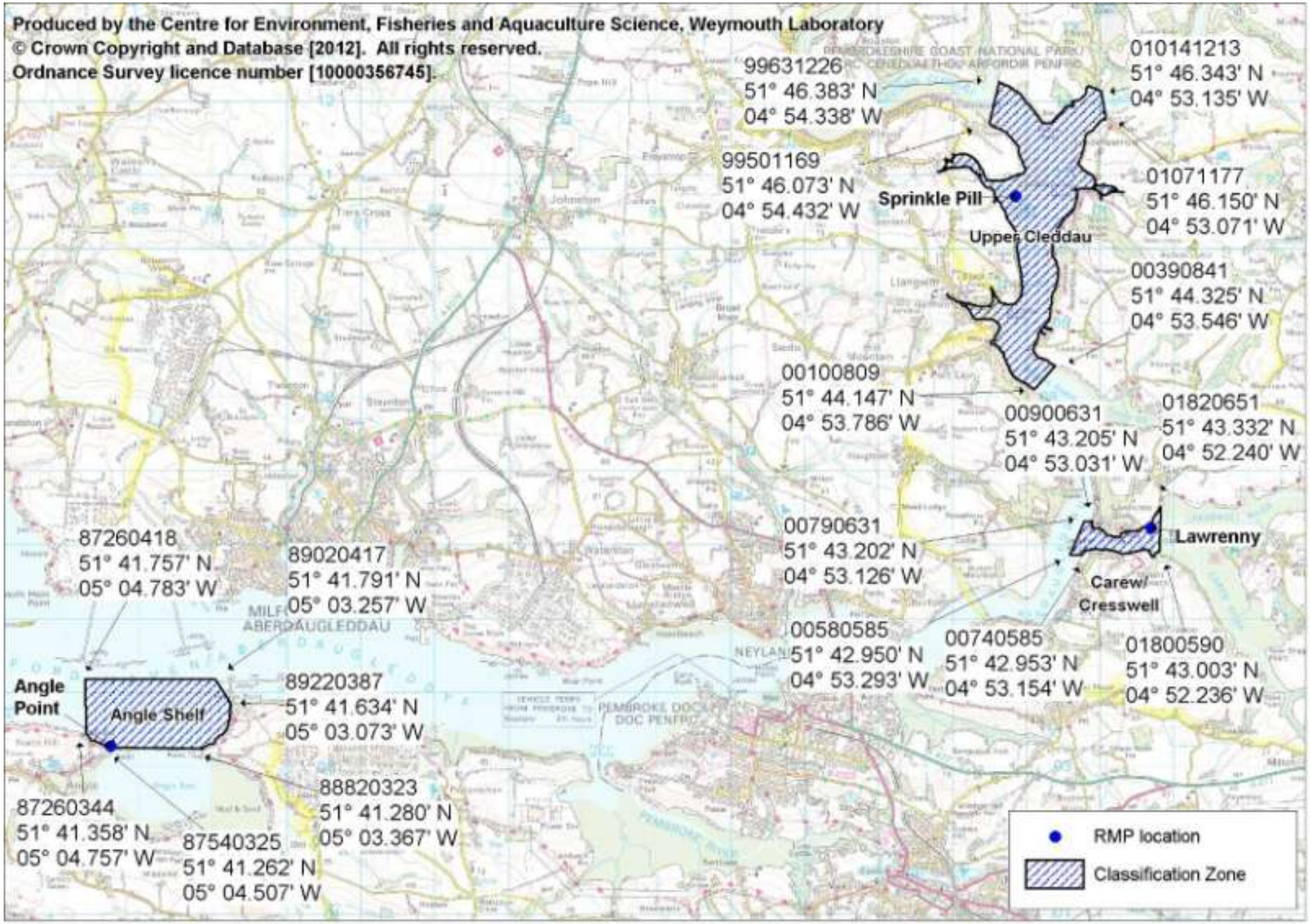


Figure 5.3 Recommended classification zone boundaries and RMP locations for mussels

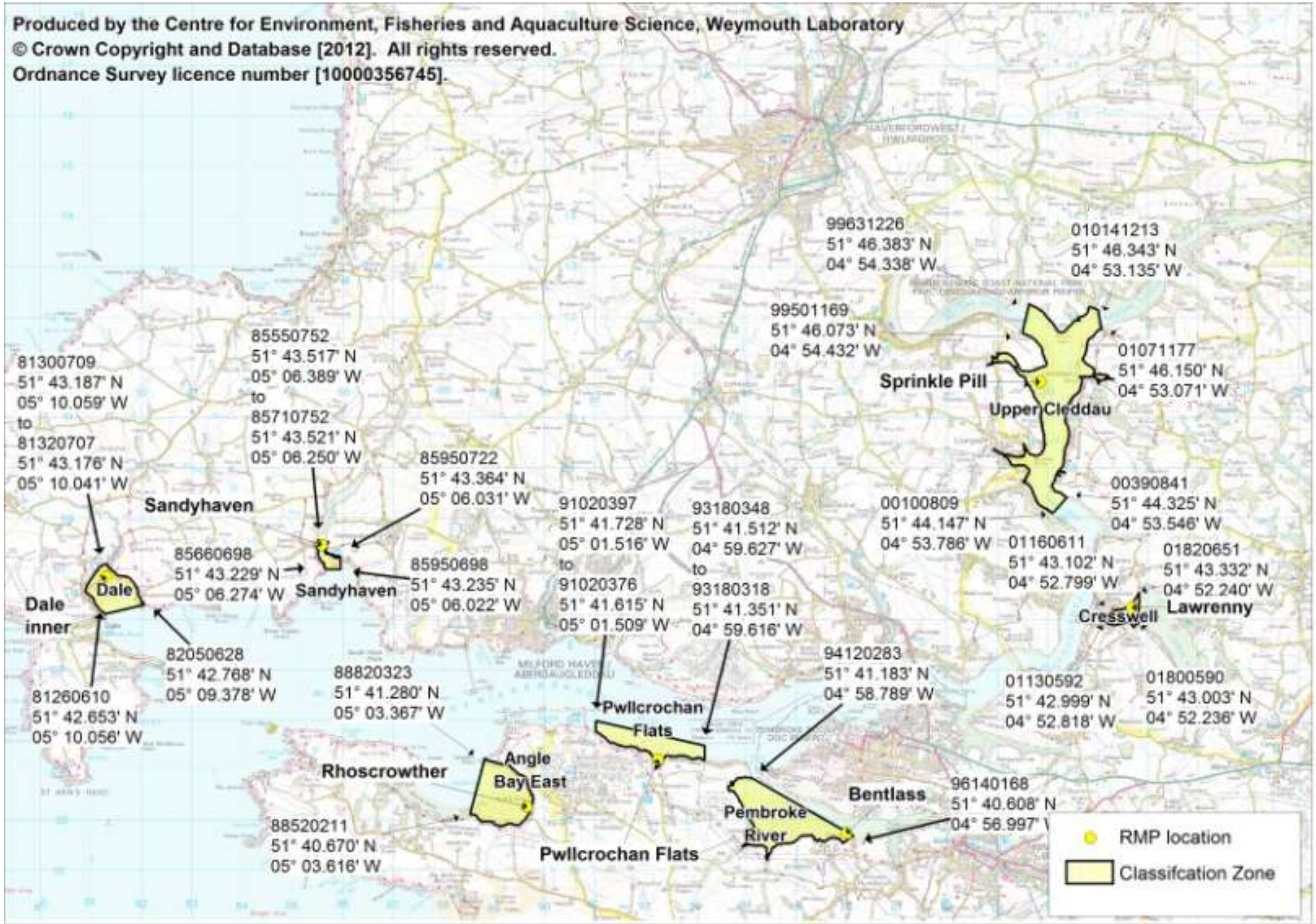


Figure 5.4 Recommended classification zone boundaries and RMP locations for cockles

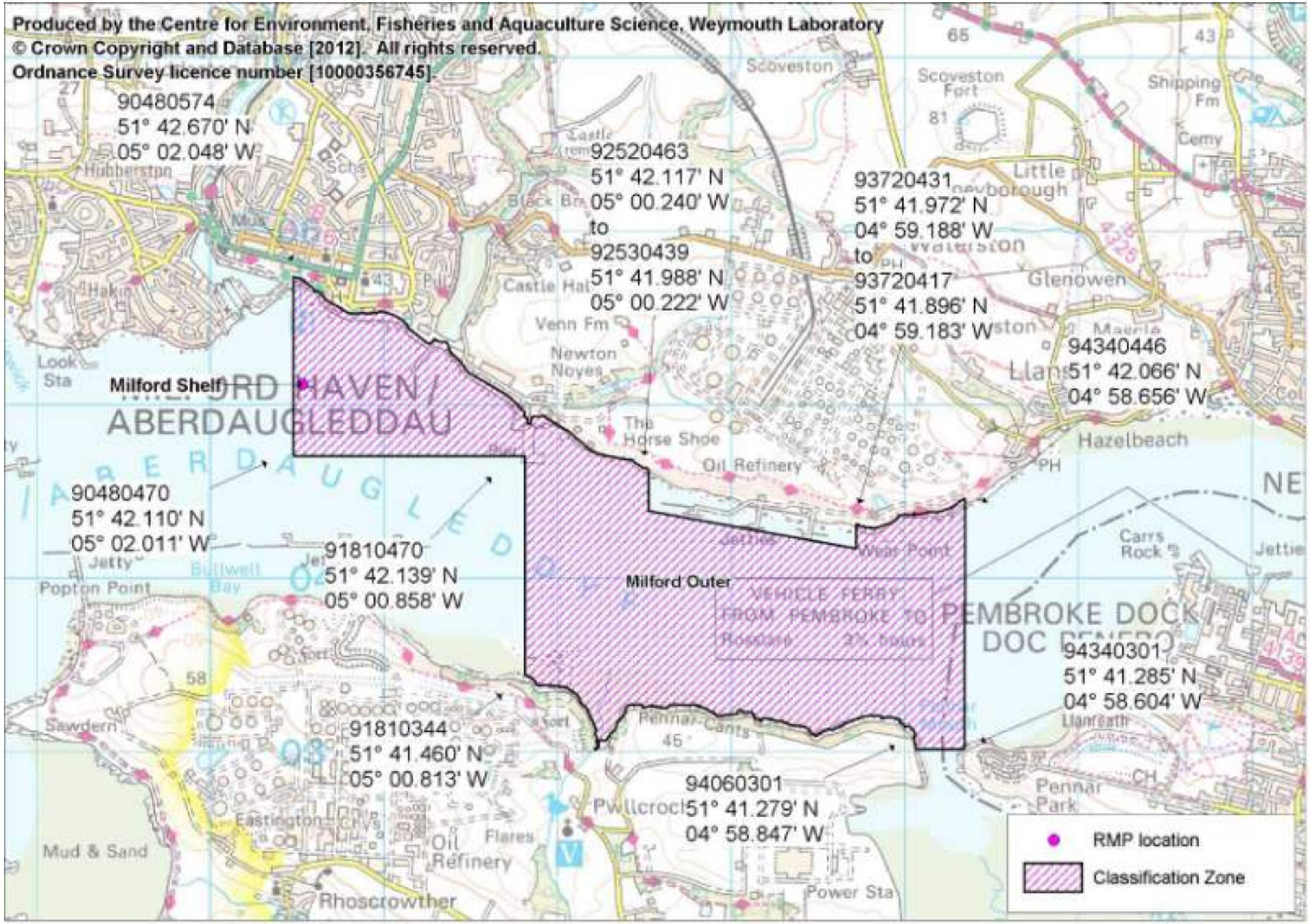


Figure 5.5 Recommended classification zone boundaries and RMP locations for carpet shell clams

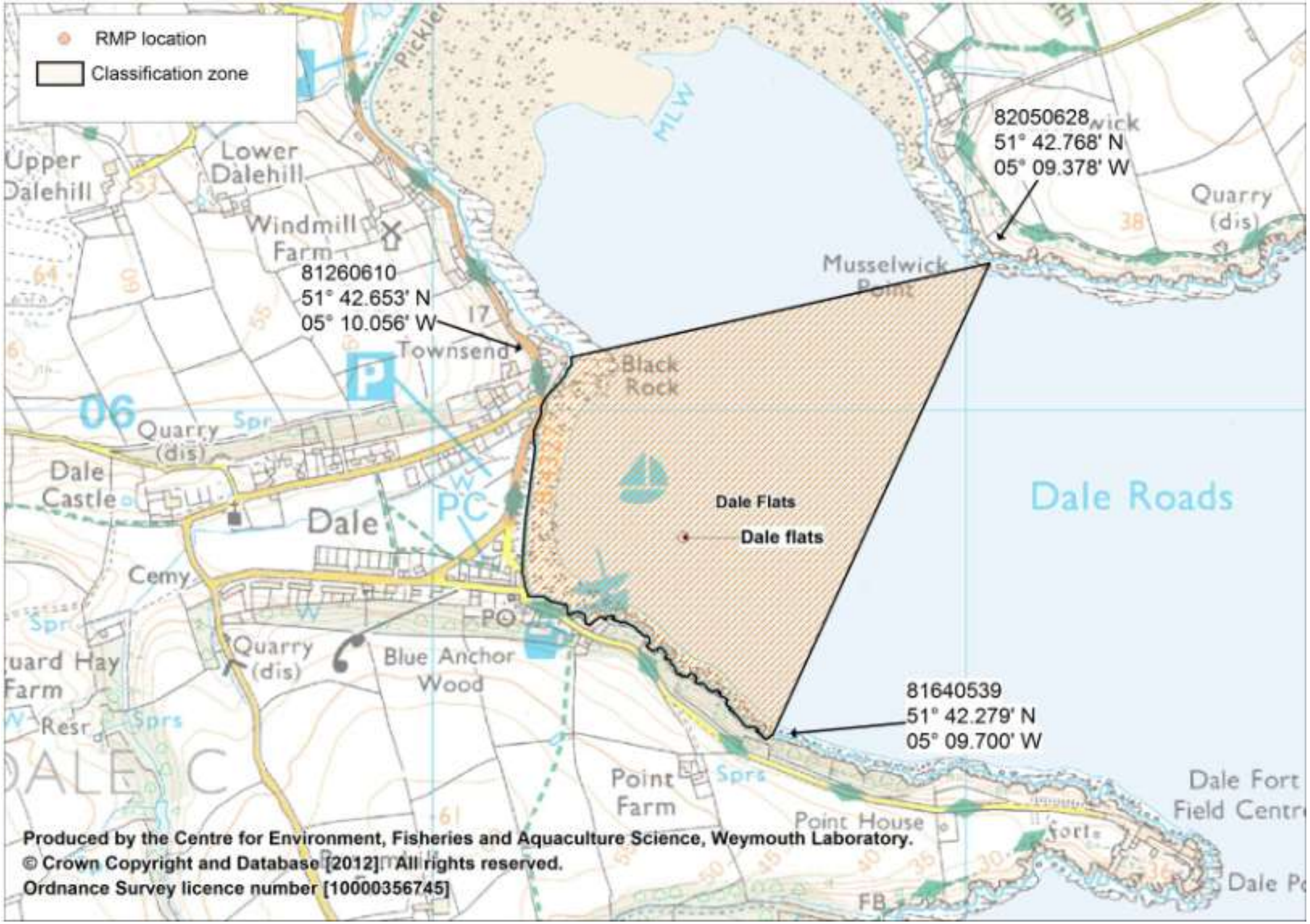


Figure 5.6 Recommended classification zone boundaries and RMP locations for razors

APPENDICES

APPENDIX I
HUMAN POPULATION

The distribution of resident human population by Super Output Area Boundary totally or partially included within the Milford Haven catchment area is shown in Figure I.1. Total resident human population in the census areas within or partially within the Milford Haven catchment area was 93,807at the last census in 2001.

Figure I.1 Human population density in the Milford Haven catchment area.
Source: ONS, Super Output Area Boundaries (Middle layer). Crown copyright 2004. Crown copyright material is reproduced with the permission of the Controller of HMSO.

The majority of the catchment area is rural in character and sparsely populated, particularly within the upper reaches. Most of the population is concentrated in three main towns all of which border the estuary (Pembroke Dock, Milford Haven and Haverfordwest).

Pembrokeshire is a popular tourist destination, largely for outdoor attractions and activities. It receives about 14 million visitor days per year, compared with a resident population of ~120,000 for the whole county (Pembrokeshire Tourism Industry website, 2011). Milford Haven itself is a popular area for water sports such as dinghy sailing, windsurfing, powerboating, canoeing, waterskiing and kayaking. Visitor numbers peak in the summer holiday season. It is therefore concluded that the volumes of sewage passing through sewage works in the Milford Haven area will be higher in the summer than in the winter.

APPENDIX II
HYDROMETRIC DATA: RAINFALL

Wales is one of the wetter regions of England and Wales, but rainfall varies considerably across the region. Areas with higher elevations tend to receive higher rainfalls, so rainfall will be higher in the upper Cleddau catchment than in coastal areas. Figure II.1 presents a boxplot of daily rainfall totals by month for rain gauges located Bolton Hill in the lower catchment, about 6km north of Milford Haven Town, and Maenclochog in the upper catchment, about 20km north of Picton Point.

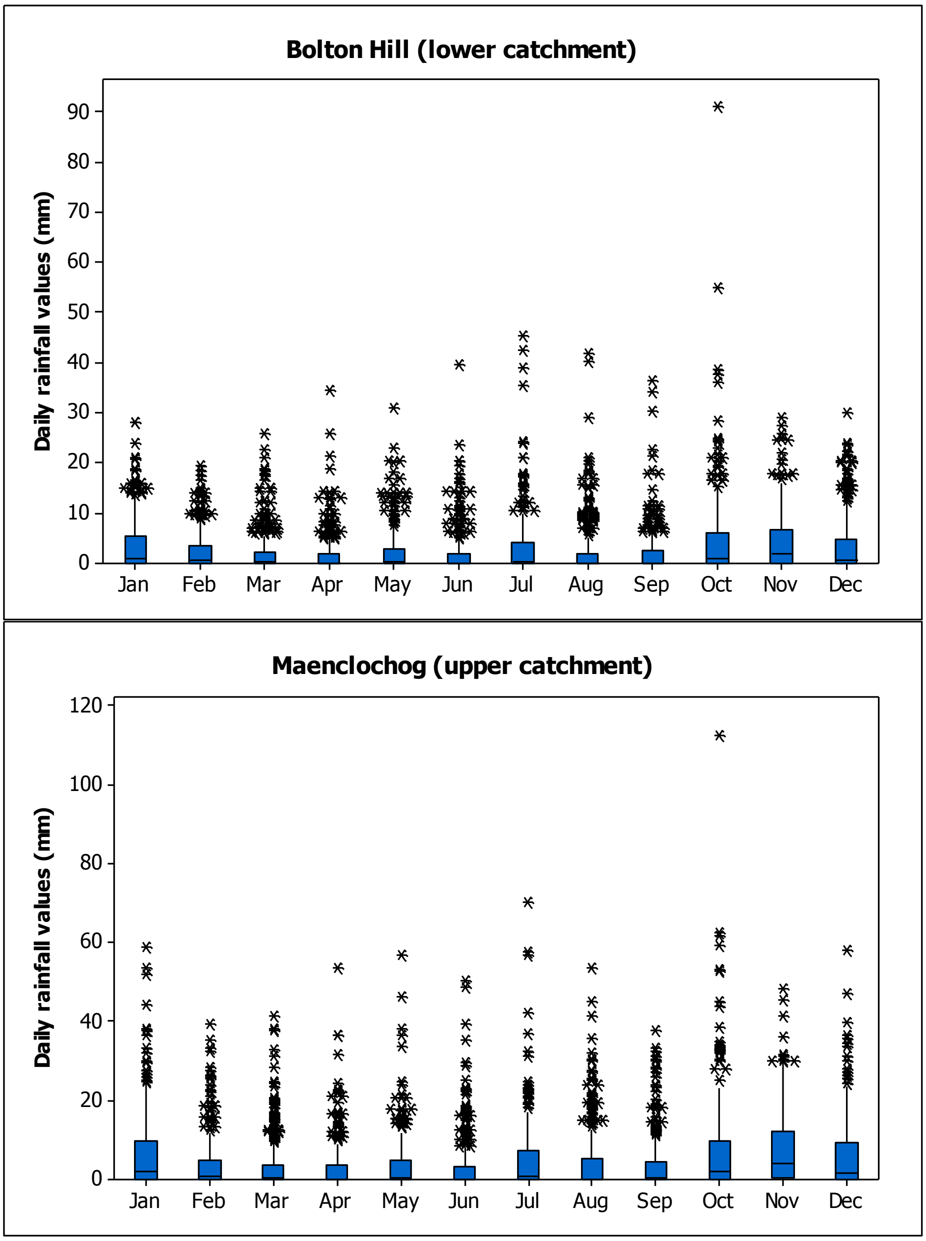


Figure II.1 Boxplot of daily rainfall totals at Bolton Hill and Maenclochog, January 2002 to January 2012. *Data from the Environment Agency.*

Rainfall at both these sites is highest on average from October to January. A secondary peak is apparent in July as a result of a series of wet Julys from 2007 to 2010, and this pattern is not apparent in long term averages for the region (Met Office 2012). As expected, rainfall was higher on average in the upper catchment.

At Bolton Hill, 43.4% of records were dry days, and rainfall exceeded 20mm on 1.9% of days. At Maenclochog, 32.2% of records were dry days and rainfall exceeded 20mm on 6.2% of days. At both sites, high rainfall events exceeding 20mm occurred in all months of the year.

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

APPENDIX III
HYDROMETRIC DATA: FRESHWATER INPUTS

The catchment area for Milford Haven totals 820km^2. The main freshwater inputs are the East and West Cleddau, which converge at Picton Point, 6-8km below their tidal limits.

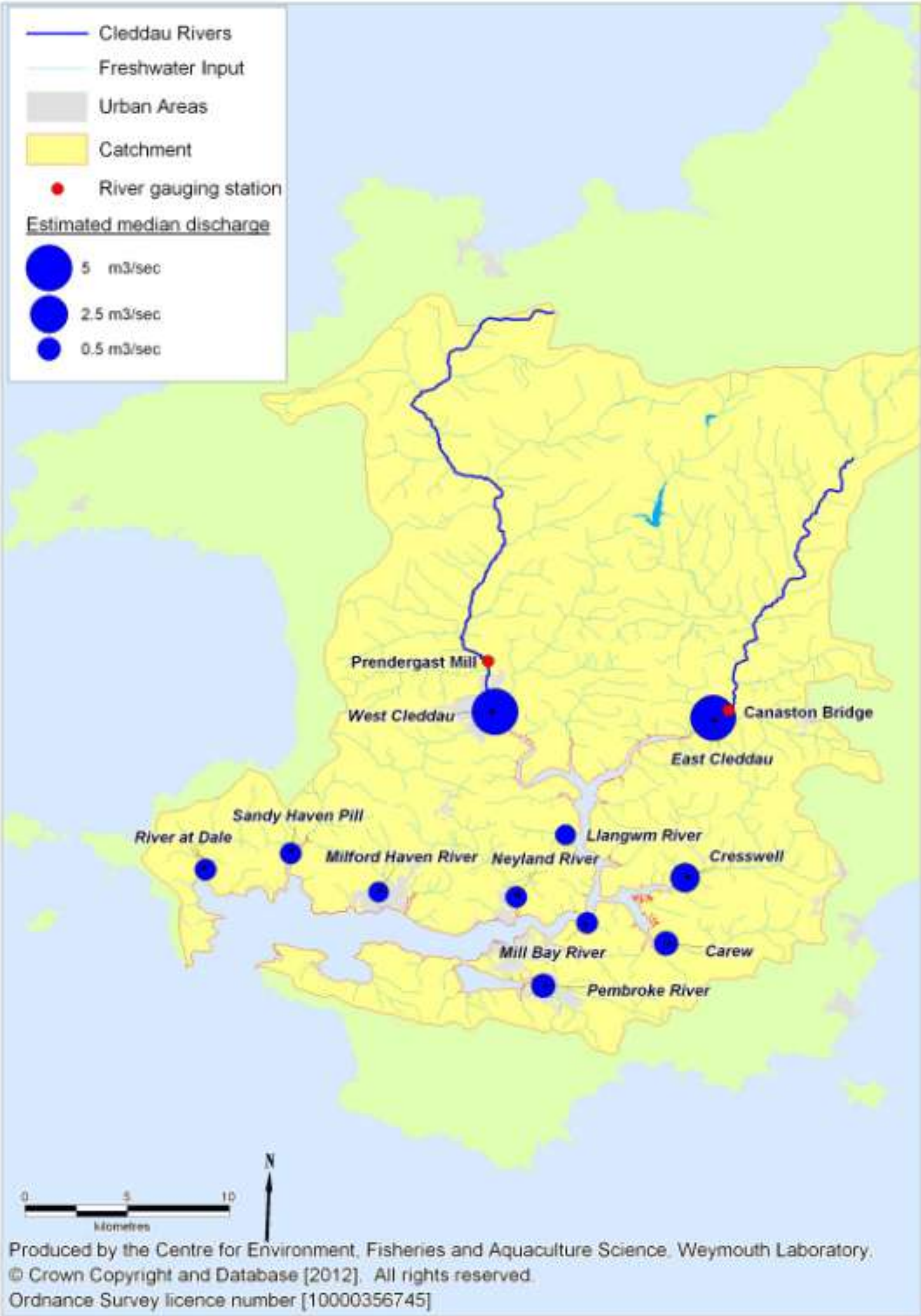


Figure III.1 Freshwater inputs to Milford Haven. Estimated median (50%ile) flows from Table III.2 (METOC, 2008).

About 65% of the Milford Haven catchment area drains to the estuary upstream of Picton Point, so freshwater influence and associated contamination will be highest in the upper estuary. There are several smaller watercourses discharging to the middle and lower estuary which will have a more localised influence. Many of these such as the Carew, Cresswell and Pembroke River discharge to shallow embayments or side arms of the main estuary within which their influence will be most marked.

The only two flow gauging stations are on the East and West Cleddau, the locations of which are shown in Figure III.1. Significant tributaries join both these rivers downstream of these gauging stations. Summary statistics for each are presented in Table III.1.

Table III.1 Summary discharge statistics (1965-2010) for the East and West Cleddau. From National River Flow Archive (NERC, 2012).

River	Station	Catchment area (km^2)	Mean Daily Flow ($m^3 s^{-1}$)	Flow exceeded 50% of the time ($m^3 s^{-1}$)	Flow exceeded 10% of the time ($m^3 s^{-1}$)
West Cleddau	Prendergast Mill	197.6	5.606	3.899	12.4
East Cleddau	Canaston Bridge	183.1	6.104	3.95	13.3

The combined flows for these two gauging stations represent about 46% of the Milford Haven catchment area so the total volumes of freshwater entering Milford Haven will be roughly double the combined flows from these stations. Individual daily flows for recent years were only available for Canaston Bridge, as recent records from the Prendergast Mill gauging station are reported to be inaccurate. Figure III.2 presents a boxplot of mean daily flow by month for Canaston Bridge which should give a broad indication of the seasonal variation in freshwater input to Milford Haven.

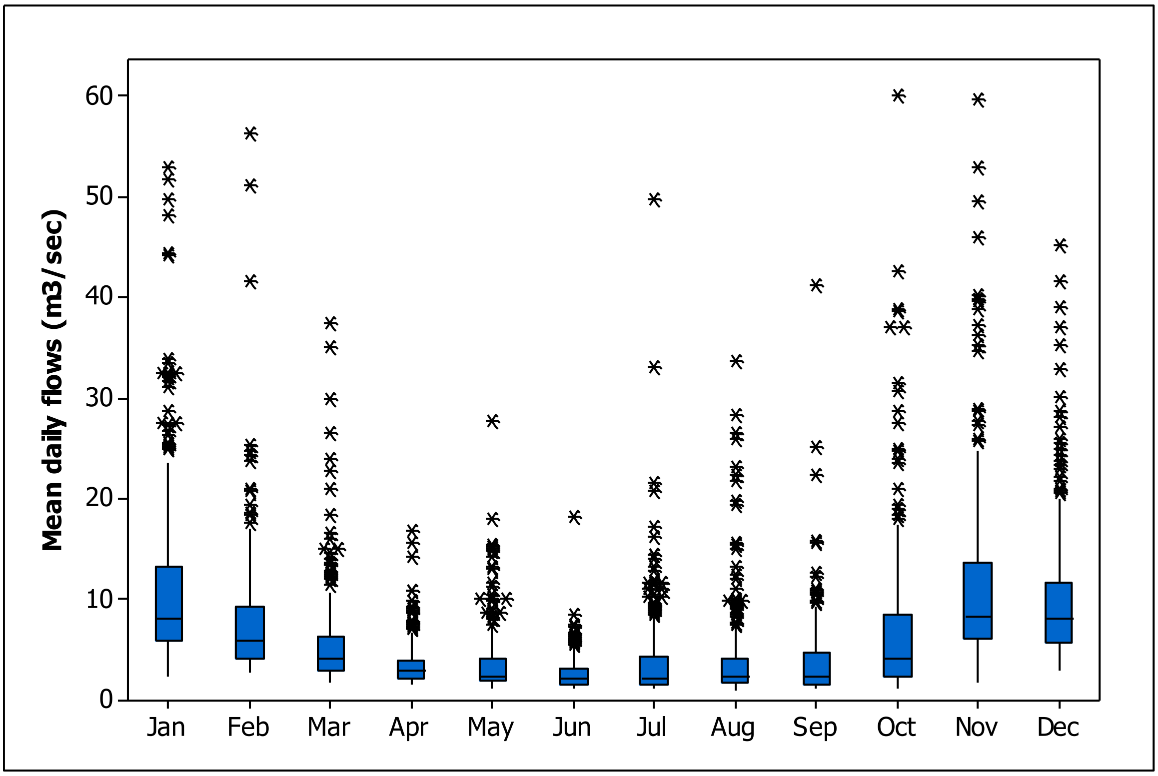


***Figure III.2 Boxplots of mean daily flow records from Canaston Bridge, East Cleddau, January 2002 to January 2012** (Data from the Environment Agency)*

Flows were markedly higher on average from October to February, and generally low from April to September. High flow events were most common during the autumn and winter, but were recorded in most months of the year. The seasonal pattern of flows is not entirely dependent on rainfall as during the colder months there is less evaporation, less transpiration, and soils are more likely to be waterlogged so higher proportion of rainfall will run off. Increased levels of runoff are likely to result in an increased bacterial loading carried into coastal waters. They will also decrease residence time in rivers and estuaries and so contamination from more distant sources may have an increased impact during high flow events.

