Scottish Sanitary Survey Project

Sanitary Survey Report
Loch Leurbost and Loch Leurbost: Crosbost
LH 168, LH 339
March 2011

Report Distribution – Loch Leurbost and Loch Leurbost: Crosbost

Date	Name	Agency*
	Linda Galbraith	Scottish Government
	Mike Watson	Scottish Government
	Morag MacKenzie	SEPA
	Douglas Sinclair	SEPA
	Judy Dobson	SEPA
	Fiona Garner	Scottish Water
	Alex Adrian	Crown Estate
	Colm Fraser	Comhairle nan Eilean Siar
	Paul Tyler	Comhairle nan Eilean Siar
	Ian Campbell	Harvester
	Calum Iain	Harvester
	Malcolm MacDonald	Harvester
	Kenneth Macleod	Harvester
	Michael Macleod	Harvester

* 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 Leurbost is situated on the east coast of the Isle of Lewis in the Outer Hebrides. It is approximately 4 km long and 0.5 km wide and oriented along a southeast to northwest axis. A series of small islands are situated across the mouth of the loch, where it opens into Loch Erisort. The land around the loch is mainly low-lying and pockmarked with small freshwater lochans, a number of which flow into the loch. Figure 1.1 shows the location of Loch Leurbost

Figure 1.1 Location of Loch Leurbost survey area

2. Fishery

The sanitary survey was undertaken as a result of the ranking the area received on a risk matrix. The high ranking was primarily caused by the number of unusual results (i.e. results outwith classification) and the species involved (Pacific oysters) in the Loch Leurbost: Crosbost production area.

Table 2.1 Loch Leurbost shellfish farms

Production Area	Site	SIN	Species	RMP
Loch Leurbost: Crosbost	Site 1 Crosbost	LH 339 795 13	Pacific oyster	NB 394 242
	Site 2 Crosbost	LH 339 721 13	Pacific oyster	
Loch Leurbost	Creag an Rainich	LH 168 113 08	Common mussel	NB 378 248
	Loch Leurbost	LH 168 114 08	Common mussel	
	Creag an Mhiabhaig	LH 168 732 08	Common mussel	

Loch Leurbost: Crosbost
The Loch Leurbost: Crosbost production area is defined as an area bounded by lines drawn between NB 3800 2476 to NB 3800 2404 and between NB 3939 2368 and NB 4000 2410. The nominal RMP is NB 394 242, which is located on the east side of the point at Aird Feiltinis.

At the time of shoreline survey, the fishery consisted of an single row of trestles on the intertidal shore to the west of Aird Feiltinis and east of the Crosbost jetty. The harvester advised that a single trestle lay to the east of the point, though it was not possible to get to this trestle during the survey. The trestles are only accessible at low spring tides of 1.3 m or less.

Although the nominal RMP was established to the east of the point, samples have normally been taken from the western end of the western set of trestles.

Harvest takes place year-round in accordance with demand.

Loch Leurbost
The Loch Leurbost production area is defined as the area bounded by lines drawn between NB 3700 2544 and NB 3700 2503 and between NB 3800 2476 and NB 3800 2404 extending to MHWS. The nominal RMP is NB 378 248, which plots on the MHWS line 50 m from the northeast corner of the fishery.

All of the mussel sites are long-line mussel farms, with droppers to between 5 and 7 meters depth. The Creag an Rainich site consisted of 5 sets of long lines that had been completely harvested prior to survey, so it was not possible to obtain samples from this site.

The Eilean Mhiabhaig site had 2 long lines at the western end and a series of old salmon cage rafts fitted with droppers at the eastern end of the site. The harvester planned to phase out use of the rafts as they had reached the end of their useful life. Additional rafts were anchored beyond the recorded area. These were reported by the harvester to be used only for storage of gear. Some of the lines were being harvested at the time of survey, and the harvester reports the farm is normally harvested in rotation with some lines harvested each year.

The Leurbost site consisted of 5 sets of long lines near the north shore of the loch, with some of the lines too heavy to raise and some of the floats nearly sinking. One of the lines was set well away from the others and was nearly in the centre of the loch.

The harvesters generally collect spat from two sets of spat collection lines set in Loch Erisort, where there is reported to be better settlement. These are considered further in the Loch Erisort sanitary survey report.

Monitoring samples for mussels are taken from variable locations and not specifically from the RMP. Sometimes they are taken from the Leurbost site, but often from Creag an Rainich. It varies according to which harvester has provided transport out to the site and where stock is available.

All of the Loch Leurbost production area and the outer part of the Crosbost production area are located within designated Shellfish Growing Waters. See section 12 for more details on these designations.

Figure 2.1 shows the location of the recorded shellfish farms, production area boundaries, RMPs and seabed (Crown Estate) lease areas in Loch Leurbost.

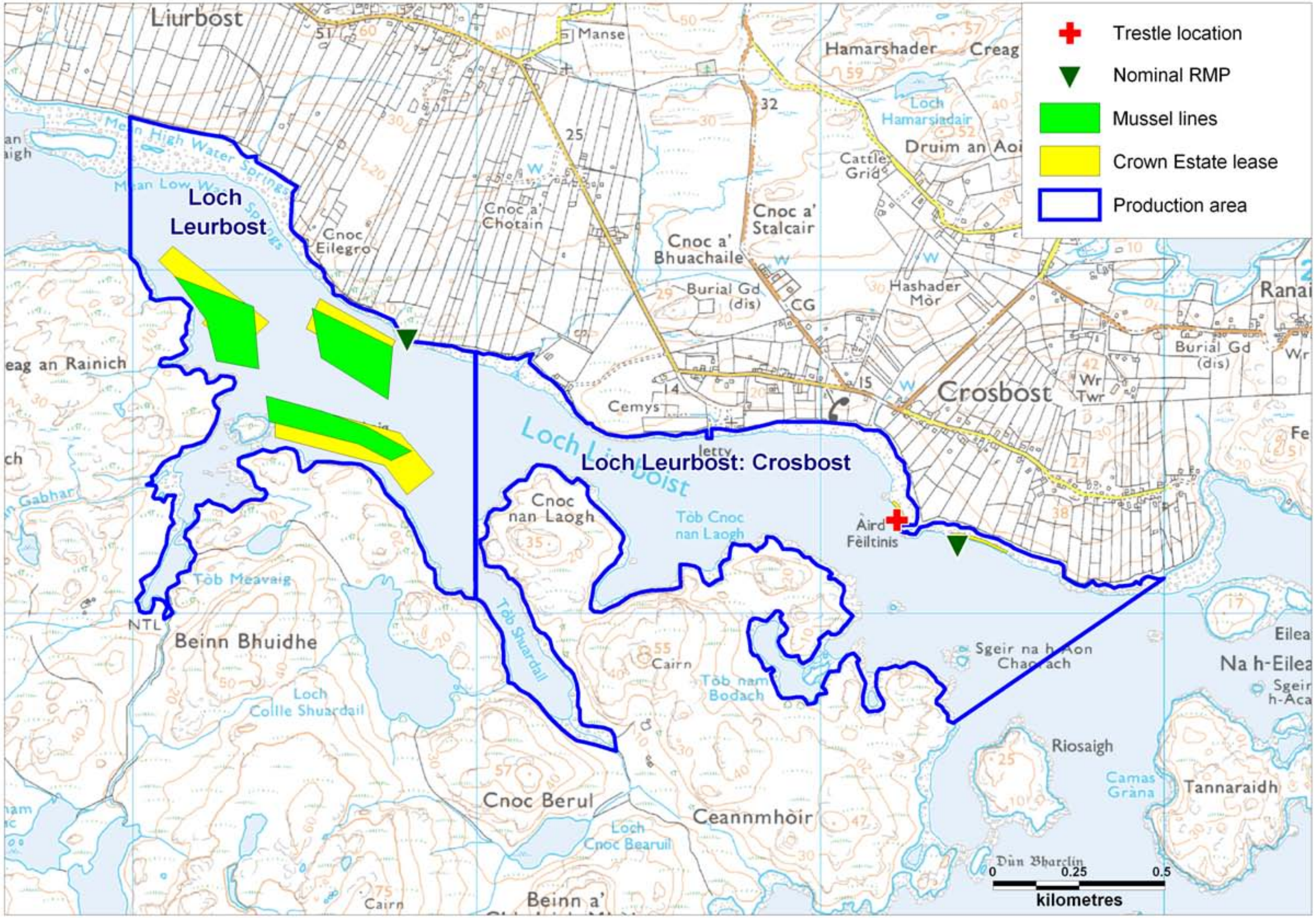
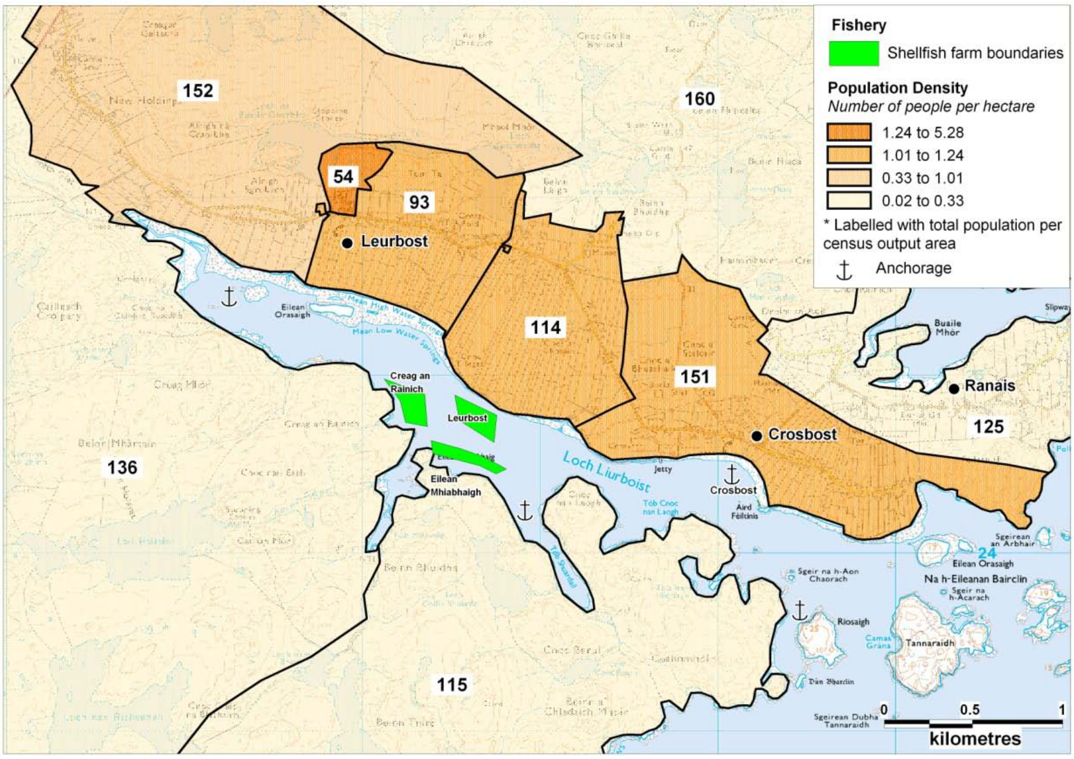


Figure 2.1 Loch Leurbost: Crosbost and Loch Leurbost shellfisheries

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 the Loch Leurbost fisheries. The last census was undertaken in 2001.



2001 Population Census Data, General Register Office, Scotland.

Figure 3.1 Human population surrounding Loch Leurbost

Figure 3.1 shows the population density for the census output areas surrounding Loch Leurbost. The settlements of Leurbost (Liurbost), Crosbost and Ranais are situated along the road on the north side of the loch. The exact population of each settlement is not known, however the total populations for each census output is available and shown in Figure 3.1. There is at least 1 B&B and 5 self catering apartments in the area. There are no specific tourist attractions in the area. The south shore is unpopulated and inaccessible by road.

Four anchorages were identified in the loch. These are likely to be used by visiting yachts, primarily in summer, and by local fishing boats year-round. One lies near the oyster farm at Crosbost and a second lies south-southeast of the Eilean Mhiabhaig mussel site. Yachts discharging overboard in these areas may contribute to faecal contamination levels observed at these sites. The other two anchorages are sufficiently distant from the shellfish farms that they are unlikely to pose a direct contamination risk. The resident population along the north shore of the loch is likely to generate sufficent sewage waste to affect water quality at the fishery.

4. Sewage Discharges

Scottish Water identified the community septic tanks and sewage discharges listed in Table 4.1.

Table 4.1 Discharges identified by Scottish Water

Consent Ref No.	NGR of discharge	Discharge Name	Discharge Type	Level of Treatment	Consented flow m^3/day	Consented Design PE
CAR/L/1001879	NB 3823 2460	Leurbost East ST, CSO/EO	Intermittent	Screened	404	350
CAR/L/1001870	NB 3642 2538	Leurbost West ST, CSO/EO	Intermittent	Screened	397	350
CAR/L/1002871	NB 3920 2450	Crossbost ST, CSO/EO	Intermittent	Screened	111.5	100
CAR/L/1001879	NB 3852 2284	Leurbost East	Combined effluent	Septic tank	912.5	800

Improvement works at Loch Leurbost were completed by Scottish Water in 2009. New septic tanks were installed at Leurbost East and Leurbost West, and a storm tank was installed for storage of effluent prior to overflow. Effluent from these two tanks plus Crossbost West are now pumped to a station near the jetty. Final effluent is then pumped to a discharge location south of the headland at Ceannmhoir in Loch Erisort, southwest of Loch Leurbost. No sanitary or microbiological data were made available for this discharge. The final effluent discharge location was observed during the shoreline survey for Loch Erisort and further information can be found in that report. The CSO and treated EO discharges have been retained as identified in the table above.

Information on consented discharges to Loch Leurbost was sought from the Scottish Environment Protection Agency (SEPA). A large number of discharge consents were identified for the area around Loch Leurbost. Many of these related to discharges to the waters of, or land adjacent to, Loch Griomsiadair (Grimshader) and are not considered in this report. Consents pertaining to the areas nearest the shore of Loch Leurbost, and therefore of greater relevance to the fishery, are listed in Table 4.2.

Three of the discharge consents listed in Table 4.2 have been ascribed multiple locations (NGR). All are related to Scottish Water septic tanks. It is not clear whether these separate locations pertain to inspection ports and other infrastructure or whether they refer to redundant discharges. Item 4 relates to the final effluent discharge point in Loch Erisort. It is not clear where the overflow for the storm tank is located. It is presumed that each ST has a separate EO, though it is not clear whether these are still at the original locations or whether they were moved during the upgrade.

The two remaining consents are for individual dwellings not connected to the mains sewerage system.

Table 4.2 Discharge consents identified by SEPA

No.	Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consented/ design PE	Discharges to
1A	CAR/L/1001870	NB 3619 2570	Continuous	Primary	77	350	Loch Leurbost
1B	CAR/L/1001870	NB 3622 2571	CSO				Loch Leurbost
1C	CAR/L/1001870	NB 3642 2538					Loch Leurbost
1D	CAR/L/1001870	NB 3652 2546	EO				Loch Leurbost
2A	CAR/L/1001879	NB 3823 2462	Continuous	Primary	55	350	Loch Leurbost
2B	CAR/L/1001879	NB 3825 2463					Loch Leurbost
2C	CAR/L/1001879	NB 3830 2470	CSO				Loch Leurbost
3A	CAR/L/1002871	NB 3917 2451	Continuous	Septic tank	111.5	10	Loch Leurbost
3B	CAR/L/1002871 & WPC/N/62415	NB 3920 2450			22	100	Loch Leurbost
3C	CAR/L/1002871	NB 3921 2448					Loch Leurbost
4	**CAR/L/1001879**	**NB 3844 2295**	**Combined effluent**	**Septic tank**	**912.5**	**800**	**Outer Loch Erisort**
5	CAR/R/1033957	NB 3710 2591	Continuous	Septic tank	-	5	Soakaway
6	CAR/R/1021958	NB 3990 2472	Continuous	Septic tank	-	5	Land

Sewage infrastructure and/or discharges recorded during the shoreline survey are listed in Table 4.3.

Table 4.3 Discharges and septic tanks observed during shoreline surveys

No.	Date	NGR	Description
1	21/09/2010	NB 39162 24551	WWTW Crosbost
2	23/09/2010	NB 36603 25565	Concreted and steel access cover on shoreline
3	23/09/2010	NB 36220 25676	Septic tank Leurbost West
4	23/09/2010	NB 40136 24418	Septic tank
5	23/09/2010	NB 38289 24651	WWTW Leurbost East

Four septic tanks were identified during the shoreline survey. Three of these were associated with the Scottish Water septic tanks listed in Tables 4.1 and 4.2. Number 3 was a new septic tank and what was most likely the storm storage tank (Appendix 8, Figures 11 & 12). The location corresponded roughly with items 1A and 1B in Table 4.1. An access cover was observed further east along the shoreline, in line with Items 1C and 1D in Table 4.1.

Item 4 was a Scottish Water septic tank found at the eastern end of Crosbost, at the head of an inlet approximately 1 km east of the oyster farm. No consent was identified for this discharge. It was found to be listed in the SEPA Shellfish Growing Water report for Outer Loch Leurbost (SEPA 2011) as Crossbost (East) Scottish Water Asset No. 2770, an unconsented discharge with a population equivalent (PE) of 80.

The removal of the final effluent discharges of the three main septic tanks from the loch is likely to have improved overall water quality at the fishery. The remaining continuous discharge at East Crosbost may have a negative impact on water quality at the oyster fishery.

Intermittent discharges related to storm overflows or emergency overflows at the pumping stations would markedly affect water quality in the loch during and immediately after the spill. This is likely to be of greatest concern at the

Crosbost oyster fishery, where the oyster trestles are located approximately 250 m east of the CSO. Intermitten discharges to the head of the loch would potentially impact water quality at the Creag an Rainich site most as it lies furthest up the loch of the three farms. Intermittent discharges from Leurbost East may affect the Luerbost and Eilean Mhiabhaigh mussel farms and the oyster farm at Crosbost, depending on the state of tide and duration of spill.

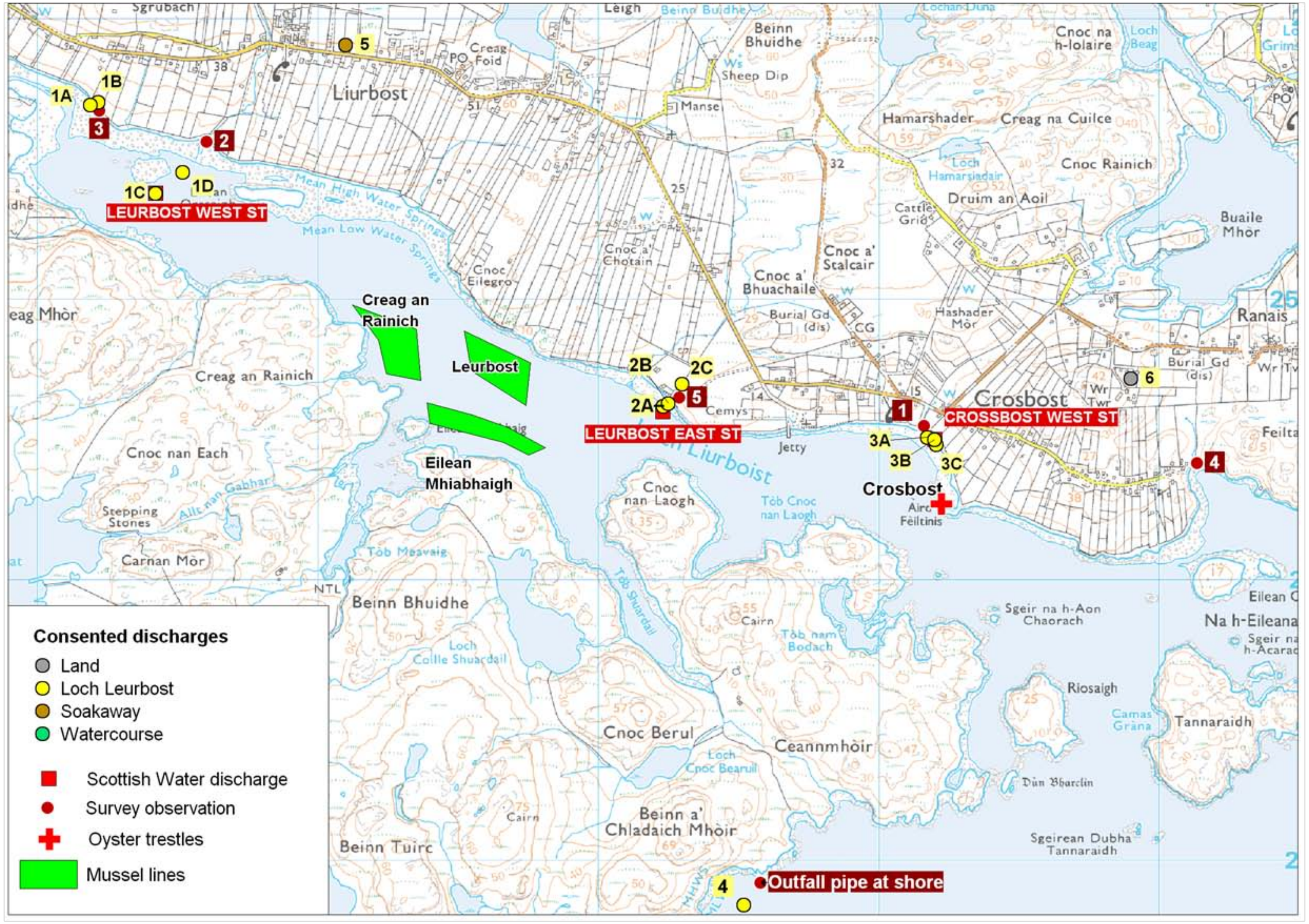


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Figure 4.1 Map of discharges for Loch Leurbost

5. Geology and Soils

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

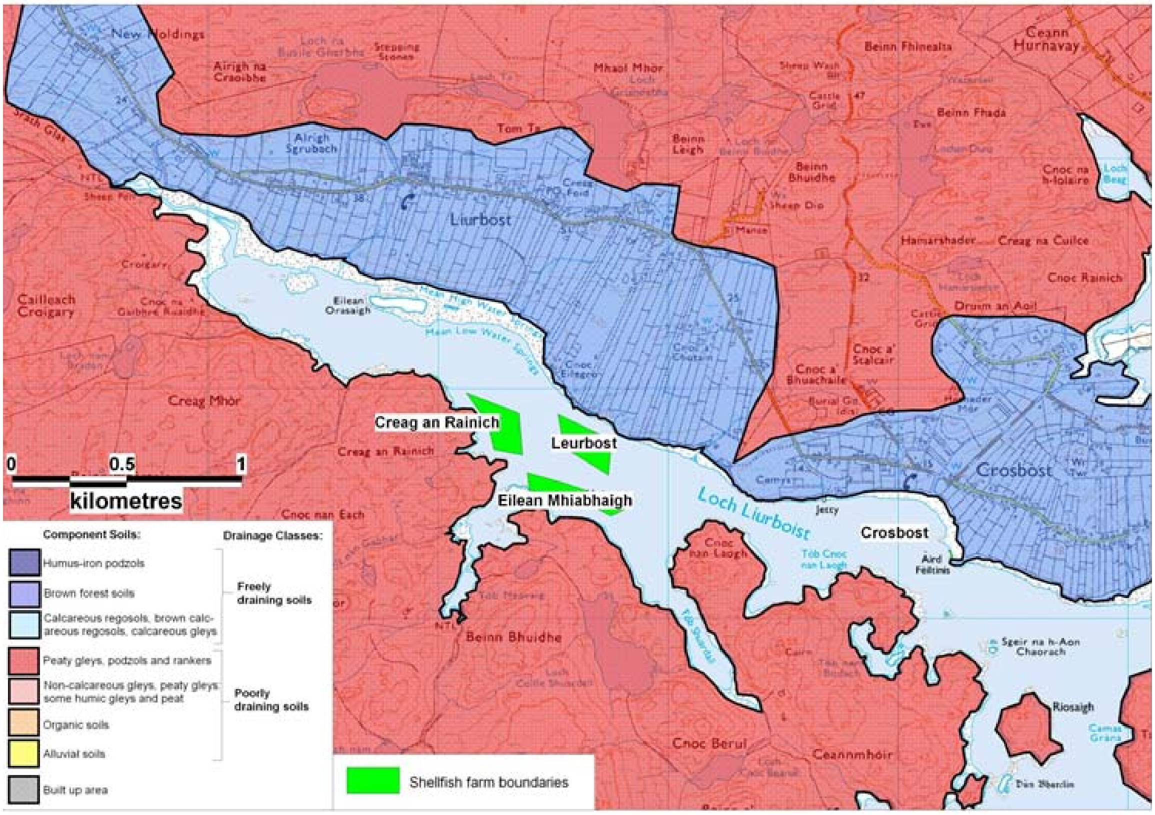

Figure 5.1 Component soils and drainage classes for Loch Leurbost

Two types of component soils are present in the area: peaty gleys, podzols and rankers and brown forest soils. The brown forest soils present along the northern shoreline of the loch and fishery are freely draining and the peaty gleys, podzols and rankers found inland to the north of the loch and along the southern coastline are poorly draining. The Abhainn Ghlas, which discharges to the head of the loch, flows through an area of poorly drained soils. Freshwater lochans are also found on poorly drained areas north of Leurbost and therefore streams draining to Loch Leurbost from these would carry runoff from more poorly drained areas.

The potential for diffuse contamination in runoff attributable to soil drainage is higher for the Abhainn Ghlas and the entire southern shoreline, as well as for areas east of the Leurbost site and near the head of the loch where streams originate within areas of more poorly drained soils north of Leurbost. This may impact the Creah an Rainich and Eilean Mhiabhaigh sites more than the other two sites.

6. Land Cover

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

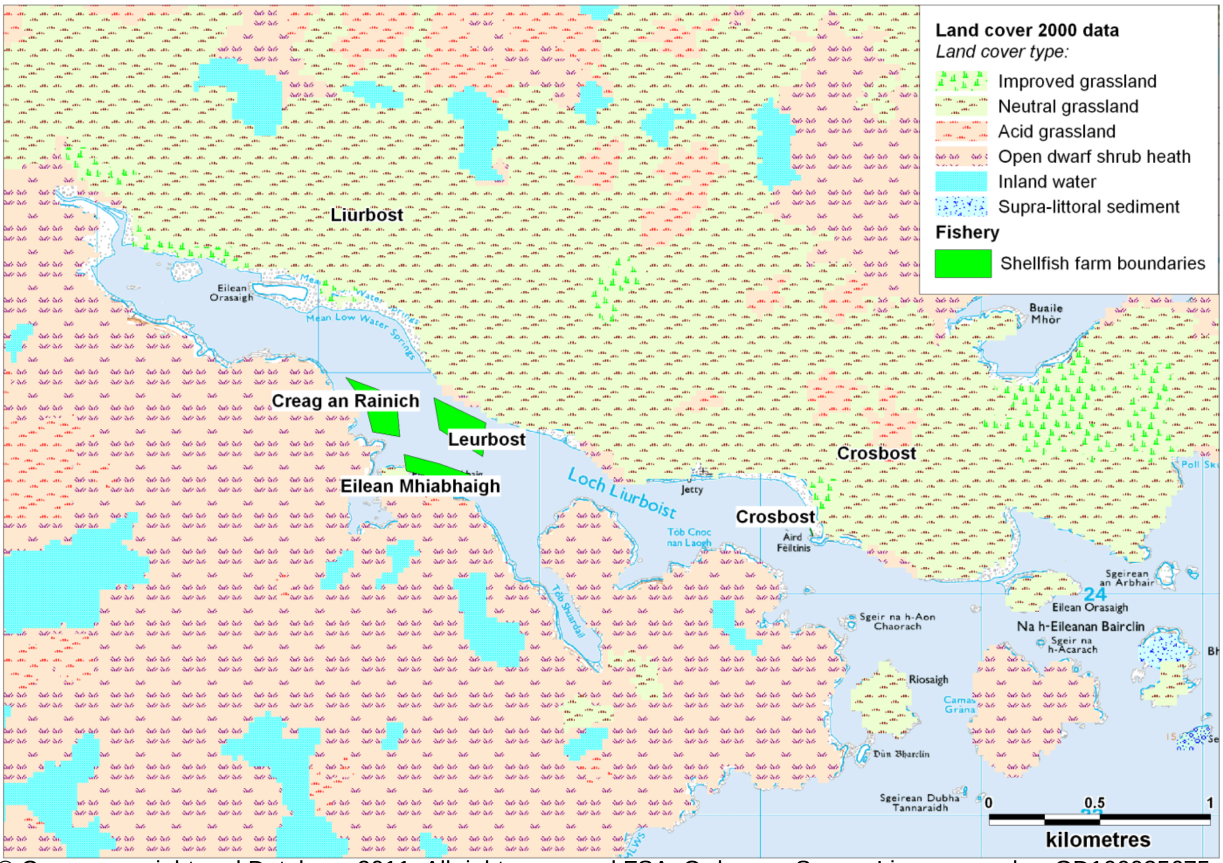

Figure 6.1 LCM2000 class land cover data for Loch Leurbost

Most of the landcover on the south shore is open heath with small areas of grassland. Landcover on the north shore of the loch is nearly all neutral grassland. Areas of improved grassland are found along the shoreline at the head of the loch and adjacent to the site at Crosbost. Most of the northern shore is lined with crofts, therefore much of the grassland on this shore is likely to be used for grazing. The north shore is served by roads and is moderately populated, though it has not been classed as developed there is likely to be increased runoff from areas of paving and hardstanding.

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 rainfall events, however this effect would be particularly marked from improved grassland areas (roughly 1000-fold) (Kay *et al*. 2008).

