Scottish Sanitary Survey Project

Sanitary Survey Report
Oitir Mhòr Bay
AB 308
March 2011

Cefas

Food Standards Agency
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Report Distribution – Oitir Mhòr Bay

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1. General Description

Oitir Mhòr Bay is located on the north-western shore of the island Kerrera, situated in the Firth of Lorn west of Oban. Oitir Mhòr Bay is approximately 1.5km in length and faces north-west. The bay is sheltered from the prevailing south-west winds.

Oban is the nearest town to Oitir Mhòr Bay, lying approximately 3km to the west, with a population of approximately 8,120 (from the 2001 population census). The town is popular for sailing as well as a popular tourist destination, and also boasts a large fishing fleet.

Figure 1.1 shows the location of Oitir Mhòr Bay on the island of Kerrera.

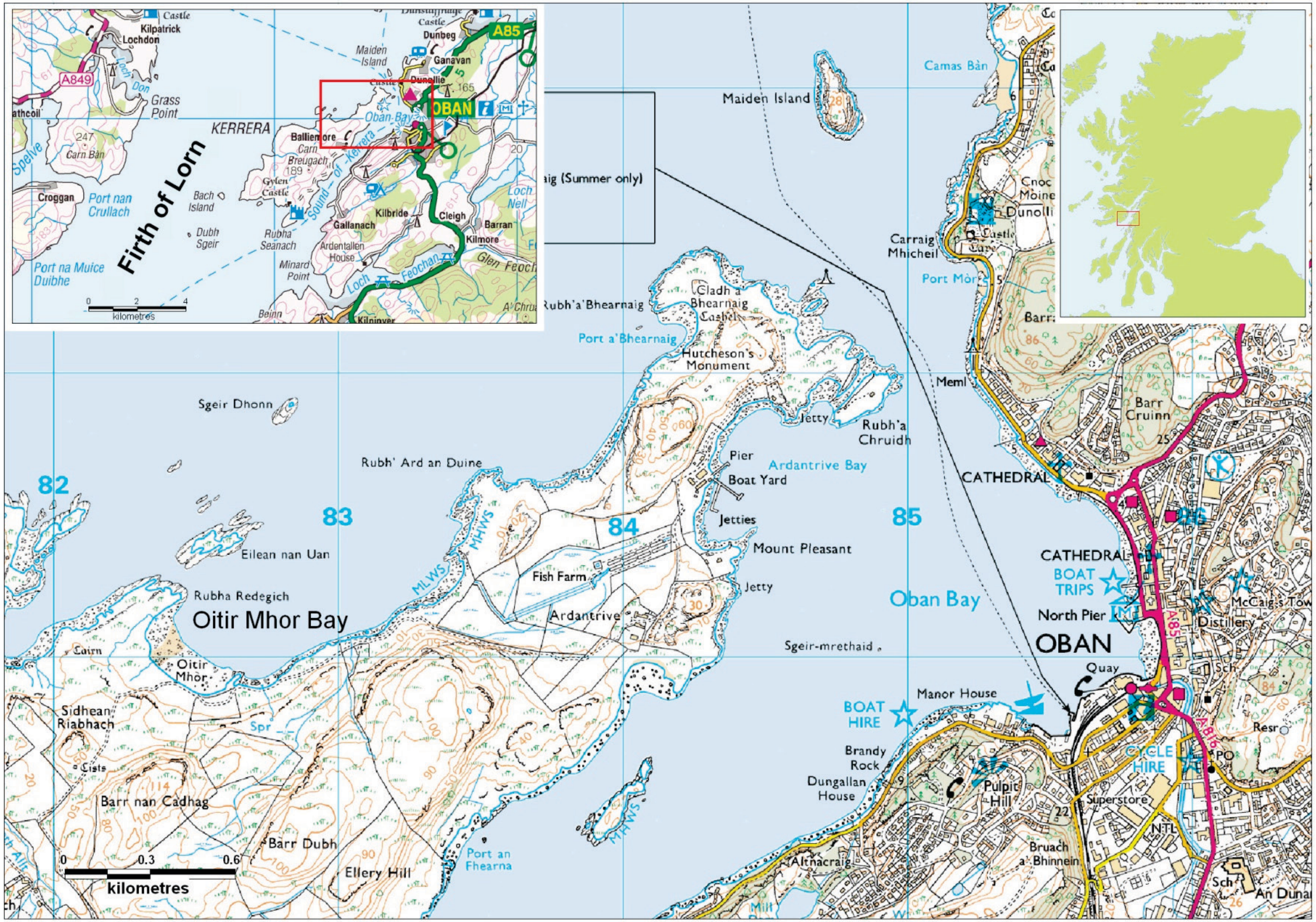


Figure 1.1 Location of Oitir Mhòr Bay

2. Fishery

The sanitary survey was being undertaken as a result of the ranking of the production area in the risk matrix assessment. The ranking was primarily caused by the number of unusual results (i.e. results outwith classification), changes in classification status over a 3 year period, the species involved (Pacific oysters) and the population in the surrounding area.

A restricted sanitary survey was carried out for periwinkles in the bay in 2008. However, the potential sources of contamination were only considered in an area directly adjacent to the production area, and the Pacific oysters were only taken into account in terms of the historic *E. coli* data.

Table 2.1 Oitir Mhòr Bay shellfish farms

Production Area	Site	SIN	Species
Oitir Mhòr Bay	Oitir Mhòr	AB 308 701 13	Pacific Oyster

The Oitir Mhòr Bay Pacific oyster production area is defined by an area bounded by lines drawn between NM 8236 3028 and NM 8348 3050 extending to MHWS. The RMP is located at NM 825 300.

There are no Crown Estate (CE) lease areas within the production area.

Oitir Mhòr Bay falls within a designated shellfish growing water (SGW) which was designated in 2002 and covers an area of 0.4km^2. The SGW is an area inshore of a line drawn between NM 824 303 and NM 834 306 (Rubh'Ard an Duine) and extending to MLWS.

The fishery consists of a small intertidal area of 48 trestles with full bags of oysters, and four empty trestles. Much of the stock was at harvestable size at the time of the sanitary survey, and harvesting had begun the week previous to the shoreline survey. The official RMP is located approximately 100m from the oyster trestles. A sample bag of mussels maintained at that location for biotoxin testing.

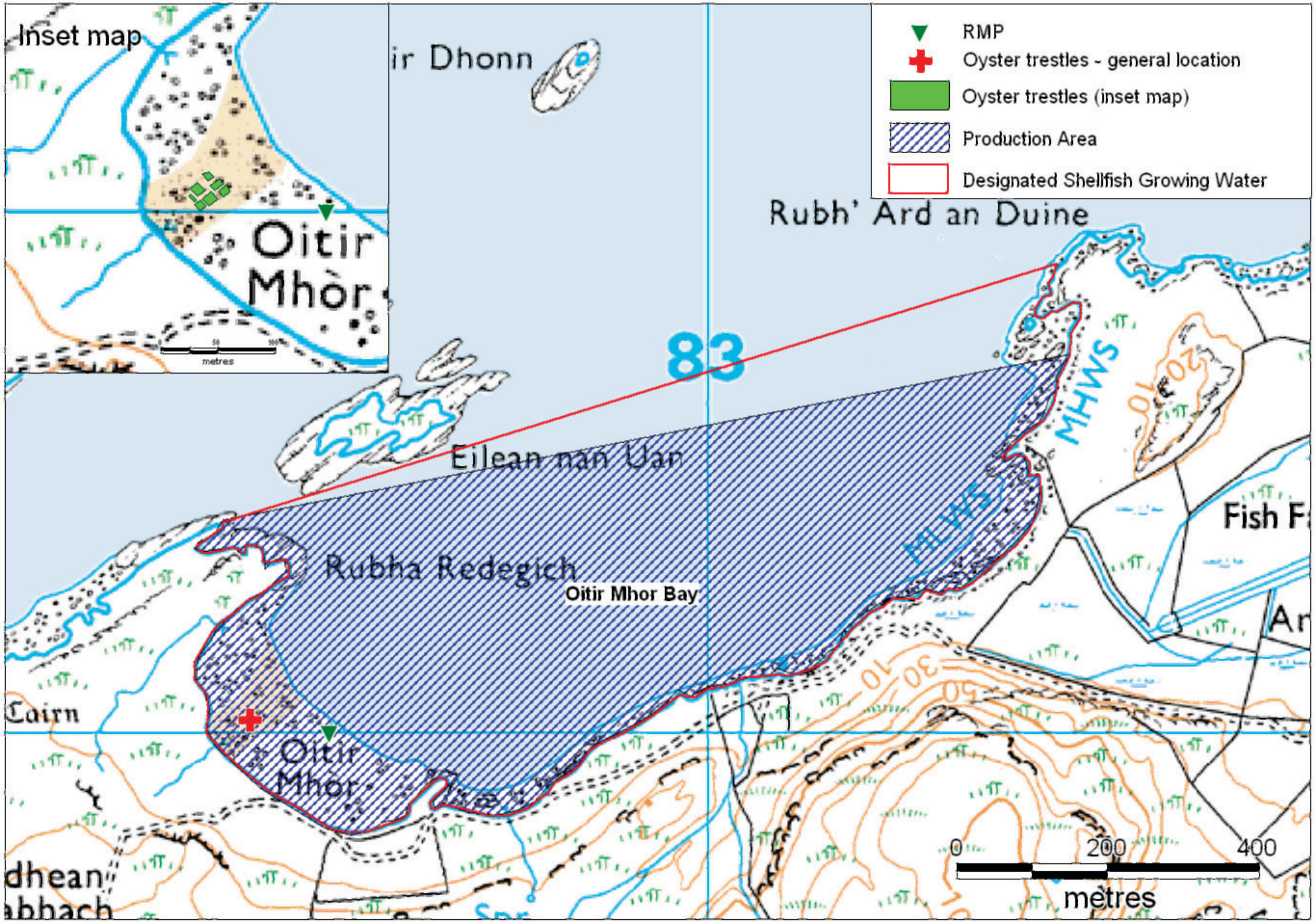
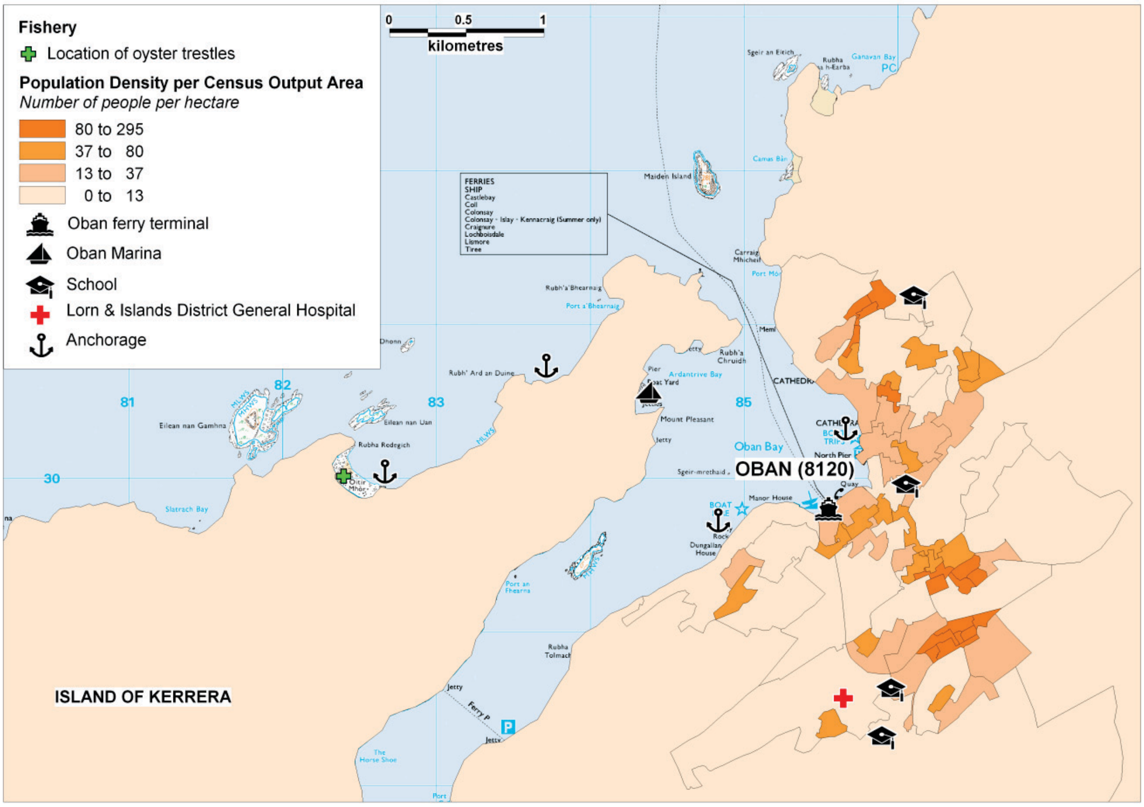


Figure 2.1 Oitir Mhòr Bay oyster fishery

3. Human Population

Figure 3.1 shows information obtained from the General Register Office for Scotland on the population within the census output areas in the vicinity of Oitir Mhòr Bay. The last census was undertaken in 2001.



Produced by Cefas Weymouth Laboratory © Crown copyright and Database 2011. All rights reserved FSA, Ordnance Survey Licence number GD100035675. 2001 Population Census Data, General Register Office, Scotland.

Figure 3.1 Human population surrounding Oitir Mhòr Bay

Figure 3.1 shows the population density for the census output areas in the area surrounding Oitir Mhòr Bay. The northern end of the island of Kerrera is very sparsely populated and there are very few dwellings in close proximity to the oyster farm. The entire island has a population of approximately 40 residents. During the shoreline survey six houses were observed, five of which were around Ardantrive Bay of the east side of Kerrera and one which was on the north east shoreline of Oitir Mhòr Bay. There is a B&B in Ardantrive. There are two historical attractions on the island, Gylen Castle at the south end of the island and Hutcheson's Monument at the very north end of the island. Oban Marina is located at Ardantrive bay and this has 94 floating pontoon berths, 33 moorings a fuel berth, 4 shower rooms, laundry facilities and a restaurant.

The town of Oban, population 8120, is located 3 km from Oitir Mhòr Bay on the mainland. Oban is a popular tourist attraction and in Oban and the surrounding area there are museums, a Sea Life Centre, McCaig's Tower and the Oban Distillery. There is a district general hospital on the southern outskirts of the town. There are also three primary schools with approximately 664 pupils in total and a high school with the capacity for 1150 pupils.

There is a large ferry terminal at Oban harbour where Caledonian MacBrayne provide a return ferry to the Isle of Mull 6-7 times a day, in addition to a twice daily ferry service to Kerrera. There are also ferries from Oban to Lismore, Lochboisdale, Craignure, Castlebay, Coll, Tiree and Colonsay. Large cruise ships often dock outside Oban harbour and smaller ferries will run between the cruise ship and harbour for the passengers. There are also several tourist sightseeing and fishing trip boats that operate from the harbour. There are four anchorages in the area surrounding Oitir Mhòr Bay. The first is located directly adjacent to the oyster trestles, the second is in the next bay to the east of Oitir Mhòr Bay and the remaining two are located near Oban.

4. Sewage Discharges

Scottish Water identified several community septic tanks and sewage discharges for the area surrounding Oitir Mhòr Bay. They are detailed in Table 4.1 and mapped in Figure 4.1. No sanitary or microbiological data were available for these discharges.

Table 4.1 Discharges identified by Scottish Water

Consent Ref No.	NGR of discharge	Discharge Name	Discharge Type	Level of Treatment	Consented flow m^3/day	Consented Design PE
CAR/L/1003475	NM 8490 3060	Oban STW	Continuous	Secondary	4958	26600
CAR/L/1000554	NM 8581 2998	Oban George Street CSO	Intermittent	10mm screening	4998	22200
	NM 849 306	Oban Corran Parks WWPS	Intermittent	6mm screening	4998	22200
CAR/L/1000781	NM 8585 3062	Oban Burnbank Crescent CSO	Intermittent	6mm screening	605	Not stated
CAR/L/1000780	NM 8555 2972	Oban Alma Crescent CSO	Intermittent	15mm screening	173	Not stated
CAR/L/1000779	NM 8606 2930	Oban Soroba Road CSO	Intermittent	15mm screening	1037	Not stated
CAR/L/1000889	NM 8592 3259	Ganavan WWPS (EO only)	Intermittent	10mm screening	Not stated	Not stated

SEPA provided information regarding a number of discharge consents held for the area of Oitir Mhòr Bay. These are listed in Table 4.2 and mapped in Figure 4.1. At the time of writing this report, full details of some discharge consents were not available. Only one of these is located on the island of Kererra and none of these discharge directly to Oitir Mhòr Bay. The closest discharge, discharges into Charlotte Bay which is located east of Oitir Mhòr Bay. Details of the soakaways can be found in the appendices.

Table 4.2 Discharge consents identified by SEPA

No.	Ref No.	NGR of discharge	Consented flow (DWF) m^3/d	Consented /design PE	Discharges to
1	CAR/L/1008759	NM 8350 30700	-	-	Charlotte Bay, Firth of Lorne
2	CAR/R/1009285	NM 84511 30847	-	6	Ardantrive Bay, Sound of Kerrera
3	CAR/R/1081644	NM 84860 30860	-	6	Sound of Kerrera
4	CAR/R/1069872	NM 84310 30570	-	-	Ardantrive Bay, Sound of Kerrera
5	CAR/L/1008857	NM 84470 30320	-	-	Ardantrive Bay, Sound of Kerrera
6	CAR/R/1038293	NM 84043 29958	-	10	Sound of Kerrara
7	CAR/R/1022607	NM 84750 29250	-	5	U/T of Sound of Kerrera
8	CAR/L/1003525	NM 84810 29460	-	-	Sound of Kerrera
9	CAR/L/1000779	NM 86044 29338	1037	-	CSO to Black Lynn Burn to Sound of Kerrera
10	CAR/L/1000780	NM 85508 29727	173	-	CSO to Oban Bay, Sound of Kerrera
11	CAR/L/1000554	NM 85793 30010	4958	26600	CSO to Oban Bay, Sound of Kerrera
12	CAR/R/1039984	NM 86619 29730	-	6	Alltan Tertach, Oban
13	CAR/R/1039448	NM 86596 29768	-	5	U/T of Alltan Tartach, Oban
14	CAR/L/1000552	NM 85623 30556	-	-	CSO to Sound of Kerrera

No.	Ref No.	NGR of discharge	Consented flow (DWF) m^3/d	Consented /design PE	Discharges to
15	CAR/L/1000781	NM 85871 30609	605	-	CSO to U/T of Oban Bay, Sound of Kerrera
16	CAR/L/1003475	NM 85185 30824	4958	26600	Oban Bay, Sound of Kerrera
17	CAR/R/1039308	NM 85340 31870	-	6	Camas Ban, Firth of Lorne
18	CAR/R/1014806	NM 85335 31871	-	5	Firth of Lorne
19	CAR/R/1014140	NM 85380 32040	-	5	Firth of Lorne
20	CAR/R/1013629	NM 85399 32030	-	5	Firth of Lorne
21	CAR/R/1014557	NM 85370 32080	-	5	Camas Ban, Firth of Lorne
22	CAR/R/1037465	NM 85370 32060	-	5	Camas Ban, Firth of Lorne
23	CAR/R/1038157	NM 85740 32540	-	10	Firth of Lorne
24	CAR/L/1000889	NM 85920 32590	-	-	Ganavan Bay, Firth of Lorne
25	CAR/L/1003316	NM 86052 32694	-	1	Ganavan Bay, Firth of Lorne

Entry 16 in Table 4.2 relates to the Oban STW continuous discharge.

Sewage infrastructure recorded during the 2010 and 2008 shoreline surveys are listed in Table 4.3.

Table 4.3 Discharges and septic tanks observed during shoreline surveys

No.	Date	NGR	Description
A	16/10/2008	NM 8310 3002	Septic tank for new house, no discharge pipe
1	25/08/2010	NM 84310 30600	Marina toilet and shower block
2	25/08/2010	NM 84525 30888	House, possibly only used as a holiday home. Septic tank with outlet pipe
3	25/08/2010	NM 84593 30843	Small island with one house currently under construction. Old house had a septic tank
4	25/08/2010	NM 84838 29420	Gallanach pumping station
5	25/08/2010	NM 84983 29641	Pipe
6	25/08/2010	NM 85013 29704	Slipway with pipe
7	25/08/2010	NM 85170 29812	Back of three houses, no sign of any sewage discharges
8	25/08/2010	NM 85522 29708	CSO? Not accessible to take sample
9	25/08/2010	NM 85799 30351	Pipe running off beach, possibly redundant
10	25/08/2010	NM 85694 30496	Possibly overflow pipe with grill over the end

The septic tank for the new house observed during the 2008 shoreline survey is most likely to discharge to soakaway as no discharge pipe was observed. Should this become clogged and fail to operate properly, septic waste from the property would impact the eastern half of the shoreline along Oitir Mhòr Bay.

As well as Oban Marina on the north-east of Kerrera, there are recommended anchorages in both Oitir Mhòr Bay and Charlotte Bay (see Figure 3.1). Discharges from yachts are likely during the summer season when yachts looking to avoid congestion in Oban are most likely to use the anchorage in Oitir Mhòr (Clyde Cruising Club, 2007).

The discharges at Oban are a separated from the production area by both distance and topography and are less likely to significantly impact the fishery at Oitir Mhòr than other sources more local to the fishery.

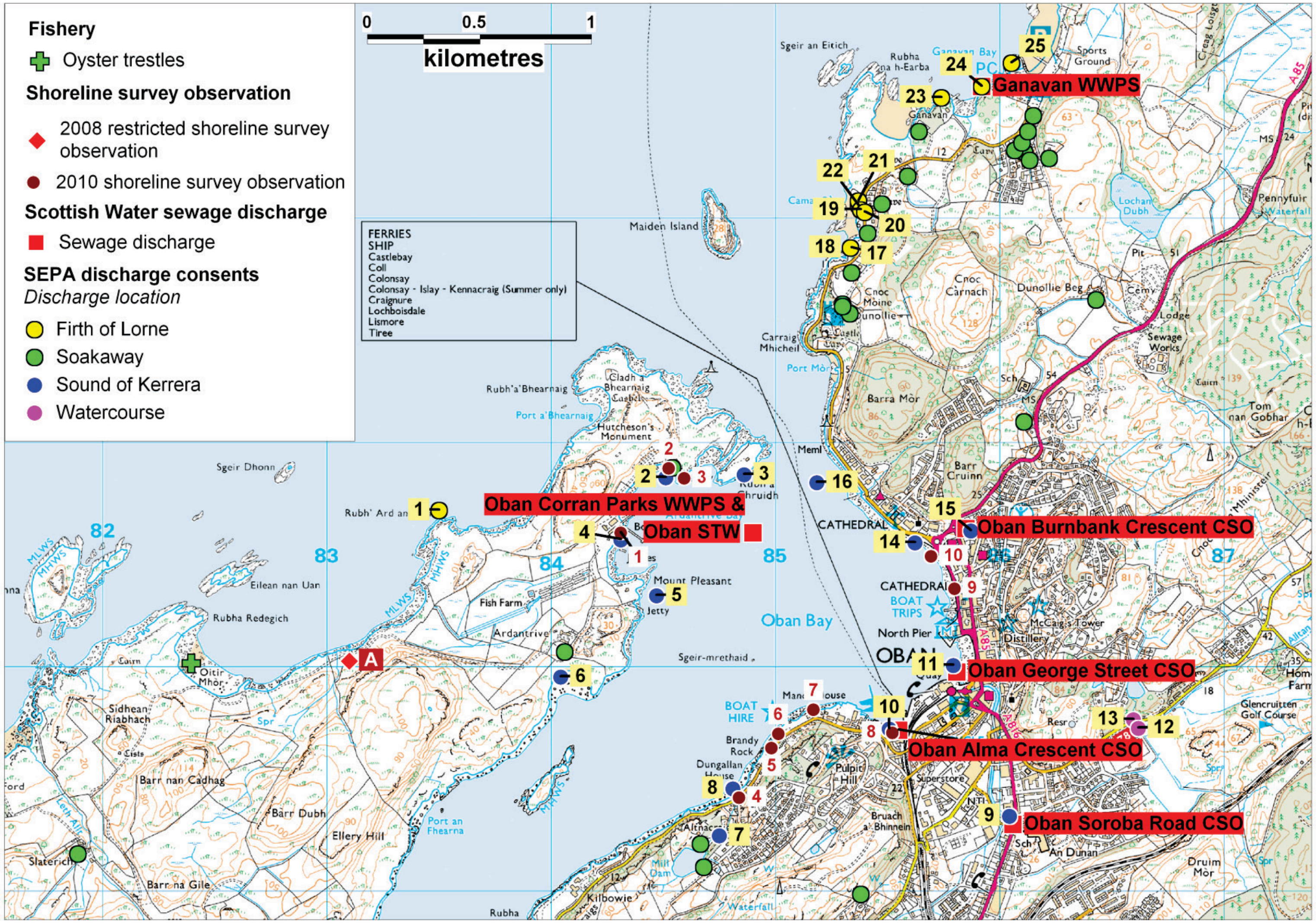


Figure 4.1 Map of discharges for Oitir Mhòr Bay

5. Geology and Soils

Geology and soil types were assessed following the method described in Appendix 3. A map of the resulting soil drainage classes is shown in Figure 5.1. Areas shaded red indicate poorly draining soils and areas that are shaded blue indicate freely draining soils. Solid grey areas indicate predominantly impermeable surfaces on built-up areas.