A water quality model applied to Milford Haven to inform the AMP5 discharge improvement scheme (METOC, 2008) included some information on estimated discharges of some of the watercourses discharging to Milford Haven. These are shown in Figure III.1 and Table III.2.

Table III.2 Estimated flows from selected watercourses draining to Milford Haven (from METOC, 2008)

Watercourse	Flow exceeded 50% of the time ($m^3 s^{-1}$)	Flow exceeded 10% of the time ($m^3 s^{-1}$)
West Cleddau group	5.7	19.9
East Cleddau group	4.5	15.6
Cresswell	1	3.4
Pembroke River	0.6	2.2
Carew	0.6	2.1
Neyland River	0.4	1.4
River at Dale	0.4	1.3
Sandy Haven Pill	0.4	1.3
Milford Haven River	0.3	1

Mill Bay River	0.1	0.4
Llangwm River	0.1	0.3

Table III.2 covers most of the larger watercourses draining to the estuary. Of these a high proportion of flows are attributable to the East and West Cleddaus. As well as the flow estimates, METOC (2008) presents the results of intensive repeated sampling for faecal coliforms during a three day period in March 2007. Due to the limited window in which the samples were taken results are unlikely to fully represent the range of conditions likely to arise despite the large number of samples. The results of these samples are summarised in Table III.3.

Table III.2 Bacteriological sampling results from selected watercourses draining to Milford Haven, March 2007 (from METOC, 2008)

	Faecal coliforms results (cfu/100ml)			
Watercourse	No.	Geomean	Min.	Max.
East Cleddau	144	417	50	5000
West Cleddau	144	1260	100	16000
Sprinkle Pill	48	266	70	6000
Neyland River	48	369	120	4000
Cresswell	48	1601	200	6000

The results indicate that the watercourses samples were generally carrying moderate levels of contamination at the time of sampling, although some quite high results were recorded. The West Cleddau carried higher levels of faecal coliforms than the East Cleddau by a factor of three on average. The Cresswell carried the highest concentration of all watercourses on average. Sprinkle Pill is a minor watercourse of approximately the same size of Llangwm River and drains to the west shore of the estuary just below the Cleddau confluence. In addition to these samples, four freshwater samples were taken by the Environment Agency from the Pembroke River in December 2011 and January 2012. These contained from 420 to 2400 faecal coliforms/100ml with a geometric mean of 1380, again indicating moderate levels of contamination at the time of sampling.

In conclusion, the majority of runoff (representing about 65% of the total catchment area) enters the estuary upstream of the Cleddau confluence and hence upstream of the fisheries. Freshwater borne contamination would therefore be expected to have the greatest influence towards the head of the main estuary. A significant freshwater influence is also anticipated within the Carew/Cresswell side channel as two minor rivers discharge here. Increased freshwater influence is also likely to be felt within other embayments or small side channels to which significant watercourses drain. These include the Garron Pill, Cocheston Pill, Pembroke River, Sandy Haven and Dale. Those watercourses which have been sampled generally carried moderate and occasionally high concentrations of faecal coliforms. Volumes of runoff vary with season, and are highest on average from October to February, although high flow events may occur at any time of the year.

APPENDIX IV
HYDROGRAPHIC DATA: BATHYMETRY

Milford Haven is a drowned river valley which measures about 32km from its mouth to its head and covers an area of about 55km^2 and is the largest of its type within the UK. Its bathymetry is quite complex. The mouth faces south and is just over 2km wide, with a maximum depth of about 25m. The estuary then bends immediately round to an east west orientation and is afforded shelter from westerly winds by the Dale peninsula. Throughout its outer reaches it is characterised by a central channel up to almost 30m deep in places flanked by extensive shallower subtidal areas. Its outer reaches are between 1-3km wide so offer significant potential for dilution of contamination. It gradually narrows and intertidal areas tend to increase in size through its middle reaches, then bends round to a north south orientation in its upper reaches. The width of the upper main channel varies from about 200-500m, and maximum depth decreases from almost 20m down to less than 3m at Picton Point. The channel splits in two at Picton Point where the East and West Cleddau estuaries meet. The overall profile of gradually narrowing and shallowing waters along the main channel suggests a decreasing dilution potential towards the head of the estuary. Therefore contamination sources within the outer reaches will have a more localised effect compared to those discharging to the upper reaches.

There are no major sills or constrictions within the main estuary channel which may create areas of turbulent mixing or major step changes in water quality across them, although there is a shallow bar extending across the main Cleddau channel just upstream of the Carew/Cresswell confluence where tidal streams are likely to accelerate and some mixing may occur.

There are several side channels and embayments at various locations throughout the estuary, most of which are where small rivers feed into the estuary. These are generally shallow throughout with large intertidal areas, and as such may be considered to form hydrographic zones distinct from the main channel, especially those with a constriction at their mouth. Some contain shellfish stocks of potential commercial interest (Angle Bay, Pembroke River, Carew and Cresswell Rivers, and possibly Sandy Haven and Dale Flats). Due to their shallow intertidal nature, there will be less potential for dilution within them, but a large proportion of the water within them will be exchanged each tidal cycle.

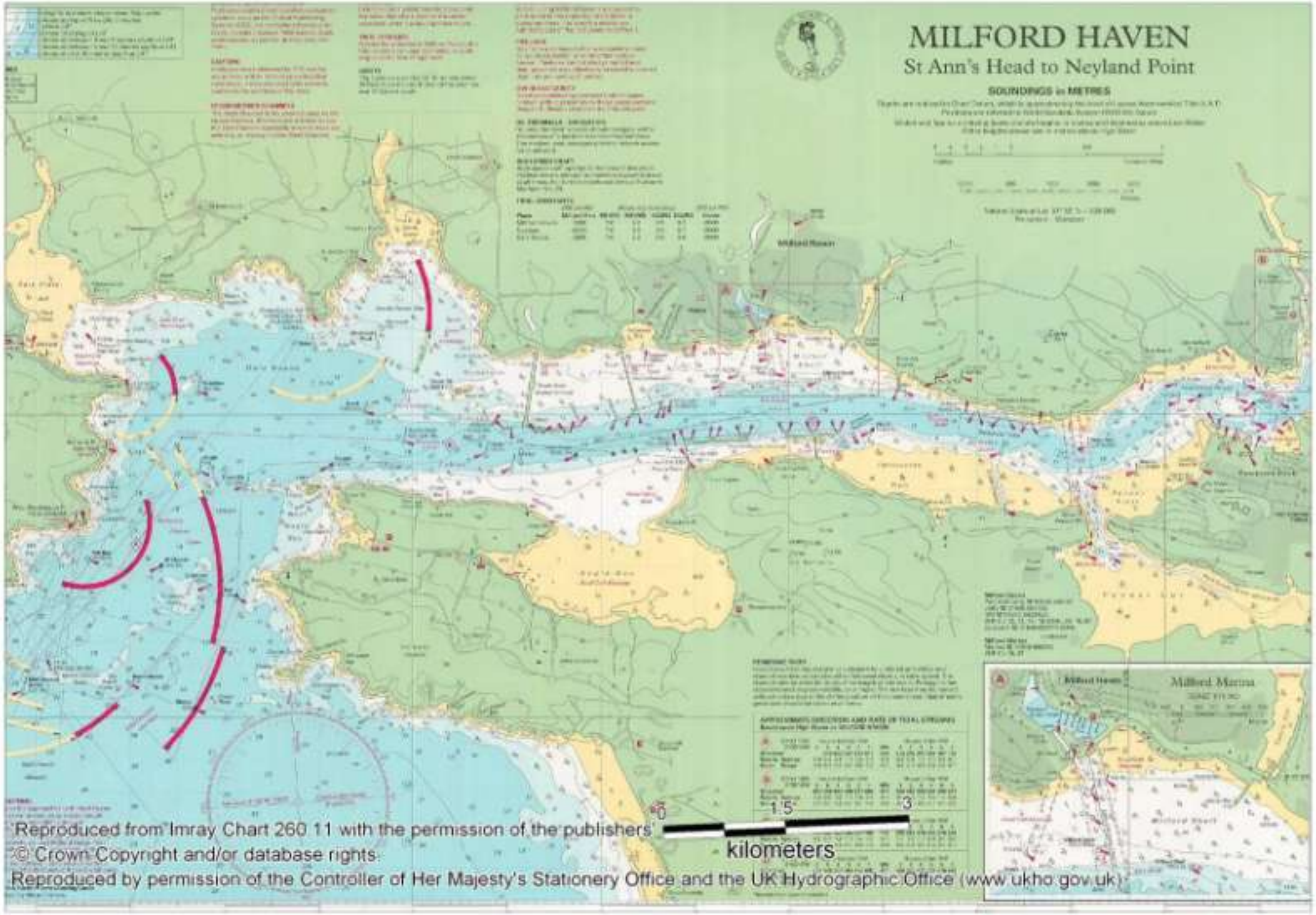


Figure IV.1 Bathymetry chart of Lower Milford Haven

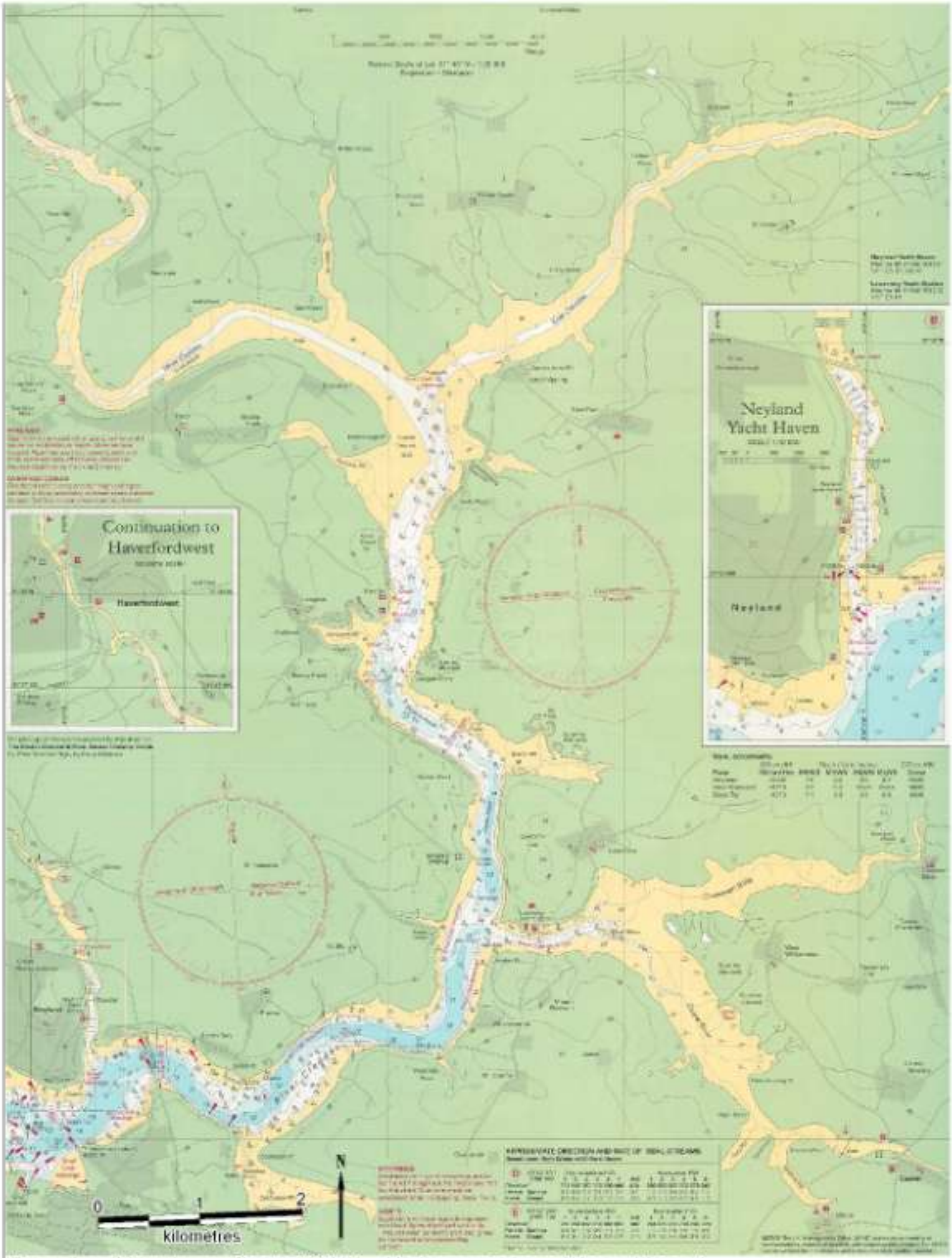


Figure IV.2 Bathymetry chart of Upper Milford Haven

APPENDIX V
HYDRODYNAMIC DATA: TIDES AND CURRENTS

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. Tidal amplitude is large (Table V.1) and this drives extensive water movements within Milford Haven.

Table V.1 Tide levels and ranges at various tidal stations within Milford Haven.

	Height (m) above Chart Datum				Range (m)	
Port	MHWS	MHWN	MLWN	MLWS	Springs	Neaps
Dale Roads	7.00	5.20	2.50	0.60	6.40	2.70
Milford Haven	6.87	5.26	2.43	0.82	6.05	2.83
Neyland	7.00	5.20	2.50	0.70	6.30	2.70
Black Tar	7.10	5.30	2.50	0.60	6.50	2.80
Haverfordwest	2.20	0.30	-	-	-	-

Data from the Proudman Oceanographic Office

The positions of tidal diamonds within Milford Haven are shown in Figures V.1, and tidal stream data for these diamonds taken from Admiralty Charts 3274 and 3275 are shown in Table V.2. They indicate that the main tidal stream is bi-directional, with water moving up the estuary on the flood, and down the estuary on the ebb. The flood tide will convey relatively clean water originating from the open Atlantic Ocean into the estuary, whereas the ebb tide will carry contamination from catchment sources out through the estuary. Contamination from shoreline sources such as small watercourses under such a bi-directional tidal regime will generally travel parallel to the shore. Impacts will arise to either side of them, and the magnitude of their impacts will decrease with distance as the plume spreads and becomes more diluted. Sources discharging to deeper waters such as the Pembroke Dock STW will also generally create a plume aligning with the orientation of the estuary. This simplistic view will be complicated in some areas by localised variations arising from the relatively complex bathymetry, such as the formation of eddy currents. At diamond F for example (off Neyland) a back flow forms for part of the ebb tide. It is likely that other eddies form on various scales outside of the main flow, but it is difficult to establish where these may form without undertaking detailed observations or modelling.

Current velocities on spring tides are on average just over double that on neap tides. They peak at 0.57m/s in the mouth, and generally become stronger at the more upstream tidal diamonds, with a peak of 1.29m/s at diamond G (off Burton Point). Current speeds are likely to be lower close to the shore due to friction effects. Extrapolating from the diamonds, tidal excursion (the distance a particle would be carried during the course of a single flood or ebb tide) is in the approximate order of 7-15km on spring tides and 3.5-7km on neap tides within the area represented. Drogues released from Picton Point gave an indication of tidal excursion in the upper reaches, and travelled as far as Pwllcrochan Flats (15.3km) on a spring ebb and as from Beggars Reach as far as Pembroke Dockyard (9.2km) on a neap tide (Nelson-Smith, 1965). Therefore, the maximum tidal excursion is approximately half of the total length of the estuary, and it is generally less within the outer reaches. Major sources may therefore potentially impact over large areas.

Table V.2 Tidal stream information for tidal diamonds in Milford Haven (Admiralty charts 3274 and 3275)

Time in relation to HW (hrs)	A			B			C			D			E			F			G		
	Direction (°)	Spring rate (m/s)	Neap rate (m/s)	Direction (°)	Spring rate (m/s)	Neap rate (m/s)	Direction (°)	Spring rate (m/s)	Neap rate (m/s)	Direction (°)	Spring rate (m/s)	Neap rate (m/s)	Direction (°)	Spring rate (m/s)	Neap rate (m/s)	Direction (°)	Spring rate (m/s)	Neap rate (m/s)	Direction (°)	Spring rate (m/s)	Neap rate (m/s)
HW-6	0	0.00	0.00	3	0.15	0.10	310	0.21	0.10	100	0.05	0.00	0	0.00	0.00	171	0.10	0.05	210	0.15	0.05
HW-5	13	0.15	0.05	60	0.31	0.15	73	0.21	0.10	97	0.36	0.15	67	0.31	0.15	116	0.41	0.21	58	0.05	0.05
HW-4	23	0.41	0.21	86	0.62	0.31	85	0.51	0.26	95	0.51	0.21	82	0.77	0.36	107	0.82	0.36	42	0.21	0.10
HW-3	27	0.57	0.26	88	0.87	0.41	89	0.77	0.36	95	0.57	0.26	83	0.93	0.41	103	1.08	0.51	58	0.46	0.21
HW-2	23	0.51	0.26	87	0.77	0.36	97	0.67	0.31	97	0.72	0.31	81	0.93	0.41	100	1.18	0.62	62	0.67	0.31
HW-1	17	0.36	0.15	84	0.46	0.21	98	0.57	0.26	102	0.46	0.21	81	0.77	0.36	95	0.98	0.46	63	0.57	0.26
HW	354	0.15	0.05	17	0.05	0.00	83	0.15	0.10	100	0.05	0.00	89	0.15	0.05	79	0.36	0.15	82	0.10	0.05
HW+1	214	0.26	0.10	266	0.21	0.10	294	0.21	0.10	285	0.57	0.26	256	0.51	0.26	280	0.62	0.31	244	0.87	0.41
HW+2	207	0.46	0.21	260	0.62	0.26	272	0.51	0.26	280	0.62	0.26	262	0.87	0.41	33	0.15	0.05	245	1.29	0.62
HW+3	207	0.57	0.26	260	0.87	0.41	263	0.57	0.26	278	0.57	0.26	259	0.98	0.46	66	0.21	0.10	243	1.23	0.57
HW+4	200	0.57	0.26	261	0.72	0.36	257	0.67	0.31	276	0.46	0.21	259	0.87	0.41	300	0.10	0.05	238	0.98	0.41
HW+5	187	0.31	0.15	265	0.51	0.26	263	0.62	0.31	270	0.26	0.10	260	0.51	0.26	270	0.21	0.10	233	0.62	0.26
HW+6	120	0.05	0.05	120	0.05	0.05	278	0.36	0.15	258	0.10	0.05	267	0.10	0.05	240	0.10	0.05	224	0.26	0.10

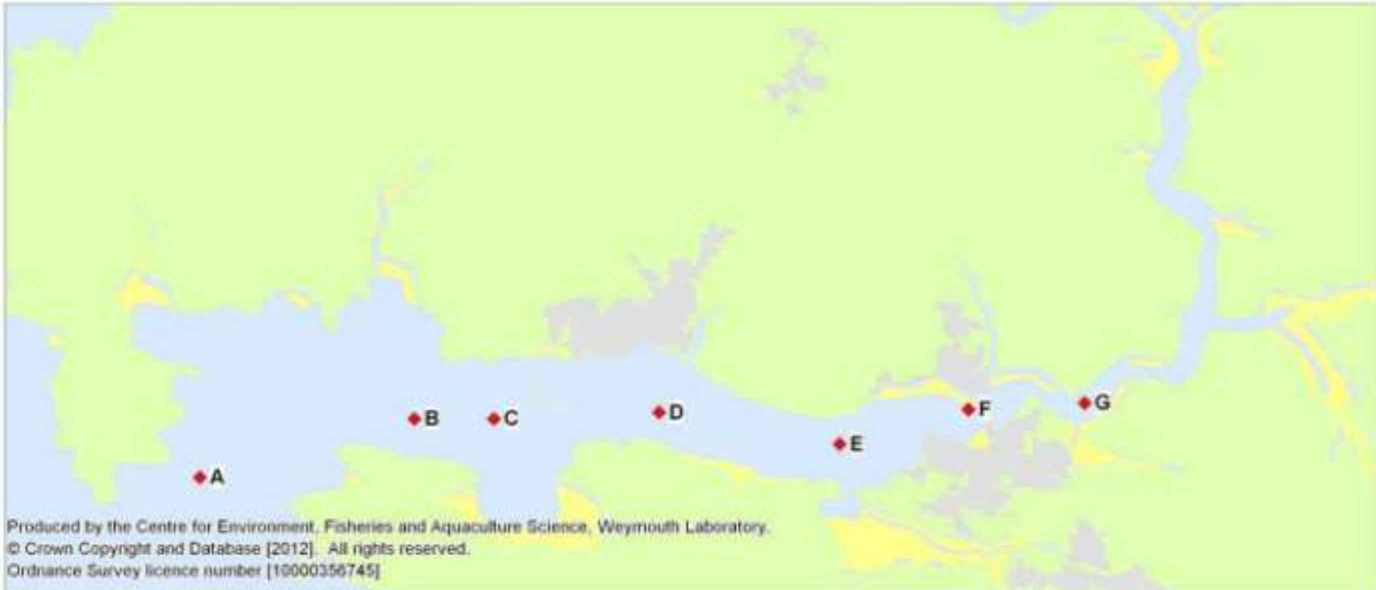


Figure V.1 Location of tidal diamonds within Milford Haven

Background levels of contamination within the side channels and embayments are likely to be increased by any sources discharging to the flood streams moving into them (i.e. down estuary sources). Contamination from up-estuary sources will tend to be carried past them rather than into them during the ebb. Sources discharging directly inside these are likely to result in the most acute 'hotspots' and account for most of the spatial variation within them, so should therefore be the most important consideration for the sampling plan. For those with defined channels, such as the Pembroke River and Carew/Cresswell, the main flows will be along these and tidal currents over the extensive intertidal areas will be slower.

Superimposed on tidally driven currents are the effects of freshwater inputs and wind. The majority of freshwater enters the estuary via the East and West Cleddau Rivers, with additional small to medium sized watercourses entering at various other locations throughout the estuary, often via the partially enclosed side branches. Surface salinity measurements taken during the shoreline survey (Appendix XV, Figure XV.3) indicate a steady increase in salinity from Picton Point, where salinities were between 9 and 10ppt, to the outer part of the haven by Angle Bay, where the salinity was 32.7ppt. Nelson-Smith (1965) presented surface isohalines at high and low water on spring and neap tides. These indicate there is little freshwater influence downstream of Neyland, but in the upper reaches salinity drops as low as 9ppt at Picton Point at certain stages of the tidal cycles. There is considerable variation in salinity across the high/low tidal cycle in the upper reaches, with salinity at its lowest around low water. Greater variation was reported on spring tides, but lowest salinities arose during neap tides. Elevated river flows would result in lowered salinity in the upper reaches, and some slight salinity reductions in the middle reaches. Lower salinity waters will tend to carry higher levels of contamination, so this salinity gradient is likely to translate to a similar underlying gradient in *E. coli* levels as was observed in the shoreline survey (Appendix XV).

Vertical salinity profiles were taken during the shoreline survey in the outer estuary up as far as Burton Ferry and showed very little in the way of stratification. The flow ratio (freshwater input: tidal exchange) is low and the system is well mixed (Futurecoast, 2002) so density driven currents are unlikely to be of significance in the outer and middle reaches at least. Although some stratification and vertical difference in flows occurs in the upper reaches upstream of Mill Bay (Nelson-Smith, 1965) tidally driven circulation processes are likely to dominate over density effects. One density effect of potential importance to the assessment is the tendency for sewage effluent, which will be of lower salinity and at times warmer than the receiving water, to float to the surface and away from benthic shellfish.

Strong winds will modify surface currents. Winds typically drive surface water 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}. The mouth of the estuary is exposed to the prevailing winds from the southwest, the outer and middle reaches are orientated on the east-west plane and so are most exposed to winds from these directions, and the upper estuary has a north-south orientation. Winds from the prevailing south westerly direction would tend to be funnelled up the estuary to some extent by the local topography, so this would tend to push surface water up the estuary. The surface currents would create return currents either at depth of in sheltered margins. Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great range of scenarios may arise. The shape of the buoyant plumes from the larger sewage discharges such as Pembroke Dock may for example be significantly altered by wind effects thereby making the spatial profile of their impacts less predictable. As well as driving surface currents, strong winds will create wave action which may resuspend any contamination held within the sediments of the intertidal zone, temporarily increasing levels of contamination within the water column until it is carried away by the tides. The majority of the estuary is sheltered from the prevailing swell, which is only carried up the estuary as far as Gelliswick Bay. The razor bed at Dale is located within a sheltered embayment so would not be directly exposed to these swells.

APPENDIX VI
METEOROLOGICAL DATA: WIND

Wales is one of the windier parts of the UK, particularly its west facing coasts (Met Office, 2012). The strongest winds are associated with the passage of deep areas of low pressure close to or across the UK. The frequency and strength of these depressions is greatest in the winter half of the year, especially from November to February, and this is when mean speeds and gusts are strongest (Met Office, 2012).

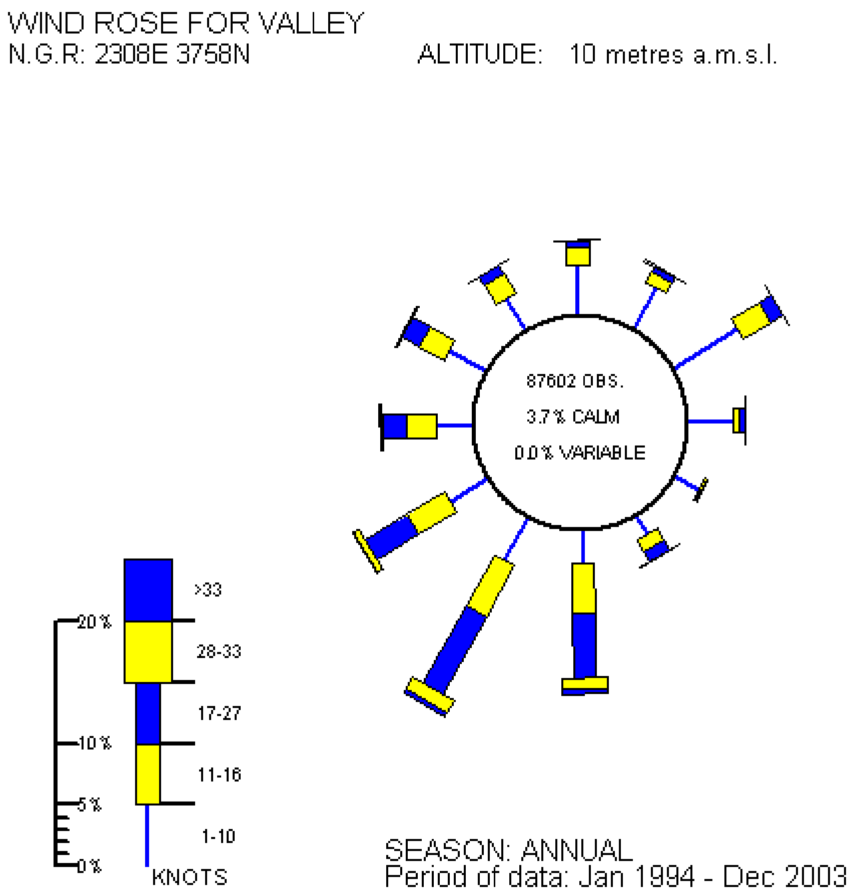


Figure VI.1 Wind rose for Valley.
Produced by the Meteorological Office. Contains public sector information licensed under the Open Government Licence v1.0

The wind rose for Valley (Anglesey) is typical of coastal locations in Wales. The prevailing wind direction is from the south west and the strongest winds usually blow from this direction. A higher frequency of north easterly winds occurs during spring. Coastal Pembrokeshire has the highest frequency of gales in Wales, recording approximately 30 days of gales a year. The outer reaches up to Gelliswick Bay are most exposed to south westerly winds from the open Atlantic blowing into the mouth of the estuary, and the rest of the estuary is relatively sheltered from winds due to its orientation and the surrounding topography. The surrounding topography will tend to funnel winds up or down the estuary, so the directional profile of winds within Milford Haven is likely to be somewhat skewed towards the east west plane in the middle reaches and the north south plane in the upper reaches.

APPENDIX VII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: SEWAGE DISCHARGES

Details of all consented discharges were taken from the Environment Agency's national discharge database (January 2012). There are a total of 45 water company owned sewage treatment works within the Milford Haven catchment (Figure VII.1 and Table VII.1).

