Scottish Sanitary Survey Project

Sanitary Survey Report
Loch Erisort: Outer
LH 357
February 2010

Cefas

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Report Distribution – Loch Erisort: Outer

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1. General Description

Loch Erisort (Gaelic name *Loch Éireasort*) is a sea loch located on the eastern side of the Isle of Lewis in the Outer Hebrides (Figure 1.1). It is approximately 15km in length, and 4km wide at its mouth. Several small freshwater lochs drain into Loch Erisort. Maximum depth is reported to be 22 m, with two sills both at mean depths of 4 m. It is oriented east-west with its mouth to the east. The entrance to the loch is protected by the island Eilean Chaluim Chille, leaving an open channel approximately 0.5 km wide facing northeast.

Loch Erisort is located approximately 15 km southwest of the town of Stornoway and the village of Baile Ailein (Balallan) stretches along the north shore at the head of the loch. Settlement along the south shore is concentrated around two villages of Tabost and Gearraidh Bhaird.

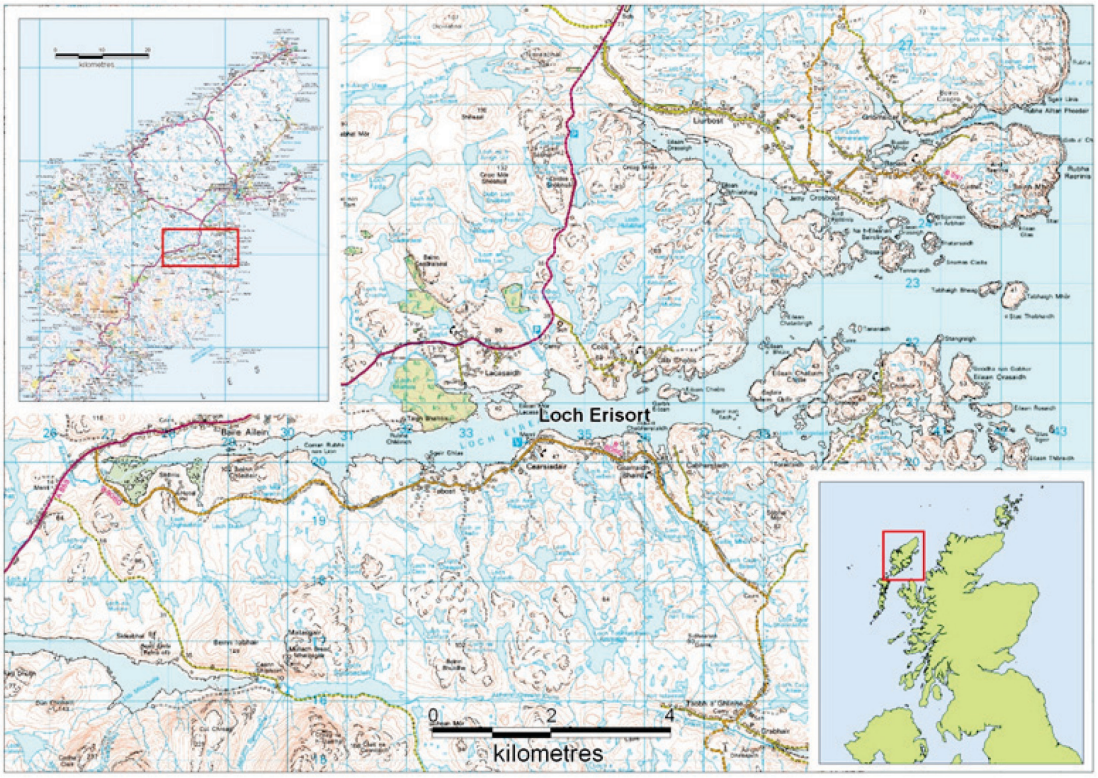

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Figure 1.1 Location Loch Erisort

2. Fishery

The sanitary survey was undertaken as a result of the ranking achieved by the site on a risk matrix. The high ranking was primarily driven by the number of changes to classification and the number of unusual results (i.e. results outwith classification).

Table 2.1 Loch Erisort shellfish farms

Production Area	Site	SIN	Species	RMP
Loch Erisort: Outer	Garbh Eilean	LH 357 747 08	Common mussels	N/A
	Gob Glas	LH 357 744 08	Common mussels	NB 352 206

The Loch Erisort: Outer production area is defined as an area bounded by lines drawn between NB 3300 2069 to NB 3300 1993 and between NB 3700 2064 to NB 3700 2144. The RMP is located on the Gob Glas site. Loch Erisort is not a designated Shellfish Growing Water.

At the time of shoreline survey, the mussel farm at Gob Glas consisted of 6 double-headed long lines with 6 metre droppers. These extended along the south shore of the loch over a distance of approximately 1km.

The mussel farm at Garbh Eilean consisted of a number of fish cage platforms from which mussel lines were suspended plus 2 double-headed long lines with droppers to a depth of 6 metres. The farm is situated north of the two islands of Garbh Eilean and Eilean Cheois.

Both areas are harvested according to demand and availability of mature stock.

Three spat lines were installed in two locations outwith the boundaries of the classified area. The spat lines were not visited by boat: their positions were estimated from observations and photographs taken from shore. Subsequent to the shoreline survey, interest was expressed in using these two locations for production of mature mussels.

Figure 2.1 shows the location of the Loch Erisort: Outer production area, mussel lines, CE lease area and RMP.

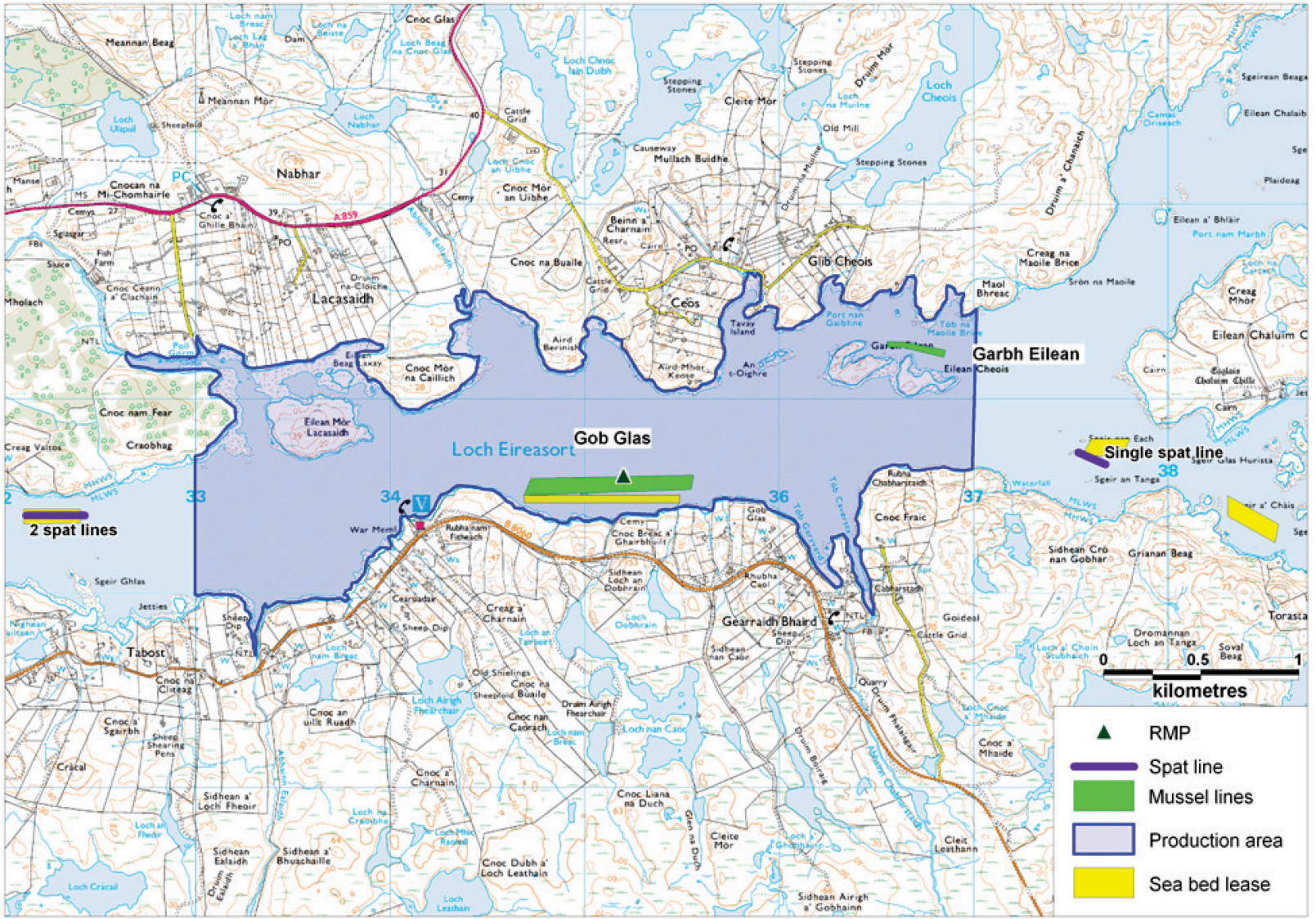

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Figure 2.1 Loch Erisort: Outer mussel fishery

3. Human Population

Data on human population from the 2001 census was obtained from the General Register Office for Scotland for the area around Loch Erisort. Figure 3.1 shows the population density for census output areas adjacent to the fishery.

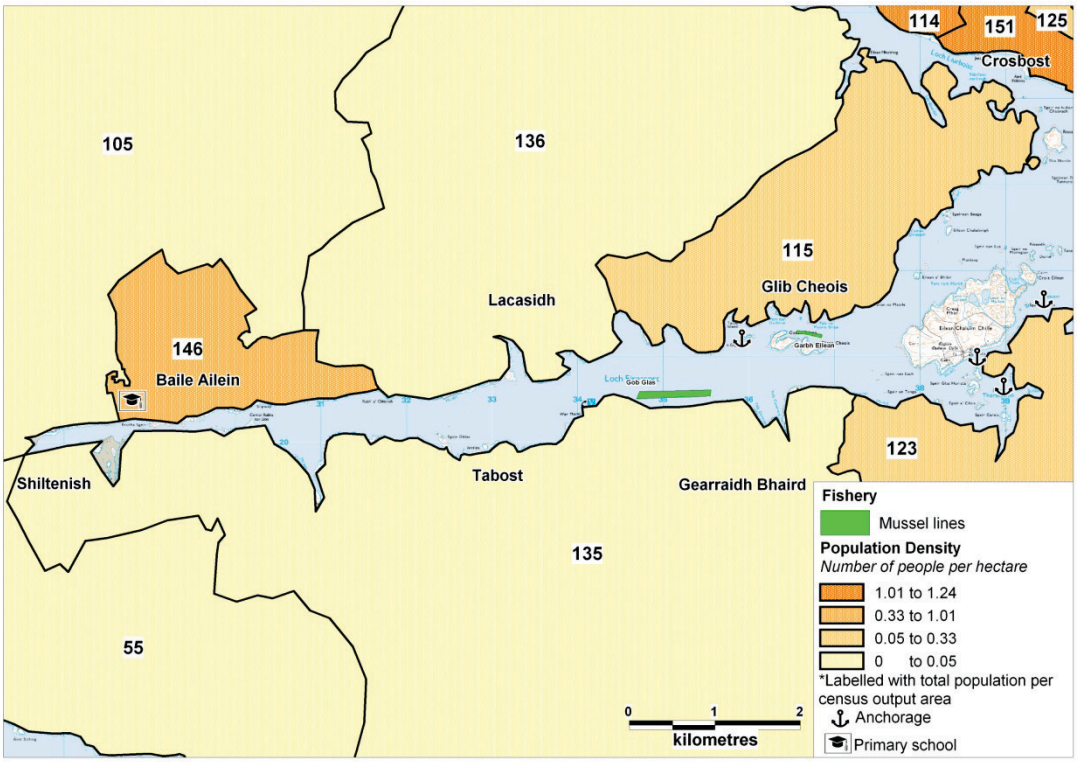

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Figure 3.1 Human population surrounding Loch Erisort: Outer

Figure 3.1 shows the population density for the census output areas surrounding the Loch Erisort fishery. The area surrounding Loch Erisort is relatively heavily populated. The village of Baile Ailein (Balallan) stretches along the north shore at the head of the loch, 3-4.5 km west of the western production area boundary. The Balallan East septic tank (Scottish Water) has a consented population equivalent of 175 and is located 3.3 km west of the production area boundary (see section 4). There is a primary school in Baile Ailein with 42 pupils. On the north shore adjacent the production area are the hamlets of Lacasaidh and Glib Cheois.

The population along the south shore is concentrated around the villages of Tabost and Gearraidh Bhaird. There is a small tea room, a visitors' centre attached to a hostel (sleeps 14) and public toilets at Tabost. There is a hotel at the hamlet of Shiltenish that sleeps 12 people, as well as small number of farms. Some of the homes around the loch are reportedly only occupied during the summer tourist season, however exact details are unknown.

Four anchorages were identified within Loch Erisort, three of which are east of the shellfish farms and one which is located west of Garbh Eilean (Clyde Cruising Club, 2003). The locations of these are indentified in Figure 3.1

Much of the population in the census output areas identified is located along the coast of the loch. The population at Baile Ailein and Shiltenish is likely to impact water quality at the head of the loch, with a higher impact from Shiltenish during the summer months. This would particularly affect the spat lines nearest the head of the loch. The Gob Glas farm lies closer to the population centres at Tabost and Gearraidh Bhaird and so would be more impacted by human-source contamination from these locations. Impacts from Tabost are likely to be higher in summer due to the visitor centre. The Garbh Eilean site lies closest the populations at Cheos, which lies west of the mussel farm.

4. Sewage Discharges

Scottish Water identified community septic tanks and sewage discharges for the area surrounding Loch Erisort. These are detailed 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/1002364	NB 2970 2040	Balallan East	Continuous	Septic tank	35	175
WPC/N/62371(01)	NB 3580 2150	Keose ST 2	Continuous	Septic tank	15	69
none provided	NB 3620 2150	Keose ST 1	Continuous	Septic tank	10	47
CAR/L/1001879	NB 3852 2284	Leurbost East Location 2	Combined effluent	Septic tank	912.5	800

No sanitary or microbiological data were available for these discharges. Effluent from septic tanks along Loch Leurbost to the north discharge to waters in outer Loch Erisort, south of the headland at Ceannmhóir. This discharge was commissioned in 2009.

A large number of discharge consents were identified by SEPA for the area around Loch Erisort. The majority of these are for discharge of septic tank effluent to soakaway or to land from single dwellings. Those discharging directly to watercourses or to the loch are listed in Table 4.2 below.

Table 4.2 Discharge consents identified by SEPA

No.	Ref No.	NGR of discharge	Discharge Type	Consented flow (DWF) m^3/d	Consented/ design PE	Discharges to
1	CAR/L/1002363	NB 3585 2160	Sewage (Public) Primary			Loch Erisort
2	WPC/N/62371(01)	NB 3580 2150	Treated sewage effluent	15	69	Loch Erisort
3	CAR/R/1047393	NB 3636 2018	Sewage (Private) Primary		5	STE to Loch Erisort
4	CAR/R/1059933	NB 3637 2002	Sewage (Private) Primary		6	STE to Loch Erisort
5	CAR/R/1056224	NB 3618 1979	Sewage (Private) Primary		5	STE to unnamed watercourse
6	CAR/R/1041907	NB 3420 2030	Sewage (Private) Primary		5	STE to Loch Erisort
7	CAR/R/1059559	NB 3417 2018	Sewage (Private) Primary		5	STE to unnamed tributary of Loch Erisort
8	CAR/R/1062183	NB 3414 2040	Sewage (Private) Primary		5	STE to Loch Erisort
9	CAR/R/1070994	NB 3379 2006	Sewage (Private) Primary		5	STE to Loch Erisort
10	CAR/R/1057064	NB 3220 1967	Sewage (Private) Primary		7	STE to Loch Nighean Fhailtean

Items 1 and 2 both relate to the Keose 2 septic tank. Item 2 corresponds with the discharge location and Item 1 is likely to refer to the location of the tank itself. The remaining consents relate to discharges from small private septic tanks. As there has not historically been a requirement to register septic tanks in Scotland, the discharge consents identified may not represent all private discharges in the area.

Sewage-related observations 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	22/09/2010	NB 3858 2292	Sewage outfall pipe for Loch Leurbost works, no boil seen
2	29/09/2010	NB 3637 2017	Septic tank, odorous. Pipe runs underground - puddled water at surface appears foul, sewage fungus apparent
3	29/09/2010	NB 3638 2015	Septic tank, no detectable odour, pipe runs underground
4	29/09/2010	NB 3640 2006	Septic tank in garden approx 5 m S of waypoint
5	29/09/2010	NB 3634 2005	Construction site with septic tank in place not yet connected Large yacht at head of Tob
6	29/09/2010	NB 3613 2007	Septic tank roughly 15 m from road below house, pipe runs underground
7	30/09/2010	NB 3590 2163	Septic pipe through wall, no signs of use, not clear whether house above pipe is occupied
8	30/09/2010	NB 3630 1979	Septic tank
9	30/09/2010	NB 3417 2034	Visitor Centre toilets

Observation number 2 relates to discharge consent CAR/R/1047393 (Item 3 in Table 4.2). Although there was a discharge consent associated with the approximate location of observation 9 (Item 8 in Table 4.2) they are not related.

Neither of the Keose septic tanks or discharges were located during the shoreline survey. A dry pipe was seen exiting a wall at the shoreline near the reported location of the Keose 2 discharge, however the active discharge pipe was not seen. The Keose 1 discharge location lies down a steep hillside behind a row of crofts. No pipe was found at this location. The discharge pipes from these tanks may either have been rerouted or buried under the shoreline.

The majority of small private discharges are located along the southern shoreline of the loch, where there is no public sewerage provision.

The relocated combined sewage discharge from Loch Leurbost is situated approximately 2.5 km to the northeast of the outer edge of the Garbh Eilean mussel farm. The consented dry weather flow of 912.5 m^3 per day equates an approximate loading of 6.6 x 10^{13} *E. coli*/day (Kay et al 2008). Although the discharge lies near deeper and more open water (allowing for more opportunity for dilution and dispersion) it could potentially affect water quality at the Garbh Eilean site, particularly on the flood tide.

Depending on the predicted movement of contaminants, the Garbh Eilean site is most likely to be influenced by the community discharges along the north shore, particularly those from the Keose septic tanks.

The Gob Glas site is located between two clusters of small discharges along the south shore of the loch, each approximately 1 km from the nearest end of the mussel farm. Although each discharge is small, the SEPA consents to water only comprise a combined population equivalent of 43, therefore similar in size to the Keose 1 septic tank. This does not include discharges for which

no consents were received, the largest of which is most likely to be the Visitor centre west of the site. The centre houses a small shop and tea room, a hostel and both public toilets outdoors and toilets for the tea room indoors. These are likely to comprise a larger discharge in terms of population equivalent than the 5 covered by the consent provided. Therefore, it is likely that consent CAR/R/1062183 pertains to an adjacent dwelling and not to the centre itself. Discharges from the visitors centre are likely to be greater during the summer tourist season and would constitute the largest local source of sewage to the Gob Glas site.

Discharges from the Balallan East septic tank, though further away from the Gob Glas and Garbh Eilean mussel farms, may contribute to background levels of contamination throughout the loch. Effects from this discharge would be greatest at the eastern pair of spat lines.

The western spat line lies near the southern shore of the outer loch, which was not visited during the shoreline survey.

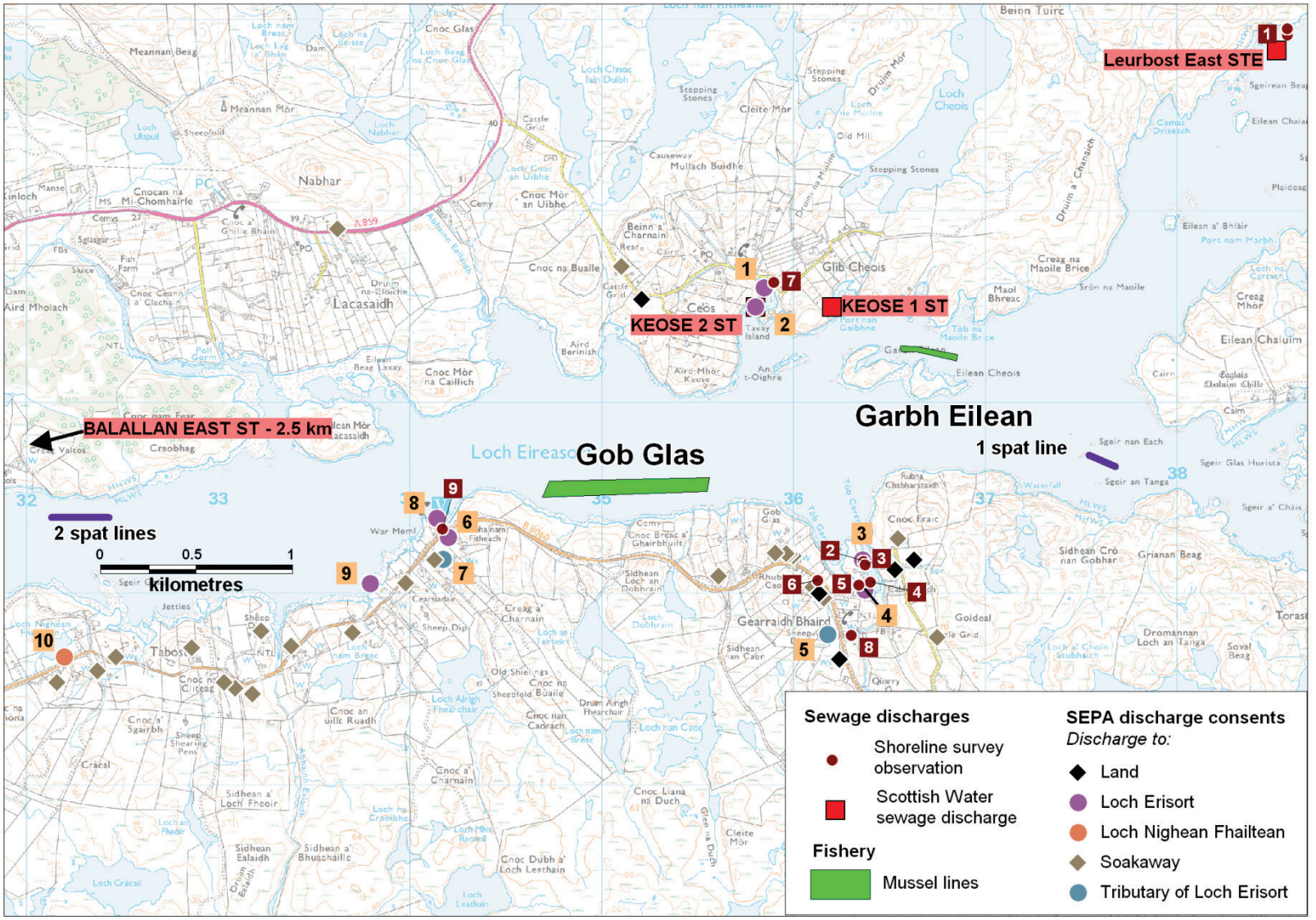

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Figure 4.1 Map of discharges for Loch Erisort

5. Geology and Soils

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

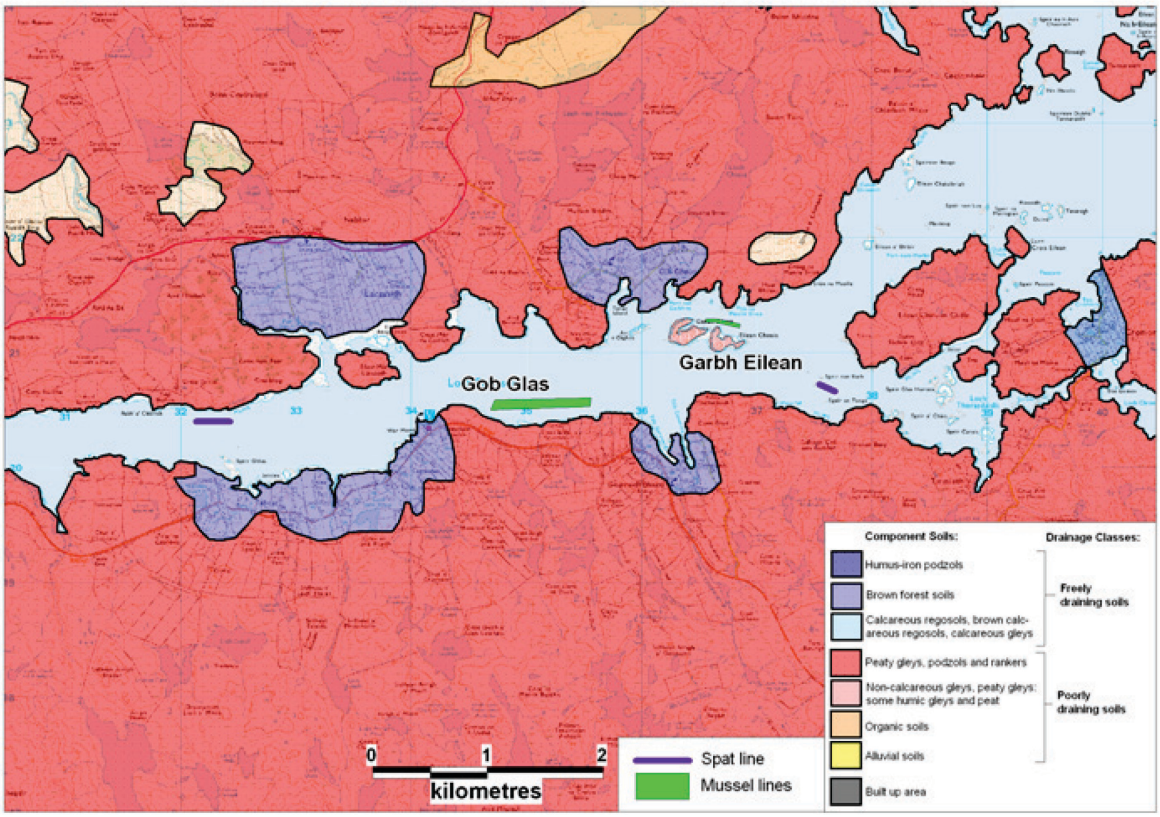

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Figure 5.1 Component soils and drainage classes for Loch Erisort

Three types of component soils are present in the area: peaty gleys, podzols and rankers, organic soils and brown forest soils. The peaty gleys, podzols and rankers and organic soils that cover the majority of the land surrounding Loch Erisort are poorly draining. Brown forest soils are found in small areas directly along the shoreline of the loch and are freely draining.

