Scottish Sanitary Survey Project

Sanitary Survey Report
Loch Harport Inner
SL 159
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Cefas

Food Standards Agency
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Buidheann Inbhe-Bìdhe

Report Distribution – Loch Harport Inner

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* Distribution of both draft and final reports to relevant agency personnel and harvesters is undertaken by FSAS.

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1. General Description

Loch Harport is located on the south-western coast of the Isle of Skye. It is approximately 9km in length and has a maximum depth of about 30m. The eastern side of the loch is uninhabited, and on the south-western side are a number of small settlements including Carbost.

Major freshwater inputs into the loch include the River Drynoch and the Vikisgill Burn which enter in the vicinity of the head of the loch. The Amar River enters Loch Beag at the mouth of Loch Harport.

Figure 1.1 shows the location of Loch Harport on the Isle of Skye.

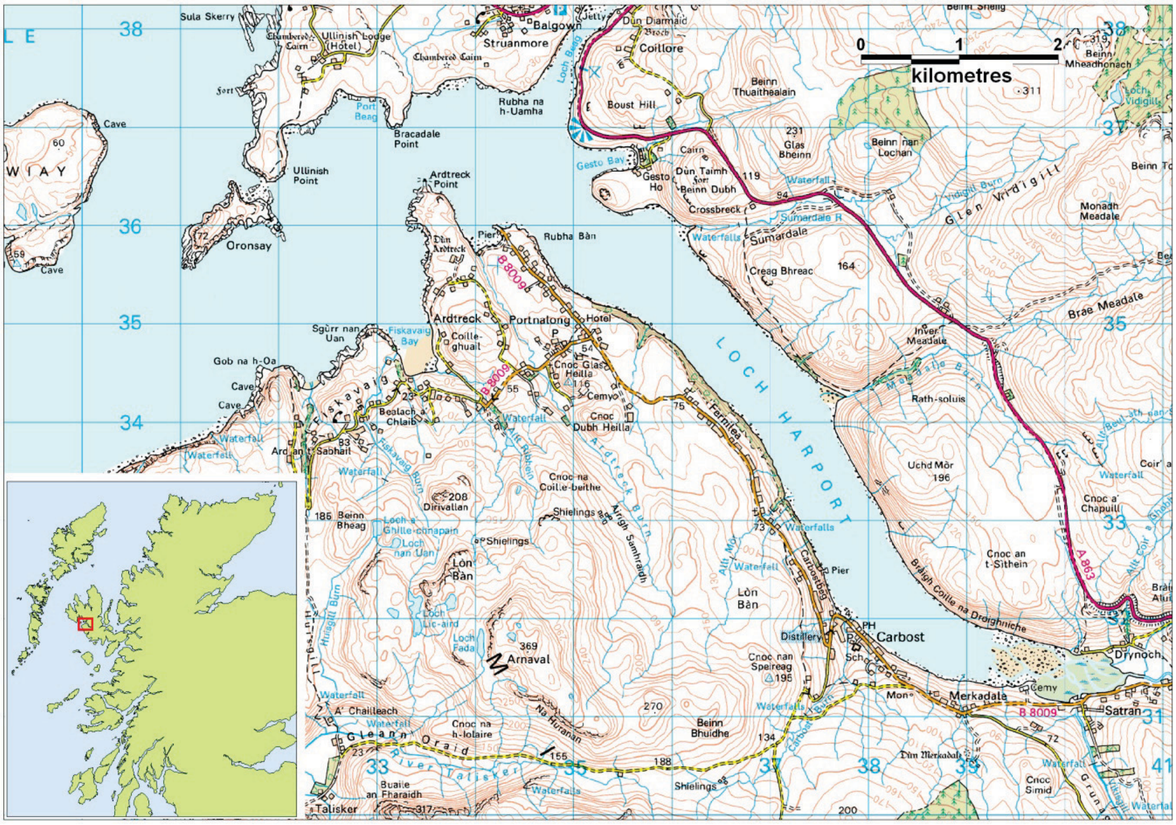


Figure 1.1 Location of Loch Harport

2. Fishery

The sanitary survey is being undertaken as a result of the high ranking obtained in the risk matrix. The high ranking was primarily caused by recent changes in classification and the species involved (Pacific oysters) in the Loch Harport Inner: Carbost production area.

Table 2.1 Loch Harport shellfish farm

Production Area	Site	SIN	Species	RMP
Loch Harport: Inner	Carbost	SL 159 286 13	Pacific Oysters	NG 392 314

The production area within Loch Harport Inner is defined as the area east of line drawn between NG 3800 3329 and NG 3800 3180 and between NG 4000 3167 and NG 4000 3113. The RMP is located at NG 392 314, although all samples have been recorded as being taken from NG 395 315.

There are seven Crown Estate (CE) seabed lease areas in Loch Harport, three of which fall within the production area boundaries. One of these is in the general area of the current oyster farm but lies below MLWS.

The Pacific oyster fishery at Loch Harport Inner has been established for many years and consists of several blocks of trestles in 3 main areas in the intertidal area towards the head of the loch (Figure 2.1). One is located relatively high up the foreshore and can be accessed at tide heights under which the other blocks are still submerged. The other two areas are located further towards the centre of the loch. Oysters are grown in poches on the trestles and are harvested by hand although a tractor is used to move stock and equipment to and from, and round, the fishery. Harvest occurs throughout the year although closures occur during certain periods due to elevated biotoxin levels.

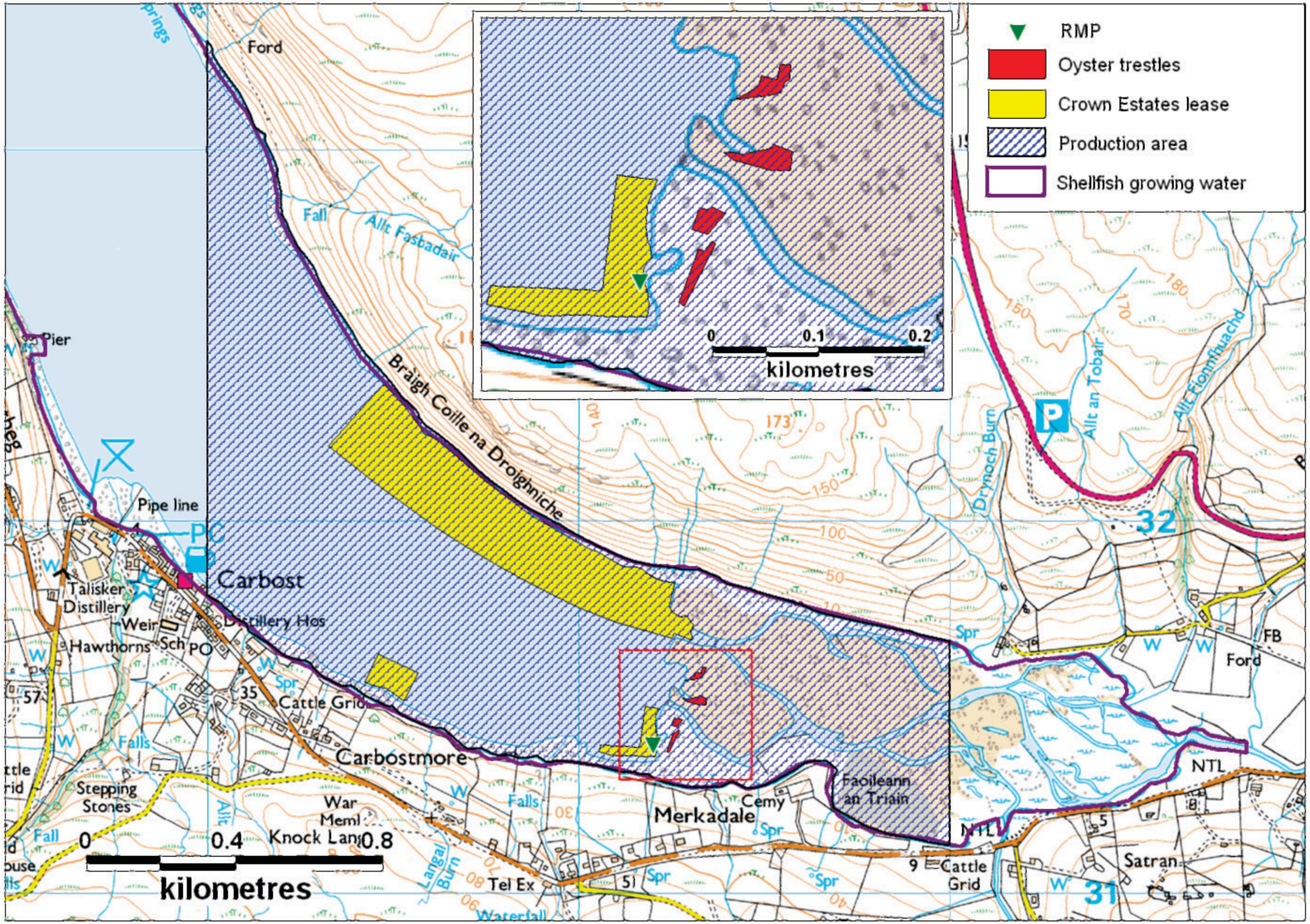
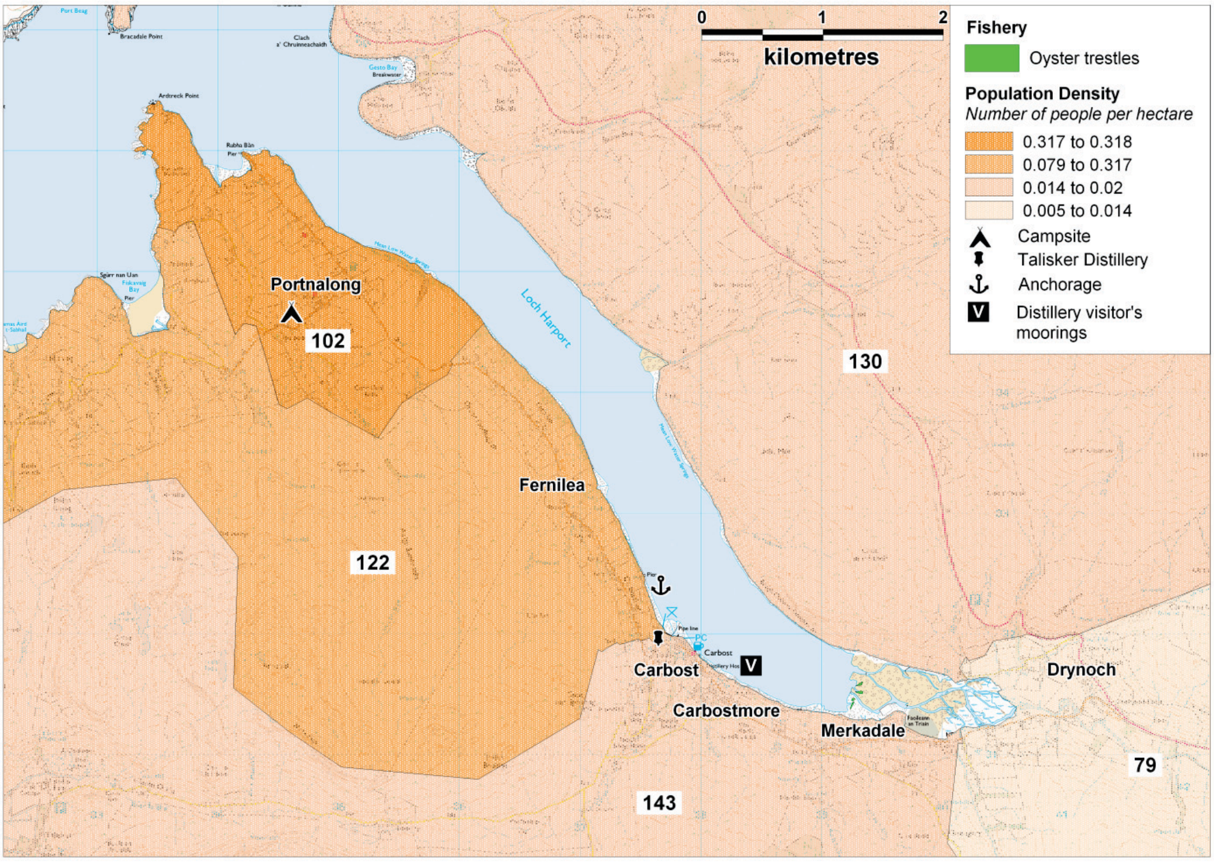


Figure 2.1 Loch Harport: Inner Pacific oyster fishery

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 Loch Harport. The last census was undertaken in 2001.



2001 Population Census Data, General Register Office, Scotland.

Figure 3.1 Human population surrounding Loch Harport

Figure 3.1 shows the population density for the census output areas in the area surrounding Loch Harport. Each census output area is labelled with the total population. The southern end of the loch is relatively densely populated with the settlements of Fernilea, Carbost, Carbostmore, Merkadale and Drynoch. The settlement of Portnalong is located at the northern end of the loch. The 1996 population of the Bracadale and Minginish Parish was 698 and approximately a fifth of this was identified as being located in Carbost (The Highland Council, 1999): the population of the parish was then predicted to rise to 763 by 2006.

There is a large amount of tourist accommodation in the area. In Portnalong there is a 12 acre croft with a bunkhouse, 3 bothys, 3 cabins, tent pitches and shower and toilet facilities sleeping a total of 40 people. There is also two B&Bs, sleeping 2 and 6, a hostel sleeping 40 people and a self catering unit sleeping 7. Near Fernilea there are three self catering units, one sleeping 6 and two sleeping 8. In Carbost there is an Inn/hostel that sleeps 13, two self catering units sleeping 3 and 10 and a B&B sleeping 4. Near Merkadale there are four self catering units, three sleeping 4 and the other sleeping 8.

There are no residential dwellings on the northern side of the loch, between the shoreline and the road. There are however, three self-catering units sleeping 2, 4 and 5, on the land side of the road towards the northern end of the loch. The settlement of Portnalong is located at the north-western end of the loch.

Attractions in the area include the Talisker Distillery, which is located in Carbost and has its own distillery visitor's mooring just offshore of Carbost. There is also an anchorage and a small pier north of Carbost. The distillery is one of the foci of the "Classic Malts" cruise which generally takes place annually (but not in 2010) in July has seen up to 100 boats take part. The yachts taking part will moor off Carbost and represent a transient marked increase in boats in the area with an associated potential for increased pollution.

The largest concentration of population in the area is therefore located at Carbost and the number of visitors to that location will greatly exceed the resident population. While tourism will take place throughout the year, the influx will be greatest in the summer months.

4. Sewage Discharges

Information on discharges in the vicinity of Loch Harport was solicited from Scottish Water and the Scottish Environment Protection Agency (SEPA). One community sewage discharge was identified for Loch Harport by Scottish Water.

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
WPC/N/71298	NG 3788 3208	Carbost WWTW	Continuous	Secondary	40.1	252

No microbiological data were available for this discharge, which lies 1.5 km northwest of the oyster trestles. The potential faecal coliform loading, based on a geometric mean high flow concentration of $5.0x10^5$/100 ml for secondary treated sewage (Kay et al 2008), would be 2.01×10^{11} FC/day.

A larger number of consented discharges in the area were listed by SEPA, the majority of which discharged either to soakaway or to land. Details of those nearest the head of the loch are presented in Table 4.2.

Table 4.2 Discharge consents identified by SEPA

No.	Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented/ design PE	Discharges to
1	CAR/R/1035862	NG 4113 3168	Domestic	Septic tank	6	Soakaway
2	CAR/R/1036062	NG 4118 3154	Domestic	Septic tank	8	Soakaway
3	CAR/R/1036066	NG 4123 3152	Domestic	Septic tank	8	Soakaway
4	CAR/R/1041489	NG 4120 3145	Domestic	Septic tank	9	Allt na Drochaide Baine
5	CAR/R/1041490	NG 4139 3135	Domestic	Septic tank	5	land
6	CAR/R/1048478	NG 4095 3126	Domestic	Septic tank	6	Soakaway
7	CAR/R/1048479	NG 4092 3113	Domestic	Septic tank	5	Soakaway
8	CAR/R/1071634	NG 4021 3109	Domestic	Septic tank	5	Soakaway
9	CAR/R/1053461	NG 4018 3097	Domestic	Septic tank	5	Soakaway
10	CAR/R/1048495	NG 4015 3107	Domestic	Septic tank	5	Soakaway
11	CAR/R/1048482	NG 4002 3109	Domestic	Septic tank	5	Soakaway
12	CAR/R/1044643	NG 3971 3090	Domestic	Septic tank	5	Soakaway
13	CAR/R/1076953	NG 3939 3091	Domestic	Septic tank	5	Soakaway
14	CAR/R/1075558	NG 3894 3111	Domestic	Septic tank	5	Soakaway
15	CAR/R/1073662	NG 3876 3113	Domestic	Septic tank	5	Soakaway
16	CAR/R/1016454	NG 3876 3118	Domestic	Septic tank	7	Land
17	CAR/R/1046653	NG 3868 3119	Domestic	Septic tank	5	Soakaway
18	CAR/R/1076137	NG 3861 3122	Domestic	Septic tank	6	Soakaway
19	CAR/R/1045879	NG 3852 3138	Domestic	Septic tank	5	Soakaway
20	CAR/R/1077528	NG 3845 3137	Domestic	Septic tank	5	Soakaway
21	CAR/R/1014034	NG 3832 3143	Domestic	Septic tank	15	Land
22	CAR/R/1067673	NG 3804 3141	Domestic	Septic tank	6	Soakaway
23	CAR/R/1046778	NG 3804 3145	Domestic	Septic tank	5	Soakaway
24	CAR/R/1017677	NG 3811 3152	Domestic	Septic tank	8	Land
25	CAR/R/1010631	NG 3750 3150	TSE	*	5	Soakaway
26	CAR/R/1021619	NG 3786 3177	Domestic	Septic tank	5	Soakaway
27	CAR/R/1077929	NG 3758 3179	Domestic	Septic tank	5	Soakaway

No.	Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented/ design PE	Discharges to
28	CAR/R/1077119	NG 3758 3191	Domestic	Septic tank	6	Soakaway
29	CAR/R/1077554	NG 3749 3207	Domestic	Septic tank	6	Soakaway
30	CAR/L/1003077	NG 3788 3208	TSE	*	*	Loch Harport
31	CAR/R/1076731	NG 3733 3249	Domestic	Septic tank	6	Soakaway
32	CAR/R/1077856	NG 3728 3250	Domestic	Septic tank	5	Soakaway
33	CAR/R/1054249	NG 3723 3256	Domestic	Septic tank	5	Soakaway
24	CAR/R/1041496	NG 3747 3114	Domestic	Septic tank	5	Land

TSE- treated sewage effluent * data not provided

Item number 30 relates to the Scottish Water discharge identified in Table 4.1. The number of septic tank registrations in the area indicates that a large proportion of the domestic dwellings in the area are not connected to mains sewerage. The total population equivalent of only those domestic septic discharges listed above totals 192 and this list does not represent all discharges in the area. A separate discharge consent was not provided for the Talisker distillery.

A shoreline survey was undertaken in September 2010 and observations relating to sewage infrastructure and other potential discharges made during the survey are listed in Table 4.3 below.

Table 4.3 Discharges and septic tanks observed during shoreline surveys

No.	Date	NGR	Description	SEPA consent ref.
1	08/09/2010	NG 40210 31640	Septic tank near possible holiday cottage	
2	08/09/2010	NG 40215 31609	Broken pipe from septic tank - not flowing	
3	09/09/2010	NG 37757 31976	Possible flow from septic tank; 10" pipe with liquid flowing round it; several surface water pipes (not flowing)	
4	09/09/2010	NG 37762 31950	several pipes (not flowing) protruding from distillery wall	
5	09/09/2010	NG 37807 31957	Scottish Water Septic Tank; 20° to outfall buoy	CAR/L/1003077 WPC/N/71298
6	09/09/2010	NG 37812 31982	Approximate area of "boil" seen 08/09/10; not present at this time	
7	09/09/2010	NG 37871 31938	21 cm outflow pipe; slight trickle only; not sampled; one yacht offshore	
8	09/09/2010	NG 37918 31887	Concrete construction with manhole; no outlet seen	
9	09/09/2010	NG 37923 31880	11 cm outflow pipe; no flow	
10	09/09/2010	NG 37935 31853	24 cm clay outflow pipe below bunkhouses; no flow	
11	09/09/2010	NG 37957 31835	8" metal outflow pipe; end went under water	
12	09/09/2010	NG 37995 31807	14 cm plastic pipe joining metal outflow pipe; end went under water	
13	09/09/2010	NG 38003 31795	15 cm plastic outflow pipe; not flowing	

The Carbost septic tank was observed during the survey, and evidence of a discharge from the distillery was also seen. The boil that was observed was not at the location of the Carbost discharge and was presumed to be related to the distillery discharge. The location of the buoy marking the end of the distillery discharge was determined by using recording bearings from the shoreline. A number of other pipes were present but not flowing and some of these appear to be related to holiday cottages and so would only be in use when the unit is occupied. As there is a significant amount of holiday accommodation in the area, it is anticipated that overall, sewage discharge volumes will be higher during summer than winter. The large number of visitors to the distillery (over 50,000 per year, Appendix 8) will increase the risk to the area from norovirus especially as it draws visitors throughout the winter months as well as summer.