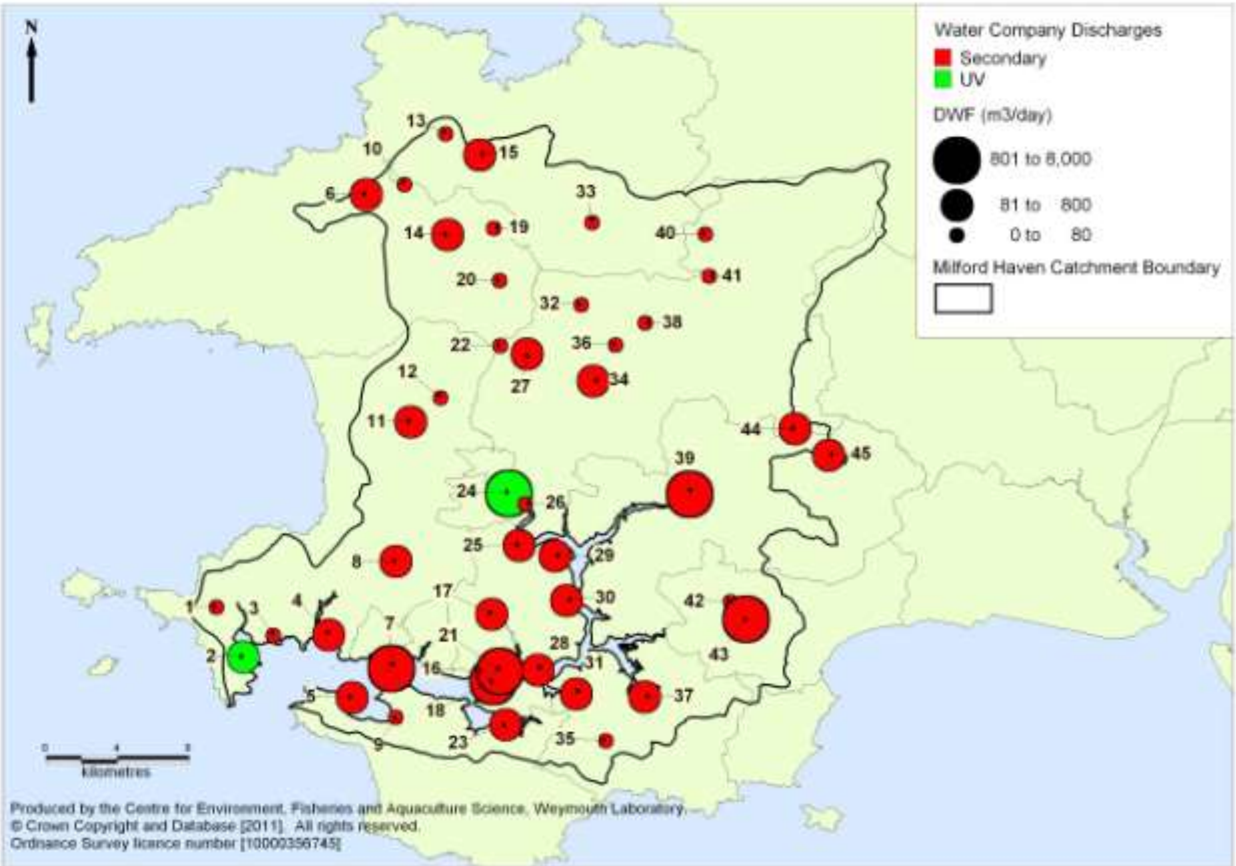


Figure VII.1. Locations and size of major continuous water company sewage discharges

Bacteriological testing results of final effluents from Merlin's Bridge and Dale STWs, both of which receive UV treatment, are presented in Table VII.2 and Figure VII.2. No bacteriological testing data was available for the discharges receiving secondary treatment so estimated of bacterial loadings were calculated using the reference values for bacterial concentrations shown in Table VII.3. These estimates give some indication of the relative importance of the various works, but should be treated with caution as they are not based on measured discharge volumes or indicator bacteria concentrations.

Table VII.1 Details of major continuous water company sewage discharges to the area

ID	Name	Location	DWF (m^3/day)	Treatment Level	Estimated bacterial loading (faecal coliforms/day)	Receiving Water
1	Marloes STW	SM7997008360	56	Secondary	1.85×10^{11}	Unnamed watercourse
2	Dale WWTW	SM8147005560	180	Tertiary (UV)	4.17×10^{8}	Milford Haven
3	St. Ishmaels STW	SM8314006770	79.4	Secondary	2.62×10^{11}	Monk Haven Stream
4	Herbrandston WWTW	SM8624006800	122	Secondary	4.03×10^{11}	Milford Haven
5	Angle WWTW	SM8755503310	194	Secondary	6.40×10^{11}	Angle Bay
6	Mathry STW	SM8833931395	151	Secondary	4.98×10^{11}	Western Cleddau
7	Milford Haven STW	SM8976004980	3850	Secondary	1.27×10^{13}	Milford Haven
8	Tiers Cross WWTW	SM8999910909	90	Secondary	2.97×10^{11}	Tributary of Sandy Haven Pill
9	Rhoscrowther STW	SM9000002200	19.1	Secondary	6.30×10^{10}	Unnamed watercourse
10	Castlemorris WWTW	SM9048831957	16.8	Secondary	5.54×10^{10}	Western Cleddau
11	Keeston Works inlet	SM9082018690	129.2	Secondary	4.26×10^{11}	Tributary of Knock Brook
12	Camrose STW	SM9250020040	32	Secondary	1.06×10^{11}	Camrose Brook
13	Panteg STW	SM9280034800	15.3	Secondary	5.05×10^{10}	Tributary of Cleddau
14	Letterston West STW	SM9290029150	361.1	Secondary	1.19×10^{12}	Tributary of Western Cleddau
15	Scleddau STW	SM9470033600	93.7	Secondary	3.09×10^{11}	Western Cleddau
16	Waterston STW	SM9485004750	44	Secondary	1.45×10^{11}	Milford Haven
17	Rosemarket STW	SM9535007950	124	Secondary	4.09×10^{11}	Tributary of Westfield Pill
18	Pembroke Dock STW	SM9545004250	7670.3	Secondary	2.53×10^{13}	Milford Haven
19	Letterston East WWTW	SM9549029520	40	Secondary	1.32×10^{11}	Tributary of Afon Anghof
20	Wolfscastle STW	SM9580026600	77.3	Secondary	2.55×10^{11}	Afon Anghof
21	Neyland WWTW	SM9583204826	1274	Secondary	4.20×10^{12}	Milford Haven
22	Treffgarne STW	SM9585022950	50	Secondary	1.65×10^{11}	Western Cleddau
23	Hundleton WWTW	SM9615201782	105.3	Secondary	3.47×10^{11}	Pembroke River
24	Merlin’s Bridge STW	SM9633014740	7221	Tertiary (UV)	6.62×10^{10}	Western Cleddau
25	Johnston STW	SM9690011800	314.8	Secondary	1.04×10^{12}	Western Cleddau
26	Uzmaston WWTW	SM9723714126	14	Secondary	4.62×10^{10}	Tributary of Western Cleddau
27	Spittal WWTW	SM9734822501	81.4	Secondary	2.69×10^{11}	Tributary of Rudbaxton Water
28	Burton Ferry WWTW	SM9794704840	82	Secondary	2.71×10^{11}	Milford Haven
29	Hook STW	SM9890011200	218	Secondary	7.19×10^{11}	Sprinkle Pill
30	Llangwm STW	SM9955008730	289.6	Secondary	9.56×10^{11}	Milford Haven
31	Cosheston STW	SN0010003500	129.8	Secondary	4.28×10^{11}	Cosheston Pill
32	Ambleston STW	SN0037025240	30.5	Secondary	1.01×10^{11}	Spittal Brook

ID	Name	Location	DWF (m^3/day)	Treatment Level	Estimated bacterial loading (faecal coliforms/day)*	Receiving Water
33	Puncheston STW	SN0098029830	36.4	Secondary	$1.20x10^{11}$	Tributary of Afon Anghof
34	Clarbeston STW	SN0105020970	84	Secondary	$2.77x10^{11}$	Cartlett Brook
35	Lamphey WWTW	SN0175800900	78	Secondary	$2.57x10^{11}$	Pembroke River
36	Walton East STW	SN0230023000	16.4	Secondary	$5.41x10^{10}$	Tributary of River Syfynwy
37	Carew/Milton WWTW	SN0392003349	245	Secondary	$8.09x10^{11}$	Radford Pill
38	Llys y Fran WWTW	SN0396324241	9.9	Secondary	$3.27x10^{10}$	Tributary of River Syfynwy
39	Narberth West STW	SN0644014710	1100.8	Secondary	$3.63x10^{12}$	Eastern Cleddau
40	Rosebush STW	SN0732029190	50	Secondary	$1.65x10^{11}$	Land
41	Maenclochog STW	SN0753026850	59.1	Secondary	$1.95x10^{11}$	River Rhydyfallen
42	Reynalton WWTW	SN0873008653	11.2	Secondary	$3.70x10^{10}$	Lovestone Lake
43	Langdon WWTW	SN0959807726	848	Secondary	$2.80x10^{12}$	River Cresswell
44	Clynderwen STW	SN1233018310	182.8	Secondary	$6.03x10^{11}$	Pont Shan Brook
45	Llanddewi Velfrey STW	SN1421016830	92	Secondary	$3.04x10^{11}$	Tributary of Pont Shan Brook

*Based on geometric mean concentration of faecal coliforms in effluents in 2011 (Table VII.2) for UV treated discharges. For secondary discharges based on geometric mean result of base flow averages from a range of UK STWs (Table VII.3). These estimates are intended for comparative purposes only, and bacterial loadings generated by each STW are likely to fluctuate significantly.

Table VII.2 Summary of final effluent testing results, 2011.

Name	No.	Geometric mean	Min.	Max.
	Faecal coliforms results (cfu/100ml)			
Dale STW	26	232	<100	11000
Merlin's Bridge STW	26	916	<100	410000

Data from the Environment Agency

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

Treatment Level	Flow			
	Base-flow		High-flow	
	n	Geometric mean	n	Geometric mean
Storm sewage overflows (53)			200	$2.5x10^6$
Primary (12)	127	$1.0x10^7$	14	$4.6x10^6$
Secondary (67)	864	$3.3x10^5$	184	$5.0x10^5$
Tertiary (UV) (8)	108	$2.8x10^2$	6	$3.6x10^2$

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

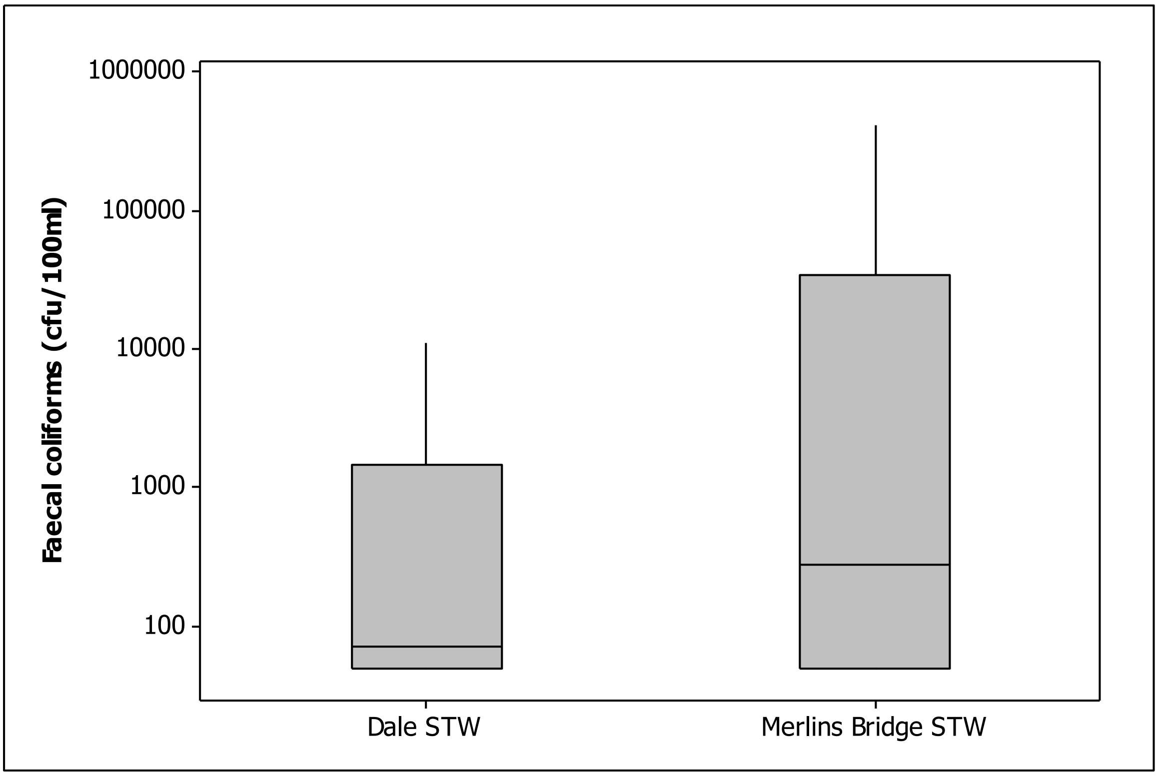


Figure VII.2. Boxplot of final effluent faecal coliforms results from UV treated discharges, 2011

Merlin's Bridge, Uzmaston and Johnston STWs discharge to the tidal West Cleddau with an estimated combined loading of $1.1x10^{12}$ faecal coliforms/day, mostly originating from Johnston STW. Merlin's Bridge STW, although large in terms of volumes employs UV disinfection prior to discharge so the bacterial loadings from here are of reduced impact on levels of *E. coli* within the shellfish beds, although some periods of decreased effluent quality are apparent. Narberth West STW ($3.6x10^{12}$ faecal coliforms/day) discharges near the tidal limit of the Eastern Cleddau. A further 20 small sewage works serve the inland areas of the East and West Cleddau catchments which generate a combined estimated bacterial loading of $5.4x10^{12}$ faecal coliforms/day, although some bacterial die-off during transit to the estuary is likely to occur. It is therefore concluded that there are significant sewage inputs entering up-estuary from all the shellfish beds.

There are three small sewage works discharging to the main estuary channel from Picton Point through to the Cleddau Bridge (Hook, Llangwm and Burton Ferry STWs) all of which generate bacterial loadings which may be of local significance (estimated at $7.2x10^{11}$, $9.6x10^{11}$ and $2.7x10^{11}$ faecal coliforms/day respectively). The Carew/Cresswell side arm and its tributaries receive effluent from the Langdon, Reynalton and Carew/Milton STWs ($2.8x10^{12}$, $3.7x10^{10}$ and $8.1x10^{11}$ faecal coliforms/day respectively), all of which discharge upstream of the mussel beds here.

The three largest continuous discharges in terms of the estimated bacterial loading they generate are Pembroke Dock STW ($2.5x10^{13}$ faecal coliforms/day), Milford Haven STW ($1.3x10^{13}$ faecal coliforms/day) and Neyland WWTW ($4.2x10^{12}$ faecal coliforms/day). Pembroke Dock and Neyland outfalls are located within 700m of each other between 1.5 and 2km downstream of the Cleddau Bridge, so significant deteriorations in water quality are anticipated in this area, from which shellfish harvesting was prohibited until recently on hygiene grounds. The Milford Haven STW will also create a significant hotspot of contamination just off Milford Haven Town. There are also two minor sewage works (Waterston and Rosemarket STWs) which will be of little significance relative to the main three.

The Coheston Pill and Pembroke River side channels both receive effluent from small sewage works in their upper reaches (Coheston and Hundleston STWs, $4.3x10^{11}$ and $3.5x10^{11}$ faecal coliforms/day). Other small continuous sewage discharges in the outer estuary which may impact on nearby shellfish beds are Angle WWTW in the mouth of Angle Bay ($6.4x10^{11}$ faecal coliforms/day), Herbrandston WWTW at Sandy Haven ($4.03x10^{11}$ faecal coliforms/day), and Dale and Marloes STWs at Dale Bay ($4.17x10^{8}$ and $1.85x10^{11}$ faecal coliforms/day). Dale STW receives UV treatment so the estimated bacterial loading it generates is very small, and final effluent testing data suggests the treatment is consistently effective.

It must be noted that UV disinfection is less effective at removing viruses than bacteria, and the majority of reported bivalve related illness outbreaks in the UK are associated with norovirus (e.g. Lees, 2000). The discharger must demonstrate a minimum 180,000-fold (5.25 log) reduction in faecal coliforms between the crude influent to the treatment works and in or at the edge of the shellfish water after initial dilution, based on standard influent concentrations. They can achieve this reduction by combining conventional treatment, disinfection and dilution/or dispersion[1] (Environment Agency, 2011). Should the UV plants fail, the *E. coli* loading discharged by these works (Merlin's Bridge and Dale STWs) may increase by about 3 orders of magnitude.

[1] EA Policy requires there design requirement of a minimum of a 10-fold (1 log) reduction in enteroviruses through the disinfection process itself. Use of F+ bacteriophage as a surrogate is required in this respect. On a case by case basis the EA may waive the above minimum pathogen reduction requirement for disinfection post-secondary treatment where the pre-treatment process can be demonstrated to have a particularly high removal rate for F+ bacteriophages (Environment Agency, 2011)

In addition to the continuous sewage discharges, there are a large number of intermittent water company discharges within the area associated with the various sewerage networks. Figure VII.2 shows the locations of these as well as private discharges directly to or within close proximity to the estuary. There are many more intermittent and private discharges distributed within the catchment (inland) that are not shown on the map.

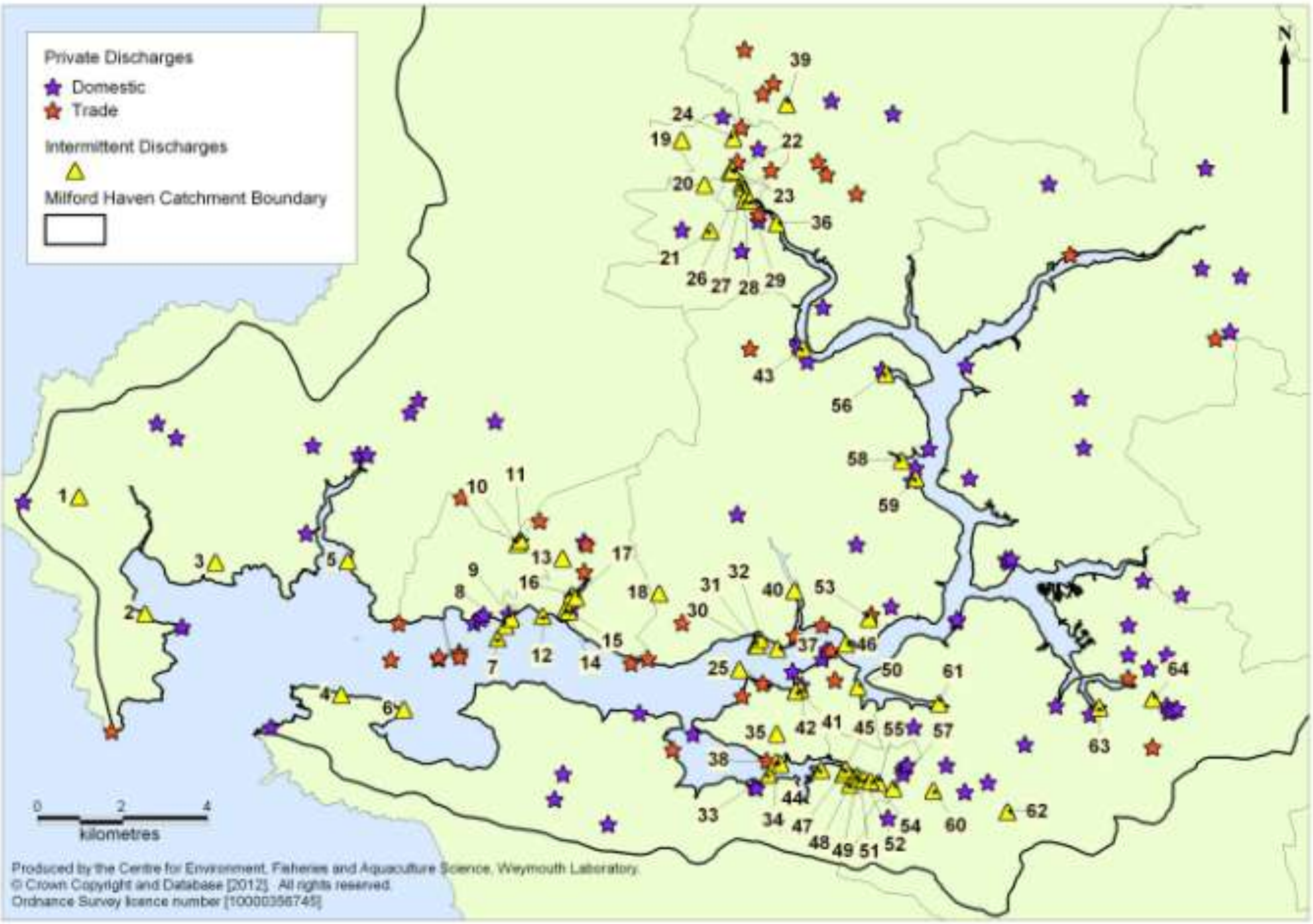


Figure VII.2. Locations of intermittent and private discharges within the area.

Table VII.3 Details of intermittent discharges to Milford Haven Estuary

ID	Name	Location	Type
1	Marloes Works Inlet	SM7991008310	Storm
2	Dale WWTW	SM8147005560	Storm & Emergency
3	St Ishmaels Works Inlet	SM8312006770	Storm
4	Angle Village PS	SM8608003650	Storm & Emergency
5	Herbrandston WWTW	SM8624006800	Storm & Emergency
6	Angle WWTW	SM8755503310	Storm & Emergency
7	Milford Haven STW	SM8976004980	Storm
8	Milford Haven Storm Overflow	SM8995005280	Storm
9	Milford Haven SWO	SM9008005450	Storm
10	Priory	SM9023107196	Storm & Emergency
11	Lower Priory PS	SM9030007300	Storm
12	Milford Haven Rath SWO	SM9082605501	Storm & Emergency
13	Steynton SPS	SM9129306858	Storm
14	A CSO at Beach Hill	SM9136405650	Storm
15	A CSO at Beach Hill	SM9143305615	Storm
16	Castle Pill SWO	SM9150606004	Storm & Emergency
17	PS Ex RNAD Site Newton Noyes	SM9161005940	Storm
18	Waterston Works Inlet	SM9356006040	Storm & Emergency
19	Slade PS	SM9410016700	Storm
20	CSO No. 10 (Hawthorn Rise)	SM9463415653	Storm
21	Merlin's Bridge SWO	SM9477014570	Storm
22	Northgate/Fred Rees CSO	SM9523015940	Storm
23	CSO No. 6	SM9529015994	Storm
24	Crowhill	SM9531016750	Storm & Emergency
25	Pembroke Dock STW	SM9545004250	Storm
26	Castle Bank	SM9551015670	Storm
27	New Quay CSO	SM9553015570	Storm & Emergency
28	Picton PS & Picton Fields CSO	SM9557015290	Storm
29	CSO 7 Union Hill	SM9568715273	Storm & Emergency
30	Neyland WWTW	SM9583204826	Storm & Emergency
31	Neyland PS	SM9587004810	Storm
32	Promenade Neyland SWO	SM9594004960	Storm
33	Hundleton WWTW Inlet	SM9615201782	Storm & Emergency
34	Fleet Street	SM9632002080	Storm
35	School Garden PS	SM9632902741	Storm & Emergency
36	Merlin's Bridge STW	SM9633014740	Storm & Emergency
37	Neyland Promenade CSO	SM9635004740	Storm
38	Lower Pennar	SM9642002030	Storm
39	Crundale SPS	SM9656517548	Storm & Emergency
40	PS at Wood Lane Housing Development	SM9675006100	Storm & Emergency
41	Meyrick Street SWO	SM9677003730	Storm
42	Water Street SWO	SM9688003780	Storm
43	Johnston STW SSO	SM9695011800	Storm
44	Catshole Quarry PS	SM9738001890	Storm & Emergency
45	Pembroke River PS (Emergency)	SM9790001800	Storm & Emergency
46	Burton Ferry WWTW	SM9794704840	Storm & Emergency
47	Pembroke River PS (Catshole Quarry)	SM9795001900	Storm & Emergency
48	Monkton Bridge SWO	SM9805001540	Storm
49	CSO At 3/4 St Nicholas Crescent	SM9822001750	Storm
50	Waterloo PS	SM9824003840	Storm & Emergency
51	Mill Bridge CSO	SM9827001680	Storm
52	Woodbine Terrace SWO	SM9838001670	Storm
53	Church Road SPS	SM9850005450	Storm & Emergency
54	Golden Hill	SM9854001620	Storm
55	CSO Woodbine Close	SM9872001590	Storm
56	Hook STW	SM9890011200	Storm & Emergency
57	Holyland Road CSO	SM9907001450	Storm

ID	Name	Location	Type
58	Emergency Discharge from Llangwm WWTW	SM9927009170	Storm & Emergency
59	Llangwm WWTW	SM9960808745	Storm & Emergency
60	Lords Meadow Farm PS	SN0001001400	Storm & Emergency
61	Cosheston STW	SN0015003450	Storm & Emergency
62	Lamphey WWTW	SN0175800900	Storm & Emergency
63	Carew/Milton WWTWs	SN0392003349	Storm & Emergency
64	Carew WWTW	SN0517703548	Storm & Emergency

Discharges highlighted in yellow have estimated spill data presented in Table VII.4

Modelled estimates of spill volumes and frequencies are presented for a number of intermittent discharges in Table VII.4.

Table VII.4 Modelled spill data for intermittent discharges (METOC, 2008).

Discharge Name (catchment name in bold)	AMP4 Modelled Annual Spill Volume (m^3)	AMP4 Estimated No. Spills per year	AMP4 Modelled Spill Duration (hours)
MILFORD HAVEN			
Milford Haven SWO	50443	29.9	120
Lower Priory PS	119	2.4	1.3
Milford Haven Rath SWO	27500	29.9	137.7
Steynton SPS	2480	20.7	40.7
A CSO at Beach Hill	8021	29	61.7
Castle Pill SWO	10230	29	54.3
Catchment Total	**98793**		
HAVERFORDWEST			
CSO No. 10 (Hawthorn Rise)	329	8.1	3.1
Castle Bank	2619	20.7	18.2
Northgate/Fred Rees CSO	5475	28.2	60.3
New Quay CSO	4529	14	9.5
CSO 7 Union Hill	3434	29.2	59.6
Picton PS/Picton Fields CSO	83657	29.6	121.7
Catchment Total	**100043**		
PEMBROKE DOCK			
Pembroke Dock STW	11898	19	68.2
Fleet Street	188	11.1	6.8
Lower Pennar	213	10.5	9.8
School Garden PS	3325	29.5	97
Meyrick St SWO	1559	17.6	14.8
Mill Bridge CSO	31	0.7	0.7
Woodbine Terrace SWO	864	22.9	24.7
CSO Woodbine Close	29	2.2	1
Catchment Total	**18107**		
NEYLAND			
Neyland Promenade CSO	1497	19.9	18.1
Promenade Neyland SWO	4253	27.6	54.7
Catchment Total	**5750**		
BURTON FERRY			
Burton Ferry WWTW	135	15.2	8.5
Catchment Total	**135**		
HOOK			
Hook STW (CSO2)	1244	29.5	121.1
Hook STW (CSO1)	8122	29.5	230.3
Catchment Total	**9366**		
LLANGWM			
Llangwm WWTW	848	20.7	31.5
Catchment Total	**848**		

The spill information presented in Table VII.4 is modelled rather than recorded information and was produced to investigate where further improvements might be required under the AMP4 and AMP5 programmes (METOC, 2008). These spill events will generally be associated with wet weather and emergency discharges which may occur due to equipment malfunction have not been taken into consideration here. Also, some sewerage catchments which may be of potential significance to the various shellfisheries such as Dale and Angle were not included in this study.

Highest spills volumes are likely to occur within the Haverfordwest and the Milford Haven sewage catchments. At Haverfordwest, the majority of spills by volume arise from the Picton PS/Picton Fields CSO. Although only active for 121.7 hours per year (1.4% of the time) it spills at an estimated rate of 687m^3/hour. Using reference values from Table VI.2, this outfall, when active, would generate a bacterial loading of about 16 times that generated by the Pembroke Dock STW. Although such estimates should be treated with great caution as they are derived from models and reference values it is appropriate to conclude that spills from this network will add greatly to bacterial loadings entering the upper reaches of the tidal Western Cleddau.

Within the Milford Haven network, most of the spilled volume arises from the Milford Haven SWO and Milford Haven Rath SWO. Again, these outfalls are only active for a small fraction of the time, but when active will greatly increase the bacterial loading discharged from this network (estimated around 20fold). Significant volumes of storm water are also spilled from the Pembroke Dock sewerage catchment, mainly via the main STW outfall, and when active the bacterial loading from this network may increase by about 4fold. Lesser but nonetheless possibly significant spills are likely to arise from intermittent outfalls within the Hook and Neyland STW catchments from time to time. Spills from the Llangwm and Burton Ferry catchments were smaller in volume and so are likely to be of more localised impact.

Although the majority of properties in the Milford Haven catchment are connected to mains sewers, there are a significant number of small private discharges to the area, some of which discharge to soakaway and others to watercourses. Of the 102 private discharges within the catchment which contain sewage (i.e. excluding discharges such as cooling water or surface water), the majority (60) discharge to freshwater watercourses, with 34 discharging to land/soakaway, 5 direct to the estuary and 3 to enclosed waterbodies (ponds/lakes). Most serve one or a small number of properties so the bacterial loadings generated will generally be very minor in relation to those from water company discharges. An exception is a private discharge serving a large holiday camp (Bluestone Project) which has a maximum consented flow of 410m^3/day and discharges to the Penglyn Brook, a tributary of the Eastern Cleddau.

In summary, the large secondary treated water company discharges are responsible for the majority of the sewage related *E. coli* loading which the estuary receives under normal conditions. Of particular importance are Milford Haven STW and Pembroke Dock STW which are both located mid estuary within close proximity to shellfish beds and have the highest discharge flows. There are also significant volumes of sewage discharges to the estuary and surrounding catchment upstream of Picton Point. Other continuous discharges will contribute to a combined bacterial loading that may have a significant impact more locally, including those discharging to the various side arms and embayments such as the Carew/Cresswell and Pembroke River. There are many intermittent discharges which have the potential to cause sporadic decreases in water quality. The main spillers identified by a modelling study were the Picton PS/Picton Fields CSO at Haverfordwest, the Milford Haven SWO and Milford Haven Rath SWO at Milford Haven, and to a lesser extent the main Pembroke Dock STW outfall. Although only active for a very small proportion of the time, when active tentative estimates suggest these may potentially generate bacterial loadings far in excess of that generated by their respective sewage treatment works under normal operating conditions. There are significant numbers of small private discharges within the catchment, but their cumulative effects are likely to be very minor in relation to the water company discharges.

