Scottish Sanitary Survey Report

Sanitary Survey Report
Loch Roag: Barraglom
LH-185-120-08
September 2013

Cefas

Food Standards Agency
food.gov.uk
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Report Title	Loch Roag: Barraglom Sanitary Survey Report
Project Name	Scottish Sanitary Survey
Client/Customer	Food Standards Agency Scotland
Cefas Project Reference	C5792C
Document Number	C5792C_2013_8
Revision	Final V1.0
Date	6/1/2014

Revision History

Revision number	Date	Pages revised	Reason for revision
0.1	30/9/2013	All	External draft
1.0	6/1/2014	14,19	Correction of typographical errors/omissions identified during consultation

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The hydrographic assessment and the shoreline survey and its associated report were undertaken by SRSL, Oban.

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Appendices

I. Executive Summary

Under (EC) Regulation 854/2004, which sets forth specific rules for the organisation of official controls on products of animal origin intended for human consumption, sanitary surveys of production areas and their associated hydrological catchments and coastal waters are required in order to establish the appropriate representative monitoring points (RMPs) for the monitoring programme.

The purpose of the sanitary survey is to demonstrate compliance with the requirements stated in Annex II (Chapter II Paragraph 6) of Regulation (EC) 854/2004. The sanitary survey results in recommendations on the location of RMPs, the frequency of sampling for microbiological monitoring, and the boundaries of the production areas deemed to be represented by the RMPs.

A sanitary survey was undertaken on the classified mussel fishery at Loch Roag: Barraglom on the basis recommended in the European Union Reference Laboratory publication: "Microbiological Monitoring of Bivalve Mollusc Harvesting Area Guide to Good Practice: Technical Application" (http://www.crlcefas.org/gpg.asp). This production area was selected for survey at this time based on a risk-based ranking of the area amongst those in Scotland that have yet to receive sanitary surveys.

Loch Roag is a remote complex of lochs and small islands on the western coast of the Isle of Lewis. Loch Barraglom is located in the eastern section of the loch and forms part of the channel separating the island of Great Bernera from the Isle of Lewis.

The fishery at Loch Roag: Barraglom is comprised of a single, long-line mussel farm with three sets of double headed long-lines and 8 metre droppers located along the north shore of Loch Barraglom.

The principal sources of faecal contamination to the fishery are:

- Diffuse agricultural pollution, mainly from sheep
- Discharge from the Kirkibost community septic tank east of the fishery
- A number of private septic tanks, most of which are along the north shore or west of the road bridge
- Wildlife, mainly geese

Diffuse contamination arising on shore, whether from livestock, wildlife or septic tanks, will be carried via freshwater runoff during and immediately after rainfall. Contamination from Kirkibost and other septic tanks discharging to sea will be carried via tidal flow to the mussel farm.

It is recommended that the production area be curtailed along the eastern boundary to exclude the Kirkibost discharge. It is further recommended that the RMP be moved to the western side of the fishery to reflect contamination arising from septic tanks located to the east of the mussel farm.

II. Sampling Plan

Production Area	LochRoag: Barraglom
Site Name	Loch Barraglom
SIN	LH-185-120-08
Species	Common mussels
Type of Fishery	Long-line aquaculture
NGR of RMP	NB 1669 3421
East	116690
North	934210
Tolerance (m)	40 m
Depth (m)	Not specified
Method of Sampling	Hand
Frequency of Sampling	Monthly
Local Authority	CnES
Authorised Sampler(s)	Paul Tyler
Local Authority Liaison Officer	Colm Fraser
Recommended Production Area	The area bounded by lines drawn from NB 1800 3429 to NB 1800 3344 and from NB 1667 3444 to NB 1669 3445, extending to MHWS, and from NB 1647 3423 to NB 1648 3412 (the line of the B8059).

III. Report

1. General Description

Loch Roag is a remote complex of lochs and small islands on the western coast of the Isle of Lewis. Its shores are sparsely populated and the loch supports a significant number of shellfish and salmon farms. It is approximately 8 km long and 11 km wide and split into east and west halves by the island of Great Bernera. The loch overall has a maximum depth of 40m, though at the production areas examined for this report it is 1-25 metres in depth. Loch Barraglom is located in the eastern section of the loch and forms part of the channel separating Great Bernera from the Isle of Lewis. The location of Loch Barraglom is shown in Figure 1.1.

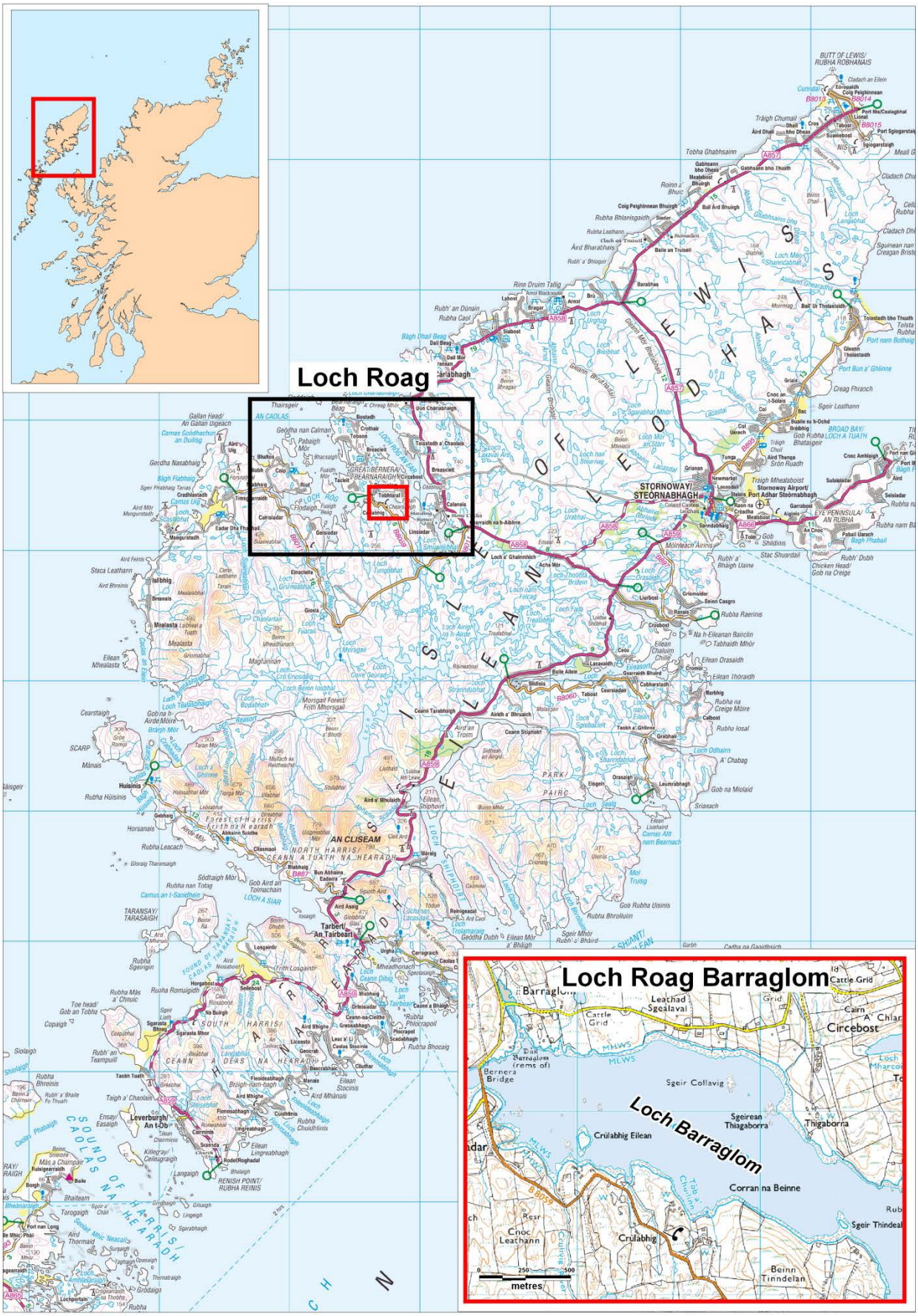

Figure 1.1 Location of Loch Roag Barraglom

2. Fishery

The fishery at Loch Roag: Barraglom is a single common mussel (*Mytilus edulis*) farm which has been classified since 2003. Details of the site are presented in Table 2.1.

Table 2.1 Site details

Production area	Site	SIN	Species	Representative monitoring point (RMP)
Loch Roag: Barraglom	Loch Barraglom	LH-185-120-08	Common Mussels	NB 1669 3413

The current production area boundary is defined by lines drawn between NB 1860 3322 and NB 1886 3365 extending to MHWS and the B8059.

At the time of the shoreline survey, the mussels were reported to be grown on three rows of longlines with 8 meter droppers. The actual location of the mussel farm was recorded during the shoreline survey and is shown together with the current production area boundaries, RMP and Crown Estate seabed lease areas in Figure 2.1.

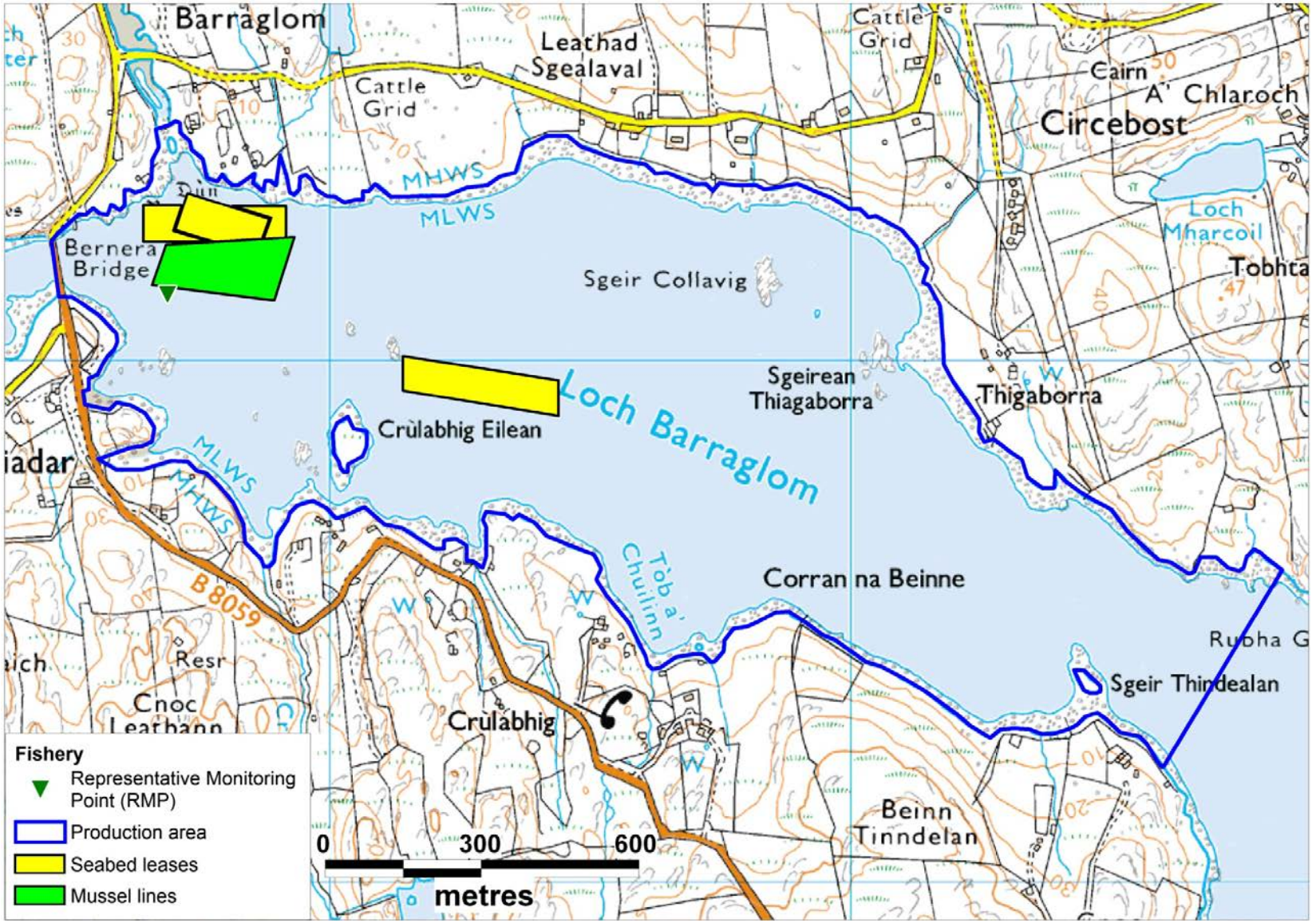

Figure 2.1 Loch Roag: Barraglom Area Fishery

3. Human Population

Information was obtained from the General Register Office for Scotland on the population in the vicinity of the Loch Barraglom fishery. The last census was undertaken in 2011. The census output areas surrounding Loch Barraglom are shown thematically mapped by the 2011 population densities in Figure 3.1.

The population density around Loch Barraglom is low. Several small settlements (Crulabhig, Iarsiadar, Barraglom and Circebost) are located in the vicinity of Loch Barraglom. Each settlement encompasses less than a dozen dwellings. The north east and south east shorelines of the rock are only accessible by tracks or on foot. There is a self catering tourist accommodation (sleeps 2) along the road north of Circebost.

There is an anchorage at the entrance to Loch Barraglom. A small slipway was observed on the northern shoreline east of Bernera Bridge during the shoreline survey. Two small vessels were also observed moored in the bay south of the bridge.

Overall, impacts from human sources to the water quality of the shellfish farm are likely to be low due to the low population density of the area, with any effects predominating in the west towards the road bridge.

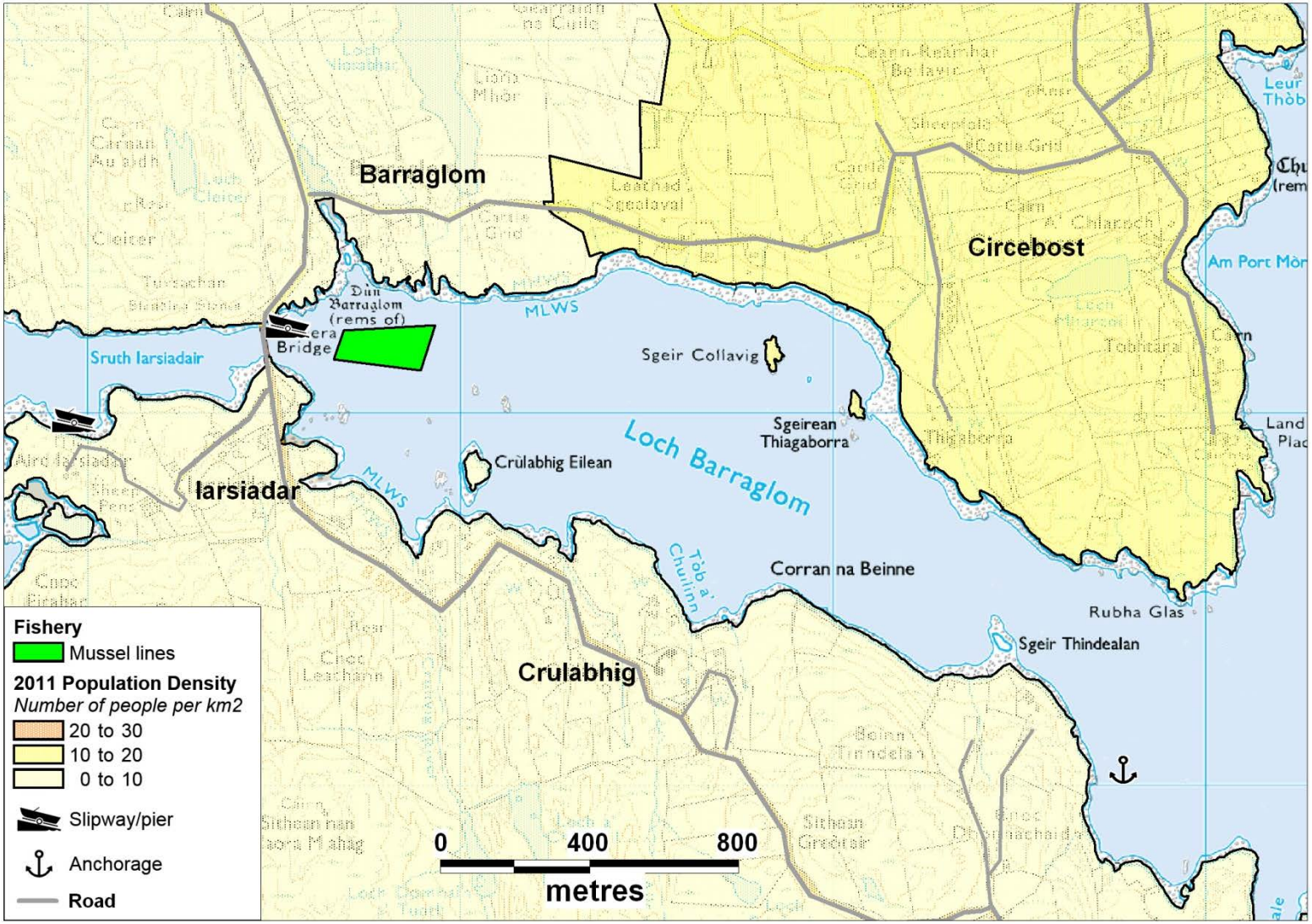

Figure 3.1 Population map for the area in the vicinity of Loch Roag Barraglom

4. Sewage Discharges

Information on sewage discharges in an area 5 km around point NB 1550 3400 was sought from Scottish Water and the Scottish Environment Protection Agency (SEPA). Data requested included the name, location, type, size (in either flow or population equivalent), level of treatment, sanitary or bacteriological data, spill frequency, discharge destination (to land, freshwater body or sea), any available dispersion or dilution modelling studies, and whether improvements were in work or planned.

Scottish Water and SEPA datasets were compared to each other and also to the information contained in the shellfish growing water report for Loch Roag. Where differences or omissions were observed, clarification was sought from the data providers. However, at the time of writing requested clarification had not been received from SEPA.

Scottish Water Discharges

Scottish Water provided information of two septic tanks which are listed in Table 4.1. Kirkibost SEP, which discharges to Loch Roag Barraglom, is shown mapped in Figure 4.1 Breasclete septic tank discharges to a freshwater loch (Loch Geal), which feeds into a series of lochs that eventually enter the sea at Bhalasaigh on the western shore of Great Bernera, around 5 km away from the production area.

Kirkibost septic tank discharges into the eastern end of the Loch Roag: Barraglom production area.

No information on the receiving body of these discharges was given, so this has been assumed to be the plotted discharge location.

No CSOs or EOs were identified as being present in the area.

Table 4.1 Scottish Water Sewage Discharges

Discharge Name	Discharge Licence	NGR of discharge	Level of Treatment	DWF m^3/d	PE	Shoreline survey observation
BREASCLETE SEP	CAR/L/1002882	NB 1600 3630	Septic Tank	4	20	Not observed
KIRKIBOST SEP	WPC/N/60942	NB 1810 3420	Septic Tank	10.8	144	Observation 2

DWF=Dry Weather Flow PE=Population Equivalent

Consented Discharges (SEPA)

SEPA provided information on 105 consents. No discharge type was given for fifty-one of the consents. However, population equivalents were given for these and so they are presumed to relate to septic tanks. Forty-three of the other consents were listed as sewage discharges. Forty of those were identified as primary treated private sewage discharges, one secondary treated private sewage discharge and two

primary treated public discharges. Thirty-two were stated to discharge to soakaway, eight to salt water and three to freshwater bodies.

The PE for one of the public discharges was not given: The combined PE of the other identified as sewage discharges was 261. The total PE for sewage discharges in the area is likely to be higher than this.

The remaining consents related to seven marine cage fish farms, one freshwater fish farm and three sheep dips to land.

Many of the consents related to discharges outside the production area and immediately adjacent areas.

Table 4.2 presents information on those discharge consents considered likely to impact on the production area.

The shellfish growing water report, which covers the designated area of Loch Roag including Loch Roag Barraglom (and the parts of Loch Roag to the West of this) stated that sewage discharges into the waters are confined to those from private household septic tanks, and estimated the combined population equivalent of less than 100(SEPA , 2011).

Table 4.2 Consented discharges potentially impacting on production area

Licence No.	NGR*	Site Name	Discharge Type	Discharges to	PE	Shoreline survey observation
WPC/N/60942	NB 1810 3420	Dun innes Housing Site, Kirkibost	Sewage (Public) Primary	Loch Barraglom	144	Observation 2
CAR/R/1075450	NB 1831 3397	20 Kirkibost, Bernera, Isle of Lewis	Sewage (Private) Primary	Soakaway	15	Observation 1
CAR/R/1063347	NB 1753 3441	25 Kirkbost/ Thristlecroft, Bereravig Lewis	Sewage (Private) Primary	Loch Barraglom	5	Observation 3
CAR/R/1056487	NB 1768 3336	6A CRULIVIG, VIG, ISLE OF LEWIS	-	-	5	Observation 5
CAR/R/1056240	NB 1771 3329	6 Crulivig, Isle of Lewis	-	-	6	Observation 6
CAR/R/1077617	NB 1690 3360	1Crulivig, Uig, Isle of Lewis	Sewage (Private) Primary	Soakaway	5	
CAR/R/1049534	NB 1674 3452	3 Hacklete, Bernera, Isle of Lewis	Sewage (Private) Primary	Soakaway	5	Observation 4
CAR/R/1066509	NB 1669 3370	5 Earshader, Isle of Lewis	-	-	5	
CAR/R/1044392	NB 1648 3395	4 Earshader, Isle of Lewis	-	-	5	
CAR/R/1087895	NB 1647 3392	New Build, 6 Earshader, Isle of Lewis	-	-	5	
CAR/R/1064030	NB 1636 3405	3 Earshader, Uig, Isle of Lewis	Sewage (Private) Primary	Sruth Iarsiadar	5	
CAR/L/1002198	NB 1599 3393	Earshader Shellfish Dispatch Centre	-	-	-	
CAR/L/1009011	NB 1599 3393	Earshader Dispatch Centre - Mussel Tanks	-	-	-	
CAR/R/1063357	NB 1536 3436	Hacklete, Bernera, Isle of Lewis	Sewage (Private) Primary	Loch Roag	5	
CAR/R/1049570	NB 1540 3446	9A Hacklete, Bernera, Isle of Lewis	Sewage (Private) Primary	Soakaway	5	
CAR/R/1075450	NB 1831 3397	20 Kirkibost, Bernera, Isle of Lewis	Sewage (Private) Primary	Soakaway	15	Observation 1
CAR/R/1063347	NB 1753 3441	25 Kirkbost/ Thristlecroft, Bereravig Lewis	Sewage (Private) Primary	Loch Barraglom	5	Observation 3
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CAR/R/1066509	NB 1669 3370	5 Earshader, Isle of Lewis	-	-	5	
CAR/R/1044392	NB 1648 3395	4 Earshader, Isle of Lewis	-	-	5	

- No data provided * NGRs rounded to nearest 10 m

Shoreline Survey Discharge Observations

Seven observations of sewage infrastructure were noted during the shoreline survey. These are listed in Table 4.3.

Table 4.3 Discharge-associated observations made during the shoreline survey

No.	Date	Associated photograph	*E. coli* cfu/100ml (Sample No.)	Description
1	26/06/2013	Appendix 6; Fig 4		A concrete encased pipe near house, no visible outfall/flow. No access to it.
2	26/06/2013	Appendix 6; Fig 5	26000 (LBFW01)	Loch Roag outfall marked on map. Smell of sewage discharging into water course, flowing straight into the Loch.
3	26/06/2013	Appendix 6; Fig 10 & 11		Small concrete housing beside house with pipe protruding, no access to this. Clay piping in channel runs down from building on field towards shore. No outflow
4	26/06/2013	Appendix 6; Fig 15		Clay pipe running from house to shoreline no outflow Figure 15. Pipe was dry but markings of historic flow on pipe and rocks.
5	26/06/2013	Appendix 6; Figure 18	260000 (LBFW07)	Pipe discharging into watercourse at approximately 2ml/sec.
6	26/06/2013			Concrete structure in garden of unknown purpose situated beside burn. Manhole cover 20m to the right of concrete structure.
7	26/06/2013	Appendix 6; Fig 23		Possible septic tank 20m below house.

Observation 1 relates to a concrete structure with a pipe coming out of it. No discharge was noted during the shoreline survey. This structure looks like it may be old septic tank with overflow pipe, possibly relating to consent CAR/R/1075450 provided by SEPA.

Observation 2 relates to the Kirkibost septic tank. This discharges to a watercourse at the shoreline of the loch. A sample taken from this watercourse returned a result of 26000 *E. coli* cfu/100ml, which was indicative of significant faecal input.