All of the sewage discharges identified in the tables are shown mapped in Figure 4.1 along with the location of the fishery.

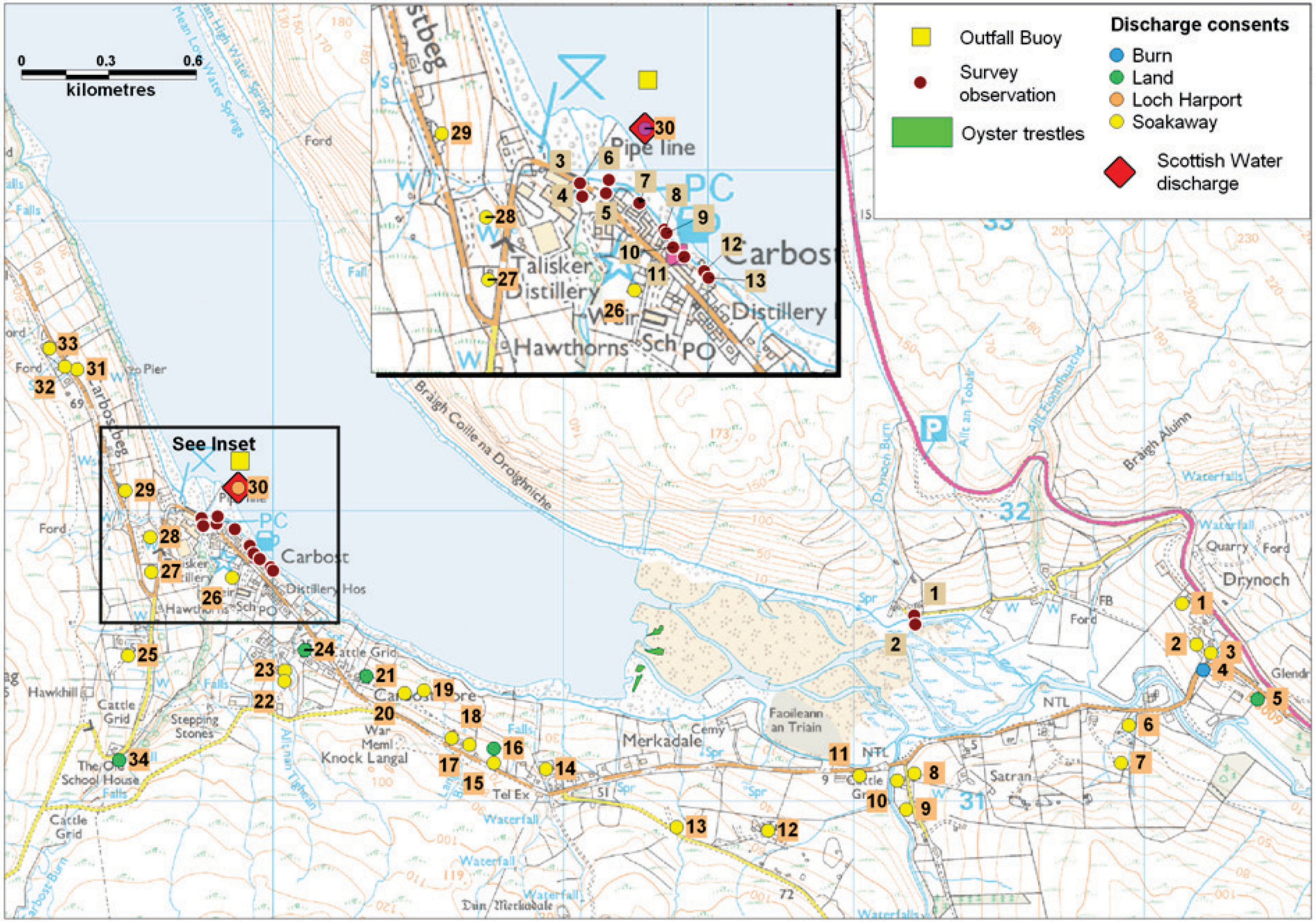


Figure 4.1 Map of discharges for Loch Harport Inner

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 and yellow indicate poorly draining soils and areas shaded blue indicate freely draining soils.

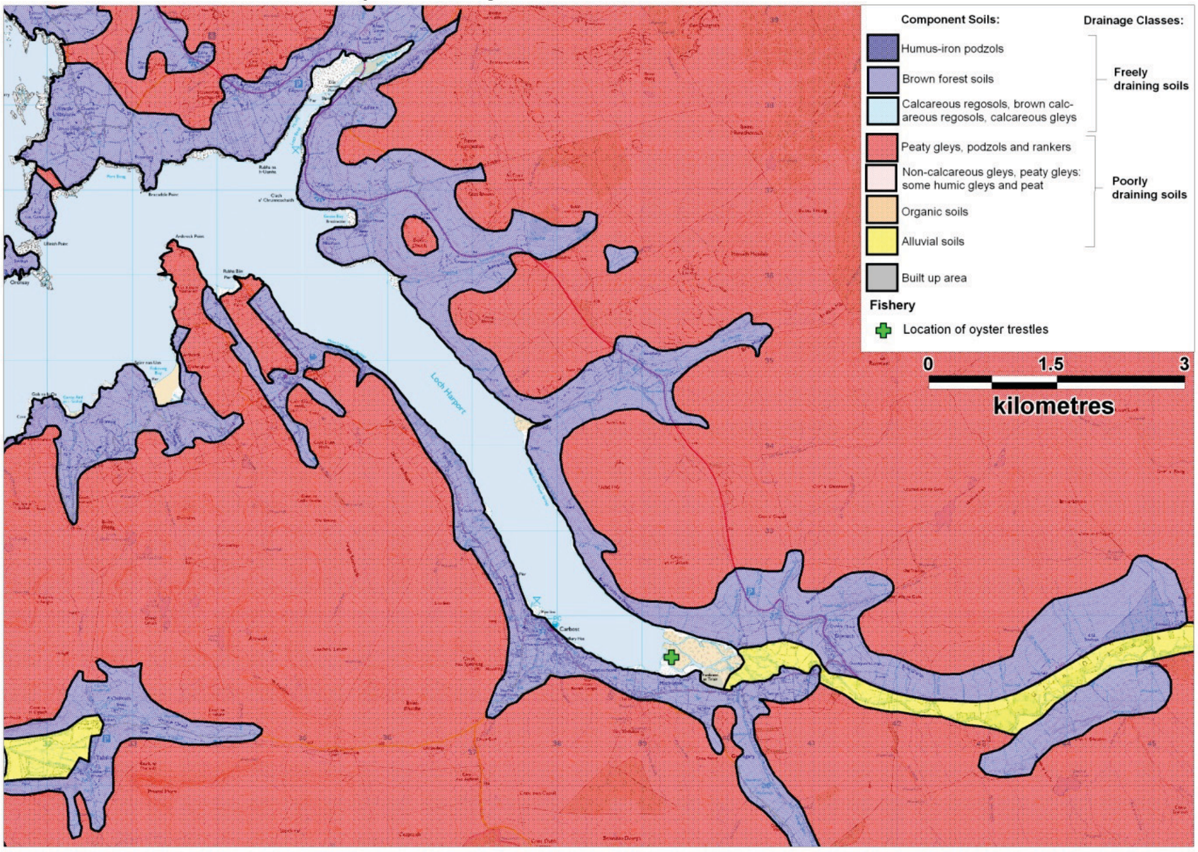


Figure 5.1 Component soils and drainage classes for Loch Harport

There are three types of component soils present in the area: peaty gleys, podzols and rankers, alluvial soils and brown forest soils. The peaty gleys, podzols, rankers and alluvial soils are mostly located inland although alluvial soils are also located along the course of the River Drynoch: these soils are all poorly draining. The brown forest soils found along most of the coastline of the loch are freely draining. Therefore, the potential for runoff contaminated with *E. coli* from human and/or animal waste is low for all the land surrounding the Loch Harport fishery except for the head of the loch where poorly draining alluvial soils are present. Burns and streams running through poorly draining areas (red on the map) will be subject to a greater degree of run-off and will carry any associated contamination to the loch.

6. Land Cover

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

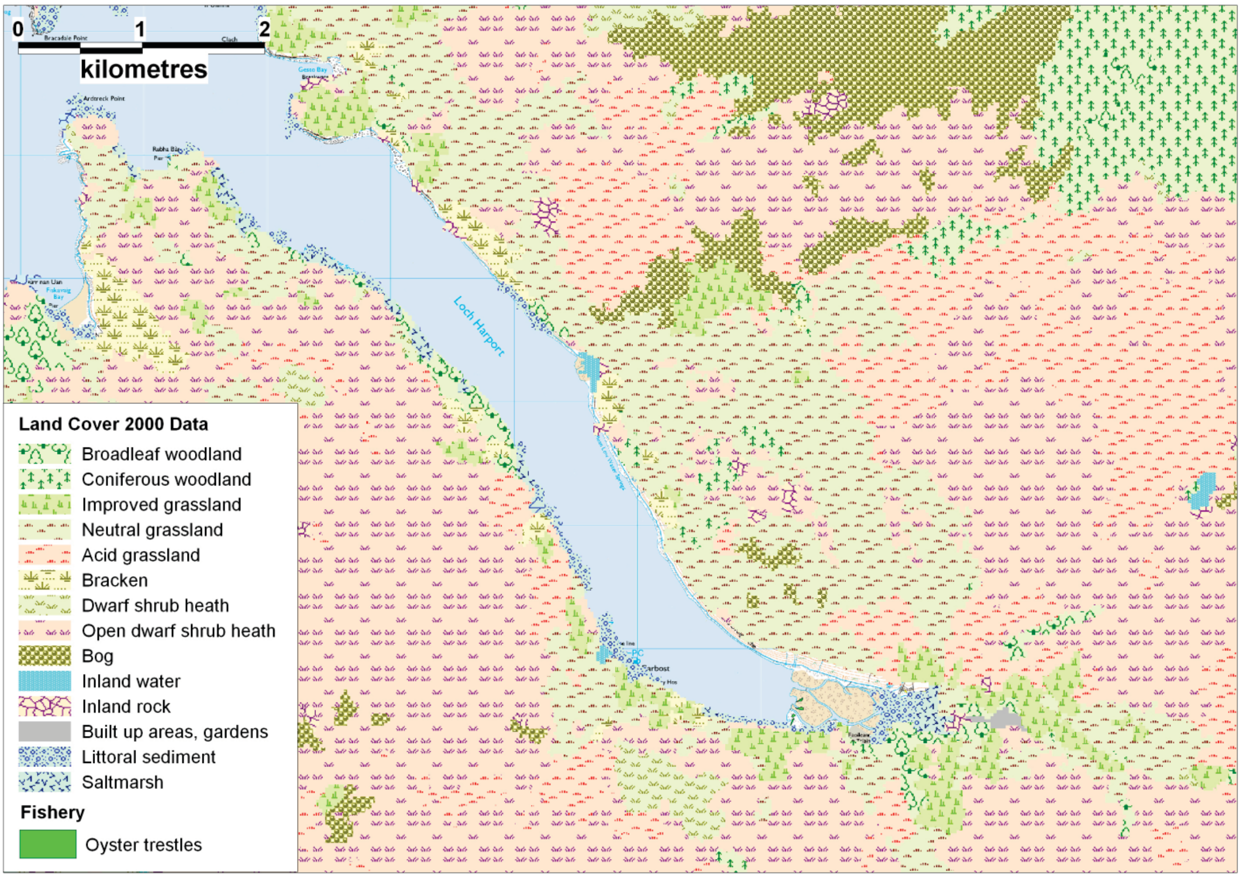


Figure 6.1 LCM2000 class land cover data for Loch Harport

The land cover on the east side of Loch Harport on the immediate shoreline is predominantly neutral grassland, with small patches of improved grassland and bracken in places. Further inland on the eastern shore are large areas of acid grassland, bog, open dwarf shrub heath and coniferous woodland. On the western side of the loch along the shoreline there are patches of improved grassland, coniferous woodland and acid grassland with large areas of open dwarf shrub heath and bracken inland. At the head of the loch there is an area of saltmarsh. Hard-standing areas associated with the village of Carbost are not identified by the LCM2000 data.

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 patches of improved grassland found along the Drynoch River and on the southern shoreline. However, other areas, including the saltmarsh, may be used for rough grazing.

7. Farm Animals

Agricultural census data to parish level was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for the parishes of Bracadale, which encompasses a land area of 381.7 km^2. No data were received from RERAD for this parish. Therefore, the only information available regarding the numbers of animals present near the fishery is that recorded during the shoreline survey (Section 15 and Appendix 7). This information relates only to the time of the site visit on the 08-09 September 2010 and is dependent upon the point of view of the observer. Observations are presented in Figure 7.1.

Cattle and sheep were observed along much of the land around the head of the loch. Although the majority of animals observed were contained behind fences, local information obtained by the surveyor indicated that sheep were present on the intertidal area at the head of the loch through much of the winter. At the time of survey, sheep were observed at the north side of the intertidal area at the head of the loch.

Therefore, it is likely that livestock faeces impact water quality at the head of the loch and the impact may be higher in winter, when sheep are allowed onto the shore to graze.

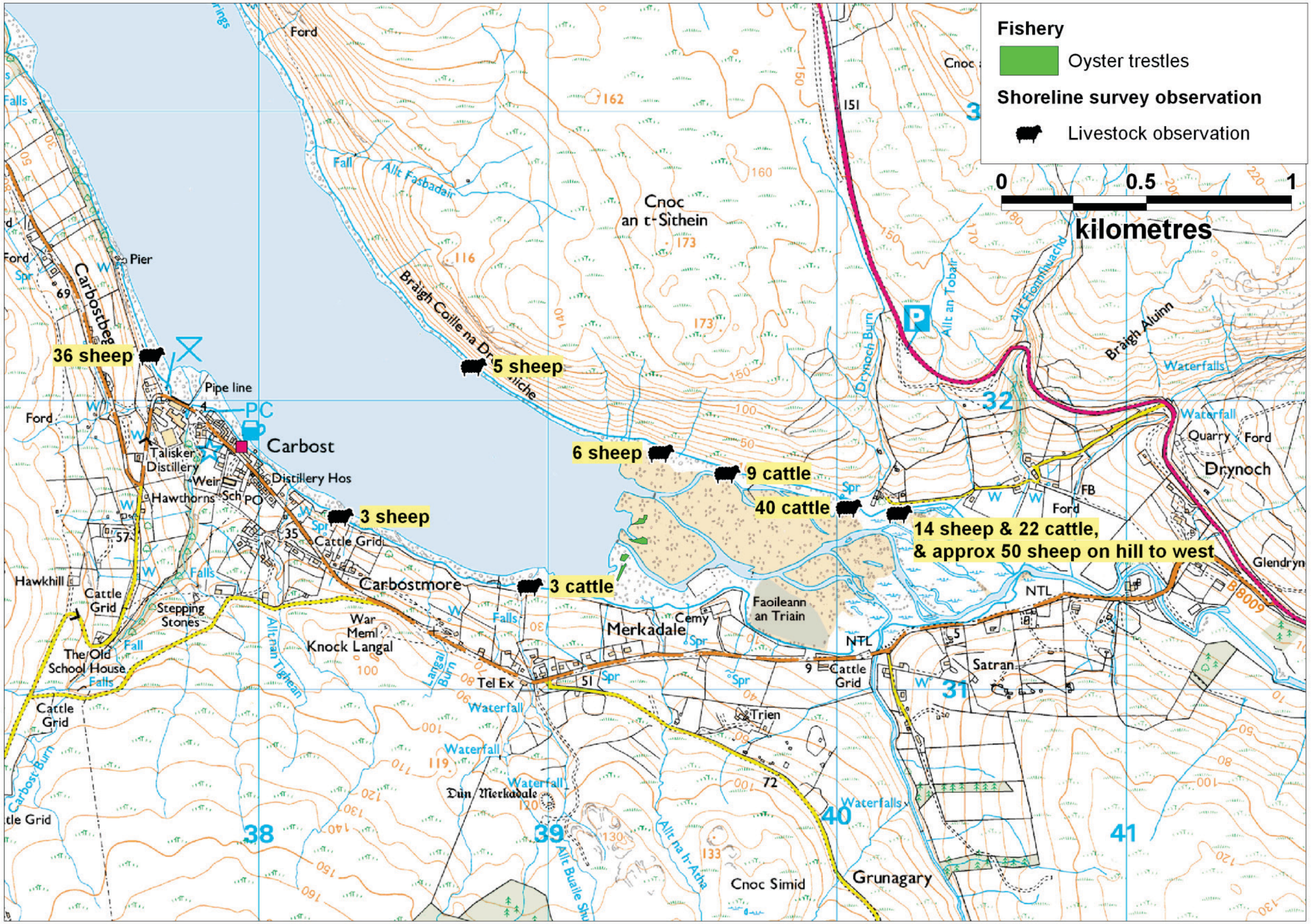


Figure 7.1 Livestock observations at Loch Harport

8. Wildlife

There are several protected areas in a 10 km radius of Loch Harport. Only one is directly adjacent to the loch and this is the Special Protection Area (SPA) covering the Cuillins, which protects breeding pairs of Golden eagle (*Aquila chrysaetos*) at the head of the loch. Approximately 5 km southeast of the loch is the Sligachan Site of Special Scientific Interest (SSSI), the Sligachan Peatlands Special Area of Conservation (SAC) and The Cuillin Hills National Scenic Area (NSA). To the north of the loch is Roineval SSSI and to the south west of the loch is Talisker SSSI.

Seals

The Sea Mammal Research Unit has recorded a growing number of common seals on the Isle of Skye over the past twenty years (Table 8.1). The data shows a steady increase in seal numbers during this time. There are three SAC's on the north western coast of Skye protecting seal breeding areas, however they are on the opposite side of Skye so are not expected to affect the fishery. Seal population numbers in close vicinity of Loch Harport are unknown and none were observed during the shoreline survey.

Table 8.1 Common Seals

Location	Aug 1988	Aug 1989	Aug 1992	Aug 2000	Aug 2008
Isle of Skye	1233	1269	1296	1728	2200

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, 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).

Birds

While the Isle of Skye does host some colonies of breeding seabirds, Loch Harport does not host significant colonies. Seabird 2000 data was requested for a 5 km radius of Loch Harport and no observations were returned for this area. During the shoreline survey at Loch Harport a single seagull, 4 cormorants and 1 heron were observed on the shoreline near Carbost (Figure 8.1). Overall, seabirds such as gulls will always be present in the loch but no significant geographical concentrations have been identified.

Deer

Reed deer are present on the Isle of Skye. However, it was not possible to find any information on population numbers or distribution.

Other

Other species of wildlife including otters, dolphins and other seabirds may be present in the area, although numbers and distribution are not known.

Summary

Species potentially impacting on Loch Harport include seabirds such as gulls and cormorants. However, no major concentrations, such as beeding locations, have been identified and the impacts of on the fishery will be small and unpredictable in terms of time and location.

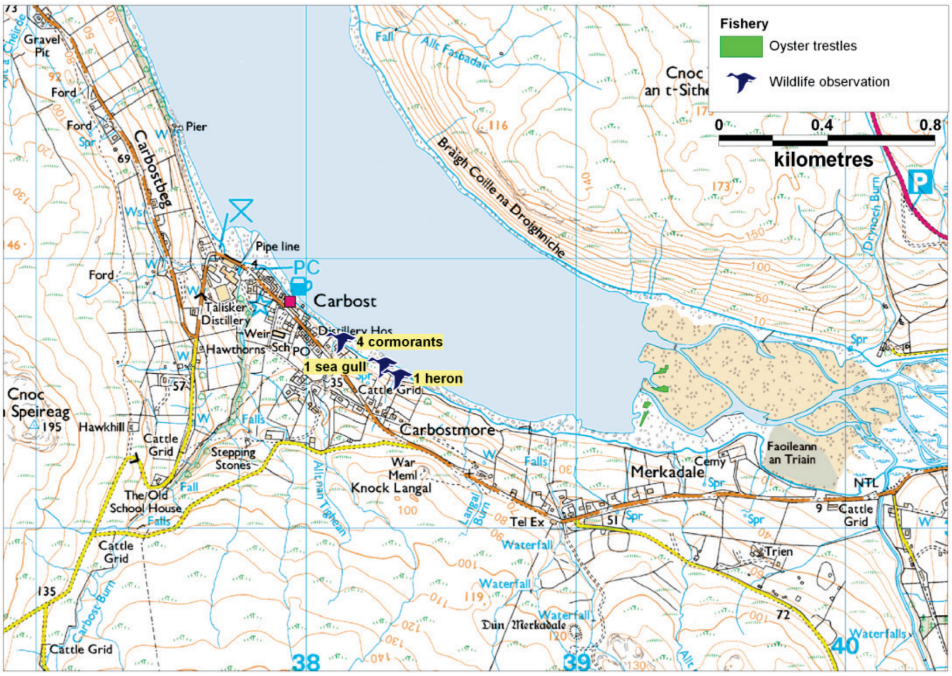


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Figure 8.1 Map of wildlife observations at Loch Harport Inner

9. Meteorological data

The nearest weather station for which rainfall records were available is located at Skye: Portnalong, approximately 4 km from the Loch Harport: Inner production area, and 1.5 km from Loch Bracadale. Rainfall data was available for 2003-2009 inclusive, aside from the months of January, February and November 2004, November 2005, August and parts of November and December 2006, August, September and parts of November and December 2007, and April and parts of October and November 2008. Despite the large amounts of missing records, this station was used as the next nearest station is over 30 km from the fishery. The nearest station for which wind data was available is Tiree, about 90 km to the south of the fishery. However, whilst overall patterns of windy weather may be similar, there are likely to be significant local differences in wind direction. This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish at Loch Harport: Inner.