Although not identified specifically in the land cover data, the settlements at Luerbost and Crosbost would constitute developed areas though the extent of their coverage is very low relative to the undeveloped area around them. The expected contribution of faecal indicator bacteria attributable to land cover type would be highest along the north side of the loch around the settlements of Liurbost and Crosbost and the areas of improved grassland at the northern end of the loch and adjacent to the Crosbost fishery.

7. Farm Animals

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

Table 7.1 Livestock numbers in Lochs parish 2008 - 2009

	Lochs (488.8 km^2)			
	2008		2009	
	Holdings	Numbers	Holdings	Numbers
Pigs	*	*	*	*
Poultry	38	610	40	661
Cattle	41	334	41	316
Sheep	285	24,632	289	24,739
Horses and ponies	18	47	18	44

* Data withheld for reasons of confidentiality

Sheep are the predominant type of livestock kept in the parish, with relatively very small numbers of cattle and poultry also kept. While the numbers of sheep and poultry kept increased between 2008 and 2009, the numbers of cattle decreased. No information was provided on numbers of pigs in the parish due to the small number of farms reporting. The density of sheep is relatively low at 50.6/km^2, however the distribution of animals within the parish is ulikely to be even.

Information on the spatial distribution of animals on land adjacent to or near the fishery can provide an indication of the potential amount of organic pollution from livestock entering the shellfish production area. However, due to the large geographic area of the parish and the missing data, 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 21, 23 and 29 September 2010 and is dependent upon the viewpoint of the observer.

The locations of the livestock observed in the area nearest the mussel farms during the shoreline survey are illustrated in Figure 7.1.

During the shoreline survey, over 250 sheep, plus a small number of cattle and horses were observed on or near crofts along the north shore and at the head of the loch. Sheep were observed on the shoreline east of Crosbost, but for the most part were fenced away from the intertidal shore. Some of the crofted land was cropped, possibly with silage. The southern side of the loch was not specifically surveyed by foot. No concentrations of animals were seen on that shore during the boat work of the survey. The land on the southern side is principally shrub heath (see Section 6) and is likely to support lower numbers of sheep than the grassland on the northern side.

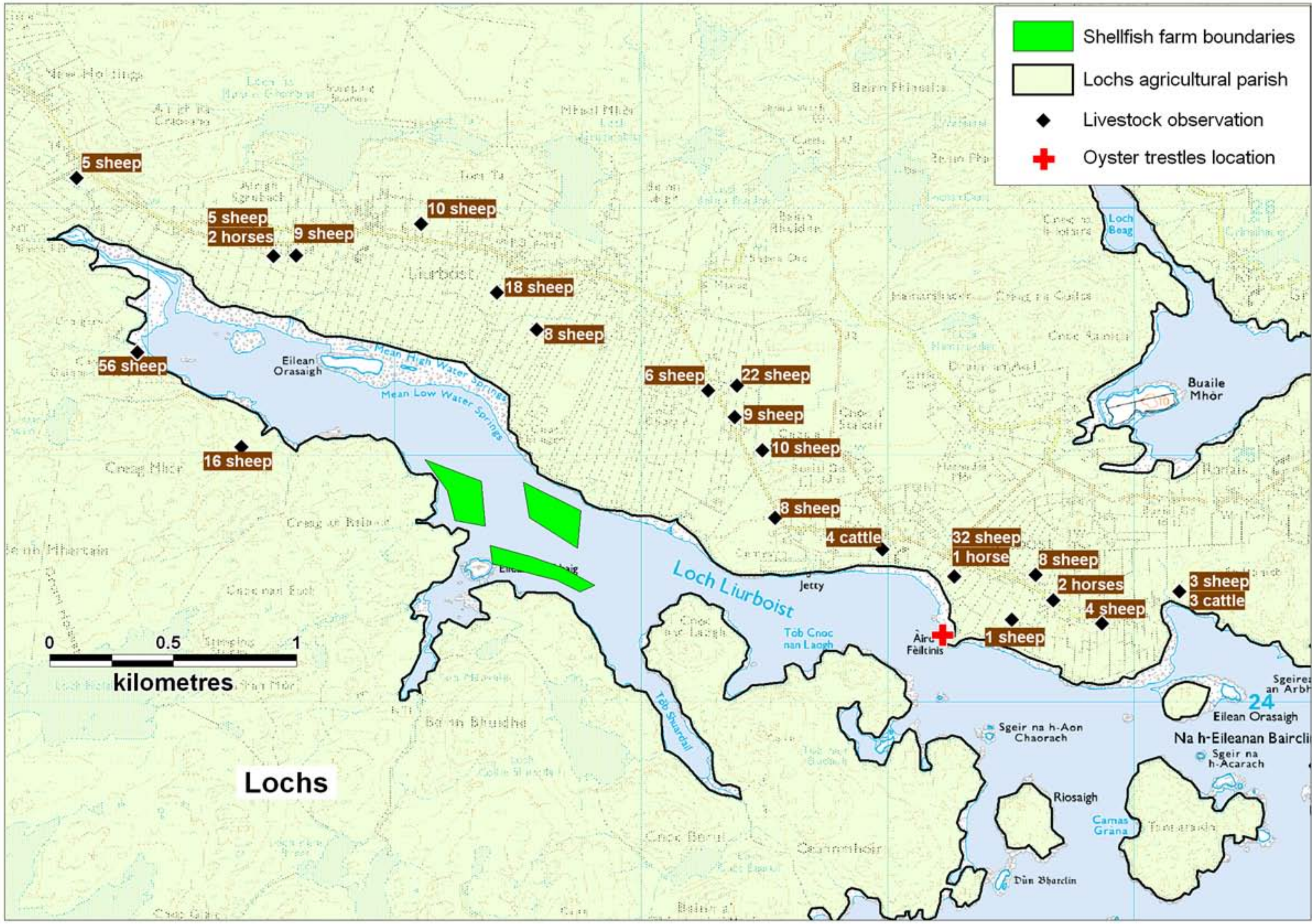

Figure 7.1 Livestock observations at Loch Leurbost

8. Wildlife

Loch Leurbost lies north of the Lewis Peatlands Special Protection Area and Special Area of Conservation. The SPA supports nationally and internationally important populations of breeding birds including golden plover (*Pluvialis apricaria* - 1800 pairs) and dunlin (*Calidris alpina* - 3400 pairs). It covers an area of approximately 59000 hectares. The SAC was identified for blanket bog habitat and natural dystrophic lakes, and lists otters (*Lutra lutra*) as present. Neither of these areas encompasses shoreline directly adjacent to Loch Leurbost. There is also a Site of Special Scientific Interest at Loch Orasay which is located north of Loch Leurbost. The site is renowned for its aggregations of breeding Greylag geese.

Seals

Both grey seals (*Halichoerus grypus*) and harbour seals (*Phoca vitulina vitulina*) are recorded in the Outer Hebrides, and though no breeding colonies are identified in the vicinity of Loch Leurbost. Seals are likely to forage widely and so it is probable that they will be present near the mussel farms from time to time. No seals were seen during the shoreline survey.

Otters

Otters are known to be present on the island and within the adjacent SAC and so are likely to be present along the shores of Loch Leurbost. However, the typical population densities of coastal otters are low and their impacts on the shellfishery are expected to be very minor. No otters were observed during the shoreline survey.

Birds

Seabird 2000 data has been provided for a 5 km radius of Loch Leurbost. In total there are three separate wildlife observations for the area. All three observations were located east of Loch Leurbost on the cliffs of Aird Ranais headland, see Figure 8.1. The observations were three groups of fulmars, in fairly large numbers of 32, 105, and 114.

Table 8.1 Seabird counts within 5km of the site

Common name	Species	Count	Method
Northern Fulmar	*Fulmarus glacialis*	251	Occupied sites

During the shoreline survey, small numbers of gulls and cormorants were observed on the mussel floats. Both geese and their droppings were seen near the head of the loch. Given the proximity of an area known for breeding populations of geese, it is likely that geese will graze grassland on the north side of the loch and therefore will contribute faecal contamination to runoff from land along this shore.

Deer

Although no deer were seen during the shoreline survey, there are deer in many parts of the island so it is likely that they may be present around Loch Leurbost, particularly along the south shore away from crofted areas.

Faecal contamination from deer is most likely to be carried to the loch via freshwater streams and burns.

Summary

A variety of wildlife species are known to be present in the area and may contribute to background levels of faecal contamination present in the waters of Loch Leurbost. Of these, seals and seabirds such as gulls are most likely to occur in the vicinity of the fisheries and may directly deposit faecal material to the waters near the shellfish farms. However, the presence and movements of these animals are likely to be highly variable and their impact at any given time difficult to predict. Faecal contamination levels from birds may be higher in the vicinity of the floats used to support the mussel lines, where they are likely to rest and toward the known nesting sites at the mouth of the loch.

Deer may be present in the area, and any impacts to the fisheries from this source are likely to be highest near the outlet of streams and burns along the shore.

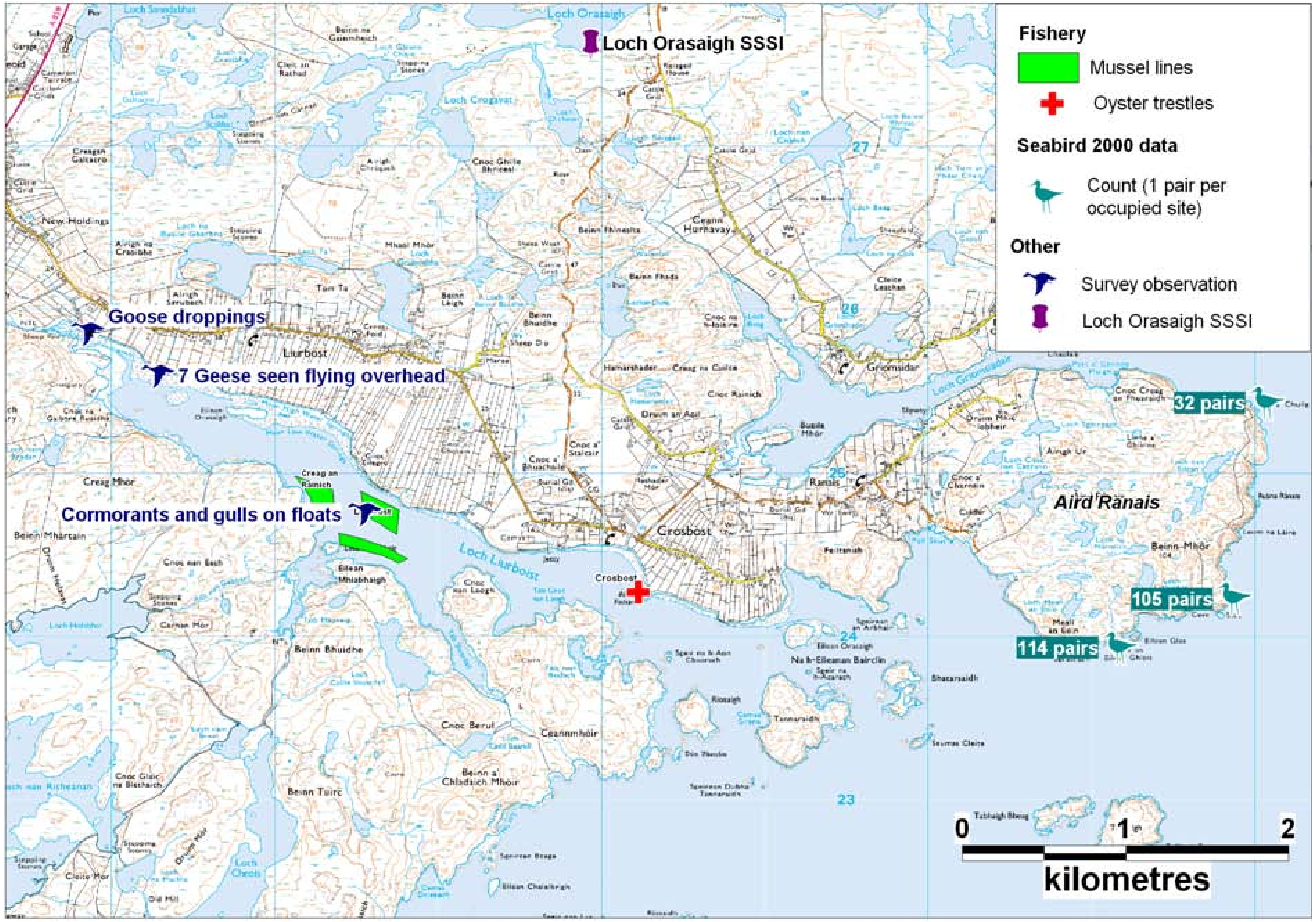

Figure 8.1 Map of seabird distributions at Loch Leurbost

9. Meteorological data

The nearest weather station for which nearly complete rainfall records were available is located at Stornoway, 11 km to the north east. Rainfall data was available for 2003-2009 inclusive, aside from 8 days in September 2003, 3 days in November 2006, 2 days in December 2006 and one day in September 2008. Wind data from this station was also used. It is likely that overall wind patterns are quite similar at the two, but local topography may skew the direction. This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish at Loch Leurbost.

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 represented by a line within the box. 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 *.

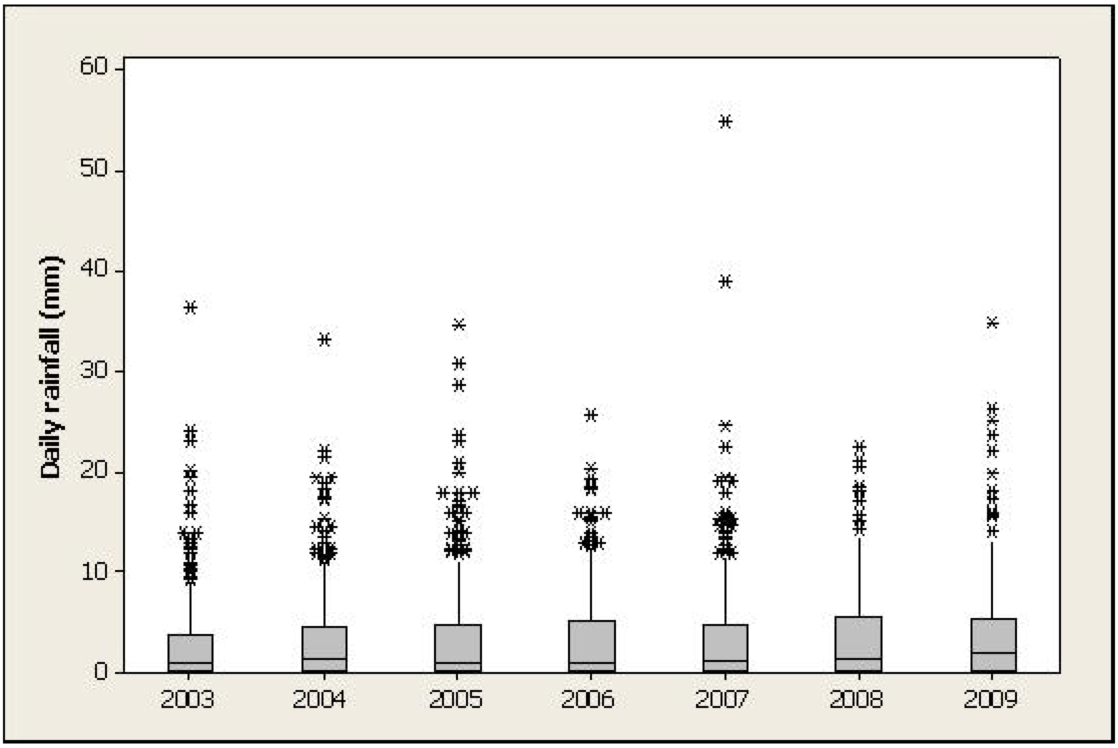

Figure 9.1 Box plot of daily rainfall values by year at Stornoway, 2003-2009

Figure 9.1 shows that rainfall patterns were similar between the years presented here, with 2003 the driest and 2009 the wettest.

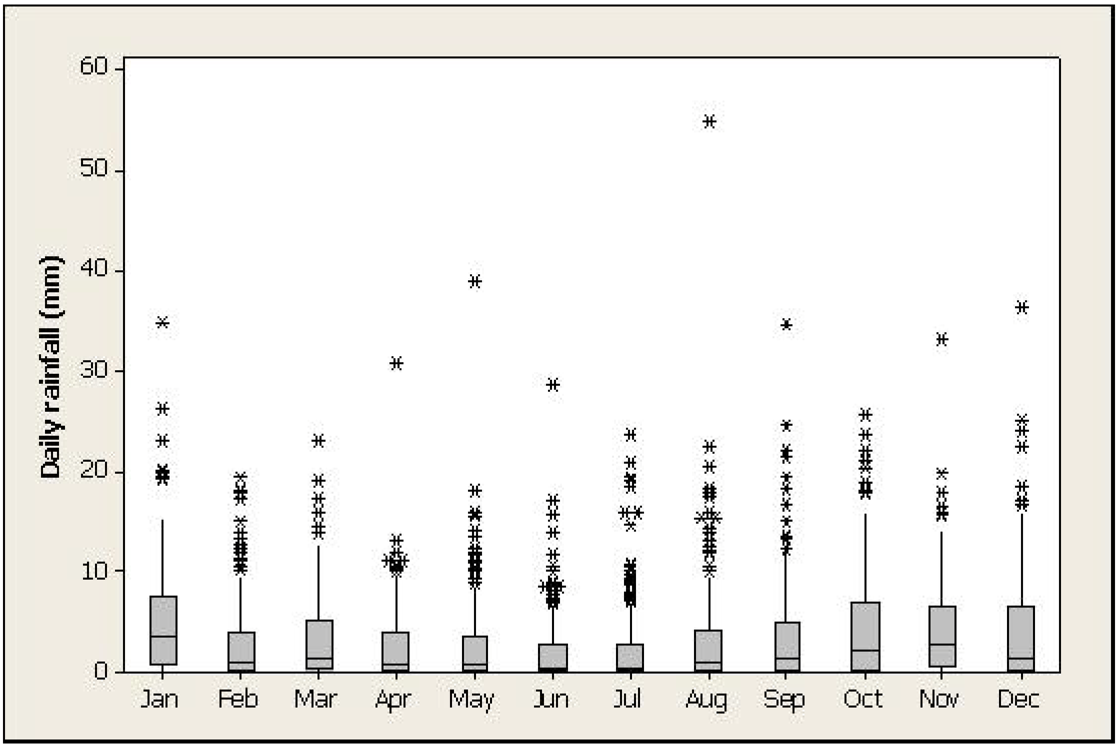

Figure 9.2 Box plot of daily rainfall values by month at Stornoway, 2003-2009

Figure 9.2 shows that weather was wettest from October to January, and driest in June and July. More extreme rainfall events (in which over 20mm fell in a day) occurred during all months except February, with no obvious seasonal pattern so it is concluded that these may occur at any time of the year. For the period considered here (2003-2009), 43% of days experienced rainfall less than 1 mm, and 8% 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 after a build-up of faecal matter on pastures during dry periods and when livestock numbers are at their highest.

9.2 Wind

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

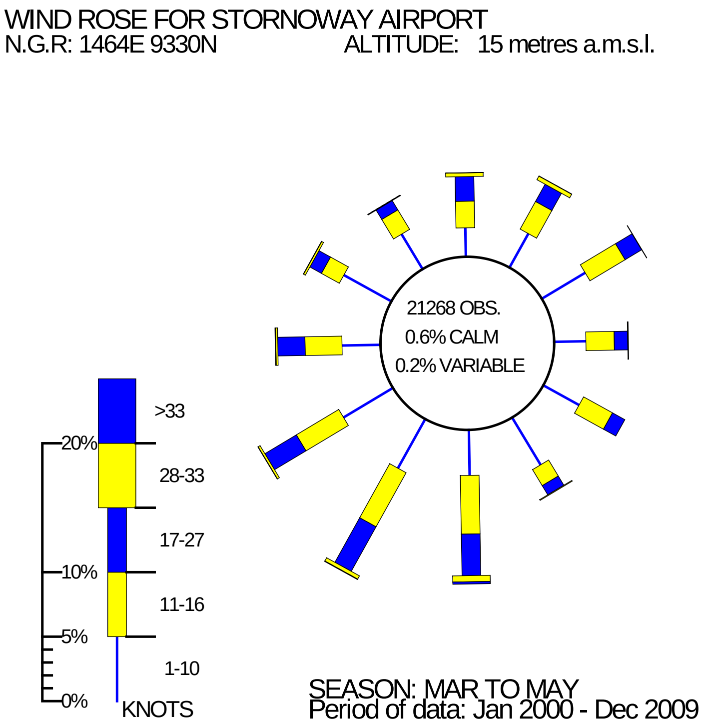

Figure 9.3 Wind rose for Stornoway (March to May)

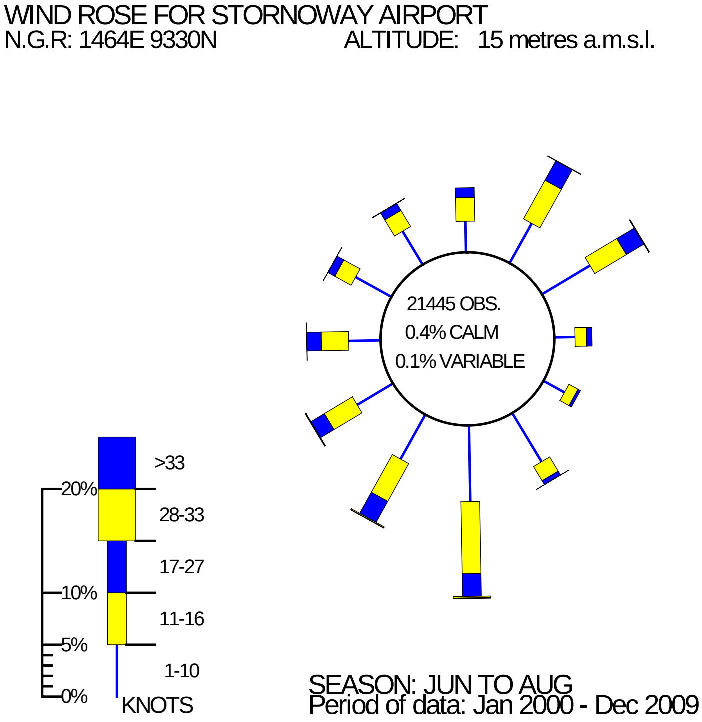

Figure 9.4 Wind rose for Stornoway (June to August)

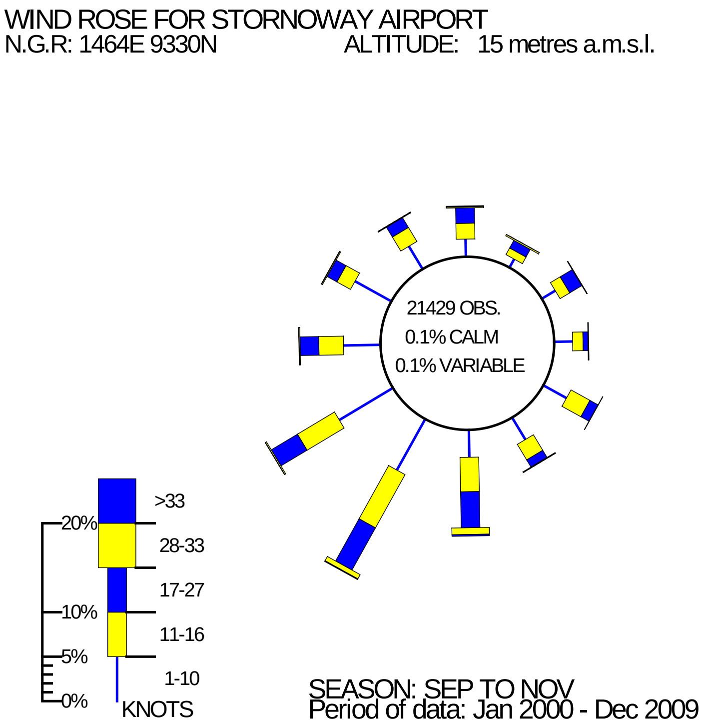

Figure 9.5 Wind rose for Stornoway (September to November)

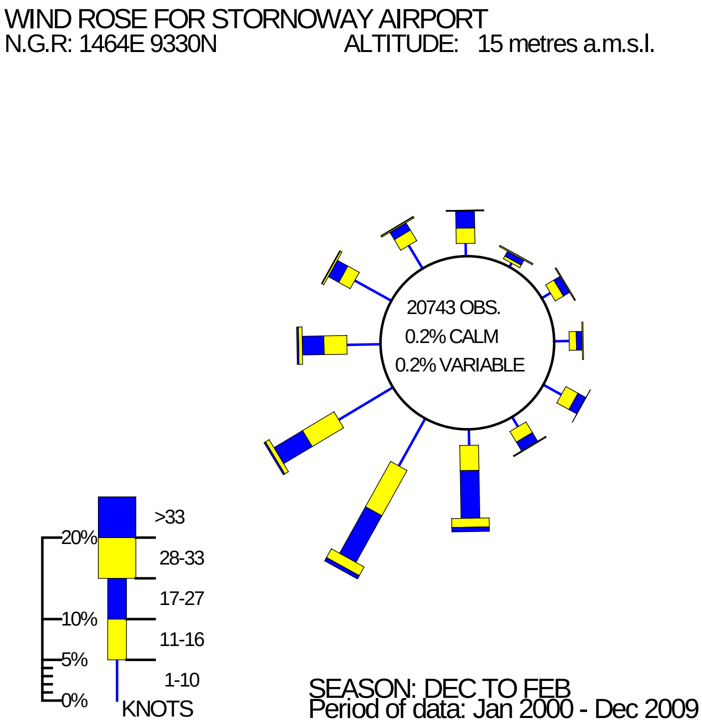

Figure 9.6 Wind rose for Stornoway (December to February)

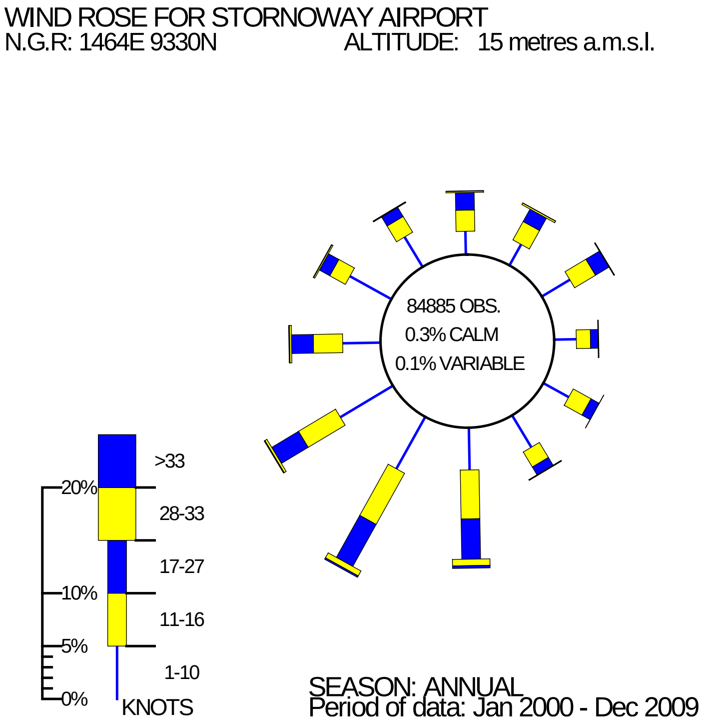

Figure 9.7 Wind rose for Stornoway (All year)

The prevailing wind direction at Stornoway is from the south-southwest. There is a higher occurrence of northeasterly winds during the spring and summer. Winds are generally lightest in the summer and strongest in the winter. The terrain surrounding Stornoway airport is low lying and so the weather station is relatively exposed to wind from all directions. Loch Leurbost has a northwest to southeast aspect, so it is likely that wind patterns there are more skewed along this axis. The surrounding land and some small islands at its mouth will afford it some protection from winds of all directions, although the surrounding land is fairly low lying.

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 Loch Leurbost. Strong winds may affect tide height depending on wind direction and local hydrodynamics. A strong wind combined with a spring tide may result in higher than usual tides, which will carry accumulated faecal matter from livestock, in and above the normal high water mark, into the production area. A strong southerly or south easterly wind will result in increased wave action and tidal height at the oyster site, which may resuspend any organic matter settled in the substrate.

10. Current and historical classification status

Loch Leurbost first received a provisional classification for the production of common mussels in 2001. In 2006, there was an application for production of Pacific oysters at Crosbost, but there were insufficient samples to issue a classification. The area was first classified for Pacific oysters in 2007 and the classification histories for the two species are presented in Tables 10.1 and 10.2 below.

Table 10.1 Classification history, Loch Leurbost, common mussels

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	a	a	a	a	a	a	a	a	a	a	a	a
2002	B	B	B	A	A	A	A	A	B	B	B	B
2003	A	A	A	A	A	A	A	B	A	A	A	A
2004	A	A	A	A	A	A	A	B	A	A	A	A
2005	A	A	A	A	A	A	A	A	A	A	A	A
2006	A	A	A	A	A	A	A	A	A	A	A	A
2007	A	A	A	A	A	A	A	A	A	A	A	A
2008	A	A	A	A	A	A	A	A	A	A	A	A
2009	A	A	A	A	A	A	A	B	B	B	A	A
2010	A	A	A	A	A	A	A	B	B	B	A	A
2011	A	A	A	A	A	A	A	A	A	A	A	A
2012	A	A	A									

Lower case denotes provisional classification

Loch Leurbost has been classified A for common mussels in most months and year-round from 2005 until 2009, when it reverted to a seasonal classification. Months with class B tended to be during the late summer to autumn. In 2002, the area was class B through the winter.