APPENDIX VIII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: AGRICULTURE

Figure VIII.1 presents thematic maps of livestock densities for river subcatchment areas draining to Milford Haven. This data was provided by Welsh Government and is based on 2010 census data. Geographic assignment of animal counts in this dataset is based on the allocation of a single point to each farm, whereas in reality an individual farm may span two or more of the subcatchment areas. Nevertheless, Figure VII.1 should give a broad overview of the distributions of livestock within the catchment, and Table VII.1 presents summary statistics by subcatchment.

Table VIII.1 Summary statistics from 2010 livestock census by subcatchment

	Numbers				Density (animals/km^2)			
Catchment name	Sheep	Cattle	Pigs	Poultry	Sheep	Cattle	Pigs	Poultry
Milford Haven Sth,Sth Pembroke	31,076	35,090	264	8,487	90.9	102.6	0.8	24.8
Milford Nth, St Brides Nth	15,495	9,808	30	120,926	45.3	28.7	0.1	353.6
Western Cleddau	39,008	44,185	339	14,786	114.1	129.2	1.0	43.2
Eastern Cleddau	40,561	27,976	138	10,497	118.6	81.8	0.4	30.7
Total	126,140	117,059	771	154,696	126	117	1	155

The agricultural land is almost all pasture (Figure 1.2) with some small isolated pockets used for arable farming. There are substantial populations of grazing animals throughout most of the area, although they are present at notably lower densities in the Milford Haven North subcatchment. Significant diffuse inputs associated with grazing livestock are therefore anticipated. Well over half of these are within the East and West Cleddau subcatchments, so highest impacts are anticipated towards the head of the estuary on this basis, although all major watercourses are likely to be subject to some livestock related contamination. There are also some poultry rearing operations, mainly in the Milford North subcatchment as well as very small numbers of pigs throughout the four subcatchments. 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).

Manure/slurry from pig and poultry operations is typically spread periodically on nearby farm land (Defra, 2009), whilst grazing animals deposit directly on pastures. Information provided by the Environment Agency showed no records of sewage sludge applications to farmland in the Cleddau catchment from 2009 to 2012. The primary mechanism for mobilisation of faecal matter deposited on agricultural land into watercourses is via land runoff, so fluxes of livestock related contamination into the estuary will be highly rainfall dependent. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the 'first flush'). Runoff from the majority of the catchment area enters the estuary upstream of the fishery, so higher impacts may be anticipated towards the up-estuary ends of the shellfish beds on this basis.

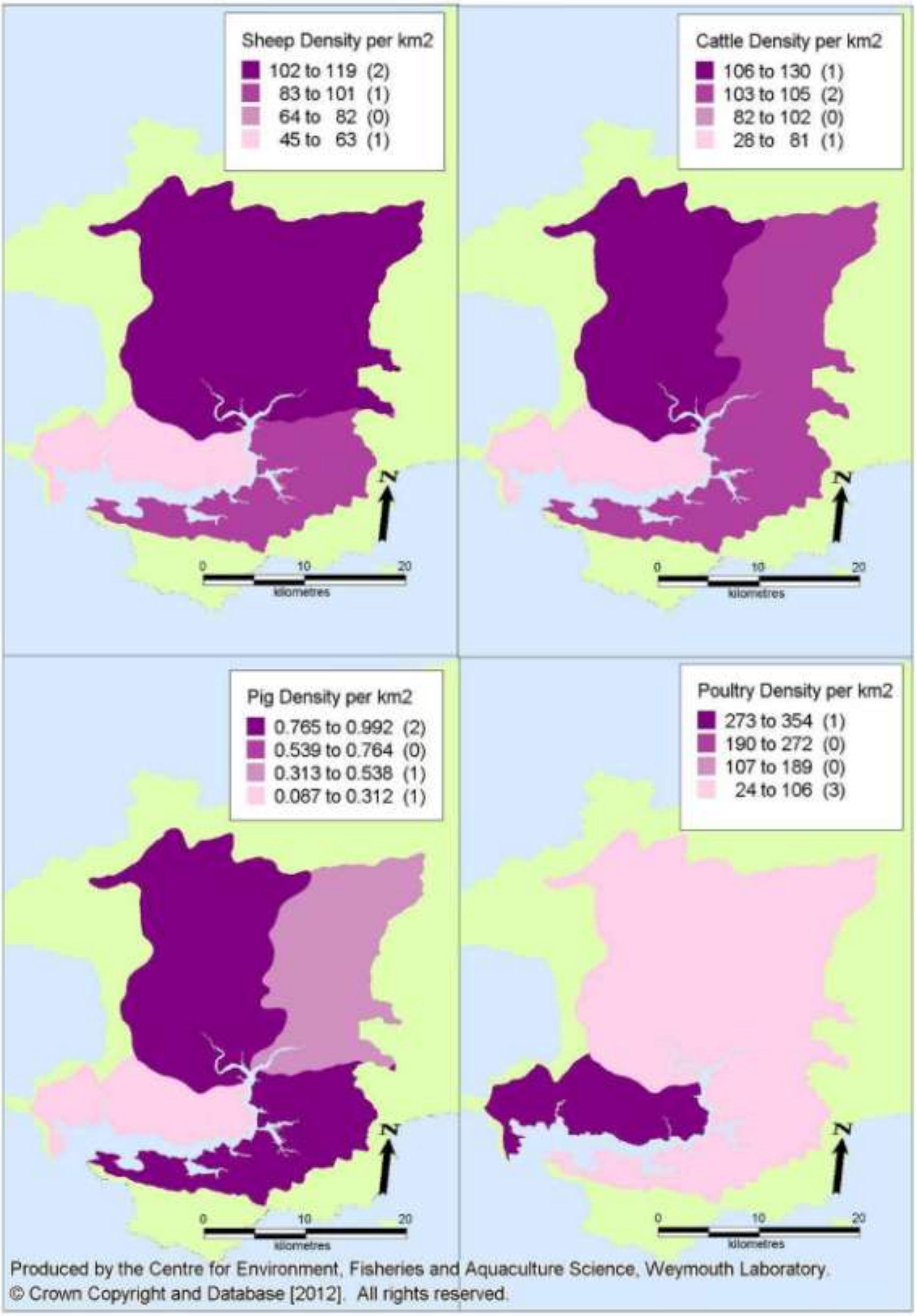


Figure VIII.1 Estimated densities of livestock by subcatchment
(Data provided by Welsh Government)

There is likely to be seasonality in levels of contamination originating from livestock. Numbers of sheep and cattle will increase significantly in the spring, with the birth of lambs and calves, and decrease in the autumn when animals are sent to market. During winter cattle may be transferred from pastures to indoor sheds, and at these times slurry will be collected and stored for later application to fields. Timing of these applications is uncertain, although farms without large storage capacities are likely to spread during the winter and spring. Applications of manure from pig and poultry operations may take place at any time of the year. No detailed geographical or temporal information was available on the spreading of manures within the area. Therefore peak levels of contamination from sheep and cattle may arise following high rainfall events in the summer, particularly if these have been preceded by a dry period which would allow a build up of faecal material on pastures. Contamination events may occur on a more localised basis if wet weather follows a manure/slurry application which is perhaps more likely in winter or spring.

APPENDIX IX
SOURCES AND VARIATION AND MICROBIOLOGICAL POLLUTION: BOATS

Milford Haven is a major deepwater port mainly serving the hydrocarbon industry, but also handling smaller volumes of other cargoes, and a twice daily Ireland ferry. It is also extensively used by recreational craft, ranging from kayaks to large yachts and cabin cruisers, as well as a few commercial fishing vessels. As the discharge of sewage to the sea by merchant shipping is not permitted within 3 nautical miles of land[2] no impacts on the shellfish bed from sewage discharged by commercial shipping traffic are anticipated.

Smaller vessels such as yachts, pleasure craft and fishing vessels are not covered by the specific sewage disposal regulations for commercial shipping, and so are likely to be responsible for any overboard discharges, although this practice is discouraged. Figure IX.1 shows the locations of moorings and marinas used by such vessels.

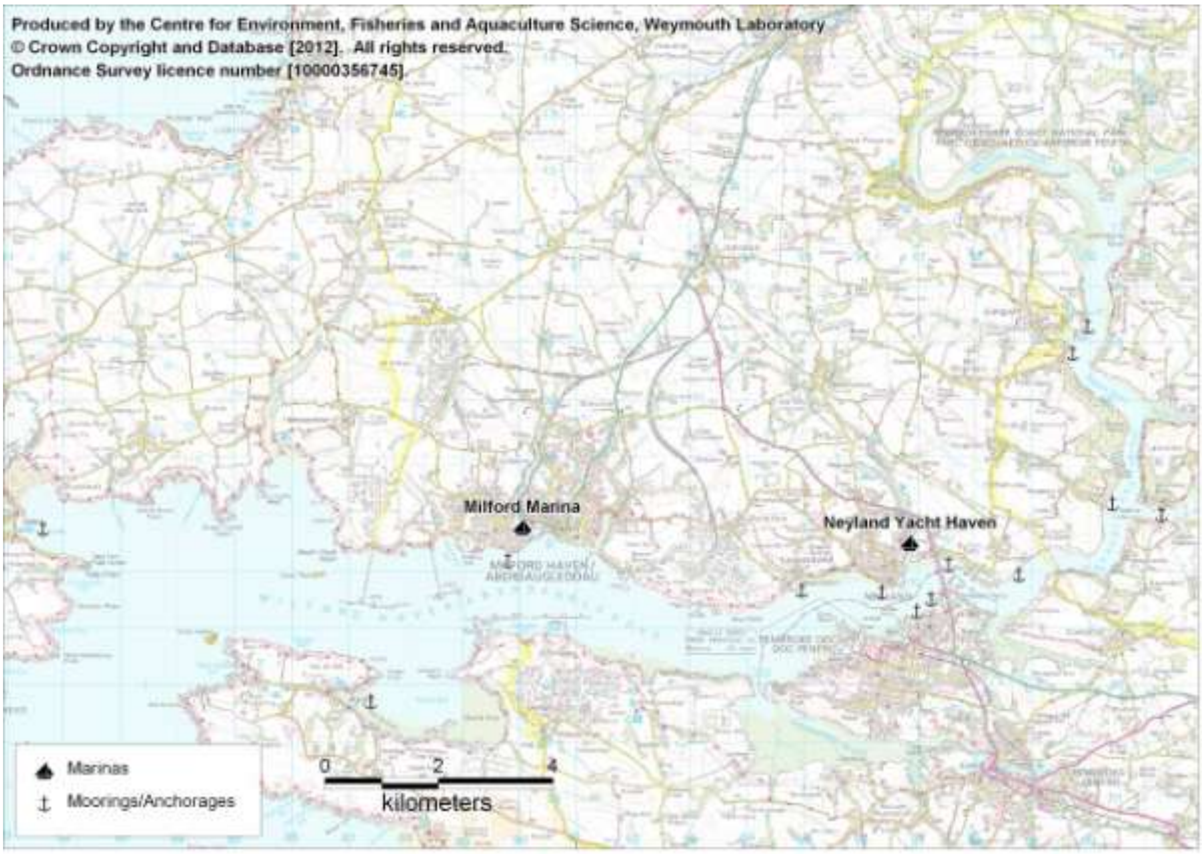


Figure IX.1 Locations of marinas, moorings and anchorages.

There are marinas at Neyland (420 berths) and at Milford town (328 berths), both of which provide a range of services but do not have sewage pumpout facilities. There are several hundred moorings throughout Milford Haven, the main areas of which

[2] The Merchant Shipping (Prevention of Pollution by Sewage and Garbage from Ships) Regulations 2008.

are at Dale, the Milford Shelf, at several areas around Neyland, Pembroke Dock and the Cleddau Bridge, at Lawrenny Yacht station and at Black Tar Point. The boats most likely to make overboard discharges are probably yachts or cabin cruisers in overnight occupation on moorings, and it is also quite likely that the crew of transiting private vessels use their onboard facilities in the relative calm of the estuary. Shellfish beds in the vicinity of these moorings are therefore probably at the highest risk of impacts from overboard discharges at times when there are boats present in overnight occupation. It is also possible that boats may tend to discharge their tanks shortly after leaving the marinas so navigation lanes to and from these marinas may also be at increased risk. The two marinas may also be subject to inputs from overboard discharges, although such discharges are though less likely within the marina setting as onshore facilities are easily accessible and overboard discharges are somewhat antisocial in a confined and crowded marina. The Good Practice Guide indicates that areas within active marinas should not be classified for the harvest of bivalves (EU Working Group on the Microbiological Monitoring of Bivalve Harvest Areas, 2010).

On this basis, stocks in the vicinity of Dale, Milford Shelf, Neyland, the Cleddau Bridge, Lawrenny and Coedcanlas may be most affected. As the moorings are spread over wide areas they may be considered more as a diffuse rather than a point source of contamination. There is considerable uncertainty about the extent to which these discharges occur and whether they will impact significantly on shellfish hygiene. Volumes of small boat traffic will peak during the summer, as will levels of overnight occupancy, so any impacts would be greatest at these times.

Although it is beyond the formal scope of this report to consider chemical contamination of shellfish, small operational spills associated with the hydrocarbon industry are likely to occur from time to time. As a consequence, contamination of shellfish from such incidences is a potential public health issue which the competent authority (the FSA) may wish to consider further for this area. One suspected spill or release of detergent was seen during the shoreline survey under the oil terminal jetties on the south shore just to the east of Angle Bay.

APPENDIX X
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: WILDLIFE

Studies in the UK have found significant concentrations of microbiological contaminants (thermopile campylobacter's, salmonellae, faecal coliforms and faecal streptococci) from intertidal sediment samples supporting large communities of birds (Obiri-Danso and Jones, 2000). The estuary contains large a diversity of habitats including intertidal mud/sandflats and saltmarsh, and attracts large numbers of overwintering waterbirds (wildfowl and waders). An average total count of 23,422 waterbirds was reported over the five winters up to 2009/10 throughout the entire Cleddau estuary (Holt *et al*, 2011). Many of these are likely to forage on intertidal areas where the cockle and mussel fisheries are present. Those foraging on the intertidal areas may tend to favour areas closer to the shore, as has been reported at cockle beds on the north Wirral (Cefas, 2010). Therefore, impacts from these waterbirds are likely to peak in the winter, and impact on the shellfisheries via direct deposition on the intertidal or via runoff or tidal inundation of areas of saltmarsh. Whilst direct deposition from birds may be considered as a diffuse input, it is possible that impacts may be greater on the more inshore areas although there are no direct observations to support this within the survey area. Contamination via direct deposition may be quite patchy, with some shellfish containing quite high levels of *E. coli* with others a short distance away unaffected.

Of these birds, some species may remain in the area to breed in the summer, but the majority are likely to migrate elsewhere to breed. The seabird 2000 survey carried out counts of breeding seabirds (gulls, cormorants etc) during the early summer of 2000 (Mitchell *at al*, 2004). Some breeding seabirds were recorded within the outer estuary (344 pairs of gulls and 32 pairs of cormorants) mainly on the rocky islands in the outer areas (Thorn Island, Stack Rock and Sheep Island). Numbers are small relative to the bird population reported to be present during the winter months. Again, any impacts will be either via direct deposition which will be widely distributed, or via runoff from their nesting and resting sites.

There are about 5000 grey seals in west Wales, the majority of which are found on the Pembrokeshire coast. There are no seal colonies within Milford Haven, but the closest is at Skomer Island colonies on the Pembrokeshire Coast, and whilst some of these are in close proximity to Milford Haven, none are actually within it (SMRU, 2010). The closest colony is at Skomer Island, about 10km from the mouth of Milford Haven. They are present year round, and in 2010, a peak count of 354 seals was recorded here (Boyle, 2010). They forage over a wide area and have been recorded in Milford Haven upstream of the Cleddau Bridge, and are reported to haul out on Stack Rock (Burton, 2008). Therefore, any impacts from seals are likely to be concentrated in the vicinity of Stack Rock and possibly any other small rocky islands free from disturbance which could be used as haulout sites.

Otters are present within Milford Haven, and have been observed from the outer reaches through to Picton Point (Burton, 2008). No information on numbers was available but the population is likely to be small. They tend to favour the more secluded areas with access to watercourses. However, given their wide distribution and small numbers otters have no material bearing on the sampling plan.

No other wildlife species which have a potentially significant influence on levels of contamination within shellfish within the survey area have been identified. Dogs are exercised on the beaches along this shore also represent a potential source of diffuse contamination to the near shore zone. It is likely that the intensity of this is greatest on areas of foreshore adjacent to urban areas.

APPENDIX XI
MICROBIOLOGICAL DATA: WATER

BATHING WATERS

There are two bathing waters within the survey area (Dale Beach and West Angle Bay) designated under the Directive 76/160/EEC (Council of the European Communities, 1975). Both of these lie in the outer reaches of Milford Haven downstream of the shellfish harvesting areas (Figure XI.1). In addition to these designated waters the Environment Agency also monitored the bacteriological content of other undesignated bathing beaches within Milford Haven, as shown in Figure XI.1.

Figure XI.1 Location of designated bathing waters and shellfish growing waters monitoring points within Milford Haven.

Around 20 samples were taken from each of these sites during each bathing season, which runs from the 15th May to the 30th September although not all sites were sampled every year. Faecal coliforms (confirmed) were enumerated in all these samples. The last major sewerage upgrade occurred in 2005, so only results from 2006 onwards are considered here. Figure XI.2 presents box plots of all results from 2006 to 2011 by sampling point.

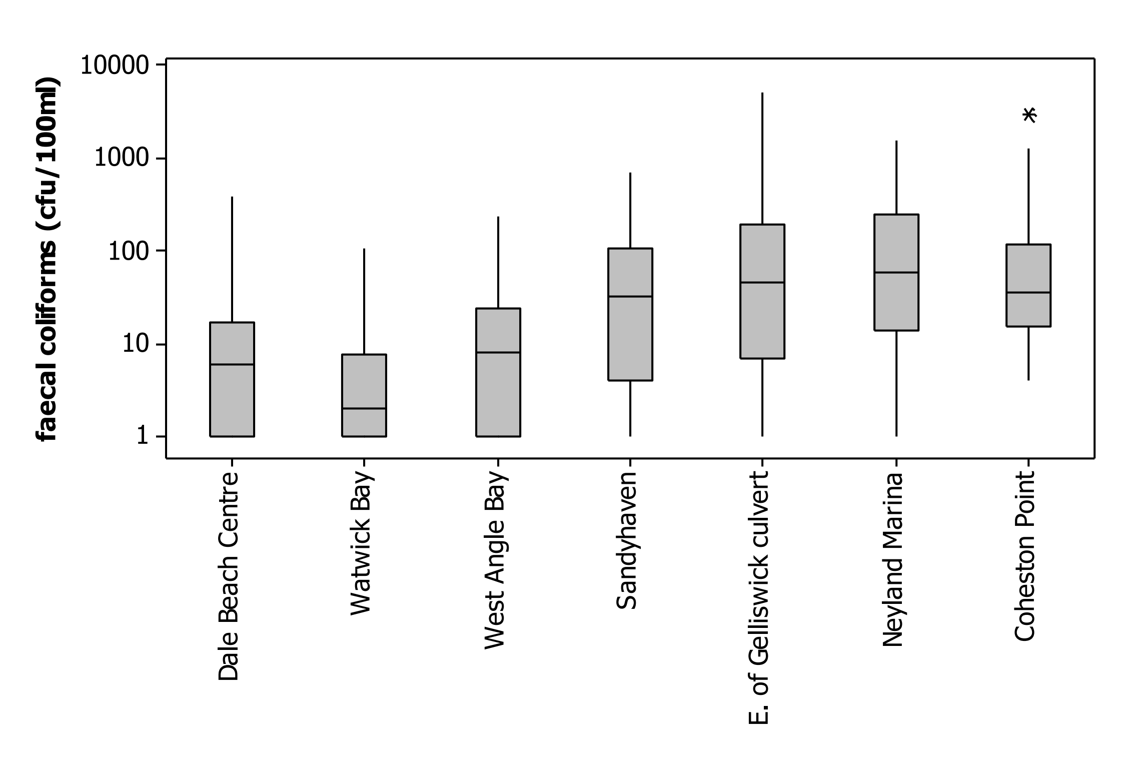


Figure XI.2 Box-and-whisker plots of all faecal coliforms results by site (2006-2011)

Table XI.1 Summary statistics for bathing waters faecal coliforms results (cfu/100ml) by site.

Site	Year	No.	Geo-mean	Min.	Max.	% exceeding 100 cfu/100ml	% exceeding 1000 cfu/100ml
Dale Beach Centre	2006-2011	120	5.5	<2	385	4%	0%
Watwick Bay	2007-2008	41	3.7	<2	106	2%	0%
West Angle Bay	2006-2011	121	7.0	<2	231	6%	0%
Sandyhaven	2007-2011	101	20.4	<2	692	26%	0%
E. of Gelliswick culvert	2007-2011	101	38.2	<2	5000	36%	8%
Neyland Marina	2007-2008	42	59.6	<2	1548	38%	2%
Coheston Point	2007-2008	41	50.4	4	3000	34%	5%

There is a clear increase in faecal coliforms concentrations with distance from the estuary mouth. A significant difference in mean result by site was found when all results were compared (one-way ANOVA, p=0.000). A post ANOVA test (Tukeys comparison) indicated that results for Sandyhaven, E. of Gelliswick Culvert, Neyland Marina and Coheston Point were significantly higher than those for Dale Beach Centre, Watwick Bay and West Angle Bay. Results for Neyland Marina were also significantly higher than for Sandyhaven.

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

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

		High/Low cycle		Spring/Neap cycle	
Site	**No.**	**r**	**p**	**r**	**p**
Dale Beach Centre	120	0.249	<0.001	0.128	0.148
Watwick Bay	41	0.056	0.888	0.047	0.919
West Angle Bay	121	0.025	0.928	0.188	0.015
Sandyhaven	101	0.297	<0.001	0.297	<0.001
E. of Gelliswick culvert	101	0.389	<0.001	0.311	<0.001
Neyland Marina	42	0.331	0.014	0.289	0.039
Coheston Point	41	0.284	0.047	0.231	0.132

Figure XI.3 to XI.7 present polar plots of $\log_{10}$ faecal coliform results against tidal states on the high/low cycle for the correlations indicating a statistically significant effect. High water at Milford Haven is at 0° and low water is at 180°. Results of 100 faecal coliforms/100ml or less are plotted in green, those from 101 to 1000 are plotted in yellow, and those exceeding 1000 are plotted in red.

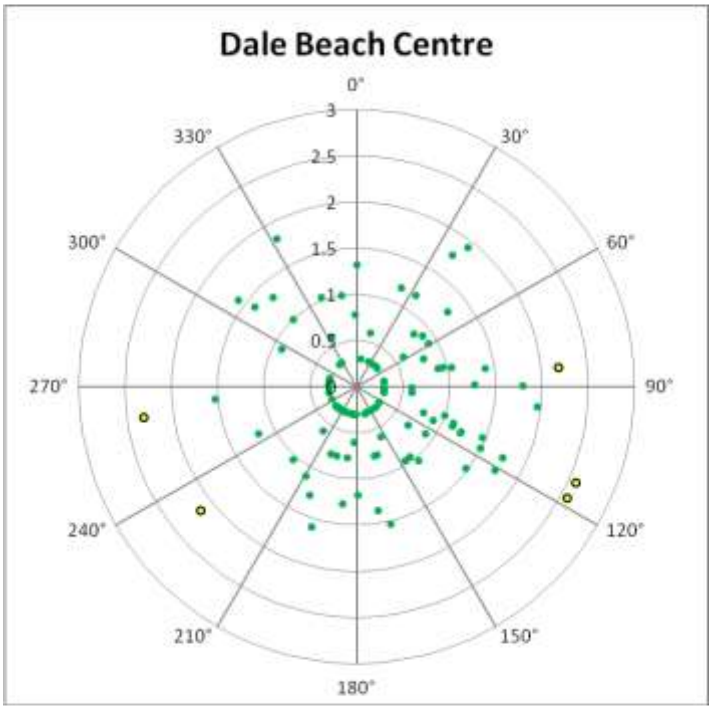


Figure XI.3 Polar plot of $\log_{10}$ faecal coliforms results against the high/low tidal cycle at Dale Beach Centre

At Dale Beach Centre, a strong correlation was observed and results tended to be higher later in the ebb tide suggesting important sources of contamination lie a distance up-estuary, or reflecting the influence of local 'freshwater' input as the tide recedes.

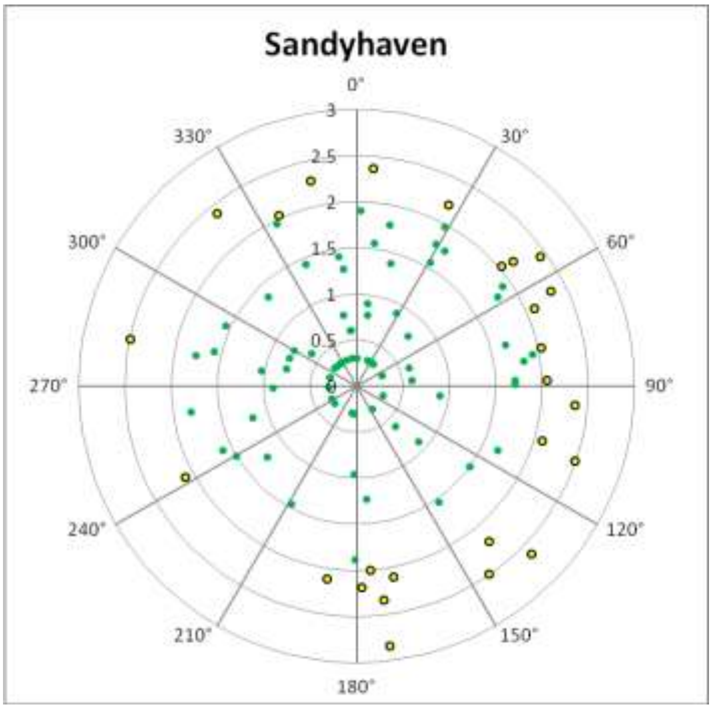


Figure XI.4 Polar plot of log_{10} faecal coliforms results against the high/low tidal cycle at Sandyhaven

At Sandyhaven, a strong correlation was observed and results tended to be higher throughout the ebb tide suggesting important sources of contamination lie up-estuary.

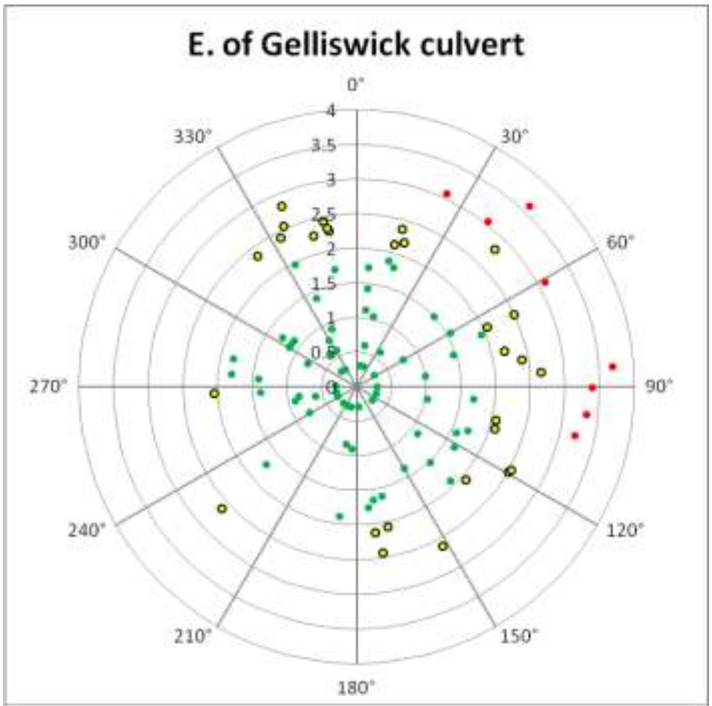


Figure XI.5 Polar plot of log_{10} faecal coliforms results against the high/low tidal cycle at E. of Gelliswick culvert

A very strong correlation was found at Gelliswick, with results considerably higher on average throughout the ebb tide, suggesting that the most important sources of contamination lie nearby and up-estuary.

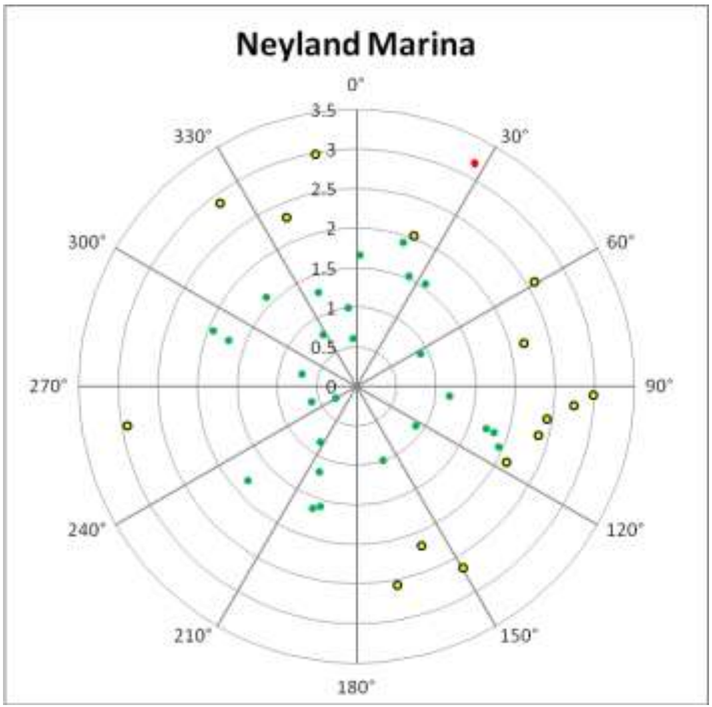


Figure XI.6 Polar plot of $\log_{10}$ faecal coliforms results against the high/low tidal cycle at Neyland Marina

The correlation at Neyland Marina was relatively weak, but there does appear to be a vague tendency for higher results to occur during the ebb tide.