The shoreline adjacent to both mussel farms is comprised of poorly-draining soils and therefore potentially subject to an increased risk of runoff contaminated with *E. coli* from human and/or animal waste.

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

6. Land Cover

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

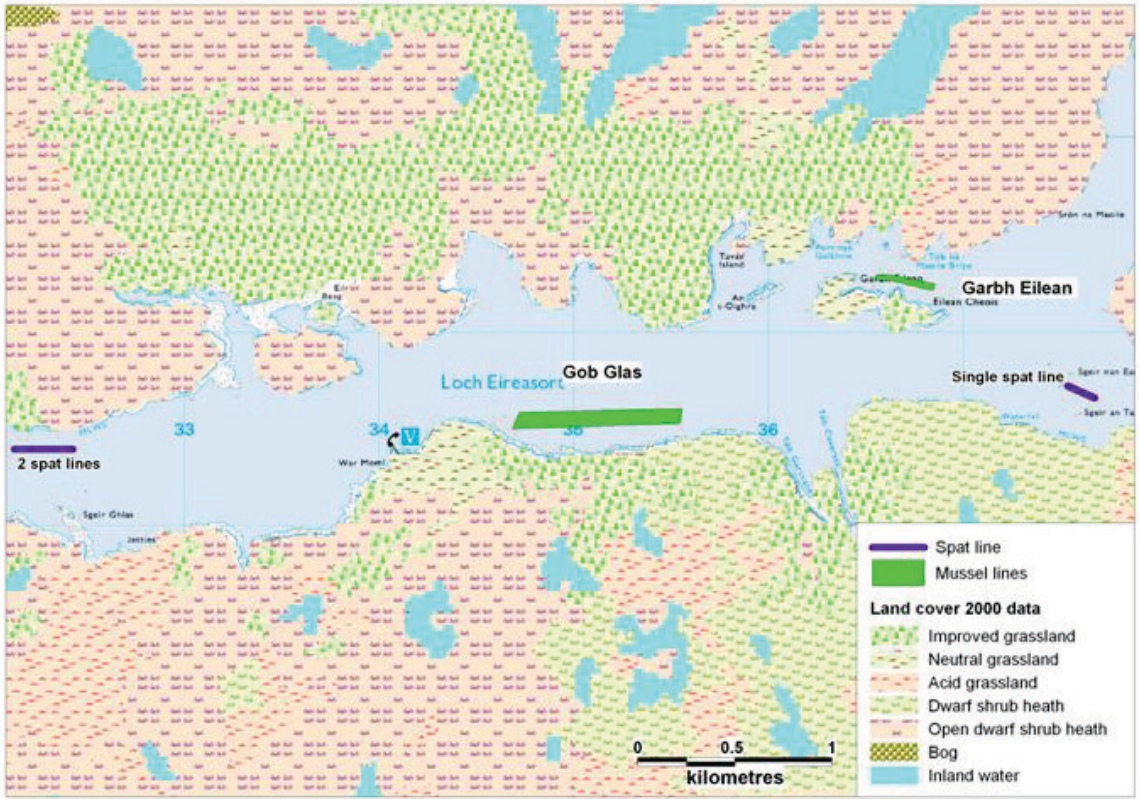

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Figure 6.1 LCM2000 class land cover data for Loch Erisort: Outer

On the north shoreline of the loch, land cover is mainly composed of improved grassland and open dwarf shrub heath with areas of inland water. The land adjacent to the Garbh Eilean site, both on the island and the mainland, is a mix of improved grassland and natural grassland types suitable for rough grazing.

Land cover on the south shore of the loch is a greater mixture of acid grassland, dwarf shrub heath, open dwarf shrub heath, improved grassland and neutral grassland. Improved grassland lines the shore immediately adjacent to most of the length of the Gob Glas site. Inland of this strip are areas of heath and grassland suitable for rough grazing.

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 the bulk of the catchment areas around Loch Erisort are open land that could be used as rough grazing, smaller areas of improved grassland adjacent to the fishery drained by short watercourses could contribute higher levels of contaminated runoff than the catchment as a whole. Therefore, areas of west of the Garbh Eilean site and south of the Gob Glas site may be contribute higher levels of faecal contaminants to waters around the fisheries, particularly after heavy rainfall.

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 km2)			
	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 unlikely 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 22, 29, and 30 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. Over 800 sheep were seen, with fewer cattle (77) and horses (11) present. The majority of animals were kept in fenced pastures associated with the many crofts along the shoreline, though some were observed on rough pasture or grazing along road verges. Not all crofts were observed, therefore the numbers identified during the survey are likely to under represent the total present in the area.

More animals were seen toward the head of the loch on crofts around Balallan. A large number of sheep and some cattle were present in multiple

fields south of the Gob Glas mussel farm, as well as on land adjacent streams discharging to the loch near the farm. These are likely to present a significant source of faecal contaminants in waters around the Gob Glas site particularly considering that the steep gradient of the land and poor soil permeability (Section 5) in this area will contribute to higher levels of rainfall runoff. At the Garbh Eilean site, sheep were observed on rough grazing and pasture to the north and west of the site though in smaller numbers than were present south of Gob Glas. Therefore, the Garbh Eilean site may be less affected by livestock-source contamination than Gob Glas.

Livestock kept further west of the fishery, toward the head of the loch, may still contribute to background levels of *E. coli* found in waters at the fishery and in particular at the westernmost spat line, depending on the predicted movement of contaminants.

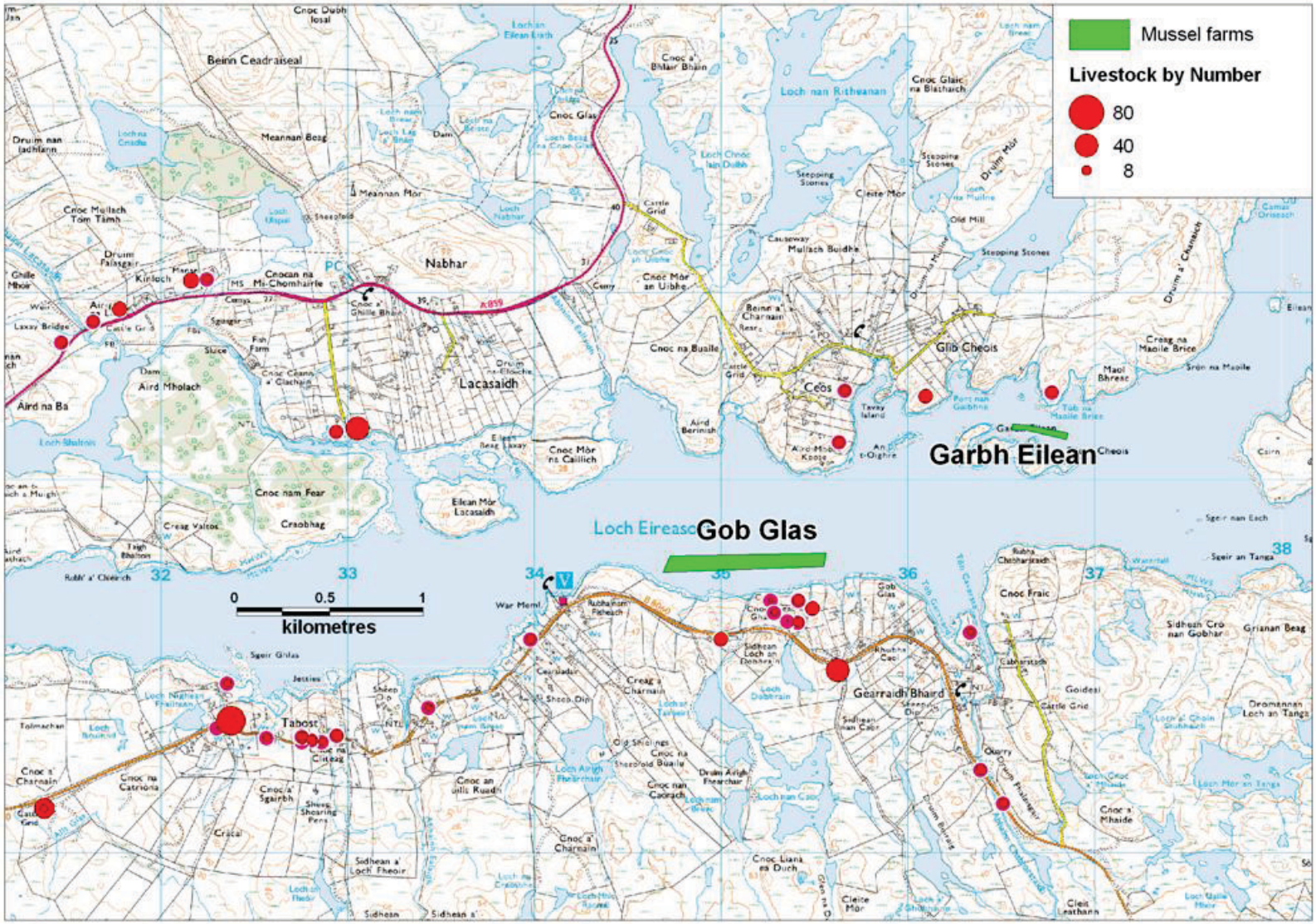

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Figure 7.1 Livestock observed during the shoreline survey at Loch Erisort

8. Wildlife

Loch Erisort lies south 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 Erisort.

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 Erisort, surveys of harbour seals in 2007-2008 identified small numbers of animals hauled out in the upper loch. Seals are likely to forage widely and so it is probable that they will be present near the mussel farms from time to time. As only small numbers were identified in the loch, it is unlikely that the presence of seals in the area will lead to a marked decline in water quality around the fishery. No seals were seen during the shoreline survey.

Whales/dolphins
Given the shallow depths and narrow entrances to the loch, it is unlikely that whales or dolphins frequent the area around the fishery.

Otters
One otter was seen swimming near the Garbh Eilean site during the shoreline survey. 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 Erisort. However, the typical population densities of coastal otters are low and their impacts on the shellfishery are expected to be very minor.

Birds
There were no Seabird 2000 records for a 5 km radius surrounding the shellfishery in Loch Erisort. A large area of intertidal mud at the head of the loch is likely to attract wading birds and 34 birds were seen there during the survey. An eagle was seen on the north shore of the outer part of the loch, but while their numbers are significant in terms of conservation they are unlikely to pose a significant risk of faecal contamination to the fisheries in Loch Erisort. A small number of gulls and cormorants were also observed during the shoreline survey. The locations of all wildlife observed during the shoreline survey are shown in Figure 8.1.

Birds species such as gulls or cormorants are likely to be present year round and also to rest on the floats, and therefore directly deposit faecal material to the waters around the fishery. However, this is difficult to predict in terms of time or exact location therefore any impact will be presumed to be evenly distributed across the fishery.

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 Erisort, particularly further inland 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 Erisort. 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 farm. However, the presence and movements of these animals are likely to be highly variable and their impact at any given time difficult to predict. 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.

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.

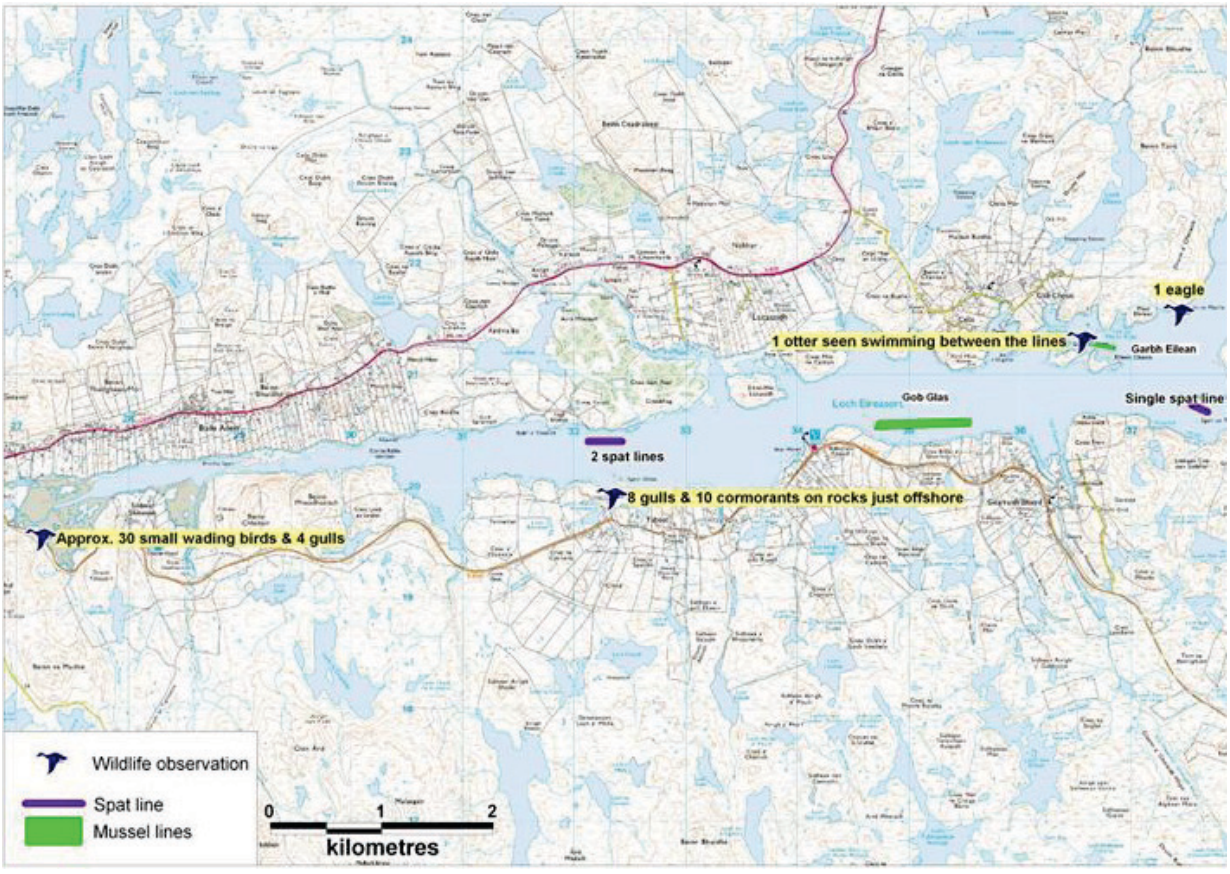

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Figure 8.1 Map of seabird distributions at Loch Erisort: Outer

9. Meteorological data

The nearest weather station for which nearly complete rainfall records were available is located at Stornoway, 15 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. Although overall wind patterns may be similar at the two, local topography may skew these patterns in different ways and conditions at any given time may differ slightly due to the distance between them. This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish at Loch Erisort Outer.

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 *.

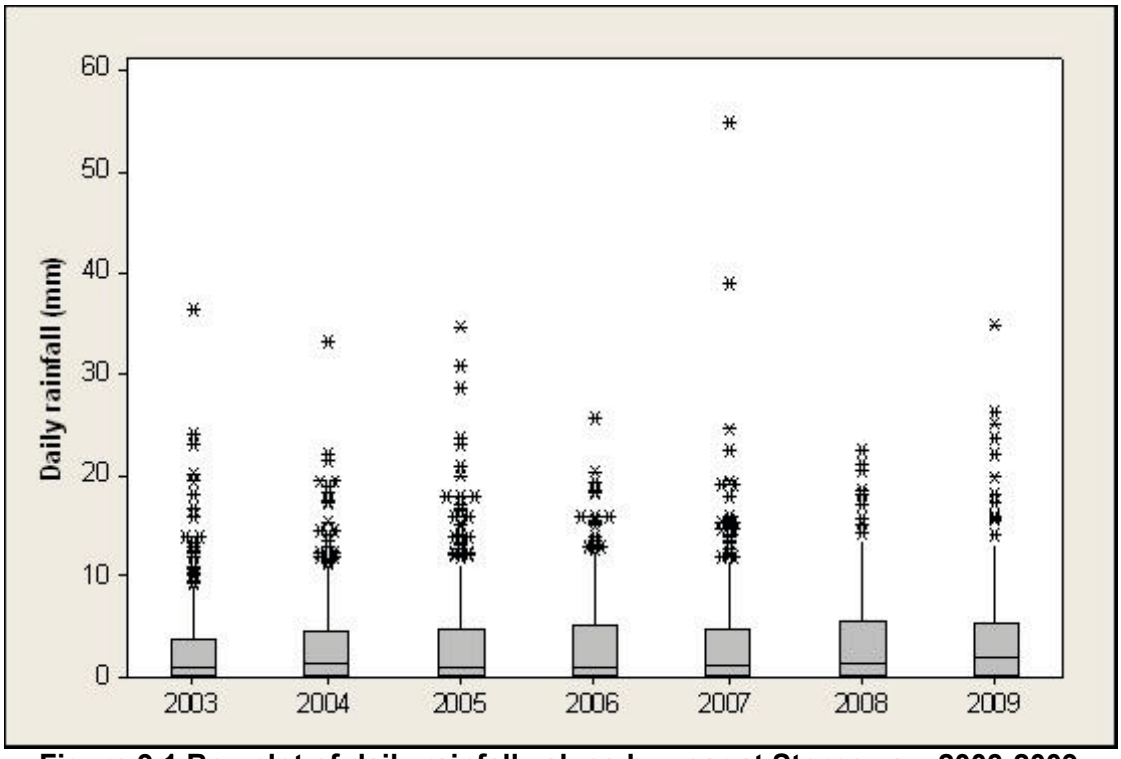

Figure 9.1 Box plot of daily rainfall values by year at Stornoway, 2003-2009

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

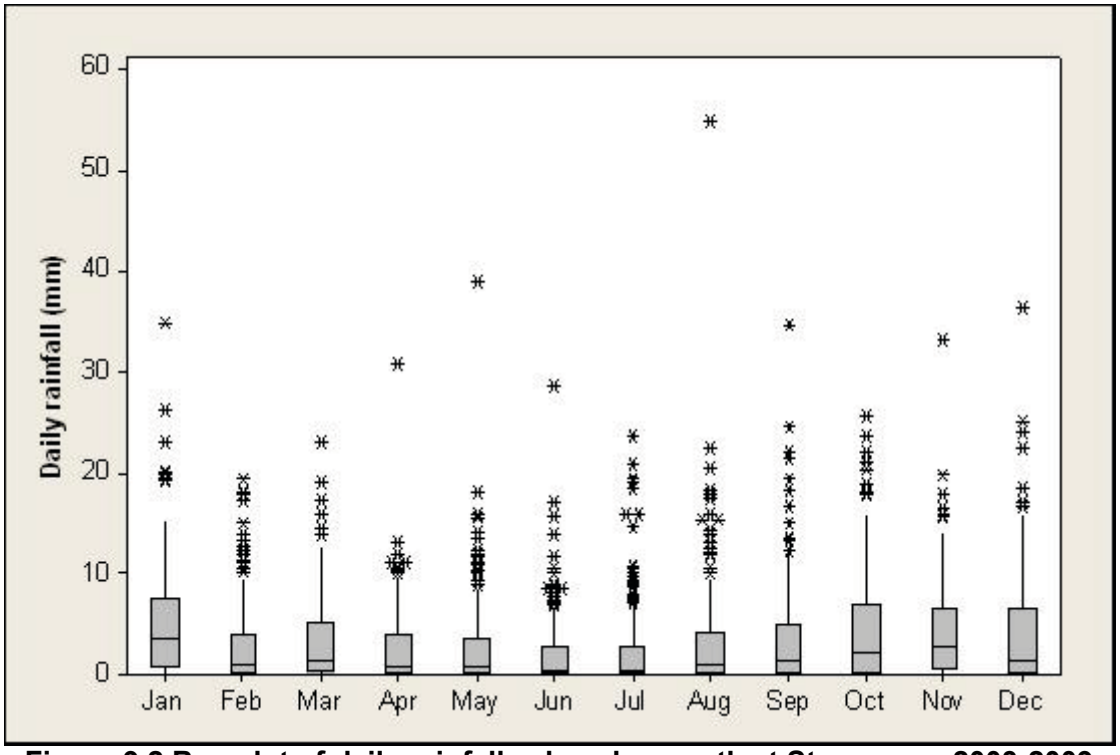

Figure 9.2 Box plot of daily rainfall values by month at Stornoway, 2003-2009

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 populations 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.

