Scottish Sanitary Survey Programme

Sanitary Survey Report

Production Areas: Loch Roag: Linngeam, Torranish and Drovinish

SIN: LH 187, LH 189 and LH 186

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Cefas

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Report Distribution – Loch Roag: Linngeam, Torranish and Drovinish

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I. Executive Summary

A sanitary survey at Loch Roag: Linngeam, Torranish and Drovinish has been undertaken as the area was first classified after 2006, when the requirement for conduct of sanitary surveys under Regulation (EC) No. 854/2004 came into force. Loch Roag is located on the west coast of the Isle of Lewis, in the Outer Hebrides. It lies approximately 35 km west of the island capital, Stornoway. The surrounding area is rugged and sparsely populated.

All three production areas are used for long-line mussel aquaculture. The areas are intensively developed, with eight active sites located in the three areas and a further active site (Aird Chaol) located outside the production area boundaries. Harvest may occur throughout the year, in accordance with market demand and fishery status.

The principal sources of faecal contamination to the fishery are diffuse agricultural pollution mainly from sheep, a small number of private septic tank discharges, and wildlife, mainly geese. The majority of these sources are located along areas of grassland associated with crofts at Tacleit, on the north shore of the loch and at larsiadar, on the southeast shore. A smaller number of livestock were observed at the head of Loch Drovinish.

Historical monitoring of *E. coli* in shellfish indicates that higher results tended to occur on the western side of the present mussel lines at Drovinish, and on the north-eastern side of the lines at Torranish. Torranish has shown the greatest number of results exceeding 230 *E. coli* MPN/100g.

At Linngeam and Torranish, there was a trend to higher results approximately every two years however there was no overall change in the extent of contamination at any of the areas over the period examined. Results in summer and autumn tended to be higher than in winter and spring. Significant correlation was found between *E. coli* results and rainfall in the 7 days prior to sampling at Drovinish and Torranish, but not Linngeam.

The rivers Torranish and Drovinish were found to be the largest potential sources of waterborne faecal contamination to the fisheries. Smaller watercourses and areas of land seepage may also lead to localised deterioration in water quality. Tidal flow rates are low, indicating that the most significant sources of contamination are likely to be very localised and that likely particle transport distances are low and possibly more influenced by wind-driven flow. The easternmost side of the Torranish 1 site lies closest to larsiadar and therefore is most likely to be affected by contamination from sources arising there, particularly on an ebb tide. The southern end of the Drovinish site lies closest to the mouth of the Drovinish River and is likely to be more affected by that source than other locations on the fishery.

<u>Recommendations</u>

As there were differences in peak contamination levels and sources of contamination between the areas, it is recommended that the three production

areas be retained. Although the Aird Chaol site has been sampled for the Linngeam production area, geographically it is better placed within the Drovinish production area. Where the recorded Torranish and Drovinish sites overlapped production area boundaries, the boundaries have been adjusted to eliminate the overlap. Recommended monitoring points have been adjusted to reflect the locations that are most likely to be impacted by the identified sources of contamination. The recommendations for the three production areas are:

Linngeam
The area bounded by lines drawn between NB 1497 3366 to NB 1480 3446 and between NB 1439 3311 to NB 1300 3309 and between NB 1300 3342 to NB 1300 3435 and between NB 1356 3470 to NB 1419 3470 and extending to MHWS.

Torranish
The area bounded by lines drawn between NB 1584 3422 to NB 1583 3400 and between NB 1576 3376 to NB 1584 3363 and between NB 1497 3366 to NB 1480 3446 and extending to MHWS.

Drovinish
The area bounded by lines drawn between NB 1439 3311 and NB 1300 3309 and between NB 1300 3309 to NB 1291 3233 and between NB 1291 3233 to NB 1338 3239 and extending to MHWS.

Continued monthly monitoring is recommended for all three sites. Further information on sampling depth and tolerance can be found in the sampling plan.