Table 10.2 Classification history, Loch Leurbost: Crosbost, Pacific oysters

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007				A	B	B	B	B	B	B	B	A
2008	A	A	A	A	B	B	B	B	B	B	B	A
2009	A	A	A	A	A	A	A	B	B	B	B	B
2010	A	A	A	B	B	B	B	B	B	B	B	B
2011	B	B	B	B	B	B	A	A	A	A	A	A
2012	B	B	B									

The area has been classed B most of the time, with A months tending to occur early in the year. However, it was classed B for the entire classification period of April 2010 to March 2011.

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken the two Loch Leurbost production areas from the beginning of 2002 up to the 11th 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.

Two mussel samples had no reported sampling location, and one mussel sample had a reported sampling location 10 km to the north of the production area, so these samples were excluded from the analysis. Four oyster samples had reported sampling locations of 4.7 km north of the production area so these were excluded from the analysis. One oyster sample had a reported sampling location 9.4 km to the north of the production area, so this was excluded from the analysis. One oyster sample had the incorrect site details entered on the database, so paper records were checked and site details adjusted. Another oyster sample appeared twice on the database, so the duplicate record was removed. Another oyster sample had the sampling location incorrectly entered on the database, and this was adjusted to agree with the paper records. All other reported sampling locations plotted within 100 m of their respective production area boundaries.

All samples were received by the testing laboratory within two days of collection. A total of 14 mussel samples had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation.

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

11.2 Summary of microbiological results

A summary of all sampling and results is presented in Table 11.1 by site/species combinations.

Table 11.1 Summary of historical sampling and results

Sampling Summary					
Production area	Loch Leurbost	Loch Leurbost	Loch Leurbost	Loch Leurbost: Crosbost	Loch Leurbost: Crosbost
Site	Creag an Rainich	Loch Leurbost	Eilean Mhiabhaig	Site 2 Crosbost	Site 1 Crosbost
Species	Common mussels	Common mussels	Common mussels	Pacific oysters	Pacific oysters
SIN	LH-168-113-08	LH-168-114-08	LH-168-732-08	LH-339-721-13	LH-339-795-13
Location	6 locations	11 locations	3 locations	4 locations	4 locations
Total no of samples	57	39	24	29	20
No. 2002	11	10	11	0	0
No. 2003	6	3	4	0	0
No. 2004	4	5	4	0	0
No. 2005	11	0	1	5	0
No. 2006	12	0	0	11	0
No. 2007	6	6	1	10	3
No. 2008	0	11	0	3	8
No. 2009	5	4	2	0	7
No. 2010	2	0	1	0	2
Results Summary					
Minimum	<20	<20	<20	20	20
Maximum	1100	5400	16000	9100	1300
Median	50	130	135	220	220
Geometric mean	58.8	158	116	189	151
90 percentile	382	1100	443	860	740
95 percentile	942	1165	1180	1300	1110
No. exceeding 230/100g	9 (16%)	15 (38%)	5 (21%)	13 (45%)	7 (35%)
No. exceeding 1000/100g	2 (4%)	5 (13%)	2 (8%)	3 (10%)	2 (10%)
No. exceeding 4600/100g	0 (0%)	1 (3%)	1 (4%)	1 (3%)	0 (0%)
No. exceeding 18000/100g	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

11.3 Overall geographical pattern of results

For the purposes of analysis , the oyster and mussel sites will be considered separately as the different species are grown in geographically distinct areas.

Common mussels

Sample results prior to June 2007 were reported against the nominal RMP only and there is little confidence that this accurately reflects the actual sampling position. Since June 2007, samples have been collected by the official control sampling officer, who recorded sampling grid references using GPS equipment. Therefore, only samples collected from this date onward have been included in the geographic analysis. Figure 11.1 presents a thematic map of individual sample *E. coli* result by sampling location for mussels.

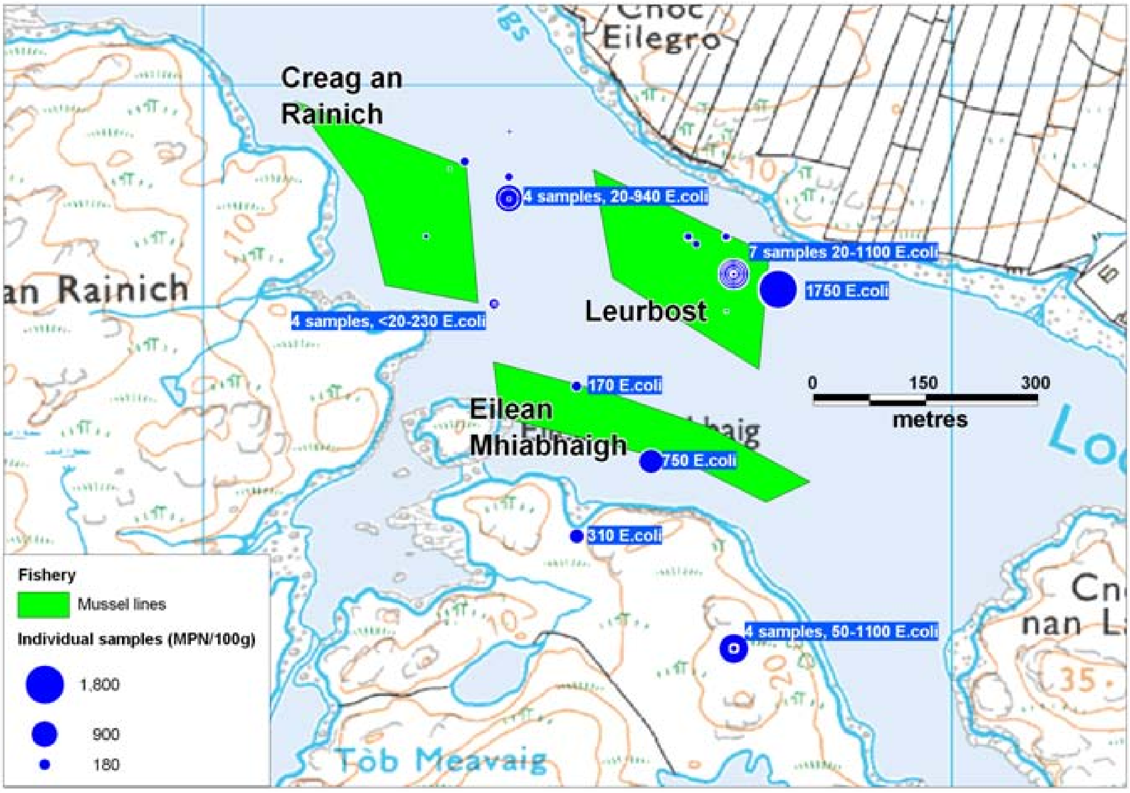

Figure 11.1 Map of individual *E. coli* results in mussels for 2007-2011

Samples reported from the northern boundary of the Creag an Rainich farm were attributed to both Creag an Rainich and to Loch Leurbost. It is assumed that they all came from Creag an Rainich. Four samples attributed to the Luerbost site plotted on land approximately 200 m south of the Eilean Mhiabhaigh site. A single sample attributed to the Eilean Mhiabhaigh site was reported to a grid reference near the MHWS line 130 m south of the site. If the grid references are assumed to be the correct sample location, and those samples plotting on land are ignored, there appears to be a tendency toward higher results at the eastern side of the fishery.

Pacific oysters
Reported sampling locations from the different sites did not consistently align with the location of their respective site or with the locations of the seabed leases. Therefore, a geographic assessment of contamination levels was not supported. Given the lack of clarity with regards to geographical attribution of results to one site or the other, results from both oyster sites have been considered together in the following analysis of temporal patterns and effects of environmental variables.

11.4 Overall temporal pattern of results

Due to time gaps in data collected for each of the different mussel sites, these data have been combined for the purposes of assessing temporal variation in results. Figures 11.2 and 11.3 present scatter plots of individual results against date for mussels and oysters respectively. They are fitted with Loess lines, 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 lines help to highlight any apparent underlying trends or cycles.

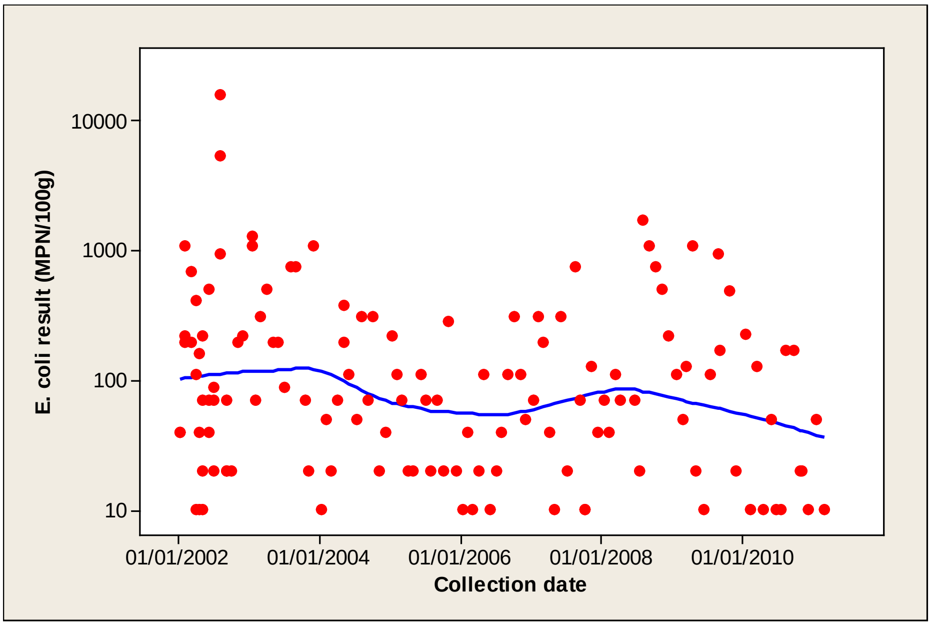

Figure 11.2 Scatterplot of *E. coli* results by date with Loess line (mussels)

A general improvement in the results is seen over the period, with fewer high results and a greater number of very low results in 2010 than in previous years.

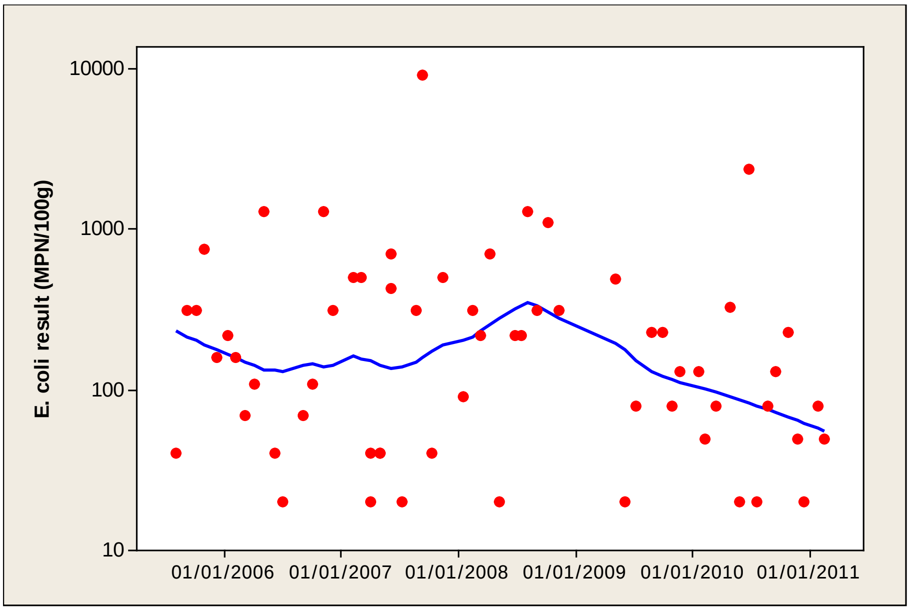

Figure 11.3 Scatterplot of *E. coli* results by date with Loess line (oysters)

An overall improvement in results is apparent in Figure 11.3, particularly from 2009 onward.

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.

Mussels

Figure 11.4 presents a box plot of *E. coli* result by month for mussels at all three sites combined. Results were broadly similar through all months except August, which experienced the highest results. Fewer low results occurred in August, September and November.

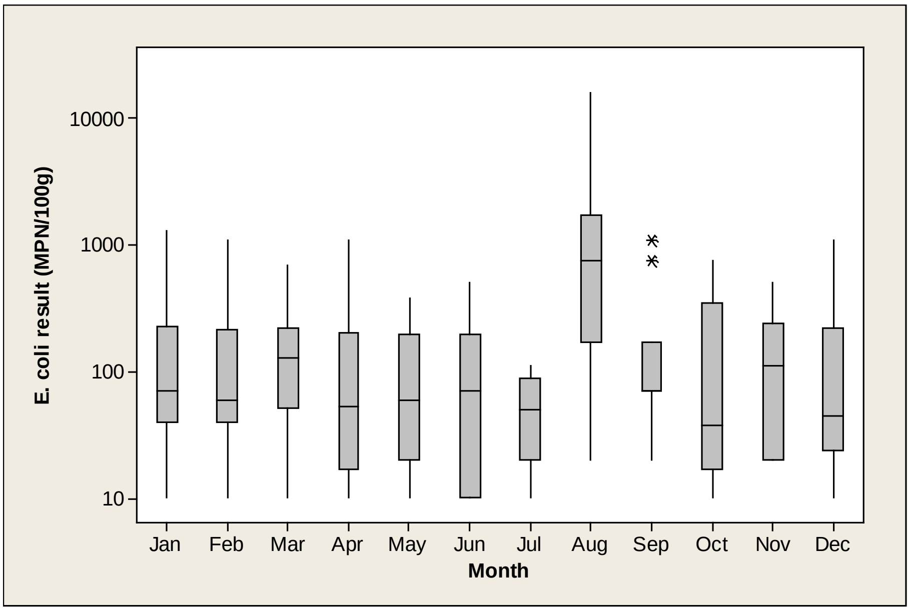

Figure 11.4 Boxplot of results by month (mussels)

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

Figure 11.5 presents a box plot of *E. coli* results in mussels by season.

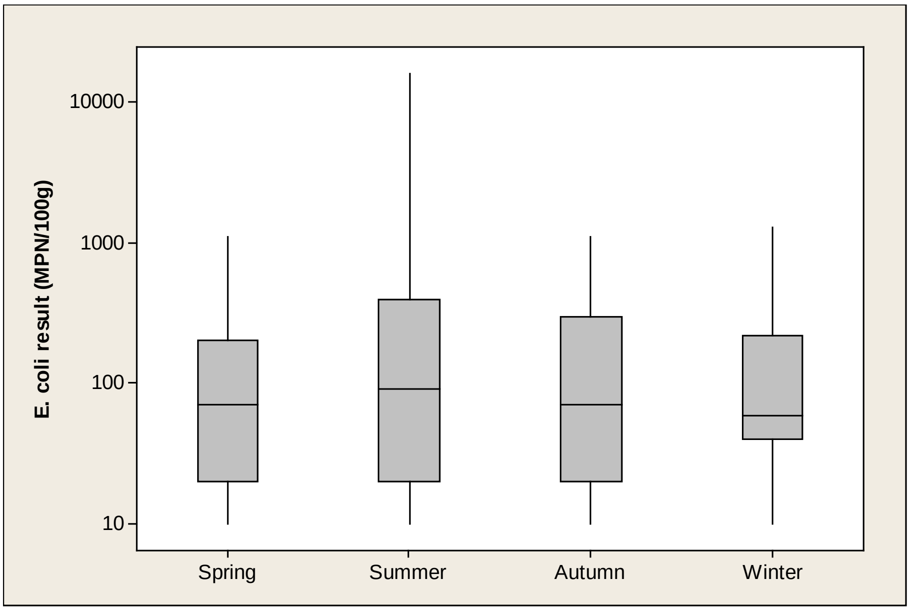

Figure 11.5 Boxplot of result by season (all mussel sites combined)

Results were more variable in summer, and highest results occurred then. No significant difference was found between results by season for mussels (One-way ANOVA, p=0.607, Appendix 6).

Pacific oysters

Figure 11.6 presents a box plot of *E. coli* results by month for the two oyster sites. Results varied more markedly than for mussels, with highest individual results in June and September. Otherwise, no clear pattern was discernable.

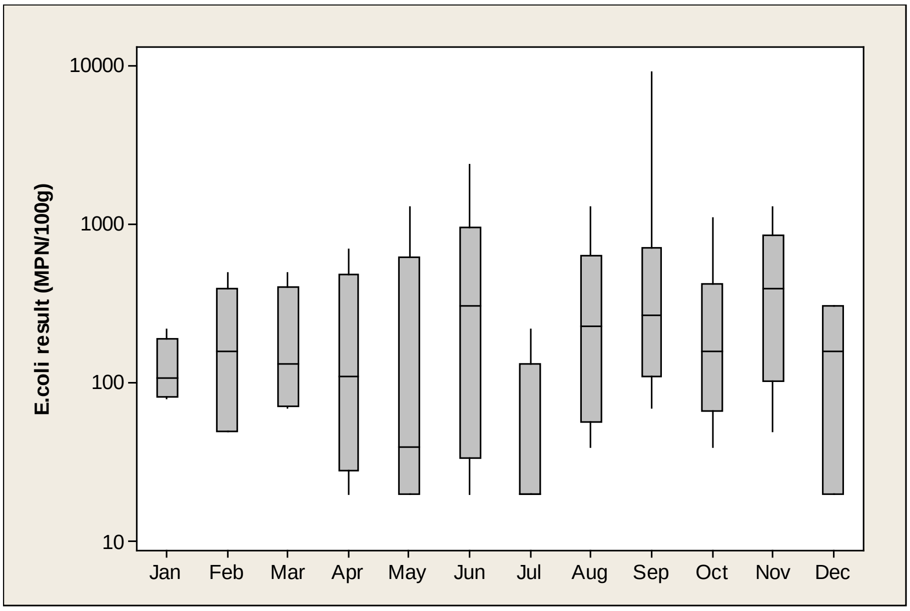

Figure 11.6 Box plot of results by month (oysters)

Figure 11.7 presents a box plot of E. coli results in Pacific oysters by season.

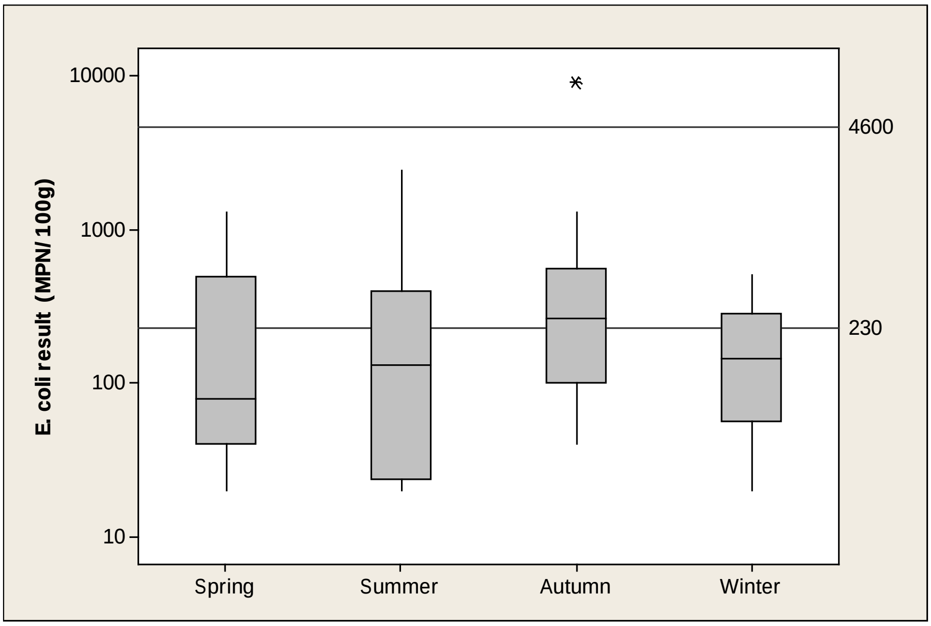

Figure 11.7 Boxplot of result by season (Crosbost oysters combined)

No significant difference was found between results by season for oysters (One-way ANOVA, p=0.226, Appendix 6).

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. For the following analyses, results reported against each of the mussel sites are considered separately as they are likely to be influenced by different sources and pathways of contamination.

11.6.1 Analysis of results by recent rainfall

The nearest weather station is at Stornoway, 11 km to the north east. 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

Figures 11.8 to 11.11 present scatterplots of *E. coli* results against rainfall in the previous two days for Creag an Rainich mussels, Eilean Mhiabhaig mussels, Loch Leurbost mussels and both oyster sites combined. Spearman's Rank correlations were carried out between results and rainfall.

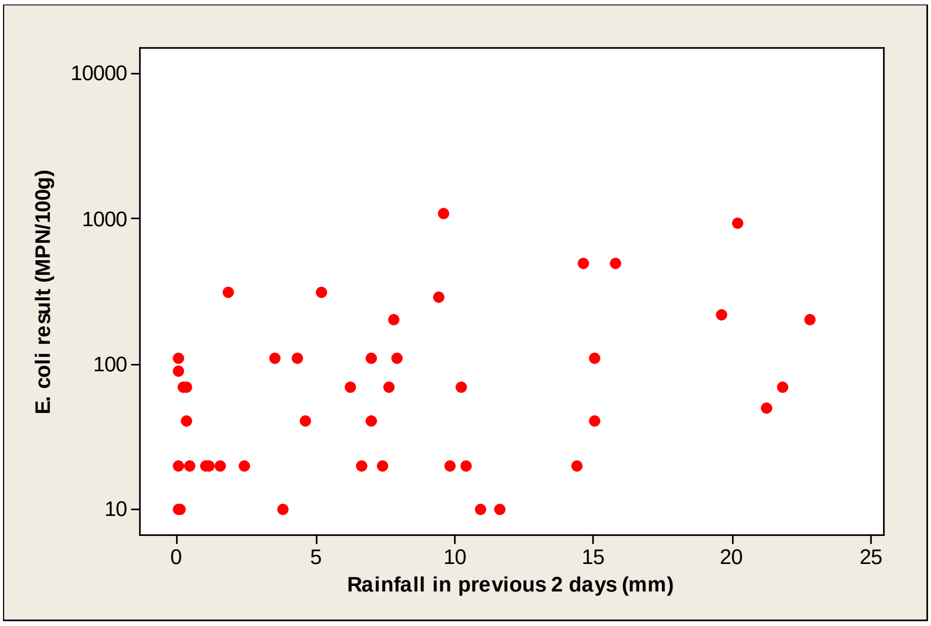

Figure 11.8 Scatterplot of result against rainfall in previous 2 days (Creag an Rainich mussels)

A positive correlation was found between *E. coli* result and rainfall in the previous 2 days for Creag an Rainich mussels (Spearman's rank correlation=0.321, p<0.025, Appendix 6).

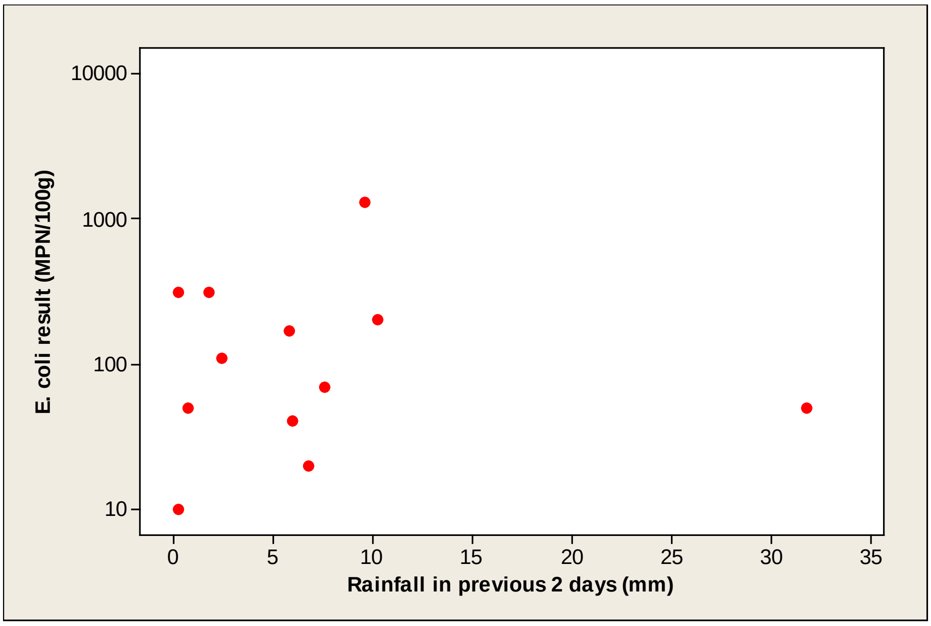

Figure 11.9 Scatterplot of result against rainfall in previous 2 days (Eilean Mhiabhaig mussels)

No significant correlation was found between *E. coli* result and rainfall in the previous 2 days for Eilean Mhiabhaig mussels (Spearman's rank correlation=0.056, p>0.25, Appendix 6).

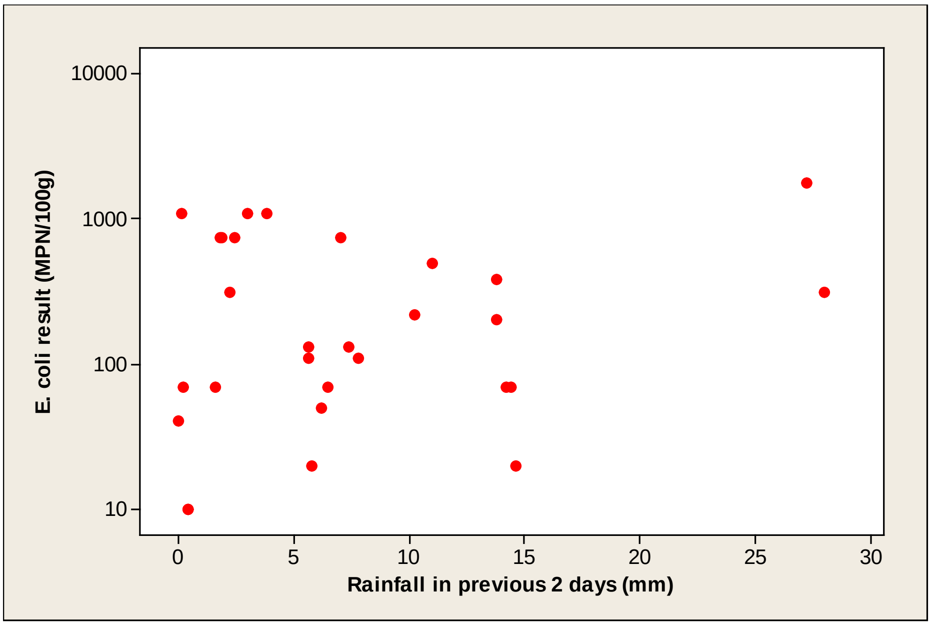

Figure 11.10 Scatterplot of result against rainfall in previous 2 days (Loch Leurbost mussels)

No significant correlation was found between *E. coli* result and rainfall in the previous 2 days for Loch Leurbost mussels (Spearman's rank correlation=0.091, p>0.25 Appendix 6). No low results occurred after >15mm rainfall, but only two results were recorded under these conditions.

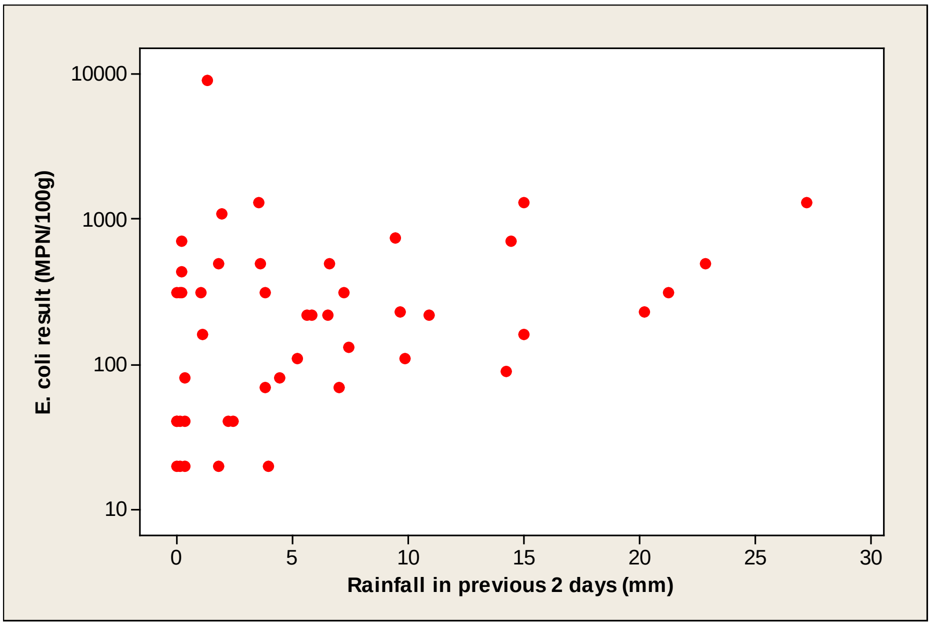

Figure 11.11 Scatterplot of result against rainfall in previous 2 days (Crosbost oysters combined)

A positive correlation was found between *E. coli* result and rainfall in the previous 2 days for oysters from site 1 and site 2 (Spearman's rank correlation=0.330, p<0.025, Appendix 6). The correlation appears to be driven by a decrease in lower results as rainfall increases above 5 mm for the two days prior to sampling. However, results >1000 MPN/100 g occurred across the range of 2-day rainfall totals.

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.