Observation 3 relates to a small concrete structure with pipe protruding out of it. Clay piping runs in a channel down from the structure towards the shore. No outfall was noted, however. This structure looks like an old concrete septic tank with overflow and outfall. It may represent CAR/R/1063347 septic tank which plots less than 100 m to the east, or could be a septic tank unreported to SEPA.

Observation 4 relates to a run of clay pipes from a house to shoreline. The pipe was not flowing at the time of survey, but showed evidence of historic flow. It is likely this pipe represents an outfall for a sewage system. This could relate to consent

CAR/R/1049534 which is recorded as discharging to land but may have been re-routed.

Observation 5 relates to a pipe flowing at about 2 ml/second discharging to a watercourse below a house. A sample taken from the watercourse returned a high value of 260000. This suggests that the effluent may be raw or partially treated sewage.

Observation 6 relates to a concrete structure in a garden. A manhole cover was located 20 m away from the structure. Photographs taken during the shoreline survey, but not included in the shoreline survey report suggest these may be related to sewage infrastructure. These photographs have been included as Figures 4.2, 4.3 and 4.4. This discharge may relate to consent CAR/R/1056487 which both plot within 100 m of the observation location.

Observation 7 relates to a septic tank about 20 m below a house. This appears to relate to CAR/R/1056240.

Summary

The public consent (Kirkibost septic tank WPC/N/60942) discharges on the northern east of the production area and has a PE of 144. A water sample taken from near the outfall of this location returned a moderately high value of 26000 *E. coli* cfu/100ml.

A large number of other discharges are located in the surrounding area. Three private consented septic tanks also discharge into the production area or adjacent waters.

List of Acronyms

CSO	Combined Sewage Overflow
DWF	Dry weather flow
EO	Emergency Overflow
FE	Final Effluent
PE	Population Equivalent
PS	Pumping Station
ST	Septic Tank
WWPS	Wastewater Pumping Station
WWTW	Wastewater Treatment Work

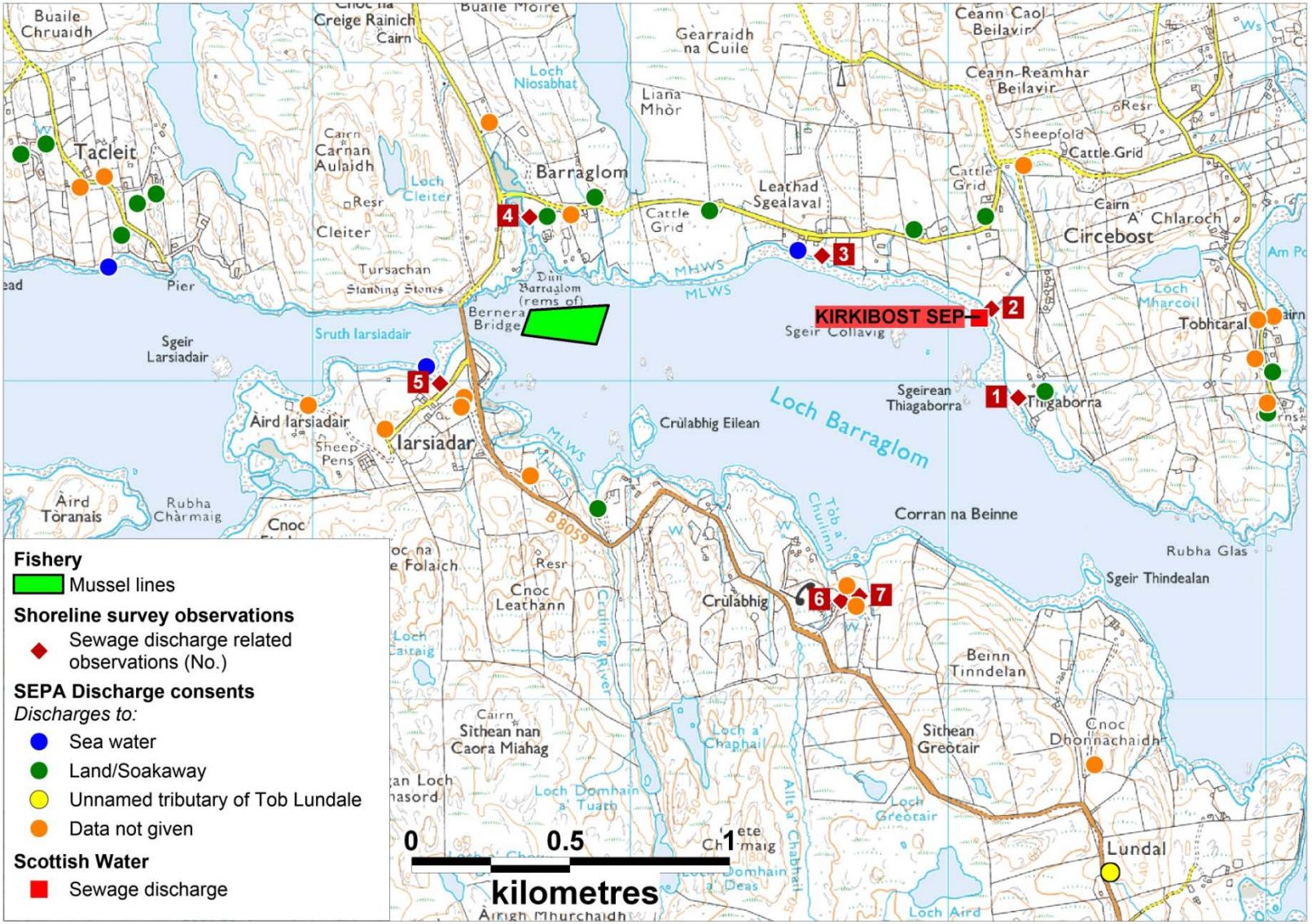

Figure 4.1 Map of discharges for Loch Roag: Barraglom

Figure 4.2 Manhole cover reported in Shoreline Survey Observation 5

Figure 4.3 Location of concrete structure reported in Shoreline Survey Observation 5

Figure 4.4 Concrete structure reported in Shoreline Survey Observation 5

5. Agriculture

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. Agricultural census data to parish level was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for the Uig parish. Reported livestock populations for the parish in 2012 are listed in Table 5.1.

Table 5.1 Livestock numbers in the Uig agricultural parish 2012

	Uig	
	567 km^2	
	Holdings	Numbers
Pigs	5	27
Poultry	26	389
Cattle	24	286
Sheep	65	5,648
Other horses and ponies	6	10

The livestock census numbers relate to a very large parish area, therefore it is not possible to determine the spatial distribution of the livestock in relation to the Loch Roag: Barraglom area or to identify how many animals are likely to impact the catchment around the fishery. Therefore the figures are of little use in assessing the potential impact of livestock contamination to the fishery; however they do give an idea of the total numbers of livestock over the broader area. The livestock numbers indicate that all livestock types are present in low numbers in relation to parish size.

Agricultural practices in Lewis were observed by Osgathorpe et al (2011) to consist predominantly of store lamb production on 'inbye' land – small, enclosed areas of lowland grass. They noted that no arable agriculture was carried out, and that the majority of crofters did not have access to upland grazing areas. This suggests that the majority of livestock within the Uig parish is likely to be kept on or very close to enclosed croft areas.

An additional significant source of spatially relevant information on livestock population in the area was the shoreline survey (see Appendix 5) which only relates to the time of the site visit on the 26th June 2013 (see Table 5.1). Observations made during the survey are dependent upon the viewpoint of the observer some animals may have been obscured by the terrain. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 5.1.

During the survey livestock were observed grazing along the northern shoreline of Loch Barraglom. In total approximately 103 sheep were observed grazing along the shoreline north of the fishery. Cattle droppings were also observed on the shoreline north east of the fishery, although no cattle were seen.

Numbers of sheep will be approximately double during late spring following the birth of lambs, and decrease again in the autumn when they are sent to market.

Any contributions of faecal contamination from livestock grazing along the northern of the loch would be most likely to affect the long lines on the mussel farm which are closest to this shoreline.

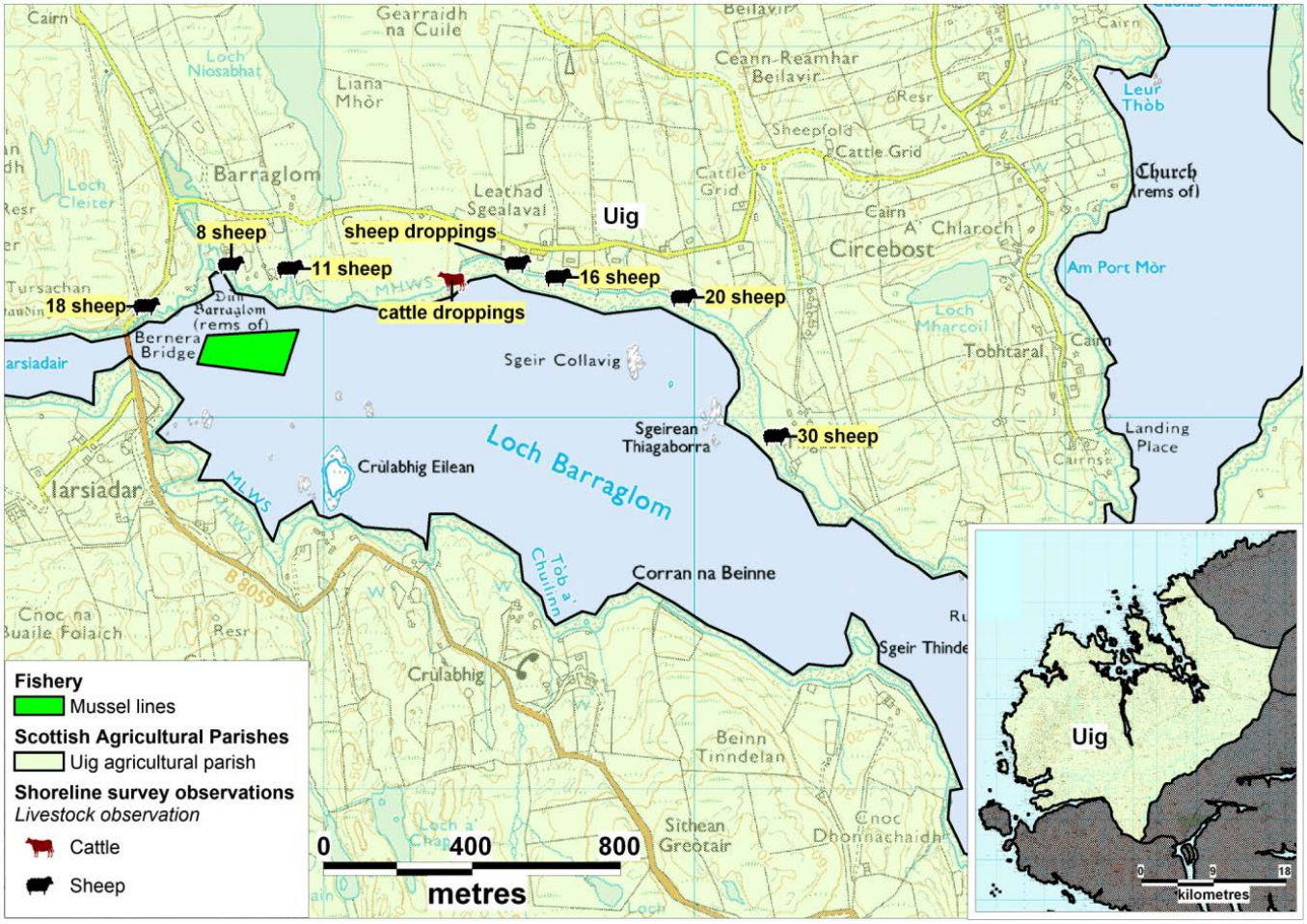

Figure 5.1 Agricultural parish boundaries

6. Wildlife

Wildlife species present in and around the production area will contribute to background levels of faecal contamination at the fishery, and large concentrations of animals may constitute significant sources when they are present. Seals, cetaceans and some seabirds may deposit faeces directly into the sea, while birds and mammals present on land will contribute a proportion of any faecal indicator loading carried in diffuse run-off or watercourses.

The species most likely to contribute to faecal indicator levels at the Loch Roag: Barraglom mussel farm are considered below.

Pinnipeds

The Western Isles hosts significant populations of both grey and common seals. The common seal population of the Outer Hebrides in 2008 was estimated at 1804, while the grey seal population was estimated to be 29700, with one breeding colony identified in outer Loch Roag (SMRU 2010). Seals forage widely for food and are likely to range throughout the loch and beyond, and therefore may only be present for a proportion of the time. These animals are likely to contribute to background faecal bacterial levels within the loch generally, and may lead to locally high levels of faecal contamination if they defecate in close proximity to the shellfish. No seals were observed during the shoreline survey.

Cetaceans

The waters surrounding the Outer Hebrides are recognised as supporting large number of cetaceans. Due to the intricate navigation required to get to Loch Roag Barraglom, it is unlikely that large cetaceans such as whales will enter the loch. However, smaller whales and dolphins may occasionally be present: in 2007 a northern bottlenose whale stranded itself in Loch Roag (Herald Scotland, 2007). It is therefore possible that smaller cetaceans such as dolphins and porpoise will enter Loch Roag from time to time.

Birds

Results from the Seabird2000 census (Mitchell *et al*. 2004) were queried to ascertain the likely distribution and numbers of seabirds at or near the Barraglom production area. No breeding seabirds were identified within a 3 km radius of the mussel farm. The Lewis Peatland Ramsar site is located to the east of Barraglom and is designated for wetlands habitat and breeding waterfowl.

During the shoreline survey, birds were the most common wildlife observed. Gulls were the most numerous, with geese also common and ducks and oystercatchers also present. Geese droppings and unspecified bird droppings were seen on five

occasions, mostly on the north shore. Locations of observed birds are shown in Figure 6.1.

Deer

Deer are known to inhabit many parts of the island so it is likely that they may be present around Loch Roag. Faecal contamination from deer is most likely to be carried to the loch via freshwater streams and burns. The Visit Hebrides website identified that the population of deer on Lewis & Harris was just over 4000. (http://www.visithebrides.com/wildlife/topten/index.php, accessed 30/09/2013).

No deer were seen during the shoreline survey.

Otters

The Eurasian otter (*Lutra lutra*) is common on the Isle of Lewis. Lewis Peatlands Special Protection Area (SPA) lies within 10 km of Loch Roag: Barraglom. It is designated for its population of coastal otters, though no population data could be found at the time of compiling this report. Otters are likely to be present in Loch Roag. However, the typical population densities of coastal otters are low and their impacts on the shellfishery are expected to be very minor. No otters were seen during the shoreline survey.

Overall

Species potentially impacting Loch Roag: Barraglom include seals, cetaceans, deer and otters. Wildlife impacts from birds are expected to predominate although there was insufficient data on which to assess any potential spatial variation in these impacts. Faecal contamination from deer is likely to be present in watercourses flowing into the loch.

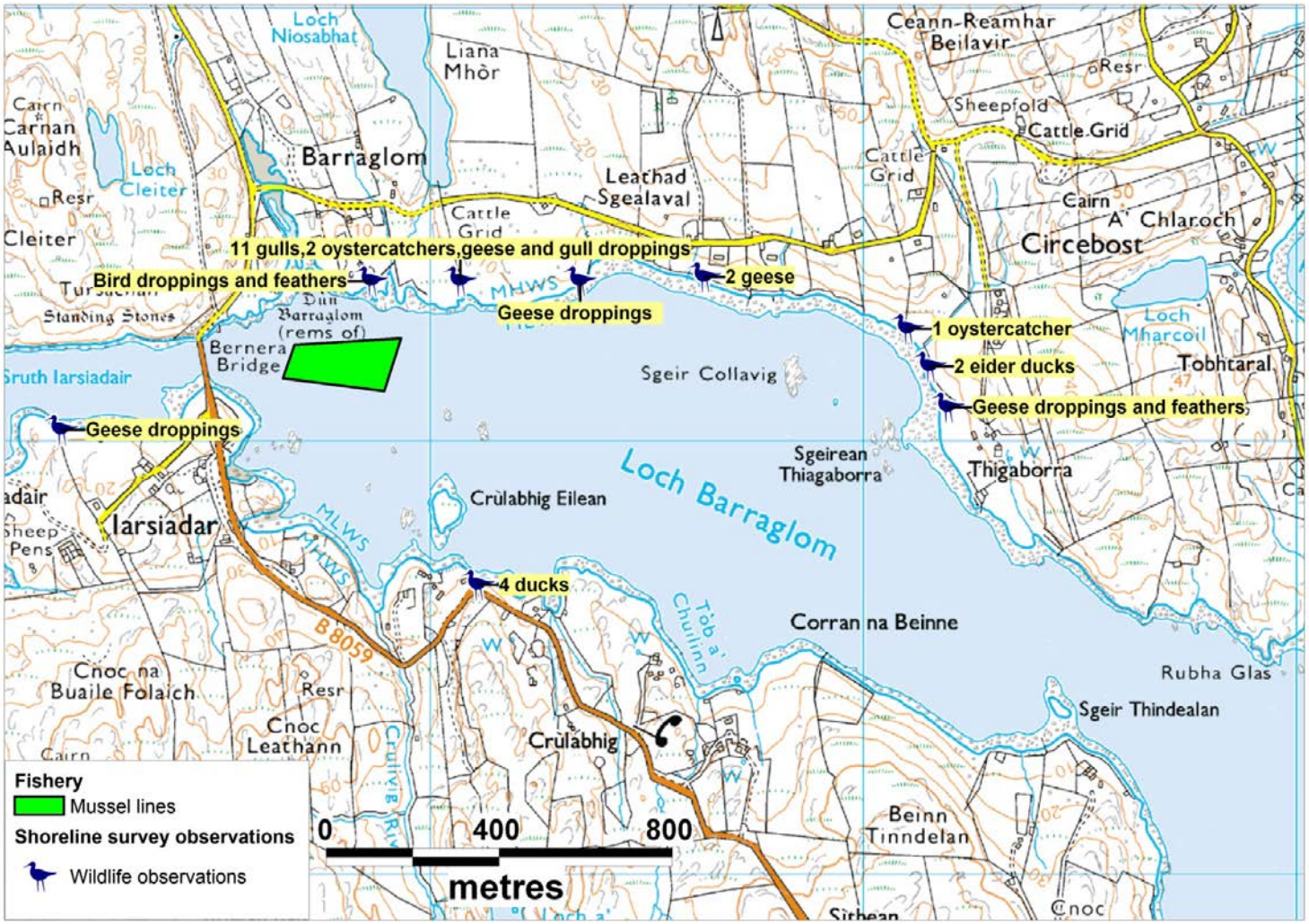

Figure 6.1 Shoreline survey wildlife observations around Loch Roag Barraglom

7. Land Cover

The Land Cover Map 2007 data for the area is shown in Figure 7.1 below:

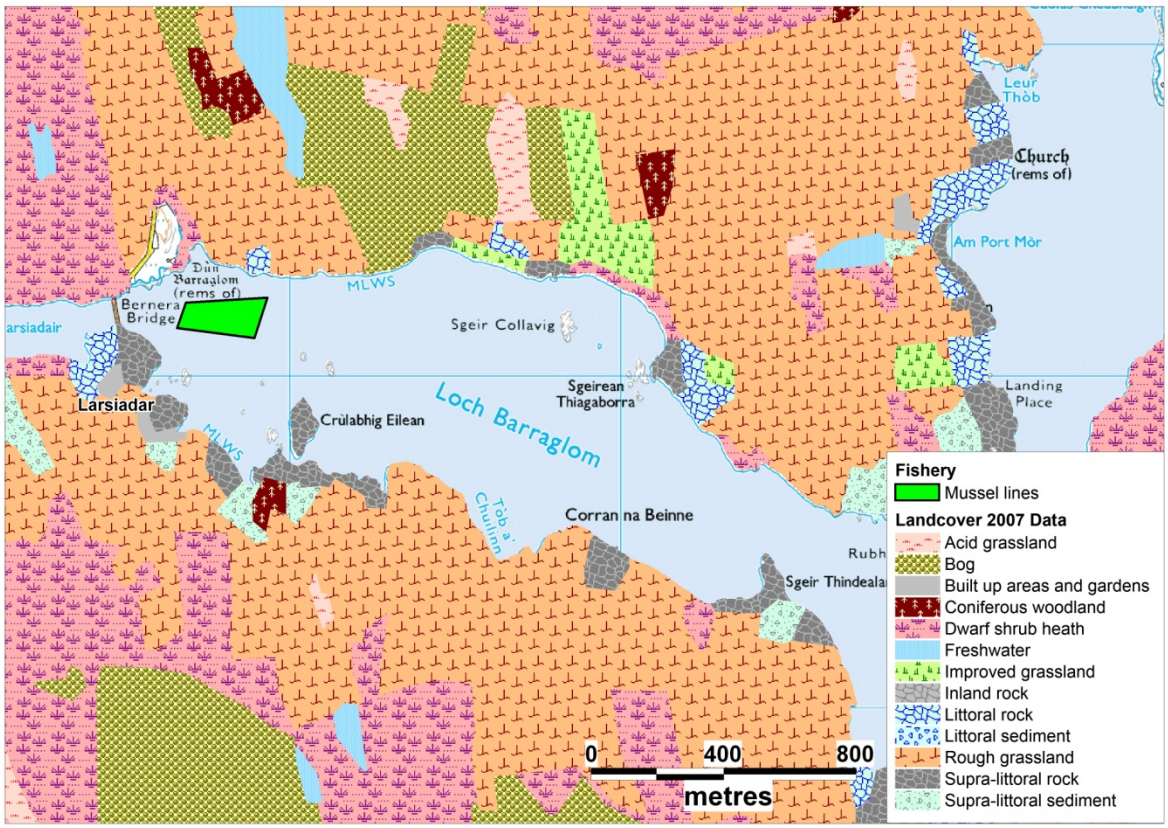

Figure 7.1 LCM2007 land cover data for the area around Loch Roag Barraglom

Rough grassland, dwarf shrub heath, bog and improved grassland are the predominant land cover types on the shoreline adjacent to the Loch Roag Barraglom fishery. There are smaller areas of acid grassland, coniferous grassland and supra-littoral sediment. The areas of improved grassland are situated on the northern shoreline of Loch Barraglom. The settlement of Iarsiadar is shown as a built up areas and gardens.

Faecal indicator organism export coefficients for faecal coliform bacteria have been found to be approximately 1.2 – 2.8x10^9 cfu/km^2/hr for urban catchment areas, approximately 8.3x10^8 cfu/km^2/hr for areas of improved grassland and approximately 2.5x10^8 cfu/km^2/hr for rough grazing (Kay, et al., Faecal indicator organism in concentration sewage and treated effluents, 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., Faecal indicator organism in concentration sewage and treated effluents, 2008).

The highest potential contribution of contaminated run-off to the Loch Roag Barraglom fishery is from the built up area around Iarsiadar on the southern shoreline, south west of the shellfish farm and from the areas of improved grassland located along the northern shoreline of the loch to the east of the mussel farm. The potential contribution of contaminated run-off to the shellfish farm would be highest in these areas.

8. Watercourses

There are no gauging stations on watercourses entering into Loch Roag Barraglom.

The shoreline survey was conducted between the 26th and 27th June 2013. Prevailing weather conditions were dry, with some small amounts of rainfall recorded in the 48 hrs prior to the survey. Table 8.1 lists the major freshwater inputs to Loch Roag: Barraglom on the days of the survey. Three other areas of land drainage and one area of bog were recorded and have been displayed in Figure 8.1.

Table 8.1 Watercourses entering Loch Roag Barraglom

No.	Description	NGR	Width (m)	Depth (m)	Flow (m^3/d)	*E. coli* (cfu/ 100 ml)
1	Allt Millegro	NB 1814 3423	0.50	0.04	95	$2.5x10^{10}$
2	Land drainage	NB 1739 3443	-	-	0.0800	$1.1x10^{5}$
3	Watercourse	NB 1691 3440	4.00	0.10	1600	$1.7x10^{8}$
4	River Cruilivig	NB 1694 3349	1.50	0.06	3400	$1.5x10^{10}$
5	Watercourse	NB 1758 3322	1.80	0.10	1300	$1.3x10^{8}$

-No measurement/sample data available.

One identified watercourse related to the inlet the east of the Bernera Bridge where it flows through culverts under the road; these could not be accessed at the time of survey and therefore were not sampled.

The highest loading was recorded to the northeast of the production area, at Allt Millegro at $2.5x10^{10}$ *E. coli* per day. The catchment area of this watercourse includes farmland, dwelling houses and a pipe suspected to be from the Kirkibost septic tank was also noted further upstream. The freshwater input lies >1 km east of the fishery.