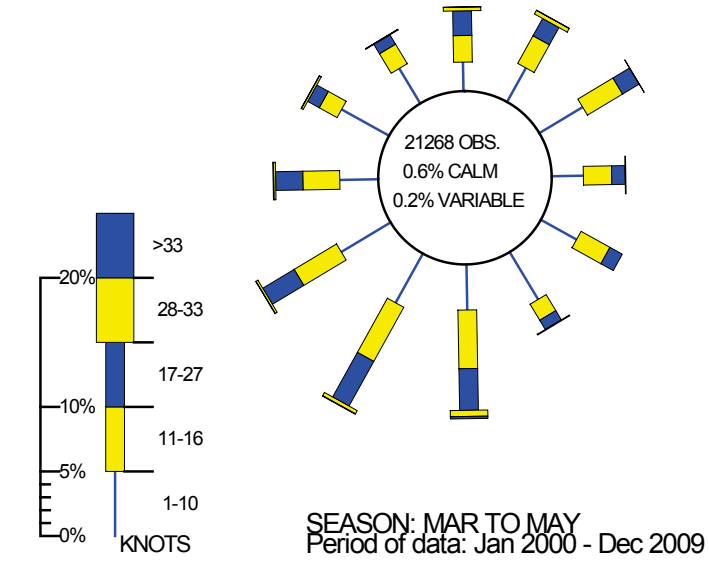

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Figure 9.3 Wind rose for Stornoway (March to May)

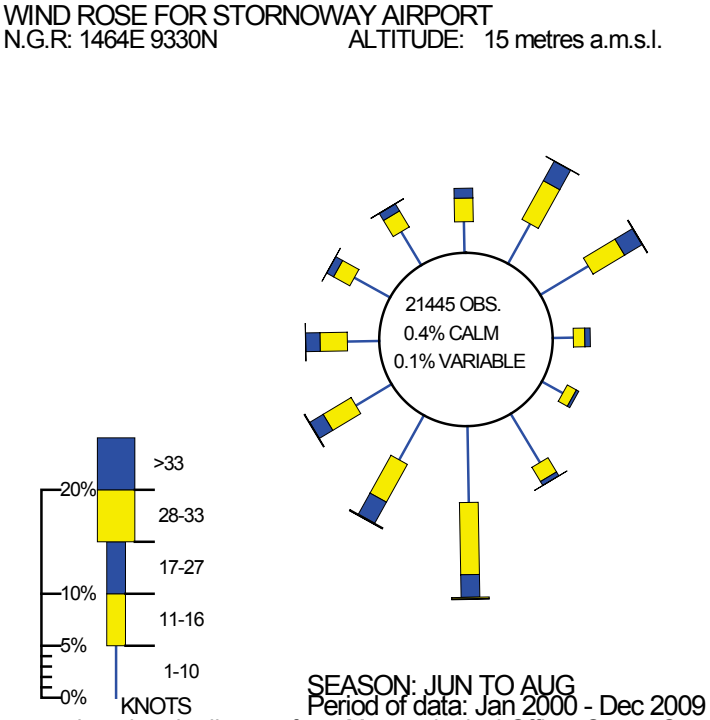

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Figure 9.4 Wind rose for Stornoway (June to August)

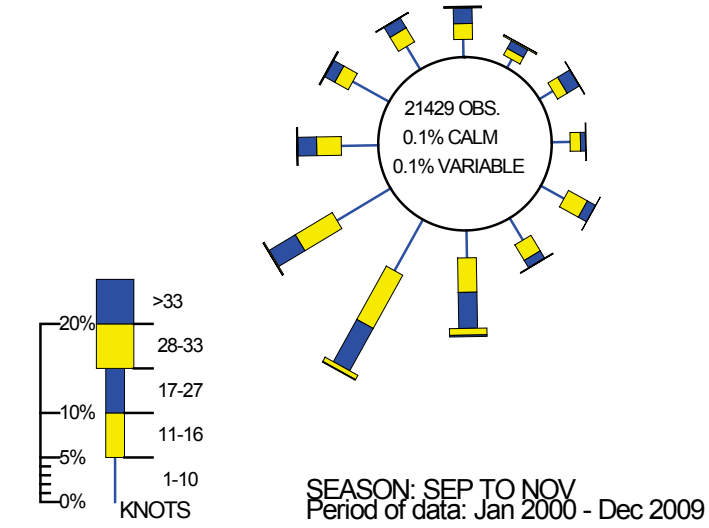

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Figure 9.5 Wind rose for Stornoway (September to November)

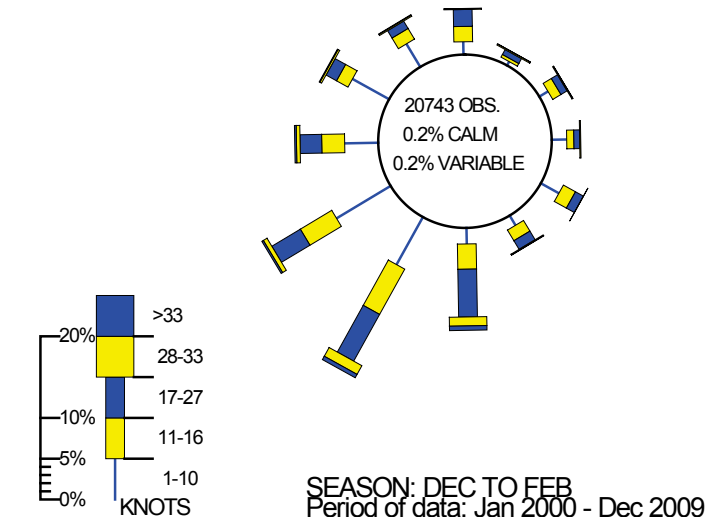

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Figure 9.6 Wind rose for Stornoway (December to February)

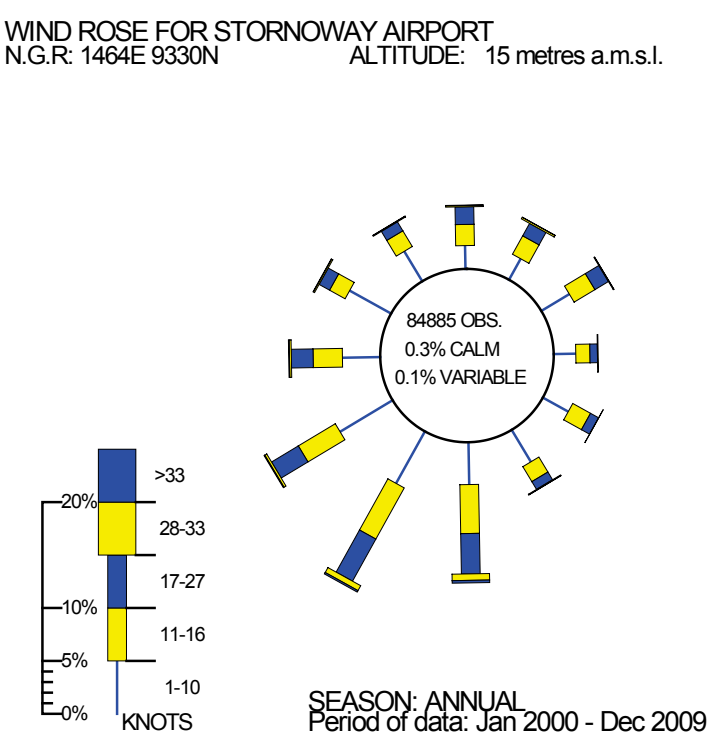


Figure reproduced under license from Meteorological Office. Crown Copyright 2010.

Figure 9.7 Wind rose for Stornoway (All year)

The prevailing wind direction at Stornoway is from the south west. 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 Erisort has a west to east 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 Erisort, particularly those from the east or west. 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.

10. Current and historical classification status

Classification records for the Loch Erisort: Outer production area were available from 2005, when it was first given a provisional classification for production of common mussels.

Table 10.1 Classification history, Loch Erisort: Outer

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

Lower case denotes provisional classification

Seasonal classifications have been awarded in all years but one, with class B months tending to be during the summer and autumn months except in 2001 and 2010/11.

Table 10.2 Classification history, Loch Erisort

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	b	b	b	b	b	b	b	b	b	b	b	b
2006	B	B	B	B	B	B	B	B	B	B	B	B
2007	B	B	B									

The Loch Erisort production area contained one site: Rubh A Chleirich. The production area was declassified in 2007 due to an insufficient number of samples.

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken Loch Erisort from the beginning of 2002 up to the 11th May 2010 (all analyses) and up to 24th February 2011 (sections 11.1 to 11.5 only) were extracted from the database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. These included 10 mussel samples taken from the original (now declassified) Loch Erisort production area in the upper reaches of the loch. A total of 11 samples from the Gob Glas site had reported sampling locations which fell approximately 3.5 km to the north of the production area, and these were removed from the analysis.

All samples were received by the testing laboratory within two days of collection. One mussel sample had an invalid test result and so could not be used. Eight 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 (MPN) per 100g of shellfish flesh and intravalvular fluid.

11.2 Summary of microbiological results

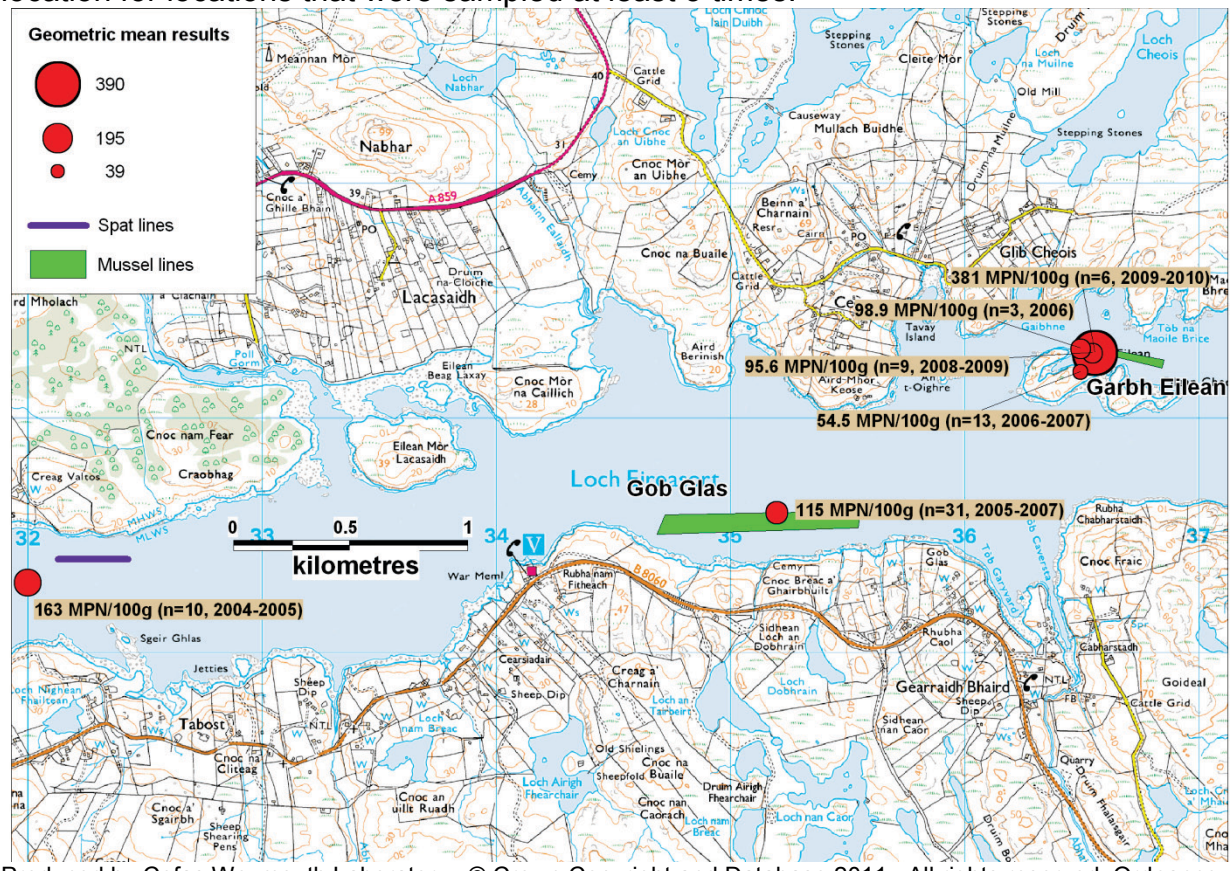
A summary of all sampling and results is presented in Table 11.1 by site.

Table 11.1 Summary of historical sampling and results

Sampling Summary			
Production area	Loch Erisort	Loch Erisort Outer	Loch Erisort Outer
Site	Rubh A Chleirich	Gob Glas	Garbh Eilean
Species	Common mussels	Common mussels	Common mussels
SIN	LH-140-112-08	LH-357-711-08	LH-357-747-08
Location	NB320203	3 locations	6 locations
Total no of samples	10	40	40
No. 2002	0	0	0
No. 2003	0	0	0
No. 2004	7	0	0
No. 2005	3	14	0
No. 2006	0	12	10
No. 2007	0	7	6
No. 2008	0	0	5
No. 2009	0	0	11
No. 2010	0	7	6
No. 2011	0	0	2
Results Summary			
Minimum	<20	<20	<20
Maximum	9100	1700	16000
Median	255	80	90
Geometric mean	163	99.8	97
90 percentile	1590	705	666
95 percentile	5340	1300	970
No. exceeding 230/100g	5 (50%)	11 (28%)	9 (23%)
No. exceeding 1000/100g	1 (10%)	3 (8%)	3 (8%)
No. exceeding 4600/100g	1 (10%)	0 (0%)	1 (3%)
No. exceeding 18000/100g	0 (0%)	0 (0%)	0 (0%)

11.3 Overall geographical pattern of results

Figure 11.1 presents a thematic map of geometric mean *E. coli* result by sampling location for locations that were sampled at least 3 times.



Produced by Cefas Weymouth Laboratory. © Crown Copyright and Database 2011. All rights reserved. Ordnance Survey licence number [GD100035675]

Figure 11.1 Map of geometric mean *E. coli* result by sampling location.

The highest geometric mean result in this data set occurs at the western end of the Garbh Eilean site. The cluster of results located near it are most likely all taken from the same end of the mussel farm. A statistical comparison of all results by site revealed no significant difference (One-way ANOVA, p=0.647, Appendix 6). It must be noted however that the samples were taken from the different sites at different times, so results may not be directly comparable. On 13 occasions, samples were taken from both Gob Glas and Garbh Eilean on the same day and hence under the same environmental conditions permitting a more robust comparison of levels of contamination at these two sites. Figure 11.2 presents a boxplot of these paired results.

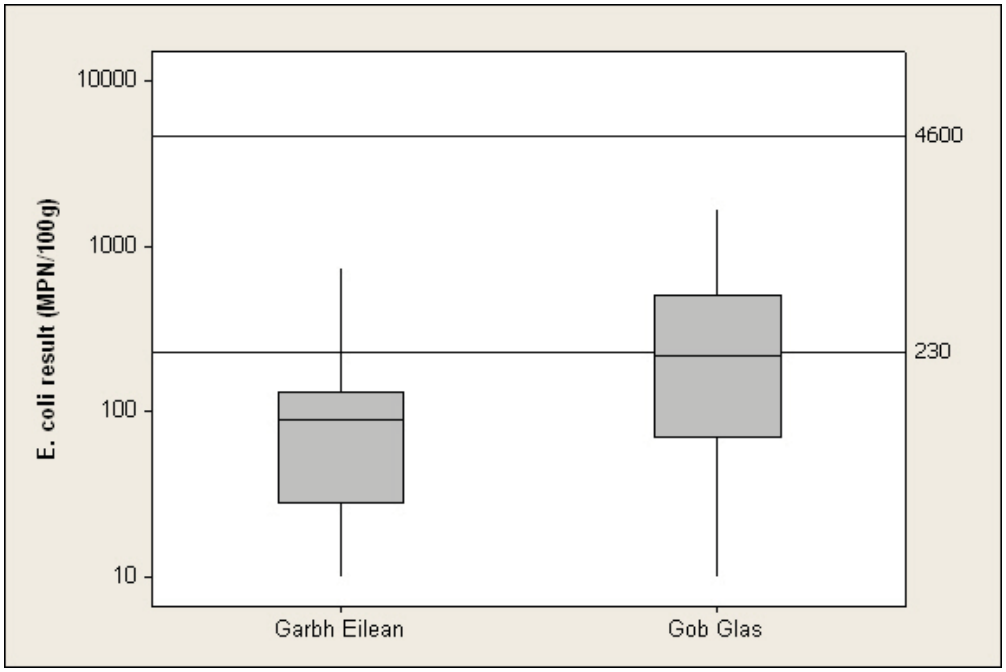


Figure 11.2 Boxplot of *E. coli* results at Garbh Eilean and Gob Glas when both sites were sampled on the same day

For these paired samples, the geometric mean result was higher at Gob Glas (184 *E. coli* MPN/100g) than at Garbh Eilean (65.6 *E. coli* MPN/100g), and Gob Glas also had a higher proportion of results exceeding 230 *E. coli* MPN/100g than Garbh Eilean (38% and 8% respectively). However, neither of these differences were statistically significant (Paired T-test, t=-1.87, p=0.086; Fisher exact test, p=0.160, Appendix 6). Although not statistically significant, these results suggest the two sites may be subject to differing impacts from contamination and so were considered separately in the following, more detailed, analyses. Insufficient samples were taken from the Rubh A Chleirich site for a more detailed analysis of the results.

11.4 Overall temporal pattern of results

Figures 11.3 and 11.4 present a scatter plot of individual results against date. They is fitted with a trend line indicating the geometric mean of the previous 5 samples, the current sample and the following 6 samples, referred to as a rolling geometric mean. It was not appropriate to apply the Loess smoother line in these cases due to large gaps in sampling.

Garbh Eilean

Figure 11.3 suggests that results deteriorated over the period. Two gaps in sampling from August 2007 to November 2008 and from July to October 2008 show as horizontal segments in the trend line. However, no results below 20 MPN/100 g have occurred since 2007 and peak results were higher from mid 2009 onward.

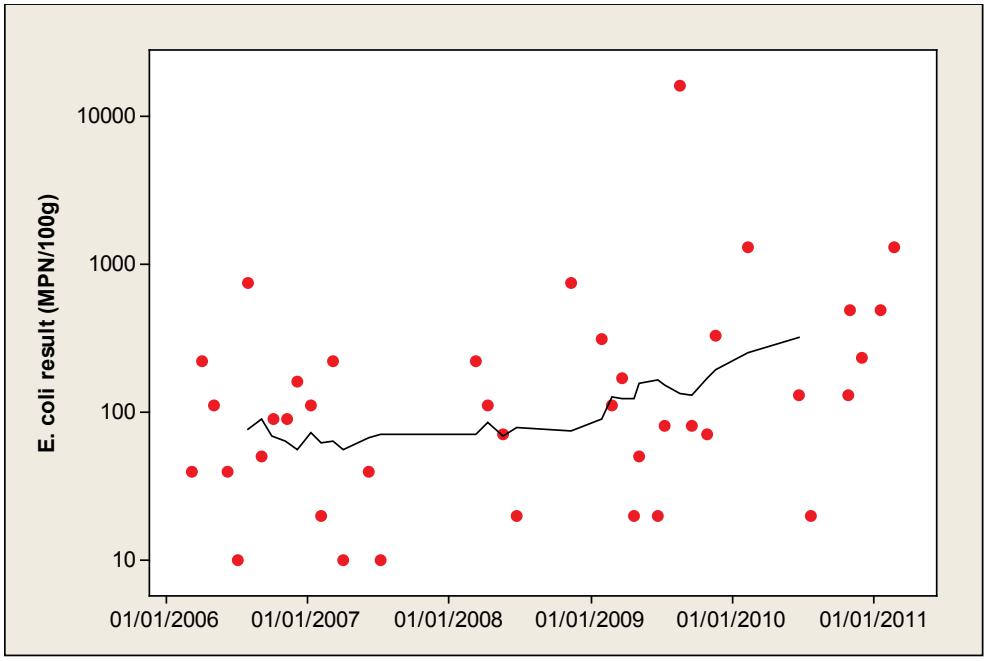


Figure 11.3 Scatterplot of *E. coli* results by date with trend line (Garbh Eilean)

Gob Glas

Figure 11.4 shows no obvious trends or cycles. A large gap in sampling occurred between September 2007 and March 2010, making it difficult to draw conclusions regarding trends at this site.

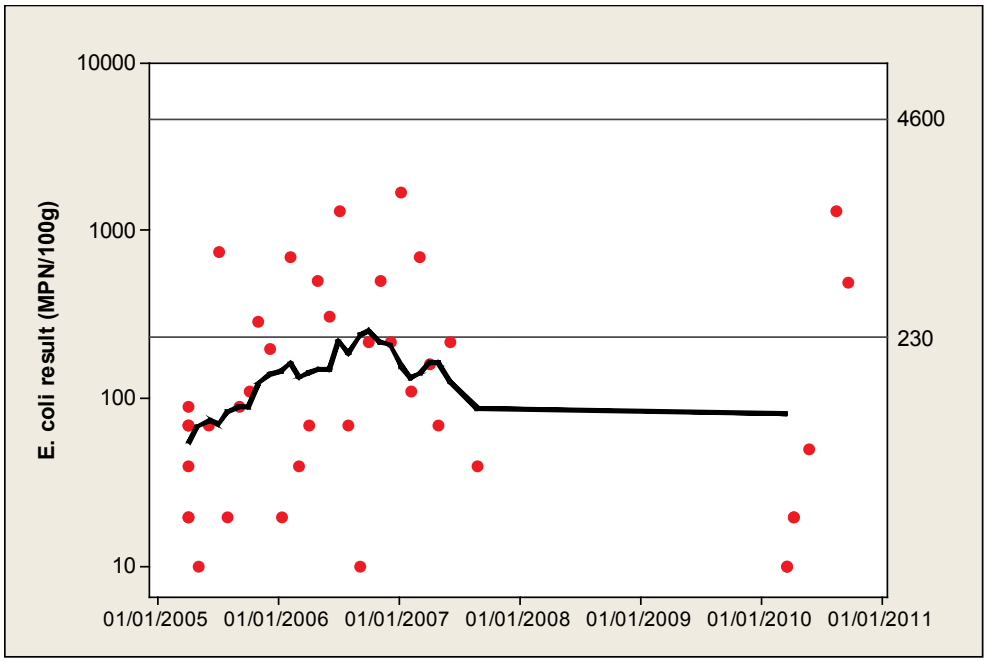


Figure 11.4 Scatterplot of *E. coli* results by date with trend line (Gob Glas)

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.

Garbh Eilean

Figure 11.5 presents a scatterplot of *E. coli* result by month at Garbh Eilean overlaid with a Loess line to highlight any trends. The data suggest a tendency for higher results during the winter, but sample numbers for any given month were low and the highest results occurred during August.

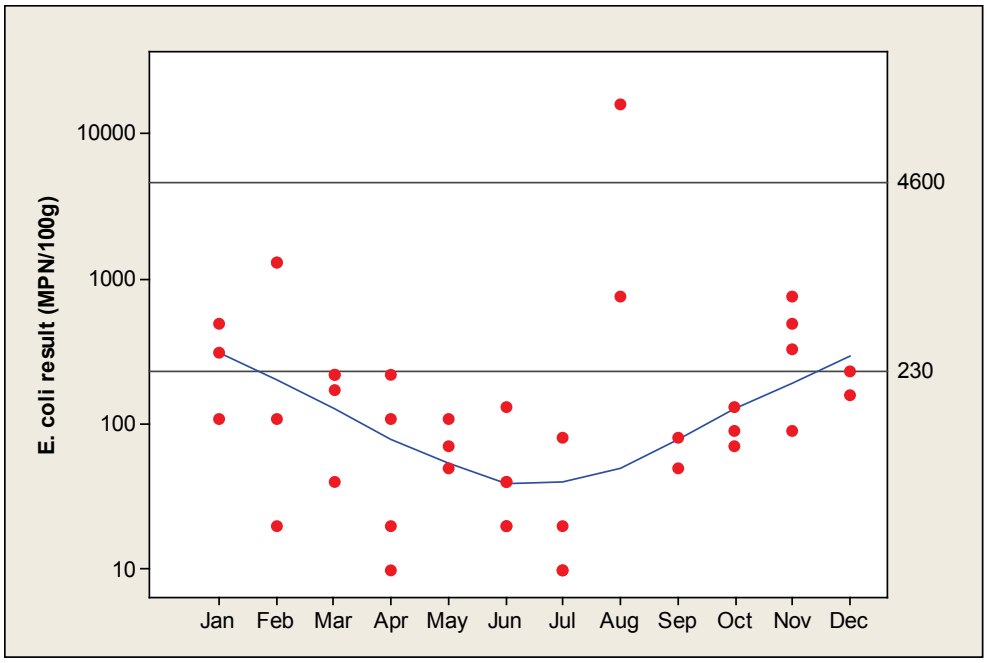


Figure 11.5 Scatterplot of results by month (Garbh Eilean)

For statistical evaluation, seasons were split into spring (March - May), summer (June - August), autumn (September - November) and winter (December - February). Results by season for Garbh Eilean are presented in Figure 11.6.

The lowest results occurred during spring and summer, and more results greater than 230 MPN/100 g occurred during autumn and winter. No statistically significant difference was found between results by season at this site (One-way ANOVA, p=0.239, Appendix 6). The highest individual result occurred in summer.

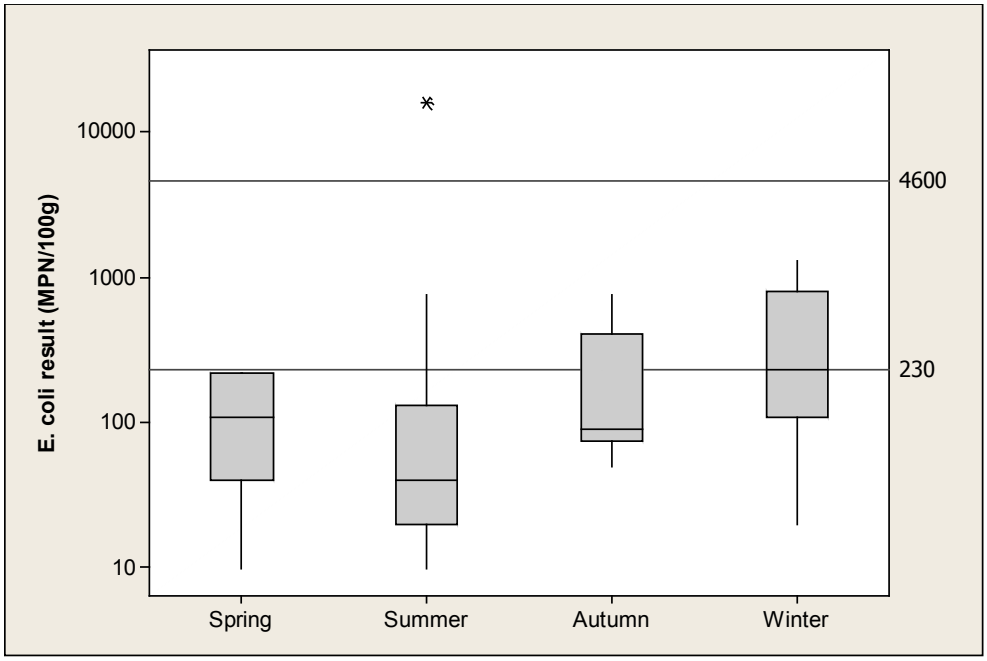


Figure 11.6 Boxplot of result by season (Garbh Eilean)

Gob Glas

Figure 11.7 presents a scatterplot of *E. coli* result by month at Gob Glas. This has been overlaid with a Loess line. No consistent seasonal pattern is apparent in Figure 11.5. Sample numbers for any given month were low.