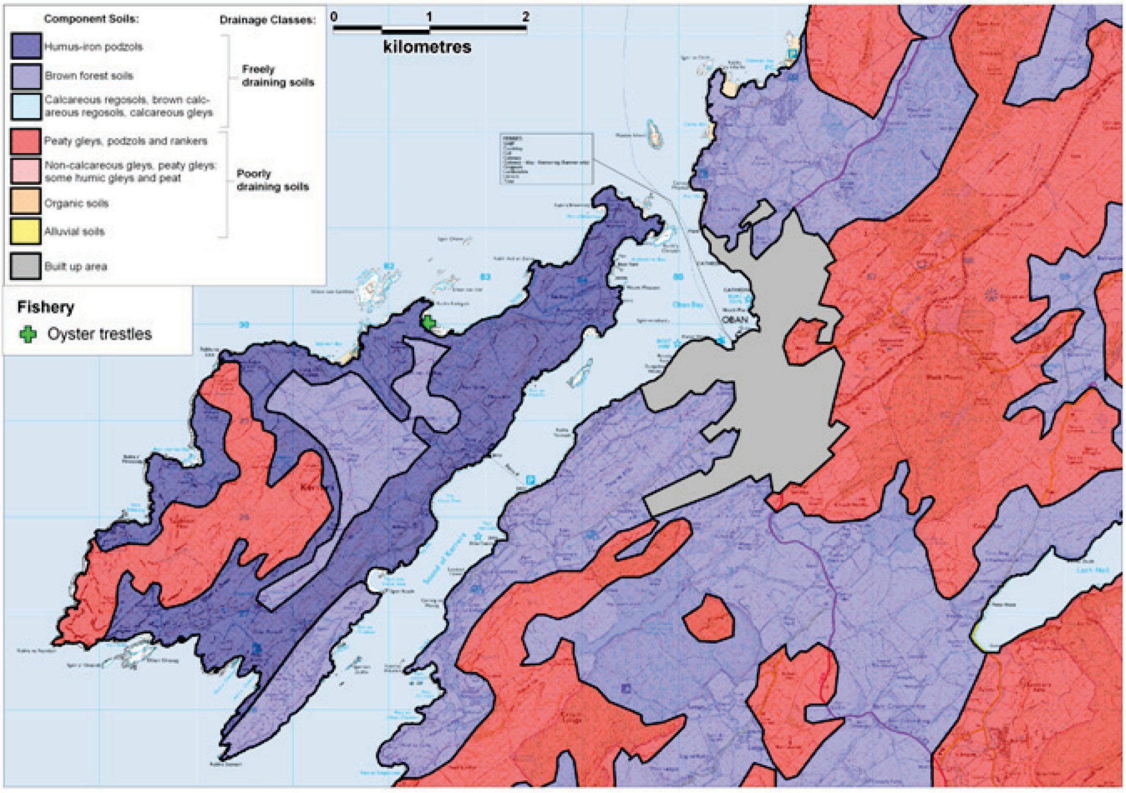


Figure 5.1 Component soils and drainage classes for Oitir Mhòr Bay

Three types of component soils are present in the area: peaty gleys, podzols and rankers, humus-iron podzols and brown forest soils. The humus-iron podzols surround Oitir Mhòr Bay and the majority of the east coast of Kerrera. Brown forest soils are present either side of Oban along the coastline and also on Kerrera. There are areas of peaty gleys, podzols and rankers further inland on the mainland and also at the south-western end of Kerrera. The built-up area represents Oban. Overall, the potential for runoff contaminated with *E. coli* from human and/or animal waste will be low from the area immediately surrounding Oitir Mhòr Bay and high from the built-up Oban area, although this 3 km away (direct line distance).

For information on how these soil types and permeability characteristics were derived, please see the geology and soils document in the appendix.

6. Land Cover

The Land Cover Map 2000 data for the area is shown in Figure 6.1 below:

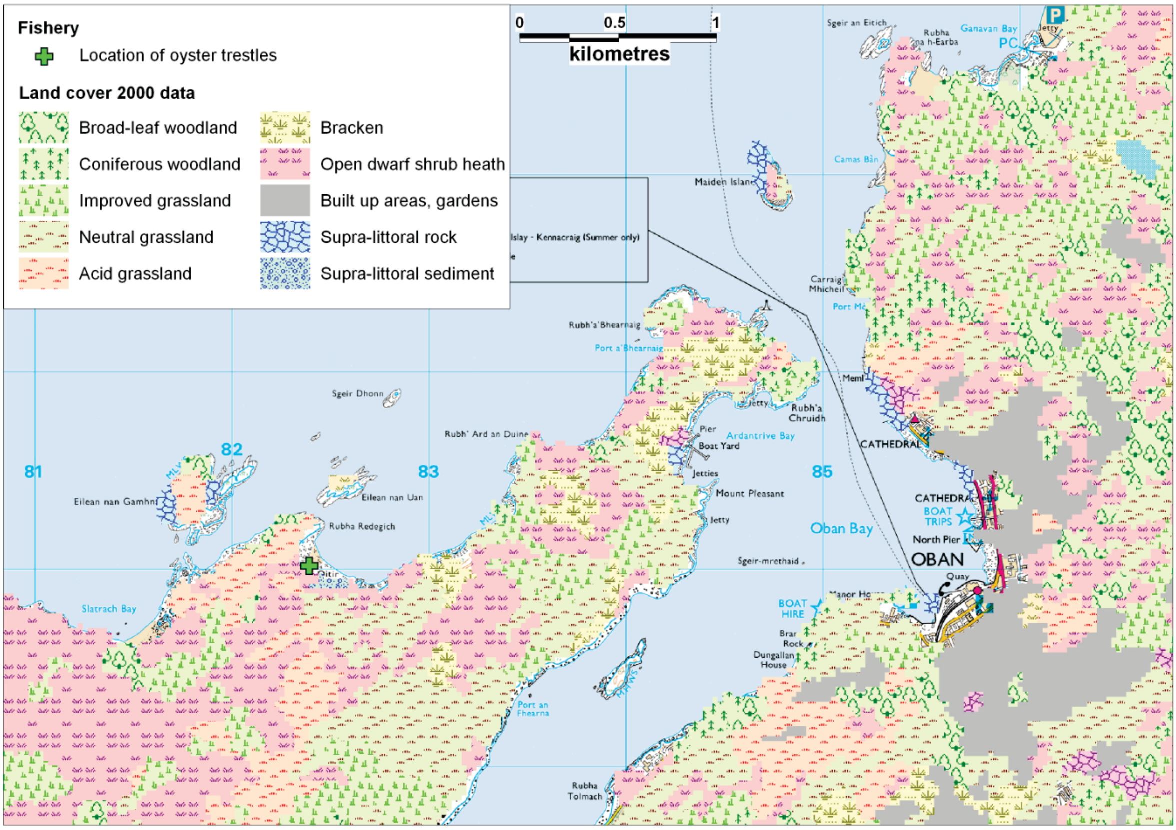


Figure 6.1 LCM2000 class land cover data for Oitir Mhòr Bay

The landcover surrounding Oitir Mhòr Bay is a mixture of acid grassland, open dwarf shrub heath, bracken and neutral grassland. Further inland from the fishery the landcover is predominantly neutral grassland, open dwarf shrub heath, acid grassland and improved grassland. On the mainland there is similar landcover with additional patches of coniferous and broadleaf woodland and a built-up area representing Oban.

Studies undertaken by Kay et al (2008) found that faecal indicator organism export coefficients for faecal coliform bacteria were highest for urban catchment areas (approx 1.2 – 2.8x10^9 cfu km^{-2} hr^{-1}) and lower for areas of improved grassland (approximately 8.3x10^8 cfu km^{-2} hr^{-1}) and rough grazing (approximately 2.5x10^8 cfu km^{-2} hr^{-1}) areas. Lowest contributions would be expected from areas of woodland (approximately 2.0x10^7 cfu km^{-2} hr^{-1}) (Kay *et al*. 2008). The contributions from all land cover types would be expected to increase significantly after marked rainfall events, however this effect would be particularly marked from improved grassland areas (roughly 1000-fold) (Kay *et al*. 2008).

The risk to the oyster fishery from faecal contamination attributable to land cover is low to moderate, with the areas of highest potential risk around the small improved grassland area to the north east of Oitir Mhòr Bay and the built-up area of Oban, although this is some distance away.

7. Farm Animals

Agricultural census data to parish level was requested from the Scottish Government and this was provided by the Rural Environment, Research and Analysis Directorate (RERAD) for the parish of Kilmore and Kilbride, encompassing a land area of 118.8 km^2. Reported livestock populations for the parishes in 2008 and 2009 are listed in Table 7.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data. Any entries which relate to less than five holdings, or where two or fewer holdings account for 85% or more of the information, are replaced with an asterisk.

Table 7.1 Livestock numbers in Kilmore and Kilbride parish 2008 - 2009

	Kilmore and Kilbride			
	2008		2009	
	Holdings	Numbers	Holdings	Numbers
Pigs	*	*	*	*
Poultry	5	51	5	45
Cattle	20	762	23	783
Sheep	32	16,838	32	15,797
Horses and ponies	10	48	11	53

* Data withheld for reasons of confidentiality

Cattle and sheep predominate in the Kilmore and Kilbride parish. However, the parish covers a large area of land on the adjacent mainland as well as all of the island. Due to this, and the missing data for pig holdings, livestock information directly relevant to the shore in the vicinity of Oitir Mhòr Bay is only available from the shoreline survey (see section 15 and Appendix 7). This information only relates to the time of the site visit on 25th August 2010. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1.

No livestock were observed directly adjacent to Oitir Mhòr Bay, however a farm was observed on the island along the track between Oitir Mhòr Bay and Oban Marina. In a field adjacent to the farm were approximately 50 sheep. Five cattle were also observed on the beach south of the farm. The farm yard also had a pony, 10 chickens, a duck and a peacock. The recorded locations were towards the eastern side of the island and it is unlikely that the animals would impact on the water quality at the south-western end of Oitir Mhòr Bay. Local information at the time of the 2008 restricted shoreline survey identified that the area around the bay is used for rough grazing, with direct access to the shoreline, and animals in the immediate vicinity of the oyster farm are more likely to be a source of faecal contamination at the trestles.

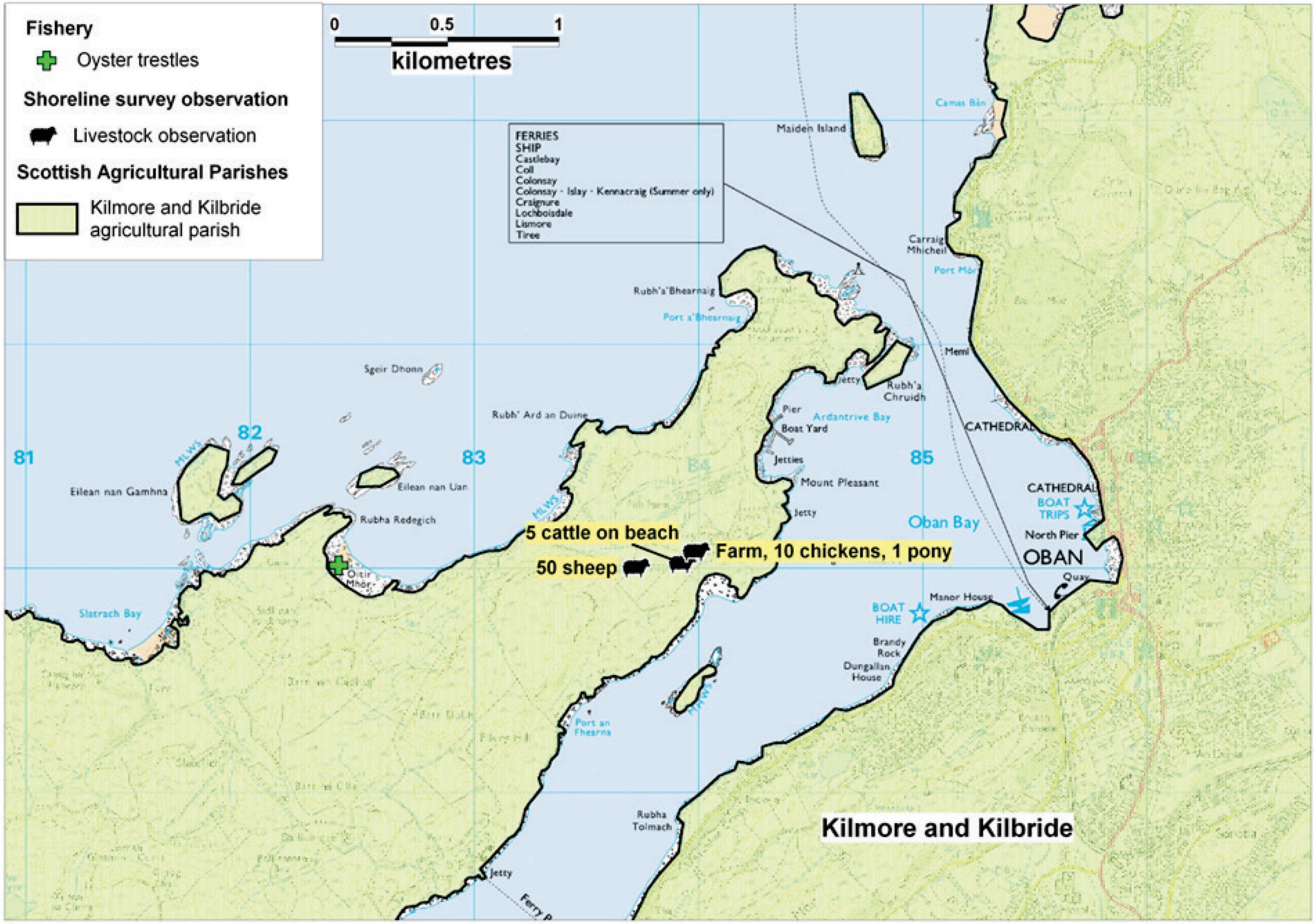


Figure 7.1 Livestock observations at Oitir Mhòr Bay

8. Wildlife

Seals

The Sea Mammal Research Unit has recorded a growing number of harbour seals in the Isle of Kerrera area over the past twenty years (Table 8.1). There have also been some specifically in the Oitir Mhòr Bay area. Grey seals have also been spotted but in very small numbers and were absent during 1988, 1991 - 1996 (Table 8.2).

Table 8.1 Harbour Seals

Location		**Aug 1988**	**Aug 1989**	**Aug 1990**	**Aug 1991**	**Aug 1992**	**Aug 1993**	**Aug 1996**	**Aug 2000**	**Aug 2007**
Kerrera	**Oitir Mhòr**	-	-	42	-	-	-	50	95	40
	Wider area	217	209	351	225	149	301	373	464	297

Table 8.2 Grey Seals

Location		**Aug 1988**	**Aug 1989**	**Aug 1990**	**Aug 1991**	**Aug 1992**	**Aug 1993**	**Aug 1996**	**Aug 2000**	**Aug 2007**
Kerrera	**Oitir Mhòr**	-	-	30	-	-	-	14	6	16
	Wider area	0	2	0	0	0	0	0	24	3

According to the local authority, there is currently a seal colony (estimated 20-30 seals) resident in the Oitir Mhòr Bay area. Daily boat trips are run from Oban to view the seal colony. According to one of the tour operators, the seals are primarily found on the rocks at Sgier Dhonn and more rarely at Eilean nan Uan, both offshore of the fishery (Figure 8.1). They are also sometimes found near a cage fish farm off the east end of the production area.

The amount of *E. coli* and other faecal indicator bacteria contained in seal faeces has been reported as being similar to that found in raw sewage (Lisle et al 2004).

Given the proximity and numbers of seals present near the fishery, it is likely that they contribute to the load of faecal bacteria in the waters around Oitir Mhòr. Any impact is anticipated to be highest near where they haulout on the rocks to the north of the fishery and dependent upon the predicted movement of contaminants.

Birds

While the Isle of Kerrera does host some colonies of breeding seabirds, Oitir Mhòr Bay does not host significant colonies. Seabird 2000 data has been provided for a 5 km radius of Oitir Mhòr Bay. In total there are five separate wildlife observations for the area. All observations represent low counts of seabirds. Observations are plotted in Figure 8.1 and listed in Table 8.3.

Table 8.3 Seabird counts within 5km of the site.

Common name	Species	Count	Method
Herring Gull	*Larus argentatus*	2	Occupied nests
Common Gull	*Larus canus*	3	Occupied nests
Black Guillemot	*Cepphus grylle*	6	Individuals on land

During the shoreline survey in Oitir Mhòr Bay approximately 5 gulls, 3 oyster catchers and 1 cormorant were observed. At Ardantrive 1 duck and 1 peacock were observed. In Oban bay larger populations of seabirds were observed including two large groups of gulls (100+), 10 ducks and 2 swans (see Figure 8.1). Overall, seabirds such as gulls will always be present in the bay but their distribution is likely to be even over time and as such would not materially affect placement of an RMP.

Deer

There are no deer on the Isle of Kerrera.

Other

Feral goats can be found all over the isle of Kerrera, although they are concentrated towards the southern end of the island. Population numbers are unknown. Otters are also common in the area, although distribution and population numbers are not known.

Summary

A variety of wildlife species are known to be present in the area and may contribute to background levels of faecal contamination present in the waters of Oitir Mhòr Bay. Of these, seals and seabirds such as gulls are most likely to occur in the vicinity of the fishery and may directly deposit faecal material to the waters near the shellfish farm. However, the presence and movements of these animals are likely to be highly variable and their impact at any given time difficult to predict.

Figure 8.1 Map of wildlife distributions at Oitir Mhòr Bay

9. Meteorological data

The nearest weather station for which rainfall records were available is located at Lismore: Frackersaig Farm, about 10 km to the north of the fishery. Rainfall data was available for 2003-2009 inclusive, aside from the months of July 2003, September 2005 and September 2006. The nearest weather station for which wind data was available is at Glasgow: Bishopton, about 85 km to the south east of the fishery. Overall wind patterns may be broadly similar at Glasgow and the fishery, but local topography may affect the actual wind direction seen at the two locations. This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish at Oitir Mhòr Bay.

9.1 Rainfall

High rainfall and storm events are commonly associated with increased faecal contamination of coastal waters through surface water run-off from land where livestock or other animals are present, and through sewer and waste water treatment plant overflows (e.g. Mallin et al, 2001; Lee & Morgan, 2003). Figures 9.1 and 9.2 present box and whisker plots summarising the distribution of individual daily rainfall values by year and by month. The grey box represents the middle 50% of the observations, with the line within the box representing the median. The whiskers extend to the largest or smallest observations up to 1.5 times the box height above or below the box. Individual observations falling outside the box and whiskers are represented by the symbol *.

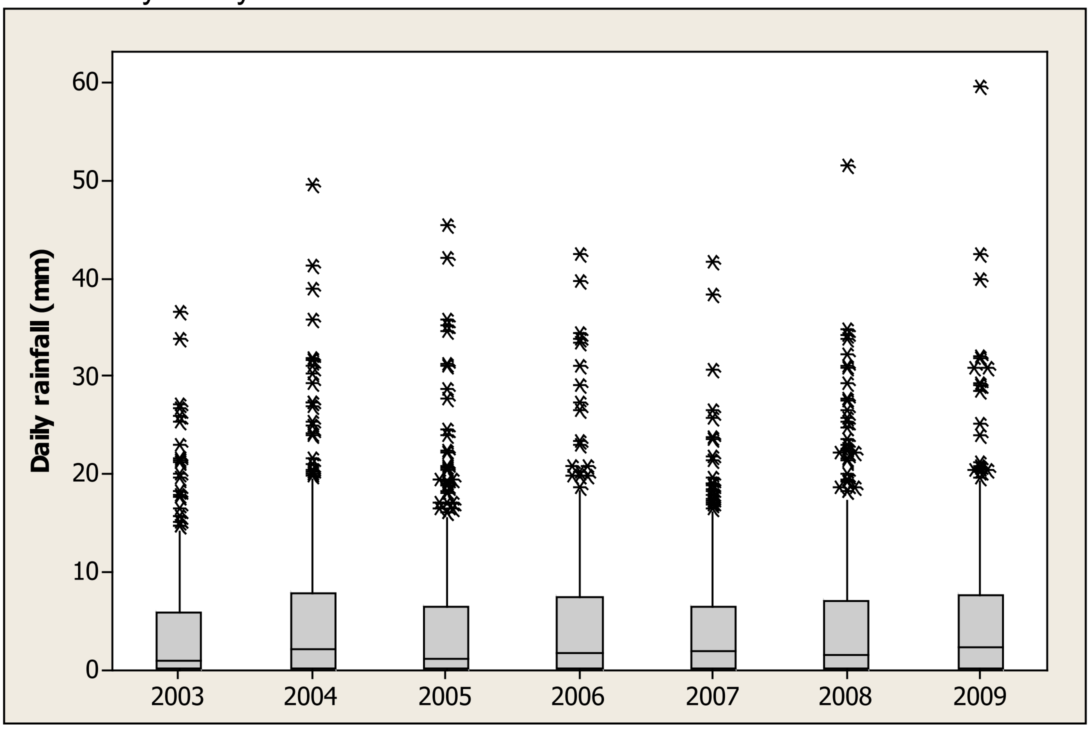


Figure 9.1 Box plot of daily rainfall values by year at Lismore: Frackersaig Farm, 2003-2009

Figure 9.1 shows that rainfall patterns were very similar between the years for which data is presented, with 2003 the driest and 2004 the wettest. Total annual rainfall at this station is relatively high: the total for 2004 was 1982 mm.

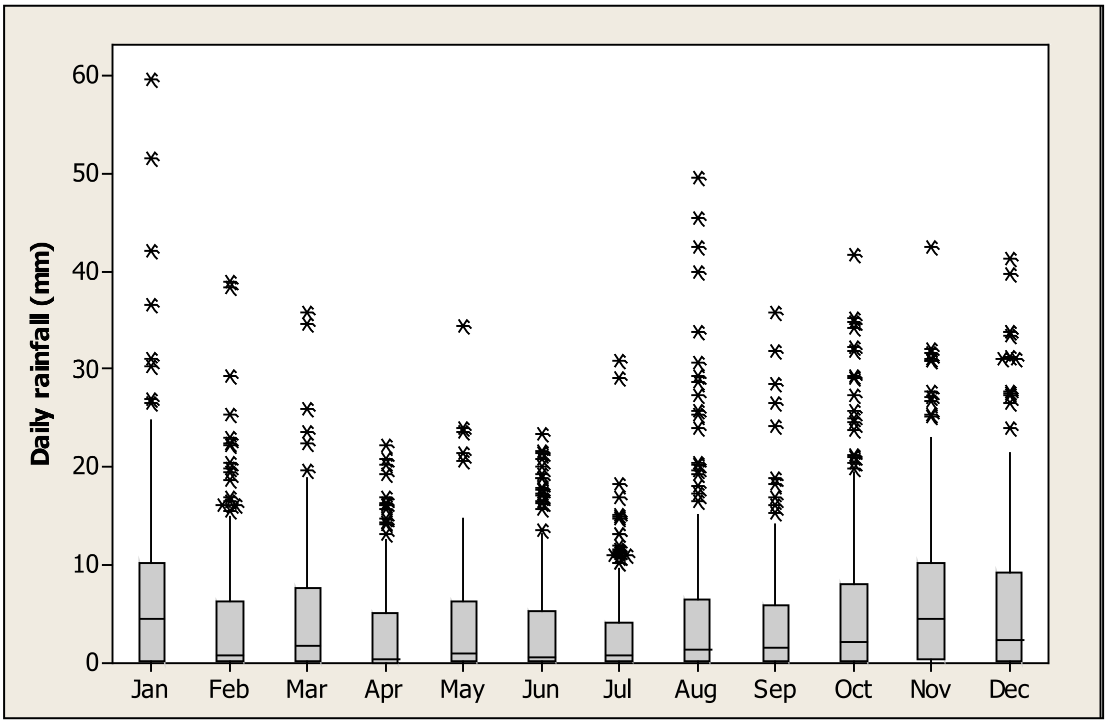


Figure 9.2 Box plot of daily rainfall values by month at Lismore: Frackersaig Farm, 2003-2009

Figure 9.2 shows that weather was wettest from October to January, and driest from April to July. More extreme rainfall events (in which over 20mm fell in a day) occurred during all months, with rainfall events of more than 40 mm in 24 hours occurring between August and January. For the period considered here (2003-2009), 44% of days experienced rainfall less than 1 mm, and 17% of days experienced rainfall of 10 mm or more.

It can therefore generally be expected that levels of run-off will be higher during the autumn and winter months. However, diffuse pollution into the production area will tend to be greater when extreme rainfall events occur after dry periods during summer or early autumn.