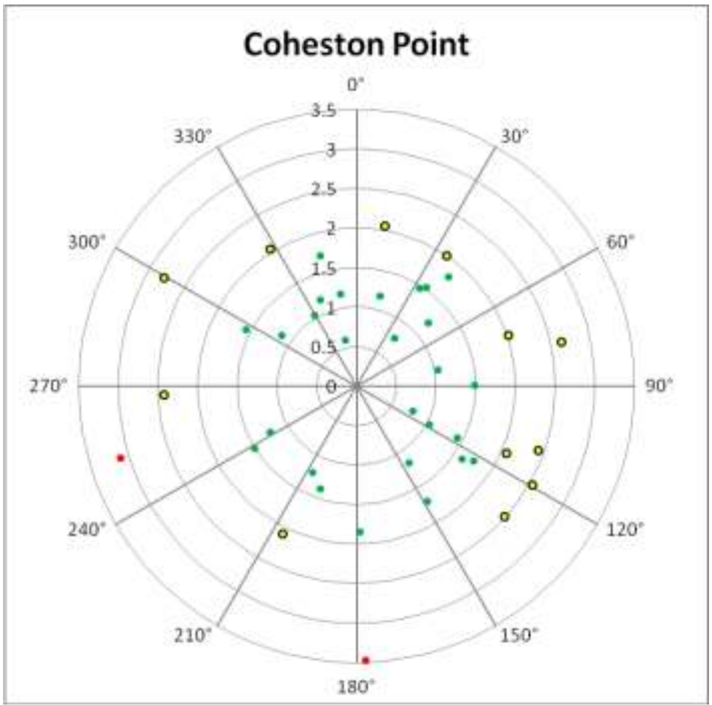


Figure XI.7 Polar plot of $\log_{10}$ faecal coliforms results against the high/low tidal cycle at Coheston Point

The correlation at Coheston Point was weak, and no clear pattern in results is apparent in Figure XI.7.

Figures XI.8 to XI.11 present polar plots of faecal coliform results against the lunar spring/neap cycle, where a statistically significant correlation was found. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 100 faecal coliforms/100ml or less are plotted in green, those from 101 to 1000 are plotted in yellow, and those exceeding 1000 are plotted in red.

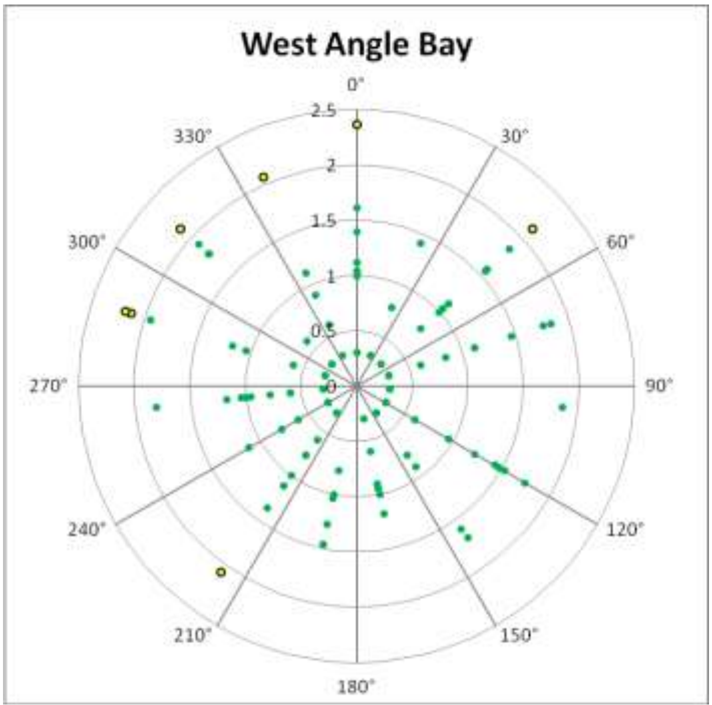


Figure XI.8 Polar plot of log_{10} faecal coliforms results against the spring/neap tidal cycle at West Angle Bay

A weak correlation was found at West Angle Bay, but no clear pattern in results is apparent in Figure XI.8.

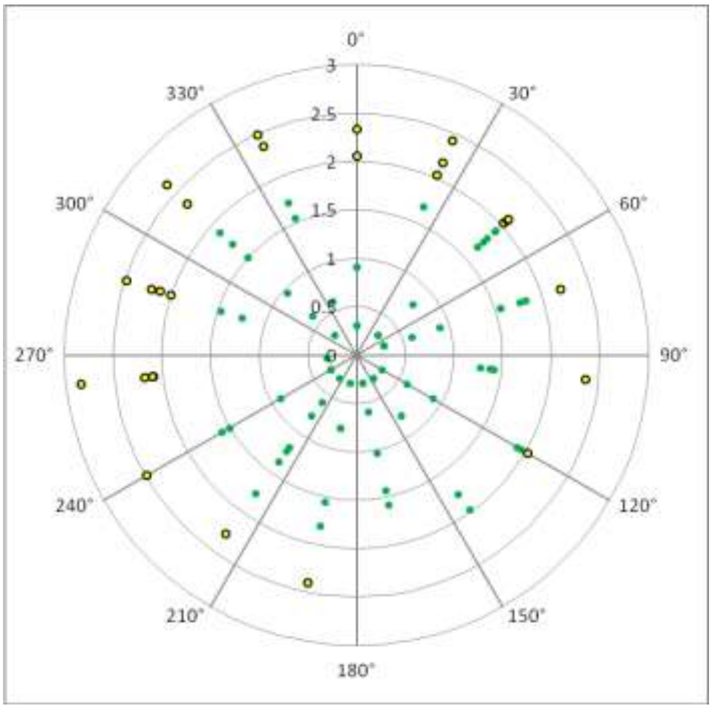


Figure XI.9 Polar plot of log_{10} faecal coliforms results against the spring/neap tidal cycle at Sandyhaven

A strong correlation was found at Sandyhaven, and Figure XI.9 suggests that results are generally lower as the tides are decreasing in size.

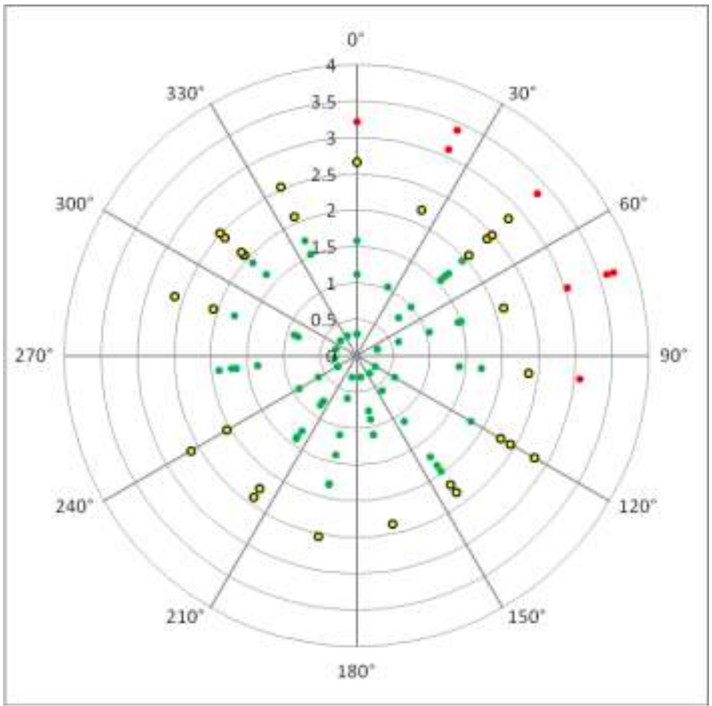


Figure XI.10 Polar plot of log_{10} faecal coliforms results against the spring/neap tidal cycle at E. of Gelliswick Culvert

A strong correlation was found at Gelliswick, and Figure XI.10 illustrates that results are generally higher during the larger spring tides.

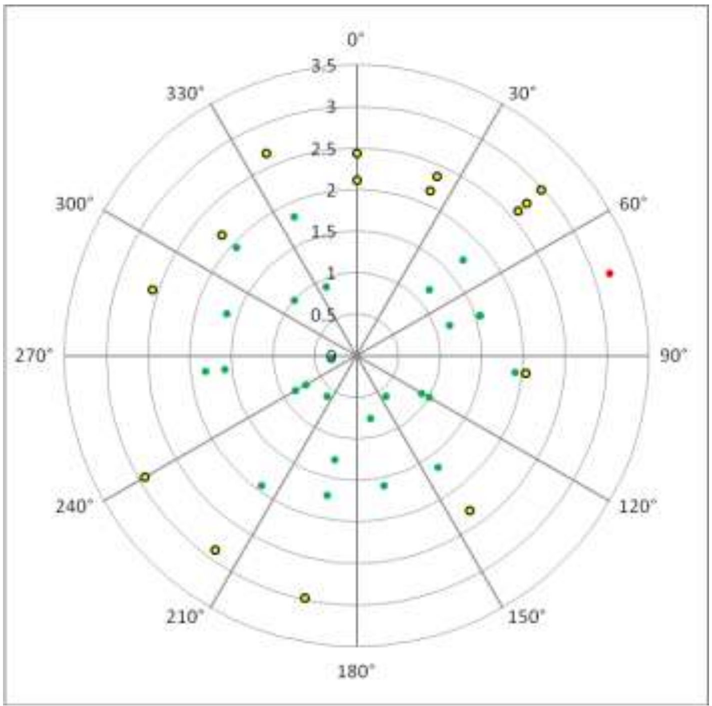


Figure XI.11 Polar plot of log_{10} faecal coliforms results against the spring/neap tidal cycle at Neyland Marina

A weak correlation was found at Neyland Marina, but no clear pattern in results is apparent in Figure XI.11.

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

Table XI.3 Spearman's Rank correlations between rainfall recorded at Bolton Hill and Bathing Waters sample results from sites in Milford Haven (2006-2011)

		Dale Beach	Watwick Bay	West Angle	Sandy-haven	Gellis-wick	Neyland Marina	Coheston Point
	No.	95	24	94	88	88	27	26
24 hour periods prior to sampling	1 day	0.254	0.125	0.394	0.265	0.293	0.343	0.253
	2 days	0.334	0.403	0.524	0.333	0.388	0.065	0.121
	3 days	0.132	0.170	0.212	0.306	0.315	0.435	0.238
	4 days	-0.104	0.330	0.019	0.206	0.232	0.249	0.159
	5 days	0.202	0.147	0.249	0.111	0.117	0.004	0.106
	6 days	-0.008	0.043	0.086	0.047	0.107	0.109	0.190
	7 days	0.111	0.179	0.164	0.142	0.221	0.420	0.418
Total prior to sampling over	2 days	0.349	0.231	0.507	0.356	0.389	0.380	0.315
	3 days	0.302	0.225	0.462	0.386	0.442	0.501	0.382
	4 days	0.267	0.235	0.396	0.367	0.409	0.442	0.292
	5 days	0.295	0.317	0.420	0.326	0.360	0.474	0.384
	6 days	0.258	0.218	0.374	0.308	0.345	0.482	0.377
	7 days	0.273	0.225	0.407	0.338	0.401	0.530	0.431

No correlations were found between recent rainfall and levels of faecal coliforms at Watwick Bay. This site is in the mouth of the estuary and the only direct freshwater input is a very small spring fed stream. Some influence of rainfall was detected at all other locations investigated indicating a widespread influence of rainfall dependent sources even within the outer estuary at places such as West Angle.

SHELLFISH WATERS

Two areas within Milford Haven have been designated under Directive 2006/113/EC as Shellfish Waters since 1999 (European Communities, 2006) (Figure XI.12). One monitoring point lies in the Carew side channel, and the other lies under the Cleddau Bridge. Seawater samples were taken from here on a quarterly basis and tested for faecal coliforms. Only water sampling results are considered in this section as a subset of shellfish flesh sample results collected under the shellfish hygiene monitoring programme are used to assess compliance with bacteriological standards in shellfish flesh, and these are presented and discussed in Appendix XII.

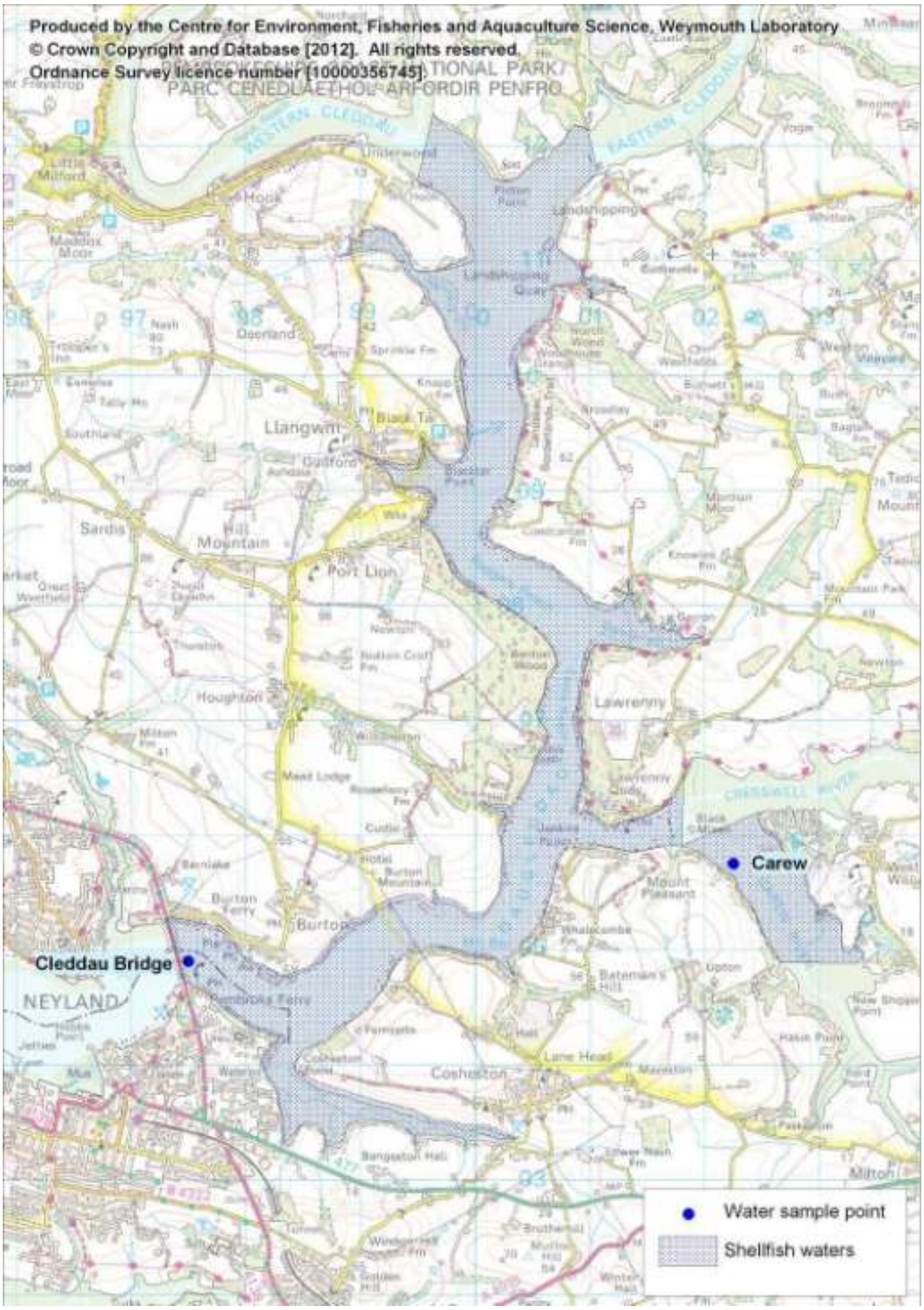


Figure XI.12 Shellfish waters within Milford Haven

Table XI.4 presents summary statistics for recent bacteriological monitoring results from the water monitoring points, and the same results are presented in Figure XI.13.

Table XI.4 Summary statistics for shellfish waters faecal coliforms results (cfu/100ml), 2006-2011.

Site	No.	Geometric mean	Minimum	Maximum	% exceeding 100 cfu/100ml	% exceeding 1000 cfu/100ml
Cleddau Bridge	24	29.9	<2	880	20%	0%
Carew	24	46.6	<2	3120	28%	4%

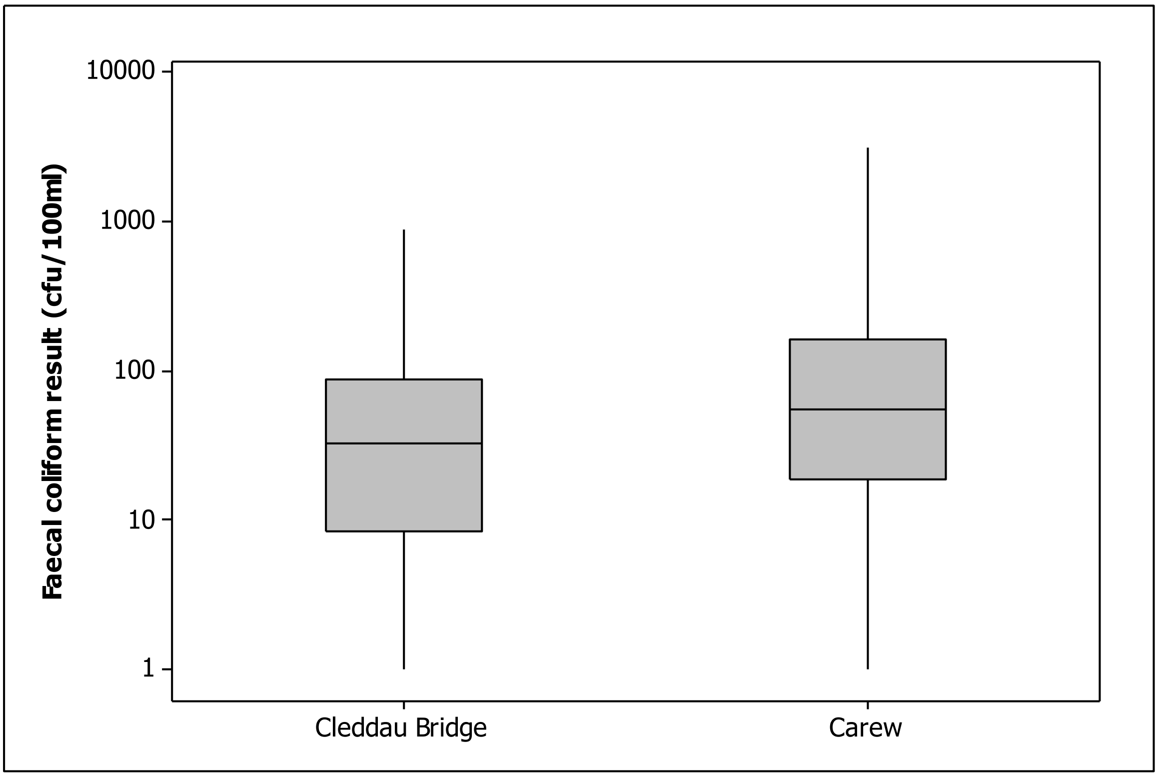


Figure XI.13 Boxplot of shellfish waters faecal coliforms results (cfu/100ml), 2006-2011.

Results at the two sites were similar, and were strongly correlated on a (same day) sample by sample basis (Pearsons correlation, r=0.673, p=0.000) suggesting the two sites are under similar contaminating influences. Although results were higher at Carew the difference between the average result was not statistically significant (paired T-test, p=0.145).

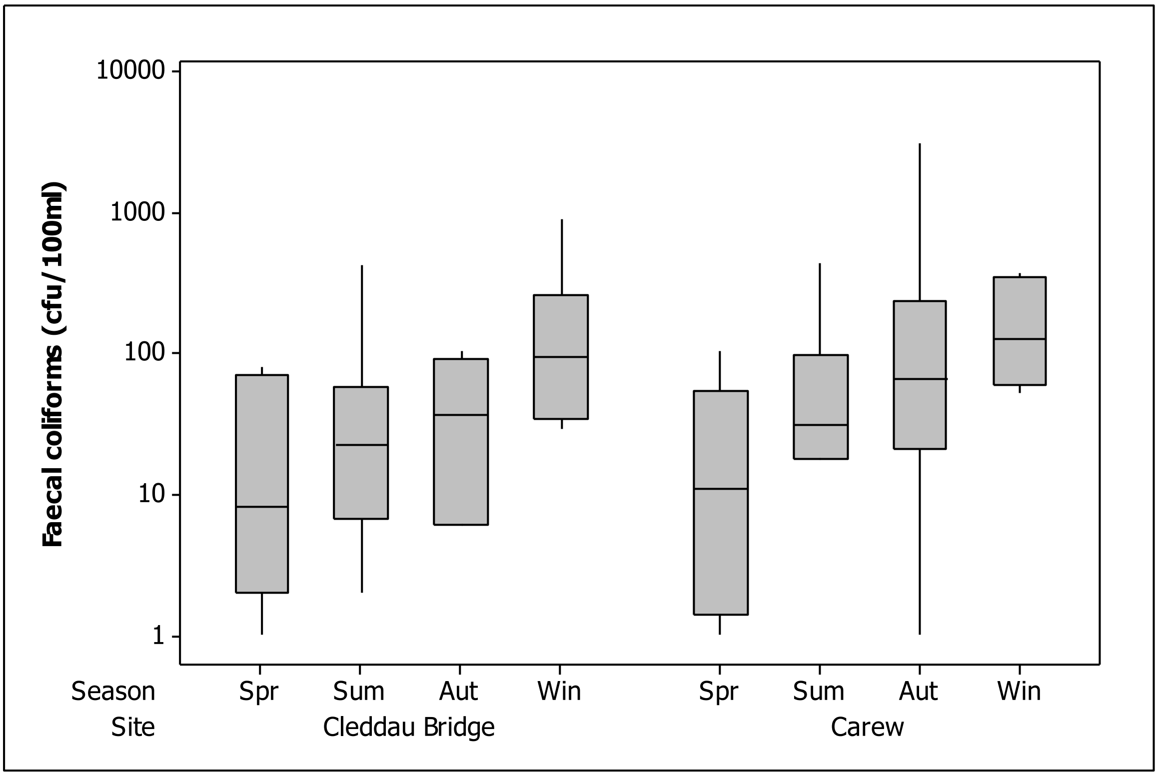


Figure XI.14 Boxplot of shellfish growing waters faecal coliforms results by season (2006-2011)

Figure XI.14 indicates that there are similar seasonal patterns at these two sites, with increasing levels of faecal coliforms from spring through to winter, although this effect was not statistically significant in either case (One-way ANOVA, p=0.111 and 0.116).

No correlations were found between tidal state on both the high/low and spring/neap tidal cycles at either of the two shellfish water monitoring points (circular-linear correlations, r=0.308 or less, p=0.135 or greater).

On each sampling occasion, salinity readings were taken. Figure XI.15 presents a scatterplot of results against salinity.

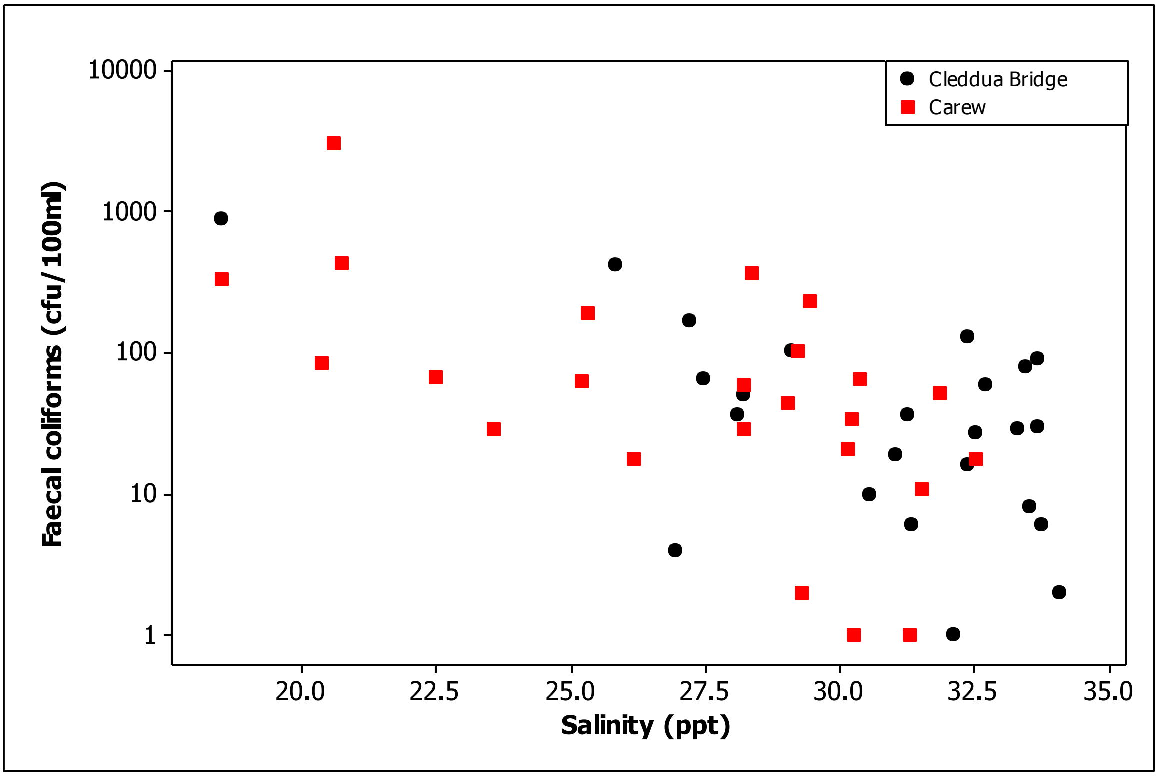


Figure XI.15. Scatterplot of shellfish water faecal coliforms results against salinity

Strong negative correlations between faecal coliforms and salinity were found at both Cleddau Bridge (Pearsons correlation, r=-0549, p=0.005) and Carew (Pearsons correlation, r=-0589, p=0.002). As may be expected, salinities were generally lower at Carew. Across the two sites, levels of contamination were similar with respect to salinity.

Spearman's rank correlations were carried out between rainfall recorded at the Bolton Hill rain gauge over various periods running up to sample collection and faecal coliforms results. These are presented in Table XI.3, and statistically significant correlations (p<0.05) are highlighted in yellow.

Table XI.5 Spearman's Rank correlations between rainfall at Bolton Hill and shellfish growing waters sample results (2006-2011)

		Cleddau Bridge	Carew
	No.	16	16
24 hour periods prior to sampling	1 day	0.177	0.119
	2 days	0.212	0.362
	3 days	0.324	0.453
	4 days	0.390	0.457
	5 days	0.204	0.148
	6 days	0.075	0.075
	7 days	0.402	0.413
Total prior to sampling over	2 days	0.164	0.179
	3 days	0.321	0.438
	4 days	0.450	0.599
	5 days	0.400	0.564
	6 days	0.416	0.580
	7 days	0.540	0.626

The number of samples considered in the analyses was relatively low. Nevertheless, influence of rainfall was detected at both sites. Unsurprisingly this was stronger at Carew than at Cleddau Bridge.

APPENDIX XII
MICROBIOLOGICAL DATA: SHELLFISH FLESH

Shellfish flesh has been sampled and tested for hygiene classification monitoring purposes from a large number of RMPs within Milford Haven in recent years. The last major sewerage upgrade occurred in 2005, so only results from 2006 onwards are considered here.