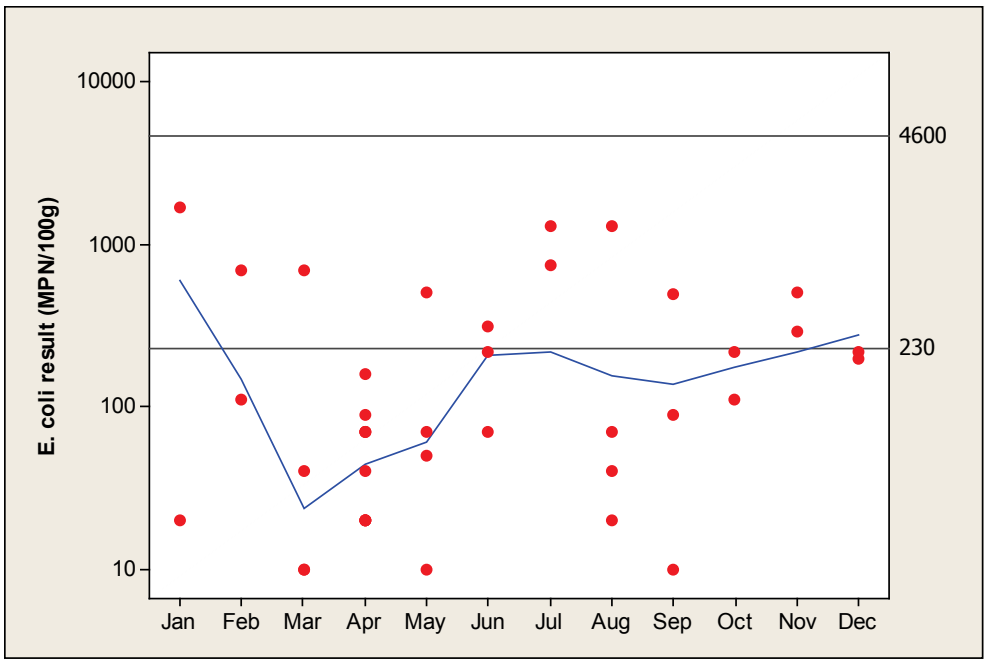


Figure 11.7 Scatterplot of results by month (Gob Glas)

A box plot of results by season for Gob Glas is presented in Figure 11.8. A relatively low number of samples Lowest results occurred in Spring and Autumn, though results greater than 230 MPN/100 g occurred in all seasons. A statistically significant difference was found between results by season, with results lower in spring than in other seasons (One-way ANOVA, p=0.031, Appendix 6).

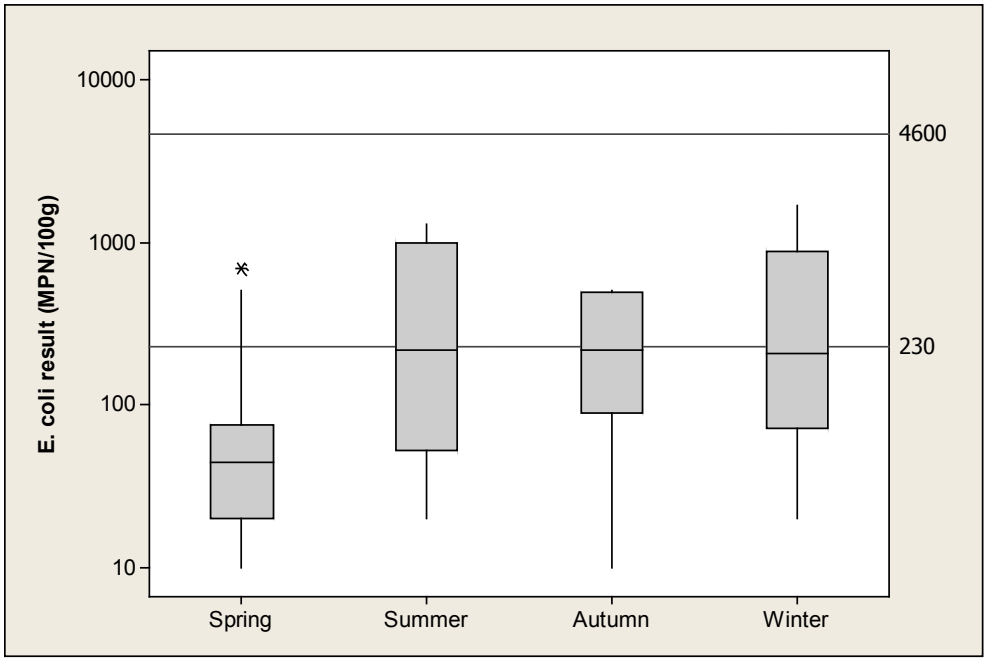


Figure 11.8 Boxplot of result by season (Gob Glas)

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. The following analyses were carried out on a subset of the monitoring data.

11.6.1 Analysis of results by recent rainfall

The nearest weather station is at Stornoway, 15 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). As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationships between rainfall in the previous 2 and 7 days and sample results were investigated. Spearman's Rank correlations were carried out between results and rainfall.

Garbh Eilean

Figures 11.9 and 11.10 present scatterplots of *E. coli* results against rainfall in the two and seven days prior to sampling at Garbh Eilean.

2-day rainfall

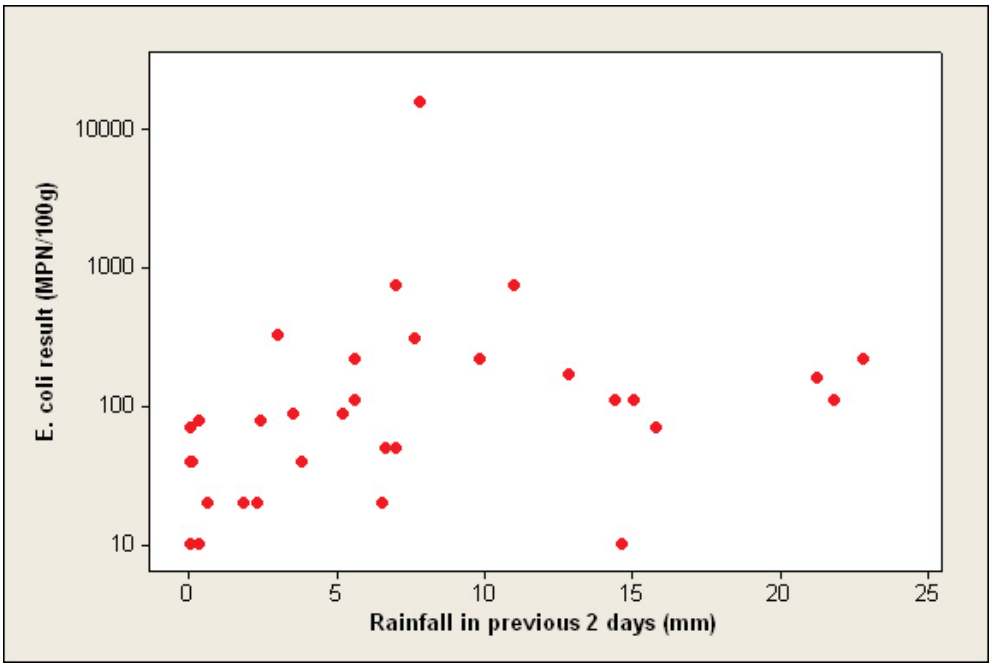


Figure 11.9 Scatterplot of result against rainfall in previous 2 days (Garbh Eilean)

A significant positive correlation was found between *E. coli* result at Garbh Eilean and rainfall in the previous 2 days (Spearman's rank correlation=0.525, $p<0.0025$, Appendix 6). However, it should be noted that the highest result occurred after relatively moderate rainfall of 7.8 mm.

7-day rainfall

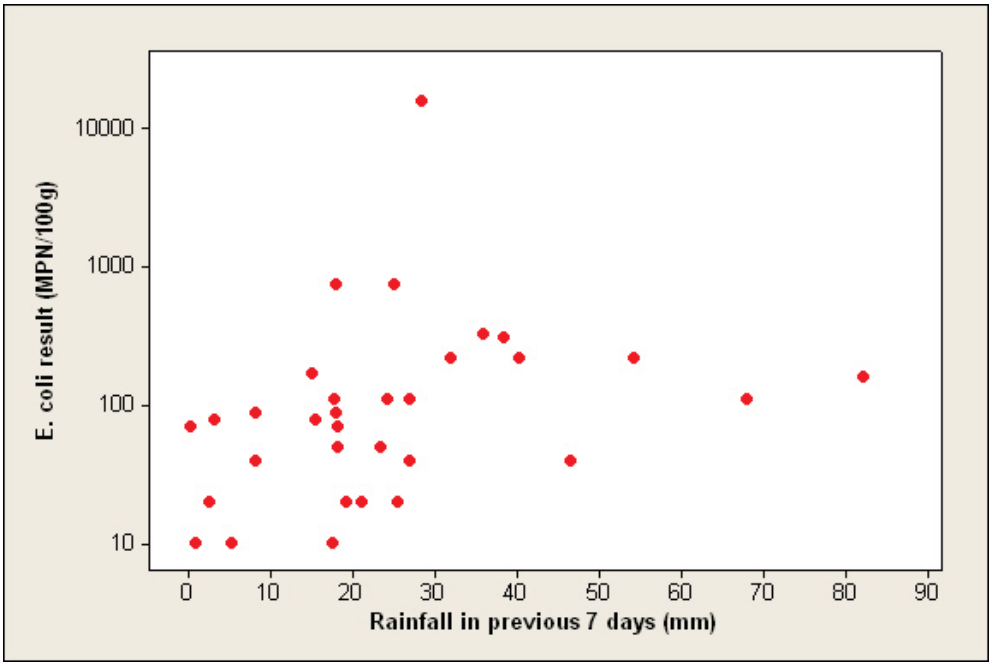


Figure 11.10 Scatterplot of result against rainfall in previous 7 days (Garbh Eilean)

A significant positive correlation was found between *E. coli* result and rainfall in the previous 7 days (Spearman's rank correlation= 0.487, $p<0.005$, Appendix 6). As with 2-day rainfall, the highest results occurred at moderate rainfall levels. However,

no very low results (20 or fewer MPN/100 g) corresponded with rainfall totalling greater than 30 mm in the 7 days prior to sampling.

Gob Glas

Figures 11.11 and 11.12 present scatterplots of *E. coli* results against rainfall in the two and seven days prior to sampling at Gob Glas.

2-day rainfall

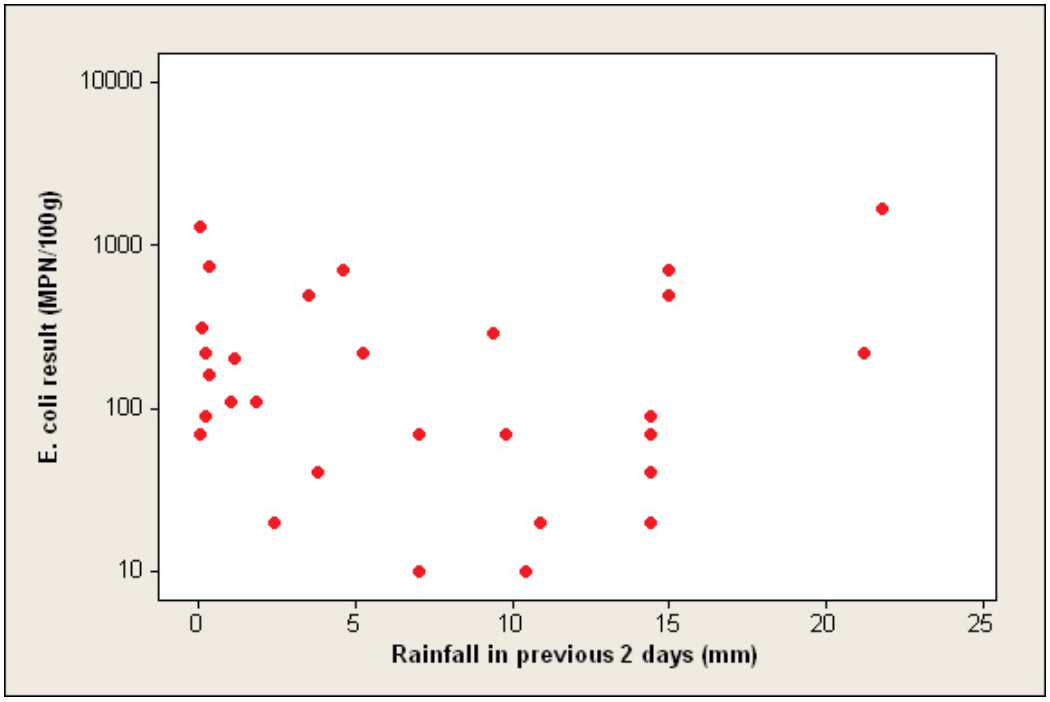


Figure 11.11 Scatterplot of result against rainfall in previous 2 days (Gob Glas)

No significant correlation was found between *E. coli* result at Gob Glas and rainfall in the previous 2 days (Spearman's rank correlation=-0.122, p>0.10, Appendix 6).

7-day rainfall

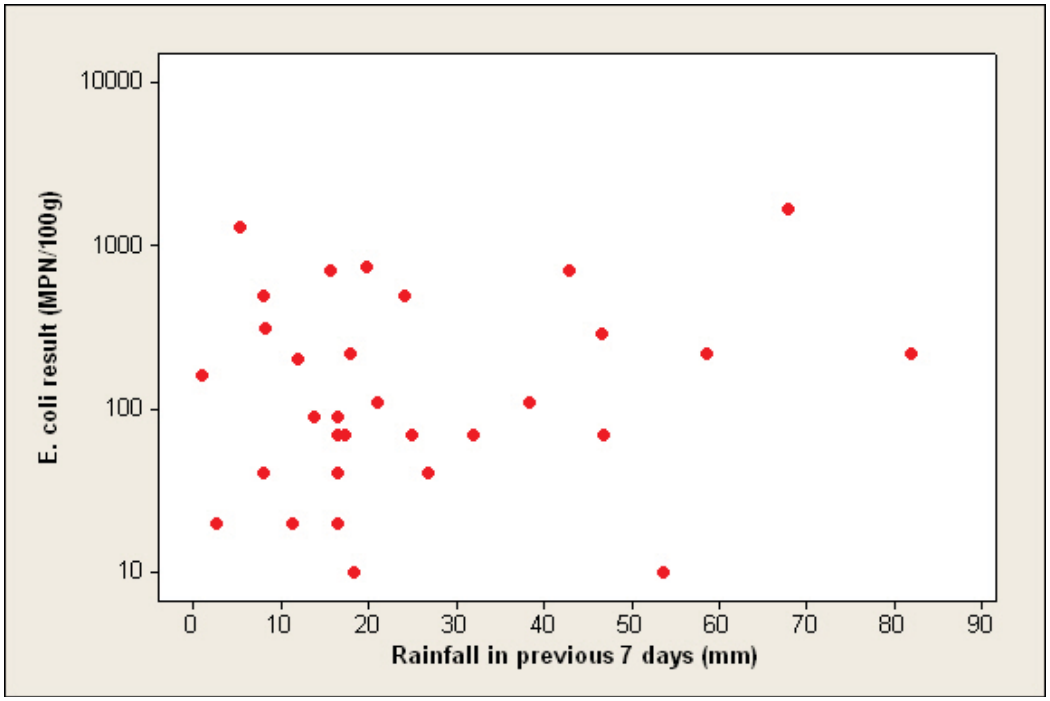


Figure 11.12 Scatterplot of result against rainfall in previous 7 days (Gob Glas)

No significant correlation was found between *E. coli* result at Gob Glas and rainfall in the previous 7 days (Spearman's rank correlation= 0.104, p>0.25, Appendix 6).

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 11.13 and 11.14 present a polar plots of $\log_{10}$ *E. coli* results on the lunar spring/neap tidal cycle by site. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of under 230 *E. coli* MPN/100g are plotted in green, those between 230 and 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.

Garbh Eilean

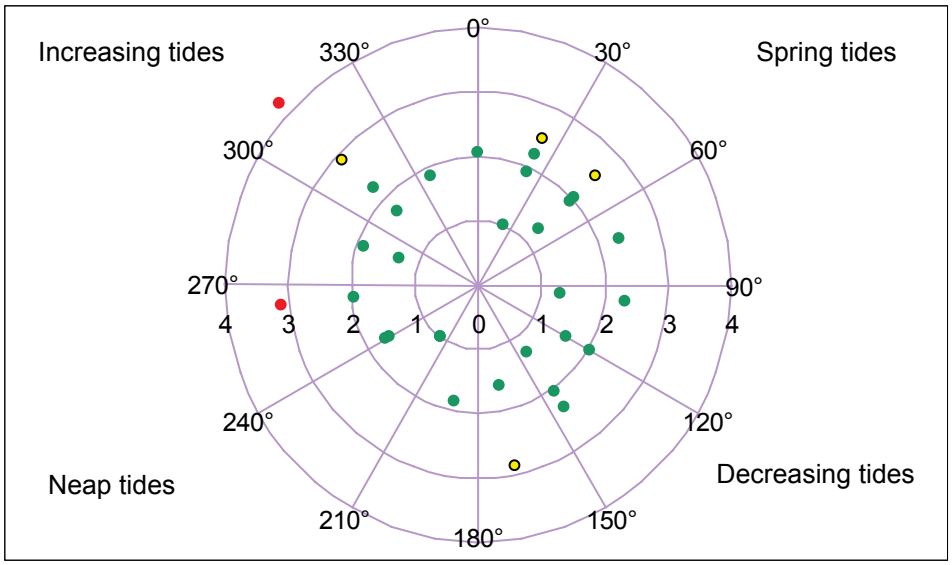


Figure 11.13 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle (Garbh Eilean)

No significant correlation was found between *E. coli* results and the spring/neap cycle (circular-linear correlation, r=0.238, p=0.183, Appendix 6).

Gob Glas

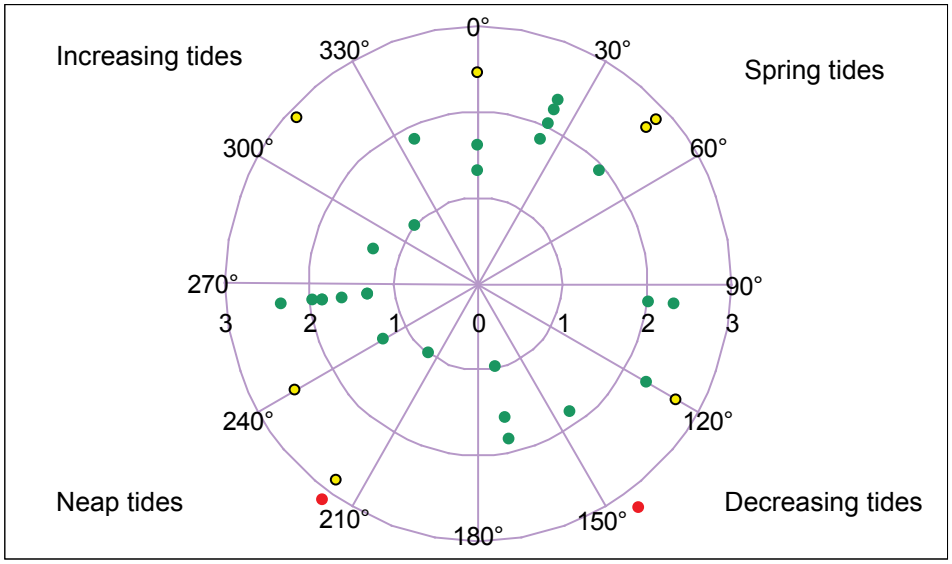


Figure 11.14 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle (Gob Glas)

A significant correlation was found between *E. coli* results and the spring/neap cycle (circular-linear correlation, r=0.338, p=0.025, Appendix 6). Figure 11.13 shows that whilst there are no strong patterns apparent, fewer low results arose 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 11.15 and 11.16 present polar plots of log-10 *E. coli* results on the lunar high/low tidal cycle for each site. High water is located at 0º, and low water at 180º. Again, results of under 230 *E. coli* MPN/100g are plotted in green, those between 230 and 1000 *E. coli* MPN/100g are plotted in yellow, and those over 1000 *E. coli* MPN/100g are plotted in red.

Garbh Eilean

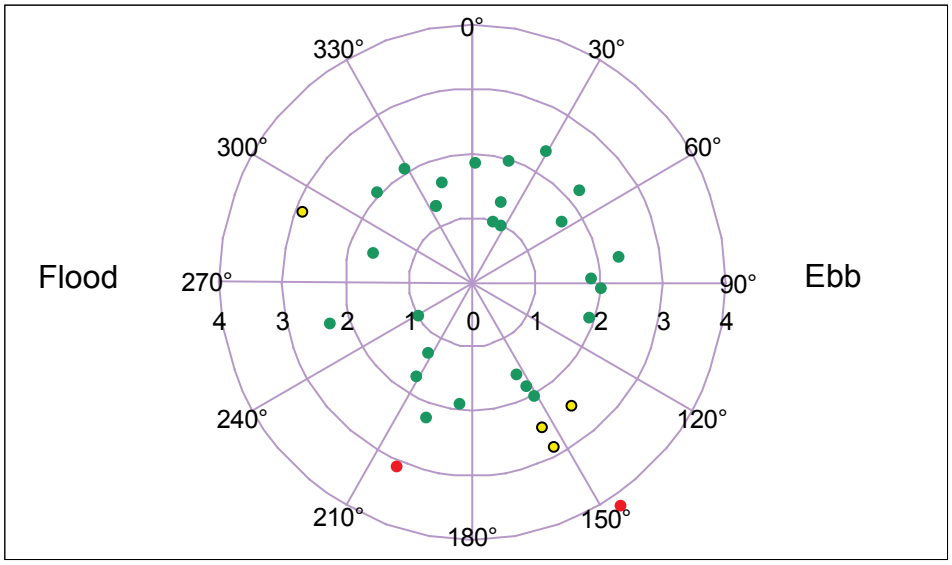


Figure 11.15 Polar plot of log_{10} *E. coli* results on the high/low tidal cycle (Garbh Eilean)

A significant correlation was found between *E. coli* results and the high/low tidal cycle (circular-linear correlation, r=0.413, p=0.006, Appendix 6). Figure 11.16 indicates that results were highest around low water, and lowest around high water.

Gob Glas

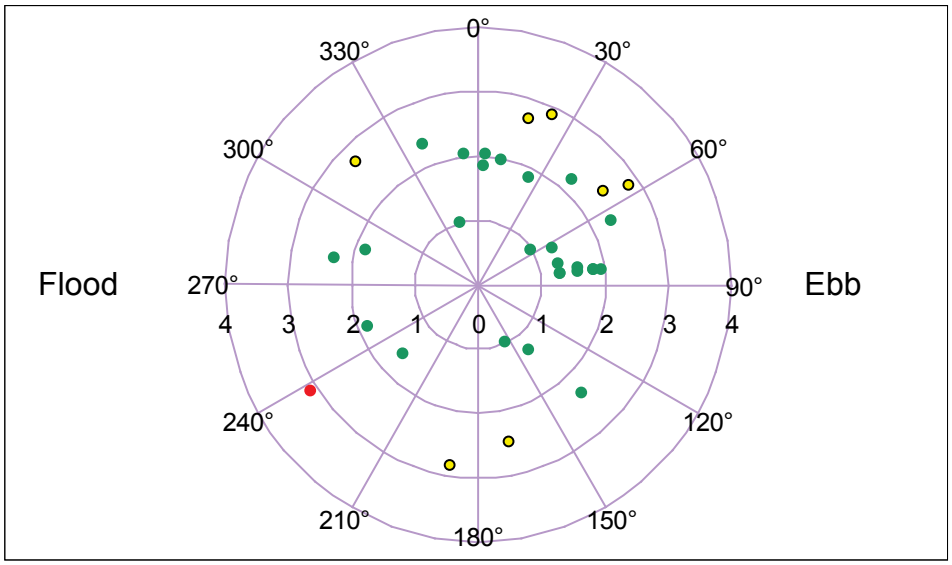


Figure 11.16 Polar plot of log_{10} *E. coli* results on the high/low tidal cycle (Gob Glas)

No statistically significant correlation was found between *E. coli* results for Gob Glas and the high/low tidal cycle (circular-linear correlation, r=0.309, p=0.051, Appendix 6).

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 on four occasions for Gob Glas and on no occasion for Garbh Eilean, so comparisons with *E. coli* results was not possible for either site.

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. Salinity was only recorded on 7 occasions for Gob Glas, so a comparison with *E. coli* results was not possible for this site. At Garbh Eilean salinity was recorded on 18 occasions. Figure 11.17 presents a scatterplot of *E. coli* results against salinity for this site.