9.2 Wind

Wind data collected at the Glasgow: Bishopton weather station is summarised by season and presented in Figures 9.3 to 9.7.

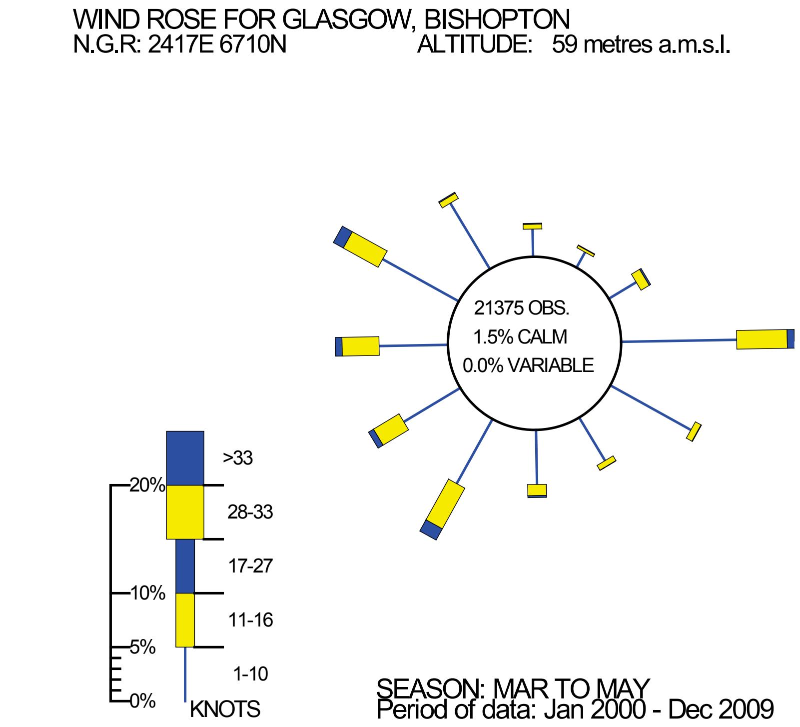


Figure 9.3 Wind rose for Glasgow Bishopton (March to May)

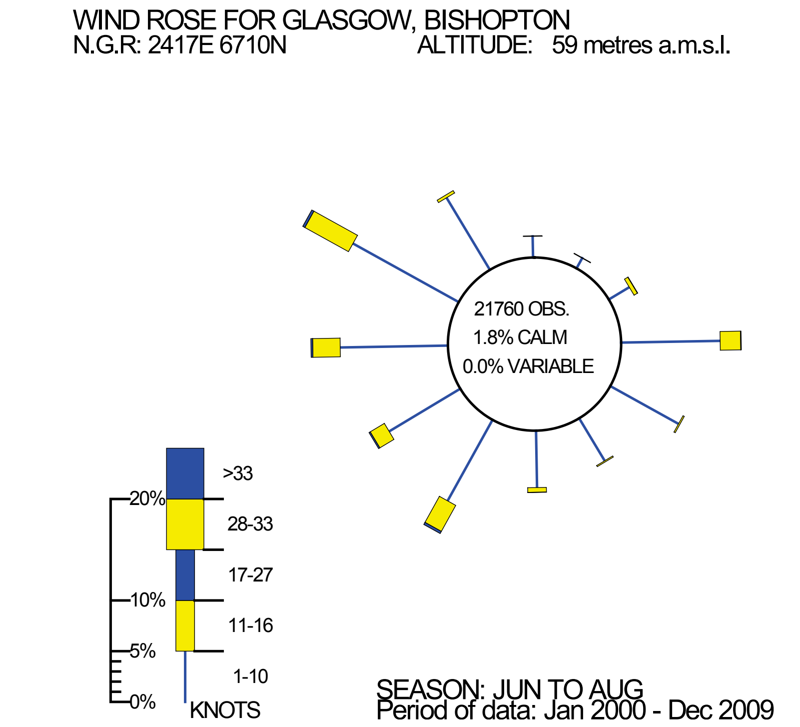


Figure 9.4 Wind rose for Glasgow Bishopton (June to August)

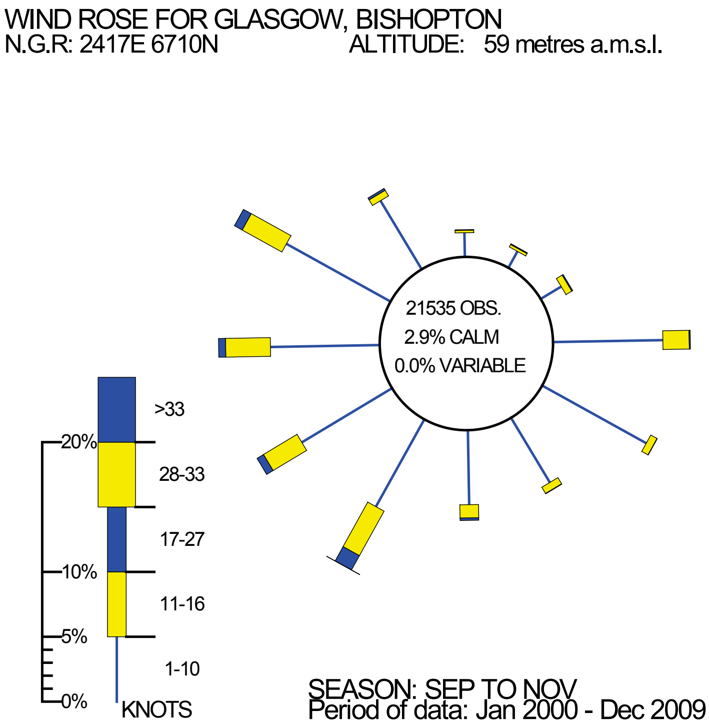


Figure 9.5 Wind rose for Glasgow Bishopton (September to November)

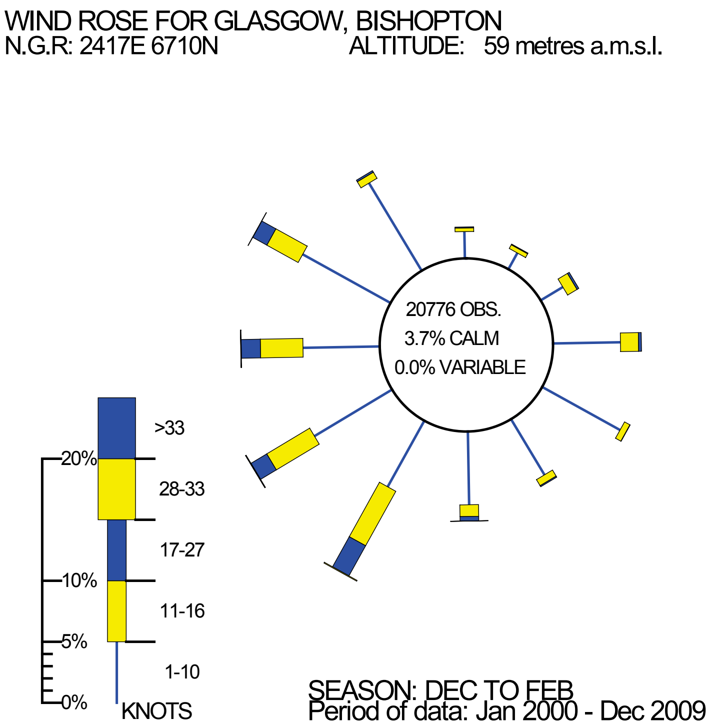


Figure 9.6 Wind rose for Glasgow Bishopton (December to February)

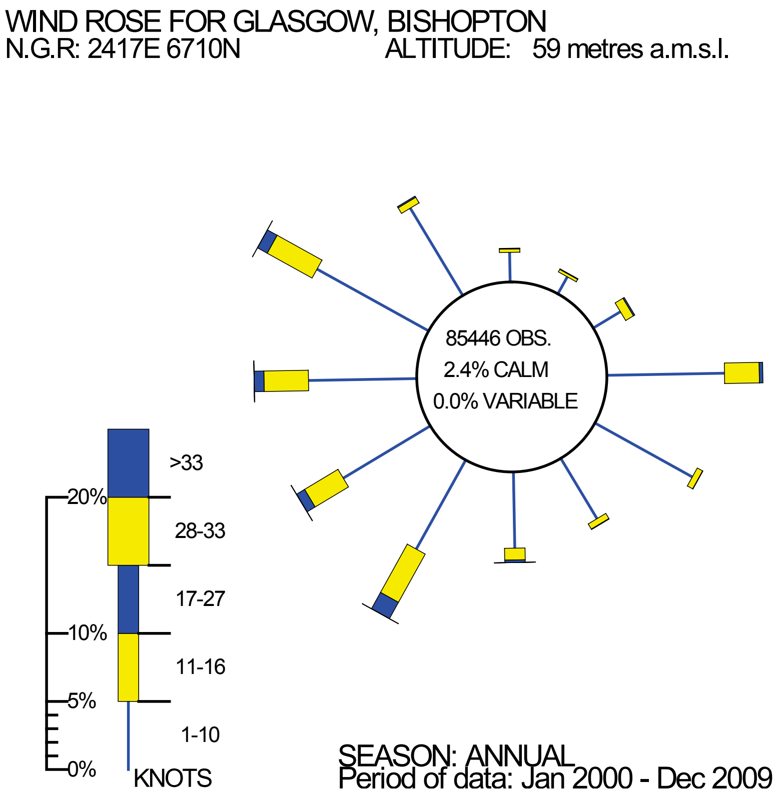


Figure 9.7 Wind rose for Glasgow Bishopton (All year)

The prevailing wind direction at Glasgow Bishopton is from the south west. There is a higher occurrence of easterly winds during the spring. Winds are generally lightest in the summer and strongest in the winter. Overall patterns appear to be skewed along the east west axis. Presumably this is due in part at least to its location in the Clyde valley, which has an east west aspect. Oitir Mhòr Bay is exposed to the north, and receives shelter from hills rising to 100 m to its south.

Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s. Therefore strong winds may significantly alter the pattern of surface currents in the area, particularly northerly winds. Strong winds may affect tide height depending on wind direction and local hydrodynamics. A strong wind combined with a spring tide may result in higher than usual tides, which will carry accumulated faecal matter from livestock, in and above the normal high water mark, into the production area. A strong northerly wind will result in increased wave action at Oitir Mhòr Bay, which may resuspend any organic matter settled in the substrate.

10. Current and historical classification status

Oitir Mhòr Bay was first classified for the production of Pacific oysters in 2006. Its classification history since then is presented in Table 10.1 below.

Table 10.1 Oitir Mhòr Bay

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2006	B	B	B	B	B	B	B	B	B	B	B	B
2007	B	B	B	B	B	B	B	B	B	B	B	B
2008	B	B	B	A	A	B	B	B	B	B	B	B
2009	B	A	A	A	A	A	B	B	B	B	B	B
2010	A	A	A	A	A	A	B	B	B	A	A	A
2011	A	A	A									

Over the classification history, the Oitir Mhòr area has received steadily improving classifications going from year-round B in 2006 and 2007 to B for only three months in 2010.

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken Oitir Mor Bay from February 2005 (when monitoring began) up to the 5th May 2010 were extracted from the database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. Additional results for samples collected up to 8th March 2011 were incorporated for the data summary presented in Table 11.1, the geographical and temporal summaries presented in Figures 11.1 and 11.2, and the evaluation of high results in Section 11.7.

All reported sampling locations fell within the production area, and all samples were received by the testing laboratory within two days of collection. Duplicate samples had been taken on the first 3 sampling occasions in 2005: the replicate results were retained in the data set.

One sample had an invalid test result and so could not be used in the analysis. Four samples (3 prior to 6th May 2010) had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation.

All *E. coli* results are reported in most probable number per 100g of shellfish flesh and intravalvular fluid.

11.2 Summary of microbiological results

A summary of all sampling and results is presented in Table 11.1.

Table 11.1 Summary of historical sampling

Sampling Summary	
Production area	Oitir Mhòr Bay
Site	Oitir Mhòr
Species	Pacific oysters
SIN	AB-308-701-13
Location	33 locations
Total no of samples	66
No. 2005	13
No. 2006	9
No. 2007	7
No. 2008	11
No. 2009	11
No. 2010	12
No. 2011	3

Table 11.2 Summary of historical results

Results Summary	
Minimum	<20
Maximum	9200
Median	220
Geometric mean	228
90 percentile	4450
95 percentile	5400
No. exceeding 230/100g	27 (41%)
No. exceeding 1000/100g	17 (26%)
No. exceeding 4600/100g	7 (11%)
No. exceeding 18000/100g	0 (0%)

11.3 Overall geographical pattern of results

Until 2007, all samples were reported from the nominal RMP. After this time, sampling officers were equipped with GPSs with which sampling location was recorded to nominal 1 m accuracy at the time of collection. The results for the locations assumed to be recorded by GPS are thematically mapped in Figure 11.1.

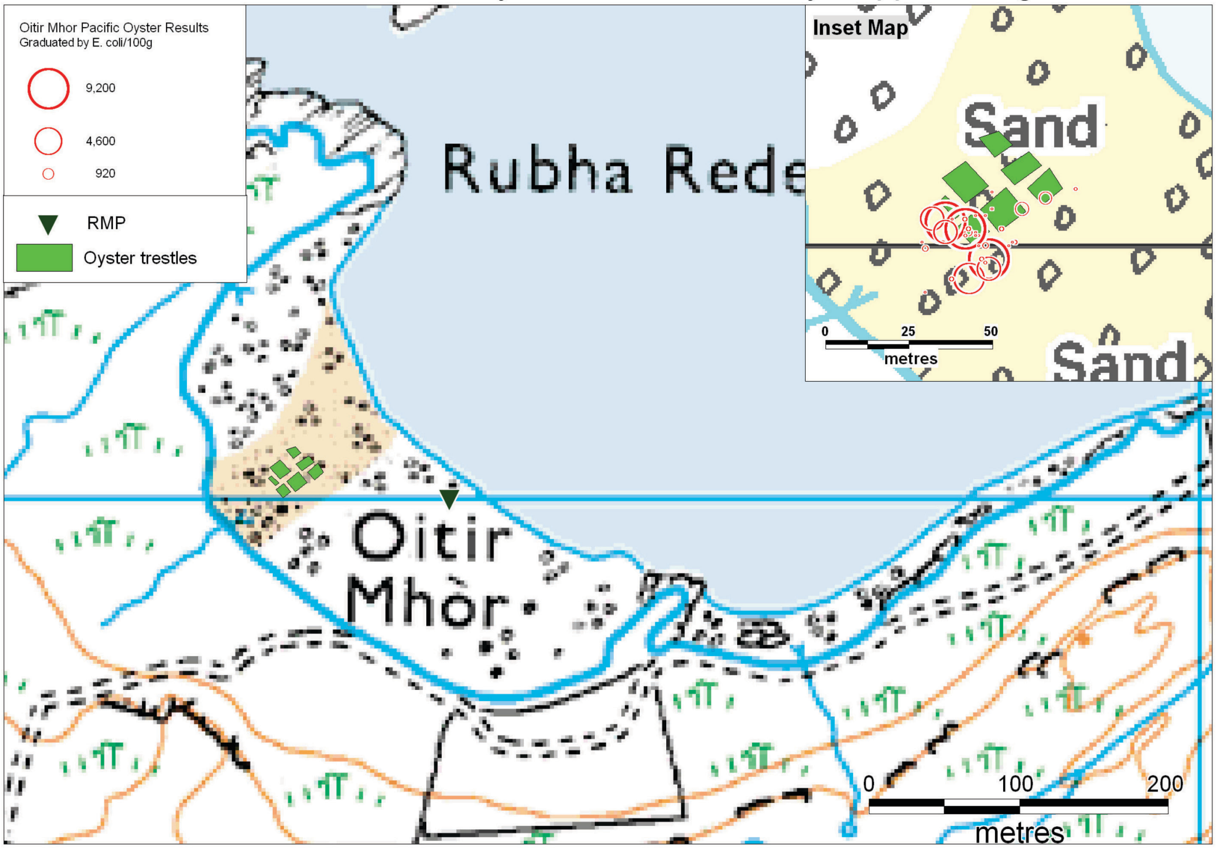


Figure 11.1 Map of geometric mean *E. coli* results when sample location was accurately recorded by GPS.

Although Figure 11.1 gives the impression that higher results occur nearer to the MHWS mark, few samples were taken from further down the shore and so no firm conclusions can be drawn from this data with regard to spatial effects.

11.4 Overall temporal pattern of results

Figure 11.2 presents a scatter plot of individual results against date, fitted with a loess lines (blue line), which stands for 'locally weighted regression scatter plot smoothing'. At each point in the data set an estimated value is fit to a subset of the data, using weighted least squares. The approach gives more weight to points near to the x-value where the estimate is being made and less weight to points further away. In terms of the monitoring data, this means that any point on the loess line is influenced more by the data close to it (in time) and less by the data further away. This trend line helps to highlight any apparent underlying trends or cycles.

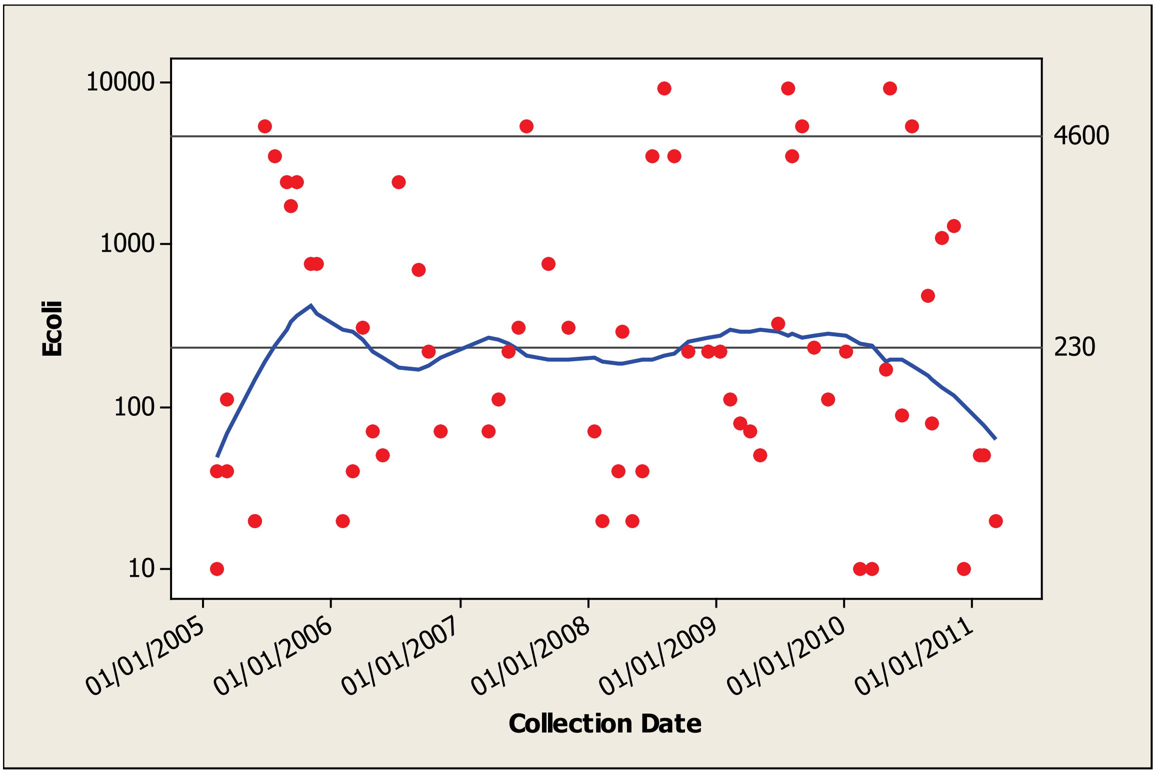


Figure 11.2 Scatterplot of *E. coli* results by date with loess line

No obvious trends or cycles are apparent in Figure 11.2. The rise of the trend line at the beginning of the graph, and the fall at the end, are probably due to the way the data has been interpolated at those locations rather than being due to changes in overall microbiological quality.

11.5 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns of human occupation. All of these can affect levels of microbial contamination, and cause seasonal patterns in results. Figure 11.3 presents a scatterplot of *E. coli* result by month, with a loess line to highlight any trends.

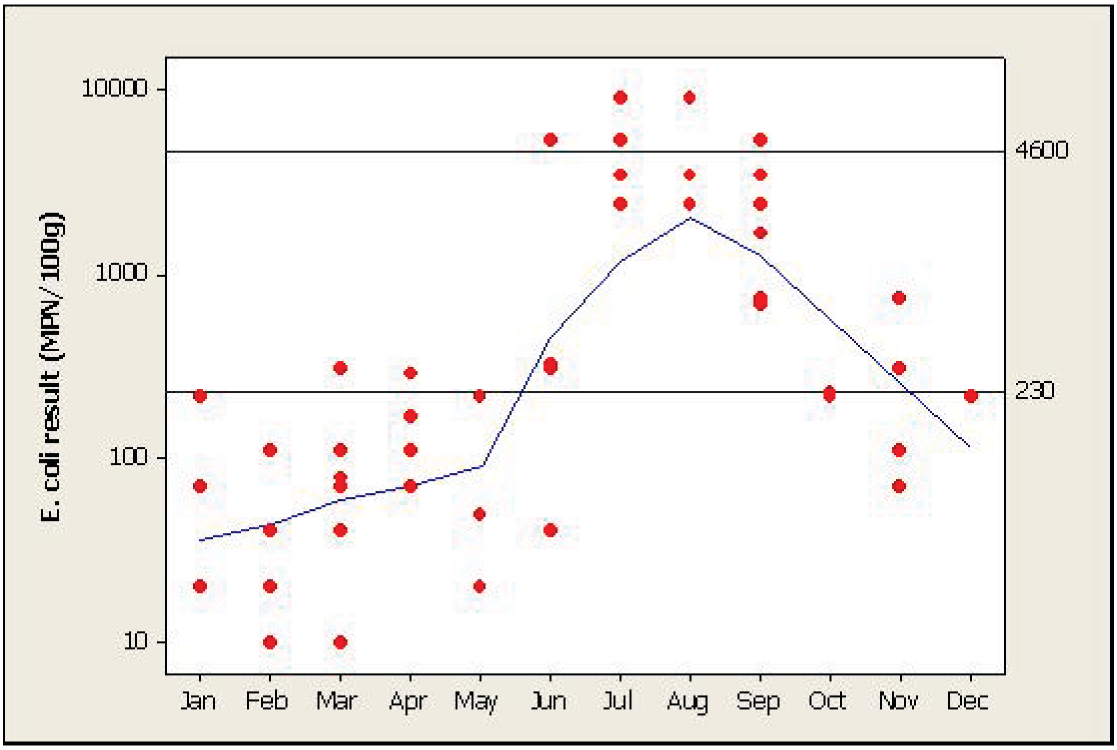


Figure 11.3 Scatterplot of results by month

A strong seasonal pattern is apparent in Figure 11.3, with much higher results arising from June to September.

For statistical evaluation, seasons were split into spring (March - May), summer (June - August), autumn (September - November) and winter (December - February).

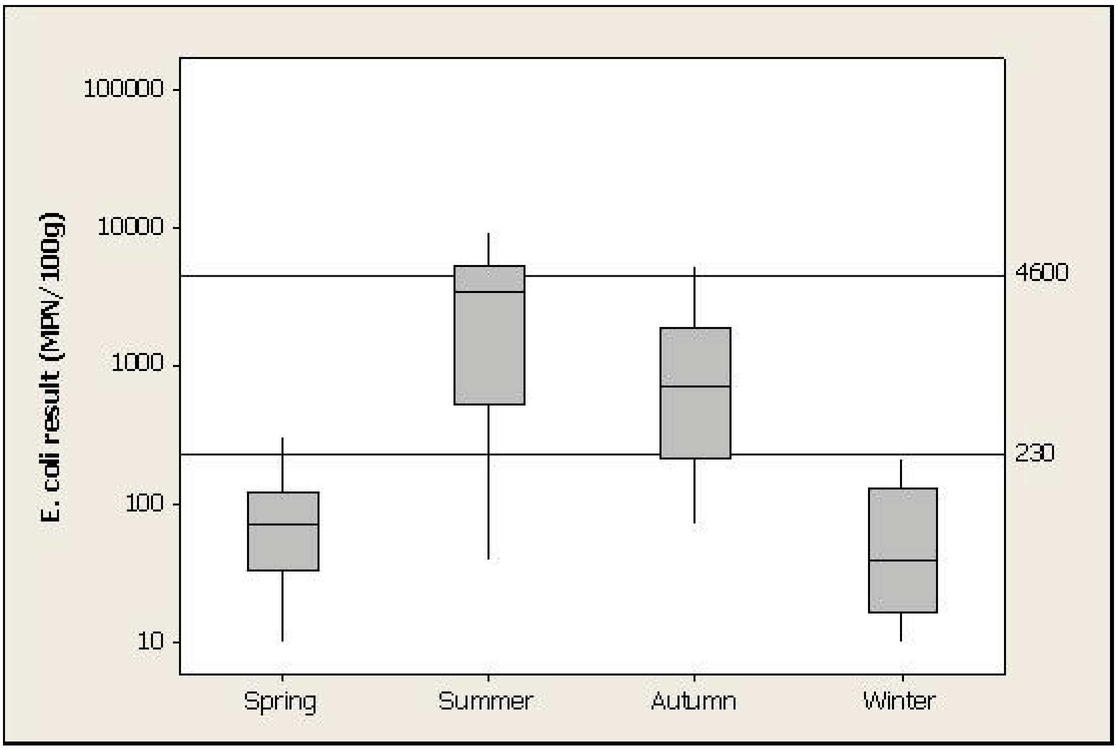


Figure 11.4 Boxplot of result by season

A significant difference was found between results by season (One-way ANOVA, p=0.000, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicates that results for the summer and autumn were significantly higher than those for both the spring and winter.