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 median at the midline. 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 *.

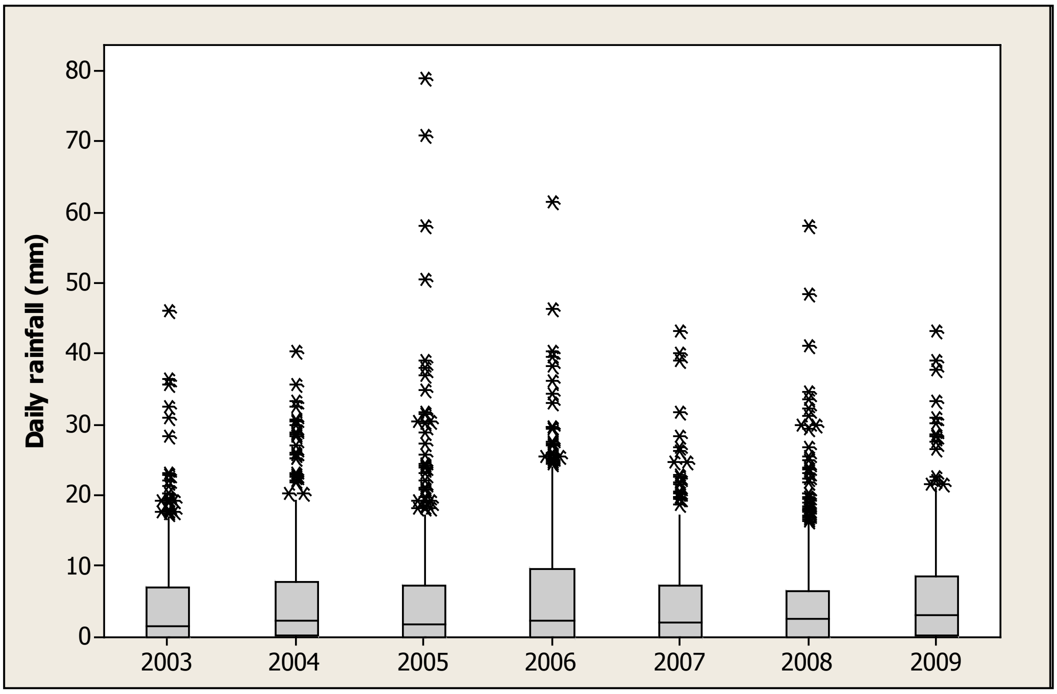

Figure 9.1 Box plot of daily rainfall values by year at Skye: Portnalong, 2003-2009

Figure 9.1 shows that rainfall patterns were similar between the years presented here, although the data presented may be slightly misleading due to the varying distribution of missing records between years.

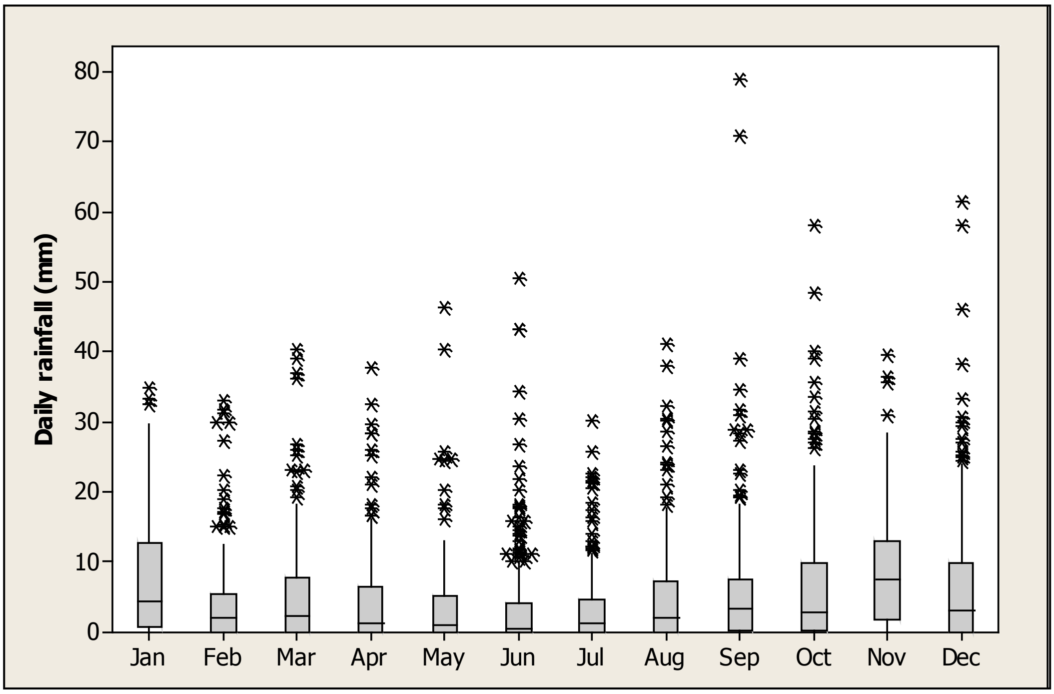

Figure 9.2 Box plot of daily rainfall values by month at Skye: Portnalong, 2003-2009

Weather was wettest from October to January, and driest in June and July. Rainfall events in which over 20mm fell in a day occurred during all months, with the most extreme events occurring between September and December. For the period considered here (2003-2009), 39% of days experienced rainfall less than 1 mm, and 20% 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, it is likely that associated faecal contamination entering the production area will be greatest when extreme rainfall events occur during summer or early autumn: build-up of faecal matter on pastures is likely to occur during dry periods when stock levels are at their highest.

9.2 Wind

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

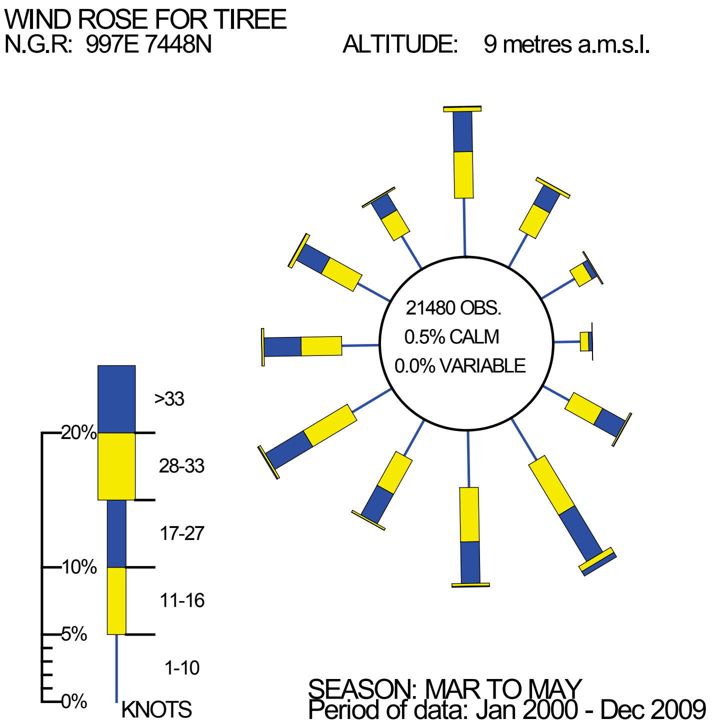

Figure 9.3 Wind rose for Tiree (March to May)

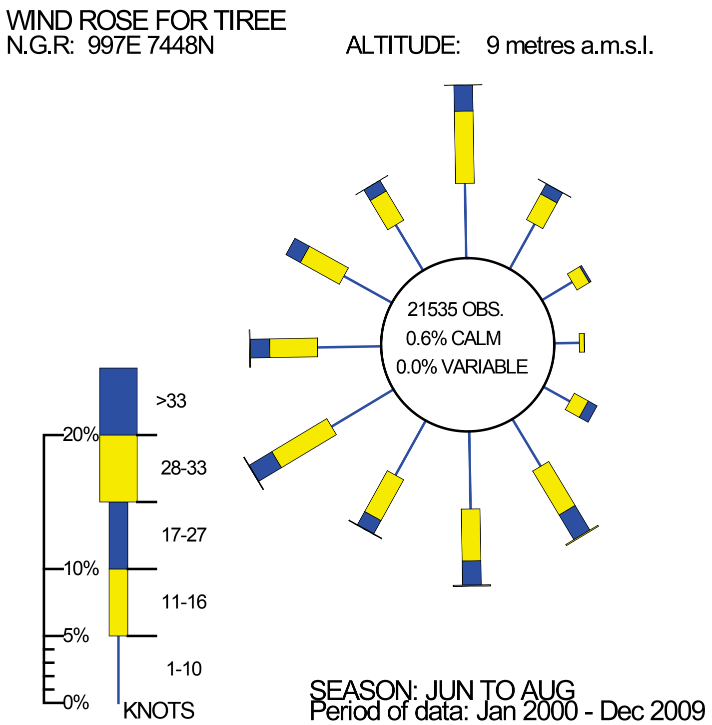

Figure 9.4 Wind rose for Tiree (June to August)

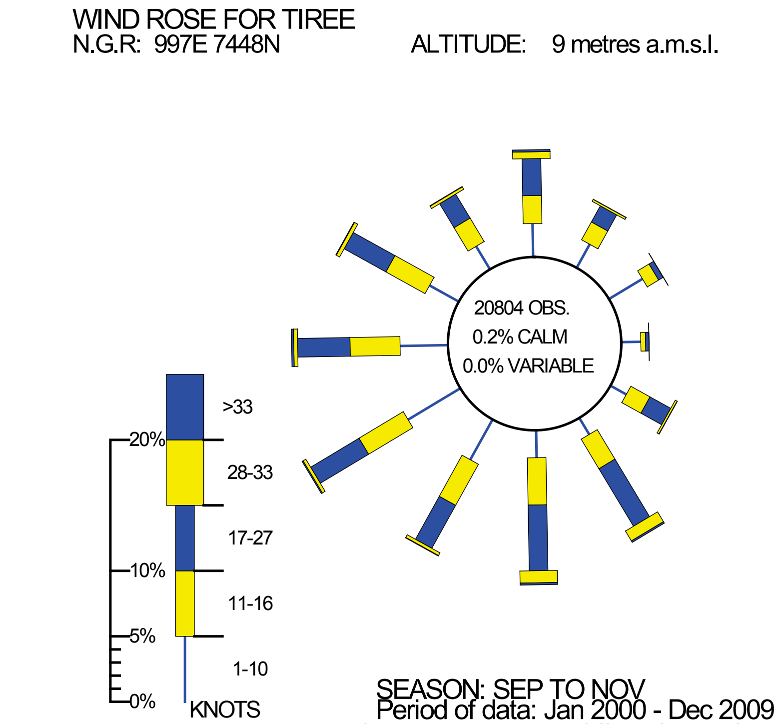

Figure 9.5 Wind rose for Tiree (September to November)

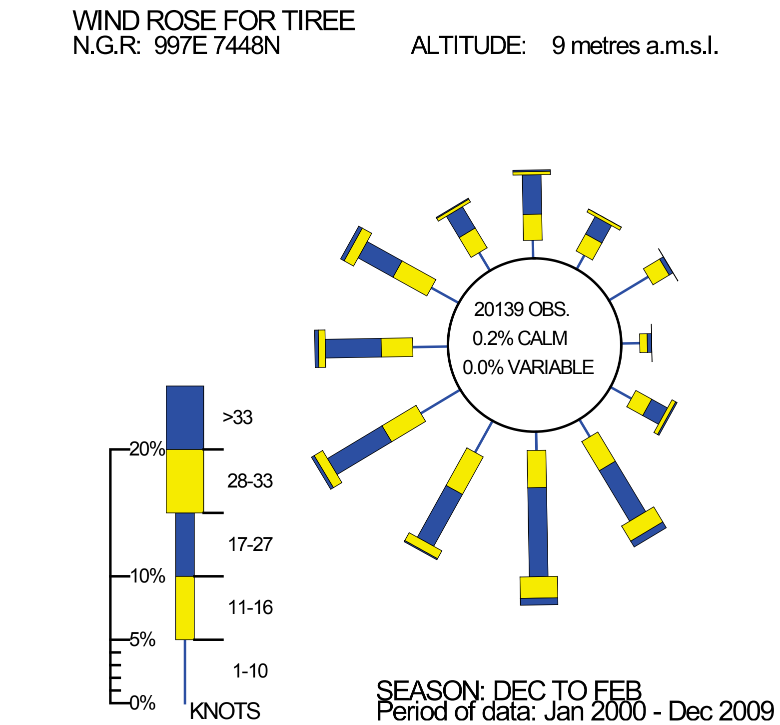

Figure 9.6 Wind rose for Tiree (December to February)

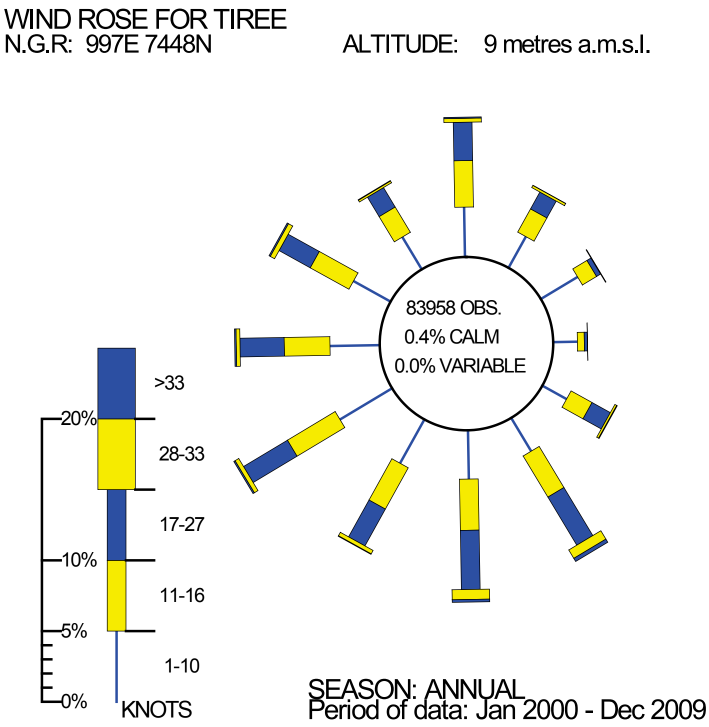

Figure 9.7 Wind rose for Tiree (All year)

The prevailing wind direction at Stornaway is from the south and west. There is a higher occurrence of northerly winds during the spring and summer. Winds are generally lightest in the summer and strongest in the winter. Tiree is a low lying island which is fully exposed to the Atlantic. Loch Harport has a south east to north west orientation, and is surrounded by hills rising to over 200m in places, so it is likely that wind patterns here are more skewed along this axis as winds will be funnelled up and down the loch, and generally lighter due to the additional shelter.

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 at both production areas, particularly those from directions to which they are most exposed. 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. Onshore winds will result in increased wave action at the fisheries, which may resuspend any organic matter settled in the substrate.

10. Current and historical classification status

Loch Harport: Inner was first classified for both Pacific oysters (*Crassostrea gigas*) and common cockles (*Cerastoderma edule*) in 2001. The classification histories for both species are presented in Tables 10.1 and 10.2 below.

Table 10.1 Classification history, Loch Harport: Inner, Pacific oysters

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	B	B	B	B	B	B	B	B	B	B	B	B
2002	B	B	B	B	B	B	B	B	B	B	B	B
2003	B	B	B	B	B	B	B	B	B	B	B	B
2004	A	B	B	B	B	B	B	B	B	B	B	B
2005	B	B	B	B	B	B	B	B	B	B	B	B
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	A	A	A	A	A	B	B	B	B	A	A	A
2010	A	A	A	A	A	B	B	B	B	B	B	A
2011	A	A	A									

Table 10.2 Classification history, Loch Harport: Inner, common cockles

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	B	B	B	B	B	B	B	B	B	B	B	B

The area was only classified for cockles in 2001, and it was class B year-round. The production area was class B for Pacific oysters for all but one month from January 2001 to March 2008 inclusive. Although the classification status has varied over time, the area has always been class B for the months June to September inclusive.

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken at Loch Harport: Inner from the beginning of 2002 up to the 17th 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. All *E. coli* results are reported in most probable number per 100g of shellfish flesh and intravalvular fluid.

All reported sampling locations fell within the production area, and all samples were received by the testing laboratory within two days of collection. A total of 10 samples from had reported results of <20, and were assigned a nominal value if 10 for statistical assessment and graphical presentation, and one had a reported result of >18000, and was assigned a nominal value of 36000.

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 and results

Sampling Summary	
Production area	Loch Harport: Inner
Site	Carbost
Species	Pacific oysters
SIN	SL-121-278-142
Location	5 locations
Total no of samples	81
No. 2005	9
No. 2006	8
No. 2007	10
No. 2008	12
No. 2009	7
Results Summary	
Minimum	<20
Maximum	>18000
Median	220
Geometric mean	224
90 percentile	3500
95 percentile	9100
No. exceeding 230/100g	37 (46%)
No. exceeding 1000/100g	17 (21%)
No. exceeding 4600/100g	8 (10%)
No. exceeding 18000/100g	1 (1%)

11.3 Overall geographical pattern of results

Within the Loch Harport: Inner production area, five locations were sampled, three of which were sampled on multiple occasions. Figure 11.1 presents a map of these results.

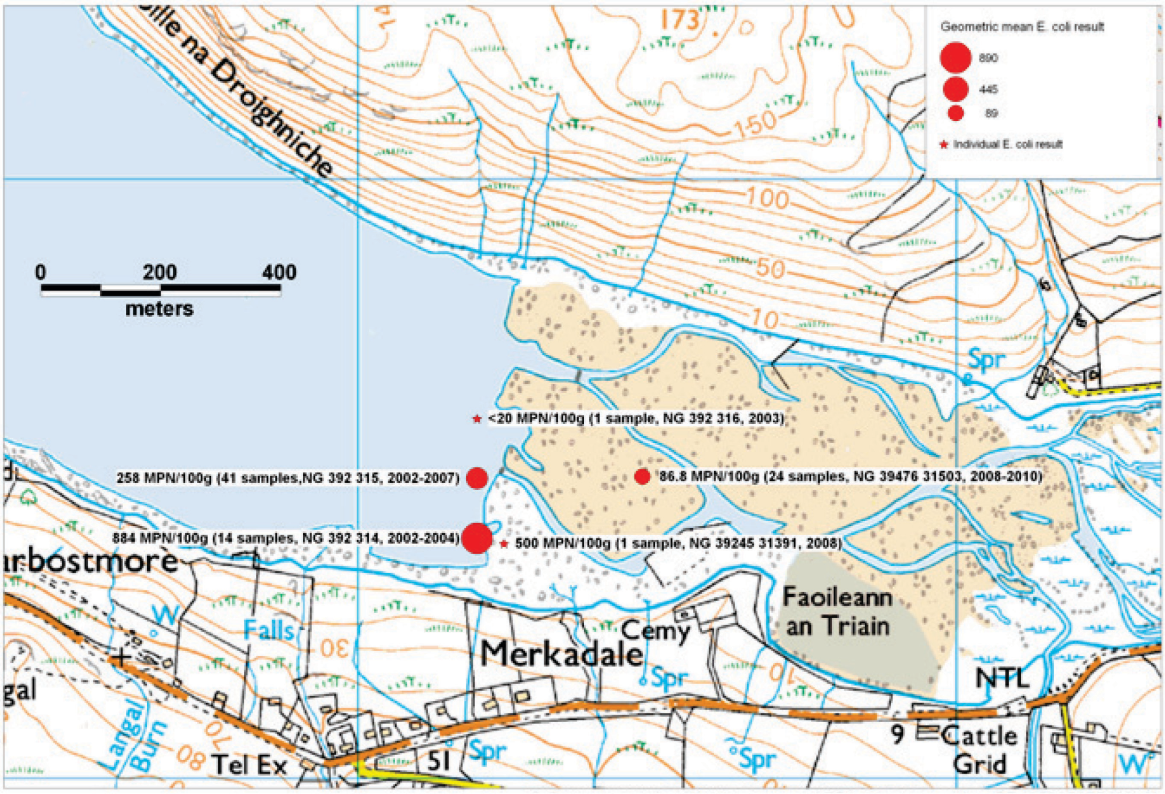

Figure 11.1 Geometric mean *E. coli* result by sampling location

Figure 11.1 gives the impression of higher results at locations closest to the south shore. A comparison of results from the three locations sampled on multiple occasions reveals a significant difference (One-way ANOVA, p=0.002). A post ANOVA test (Tukeys comparison, Appendix 6) revealed that results from NG 392 314 were significantly higher than those from NG 39476 31503. It must be noted that these locations were sampled on different occasions and hence under differing environmental conditions, so the differences may be attributable to temporal rather than spatial variations.