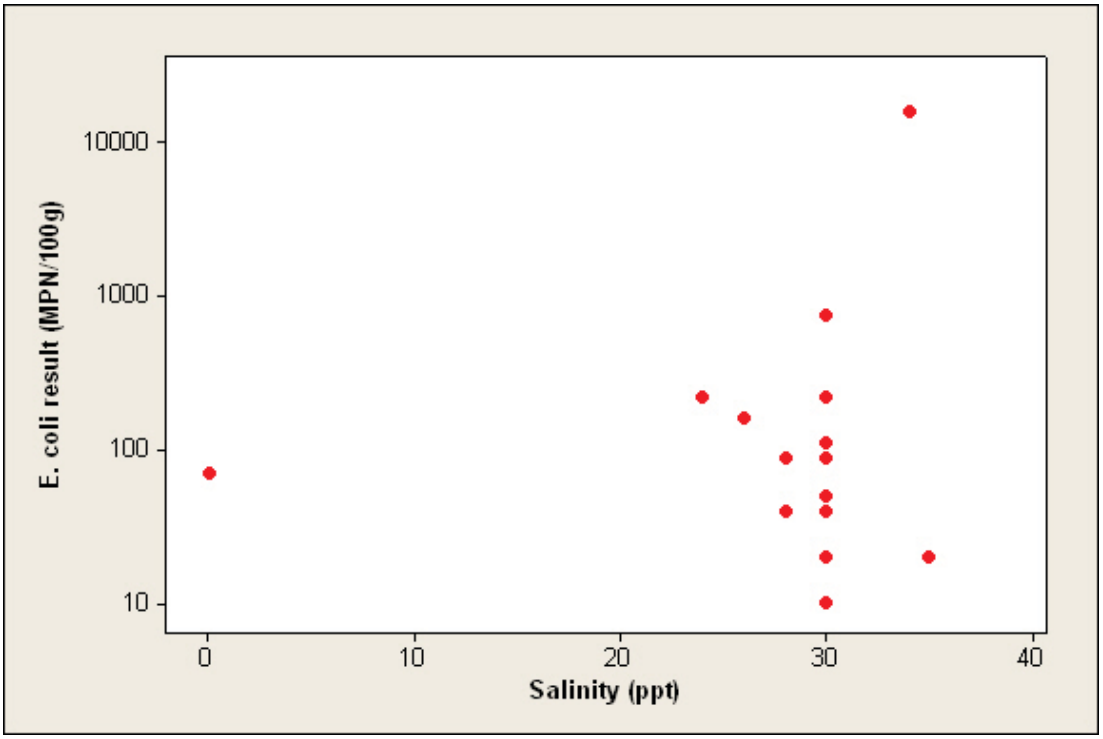


Figure 11.17 Scatterplot of E. coli results against salinity (Garbh Eilean)

No correlation was found between *E. coli* result at Garbh Eilean and salinity (Spearman's rank correlation= -0.099, p>0.25, Appendix 6).

11.7 Evaluation of results over 1000 *E. coli* MPN/100g

A total of 5 samples taken up to May 2010 gave a result of over 1000 *E. coli* MPN/100g, details of which are presented in Table 11.2.

Table 11.2 Historic *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)
02/11/2004	Rubh A Chleirich	9100	NB 320 203	0.4	17.4	*	*	High	Decreasing
04/07/2006	Gob Glas	1300	NB 352 206	0	5.2	*	*	Flood	Neap
09/01/2007	Gob Glas	1700	NB 352 206	21.8	67.8	*	*	*	Decreasing
19/08/2009	Garbh Eilean	16000	NB 3656 2128	7.8	28.4	*	34	Low	Increasing
10/02/2010	Garbh Eilean	1300	NB 3656 2128	*	*	*	*	Low	Neap

* Data unavailable

Results >1000 *E. coli* MPN/100g arose at all three sites. Samples were taken in January, February, July, August and November, so there was no clear season in which these higher results arose. They were generally taken following moderate to high total rainfall in the 7 days prior to sampling, and under a range of tidal conditions.

11.8 Summary and conclusions

Three sites were sampled within the survey area (Rubh A Chleirich, Gob Glas and Garbh Eilean) 10, 35 and 33 times respectively. When these results were thematically mapped by sampling location, no obvious geographical patterns were apparent. There was no significant difference in results by site when all results were considered. For the 13 occasions where Gob Glas and Garbh Eilean were both sampled on the same day, both geometric mean result and the proportion of results over 230 *E. coli* MPN/100g were higher at Gob Glas, although these differences were not statistically significant. Due to the low numbers of samples taken at Rubh A Chleirich more detailed analyses of temporal patterns of results and relationships with environmental variables were not undertaken for this site.

In terms of overall temporal trends, results appear to have deteriorated at Gob Glas between 2005 and 2007, though too few samples have been taken since 2007 to suggest any further trends in results. At Garbh Eilean no obvious trends or cycles were apparent, aside from perhaps a slight deterioration in results in 2009. No significant seasonal effect was found at Garbh Eilean, though results were generally higher in winter. At Gob Glas, results were significantly lower in spring than in other seasons.

Table 11.3 shows a summary of the significant correlations with environmental factors by site.

Table 11.3 Summary of significant correlations at Loch Erisort: Outer

	Garbh Eilean	Gob Glas
Season	No	Lower results in Spring
2-day rainfall	Positive	No
7-day rainfall	Positive	No
Temperature	*	*
Salinity	No	*
Spring/Neap tide	No	Higher results at spring tides
High/Low tide	Higher results at low tide	No

* Insufficient data for analysis

No correlations were found between *E. coli* results and rainfall in the previous 2 and 7 days at Gob Glas, whereas relatively strong positive correlations were found between these variables for Garbh Eilean, suggesting that this site is more influenced by rainfall dependent sources than is Gob Glas. No correlation was found between *E. coli* results and salinity at Garbh Eilean and the relationship between results and salinity was not investigated for Gob Glas as salinity was recorded on too few occasions.

At Gob Glas, a correlation was found between *E. coli* results and the spring/neap tidal cycle, where fewer low results arose during spring and decreasing tides. No correlation was found between results and the high/low tidal cycle at this site.

At Garbh Eilean, no correlation was found between *E. coli* results and the spring/ neap tidal cycle, but a correlation was found with the high/low tidal cycle, with highest results around low water, and lowest results around high water.

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

11.9 Sampling frequency

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

12. Designated Shellfish Growing Waters Data

Loch Erisort has not been designated as a Shellfish Growing Water under the European Community Shellfish Waters Directive 79/923/EEC.

13. River Flow

There are no gauging stations on watercourses along the Loch Erisort: Outer coastline.

The watercourses listed in Table 13.1 were measured and sampled during the shoreline survey. The weather was dry on the day that the watercourses were measured and sampled but it had been raining on the previous day. 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 Erisort: Outer

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 35809 21636	Stream	0.50	0.18	0.028	218	60	1.3×10^8
2	NB 35833 21639	Culverted stream	0.27	0.04	0.453	423	150	6.3×10^8
3	NB 32426 21626	Weir with central spillway	6.7	0.17[1]	0.73[1]	199000	60	1.2×10^{11}
4	NB 35131 20295	Stream	0.45	0.15	0.359	2090	<10	$<2.1 \times 10^8$
5	NB 36485 19855	Abhainn Chabharstaidh	2.3	0.3	0.857	51100	60	3.1×10^{10}

[1]Depth and flow varied across the width: values given are weighted averages

The calculated loading for watercourse number 3 in Table 13.1 was high. However, this is located more than one kilometre from the nearest mussel lines. The loading for watercourse number 5 was moderately high. Again, it is located some distance from the nearest mussel lines. However, depending on the currents in the area, these two could impact on the lines at Gob Glas under certain conditions. Loadings for the other three watercourses were low. Although one of these entered the loch on the shore immediately adjacent to the mussel lines at Gob Glas, the *E. coli* results for the water sample collected at the time of the shoreline survey was below the limit of detection of the test, indicating that no significant amount of faecal contamination was present. Loadings from all of these watercourses would be expected to increase following heavy rain.

Some other small watercourses are marked on the OS map on the shores adjacent to the mussel lines at Gob Glas and Garbh Eilean. The shore at these points could not be accessed during the shoreline survey. It is likely that these watercourses only flow following moderate to heavy rainfall. Two named watercourses, Abhainn Eallaidh (on the north side of the loch) and Abhainn Eallaidh (on the south side) were not recorded or sampled during the shoreline survey. Due to their location and distance from the fisheries, these are unlikely to impact significantly on the water quality at the mussel farms.

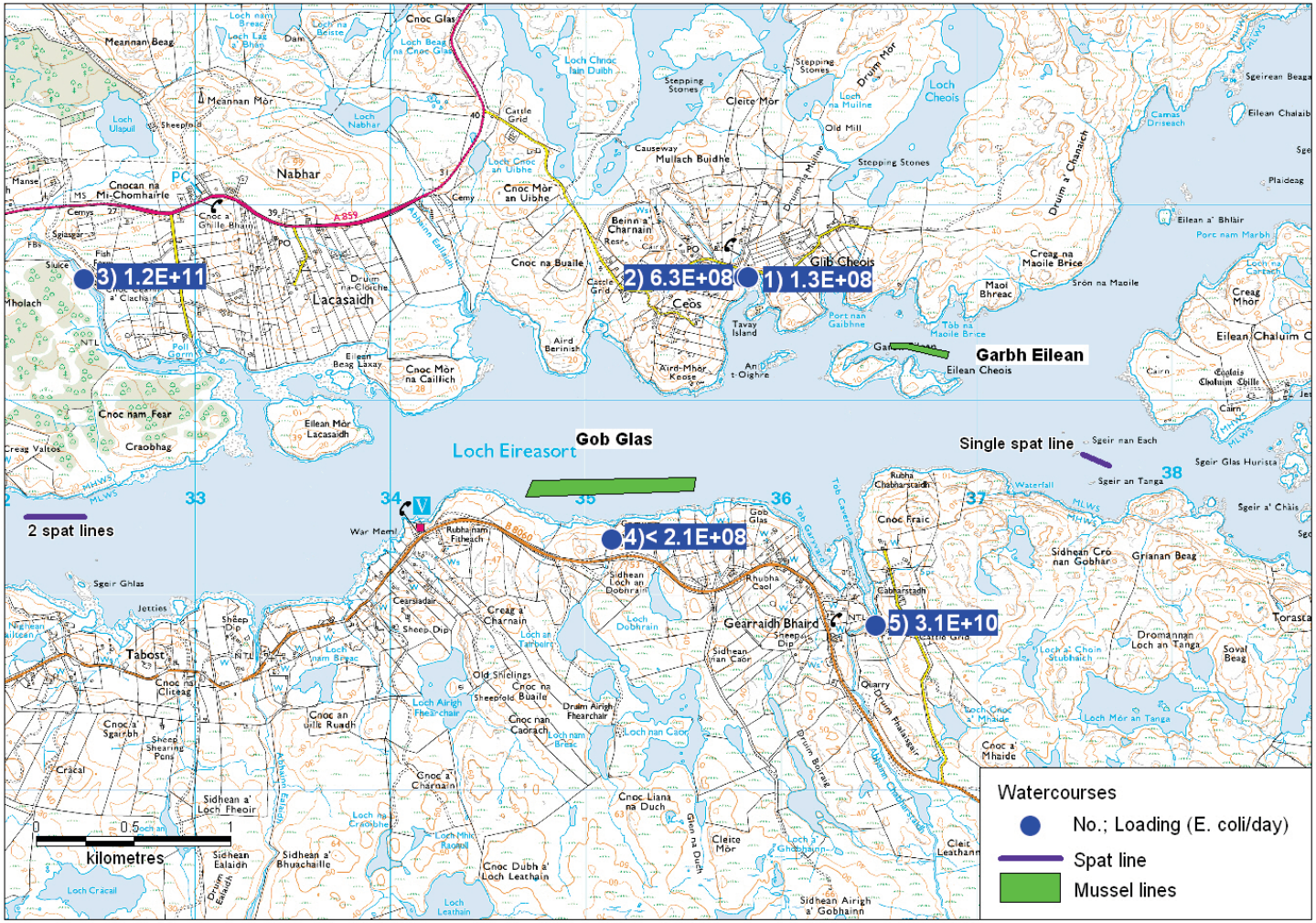


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Figure 13.1 Map of stream loadings at Loch Erisort: Outer

14. Bathymetry and Hydrodynamics

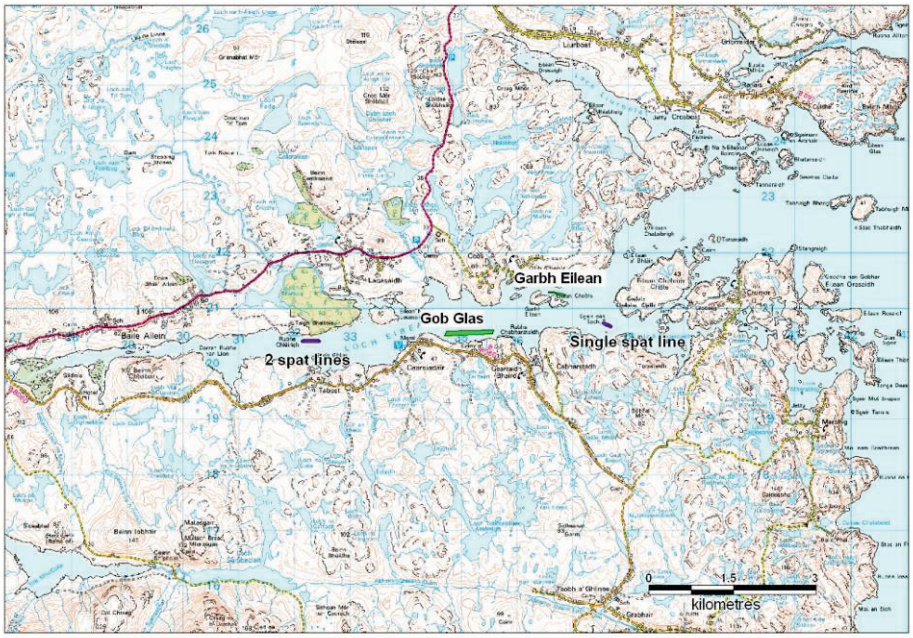

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Figure 14.1 OS map of Loch Erisort

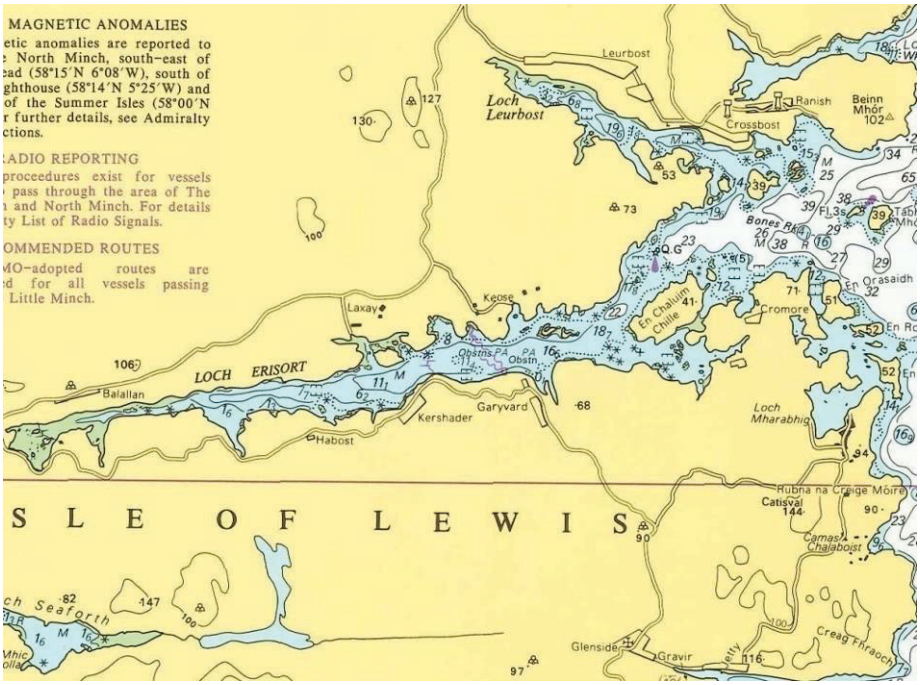

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Figure 14.2 Bathymetry at Loch Erisort

Loch Erisort lies in an east-west direction with the mouth at the eastern end. Edwards and Sharples (1991) give the length as 12 km. However, the distance from its head to the confluence with Loch Leurbost is approximately 14 km. It is 0.5 to 1 km wide in the outer part but less then 0.3 km wide

towards the head. Edwards and Sharples (1991) identify the presence of two sills in the loch although the map they present does not identify the location of these. The chart in Figure 14.2 indicates a significant drying area at the head of the loch and that the depth gradually increases from there towards a basin located towards the mouth. The depth of the basin is given as 22 m. Depths exceeding this figure occur towards the confluence with Loch Leurbost. Although the depth increases gradually in a longitudinal direction, the seabed shelves rapidly away from shore in the outer loch. Depths at the mussel lines exceed 10 m. There are numerous islands in the outer loch, the largest of which is Eilean Chaluim Chille. This island is connected to the rest of Lewis by a causeway at low tide. Numerous obstructions, submerged rocks and small islands in the loch will affect water movement in their vicinity, particularly within the outer loch.

14.1 Tidal Curve and Description

The two tidal curves below are for Stornoway, approximately 12 km from the mouth of Loch Erisort. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 BST on 22/09/10 and the second is for seven days beginning 00.00 BST on 29/09/10. 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.

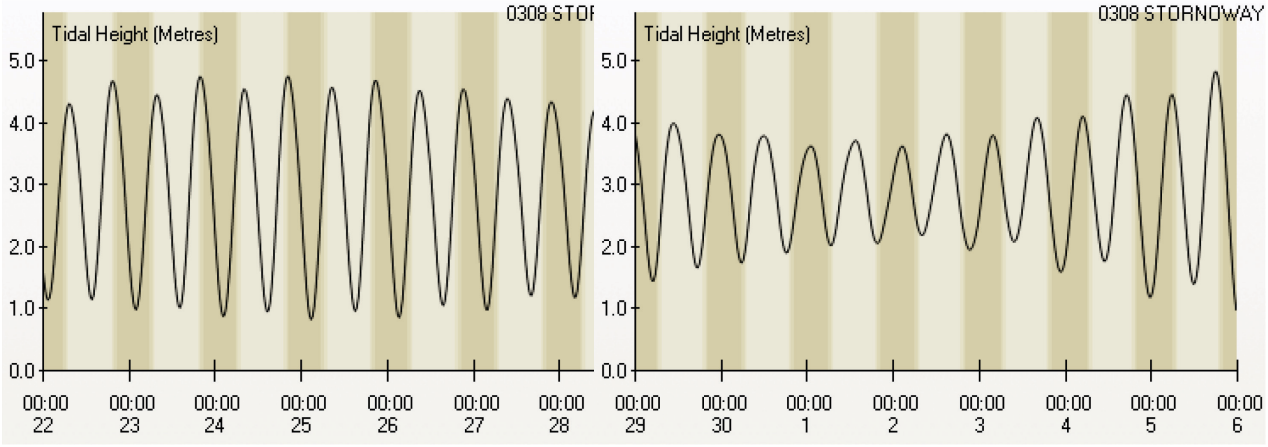

Figure 14.3 Tidal curves for Stornoway

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

There is no UKHO tidal stream information available for the vicinity of Loch Erisort. The Clyde Cruising Club Directions for the area identify that the ingoing stream begins 6 h 10 m before HW Ullapool and the outgoing stream begins 0 h 05 m after HW Ullapool (CCC, 2007). The directions also note that "the streams are barely perceptible except in the narrow channels".

SEPA provided summary current meter data for the area. The locations of the current meters are shown in Figure 14.4: they were all sited at the mouth of the loch. The summary data are presented in Table 14.1.

The current meter data indicates that average currents in the area were very weak, with values not exceeding 0.073 m/s (0.15 knots). The percentage of current speeds <0.095 m/s was high at 70 to 86%, confirming the generally weak currents. The principal current and residual direction was WSW, i.e. roughly in line with the lie of the loch. The major axis amplitude to minor axis amplitude ratio was approximately 2, indicating a weakly elliptical current vector plot. A much larger ratio would be obtained if the current simply switched direction back and forth along the axis of the loch with the ebb and flood tide.

At a peak current speed of 0.1 m/s, contaminants would be expected to travel a maximum distance of approximately 1.4 km over a flood or ebb tide.

Edwards and Sharples (1991) gave a flushing time of 1 day for Loch Erisort. This figure was calculated based on OS map and UKHO chart data and does not appear to concur with the current data described above.

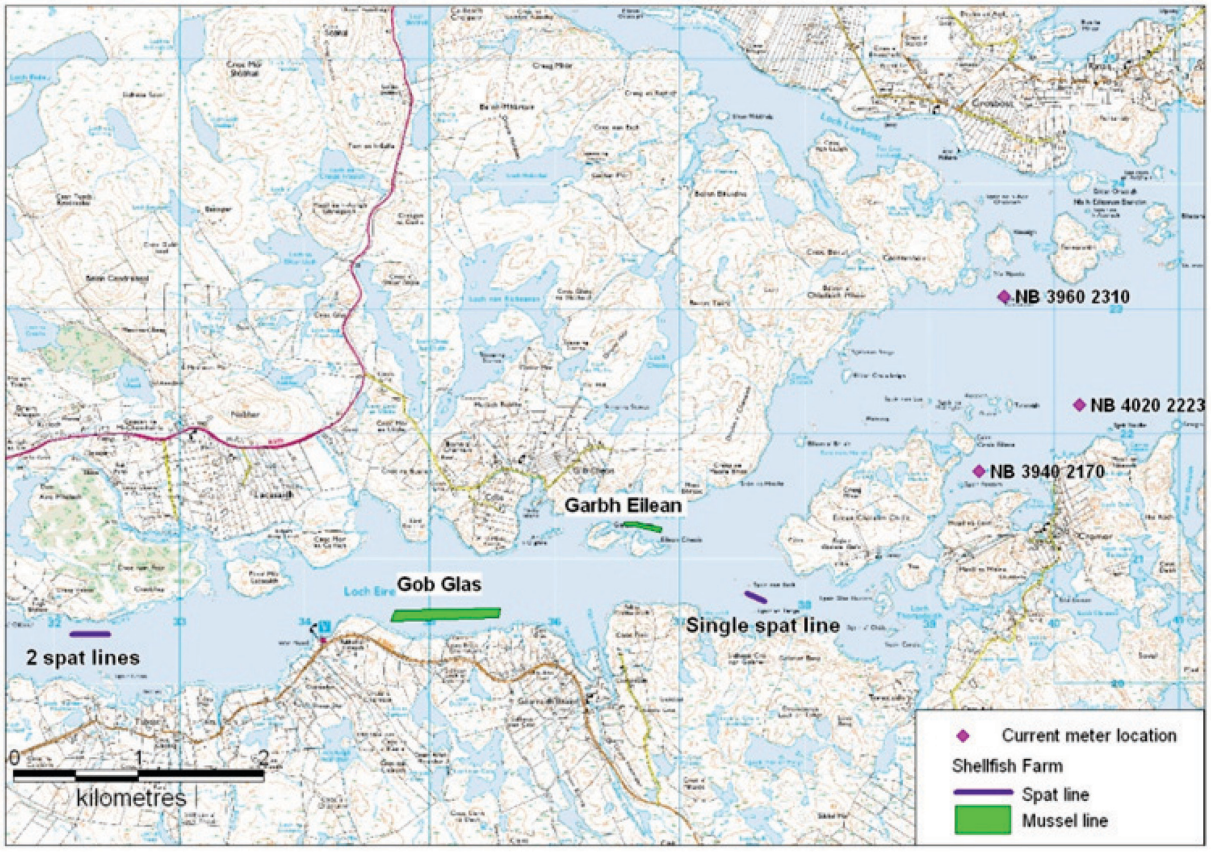

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Figure 14.4 Location of current meters

Table 14.1 Summary current meter data for Loch Erisort

Location	Depth	Current speed			Major amp./min or amp.	Residual	
		Mean (m/s)	%<0.09 5 m/s	Major axis		Speed (m/s)	Direction (Deg G)
NB 3960 2310 (1997)	Sub-surface	0.061				0.008	003
	Mid-depth	0.056				0.017	297
	Near-bottom	0.053				0.021	247
NB 3960 2310 (2009)	Sub-surface	0.073	74	260	1.83	0.017	029
	Mid-depth	0.072	70	260	2.39	0.042	260
	Near-bottom	0.067	78	250	2.21	0.037	250
NB 3940 2170	Sub-surface	0.027				0.007	263
	Mid-depth						
	Near-bottom	0.017				0.008	210
NB 4020 2223	Sub-surface	0.058	86	085	1.84	0.025	087
	Mid-depth	0.061	82	265	2.8	0.026	259
	Near-bottom	0.053	86	260	2.35	0.03	257

14.3 Salinity profiles

Salinity profiles were recorded during the shoreline survey at the locations shown in Figure 14.5. The salinity values are shown in Table 14.2.