11.6 Analysis of results against environmental factors

Environmental factors such as rainfall, tides, winds, sunshine and temperatures can all influence the flux of faecal contamination into growing waters (e.g. Mallin et al, 2001; Lee & Morgan, 2003). The effects of these influences can be complex and difficult to interpret. This section aims to investigate and describe the influence of these factors individually (where appropriate environmental data is available) on the sample results using basic statistical techniques.

11.6.1 Analysis of results by recent rainfall

The nearest weather station is at Lismore: Frackersaig Farm, about 10 km to the north of the fishery. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2009 (total daily rainfall in mm). Figure 11.5 presents a scatterplot of *E. coli* results against rainfall in the previous two days. A Spearman's Rank correlation was carried out between results and rainfall.

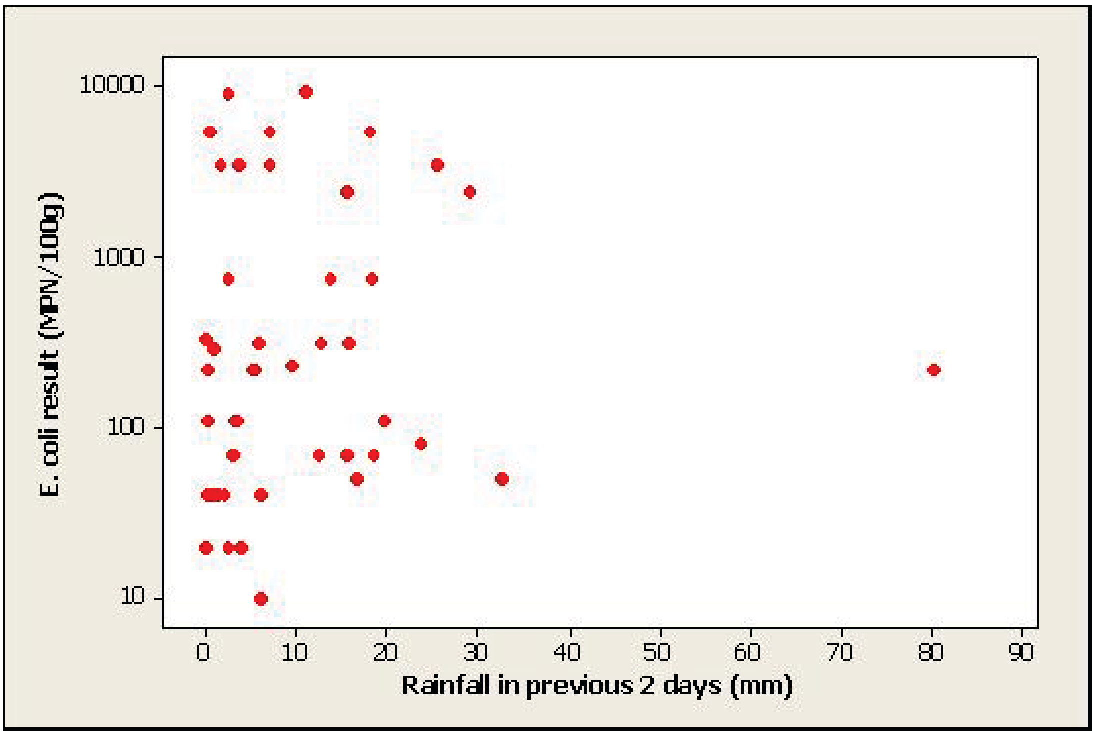


Figure 11.5 Scatterplot of result against rainfall in previous 2 days

No significant correlation was found between *E. coli* result and rainfall in the previous 2 days (Spearman's rank correlation=0.229, p>0.05, Appendix 6).

As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationship between rainfall in the previous 7 days and sample results was investigated in an identical manner to the above.

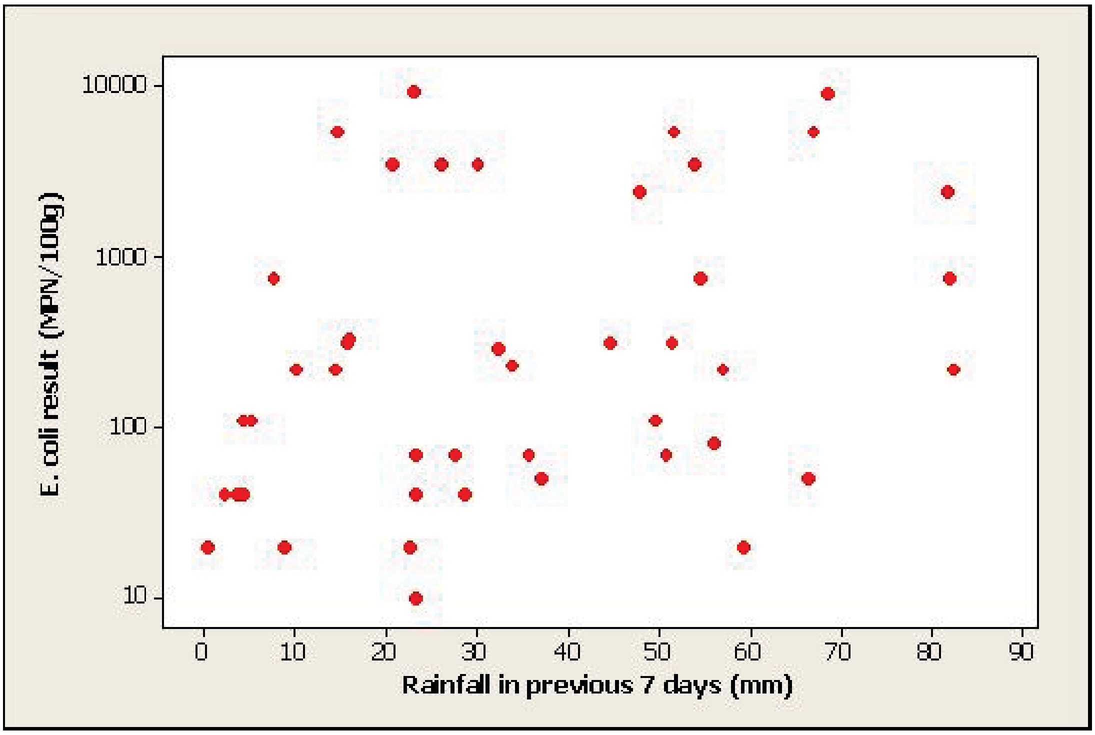


Figure 11.6 Scatterplot of result against rainfall in previous 7 days

A positive correlation was found between *E. coli* result and rainfall in the previous 7 days (Spearman's rank correlation= 0.334, p<0.025, Appendix 6). However, low results were still seen at rainfall levels up to 65 mm in the 7 days preceding sampling and results >230 E. coli MPN/100 g occurred at rainfall levels less than 10 mm.

11.6.2 Analysis of results by tidal height and state

Spring/Neap tidal cycle

When the larger (spring) tides occur every two weeks, circulation of water and particle transport distances will increase, and more of the shoreline will be covered at high water, potentially washing more faecal contamination from livestock into the area. Figure 11.7 presents a polar plot of $\log_{10}$ *E. coli* results on the lunar spring/neap tidal cycle. The largest (spring) tides start about 2 days after the full/new moon, and last approximately 3 or 4 days (centred at about 45º on the plot). The tides then decrease to the smallest (neap tides; centred at about 225º) and then increase back to spring tides. Results less than 230 *E. coli* MPN/100g are plotted in green, those between 230 and 4600 *E. coli* MPN/100g are plotted in yellow, and those over 4600 *E. coli* MPN/100g are plotted in red. It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account.

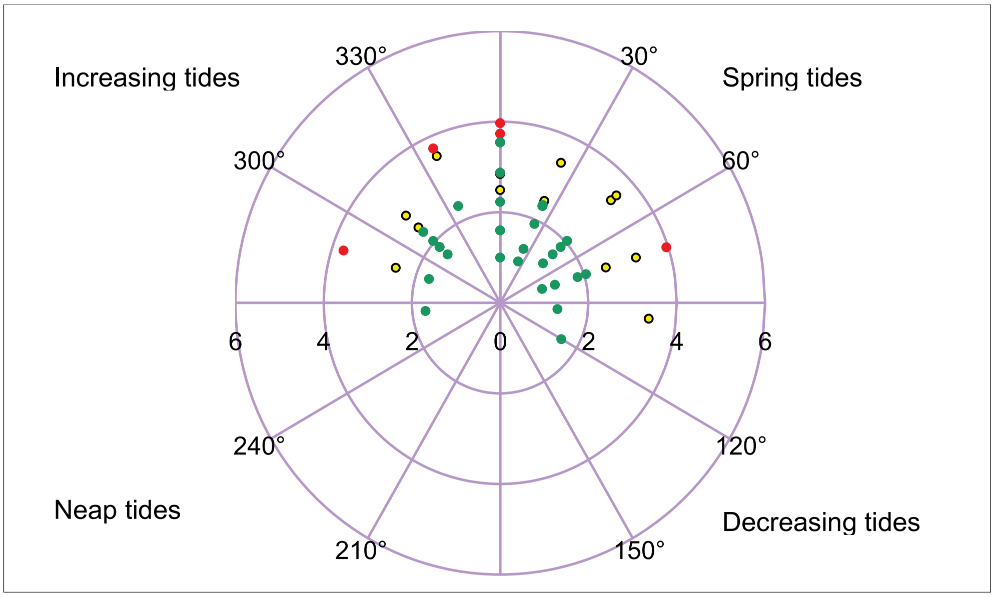


Figure 11.7 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle

No significant correlation was found between *E. coli* results and the spring/neap cycle (circular-linear correlation, r=0.173, p=0.217, Appendix 6). Sampling was targeted towards increasing and spring tides.

High/Low tidal cycle

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As *E. coli* levels in some shellfish species can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (hours post high water) was compared with *E. coli* results. Figure 11.8 presents a polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle. High water is at 0º, and low water is at 180º. Results less than 230 *E. coli* MPN/100g are plotted in green, those between 231 and 4600 *E. coli* MPN/100g are plotted in yellow, and those over 4600 *E. coli* MPN/100g are plotted in red.

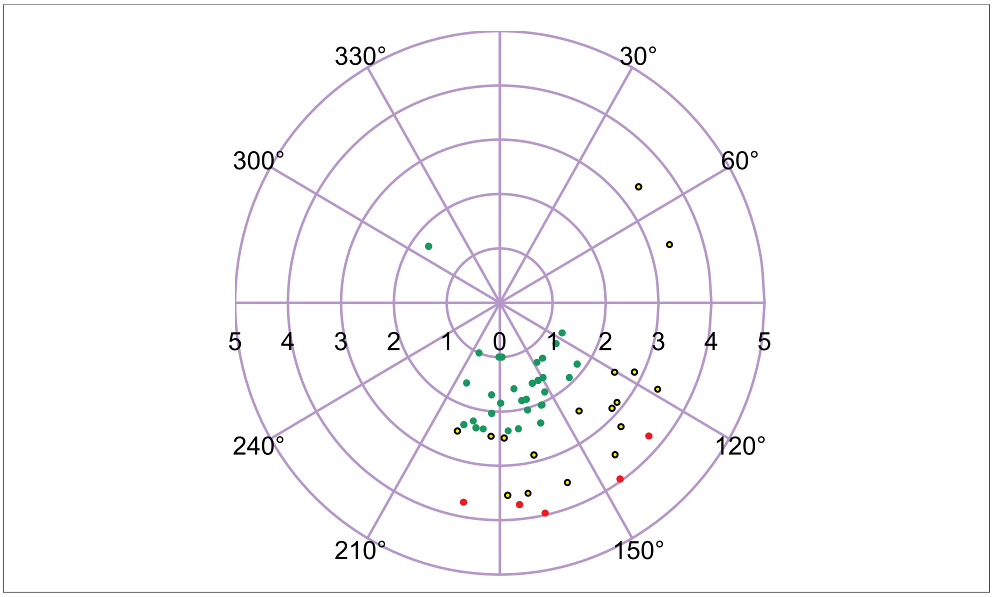


Figure 11.8 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle

No significant correlation was found between *E. coli* results and the high/low tidal cycle (circular-linear correlation, r=0.173, p=0.217, Appendix 6). Sampling was targeted towards low water.

11.6.3 Analysis of results by water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) and the feeding and elimination rates of shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. It is of course closely related to season, and so any correlation between temperatures and *E. coli* levels in shellfish flesh may not be directly attributable to temperature, but to other factors such as seasonal differences in livestock grazing patterns. Figure 11.9 presents a scatterplot of *E. coli* results against water temperature.

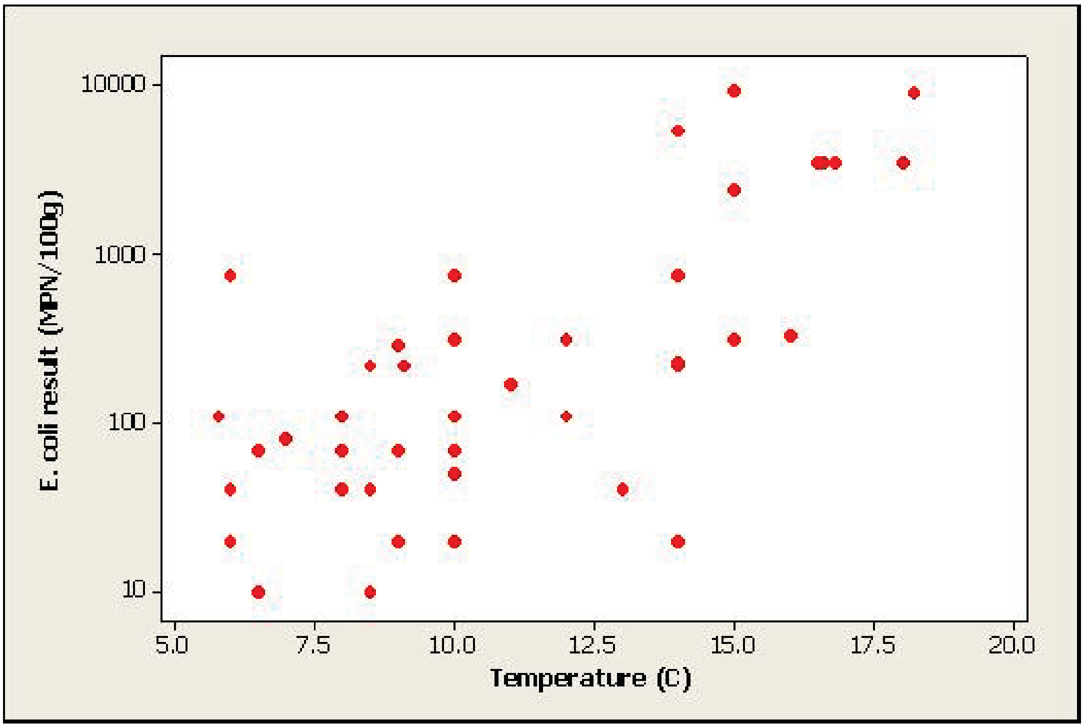


Figure 11.9 Scatterplot of result by water temperature

A positive correlation was found between *E. coli* result and water temperature (Spearman's rank correlation= 0.630, $p<0.0005$, Appendix 6).

11.6.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater borne contamination at the site. Figure 11.10 presents a scatter plots of *E. coli* result against salinity.

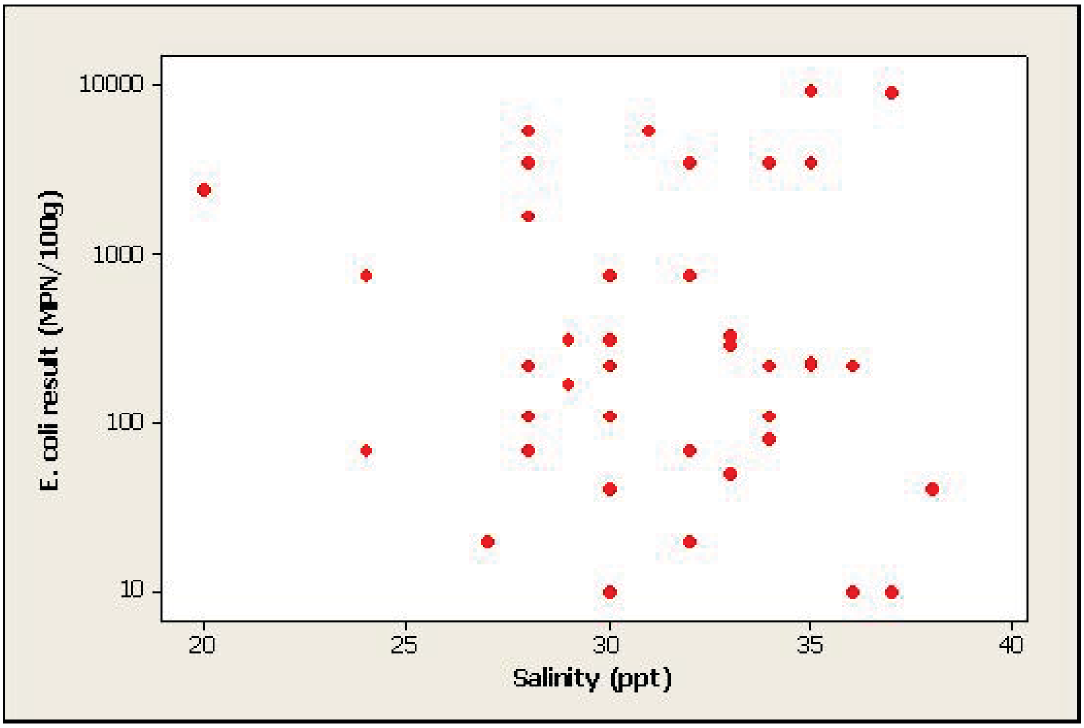


Figure 11.10 Scatterplot of result by salinity

No significant correlation was found between the *E. coli* result and salinity (Spearman's rank correlation= -0.031, p>0.25, Appendix 6).

11.7 Evaluation of peak results

A total of 7 samples gave a result of over 4600 *E. coli* MPN/100g, details of which are presented in Table 11.2.

Table 11.3 Historic *E. coli* sampling results over 4600 *E. coli* MPN/100g

Collection date	*E. coli* (MPN/100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tidal state (high/low)	Tidal state (spring/neap)
22/06/2005	5400	NM825300	18.1	51.7	*	28	Ebb	Spring
12/07/2007	5400	NM 82387 30008	0.3	14.7	14	*	Low	Increasing
04/08/2008	9100	NM 82381 30007	2.4	68.6	18.2	37	Low	Spring
22/07/2009	9200	NM 82394 29996	11	23	15	35	Low	Spring
03/09/2009	5400	NM 82388 29990	7.1	67	*	31	Low	Increasing
12/05/2010	9200	NM 82387 30005	0.0	0.6	12	35	Low	Increasing
15/07/2010	5400	*	8.4	55.3	14	33	Low	Spring

* Data unavailable

The high results all arose from May to September, and where water temperatures were recorded they were 12 ºC or higher. The results occurred after varying 2 day rainfall, but in 4 cases they arose after relatively heavy 7 day rainfall. Sampling was targeted towards low water on spring tides for access reasons, so the tidal states at which these samples were taken are typical for all samples.

11.8 Summary and conclusions

Until 2007, all samples were reported from the nominal RMP. After this time, sampling officers were equipped with GPSs with which sampling location was recorded accurately at the time of collection. However, the geographical distribution of high results coincided with the area on the trestles where most sampling effort had been concentrated..

In terms of overall temporal patterns in levels of contamination, no trends were seen since the start of sampling in 2005. A strong seasonal effect was found, with results for the summer and autumn significantly higher than those for both the spring and winter. A strong positive relationship was also found between *E. coli* results and water temperature at the time of sampling.

No significant correlation was found between *E. coli* results and rainfall in the previous 2 days, but a fairly weak positive correlation was found between *E. coli* results and rainfall in the previous 7 days. However, there was no significant correlation between *E. coli* results and salinity. More than half of the resutls that exceeded 4600 *E. coli* MPN/100 g occurred after relatively heavy rainfall over the seven days preceding sampling but results less than 100 *E. coli* MPN/100 g were also seen after such rainfall.

No correlation was found between *E. coli* results and either the spring/neap or high/low tidal cycle, but sampling was strongly targeted towards low water on larger tides.

It should be noted that the relatively small amount of data precluded the assessment of the effect of interactions between environmental factors on the *E. coli* concentrations in shellfish.

11.9 Sampling frequency

When a production area has held the same (non-seasonal) classification for 3 years, and the geometric mean of the results falls within a certain range it is recommended that the sampling frequency be decreased from monthly to bimonthly. This is not appropriate for this production area as it has held seasonal classifications within the last three years.

12. Designated Shellfish Growing Waters Data

Oitir Mhòr Bay falls within the Kerrera designated shellfish growing water. The designation was made in 2002 and monitoring started in 2003. The designated area is described as: "An area inshore of a line between NM8228830258 and NM8346230619, and extending to MLWS.". The associated sampling point is given by SEPA as: NM 82981 30117. The extent of the designation, and location of the sampling point, are shown in Figure 12.1.

Under the Shellfish Waters Directive (European Communities, 2006), designated waters must be monitored quarterly for faecal coliforms in the shellfish flesh and intervalvular fluid. The Directive includes a guideline value of 300 faecal coliforms in 75% of samples. The minimum specified sampling frequency is quarterly.

Monitoring of shore mussels at Lismore started in the fourth quarter of 2002. The faecal coliform results are presented in Table 12.1. The first two results were reported against NM 815 267: this is actually located within the Sound of Kerrera. Subsequent results were reported against the designated sampling point: NM 82981 30117. No faecal coliform results were available after the first quarter of 2006. From 2007, SEPA started to use the FSAS *E. coli* data for determining compliance for most shellfish waters. A review of those *E. coli* results will have been included in Section 11 and so will not be presented in this section.

Table 12.1 SEPA faecal coliform results (faecal coliforms /100 g) for shore mussels gathered from Kerrera

Year	Quarter	OS Grid Ref.	
		NM 815 267[1]	NM 8298 3012
2002	Q4	220	
2003	Q1	20	
	Q2		*
	Q3		5400
	Q4		20
2004	Q1		<20
	Q2		750
	Q3		9100
	Q4		110
2005	Q1		5000
	Q2		20
	Q3		500
	Q4		18000
2006	Q1		16000
	Q2		*
	Q3		*
	Q4		*
2007	Q1		*
	Q2		*
	Q3		*
	Q4		*

[1]Located in the Sound of Kererra, not in the designated shellfish growing water
*No result available

The SEPA sampling point is located towards the middle of the bay, 600 m from the present oyster trestles. The results show that at least intermittent significant levels of faecal contamination occur in shore mussels within the bay. The mussel results tended to be slightly higher than those seen in the Pacific oysters. The highest faecal coliform results in the mussels occurred during the first, third and fourth quarters of the year, somewhat different to the summer/autumn bias seen with *E. coli* in the Pacific oysters.