The other significant freshwater input noted during the survey entered from the south from the River Cruilivig at $1.5x10^{10}$ *E. coli* per day. This watercourse enters 600 m south of the southern extent of the fishery.

Two watercourses enter Loch Roag Barraglom directly north of the fishery. These are the watercourse Allt Glaagn an Toib which discharges at the head of an inlet northeast of the Bernera Bridge and freshwater discharge from Loch Niosabhat. A moderate loading of $1.7x10^{8}$ *E. coli* per day was calculated for the freshwater input from Niosabhat Loch. No estimate of loading was obtained from Allt Glaagn an Toib, which was not accessed during the shoreline survey.

Under rainfall conditions, it is expected that the areas of stagnant water identified during the shoreline survey would flow into the loch.

Overall freshwater contamination is expected to have a moderate impact on the fishery at Loch Roag Barraglom, with significant sources to the east of the mussel farm. It is expected the contamination from such sources will increase following rainfall.

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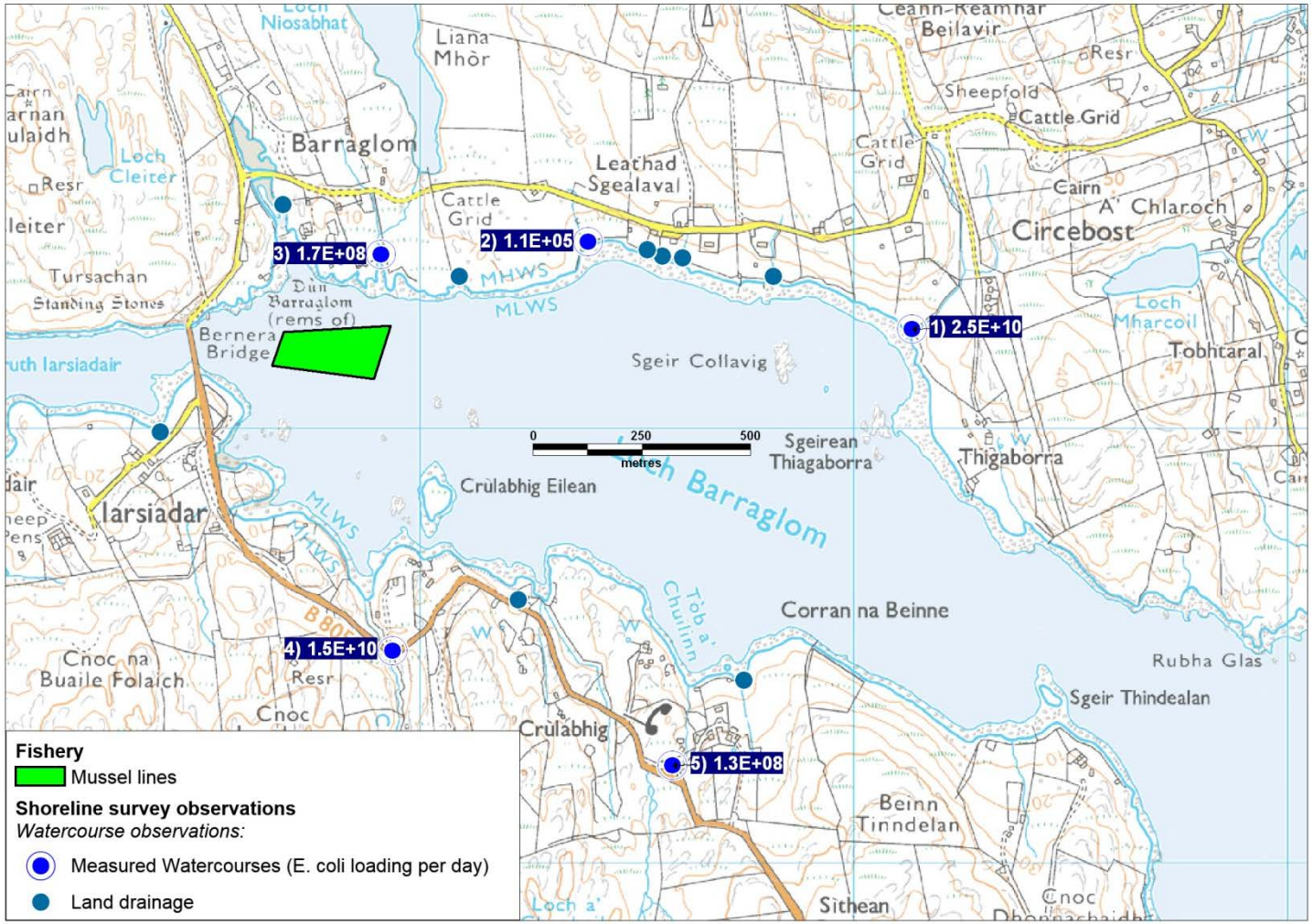


Figure 8.1 Watercourse locations and estimated loadings

9. Meteorological Data

The nearest UK Meteorological Office (Met Office) weather station for which complete rainfall data was available is located at Stornoway Airport, situated approximately 30 km to the east of the fishery. Rainfall data was available for January 2007 – August 2012. At the time of writing this report rainfall data was only available up until August 2012. Although a smaller weather station (Lewis Creed) is located nearer to the fishery, data from this station were incomplete. The nearest wind station is Stornoway Airport, at the same location. Conditions at the wind station and the fishery should be similar and the data can be useful in identifying seasonal variation in wind patterns.

Data for these stations was purchased from the Meteorological Office. Unless otherwise identified, the content of this section (e.g. graphs) is based on further analysis of this data undertaken by Cefas. This section aims to describe the local rain and wind patterns in the context of the bacterial quality of shellfish at Loch Roag Barraglom.

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, Ensign, McIver, Shank, & Fowler, 2001); (Lee & Morgan, 2003)). The box and whisker plots in Figures 9.1 and 9.2, present a summary of the distribution of individual daily rainfall values by year and by month. The grey box represents the middle 50% of the observations, with the median at the midline. The whiskers extend to the largest or smallest observations up to 1.5 times the box height above or below the box. Individual observations falling outside the box and whiskers are represented by the symbol *.

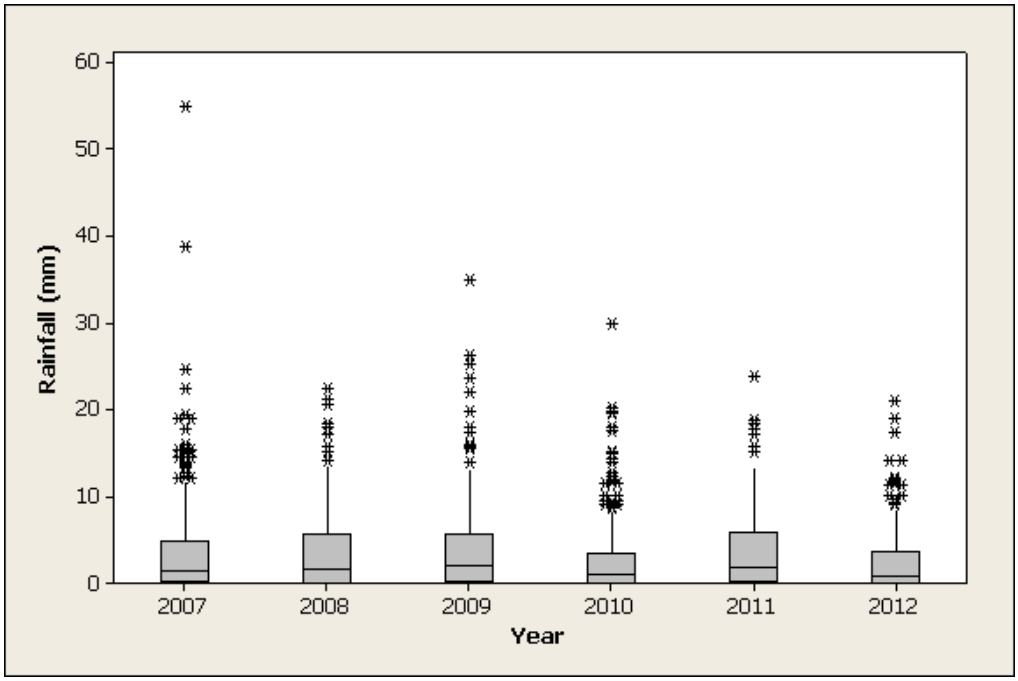


Figure 9.1 Box plot of daily rainfall values by year at Stornoway Airport (2007 – 2012)

Daily rainfall values varied from year to year, with 2010 being the driest year. The wettest year was 2011. High rainfall values of more than 30 mm/d occurred in 2007, 2009 and 2010 and an extreme rainfall event of nearly 60 mm/d was seen in 2007.

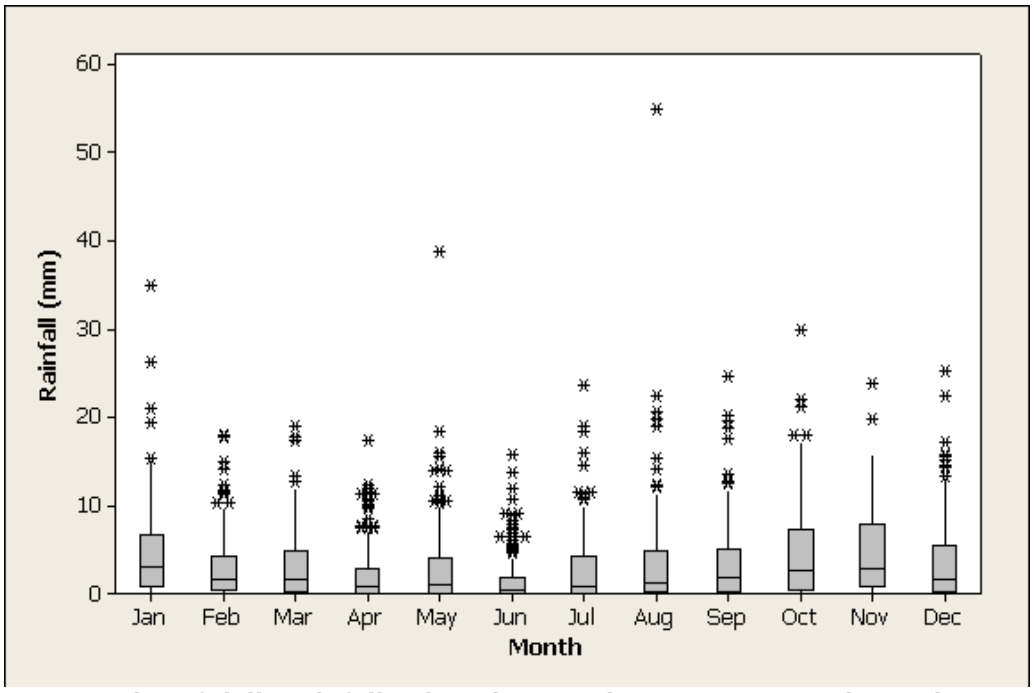


Figure 9.2 Box plot of daily rainfall values by month at Stornoway Airport (2007 – 2012)

Daily rainfall values were higher during the autumn and winter. Rainfall increased from July onward and was highest in October and November. Weather was drier from April to June. Rainfall values exceeding 30 mm/d were seen in January, May and August. The 2007 extreme event occurred in August.

For the period considered here (2007 – 2012) 43 % of days received daily rainfall of less than 1 mm and 8 % of days received rainfall of over 10 mm.

It is therefore expected that run-off due to rainfall will be higher during the autumn and winter months. However, extreme rainfall events leading to episodes of high runoff can occur in most months and when these occur during generally drier periods in summer and early autumn, they are likely to carry higher loadings of faecal material that has accumulated on pastures when greater numbers of livestock were present.

9.2 Wind

Wind data was collected from Stornoway Airport and summarised in seasonal wind roses in Figure 9.3 and annually in Figure 9.4.

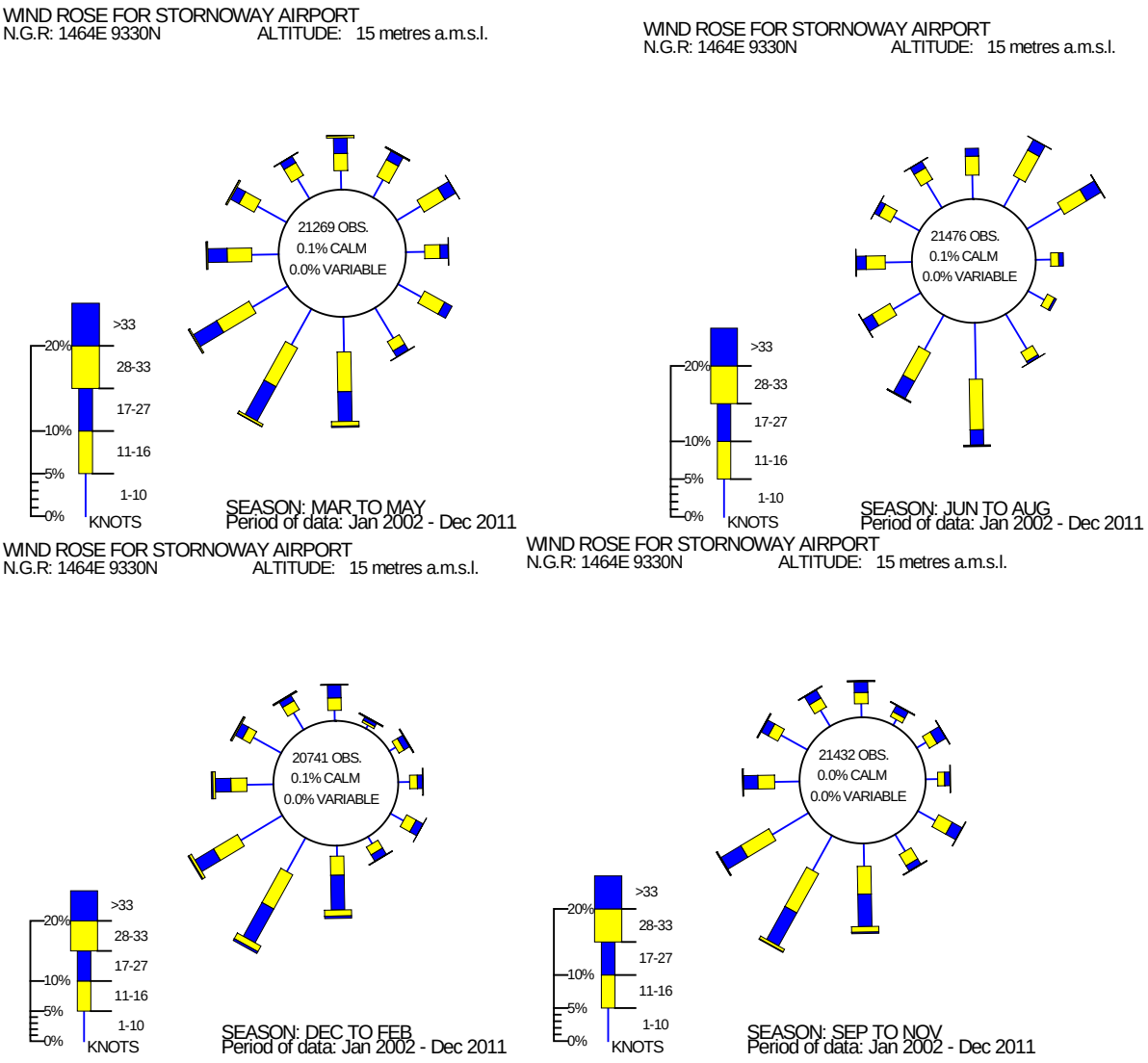


Figure reproduced under license from Meteorological Office. Crown Copyright 2012.

Figure 9.3 Seasonal wind roses for Stornoway Airport

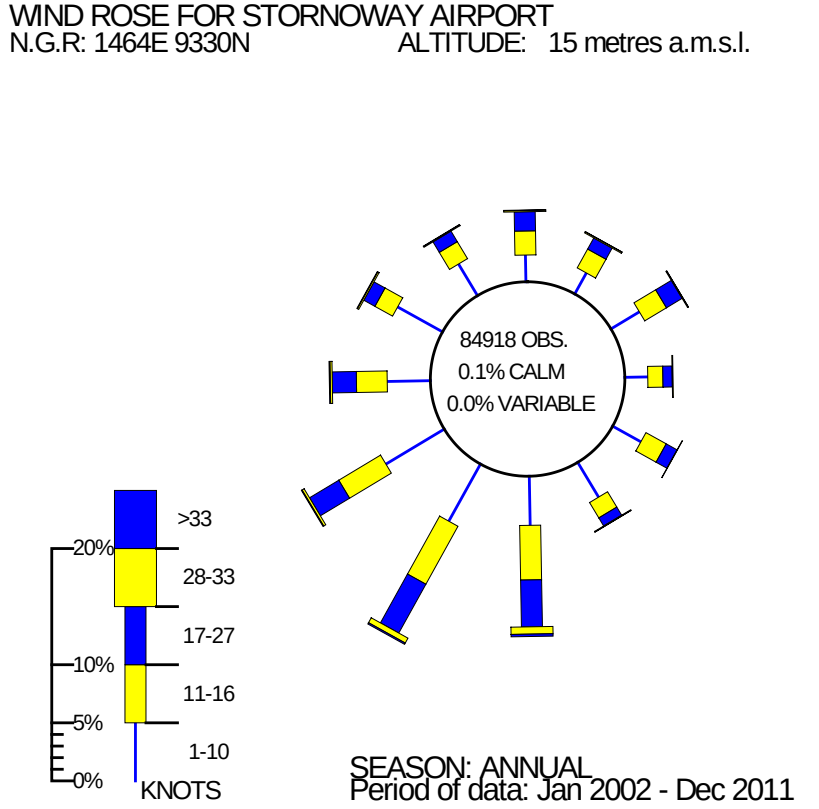


Figure 9.4 Annual wind rose for Stornoway Airport

Overall, winds were predominantly from the southwest. However, during summer, southerly winds predominated and there were also relatively strong winds from the north-west. Wind is an important factor in the spread of contamination as it has the ability to 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 can significantly alter the pattern of surface currents. Strong winds also have the potential to affect tide height depending on wind direction and local hydrodynamics of the site. A strong wind combined with a spring tide may result in higher than usual tides, which will carry any accumulated faecal matter at and above the normal high water mark into the fishery area.

10. Classification Information

Loch Roag; Barraglom has been classified for production of common mussels since 2004. The classification history since 2006 is listed in table 10.1.

Table 10.1 Loch Roag: Barraglom classification history

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2006				A	A	A	A	A	A	A	A	A
2007	A	A	A	A	A	A	A	A	A	A	A	A
2008	A	A	A	A	A	A	B	B	B	B	A	A
2009	A	A	A	A	A	A	B	B	B	B	A	A
2010	A	A	A	A	A	B	B	B	B	B	B	A
2011	A	A	A	A	A	B	B	B	B	B	B	A
2012	A	A	A	A	A	B	B	B	B	B	B	A
2013	A	A	A	A	A	A	B	B	B	A	A	A
2014	A	A	A									

11. Historical *E. coli* Data

11.1 Validation of historical data

Results for all samples assigned against the Loch Roag Barraglom site for the period 01/01/2007 to the 20/08/2013 were extracted from the FSAS database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. The data was extracted from the database on 20/08/2013. All *E. coli* results were reported as most probable number (MPN) per 100 g of shellfish flesh and intravalvular fluid.

All 68 samples were recorded as valid on the FSAS database, were received by the laboratory within the 48 hr window and had box temperatures of <8^{o}C. All reported sampling locations plotted within the current production area boundaries

11.2 Summary of microbiological results

Table 11.1 Summary of historical sampling and results

Sampling Summary	
Production area	Loch Roag: Barraglom
Site	Loch Barraglom
Species	Common mussels
SIN	LH-185-120-08
Location	Various
Total no of samples	68
No. 2008	12
No. 2009	12
No. 2010	12
No. 2011	12
No. 2012	12
No. 2013	8
Minimum	<20
Maximum	3500
Median	80
Geometric mean	93
90 percentile	790
95 percentile	1300
No. exceeding 230/100g	15 (22%)
No. exceeding 1000/100g	5 (7%)
No. exceeding 4600/100g	0
No. exceeding 18000/100g	0

Sampling has been even across the sampling period, with one sample for each month taken between 2008 and 2012. Although 22% of results exceeded 230 *E. coli* MPN/100 g, no result exceeded 4600 I MPN/100 g.

11.3 Overall geographical pattern of results

The geographical locations of Loch Roag: Barraglom sample results are displayed in Figure 11.1, with the symbols thematically mapped by size with respect to the magnitude of the *E. coli* result.

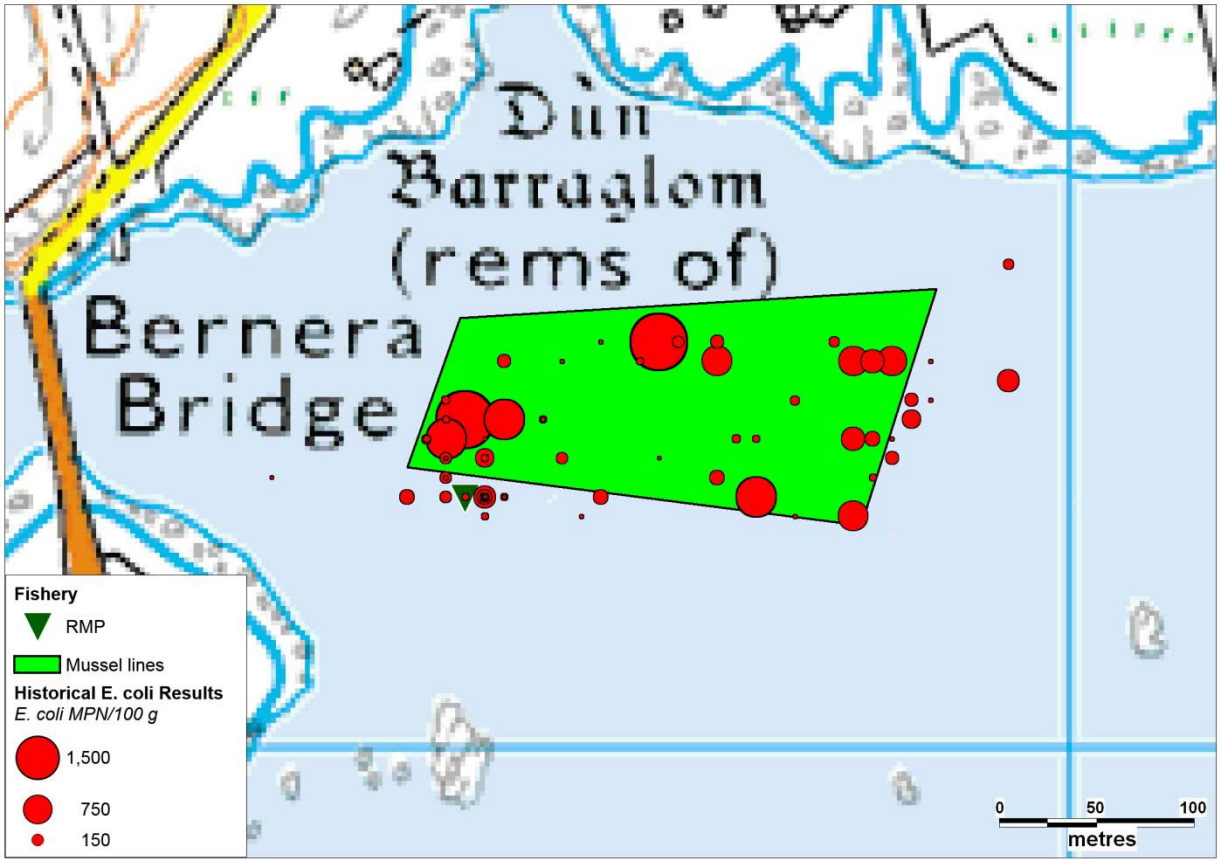


Figure 11.1 Reported sampling locations for common mussels at Loch Roag Barraglom, with symbols graduated by *E. coli* result

Samples have been taken from across the area of the mussel farm (Figure 11.1). The location of the current RMP (NB 1669 3413), lies just outside the recently recorded extent of the mussel farm. Samples from 2013 have so far mostly been taken within 20 m of the RMP. The highest samples have been recorded to the southwest and north extent of the mussel farm, all within the western half of the recently recorded extent of the lines.

11.4 Overall temporal pattern of results

A scatterplot of *E. coli* results against date for Loch Roag Barraglom is presented in Figure 11.2. The dataset is fitted with a lowess trend line. Lowess trendlines allow for locally weighted regression scatter plot smoothing. At each point in the dataset an estimated value is fitted to a subset of the data, using weighted least squares. The approach gives more weight to points near to the x-value where the estimate is being made and less weight to points further away. In terms of the monitoring data, this

means that any point on the lowess line is influenced more by the data close to it (in time) and less by the data further away. A trend line helps to highlight any apparent underlying trends or cycles.