11.4 Overall temporal pattern of results

Figure 11.2 presents a scatter plot of all individual results against date, fitted with trend lines calculated using two different techniques. It is fitted with a line indicating the geometric mean of the previous 5 samples, the current sample and the following 6 samples, referred to as a rolling geometric mean (thick line). It is also fitted with a loess line (thin 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. These trend lines help to highlight any apparent underlying trends or cycles.

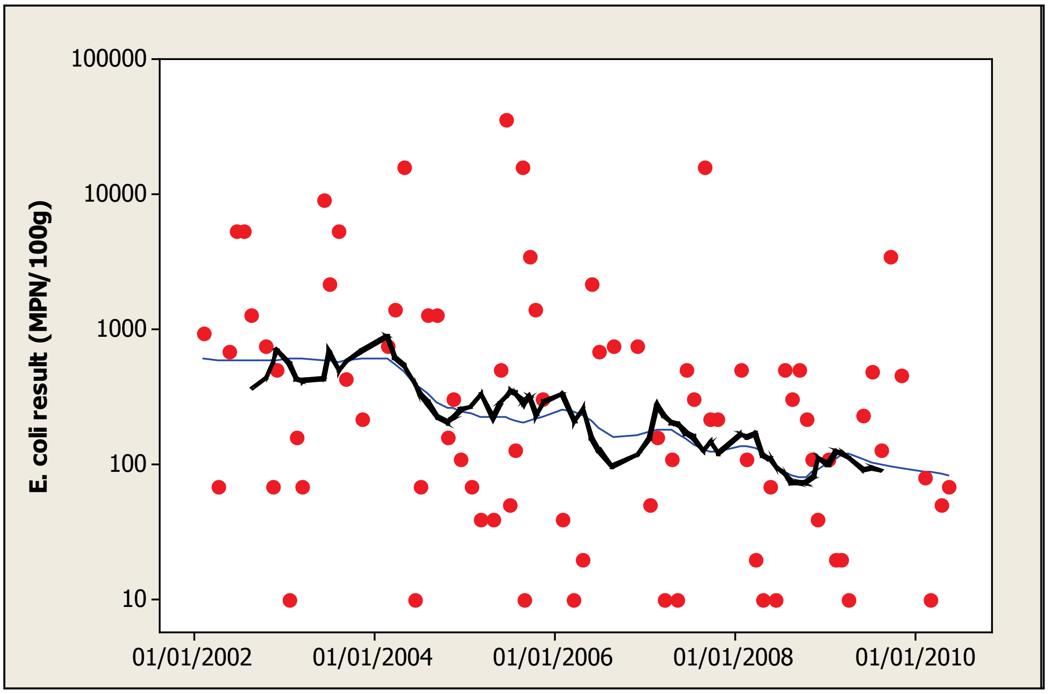

Figure 11.2 Scatterplot of *E. coli* results by date with rolling geometric mean (thick line) and loess line (thin line).

Figure 11.2 suggests a gradual but marked improvement in levels of contamination between 2002 and 2010. The frequency of higher results (over 1000 *E. coli* MPN/100g) decreased from the start of 2007 onwards, suggesting there may have been a significant reduction of inputs around this time. It is, however, also possible that this change may have been a consequence of the changes in sampling location.

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 boxplot of *E. coli* result by month.

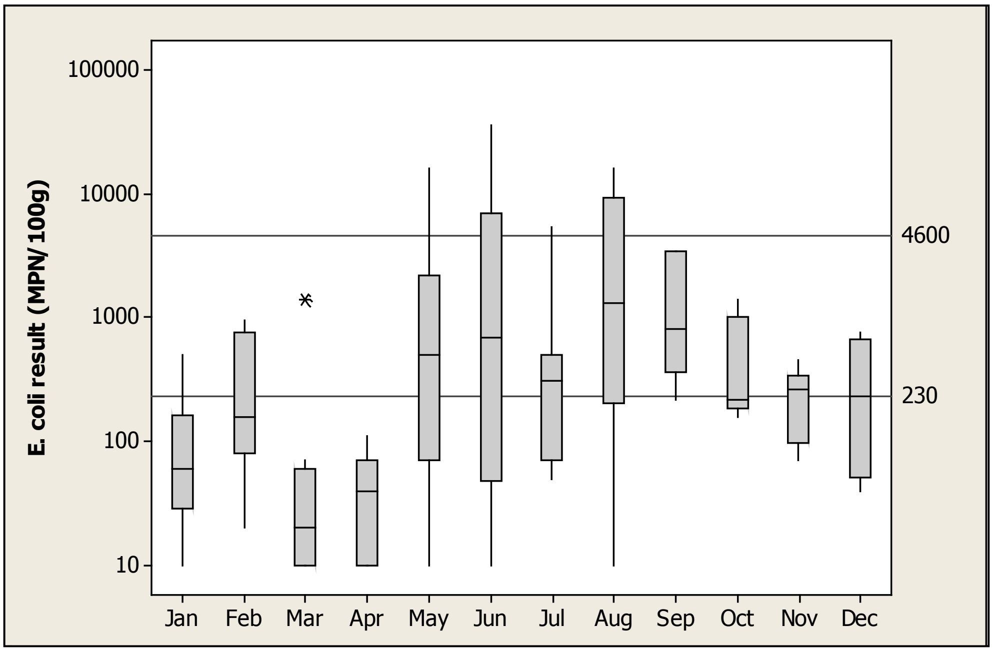

Figure 11.3 Boxplot of *E. coli* results with loess lines by month

Figure 11.3 suggests a strong seasonal pattern, with generally higher results being seen from May to October, although results above 230 *E. coli* MPN/100 g occurred in all months apart from March and April.

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

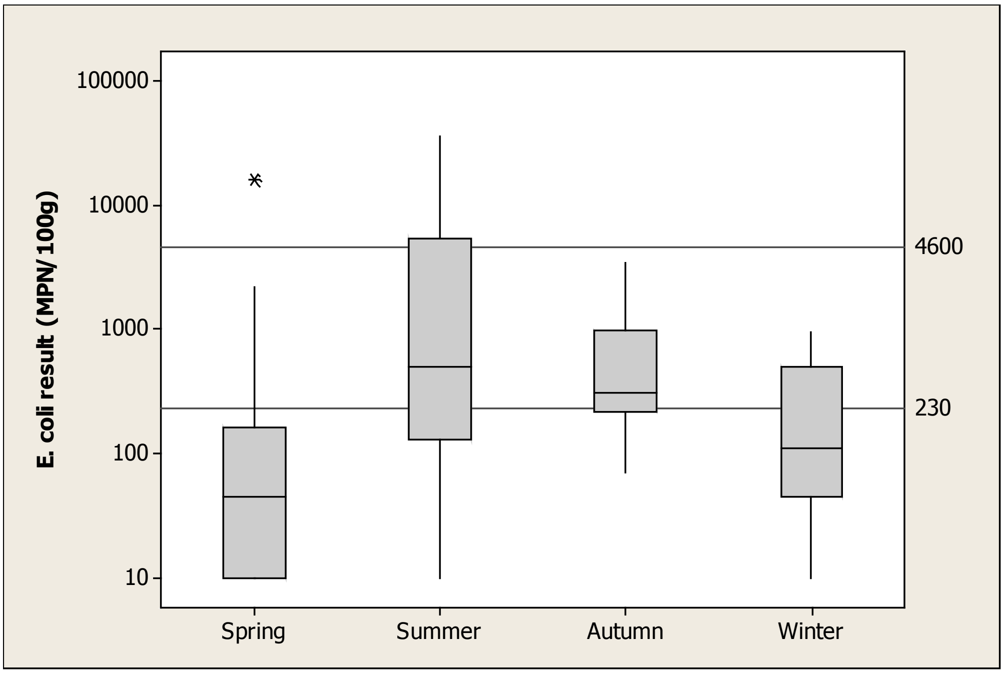

Figure 11.4 Boxplot of result by season

A significant seasonal difference was found (One-way ANOVA, p=0.001, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicated that results for the summer were significantly higher than those for the winter and spring, and results for the autumn were significantly higher than those for the spring.

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 Skye Portnalong, approximately 4km from the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2009 (total daily rainfall in mm).

Two-day antecedent rainfall

Figure 11.5 presents a scatterplot of *E. coli* results against rainfall in the previous two days by area. Spearman's Rank correlations were carried out between results and rainfall for each area.

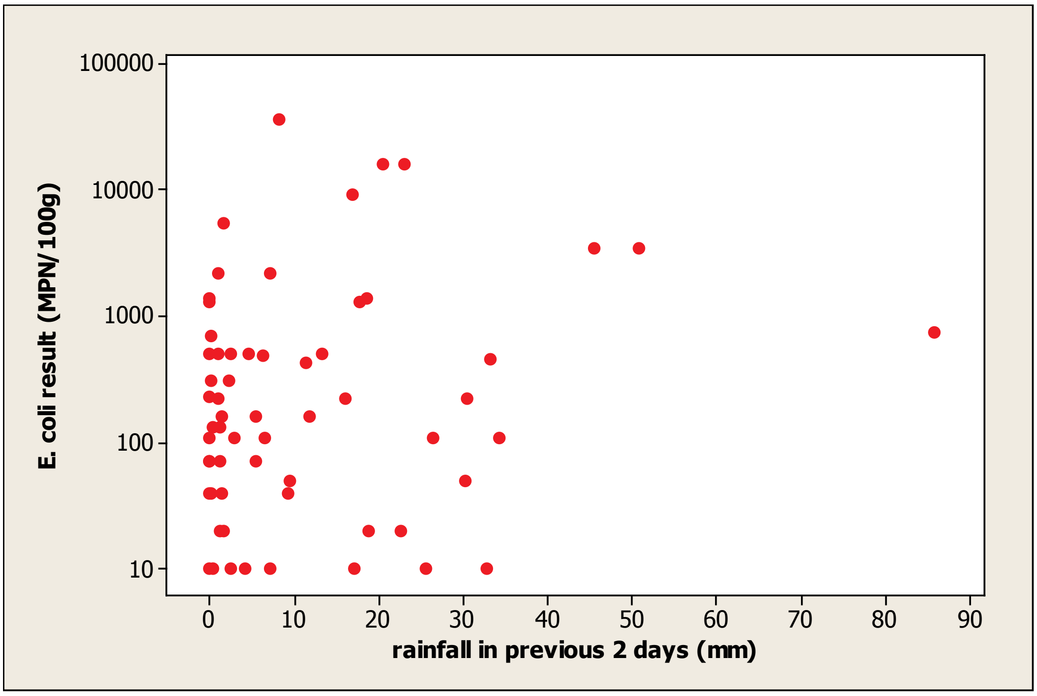

Figure 11.5 Scatterplot of result against rainfall in previous 2 days

No significant correlation was found between 2 day rainfall and *E. coli* results (Spearman's rank correlation=0.118, p>0.10, Appendix 6).

Seven-day antecedent rainfall

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.

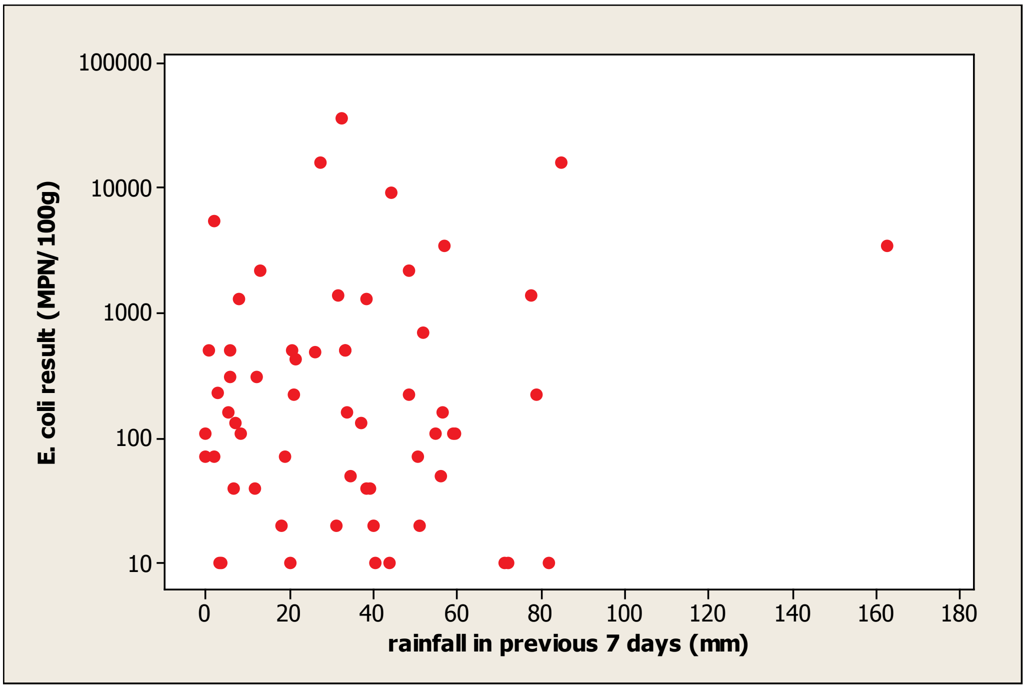

Figure 11.6 Scatterplot of result against rainfall in previous 7 days

No significant correlation was found between *E. coli* result and rainfall in the previous 7 days (Spearman's rank correlation= 0.009, p>0.25, Appendix 6).

11.6.2 Analysis of results by tidal height and state

Spring/Neap 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. Full/new moons are located at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of under 230 *E. coli* MPN/100g are plotted in green, those between 230 and 1000 *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.

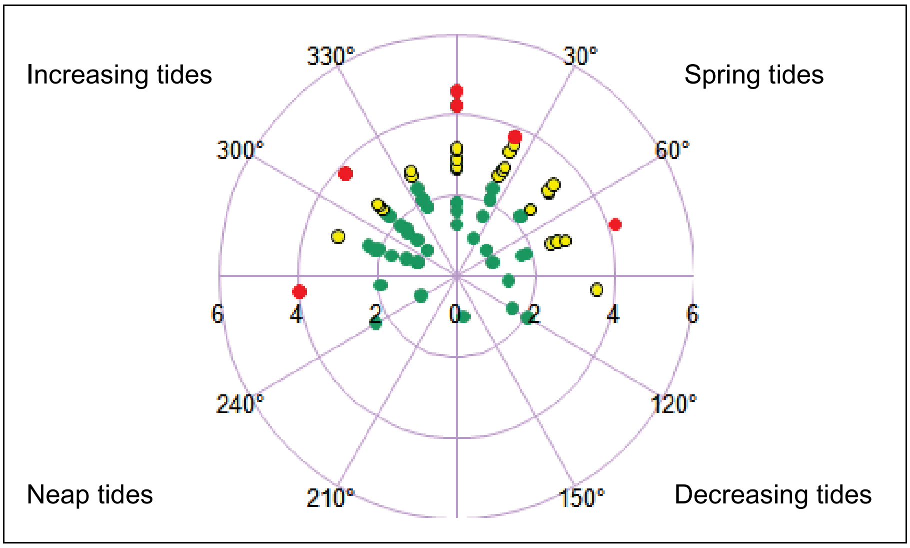

Figure 11.7 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle

A significant correlation was found between *E. coli* results and the spring/neap cycle (circular-linear correlation, r=0.286, p=0.002, Appendix 6) with a higher proportion of elevated results occurring around spring tides. However, in general, sampling was targeted towards increasing and spring tides and this may have limited the detection of effects on other tidal states.

<u>High/low cycle</u>

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 lunar high/low tidal cycle. High water is located at 0º, and low water is at 180º. Again, results of under 230 *E. coli* MPN/100g are plotted in green, those between 230 and 1000 *E. coli* MPN/100g are plotted in yellow, and those over 4600 *E. coli* MPN/100g are plotted in red.

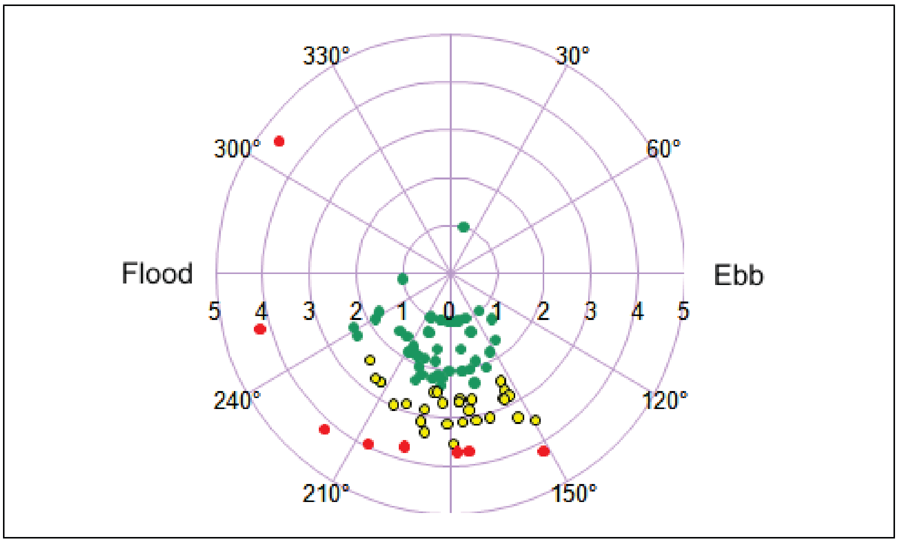

Figure 11.8 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle

No significant correlation was found between *E. coli* results and the high/low tidal cycle (circular-linear correlation, r=0.047, p=0.843, 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.

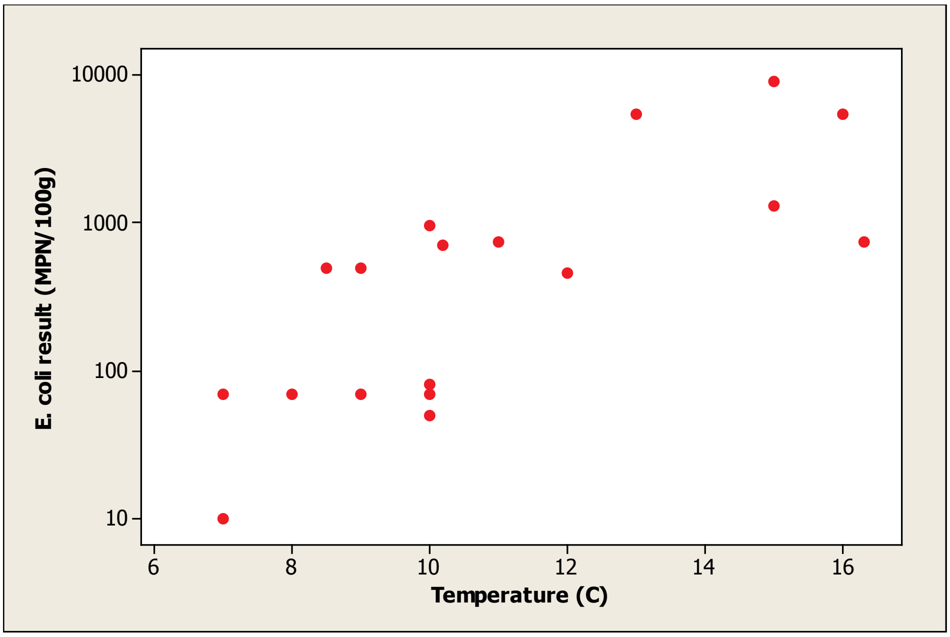

Figure 11.9 Scatterplot of *E. coli* result by water temperature

A positive correlation was found between *E. coli* result and water temperature (Spearman's rank correlation=0.772, p<0.0005, Appendix 6). This apparent effect may be coincidental with other seasonal factors.

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 plot of *E. coli* result against salinity. A significant negative correlation was found between *E. coli* results and salinity (Spearman's rank correlation= -0.522, p<0.0005, Appendix 6).