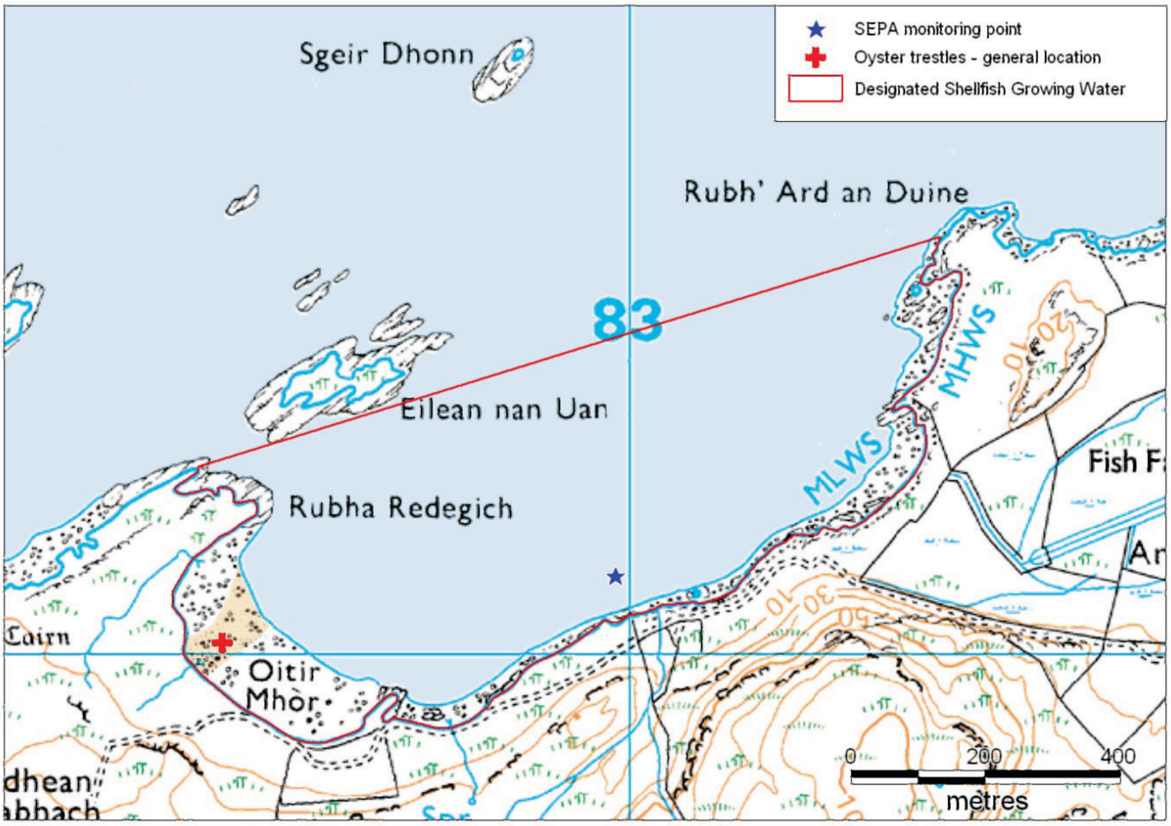


Figure 12.1 Designated Shellfish Growing Water and sampling point

13. River Flow

There are no gauging stations on watercourses in the vicinity of Oitir Mhòr Bay.

The watercourses listed in Table 13.1 were recorded along the shore of Oitir Mhòr Bay during the shoreline survey. Other watercourses were recorded within Oban Bay itself but these were deemed unlikely to have a direct impact on the water quality within Oitir Mhòr Bay. There was light rain on the afternoon of the survey and there had been heavy rain in the preceding days. The locations are shown on the map presented in Figure 13.1. Where the bacterial loading is labelled on the map, the scientific notation is written in digital format, as this is the only format recognised by the mapping software. So, where normal scientific notation for 1000 is 1×10^3, in digital format it is written as 1E+3.

Table 13.1 Watercourse loadings for Oitir Mhòr Bay

No	Grid Reference	Description	Width (m)	Depth (m)	Flow (m/s)	Flow in m^3/day	*E.coli* (cfu/ 100ml)	Loading (*E.coli* per day)
1	NM 83456 30253	Stream	1.9	0.12	0.172	3388.3	280	9.5E+09
2	NM 83322 30160	Stream	Not measured or sampled					Not determined
3	NM 83173 30069	Stream	0.3	0.04	0.113	117.2	10	1.2E+07
4	NM 83138 30054	Stream	Not measured or sampled					Not determined
5	NM 83045 30031	Stream	0.35	0.12	1.009	3661.5	40	1.5E+09
6	NM 82743 29875	Stream	0.35	0.06	3 secs to fill 2 l[1]	57.6	Not sampled	Not determined
7	NM 82347 29976	Stream	0.34	0.1	3 secs to fill 500ml[1]	14.4	10	1.44E+06
8	NM 82347 30127	Stream	0.54	0.05	6 secs to fill 1 litre[1]	14.4	10	1.44E+06

[1]Flow determined by the time taken to fill a graduated vessel to a marked volume

Calculated loadings were low to moderate. The streams with the highest loadings were located along the south-eastern shore of the bay and could potentially affect the water quality at the oyster trestles if the current flowed from there towards the trestles. Streams numbered 7 and 8 in Table 13.1 were located within the inner bay in the vicinity of the trestles. Both gave low calculated loadings on the basis of the shoreline survey measurements. However, stream 7 flowed down through the trestles and therefore, despite the low loading, could significantly contribute to the *E. coli* levels at the trestles.

Loadings from the watercourses would be expected to be significantly lower after a period of dry weather.

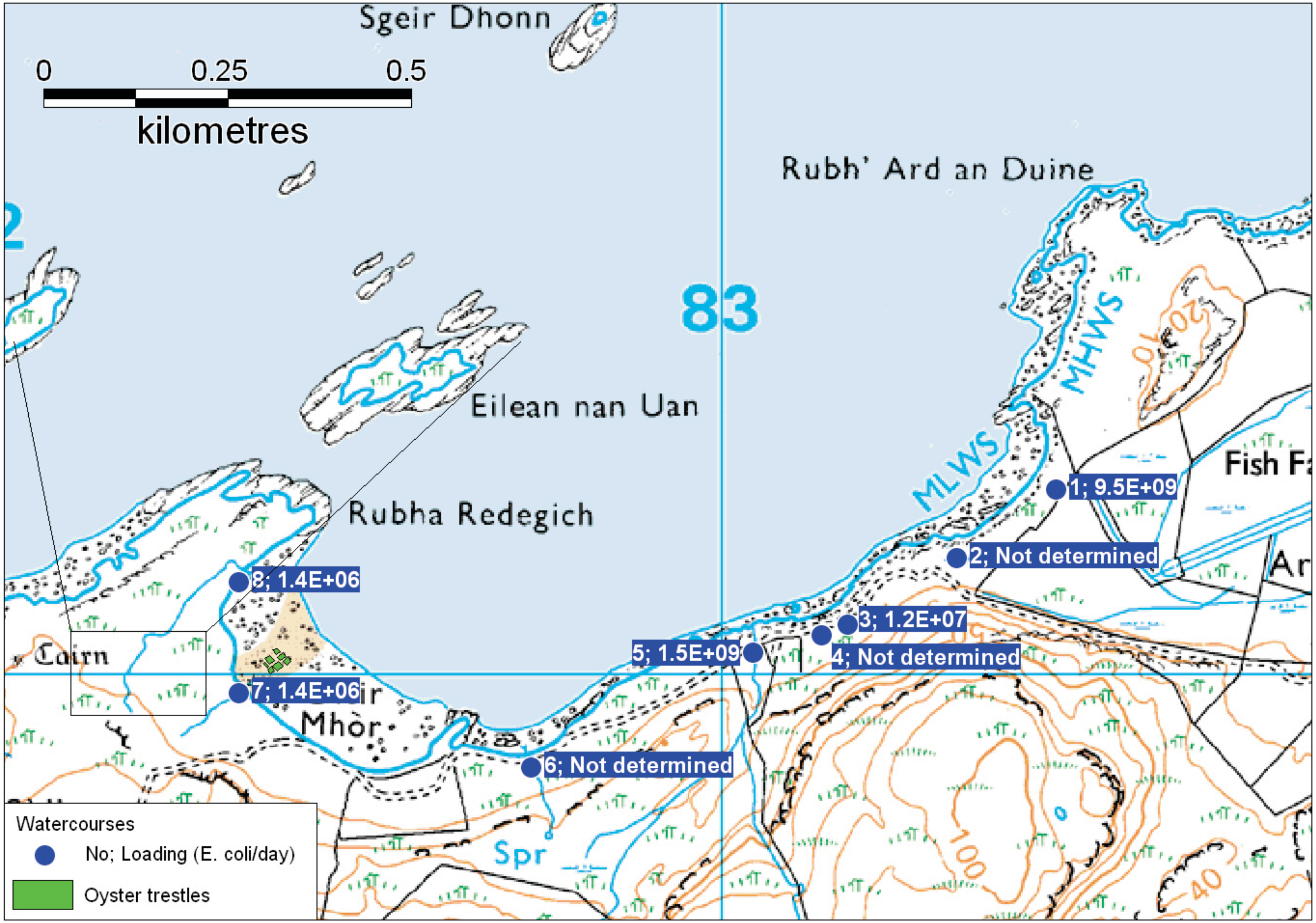


Figure 13.1 Map of watercourse loadings at Oitir Mhòr Bay

14. Bathymetry and Hydrodynamics

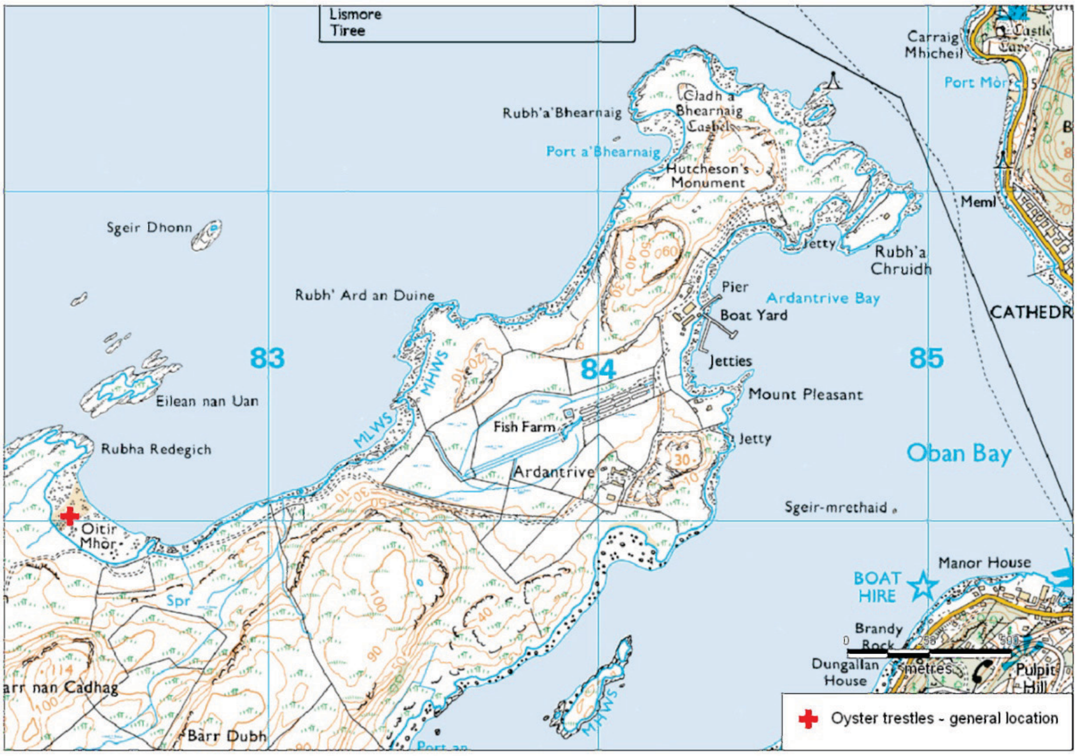


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Figure 14.1 OS map of Oitir Mhòr

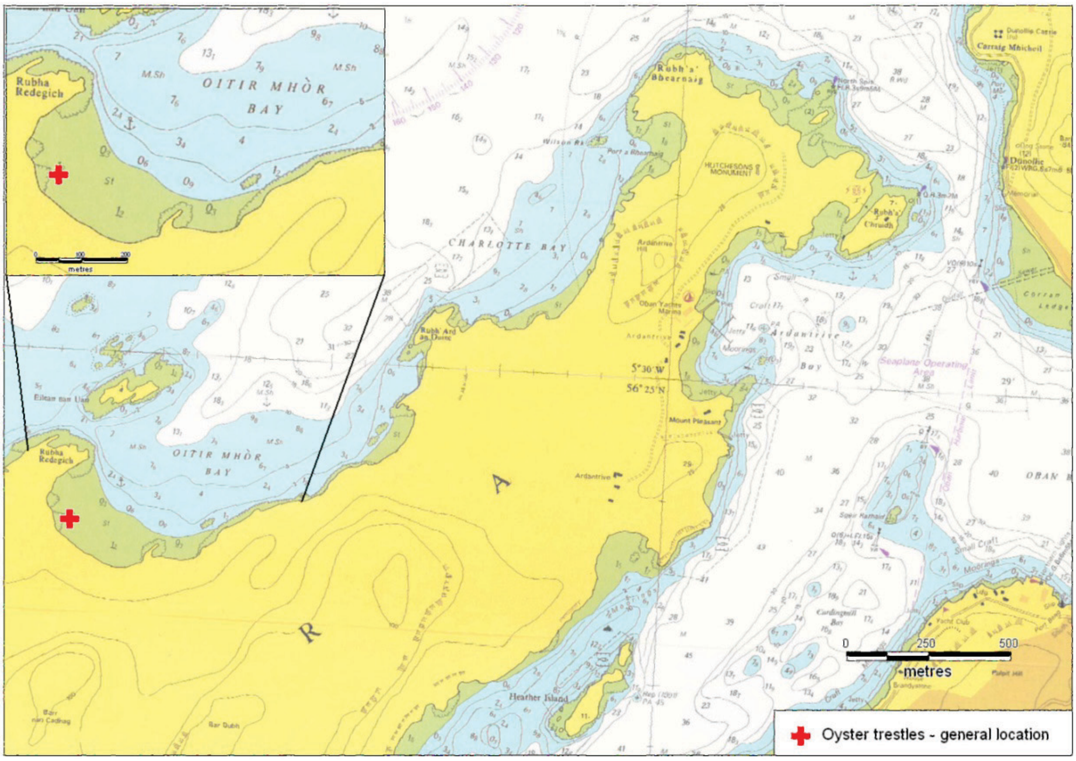

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Figure 14.2 Bathymetry at Oitir Mhòr

Oitir Mhòr Bay is located on the north-west side of the Isle of Kerrera which itself is located at the south-west end of the Lynn of Lorne. The Firth of Lorne lies between Kerrera and the island of Mull to the west. Oitir Mhòr Bay is open to the north-west. The oyster trestles are located on a drying area at the south-western end of the bay. This end is protected to the west by a promontory named Rubha Redegich. Depths within the bay are less generally than 10 m. To the north of the bay, the depths approach 40 m in places. To the west, between Kerrera and the Firth of Lorn channel, there is a relativelu shallow area with a number of islands: depths in this area are all less than 5 m. Further west, the Firth of Lorn reaches depths of greater than 90 m in places. One of the islands to the west is Eilean nan Uan. This lies of Rhubha Redegich and this will add to the protection of the bay from the west.

There is a recommended anchorage in the middle of Oitir Mhòr Bay.

14.1 Tidal Curve and Description

The two tidal curves below are for Oban, approximately 3 km to the east of Oitir Mhòr. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 BST on 25/08/10 and the second is for seven days beginning 00.00 BST on 01/09/10. This two-week period covers the dates of the shoreline survey. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

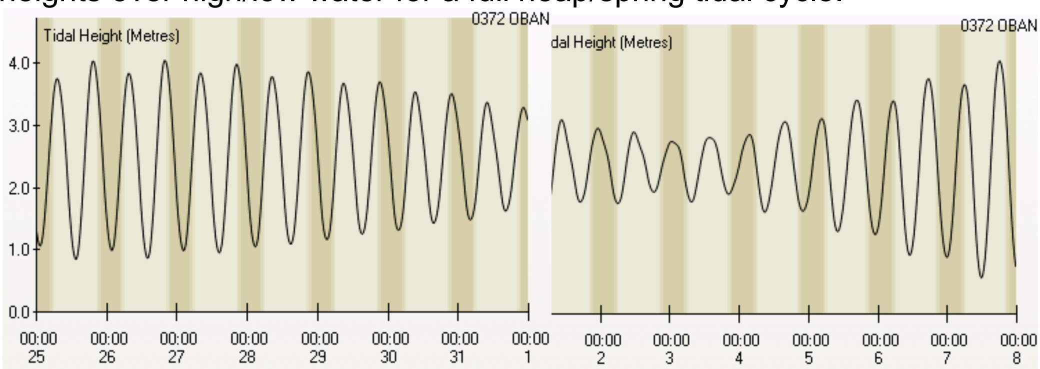


Figure 14.3 Tidal curves for Oban

The following is the summary description for Oban from TotalTide:

The tide type is Semi-Diurnal.

HAT	4.5 m
MHWS	4.0 m
MHWN	2.9 m
MSL	2.39 m
MLWN	1.8 m
MLWS	0.7 m
LAT	0.0 m

Predicted heights are in metres above chart datum. Tidal range at spring tide is 3.3 m, and at neap tide 1.1 m, and so tidal ranges here are relatively small.

14.2 Currents

Tidal stream information was available for a station in the Firth of Lorne to the north-west of Oitir Mhòr Bay. The location of this station, together with the tidal streams for peak flood and ebb tide, are presented in Figures 14.4 and 14.5, and the tidal diamond is presented in Table 14.1.

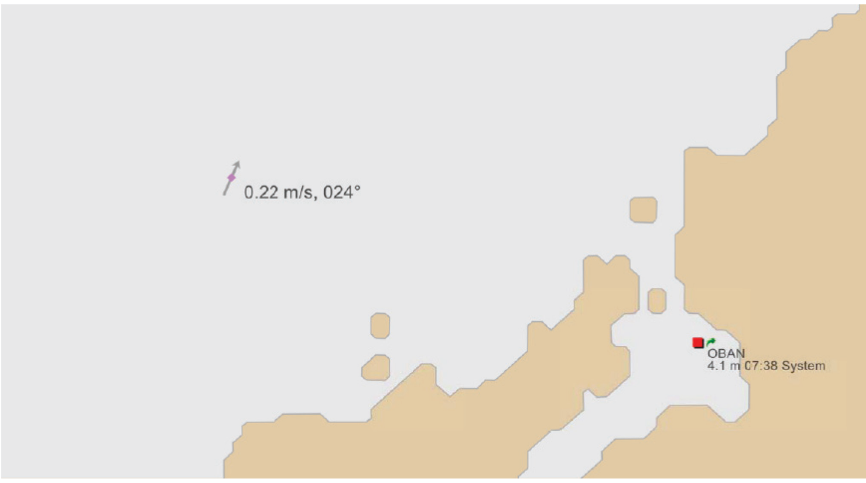


Figure 14.4 Spring flood tide in Firth of Lorne

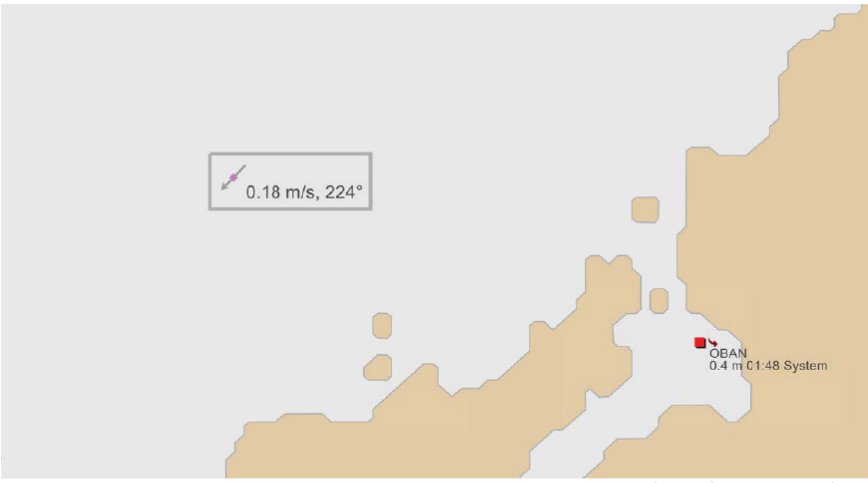


Figure 14.5 Spring ebb tide in Firth of Lorne

Table 14.1 Tidal streams for station SN037I (56°25.99'N 5°34.07'W) (taken from Totaltide)

Time	Direction (Degrees)	Spring rate (m/s)	Neap rate (m/s)
-06h	212	0.05	0.00
-05h	029	0.05	0.00
-04h	026	0.10	0.05
-03h	022	0.15	0.05
-02h	022	0.21	0.05
-01h	028	0.15	0.05
HW	049	0.05	0.00
+01h	145	0.05	0.00
+02h	184	0.10	0.05
+03h	204	0.15	0.05
+04h	219	0.15	0.05
+05h	226	0.15	0.05
+06h	219	0.05	0.00

Tidal streams at the station are largely bidirectional but weak. The Clyde Cruising Club sailing direction for the area identifies that between Kerrera and Loch Don (Isle of Mull) spring rates are 1 kn (approx 0.5 m/s) which is significantly greater than the values given in Table 14.1 (Clyde Cruising Club, 2007). It also identifies that currents are stronger still in the channel between the north end of Kerrera and the mainland, with streams up to 2.5 knots (approx 1.3 m/s) at springs, depending on the channel width.

Summary current data was provided by SEPA for two locations near to Oitir Mhòr Bay. One was at the southern end of Ardantrive Bay, located on the north-east side of Kerrera. The other was in Charlotte Bay, immediately to the north-east of Oitir Mhòr Bay. The locations are identified in Figure 14.6. The summary data is presented in Table 14.2.

Table 14.2 Summary current data

Location	Depth	Mean current speed (m/s)	Residual current speed (m/s)	Residual current direction (degrees)	%≤0.03 m/s
Ardantrive	Near-surface	0.1	0.051	264	20[1]
	Mid-depth	0.069	0.023	031	23[2]
	Near-bottom	0.053	0.038	057	42[2]
Charlotte Bay	Near-surface	0.086	0.019	233	31[2]
	Mid-depth	0.059	0.013	243	31[2]
	Near-bottom	0.062	0.033	301	22[2]

[1]Assessed by SEPA as strongly flushed
[2]Assessed by SEPA as moderately flushed

Current speeds recorded at both locations were of the same order as that given in Table 14.1 for the tidal stream station. The magnitude of the residual current at each location was a significant proportion of the mean current value. At Ardantrive, the direction of the residual current was approximately north-easterly at the surface and north-westerly at depth. At Charlotte Bay, the direction of the residual current was approximately north-north-easterly at all depths.

14.3 Conclusions

Depths within Oitir Mhòr Bay are relatively shallow and this will limit the dilution of any contamination arising in the vicinity of the fishery. However, depths outside of the bay are more marked and thus contamination arising from more distant sources will be subject to a high degree of dilution.

Currents in the area are weak and this will limit the distance over which contamination will travel. At a peak current speed of 0.21 m/s, the maximum distance will be 3 km over a single ebb or flood tide, ignoring any effects of dilution or dispersion. On the same basis, at a peak current speed of 1.3 m/s, the distance of travel would be over 18 km. Therefore, discharge from the Oban STW would be travel out of the channel at the northern end of the Sound of Kerrera on the flood tide. However, it would be unlikely to impact on the oyster trestles on the next ebb tide, both due to the limited distance of travel over that ebb tide, and the degree of dilution that would occur (also, see below with regard to the ebb tide effects).

Oitir Mhòr Bay itself would fill from the south-west on the flood tide and empty in that direct ion on the ebb tide. Currents on the western side of the fishery would be complex due to the presence of the promontory and islands. However, contamination from sources to at the north side of the bay, and within Charlotte Bay, are unlikely to impact at the trestles as, on the ebb tide, the water level is likely to have dropped below the level of the trestles before any contamination reaches the southern end of the bay. The main contaminating effects are likely to be local sources on the shore in the vicinity of the trestles and these would mainly impact during the ebb tide. Some contamination could arise from sources on the shore immediately to the south of Oitir Mhòr Bay and these would impact on the rising tide.

Figure 14.6 Current and wind plots for Dubh Sgeir and Port na Moralachd

15. Shoreline Survey Overview

The shoreline survey was conducted on the 25th and 26th August 2010 under mostly calm weather conditions with some light rain showers. A restricted shoreline survey had been undertaken previously in 2008 in support of classification of the area for periwinkles.

Pacific oysters are grown on approximately 48 trestles on the intertidal area on the western side of Oitir Mhòr bay. The majority of the stock was at harvestable size at the time of the sanitary survey, and harvesting had begun the week previous to the shoreline survey. The official RMP is located approximately 100m from the oyster trestles. A sample bag of mussels is located here for biotoxin testing.

During the shoreline survey six houses were observed, five of which were around Ardantrive Bay on the east side of Kerrera and the remaining which was on the north east shoreline of Oitir Mhòr Bay. The shoreline of Oban Bay was walked during the survey. Sewage discharges were observed along the Oban Bay shoreline and Ardantrive Bay shoreline but not on the shoreline immediately adjacent to Oitir Mhòr Bay. On the shoreline of Ardantrive Bay, toilet and shower facilities for Oban Marina, a pipe pumping water and a private septic tank and outfall were observed. On the shoreline surrounding Oban Bay four outfall pipes, a CSO and Gallanach pumping station were observed.