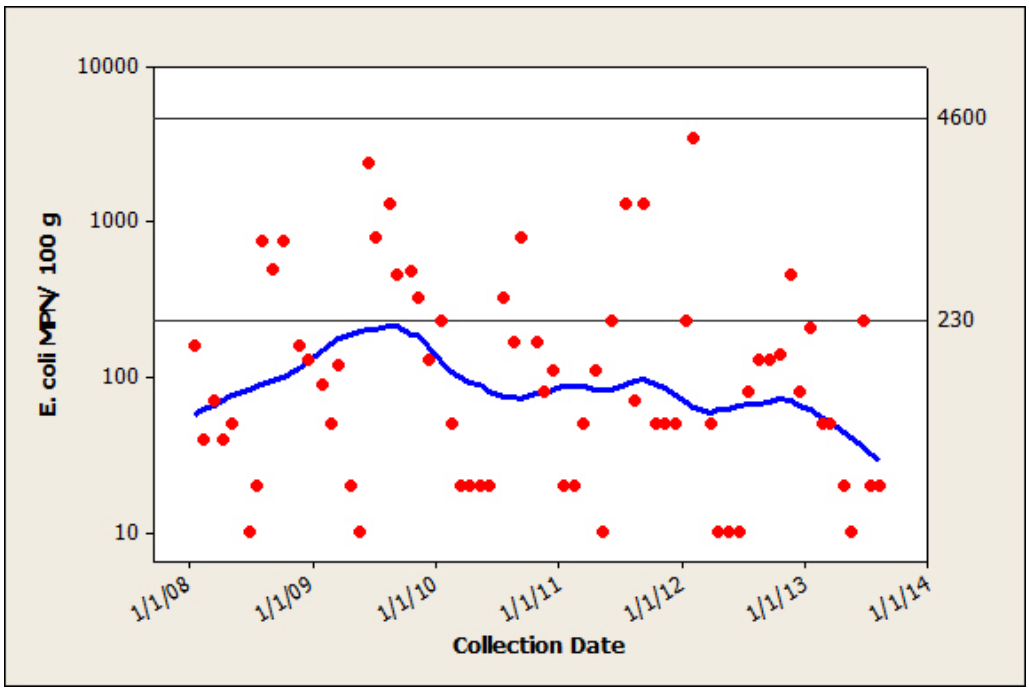


Figure 11.2 Scatterplot of *E. coli* results by collection date at Loch Roag Barraglom, fitted with a lowess line

Contamination levels are shown to have peaked in 2009 and have since gradually declined, although the highest result of 3500 *E. coli* MPN/100 g was seen in early 2012.

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 in human distribution. All of these can affect levels of microbial contamination, causing seasonal patterns in results. A scatterplot of *E. coli* results by month, overlaid by a lowess line to highlight trends is displayed in Figure 11.3. Jittering was applied at 0.01 (x-axis) and 0.001 (y-axis) respectively.

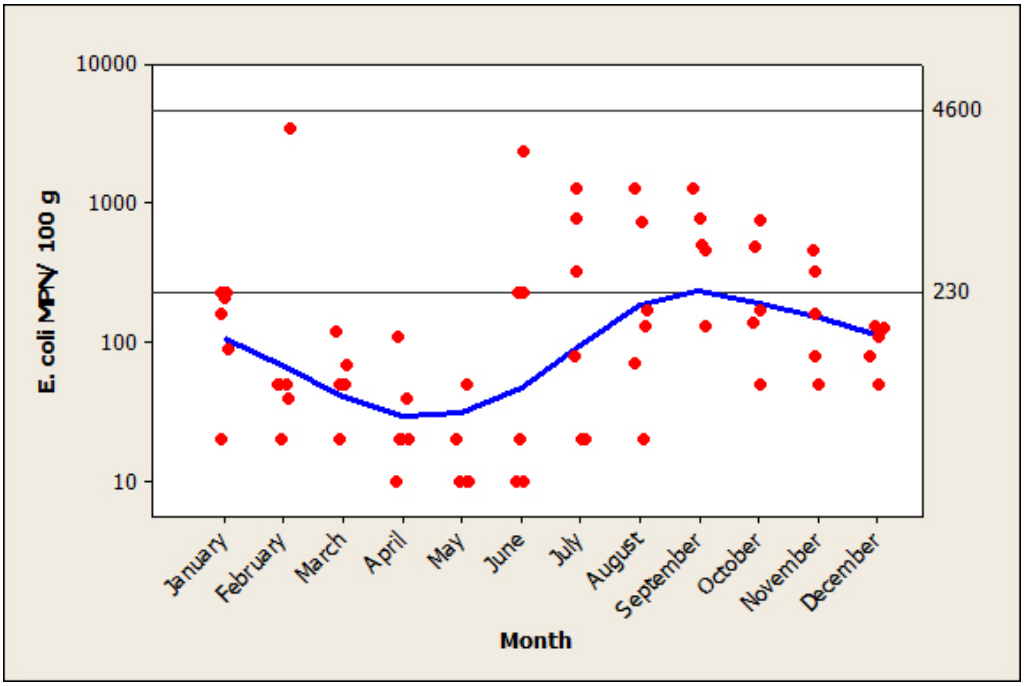


Figure 11.3 Scatterplot of *E. coli* results by month at Loch Roag Barraglom, fitted with a lowess line

The trend line shows a minimum in May and a maximum in September. Despite the highest result being recorded in February, higher results were generally seen from June to November.

For statistical evaluation, seasons were split into spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). A boxplot of *E. coli* results by season is presented in Figure 11.4.

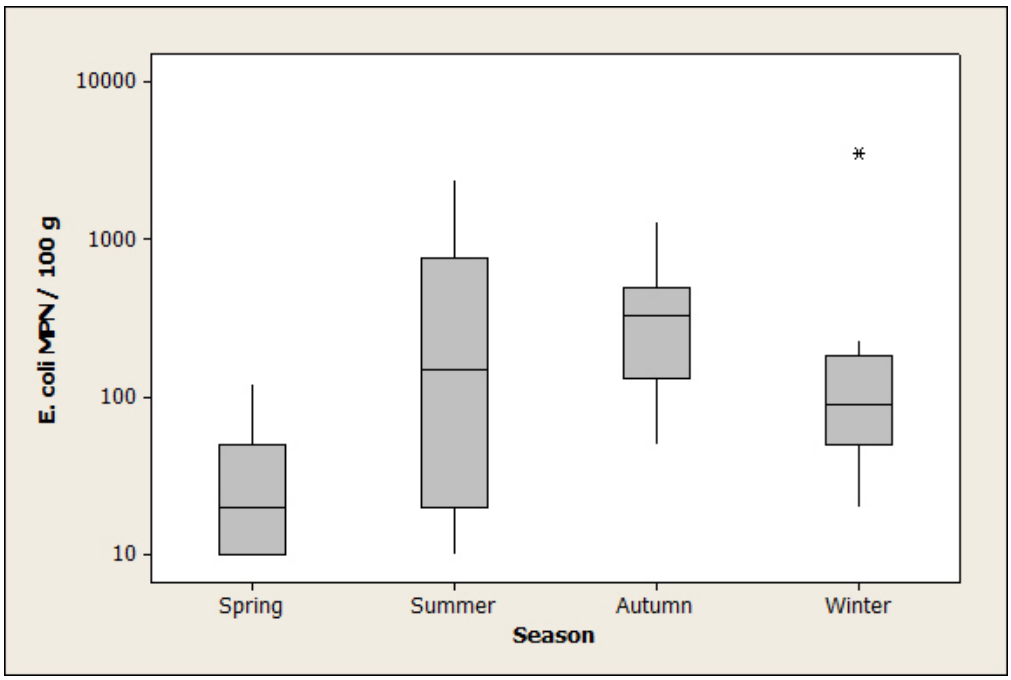


Figure 11.4 Boxplot of *E. coli* results by season at Loch Roag Barraglom

A significant difference was found between *E. coli* results by season (one-way ANOVA, p = 0.000, Appendix 4), with results in spring lower than those in summer, autumn and winter.

11.5.1 Analysis of results against environmental factors

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

11.5.2 Analysis of results by recent rainfall

Rainfall data was purchased from the Meteorological Office for Stornoway Airport station for the period of 01/01/07 - 31/12/2012 (total daily rainfall in mm). Data was extracted from this for all sample results at Loch Barraglom between 01/01/2008 – 31/12/2012.

Two-day antecedent rainfall

A scatterplot of *E. coli* results against total rainfall recorded on the two days prior to sampling is displayed in Figure 11.5. Jittering was applied to results at 0.02 (x-axis) and 0.001 (y-axis) respectively.

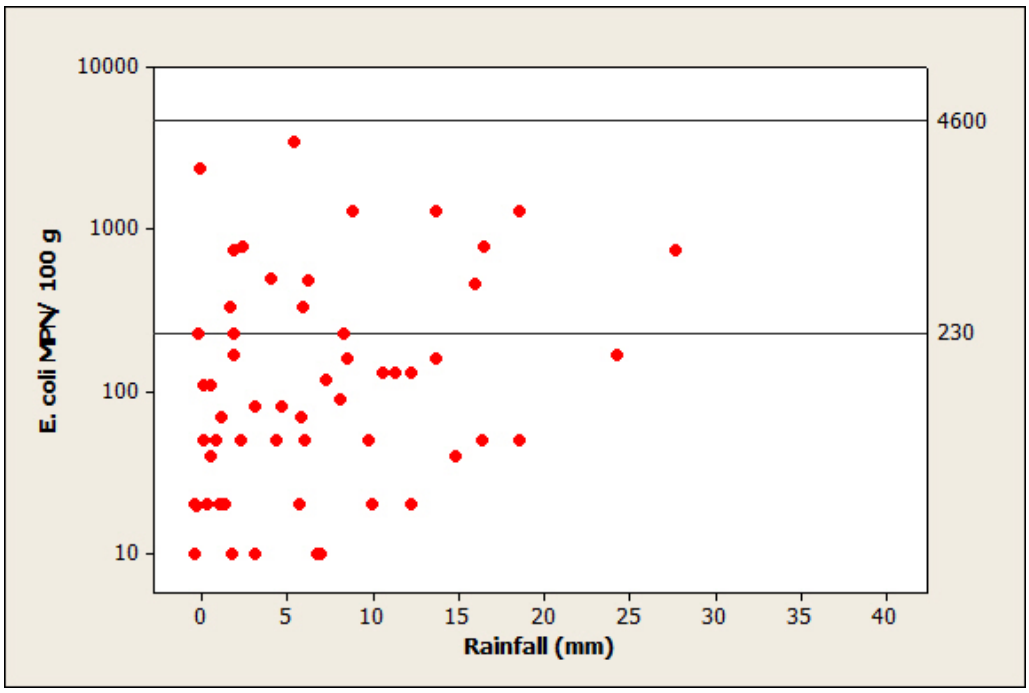


Figure 11.5 Scatterplot of *E. coli* results against rainfall in the previous two days at Loch Roag Barraglom

A significant correlation was found between *E. coli* results and the previous two day rainfall (Spearman's rank correlation r = 0.266, p = 0.047). However, this appears to be related to a decrease in the number of low results seen after increasing amounts of rainfall and the two highest *E. coli* results were seen after no or low amounts of rainfall.

Seven-day antecedent rainfall

The effects of heavy rainfall may take differing amounts of time to be reflected in shellfish sample results in different system, the relationship between rainfall in the previous seven days and sample results was investigated in an identical manner to the above. A scatterplot of *E. coli* results against total rainfall recorded for the seven days prior to sampling at Loch Roag Barraglom is shown in Figure 11.6. Jittering was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

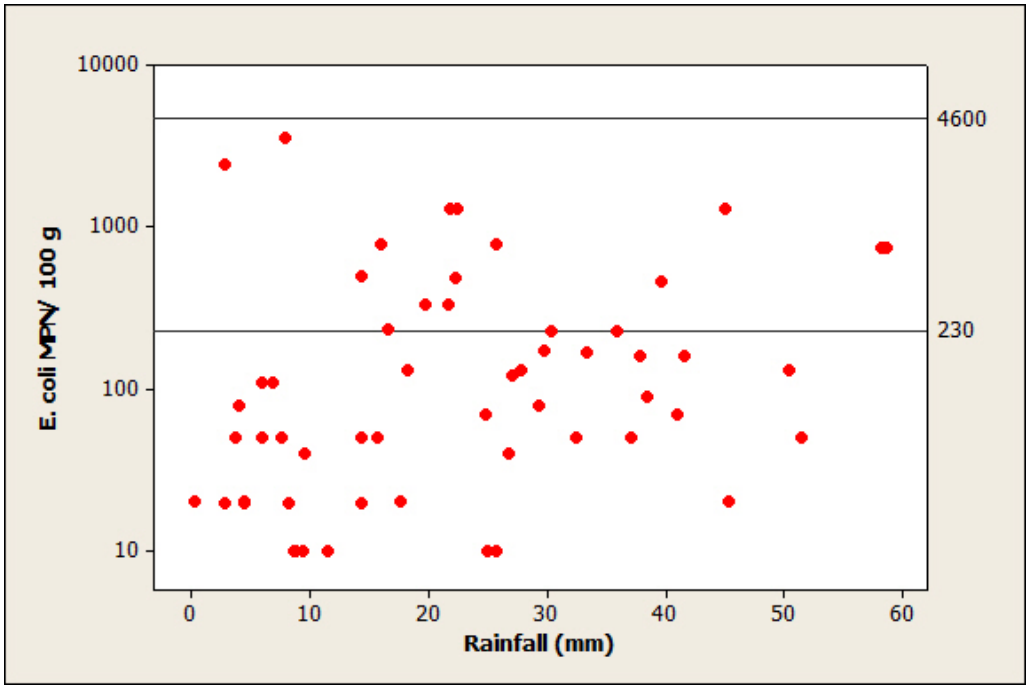


Figure 11.6 Scatterplot of *E. coli* results against rainfall in the previous seven days at Loch Roag Barraglom

A significant correlation was found between *E. coli* results and the previous seven day rainfall (Spearman's rank correlation r = 0.332, p = 0.012). While the two highest *E. coli* results were seen after low seven-day rainfall amounts, there appeared to be some general increase in *E. coli* results with increasing rainfall values.

11.5.3 Analysis of results by tidal height

Spring/Neap Tidal Cycle

Spring tides are large tides that occur fortnightly and are influenced by the state of the lunar cycle. They reach above the mean high water mark and therefore increase

circulation and particle transport distances from potential contamination sources on the shoreline. The largest spring tides occur approximately two days after the full moon, located at about 45^{o} on the diagram below, and then decrease to the smallest neap tides, located at about 225^{o}, before increasing back to spring tides. Figure 11.7 presents a polar plot of *E. coli* results against the lunar cycle**.** It should be noted local meteorological conditions (e.g. wind strength and direction) can also influence tide height, but is not taken into account in this section.

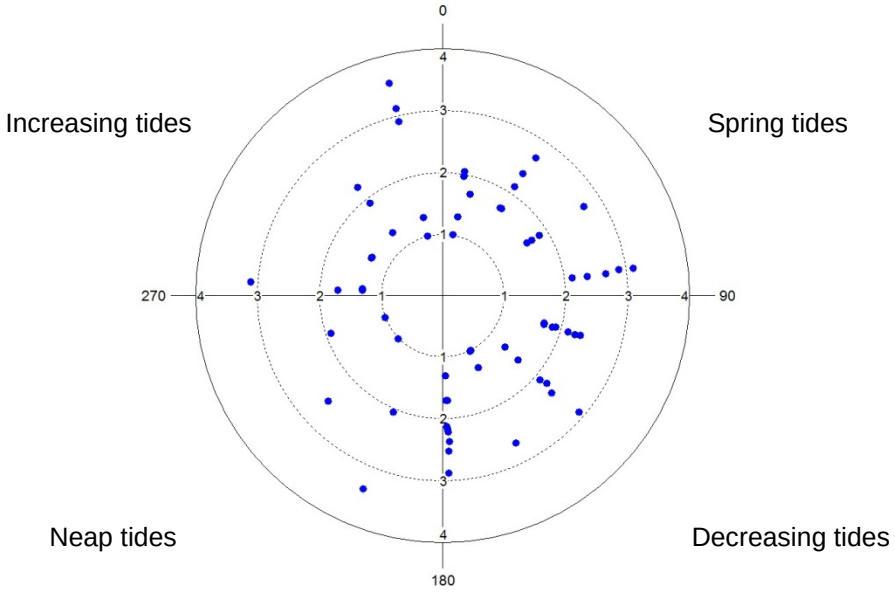


Figure 11.7 Polar plots of log_{10} *E. coli* results versus the spring/neap tidal cycle at Loch Roag Barraglom

A significant correlation was found between log_{10} *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r = 0.219, p = 0.044). A greater proportion of samples taken during decreasing tides gave *E. coli* results >100 MPN/100 g than over other parts of the spring/neap tidal cycle although high results did occur at other tidal states.

High/Low Tidal Cycle

Tidal state (high/low tide) changes the direction and strength of water flow around production areas. Depending on the location of contamination sources, tidal state may cause marked changes in water quality near the vicinity of the farms. Shellfish species response time to *E. coli* levels can vary from within an hour to a few hours. Figure 11.8 presents a polar plot of *E. coli* results against the high/low tidal cycle. High water is at located at 0^{o} and low water at 180^{o} in the diagram.

High and low water data from Little Bernera was extracted from POLTIPS-3 in August 2013. This site was the closest to the production area (approximately 6.4 km to the north) and it is assumed that tidal flow will be similar between sites.

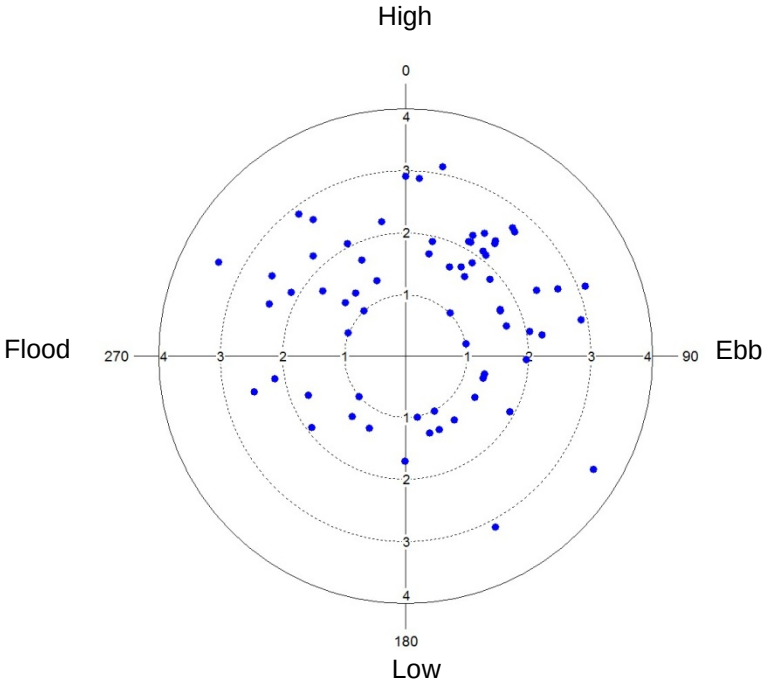


Figure 11.8 Polar plots of log_{10} *E. coli* results on the high/low tidal cycle at Loch Roag Barraglom

A significant correlation was found between log_{10} *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.305, p = 0.002). The majority of elevated results were taken between the last half of flood tide and the first half of ebb tide.

11.5.4 Analysis of results by water temperature

Water temperature can affect survival time of bacteria in seawater (Burkhardt, Calci, Watkins, Rippey, & Chirtel, 2000). It can also affect the feeding and elimination rates in shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. Water temperature is obviously closely related to season. Any correlation between temperatures and *E. coli* levels in shellfish flesh may therefore not be directly attributable to temperature, but to the other factors e.g. seasonal differences in livestock grazing patterns. Figure 11.9 presents *E. coli* results against water temperature. Water temperature was recorded for 34 out of the 68 samples. Jittering of results was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

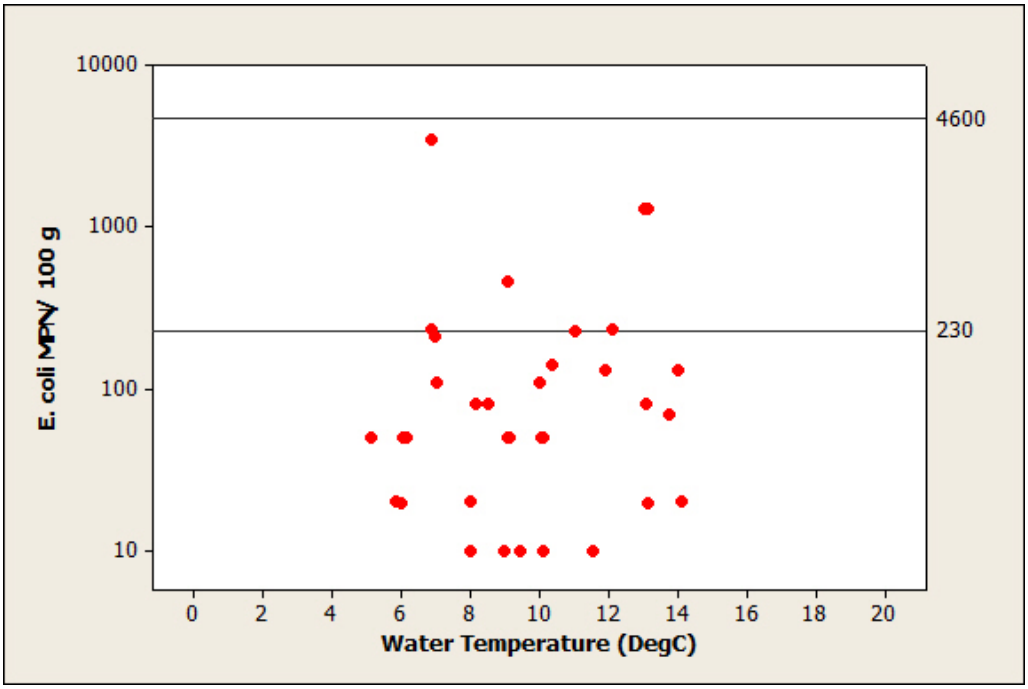


Figure 11.9 Scatterplot of *E. coli* results against water temperature at Loch Roag Barraglom

No significant correlation was found between *E. coli* results and water temperature (Spearman's rank correlation r = 0.157, p = 0.376).

11.5.5 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence and hence freshwater borne contamination at a site. A scatterplot of *E.* coli results against salinity is shown in Figure 11.10. Salinity was recorded for 48/68 samples. Jittering was applied to results at 0.02 (x-axis) and 0.001 (y-axis) respectively.

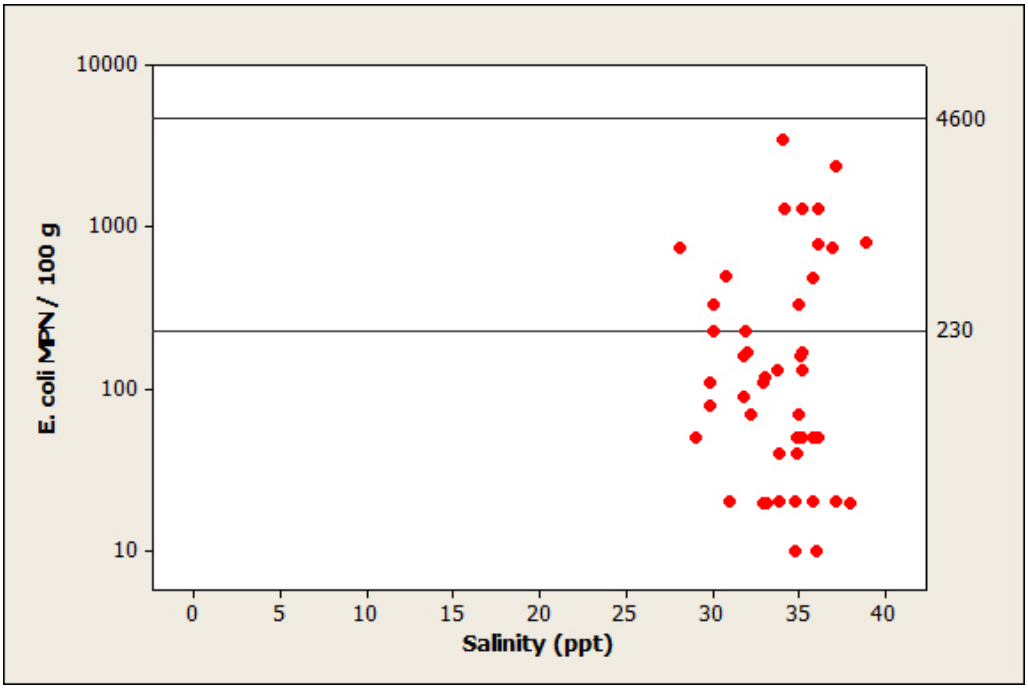


Figure 11.10 Scatterplot of *E. coli* results against salinity at Loch Roag Barraglom

No significant correlation was found between *E. coli* results and salinity (Spearman's rank correlation r = -0.086, p = 0.561).