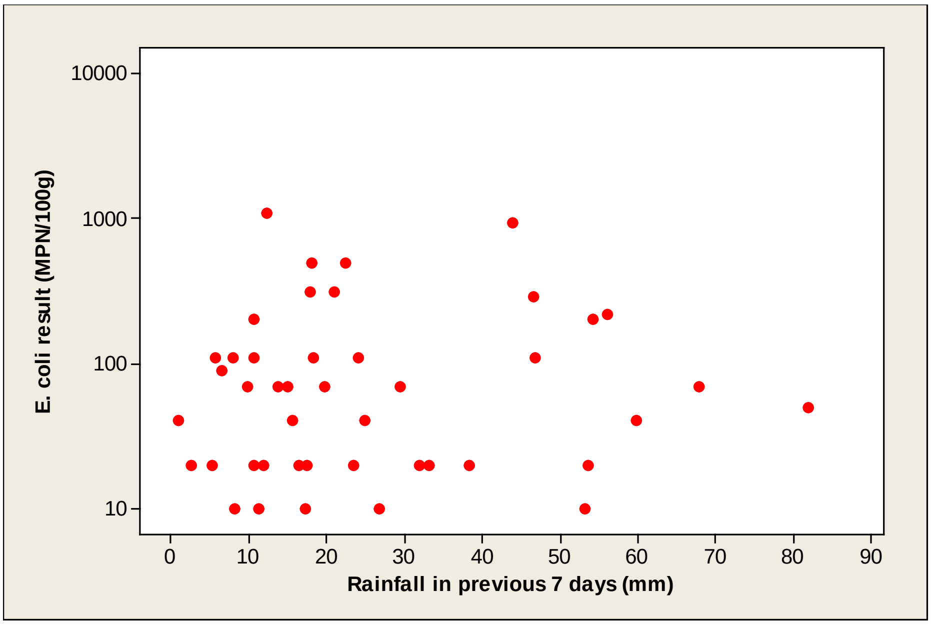

Figure 11.12 Scatterplot of result against rainfall in previous 7 days (Creag an Rainich mussels)

No significant correlation was found between *E. coli* result and rainfall in the previous 7 days for Craig an Rainich mussels (Spearman's rank correlation=0.094, p>0.25, Appendix 6).

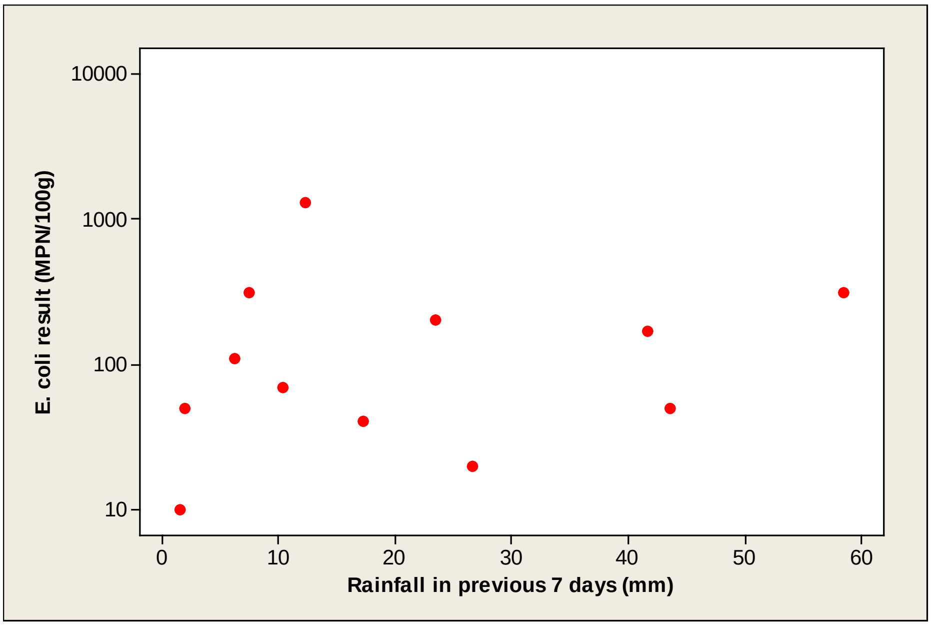

Figure 11.13 Scatterplot of result against rainfall in previous 7 days (Eilean Mhiabhaig mussels)

No significant correlation was found between *E. coli* result and rainfall in the previous 7 days for Eilean Mhiabhaig mussels (Spearman's rank correlation=0.242, p>0.10, Appendix 6). However, fewer low results appeared to occur with increasing rainfall.

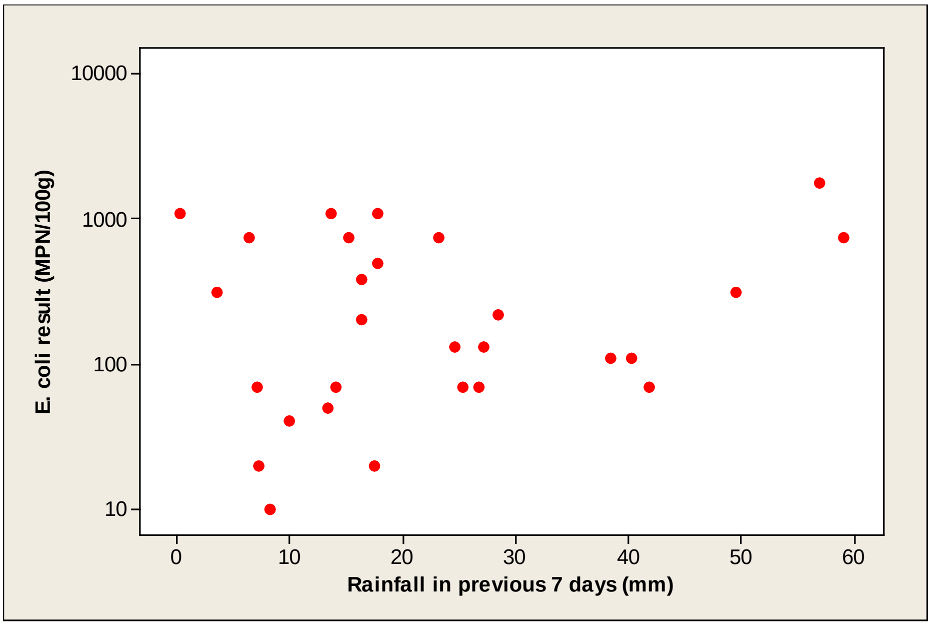

Figure 11.14 Scatterplot of result against rainfall in previous 7 days (Loch Leurbost mussels)

No significant correlation was found between *E. coli* result and rainfall in the previous 7 days for Loch Leurbost mussels (Spearman's rank correlation=0.187, p>0.10, Appendix 6). However, fewer low results occurred with increasing rainfall. No very low results coincided with rainfall totalling >20 mm in the 7-day period prior to sampling.

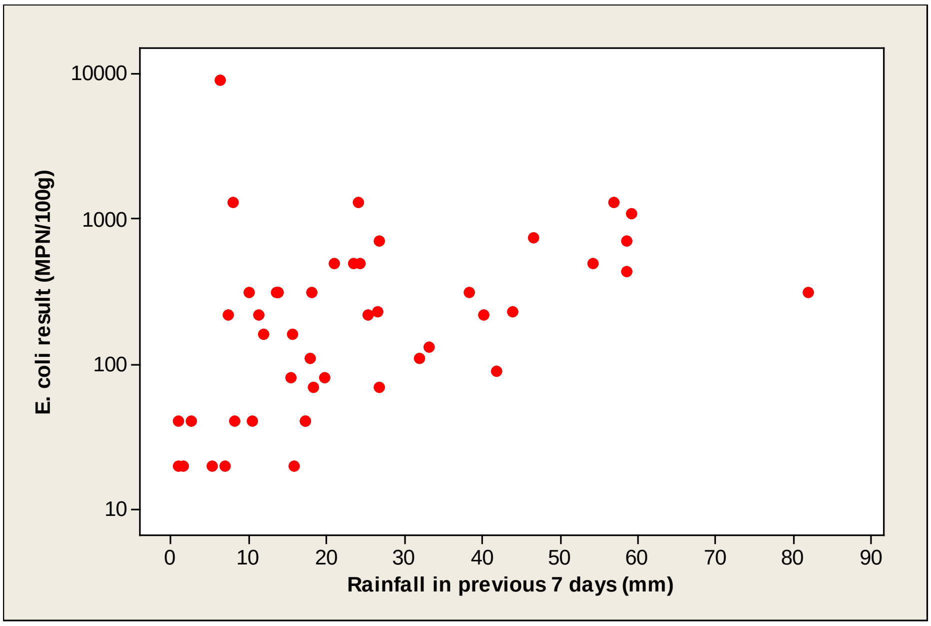

Figure 11.15 Scatterplot of result against rainfall in previous 7days (Crosbost oysters combined)

A positive correlation was found between *E. coli* result and rainfall in the previous 7 days for oysters from site 1 and site 2 (Spearman's rank correlation=0.500, p<0.0005, Appendix 6). However, as was observed with 2-day rainfall, the effect appeared to mainly be in the occurrence of fewer low results at higher rainfall, with very high results occurring also after very little rainfall.

11.6.2 Analysis of results by tidal height and state

Spring/Neap tidal cycle

When the larger (spring) tides occur every two weeks, circulation of water and particle transport distances will increase, and more of the shoreline will be covered at high water, potentially washing more faecal contamination from livestock into the area. Figures 11.16 to 11.19 present polar plots of $\log_{10}$ *E. coli* results on the lunar spring/neap tidal cycle for Creag an Rainich mussels, Eilean Mhiabhaig mussels, Loch Leurbost mussels and both oyster sites combined. Full/new moons are located at 0º, and half moons at 180º. The largest (spring) tides start about 2 days after the full/new moon, and last approximately 3 or 4 days (centred at about 45º on the plot). Tides then decrease to the smallest (neap tides; centred at about 225º) and then increase back to spring tides. Results less than 231 *E. coli* MPN/100g are plotted in green, those between 231 and 1000 *E. coli* MPN/100g are plotted in yellow, and those over 1000 *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.

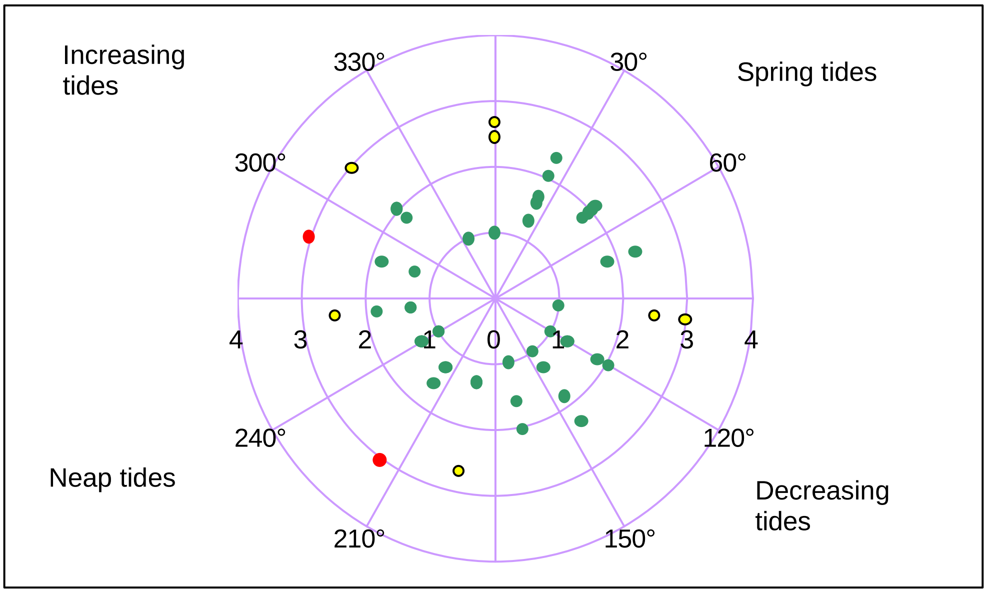

Figure 11.16 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle (Creag an Rainich mussels)

A significant correlation was found between *E. coli* results and the spring/neap cycle for Creag an Rainich mussels (circular-linear correlation, r=0.264, p=0.023, Appendix 6). Results were highest on average during increasing tides, and lowest on average on neap tides.

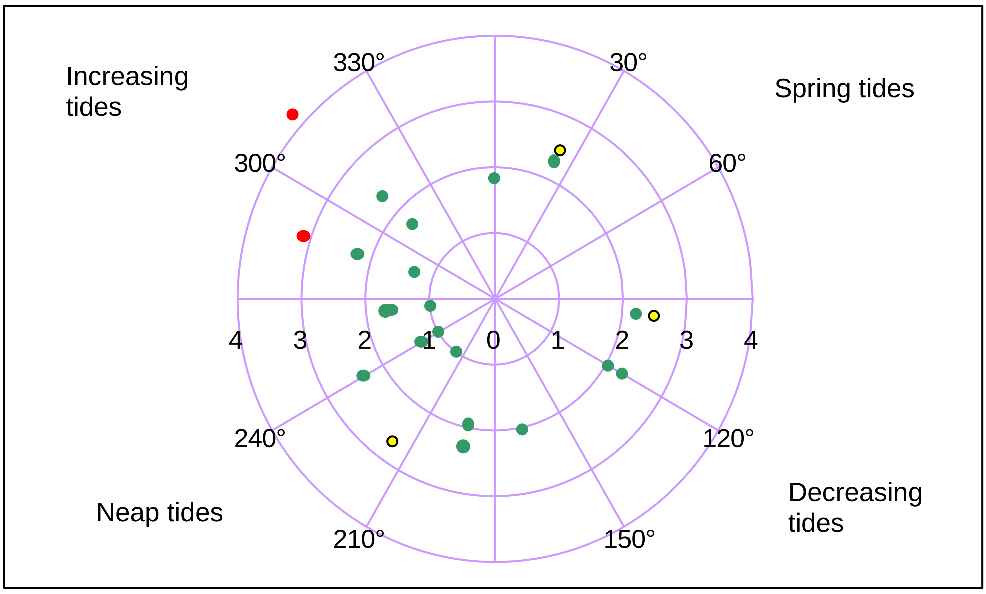

Figure 11.17 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle (Eilean Mhiabhaig)

No significant correlation was found between *E. coli* results and the spring/neap cycle for Eilean Mhiabhaig mussels (circular-linear correlation, r=0.354, p=0.071, Appendix 6).

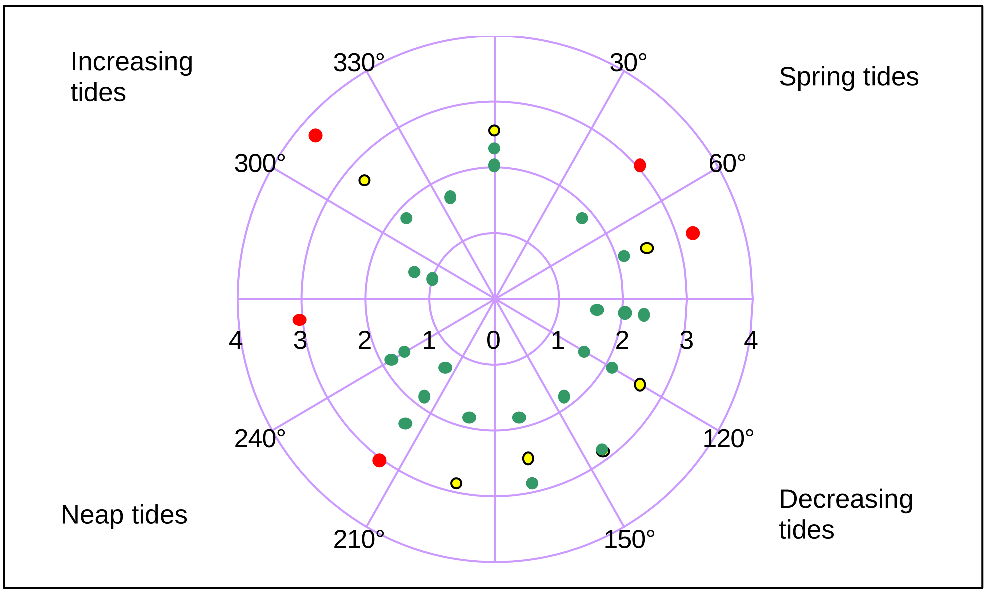

Figure 11.18 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle (Loch Leurbost mussels)

No significant correlation was found between *E. coli* results and the spring/neap cycle for Loch Leurbost mussels (circular-linear correlation, r=0.261, p=0.086, Appendix 6).

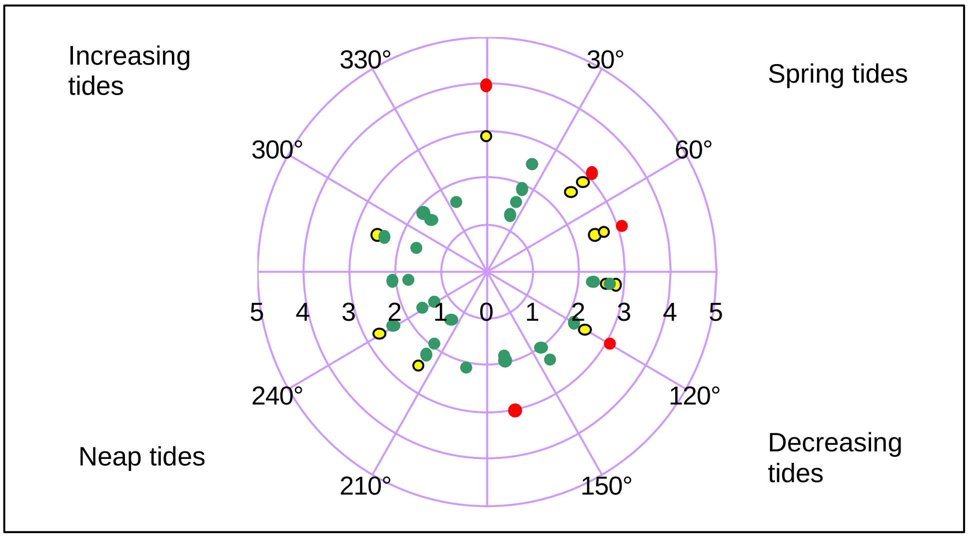

Figure 11.19 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle (Crosbost oysters combined)

A correlation was found between *E. coli* results and the spring/neap cycle for oysters from site 1 and site 2 (circular-linear correlation, $r=0.446$, $p<0.001$, Appendix 6). Results were higher on average during spring and decreasing tides.

High/Low tidal cycle

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As *E. coli* levels in some shellfish species can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (hours post high water) was compared with *E. coli* results. Figures 11.28 to 11.31 present polar plots of $\log_{10}$ *E. coli* results on the lunar high/low tidal cycle for Creag an Rainich mussels, Eilean Mhiabhaig mussels, Loch Leurbost mussels and both oyster sites combined. High water is located at 0º, and low water is at 180º. Results less than 231 *E. coli* MPN/100g are plotted in green, those between 231 and 1000 *E. coli* MPN/100g are plotted in yellow, and those over 1000 *E. coli* MPN/100g are plotted in red.

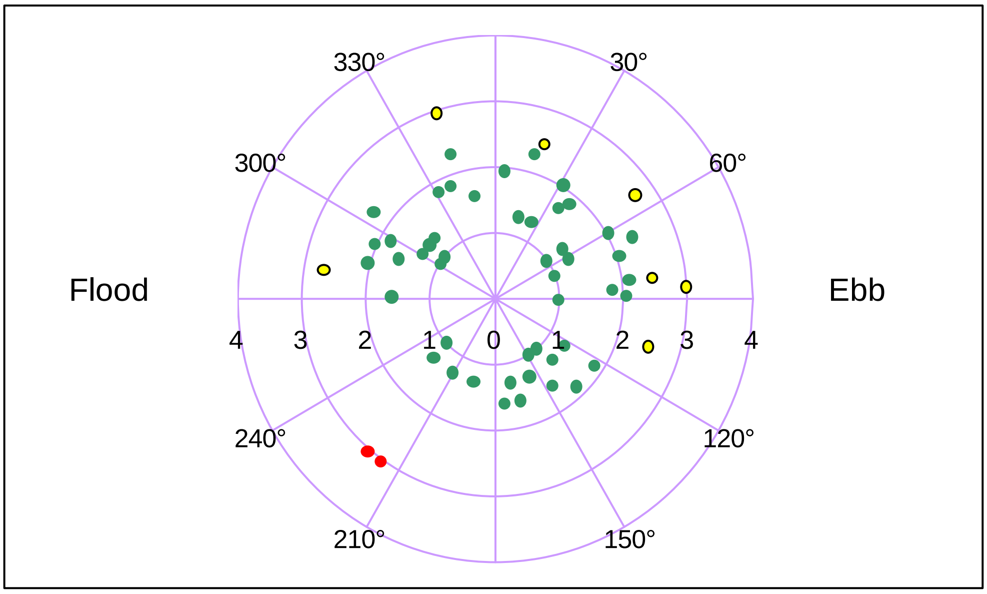

Figure 11.20 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle (Creag an Rainich mussels)

No significant correlation was found between *E. coli* results and the high/low tidal cycle for Creag an Rainich mussels (circular-linear correlation, r=0.172, p=0.202, Appendix 6). The highest results occurred on the beginning of the flood tide, though other results at that state of tide were very low. No results >230 occurred at the end of the ebb tide and at low tide.

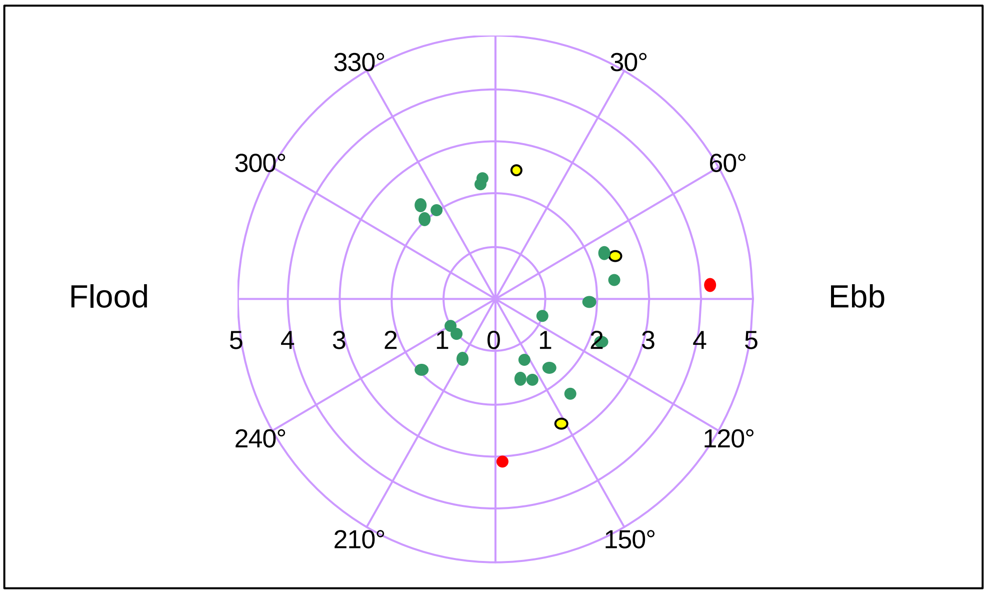

Figure 11.21 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle (Eilean Mhiabhaig mussels)

A significant correlation was found between *E. coli* results and the high/low tidal cycle for Eilean Mhiabhaig mussels (circular-linear correlation, r=0.474, p=0.008, Appendix 6). Results were higher on the ebb tide than on the flood tide.

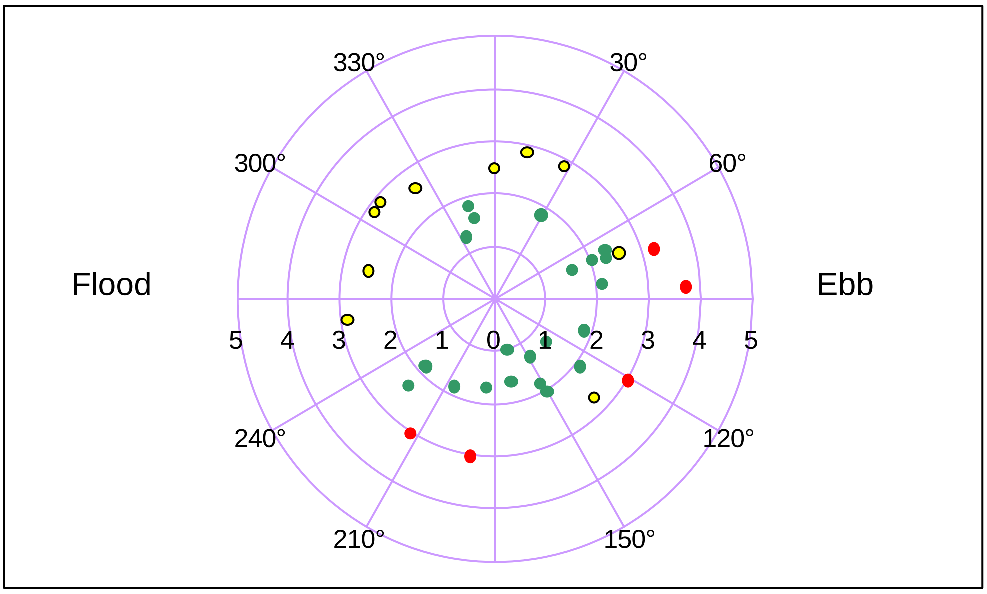

Figure 11.22 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle (Loch Leurbost mussels)

No significant correlation was found between *E. coli* results and the high/low tidal cycle for Loch Leurbost mussels (circular-linear correlation, r=0.271, p=0.071, Appendix 6). However, highest results occurred from around mid-ebb tide through the beginning of the flood tide.

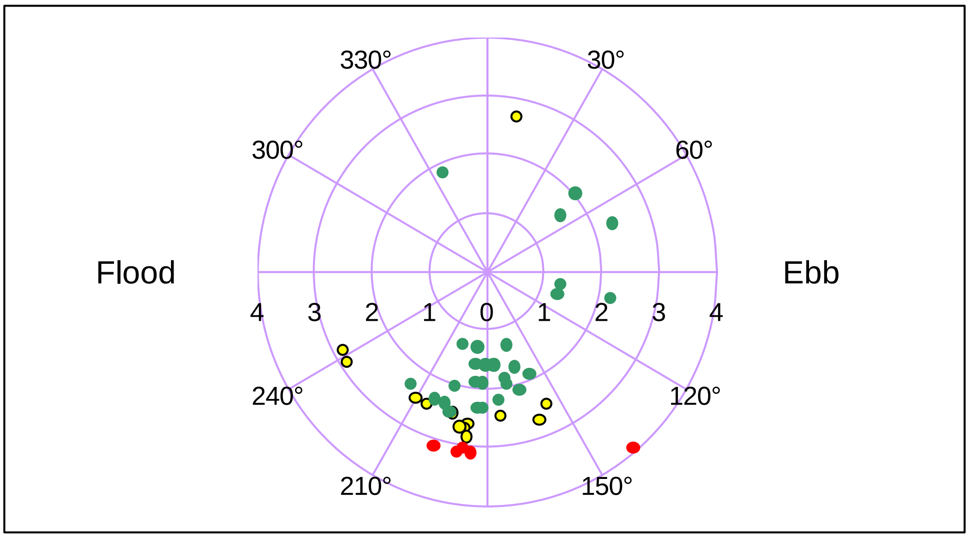

Figure 11.23 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle (Crosbost oysterscombined)

A significant correlation was found between *E. coli* results and the high/low tidal cycle for oysters from site 1 and site 2 (circular-linear correlation, r=0.279, p=0.027, Appendix 6). The highest results occurred around low water. However, the correlation was weak and 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. Water temperature was only recorded for a small proportion of samples, so it was only possible to make a meaningful comprison with *E. coli* results for Creag an Rainich.

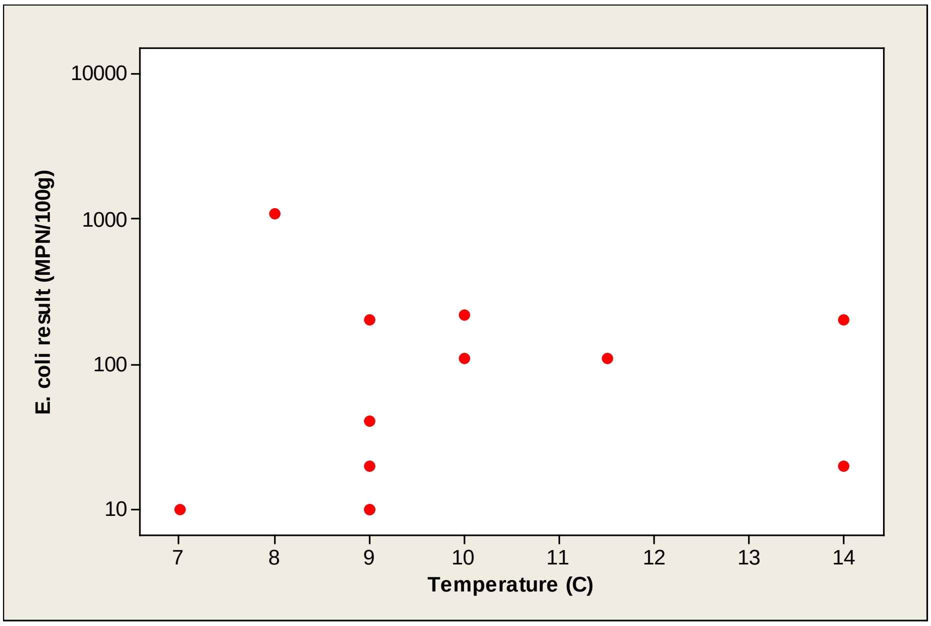

Figure 11.24 Scatterplot of *E. coli* results against water temperature (Creag an Rainich)

No significant correlation was found between *E. coli* result and water temperature for Craig an Rainich mussels (Spearman's rank correlation=0.238, p>0.10, Appendix 6).