II. Sampling Plan

PRODUCTION AREA	Loch Roag: Torranish	Loch Roag: Linngeam	Loch Roag: Drovinish
SITE NAME	Torranish 1	Mol Mor	Loch Drovinish
SIN	LH 189 124 08	LH 187 710 08	LH 186 121 08
SPECIES	Common mussel	Common mussel	Common mussel
TYPE OF FISHERY	Long-line aquaculture	Long-line aquaculture	Long-line aquaculture
NGR OF RMP	NB 1556 3384	NB 1462 3323	NB 1397 3231
EAST	11556	11462	11397
NORTH	93384	93323	93231
TOLERANCE (M)	40	40	40
DEPTH (M)	1	1	1
METHOD OF SAMPLING	Hand	Hand	Hand
FREQUENCY OF SAMPLING	Monthly	Monthly	Monthly
LOCAL AUTHORITY	Comhairle nan Eilean Siar	Comhairle nan Eilean Siar	Comhairle nan Eilean Siar
AUTHORISED SAMPLER(S)	Paul Tyler	Paul Tyler	Paul Tyler
LOCAL AUTHORITY LIAISON OFFICER	Colm Fraser	Colm Fraser	Colm Fraser

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. Linngeam, Torranish and Drovinish are located in the western half of the loch, along the easternmost side near the bridge to Great Bernera.