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

In the results from Loch Roag Barraglom, five common mussel samples had results >1000 *E. coli* MPN/ 100 g and are listed below in Table 11.2.

Table 11.11 Historic at Loch Roag Barraglom
***E. coli* sampling results over 1000 *E. coli* MPN/100g**

Collection Date	*E. coli* (MPN/ 100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (^{o}C)	Salinity (ppt)	Tidal State (high/low)	Tidal state (spring/neap)
15/06/2009	2400	NB 1679 3421	0.40	1.70	-	37	Flood	Neap
17/08/2009	1300	NB 1684 3413	8.80	22.60	-	35	Ebb	Increasing
18/07/2011	1300	NB 1668 3416	18.80	22.40	13.0	36	High	Spring
12/09/2011	1300	NB 1671 3417	13.20	44.00	13.0	34	High	Increasing
06/02/2012	3500	NB 1669 3417	5.40	7.80	7.0	34	Ebb	Increasing

-No data available

Elevated sample results occurred in 2009, 2011 and 2012. One sample had been taken in February while the others had been taken between June and September. Results varied between 1300 – 3500 *E. coli* MPN/100 g. Locations were largely in the western half of the mussel farm. Rainfall for 4/5 samples over the two days prior to sampling were >5 mm, whilst three of the five samples were associated with rainfall levels >22 mm over the seven days prior to the survey.

Water temperature was recorded for three out of the five samples and varied between 7-13^{o}C. Salinity was recorded for all samples and varied between 34 and 37 ppt. There did not appear to be any consistent pattern to the tidal state under which samples had been taken.

11.7 Summary and conclusions

Samples had been taken from across the general extent of the mussel farm with higher results being associated with samples taken over the western half of the location of the present mussel lines.. Results varied between <20 and 3500 *E. coli* MPN / 100 g. A statistically significant difference was found between results and season, with lower results being obtained from samples taken in spring compared to summer, autumn and winter. Location of samples varied, though the majority were taken within the recorded mussel farm area.

Statistically significant correlations were found between results and rainfall over both the two and seven days prior to the survey, although the effect of these rainfall periods appeared to vary with respect to low and high *E. coli* results. No statistically significant correlations were found between results and sea water temperature or

salinity. Statistically significant correlations were found between results and high/low and spring/neap tidal states, with higher results tending to occur when tides were decreasing from spring to neap and during the last half of the flood and first half of the ebb tide.

12. Designated Waters

The Loch Roag designated shellfish growing water (SGW) encompasses the Loch Roag Barraglom production area as well as other Loch Roag production areas lying to the west (see Figure 12.1). The SGW was designated in 2002 (before which it was 4 separate areas which were designated in 1998). Under the current shellfish growing waters legislation it must be monitored quarterly for faecal coliforms in the shellfish flesh and intervalvular fluid.

The relative positions of the production area, RMP, Shellfish Growing Waters (SGW) boundary and the SGW monitoring point are shown in Figure 12.1. Since 2007, SEPA have based the SGW assessment on FSAS *E. coli* results. It is understood that the protocol used for these assessments will mean that compliance will have been determined on the basis of the data from all of the production areas covered by the Loch Roag designated shellfish water.

The shellfish growing water report for the area (SEPA, 2011) identified that:

- The land bordering Loch Roag is a mixture of heather moorland, rough ground and lochans interspersed with small areas of improved grassland.
- The area does not have any settlements of significant size.
- Freshwater inputs to the designated area due to low population density and non-intensive land use are considered to be of good quality.
- The waters have consistently complied with the Guideline standard for faecal coliforms since monitoring began in 2003.

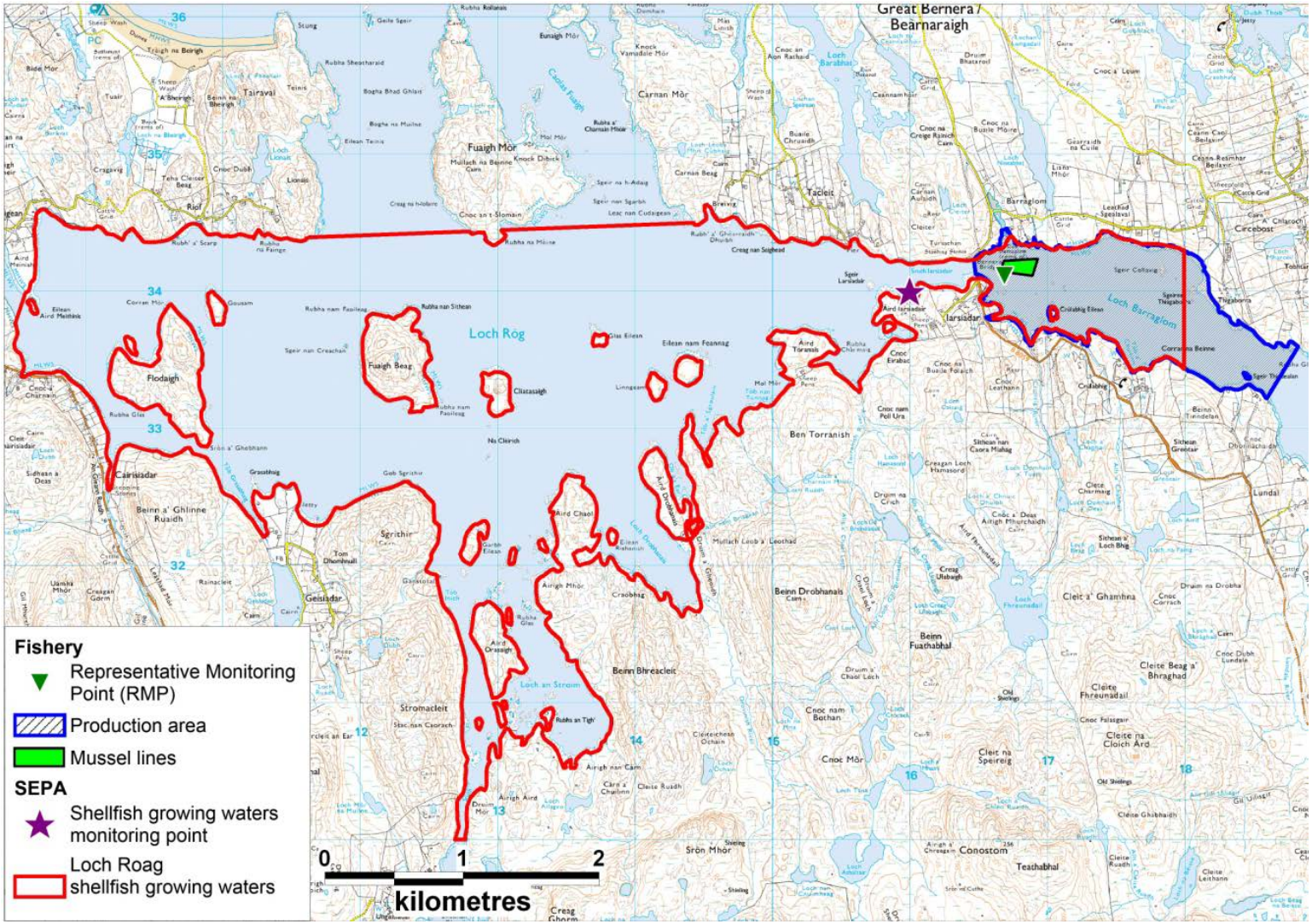


Figure 12.1 Designated shellfish growing water – Loch Roag

13. Bathymetry and Hydrodynamics

13.1 Introduction

13.1.1 The Study Area

Loch Roag: Barraglom is situated on the west of the Isle of Lewis adjacent to Bernera Bridge which connects the island of Great Bernera to the main body of Lewis. Loch Roag, as a whole, is separated into two inlets by Great Bernera; East Loch Roag and West Loch Roag. These east and west branches connect to the south of Great Bernera in Loch Barraglom where the hydrographic assessment area is positioned. Barraglom village itself is situated on Great Bernera and the loch is NW facing. The loch is surrounded by a small number of private dwellings on all sides comprising mostly of crofts but there are no major settlements. The area is extremely complex with multiple inlets and islands. The assessment area is relatively small and is shown in Figure 13.1.

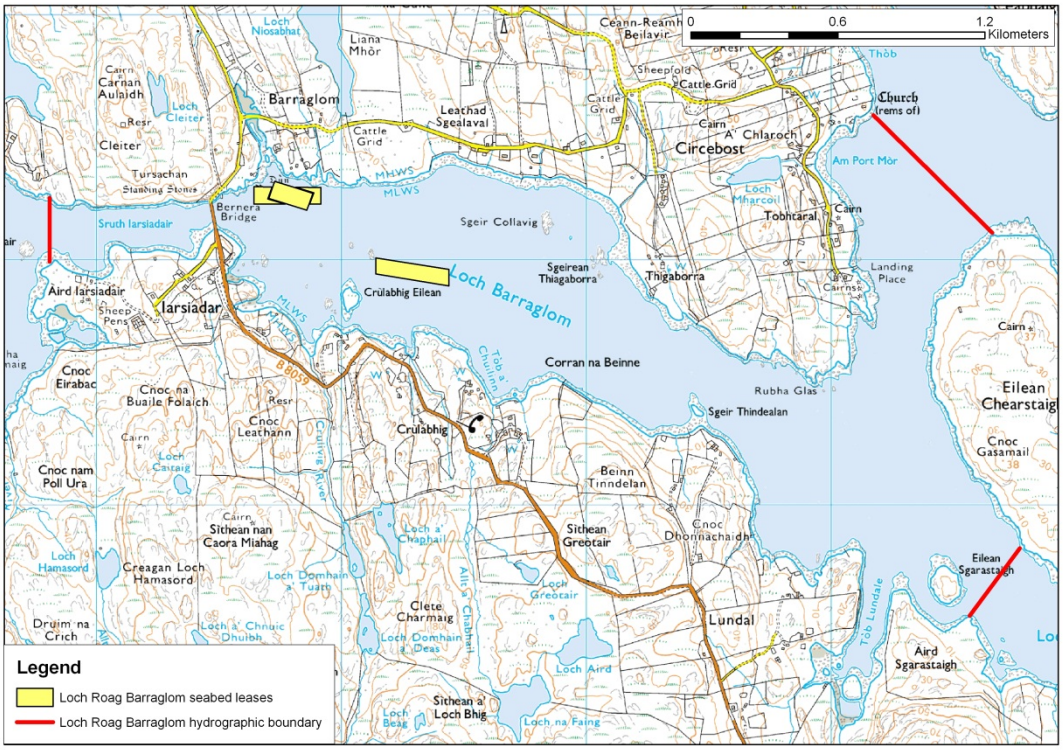


Figure 13.1 Extent of hydrographic study area

Coordinates for middle of Loch Barraglom:

58° 12.21’ N 006° 48.42’ W

NB 17714 33937

13.2 Bathymetry and Hydrodynamics

13.2.1 Bathymetry

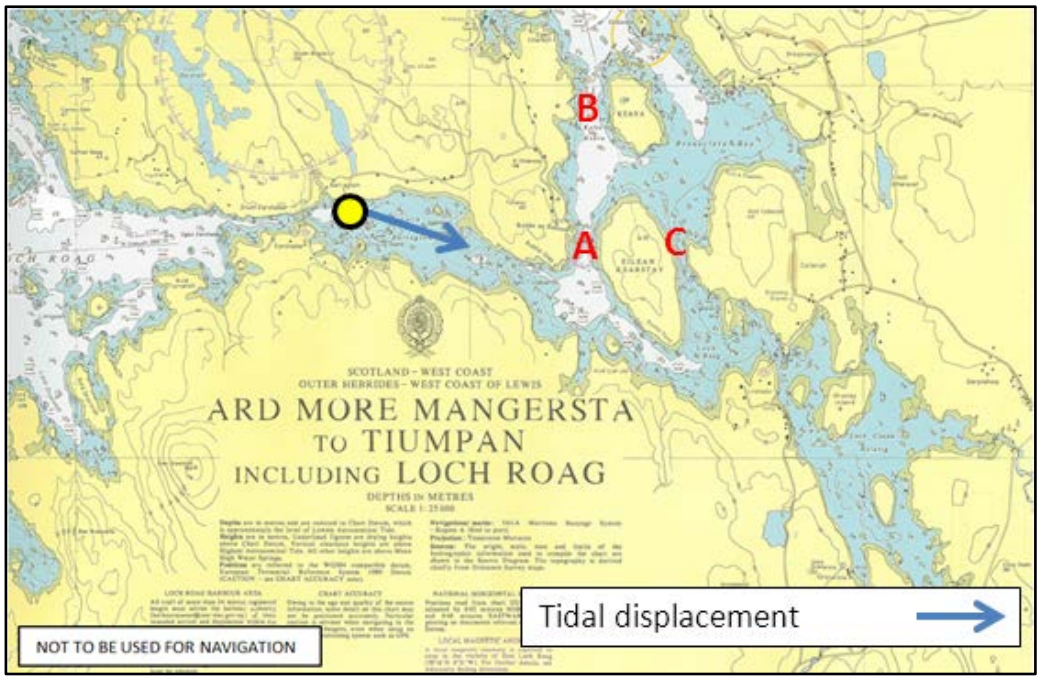


Figure 13.2 Admiralty chart extract for Loch Roag: Barraglom. Note that the length of the flow arrow at the current meter site approximately equates with the estimated transport distance during the flood or ebb phases of the tide.

Loch Roag spans a vast area and encompasses the large island of Great Bernera. The loch separates into West Loch Roag, East Loch Roag and Little Loch Roag. Loch Barraglom lies within the Loch Roag system, with Figure 13.2 showing the bathymetry of the area.

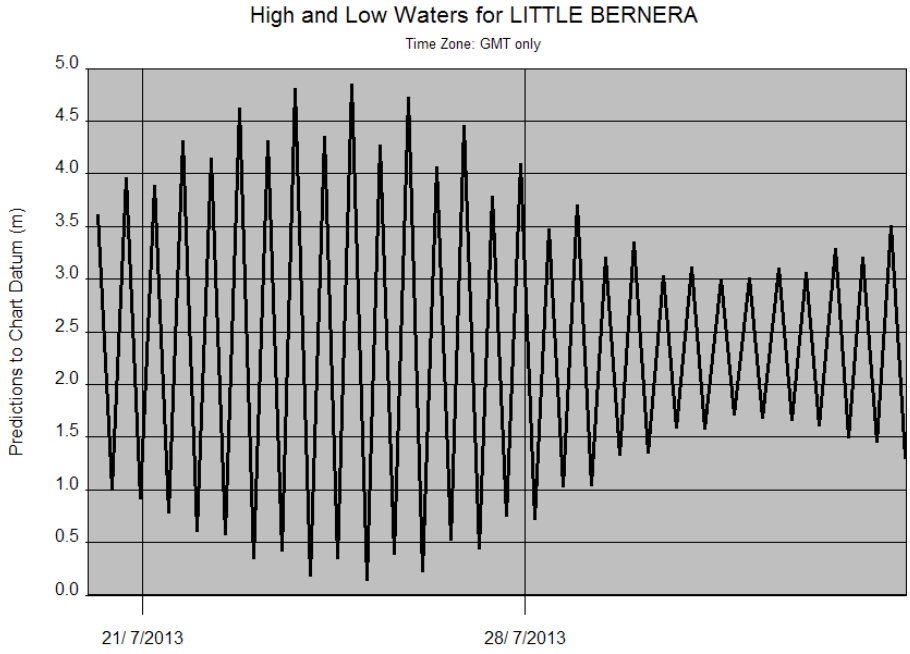
The general area of Loch Roag is characterised by numerous islands and this creates a complex system of sills and straits with fast-flowing currents. In the general area the bathymetry and topography is intricate leading to complex hydrographic conditions. East Loch Roag is 16.78 km in length with an area of 36.6 km^2 and a total volume of 7.39 x 10^8 m^3. The average depth of East Loch Roag is 20 m with a maximum charted depth of 30 m at the mouth (Spurway, 2001). The assessment area of Loch Barraglom is connected to East Loch Roag at its southern end near Eilean Kearstay (or Chearstaigh on the OS map). Loch Barraglom is relatively shallow compared to the surrounding areas with a maximum charted depth of 17 m. There is a continuous connection between Loch Barraglom and West Loch Roag through a narrow strait at Earshader (Iarsiadar on the OS map) that has a maximum cross-sectional area of ~1295 m^2 and an ebb/flood flow rate of 51.8 m^3s^{-1} (Tyler & Bass, 2005). This constriction limits the exchange between East and West Loch

Roag to 0.1% of the tidal flux in both lochs, such that they are effectively hydrographically separate (Tyler & Bass, 2005).

13.2.2 Tides

The study area in Loch Roag has a typical semi-diurnal tidal characteristic. Data on tidal information is given from charted information. The nearest location for tidal predictions is Little Bernera approximately 7.5 km from the assessment area [http://easytide.ukho.gov.uk].

Standard tidal data for Little Bernera are given below and the spring/neap cycle of tidal height around the time of the survey (26th & 27th of June 2013) is shown in Figure 13.3:



Reproduced from Poltips3 [www.pol.ac.uk/appl/poltips3]

Figure 13.3Two week tidal curve for Little Bernera.

Tidal Heights for Little Bernera (from Admiralty Chart 2515):

Mean High Water Springs = 4.3 m
Mean Low Water Springs = 0.5 m
Mean High Water Neaps = 3.1 m
Mean Low Water Neaps = 1.6 m

Tidal Ranges averaged for Little Bernera:

Mean Spring Range = 3.8 m
Mean Neap Range = 1.5 m

13.2.3 Tidal Streams/Currents

Most of the measured tidal flow data comes from Admiralty Chart 2515 and relates to peak flows in straits between a number of islands in Loch Roag. Within the assessment area, the only published tidal flow is for the channel between Eilean Kearstay and Rubha na Sidheon on Great Bernera ['A' on Figure 13.2] having velocities of 1.5 knots (0.77 m/s) during the flood tide. Other published tidal velocities are through the Kyles Keava just north of Eilean Kearstay ['B' in Figure 13.2] at 0.75 knots (0.39 m/s) on both the ebb and flood tide and to the east of Eilean Kearstay ['C' in Figure 13.2] where there is a flow of 0.8 knots (0.41 m/s) on the flood and 0.75 knots (0.39 m/s) on the ebb (CEFAS on behalf of Food Standards Agency Scotland, 2008).

Modelling studies have shown the tidal currents to be generally weak in the area with the exception of narrow straits and channels (CEFAS on behalf of Food Standards Agency Scotland, 2008).Typical residual flows at the southern end of East Loch Roag have been found to be around 0.05 ms^{-1} with the formation of gyres within bays. A similar residual flow is found to occur within Loch Barraglom where there is a weak circulation. Tidal transport will be variable over the area but have been reported to have a maximum value of 1 km(CEFAS on behalf of Food Standards Agency Scotland, 2008).

There is one current meter record available from SEPA. It is at a location within the narrows at Earshader (shown in Figure 13.2) in the mid-water at a depth 5.5 m from the bottom. The record is 2 days long and is therefore limited in its accurate representation of the spring/neap variance. However the record does show that the flow is dominated by a semi-diurnal flow with the current aligned in the direction of the narrows as expected. The record is too short to give a reliable measure of the residual flow.

Table 13.1 Loch Barraglom current data measured in 1998

	Mid-depth
Mean Speed (ms^{-1})	0.08
Principal Axis Amp (ms^{-1})	0.1
Residual speed (ms^{-1})	Not reported
Residual direction (^{o}M)	Not reported

Using a surface principal current amplitude of 0.1 m/s (Table 13.1) and the assumption of a uniform sinusoidal tide, the cumulative transport that might be expected during each phase of the tide has been estimated as approximately 1.4 km. No distinction is made here for springs and neaps.

There are no direct measures of dispersion in Loch Roag, however owing to the complexity of the bathymetry and coastline one might anticipate a rather highly dispersive environment near fast flowing channels.

13.2.4 River/Freshwater Inflow

There are a number of watercourses marked on the OS map of which the main ones include Abhainn Dhubh and Grimersta which flow into Loch Ceann Hulavig to the south east of the study area at the south end of East Loch Roag. The Breasclete flows into Breasclete Bay which is north-east of Eilean Kearstay. Due to the location of these rivers, i.e. restricted exchange with East Loch Roag and to the assessment area of Loch Barraglom, they are expected to have a minor impact on density driven circulation. In general the fresh water input will be confined to the surface layers and will only locally effect stratification and surface flows.

There is rather little fresh water input directly to the waters of Loch Barraglom. The shallow water and tidal flow in the area will tend to keep waters in the assessment area well mixed with minimal surface effects.

13.2.5 Meteorology

East and West Loch Roag are exposed predominantly to southwest winds. Loch Barraglom, because of its position at the south of Great Bernera and between East and West Loch Roag may be more sheltered.

Meteorological data is collated from Stornoway Airport, approximately 30 km to the east of the assessment area. Given the terrain of Lewis and the proximity of the station, it is expected that broadly similar patterns would be found in the meteorological conditions for the assessment area. Wind data spanned from January 2002 – December 2011 whilst rainfall data spanned from January 2007 – August 2012.

The wind data from Stornoway shows that overall westerly winds and southerly winds were stronger than northerly or easterly winds. The dominant airflow year round is south-westerly and winds are generally stronger in the winter. Northeast winds become more frequent in summer compared to winter. Winds that align with the sea loch axis (northwest-southeast) are relatively infrequent.

There were differing rainfall levels from year to year with the highest rainfall being recorded in 2011 and the least in 2010. Rainfall reached more than 30 mm/d throughout in 2007, 2009 and 2010 and in 2007 an extreme level of rainfall of approximately 60 mm/d was recorded.

Rainfall values were, overall, higher during the autumn and winter months. The rainfall generally increases from July onwards and is highest in October and November. April to June are the months with the least rainfall. Levels of rainfall reached more than 30 mm/d in January, May and August.

43% of days from 2007 to 2012 had rainfall below 1 mm with over 10 mm of rainfall being recorded on 8% of the days. Consequently, it can be assumed that run-off because of rainfall will be high throughout both the autumn and winter months. However, whilst a general seasonal pattern in rainfall can be deduced from the historic data, periods of high rainfall can be recorded in the majority of months.

13.2.6 Model Assessment

A box modelling study has been carried out for both East and West Loch Roag previously (Tyler & Bass, 2005). Further, a hydrodynamic model of the southern part of East Loch Roag and the southward connected basin of Loch Ceann Hulavig has been run in previous assessments (CEFAS on behalf of Food Standards Agency Scotland, 2008). These models are not replicated here; however, the important conclusions are drawn out as they relate to Loch Barraglom. However, neither model reports extensively on their results with respect to Loch Barraglom and so inferences have been made to establish some of the characteristics of the assessment area.

The box model was based on data from a study by SEPA (Spurway, 2001). It was run for both East and West Loch Roag and the tidal flushing was calculated using a simple tidal prism flushing model.

Table 13.2 Summary of mean parameter values from the flushing modelling exercise for West Loch Roag

Parameter	Value
Mean neap flushing time (tidal cycles)	16.88
Mean neap flushing time (days)	8.44
Mean spring flushing time (tidal cycles)	8.08
Mean spring flushing time (days)	4.03
Mean neap daily flushing rate (m3/day)	160 x 106
Mean spring daily flushing rate (m3/day)	336 x 106
Mean monthly water exchange in West Loch Roag (m3/month)	5500 x 106
Mean daily water exchange in West Loch Roag (m3/day)	248 x 106

Table 13.3 Summary of mean parameter values from the flushing modelling exercise for East Loch Roag

Parameter	Value
Mean neap flushing time (tidal cycles)	13.63
Mean neap flushing time (days)	6.81
Mean spring flushing time (tidal cycles)	6.61
Mean spring flushing time (days)	3.31
Mean neap daily flushing rate (m^3/day)	108 x 10^6
Mean spring daily flushing rate (m^3/day)	223 x 10^6
Mean monthly water exchange in East Loch Roag (m^3/month)	5051 x 10^6
Mean daily water exchange in East Loch Roag (m^3/day)	166 x 10^6

This model shows that the mean flushing time in West Loch Roag is between 4.03 to 8.44 days. This model shows that the mean flushing time in East Loch Roag is between 3.31 to 6.81 days. West Loch Roag had a greater tidal flushing time than East Loch Roag by around 50% and this can be attributed to its greater volume.