11.6.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater borne contamination at the site. Figures 11.33 to 11.36 present scatterplots of *E. coli* results against salinity for Creag an Rainich mussels, Eilean Mhiabhaig mussels, Loch Leurbost mussels and both oyster sites combined.

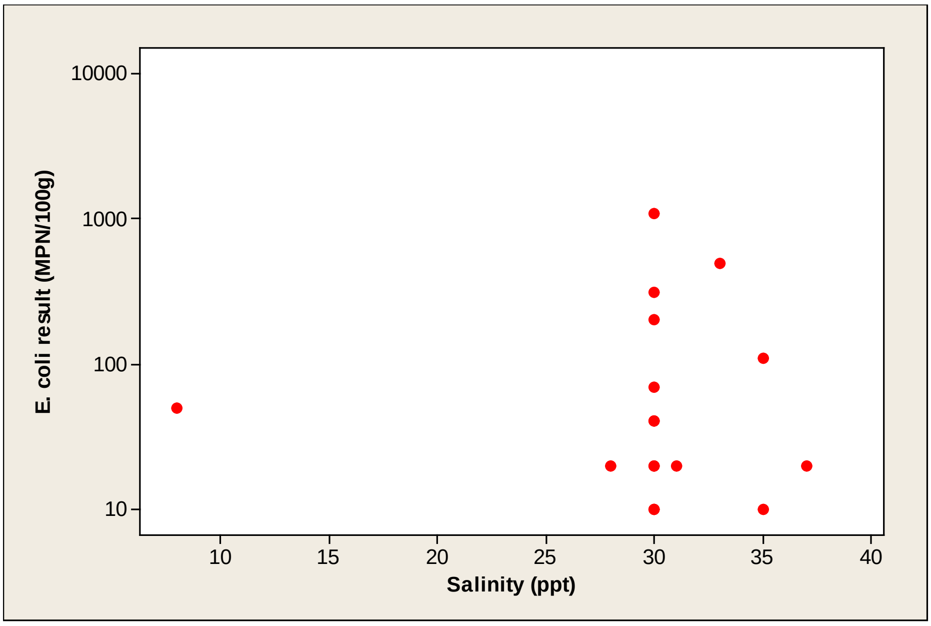

Figure 11.25 Scatterplot of result against salinity (Creag an Rainich mussels)

No significant correlation was found between *E. coli* result and salinity for Craig an Rainich mussels (Spearman's rank correlation=-.0.56, p>0.25, Appendix 6).

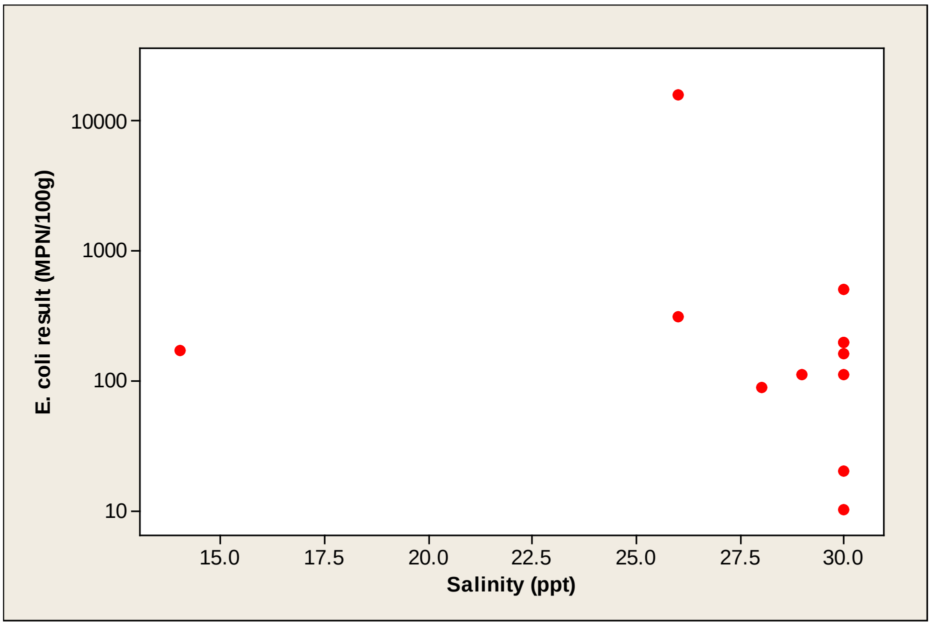

Figure 11.26 Scatterplot of result against salinity (Eilean Mhiabhaig mussels)

No signficant correlation was found between *E. coli* result and salinity for Eilean Mhiabhaig mussels (Spearman's rank correlation=-0.290, p>0.10, Appendix 6).

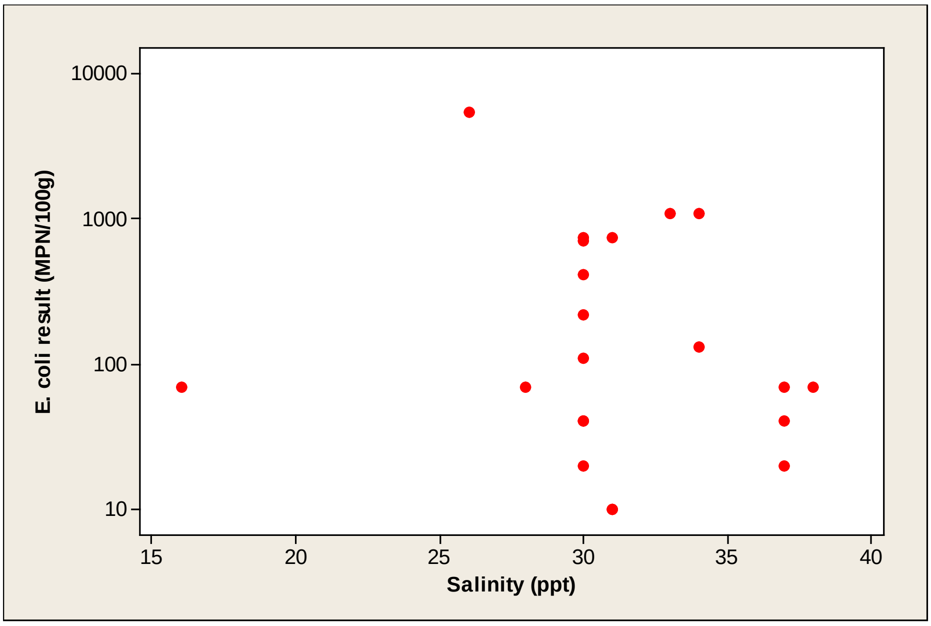

Figure 11.27 Scatterplot of result against salinity (Loch Leurbost mussels)

No significant correlation was found between *E. coli* result and salinity for Loch Leurbost mussels (Spearman's rank correlation=-0.176, p>0.10, Appendix 6).

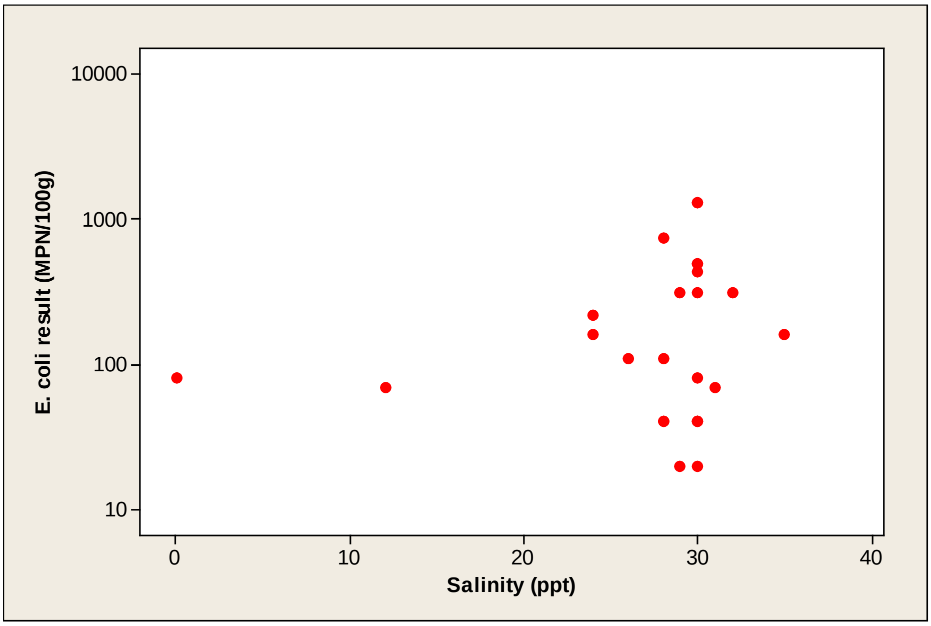

Figure 11.28 Scatterplot of result against salinity (Crosbost oysters combined)

No significant correlation was found between *E. coli* result and salinity for oysters from site 1 and site 2 (Spearman's rank correlation=0.143, p>0.10, Appendix 6).

At all sites, recorded salinities clustered mainly around 30 ppt, with only a few samples taken at recorded salinities below 25 ppt. There were no recorded salinities above 30 ppt at Eilean Mhiabhaigh and few recorded above this value at the Crosbost oyster sites. This seemed to indicate that there was more consistently observed salinity reduction, and hence greater freshwater influence at Eilean Mhiabhaigh and Crosbost.

11.7 Evaluation of peak results

A total of 9 mussel samples gave a result of over 1000 *E. coli* MPN/100g, details of which are presented in Table 11.2.

Table 11.2 Historic mussel *E. coli* sampling results over 1000 *E. coli* MPN/100g

Collection date	Site	*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)
06/02/2002	Creag an Rainich	1100	NB 373 249	*	*	8	30	Low	Neap
06/08/2002	Loch Leurbost	5400	NB 377 247	*	*	*	26	Ebb	Increasing
06/08/2002	Eilean Mhiabhaig	16000	NB 374 247	*	*	*	26	Ebb	Increasing
14/01/2003	Creag an Rainich	1100	NB 373 249	9.6	12.3	*	*	Low	Increasing
14/01/2003	Eilean Mhiabhaig	1300	NB 374 247	9.6	12.3	4	*	Low	Increasing
02/12/2003	Loch Leurbost	1100	NB 377 247	3	17.8	*	*	Low	Neap
04/08/2008	Loch Leurbost	1750	NB 3777 2473	27.2	57	*	*	Ebb	Spring
01/09/2008	Loch Leurbost	1100	NB 3771 2475	3.8	13.6	*	33	Ebb	Spring
20/04/2009	Loch Leurbost	1100	NB 3771 2425	0.1	0.2	*	34	Low	Neap

* Data unavailable

High results were recorded at all three mussel sites sampled. Five of 9 arose at the Loch Leurbost site, although on one of these occasions the Eilean Mhiabhaig site was also sampled and the result there was higher. No high results arose from 2004 through to 2007. High results occurred in January (2), February (1), April (1), August (3) and September (1). The samples for which records were available were taken under varying rainfall conditions and salinities. Although they were taken under a variety of tidal conditions on the spring/neap cycle, they were all taken on an ebbing tide or around low water.

A total of 5 oyster samples gave a result of over 1000 *E. coli* MPN/100g, details of which are presented in Table 11.3.

Table 11.3 Historic oyster *E. coli* sampling results over 1000 *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)
02/05/2006	1300	NB 394 242	15	24.1	*	30	Low	Decreasing
07/11/2006	1300	NB 394 242	3.5	8	*	30	Low	Spring
11/09/2007	9100	NB 394 242	1.3	6.3	*	*	Low	Spring
04/08/2008	1300	NB 3923 2429	27.2	57	*	*	Low	Spring
06/10/2008	1100	NB 3923 2429	1.9	59.1	*	*	Low	Decreasing

* Data unavailable

High results arose arose during May (1), August (1), September (1), October (1) and November (1) following varying 2 and 7 day rainfalls. All were taken around low tide, but sampling was strongly targeted towards low tide. All were taken on spring or decreasing tides.

11.8 Summary and conclusions

There was some confusion regarding the sampling sites and location references. However, if the grid references are assumed to be correct and those samples plotting on land are ignored, there appears to be a tendency toward higher results at the eastern side of the fishery.

It was not possible to evaluate geographic variation in results at the oyster sites due to lack of clarity regarding sampling location and assigned site.

In terms of overall temporal trends, an overall decrease in *E. coli* results was observed for both species, implying a corresponding improvement in water quality within the loch. Whilst little variation was observed in mussel results over the seasons, analysis by month showed higher results in August.

Water temperature at the time of sampling was not generally recorded so an analysis of results against water temperature was only possible for the Creag an Rainich mussel site, and no signficant correlation with results was found.

For the three mussel sites, a significant correlation between results and recent rainfall was only found between results at Creag an Rainich and rainfall in the previous 2 days. For oysters, correlations were found between *E. coli* results and rainfall in both the preceding 2 and 7 days. The correlation with 7 day rainfall was strongest. No correlation was found between either mussel or oyster results and salinity at the time of sampling.

Significant correlations between *E. coli* results and tidal state on the spring/neap cycle were found for mussels from Craig an Rainich and for oysters. For the former, the correlation was relatively weak, and results were highest on average during increasing tides, and lowest on average on neap tides. For oysters, the correlation was much stronger, with higher results during spring and decreasing tides. Correlations between *E. coli* results and tidal state on the high/low cycle were found for mussels from Eilean Mhiabhaig and for oysters. At Eilean Mhiabhaig results were higher on the ebb tide than on the flood tide. For oysters however, the correlation was weak, sampling was targeted towards low water, and no strong patterns in results are apparent when this data was plotted.

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.

Table 11.4 shows a summary of the significant correlations with environmental factors by site.

Table 11.4 Summary of significant correlations at Loch Leurbost

	Creag an Rainich	Eilean Mhiabhaig	Leurbost	All mussels	Crosbost
Month				higher Aug	variable
Season				o	o
2-day rainfall	**+**	o	o		**+**
7-day rainfall	o	o	o		**+**
Temperature	o	*	*		*
Salinity	o	o	o		o
Spring/Neap tide	1	o	o		2
High/Low tide	o	3	o		4

* Not analysed – insufficient data
o No signficant correlation
1 higher results increasing tides
3 Higher results at ebb tide
2 higher results at spring and decreasing tides
4 Higher results at low tide

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 either production area as they have both held seasonal classifications within the last three years.

12. Designated Shellfish Growing Waters Data

Loch Leurbost contains two separate areas designated as Shellfish Growing Waters under the European Community Shellfish Waters Directive 2006/113/EC.

The Inner Loch Leurbost (previously Loch Leurbost West) SGW is defined as an area bounded by lines drawn between NB 37000 2545 and NB 3700 2504 and between NB 3800 2476 and NB 3800 2404 and extending to MLWS. This area was designated in 2002 and covers a total area of 0.7km^2. Monitoring commenced in 2003 and the current designated sampling point is NB 3799 2472.

The Outer Loch Leurbost (previously Loch Leurbost East) SGW is defined as an area bounded by lines drawn between NB 3906 2407 and NB 3924 2424 (Aird Feiltanish) and between NB 3929 2349 and NB 3987 2407 and extending to MLWS. The area was designated in 2002 and covers a total area of 0.3km^2. Sampling commenced in 2003 and the current designated sampling point is NB 3937 2423.

The locations of both Shellfish Growing Waters and monitoring points, as well as the fishery locations recorded during the shoreline survey, are shown in Figure 12.1.

Monitoring results for faecal coliforms in mussels taken at the Loch Leurbost West and Loch Leurbost East monitoring points from 2003 to the end of 2007 have been provided by SEPA. These results are presented in Table 12.1.

The geometric mean result of all mussel samples from Loch Leurbost West was 625 faecal coliforms / 100 ml. Results ranged from 20 to 9100 faecal coliforms/100 ml. Results were highest for quarter 3, and lowest for quarter 4, but differences between results by quarter were not significant (One-way ANOVA, p=0.367, Appendix 4).

The geometric mean result of all mussel samples from Loch Leurbost East was 510 faecal coliforms / 100 ml. Results ranged from 20 to >18000 faecal coliforms/100 ml. Results were highest for quarter 3, and lowest for quarter 4, but differences between results by quarter were not significant (One-way ANOVA, p=0.673, Appendix 4).

Levels of faecal coliforms are usually closely correlated to levels of *E. coli*, often at a ratio of approximately 1:1. The ratio depends on a number of factors, such as environmental conditions and the source of contamination and as a consequence the results presented in Table 12.1 are not directly comparable with other shellfish testing results presented in this report. The results indicate that shore mussels at both locations are subject to signficant levels of faecal contamination. The very high result obtained in the shellfish waters monitoring at Loch Leurbost East in Q3 of 2004 (>18000 /100 ml) indicates that the monitoring point at that location is subject to extreme levels of faecal contamination on occasions.

From 2008 onwards, microbiological data obtained under the classification monitoring programme overseen by FSAS were shared with SEPA for use in meeting the monitoring requirements under the shellfish growing water programme. Therefore, these results have already been considered within the analysis in Section 11.

Table 12.1 SEPA faecal coliform results (faecal coliforms/100ml[1]) for non-commercial shellfish gathered from Loch Leurbost West and Loch Leurbost East

	Site	Loch Leurbost West - 57	Loch Leurbost East - 58
	OS Grid Ref.	NB 37992 24722	NB 39367 24225
2003	Q1	3500	
	Q2		
	Q3	1100	220
	Q4	2200	40
2004	Q1	130	50
	Q2	70	5400
	Q3	9100	>18000[2]
	Q4	90	20
2005	Q1	750	5400
	Q2	2400	2400
	Q3	9100	310
	Q4	110	50
2006	Q1	1300	200
	Q2	3500	5400
	Q3	20	40
	Q4	3500	X
2007	Q1	X	5400
	Q2	110	
	Q3	1075	
	Q4	50	

[1] The faecal coliform determined in the Shellfish Waters Directive is expressed per 100 ml, rather than the more usual per 100 g used in shellfish hygiene – in practice, the difference is not important

[2] Assigned a nominal value of 36000 for the purpose of calculating the geometric mean

X – sample cancelled

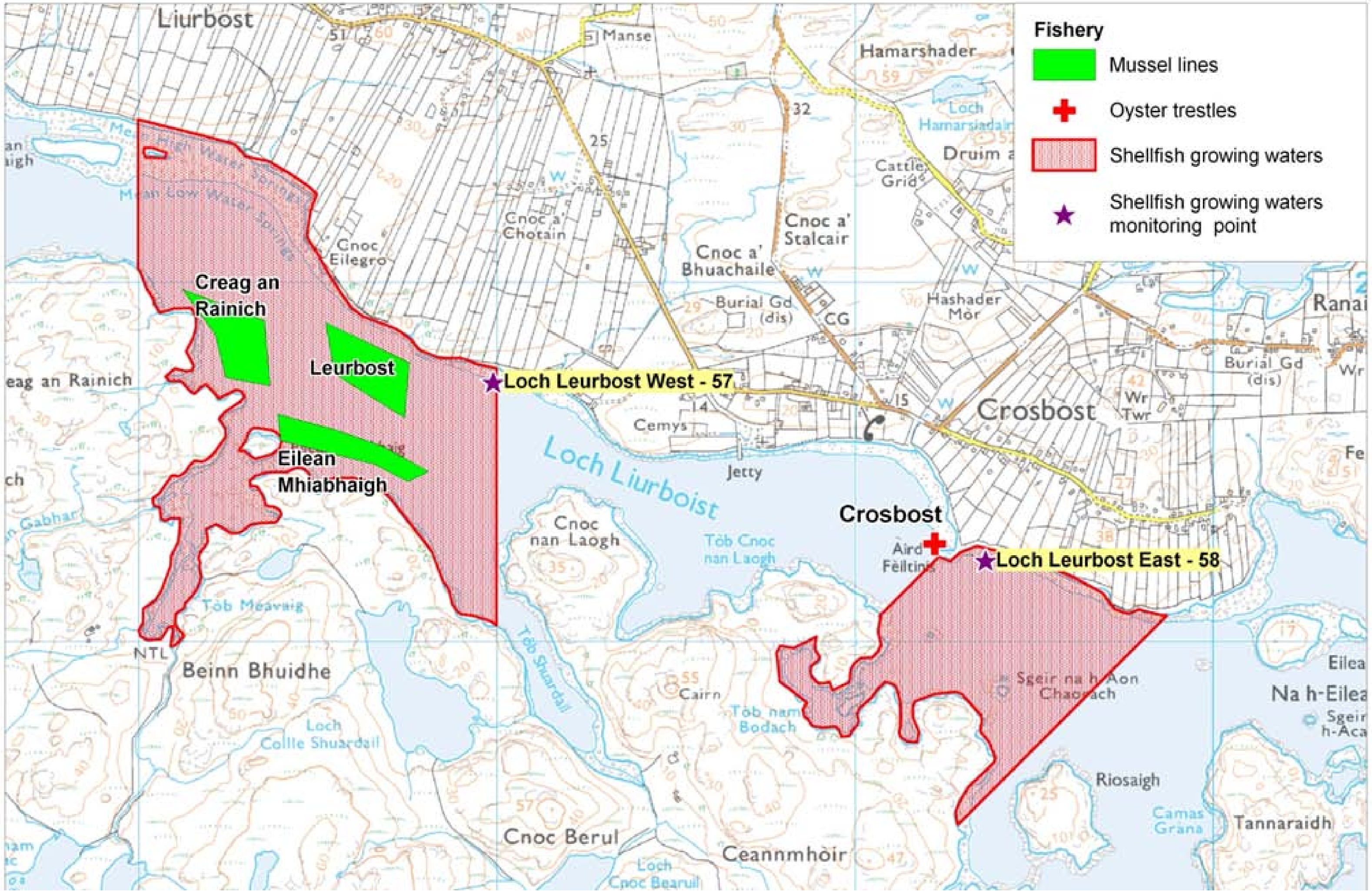

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Figure 12.1 Shellfish Growing Water map

13. River Flow

There are no gauging stations on watercourses entering Loch Leurbost.

The watercourses listed in Table 13.1 were measured and sampled during the shoreline survey. There was rain at the time of the survey. The locations are shown on the map presented in Figure 13.1. Where the bacterial loading is labelled on the map, the scientific notation is written in digital format, as this is the only format recognised by the mapping software. So, where normal scientific notation for 1000 is 1×10^3, in digital format it is written as 1E+3.

Table 13.1 Watercourse loadings for Loch Leurbost

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	NB 35762 25907	Stream	1.7	0.1	0.304	4470	80	3.6×10^9
2	NB 35739 25890	Stream	6.7	0.36	0.600	125000	210	2.6×10^{11}
3	NB 35727 25873	Stream	3	0.23	1.146	68300	250	1.7×10^{11}
4	NB 35708 25824	Stream	2.7	0.32	0.743	55500	No sample taken	-
5	NB 36609 25567	Stream	1.3	0.27	0.622	18900	70	1.3×10^{10}
6	NB 37285 25355	Stream	0.7	0.27	0.222	3630	470	1.7×10^{10}
7	NB 39166 24528	Stream	0.45	0.11	0.455	1950	220	4.3×10^9
8	NB 40130 24417	Culvert: 3 piped sections	1.0	0.09[1]	0.171[1]	1370	410	5.6×10^9

[1]Average of three separate values

Calculated loadings were moderate to high. The highest loadings were seen at the head of the loch (separate arms of Abhainn Ghlas) and moderately high loadings on the north side of the loch nearer to the fishery. The southern shore of the loch was not surveyed. The OS map indicates that there are watercourses that enter that side of the loch in the vicinity of the fishery. These will have the potential to impact more directly on the water quality at the mussel lines. Seawater samples taken at the fishery indicated the presence of moderately high levels of faecal contamination (140 to 420 *E. coli* cfu/100 ml).

Loadings calculated for the two streams on the north towards the mouth of the loch were low. A seawater sample taken off watercourse No. 8 yielded a high result of 2500 *E. coli* cfu/100 ml. This was likely to have been the combined result of the contamination from the stream and a Scottish Water septic tank located in the vicinity.

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

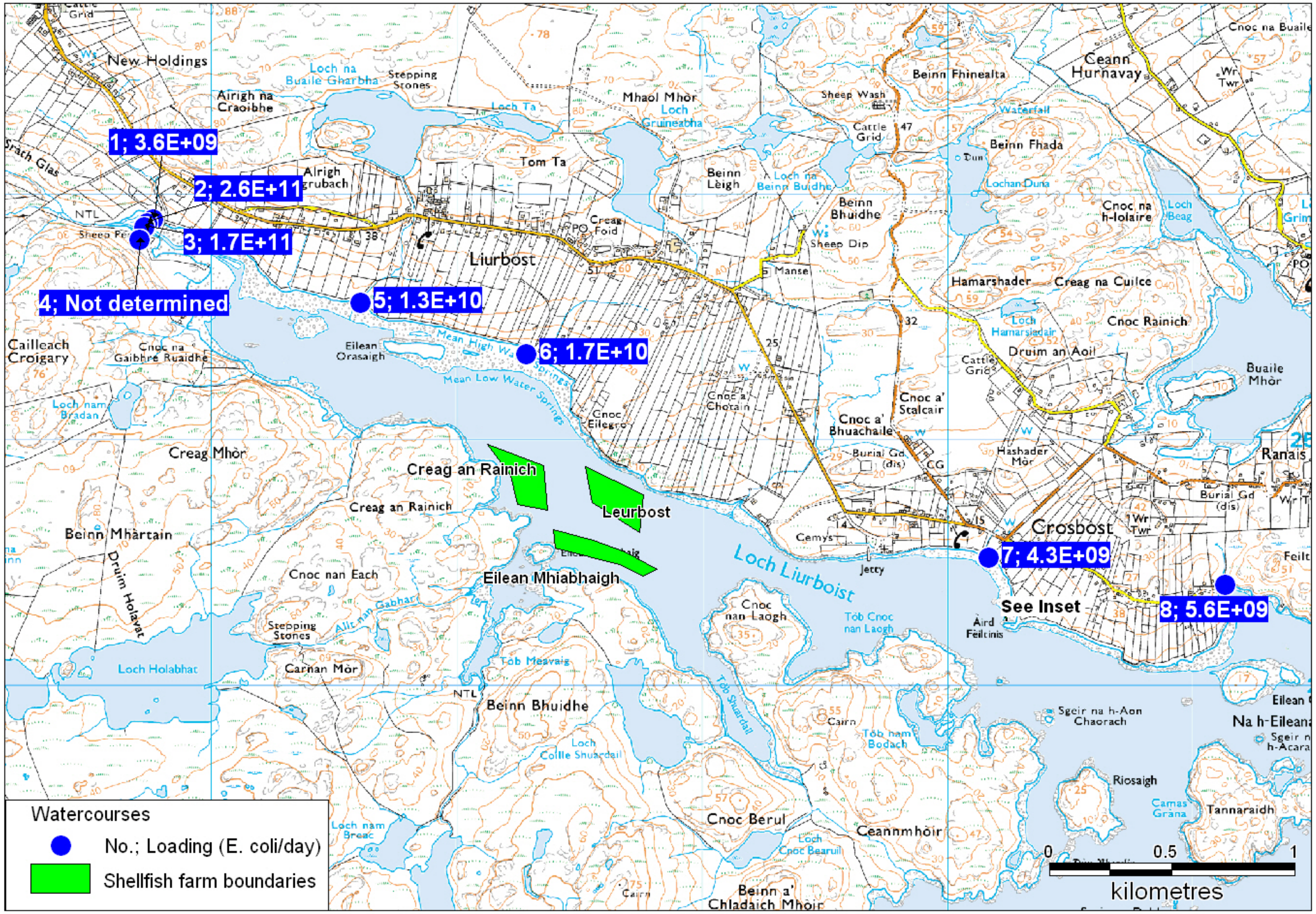

Figure 13.1 Map of stream loadings at Loch Leurbost

14. Bathymetry and Hydrodynamics

The OS map and Hydrographic Chart for Loch Leurbost are shown in Figures 14.1 and 14.2 respectively.