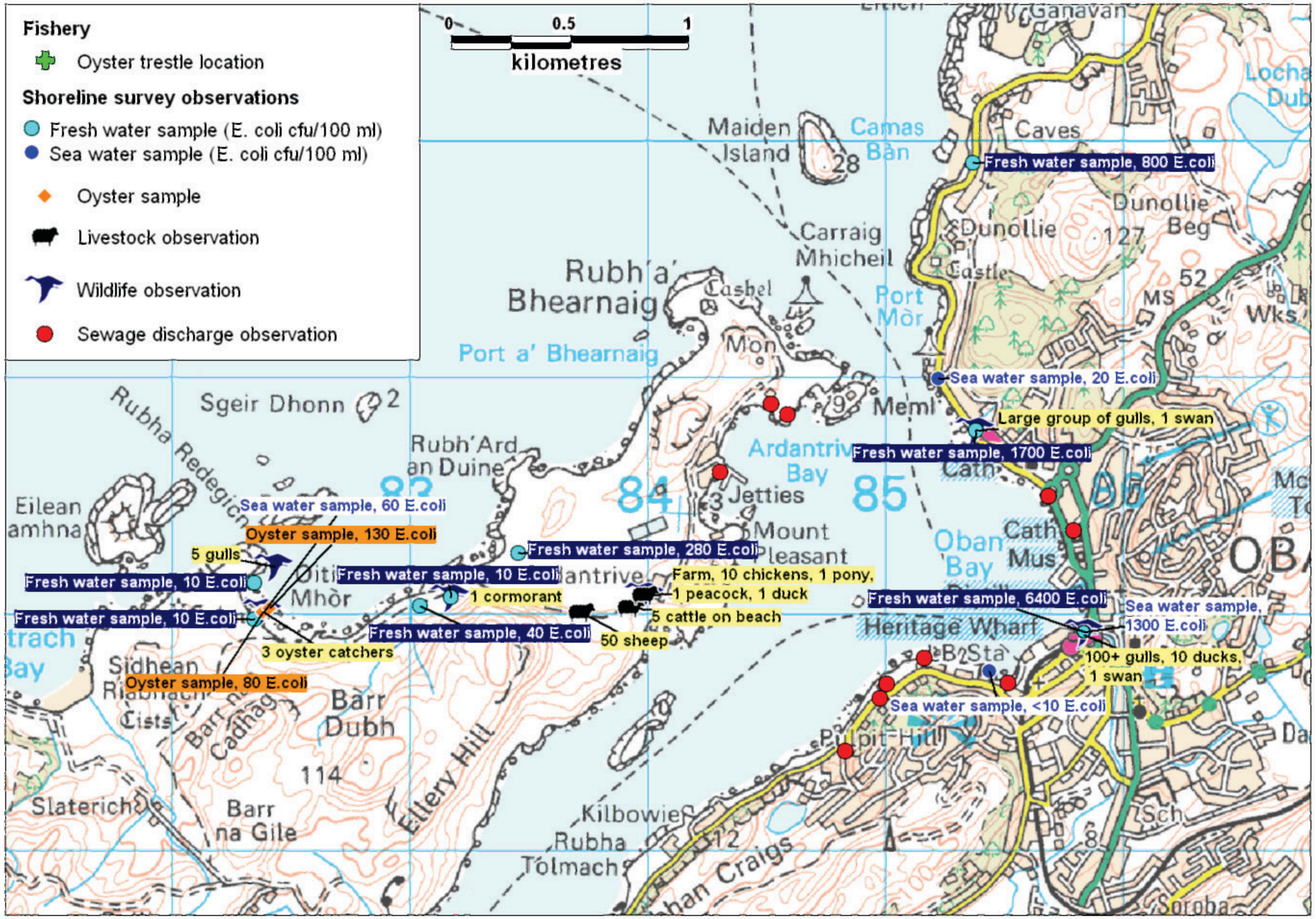
There was no livestock observed directly adjacent to Oitir Mhòr Bay, however a farm was observed on the island along the track between Oitir Mhòr Bay and Oban Marina. In a field adjacent to the farm were approximately 50 sheep. Five cattle were also observed on the beach south of the farm. The farm yard also had a pony, chickens, a duck and a peacock.

Approximately 5 gulls, 3 oyster catchers and 1 cormorant were observed at Oitir Mhòr Bay. Surrounding Oban bay larger populations of seabirds were observed including two large groups of gulls (100+), 10 ducks and 2 swans. No other wild animals were seen.

The streams with the highest loadings were located along the south-eastern shore of the bay and could potentially affect the water quality at the oyster trestles if the current flowed from there towards the trestles. Two streams were located within the inner bay in the vicinity of the trestles. Both gave low calculated loadings on the basis of the shoreline survey measurements. However, one of the streams flowed down through the trestles and therefore, despite the low loading, could significantly contribute to the *E. coli* levels at the trestles.

Seawater samples were collected from various points along the shoreline. A seawater sample taken where the main stream entering Oban Bay met the main water body, (close to the buoy marking the CSO outfall) gave a high result of 1300 *E. coli* cfu/100ml. Two shellfish samples were taken and the sample taken closer to MHWS had a higher result of 130 *E. coli* MPN/100 g compared to the sample taken near the shoreline which had a result of 80 *E. coli* MPN/100 g.

Figure 15.1 shows a summary map of the most significant findings from the shoreline survey.



Produced by Cefas Weymouth Laboratory.

Figure 15.1 Summary of shoreline survey findings for Oitir Mhòr Bay

16. Overall Assessment

The fishery at Oitir Mhòr Bay consists of a small intertidal area of 48 trestles with full bags of oysters, and four empty trestles. The majority of stock is of harvestable size and harvesting had begun the week previous to the shoreline survey.

Human sewage impacts

The island of Kerrera has a population of approximately 40 permanent residents. The settlement of Oban adjacent to the island has a population of 8120 (2001 census) and though it has significant sewage discharges, these are not considered likely to impact heavily at Oitir Mhòr Bay. There is no mains sewerage system on the Isle of Kerrera, however a new septic tank was identified on the shoreline of Oitir Mhòr Bay close to the shellfish bed during the 2008 shoreline survey. The septic tank belongs to the only house on the shore of Oitir Mhòr Bay and is thought to be a holiday home. There is a fish farm with 6 cages and a service barge located at the north-eastern end of the bay and if toilet facilities are present on the barge, these may discharge directly into the bay.

Further sewage input is likely from the wildlife tour boats that frequent Oitir Mhòr Bay and from the yachts that anchor within the bay. Potential contamination from these sources is likely to be seasonal, with higher impact during the summer months. Oban Harbour and the ferries operating from Oban are not thought to impact on the fishery.

Agricultural impacts

There is no arable agriculture in the vicinity of Oitir Mhòr Bay. Livestock graze near and possibly on the shoreline of Oitir Mhòr Bay. A farm is located on the track between Oitir Mhòr Bay and Oban Harbour: however, this farm is located towards the eastern side of the island and so may not impact on water quality within the bay.

Wildlife impacts

Significant numbers of seals have been recorded in the vicinity of Oitir Mhòr Bay and these animals are a potential source of faecal contamintion to the fishery. Faecal matter deposited at haulout sites to the north of the fishery may lead to locally high concentrations of faecal indicator bacteria in the water. As currents in the area are predicted to move generally along the island, the main haulout site is not anticipated to impact significantly on water quality at the fishery. Animals present nearer the fishery may contribute to faecal contamination levels within the bay where the oyster trestles are located, however their presence in this area is anticipated to be less frequent and less predictable.

Small numbers of bulls and other seabirds are recorded as breeding in the vicinity of the fishery. However, their numbers in the area are small and they are not considered likely to significantly impact water quality at the fishery.

Seasonal variation

Population in the area is likely to be higher during the summer months, although the majority of visitors are likely to be day visitors due to the lack of accommodation on the island. Boat traffic is likely to be higher in summer as yachts that cannot find moorings on the Oban side of the island choose to anchor in Oitir Mhòr Bay. Visiting boats are most likely to impact the eastern side of the fishery, as this is where the anchorage is located. Traffic from wildlife tour boats is likely to also be more frequent during the late spring and summer months.

Daily rainfall has tended to be higher from October to January and lowest during April to July. Extreme rainfall events of greater than 20 mm per day were found to occur during all months of the year, indicating little seasonality to heavy rainfall.

Statistical analysis of historical monitoring results at Oitir Mhòr Bay indicated that results for the summer and autumn were significantly higher than those for both the spring and winter.

Seasonal variation is likely to occur in populations of humans, livestock and wildlife in the area. Populations of humans, livestock and seabirds are likely to be higher in summer. Insufficient information was available to assess seasonal variation in the numbers of seals present in the area.

Rivers and streams

Five of the eight streams discharging into Oitir Mhòr Bay were measured during the shoreline survey. Two of the streams were located within the inner bay in the vicinity of the trestles and both gave low calculated loadings on the basis of the shoreline survey measurements. However, one of the streams flowed through the trestles and therefore, despite the low loading, could significantly contribute to the *E. coli* levels at the trestles. The stream with the highest loading was located on the eastern shore of the bay and could potentially affect the water quality at the oyster trestles if the current flowed from there towards the trestles.

Movement of contaminants

Dilution of contamination arising within Oitir Mhòr Bay will be limited due to the shallow depths. Contamination arising outside the bay will be significantly greater. Currents in the area are weak and this will limit the distance over which contamination will travel. It is expected that the main impact on the trestles on the ebb tide will occur from sources on the adjacent shore and that sources a short distance to the south-west of the bay could impact on the trestles on the flood tide.

Temporal and geographical patterns of sampling results

Higher *E. coli* results had been seen in the oysters towards the high water mark: however, this was the location at which most samples had been taken and so the pattern may not be significant in terms of the underlying pattern of contamination. There are no overall temporal patterns in levels of contamination; no trends were seen since the start of sampling in 2005.

Conclusions

There is very limited human sewage discharging into Oitir Mhòr Bay and intermittent contributions from boating activity may be more significant than the contribution from the single septic tank. It is not thought likely that contamination from within the Sound of Kerrera will impact at the oyster farm. Most significant contamination is likely to arise from diffuse sources carried to the bay by streams: the two located in the immediate vicinity of the trestles will have the greatest effect.

17. Recommendations

Production area

The recommended production area is: “The area bounded by a line drawn between NM 8245 3023 and NM 8266 2994 and extending to MHWS”.

This area covers the extent of the present oyster farm and the adjacent intertidal area, while excluding identified sources of contamination in the other parts of the bay.

RMP

The recommended RMP is at NM 8239 3001. This is located towards the low water mark and should reflect diffuse pollution arising from the nearby shore, including that borne by the adjacent stream. It should also be accessible over a reasonable range of low tides.

Tolerance

Given that the samples will be hand-picked, the recommended tolerance is 10 m. If stock of sufficient size for sampling will not be present at the identified location for a period of time, bagged stock should be placed at that point. The bagged stock should be at the RMP for at least two weeks prior to sampling in order that the animals equilibrate to the water quality at that point.

Frequency

Given the seasonal variability in sampling results and classification, the recommended frequency for ongoing monitoring is monthly.

Depth of sampling

Not applicable, as the samples will be hand-picked from poches on the trestles.

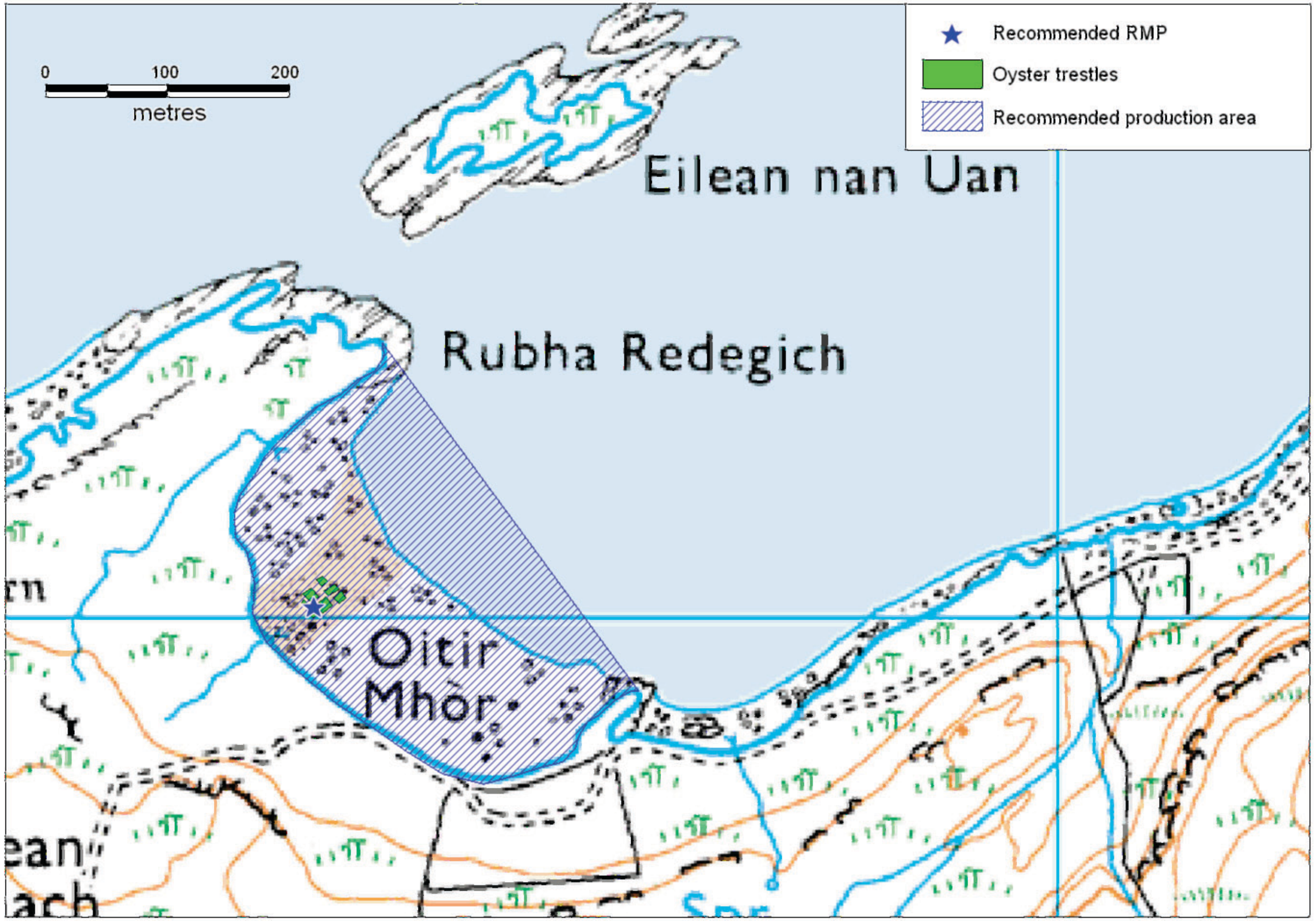


Figure 17.1 Map of recommendations at Oitir Mhòr

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Sampling Plan for Oitir Mhor Bay

PRODUCTION AREA	Oitir Mhor Bay
SITE NAME	Oitir Mhor
SIN	AB 308 701 13
SPECIES	Pacific oysters
TYPE OF FISHERY	Trestles
NGR OF RMP	NM 8239 3001
EAST	182390
NORTH	730010
TOLERANCE (M)	10
DEPTH (M)	N/A
METHOD OF SAMPLING	Hand-picked
FREQUENCY OF SAMPLING	Monthly
LOCAL AUTHORITY	Argyll & Bute Council
AUTHORISED SAMPLER(S)	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell
LOCAL AUTHORITY LIAISON OFFICER	Christine McLachlan

Table of Proposed Boundaries and RMPs

PRODUCTION AREA	**Oitir Mhor Bay**
SPECIES	**Pacific oysters**
SIN	**AB 308 701 13**
EXISTING BOUNDARY	Defined by the area bounded by lines drawn between NM 8236 3028 and NM 8348 3050 extending to MHWS
EXISTING RMP	NM 825 300
RECOMMENDED BOUNDARY	The area bounded by a line drawn between NM 8245 3023 and NM 8266 2994 and extending to MHWS
RECOMMENDED RMP	NM 8239 3001
COMMENTS	The production area has been reduced in size. The RMP has been relocated and defined to 10 m accuracy.

Geology and Soils Assessment

Component soils and their associations were identified using uncoloured soil maps (scale 1:50,000) obtained from the Macaulay Institute. The relevant soils associations and component soils were then investigated to establish basic characteristics. From the maps seven main soil types were identified: 1) humus-iron podzols, 2) brown forest soils, 3) calcareous regosols, brown calcareous regosols, calcareous gleys, 4) peaty gleys, podzols, rankers, 5) non-calcareous gleys, peaty gleys: some humic gleys, peat, 6) organic soils and 7) alluvial soils.

Humus-iron podzols are generally infertile and physically limiting soils for productive use. In terms of drainage, depending on the related soil association they generally have a low surface % runoff, of between 14.5 – 48.4%, indicating that they are generally freely draining.

Brown forest soils are characteristically well drained with their occurrence being restricted to warmer drier climates, and under natural conditions they often form beneath broadleaf woodland. With a very low surface % runoff of between 2 – 29.2%, brown forest soils can be categorised as freely draining (Macaulay Institute, 2007).

Calcareous regosols, brown regosols and calcareous gleys are all characteristically freely draining soils containing free calcium carbonate within their profiles. These soil types have a very low surface % runoff at 14.5%.

Peaty gleys, peaty podzols and peaty rankers contribute to a large percentage of the soil composition of Scotland. They are all characteristically acidic, nutrient deficient and poorly draining. They have a very high surface % runoff of between 48.4 – 60%.

Non-calcareous gleys, peaty gleys and humic gleys are generally developed under conditions of intermittent or permanent water logging. In Scotland, non-calcareous gleys within the Arkaig association are most common and have an average surface % runoff of 48.4%, indicating that they are generally poorly draining.

Organic soils often referred to as peat deposits and are composed of greater than 60% organic matter. Organic soils have a surface % runoff of 25.3% and although low, due to their water logged nature, results in them being poorly draining.

Alluvial soils are confined to principal river valleys and stream channels, with a wide soil textural range and variable drainage. However, the alluvial soils encountered within this region have an average surface % runoff of 44.3%, so it is likely that in this case they would be poorly draining.

These component soils were classed broadly into two groups based on whether they are freely or poorly draining. Drainage classes were created based on information obtained from the both the Macaulay Institute website and personal communication with Dr. Alan Lilly. GIS map layers were created for each class with poorly draining classes shaded red, pink or orange and freely draining classes coloured blue or grey. These maps were then used to assess the spatial variation in soil permeability across a survey area and it's potential impact on runoff.

Glossary of Soil Terminology

Calcareous: Containing free calcium carbonate.

Gley: A sticky, bluish-grey subsurface layer of clay developed under intermittent or permanent water logging.

Podzol: Infertile, non-productive soils. Formed in cool, humid climates, generally freely draining.

Rankers: Soils developed over noncalcareous material, usually rock, also called 'topsoil'.

Regosol: coarse-textured, unconsolidated soil lacking distinct horizons. In Scotland, it is formed from either quartzose or shelly sands.

General Information on Wildlife Impacts

Pinnipeds

Two species of pinniped (seals, sea lions, walruses) are commonly found around the coasts of Scotland: These are the European harbour, or common, seal (*Phoca vitulina vitulina*) and the grey seal (*Halichoerus grypus*). Both species can be found along the west coast of Scotland.

Common seal surveys are conducted every 5 years and an estimate of minimum numbers is available through Scottish Natural Heritage.

According to the Scottish Executive, in 2001 there were approximately 119,000 grey seals in Scottish waters, the majority of which were found in breeding colonies in Orkney and the Outer Hebrides.

Adult Grey seals weigh 150-220 kg and adult common seals 50-170kg. They are estimated to consume between 4 and 8% of their body weight per day in fish, squid, molluscs and crustaceans. No estimates of the volume of seal faeces passed per day were available, though it is reasonable to assume that what is ingested and not assimilated in the gut must also pass. Assuming 6% of a median body weight for harbour seals of 110kg, that would equate to 6.6kg consumed per day and probably very nearly that defecated.

The concentration of *E. coli* and other faecal indicator bacteria contained in seal faeces has been reported as being similar to that found in raw sewage, with counts showing up to 1.21×10^4 CFU (colony forming units) *E. coli* per gram dry weight of faeces (Lisle *et al* 2004).

Both bacterial and viral pathogens affecting humans and livestock have been found in wild and captive seals. *Salmonella* and *Campylobacter* spp., some of which were antibiotic-resistant, were isolated from juvenile Northern elephant seals (*Mirounga angustirostris*) with *Salmonella* found in 36.9% of animals stranded on the California coast (Stoddard et al 2005). *Salmonella* and *Campylobacter* are both enteric pathogens that can cause acute illness in humans and it is postulated that the elephant seals were picking up resistant bacteria from exposure to human sewage waste.

One of the *Salmonella* species isolated from the elephant seals, *Salmonella typhimurium*, is carried by a number of animal species and has been isolated from cattle, pigs, sheep, poultry, ducks, geese and game birds in England and Wales. Serovar DT104, also associated with a wide variety of animal species, can cause severe disease in humans and is multi-drug resistant (Poppe et al 1998).

Cetaceans

As mammals, whales and dolphins would be expected to have resident populations of *E. coli* and other faecal indicator bacteria in the gut. Little is known about the concentration of indicator bacteria in whale or dolphin faeces, in large part because the animals are widely dispersed and sample collection difficult.

A variety of cetacean species are routinely observed around the west coast of Scotland. Where possible, information regarding recent sightings or surveys is gathered for the production area. As whales and dolphins are broadly free ranging, this is not usually possible to such fine detail. Most survey data is supplied by the Hebridean Whale and Dolphin Trust or the Shetland Sea Mammal Group and applies to very broad areas of the coastal seas.

It is reasonable to expect that whales would not routinely affect shellfisheries located in shallow coastal areas. It is more likely that dolphins and harbour porpoises would be found in or near fisheries due to their smaller physical size and the larger numbers of sightings near the coast.

Birds

Seabird populations were surveyed all over Britain as part of the SeaBird 2000 census. These counts are investigated using GIS to give the numbers observed within a 5 km radius of the production area. This gives a rough idea of how many birds may be present either on nests or feeding near the shellfish farm or bed.

Further information is gathered where available related to shorebird surveys at local bird reserves when present. Surveys of overwintering geese are queried to see whether significant populations may be resident in the area for part of the year. In many areas, at least some geese may be present year round. The most common species of goose observed during shoreline surveys has been the Greylag goose. Geese can be found grazing on grassy areas adjacent to the shoreline during the day and leave substantial faecal deposits. Geese and ducks can deposit large amounts of faeces in the water, on docks and on the shoreline.

A study conducted on both gulls and geese in the northeast United States found that Canada geese (*Branta canadiensis*) contributed approximately 1.28×10^5 faecal coliforms (FC) per faecal deposit and ring-billed gulls (*Larus delawarensis*) approximately 1.77×10^8 FC per faecal deposit to a local reservoir (Alderisio and DeLuca, 1999). An earlier study found that geese averaged from 5.23 to 18.79 defecations per hour while feeding, though it did not specify how many hours per day they typically feed (Bedard and Gauthier, 1986).

Waterfowl can be a significant source of pathogens as well as indicator organisms. Gulls frequently feed in human waste bins and it is likely that they carry some human pathogens.

Deer

Deer are present throughout much of Scotland in significant numbers. The Deer Commission of Scotland (DCS) conducts counts and undertakes culls of deer in areas that have large deer populations.

Four species of deer are routinely recorded in Scotland, with Red deer (*Cervus elaphus*) being the most numerous, followed by Roe deer (*Capreolus capreolus*), Sika deer (*Cervus nippon*) and Fallow deer (*Dama dama*).

Accurate counts of populations are not available, though estimates of the total populations are >200,000 Roe deer, >350,000 Red deer, < 8,000 Fallow deer and an unknown number of Sika deer. Where Sika deer and Red deer populations overlap, the two species interbreed further complicating counts.

Deer will be present particularly in wooded areas where the habitat is best suited for them. Deer, like cattle and other ruminants, shed *E. coli*, *Salmonella* and other potentially pathogenic bacteria via their faeces.

Other

The European Otter (*Lutra lutra*) is present around Scotland with some areas hosting populations of international significance. Coastal otters tend to be more active during the day, feeding on bottom-dwelling fish and crustaceans among the seaweed found on rocky inshore areas. An otter will occupy a home range extending along 4-5km of coastline, though these ranges may sometimes overlap (Scottish Natural Heritage website). Otters primarily forage within the 10 m depth contour and feed on a variety of fish, crustaceans and shellfish (Paul Harvey, Shetland Sea Mammal Group, personal communication).

Otters leave faeces (also known as spraint) along the shoreline or along streams, which may be washed into the water during periods of rain.

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Tables of Typical Faecal Bacteria Concentrations

Summary of faecal coliform concentrations (cfu 100ml-1) for different treatment levels and individual types of sewage-related effluents under different flow conditions: geometric means (GMs), 95% confidence intervals (Cis), and results of t-tests comparing base- and high-flow GMs for each group and type.