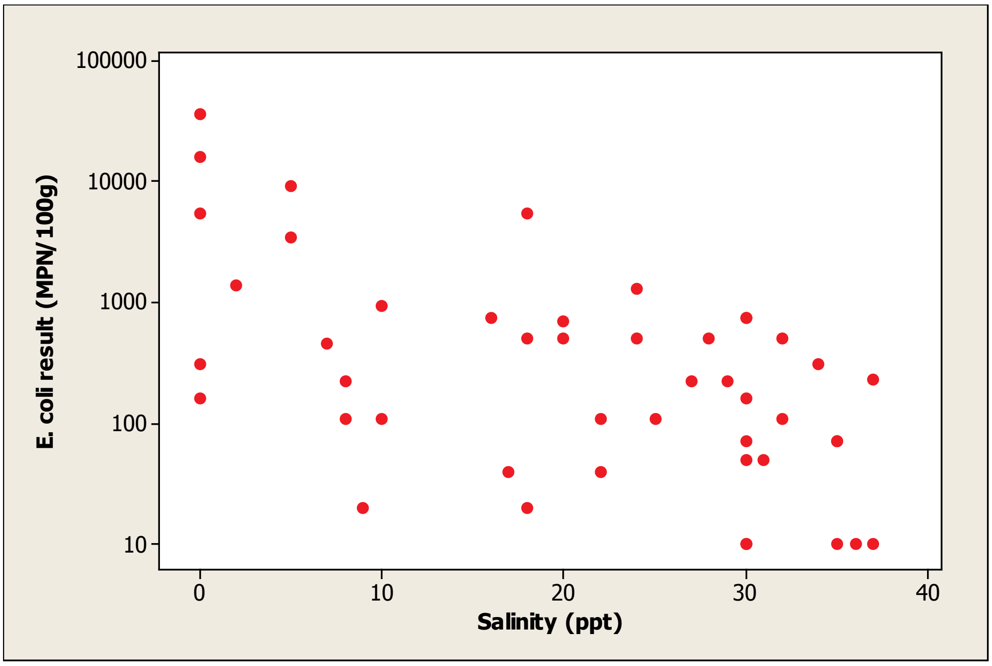

Figure 11.10 Scatterplot of *E. coli* result by salinity

11.7 Evaluation of results over 4600 E. coli MPN/100g

A total of 8 samples gave a result of over 4600 *E. coli* MPN/100g, details of which are presented in Table 11.2.

Table 11.2 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)
25/06/2002	5400	NG392314	*	*	13	0	Low	Spring
23/07/2002	5400	NG392315	*	*	16	18	Low	Increasing
11/06/2003	9100	NG392314	16.8	44.2	15	5	Low	Neap
11/08/2003	5400	NG392314	1.6	2	*	*	Low	Increasing
04/05/2004	16000	NG392314	23	27.6	*	*	Low	Spring
21/06/2005	>18000	NG392315	8.1	32.5	*	0	Flood	Increasing
22/08/2005	16000	NG392315	20.5	84.7	*	0	Low	Spring
27/08/2007	16000	NG392315	*	*	*	*	Flood	Increasing

* Data unavailable

All samples were collected during the months of May (1), June (3), July (1) or August (3) so these high results were strongly centered around the warmer months. Since August 2007, there have been no results of over 4600 *E. coli* MPN/100g. All samples were reported from either NG392314 or NG392315, towards the south western corner of the area sampled. Where rainfall data was available recent rainfall was generally moderate to high, and where salinity was recorded it was generally low. These results generally arose around low water on increasing or spring tides, but sampling was targeted towards these tidal states presumably for access reasons.

11.8 Summary and conclusions

When *E. coli* results were thematically mapped by reported sampling location, it gave the impression of higher results at locations closest to the south shore. A comparison of results from the three locations sampled on multiple occasions indicated a statistically significant difference in mean result, with results from the most south westerly location samples significantly higher than those at the most easterly location sampled. However, it must be noted that these locations were sampled on different occasions and hence under differing environmental conditions, so may reflect temporal rather than spatial variations in levels of contamination.

In terms of overall temporal trends, a gradual but quite marked improvement in levels of contamination was seen between 2002 and 2010. The frequency of higher results decreased from the start of 2007 onwards, suggesting there may have been a significant reduction of inputs around this time. It is however possible that this change may have been a consequence of the changes in sampling location. A significant seasonal pattern was found, with results for the summer were significantly higher than those for the winter and spring, and results for the autumn were significantly higher than those for the spring. All class C results arose between May and August, and a strong positive correlation was found between *E. coli* results and water temperature was also found.

Although no correlation was found between *E. coli* results and recent rainfall, a strong negative correlation between *E. coli* results and salinity was found, indicating higher levels of contamination at times of higher freshwater input.

A correlation was found between *E. coli* results and the spring/neap tidal cycle. However, sampling was targeted towards increasing and spring tides, and no pattern was apparent when this data was plotted, aside from perhaps highest average results on spring tides and lowest average results on decreasing tides. No correlation was found between *E. coli* results on the high/low tidal cycle.

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

Loch Harport was designated as a Shellfish Growing Water in 2002. The designated area is described as: “An area bounded by lines drawn between NG 332 370 (Bracadale Point) and NG 335 364 (Ardtreck Point) and between NG 334 374 (Rubha na h-Uamha) and NG 352 364 and extending to MLWS.”. The associated sampling point is given by SEPA as: NG 37680 32133. 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 in Loch Harport started in the last quarter of 2002. The faecal coliform results are presented in Table 12.1. The results were reported against two locations: the results from Q4 2002 and Q1 2003 were reported against NG 334 373 and the rest of the results up to Q1 2007 were reported against NG 37680 32133 (subsequently the designated sampling point). From 2007, SEPA started to use the FSAS *E. coli* data for determining compliance for most shellfish waters and this included Loch Harport. A review of those *E. coli* results will have been included in Section 12 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 Loch Harport

Year	Quarter	OS Grid Ref.	
		NG 334 373	NG 37680 32133
2002	**Q1**		
	Q2		
	Q3		
	Q4	70	
2003	**Q1**	<20	
	Q2		
	Q3		2200
	Q4		220
2004	**Q1**		220
	Q2		70
	Q3		160
	Q4		2400
2005	**Q1**		750
	Q2		16000
	Q3		130
	Q4		<20
2006	**Q1**		<20
	Q2		9100
	Q3		310
	Q4		40
2007	**Q1**		9100

The results show that at least intermittent significant levels of faecal contamination occur in shore mussels in the vicinity of Carbost. There are too few results, especially for the initial monitoring point, to determine whether the levels differed significantly between the two SEPA sampling locations. The mussel results were of the same order as those seen in the Pacific oysters at the head of the loch.

Figure 12.1 SEPA designated growing water and monitoring points

13. River Flow

There are no gauging stations on watercourses entering Loch Harport.

The watercourses listed in Table 13.1 were measured and sampled during the shoreline survey. The weather was dry in the days prior to the survey and there was light rain overnight between the two days of the survey itself. The locations are shown on the map presented in Figure 13.1.

Table 13.1 Watercourse loadings for Loch Harport

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	NG 4004 3163	Drynoch Burn	1.3	0.1	0.022	247	2100	5.2×10^9
2	NG 4018 3157	Stream	1.5	0.09	0.303	3530	240	8.5×10^9
3	NG 4018 3151	River	6.9	0.173[1]	0.169[1]	17500	60	1.1×10^{10}
4	NG 4111 3132	River Drynoch	2.8	0.165[2]	0.341[2]	13800	50	6.9×10^9
5	NG 4015 3115	Vikisgill Burn	4.5	0.13[1]	0.12[1]	5640	60	3.4×10^9
6	NG 3935 3132	Allt na h-Atha	0.6	0.04	0.118	245	2300	5.6×10^9
7	NG 3894 3136	Allt Buaile Shuaine	0.3	0.21	0.184	1000	80	8.0×10^8
8	NG 3876 3136	Small stream	Not measured[3]			-	10	Not determined
9	NG 3862 3143	Langal Burn	Not measured[3]			-	20	Not determined
10	NG 3813 3169	Allt nan Tighean	0.32	0.09	0.055	137	60	8.2×10^7
11	NG 3776 3195	Carbost Burn	0.43	0.07	0.202	525	120	6.3×10^8

[1]Average of three values; [2]Average of two values; [3]Too small to measure

Entries 2 and 3 in Table 13.1 represent watercourses running across the intertidal area at the head of the loch. Number 2 largely consists of the combined inputs from Allt an Tobair and Allt Fionnfhuachd while number 3 largely consisted of the combined inputs of the River Drynoch and Allt nan Guile. However, there are a number of additional small watercourses in the locality and the channels across the intertidal area interconnect in a complex manner.

Calculated loadings were low to moderate. Despite the low *E. coli* concentrations in the watercourses at the head of the loch, the loadings were moderate due to the relatively large flows. These watercourses, including the River Drynoch, will impact on the water quality at the oyster trestles over the course of the ebb tide until the seawater is below the level of the oysters. Two streams (6 and 7 in Table 13.1) were close to the oyster farm and would be expected to contribute to contamination at the trestles despite having low loadings: stream 6 drained across the foreshore directly towards the trestles. Loadings from all of the watercourses would be expected to be significantly higher following moderate to heavy rainfall. A number of small watercourses were marked on the OS map on both sides of the loch but not recorded during the shoreline survey: these were not flowing at the time of the survey but would be expected to run after rainfall and to be a conduit for land run-off.

Figure 13.1 Map of stream loadings at Loch Harport

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.

14. Bathymetry and Hydrodynamics

Figure 14.1 shows the OS map of Loch Harport and Figure 14.2 shows the UKHO chart of the same area. Loch Harport is located on the western side of the Isle of Skye. It is approximately 20 km in length. It opens on to Loch Bracadale at the western end and at the mouth is oriented in a westerly to easterly direction. The main part of the loch runs in approximately a north-west to south-east direction. At the head, it curves round again to run westerly to easterly.

Figure 14.1 OS map of Loch Harport

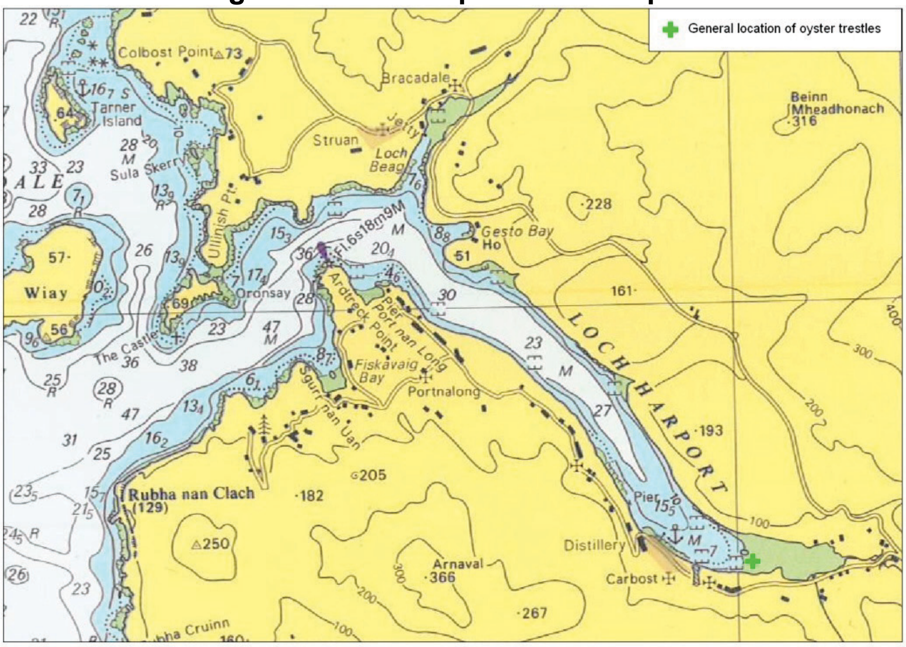

Figure 14.2 Bathymetry at Loch Harport

There is a significant drying area at the head of the loch. The drying area is crossed by a complex of intersecting channels that carry brackish to freshwater from rivers and streams at certain states of tide. The oyster trestles are located towards the seaward edge of the drying area. Within 500 m of the edge of the drying area, the depth reaches 7 m. In the middle and outer parts of the loch, depths mainly exceed 20 m, except near the very edge of the loch.

No information for Loch Harport is given in the Scottish Sea Lochs Catalogue.

14.1 Tidal Curve and Description

The two tidal curves below are for Loch Harport, at the mouth of the loch. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 BST on 08/09/10 and the second is for seven days beginning 00.00 BST on 15/09/10. 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.

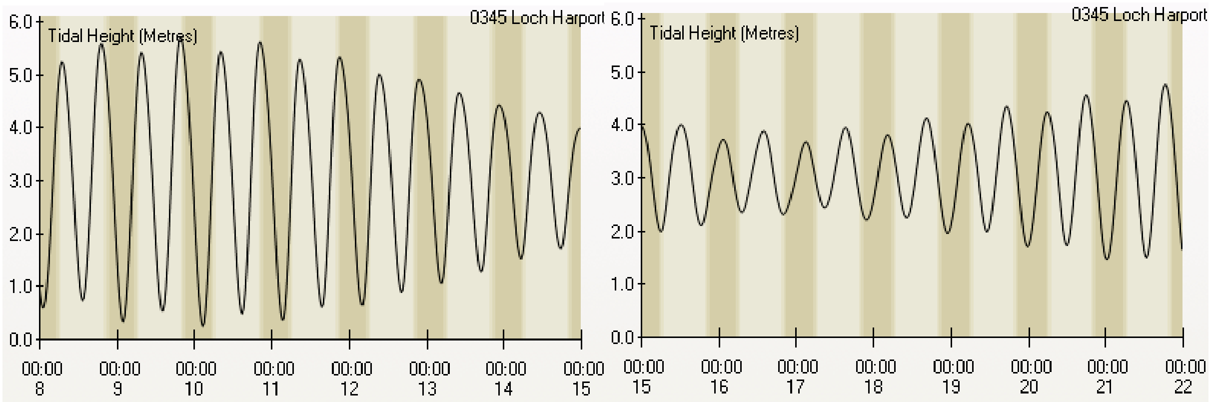

Figure 14.3 Tidal curves for Loch Harport

The following is the summary description for Loch Harport from TotalTide:

The tide type is Semi-Diurnal.

HAT	5.8 m
MHWS	5.1 m
MHWN	3.8 m
MLWN	2.1 m
MLWS	0.8 m
LAT	0.2 m

Predicted heights are in metres above chart datum. Tidal range at spring tide is 4.3 m and at neap tide 1.7 m and so tidal ranges at this location are moderate.

14.2 Currents

There is no current stream information in the vicinity of Loch Harport. SEPA provided information on currents recorded at two locations near the mouth of Loch Harport. The locations at which the current meters were deployed are shown in Figure 14.4. The survey periods were as given in Table 14.1.

Table 14.1 Survey periods for the current meter studies

Location	NGR	Survey period
Portnalong NW	NG 3501 3557	19/06/2006 - 04/07/2006
Portnalong SE	NG 3523 3543	16/05/2006 - 31/05/2006

Polar plots of the current directions and speeds at the two locations, together with the wind direction and speeds over the relevant periods, are shown in Figure 14.5.

Maximum currents at both locations were recorded at near-surface: 21.5 cm/s at NW and 23.3 cm/s at SE. Mean recorded speeds were all <6 cm/s (<0.12 knots). Currents in the area are therefore generally weak. The currents were strongly bidirectional, flowing parallel to the edges of the loch. In general, the flood tides were stronger than the ebb tides. Ebb currents at the surface were stronger than at depth. This may have been due to the influence of south-easterly winds. At the maximum recorded current, contaminants would be expected to be carried approximately 3 km over a flood or ebb tide, ignoring any effects of dilution or dispersion.

Currents at the head of the loch may be different to those recorded at the current meter locations. It would be expected that currents over the drying area would be somewhat higher, due to the loch being narrower and shallower in that area.

14.3 Conclusions

Loch Harport is a relatively short and shallow loch and does not appear to contain any sills. Contamination arising within one tidal excursion of the oyster trestles would not be subject to marked dilution. In general, currents are weak but follow the direction of the loch. At the surface, they are subject to the influence of winds.

Contamination arising from sources at the head of the loch would be taken across the oysters during the ebbing tide, with little dilution, although any effects would cease once the water had dropped below the level of the trestles. The trestles are well within the expected maximum transport distance of sources at Carbost.