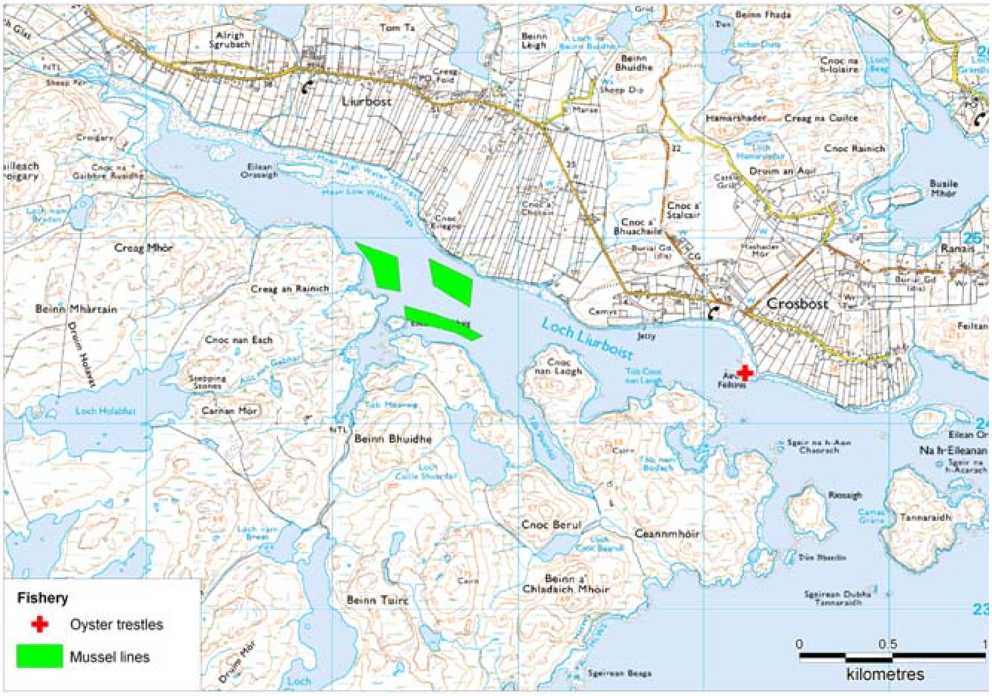

Figure 14.1 OS map of Loch Leurbost

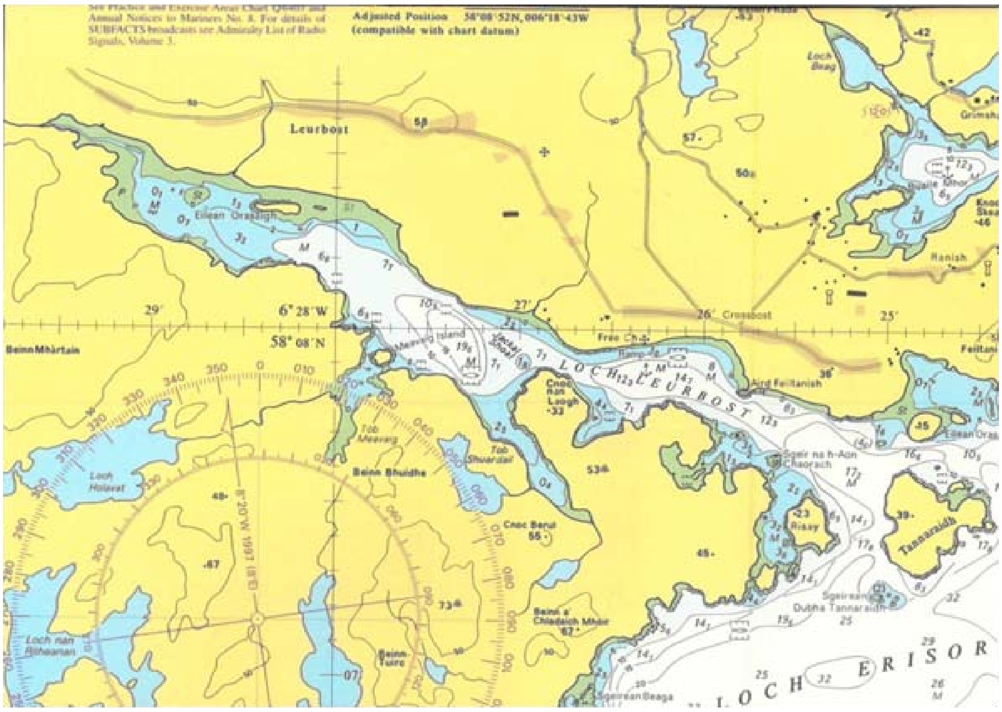

Figure 14.2 Bathymetry at Loch Leurbost

Loch Leurbost lies on the eastern side of the Isle of Lewis. It is on the northern side of Loch Erisort. It lies in an ENE to WSW direction, with the mouth opening onto the outer part of Loch Erisort. Loch Leurbost is approximately 4 km in length and the maximum depth is approximately 20 m (Edwards and Sharples, 1991). There is one sill in the vicinity of Cnoc nan Laogh. The mussel farm is in the vicinity of the basin located on the loch head side of the sill. Depths also increase towards the mouth of the loch where they exceed 17 m. The mouth is partly obstructed by the island of Tannaraidh immediately outside, and by other small islands to each side of the mouth. From the basin in the middle of the loch, depths decrease towards the head. There is a significant drying area in the inner loch, principally at the head and on the north shore. In the vicinity of the basin, two large inlets project into the southern shore of the loch: Tob Meavaig and Tob Shuardell.

14.1 Tidal Curve and Description

The two tidal curves below are for Stornoway, approximately 13 km from the oyster farm and 15 km from the mussel farm. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 BST on 09/09/10 and the second is for seven days beginning 00.00 BST on 16/09/10. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle, including the dates of the shoreline survey.

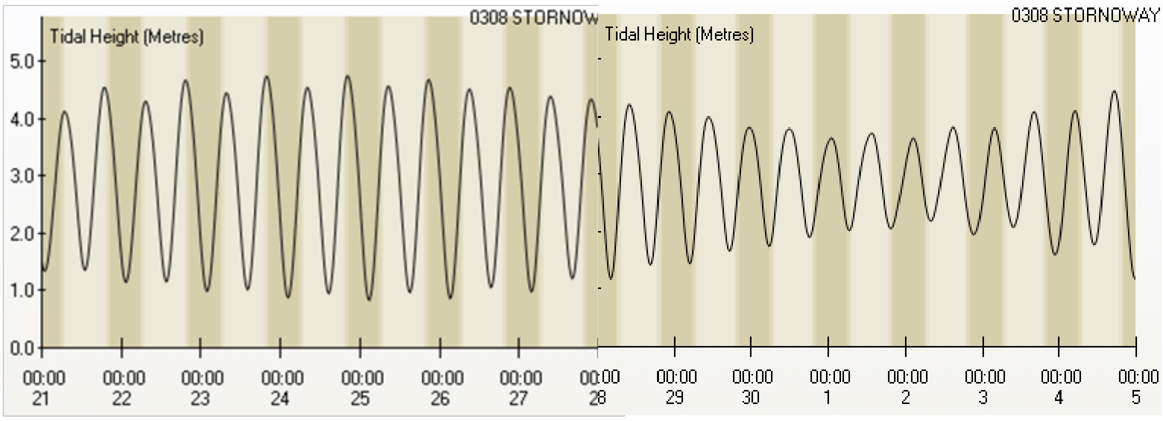

Figure 14.3 Tidal curves for Stornoway

The following is the summary description for Stornoway from TotalTide:

0308 STORNOWAY is a Standard Harmonic port. The tide type is Semi-Diurnal.

HAT	5.5 m
MHWS	4.8 m
MHWN	3.7 m
MSL	2.84 m
MLWN	2.0 m
MLWS	0.7 m
LAT	0.0 m

Predicted heights are in metres above Chart Datum. The tidal range at spring tide is 4.1 m, and at neap tide 1.7 m, and so tidal ranges in the area are moderate.

14.2 Currents

No tidal stream data was available for the vicinity of Loch Leurbost.

SEPA provided data from two current meters at locations immediately outside Loch Leurbost (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
Arbhair	NB 4108 2427	26/01/2001 - 10/07/2001
North Shore	NB 3911 2272	24/11/2008 - 09/12/2008

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.

Mean current speeds at Arbhair were 4.1 cm/s (near-surface), 3.9 cm/s (mid-depth), and 4.6 cm/s (near-bottom). The highest current speed recorded during the period occurred at near-surface and was 38 cm/s (0.38 m/s; approximately 0.8 knots). Current directions at all three depths were quite variable, although there proportion flowing in the south-westerly quadrant was less than in the other quadrants at all three depths. At near-bottom and mid-depth, there was a preponderance of currens flowing towards the north-west and east-south-east. At near-surface, the current flowed northwards over a significant proportion of time. During the period, the strongest winds were from the south and this appears to have modified the currents at near-surface.

Mean current speeds at North Shore were 7.3 cm/s (near-surface), 7.2 cm/s (mid-depth) and 6.7 cm/s (near-bottom). The highest current speed recorded during the period occurred at near-surface and was 30 cm/s (0.30 m/s; approximately 0.6 knots). Current directions at all three depths were more directional than at Arbhair. At near-bottom and mid-depth, the strongest currents flowed in a westerly to south-westerly direction. Although such currents were seen at the surface, there was a stronger flow towards the north-east. During the period, the strongest winds were from the west to south-west direction, although over a significant proportion of the period there were weaker winds from the north.

The currents seen at the two meter locations will not directly relate to those within Loch Leurbost itself but give a general indication of the magnitude to be expected. The Scottish Sea Lochs Catalogue gives a current speed of 18 cm/s at the sill in Loch Leurbost (Edwards and Sharples, 1991). This location is immediately to the east of the mussel farm: currents at the mussel farm would be expected to be somewhat less given the wider and deeper nature of the loch at the farm than at the sill. Currents at the oyster farm would be expected to be slightly lower than at the sill, given the greater depth. The main oyster farm is at one end of a small bay and just west of a promontory: these features would modify the direction of currents with eddies around the promontory occurring on the flood tide and currents following the sweep of the bay on the ebb tide. The oyster trestle on the east side of the promontory would be open to currents from the east during the flood tide and may be subject to currents swept around the promontory on a the ebb tide. The trestles are submerged except at low spring tides, therefore will be affected by the full range of flows through high and low tides most of the time.

The currents recorded at the North Shore location are relevant to movement of contaminants from the new combined Leurbost sewage discharge, which is located approximately 600 m WNW of where the current meter was deployed. A stronger northeasterly current flow at this location suggests that contaminants from the discharge would be carried toward the mouth of Loch Leurbost, at least on the ebbing tide. Currents would also be moving out of Loch Leurbost at the same time, therefore it is unlikely that diluted effluent would be carried toward the fishery. However, should winds drive surface currents northeasterly during a flood tide it is conceivable that these might travel toward, and reach, the oyster fishery at Crosbost.

At a maximum current speed of 0.38 m/s, contaminants would be expected to be taken a maximum distance of just over 5 km over one ebb or flood tide, ignoring any dispersion or dilution. At the speed given in the Sea Lochs Catalogue, perhaps more relevant to the situation within the loch itself, the maximum transport distance would be expected to be less than 3 km.

The Sea Lochs Catalogue gives a calculated flushing time for the loch of 1 day: this is to be expected, despite the relatively slow currents, given the small size of the loch.

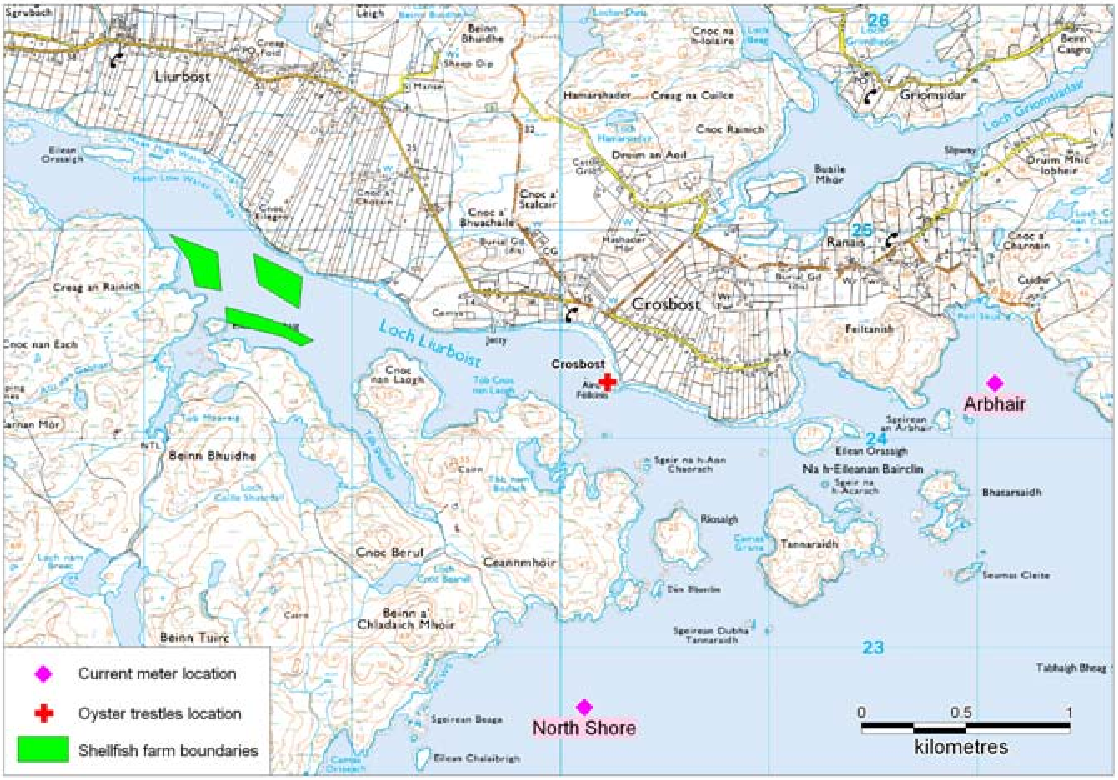

Figure 14.4 Current meter locations

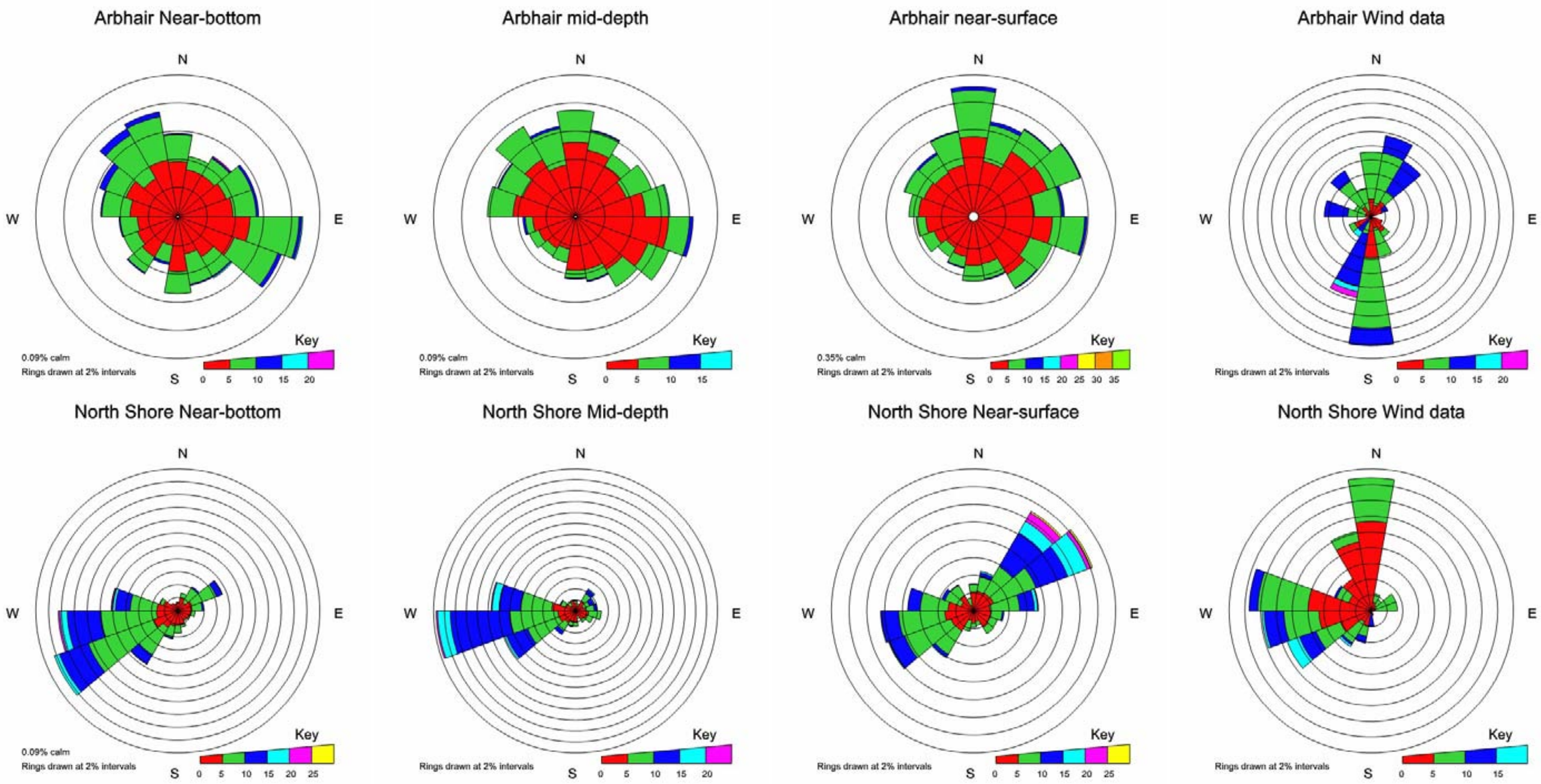

Figure 14.5 Current and wind plots for Arbhair and North Shore

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. The blank space in the centre of a plot relates to the proportion of time for which the current or wind was recorded as stationary. Directions are in degrees magnetic.

14.3 Salinity profiles

Salinity profiles were recorded during the shoreline survey at the locations shown in Figure 14.6. The salinity values are shown in Table 14.2.

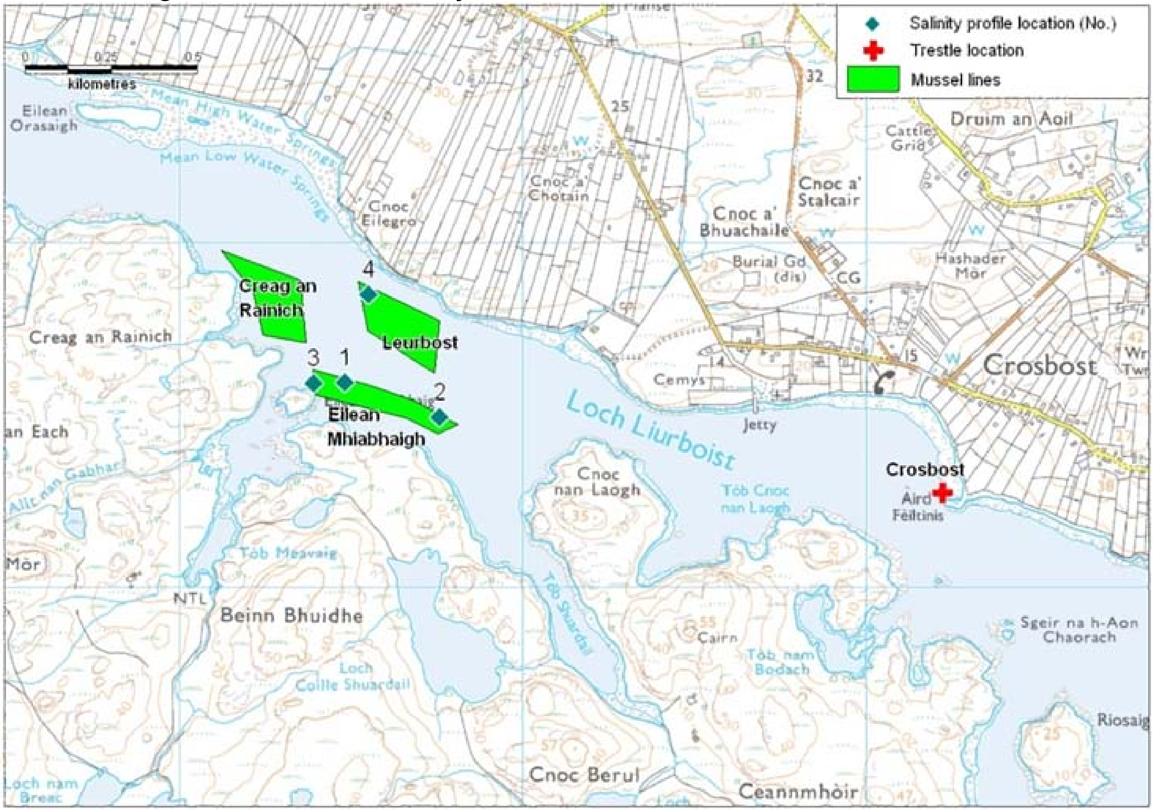

Figure 14.6 Location of salinity profiles

Table 14.2 Salinity profiles recorded during the shoreline survey

Profile	Position	Depth (m)	Salinity (ppt)
1	NB 39162 24551	Surface	17.0
		1	31.9
		5	34.8
		10	34.9
2	NB 38682 24507	Surface	26.8
		1	-
		5	34.9
		10	35.0
3	NB 37393 24595	Surface	-
		1	33.0
		5	34.0
		10	35.0
4	NB 37552 24854	Surface	-
		1	23.0
		5	33.9
		10	34.9

The salinities at depth in each location were similar. The surface and 1 m values show evidence of freshwater influence. There were rain showers on the day the profiles were taken and so this could have contributed to the lower values near, and at, the surface. Edwards and Sharples (1991) gave a fresh to tidal flow ratio of 8 with a calculated salinity reduction of 0.3 ppt. The values recorded during the shoreline survey show a much greater reduction in salinity. This could result in density driven currents within the loch.

14.4 Conclusions

In the vicinity of the mussel farms, the loch is relatively deep and contaminants will be subject to significant dilution. However, stratification detected during the shoreline survey indicates that freshwater-borne pollution may be confined to the upper layer and therefore may receive less dilution than if this did not occur. The oyster farm is located in a drying area and thus contamination arising locally from the shore will be subject to a low level of dilution.

Current speeds within the loch are low. However, due to its small size, predicted maximum transport distances mean that contamination from sources both at the head of the loch and at Crosbost may reach the mussel farm. Contamination arising in the bay at Crosbost will impact on the oyster farm during the ebbing tide.

A stronger northeasterly current flow outside Loch Leurbost suggests that although contaminants from the relocated Luerbost final effluent discharge could be carried toward Loch Leurbost on the ebbing tide, it is unlikely that diluted effluent would be carried toward the Loch Leurbost fisheries as currents would also be moving out of Loch Leurbost at the same time. However, should winds drive surface currents northeasterly during a flood tide it is conceivable that these might travel toward, and reach, the oyster fishery at Crosbost.

15. Shoreline Survey Overview

The shoreline survey was conducted on 21,23 and 29 September 2010 under predominantly rainy conditions. Heavy rain fell on 22 September.

The Creag an Rainich mussel farm consisted of 5 sets of long lines that had been completely harvested prior to survey and so it was not possible to obtain samples from this site.

The Eilean Mhiabhaig site had 2 long lines at the western end and a series of old salmon cage rafts fitted with droppers at the eastern end of the site. The harvester planned to phase out use of the rafts. Some of the lines were being harvested at the time of survey, and the farm is normally harvested in rotation with some lines harvested each year.

The Leurbost site consisted of 5 sets of long lines near the north shore of the loch, with some of the lines too heavy to raise and some of the floats nearly sinking. One of the lines was set toward the centre of the loch.

The harvesters generally collected spat from two sets of spat collection lines set in Loch Erisort, where there was reported to be better settlement.

Monitoring samples for mussels are taken from variable locations and not specifically from the RMP. Sometimes they are taken from the Leurbost site, but often from Creag an Rainich. It varies according to which harvester has provided transport out to the site and where stock is available.

The Pacific oyster farm was comprised of trestles placed to either side of the point at Àird Fèiltinis. A single row of trestles was observed west of the point, although it was not possible to obtain samples for *E. coli* analysis due to poor weather and timing of low tide. The harvester advised that a single trestle was kept east of the point, though this trestle was not seen or sampled during the survey. The RMP was located east of the point, though samples are normally taken from the western end of row of trestles west of the point. The harvester reports that the trestles are only accessible at low spring tides of 1.3 m or less.

Four septic tanks were observed along the north shore, all of which were community tanks. Of these, three were relatively new. No discharge pipes were observed on the shoreline. The fourth tank, at the eastern end of Crosbost, was covered in grass. No pumping apparatus was observed though a confined space warning placard had been installed on the seawall and Scottish Water signage was in place on a fence beyond the seawall. No discharge pipe was found.

Over 250 sheep, plus a small number of cattle and horses, were observed on or near crofts along the north shore and at the head of the loch. Sheep were observed on the shoreline east of Crossbost, but for the most part were all livestock were fenced away from shore.

Small numbers of gulls and cormorants were observed on the mussel floats, and both geese and their droppings were seen on the south shore. No other wildlife was seen.

Water and mussel samples were obtained during the shoreline survey. Samples from freshwater courses in the area contained relatively low concentrations of *E. coli*. Seawater samples were considerably more contaminated, with the highest results obtained from one sample taken from the shoreline between the two septic tanks near the head of the loch and one taken from near the septic tank east of Crosbost (1100 and 2500 *E.coli* cfu/100 ml, respectively).

A marked difference in shellfish E. coli results was observed at the Eilean Mhiabhaigh site. Samples from the southeastern end of the site contained <20 and 230 MPN/100 g, while samples from the northwestern end of the site contained 9200 and 330 MPN/100 g. Samples from the northern end of the Luerbost site contained 1300 and 130 MPN/100 g. At the latter two sample sites, results were considerably lower at 7 m depth than near the surface. However at the remaining sample location the pattern was reversed, though both samples were relatively clean.

Figure 15.1 should show a summary map of most significant findings from survey.

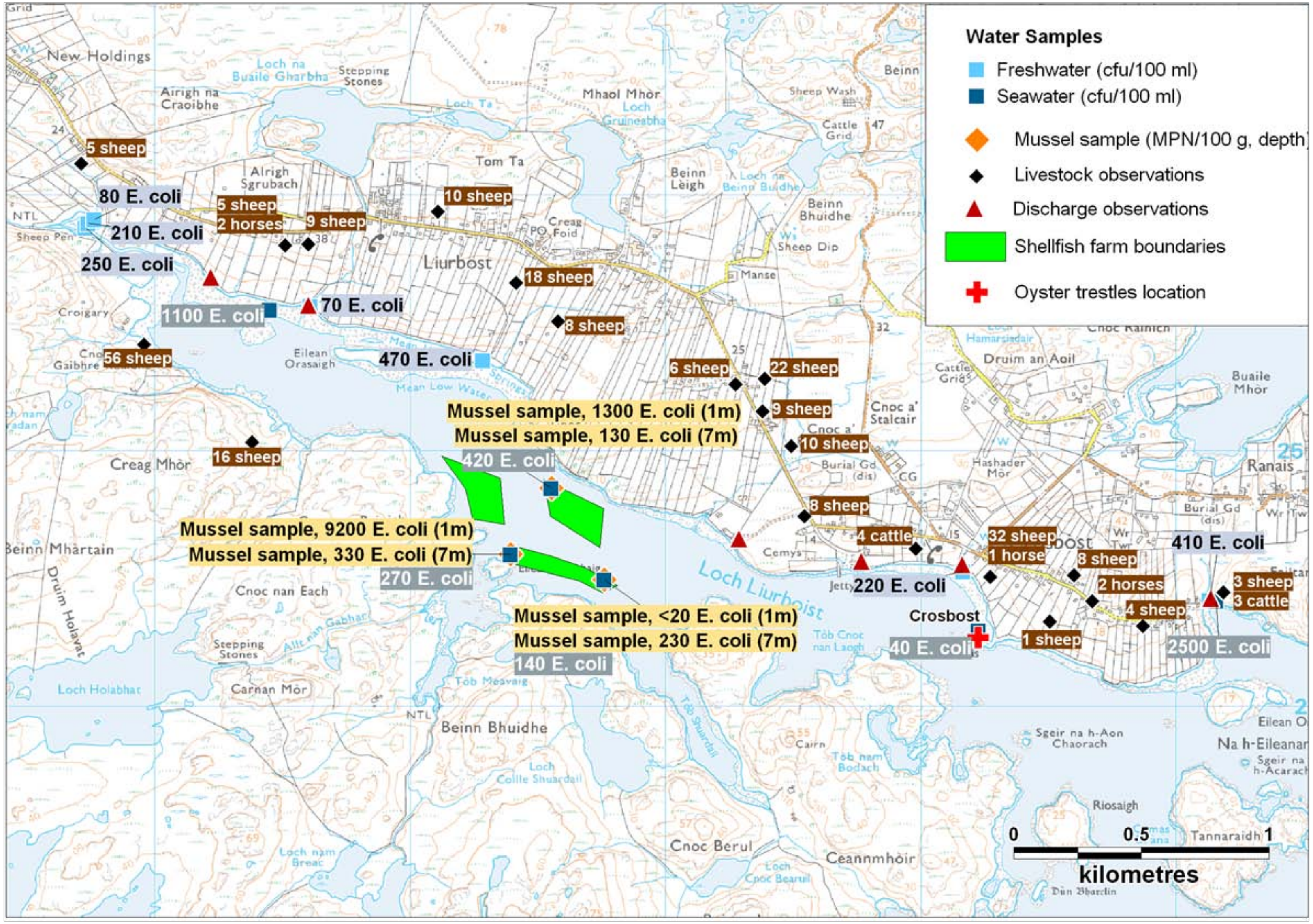

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Figure 15.1 Summary of shoreline survey findings for Loch Leurbost and Loch Leurbost: Crosbost

16. Overall Assessment

Human sewage impacts

Improvement works were completed on three of four Scottish Water discharges to Loch Leurbost. The resulting relocation of the majority of continuous discharges to Loch Erisort is likely to have led to improvements in overall water quality at the fisheries. Improvements in shellfish hygiene monitoring results since 2009, when the improvement works were undertaken, are apparent at both the Loch Leurbost and Loch Leurbost: Crosbost production areas.

Intermittent discharges from storm overlows or emergency overflows at the pumping stations would continue to affect water quality in the loch during and immediately after a spill. The impact from these is likely to be of greatest concern to the Crosbost oyster fishery as the oyster trestles west of Aird Feiltinis lie approximately 250 m from the Crosbost west tank. The mussel farms further to the west lie between two tanks and so may be affected by discharges from either location.

The discharge from the Crosbost East septic tank is still active and is likely to have contributed to the high *E. coli* concentration measured in a seawater sample taken from near the tank during the shoreline survey. Impacts from this discharge are most likely to impact the oyster fishery on the flood tide, when contaminants would be carried westward along the shore. The trestle east of Aird Feiltinis may be more affected by this discharge than the trestles west of the point.