SUMMARY STATISTICS AND GEOGRAPHICAL VARIATION

Native oysters

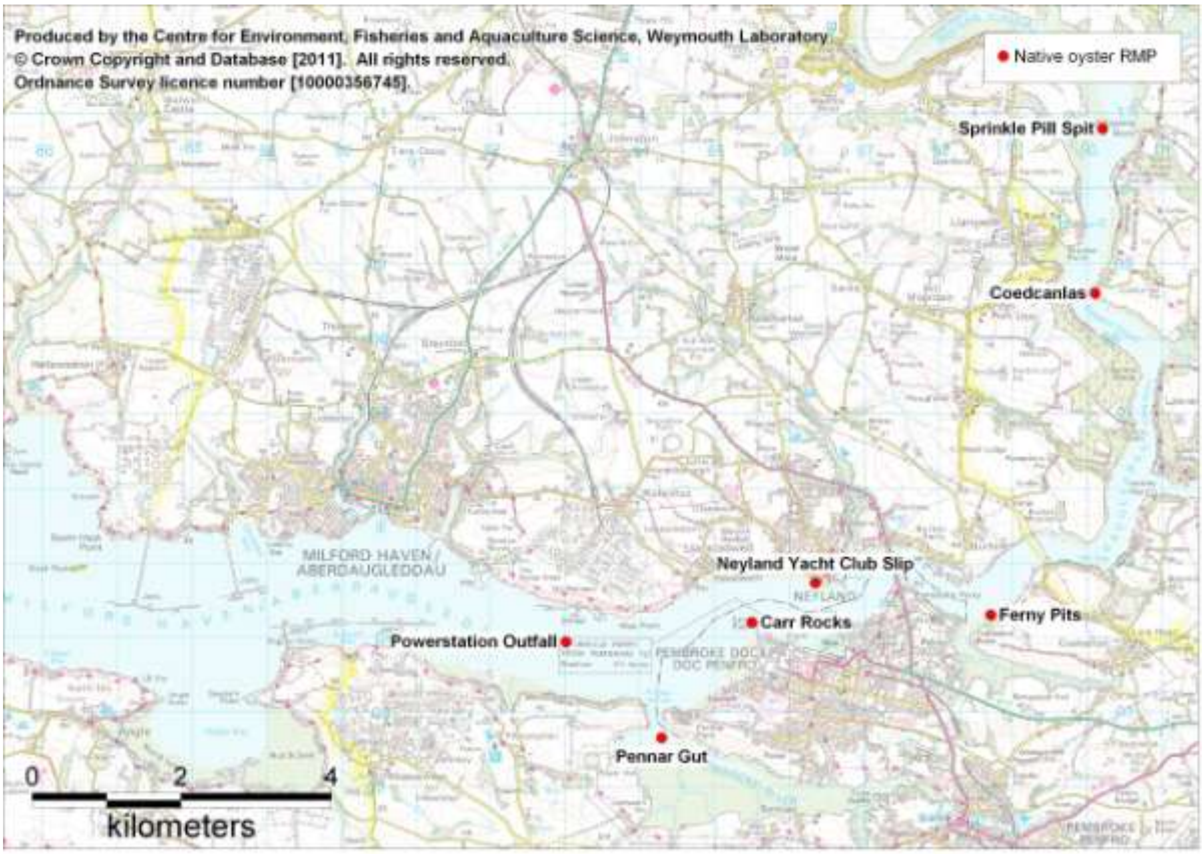


Figure XII.1 Native oyster RMPs active since 2006

Table XII.1 Summary statistics of E. coli *results (MPN/100g) from native oyster RMPs sampled from 2006 onwards*

RMP	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 230	% over 4600
Sprinkle Pill Spit	67	30/01/2006	23/11/2011	362	<20	16000	55%	4%
Coedcanlas	69	30/01/2006	23/11/2011	397	<20	>18000	64%	7%
Ferny Pits	70	28/01/2006	23/11/2011	518	70	>18000	70%	4%
Neyland Yacht Club	8	21/02/2011	23/11/2011	2931	940	24000	100%	25%
Carr Rocks	9	21/02/2011	23/11/2011	1239	130	16000	78%	33%
Pennar Gut	70	18/01/2006	07/12/2011	472	<20	9200	74%	4%
Powerstation Outfall	70	18/01/2006	07/12/2011	421	<20	5400	70%	3%

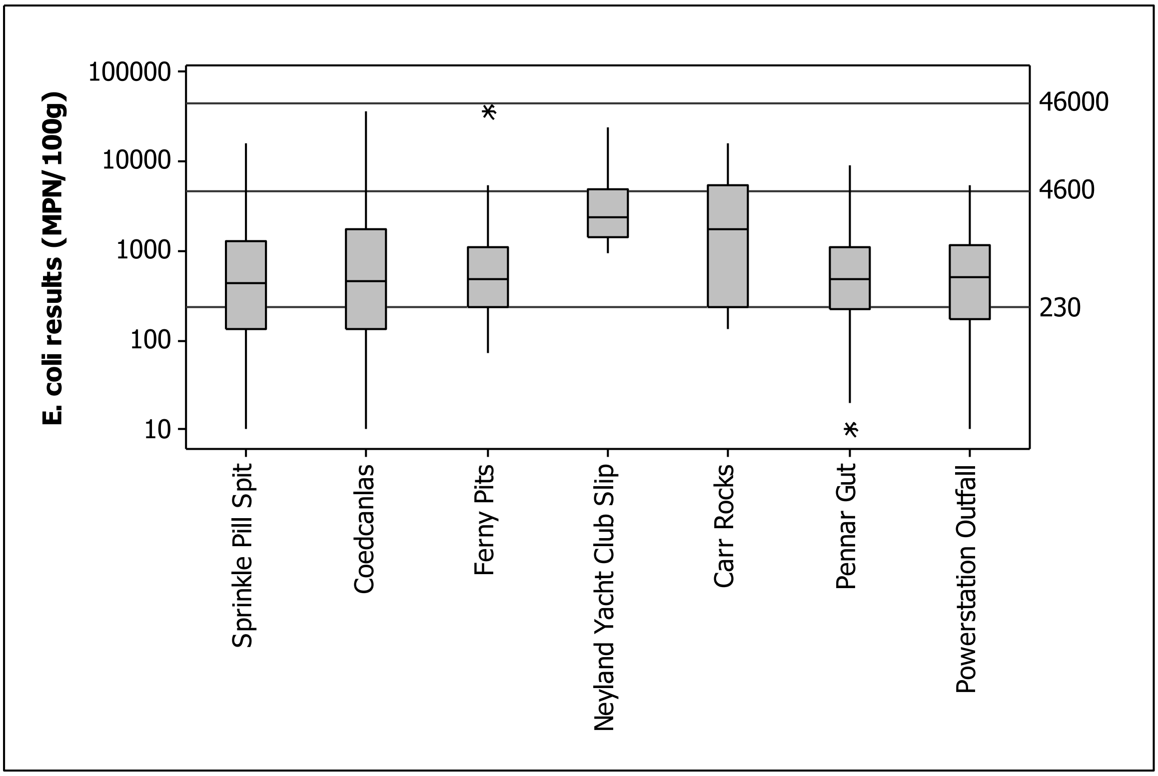


Figure XII.2 Boxplots of* E. coli *results from native oyster RMPs sampled from 2006 onwards

Sampling has only been underway at Neyland Yacht Club and Carr Rocks since early 2011. The other five RMPs, which have been subject to ongoing sampling since 2006 showed similar levels of *E. coli*, although the highest peak results arose at the three RMPs upstream of the Cleddau Bridge (Sprinkle Pill Spit, Coedcanlas and Ferny Pits). When all results from all RMPs were compared, a significant difference in mean result was found (One way ANOVA, p=0.004), with post ANOVA tests (Tukeys comparison) indicating results at Neyland Yacht Club slip were significantly higher than at all other RMPs except Carr Rocks. Levels of contamination in the areas by Neyland and Pembroke Docks are higher than at the other five native oyster RMPs to the extent that they are likely to receive C rather than B classifications.

The three RMPs upstream of the Cleddau Bridge were all sampled on the same day on 62 occasions, allowing a more robust comparison of results from these. No significant difference was found in mean result by site (two way ANOVA, p=0.054) but the effect of sample date was highly significant (two way ANOVA, p=0.000) indicating that these RMPs were subject to broadly similar levels of contamination which fluctuated with a similar manner at all three. Perhaps surprisingly, the average *E. coli* result within this reach decreased slightly towards the head of the estuary. This may reflect a change in filter feeding by this species at lower salinities.

The two RMPs in the outer reaches of the area (Pennar Gut and Power Station Outfall) were also generally sampled on the same occasions. A comparison of the paired sample results from these two RMPs showed no significant difference in mean result (paired T-test, p=0.482) and that results were strongly correlated on a sample by sample basis (Pearsons correlation, r=0.603, p=0.000).

The two RMPs at Neyland Slip and Carr Rocks were sampled on too few occasions for any meaningful statistical comparisons. Geometric mean result was higher at Neyland Slip, and the lowest result recorded here was 940 *E. coli* MPN/100g, indicating that this latter site was more consistently subject to high levels of contamination.

Mussels

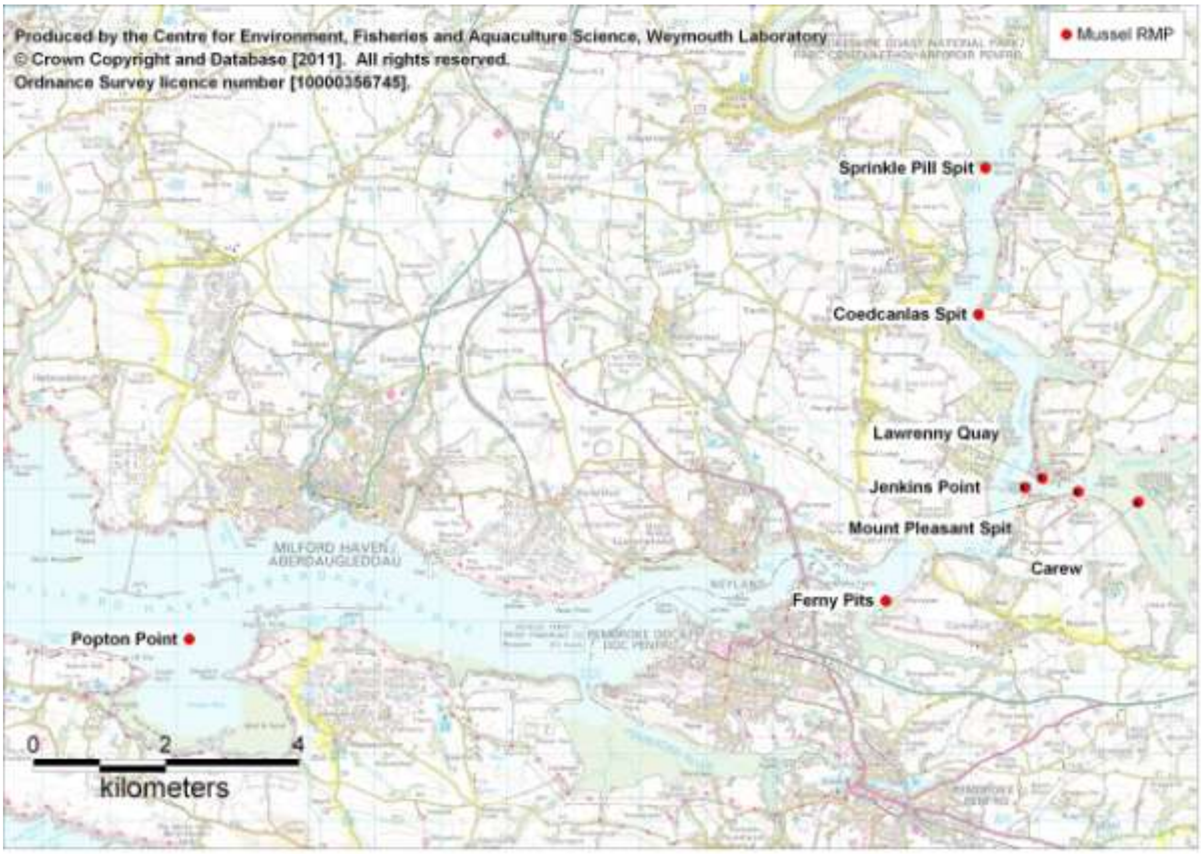


Figure XII.3 Mussel RMPs active since 2006

Table XII.2 Summary statistics of* E. coli *results (MPN/100g) from mussel RMPs sampled from 2006 onwards

RMP	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 230	% over 4600
Sprinkle Pill Spit	3	12/07/2006	22/01/2007	4246	2400	9100	100%	33%
Coedcanlas Spit	2	12/07/2006	25/09/2006	923	500	1700	100%	0%
Lawrenny Quay	32	27/05/2009	07/12/2011	897	80	>18000	84%	16%
Carew	5	25/03/2010	01/02/2011	513	40	2400	80%	0%
Mount Pleasant Spit	72	30/01/2006	07/12/2011	1345	110	>18000	92%	15%
Jenkins Point	46	30/01/2006	01/03/2010	878	20	>18000	80%	11%
Ferny Pits	1	12/07/2006	12/07/2006	310	310	310	100%	0%
Popton Point	61	04/10/2006	07/12/2011	220	<20	3500	49%	0%

Four of these RMPs were only sampled on 5 or less occasions so it is difficult to draw any conclusions from these results. Nevertheless, results were highest on average at Sprinkle Pill Spit, the furthest upstream location. A comparison of results from the other four RMPs, all of which were sampled on more than 30 occasions showed a significant difference (One Way ANOVA, p=0.000) with results from Popton Point significantly lower on average than at the other three sites (Tukeys comparison). These three sites all lie in close proximity to each other within the Carew side channel. Paired (same day) samples were taken from Mount Pleasant Spit and Lawrenny Quay on 32 occasions allowing a more robust comparison of results from these two RMPs. Results were significantly higher on average at Mount Pleasant Spit (paired T-test, p=0.007) and results at the two RMPs were strongly correlated on a sample by sample basis (Pearson correlation, r=0.684, p=0.000). Similarly, Mount Pleasant Spit and Jenkins Point were sampled together on 46 occasions, and for these paired samples results were significantly higher at Mount Pleasant Spit (paired T-test, p=0.048) and results at these two RMPs were strongly correlated on a sample by sample basis (Pearson correlation, r=0.455, p=0.002). This suggests these three nearby sites are subject to similar contaminating influences but these influences were stronger at the RMP further upstream in the side channel (Mount Pleasant Spit).

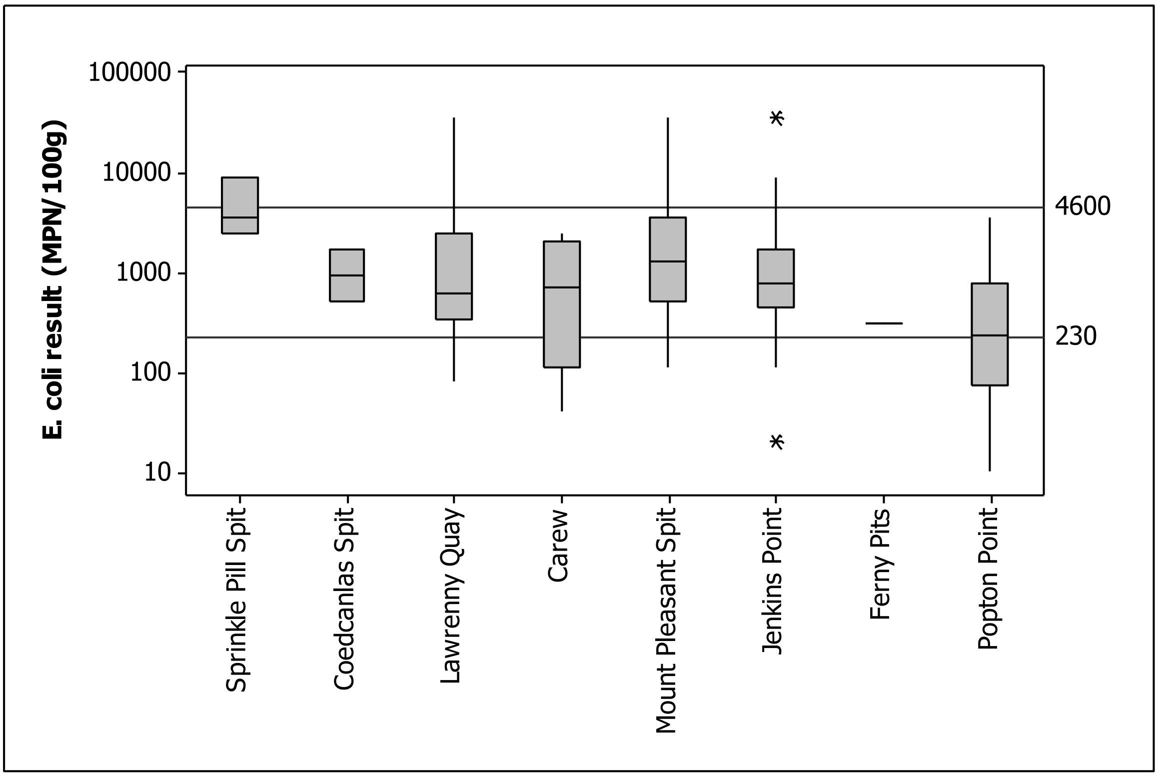


Figure XII.4 Boxplots of* E. coli *results from mussel RMPs sampled from 2006 onwards

<u>Cockles</u>

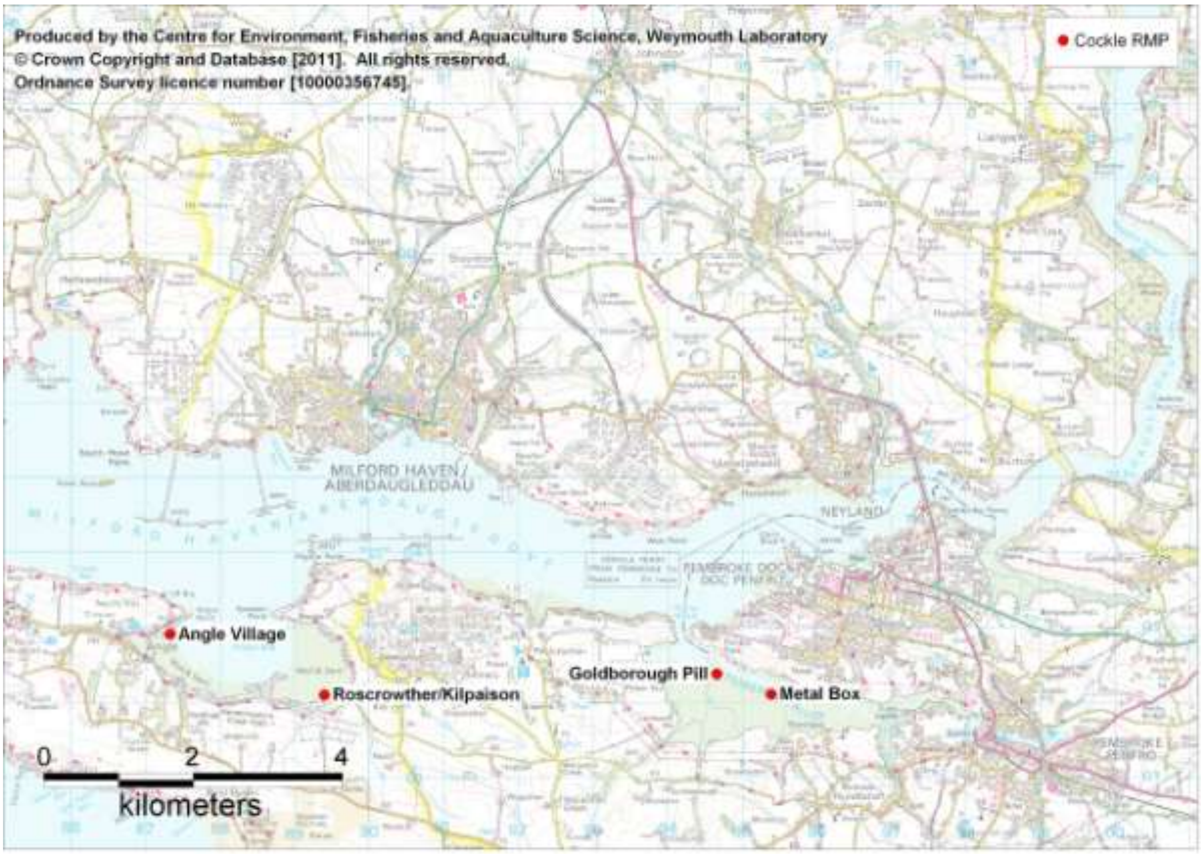


Figure XII.5 Cockle RMPs active since 2006

Table XII.3 Summary statistics of* E. coli *results (MPN/100g) from cockle RMPs sampled from 2006 onwards

RMP	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 230	% over 4600
Metal Box	43	10/01/2006	16/03/2010	394	20	9200	56%	9%
Goldborough Pill	43	10/01/2006	16/03/2010	430	20	16000	67%	5%
Roscrowther/Kilpaison	44	18/01/2006	01/12/2009	231	<20	5400	45%	2%
Angle Village	31	18/01/2006	12/01/2009	331	20	>18000	55%	6%

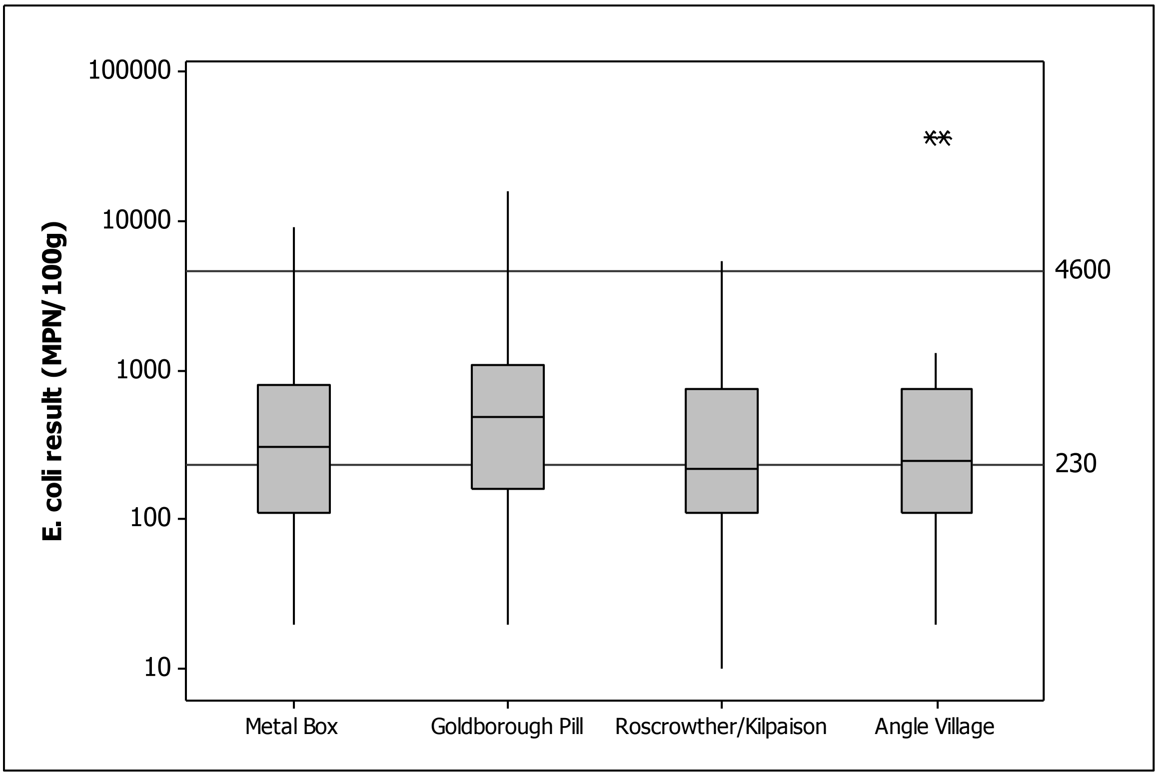


Figure XII.6 Boxplots of* E. coli *results from cockle RMPs sampled from 2006 onwards

A comparison of all results indicated no significant difference in mean result between the four RMPs (One way ANOVA, p=0.228). The two RMPs within the Pembroke River side channel (Metal Box and Goldborough Pill) were usually sampled on the same days allowing a more robust comparison of results. Again no significant difference in mean result was found (Paired T-test, p=0.687) and results were found to be strongly correlated on a sample by sample basis (Pearson correlation, r=0.581, p=0.000) suggesting that they were under the influence of similar sources. The two sites within Angle Bay (Roscrowther/Kilpaison and Angle Village) were also generally sampled on the same day. No significant difference in mean result was found (Paired T-test, p=0.066) but there was no correlation on a sample by sample basis (Pearson correlation, r=0.264, p=0.166), suggesting that although levels of contamination ere similar these two RMPs are subject to differing contaminating influences.

OVERALL TEMPORAL PATTERN IN RESULTS

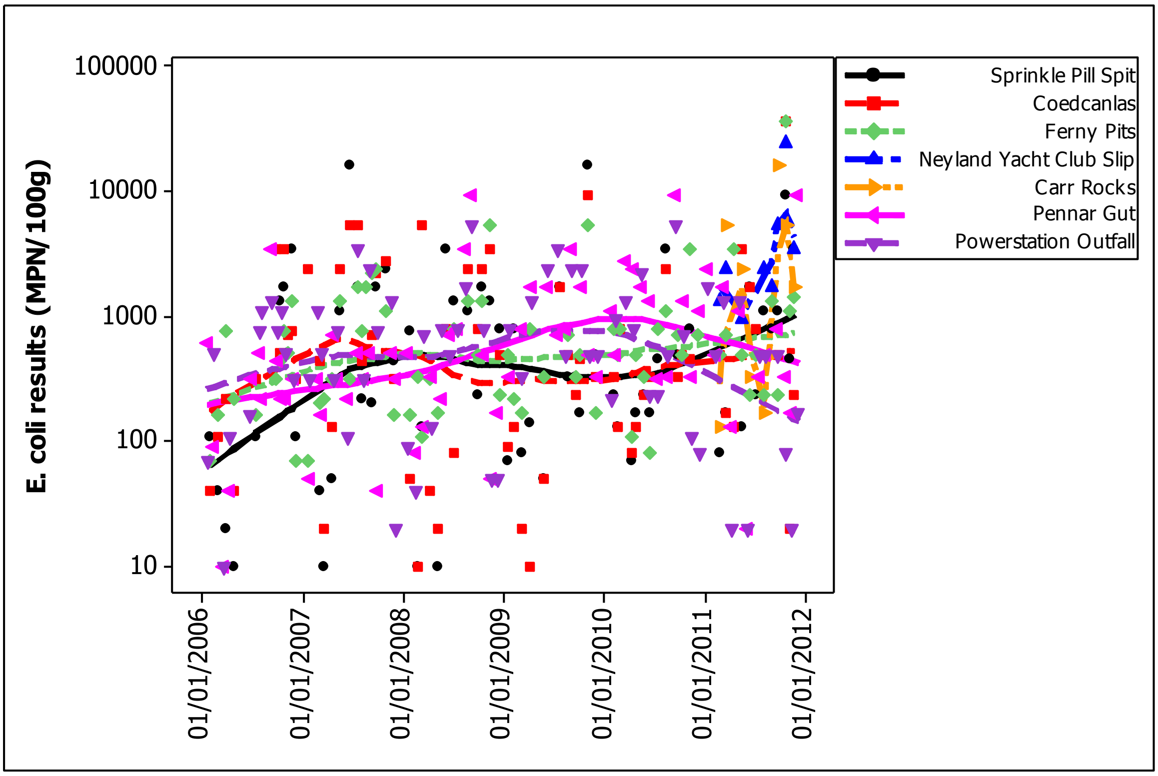


Figure XII.7 Scatterplot of* E. coli *results for native oysters by RMP and date, overlaid with lowess lines for each RMP

Figure XII.7 suggests that there may have been a slight overall deterioration in results at most sites since 2006.

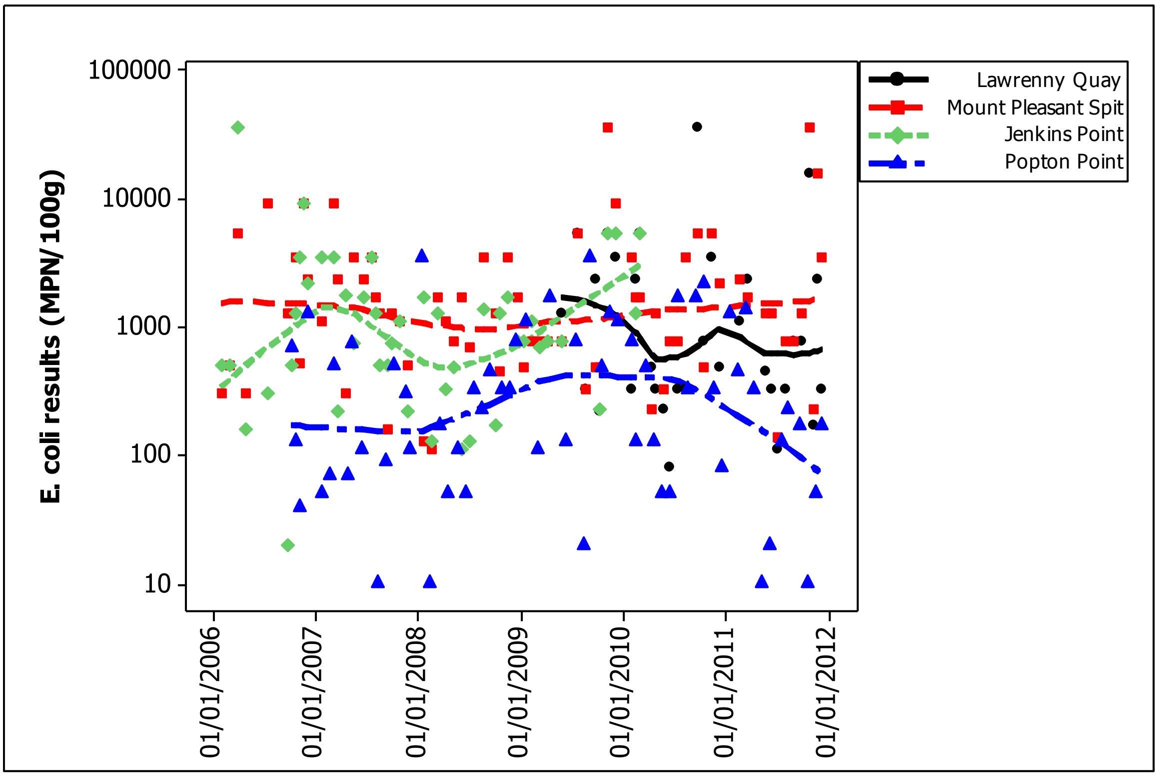


Figure XII.8 Scatterplot of* E. coli *results for mussels by RMP and date, overlaid with lowess lines for each RMP

Figure XII.8 shows that results fluctuate with time but there is no consistent pattern apparent, even for the three sites which are close to each other within the Carew side channel.