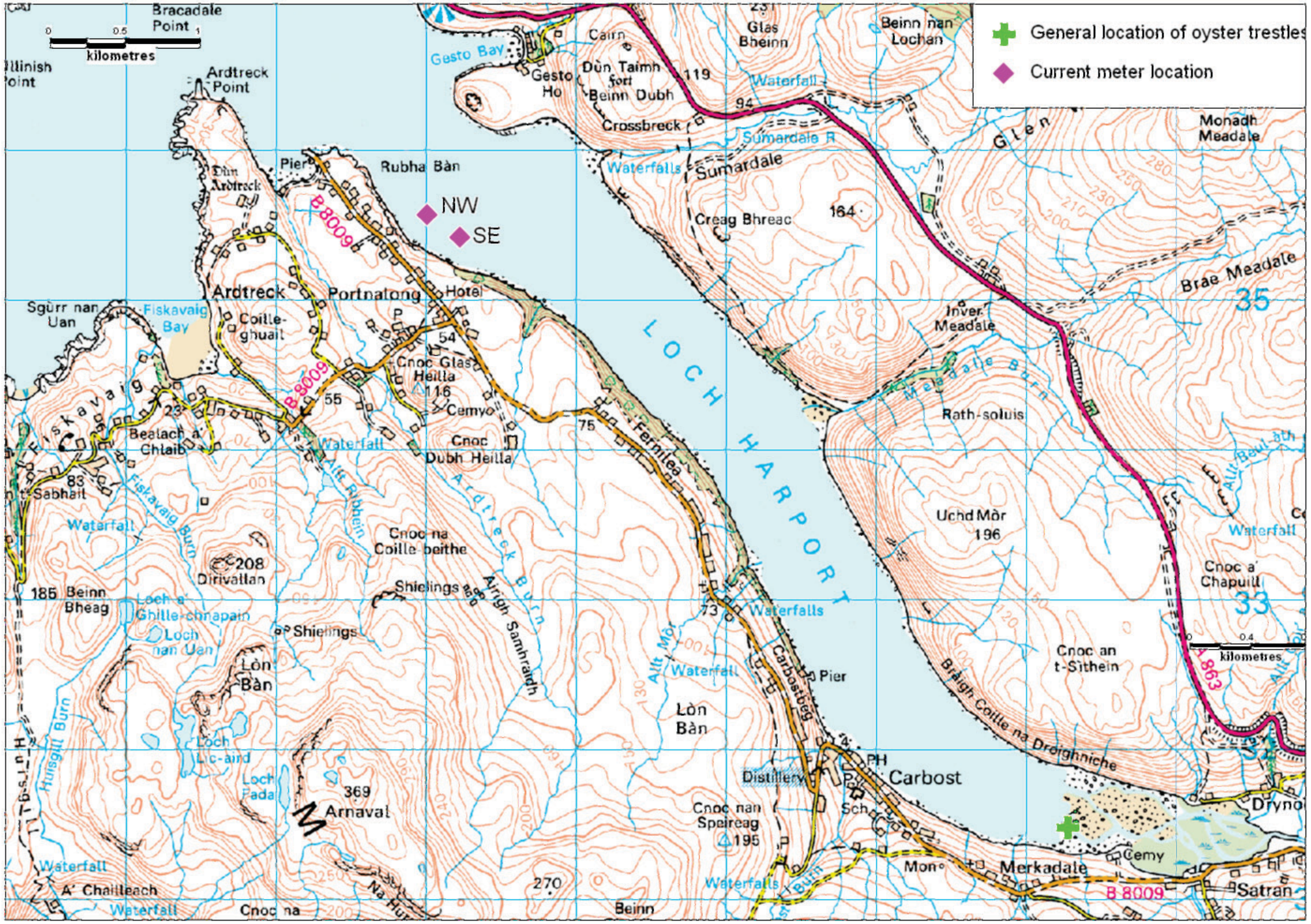

Figure 14.4 Current meter locations

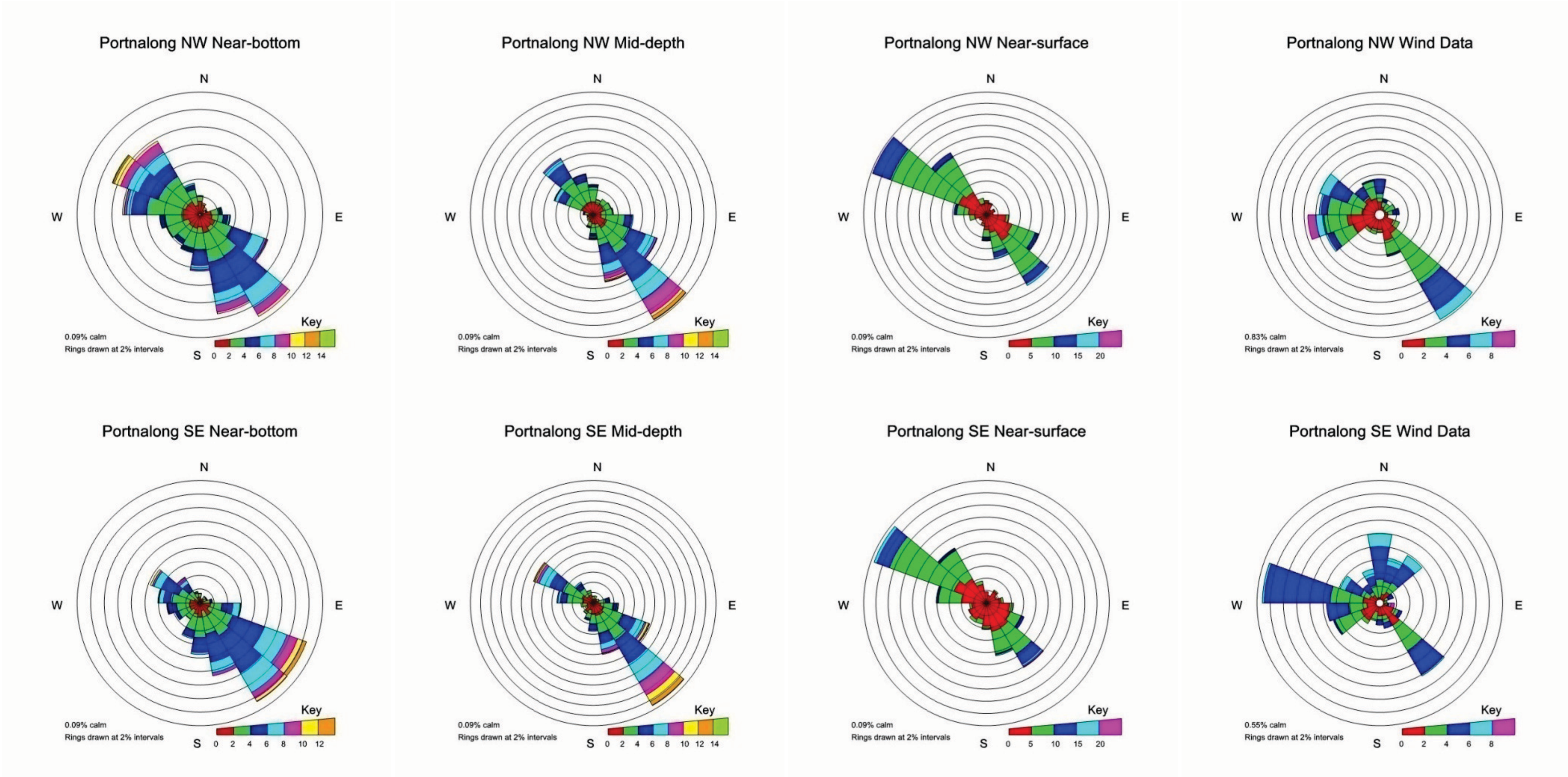

Figure 14.5 Current and wind plots for the Portnalong NW and SE current meters

Currents measured in cm/s. Wind measured in m/s. As per convention, currents are plotted against the direction towards which they are travelling while winds are plotted against the direction from which they are travelling. The length of each segment in a plot relates to the proportion of observations lying in that direction. The speed relates to the colour key beneath each plot. The proportion that each colour takes up in an individual segment relates to the proportion of observations in that direction having speed in that range.

15. Shoreline Survey Overview

The physical survey of the shoreline at Loch Harport was conducted on the 8th and 9th September 2010 under conditions that varied between overcast and sunny.

The fishery consisted of Pacific oysters grown in poches on several blocks of trestles on the drying area off Merkadale, located towards the head of the loch. The blocks grouped into 3 main areas.

Population is mainly centred in Carbost, west of the fishery. Due to the distillery at Carbost, there is a significant number of visitors to the area year round, although they will peak during the summer period. At that location, a Scottish Water community septic tank was recorded together with a number of potential smaller septic tank outlets. Some of those may have been superseded by the community discharge. There were a small number of other dwellings towards the head of the loch east of the fishery. A sample of suspected sewage taken from a presumed septic tank outlet on the shore below the distillery gave a result of >100,000 *E. coli* cfu/100 ml. At the time of the survey, the discharge was flowing across the shore to the loch.

A small number of moored boats, and a number of unoccupied moorings, were located on the southern side of the loch near Carbost.

Sheep and cattle were recorded at a number of locations around the loch. These were mostly fenced off from the shoreline but sheep were observed on the shore on the north side of the head of the loch and local information identified that grazing across the drying area took place during much of the winter.

Two relatively large watercourses were identified towards the head of the loch and a number of smaller streams were recorded at other locations around the shoreline. These were measured and sampled. The larger watercourses flowed across the drying area towards the trestles and some of the smaller watercourses were located on the southern shore in the near vicinity of the fishery. Most of the watercourses contained low concentrations of *E. coli*. However, two of the smaller watercourses, one located immediately south of the oyster trestles, and the other to the north-east of the trestles, contained moderate concentrations of 2,300 and 2,100 *E. coli* cfu/100 ml respectively.

Seawater samples were taken from the shore at four locations over the survey area. They returned results that ranged from <10 to 70 *E. coli* cfu/100 ml. Pacific oyster samples were taken from three locations across the trestles: these showed results ranging from <20 to 50 *E. coli* MPN/100 g. The survey was conducted during the early autumn, part of the year when high results are often seen in the routine monitoring programme.

Figure 15.1 shows a map summarizing the findings from the shoreline survey.

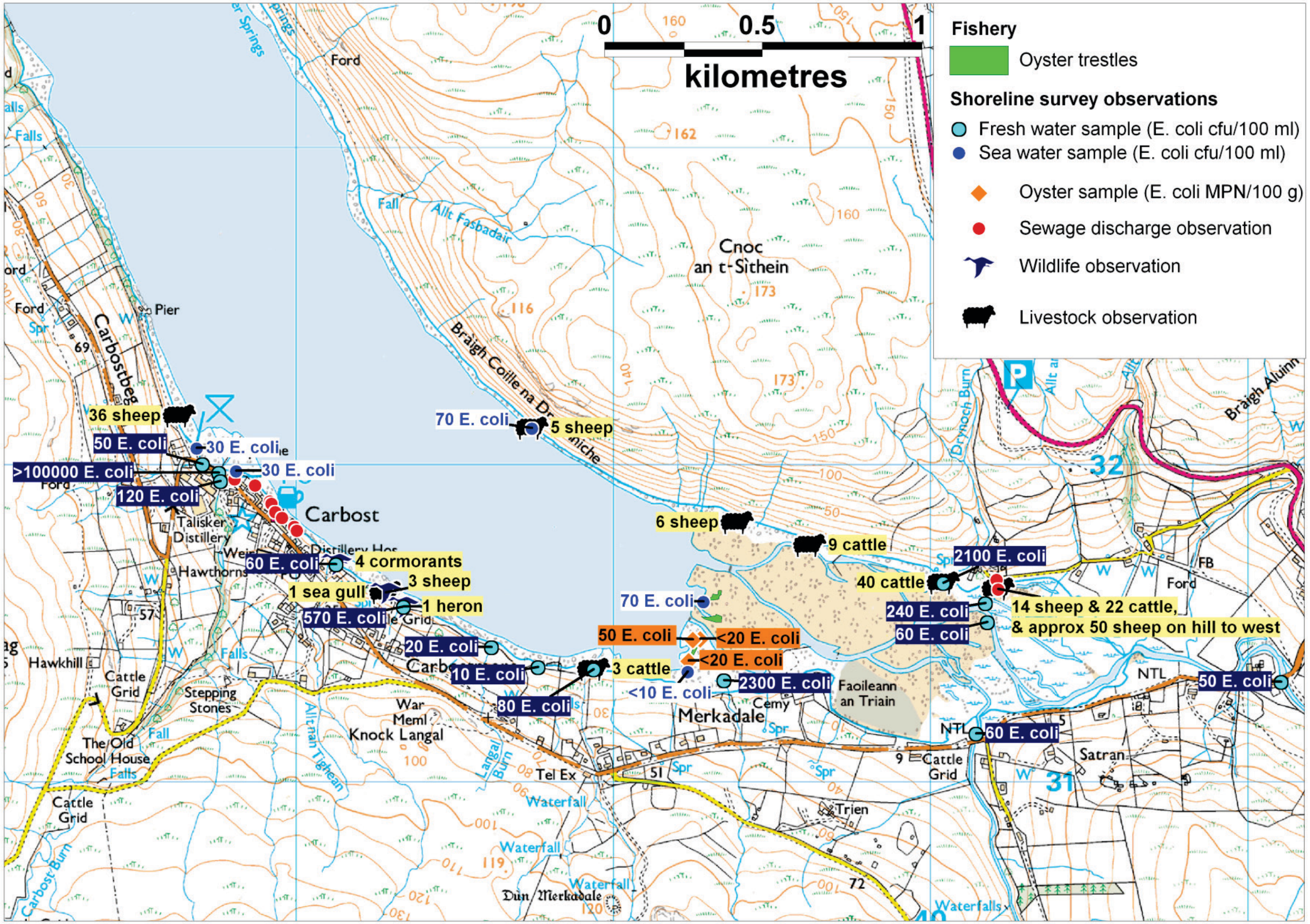

Figure 15.1 Summary of shoreline survey findings for Loch Harport Inner

16. Overall Assessment

Human sewage impacts

The most immediate potential sources of human pollution for the fishery will be from individual properties located around the head of the loch. Although most of the consents identify that these go to soakaway, some are located very close to small streams and thus could possibly impact on the loch via the watercourses. The combination of the community septic tank discharge and other smaller discharges at Carbost could impact at the trestles, especially on a spring flood tide.

Visitors to the distillery are expected to peak in the summer months and this will markedly increase the discharge loading from the Carbost area. While the number of boats in the area is generally small, the marked increase for a short period in July associated with the Classic Malts cruise will enhance the potential for discharges from this source.

Agricultural impacts

Livestock were widely located around the loch, including on the intertidal area, and thus provide a source of faecal pollution directly to the fishery and via the watercourses. Other livestock not recorded during the shoreline survey, but located in the catchments of the two larger watercourses, are likely to contribute to faecal contamination of the head of the loch. While there will be a tendency for the farm animal populations to be larger during the warmer months, e.g. due to lambing, the practice of grazing on the intertidal area during the winter months would increased the direct contamination of the area during those months.

Wildlife impacts

No significant wildlife populations have been identified and so the impact of these on the water quality at the fishery is likely to be small in relation to other sources.

Seasonal variation

Seasonal variations in human and animal populations have been considered above. Analysis of historical shellfish *E. coli* data showed a tendency to higher concentrations during summer and autumn.

Rivers and streams

Several watercourses were measured and sampled during the shoreline survey. Other small watercourses marked on the OS map may only flow after heavy rainfall. In terms of *E. coli* concentration, Drynoch Burn and Allt na h-Atha were markedly more contaminated than the other watercourses.

However, a number of watercourses around the head of the loch and also adjacent to the fishery had comparable and moderate loadings. These will all tend to impact on the microbiological quality of the oysters during the ebb tide until the level of the seawater has fallen below that of the trestles.

Rainfall tends to be higher from October to January. Although high rainfall events (>20 mm in 24 hours) occurred in all months, these were more extreme between September and December. No significant correlation was found between rainfall in either 2 or 7 days prior to sampling and *E. coli* in the oysters.

Temporal and geographical patterns of sampling results

There appears to have been a slight overall improvement in oyster *E. coli* results over time and an associated reduction in the occurrence of results >1000 *E. coli* MPN/100 g. However, it is not clear whether this is due to change in reported sampling location from 2007 onwards. Samples had been recorded against 5 locations overall, with three of these having been sampled on more than one occasion. Higher results tended to be recorded against locations closer to the southern shore, although none of the locations had been sampled in parallel on the same date and therefore the results of samples taken under the same environmental conditions could not be compared.

Samples of Pacific oysters taken from 3 locations on the farm during the shoreline survey all showed low concentrations of *E. coli* (<20, <20 and 50 *E. coli* MPN/100 g). Seawater samples taken in the vicinity of the trestles, and from the shore at locations further down the loch, showed relatively low *E. coli* concentrations (<10 to 70 *E. coli* cfu/100 ml). The two highest results were seen at the trestles and on the north side of the loch. It should be noted that a geometric mean *E. coli* concentration in seawater of <10/100 ml (actual value varying with bivalve species) has been suggested as being necessary to reliably result in class A compliance in shellfish (EU Scientific Veterinary Committee Working Group, 1996). SEPA results for shore mussels sampled at Carbost show that the area is subject to relatively high levels of faecal contamination on at least an intermittent basis (with results up to 16,000 *E. coli* MPN/100 g).

Bathymetry and hydrodynamics

Faecal contamination arising in the vicinity of the oyster farm will be subject to very limited dilution due to the location on the drying area and the fairly limited depths between that location and the mid-loch. Currents in the area are generally weak and therefore the distances over which contamination may be transported on one ebb or flood tide will be limited. The impact from sources at the head of the loch will be greatest on the ebb tide. Sources in the Carbost area may impact at the trestles, especially on a spring flood tide. Analysis of historical shellfish *E. coli* data with respect to tide showed a significant correlation with respect to the spring/neap tidal cycle, with high results generally being found at or near spring tides. No significant correlation was found with the high/low tidal cycle. However, sampling was skewed towards low tide coming up to, or at, springs.

Conclusions

The principal potential sources of contamination of the Pacific oysters are:

- The watercourses at the head of the loch and adjacent to the oyster trestles
- Farm animals at the head of the loch and above the shores in the vicinity of the oyster trestles
- Sources, including the community sewage discharge and other septic tanks, at Carbost, primarily on spring tides.

Due to the complexity of the channels at the head of the loch, direct contamination from animals on or adjacent to the drying area, or from the watercourses, may impact at varying locations across the area of trestles. However, at the time when the channels nearest to the oyster farm are exposed, the trestles themselves will be out of the water. Therefore, during the portion of the ebb tide over which the trestles will be submerged, contamination will be likely to be greatest towards the southern shore due to the greater impact of the watercourses located at the head of the loch and on the southern shore. Contamination arsing from sources further west, towards and at Carbost, will impact at the trestles on a flooding tide, with the further sources having a potential effect only on a spring tide.

17. Recommendations

Production area

The recommended production area boundaries are: Bounded by lines drawn between NG 3900 3196 and NG 3900 3135 and between NG 3964 3175 and NG 3964 3135 and extending to MHWS. This covers the entire extent of the present fishery, with a latitude around it, while keeping the boundaries away from direct impact from the larger watercourses to the east and the more significant sources of human pollution to the west.

RMP

The recommended RMP is NG 3924 3138. This is located towards the southern shore and so will detect the potential effects from the principal watercourses and the main sources of human pollution. The location will also mean that sampling can be undertaken over a wider range of low tides than would be possible for a point further from the shore.

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, 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.

A summary of the recommendations is shown in Figure 17.1.

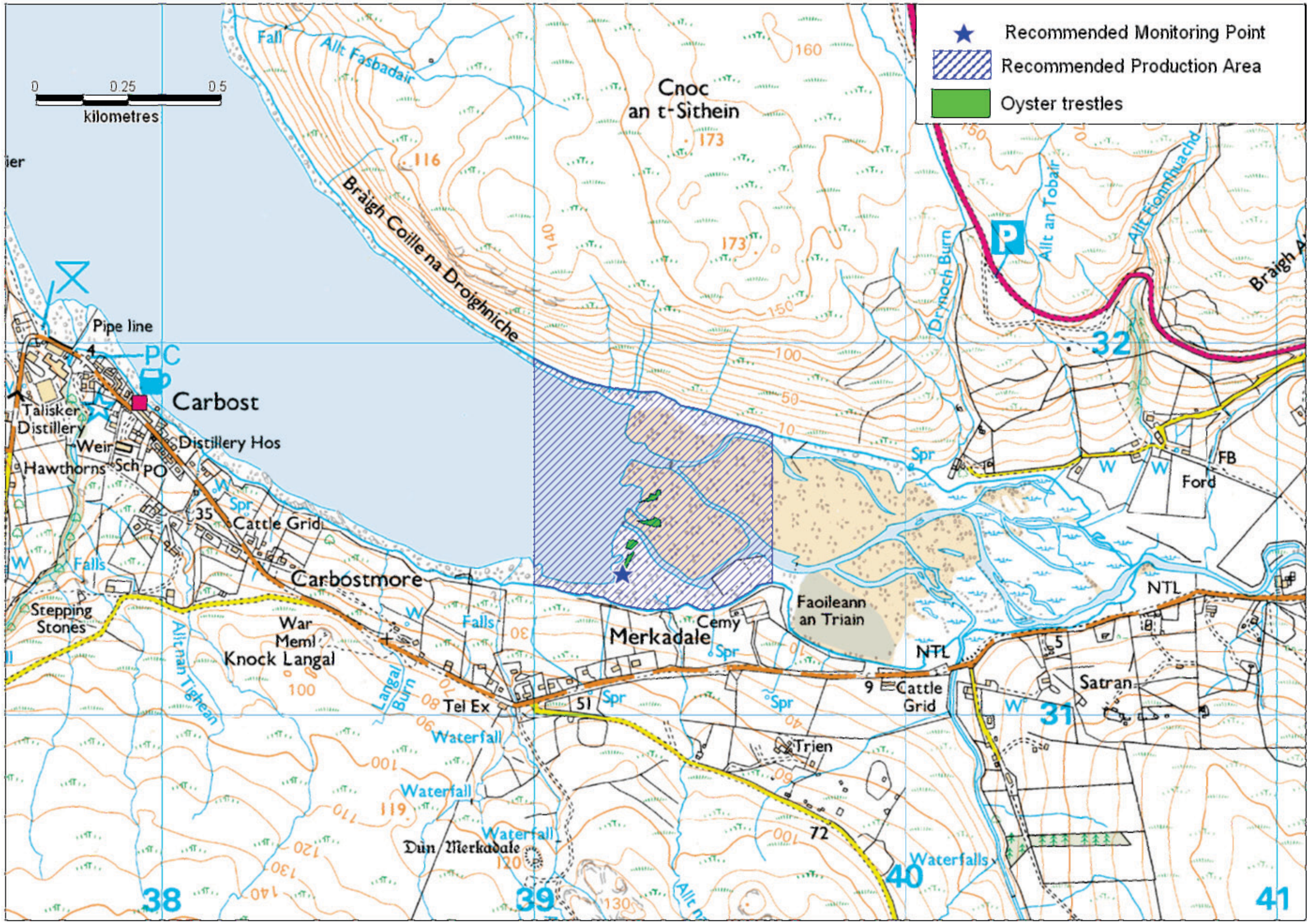

Figure 17.1 Map of recommendations at Loch Harport Inner

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Sampling Plan for Loch Harport Inner

PRODUCTION AREA	Loch Harport Inner
SITE NAME	Carbost
SIN	SL 159 286 13
SPECIES	Pacific oysters
TYPE OF FISHERY	Trestle
NGR OF RMP	NG 3924 3138
EAST	139240
NORTH	831380
TOLERANCE (M)	10
DEPTH (M)	N/A
METHOD OF SAMPLING	Hand-picked
FREQUENCY OF SAMPLING	Monthly
LOCAL AUTHORITY	The Highlands Council - Skye & Lochalsh
AUTHORISED SAMPLER(S)	Allan MacDonald
LOCAL AUTHORITY LIAISON OFFICER	Alan Yates

Table of Proposed Boundaries and RMPs

PRODUCTION AREA	Loch Harport Inner
SPECIES	Pacific oysters
SIN	SL 159 286 13
EXISTING BOUNDARY	Defined as the area east of line drawn between NG 3800 3329 and NG 3800 3180 and between NG 4000 3167 and NG 4000 3113
EXISTING RMP	NG 392 314
RECOMMENDED BOUNDARY	Bounded by lines drawn between NG 3900 3196 and NG 3900 3135 and between NG 3964 3175 and NG 3964 3135 and extending to MHWS
RECOMMENDED RMP	NG 3924 3138
COMMENTS	The extent of the production area has been reduced. The RMP is redefined 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 11.3 One way ANOVA comparison of results by sampling location

```
Source   DF      SS     MS     F      P
GridRef   2   9.188  4.594  6.71  0.002
Error    76  52.061  0.685
Total    78  61.249

S = 0.8277   R-Sq = 15.00%   R-Sq(adj) = 12.76%


                                    Individual 95% CIs For Mean Based on
                                    Pooled StDev
Level            N    Mean   StDev  --------+---------+---------+---------+-
NG 39476 31503  24  1.9386  0.6746  (------*------)
NG392314        14  2.9466  0.8943                    (--------*--------)
NG392315        41  2.4116  0.8832             (----*----)
                                    --------+---------+---------+---------+-
                                          2.00      2.50      3.00      3.50

Pooled StDev = 0.8277


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

Individual confidence level = 98.07%


GridRef = NG 39476 31503 subtracted from:

GridRef     Lower  Center   Upper  ----+---------+---------+---------+-----
NG392314   0.3428  1.0080  1.6732                   (--------*-------)
NG392315  -0.0354  0.4730  0.9814               (-----*-----)
                                   ----+---------+---------+---------+-----
                                     -0.80      0.00      0.80      1.60


GridRef = NG392314 subtracted from:

GridRef     Lower   Center   Upper  ----+---------+---------+---------+-----
NG392315  -1.1473  -0.5350  0.0773  (------*-------)
                                    ----+---------+---------+---------+-----
                                      -0.80      0.00      0.80      1.60
```