Loch Barraglom is likely to have a flushing time that it similar to or less than that for East Loch Roag, given its shallow depths and small volume.

13.3 Hydrographic Assessment

13.3.1 Surface flow

Throughout the overall area of Loch Roag, freshwater is unlikely to have a significant impact. This is even more so within the confines of Loch Barraglom where there is no major riverine input. Consequently, it is expected that the assessment area will be well mixed and this has been confirmed for East Loch Roag in previous studies (Spurway, 2001) where there was little or no vertical stratification and temperature and salinity differences between surface and bottom waters were negligible.

In some parts of East Loch Roag, surface flow is evident under some wind forcing conditions and can be particularly influential if the direction is concurrent with the axis orientation of the loch (north-westerly or south easterly). However, the impact of wind on surface flows in Loch Barraglom has been shown to be rather minimal with the surface flow being dominated by any residual gyre circulation that exists within the Loch (CEFAS on behalf of Food Standards Agency Scotland, 2008).

There are strong tidal flows in the narrows between islands but otherwise the tidal currents are generally weak with transport being up to 1km (CEFAS on behalf of Food Standards Agency Scotland, 2008).

Although the current meter record was not sufficient to determine all parameters, it is likely that the principle current direction in the mid water will be aligned with the shore line with a magnitude of ~ 0.1 ms^{-1}. Cumulative transport during each phase of the tide has been estimated to be around 1.4 km.

At the eastern end of the assessment area, close to the channels around Eilean Kearstay, the dispersion in the surface is likely to be higher.

13.3.2 Exchange Properties

The exchange through Loch Barraglom, between East and West Loch Roag is a maximum of 0.1% of the collective tidal flux into both lochs. Therefore, Loch Barraglom can be considered as a part of the East Loch Roag system rather than a body of water connected freely to both the East and West Lochs.

The numerical model showed that given favourable wind conditions that there is potential for wind driven exchanges from pollution sources within East Loch Roag to enter the assessment area of Loch Barraglom. However, these exchanges would take place over a time scale of several days and one might anticipate significant dispersion over that time.

It is anticipated that Loch Barraglom will be moderately well-flushed, with a flushing time of less than 6 days in general, with the potential for some particulates to be trapped within a weak gyre that is reported to exist.

There is a lack of long term hydrographic data coverage for this area, particularly data sets with seasonal resolution. Further, the site is rather complex in topography leading to rather complex flow regimes. Therefore the confidence level of this assessment is LOW.

14. Shoreline Survey Overview

The shoreline survey at Loch Roag: Barraglom was conducted between the 26th and 27th June 2013. Small amounts of rainfall were recorded in the 48 hrs prior to the survey, though the weather was dry during the two survey days. Temperatures varied between 11-12°C, with wind gusting to 20 km/h on the first day of survey, reducing to 10 km/h on the second day.

The fishery was situated east of the Bernera Bridge and consisted of a single mussel farm comprised of three long-lines running parallel to shore. Droppers were 8 m deep and the site has been classified since 2003. The mussel farm staff stated that harvesting takes place year round except for July-August when maintenance takes place.

A septic tank was noted at NB 1814 3423, with a strong smell of sewage associated with the watercourse Allt Millegro. A sample of the watercourse just below an outfall pipe returned a result of 26000 *E. coli* cfu / 100 ml, indicating a significant faecal content. Another discharge was located to the west of the Bernera Bridge along the southern shore. A pipe was noted to be discharging into a stagnant watercourse, and the sample returned a level of 260000 *E. coli* cfu/ 100 ml: this represented marked faecal contamination. No other discharges were observed during the survey.

Only two vessels were noted during the survey; one associated with the seaweed farm, and another small boat moored south of Bernera Bridge.

The majority of the land was used to rear sheep, with roads and the shoreline fenced off to prevent animal access. Land cover consisted of mainly rough grassland with a rocky shoreline. No arable agriculture was noted during the survey.

A large number of small watercourses and areas of land drainage were noted during the survey. Birds were the only wildlife observed during the survey and included: Eider ducks, oyster catchers, geese and gulls. Goose feathers and droppings were also frequently observed along the shoreline.

Shellfish samples taken during the survey returned low results of 20 *E. coli* MPN/100g for three of the samples taken at the southeast extent of the mussel lines and for one of the southwestern samples. The other sample was taken at 8 m depth and returned a result of 50 *E. coli* MPN/100 g.

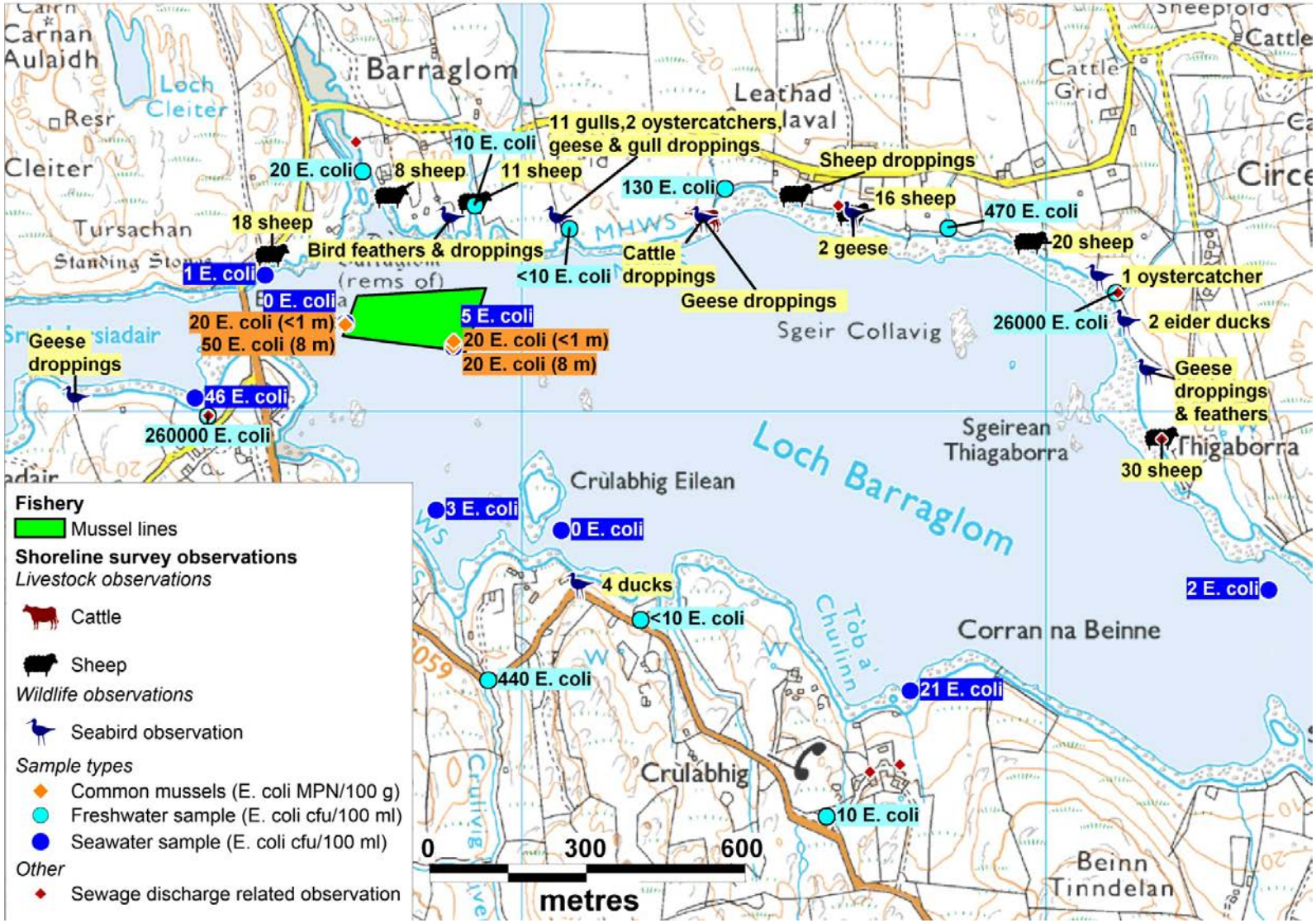


Figure 14.1 Principal shoreline survey observations at Loch Roag Barraglom

15. Overall Assessment

Human sewage impacts

Scottish Water identified two community septic tanks in the vicinity of Loch Barraglom. One of these, Kirkibost septic tank, has a reported PE of 144 and discharges adjacent to a stream approximately 1.2 km east of the mussel farm. The predicted tidal transport of contaminants was identified in the hydrographic analysis as 1.4 km, suggesting that this septic tank may contribute to faecal contamination at the fishery.

The other, at Breasclete, discharges via a series of freshwater lochs into West Loch Roag on the west side of Great Bernera. Due to the distance and predicted movement of contaminants, is not considered likely that any impacts arising from this septic tank discharge will reach the fishery at Barraglom.

The majority of smaller, private septic tanks are associated with homes built along the north shore of the loch. Whilst many of these were reported to discharge to soakaway, some may actually discharge to water or are located in areas where there are likely to be waterlogged soils and therefore these may have an impact on water quality nearby. Two private discharges to sea lie within 1km of the fishery. A discharge west of the Bernera Bridge and within 400m of the fishery was observed during the shoreline survey. However, a the presence of a consented discharge on the south shore of Great Bernera was not confirmed during that site visit.

Agricultural impacts

Sheep are raised throughout the area, though only limited numbers were seen during the shoreline survey, and these were all observed along the north shore of the loch where there are a larger number of crofts along the road. Any contributions of faecal contamination from livestock grazing along the northern of the loch would be most likely to affect the long lines on the mussel farm closest to this shoreline.

Wildlife impacts

No specific aggregations of wildlife were noted for the area. Gulls and geese were seen in the greatest numbers during the shoreline survey, with geese and goose droppings seen on grassland along the north shore of the loch. Impacts are likely to be diffuse, and potentially higher along the shore nearest the mussel lines.

Seasonal variation

Significant seasonal variation is likely to occur in livestock populations, with sheep numbers roughly doubling after lambing in spring. Although there is little in the way of hotel accommodation, a significant number of the properties in the area may be used

only seasonally. Significant seasonal variation was seen in *E. coli* monitoring history, with results significantly lower in spring than in all other seasons.

Rivers and streams

No large watercourses discharge to Loch Barraglom, though a large number of small watercourses and areas of land drainage were observed during the shoreline survey. These watercourses are likely to receive diffuse contamination from livestock, wildlife and potentially septic tank sources.

Of the watercourses flowing strongly enough to measure and sample during the shoreline survey, the two highest estimated loadings were from the watercourse adjacent to the Kirkibost septic tank outfall, and from the Crulivig River, which discharges approximately 500 m south of the mussel farm. Areas of standing water observed during the survey would be likely to flow under rainfall conditions.

In light of the large number of observed drainage areas, it is likely that runoff carrying faecal contamination from livestock, wildlife and septic tanks will contribute to faecal contamination at the fishery.

Statistically significant correlation was found between rainfall occurring over two and seven days prior to sampling and *E. coli* monitoring results, suggesting that rainfall and resulting freshwater flow is an important contamination pathway at this fishery.

Movement of contaminants

Loch Barraglom is shallow and predicted to be relatively well mixed. Tidal flows are predicted to be stronger in the narrows under the bridge than elsewhere within the loch, and the predicted tidal transport distance is 1.4 km. This suggests that sources arising along most of the length of the loch may contribute to contamination levels at the fishery. Overall, sources arising very near the mussel farm are likely to have a greater impact than those arising over 1 km away. However, as it is not known whether the predicted flow is likely to be more representative of spring or neap tidal conditions, it is not possible to identify whether this is a maximum distance.

Statistically significant correlations were found between results and high/low and spring/neap tidal states, with higher results tending to occur either side of high tide and as the tide was decreasing from springs to neaps. This suggests that tidal transport is an important mechanism of contaminant transport and that periods of greater tidal movement are carrying contaminants in from further away from the mussel farm.

Temporal and geographical patterns of sampling results

Spatial variation in historical sampling results suggests that higher contamination levels may have occurred in the western half of the production area, where a greater proportion

of the highest results were found. Although sample results appear to have improved over time, a result of 3500 *E. coli* cfu/100 ml was recorded in 2012, suggesting that higher contamination levels may be episodic.

Conclusions

The Barraglom mussel farm receives faecal contamination from a mix of both continuous point and diffuse sources. Septic tank discharges from Kirkibost and from various private septic tanks and faecal wastes from livestock kept on crofts along the north shore are likely to be the main contributors to faecal contamination of water at the mussel farm. Statistically significant correlations with rainfall suggest that diffuse contamination is an important contributor, however the occurrence of high results under low rainfall conditions suggests that this is not entirely predictive of contamination levels. There is clear evidence of a seasonal trend in historical monitoring results, with lowest results occurring during the spring.

16. Recommendations

The recommendations relevant to the sampling plan are described below and shown on the map in Figure 16.1.

Production area

Due to the presence of the Kirkibost septic tank discharge within the eastern end of the current production area, it is recommended that the eastern boundary be curtailed to exclude the discharge. It is also recommended that a boundary be specified at the entrance to the inlet southwest of Barraglom, which may receive effluent from private septic tanks. The recommended boundaries are therefore the area bounded by lines drawn from NB 1800 3429 to NB 1800 3344 and from NB 1667 3444 to NB 1669 3445, extending to MHWS, and from NB 1647 3423 to NB 1648 3412 (the line of the B8059).

RMP

It is recommended that the RMP be relocated to NB 1669 3421, which lies on the northwestern side of the mussel farm, nearer to potential sources along the north shore and west of the bridge.

Tolerance

A sampling tolerance of 40 metres is recommended to allow for some movement of the mussel lines.

Frequency

It is recommended that standard monthly sampling be maintained.

Depth of sampling

As the hydrographic assessment suggests that the waters will be well mixed, and no evidence of variation in contamination with depth was found in samples taken during the shoreline survey, no specific sampling depth is recommended.

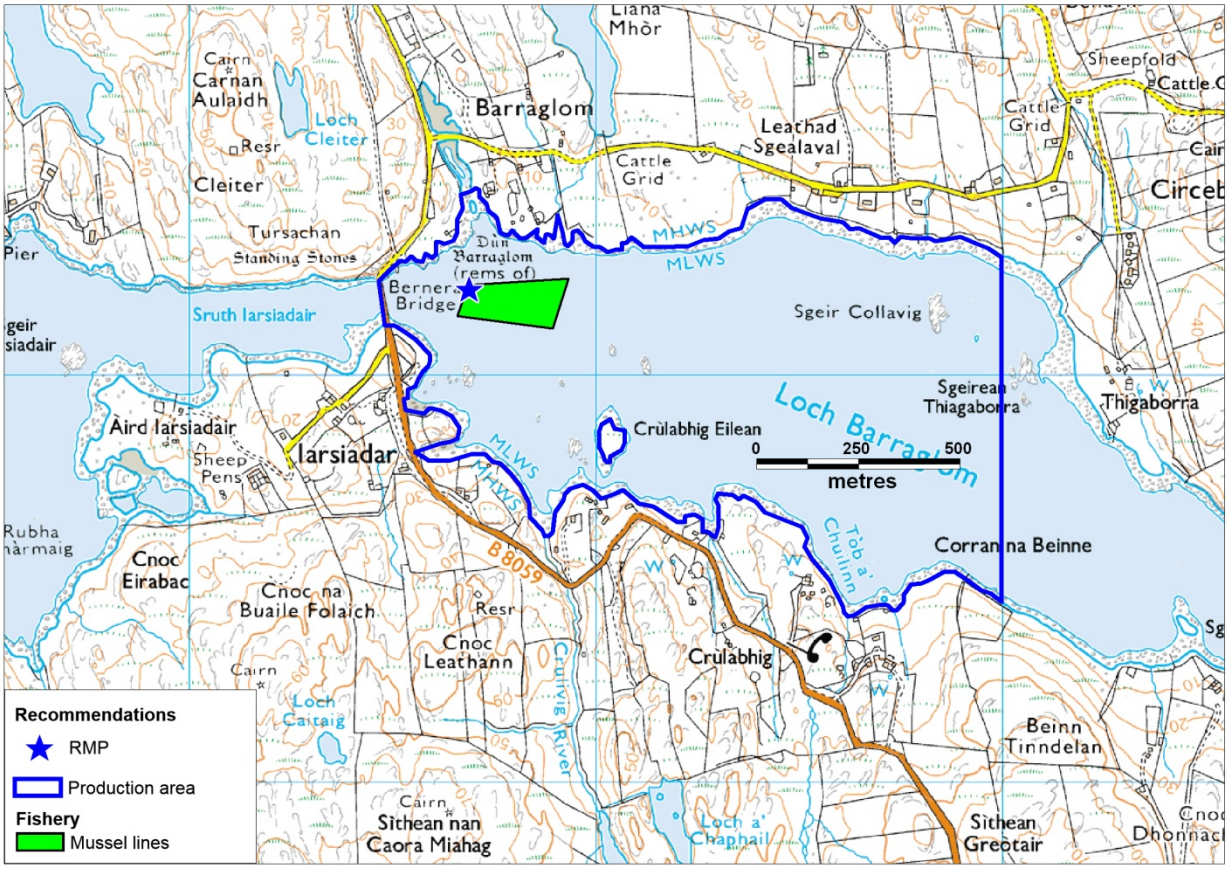


Figure 16.1 Map of recommendations at Loch Roag: Barraglom

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4. **Hydrographic Section Glossary**
5. **SEPA discharge consents**
6. **Shoreline Survey Report**
7. **CTD data**

1. 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 50-170 kg. 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 & 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 (Gauthier & Bedard, 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 National Heritage, n.d.). Otters primarily forage within the 10 m depth contour and feed on a variety of fish, crustaceans and shellfish (Paul Harvey, Shetland Sea Mammal Group, personal communication).

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

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2. 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.

Source: (Kay, et al., 2008b)

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

Table 3 – Geometric mean (GM) and 95% confidence intervals (CIs) of the GM faecal indicator organism (FIO) concentrations (cfu/100ml) under base- and high-flow conditions at the 205 sampling points and for various subsets, and results of paired t-tests to establish whether there are significant elevations at high flow compared with base flow

FIO	*n*	**Base Flow**			**High Flow**		
Subcatchment land use		Geometric mean	Lower 95% CI	Upper 95% CI	Geometric mean[a]	Lower 95% CI	Upper 95% CI
Total coliforms							
All subcatchments	205	5.8×10^{3}	4.5×10^{3}	7.4×10^{3}	7.3×10^{4}**	5.9×10^{4}	9.1×10^{4}
Degree of urbanisation							
Urban	20	3.0×10^{4}	1.4×10^{4}	6.4×10^{4}	3.2×10^{5}**	1.7×10^{5}	5.9×10^{5}
Semi-urban	60	1.6×10^{4}	1.1×10^{4}	2.2×10^{4}	1.4×10^{5}**	1.0×10^{5}	2.0×10^{5}
Rural	125	2.8×10^{3}	2.1×10^{3}	3.7×10^{3}	4.2×10^{4}**	3.2×10^{4}	5.4×10^{4}
Rural subcatchments with different dominant land uses							
≥75% Imp pasture	15	6.6×10^{3}	3.7×10^{3}	1.2×10^{4}	1.3×10^{5}**	1.0×10^{5}	1.7×10^{5}
≥75% Rough Grazing	13	1.0×10^{3}	4.8×10^{2}	2.1×10^{3}	1.8×10^{4}**	1.1×10^{4}	3.1×10^{4}
≥75% Woodland	6	5.8×10^{2}	2.2×10^{2}	1.5×10^{3}	6.3×10^{3}*	4.0×10^{3}	9.9×10^{3}
Faecal coliform							
All subcatchments	205	1.8×10^{3}	1.4×10^{3}	2.3×10^{3}	2.8×10^{4}**	2.2×10^{4}	3.4×10^{4}
Degree of urbanisation							
Urban	20	9.7×10^{3}	4.6×10^{3}	2.0×10^{4}	1.0×10^{5}**	5.3×10^{4}	2.0×10^{5}
Semi-urban	60	4.4×10^{3}	3.2×10^{3}	6.1×10^{3}	4.5×10^{4}**	3.2×10^{4}	6.3×10^{4}
Rural	125	8.7×10^{2}	6.3×10^{2}	1.2×10^{3}	1.8×10^{4}**	1.3×10^{4}	2.3×10^{4}
Rural subcatchments with different dominant land uses							
≥75% Imp pasture	15	1.9×10^{3}	1.1×10^{3}	3.2×10^{3}	5.7×10^{4}**	4.1×10^{4}	7.9×10^{4}
≥75% Rough Grazing	13	3.6×10^{2}	1.6×10^{2}	7.8×10^{2}	8.6×10^{3}**	5.0×10^{3}	1.5×10^{4}
≥75% Woodland	6	3.7×10	1.2×10	1.2×10^{2}	1.5×10^{3}**	6.3×10^{2}	3.4×10^{3}
Enterococci							
All subcatchments	205	2.7×10^{2}	2.2×10^{2}	3.3×10^{2}	5.5×10^{3}**	4.4×10^{3}	6.8×10^{3}
Degree of urbanisation							
Urban	20	1.4×10^{3}	9.1×10^{2}	2.1×10^{3}	2.1×10^{4}**	1.3×10^{4}	3.3×10^{4}
Semi-urban	60	5.5×10^{2}	4.1×10^{2}	7.3×10^{2}	1.0×10^{4}**	7.6×10^{3}	1.4×10^{4}
Rural	125	1.5×10^{2}	1.1×10^{2}	1.9×10^{2}	3.3×10^{3}**	2.4×10^{3}	4.3×10^{3}
Rural subcatchments with different dominant land uses							
≥75% Imp. pasture	15	2.2×10^{2}	1.4×10^{2}	3.5×10^{2}	1.0×10^{4}**	7.9×10^{3}	1.4×10^{4}
≥75% Rough Grazing	13	4.7×10	1.7×10	1.3×10^{2}	1.2×10^{3}**	5.8×10^{2}	2.7×10^{3}
≥75% Woodland	6	1.6×10	7.4	3.5×10	1.7×10^{2}**	5.5×10	5.2×10^{2}
[a] Significant elevations in concentrations at high flow are indicated: **po0.001, *po0.05.							
[b] Degree of urbanisation categorised according to percentage built-up land: 'Urban' (X10.0%), 'Semi-urban' (2.5–9.9%) and 'Rural' (o2.5%).							

Source: (Kay, et al., 2008a)

Table 4 - 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: (Gauthier & Bedard, 1986)

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3. Statistical Data

One-way ANOVA: logec versus Season

```
Source  DF      SS     MS     F      P
Season   3   8.331  2.777  9.02  0.000
Error   64  19.710  0.308
Total   67  28.041
S = 0.5550   R-Sq = 29.71%   R-Sq(adj) = 26.42%
                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev   -+---------+---------+---------+--------
1      18  1.4372  0.3673   (------*-----)
2      18  2.1066  0.7798                  (------*-----)
3      15  2.4077  0.4433                         (------*------)
4      17  1.9953  0.5201                (------*------)
                            -+---------+---------+---------+--------
                           1.20      1.60      2.00      2.40
Pooled StDev = 0.5550
Grouping Information Using Tukey Method
Season   N    Mean  Grouping
3       15  2.4077  A
2       18  2.1066  A
4       17  1.9953  A
1       18  1.4372    B
Means that do not share a letter are significantly different.
Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Season
Individual confidence level = 98.95%
Season = 1 subtracted from:
Season   Lower  Center   Upper  ---+---------+---------+---------+------
2       0.1816  0.6695  1.1574                (------*------)
3       0.4588  0.9705  1.4823                    (------*------)
4       0.0631  0.5582  1.0532               (------*------)
                            ---+---------+---------+---------+------
                           -0.70      0.00      0.70      1.40
Season = 2 subtracted from:
Season    Lower   Center   Upper  ---+---------+---------+---------+------
3       -0.2106   0.3011  0.8128           (------*-------)
4       -0.6063  -0.1113  0.3837      (------*------)
                              ---+---------+---------+---------+------
                              -0.70      0.00      0.70      1.40
Season = 3 subtracted from:
Season    Lower   Center   Upper  ---+---------+---------+---------+------
4       -0.9309  -0.4124  0.1061  (------*-------)
                              ---+---------+---------+---------+------
                              -0.70      0.00      0.70      1.40
```

4. Hydrographic Assessment 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.

MHW. Mean High Water, The highest level that tides reach on average.

MHWN. Mean High Water Neap, The highest level that tides reach on average during neap tides.