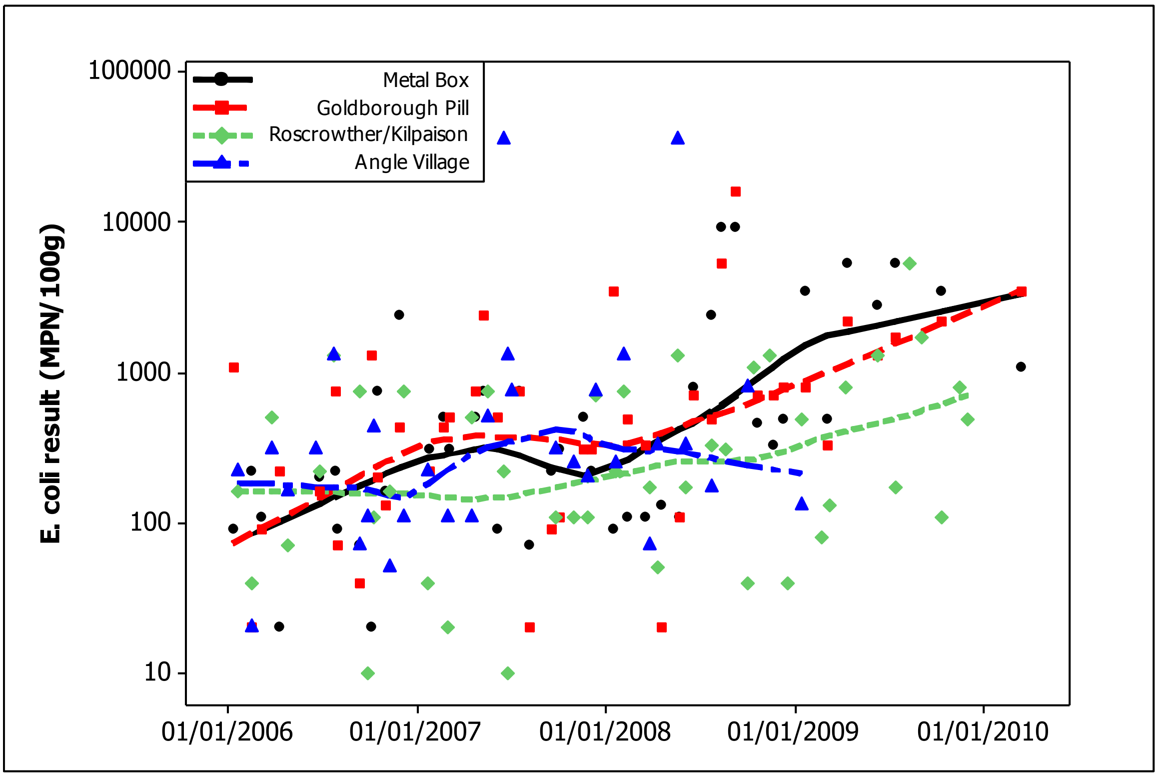


Figure XII.9 Scatterplot of* E. coli *results for cockles by RMP and date, overlaid with lowess lines for each RMP

A marked deterioration in results is apparent since 2006 in the two sites within the Pembroke River side channel, and to a lesser extent within Angle Bay. The reasons for this are unclear.

SEASONAL PATTERNS OF RESULTS

The seasonal patterns of results from 2006 onwards were investigated by RMP for all RMPs where at least 30 samples had been taken.

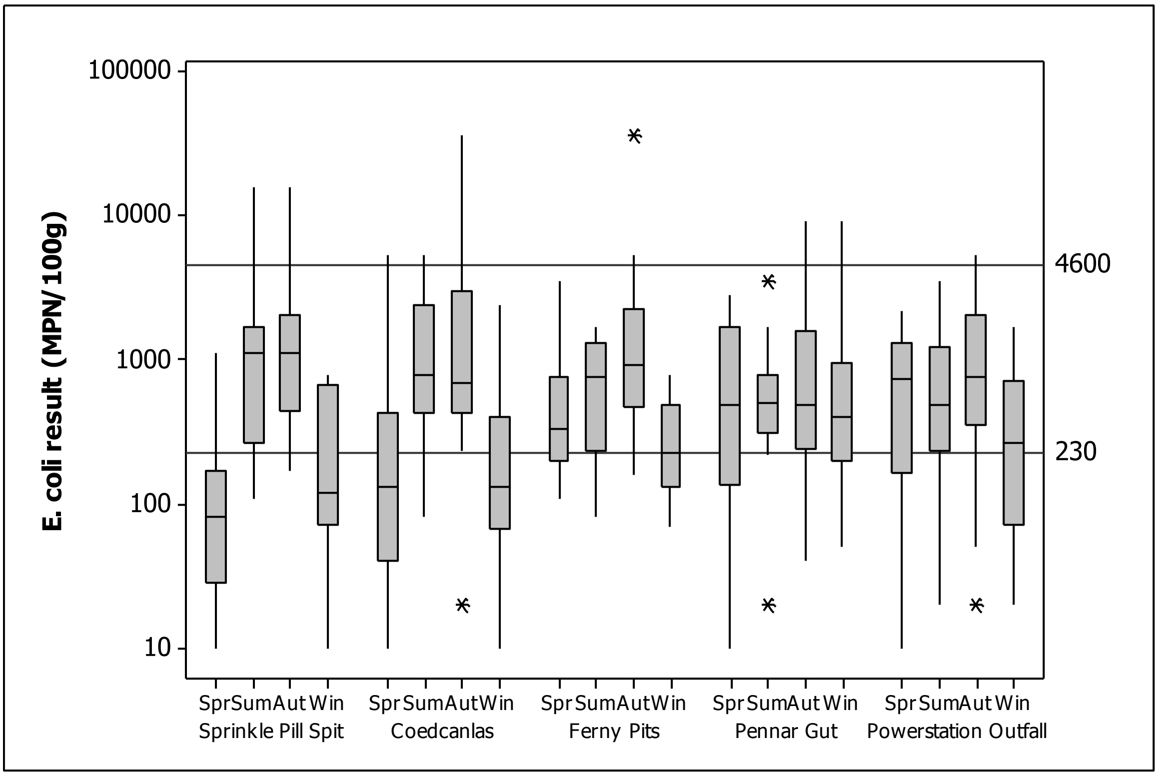


Figure XII.10 Boxplot of native oyster* E. coli *results by RMP and season

Statistically significant seasonal variation was found at the three RMPs upstream of the Cleddau Bridge (one way ANOVA, p=0.000 in all cases). The general pattern was for highest results in the summer and autumn and much lower results in the winter and spring, although this pattern was slightly less marked at the furthest downstream of these three sites (Ferny Pits). No obvious seasonal variation was apparent at Pennar Gut and Powerstation Outfall (one way ANOVA, p=0.842 and 0.177 respectively). Seasonal patterns at Neyland Yacht Club and Carr rocks were not examined due to low sample numbers.

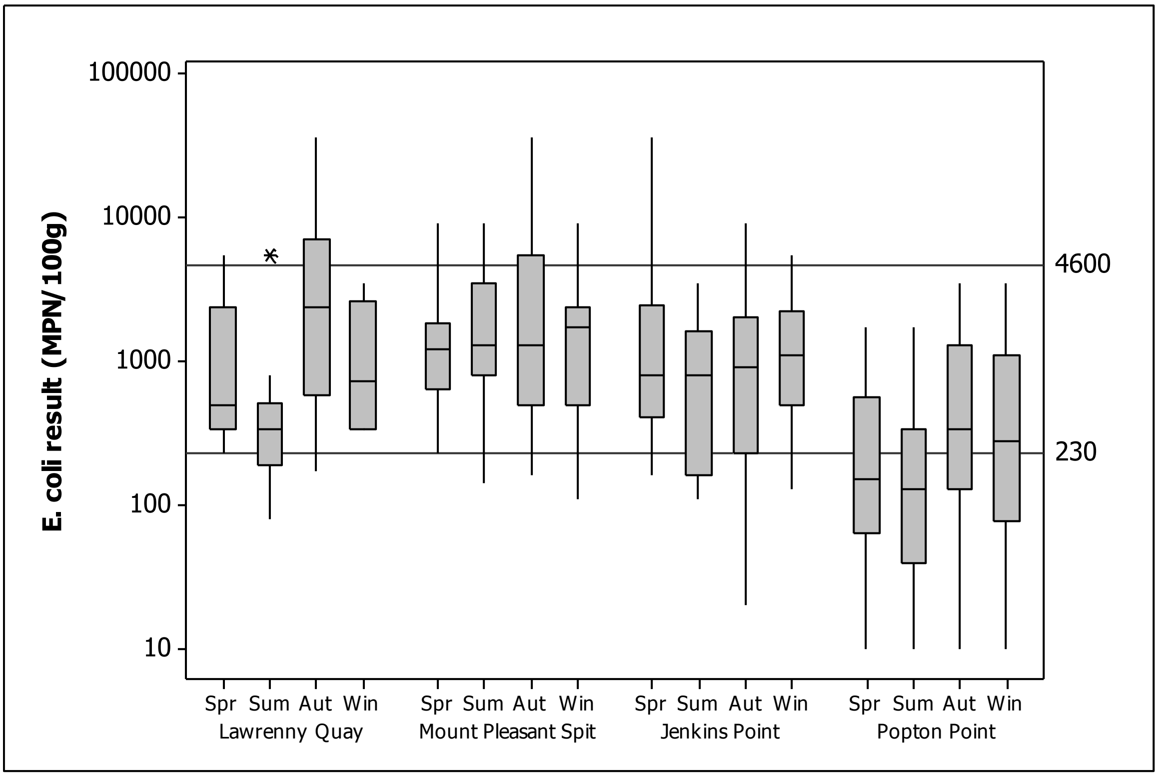


Figure XII.11 Boxplot of mussel* E. coli *results by RMP and season

No significant seasonal pattern was found at any of the mussel RMPs shown in Figure XII.11 (one way ANOVA, p=0.079 or greater). The seasonal pattern of results at the other four mussel RMPs was not investigated due to low sample numbers.

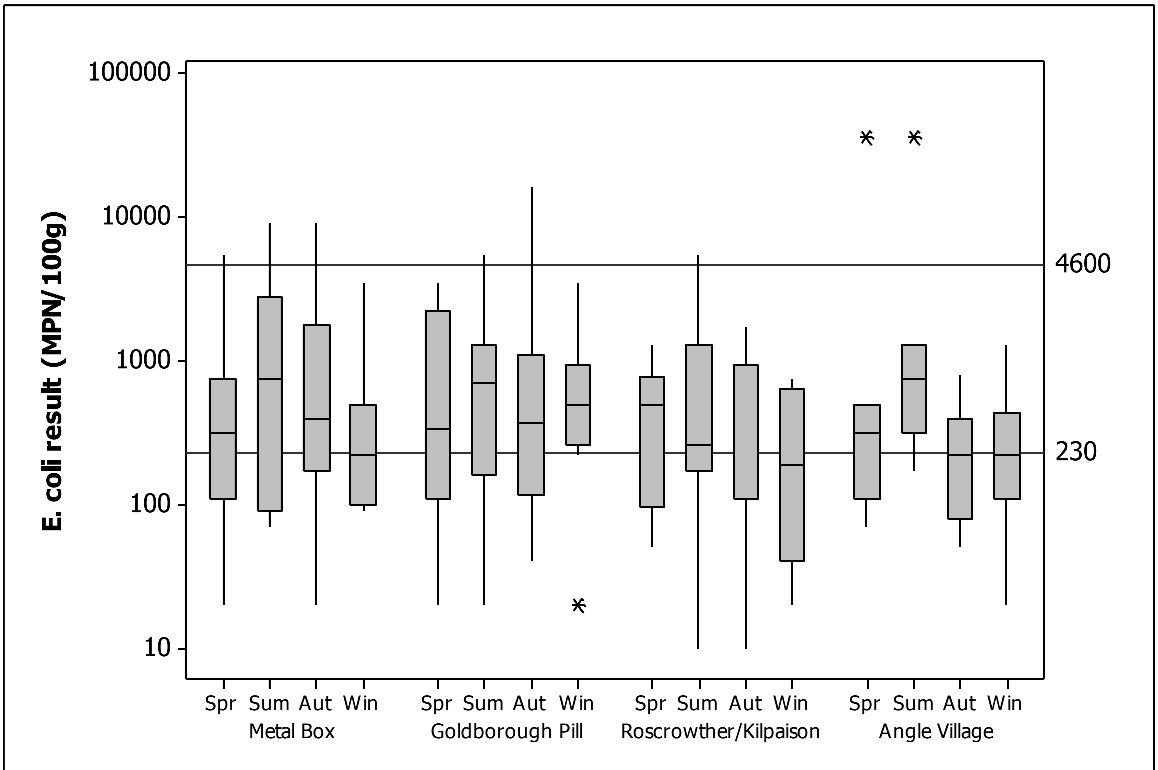


Figure XII.12 Boxplot of cockle* E. coli *results by RMP and season

No significant seasonal pattern was found at any of the cockle RMPs (one way ANOVA, p=0.149 or greater).

INFLUENCE OF TIDE

To investigate the effects of tidal state on *E. coli* results, circular-linear correlations were carried out against both the high/low and spring/neap tidal cycles for each RMP where at least 30 samples had been taken since 2006. No correlation was found with either tidal cycle at the majority of RMPs (Table XII.4) and in many cases sampling was targeted towards a particular tidal state.

Table XII.4 Circular linear correlation coefficients (r) and associated p values for* E. coli *results against the high low and spring/neap tidal cycles

			High/Low cycle		Spring/Neap cycle	
RMP	Species	No.	r	p	r	p
Sprinkle Pill Spit	Native oyster	67	0.133	0.323	0.078	0.677
Coedcanlas	Native oyster	69	0.132	0.316	0.288	0.004
Ferny Pits	Native oyster	70	0.142	0.258	0.202	0.066
Pennar Gut	Native oyster	70	0.128	0.334	0.026	0.956
Powerstation Outfall	Native oyster	70	0.216	0.044	0.129	0.331
Lawrenny	Mussels	32	0.373	0.017	0.257	0.147
Mount Pleasant	Mussels	72	0.132	0.298	0.122	0.357
Jenkins Point	Mussels	46	0.157	0.345	0.218	0.129
Popton Point	Mussels	61	0.125	0.403	0.144	0.301
Angle Village	Cockles	31	0.289	0.096	0.198	0.334
Goldborough Pill	Cockles	43	0.057	0.878	0.057	0.880
Metal Box	Cockles	43	0.084	0.752	0.154	0.386
Roscrowther/Kilpaison	Cockles	44	0.267	0.053	0.398	0.001

Figure XII.13 presents polar plots of $\log_{10}$ *E. coli* results against tidal states for the four correlations indicating a statistically significant effect. For plots of the high/low tidal cycle, high water at Milford Haven is at 0° and low water is at 180°. For plots of the spring/neap cycle, 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 230 *E. coli* MPN/100g less are plotted in green, those from 231 to 4600 are plotted in yellow, and those exceeding 4600 are plotted in red.

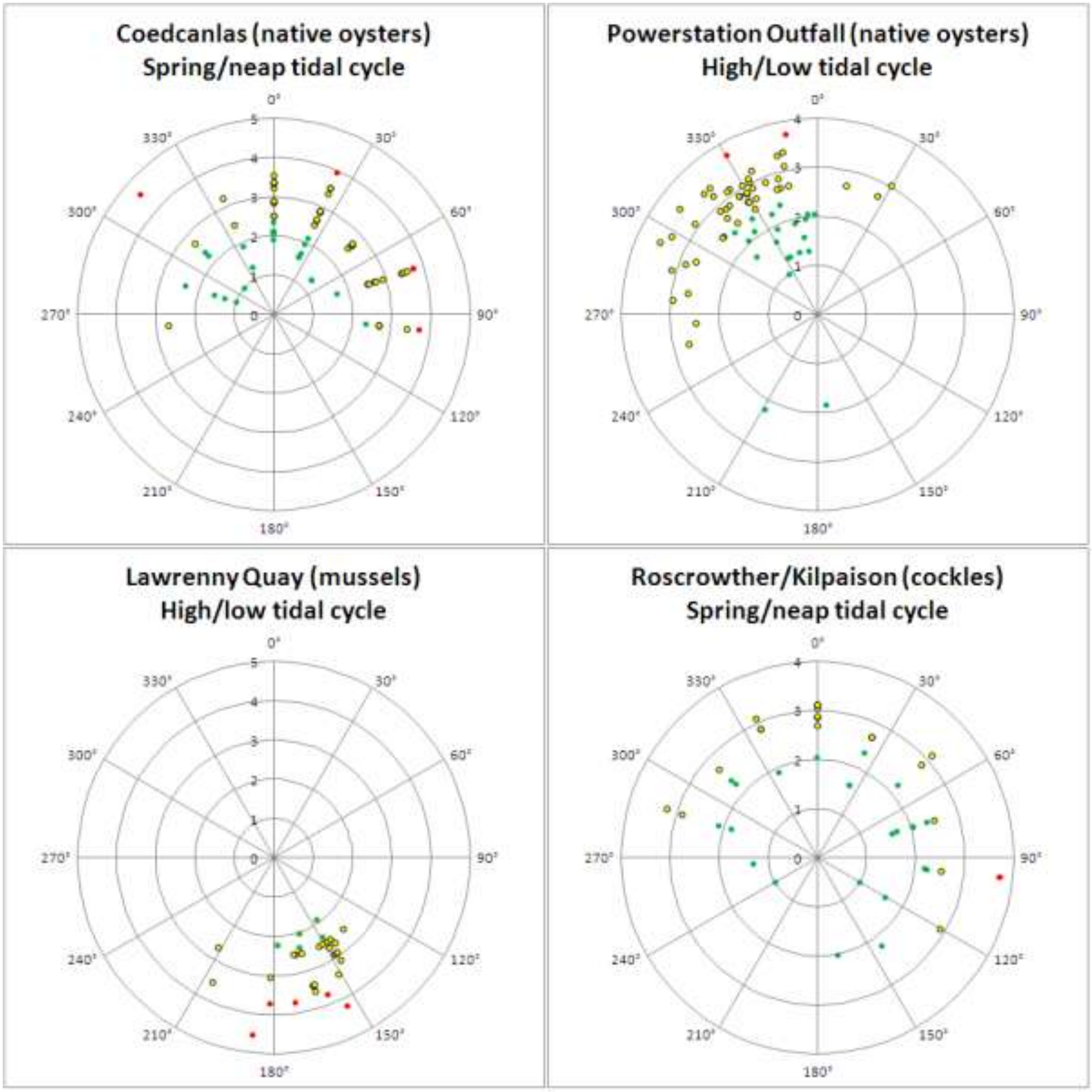


Figure XII.13 Polar plots of log$_{10}$* E. coli *results (MPN/100g) against tidal state for significant correlations found in Table XII.4

At Coadcanalas there appeared to be a slight tendency for lower results as the tide size increased (270 to 0°) compared to around spring tides (0 to 90°). At Powerstation Outfall, more low results were seen nearer high water (315 to 0°) compared to earlier in the flood tide (270 to 315°). This suggests that contamination clears as the cleaner water flows in on the flood tide. No obvious pattern of results in relation to tidal cycle is apparent for either Lawrenny Quay or Roscrowther/Kilpaison. For all cases presented in Figure XII.3, sampling was targeted towards a particular tidal state, any patterns of observed were not particularly strong, and so it is difficult to draw meaningful conclusions about how these variations relate to sources of contamination.

INFLUENCE OF RAINFALL

To investigate the effects of rainfall on levels of contamination within shellfish samples Spearman's rank correlations were carried out between *E. coli* results and rainfall recorded at the Bolton Hill weather station (Appendix II for details) over various periods running up to sample collection. These are presented in Table XII.5, and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Correlations were found at all the native oyster sites. These were strongest at the two sites closest to the head of the estuary (Sprinkle Pill Spit and Coedcanlas). Similar but slightly weaker correlations were found at Ferny Pits, just upstream from the Cleddau Bridge. The pattern was different at the two sites in the lower estuary, where correlations only arose for less recent rainfall, suggesting that there is a lag of several days following rainfall events before the effects are felt here. These observations are consistent with the locations of the main freshwater inputs and the bathymetry and hydrography of the area.

Correlations were found across all four mussel sites including Popton Point for most rainfall totals. Rainfall was not an influence across the cockle beds in Angle Bay and Pembroke River where only two correlations were found both at Metal Box in Pembroke River.

Table XII.5 Spearman's Rank correlations between rainfall recorded at Bolton Hill and shellfish hygiene* E. coli *results

	Site	Sprinkle Pill Spit	Coed-canlas	Ferny Pits	Pennar Gut	Powerstation Outfall	Lawrenny Quay	Mount Pleasant Spit	Jenkins Point	Popton Point	Metal Box	Goldborough Pill	Roscrowther /Kilpaison	Angle Village
	Species	Native oyster	Native oyster	Native oyster	Native oyster	Native oyster	Mussels	Mussels	Mussels	Mussels	Cockles	Cockles	Cockles	Cockles
	No.	45	43	45	48	49	29	47	24	42	24	24	25	15
24 hour periods prior to sampling	1 day	0.187	0.386	0.313	-0.012	0.179	-0.096	0.203	0.133	0.231	0.013	0.029	0.136	-0.004
	2 days	0.188	0.116	0.231	0.097	0.234	0.557	0.431	0.496	0.397	0.005	0.118	-0.017	-0.029
	3 days	0.488	0.484	0.399	-0.047	0.179	0.188	0.491	0.129	0.203	-0.104	-0.302	0.244	0.067
	4 days	0.568	0.561	0.367	0.021	0.253	0.399	0.626	0.357	0.179	0.383	0.298	0.118	0.274
	5 days	0.301	0.434	0.245	0.128	0.391	0.092	0.450	0.460	0.186	0.044	0.022	0.238	0.176
	6 days	0.312	0.366	0.226	-0.022	0.002	0.096	0.319	0.394	0.254	-0.012	-0.090	-0.142	0.393
	7 days	0.258	0.140	0.259	0.293	0.227	-0.029	0.146	0.349	0.142	0.231	0.099	-0.107	0.022
Total prior to sampling over	2 days	0.178	0.308	0.310	-0.026	0.227	0.252	0.327	0.240	0.335	0.038	0.054	0.180	0.051
	3 days	0.302	0.379	0.402	-0.124	0.193	0.234	0.501	0.294	0.330	-0.025	-0.009	0.197	0.007
	4 days	0.495	0.543	0.459	-0.080	0.186	0.353	0.598	0.400	0.364	0.038	0.079	0.253	0.145
	5 days	0.482	0.558	0.461	0.106	0.405	0.323	0.628	0.466	0.404	0.222	0.229	0.276	0.098
	6 days	0.526	0.592	0.480	0.155	0.426	0.327	0.664	0.465	0.412	0.246	0.233	0.276	0.172
	7 days	0.574	0.601	0.533	0.258	0.500	0.426	0.624	0.506	0.508	0.411	0.340	0.183	0.233

APPENDIX XIII
SHORELINE SURVEY

Date (time): 2nd March 2011 (10:00-15:00 GMT) and
3rd March 2011 (09:00-13:00 GMT)

Applicant: Milford Port Health Authority (on behalf of Fenton Duke)

Cefas Officers: Simon Kershaw, Alastair Cook

Local Enforcement Authority Officer: Victor Felstead (2nd March).

Observer: Jayne Griffiths, FSA Wales (3rd March)

Area surveyed: Angle Bay to Picton Point.

Weather: 2nd March – winds E force 2, 6°C, overcast
3rd March – winds NE force 1, 3°C, sunny, some mist

Tidal predictions (Milford Haven):
Admiralty TotalTide – Milford Haven 51°42'N 5°01'W Wales. Times GMT+0000. Milford Haven is a standard port.

02/03/2011			03/03/2011		
High	04:50	6.2m	High	05:30	6.5m
Low	11:13	1.5m	Low	11:50	1.2m
High	17:13	6.2m	High	17:50	6.4m
Low	22:30	1.4m			

Predicted heights are in metres above Chart Datum

Objectives: (a) confirm the location of sources of contamination to the shoreline; (b) identify any additional sources of contamination in the area and; (c) obtain further details of the extent and *modus operandi* of the shellfisheries. A full list of recorded observations is presented in Table XIII.1 and the locations of these observations are mapped in Figure XIII.1. Photographs referenced in the Table XIII.1 are presented in Figures XIII.6-19. The survey was undertaken by boat, covering the area from Stack Rock up as far as Picton Point.

Description of Fishery

The following information was obtained on the various bivalve fisheries through observations made on site and discussions with the applicant and Milford Port Health Authority. Further details will be required in some instances to ensure the full report and sampling plans cover the desired areas.

The application which prompted this survey was for the classification of three areas (one at Milford Shelf, one by Pwllcrochan Flats, and a much smaller one at Wear Point) for carpet shell clams (*Venerupis pullastra*). An application was also received at the same time to extend the native oyster (*Ostrea edulis*) classification to cover the

Milford Shelf. Carpet shell clams are believed to be present in suitable sand, gravel or mud substrates throughout Milford Haven up as far as Carr Rocks and possibly further, so the area for which the application was made is likely to represent only a small fraction of the exploitable area. The applicant indicated that the areas in the application would however contain sufficient stock to meet his individual needs for several years. Although dredging for oysters is permitted within Milford Haven, the type of dredges required for clams is different from those required for oysters as the clams reside within rather than on the bottom, so clam dredges cause more disturbance to the substrate. The use of clam dredges within Milford Haven is not yet approved, and it is possible that the Countryside Council for Wales may oppose this development. At present it is unclear whether a clam dredge may be legally used for the harvesting of clams or the collection of samples.

Native oysters are present throughout estuary from about Thorne Island as far up as Picton Point. During the survey specimens were seen on mussel beds just downstream from Picton Point, under the Cleddau Bridge and in a dredge catch from Pennar Gut indicating a widespread distribution. An application was made for a further area to be classified for this species at the same time as the clam application. This area coincides exactly with the area requiring classification for clams at Milford Shelf. There are thought to be significant stocks within the zone classified as prohibited around Neyland and Pembroke Dock and it would be desirable if the hygiene status of this area could be revisited as improvements to the sewerage network have been made here since the prohibited hygiene status was assigned. The currently classified areas for this species are fished commercially on a part time basis by 3 licensed dredgers.

Pacific oysters (*Crassostrea gigas*) were formerly cultured on trestles within the Cresswell/Carew Rivers, but this no longer occurs and no classifications for Pacific oysters have been issued within Milford Haven since 2002. A possible legacy of this fishery is the presence of small numbers of naturally occurring specimens of this species. Little is known about these stocks, which are thought to be present in the Carew/Cresswell and the main (Cleddau) channel between the Carew/Cresswell and Carron Pill. Whereas there is no specific fishery for this species, it is likely that they are caught in dredges targeting native oysters, so it may be desirable for the dredged areas to be classified for Pacific oysters as well so any catches can be landed and marketed. It is quite possible that significant increases of stocks of this species may occur in future and should this happen increased commercial interest is likely.

Wild stocks of mussels are present in numerous patches throughout Milford Haven, either on raised beds or on rocks. The raised beds are mainly found between the Cleddau Bridge and Picton Point. The extent to which these wild mussel stocks are exploited commercially requires clarification. The construction of a rope mussel farm just outside the mouth of Angle Bay is planned.

Cockles are present in some areas where there is suitable intertidal habitat. The main places where they have been harvested commercially by hand gatherers are the eastern half of Angle Bay, and the intertidal area just south of the Pembroke River Channel. The latter area is now out of bounds to hand gatherers due to its hazardous nature. Cockles are also reported to be present on Pwllcrochan Flats, and during the survey some specimens were seen at Sprinkle Pill, just south of

Picton Point. However, there are currently no classified areas for this species within Milford Haven, so it is assumed that there is no commercial interest in these stocks at present.

Sources of contamination

There are numerous sewage discharges to Milford Haven. The largest of the continuous discharges were observed at Pembroke Dock (observation 21) and at Milford Haven town (observation 10). At both these discharge points distinct patches of discoloured water were observed where the effluent had risen to the surface. Seawater samples were taken from these locations and both contained elevated levels of *E. coli* (3,100 and >10,000 cfu/100ml respectively). Other continuous water company discharges were observed at Neyland (observation 1), Angle Point (observation 15) and Burton Ferry (observation 44). These discharge points are also likely to host intermittent overflow discharges, where untreated sewage may be discharged at times when inflows exceed the treatment capacity of the plant. Other probable intermittent discharges associated with the sewerage network in the area were recorded at Milford Haven (observation 7), Pennar Point (observation 18) and Pembroke Dock (observation 19). Private sewage discharges to the shore of Milford Haven were observed from a few domestic properties. Most of these were to the shore just to the east of Pembroke Dock (observations 22, 45, 46, 47, 48 and 49), and some were actively discharging what appeared to be untreated sewage. A further private discharge pipe was recorded at Whalecombe Farm (observation 43). It is likely that there are further discharges potentially impacting on shellfish within Milford Haven either discharging upstream of Picton Point, to watercourses, or to areas such as the, Colocheston Pill and the Pembroke, Carew and Cresswell River estuaries, or possibly others which were within the area surveyed but which were not visible at the time. Sanitary related debris (rag) was recorded at Gelliswick Bay (observation 12) and on the mussel bed at Sprinkle Pill (observation 36) indicating that discharges of untreated sewage may have occurred near these points relatively recently.

Milford Haven is a significant deep water port, and receives commercial shipping associated with two oil refineries, a liquid natural gas plant, and Pembroke Dock and Ferry Terminal. Commercial shipping is not allowed to discharge sewage to inshore waters, so this traffic is unlikely to be of significance to the shellfisheries. A large amount of smaller craft, mainly yachts and cabin cruisers frequent the Haven, and it is likely that some of these do make overboard sewage discharges at times. There are marinas at Neyland and Milford Haven, and many areas of swinging moorings distributed throughout the Haven, mainly between Pembroke Dock and Picton Point. A large proportion of the moorings were unoccupied at the time of survey, although it is likely that traffic volumes and occupancy rates increase during the warmer months of the year.

Livestock observations were limited to 6 sheep just to the west of Neyland (observation 2) and 105 sheep on the east shore at Beggars Reach (observation 40). It is likely that further livestock were present near the shore, but were obscured by the terrain, and it is anticipated that there are significant numbers of livestock within the wider Milford Haven catchment area.