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

```
Source  DF      SS     MS     F      P
Season   3  12.874  4.291  6.56  0.001
Error   77  50.332  0.654
Total   80  63.206

S = 0.8085   R-Sq = 20.37%   R-Sq(adj) = 17.27%


                           Individual 95% CIs For Mean Based on Pooled StDev
Level   N    Mean   StDev    +---------+---------+---------+---------
1      22  1.8393  0.8885    (------*------)
2      25  2.7846  1.0139                       (------*-----)
3      17  2.6271  0.4842                   (-------*------)
4      17  2.0947  0.5772        (-------*-------)
                             +---------+---------+---------+---------
                           1.50      2.00      2.50      3.00
```

```
Pooled StDev = 0.8085


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        0.3253  0.9453  1.5653                    (-------*-------)
3        0.1029  0.7878  1.4728                 (--------*-------)
4       -0.4295  0.2554  0.9403           (-------*--------)
                                 -------+---------+---------+---------+--
                                     -0.80      0.00      0.80      1.60


Season = 2 subtracted from:

Season    Lower   Center    Upper  -------+---------+---------+---------+--
3       -0.8242  -0.1575   0.5093         (-------*-------)
4       -1.3567  -0.6899  -0.0231  (-------*--------)
                                   -------+---------+---------+---------+--
                                       -0.80      0.00      0.80      1.60


Season = 3 subtracted from:

Season    Lower   Center   Upper  -------+---------+---------+---------+--
4       -1.2599  -0.5324  0.1951   (--------*--------)
                                  -------+---------+---------+---------+--
                                      -0.80      0.00      0.80      1.60
```

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 ecoli for 2 day rain =
     0.118
```

n=61, p>0.10

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 7 day rain =
     0.009
```

n=59, p>0.25

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 11:58:12

Variables (& observations)	r	p
Angles & Linear (81)	0.286	0.002

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 11 June 2010 15:33:50

Variables (& observations)	r	p
Angles & Linear (81)	0.047	0.843

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

```
Pearson correlation of ranked temp and ranked e coli for temp = 0.772
```
n=18, $p<0.0005$