Indicator organism	Base-flow conditions				High-flow conditions			
Treatment levels and specific types: Faecal coliforms	n^c	Geometric mean	Lower 95% CI	Upper 95% CI	n^c	Geometric mean	Lower 95% CI	Upper 95% CI
Untreated	252	$1.7 \times 10^{7*}$ (+)	1.4×10^7	2.0×10^7	282	$2.8 \times 10^{6*}$ (-)	2.3×10^6	3.2×10^6
Crude sewage discharges	252	$1.7 \times 10^{7*}$ (+)	1.4×10^7	2.0×10^7	79	$3.5 \times 10^{6*}$ (-)	2.6×10^6	4.7×10^6
Storm sewage overflows					203	2.5×10^6	2.0×10^6	2.9×10^6
Primary	127	$1.0 \times 10^{7*}$ (+)	8.4×10^6	1.3×10^7	14	4.6×10^6 (-)	2.1×10^6	1.0×10^7
Primary settled sewage	60	1.8×10^7	1.4×10^7	2.1×10^7	8	5.7×10^6		
Stored settled sewage	25	5.6×10^6	3.2×10^6	9.7×10^6	1	8.0×10^5		
Settled septic tank	42	7.2×10^6	4.4×10^6	1.1×10^7	5	4.8×10^6		
Secondary	864	$3.3 \times 10^{5*}$ (-)	2.9×10^5	3.7×10^5	184	$5.0 \times 10^{5*}$ (+)	3.7×10^5	6.8×10^5
Trickling filter	477	4.3×10^5	3.6×10^5	5.0×10^5	76	5.5×10^5	3.8×10^5	8.0×10^5
Activated sludge	261	$2.8 \times 10^{5*}$ (-)	2.2×10^5	3.5×10^5	93	$5.1 \times 10^{5*}$ (+)	3.1×10^5	8.5×10^5
Oxidation ditch	35	2.0×10^5	1.1×10^5	3.7×10^5	5	5.6×10^5		
Trickling/sand filter	11	2.1×10^5	9.0×10^4	6.0×10^5	8	1.3×10^5		
Rotating biological contactor	80	1.6×10^5	1.1×10^5	2.3×10^5	2	6.7×10^5		
Tertiary	179	1.3×10^3	7.5×10^2	2.2×10^3	8	9.1×10^2		
Reedbed/grass plot	71	1.3×10^4	5.4×10^3	3.4×10^4	2	1.5×10^4		
Ultraviolet disinfection	108	2.8×10^2	1.7×10^2	4.4×10^2	6	3.6×10^2		

Source: Kay, D. et al (2008) Faecal indicator organism concentrations in sewage and treated effluents. *Water Research* 42, 442-454.

Comparison of faecal indicator concentrations (average numbers/g wet weight) excreted in the faeces of warm-blooded animals

Animal	Faecal coliforms (FC) number	Excretion (g/day)	FC Load (numbers /day)
Chicken	1,300,000	182	2.3×10^8
Cow	230,000	23,600	5.4×10^9
Duck	33,000,000	336	1.1×10^{10}
Horse	12,600	20,000	2.5×10^8
Pig	3,300,000	2,700	8.9×10^8
Sheep	16,000,000	1,130	1.8×10^{10}
Turkey	290,000	448	1.3×10^8
Human	13,000,000	150	1.9×10^9

Source: Adapted from Geldreich 1978 by Ashbolt et al in World Health Organisation (WHO) Guidelines, Standards and Health. 2001. Ed. by Fewtrell and Bartram. IWA Publishing, London.

Statistical Data

All *E. coli* data was log transformed prior to statistical tests.

Section 11.5 One way ANOVA comparison of *E. coli* results by season

```
Source  DF      SS     MS      F      P
Season   3  23.260  7.753  25.87  0.000
Error   50  14.985  0.300
Total   53  38.245

S = 0.5474   R-Sq = 60.82%   R-Sq(adj) = 58.47%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  --------+---------+---------+---------+-
1      18  1.8085  0.4211      (---*---)
2      12  3.2827  0.7125                           (-----*----)
3      14  2.7701  0.5647                   (----*----)
4      10  1.6378  0.4991  (----*-----)
                           --------+---------+---------+---------+-
                                1.80      2.40      3.00      3.60

Pooled StDev = 0.5474


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Season

Individual confidence level = 98.95%


Season = 1 subtracted from:

Season    Lower   Center   Upper  ---------+---------+---------+---------+
2        0.9317   1.4742  2.0166                           (---*----)
3        0.4430   0.9616  1.4803                       (---*---)
4       -0.7448  -0.1707  0.4033              (----*---)
                                  ---------+---------+---------+---------+
                                        -1.2       0.0       1.2       2.4


Season = 2 subtracted from:

Season    Lower   Center    Upper  ---------+---------+---------+---------+
3       -1.0851  -0.5126   0.0600            (----*----)
4       -2.2681  -1.6449  -1.0217  (----*----)
                                   ---------+---------+---------+---------+
                                         -1.2       0.0       1.2       2.4


Season = 3 subtracted from:

Season    Lower   Center    Upper  ---------+---------+---------+---------+
4       -1.7350  -1.1324  -0.5297       (----*----)
                                   ---------+---------+---------+---------+
                                         -1.2       0.0       1.2       2.4
```

Section 11.6.1 Spearman's rank correlation for *E. coli* result and 2 day rainfall

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.229
```

n=46, p>0.05

Section 11.6.1 Spearman's rank correlation for *E. coli* result and 7 day rainfall

```
Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.334
```
n=46,p<0.025

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the spring/neap cycle

CIRCULAR-LINEAR CORRELATION
Analysis begun: 21 May 2010 14:33:57

Variables (& observations)	r	p
Angles & Linear (54)	0.173	0.217

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the high/low cycle

CIRCULAR-LINEAR CORRELATION
Analysis begun: 15 June 2010 15:05:36

Variables (& observations)	r	p
Angles & Linear (54)	0.208	0.109

Section 11.6.3 Spearman's rank correlation for *E. coli* result and water temperature

```
Pearson correlation of ranked temperature and ranked E coli for temperature
=0.630
n=43, p<0.0005
```

Section 11.6.5 Spearman's rank correlation for *E. coli* result and salinity