MHWS. Mean High Water Spring, The highest level that tides reach on average during spring tides

MLW. Mean Low Water, The lowest level that tides reach on average.

MLWN. Mean Low Water Neap, The lowest level that tides reach on average during neap tides.

MLWS. Mean Low Water Spring, The lowest level that tides reach on average during spring tides.

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. Spring tides occur during or just after new moon and full moon when the tide-generating force of the sun acts in the same direction as that of the moon, reinforcing it. The tidal range is greatest and tidal currents strongest during spring tides.

Neap tides occur during the first or last quarter of the moon when the tide-generating forces of the sun and moon oppose each other. The tidal range is smallest and tidal currents are weakest during neap 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. A surface flow at the surface may be accompanied by a compensating flow in the opposite direction at the bed.

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.

5. SEPA Discharge Consents

Licence No.	NGR	Site Name	Discharge Type	Discharges to	PE	Shoreline survey observation
CAR/R/1047232	NB 10560 34550	4 Reef, Uig	Sewage (Private) Primary	Soakaway	5	
CAR/R/1066368	NB 10652 34536	5 Reef, Uig, Isle of Lewis	-	-	5	
CAR/R/1062064	NB 10686 34609	6 Reef, Uig, Isle of Lewis	-	-	5	
CAR/R/1054904	NB 10809 34521	Chalet, 7 Reef, Uig	-	-	5	
CAR/R/1054897	NB 10820 34555	7 Reef Uig	-	-	6	
CAR/R/1038779	NB 10885 34537	8 Reef, Uig, Isle of Lewis	-	-	5	
CAR/R/1048511	NB 10964 34446	10 Reef Uig, Isle of Lewis	Sewage (Private) Primary	Loch Roag	5	
CAR/R/1043318	NB 11087 34475	10A Reef, isle Of Lewis	Sewage (Private) Primary	Soakaway	6	
CAR/R/1041208	NB 11089 34673	11 Reef, Isle Of Lewis	-	-	5	
CAR/R/1061947	NB 11099 34664	11A & B Reef, Uig, Isle of Lewis	Sewage (Private) Primary	Soakaway	10	
CAR/L/1002929	NB 11100 33800	Gousam MCFF, West Loch Roag	Fish Farm Marine Cage	West Loch Roag	-	
CAR/R/1043395	NB 11363 34580	13 Reef, Isle Of Lewis	-	-	5	
CAR/R/1041207	NB 11392 34518	Driftwood, Isle Of Lewis	-	-	5	
CAR/R/1059982	NB 11396 31303	3 Geshader, UIG, Isle of Lewis	Sewage (Private) Primary	UT of Loch Geisiadair	5	
CAR/R/1057456	NB 11400 32216	11 Geshader, Uig, Isle of Lewis	-	-	7	
CAR/R/1056250	NB 11446 31441	4 Geshader, Uig, Isle of Lewis	-	-	5	
CAR/R/1068150	NB 11483 32110	10 Geshader, Uig, Isle of Lewis	-	-	5	
CAR/R/1059468	NB 11670 31893	7 Geshader, Uig, Isle of Lewis	-	-	7	
CAR/R/1042013	NB 11766 31528	5 Geshader, Isle of Lewis	-	-	5	
CAR/R/1061863	NB 11808 31669	9 Geshader, Uig, Isle of Lewis	-	-	5	
CAR/S/1097483	NB 11860 31280	Geshader Common Grazings, Isle of Lewis	Sheep Dip onto Land	Soakaway	-	
CAR/L/1015852	NB 12100 33100	Vuia Beag MCFF, West Loch Roag	Fish Farm Marine Cage	West Loch Roag	-	
CAR/L/1011812	NB 12680 34310	Vuia Mor MCFF, West Loch Roag	Fish Farm Marine Cage	West Loch Roag	-	
CAR/S/1088784	NB 13470 29800	Scaliscro Farm Partnership,GWR-BH1	Sheep Dip onto Land	Soakaway	-	
CAR/L/1001791	NB 13530 35670	Kyles Vuia East MCFF, West Loch Roag	Fish Farm Marine Cage	-	-	
CAR/R/1064928	NB 13683 38416	16A Tobson, Bernera, Isle of Lewis	Sewage (Private) Primary	Camas Sandig	5	
CAR/R/1043306	NB 14115 38502	12 Tobson, Isle Of Lewis	-	-	5	
CAR/R/1063361	NB 14174 38530	9 Tobson, Bernera, Isle of Lewis	Sewage (Private) Primary	Soakaway	5	

Licence No.	NGR	Site Name	Discharge Type	Discharges to	PE	Shoreline survey observation
CAR/R/1026968	NB 14176 38131	21 Tobson, Great Bernera, Isle of Lewis	-	-	5	
CAR/R/1050145	NB 14210 38360	10 Tobson, Isle Of Lewis	Sewage (Private) Primary	Tob Bhalasaigh	5	
CAR/R/1067822	NB 14322 38628	6 Tobson, Bernera, Isle of Lewis	-	-	6	
CAR/R/1063161	NB 14413 38570	5 Tobson, Bernera, Isle of Lewis	Sewage (Private) Primary	Soakaway	5	
CAR/R/1048631	NB 14500 38500	Clisham, Tobson, Great Bernera, Isle of Lewis	-	-	17	
CAR/R/1100933	NB 14600 36600	Tigh na Sith, Valasay, Great Bernera, Lewis	Sewage (Private) Primary	Soakaway	5	
CAR/R/1047432	NB 14619 38443	1b Tobson, Bernera, Isle of Lewis	Sewage (Private) Primary	Soakaway	5	
CAR/R/1068536	NB 14720 35130	19 Hacklete, Bernera, Isle of Lewis	Sewage (Private) Primary	Soakaway	6	
CAR/R/1059972	NB 14799 36584	24B Valasay, Great Bernera	-	-	5	
CAR/R/1053569	NB 14809 36543	25 Valasay, Bernera, Isle of Brewis	-	-	8	
CAR/R/1060109	NB 14870 36370	24B, Tobson, Isle of Lewis	Sewage (Private) Primary	Soakaway	5	
CAR/R/1030753	NB 14904 36435	23 Valasay, Isle of Lewis	-	-	5	
CAR/R/1063365	NB 15084 34715	Ard Drobhinish,Hacklete,Great Bernera, Lewis	Sewage (Private) Primary	Soakaway	6	
CAR/R/1056225	NB 15163 34748	12 HACKLETE, BERNERA, ISLE OF LEWIS	Sewage (Private) Secondary	Soakaway	5	
CAR/S/1081100	NB 15270 34611	Hacklete Common Grazings,GWR-BH1	-	-	-	
CAR/R/1055846	NB 15346 34645	9 Hacklete, Bernera, Isle of Lewis	-	-	6	
CAR/R/1063357	NB 15360 34360	Hacklete, Bernera, Isle of Lewis	Sewage (Private) Primary	Loch Roag	5	
CAR/R/1049570	NB 15400 34460	9A Hacklete, Bernera, Isle of Lewis	Sewage (Private) Primary	Soakaway	5	
CAR/R/1042802	NB 15450 34560	8 Hacklete, Isle Of Lewis	Sewage (Private) Primary	Soakaway	5	
CAR/R/1067798	NB 15510 34590	7 Hacklete, Bernera, Isle of Lewis	Sewage (Public) Primary	Soakaway	6	
CAR/R/1059990	NB 15880 36730	Ardglas, Breacleit, Isle of Lewis	Sewage (Private) Primary	Soakaway	6	
CAR/R/1040038	NB 15887 36649	The Cottage, Breaclet, Bernera, Isle Of Lewis	Sewage (Private) Primary	Soakaway	5	
CAR/R/1098787	NB 15940 36710	Viewfield, Breaclete, Isle of Lewis	Sewage (Private) Primary	Soakaway	6	
CAR/R/1060029	NB 15977 37187	8 Breaclete, Bernera, Isle of lewis	-	-	5	
CAR/L/1002198	NB 15988 33925	Earshader Shellfish Dispatch Centre	-	-	-	
CAR/L/1009011	NB 15988 33925	Earshader Dispatch Centre - Mussel Tanks	-	-	-	
CAR/L/1002882	NB 15988 36405	Heath Park Septic Tank	Sewage (Public) Primary	Loch Geal	-	
CAR/R/1053133	NB 16025 36742	1 breaclete,Bernera,Isel Of Lewis	-	-	5	
CAR/R/1061617	NB 16040 37610	12 Breaclete, Bernera, Isle of Lewis	Sewage (Private) Primary	Loch Beag Breacleit	5	

Licence No.	NGR	Site Name	Discharge Type	Discharges to	PE	Shoreline survey observation
CAR/R/1056547	NB 16063 36682	13 Breaclete, Bernera, Isle of Lewis	-	-	6	
CAR/R/1059560	NB 16080 37030	Aiteas Mara, Breaclet, Isle of Lewis	Sewage (Private) Primary	Soakaway	15	
CAR/R/1040039	NB 16140 37240	Seacot, Breaclete, Bernera, Isle of Lewis	Sewage (Private) Primary	Soakaway	6	
CAR/R/1059557	NB 16150 37080	Fasgadh, 7B, Bernera, Isle of Lewis	Sewage (Private) Primary	Soakaway	18	
CAR/R/1019687	NB 16163 36861	Loch Allain, Loch Allain, Isle of Lewis	Sewage (Private) Primary	Soakaway	5	
CAR/R/1047070	NB 16221 36854	Lismore, Breaclete, Isle of Lewis	Sewage (Private) Primary	Loch Breacleit	6	
CAR/R/1040737	NB 16230 33850	Torranish, Earshader, Isle of Lewis	-	-	5	
CAR/R/1040037	NB 16261 36911	2 Breaclet, Bernera, Isle Of Lewis, HS2 9LT	-	-	5	
CAR/L/1003078	NB 16300 36600	An Camus MCFF, Loch Boisdale	Freshwater Cage Fish Farm	Loch Boisdale	-	
CAR/R/1025122	NB 16304 36964	Airidh Ard, Breaclete, Bernera, Lewis	-	-	5	
CAR/R/1064030	NB 16360 34047	3 Earshader, Uig, Isle of Lewis	Sewage (Private) Primary	Sruth Iarsiadar	5	
CAR/R/1087895	NB 16470 33920	New Build, 6 Earshader, Isle of Lewis	-	-	5	
CAR/R/1044392	NB 16479 33950	4 Earshader, Isle of Lewis	-	-	5	
CAR/R/1047054	NB 16558 34815	4 Hacklete, Isle of Lewis	-	-	10	
CAR/R/1066509	NB 16687 33703	5 Earshader, Isle of Lewis	-	-	5	
CAR/R/1049534	NB 16740 34520	3 Hacklete, Bernera, Isle of Lewis	Sewage (Private) Primary	Soakaway	5	Observation 4
CAR/R/1059996	NB 16815 34525	2 Hacklete, Bernera, Isle of Lewis	-	-	6	
CAR/R/1061481	NB 16890 34580	1 Hacklete, Bernera, Isle of Lewis	Sewage (Private) Primary	Soakaway	5	
CAR/R/1077617	NB 16900 33600	1Crulivig, Uig, Isle of Lewis	Sewage (Private) Primary	Soakaway	5	
CAR/R/1030323	NB 17252 34537	25 Kirkibost, Berneray, Isle of Lewis	Sewage (Private) Primary	Soakaway	5	
CAR/R/1063347	NB 17529 34412	25 Kirkbost/ Thristlecroft, Bereravig Lewis	Sewage (Private) Primary	Loch Barraglom	5	Observation 3
CAR/R/1056487	NB 17684 33358	6A CRULIVIG, VIG, ISLE OF LEWIS	-	-	5	Observation 5
CAR/R/1056240	NB 17713 33293	6 Crulivig, Isle of Lewis	-	-	6	Observation 6
CAR/R/1061687	NB 17895 34478	23 Kirkibost, Isle of Lewis	Sewage (Private) Primary	Soakaway	5	
CAR/L/1017374	NB 18060 37100	Taranaish Fish Farm, Breasclete Pier, Breascl	Fish Farm Marine Cage	-	-	
CAR/R/1062006	NB 18120 34520	21 Kirkibost, Isle of Lewis	Sewage (Private) Primary	Soakaway	6	
CAR/S/1089981	NB 18240 34680	Kirkibost Common Grazings,GWR-BH1	Sheep Dip onto Land	Soakaway	-	
CAR/L/1004023	NB 18287 35785	Kirkibost Processing Factory, Kirkibost	-	-	-	
CAR/R/1075450	NB 18307 33969	20 Kirkibost, Bernera, Isle of Lewis	Sewage (Private) Primary	Soakaway	15	Observation 1

Licence No.	NGR	Site Name	Discharge Type	Discharges to	PE	Shoreline survey observation
CAR/R/1059561	NB 18463 32794	5 Lundale, Isle of Lewis	-	-	5	
CAR/R/1068128	NB 18512 32456	3 Luindale, Isle of Lewis	Sewage (Private) Primary	U/T of Tob Lundale	6	
CAR/R/1057231	NB 18606 32181	1 Lundale, Uig, Isle of Lewis	-	-	6	
CAR/R/1067824	NB 18660 35110	Garymilis, Kiribost, Great Bernera, Lewis	Sewage (Private) Primary	Soakaway	8	
CAR/R/1056118	NB 18731 35422	3 Kirkibost, Bernera, Isle of Lewis	-	-	7	
CAR/R/1096327	NB 18770 35490	2A Kirkibost, Isle of Lewis	-	-	5	
CAR/R/1056230	NB 18797 34746	11 Kirkibost, Isle of Lewis	-	-	5	
CAR/R/1068567	NB 18819 35264	5 Kirkibost, Great Bernera, Isle of Lewis	-	-	5	
CAR/R/1023191	NB 18945 34627	14 Kirkibost, Isle of Lewis	-	-	5	
CAR/R/1026488	NB 18968 34072	Totarol, 18 Kirkibost, Isle of Lewis	-	-	5	
CAR/R/1047661	NB 18977 34194	17 Kirkibost, Isle Of Lewis	-	-	5	
CAR/R/1059576	NB 18996 34899	10 Kirkibost, Bernera, Isle of Lewis	Sewage (Private) Primary	Soakaway	5	
CAR/R/1042636	NB 19007 33932	19 Kirkibost, Isle Of Lewis	-	-	6	
CAR/R/1042610	NB 19008 33901	19A Kirkibost, Isle Of Lewis	Sewage (Private) Primary	Soakaway	5	
CAR/R/1061950	NB 19014 34939	Tigh Chladaich, 10 Kirkibost, Isle of Lewis	-	-	5	
CAR/R/1042604	NB 19024 34030	18 Kirkibost, Isle Of Lewis	Sewage (Private) Primary	Soakaway	5	
CAR/R/1047436	NB 19027 34205	17a Kirkibost, Bernera, Isle of Lewis	-	-	6	
CAR/L/1005041	NB 19300 36170	Vacassay MCFF, East Loch Roag	Fish Farm Marine Cage	East Loch Roag	-	
CAR/L/1001793	NB 20080 35580	Greinham MCFF, East Loch Roag	Fish Farm Marine Cage	-	-	
WPC/N/60942	NB 1810 3420	Dun innes Housing Site, Kirkibost	Sewage (Public) Primary	Loch Barraglom	144	Observation 2

- No data provided

Report Title	Loch Roag: Barraglom Shoreline Survey Report
Project Name	Shellfish Sanitary Surveys
Client/Customer	Cefas
SRSL Project Reference	00561_B0067

Document Number	B0067_Shoreline 0013

Revision History

Revision	Changes	Date
A	Issue for internal review	09/07/2013
01	First formal issue to Cefas	22/07/2013
02	Second issue to CEFAS incorporating comments at Rev 01	07/08/2013

	Name & Position	Date
Author	Colin Abernethy, Andrea Veszelovszki	09/07/2013
Checked	Andrea Veszelovszki	30/07/2013
Approved	John Hausrath	07/08/2013

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Shoreline Survey Report

Production area: Loch Roag: Barraglom
Site name: Loch Barraglom
SIN: LH-185-120-08
Species: Common mussels
Harvester: Ruaraidh McKay(Manager)
Local Authority: Comhairle nan Eilean Siar: Lewis and Harris
Status: Existing Area
Date Surveyed: 26-27th June 2013
Surveyed by: Andrea Veszelovszki, Colin Abernethy
Existing RMP: NB 1669 3413
Area Surveyed: Loch Barraglom north shoreline from east of the Bernera bridge to Thigaborra on the east and the south shoreline from the Aird Iarsiadair outcrop of land to the middle of Tob a Chuilinn bay.

Weather

Minimal rainfall in the 48 hours prior to survey.
Wednesday 26th June
At start of survey, cloud cover 100%; Wind was westerly, speed changeable 10-20 km/h; temperature was around 11-12 degrees during the day; sea state calm. Slightly less cloud cover in the afternoon (60% at 15:30). Later about 40% cloud cover by 16:30 with sunny spells. No precipitation all day.
Wednesday 27th May
Cloud cover 100%; Sea state calm; wind speed 10 km/h; temperature ranged between 11-13 degrees.
No precipitation during survey, slight drizzle in the afternoon after survey completion.

Stakeholder engagement during the survey

Both the harvester (site manager) Mr Ruaraidh Mackay and sampling officer (Mr Paul Tyler) were very helpful and cooperative during pre-survey arrangements. The sampling officer for the area met with the survey team on the Thursday morning after sampling on-board the harvester's vessel was undertaken. The harvester's representatives (Mr Calum Iain Mackenzie and Mr Graeme Williamson) who took the survey team to the mussel farm on the Thursday morning were also very co-operative and helpful both with sampling and with providing additional information on the fishery.

Fishery

The fishery in the area consists of a long-line mussel farm situated east of the Bernera Bridge. The site has been classified since 2003. The fishery at this location consists of three mussel lines with floats, with the length of each mussel line being 8 metres from surface to bottom.

The fishery at the time of the survey was shut down due to toxic algal bloom so there was no harvesting. Based on information from the boat crew, they usually work 6 days a week – this includes general maintenance of the lines if necessary – all year round with the exception of summer months from July to August when the main maintenance works take place.

Sewage Sources

Loch Barraglom has individual housing scattered along both the northern and southern shorelines, set in the fields running down to the shore. There is no sewerage provision in the area and there was only one obvious sewage outflow from a public septic tank observed and sampled (Loch Roag, NB 18135 34229) at the north-eastern end of the survey area which was discharging straight into a watercourse running into the Loch. Other septic tanks were not visible and therefore not observed or recorded from the shoreline.

Seasonal Population

There were no B &B's or hotels in the vicinity of the survey location. There was also no evidence of campsites near the survey site. The land use suggests that the survey site wouldn't show a flux in seasonal population.

Boats/Shipping

There is a small slipway on the northwest shoreline, just to the east of Bernera Bridge. The harvester has a shore base on the south shore, west of the bridge.

There was a small vessel moored in the bay south of the Bernera Bridge and another one which appeared to be utilised for collection of seaweed.

Farming and Land use

The majority of the land is used to rear sheep, the roads and shoreline are fenced off preventing access from the animals. There were no crops grown in regions surrounding the production area.

In addition to this seaweed farming is undertaken in the area. This was mentioned by the sampling officer in passing and a large crate was found on the shore full of seaweed (waypoint 39).

Land Cover

Loch Barraglom is surrounded by rough grassland making its way down to a rocky/bouldery shoreline.

Watercourses

There are several watercourses discharging into the production area.

Allt Millegro is situated on the north east corner of the loch along with three other unnamed watercourses running down to the north shore.

Another watercourse runs down from Loch Niosabhat which is situated north of the north shore, to the east of the Bernera Bridge. During the survey this watercourse was not flowing and did not reach Loch Roag.

Allt Leur Thob runs down towards the shore south east of the Bernera bridge. The Crulivig river runs towards the southern shore of the loch (south west from Crulabhig Eilean), with both the Allt tob a' Chuillin and Glean Greotair running towards the Tob a' Chuillin bay on the south shore.

Wildlife/Birds

No wildlife was visible or present during the survey except for birds: Eider ducks, oyster catchers, geese and seagulls were frequently observed during the survey either on the shore or on the water. Goose feathers and droppings were also frequently observed during the shoreline element of the survey.