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 = -
0.522
n=46, p<0.0005
```

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.

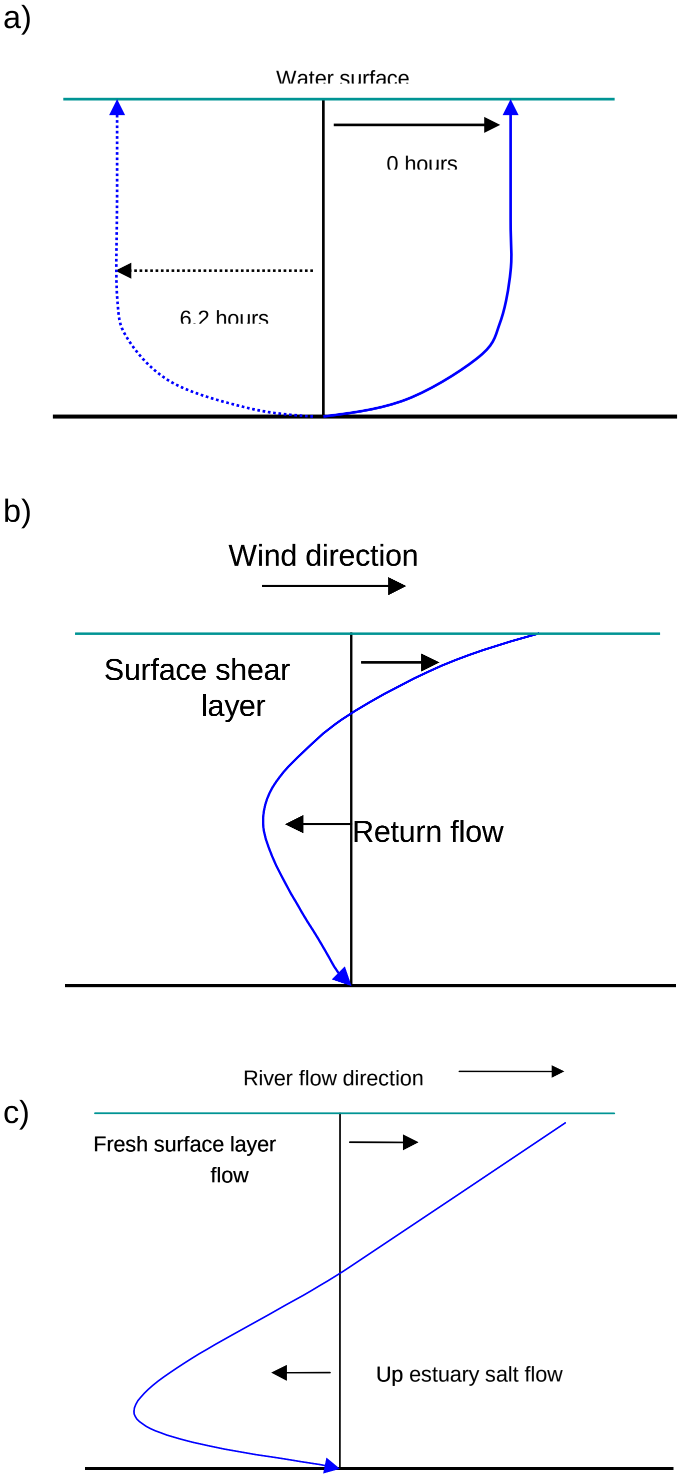

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

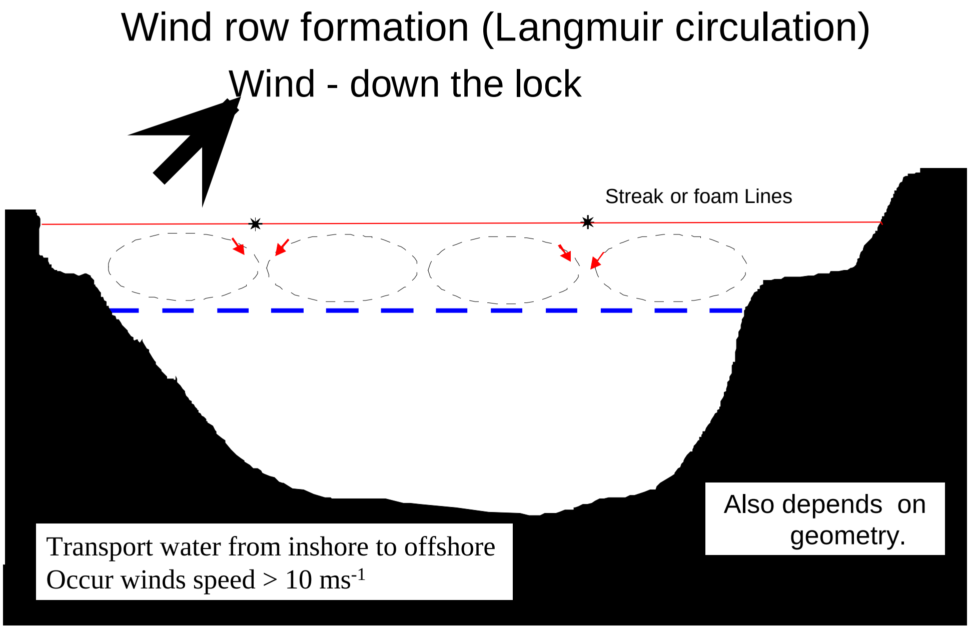

Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

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:	Loch Harport Inner
Site name:	Carbost (SL 159 286 13)
Species:	Pacific oysters *Crassostrea gigas*
Harvester:	Paul McGlynn
Local Authority:	The HighlandsCouncil - Skye & Lochalsh
Status:	Existing
Date Surveyed:	Wednesday 8th – Thursday 9th September 2010
Surveyed by:	Ron Lee, Allan MacDonald. We are grateful to Mr McGlynn and Mr Bain for providing access to the oyster trestles and for providing local information.
Existing RMP:	NG 392 314

Weather observations
Wednesday 8th September a.m. – Cloudy with sunny spells. Temperature 17.7°C. Wind SE average 5.9 knots, gusts to 12.9 knots. Weather sunny at end of survey. Light rain overnight on the Wednesday.
Thursday 9th September a.m. – Generally overcast but with breaks in cloud. Temperature 16.4°C. Wind southerly 7.8 knots. Weather sunny at end of survey.

Site Observations

Fishery
The location of the oyster trestles are mapped in Figure 1 (and shown in more detail in Figure 3). The corners of the trestles were recorded using a hand-held GPS receiver, and the waypoints mapped to produce the trestle areas.

The fishery at Loch Harport Inner has been established for many years and consists of several blocks of trestles in 3 main areas in the intertidal area towards the head of the loch (Figure 20). One is located relatively high up the foreshore and can be accessed at tide heights under which the other blocks are still submerged. The other two areas are located further towards the centre of the loch.

Sewage/Faecal Sources
The main area of housing, including the village of Carbost, is located on the south side of the loch. There are also some farms and dwellings around the head of the loch. There is a Scottish Water Community Tank system at Carbost to which many of the houses are connected (Figure 12). This discharges to the centre of the loch and therefore the effluent could not be sampled. A probable septic tank outlet was identified near the distillery – the sewage was flowing outside the pipe (see Figure 11). The bacteriological result for the sample taken from the discharge was >100,000 *E. coli* cfu/100 ml, confirming the septic nature of the content. Some other potential septic tank outlets were identified on the southern shore of the loch. Some of these

were not flowing at the time of the survey. Others ended under water and it was not possible to determine whether they were flowing. There were no observed dwellings on the north side of the loch west of the intertidal area. No attempt was made to observe and record the many permitted private septic tanks that SEPA had identified discharge to land or soakaway away from the shoreline. It was assumed that any that the impact of any of these that might be malfunctioning would be detected in the river, stream and seawater samples that were taken during the survey.

On the first day of the survey, a boil was seen rising from the seabed near the shore in front of the Scottish Water septic tank, in line with the outfall marker buoy. However, this was not seen the following day. Local information identified that this was due to discharge of waste liquid from the distillery and was not sewage. A seawater sample taken in the area of the boil on the second day of the survey (when the boil was not evident) returned a result of 30 *E. coli* cfu/100 ml, indicating that there was no significant contamination in the area at the time of sampling.

Seasonal Population
Human population around Loch Harport is concentrated on the southern side of the loch. There is an inn with bunkhouses in Carbost. A possible holiday cottage was seen on the northern shore at the head of the loch. These locations are likely to be mostly occupied during the summer period. The Tallisker distillery is reported to receive in excess of 50,000 visitors a year. These will mainly be concentrated during the summer months.

Boats/Shipping
There were small numbers of moored boats on the southern side of the surveyed area of the loch. Only two of these were of a size that they might be used for overnight stays. There were also a number of unoccupied moorings in the same area.

Land Use
The land around the upper loch is generally rough grass and fern on the hills with wooded areas nearer the shore. There are also areas of improved grassland. The hills on the northern side of the loch have few fences while parts of the southern side are divided into crofts.

Animals
Sheep and cattle occur at several locations above the shoreline of the loch, apart from the more densely developed area around Carbost. Around most of the area the animals were behind fences. However, sheep were observed at the north side of the intertidal area at the head of the loch. Local information identified that grazing across the intertidal area occurs at low tide during much of winter. Few birds and no wild animals were seen during the survey.

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.

Dimensions and flows of watercourses are estimated at the most convenient point of access and not necessarily at the point at which the watercourses enter the main body of the loch.

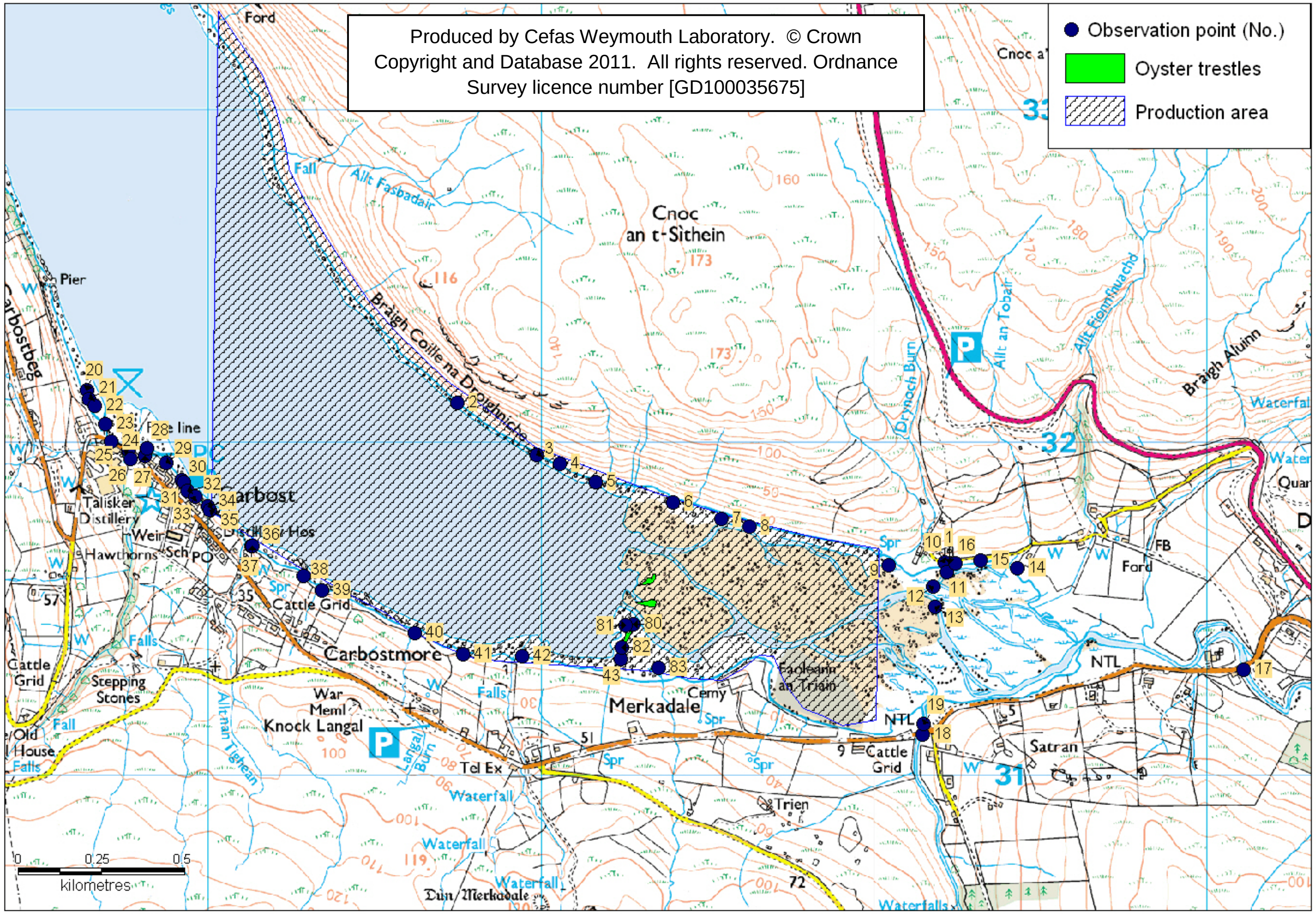

Figure 1. Map of Shoreline Observations

Table 1 Shoreline Observations

No.	Date	Time (BST)	Position	Easting	Northing	Associated photograph	Associated sample	Description
1	08/09/2010	10:22	NG 40223 31636	140223	831636			Start of outer leg; survey conducted on return leg
2	08/09/2010	11:01	NG 38744 32117	138744	832117		LH/SW/01	Under Uchd Mor; land cover rocks and gorse; 5 sheep; sheep droppings on path; no boats on north side of loch
3	08/09/2010	11:22	NG 38982 31960	138982	831960			Land seepage
4	08/09/2010	11:26	NG 39054 31934	139054	831934			Land seepage
5	08/09/2010	11:30	NG 39161 31880	139161	831880			Mussel and cockle shells from here to origin
6	08/09/2010	11:41	NG 39392 31819	139392	831819	Figure 4		About 6 sheep on hillside; shore mussels on rocks; trestles opposite
7	08/09/2010	11:46	NG 39538 31771	139538	831771			Bag of winkles on shore; Land cover: scrub above foreshore, fern on hill
8	08/09/2010	11:49	NG 39621 31747	139621	831747			9 cows behind fence (approx 20 m from foreshore)
9	08/09/2010	12:00	NG 40042 31629	140042	831629	Figure5	LH/FW/01	Small stream: width 1.3 m, depth 0.1 m, flow 0.022 m/s; approx 40 sheep behind fence about 20 m from foreshore; fertile green land and farmyard buildings
10	08/09/2010	12:29	NG 40210 31640	140210	831640			Septic tank (seeping?) by ?holiday cottage
11	08/09/2010	12:30	NG 40215 31609	140215	831609	Figure 6		Broken pipe from septic tank - not flowing; 9 sheep on shore; approx 5 sheep and 7 cows above; 15 cows in distance to east; approx 50 sheep on hill to west
12	08/09/2010	12:38	NG 40175 31565	140175	831565		LH/FW/02	Stream: width 1.5 m, depth 0.09 m, flow 0.303 m/s
13	08/09/2010	12:45	NG 40181 31505	140181	831505	Figure 7	LH/FW/03	River: width 6.9 m; depth 0.18 m flow 0.065 m/s; depth 0.18 m flow 0.278 m/s; depth 0.16 m flow 0.165 m/s
14	08/09/2010	13:00	NG 40428 31621	140428	831621			Dwelling above shoreline; no septic tank visible
15	08/09/2010	13:04	NG 40316 31644	140316	831644			Land drain; not flowing

No.	Date	Time (BST)	Position	Easting	Northing	Associated photograph	Associated sample	Description
16	08/09/2010	13:06	NG 40242 31635	140242	831635			Land drain; not flowing
17	08/09/2010	13:22	NG 41107 31317	141107	831317	Figure 8	LH/FW/04	River Drynoch; width 2.8 m; depth 0.18 m flow 0.400 m/s; depth 0.15 m flow 0.281 m/s
18	09/09/2010	09:25	NG 40142 31122	140142	831122			River by road bridge
19	09/09/2010	09:31	NG 40145 31154	140145	831154	Figure 9	LH/FW/05	Vikisgill Burn downstream from bridge; width 4.5 m; depth 0.09 m flow 0.170 m/s; depth 0.17 m flow 0.092 m/s; depth 0.13 m flow 0.097 m/s
20	09/09/2010	09:53	NG 37632 32155	137632	832155			Slipway; trees and fern above shore; 36 sheep behind fence; 7 small boats and dinghies; 86° to outfall buoy
21	09/09/2010	09:59	NG 37639 32131	137639	832131			Land seepage with bright green algae
22	09/09/2010	10:01	NG 37656 32109	137656	832109			? Stream running from under sea defence: no sign of stream by road
23	09/09/2010	10:07	NG 37687 32054	137687	832054		LH/SW/02	Seawater sample opposite outfall marker buoy
24	09/09/2010	10:12	NG 37705 32003	137705	832003	Figure 10	LH/FW/06	Under road culvert: flow 1.7l/2sec
25	09/09/2010	10:19	NG 37757 31976	137757	831976	Figure 11	LH/FW/07	Possible flow from septic tank; 10" pipe with liquid flowing round it; several surface water pipes (not flowing) between points 24 and 25
26	09/09/2010	10:27	NG 37762 31950	137762	831950	Figure 12	LH/FW/08	Stream by distillery; width 0.43 m; depth 0.07 m; flow 0.202 m/s; several pipes (not flowing) protruding from distillery wall
27	09/09/2010	10:33	NG 37807 31957	137807	831957	Figures 13, 14		Scottish Water Septic Tank; 20° to outfall buoy
28	09/09/2010	10:37	NG 37812 31982	137812	831982	Figure 15	LH/SW/03	Approximate area of "boil" seen 08/09/10; not present at this time
29	09/09/2010	10:43	NG 37871 31938	137871	831938			21 cm outflow pipe; slight trickle only; not sampled; one yacht offshore
30	09/09/2010	10:45	NG 37918 31887	137918	831887			Concrete construction with manhole; no outlet seen

No.	Date	Time (BST)	Position	Easting	Northing	Associated photograph	Associated sample	Description
31	09/09/2010	10:47	NG 37923 31880	137923	831880			11 cm outflow pipe; no flow
32	09/09/2010	10:49	NG 37935 31853	137935	831853			24 cm clay outflow pipe below bunkhouses; no flow
33	09/09/2010	10:51	NG 37957 31835	137957	831835			8" metal outflow pipe; end went under water
34	09/09/2010	10:54	NG 37995 31807	137995	831807	Figure 16		14 cm plastic pipe joining metal outflow pipe; end went under water
35	09/09/2010	10:57	NG 38003 31795	138003	831795	Figure 17		15 cm plastic outflow pipe; not flowing
36	09/09/2010	11:06	NG 38127 31687	138127	831687		LH/FW/09	Small stream; width 0.32 m; depth 0.09 cm; flow 0.055 m/s; tress/bracken above foreshore
37	09/09/2010	11:07	NG 38129 31689	138129	831689			1 yacht offshore; 4 cormorants on mooring
38	09/09/2010	11:17	NG 38284 31598	138284	831598	Figure 18		Heavily ferned croftland; 3 sheep fenced off from shore (but gate in fence); seagull nearby
39	09/09/2010	11:22	NG 38339 31554	138339	831554		LH/FW/10	Land seepage from croft; flow too small to measure; heron nearby
40	09/09/2010	11:36	NG 38617 31426	138617	831426		LH/FW/11	Small stream from croft: too small to measure
41	09/09/2010	12:02	NG 38764 31363	138764	831363		LH/FW/13	Small stream from croft; too small to measure; mussels along shore; fence above shoreline
42	09/09/2010	12:09	NG 38939 31356	138939	831356	Figure 19	LH/FW/14	Stream from croft: width 0.30 m; depth 0.21 m; flow 0.184 m/s; 3 cows in field to right of stream
43	09/09/2010	12:19	NG 39236 31349	139236	831349	Figure 20	LH/SW/04	Seawater sample south of trestles
44	09/09/2010	12:25	NG 39237 31379	139237	831379			Corner of trestle block
45	09/09/2010	12:26	NG 39255 31430	139255	831430			Corner of trestle block
46	09/09/2010	12:26	NG 39260 31428	139260	831428			Corner of trestle block
47	09/09/2010	12:26	NG 39271 31435	139271	831435			Corner of trestle block
48	09/09/2010	12:26	NG 39267 31436	139267	831436			Corner of trestle block

No.	Date	Time (BST)	Position	Easting	Northing	Associated photograph	Associated sample	Description
49	09/09/2010	12:27	NG 39276 31465	139276	831465			Corner of trestle block
50	09/09/2010	12:27	NG 39280 31464	139280	831464			Corner of trestle block
51	09/09/2010	12:27	NG 39273 31467	139273	831467			Corner of trestle block
52	09/09/2010	12:27	NG 39263 31444	139263	831444			Corner of trestle block
53	09/09/2010	12:28	NG 39259 31445	139259	831445			Corner of trestle block
54	09/09/2010	12:28	NG 39267 31469	139267	831469			Corner of trestle block
55	09/09/2010	12:28	NG 39263 31468	139263	831468			Corner of trestle block
56	09/09/2010	12:28	NG 39254 31447	139254	831447			Corner of trestle block
57	09/09/2010	12:28	NG 39249 31448	139249	831448			Corner of trestle block
58	09/09/2010	12:29	NG 39256 31468	139256	831468			Corner of trestle block
59	09/09/2010	12:36	NG 39278 31521	139278	831521			Corner of trestle block
60	09/09/2010	12:37	NG 39285 31570	139285	831570		LH/SW/05	Corner of trestle block; Seawater sample at trestles
61	09/09/2010	12:38	NG 39288 31571	139288	831571			Corner of trestle block
62	09/09/2010	12:39	NG 39303 31578	139303	831578			Corner of trestle block
63	09/09/2010	12:39	NG 39311 31584	139311	831584			Corner of trestle block
64	09/09/2010	12:39	NG 39314 31594	139314	831594			Corner of trestle block
65	09/09/2010	12:39	NG 39323 31591	139323	831591			Corner of trestle block
66	09/09/2010	12:39	NG 39329 31590	139329	831590			Corner of trestle block
67	09/09/2010	12:39	NG 39332 31604	139332	831604			Corner of trestle block
68	09/09/2010	12:40	NG 39342 31604	139342	831604			Corner of trestle block

No.	Date	Time (BST)	Position	Easting	Northing	Associated photograph	Associated sample	Description
69	09/09/2010	12:40	NG 39341 31590	139341	831590			Corner of trestle block
70	09/09/2010	12:40	NG 39337 31588	139337	831588			Corner of trestle block
71	09/09/2010	12:40	NG 39333 31578	139333	831578			Corner of trestle block
72	09/09/2010	12:40	NG 39323 31575	139323	831575			Corner of trestle block
73	09/09/2010	12:41	NG 39325 31530	139325	831530			Corner of trestle block
74	09/09/2010	12:41	NG 39325 31525	139325	831525			Corner of trestle block
75	09/09/2010	12:41	NG 39343 31522	139343	831522			Corner of trestle block
76	09/09/2010	12:41	NG 39342 31505	139342	831505			Corner of trestle block
77	09/09/2010	12:42	NG 39323 31505	139323	831505			Corner of trestle block
78	09/09/2010	12:42	NG 39296 31519	139296	831519			Corner of trestle block
79	09/09/2010	12:42	NG 39288 31516	139288	831516			Corner of trestle block
80	09/09/2010	13:11	NG 39275 31452	139275	831452		LH/SF/01	Shellfish sample x 2; one for norovirus
81	09/09/2010	13:13	NG 39252 31450	139252	831450		LH/SF/02	Shellfish sample; new stock
82	09/09/2010	13:14	NG 39239 31384	139239	831384		LH/SF/03	Shellfish sample; mature stock
83	09/09/2010	13:22	NG 39350 31322	139350	831322		LH/FW/15	Small stream; width 0.60 m; depth 0.04 m; flow 0.118 m/s

Photographs referenced in the table can be found attached as Figures 4-20.

Sampling
Water and shellfish samples were collected at sites marked on the maps shown in Figures 2 and 3. The bacteriology results are given in Tables 2 and 3.

Samples of seawater were tested for salinity by the laboratory using a salinity meter under controlled conditions. These results are shown in Table 2, given in units of grams salt per litre of water. Note that this is equivalent to ppt.

Table 2 Water Sample Results

No.	Sample	Date	Sample Type	Grid Reference	*E. coli* (cfu/100ml)	Salinity (g/L)
1	LH/FW/01	08/09/2010	Freshwater	NG 4004 3163	2100	
2	LH/FW/02	08/09/2010	Freshwater	NG 4016 3157	240	
3	LH/FW/03	08/09/2010	Freshwater	NG 4018 3151	60	
4	LH/FW/04	08/09/2010	Freshwater	NG 4111 3132	50	
5	LH/FW/05	09/09/2010	Freshwater	NG 4015 3115	60	
6	LH/FW/06	09/09/2010	Freshwater	NG 3771 3200	50	
7	LH/FW/07	09/09/2010	Freshwater	NG 3776 3198	>100000	
8	LH/FW/08	09/09/2010	Freshwater	NG 3776 3195	120	
9	LH/FW/09	09/09/2010	Freshwater	NG 3813 3169	60	
10	LH/FW/10	09/09/2010	Freshwater	NG 3834 3155	570	
11	LH/FW/11	09/09/2010	Freshwater	NG 3862 3143	20	
12	LH/FW/13	09/09/2010	Freshwater	NG 3876 3136	10	
13	LH/FW/14	09/09/2010	Freshwater	NG 3894 3136	80	
14	LH/FW/15	09/09/2010	Freshwater	NG 3935 3132	2300	
15	LH/SW/01	08/09/2010	Seawater	NG 3874 3212	70	36.3
16	LH/SW/02	09/09/2010	Seawater	NG 3769 3205	30	35.6
17	LH/SW/03	09/09/2010	Seawater	NG 3781 3198	30	36.2
18	LH/SW/04	09/09/2010	Seawater	NG 3924 3135	<10	35.8
19	LH/SW/05	09/09/2010	Seawater	NG 3929 3157	70	34.2

Table 3 Mussel Sample Results

No.	Sample	Date	Type	Grid Reference	*E. coli* (MPN/100g)	Depth
1	LH/SF/1	09/09/2010	Pacific oysters	NG 3928 3145	<20	From trestles
2	LH/SF/2	09/09/2010	Pacific oysters	NG 3925 3145	50	From trestles
3	LH/SF/3	09/09/2010	Pacific oysters	NG 3924 3138	<20	From trestles

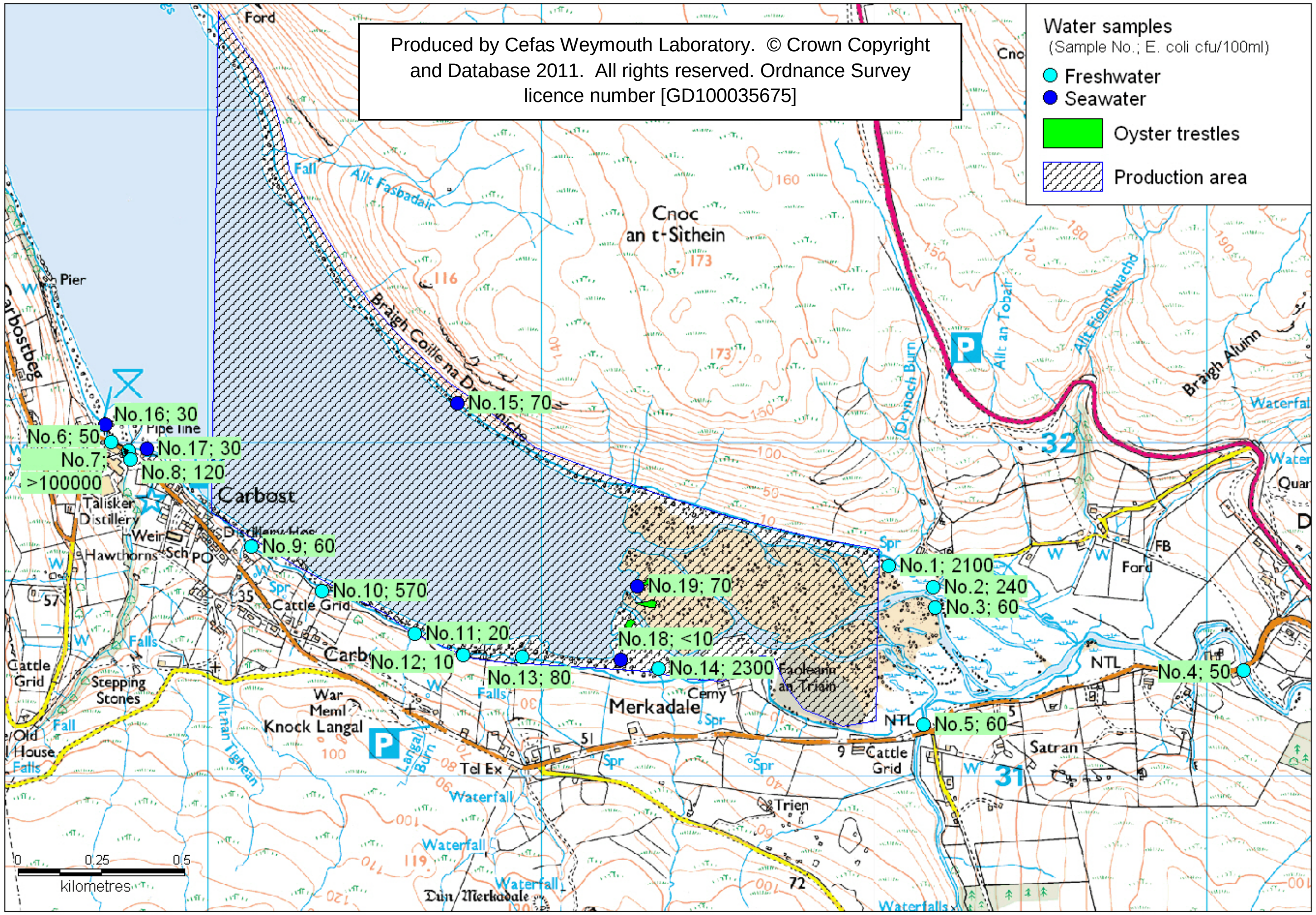

Figure 2. Water sample results map

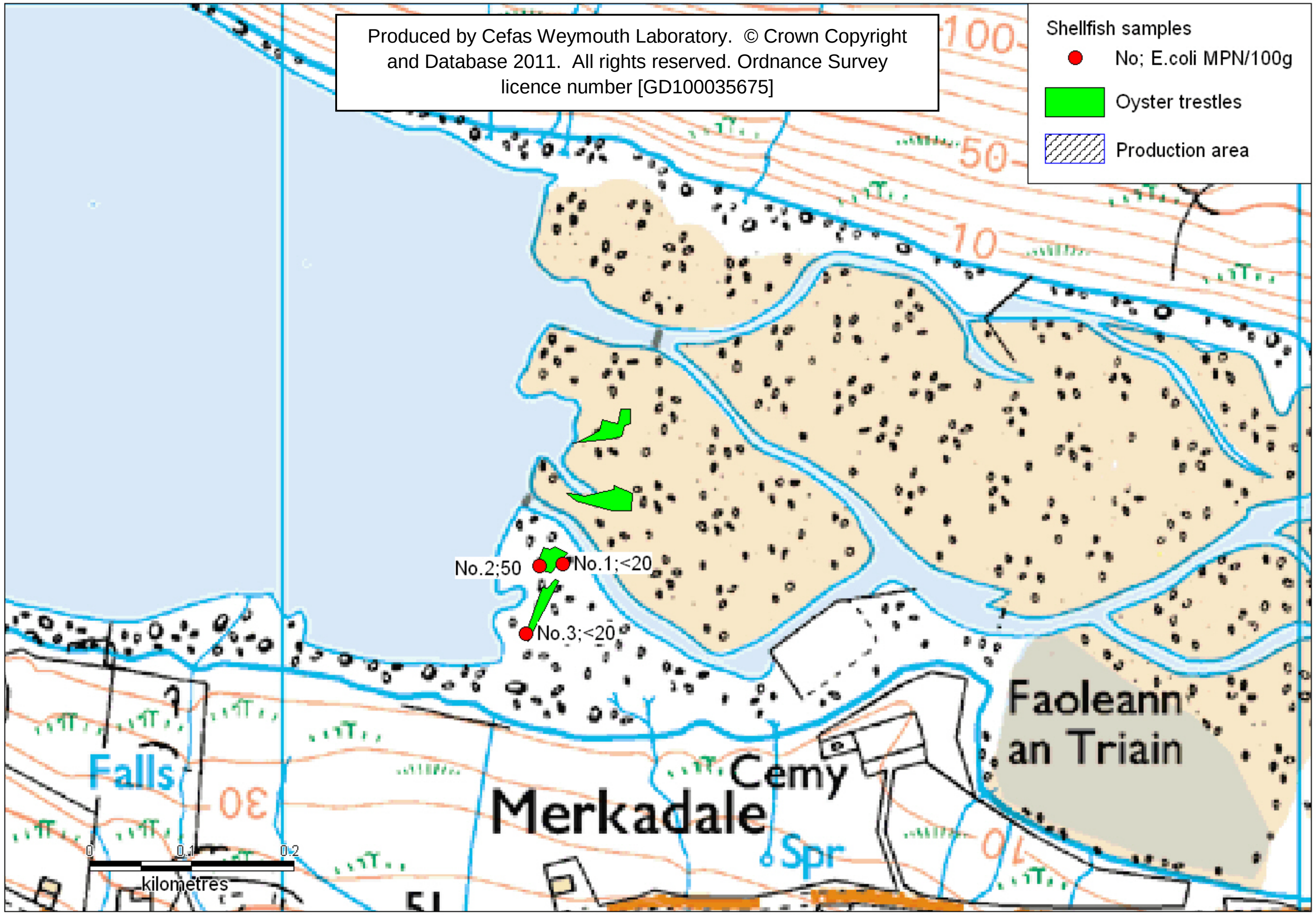

Figure 3. Shellfish sample results map

Photographs

Figure 4. View from northern shore looking towards the oyster trestles

Figure 5. Farmed area on the northern side at the head of the loch

Figure 6. Broken septic tank outlet pipe

Figure 7 River at the intertidal area


Figure 8. River Drynoch looking upstream from road bridge


Figure 9. Vikisgill Burn

Figure 10. Culvert under road

Figure 11. Probable septic tank outlet

Figure 12. Stream by Tallisker distillery

Figure 13. Scottish Water Community Septic Tank at Carbost

Figure 14. Distillery discharge marker buoy

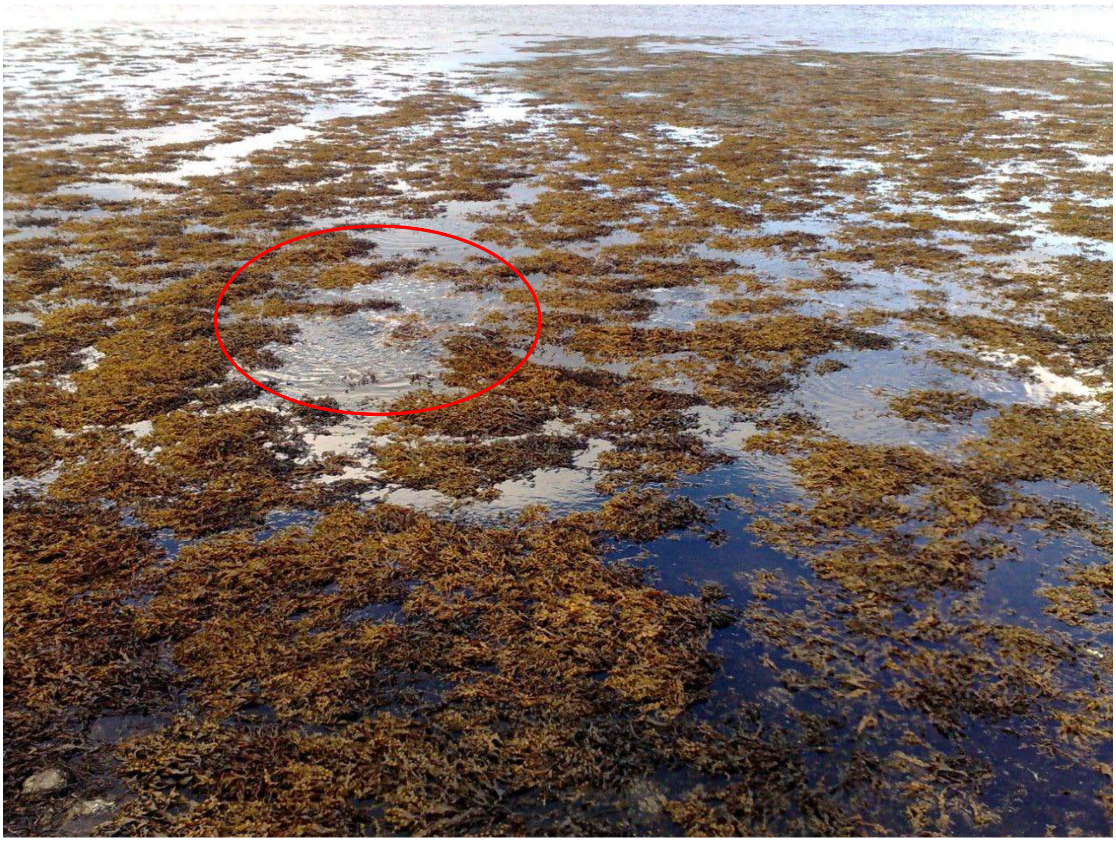

Figure 15. Location of “boil” seen offshore of community septic tank

Figure 16. Probable septic tank outlet

Figure 17. Probable septic tank outlet

Figure 18. One of a series of crofts on the southern shore

Figure 19. Small stream from croftland south-west of oyster trestles

Figure 20. Oyster trestles viewed from the southern shore

Norovirus Testing Summary

Loch Harport: Inner

Oyster samples taken from the oyster trestles at Loch Harport were submitted for Norovirus analysis quarterly from August 2010. No grid reference was supplied with the second sample, however it is presumed to have come from the near vicinity of the first sample. A third sample was obtained in early June 2011, the results of which were not yet available at the time of reporting. Results available to date are summarised in the table below.

Ref No.	Date	NGR	GI	GII
10/400	09/09/2010	NG 3928 3145	not detected	positive
11/016	10/01/2011	n/k	not detected	positive