Seagulls and other waterbirds were present throughout the area, with minor aggregations each of about 100 birds recorded at Gelliswick Bay (observation 12), Burton Ferry (observation 27) and Beggars Reach (observation 40). A few dog walkers were also observed on the north shore just upstream of the Cleddau Bridge.

The main freshwater inputs to Milford Haven are the East and West Cleddau rivers, the estuaries of which converge at Picton Point. Other significant rivers draining to the haven include the Carew, Creswell and Pembroke rivers. In addition to these, there are numerous smaller watercourses. Sampling and flow gauging of these was not undertaken due to a combination of time and access constraints.

Sample results

Surface seawater samples were taken from 19 locations during the course of the survey, four of which contained more than 200 *E. coli* cfu/100ml. All of these four samples were taken at potential ‘hotspots’ of contamination, either from the ‘boils’ associated with sewage discharge points (samples 6, 11 and 19) or from within Neyland Marina (sample 12). For all other samples, *E. coli* counts tended to decrease with increasing distance (via water) from Picton Point, at the upstream end of the survey area (Figure XIII.4, Pearson correlation, $r=-0.740$, $p=0.002$).

Surface salinity measurements indicate a steady increase in salinity from Picton Point, where salinities were between 9 and 10ppt, to the outer part of the haven by Angle Bay, where the salinity was 32.7ppt (i.e. approaching full strength seawater). The correlation between distance from Picton Point and surface salinity was a very strong one (Pearson correlation, $r=0.955$, $p=0.000$). Vertical salinity profiles were taken at four selected locations where there was sufficient depth of water (Figure XIII.3, Table XIII.3), and they indicated that there was little vertical difference in either temperature or salinity at these locations.

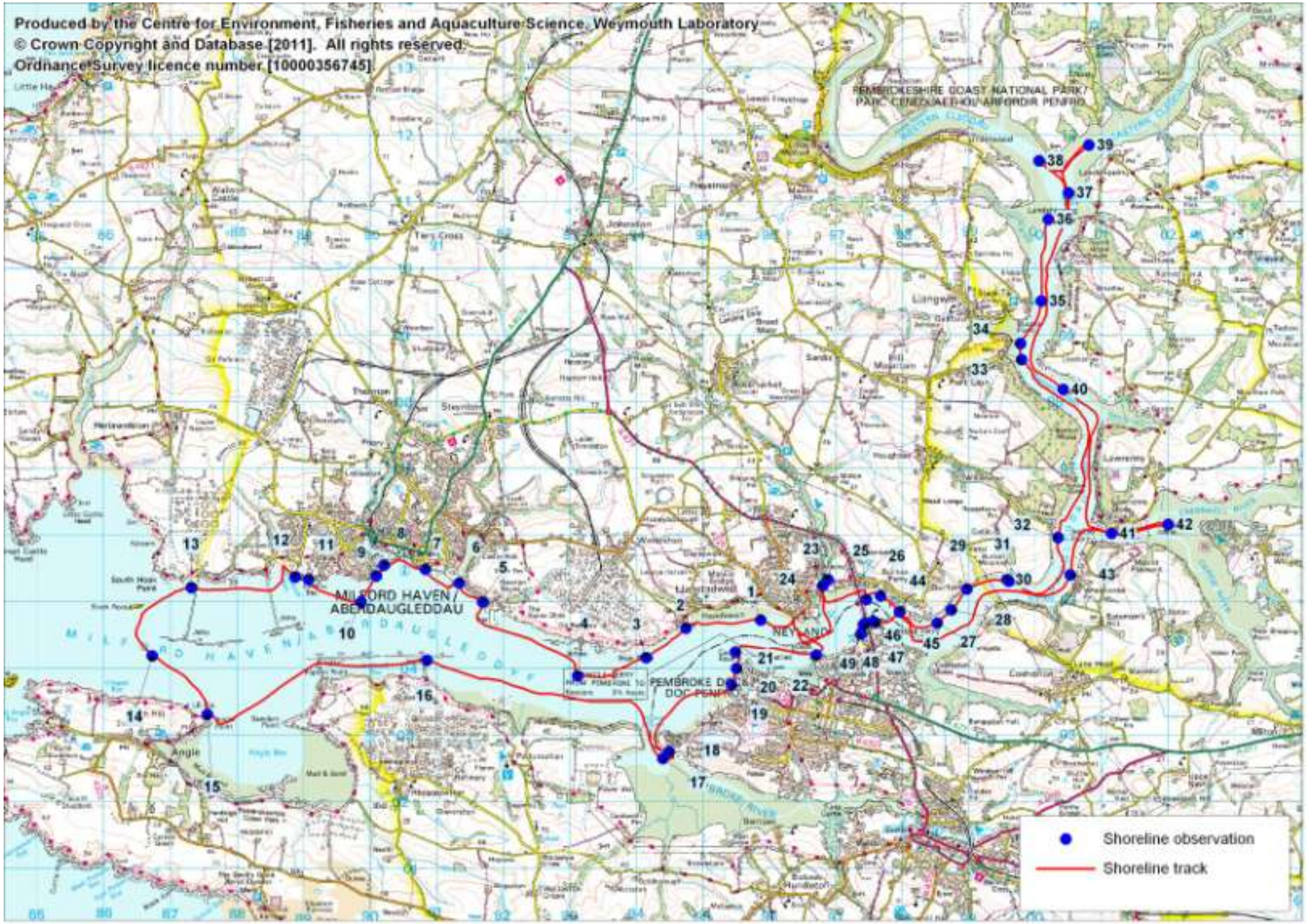


Figure XIII.1. Locations of shoreline observations

Figure XIII.2. Locations of seawater samples annotated with* E. coli *result

Figure XIII.3. Thematic map of surface salinity measurements and location of vertical salinity profiles

Table XIII.1. Details of shoreline observations

No.	Date and time	Position	Photograph	Observation
1	02/03/2011 11:01	SM 95875 04730		Outfall on shore, seawater sample 1
2	02/03/2011 11:10	SM 94747 04603		6 sheep on top of cliff
3	02/03/2011 11:14	SM 94150 04164		30 gulls on shore
4	02/03/2011 12:02	SM 93120 03888		Seawater sample 2. Salinity profile 1.
5	02/03/2011 12:15	SM 91691 04994	Figure XIII.6	Seawater sample 3. Culverted stream.
6	02/03/2011 12:19	SM 91342 05282		Seawater sample 4. 3 small surface water pipes (not flowing). >20 yachts in Castle Pill
7	02/03/2011 12:28	SM 90832 05487	Figure XIII.7	30cm diameter pipe on shore, encased in concrete, not flowing
8	02/03/2011 12:35	SM 90211 05552		Seawater sample 5
9	02/03/2011 12:38	SM 90092 05390	Figure XIII.8	Sewage pumping station on shore
10	02/03/2011 12:43	SM 89861 04997	Figure XIII.9	Outfall marker, seagulls on patch of discoloured water, Seawater sample 6
11	02/03/2011 12:49	SM 89077 05339	Figure XIII.10	broken cast iron pipe, not flowing
12	02/03/2011 12:51	SM 88874 05373		Sailing club on shore. ~100 seagulls. 2 small culverted streams. Piece of sanitary debris (rag) in water
13	02/03/2011 13:04	SM 87309 05213		Seawater sample 7. Possible outfall or intake for LNG plant on shore
14	02/03/2011 13:13	SM 86722 04192		Salinity profile 2
15	02/03/2011 13:23	SM 87550 03309		Outfall pipe, seawater sample 8
16	02/03/2011 13:42	SM 90856 04126		Seawater sample 9. Scum on surface (detergent/chemical) originating from under pier head
17	02/03/2011 13:57	SM 94401 02652		Seawater sample 10. 1 cabin cruiser on mooring
18	02/03/2011 14:00	SM 94497 02750	Figure XIII.11	Outfall (likely to be an intermittent outfall, pumping station on shore, looks new)
19	02/03/2011 14:09	SM 95436 03753		Intermittent discharge outfall
20	02/03/2011 14:11	SM 95513 04002		30cm cast iron pipe down shore, not flowing, disused log treatment plant behind.
21	02/03/2011 14:15	SM 95496 04247		Seawater sample 11 from discoloured water from Pembroke Dock STW discharge
22	02/03/2011 14:22	SM 96706 04203	Figure XIII.12	Pipe to underwater from old house
23	03/03/2011 09:22	SM 96887 05333		Neyland Marina. Many yachts on pontoons.
24	03/03/2011 09:24	SM 96812 05242		Water sample 12 (23.9ppt)
25	03/03/2011 09:30	SM 97466 05036		Salinity profile 3
26	03/03/2011 09:35	SM 97676 05093		Dog walkers on north shore
27	03/03/2011 09:40	SM 98527 04684		~100 seagulls on north shore
28	03/03/2011 09:41	SM 98743 04880		16 boats on moorings
29	03/03/2011 09:42	SM 98974 05193		Rudders boatyard
30	03/03/2011 09:46	SM 99578 05334		Seawater sample 13 (24.5 ppt)
31	03/03/2011 09:49	SM 99609 05310		Salinity profile 4
32	03/03/2011 09:57	SN 00348 05962		Moorings, most unoccupied, 3 boats

No.	Date and time	Position	Photograph	Observation
33	03/03/2011 10:13	SM 99797 08634		Large area of moorings, 6 boats
34	03/03/2011 10:16	SM 99779 08878		Seawater sample 14 (16.8 ppt)
35	03/03/2011 10:22	SN 00095 09514		Area of moorings, 5 occupied
36	03/03/2011 10:41	SN 00204 10738	Figure XIII.13	Mussels, cockles, occasional native oysters, sanitary debris (rag)
37	03/03/2011 10:48	SN 00501 11138		Seawater sample 15 (13.3 ppt). Salinity profile 5
38	03/03/2011 10:56	SN 00062 11619		Seawater sample 16 (9.0 ppt)
39	03/03/2011 11:04	SN 00813 11852		Seawater sample 17 (9.7 ppt)
40	03/03/2011 11:28	SN 00425 08188	Figure XIII.14	~100 seagulls on east shore. 105 sheep in field behind
41	03/03/2011 11:40	SN 01153 06027		Boatyard, large area of moorings
42	03/03/2011 11:45	SN 02005 06163		Seawater sample 18
43	03/03/2011 12:04	SN 00532 05406		Part buried pipe running down shore
44	03/03/2011 12:23	SM 97960 04850		Outfall pipe, small boil visible, seawater sample 19 (22.6 ppt)
45	03/03/2011 12:32	SM 97593 04693	Figure XIII.15	Septic tank, no pipe visible
46	03/03/2011 12:33	SM 97565 04705	Figure XIII.16	Ceramic pipe, not flowing
47	03/03/2011 12:36	SM 97443 04678	Figure XIII.17	Plastic sewer pipe, flowing, grey water with strong odour
48	03/03/2011 12:38	SM 97425 04665	Figure XIII.18	Plastic sewer pipe, dripping, some odour
49	03/03/2011 12:40	SM 97384 04523	Figure XIII.19	Plastic downpipe from house, end buried, may be surface drain or possibly foul water

Table XIII.2. Details of seawater samples taken

Sample	Date & Time	Position	*E. coli* (cfu/100ml)
1	02/03/2011 11:01	SM 95875 04730	90
2	02/03/2011 12:02	SM 93120 03888	20
3	02/03/2011 12:15	SM 91691 04994	6
4	02/03/2011 12:19	SM 91342 05282	60
5	02/03/2011 12:35	SM 90211 05552	25
6	02/03/2011 12:43	SM 89861 04997	>10,000
7	02/03/2011 13:04	SM 87309 05213	7
8	02/03/2011 13:23	SM 87550 03309	3
9	02/03/2011 13:42	SM 90856 04126	29
10	02/03/2011 13:57	SM 94401 02652	9
11	02/03/2011 14:15	SM 95496 04247	3,100
12	03/03/2011 09:24	SM 96812 05242	1,000
13	03/03/2011 09:46	SM 99578 05334	27
14	03/03/2011 10:16	SM 99779 08878	17
15	03/03/2011 10:48	SN 00501 11138	160
16	03/03/2011 10:56	SN 00062 11619	200
17	03/03/2011 11:04	SN 00813 11852	150
18	03/03/2011 11:45	SN 02005 06163	100
19	03/03/2011 12:23	SM 97960 04850	7,800

Table XIII.3. Vertical salinity and temperature profiles

Date and time	NGR	Profile no.	Depth (m)	Salinity (ppt)	Temperature (°C)
02/03/2011 12:02	SM 93120 03888	Salinity profile 1	0	30.3	8.5
			2.5	31.2	8.3
			5	31.4	8.2
			6.5	31.5	8.2
02/03/2011 13:13	SM 86722 04192	Salinity profile 2	0	32.7	8.2
			2.5	33.4	8.2
			5	33.5	8.2
			7.65	33.7	8.3
			10	33.8	8.3
03/03/2011 09:30	SM 97466 05036	Salinity profile 3	0	25.3	14.7
			2.5	25.3	14.6
			5	25.6	14.2
			7.5	25.8	13.7
			9	26.2	13.5
03/03/2011 09:49	SM 99609 05310	Salinity profile 4	0	22.9	13.1
			2.5	23	13.1
			5	23.3	13.1
			7	23.4	13.2

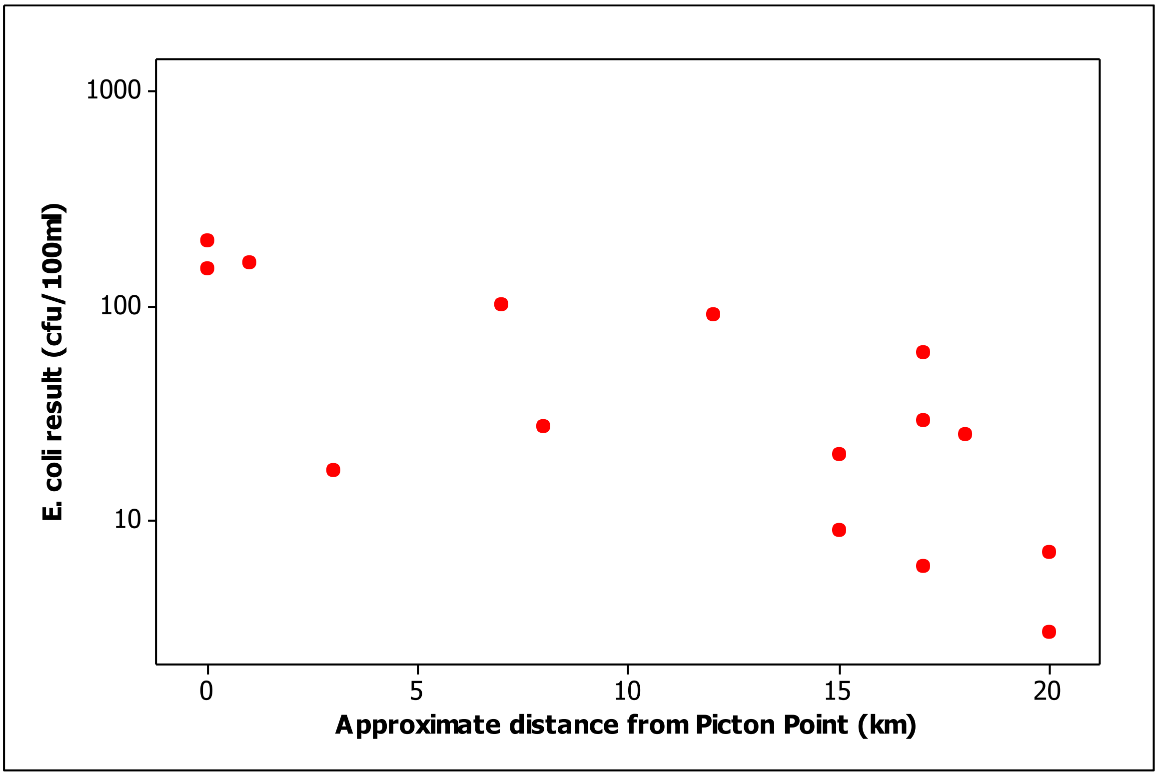


Figure XIII.4. Scatterplot of E. coli results for surface seawater samples not taken from identified 'hotspots' against approximate distance (via water) from Picton Point.

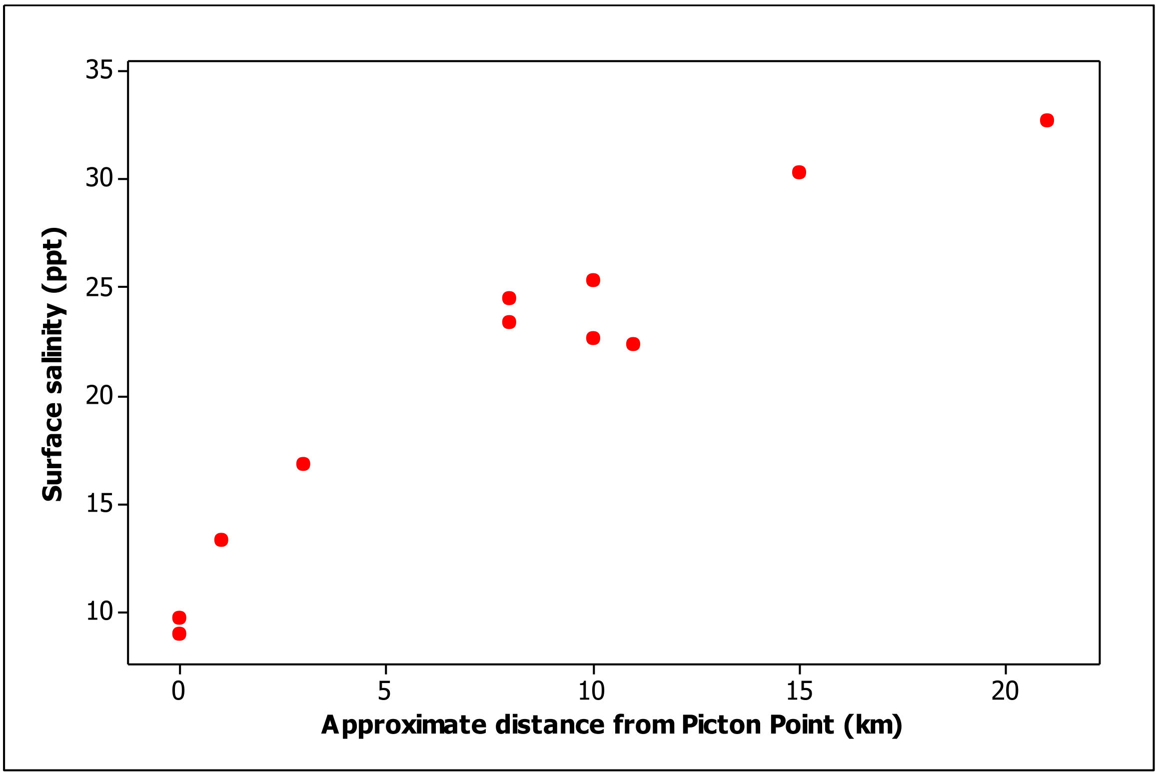


Figure XIII.5. Scatterplot of surface salinity readings against approximate distance (via water) from Picton Point.

Conclusions

Levels of contamination in the water column generally increased towards the head of the estuary, as salinity decreased correspondingly, suggesting that land runoff carried by the Cleddau rivers is a significant source to the upper estuary. Overlaid on this 'hotspots' of contamination were seen in the vicinity of continuous sewage discharges where a 'boil' of discoloured water could be observed and sampled. The main continuous sewage discharges to the Haven are the Pembroke Dock outfall, the Neyland outfall, and the Milford Haven (town) outfall. Smaller sewage works outfalls were seen at the mouth of Angle Bay and at Burton Ferry. A handful of small private domestic outfalls, some of which appeared to be discharging raw sewage were recorded on the south shore under the Cleddau Bridge, which may also be of local significance.

The Haven is used by large numbers of yachts and cabin cruisers, with several significant areas of moorings from Pembroke Dock up as far as Llangwm, and major marinas at Neyland and Milford Haven Town. Overboard discharges made by these vessels may be a significant contaminating influence at times, more so in the summer when numbers and occupancy rates are likely to be higher.

Potential sources which may cause significant spatial variation in levels of contamination across the clam beds and the oyster bed for which classification has been requested include:

- Milford Haven Town sewage outfall (continuous sewage discharge).

- An intermittent outfall between Milford Haven Town docks and Castle Pill (observation 7).
- Freshwater inputs via Milford Haven Docks, Castle Pill, an unnamed culverted stream (observation 5), the Pembroke River, and a small unnamed stream discharging across the Pwllcrochan Flats.
- Yacht traffic, which is likely to be most intense in the area just offshore of Milford Haven town.

Therefore, the area at Milford Shelf is likely to be subject to contamination from several significant local sources, the area by Pwllcrochan flats may be subject to contamination originating from land runoff at either end, and no significant local sources have been identified as yet for the smaller area at Wear Point.

Photographs

Figure XIII.6

Figure XIII.7

Figure XIII.8

Figure XIII.9

Figure XIII.10

Figure XIII.11

Figure XIII.12

Figure XIII.13

Figure XIII.14

Figure XIII.15

Figure XIII.16

Figure XIII.17

Figure XIII.18

Figure XIII.19

References

ASHBOLT, J. N., GRABOW, O. K., SNOZZI, M., 2001. Indicators of microbial water quality. *In* Fewtrell, L. and Bartram, J. (Eds). Water quality: guidelines, standards and health. IWA Publishing, London. pp. 289−315.

BOYLE, D. P., 2010. Grey Seal Breeding Census: Skomer Island, 2010. Wildlife Trust of South and West Wales CCW Regional Report CCW/WW/10/07

BROWN J., 1991. The final voyage of the Rapaiti. A measure of surface drift velocity in relation to the surface wind. *Marine Pollution Bulletin* 22: 37-40.

BURTON, S., 2008.Pembrokeshire Marine Special Area of Conservation. Management Scheme. Produced by Sue Burton on behalf of the Relevant Authorities Group, April 2008.

COUNCIL OF THE EUROPEAN COMMUNITIES, 1975. Council Directive 76/160/EEC of 8 December 1975 concerning the quality of bathing water. *Official Journal* L031: 0001-0007.

CEFAS, 2010. Sanitary survey of the North Wirral coast. 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.

CEFAS, 2011. Protocol for the Classification of Shellfish Harvesting Areas – England and Wales.

DEFRA, 2009. Pigs and Poultry Farm Practices Survey 2009 – England. http://www.defra.gov.uk/evidence/statistics/foodfarm/enviro/farmpractice/documents/FPS2009-pigspoultry.pdf. Accessed 25 October 2010.

EMU LTD, 2003. A survey of native oyster beds (Ostrea edulis) in Wales. Report No. 03/J/1/03/0458/0338, commissioned by CCW.

ENVIRONMENT AGENCY, 2011. WaterDischarge Permitting . Disinfection of wastewater operatinal instruction 347_09 Issued 07/11/2011 http://publications.environment-agency.gov.uk/PDF/GEHO0310BSBA-E-E.pdf. Accessed 18 June 2012.

ENVIRONEMENT AGENCY, 2009. Directive (2006/113/EC) on the quality required of shellfish waters. Article 5 Programme, Ribble Estuary.

EUROPEAN COMMUNITIES, 2004. EC Regulation No 854/2004 of the European Parliment and of the Council of 29 April 2004 laying down specific hygiene rules on products of animal origin intended for human consumption. *Official Journal of the European Communities* L226: 83-127.

EUROPEAN COMMUNITIES, 2006. Directive 2006/113/EC of the European parliament and of the Council of 12 December 2006 on the quality required of shellfish waters (codified version). Official Journal of the European Communities L376: 14-20.

EU WORKING GROUP ON THE MICROBIOLOGICAL MONITORING OF BIVALVE HARVEST AREAS (2010). Microbiological Monitoring of Bivalve Harvest Areas. Guide to Good Practice: Technical Application. Issue 4, August 2010.

FUTURECOAST, 2002. Department of Environment, Food and Rural Affairs (Defra), Halcrow Group Ltd 3 CD set.

GELDREICH, E.E. 1978. Bacterial and indicator concepts in feces, sewage, stormwater and solid wastes. *In* Berg, G. (ed.). *Indicators of Viruses in Water and Food.* MI: Ann Arbor.

HOLT, C., AUSTIN, G., CALBRADE, N., MELLAN, H., MITCHELL, C., STROUD, D., WOTTON, S., MUSGROVE, A., 2011. Waterbirds in the UK 2009/10. The Wetland Bird Survey.

HUGHES, C., GILLESPIE, I.A., O'BRIEN, S.J., 2007. Foodborne transmission of infectious intestinal disease in England and Wales 1992-2003. *Food Control* 18: 766−772.

KAY, D, CROWTHER, J., STAPLETON, C.M., WYLER, M.D., FEWTRELL, L., ANTHONY, S.G., BRADFORD, M., EDWARDS, A., FRANCIS, C.A., HOPKINS, M. KAY, C., MCDONALD, A.T., WATKINS, J., WILKINSON, J., 2008a. Faecal indicator organism concentrations and catchment export coefficients in the UK. Water Research 42, 442-454.

KAY, D., CROWTHER, J., STAPLETON, C.M., WYER, M.D., FEWTRELL, L., EDWARDS, A., FRANCIS, C.A., MCDONALD, A.T., WATKINS, J., WILKINSON, J., 2008b. Faecal indicator organism concentrations in sewage and treated effluents. *Water Research* 42: 442-454.

LEE, R.J., YOUNGER, A.D., 2002. Developing microbiological risk assessment for shellfish purification. *International Biodeterioration and Biodegradation* 50: 177−183.

LEES, D.N., 2000. Viruses Viruses in bivalve shellfish. *Int. J. Food. Microbiol.* 59: 81-116.

MET OFFICE, 2012. Regional Climates. Available at: http://www.metoffice.gov.uk/climate/regional/ Accessed March 2012.

METOC, 2008. Milford Haven water quality model validation. Report No. 1841, REV 0. Issued 18 February 2008.

MITCHELL, P. IAN, S. F. NEWTON, N. RATCLIFFE & T. E. DUNN, 2004. Seabird Populations of Britain and Ireland, Results of the Seabird 2000 Census (1998-2002). T&AD Poyser, London.

Nelson-Smith, A., 1965. Marine biology of Milford Haven: The physical environment. *Field Studies* 2, 155-188.

NERC, 2011. UK guaging station network. Available at: http://www.ceh.ac.uk/data/nrfa/uk_gauging_station_network.html

OBIRI-DANSO, K., JONES, K., 2000. Intertidal sediments as reservoirs for hippurate negative campylobacters, salmonellae, and faecal indicators in three EU recognised bathing waters in North-West England. *Water Research* 34(2): 519−527.

PEMBROKESHIRE TOURISM INDUSTRY WEBSITE, 2011. Pembrokeshire's Facts of Tourism. Available at www.tourismhelp.co.uk/objview.asp?object_id=460.

SMRU, 2010. Scientific Advice on Matters Related to the Management of Seal Populations: 2009. http://www.smru.st-andrews.ac.uk/documents/341.pdf

SYVRET, M., FITZGERALD, A., HOARE, P., 2008. Development of a Pacific oyster aquaculture protocol for the UK – Technical report to the Sea Fish Industry Authority, Project No. 07/Eng/46/04.

YOUNGER, A.D., LEE, R.J., LEES, D.N. 2003. Microbiological monitoring of bivalve mollusc harvesting areas in England and Wales: rationale and approach. In: Villalba, A., Reguera, B., Romalde, J. L., Beiras, R. (eds). Molluscan Shellfish Safety. Consellería de Pesca e Asuntos Marítimos de Xunta de Galicia and Intergovernmental Oceanographic Commission of UNESCO, Santiago de Compostela, Spain. pp. 265−277.

YOUNGER, A.D., REESE, R.A.R.,. 2011. *E. coli* accumulation compared between mollusc species across harvesting sites in England and Wales. Cefas/FSA internal report.

List of Abbreviations

AONB	Area of Outstanding Natural Beauty
BMPA	Bivalve Mollusc Production Area
CD	Chart Datum
Cefas	Centre for Environment Fisheries & Aquaculture Science
CFU	Colony Forming Units
CSO	Combined Sewer Overflow
CZ	Classification Zone
Defra	Department for Environment, Food and Rural Affairs
DWF	Dry Weather Flow
EA	Environment Agency
E. coli	*Escherichia coli*
EC	European Community
EEC	European Economic Community
EO	Emergency Overflow
FIL	Fluid and Intravalvular Liquid
FSA	Food Standards Agency
GM	Geometric Mean
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
NWSFC	North Western Sea Fisheries Committee
OSGB36	Ordnance Survey Great Britain 1936
mtDNA	Mitochondrial DNA
PS	Pumping Station
RMP	Representative Monitoring Point
SAC	Special Area of Conservation
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, gulleys, etc. In some areas, storm water is collected and discharged to separate sewers, whilst in combined sewers it forms a diluted sewage.
Waste water	Any waste water but see also “sewage”.

Summary of consultations on draft report

Consultee	Comment	CEFAS response
Welsh Government Fisheries	Mussel bed at Lawrenny Quay that was closed by the former IFCA has now reopened. There is an additional occasional cockle bed east of Lawrenny Quay in the Creswell Estuary.	Report adjusted to reflect this. Report and sampling plan adjusted to reflect this.
DCWW	None	-
Milford Haven Port Health Authority	Whilst the native oyster dredge fishery has a closed season above the bridge, hand gathering may occur at any time of the year here (although it does not).	Report and sampling plan adjusted accordingly to ensure classification is year round upstream of the bridge.
Environment Agency	None	-

Acknowledgements

Cefas would like to thank Victor Felstead, Carwyn Thomas and Gary Tawn, Milford Haven Port Authority, Phil Coates, Welsh Government Fisheries and Stuart Neil, Welsh Government Agriculture, and Environment Agency Wales.