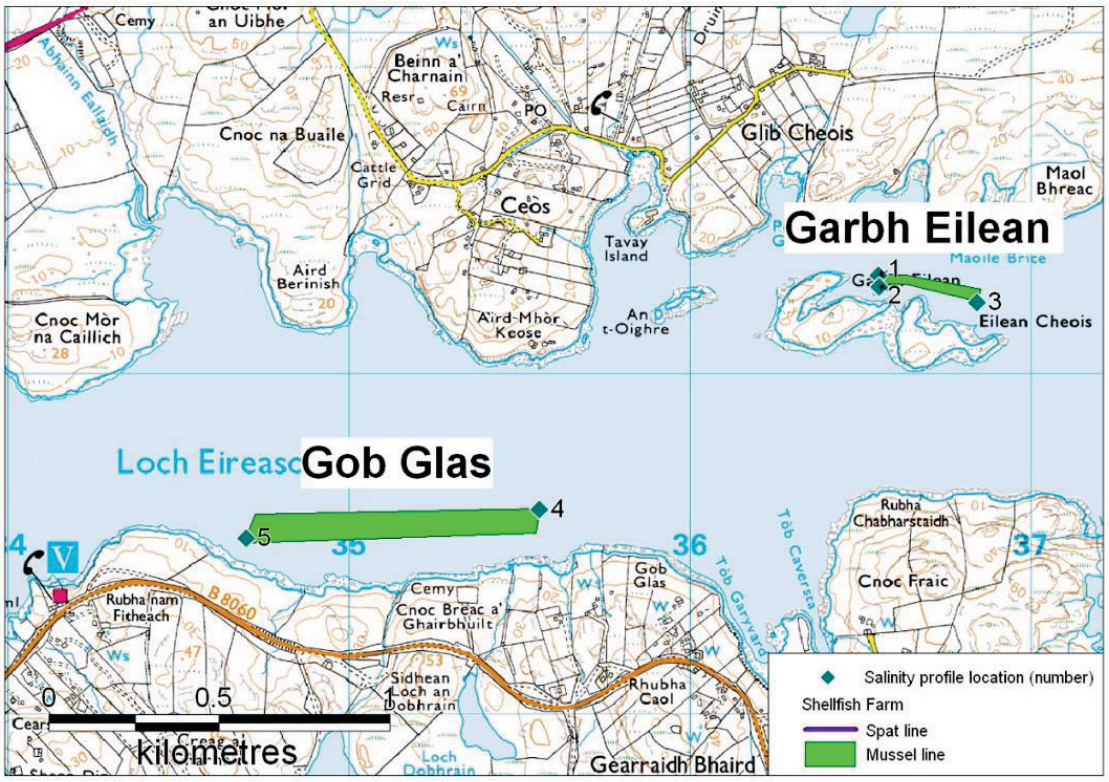

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Figure 14.5 Location of salinity profiles

Table 14.2Salinity profiles recorded during the shoreline survey

Profile	Position	Depth (m)	Salinity (ppt)
1	NB 36556 21293	Surface	11.7
		1	30.6
		5	34.5
		10	34.7
2	NB 36559 21260	Surface	30.3
		1	31.7
		5	34.6
		10	34.7
3	NB 36847 21214	Surface	31.1
		1	34.6
		5	34.6
		10	34.8
4	NB 35559 20605	Surface	29.3
		1	32.9
		5	34.2
		10	34.8
5	NB 34698 20521	Surface	Not recorded
		1	29.8
		5	34.2
		10	34.8

The salinities at depth in each location were similar. The surface and 1 m values show evidence of freshwater influence. It was raining heavily on the

day the profiles were taken, and had been raining heavily the previous day, and so the effect may have been due to this rather than more persistent stratification. Edwards and Sharples (1991) gave a fresh to tidal flow ratio of 8 with a calculated salinity reduction of 0.3 ppt.

14.4 Conclusions

In the vicinity of the mussel lines the seabed shelves deeply away from the shore and significant dilution of any contaminants would be expected to occur. Currents are generally weak although they might be expected to be faster and more directional within the body of the loch than at the mouth from where current data was available. Contaminants will generally be taken a relatively short distance from their source over a tidal cycle. There is some evidence of stratification within the loch although it is not clear as to how much the data was influenced by heavy rainfall around the time of the shoreline survey.

15. Shoreline Survey Overview

The shoreline survey was conducted on 22 and 29-30 September 2010 under variable weather conditions. Heavy rain fell on 22 September, as well as during the preceding day. Fog and rain were recorded on 29 September and the weather was fair and dry on 30 September.

The mussel farm at Gob Glas consisted of 6 double-headed long lines with 6 metre droppers. These extended along the south shore of the loch over a distance of approximately 1 km.

The mussel farm at Garbh Eilean consisted of a number of fish cage platforms from which mussel lines were suspended plus 2 double-headed long lines with droppers to a depth of 6 metres. The farm was situated north of the two islands of Garbh Eilean and Eilean Cheois.

Longlines for collection of spat were deployed in two locations outwith the boundaries of the classified area. The locations of these were estimated using observations and photographs taken from shore.

The only community discharge observed during the shoreline survey was the main discharge for Loch Leurbost: this discharges to the outer part of the loch, approximately 2.5 km northeast of the Garbh Eilean mussel farm. Private discharges were observed along the south shore at Tob Caversta. A visitors centre and public toilet at Tabost was likely to have a septic tank and discharge, though it was not possible to access the shore behind them to observe it. Some of the homes around the loch are reportedly only occupied during the summer tourist season, and there was B&B accommodation in the area.

A number of work boats were observed in the area, with moorings located in protected coves. The vast majority of these were tenders or small open boats.

Crofts line the northern shore with the main concentration toward the head of the loch at Balallan (Baile Ailein), and two other clusters at Lacasaidh and Coos. Along the south shore, crofts were found at Tabost and Gearraidh Bhaird. A large number of sheep, as well as smaller numbers of cattle and horses, were observed on the crofts, on rough grazing and along the roads.

Few wildlife were observed, with what was most likely an otter seen swimming near the Garbh Eilean site and small numbers of gulls and cormorants seen on mussel floats and mooring buoys and on areas of rocky shore.

Water samples were taken from significant and accessible watercourses and of sea water around the area. These showed higher levels of contamination in seawater than was found in the freshwater courses. A sample taken from near the discharge pipe for the Loch Leurbost septic tanks showed low levels of faecal contamination, however no boil was observed so it is not clear whether the discharge was flowing at the time. The highest result in seawater

(>10000) came from near the end of a flowing septic discharge at Tob Caversta, on the southeast shore. Seawater samples taken from shore near Ceos and Glib Cheois had *E. coli* concentrations of 380 and 900 cfu/100 ml respectively, indicating these areas were subject to significant faecal contamination. Samples taken from fresh watercourses showed lower levels of contamination in general than the seawater samples, with the highest (150 *E. coli* cfu/100 ml) being from a stream at Ceos.

Shellfish samples were taken during heavy rainfall on 22 September. At Garbh Eilean, samples taken from the western end of the mussel farm were found to contain higher concentrations of *E. coli* (460 and 490 MPN/100 g) than that taken from the eastern end (170 MPN/100 g), and there was very little difference between samples taken at depth and nearer the surface (western end only). At Gob Glas, there was no difference in samples taken from the eastern and western ends of the shellfish farm, though samples taken from the surface were more highly contaminated (490 *E. coli* MPN/100 g) than those taken from the bottoms of the lines (170 *E. coli* MPN/100 g).

Salinity profiles were taken at the same time as mussel samples, and showed that there was a reduction in salinity at the surface and at 1 metre depth.

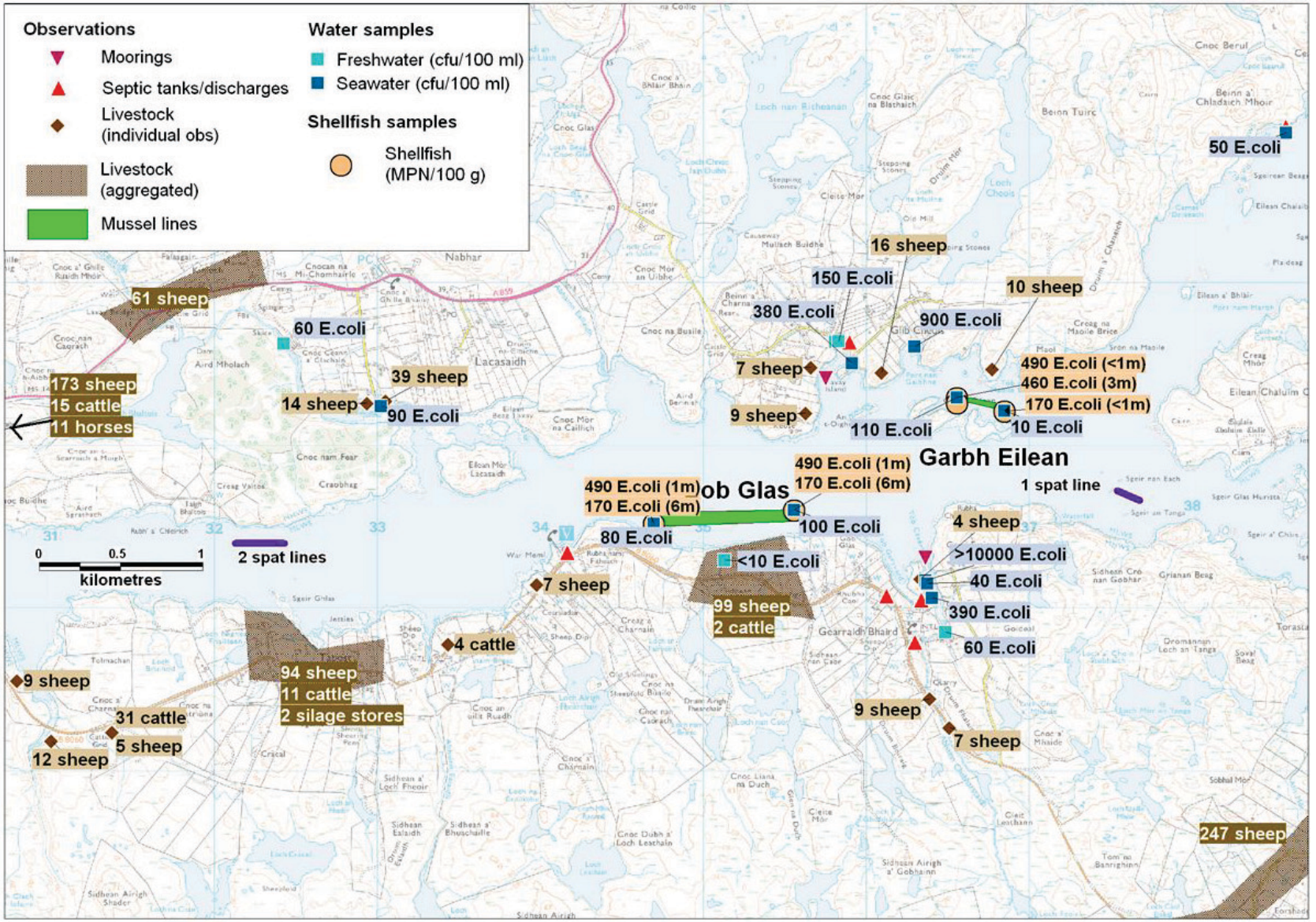

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Figure 15.1 Summary of shoreline survey findings for Loch Erisort: Outer

16. Overall Assessment

The existing fishery at Loch Erisort: Outer comprises two separate, established mussel farms at Gob Glas and Garbh Eilean. Spat lines were observed during the shoreline survey at two locations: one near the now declassified Rubh A Chleirich site west of Gob Glas and another to the southeast of Garbh Eilean near Sgier nan Each. Subsequent to survey, a request was made via the Food Standards Agency that these be considered for inclusion in the classified production areas due to interest in commercial production. Therefore, consideration of these sites has been included in the assessment and recommendations that follow.

Human sewage impacts

Sewage discharges along the north shore are primarily from community septic tanks. Elevated *E. coli* concentrations were observed in seawater samples taken near Ceos, however it is not clear what portion of this was attributable to human sewage input.

Further community sewage discharge are located at Balallan, 5 km west of the western end of the Gob Glas site (and approximately 2.4 km west of the nearest spat line) and at a point in outer Loch Erisort 2.4 km northeast of the eastern end of the Garbh Eilean site. The Balallan discharge has a consented dry weather flow of 35 m^3/day (PE 175) which could contribute approximately 2.5 x 10^{12} *E. coli*/day to the upper loch. Water depths in the area of the discharge are 10 m or less, so the potential for dilution is relatively limited. Impacts to are likely to be highest at the spat lines near the old Rubh A Chleirich site.

Combined effluent from three septic tanks in Loch Leurbost was rerouted to a discharge point in outer Loch Erisort, approximately 2.5 km northeast of the Garbh Eilean site, in 2009. Shellfish monitoring results at this site have deteriorated since mid-2009, indicating a decline in water quality at the oyster farm that appears to coincide in time with the commencement of the new discharge.

The southern shore of the loch has no community sewage provision and so individual businesses and properties are served by private septic tanks. The majority of these discharge to soakaway and presuming that the systems are functioning properly there is a relatively low risk of contamination from these to the fishery. The settlements around Tabost and Gearraidh Bhaird are established on soils identified as freely-draining, which further reduces the risk to the fishery. The most significant nearby sources of sewage to the Gob Glas site are the Tabost visitor centre and associated tea room and accommodation (600 m to the southwest) and the discharges from private homes to Tob Caversta, (1km to the southeast). No discharge consent was available for the visitor centre therefore it is difficult to assess the potential volume of discharge. This discharge volume is likely to be significantly higher

during the summer tourist season and so could particularly impact the western end of the mussel farm during the summer months.

East of the mussel farm, a small number of private septic tanks discharge to Loch Erisort near Gearraidh Bhaird. Some of the homes in the area may be only seasonally occupied. At the time of shoreline survey, two active discharges were observed and water samples from adjacent the pipe ends confirmed septic content. However, it is likely that the overall human population equivalence (and therefore the potential for contamination with human pathogens) from these sources is lower than that from the visitors centre west of the mussel farm.

Shellfish samples taken during the shoreline survey indicated similar levels of contamination at either end of the mussel farm, however the survey was undertaken outside the peak holiday months of July and August.

The spat line at Sgier nan Each lies furthest from identified sources of human sewage contamination. However, this site was not visited during the shoreline survey and therefore it is not clear how different contamination levels may be there relative to the established mussel farms.

Agricultural impacts

A large number of livestock animals were observed on crofts and grazing land around the loch. A large proportion of these were found on the north shore at the head of the loch. Animals tended to be concentrated around crofts, though some animals were found either on rough land or grazing the road verges, particularly south and east of Gearraidh Bhaird.

The most significant concentrations of livestock to the fisheries are those associated with crofts at Ceos, west of the Garbh Eilean site and those located on land directly south of the Gob Glas site.

Animals on the shore south of Gob Glas are likely to present a significant source of faecal contaminants to waters around the Gob Glas site due to the number of animals, land cover, the steep gradient of the land and poor soil permeability. At the Garbh Eilean site, sheep were observed on rough grazing and pasture to the north and west of the site though in smaller numbers than were present south of Gob Glas. Livestock keep further toward the head of the loch are likely to contribute to background levels of faecal contamination particularly nearer the head of the loch.

Wildlife impacts

A variety of wildlife species are known to be present in the area and these may contribute to background levels of faecal contamination present in the waters of the loch. 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 farm. However, the presence and movements of these animals are likely to be highly variable and their impact at any given

time difficult to predict. 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 at the head of the loch, where the shore is suitable for wading birds.

Seasonal variation

Population in the area is likely to be higher during the summer months, particularly along the south shore where there are tourist facilities. Livestock numbers are expected to be higher from May to September, when lambs and calves are present.

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

Historical monitoring results at Garbh Eilean were somewhat higher during the autumn and winter, though this difference was not statistically significant. The highest individual result occurred in summer. Results at Gob Glas were significantly lower in spring than in the other seasons.

Seasonal variation is likely to occur in populations of humans, livestock and wildlife in the area, with both humans and livestock expected to be present in higher numbers during the summer months. Insufficient information was available to accurately characterise the seasonal variation in wildlife populations in the area.

Rivers and streams

The highest calculated loadings for watercourses discharging to the loch relatively near to the fisheries were from Abhainn Lacasaidh to the north shore north of Gob Glas and east of the Rubh A Chleirich spat lines, and Abhainn Chabharstaidh, east of Gob Glas. Both are likely to contribute to background levels of faecal contamination in the loch. Salinities recorded at the fishery, both during the shoreline survey and during monitoring sampling, showed salinity reductions at up to 1 m depth of approximately 5 ppt. This suggests that freshwater input from the streams and burns in the area may have a significant impact on salinity at the top of the water column some distance from the sources. Therefore, faecal contamination carried via freshwater sources is likely to contribute to background contamination levels across the fishery. Faecal bacteria concentrations might be expected to be higher near the surface and closer to sources.

Other small watercourses marked on the OS map on the shores adjacent to the mussel lines at Gob Glas and Garbh Eilean could not be accessed during the shoreline survey. Two streams discharging south of the Sgier nan Each spat line were likewise not surveyed as the spat lines were not considered in the original survey plan. Many of the smaller watercourses discharging to the

loch are only likely to flow under heavy rainfall conditions and loadings from all of the watercourses would be expected to increase following heavy rain.

Hydrography and movement of contaminants

In the vicinity of the mussel lines the seabed shelves deeply away from the shore and significant dilution of any contaminants would be expected to occur. Recorded currents in the outer part of the loch were generally weak and the tidal ranges in the area are moderate. Currents might be expected to be more notable within the loch, particularly where rocks and small islands create constrictions. Wind-driven currents and mixing may be more important factors in the movement of contaminants than tidal flows. The large number of submerged rocks, small islands and underwater obstructions present in the loch are likely to complicate local movement of currents and contaminants particularly around the outer loch and the Garbh Eilean site.

Contaminants are expected to move a relatively short distance from their source over a tidal cycle. Therefore, local sources of contamination are more likely to directly affect the fisheries. Although the local sources of contamination may differ, sampling during the shoreline survey indicates that the extent of contamination is similar at the two sites.

There is some evidence of stratification within the loch although it is not clear as to how much the data was influenced by heavy rainfall around the time of the shoreline survey.

Analysis of historical results by tidal cycles showed a correlation between the spring/neap tidal cycle and *E. coli* results at Gob Glas, where fewer low results arose during spring and decreasing tides, and no correlation was found between results and the high/low tidal cycle. The source of this effect is not clear, though it may be that stronger currents during the spring tides carry contaminants to the fishery from further afield.

At Garbh Eilean, the opposite was the case. *E. coli* results were found to correlate with the high/low tidal cycle, with highest results around low water, and lowest results around high water. No correlation was found between *E. coli* results and the spring neap tidal cycle at this site. The closest sources of faecal contamination to Garbh Eilean are associated with the populated area around Cheos, which lies west of the fishery and therefore contamination from sources there would be transported to the mussel farm on the outgoing tide.

Temporal and geographical patterns of sampling results

Analysis of historical monitoring results indicated conflicting patterns. Geometric mean results, when mapped, seemed to indicate higher results at the Garbh Eilean site. However, analysis of paired results indicated slightly higher results at the Gob Glas site. Sampling during the shoreline survey showed the same results at both sites, with higher results at the western end of the Garbh Eilean site than at the eastern end. Results were consistently

higher for near-surface samples. The highest overall result (16000 *E. coli* MPN/100 g) occurred at Garbh Eilean.

Results at Garbh Eilean appeared to have deteriorated somewhat over the period analysed. There were large gaps in the sampling, however. No results <20 MPN/100 g have occurred since 2007 and peak results were higher in 2009 and early 2010.

At Gob Glas, a large gap in the sampling regime with only 2 recent results reported at the time of analysis meant that no meaningful assessment of trend over time was possible.

At Rubh A Chleirich in 2004-2005, the proportion of results exceeding 230 MPN/100 g was 50% at Rubh A Chleirich with one result exceeding 4600 MPN/100 g, indicating that it may be subject to greater levels of faecal contamination that Gob Glas or Garbh Eilean.

No correlations were found between *E. coli* results and rainfall at Gob Glas, whereas relatively strong positive correlations were found between these variables for Garbh Eilean, suggesting that this site is more influenced by rainfall dependent sources than is Gob Glas. No correlation was found between *E. coli* results and salinity at Garbh Eilean. However, measurements taken during the shoreline survey showed a reduction in surface salinity at the west end of the mussel farm, where all monitoring samples have been taken. The salinity profiles were taken during very heavy rainfall and little wind, therefore this may have been the cause of the reduced salinity.

Conclusions

Gob Glas and Garbh Eilean are subject to both human point source and diffuse faecal contamination from different sources. Analysis of the patterns of effects of environmental factors seem to support that the sites may be subject to differing sources or pathways of contamination. Of the two sites, Garbh Eilean lies closer to several community discharges, including that from Loch Leurbost. Gob Glas lies between small discharges to the east and west, though the discharge from the visitor centre west of the farm is potentially more significant in terms of public health.

The spat lines at Rubh A Chleirich lie nearer to the head of the loch and this site is more likely to be affected by sewage discharges and diffuse pollution from Balallan. The spat line near Sgier nan Each lies near sparsely populated and/or uninhabited shoreline and approximately the same distance from the Leurbost combined discharge as Garbh Eilean. Although no sampling has been undertaken at this location, based on the information available, contamination levels are not expected to be significantly higher than those found at Garbh Eilean.

Movement of contaminants around the loch is anticipated to be somewhat limited due to slow predicted current speeds, suggesting that sources closer to the sites are most likely to affect water quality there. Shellfish grown near

the surface are likely to be more contaminated than those at depth. Although Gob Glas and Garbh Eilean sites overall showed very similar levels of contamination, one exceptionally high result was obtained at Garbh Eilean in 2009, indicating that it may be subject at times to much higher levels of contamination. When the two sites were sampled at the same time, results were generally higher at Gob Glas, though this difference was not found to be statistically significant. Monitoring results from Rubh A Chleirich indicated that it also may be subject to higher levels of contamination than at the other two sampled sites, with a higher proportion of results >230 MPN/100 g.

17. Recommendations

In view of the identified sources and differences in effect between the sites, it is recommended that the production area be split. Furthermore, due to interest expressed in considering the spat lines for commercial production, these should be incorporated into the recommended production areas. The following areas are recommended:

Loch Erisort: Garbh Eilean

Production area

The recommended boundaries are the area bounded by lines drawn between NB 3642 2051 to NB 3606 2136 to NB 3675 2139 to NB 3694 2142 to NB 3794 2087 to NB 3800 2055 and between NB 3786 2052 to NB 3713 2062 extending to MHWS. This area excludes portions along the northern and southern shores, nearer to community septic discharges at Ceos and inlets where water courses reach the shoreline. The area has been extended to include the spat line identified approximately 800 m to the southeast of the Garbh Eilean site.

RMP

The Garbh Eilean site lies closer to larger community septic discharges than does the spat line, and has had the highest individual monitoring result, therefore it is recommended that the RMP be relocated to western end of the Garbh Eilean site at NB 3658 2128. Although there has been no sampling from the spat line site, it is expected that monitoring at the Garbh Eilean site will be sufficiently representative of peak contamination levels in the area to be protective of public health.

Frequency

As the area has held seasonal classifications for the past three years, and in light of the significant gaps in monitoring history at one or other site within the production area, it is recommended that monthly monitoring be maintained until such time as the area qualifies for reduced sampling on the basis of a stability assessment.

Depth of sampling

Higher results were found near the surface during the shoreline survey, and sources in the area are likely to be carried in freshwater, therefore it is recommended that monitoring samples be taken from within 1 meter of the surface.

Tolerance

A sampling tolerance of 40 meters is recommended to allow for movement of the lines. It is recommended that a dedicated sampling line or bag be placed at the RMP, and that stock used for monitoring be in place for at least 2 weeks prior to sampling.

Loch Erisort: Gob Glas

Production Area

The recommended production area boundaries are the area bounded by lines drawn between NB 3433 2053 to NB 3430 2100 to NB 3600 2100 to NB 3600 2040 extending to MHWS. This excludes sewage sources on the south shore to the east and west of the mussel farm, as well as inlets along the northern shore that may be subject to higher contamination levels.

RMP

The current RMP for the Gob Glas site is located near the mid point of the farm east to west and on the loch side as opposed to the shore side of the lines. It is recommended that the RMP be relocated to NB 3472 2053, a point nearer to identified sources along the south shore to the west of the site.

Frequency

As the area has held seasonal classifications for the past three years, and in light of the significant gaps in monitoring history at one or other site within the production area, it is recommended that monthly monitoring be maintained until such time as the area qualifies for reduced sampling on the basis of a stability assessment.