The combined outfall to the Leurbost East, Leurbost West and Crosbost West septic tanks discharges to the waters of Loch Erisort, approximately 2.5 km from the oyster fishery at Crosbost.

Agricultural impacts

The land along the north shore of the loch is crofted, and livestock were observed along much of this area. A significant number of sheep were observed near the head of the loch on the southern shore. It is presumed that sheep would be allowed to graze across the much of south shore. Faecal waste from animals grazing along both shores is likely to be carried to the waters of the loch in rainfall runoff and streams. Land used for growing crops along the northern shore may receive application of manure from winter housing of livestock. Given the numbers of animals recorded in the area, livestock are likely to contribute a significant proportion of the faecal indicator bacteria present in the loch.

Animals kept near the head of the loch, and on land along burns or streams discharging to the head of the loch and to the southeast of the Eilean Mhiabhaigh site are most likely to affect water quality at the mussel farms.

Animals found at or near the shoreline at Crosbost are most likely to affect water quality at the oyster farms.

Wildlife impacts

A variety of wildlife species are known to be present in the area and these may contribute to back ground levels of faecal contamination present in the waters of the loch. Of these, geese and seabirds such as gulls are most likely to occur in the vicinity of the fisheries and may directly deposit faecal material to the waters near the shellfish farms. The presence and movements of these animals are likely to be highly variable and their impact at any given time difficult to predict. Faecal contamination levels from gulls and other seabirds may be higher in the vicinity of the floats used to support the mussel lines, where they are likely to rest and near nesting areas at the mouth of the loch. Geese are likely to graze grassland on the north side of the loch and therefore will contribute faecal contamination to runoff from land along this shore

Seasonal variation

Human population in the area may be higher in the summer months, though it the increase is not likely to be substantial. An increase in livestock populations is expected from roughly May to September, when sheep kept on crofts are likely to have lambs. Winter housing of livestock and use of some of the land as arable may result in application of manure to land in spring.

Daily rainfall has tended to be higher from October to January and lowest during June and July. However, rainfall >20 mm per day was found to occur during all months of the year except February, indicating little seasonality to heavy rainfall.

Historical monitoring at the Loch Leurbost mussel sites indicated higher results were obtained in August, though there were no significant differences by season. At Loch Leurbost: Crosbost there was no clear monthly or seasonal pattern in results.

Results from the Shellfish Growing Waters monitoring scheme through 2007 showed that results at both Loch Leurbost East and Loch Leurbost West were higher during Q3 (July- September), though the difference was not found to be statistically significant.

Rivers and streams

Calculated loadings from streams measured and sampled during the shoreline survey were moderate to high, with highest loadings occurring at the head of the loch. The south shore of the loch was not surveyed, therefore it is not possible to say whether loadings from streams discharging to the south of the fishery were significant. A seawater sample taken from offshore of the stream adjacent to the Crosbost East septic tank showed much higher concentrations of *E. coli* (2500 cfu/100 ml) than were found in the stream itself (410 cfu/100 ml), indicating that the discharge was likely to have been active at the time.

The mussel farms, being nearer to the head of the loch, are likely to be affected by faecal contamination carried in the streams discharging to the head of the loch and also those along the south shore. Contamination levels may be higher at Creag an Rainich, which lies nearer the head of the loch. It is expected that Eilean Mhiabhaigh would be more affected by freshwater sources along the south shore of the loch.

Bathymetry and hydrodynamics

At the mussel farms, water depths are expected to allow for significant dilution of contaminants. However, the stratification observed during the shoreline survey suggests that freshwater-borne pollution contained within a surface layer would be subject to less dilution than would otherwise be expected. At the oyster farm, contamination arising from the areas near the shore would be subject to little dilution given the restricted depths.

The little information available on current movement within the loch suggests relatively slow current speeds. Current data from meters placed outside the loch mouth also indicated that currents are relatively weak and that surface currents may be significantly affected by wind.

Predicted maximum partical transport distances (based on tidal currents alone) within the loch are less than 3 km on a spring tide. A gale force wind would drive a surface current of up to 0.5 m/s, which is significantly higher than the predicted tidal current of 0.18 m/s. Therefore, effects of wind driven currents in this layer may result in greater transport distances than predicted by tidal currents alone inside the loch.

Currents recorded just outside the loch indicated significant wind driven currents at times, with current speeds over 4 times faster at the surface than at depth. Maximum predicted partical transport distances outside the loch, based on the observed maximum of 0.38 m/s, would be just over 5 km over one ebb or flood tide.

A predominant southwesterly wind would tend to drive contaminants from the sewage discharge southwest of the loch toward the mouth of Loch Leurbost. However, on an ebb tide the flow out of Loch Luerbost would tend to keep contaminants from this source from entering the loch.

Correlations between *E. coli* results and tidal state on the spring/neap cycle were found for mussels from Craig an Rainich and for oysters. For the former, the correlation was relatively weak, and results were highest on average during increasing tides, and lowest on average on neap tides. This could be due to contamination being carried further during the stronger tides or due to a larger proportion of the shoreline where livestock have access being inundated during spring tides.

For oysters, the correlation was much stronger, with higher results during spring and decreasing tides. Correlations between *E. coli* results and tidal state on the high/low cycle were found for mussels from Eilean Mhiabhaig and for oysters. At Eilean Mhiabhaig results were higher on the ebb tide than on the flood tide. For oysters however, the correlation was relatively weak and sampling was targeted towards low water.

Temporal and geographical patterns of sampling results

Reported sampling locations did not always align with the location of the sites. Due to this, it was not possible to assess geographic variation in results at the Crosbost site. At the mussel sites, there appeared to be a tendency toward higher results at the eastern side of the fishery.

Overall, *E. coli* results for both species decreased from 2009 onward, implying a corresponding improvement in water quality within the loch. No seasonal effects were seen in either species, though results in mussels were clearly higher in August than in other months. Results in oysters were more variable over the months, with no clear trends apparent.

Water temperature at the time of sampling was not generally recorded so an analysis of results against water temperature was only possible for the Creag an Rainich mussel site, and no significant correlation with results was found.

For the three mussel sites, a correlation between results and recent rainfall was only found between results at Creag an Rainich and rainfall in the previous 2 days. For oysters, correlations were found between *E. coli* results and rainfall in both the preceding 2 and 7 days. The correlation with 7 day rainfall was strongest. However, no correlation was found between either mussel or oyster results and salinity at the time of sampling. These correlations indicated that the oyster site was more affected by rainfall-dependent sources than were the mussel sites. This may be due to the proximity of both a stream and a septic tank, which lie approximately 200 m northwest of the oyster trestles. The correlation at Creag an Rainich is less clear and may be related to its location nearer the head of the loch and rainfall-dependent sources there.

Conclusions

Complex interactions between rainfall, tidal state, potential currents and contamination at the shellfisheries will result in differing variation between the oyster and mussel fisheries. Variation may also occur between the sites within each fishery, however uncertainty regarding the attribution of samples and sampling locations made in impossible to analyse these sufficiently. Contamination from livestock sources is likely to affect the majority of the loch and particularly areas near the head of the loch and the north shore. Although the south shore is unpopulated, its use for rough grazing is likely to result in faecal contamination in streams draining to Loch Leurbost from the south shore.

The main sources of contamination are expected to arise from the stream at the head of the loch, streams along the north shore of the loch, emergency and storm overflows at the sewage pumping stations/septic tanks, and the continuous discharge from Crosbost East. Impacts from sewage spills, when they occur, are likely to affect much of the loch. From the standpoint of human health, these will be of greatest concern at the Crosbost oyster farm as oysters are commonly consumed uncooked and therefore pose a higher health risk if contaminated with sewage.

Correlation with rainfall at the Crossbost oyster site indicated that rainfall-dependent sources of contamination have an affect on results at this fishery. Although results correlated with spring tides and low tide, sampling was targeted toward these conditions and therefore this correlation may not be indicative of pollution source. The nearest potential sources to the oyster fishery are the septic tank and stream located a short distance west of the trestles on the west side of Aird Feiltinis. The trestle east of the point may be more affected by sources east of the fishery, most significantly the septic tank discharge at Crosbost East, just over 1 km to the east. However, as only one trestle is in place at this location, it is not clear whether this area is intended to be an active part of the commercial fishery. Given the change in discharges from continuous to intermittent, it is possible that even monthly monitoring may not reflect contamination levels in oysters from the site after a sewage spill. Further, it is unlikely that *E. coli* results will adequately reflect the risk of contamination with human pathogenic viruses in the case of spillage.

17. Recommendations

Recommendations for the Loch Luerbost production areas follow. The recommended area boundaries, RMPs and the locations of the shellfish farms are shown mapped in Figure 17.1.

Loch Leurbost: Leurbost

Production area

The recommended production area boundaries for the Loch Leurbost production area are the area bounded by lines drawn between NB 3800 2476 to NB 3803 2426 to NB 3780 2428 and NB 3731 2444 to NB 3720 2449 and NB 3700 2503 to NB 3747 2522 extending to MHWS. This represents a slight truncation of the previous boundaries, with areas nearer to sources at the head of the loch and to the south at Tob Meavaig exluded from the recommended boundaries.

RMP

The recommended monitoring point is NB 3725 2492. This moves the monitoring point from the shoreline near the Leurbost site to a point midway along the northern edge of the Creag an Rainich site. This point lies nearer to significant diffuse sources at the head of the loch. As this site had no stock on it in 2010 when the shoreline survey was undertaken, it is recommended that bagged shellfish be placed at the RMP at least two weeks prior to sampling.

Frequency

This area has held seasonal classifications during the past three years, therefore it is recommended that monthly monitoring be maintained.

Depth of sampling

In view of the stratification observed during the shoreline survey, and the likelihood that the signficant sources of faecal contamination to the fishery will be carried in freshwater near the surface, it is recommended that the bagged shellfish be placed at a depth of 1 metre.

Tolerance

A sampling tolerance of 20 meters is recommended to allow for movement of the sampling bag on the lines.

Loch Leurbost: Crosbost

Production area
The recommended production area boundaries are the area bounded by lines drawn between NB 3830 2439 to NB 3835 2453 and NB 3939 2368 to NB 4000 2410 extending to MHWS. The westernmost boundary was curtailed to freshwater and potential sewage overflow in the western part of the current production area.

RMP

The recommended monitoring point is NB 3923 2430, which lies slightly above MLWS at the western end of the trestles west of Aird Feiltinis. This correspons approximately to the monitoring point currently in use, and is located nearest the stream and Crosbost West septic tank. If there are currently no trestles in place at the RMP, bagged oysters should be placed on a trestle set at the RMP at least two weeks prior to sampling.

Frequency

As the area has held seasonal classifications within the last three years, it does not qualify for reduced sampling frequency based on stability and therefore monthly monitoring should be maintained.

Depth of sampling

As the fishery is intertidal, sampling depth is not relevant.

Tolerance

A sampling tolerance of 20 meters is recommended to allow for siting of bagged shellfish at a suitable point on the shoreline that will allow reasonable access for monthly sampling.

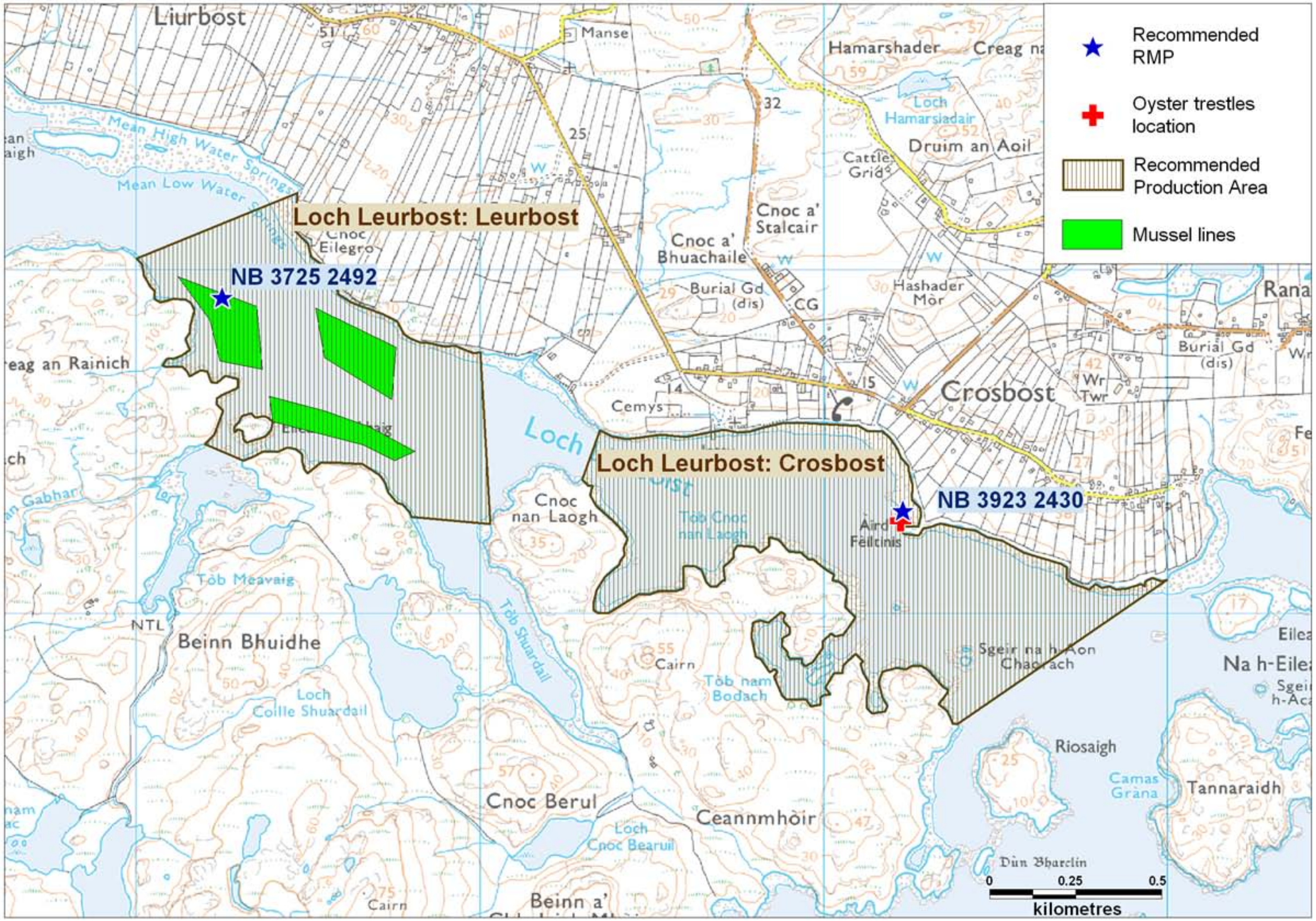

Figure 17.1 Map of recommendations at Loch Leurbost

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Sampling Plan for Loch Leurbost and Loch Leurbost: Crosbost

PRODUCTION AREA	Loch Leurbost	Loch Leurbost: Crosbost
SITE NAME	Creag an Rainich	Site 1 Crosbost
SIN	LH 168 113 08	LH 339 795 13
SPECIES	Common mussels	Pacific oysters
TYPE OF FISHERY	Long line aquaculture	Trestle aquaculture
NGR OF RMP	NB 3725 2492	NB 3923 2430
EAST	137250	139230
NORTH	924920	924300
TOLERANCE (M)	40	20
DEPTH (M)	1	N/A
METHOD OF SAMPLING	Hand	Hand
FREQUENCY OF SAMPLING	Monthly	Monthly
LOCAL AUTHORITY	Comhairle nan Eilean Siar	Comhairle nan Eilean Siar
AUTHORISED SAMPLER(S)	Paul Tyler	Paul Tyler
LOCAL AUTHORITY LIAISON OFFICER	Colm Fraser	Colm Fraser

Table of Proposed Boundaries and RMPs

PRODUCTION AREA	**Loch Leurbost**	**Loch Leurbost: Crosbost**
SPECIES	**Common mussels**	**Pacific oysters**
SIN	**LH 168 113 08**	**LH 339 795 13**
EXISTING BOUNDARY	Area bounded by lines drawn between NB 3700 2544 and NB 3700 2503 and between NB 3800 2476 and NB 3800 2404 extending to MHWS	Area bounded by lines drawn between NB 3800 2476 to NB 3800 2404 and between NB 3939 2368 and NB 4000 2410
EXISTING RMP	NB 378 248	NB 394 242
RECOMMENDED BOUNDARY	Area bounded by lines drawn between NB 3800 2476 to NB 3803 2426 to NB 3780 2428 and NB 3731 2444 to NB 3720 2449 and NB 3700 2503 to NB 3747 2522 extending to MHWS	Area bounded by lines drawn between NB 3830 2439 to NB 3835 2453 and NB 3939 2368 to NB 4000 2410 extending to MHWS
RECOMMENDED RMP	NB 3725 2492	NB 3923 2430
COMMENTS	Area curtailed to exclude intermittent discharges, RMP relocated to nearer head of the loch.	RMP restated, small amendment to boundary

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 x 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.

References:

Alderisio, K.A. and N. DeLuca (1999). Seasonal enumeration of fecal coliform bacteria from the feces of Ring-billed gulls (*Larus delawarensis*) and Canada geese (*Branta canadensis*). *Applied and Environmental Microbiology*, 65:5628-5630.

Bedard, J. and Gauthier, G. (1986) Assessment of faecal output in geese. *Journal of Applied Ecology*, 23:77-90.

Lisle, J.T., Smith, J.J., Edwards, D.D., andd McFeters, G.A. (2004). Occurrence of microbial indicators and *Clostridium perfringens* in wastewater, water column samples, sediments, drinking water and Weddell Seal feces collected at McMurdo Station, Antarctica. *Applied and Environmental Microbiology*, 70:7269-7276.

Scottish Natural Heritage. http://www.snh.org.uk/publications/on-line/wildlife/otters/biology.asp. Accessed October 2007.

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 x 10^{7*} (+)	1.4 x 10^{7}	2.0 x 10^{7}	282	2.8 x 10^{6*} (-)	2.3 x 10^{6}	3.2 x 10^{6}
Crude sewage discharges	252	1.7 x 10^{7*} (+)	1.4 x 10^{7}	2.0 x 10^{7}	79	3.5 x 10^{6*} (-)	2.6 x 10^{6}	4.7 x 10^{6}
Storm sewage overflows					203	2.5 x 10^{6}	2.0 x 10^{6}	2.9 x 10^{6}
Primary	127	1.0 x 10^{7*} (+)	8.4 x 10^{6}	1.3 x 10^{7}	14	4.6 x 10^{6} (-)	2.1 x 10^{6}	1.0 x 10^{7}
Primary settled sewage	60	1.8 x 10^{7}	1.4 x 10^{7}	2.1 x 10^{7}	8	5.7 x 10^{6}		
Stored settled sewage	25	5.6 x 10^{6}	3.2 x 10^{6}	9.7 x 10^{6}	1	8.0 x 10^{5}		
Settled septic tank	42	7.2 x 10^{6}	4.4 x 10^{6}	1.1 x 10^{7}	5	4.8 x 10^{6}		
Secondary	864	3.3 x 10^{5*} (-)	2.9 x 10^{5}	3.7 x 10^{5}	184	5.0 x 10^{5*} (+)	3.7 x 10^{5}	6.8 x 10^{5}
Trickling filter	477	4.3 x 10^{5}	3.6 x 10^{5}	5.0 x 10^{5}	76	5.5 x 10^{5}	3.8 x 10^{5}	8.0 x 10^{5}
Activated sludge	261	2.8 x 10^{5*} (-)	2.2 x 10^{5}	3.5 x 10^{5}	93	5.1 x 10^{5*} (+)	3.1 x 10^{5}	8.5 x 10^{5}
Oxidation ditch	35	2.0 x 10^{5}	1.1 x 10^{5}	3.7 x 10^{5}	5	5.6 x 10^{5}		
Trickling/sand filter	11	2.1 x 10^{5}	9.0 x 10^{4}	6.0 x 10^{5}	8	1.3 x 10^{5}		
Rotating biological contactor	80	1.6 x 10^{5}	1.1 x 10^{5}	2.3 x 10^{5}	2	6.7 x 10^{5}		
Tertiary	179	1.3 x 10^{3}	7.5 x 10^{2}	2.2 x 10^{3}	8	9.1 x 10^{2}		
Reedbed/grass plot	71	1.3 x 10^{4}	5.4 x 10^{3}	3.4 x 10^{4}	2	1.5 x 10^{4}		
Ultraviolet disinfection	108	2.8 x 10^{2}	1.7 x 10^{2}	4.4 x 10^{2}	6	3.6 x 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 x 10^{8}
Cow	230,000	23,600	5.4 x 10^{9}
Duck	33,000,000	336	1.1 x 10^{10}
Horse	12,600	20,000	2.5 x 10^{8}
Pig	3,300,000	2,700	8.9 x 10^{8}
Sheep	16,000,000	1,130	1.8 x 10^{10}
Turkey	290,000	448	1.3 x 10^{8}
Human	13,000,000	150	1.9 x 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 were log transformed prior to statistical tests.

Section 11.5 One way ANOVA comparison of *E. coli* results by season (all mussels)

```
Source   DF      SS     MS     F      P
Season    3   0.813  0.271  0.61  0.607
Error   127  56.015  0.441
Total   130  56.827

S = 0.6641   R-Sq = 1.43%   R-Sq(adj) = 0.00%

                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  ---------+---------+---------+---------+
1      36  1.8462  0.5946  (----------*----------)
2      33  2.0580  0.8062            (-----------*----------)
3      30  1.9173  0.6103     (-----------*-----------)
4      32  1.9090  0.6232     (----------*-----------)
                           ---------+---------+---------+---------+
                                 1.80      2.00      2.20      2.40
Pooled StDev = 0.6641

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

Individual confidence level = 98.96%
```

Section 11.5 One way ANOVA comparison of *E. coli* results by season (oysters from site 1 and site 2)

```
Source  DF      SS     MS     F      P
Season   3   1.543  0.514  1.49  0.226
Error   57  19.650  0.345
Total   60  21.193

S = 0.5871   R-Sq = 7.28%   R-Sq(adj) = 2.40%


                           Individual 95% CIs For Mean Based on Pooled StDev
Level   N    Mean   StDev    +---------+---------+---------+---------
1      15  2.0472  0.6123    (-----------*-----------)
2      16  2.1078  0.6818       (----------*-----------)
3      18  2.4275  0.5772                    (----------*----------)
4      12  2.0919  0.4006    (-------------*------------)
                             +---------+---------+---------+---------
                           1.75      2.00      2.25      2.50

Pooled StDev = 0.5871

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

Individual confidence level = 98.95%
```

Section 11.6.1 Spearman's rank correlation for *E. coli* result and 2 day rainfall (Creag an Rainich mussels)

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.321
```

n=44, p<0.025

Section 11.6.1 Spearman's rank correlation for *E. coli* result and 2 day rainfall (Eilean Mhiabhaig mussels)

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.056
```
n=12, p>0.25

Section 11.6.1 Spearman's rank correlation for *E. coli* result and 2 day rainfall (Loch Leurbost mussels)

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.091
```
n=29, p>0.25

Section 11.6.1 Spearman's rank correlation for *E. coli* result and 2 day rainfall (oysters from site 1 and site 2)

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.330
```
n=47, p<0.025

Section 11.6.1 Spearman's rank correlation for *E. coli* result and 7 day rainfall (Creag an Rainich mussels)

```
Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.094
```
n=44, p>0.25

Section 11.6.1 Spearman's rank correlation for *E. coli* result and 7 day rainfall (Eilean Mhiabhaig mussels)

```
Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.242
```
n=12, p>0.10

Section 11.6.1 Spearman's rank correlation for *E. coli* result and 7 day rainfall (Loch Leurbost mussels)

```
Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.187
```
n=29, p>0.10

Section 11.6.1 Spearman's rank correlation for *E. coli* result and 7 day rainfall (oysters from site 1 and site 2)

```
Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.500
```
n=47, p<0.0005

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the spring/neap cycle (Creag an Rainich mussels)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 17 June 2010 14:52:36

Variables (& observations)	r	p
Angles & Linear (57)	0.264	0.023

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

CIRCULAR-LINEAR CORRELATION

Analysis begun: 17 June 2010 14:41:14

Variables (& observations)	r	p
Angles & Linear (24)	0.354	0.071

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 17 June 2010 15:04:39

Variables (& observations)	r	p
Angles & Linear (39)	0.261	0.086

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the spring/neap cycle (oysters from site 1 and site 2)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 17 June 2010 15:28:56

Variables (& observations)	r	p
Angles & Linear (49)	0.446	9.31E-05

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the high/low cycle (Creag an Rainich mussels)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 17 June 2010 14:51:22

Variables (& observations)	r	p
Angles & Linear (57)	0.172	0.202

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 17 June 2010 14:41:55

Variables (& observations)	r	p
Angles & Linear (24)	0.474	0.008

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 17 June 2010 15:01:43

Variables (& observations)	r	p
Angles & Linear (39)	0.271	0.071

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the high/low cycle (oysters from site 1 and site 2)

CIRCULAR-LINEAR CORRELATION

Analysis begun: 17 June 2010 15:28:16

Variables (& observations)	r	p
Angles & Linear (49)	0.279	0.027

Section 11.6.3 Spearman's rank correlation for *E. coli* result and water temperature (Creag an Rainich mussels)

Pearson correlation of ranked temperature and ranked E coli for temperature = 0.238
n=12, p>0.10

Section 11.6.5 Spearman's rank correlation for *E. coli* result and salinity (Creag an Rainich mussels)

Pearson correlation of ranked salinity and ranked e coli for salinity = -0.056
n=17, p>0.25

Section 11.6.5 Spearman's rank correlation for *E. coli* result and salinity (Eilean Mhiabhaig mussels)

Pearson correlation of ranked salinity and ranked e coli for salinity = -0.290
n=12, p>0.10

Section 11.6.5 Spearman's rank correlation for *E. coli* result and salinity (Loch Leurbost mussels)

Pearson correlation of ranked salinity and ranked e coli for salinity = -0.176
n=21, p>0.10

Section 11.6.1 Spearman's rank correlation for *E. coli* result and salinity (oysters from site 1 and site 2)

Pearson correlation of ranked salinity and ranked e coli for salinity = 0.143
n=25, p>0.10

Section 12 ANOVA comparison of SEPA results by quarter

One-way ANOVA: Loch Leurbost West versus Quarter

Source	DF	SS	MS	F	P
Quarter	3	26912737	8970912	1.14	0.367
Error	14	110066220	7861873		
Total	17	136978957			

S = 2804   R-Sq = 19.65%   R-Sq(adj) = 2.43%

```
                       Individual 95% CIs For Mean Based on
                       Pooled StDev
Level  N  Mean  StDev  ------+---------+---------+---------+---
Q1     4  1420   1467  (-----------*-----------)
Q2     4  1520   1711  (-----------*-----------)
Q3     5  4079   4604              (---------*----------)
Q4     5  1190   1584  (----------*---------)
                       ------+---------+---------+---------+---
```

```
                              0       2500       5000       7500

Pooled StDev = 2804
```

One-way ANOVA: Loch Leurbost East versus Quarter

```
Source    DF          SS        MS     F      P
Quarter    3   157774819  52591606  0.53  0.673
Error     10   995642217  99564222
Total     13  1153417036

S = 9978   R-Sq = 13.68%   R-Sq(adj) = 0.00%


                       Individual 95% CIs For Mean Based on Pooled StDev
Level  N  Mean  StDev    ---+---------+---------+---------+------
Q1     4  2763   3046        (----------*----------)
Q2     3  4400   1732        (-----------*------------)
Q3     4  9143  17905              (----------*----------)
Q4     3    37     15    (------------*------------)
                         ---+---------+---------+---------+------
                       -10000         0     10000     20000

Pooled StDev = 9978
```

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>

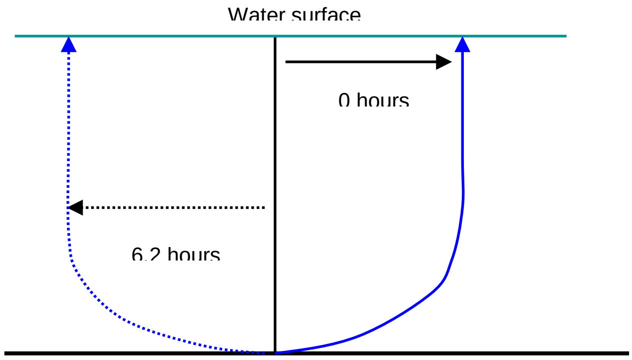
Currents in estuarine and coastal waters are generally driven by one of three mechanisms: 1) Tides, 2) Winds, 3) Density differences.

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.