```
Pearson correlation of ranked salinity and ranked e coli for salinity = -
0.031
```
n=42,p>0.25

Hydrographic Methods

The new EU regulations require an appreciation of the hydrography and currents within a region classified for shellfish production with the aim to "determine the characteristics of the circulation of pollution, appreciating current patterns, bathymetry and the tidal cycle." This document outlines the methodology used by Cefas to fulfil the requirements of the sanitary survey procedure with regard to hydrographic evaluation of shellfish production areas. It is written as far as possible to be understandable by someone who is not an expert in oceanography or computer modelling. A glossary at the end of the document defines commonly used hydrographic terms e.g. tidal excursion, residual flow, spring-neap cycle etc.

The hydrography at most sites will be assessed on the basis of bathymetry and tidal flow software only. Selected sites will be assessed in more detail using either: 1) a hydrodynamic model, or 2) an extended consideration of sources, available field studies and expert assessment. This document will consider the more basic hydrographic processes and describes the common methodology applied to all sites.

<u>Background processes</u>
Currents in estuarine and coastal waters are generally driven by one of three mechanisms: 1) Tides, 2) Winds, 3) Density differences.

Tidal flows often dominate water movement over the short term (approximately 12 hours) and move material over the length of the *tidal excursion*. Tides move water back and forth over the tidal period often leading to only a small net movement over the 12 hours tidal cycle. This small net movement is partly associated with the *tidal residual* flow and over a period of days gives rise to persistent movement in a preferred direction. The direction will depend on a number of factors including the bathymetry and direction of propagation of the main tidal wave.

Wind and density driven current also lead to persistent movement of water and are particular important in regions of relatively low tidal velocities characteristic of many of the water bodies in Scottish waters. Whilst tidal flows generally move material in more or less the same direction at all depths, wind and density driven flows often move material in different directions at the surface and at the bed. Typical vertical profiles are depicted in Figure 1. However, it should be understood that in a given water body, movement will often be the sum of all three processes.

In sea lochs, mechanisms such as "wind rows" can transport sources of contamination at the edge of the loch to production areas further offshore. Wind rows are generated by winds directed along the main length of the loch. An illustration of the waters movements generated in this way is given in Figure 2. As can be seen the water circulates in a series of cell that draw material across the loch at right angles to the wind direction. This is a particularly common situation for lochs with high land on either side as these tend to act as a steering mechanism to align winds along the water body.

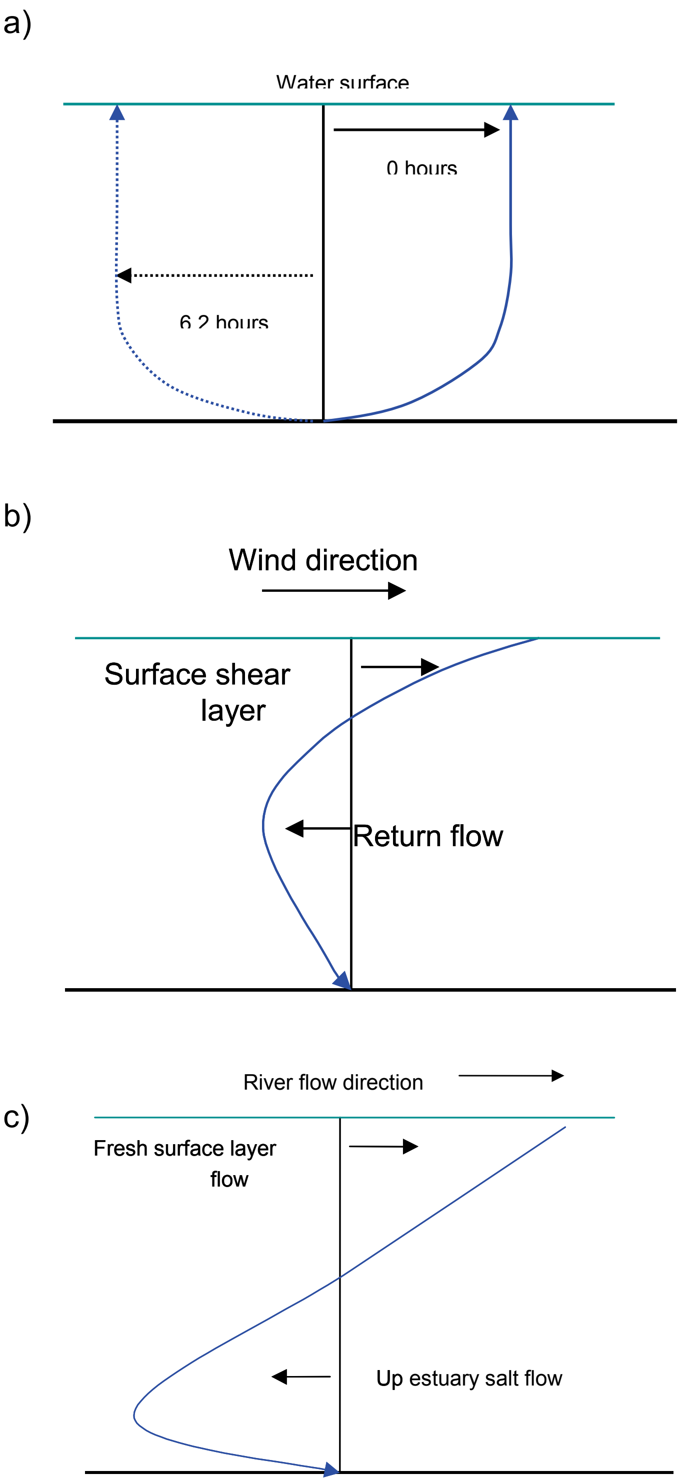

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction over a period of 6.2 hours. b) wind driven current profile, c) density driven current profile.

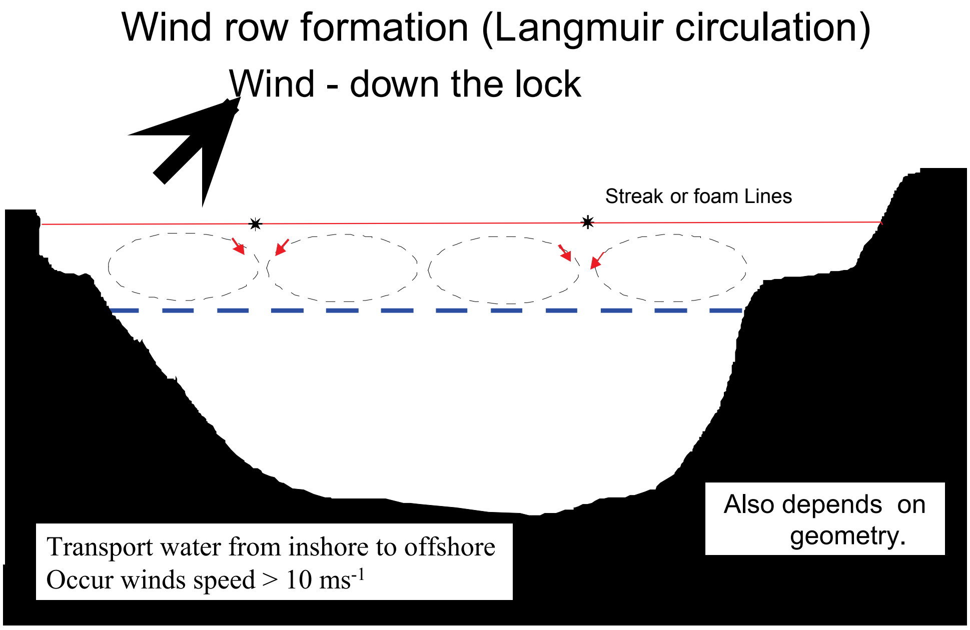

Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Non-modelling Assessment

In this approach the assessment requires a certain amount of expert judgment and subjectivity enters in. For all production areas, the following general guidelines are used:

1. Near-shore flows will generally align parallel to the shore.
2. Tidal flows are bi-directional, thus sources on either side of a production area are potentially polluting.
3. For tidal flows, the tidal excursion gives an idea of the likely main 'region of influence' around an identified pollutant source.
4. Wind driven flows can drive material from any direction depending on the wind direction. Wind driven current speeds are usually at a maximum when the wind direction is aligned with the principle axis of the loch.
5. Density driven flows generally have a preferred direction.
6. Material will be drawn out in the direction of current, often forming long thin 'plumes'.

Many Scottish shellfish production areas occur within sea lochs. These are fjord-like water bodies consisting of one or more basins, deepened by glacial activity and having relatively shallow sills that control the mixing and flushing processes. The sills are often regions of relatively high currents, while the basins are much more tranquil often containing higher density water trapped below a fresh lower density surface layer. Tidal mixing primarily occurs at the sills.

The catalogue of Scottish Sea Loch produced by the SMBA is used to quantify sills, volume fluxes and likely flow velocities. Because the flow is so constrained by the rapidly varying bathymetry, care has to be used in the extrapolation of direct measurements of current flow. Mean flow velocities can be estimated at the sills by using estimates of the sill area and the volume change through a tidal cycle. This in turn can be used to estimate the maximum distance travelled in a tidal cycle in the sill area. Away from the sill area, tidal velocities are general low and transport events are dominated by wind or density effects. Sea Lochs generally have a surface layer of fresher water; the extent of this depends on freshwater input, sill depth and quantity of mixing.

In addition to movement of particles by currents, dilution is also an important consideration. Dilution reduces the effect of an individual point source although at the expense of potentially contaminating a larger area. Thus class A production areas can be achieved in water bodies with significant faecal coliform inputs if no transport pathway exists and little mixing can occur. Conversely a poor classification might occur where high mixing causes high and permanent background concentrations arising from many weak diffuse sources.

References

European Commission 1996. Report on the equivalence of EU and US legislation for the Sanitary Production of Live Bivalve Molluscs for Human Consumption. EU Scientific Veterinary Committee Working Group on Faecal Coliforms in Shellfish, August 1996.

Glossary

The following technical terms may appear in the hydrographic assessment.

Bathymetry. The underwater topography given as depths relative to some fixed reference level e.g. mean sea level.

Hydrography. Study of the movement of water in navigable waters e.g. along coasts, rivers, lochs, estuaries.

Tidal period. The dominant tide around the UK is the twice daily one generated by the moon. It has a period of 12.42 hours. For near shore so-called rectilinear tidal currents then roughly speaking water will flow one way for 6.2 hours then back the other way for 6.2 hours.

Tidal range. The difference in height between low and high water. Will change over a month.

Tidal excursion. The distance travelled by a particle over one half of a tidal cycle (roughly~6.2 hours). Over the other half of the tidal cycle the particle will move in the opposite direction leading to a small net movement related to the tidal residual. The excursion will be largest at Spring tides.

Tidal residual. For the purposes of these documents it is taken to be the tidal current averaged over a complete tidal cycle. Very roughly it gives an idea of the general speed and direction of travel due to tides for a particle over a period of several days.

Tidal prism. The volume of water brought into an estuary or sea loch during half a tidal cycle. Equal to the difference in estuary/sea loch volume at high and low water.

Spring/Neap Tides. The strongest tides in a month are called spring tides and the weakest are called neap tides. Spring tides occur every 14 days with neaps tides occurring 7 days after springs. Both tidal range and tidal currents are strongest at Spring tides.

Tidal diamonds. The tidal velocities measured and printed on admiralty charts at specific locations are called tidal diamonds.

Wind driven shear/surface layer. The top metre or so of the surface that generally moves in the rough direction of the wind typically at a speed that is a few percent (~3%)of the wind speed.

Return flow. Often a surface flow at the surface is accompanied by a compensating flow in the opposite direction at the bed (see figure 1).

Stratification. The splitting of the water into two layers of different density with the less dense layer on top of the denser one. Due to either temperature or salinity differences or a combination of both.

Shoreline Survey Report

Prod. area: Oitir Mhor Bay
Site name: Oitir Mhor (AB 308 701 13)
Species: Pacific Oysters
Harvester: Scott Glen
Local Authority: Argyll and Bute Council
Status: Existing

Date Surveyed: 25th – 26th August 2010
Surveyed by: Fran Hockley (Cefas), Ewan McDougall (Argyll & Bute Council)

Existing RMP: NM 825 300
Area Surveyed: See Figure 1

Weather observations
25th August 2010: Sunny, turning to sunny spells in the afternoon. Light rain shower approximately 14:00. Days previous to the survey had heavy rain. No or very light wind.

Site Observations

Fishery
The fishery consists of a small intertidal area of 48 trestles with full bags of oysters, and four empty trestles. Much of the stock was at harvestable size at the time of the sanitary survey, and harvesting had begun the week previous to the shoreline survey.

The official RMP is located approximately 100m from the oyster trestles. A sample bag of mussels is located here for biotoxin testing.

Sewage/Faecal Sources

Human
At the time of the shoreline survey, construction work was being carried out on the small island of Rubh'a Chruidh. Planning applications show that the work is for the demolition of a dwelling house, with the erection of a new dwelling with a 6KW wind turbine. The planning application also includes the installation of a septic tank with puraflow system and connection to a private water supply. The septic tank is to be located on the northern side of the island, and therefore is likely to discharge in this area.

The main source of contamination in the area surveyed was from the main stream entering Oban Harbour. The freshwater sample from the stream gave a result of 6400 *E. coli* cfu/100ml and the seawater sample taken where the stream met the main water body, close to the buoy marking the CSO outfall gave a result of 1300 *E.coli* cfu/100ml.

A stream entering Oban Bay near to the cathedral also had a high *E. coli* result of 1700 *E. coli* cfu/100ml.

The outfall of a CSO (Figure 21) appeared to be flowing from the side of the pier at Oban; however the pipe was inaccessible to allow for a water sample to be taken.

None of the houses to the north of the area surveyed appeared to have septic tanks, suggesting that they are connected to the main sewerage system rather than having individual private systems. The water sample (FW07) taken from a stream which flows near these houses gave a relatively low result of 800 cfu/100ml.

There were no signs of sewage related debris at any of the outfall sites.

<u>Livestock</u>
There was no livestock observed directly adjacent to Oitir Mhor Bay, however a farm was observed on the island along the track between Oitir Mhor Bay and Oban Marina. In a field adjacent to the farm were approximately 50 sheep. Five cattle were also observed on the beach south of the farm. The farm yard also had a pony, chickens, a duck and a peacock.

Seasonal Population
Oban is a very popular town for tourism, with several regular boat trips leaving from the harbour to observe seals at Sgeir Dhoon Island. At the time of the survey there was a large cruise ship moored further out of Oban, which had two shuttle boats to ferry passengers from the cruise ship to the mainland at Oban. Oban harbour has a large number of restaurants and hotels to cater for the large number of visitors during the busy summer season. Kerrera Island is less busy, but also regularly sees tourists which visit the islands marina and oyster café, and the tea rooms to the south. Tourists are often seen walking and cycling Kerrea’s coastline.

Boats/Shipping
Kerrea Island holds Oban Marina, which has 94 floating pontoon berths and 33 moorings, and also has a boat yard and shed. The Caledonian MacBrayne Ferry (Figure 13A) docks at Oban harbour, and makes a return trip to the Isle of Mull 6-7 times a day. Large cruise ships often dock outside of the harbour where the cost of mooring is cheaper, but run smaller ferries between the cruise ship and Oban harbour for passengers. There are also several small sight-seeing boat trips which take passengers to Sgier Dhoon Island close to Oitir Mhor Bay to observe seals, and two regular ferry services to Kerrera from Oban harbour. There are also mackerel fishing boat trips from Oban Harbour.

Land Use
Land use on the north of Kerrera Island is mostly un-grazed grassland. There is a farm between the boat yard and Oitir Mhor Bay which has a few fenced fields used for grazing sheep and cattle.

Wildlife/Birds
Several hundred gulls were observed on the mainland around Oban, encouraged to the area to scavenge on dropped litter or people feeding them from the harbour side. Ducks and swans were also observed on the beach in Oban. A small group of gulls, a cormorant and three oyster catchers were also observed in Oitir Mhor Bay.

Two dogs belonging to the farm were able to freely roam the shoreline and were observed playing in the streams. There were also several other dogs with walkers on the shore of Kerrera, and were also regularly seen on the beaches on the mainland at Oban.

Comments
Recorded observations apply to the date of survey only. Animal numbers were recorded on the day from the observer's point of view. This does not necessarily equate to total numbers present as natural features may obscure individuals and small groups of animals from view.

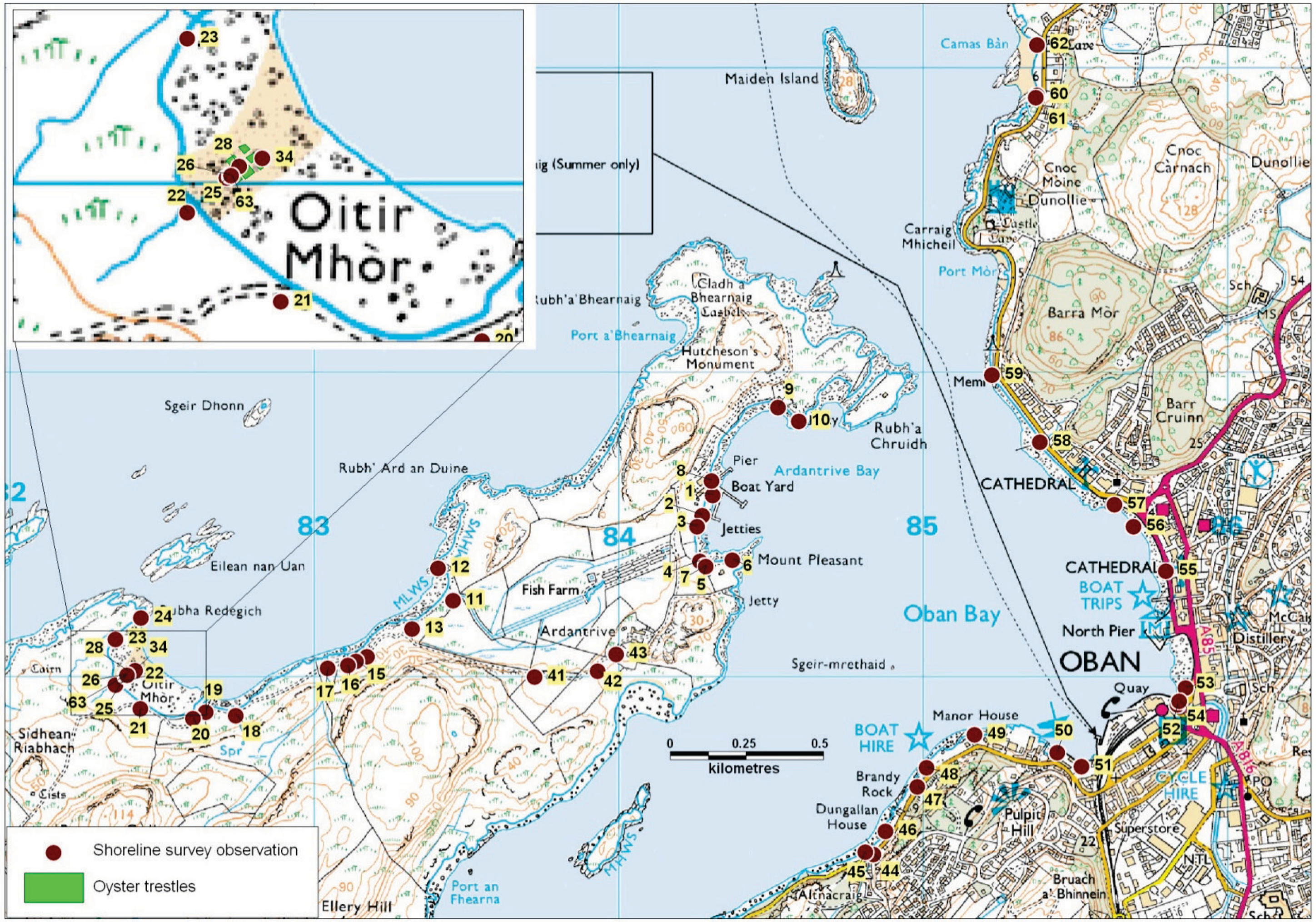

Figure 1 Map of Shoreline Observations

Table 1 Shoreline Observations

Observation Number	Date	Time	NGR	Associated photograph	Associated sample	Description
1	25/08/2010	08:27	NM 84310 30600	Figure 5		Marina toilet and shower block
2	25/08/2010	08:31	NM 84275 30532	Figure 6		Pipe pumping water to station
3	25/08/2010	08:32	NM 84258 30497			Pipe, likely to be land drain
4	25/08/2010	08:36	NM 84268 30382			Stream, W40/D2, flow 0.355m/s
5	25/08/2010	08:42	NM 84287 30367			Stream/land drain
6	25/08/2010	08:44	NM 84375 30386	Figure 7		House plus two outbuildings. No sign of septic tank
7	25/08/2010	08:50	NM 84288 30366			Broken bits of pipe where stream comes out
8	25/08/2010	08:57	NM 84306 30647	Figure 8		Oban Marina, large shed and slipway. Stream flowing through pipe. House on bank
9	25/08/2010	09:06	NM 84525 30888	Figure 9		House, possibly only used as a holiday home. Septic tank with outlet pipe
10	25/08/2010	09:11	NM 84593 30843	Figure 10		Small island with one house currently under construction. Old house had a septic tank.
11	25/08/2010	09:36	NM 83456 30253	Figure 11	OMB FW01	Stream, W190/D12, flow 0.172. Freshwater sample OMB FW01. Two dogs playing in stream, possibly affecting sample
12	25/08/2010	09:48	NM 83407 30360	Figure 12		Fish farm with 6 cages. Boat and workers on site at time of survey.
13	25/08/2010	09:54	NM 83322 30160			Stream
14	25/08/2010	09:58	NM 83173 30069	Figure 13	OMB FW02	Stream, W30/D4, flow 0.113m/s. Freshwater sample OMB FW02. Mull Ferry passing by. Boat trip on Sgeir Dhonn to observe seals. 1 cormorant
15	25/08/2010	10:05	NM 83138 30054			Stream
16	25/08/2010	10:06	NM 83111 30040	Figure 14		House, no sign of septic tank
17	25/08/2010	10:07	NM 83045 30031	Figure 15	OMB FW03	Stream over track, fast flowing. W35/D12, flow 1.009m/s. Freshwater sample OMB FW03
18	25/08/2010	10:19	NM 82743 29875			Stream, W35/D6, flow 3 secs to fill 2 litres. Two different

Observation Number	Date	Time	NGR	Associated photograph	Associated sample	Description
						boats now on Sgeir Dhonn
19	25/08/2010	10:31	NM 82644 29887			Standing water
20	25/08/2010	10:32	NM 82602 29865			Land drain
21	25/08/2010	10:36	NM 82428 29899	Figure 13		Land drain. Tourist boat crossing over close to oyster trestles. Ewan says there is also a yacht which regularly moors in Oitir Mhor Bay
22	25/08/2010	10:39	NM 82347 29976	Figure 16	OMB FW04	Stream flowing directly onto site. W34/D10, flow 3 secs to fill 500ml. Freshwater sample OMB FW04
23	25/08/2010	10:48	NM 82347 30127		OMB FW05	Stream, W54/D5, flow 6 secs to fill 1 litre. Freshwater sample OMB FW05
24	25/08/2010	10:55	NM 82431 30197			5 gulls on small island
25	25/08/2010	11:05	NM 82381 30006		OMB SW01	Seawater sample OMB SW01 (sample later lost). Retaken 26/08/10 (see waypoint 63)
26	25/08/2010	11:39	NM 82384 30008	Figure 17	OMB SHELLFISH 1	3 oyster catchers. Oyster sample OMB SHELLFISH 1
28	25/08/2010	12:10	NM 82392 30016		Norovirus sample 1	Oyster sample for norovirus analysis
34	25/08/2010	12:14	NM 82412 30023		OMB SHELLFISH 2	Corner of trestles. Oyster sample OMB SHELLFISH 2
41	25/08/2010	12:48	NM 83725 30003			Approximately 50 sheep in enclosed field
42	25/08/2010	12:51	NM 83931 30022			5 cows on beach
43	25/08/2010	12:52	NM 83993 30076			Farm and farm houses. 10 chickens, 1 duck, 1 pony, 1 peacock
44	25/08/2010	13:35	NM 84838 29420	Figure 18		Gallanach pumping station
45	25/08/2010	13:37	NM 84812 29427	Figure 19A		Stream, W130, fast flowing. Houses all along shoreline
46	25/08/2010	13:41	NM 84879 29495			Small stream/land drain
47	25/08/2010	13:45	NM 84983 29641	Figure 19B		Pipe
48	25/08/2010	13:48	NM 85013 29704	Figure 19C		Slipway with pipe
49	25/08/2010	13:56	NM 85170 29812			Back of three houses, no sign of any sewage discharges

Observation Number	Date	Time	NGR	Associated photograph	Associated sample	Description
50	25/08/2010	14:08	NM 85442 29754	Figure 20	OMB SW02	Seawater sample OMB SW02 taken from slipway by lifeboat station, as close to location of CSO as possible.
51	25/08/2010	14:14	NM 85522 29708	Figure 21		CSO. Not accessible to take freshwater sample
52	25/08/2010	14:21	NM 85838 29911	Figure 23		Large stream flowing into Oban harbour. 100+ gulls on beach
53	25/08/2010	14:26	NM 85864 29966	Figure 22		Drain cover on beach. Buoy marking CSO outfall
54	25/08/2010	14:28	NM 85843 29922	Figure 23	OMB FW08 OMB SW03	Stream, freshwater sample OMB FW08, seawater sample OMB SW03, 10 ducks, 1 swan, dogs being walked on beach
55	25/08/2010	14:42	NM 85799 30351	Figure 24		Pipe running off beach, possibly redundant
56	25/08/2010	14:45	NM 85694 30496	Figure 25		Possibly overflow pipe with grill over the end
57	25/08/2010	14:49	NM 85631 30568			Pipe running under road, moderate flow. Likely to be land drain
58	25/08/2010	14:56	NM 85385 30775	Figure 26	OMB FW06	Stream, freshwater sample OMB FW06, large group of gulls on beach. 1 swan. Buoy marking STW outfall
59	25/08/2010	15:05	NM 85228 30994		OMB SW04	Seawater sample OMB SW04
60	25/08/2010	15:19	NM 85376 31915			Stream
61	25/08/2010	15:21	NM 85373 31906		OMB FW07	Stream, freshwater sample OMB FW07
62	25/08/2010	15:27	NM 85376 32080			Small stream
63	26/08/2010	12:13	NM 82385 30008		OMB SW05	Seawater sample re-taken

Photos referenced in the table can be found attached as Figures 5-26

Sampling
Water and shellfish samples were collected at sites marked on the map in figures 3 and 4 respectively. Bacteriology results follow in Tables 2 and 3.

Samples of seawater were tested for salinity by the laboratory. These results are shown in Table 2, given in units of grams salt per litre of water. This is the same as ppt.

The seawater sample taken at the Oitir Mhor oyster trestles was later found to have leaked, and so was retaken the following day at a similar time and state of tide. However it needs to be taken into account when analysing the results that the conditions would not have been the same as on the day of the survey.

Two shellfish samples were taken from a trestle nearest the shore, and therefore closest to the stream, and a point furthers from the shore. It is interesting to note that the higher result was in the sample furthest from the stream, although the difference is marginal.

All freshwater samples taken adjacent to Oitir Mhor Bay had relative low levels of *E. coli*, with the higher results coming from samples taken from streams on the mainland at Oban.

Table 2. Water Sample Results

No.	Date	Sample	Grid Ref	Type	*E. coli* (cfu/100ml)	Salinity (mg Cl/L)
1	25/08/2010	OMB FW 01	NM 83456 30253	Freshwater	280	n/a
2	25/08/2010	OMB FW 02	NM 83173 30069	Freshwater	10	n/a
3	25/08/2010	OMB FW 03	NM 83045 30031	Freshwater	40	n/a
4	25/08/2010	OMB FW 04	NM 82347 29976	Freshwater	10	n/a
5	25/08/2010	OMB FW 05	NM 82347 30127	Freshwater	10	n/a
6	25/08/2010	OMB FW 06	NM 85385 30775	Freshwater	1700	n/a
7	25/08/2010	OMB FW 07	NM 85373 31906	Freshwater	800	n/a
8	25/08/2010	OMB FW 08	NM 85843 29922	Freshwater	6400	n/a
9	25/08/2010	OMB SW 02	NM 85442 29754	Seawater	<10	18900
10	25/08/2010	OMB SW 03	NM 85843 29922	Seawater	1300	12900
11	25/08/2010	OMB SW 04	NM 85228 30994	Seawater	20	18700
12	26/08/2010	OMB SW 05	NM 82385 30008	Seawater	60	13600

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	*E. coli* (MPN/100g)
1	25/08/2010	OMB SHELLFISH 1	NM 82384 30008	Pacific Oyster	80
2	25/08/2010	OMB SHELLFISH 2	NM 82412 30023	Pacific Oyster	130

Figure 3. Water sample results map

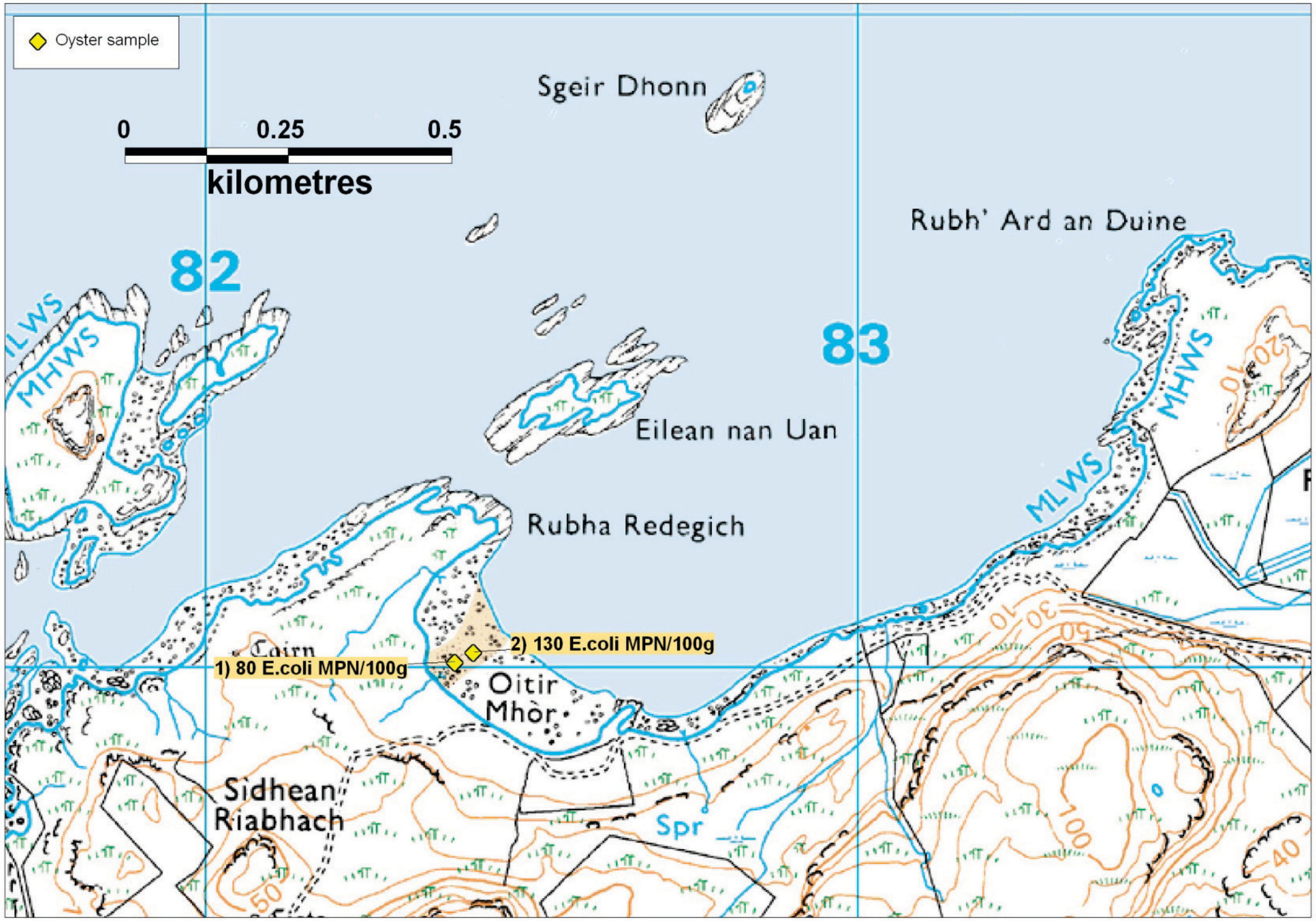

Figure 4. Shellfish sample results map

Photographs

Figure 5. Toilet block and outfall pipe at Oban Marina

Figure 6. Oban Marina with water intake pipe in foreground

Figure 7. House south of Oban marina

Figure 8. Oban marina with boat yard, boat shed, café and toilet block

Figure 9. Septic tank outfall pipe from house/holiday home

Figure 10. Construction of one new house and demolition of old house on Rubh’a Chruidh Island

Figure 11. Large stream flowing into Oitir Mhor Bay. Inset: two dogs belonging to farm in stream

Figure 12. Fish farm comprising of six cages.

Figure 13. A) Sgeir Dhoon Island with tourist boat to observe seals, and Mull Sound ferry in background. B) Tourist boat crossing close to oyster trestles

Figure 14. House on shore of Oitir Mhor Bay. No septic tank was observed

Figure 15. Stream crossing main track flowing into Oitir Mhor Bay

Figure 16. Stream flowing directly onto oyster trestle site

Figure 17. Oitir Mhor Bay Oyster Trestles

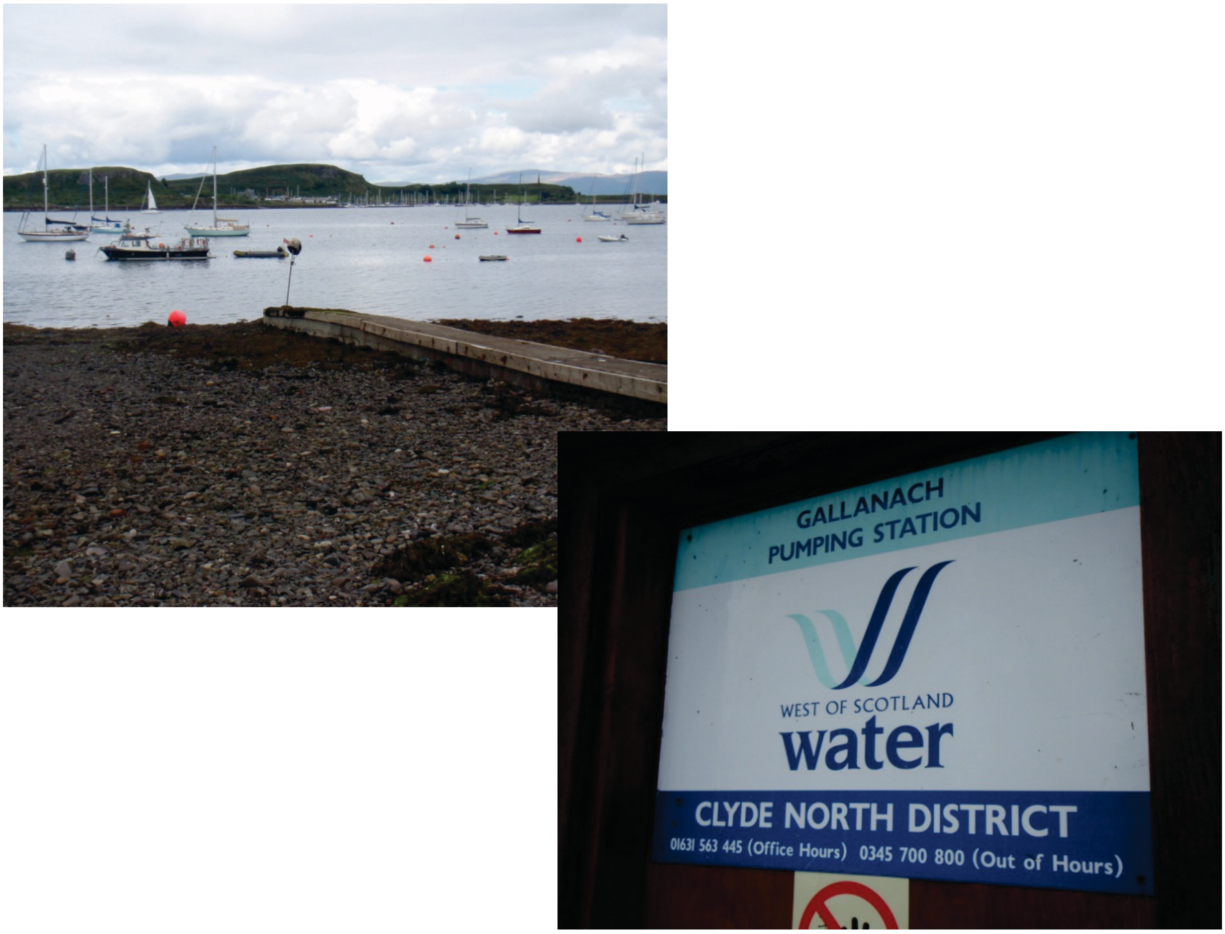

Figure 18. Gallanach Pumping Station and outfall pipe

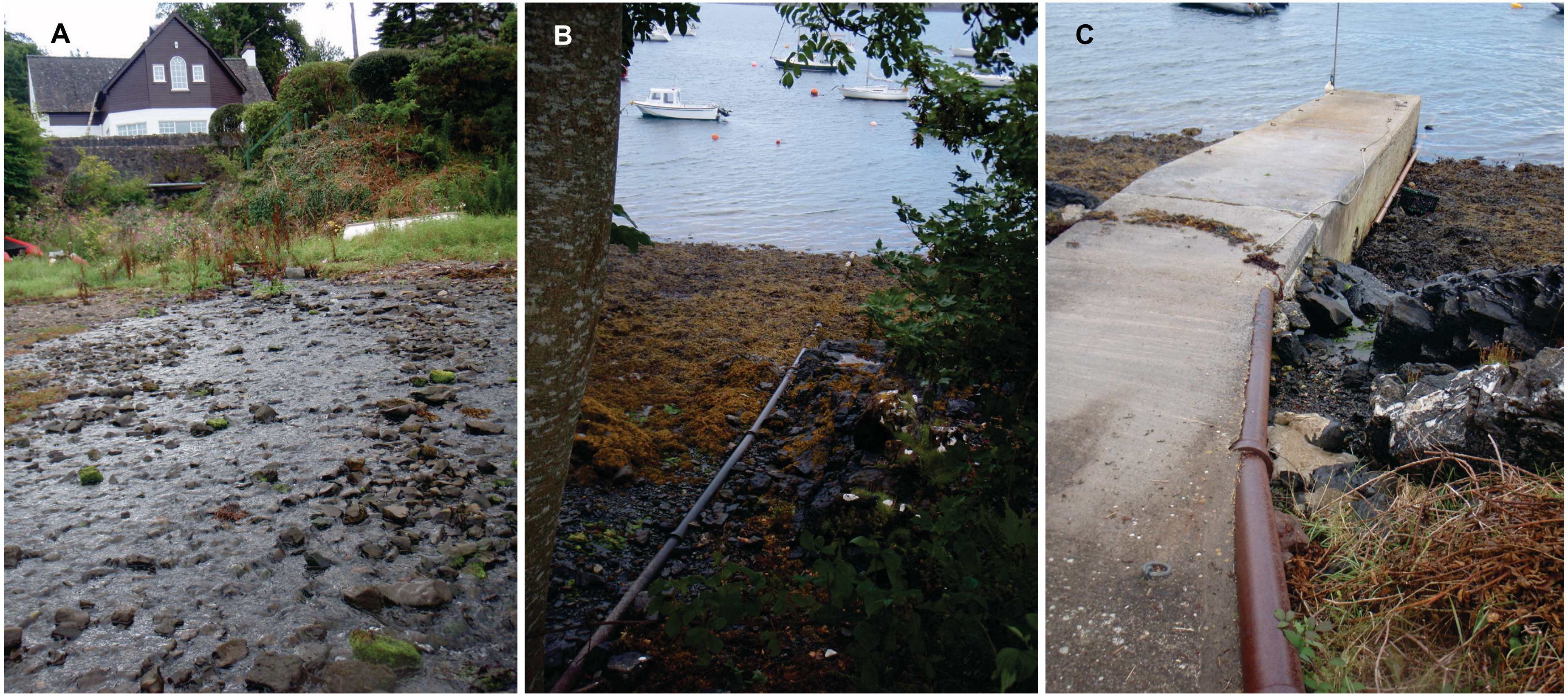

Figure 19. A) Stream running under road close to house, B) Possible outfall pipe on shore, C) Pipe running alongside slipway

Figure 20. Location of seawater sample SW02 on slipway close to pier

Figure 21. CSO outfall under pier

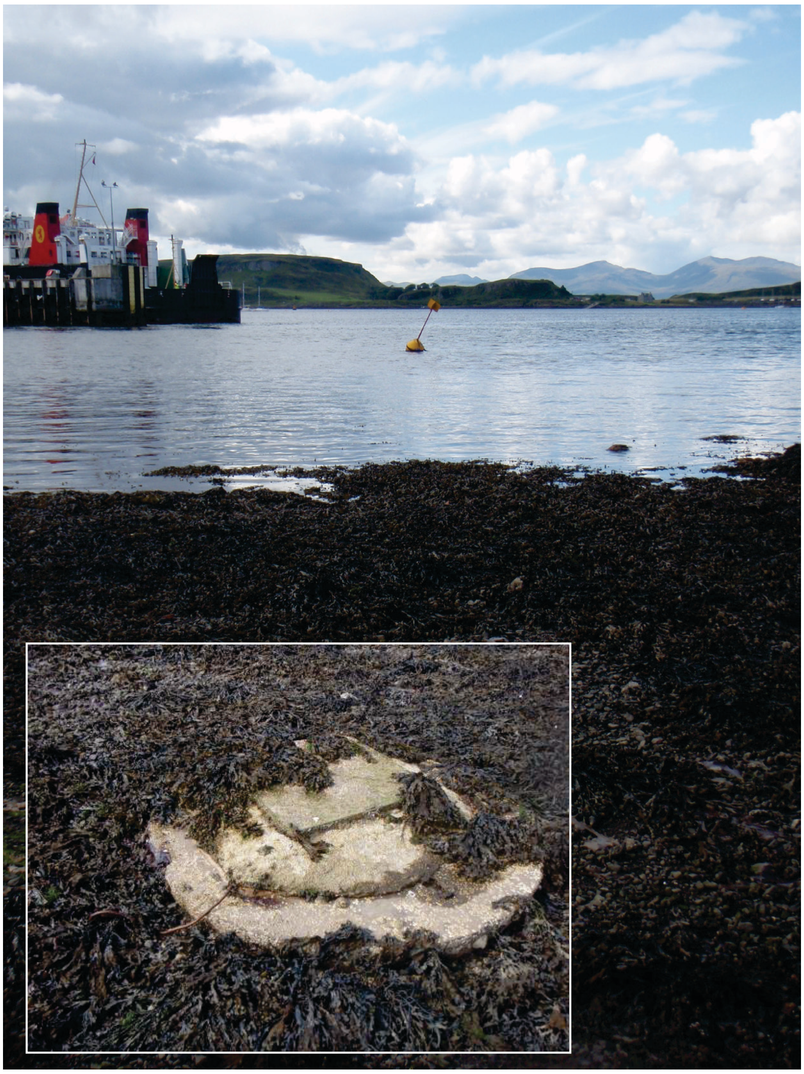

Figure 22. Buoy marking CSO outfall on beach at Oban Harbour. Inset: Drain cover on beach exposed at low tide.

Figure 23. Large stream flowing into Oban Marina, location of freshwater sample FW08 and seawater sample SW03

Figure 24. Pipe running across beach which appeared redundant

Figure 25. Possible outfall pipe running across beach with grill at the end (inset)

Figure 26. Buoy marking STW outfall in Oban Bay. Inset: Stream running under road and across beach near to buoy, freshwater sample FW06

Norovirus Testing Summary

Oitir Mhor

Oyster samples taken from the oyster farm at Oitir Mhor were submitted for Norovirus analysis quarterly between August 2010 and May 2011.

Results are tabulated below.

Ref No.	Date collected	NGR	GI	GII
10/383	25/08/2010	NM 8239 3002	not detected	not detected
10/505	08/11/2010	NM 8240 3001	not detected	not detected
11/170	03/02/2011	NM 8240 3001	positive- loq	positive - loq
11/1090	17/05/2011	NM 8241 3002	not detected	positive