Depth of sampling

Higher results were found near the surface during the shoreline survey, and sources in the area are likely to be carried in freshwater, therefore it is recommended that monitoring samples be taken from within 1 meter of the surface.

Tolerance

A sampling tolerance of 40 meters is recommended to allow for movement of the lines. It is recommended that a dedicated sampling line or bag be placed at the RMP, and that stock used for monitoring be in place for at least 2 weeks prior to sampling.

Loch Erisort: Rubh a Chleirich

Production area

This area incorporates the westernmost spat lines only and lies nearest to sources at the head of the loch. The recommended production area is the area bounded by lines drawn between NB 3200 2056 to NB 3200 2004 to NB 3300 2004 to NB 3300 2069 extending to MHWS. This excludes areas near watercourses along the southern shoreline.

RMP

The recommended RMP is NB 3213 2040. This point lies at the western end of the seabed lease area and estimated location of the spat line, where it is likely to be affected by discharges from the Balallan septic tank and diffuse sources further up the loch.

Frequency

As this area is not currently classified, monthly sampling is recommended.

Depth of sampling
Based on information obtained for other parts of the loch, there is the potential for contamination levels to be higher near the surface therefore the recommended sampling depth is within 1 m of the surface.

Tolerance
A sampling tolerance of 40 m is recommended to allow for movement of the lines .

Figure 17.1 shows the locations of the recommended boundaries and RMP along with the recorded locations of the mussel farms and spat lines.

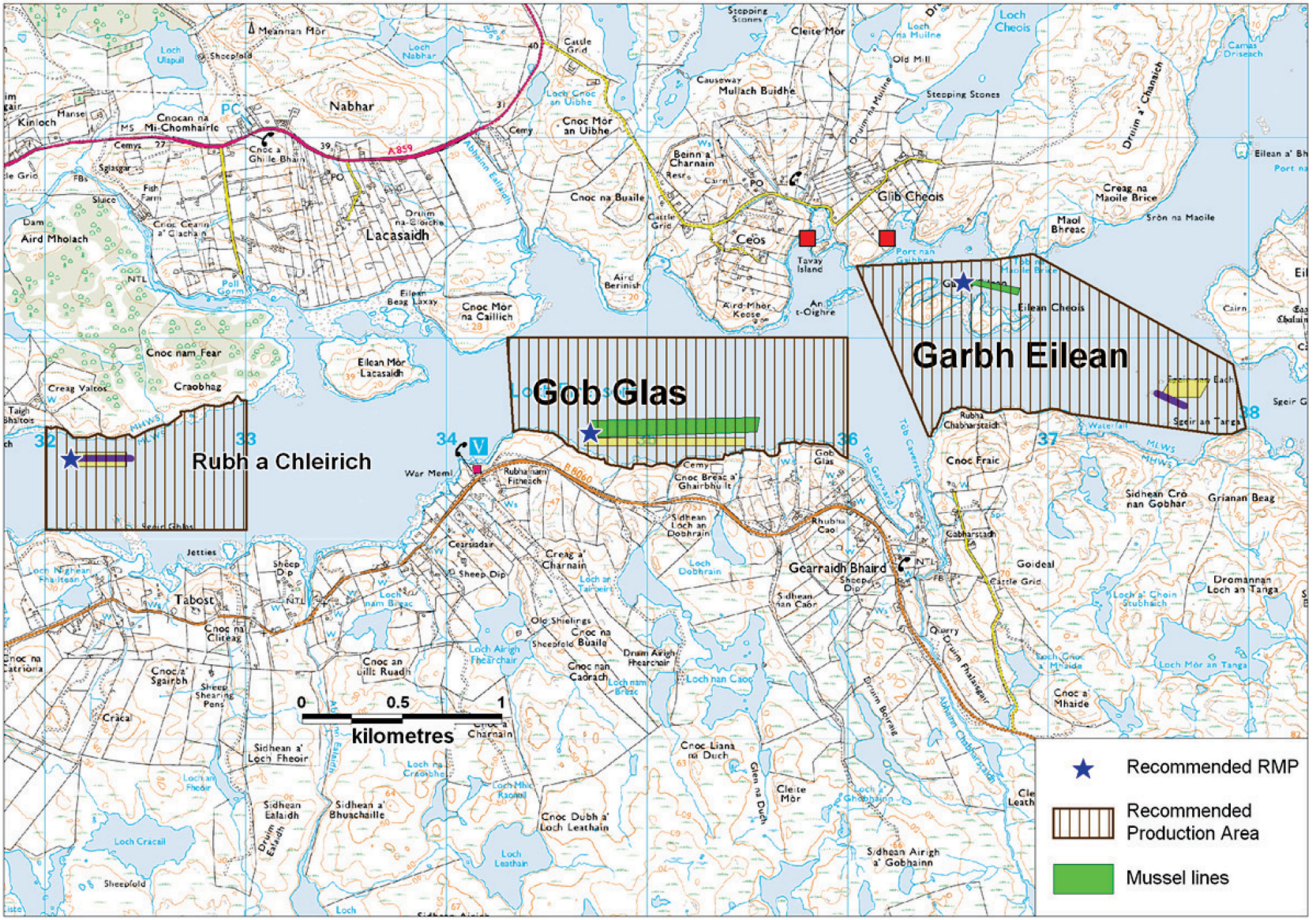

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Figure 17.1 Map of recommendations at Loch Erisort: Outer

18. References

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

Burkhardt, W., Calci, K.R., Watkins, W.D., Rippey, S.R., Chirtel, S.J. (2000). Inactivation of indicator microorganisms in estuarine waters. *Water Research*, Volume 34(8), 2207-2214.

Edwards, A. and F. Sharples. (1991) Scottish sea lochs: a catalogue. Scottish Marine Biological Association: 1991 revision, Oban. 250pp.

Kay, D, Crowther, J., Stapleton, C.M., Wyer, M.D., Fewtrell, L., Anthony, S.G., Bradford, M., Edwards, A., Francis, C.A., Hopkins, M. Kay, C., McDonald, A.T., Watkins, J., Wilkinson, J. (2008). Faecal indicator organism concentrations in sewage and treated effluents. *Water Research* 42, 442-454.

Kay, D, Crowther, J., Stapleton, C.M., Wyer, M.D., Fewtrell, L., Anthony, S.G., Bradford, M., Edwards, A., Francis, C.A., Hopkins, M. Kay, C., McDonald, A.T., Watkins, J., Wilkinson, J. (2008). Faecal indicator organism concentrations and catchment export coefficients in the UK. *Water Research* 42, 2649-2661.

Lee, R.J., Morgan, O.C. (2003). Environmental factors influencing the microbial contamination of commercially harvested shellfish. *Water Science and Technology* 47, 65-70.

Macaulay Institute. http://www.macaulay.ac.uk/explorescotland. Accessed September 2007.

Mallin, M.A., Ensign, S.H., McIver, M.R., Shank, G.C., Fowler, P.K. (2001). Demographic, landscape, and meteorological factors controlling the microbial pollution of coastal waters. *Hydrobiologia* 460, 185-193.

Mitchell, P. Ian, S. F. Newton, N. Ratcliffe & T. E. Dunn. 2004. Seabird Populations of Britain and Ireland, Results of the Seabird 2000 Census (1998-2002). T&AD Poyser, London.

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Sampling Plan for Loch Erisort: Outer

PRODUCTION AREA	Loch Erisort: Garbh Eilean	Loch Erisort: Gob Glas	Loch Erisort: Inner
SITE NAME	Garbh Eilean	Gob Glas	Rubh A Chleirich
SIN	TBD	LH 357 747	LH 140
SPECIES	Common mussel	Common mussel	Common mussel
TYPE OF FISHERY	Suspended aquaculture	Suspended aquaculture	Suspended aquaculture
NGR OF RMP	NB 3658 2128	NB 3472 2053	NB 3213 2040
EAST	136580	134720	132130
NORTH	921280	920530	920400
TOLERANCE (M)	40	40	40
DEPTH (M)	1	1	1
METHOD OF SAMPLING	Hand	Hand	Hand
FREQUENCY OF SAMPLING	Monthly	Monthly	Monthly
LOCAL AUTHORITY	Comhairle nan Eilean Siar	Comhairle nan Eilean Siar	Comhairle nan Eilean Siar
AUTHORISED SAMPLER(S)	Paul Tyler	Paul Tyler	Paul Tyler
LOCAL AUTHORITY LIAISON OFFICER	Paul Tyler	Paul Tyler	Paul Tyler

Table of Proposed Boundaries and RMPs

PRODUCTION AREA	**Loch Erisort: Garbh Eilean**	**Loch Erisort: Gob Glas**
SPECIES	**Common mussel**	**Common mussel**
SIN	**LH 357 747**	**TBD**
EXISTING BOUNDARY	**Area bounded by lines drawn between NB 3300 2069 to NB 3300 1993 and between NB 3700 2064 to NB 3700 2144**	**Area bounded by lines drawn between NB 3300 2069 to NB 3300 1993 and between NB 3700 2064 to NB 3700 2144**
EXISTING RMP	**NB 352 206**	**NB 352 206**
RECOMMENDED BOUNDARY	**Area bounded by lines drawn between NB 3642 2051 to NB 3606 2136 to NB 3675 2139 to NB 3694 2142 to NB 3794 2087 to NB 3800 2055 and between NB 3786 2052 to NB 3713 2062 extending to MHWS**	**Area bounded by lines drawn between NB 3433 2053 to NB 3430 2100 to NB 3600 2100 to NB 3600 2040 extending to MHWS**
RECOMMENDED RMP	**NB 3658 2128**	**NB 3472 2053**
COMMENTS	**PA amended to exclude areas near contamination sources. RMP established at Garbh Eilean site.**	**New production area**

PRODUCTION AREA	**Loch Erisort: Inner**
SPECIES	**Common mussel**
SIN	**LH 140**
EXISTING BOUNDARY	**Not currently classified**
EXISTING RMP	**N/A**
RECOMMENDED BOUNDARY	**Area bounded by lines drawn between NB 3200 2056 to NB 3200 2004 to NB 3300 2004 to NB 3300 2069 extending to MHWS**
RECOMMENDED RMP	**NB 3213 2040**
COMMENTS	**Re-activation of the Loch Erisort Inner production area - spat line at Rubh A Chleirich. Curtail eastern boundary to exclude area nearer to discharge in upper loch**

Geology and Soils Assessment

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

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

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

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

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

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

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

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

These component soils were classed broadly into two groups based on whether they are freely or poorly draining. Drainage classes were created based on information obtained from the both the Macaulay Institute website

and personal communication with Dr. Alan Lilly. GIS map layers were created for each class with poorly draining classes shaded red, pink or orange and freely draining classes coloured blue or grey. These maps were then used to assess the spatial variation in soil permeability across a survey area and it's potential impact on runoff.

Glossary of Soil Terminology

Calcareous: Containing free calcium carbonate.

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

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

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

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

General Information on Wildlife Impacts

Pinnipeds

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

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

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

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

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

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

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

Cetaceans

As mammals, whales and dolphins would be expected to have resident populations of *E. coli* and other faecal indicator bacteria in the gut. Little is known about the concentration of indicator bacteria in whale or dolphin

faeces, in large part because the animals are widely dispersed and sample collection difficult.

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

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

Birds

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

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

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

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

Deer

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

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

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

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

Other

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

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

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

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

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

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

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

Statistical Data

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

Section 11.3 One way ANOVA comparison of all *E. coli* results by site

```
Source      DF      SS     MS     F      P
Site (All)   2   0.411  0.206  0.44  0.647
Error       75  35.162  0.469
Total       77  35.573

S = 0.6847   R-Sq = 1.16%   R-Sq(adj) = 0.00%


Level              N    Mean   StDev
Garbh Eilean      33  1.9854  0.6678
Gob Glas          35  2.0048  0.6168
Rubh A Chleirich  10  2.2109  0.9404

                  Individual 95% CIs For Mean Based on Pooled StDev
Level               +---------+---------+---------+---------
Garbh Eilean        (--------*---------)
Gob Glas             (--------*--------)
Rubh A Chleirich     (----------------*-----------------)
                    +---------+---------+---------+---------
                  1.75      2.00      2.25      2.50

Pooled StDev = 0.6847
```

Section 11.3 Paired T-test comparison of results at Gob Glas and Garbh Eilean

```
Paired T for Garbh Eilean (log) - Gob Glas (log)

                     N    Mean  StDev  SE Mean
Garbh Eilean (log)  13   1.817  0.532    0.147
Gob Glas (log)      13   2.266  0.615    0.171
Difference          13  -0.449  0.866    0.240


95% CI for mean difference: (-0.973, 0.074)
T-Test of mean difference = 0 (vs not = 0): T-Value = -1.87  P-Value = 0.086
```

Section 11.3 Fisher's exact comparison of proportion of paired results over 230 *E. coli* MPN/100g at Gob Glas and Garbh Eilean

```
Using frequencies in freq


Rows: row   Columns: column

         Garbh   Gob
        Eilean  Glas  All

<230        12     8   20
>230         1     5    6
All         13    13   26

Cell Contents:      Count


Fisher's exact test: P-Value =  0.160248
```

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

```
Source  DF      SS     MS     F      P
Season   3   1.967  0.656  1.85  0.158
Error   31  10.967  0.354
Total   34  12.934

S = 0.5948   R-Sq = 15.21%   R-Sq(adj) = 7.01%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev  ----+---------+---------+---------+-----
1      15  1.7460  0.5449  (-------*------)
2       8  2.1770  0.6335          (---------*----------)
3       6  2.0832  0.5970      (-----------*-----------)
4       6  2.3436  0.6660            (------------*-----------)
                          ----+---------+---------+---------+-----
                            1.60      2.00      2.40      2.80

Pooled StDev = 0.5948


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

Individual confidence level = 98.93%
```

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

```
Source  DF      SS     MS     F      P
Season   3   0.607  0.202  0.43  0.733
Error   29  13.661  0.471
Total   32  14.269

S = 0.6864   R-Sq = 4.26%   R-Sq(adj) = 0.00%


                          Individual 95% CIs For Mean Based on Pooled StDev
Level   N    Mean   StDev    +---------+---------+---------+---------
1      11  1.8898  0.4512      (-----------*-----------)
2       9  1.8654  1.0467    (------------*-------------)
3       7  2.1070  0.4248         (--------------*--------------)
4       6  2.1989  0.5964          (----------------*---------------)
                            +---------+---------+---------+---------
                          1.40      1.75      2.10      2.45

Pooled StDev = 0.6864
```

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

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = -0.122
```
n=33, p>0.10

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

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.525
```
n=32, p<0.0025

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

Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.104
n=33, p>0.25

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

Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.487
n=32, p<0.005

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 21 May 2010 11:20:31

Variables (& observations)	r	p
Angles & Linear (35)	0.338	0.025

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 21 May 2010 11:27:12

Variables (& observations)	r	p
Angles & Linear (33)	0.238	0.183

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 11 June 2010 11:33:28

Variables (& observations)	r	p
Angles & Linear (34)	0.309	0.051

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 11 June 2010 11:32:44

Variables (& observations)	r	p
Angles & Linear (33)	0.413	0.006

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

Pearson correlation of ranked salinity and ranked e coli for salinity = -0.099
n=18, p>0.25

Hydrographic Methods

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

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

Background processes

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

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

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

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

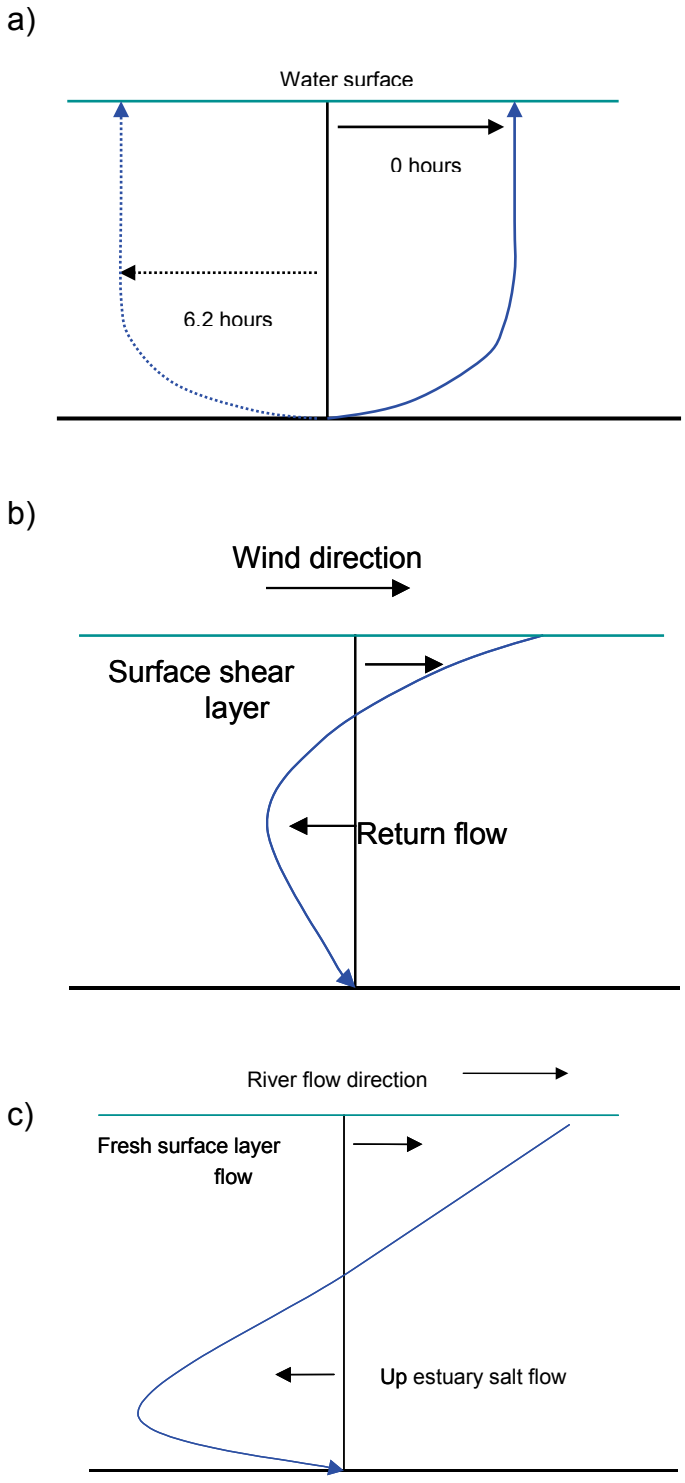

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

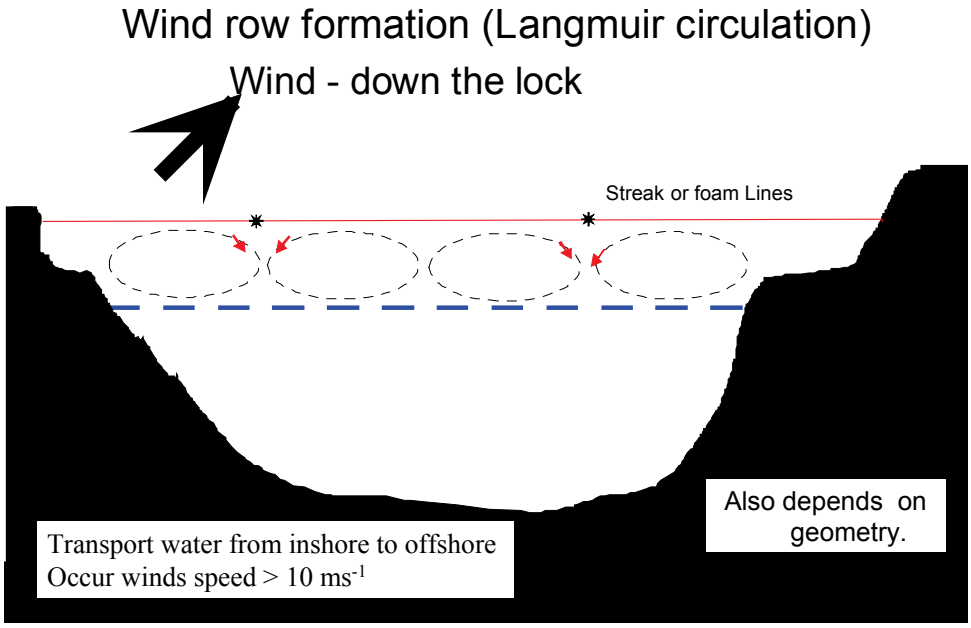

Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Non-modelling Assessment

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

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

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

The catalogue of Scottish Sea Loch produced by the SMBA is used to quantify sills, volume fluxes and likely flow velocities. Because the flow is so constrained by the rapidly varying bathymetry, care has to be used in the extrapolation of direct measurements of current flow. Mean flow velocities can be estimated at the sills by using estimates of the sill area and the volume change through a tidal cycle. This in turn can be used to estimate the

maximum distance travelled in a tidal cycle in the sill area. Away from the sill area, tidal velocities are general low and transport events are dominated by wind or density effects. Sea Lochs generally have a surface layer of fresher water; the extent of this depends on freshwater input, sill depth and quantity of mixing.

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

References

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

Glossary

The following technical terms may appear in the hydrographic assessment.

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

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

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

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

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

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

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

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

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

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

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

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

Shoreline Survey Report

Prod. area:	Loch Erisort: Outer
Site name:	Garbh Eilean (LH 357 747) and Gob Glas (LH 357 744)
Species:	Common mussel
Harvester:	Hector Martin, Malcolm MacDonald & Michael Macleod
Local Authority:	CnES, Lewis & Harris
Status:	Existing
Date Surveyed:	22, 29-30 September 2010
Surveyed by:	M. Price-Hayward, P. Tyler
Area Surveyed:	North side of loch near Garbh Eilean, south shore between Tabost and Gearraidh Bhaird. Livestock observed from road along north and south sides of loch from head to east of Gearraidh Bhaird.

Weather observations
22 September: Heavy rain. Air temperature 12C, wind calm.
29 September: Overcast, fog, rain. Air temperature 12C, wind light (F2).
30 September: Clear to partly cloudy. Air temperature 14C, wind SE up to F4.

Fishery
There are mussel farms located within the production area, as well as spat lines in two locations outwith the boundaries of the classified area. The spat lines were not visited by boat: their positions were estimated from observations and photographs taken from shore.

The mussel farm at Gob Glas consists of 6 double-headed long lines with 6 metre droppers. These extend along the south shore of the loch over a distance of approximately 1km.

The mussel farm at Garbh Eilean consists of a number of fish cage platforms from which mussel lines are suspended plus 2 double-headed long lines with droppers to a depth of 6 metres. The farm is situated north of the two islands of Garbh Eilean and Eilean Cheois.

Boundaries of the mussel farms were recorded and the areas of each, as well as the approximate locations of the spat lines, can be seen in Figures 1 and 2.

Sewage/Faecal Sources
The only community discharge observed during the shoreline survey was the main discharge for Loch Leurbost: this discharges to the outer part of the loch, approximately 2.5 km northeast of the Garbh Eilean mussel farm. Private discharges were observed along the south shore at Tob Caversta.

Seasonal Population
There is a visitors' centre and public toilets at Tabost, however it was not possible to access the shore behind them to observe the septic tank discharge. Some of the homes around the loch are reportedly only occupied during the summer tourist season, and there were some B&Bs in the area.

During the survey, 6 bicycle tourists were observed on the roads between the survey area and Stornoway.

Boats/Shipping
A number of work boats were observed in the area, with moorings located in protected coves. The vast majority of these were tenders or small open boats, though some of the larger boats were of sufficient size to have toilet facilities on board.

Land Use
There are a number of crofts along the northern shore of the loch at Lacasaidh and Ceos, with the main concentration of them nearer the head of the loch at Baile Ailein. The south shore is relatively unpopulated toward the head, with a number of crofts at Tabost and Gearraidh Bhaird, further east along the shore.

Farm animals were observed on many of the crofts, as well as on rough grazing and along the roads. Sheep were predominant, though cattle were also present. In total over 900 sheep, 82 cattle and 11 horses/ponies were observed in the extended area, though some of the sheep were observed east of the area shown on the map in Figure 2 and so are not included in Table 1.

Wildlife/Birds
Small numbers of birds, mostly gulls and cormorants, were observed on floats and on rocky shores. A small mammal, most likely either an otter or a mink, was observed swimming near the mussel farm at Garbh Eilean. No other wildlife was observed.

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.