Shoreline Survey Maps

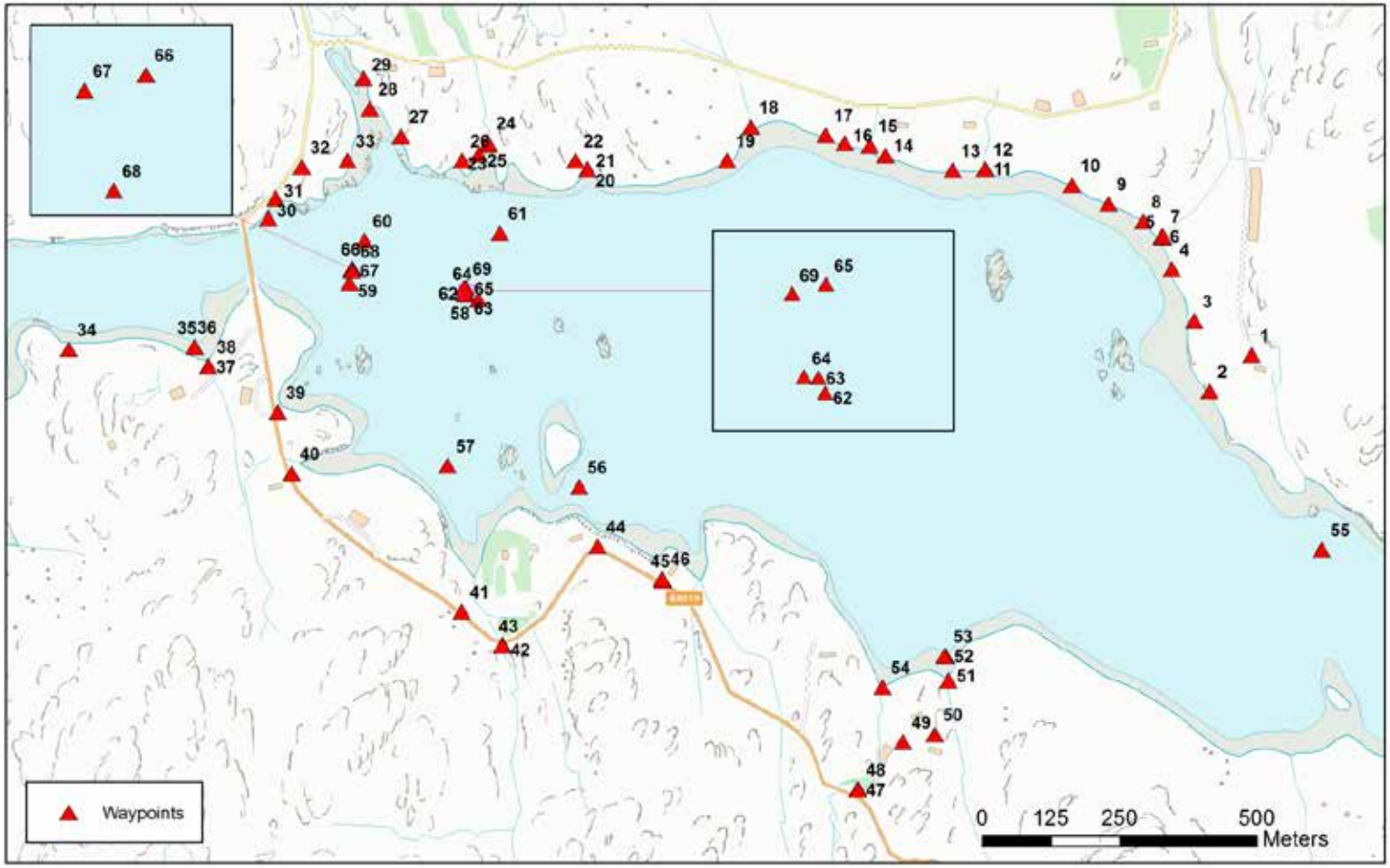

Figure 1. Loch Barraglom Waypoints

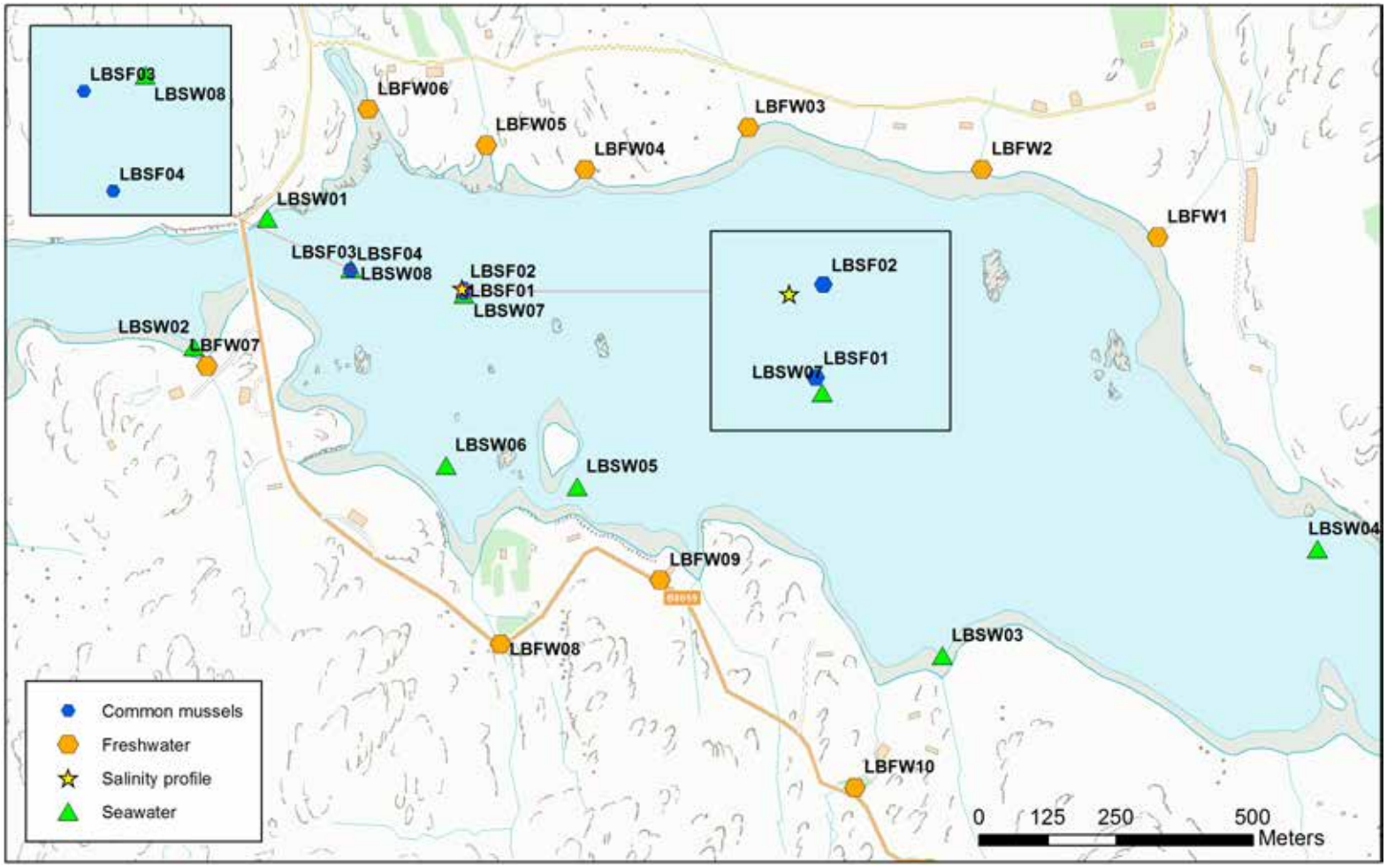

Figure 2. Loch Barraglom Samples

Table 1 Shoreline Observations

Access for sampling and observations was difficult in a number of areas due to the residential properties surrounding the loch which have their property lines established through fencing, closing off access to some areas of the shore or only allowing access through gardens or backyards of properties.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	26/06/2013	9:51	NB 18299 34014	118300	934015	Figure 3		Start of survey at North side of Loch at eastern end shoreline survey route. House name: Thigaborra, no access to property. 2 car wrecks on upper shore.
2	26/06/2013	9:58	NB 18222 33948	118223	933949	Figure 4		Below house on shore, access was gained through gate on the west side of the property. 30 sheep on the ground surrounding the house. A concrete encased pipe near house, no visible outfall/flow. No access to it.
3	26/06/2013	10:04	NB 18195 34076	118196	934077			Geese droppings and feathers on shore, no geese present at time of survey. Low lying, dry river bed with water lilies suggesting water run offs from shore in wet conditions after/during persistent rainfall.
4	26/06/2013	10:09	NB 18154 34171	118154	934171			2 Eider ducks took off from shore and settled on water off shore.
5	26/06/2013	10:13	NB 18138 34229	118139	934229	Figure 5		Loch Roag outfall marked on map. Smell of sewage discharging into water course, flowing straight into the Loch. Houses above shore not visible from shoreline.
6	26/06/2013	10:16	NB 18135 34229	118136	934229		LBFW1	Freshwater sample taken from watercourse below sewage outfall.
7	26/06/2013	10:24	NB 18137 34230	118138	934231			Measurements Width: 0.5m. Depth 4cm. Flow 0.055 metres per sec (m/s) SD 0.004
8	26/06/2013	10:30	NB 18102 34258	118103	934258	Figure 6		Debris on shore (floats and plastic piping). One oyster catcher.
9	26/06/2013	10:34	NB 18039 34289	118040	934290	Figure 7		Structure of unknown origin on shore, walkway with black square floats attached.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
10	26/06/2013	10:37	NB 17973 34323	117973	934324			Twenty sheep (2 outside fence on shore side) on top of steep bank leading to shore side. Two houses beyond field to the east, 3 to the west.
11	26/06/2013	10:47	NB 17815 34353	117816	934353	Figure 8	LBFW2	Planned sample from water course.
12	26/06/2013	10:50	NB 17814 34353	117815	934353			Measurements: only a slight trickle of water was present so no measurements possible.
13	26/06/2013	10:55	NB 17755 34350	117756	934351	Figure 9		Stone structure just below house. Tide was high.
14	26/06/2013	11:02	NB 17634 34377	117634	934378			16 sheep and 2 geese on land by house.
15	26/06/2013	11:05	NB 17605 34395	117606	934396	Figures 10 & 11		Sign of watercourse on shore which has dried out. Broken piece of clay pipe on shore. Small concrete housing beside house with pipe protruding, no access to this. Clay piping in channel runs down from building on field towards shore. No outflow.
16	26/06/2013	11:10	NB 17560 34400	117560	934400			Another possible watercourse with no flow. Section of old rusty/broken metal pipe. No indication of outflow.
17	26/06/2013	11:12	NB 17525 34414	117525	934415			Temporary watercourse running by the side of a house. Wet ground but no flow with no access to more wetter area to sample from beyond the fencing. Sheep droppings on shore.
18	26/06/2013	11:21	NB 17389 34429	117389	934430	Figure 12	LBFW03	Minimal run off with seepage through ground containing white oily substance in a shallow stagnant pool. Sample taken from small trickle. Approximate flow 1ml per second. Flow estimations made using graduated 20 ml sample bottle and wrist watch to time flow.
19	26/06/2013	11:28	NB 17346 34368	117347	934369			Geese and cow droppings on shore. Debris of engine parts on shore.
20	26/06/2013	11:34	NB 17092 34352	117092	934353		LBFW04	Planned sampling point.
21	26/06/2013	11:38	NB 17092 34352	117093	934352			Channel running down field to shore approximately 10-15m from wall. Stagnant area with oily substance. Width of channel 45cm at widest point. Minimal flow, unable to read with meter.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								Approximately 4ml/sec.
22	26/06/2013	11:48	NB 17070 34368	117070	934369			11 seagulls on shore and 2 oyster catchers (possible nesting area). Geese and seagull droppings on shore.
23	26/06/2013	11:54	NB 16912 34397	116912	934397		LBFW05	Planned water sample by mussel lines.
24	26/06/2013	11:55	NB 16911 34401	116912	934401			Watercourse running from field (no access).Sample taken shore side of fencing. Measurements: Depth 10cm, width 4m. Flow rate 0.048m/s SD: 0.004. Eleven sheep by water course. This waypoint was taken in direct line of sight of the eastern edge of the mussel lines.
25	26/06/2013	12:10	NB 16894 34379	116895	934379			Structure which appears to be old walkway from fish farm on grass verge just behind shoreline
26	26/06/2013	12:11	NB 16864 34368	116865	934369			Debris on shore. Bird feathers and droppings in field along the length of the mussel farm area.
27	26/06/2013	12:16	NB 16753 34412	116753	934412	Figure 13		Carcass of sheep decomposing in field 20m above water line just down from house. 4 sheep near house and 4 sheep just along the shoreline.
28	26/06/2013	12:24	NB 16697 34462	116697	934462		LBFW06	Planned water sample
29	26/06/2013	12:33	NB 16685 34518	116685	934518	Figures 14-16		Large watercourse/inlet in the loch, which at the north end has a road causeway built across it, with two corrugated pipes under the road allowing flow through (Figure 16). Flow not measured as could not gain access. Width of the inlet/watercourse measured across the causeway as 30m from wetted bank to wetted bank. South of the causeway, stone dam/structure built across the inlet/watercourse covered in seaweed (Figure 14). Depth 31cm. Flow 0.059m/s SD: 0.004. Measurement made on the loch side of the structure. Clay pipe running from house to shoreline no outflow (in-

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								between causeway and stone structure/dam), Figure 15. Pipe was dry but markings of historic flow on pipe and rocks. Metal debris on shore.
30	26/06/2013	13:26	NB 16512 34263	116513	934264	Figure 17	LBSW01	Sea water sample taken from slipway.
31	26/06/2013	13:30	NB 16525 34299	116525	934300			Limited access to shore from east of bridge to river. Eighteen sheep in field beside road.
32	26/06/2013	13:33	NB 16573 34356	116573	934357			Mussel farm structural debris beside ruin of house.
33	26/06/2013	13:37	NB 16655 34368	116656	934368			Waypoint marks western end of mussel farm from shore. No outflow.
34	26/06/2013	13:50	NB 16149 34024	116149	934025			Waypoint at fence marking west end of survey route. House directly behind over hill, not visible from vantage point. No outfalls. Geese droppings on grass above shore.
35	26/06/2013	13:58	NB 16378 34028	116379	934029		LBSW02	Planned seawater sample
36	26/06/2013	13:59	NB 16377 34029	116378	934030			Three houses on shore, no visible outfalls or septic tanks.
37	26/06/2013	14:09	NB 16402 33994	116403	933994		LBFW07	Unplanned water sample
38	26/06/2013	14:10	NB 16403 33993	116403	933994	Figure 18		Small watercourse which didn't reach the Loch.Pipe discharging into watercourse at approximately 2ml/sec. Depth 5cm, width 40cm. No measurable flow of water course (stagnant).
39	26/06/2013	14:24	NB 16529 33911	116529	933911			Slipway beside house, no access to property or shore (barbed wire fence). No sign of outflow. Seaweed harvester in view, collecting seaweed. Storm drain under road.
40	26/06/2013	14:27	NB 16554 33799	116555	933799			Southside of house in bay, no access to planned sampling site (barbed wire fence). No visible outflow pipes.
41	26/06/2013	14:32	NB 16863 33547	116864	933548	Figure 19		No access to shore, barbed wire fencing and steep shoreline
42	26/06/2013	14:38	NB 16937 33487	116938	933488		LBFW08	Planned water sample.
43	26/06/2013	14:38	NB 16937 33486	116937	933486	Figures 20 & 21		Measurements: Depth 6cm, width: 1.5m. Flow rate: 0.441 m/s SD: 0.016. Watercourse overgrown and deep below road. Difficult access. Harvester's boat in operation by mussel lines

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								(lifting the lines and floats).
44	26/06/2013	14:47	NB 17111 33667	117111	933667			No access to shore through private properties. Four ducks on water. One house on left by the road. Another house further to the east.
45	26/06/2013	15:00	NB 17228 33603	117229	933604		LBFW09	Planned freshwater sample. Sample full of algae, hard to avoid it due to stagnation of pool.
46	26/06/2013	15:01	NB 17227 33607	117228	933608	Figure 22		Small watercourse under road through concrete pipe. No flow, stagnant pool. Diameter 45cm (end of pipe). Depth 2-3cm. The sampling point is right beside fence of private property, no further access.
47	26/06/2013	15:15	NB 17583 33226	117584	933226		LBFW10	Planned water sample.
48	26/06/2013	15:15	NB 17584 33224	117584	933224			Measurements: Width 180cm. Depth 10cm. Flow rate 0.083m/s SD: 0.004. House below on the other side of the road.
49	26/06/2013	15:24	NB 17666 33310	117666	933311			Concrete structure in garden of unknown purpose situated beside burn. Manhole cover 20m to the right of concrete structure, both in private property with no access point.
50	26/06/2013	15:27	NB 17723 33325	117723	933325	Figure 23		Possible septic tank 20m below house.
51	26/06/2013	15:31	NB 17748 33423	117748	933423			Small watercourse running by east side of house. Width 30cm, Depth 5cm, estimated flow 10ml/sec. No samples taken, as considered low risk due to cleanliness, no smell and lack of potential contaminants upstream (ie, no animals or other dwellings).
52	26/06/2013	15:35	NB 17743 33467	117744	933467		LBSW03	Planned sample
53	26/06/2013	15:35	NB 17741 33467	117742	933468			Wild mussels on shore at lowest tide. Slippery access to shore, dangerous underfoot.
54	26/06/2013	15:40	NB 17628 33410	117628	933410			Base of stream mentioned in waypoint 47 observations. No outflow pipes run to this. Water appears to be a clean. House west of burn (approximately 50m). No outflow pipes visible.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								Steep uneven ground, fenced off.
55	27/06/2013	9:00	NB 18427 33660	118427	933661		LBSW04	Planned seawater sample
56	27/06/2013	9:07	NB 17077 33774	117077	933775		LBSW05	Planned seawater sample
57	27/06/2013	9:12	NB 16838 33813	116838	933813		LBSW06	Planned seawater sample
58	27/06/2013	9:15	NB 16893 34115	116894	934115			Western corner of mussel line, waypoint taken on harvester's boat
59	27/06/2013	9:16	NB 16659 34145	116660	934145			Eastern corner of mussel line, waypoint taken on harvester's boat
60	27/06/2013	9:17	NB 16686 34222	116687	934222			Corner of mussel line, waypoint taken on harvester's boat
61	27/06/2013	9:18	NB 16933 34236	116933	934237			Corner of mussel line, waypoint taken on harvester's boat
62	27/06/2013	9:20	NB 16871 34125	116871	934125		LBSW07	Planned seawater sample
63	27/06/2013	9:22	NB 16870 34126	116871	934127		LBSF01	Planned shell fish sample taken from top(surface) of line
64	27/06/2013	9:22	NB 16869 34126	116869	934127			CTD deployment
65	27/06/2013	9:32	NB 16871 34136	116872	934137		LBSF02	Planned shell fish sample taken from bottom(8m) of line
66	27/06/2013	9:35	NB 16665 34171	116665	934171		LBSW08	Planned seawater sample
67	27/06/2013	9:36	NB 16663 34170	116664	934171		LBSF03	Planned shell fish sample taken from top(surface) of line
68	27/06/2013	9:42	NB 16664 34168	116665	934168		LBSF04	Planned shell fish sample taken from bottom(8m) of line
69	27/06/2013	9:24	NB 16867 34135	116868	934136			Salinity profile taken using CastAway handheld CTD

Photographs referenced in the table can be found attached as Figures 3 – 23.

Sampling

Water samples were collected at sites marked on the map shown in Figures 2. Samples were transferred to Biotherm 30 boxes with ice packs and posted to Glasgow Scientific Services (GSS) for *E.coli* analysis. All samples were posted on the day of collection and all of them were received and analysed the following day. The sample temperatures on arrival to the laboratory ranged between 1.8 ˚C and 2.7 ˚C.

Seawater samples were tested for salinity by GSS and the results reported in mg Chloride per litre. These results have been converted to parts per thousand (ppt) using the following formula:

$$\text{Salinity (ppt)} = 0.0018066 \times Cl^{-} \text{ (mg/L)}$$

All shellfish samples were collected from the harvester's boat as requested by client at surface and at 8 metres depth and salinity profiles were also taken during this survey.

Table 2. Water Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (cfu/100ml)	Salinity (ppt)
1	26/06/2013	LBFW1	NB 18135 34229	Freshwater	26000	
2	26/06/2013	LBFW2	NB 17815 34353	Freshwater	470	
3	26/06/2013	LBFW03	NB 17389 34429	Freshwater	130	
4	26/06/2013	LBFW04	NB 17092 34352	Freshwater	<10	
5	26/06/2013	LBFW05	NB 16912 34397	Freshwater	10	
6	26/06/2013	LBFW06	NB 16697 34462	Freshwater	20	
7	26/06/2013	LBSW01	NB 16512 34263	Seawater	1	35.59
8	26/06/2013	LBSW02	NB 16378 34028	Seawater	46	35.23
9	26/06/2013	LBFW07	NB 16402 33994	Freshwater	260000	
10	26/06/2013	LBFW08	NB 16937 33487	Freshwater	440	
11	26/06/2013	LBFW09	NB 17228 33603	Freshwater	<10	
12	26/06/2013	LBFW10	NB 17583 33226	Freshwater	10	
13	26/06/2013	LBSW03	NB 17743 33467	Seawater	21	33.96
14	27/06/2013	LBSW04	NB 18427 33660	Seawater	2	35.59
15	27/06/2013	LBSW05	NB 17077 33774	Seawater	0	33.42
16	27/06/2013	LBSW06	NB 16838 33813	Seawater	3	36.13
17	27/06/2013	LBSW07	NB 16871 34125	Seawater	5	35.59
18	27/06/2013	LBSW08	NB 16665 34171	Seawater	0	34.33

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	Sample depth on line (m)	E. coli (MPN/100g)
1	27/06/2013	LBSF01	NB 16870 34126	Common mussels	Surface	20
2	27/06/2013	LBSF02	NB 16871 34136	Common mussels	8	20
3	27/06/2013	LBSF03	NB 16663 34170	Common mussels	Surface	20

4	27/06/2013	LBSF04	NB 16664 34168	Common mussels	8	50

Salinity Profiles

Salinity profiles were taken at two locations in the production area, one at each end of the mussel lines. One profile was either lost or was not recorded by the instrument. A non-conformance for the failed cast has been raised on the SRSL quality management system.

Photographs

Figure 3. House:Thigaborra at start of survey route. Waypoint 1.

Figure 4. Pipe within Thigaborra's property boundaries. Waypoint 2.

Figure 5. Outfall pipe discharging into watercourse. Waypoint 5.

Figure 6. Debris on shore. Waypoint 8.

Figure 7. Structure on shore. Waypoint 9.

Figure 8. Sample site LBFW2. Waypoint 11.

Figure 9. Stone structure running from shore into Loch. Waypoint 13.

Figure 10. Concrete housing next to property. Waypoint 15.

Figure 11. Pipe in channel running down from housing in field. Waypoint 15.

Figure 12. Stagnant pool beside LBFW03 sample point. Waypoint 18.

Figure 13. Decomposing sheep carcus close to shore. Waypoint 27.

Figure 14. Dam at planned water site. Waypoint 29.

Figure 15. Claypipe running from house to shoreline. Waypoint 29.

Figure 16. Road causeway across loch inlet with corrugated pipes allowing flow under road. Waypoint 29.

Figure 17. Sea water sample taken from slipway. Waypoint 30.

Figure 18. Pipe discharging into watercourse from below house. Waypoint 38.

Figure 19. No access to shore. Waypoint 41.

Figure 20. Difficult access to sampling point. Waypoint 43.

Figure 21. Harvesters' boat in operation. Waypoint 43.

Figure 22. Concrete pipe at planned sampling point. Waypoint 46.

Figure 23. Possible septic tank. Waypoint 50.

Appendix 7. Loch Roag: Barraglom CTD data

Data obtained during the shoreline survey. The location of the cast is shown in Figure A6.1.

Data Header

% Device	CC1138011
% File name	CC1138011_20130627_082413
% Cast time (local)	27/06/2013 09:24
% Sample type	Cast
% Cast data	Processed
% Location source	GPS
% Start latitude	58.2047313
% Start longitude	-6.8216051
% Start GPS horizontal error(Meter)	2.170000076
% Start GPS vertical error(Meter)	3.50999999
% Start GPS number of satellites	7
% Cast duration (Seconds)	72.8
% Samples per second	5
Calibration Date	Mar-13
Calibration offset for Temperature	-0.08
Calibration offset for Salinity	0.18

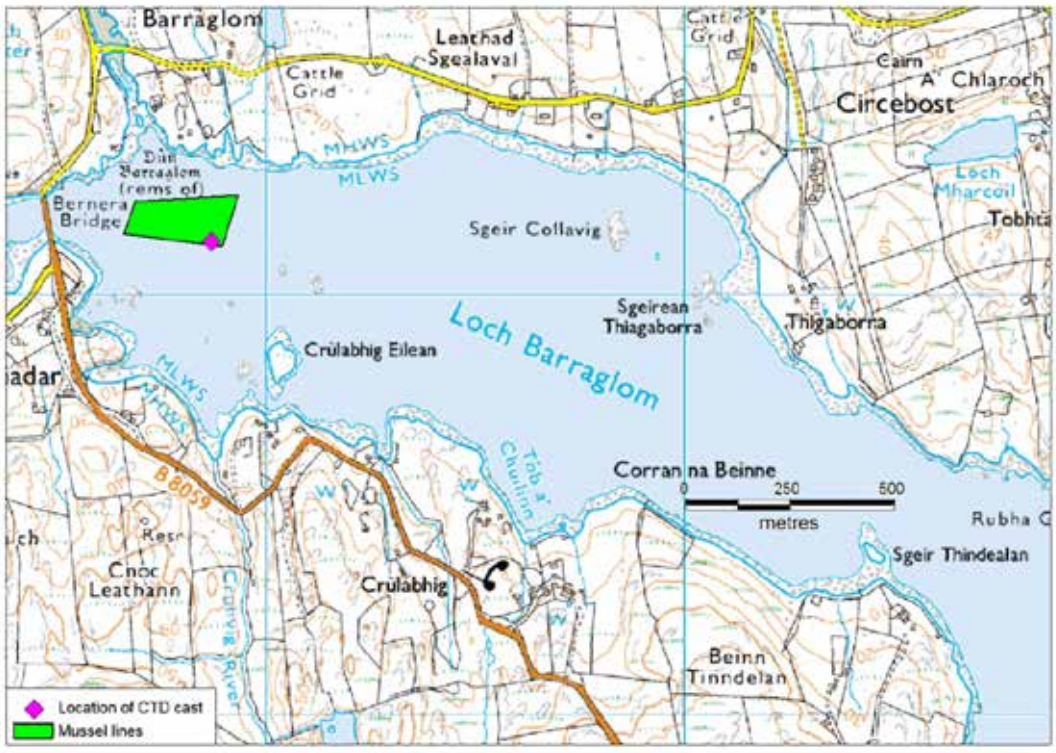

Figure A6.1 Location of CTD cast

CTD data (calibration offsets applied)

Depth (Meter)	Temperature (Celsius)	Salinity (Practical Salinity Scale)
0.148969009	12.42375852	34.06941094
0.446875036	12.42325651	34.19117097

0.7447666	12.42194731	34.24770481
1.042644314	12.42030366	34.31045105
1.340513927	12.4192365	34.31599771
1.638382131	12.41750492	34.31930141
1.936248783	12.41744154	34.3263631
2.234113957	12.41900136	34.32983019
2.531978725	12.41269969	34.32582096
2.829842784	12.41155743	34.33128186
3.127705487	12.40609779	34.33324862
3.425568196	12.40852695	34.3275065
3.723431946	12.40893028	34.32174237
4.021296092	12.40134668	34.31921755
4.319163325	12.40240347	34.28972683
4.617030415	12.39973905	34.31712148
4.914894441	12.39926428	34.31317814
5.212757782	12.39542491	34.31916845
5.510620064	12.397876	34.31925999
5.808481597	12.39569597	34.32291964
6.106342548	12.39109727	34.31975905
6.404202594	12.38594981	34.32556172
6.702060894	12.3829218	34.33023837
6.999917907	12.38537526	34.33388924
7.297773685	12.38054575	34.33763887
7.595628787	12.38268753	34.33625697
7.893484728	12.38898209	34.32933054
8.191339978	12.38442531	34.33986413
8.489194146	12.3809751	34.33397161
8.78704909	12.38589538	34.33036487
9.084904472	12.38282966	34.32758428
9.382759106	12.38005234	34.33257858
9.680612291	12.37917702	34.33656198
9.978464396	12.37322295	34.33750854
10.27631537	12.37391988	34.34228965
10.5741659	12.37304588	34.33847774
10.87201646	12.37032093	34.33811895
11.1698664	12.37192933	34.3407597
11.46771556	12.37543487	34.34341866
11.76556558	12.38598146	34.33357835
12.06341694	12.38139224	34.33008422
12.36126604	12.36342416	34.34504092
12.65911162	12.35364647	34.35147908
13.03634943	12.34730693	34.35894073