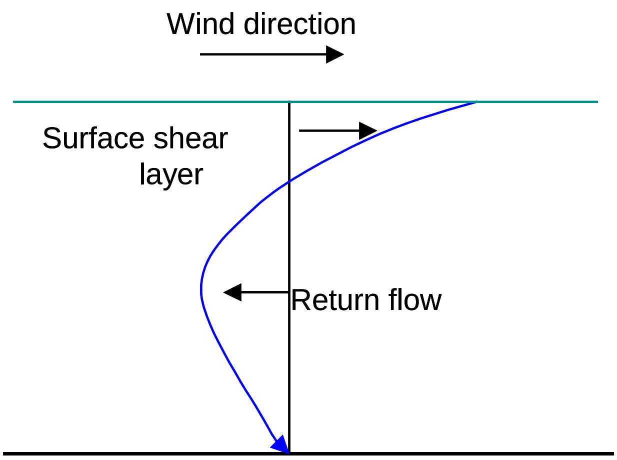
Wind and density driven current also lead to persistent movement of water and are particular important in regions of relatively low tidal velocities characteristic of many of the water bodies in Scottish waters. Whilst tidal flows generally move material in more or less the same direction at all depths, 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.

a)



b)



c)

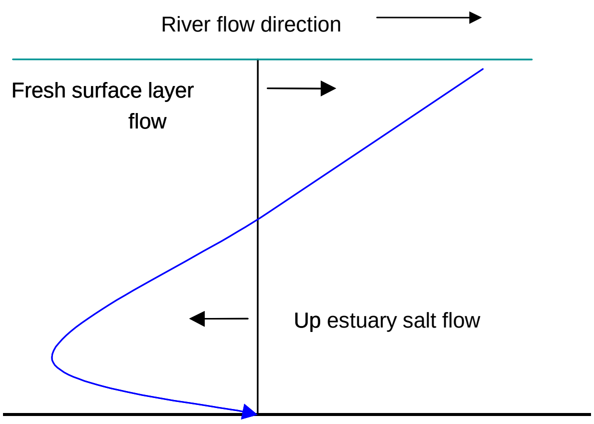


Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

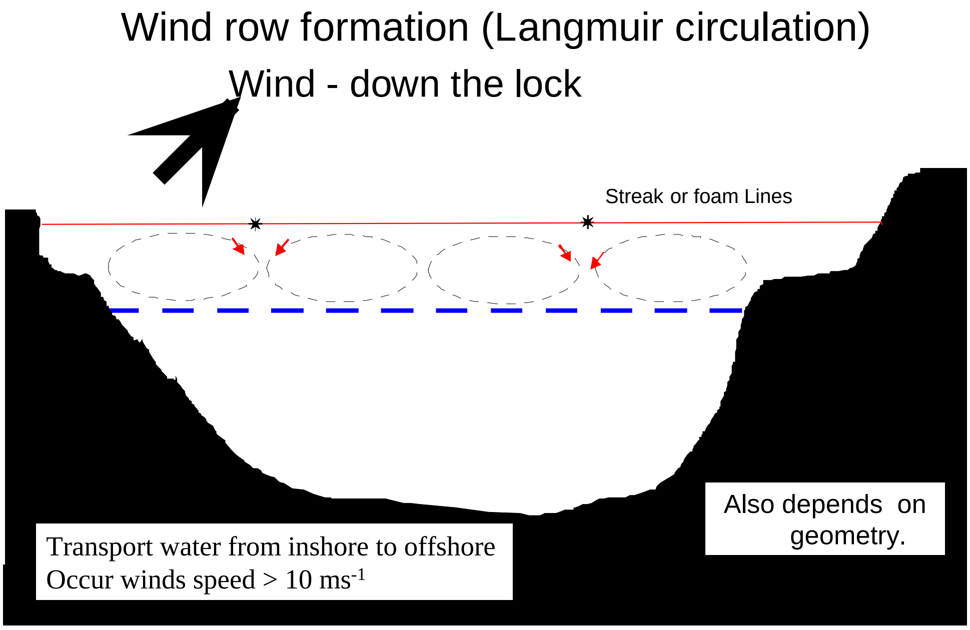


Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

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 Leurbost and Loch Leurbost: Crosbost
Site name:	Site 1 (LH 339 795), Site 2 (LH 339 721), Creag an Rainich (LH 168 113), Loch Leurbost (LH 168 114) and Creag an Mhiavhaig (LH 168 732)
Species:	Pacific oyster and common mussel
Harvester:	Ian Campbell, Calum Iain, Malcolm MacDonald, Kenneth Macleod, Michael Macleod
Local Authority:	CnES, Lewis & Harris
Status:	Existing
Date Surveyed:	21-23 and 29 September 2010
Surveyed by:	M. Price-Hayward, P. Tyler
Existing RMP:	Loch Leurbost NB 378 248, Crosbost NB 394 242
Area Surveyed:	North shore of loch from head to East of Crosbost

Weather observations

21 September: Overcast, Air temp 16C, Wind S up to F4, showers

23 September: Overcast, Air temp 12C, Wind N up to F6, showers - heavy rain on previous day

29 September: Overcast, Air temp 12C, Winds SE up to F4, rain

Site Observations

Fishery

The fishery at Loch Leurbost consists of the following sites:

Production Area	Site	SIN	Species
Loch Leurbost	Creag an Rainich	LH 168 113 08	Common Mussels
Loch Leurbost	Eilean Mhiabhaig	LH 168 732 08	Common Mussels
Loch Leurbost	Leurbost	LH 168 114 08	Common Mussels
Loch Leurbost: Crosbost	Site 1 Crosbost	LH 339 795 13	Pacific Oysters
Loch Leurbost: Crosbost	Site 2 Crosbost	LH 339 721 13	Pacific Oysters

All the mussel sites are long-line farms, with droppers to between 5 and 7 meters depth. The Creag an Rainich site consisted of 5 sets of long lines that had been completely harvested prior to survey and so it was not possible to obtain samples from this site.

The Eilean Mhiabhaig site had 2 long lines at the western end and a series of old salmon cage rafts fitted with droppers at the eastern end of the site. The harvester plans to phase out use of the rafts as they were approach the end of their useful life. Additional rafts were anchored beyond the area recorded. These were reported by the harvester to be used only for storage of gear. Some of the lines were being harvested at the time of survey, and the harvester reports the farm is normally harvested in rotation with some lines harvested each year.

The Leurbost site consisted of 5 sets of long lines near the north shore of the loch, with some of the lines too heavy to raise and some of the floats nearly sinking. One of the lines was set well away from the others and was nearly in the centre of the loch.

The harvesters generally collect spat from two sets of spat collection lines set in Loch Erisort, where there is reported to be better settlement.

Monitoring samples for mussels are taken from variable locations and not specifically from the RMP. Sometimes they are taken from the Leurbost site, but often from Creag an Rainich. It varies according to which harvester has provided transport out to the site and where stock is available.

The Pacific oyster farm lies lies east of Crosbost jetty. Oysters are grown on trestles placed to either side of the point at Àird Fèiltinis. The harvester reports that the trestles are only accessible at low spring tides of 1.3 m or less. A single row of trestles west of the point were observed during the survey, although it was not possible to obtain samples for *E. coli* analysis due to poor weather and timing of low tide coinciding with postal cutoff times. The harvester advised that a single trestle lies east of the point, though it was not possible to get to this trestle during the survey. The RMP lies east of the point, though samples are normally taken from the western end of the western set of trestles.

Sewage/Faecal Sources

Four septic tanks were observed along the north shore, all of which were community tanks. Of these, three were relatively new. No EO or CSO pipes were observed on the shoreline. The main outfall for these tanks discharges outside the loch and the location of this is recorded in the Loch Erisort shoreline survey report. A water sample taken from near the discharge pipe (shown in Figure 3) was found to contain 50 *E. coli*/100 ml.

The fourth tank, at the eastern end of Crosbost, was covered in grass. No pumping apparatus was observed though a confined space warning placard had been installed on the seawall and Scottish Water signage was in place on a fence beyond the seawall. No discharge pipe was found.

Crofts line the northern shore of the loch, and many of these had livestock. Livestock were also observed around the head of the loch. Sheep were observed on the shoreline near the East Crosbost septic tank. The south side of the loch was unpopulated and some sheep were seen grazing on this side of the loch.

Seasonal Population

The area is relatively remote, with no specific tourist attractions, though there is some B&B and guest house accommodation. Some of the homes in the area are likely to be occupied only seasonally, with a higher number of people present during the summer season than at other times of year.

Boats/Shipping
A number of tenders and small open boats, as well as some small fishing vessels, were observed at Crosbost pier and in a small cove on the opposite side of the loch. Small open boats were also seen in the small bay at the east end of Crosbost. A yacht was observed anchored in a small inlet on the south side of the loch, east of where the fishing boats were observed.

Land Use
Land use on the north side of the loch is predominantly crofting, with livestock present on most crofts. A limited amount of what appeared to be small-scale arable agriculture (possibly just silage) was observed on some of the crofts. The remainder of the land around the loch was rough and uninhabited moorland.

Over 250 sheep, plus a small number of cattle and horses, were observed on or near crofts along the north shore and at the head of the loch. Sheep were observed on the shoreline east of Crossbost, but for the most part were fenced away from shore.

Wildlife/Birds
Small numbers of gulls and cormorants were observed on the mussel floats, and both geese and their droppings were seen on the south shore. No other wildlife was seen.

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 voe or loch.

Figure 1. Map of Shoreline Observations – Loch Leurbost West

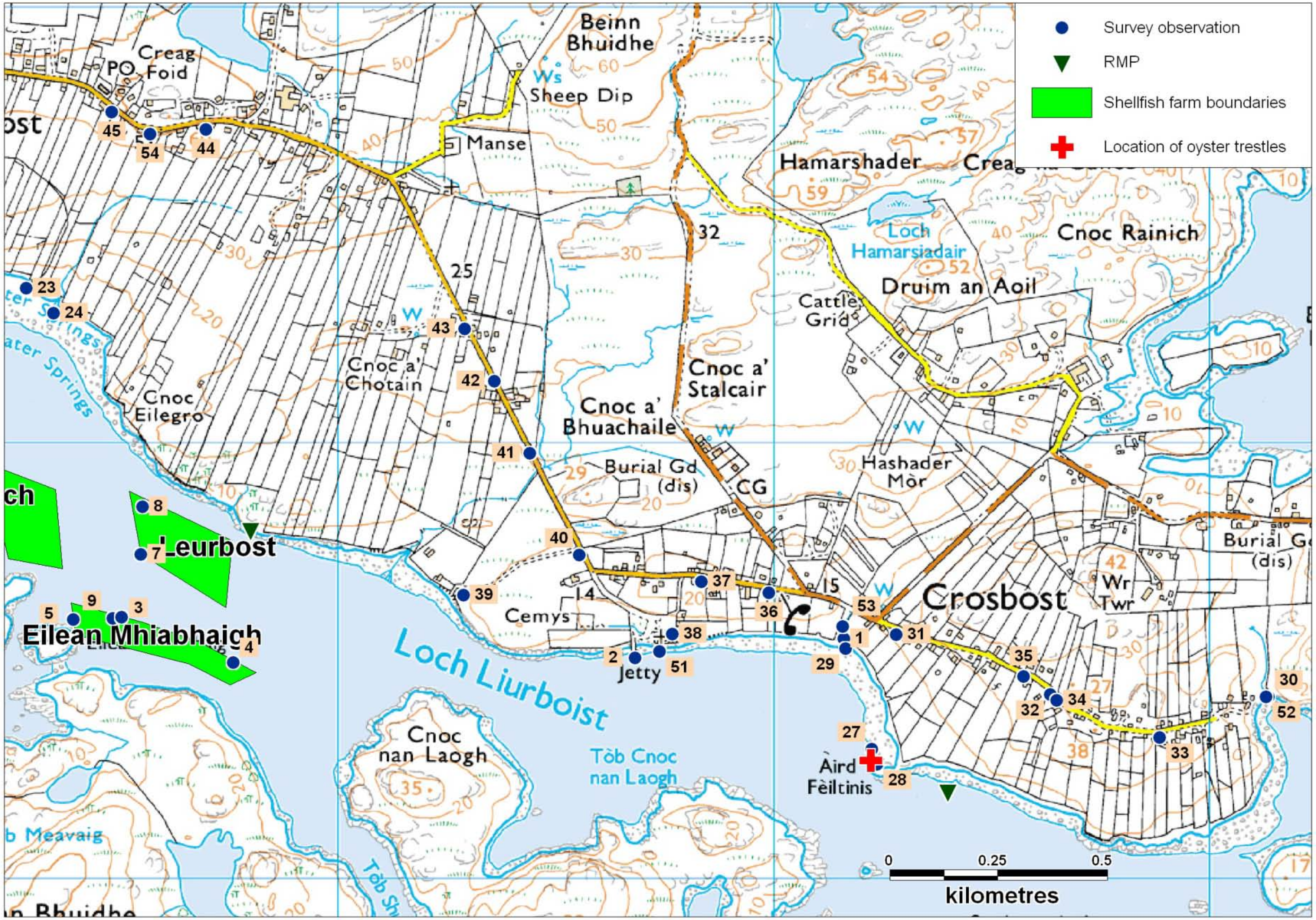


Figure 2. Map of Shoreline Observations – Loch Leurbost East

Table 1. Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Description
1	21/09/2010	09:50	NB 39162 24551	139162	924551	Figure 5	WWTW Crosbost.
2	21/09/2010		NB 38682 24507	138682	924507	Figure 6	Crosbost pier, 24 small workboats and tenders, 4 larger workboats on other side of loch
3	21/09/2010		NB 37484 24597	137484	924597	Figure 7,8	Mussel service barge used for harvesting at Eilean Mhiabhaig
4	21/09/2010		NB 37760 24496	137760	924496		Mussel samples 1 (bottom) and 2 (top), water sample 3, droppers to 7 meters
5	21/09/2010		NB 37393 24595	137393	924595		Mussel samples 4 (bottom) and 5 (top), water sample 6
6	21/09/2010		NB 37123 24980	137123	924980		Mussel farm - no stock on this site
7	21/09/2010		NB 37548 24744	137548	924744		Occassional cormorants and gulls on floats
8	21/09/2010		NB 37552 24854	137552	924854		Mussel sample 7 (bottom) and 8 (top), water sample 9
9	21/09/2010	12:10	NB 37504 24600	137504	924600		Classification and biotoxin samples, water temperature 12.5C
10	23/09/2010	10:02	NB 35762 25907	135762	925907		Stream feeding into head of loch, water sample 22, w 1.7m, d1 0.1m flow 0.304m/s, d2 0.08m flow 0.275 m/s
11	23/09/2010	10:05	NB 35739 25890	135739	925890	Figure 9	Stream at head of loch, water sample 23, w 6.7m, d 0.36m, flow 0.6 m/s
12	23/09/2010		NB 35727 25873	135727	925873		Stream at head of loch 3, water sample 24, w 3m, d 0.23m, flow 1.146 m/s
13	23/09/2010		NB 35708 25824	135708	925824		Branch 4 of stream at head of loch, no water sample, w 2.7m, d 0.32, flow 0.743m/s
14	23/09/2010		NB 35851 25852	135851	925852		Goose droppings
15	23/09/2010		NB 35916 25831	135916	925831		Shed for sheep dipping, boat
16	23/09/2010		NB 35984 25802	135984	925802		Small, shallow stream - not measured or sampled
17	23/09/2010		NB 36097 25763	136097	925763		Land drainage
18	23/09/2010		NB 36281 25592	136281	925592		7 geese seen flying overhead
19	23/09/2010		NB 36447 25570	136447	925570		Land drainage
20	23/09/2010		NB 36449 25553	136449	925553		Sample 25, sea water
21	23/09/2010	11:03	NB 36609 25567	136609	925567		Stream, water sample 26, w 1.3m, d 0.27m, flow 0.622m/s
22	23/09/2010		NB 36654 25503	136654	925503	Figure 10	Photograph looking up shore. 16 sheep observed on hill above opposite shore, 24 more at head of loch
23	23/09/2010	11:23	NB 37285 25355	137285	925355		Stream, water sample 27, w 0.7m, d 0.27m, flow 0.222m/s

No.	Date	Time	NGR	East	North	Associated photograph	Description
24	23/09/2010	11:29	NB 37348 25298	137348	925298		Stream, not sampled or measured
25	23/09/2010		NB 36603 25565	136603	925565		Concreted and steel access cover on shoreline
26	23/09/2010		NB 36220 25676	136220	925676	Figure 11,12	Septic tank, photograph
27	23/09/2010		NB 39225 24297	139225	924297	Figure 13	Oyster farm, one row of wide trestles. West end of oyster trestles, norovirus sample, water sample 28
28	23/09/2010		NB 39238 24262	139238	924262		East end of oyster trestles
29	23/09/2010		NB 39166 24528	139166	924528		Stream, water sample 29, w 0.45m, d 0.11, flow 0.455m/s
30	23/09/2010		NB 40136 24418	140136	924418	Figure 14	Septic tank at small bay, 5 small boats on moorings, 2 sheep on shoreline, photograph
31	23/09/2010		NB 39281 24560	139281	924560		1 horse, 32 sheep on crofts between septic tank and oyster farm
32	23/09/2010		NB 39635 24423	139635	924423		2 sheep on garden and porch, house uphill from road
33	23/09/2010		NB 39886 24324	139886	924324		4 sheep
34	23/09/2010		NB 39650 24410	139650	924410		2 horses uphill
35	23/09/2010		NB 39574 24464	139574	924464	Figure 15	8 sheep uphill from road, 1 downhill, view looking west along shore
36	23/09/2010		NB 38989 24656	138989	924656		4 cattle downhill from road
37	23/09/2010		NB 38834 24682	138834	924682		House under construction
38	23/09/2010		NB 38768 24562	138768	924562		Church hall/ car park
39	23/09/2010		NB 38289 24651	138289	924651	Figure 16	Septic tank/WWTW
40	23/09/2010		NB 38554 24743	138554	924743		8 sheep across road from entrance to WWTW
41	23/09/2010		NB 38441 24976	138441	924976		10 sheep uphill from road
42	23/09/2010		NB 38359 25142	138359	925142		9 sheep plus 22 further uphill and to west
43	23/09/2010		NB 38292 25262	138292	925262		6 sheep
44	23/09/2010		NB 37698 25720	137698	925720		8 sheep downhill
45	23/09/2010		NB 37481 25760	137481	925760		18 sheep downhill
46	23/09/2010		NB 37111 25855	137111	925855		10 sheep uphill
47	23/09/2010		NB 36614 25846	136614	925846		9 sheep
48	23/09/2010		NB 36525 25850	136525	925850		2 horses plus 5 sheep
49	23/09/2010		NB 36390 25858	136390	925858		56 sheep visible across loch (same as seen in obs 46)
50	23/09/2010		NB 35745 26158	135745	926158		5 sheep just below road
51	29/09/2010	07:59	NB 38739 24521	138739	924521	Figure 6	Pipe behind church, drains roof runoff

No.	Date	Time	NGR	East	North	Associated photograph	Description
52	29/09/2010	08:23	NB 40130 24417	140130	924417	Figure 17	Culvert, flowing through three pipe sections with a total width of 1m. Depth and flow recorded for each section. Seawater sample taken 5m west of stream. 3 cattle
53	29/09/2010	08:50	NB 39159 24579	139159	924579	Figure 18	Around 15 boats seen moored at Crosbost and across the loch. Bigger vessels generally across loch
54	29/09/2010	08:58	NB 37570 25709	137570	925709		Vantage point for photograph looking south across fishery

Photos referenced in the table can be found attached as Figures 5-18.

Sampling

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

These readings are recorded in Table 1 as salinity in parts per thousand (ppt).

Samples of seawater were also tested for salinity by the laboratory using a salinity meter under more controlled conditions. These results are shown in Table 2, given in units of grams salt per litre of water. This is the same as ppt.

Table 2. Water Sample Results

No.	Date	Sample	Grid Ref	Type	*E. coli* (cfu/100 ml)	Salinity (g/L)
1	23/09/2010	LBST 24	NB 3573 2587	Freshwater	250	
2	23/09/2010	LBST 23	NB 3574 2589	Freshwater	210	
3	23/09/2010	LBST 22	NB 3576 2591	Freshwater	80	
4	23/09/2010	LBST 25	NB 3645 2555	Seawater	1100	*
5	23/09/2010	LBST 26	NB 3661 2557	Freshwater	70	
6	23/09/2010	LBST 27	NB 3729 2536	Freshwater	470	
7	21/09/2010	LBST 6	NB 3739 2460	Seawater	270	16.9
8	21/09/2010	LBST 9	NB 3755 2485	Seawater	420	15.2
9	21/09/2010	LBST 3	NB 3776 2450	Seawater	140	27.4
10	23/09/2010	LBST 29	NB 3917 2453	Freshwater	220	
11	23/09/2010	LBST 28	NB 3923 2430	Seawater	40	*
12	29/09/2010	LBST 30	NB 4013 2442	Freshwater	410	
13	29/09/2010	LBST 31	NB 4013 2442	Seawater	2500	28.5
14	22/09/2010	EST 15	NB 3858 2292	Seawater	50	33.8

* No salinity recorded for these samples

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Species	Depth (m)	*E. coli* (mpn/100g)
1	21/09/2010	LBST 1	NB 3776 2450	Mussel	7	230
2	21/09/2010	LBST 2	NB 3776 2450	Mussel	1	<20
3	21/09/2010	LBST 4	NB 3739 2460	Mussel	7	330
4	21/09/2010	LBST 5	NB 3739 2460	Mussel	1	9200
5	21/09/2010	LBST 7	NB 3755 2485	Mussel	7	130
6	21/09/2010	LBST 8	NB 3755 2485	Mussel	1	1300

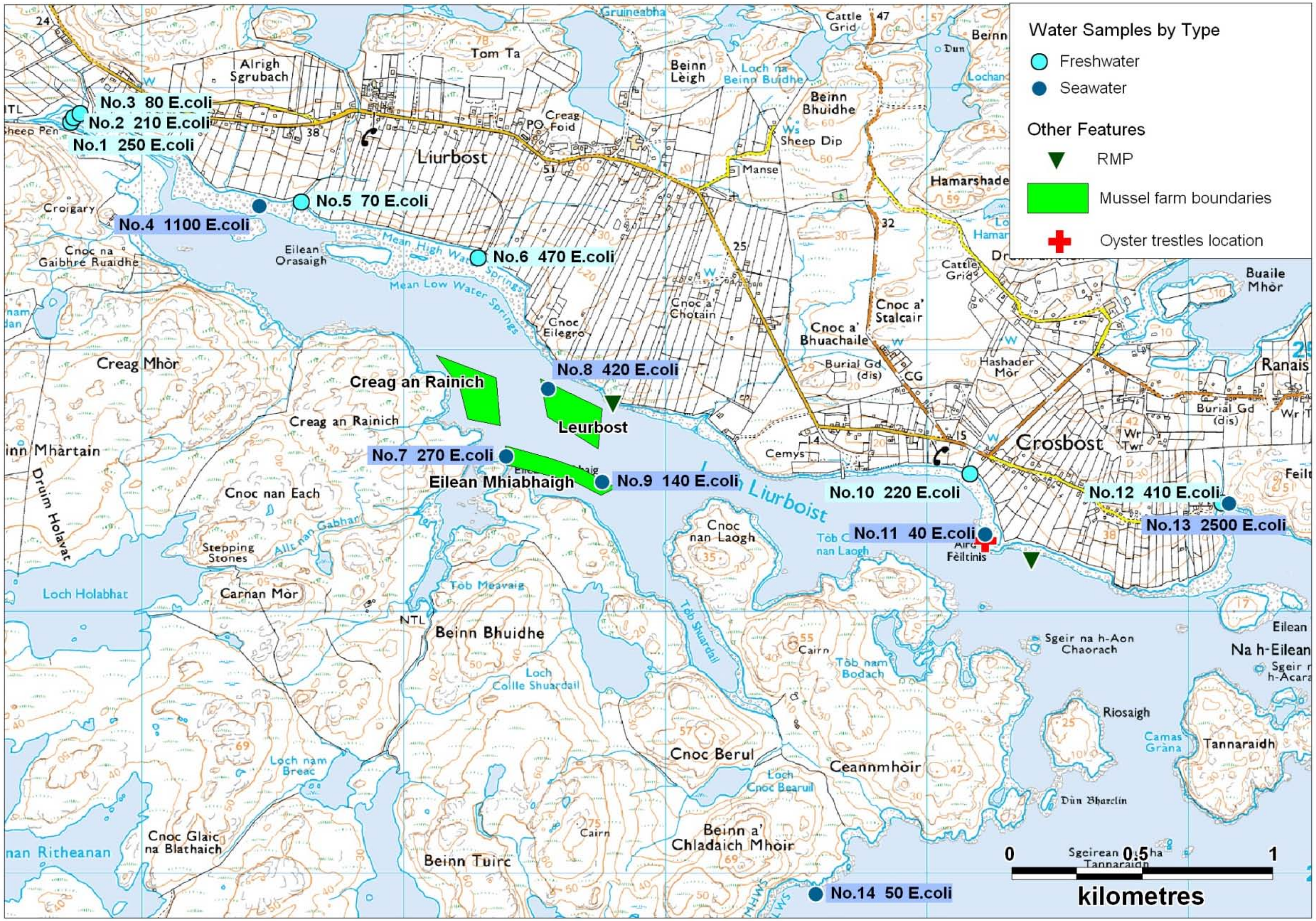


Figure 3. Water sample results map for Loch Leurbost

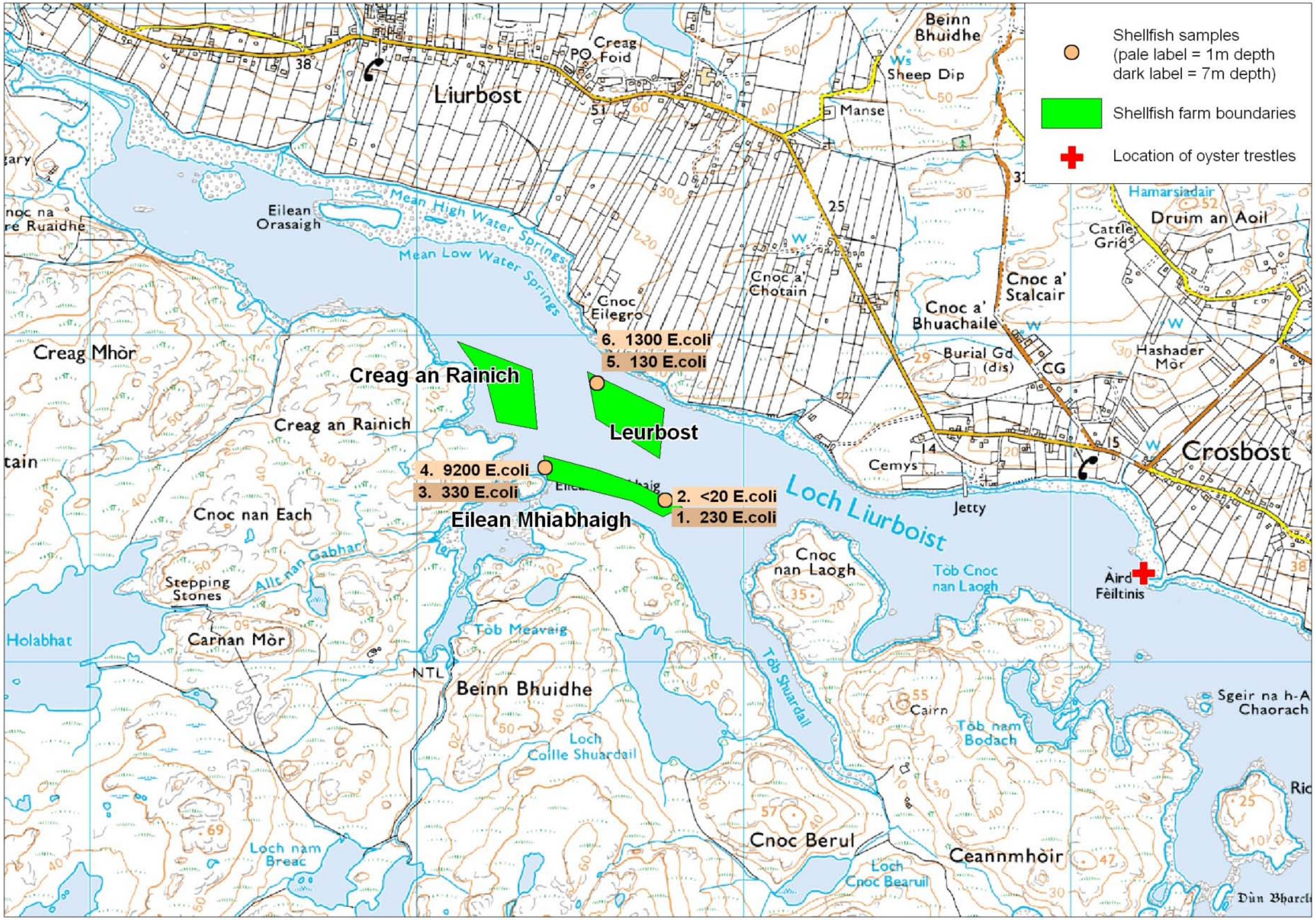


Figure 4. Shellfish sample results map for Loch Leurbost

Photographs

Figure 5. Newer septic tank at Crosbost

Figure 6. Small boats east of Crosbost pier

Figure 7. Harvesting barge at Eilean Mhiabhaig, looking toward south shore

Figure 8. Looking northwest along mussel lines from barge, Creag an Rainich site visible in distance

Figure 9. Part of the stream at the head of Loch Leurbost

Figure 10. Homes and livestock above north shore

Figure 11. Septic tank at Leurbost, near head of loch

Figure 12. View looking north across septic tank installation toward road

Figure 13. Looking east across Crosbost oyster farm

Figure 14. Near septic tank on small bay at east end of Crosbost, sheep on shore

Figure 15. View looking west along north shore from east Crosbost

Figure 16. Septic tank with mussel farms visible in background

Figure 17. Stream flowing through culvert, East Crosbost

Figure 18. Crosbost jetty, view of boats moored on opposite side of loch

Figure 19. Looking south across fishery

Norovirus Testing Summary

Loch Leurbost: Crosbost

Oyster samples taken from the oyster trestles at Crosbost were submitted for Norovirus analysis quarterly from September 2010. No further samples were obtained until May 2011. The result for that sample was not yet available at the time of reporting. Two subsequent samples are to be taken during July and December 2011. Results to date are summarised in the table below.

Ref No.	Date rec'd	NGR	GI	GII
10/419	23/09/2010	NB 3923 2430	not detected	not detected