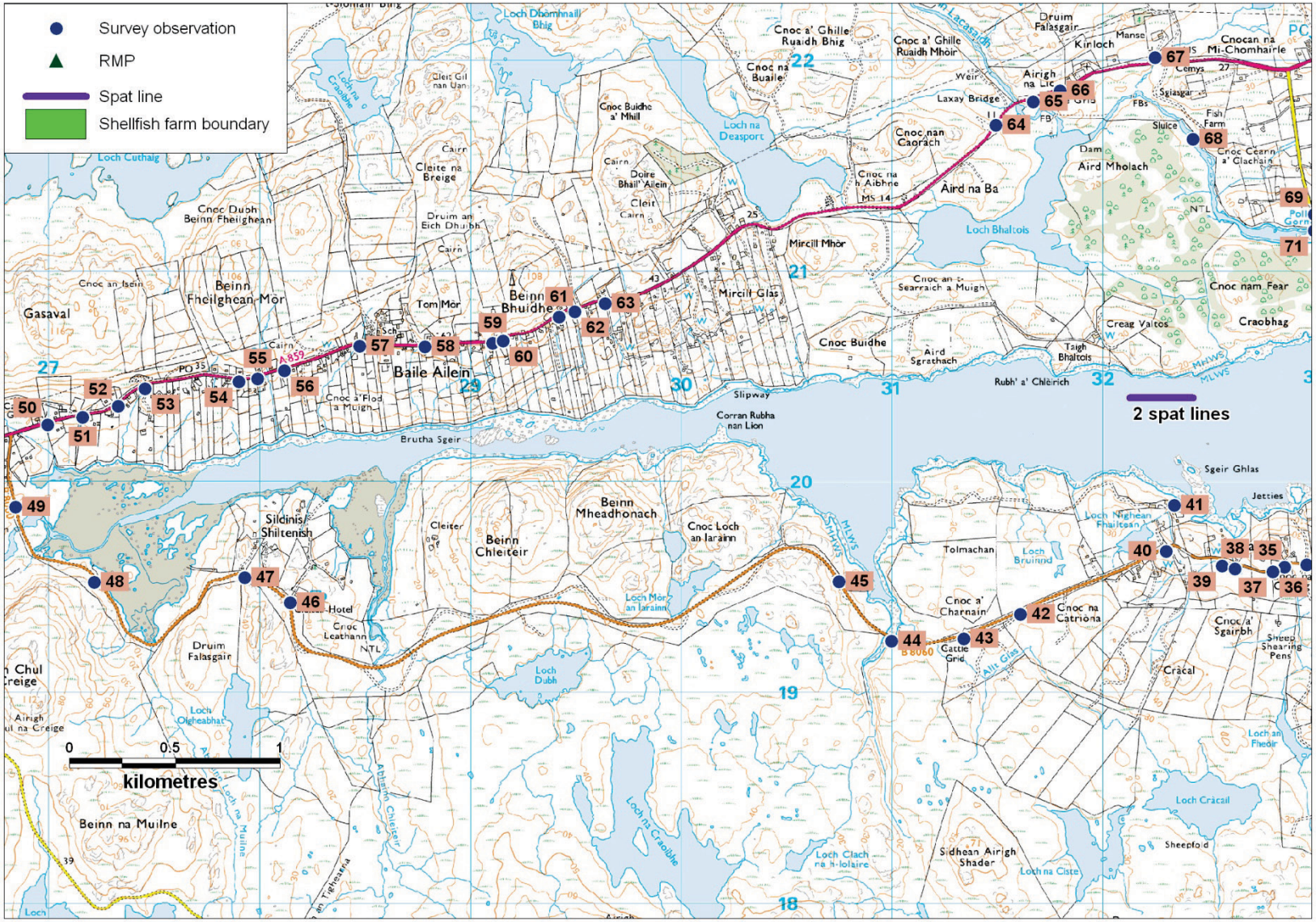

Figure 1. Map of survey observations – West Loch Erisort

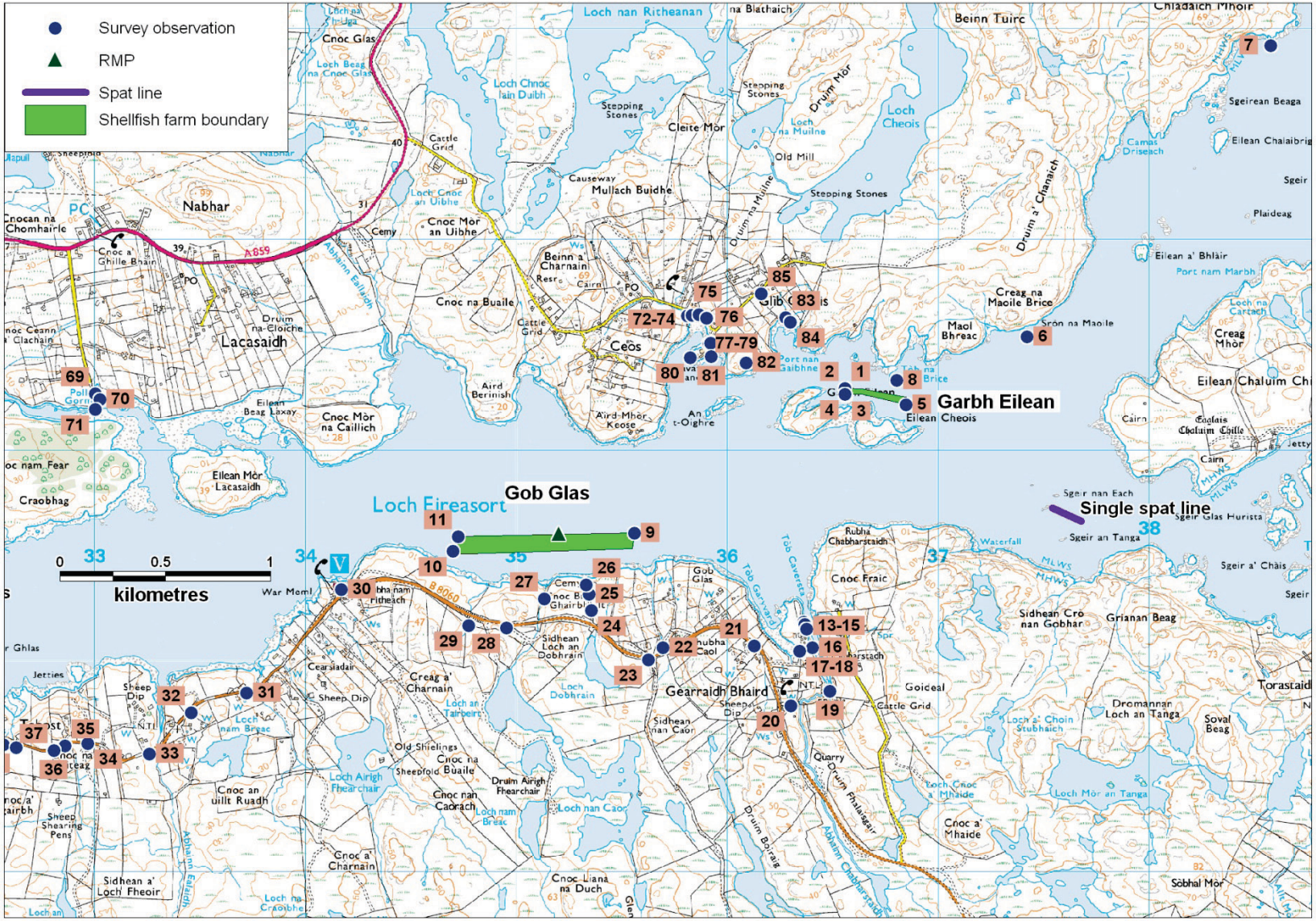

Figure 2. Map of survey observations – East Loch Erisort

Table 1. Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Description
1	22/09/2010	09:25	NB 36556 21293	136556	921293	Figure 6,7	Mussel farm - converted salmon cages with 7m droppers plus 2 long lines. Two large workboats, two small boats
2	22/09/2010	09:37	NB 36556 21293	136556	921293		Water sample 10, mussel sample 11 taken from bottom of float, salinity profile 5, 1 otter/mink seen swimming between the lines
3	22/09/2010	09:56	NB 36559 21260	136559	921260		Salinity profile 6
4	22/09/2010	09:59	NB 36557 21264	136557	921264		Mussel sample 12, 3m depth
5	22/09/2010	10:10	NB 36847 21214	136847	921214		Water sample 13 plus mussel sample 14 (surface), salinity profile 7
6	22/09/2010		NB 37421 21538	137421	921538		1 eagle. Heavy rain
7	22/09/2010	10:35	NB 38577 22920	138577	922920	Figure 8	Sewage outfall for Loch Luerbost works, no boil observed, salinity 35, water sample 15
8	22/09/2010		NB 36802 21330	136802	921330		10 sheep observed on hill above cove opposite side of loch to rafts
9	22/09/2010		NB 35559 20605	135559	920605	Figure 9	Gob Glas, 2 rows of long lines, end of lines, water sample 16, mussel sample 17 (6m) and 18 (top of lines), salinity profile 8
10	22/09/2010	11:50	NB 34698 20521	134698	920521		Far end of lines, water sample 19, mussel samples 20 (bottom) and 21(top), salinity profile 9
11	22/09/2010		NB 34723 20588	134723	920588		outer corner of lines, both have 6-7 meter droppers
13	29/09/2010	09:58	NB 36361 20184	136361	920184		Stream directly east on opposite shore of Tòb Caversta, opposite shore rocky and steep with no foreshore. 4 sheep on field to west
14	29/09/2010	10:02	NB 36366 20172	136366	920172	Figure 10,11	Septic tank, foul odour. Pipe runs underground, but puddled water at surface appears foul, sewage fungus apparent. Seawater sample EST1.
15	29/09/2010	10:14	NB 36375 20152	136375	920152		Septic tank, no detectable odour, pipe runs underground. Water sample EST 2
16	29/09/2010	10:28	NB 36402 20063	136402	920063		Stream visible across Tòb, cascading down rock. Burn at head visible, but tide too high on shoreline to access. Septic tank in garden approx 5m S of waypoint. Surface salinity 0. Water sample EST3. 12 sheep visible on hill opposite. 7 small boats on moorings.

No.	Date	Time	NGR	East	North	Associated photograph	Description
17	29/09/2010	10:53	NB 36341 20046	136341	920046	Figure 12	Construction site with septic tank in place but not connected. Large yacht at head of Tòb Garyvard.
18	29/09/2010	10:53	NB 36341 20046	136341	920046		Duplicate entry
19	30/09/2010	12:53	NB 36485 19855	136485	919855	Figure 13	Burn, 2.3m wide, 0.3m deep, flow 0.857 m/s, water sample 11
20	30/09/2010	12:45	NB 36302 19786	136302	919786		Septic tank
21	29/09/2010	12:26	NB 36127 20071	136127	920071		Septic tank roughly 15 m from road below house, pipe runs underground.
22	30/09/2010	12:36	NB 35694 20062	135694	920062		Stream bed, wet vegetation but little flow
23	30/09/2010	16:53	NB 35625 20005	135625	920005		40 sheep, 9 sheep visible on hill at Keose facing Garbh Eilean (seen in distance across shore from this point)
24	29/09/2010	11:25	NB 35354 20240	135354	920240		One ram, many sheep droppings. 10 further sheep to east.
25	29/09/2010	11:20	NB 35343 20317	135343	920317		Cemetery entrance, 10 sheep to east, 15 in view on hill beyond the 10, 4 in field to west above cemetery.
26	29/09/2010	11:15	NB 35330 20360	135330	920360	Figure 14	Corner of cemetery overlooking shellfish farm. 2 cattle visible in field to west
27	30/09/2010	12:18	NB 35131 20295	135131	920295		Stream, 0.45m wide, 0.15m deep, flow 0.359 m/s. Water sample 10. Cattle droppings along side of stream, area poached
28	29/09/2010	11:37	NB 34951 20156	134951	920156		15 sheep above concrete pens at layby
29	30/09/2010	11:59	NB 34773 20166	134773	920166		Stream, very low flow into a stagnant pond. No sample taken.
30	30/09/2010	13:09	NB 34169 20339	134169	920339		unknown
31	30/09/2010	16:01	NB 33720 19846	133720	919846		7 sheep
32	30/09/2010	16:00	NB 33458 19754	133458	919754		4 cattle toward shore
33	30/09/2010	16:00	NB 33259 19559	133259	919559		3 greenhouses

No.	Date	Time	NGR	East	North	Associated photograph	Description
34	30/09/2010	15:58	NB 32965 19607	132965	919607		11 cattle, 3 houses
35	30/09/2010	15:56	NB 32860 19597	132860	919597		6 grey sheep on left. Pairc House (Western Isles ICT Advisory Services)
36	30/09/2010	15:55	NB 32805 19575	132805	919575		new house on left, 3 sheep visible on right, farm buildings and silage beyond sheep
37	30/09/2010	15:55	NB 32806 19575	132806	919575		8 sheep on right
38	30/09/2010	15:54	NB 32627 19589	132627	919589		Spat lines visible in distance, photo, 8 sheep plus 2 homes downhill
39	30/09/2010	15:50	NB 32566 19603	132566	919603		6 sheep visible on right, driveway with dung on left
40	30/09/2010	15:48	NB 32300 19670	132300	919670		silage bales, stored to left of road, 58 sheep a little way back on right
41	29/09/2010	12:14	NB 32339 19889	132339	919889	Figure 15	View of 2 spat lines from south shore. 8 gulls and 10 cormorants on rocks just offshore, 5 sheep on shoreline
42	29/09/2010	12:51	NB 31609 19372	131609	919372		Weather clear, mostly dry, temp 10C, winds calm
43	30/09/2010	15:46	NB 31339 19257	131339	919257		31 cattle, feeding station to right of road, plus 5 sheep
44	30/09/2010	15:42	NB 30996 19245	130996	919245		12 sheep up hill right of road
45	30/09/2010	15:41	NB 30748 19527	130748	919527		9 sheep toward shore
46	30/09/2010	15:33	NB 28147 19429	128147	919429		Loch Erisort Inn, 6 cattle on shoreline beyond
47	30/09/2010	15:31	NB 27930 19547	127930	919547		5 sheep on left
48	30/09/2010	15:29	NB 27218 19525	127218	919525		Approximately 30 small wading birds and 4 gulls on shore
49	30/09/2010	15:23	NB 26843 19881	126843	919881		8 cattle near shore with access to shoreline
50	30/09/2010	15:21	NB 26995 20272	126995	920272		3 horses, 3 sheep, 2 cattle toward shore

No.	Date	Time	NGR	East	North	Associated photograph	Description
51	30/09/2010	15:18	NB 27161 20307	127161	920307		12 sheep on left, 20 sheep above concrete pens today 3 sheep visible in distance toward shore
52	30/09/2010	15:18	NB 27329 20360	127329	920360		4 sheep on right
53	30/09/2010	15:17	NB 27457 20443	127457	920443		4 ponies on left, 8 sheep on right
54	30/09/2010	15:15	NB 27903 20476	127903	920476		13 cattle, 22 sheep
55	30/09/2010	15:14	NB 27990 20490	127990	920490		10 sheep
56	30/09/2010	15:13	NB 28117 20528	128117	920528		2 fields between last point and this with 5 sheep toward shore, 3 sheep at this point
57	30/09/2010	15:11	NB 28474 20645	128474	920645		8 sheep on left, 20 sheep on right
58	30/09/2010	15:10	NB 28786 20643	128786	920643		10 sheep on left
59	30/09/2010	15:09	NB 29106 20658	129106	920658		15 sheep in view on left
60	30/09/2010	15:08	NB 29155 20669	129155	920669		3 sheep, 2 way down hill
61	30/09/2010	15:06	NB 29420 20782	129420	920782		5 sheep on right, 4 ponies downhill on left
62	30/09/2010	15:05	NB 29495 20808	129495	920808		16 sheep on right
63	30/09/2010	15:04	NB 29638 20846	129638	920846		6 sheep behind on right
64	30/09/2010	14:56	NB 31493 21694	131493	921694		8 sheep, north of road
65	30/09/2010	14:54	NB 31670 21804	131670	921804		10 sheep north of road
66	30/09/2010	14:52	NB 31796 21855	131796	921855		18 sheep on hillside north of road, large house and another church
67	30/09/2010	14:44	NB 32246 22014	132246	922014		19 sheep to North on fields, church, 6 on other side of church

No.	Date	Time	NGR	East	North	Associated photograph	Description
68	30/09/2010	11:10	NB 32426 21626	132426	921626	Figure 16	Weir with central spillway at hatchery on Abhainn Lacasaidh. Outer sections 2.7m wide, 0.15 deep, flow 1.353 m/s. Central section 1.3m wide, 0.5m deep, flow 1.859 m/s. Water sample 9, photo
69	30/09/2010	10:57	NB 33001 21269	133001	921269		14 sheep to west of track in field
70	30/09/2010	10:45	NB 33024 21240	133024	921240		Seawater sample 8. Stream to East not flowing, 39 sheep to east
71	30/09/2010	10:42	NB 33003 21192	133003	921192	Figure 17,18	Two photographs, one up burn, one along shore. Tide in, 2 small boats in photo.
72	30/09/2010	08:35	NB 35809 21636	135809	921636	Figure 19	Stream flowing into head of bay at Ceos. Width 0.5m, depth 0.18m, flow 0.028 m/s. Water sample 5
73	30/09/2010	08:48	NB 35833 21639	135833	921639	Figure 20	Culverted stream, diameter 47cm. Width of wetted surface 0.27m, depth 0.04m, flow 0.453 m/s, water sample 6
74	30/09/2010	08:59	NB 35866 21642	135866	921642		Corrugated pipe through wall - dry, 50cm diameter
75	30/09/2010	09:02	NB 35900 21627	135900	921627		White drainage pipe through wall, dripping
76	30/09/2010	09:03	NB 35898 21628	135898	921628		Septic pipe through wall, no signs of use, not clear whether house above pipe is occupied
77	30/09/2010	08:04	NB 35920 21510	135920	921510		Water trickling through rocks, too shallow to sample or measure
78	30/09/2010	08:13	NB 35913 21506	135913	921506	Figure 21	11 boats on moorings. Seawater sample 4, surface salinity 0
79	30/09/2010	08:17	NB 35921 21507	135921	921507		Dog faeces on shoreline
80	30/09/2010	08:25	NB 35823 21438	135823	921438		Viewing opposite shore, 7 sheep in third field toward point, 4 houses visible on top of hill, no pipes visible to shore, photo
81	30/09/2010	09:22	NB 35922 21445	135922	921445		Back of Marine Harvest shore base. 1 large service boat, large number of scallop shells, no discharge pipes apparent
82	30/09/2010	09:36	NB 36089 21413	136089	921413	Figure 22	Vantage point for 2 photographs of south side of loch and Garbh Eilean site. Large number of sheep droppings, 16 sheep on hill above.
83	30/09/2010	09:53	NB 36277 21629	136277	921629		Field seep, ground wet but not deep enough to measure or sample

No.	Date	Time	NGR	East	North	Associated photograph	Description
84	30/09/2010	09:57	NB 36298 21607	136298	921607		Stream bed with water seepage, not deep enough to measure or sample. Seawater sample 7 taken from the adjacent shore, no evidence of Scottish water discharge expected in vicinity
85	30/09/2010	10:13	NB 36159 21743	136159	921743		Inspection plate in field south of road, disused septic tank and pipes visible approximately 30m to SW, 13 sheep

Photos referenced in the table can be found attached as Figures 6-22.

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

Seawater samples were tested for salinity using a hand held refractometer. 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	30/09/2010	EST 9	NB 3243 2163	Freshwater	60	
2	30/09/2010	EST 8	NB 3302 2124	Seawater	90	0.6
3	22/09/2010	EST 19	NB 3470 2052	Seawater	80	30.5
4	30/09/2010	EST 10	NB 3513 2030	Freshwater	<10	
5	22/09/2010	EST 16	NB 3556 2061	Seawater	100	30
6	30/09/2010	EST 5	NB 3581 2164	Freshwater	60	
7	30/09/2010	EST 6	NB 3583 2164	Freshwater	150	
8	30/09/2010	EST 4	NB 3591 2151	Seawater	380	24.7
9	30/09/2010	EST 7	NB 3630 2161	Seawater	900	24.2
10	29/09/2010	EST 1	NB 3637 2017	Seawater*	>10000	1.6
11	29/09/2010	EST 2	NB 3638 2015	Seawater	40	0.9
12	29/09/2010	EST 3	NB 3640 2006	Seawater	390	8.1
13	30/09/2010	EST 11	NB 3649 1986	Freshwater	60	
14	22/09/2010	EST 10	NB 3656 2129	Seawater	110	32
15	22/09/2010	EST 13	NB 3685 2121	Seawater	10	31.4
16	22/09/2010	EST 15	NB 3858 2292	Seawater	50	33.8

* Sample taken of mixed seawater and effluent near foul discharge

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Species	Depth (m)	*E. coli* (MPN/100g)
1	22/09/2010	EST 11	NB 3656 2129	Mussel	<1m	490
2	22/09/2010	EST 12	NB 3656 2126	Mussel	3m	460
3	22/09/2010	EST 14	NB 3685 2121	Mussel	<1m	170
4	22/09/2010	EST 17	NB 3556 2061	Mussel	6m	170
5	22/09/2010	EST 18	NB 3556 2061	Mussel	1m	490
6	22/09/2010	EST 20	NB 3470 2052	Mussel	6m	170
7	22/09/2010	EST 21	NB 3470 2052	Mussel	1m	490

Figure 4. Water sample results map – Loch Erisort

Figure 5. Shellfish sample results map – Loch Erisort

Photographs

Figure 6. Mussel farm at Garbh Eilean with 2 large boats

Figure 7. Mussel lines at Garbh Eilean

Figure 8. Sewage discharge pipe for Loch Leurbost in Outer Loch Erisort

Figure 9. Mussel lines at Gob Glas, looking toward north shore

Figure 10. Septic tank with foul discharge

Figure 11. Sewage fungus in discharge from tank in Figure 10

Figure 12. New septic tank at Tòb Garyvard

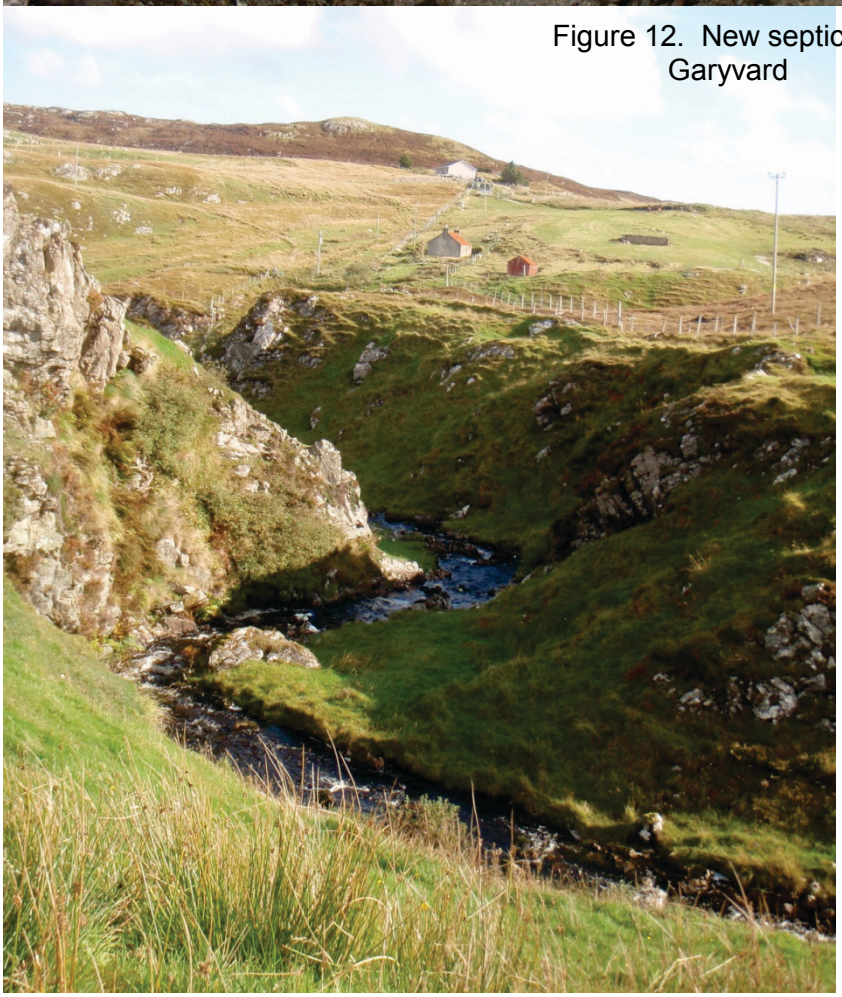

Figure 13. Abhainn Chabharstaidh above Tòb Caversta

Figure 14. View of western side of Gob Glas farm from cemetery

Figure 15. Spat lines viewed from south shore of Loch Erisort

Figure 16. Weir on Abhainn Lacasaidh

Figure 17. View looking west along Abhainn Lacasaidh

Figure 18. View looking east along shore from mouth of Abhainn Lacasaidh

Figure 19. Head of bay at Ceos, stream to left of concrete building

Figure 20. Culverted stream at Ceos

Figure 21. Small boats at Ceos

Figure 22. View across Garbh Eilean mussel farm