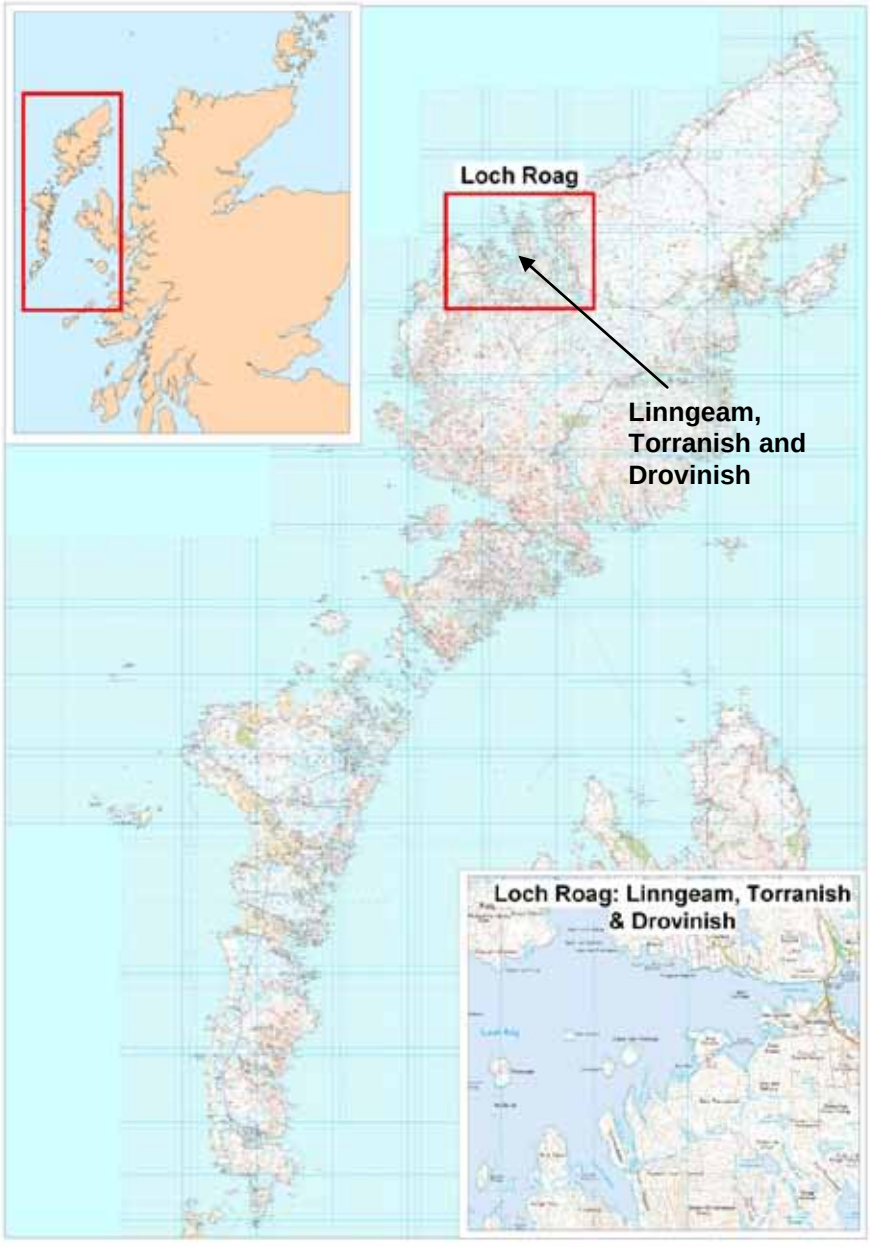

Figure 1.1 Location of Loch Roag

2. Fishery

Details of the three classified production areas surveyed are identified below in Table 2.1. All are long-line mussel farms.

Table 2.1 Area shellfish farms

Production Area	Site Name	SIN	Harvester	RMP
Loch Roag: Linngeam	Cliatasay	LH 187 699 08	C. Mackenzie	NB 133 332
	Hacklete	LH 187 698 08	C. Mackenzie	
	Linngeam	LH 187 122 08	C. Mackenzie	
	Mol Mor	LH 187 710 08	D. Smith	
	Eilean nam Feannag	not assigned	C. Mackenzie	
Loch Roag: Torranish	Loch Torranish	LH 189 124 08	C. Mackenzie	NB 155 336
Loch Roag: Drovinish	Loch Drovinish	LH 186 121 08	C. Mackenzie	NB 140 329

The current production area boundaries as stated in the 2011/12 classification document are identified in Table 2.2 below.

Table 2.2 Production area boundaries

Production Area	Boundary Description
Loch Roag: Linngeam	Area bounded by lines drawn between NB 1500 3370 and NB 1500 3442 and between NB 1419 3470 and NB 1356 3470 and between NB 1300 3435 and NB 1300 3342 and between NB 1300 3310 and NB 1353 3268 and between NB 1353 3268 and NB 1439 3311
Loch Roag: Torranish	Area bounded by lines drawn between NB 1500 3370 and NB 1500 3442 extending to the B8059
Loch Roag: Drovinish	Area bounded by lines drawn between NB 1439 3311 and NB 1353 3268 extending to MHWS

A large number of mussel farms were present in this area, only some of which were visited by boat. Therefore, the area was surveyed from land and positions of the remaining fisheries estimated using photographs, bearings, and satellite imagery. Some lines were reportedly used only for spat collection, though some of these clearly had a large number of floats on, indicating considerable weight on the lines. Harvest at all active sites is reported to be year-round, in accordance with market demand.

The Linngeam production area consisted of five separate mussel farms, only two of which (Mol Mor and Eilean nam Feannag) were recorded by boat. The Hacklete site consisted of 2 sets of long lines and was seen from the boat, though the harvester indicated that these lines were now only used for spat collection. The Mol Mor site was being harvested at the time of survey, and the harvester provided a sample from the stock that had just come off the lines. Much of the stock had been harvested from Eilean nam Feannag, leaving stock suitable for sampling at only one end of the lines.

Two additional sites were observed in passing and later recorded from the shore. One of these consisted of 4 sets of long lines lying between the islands of Cliatasaigh and Glas Eilean, the other consisted of 3 sets of long lines lying to the south of Glas Eilean and east of Linngeam. These are presumed to be the Cliatasay and Linngeam sites.

The Torranish fishery consisted of 5 double-headed long-lines with 8 meter droppers. Two of these were oriented north to south and three were oriented east to west and lay to the north of the other two.

The Drovinish fishery consisted of two double-headed longlines with 8 meter droppers, situated along the length of Loch Drovinish.

A further site was identified from the historical monitoring data. The most recent monitoring samples have come from a site west of Aird Chaol, which was not known to FSAS prior to the survey and was not visited during the shoreline survey. This site is presumed to correspond roughly with the crown estate lease in the same vicinity.

Figure 2.1 shows the relative positions of the mussel farms and the seabed lease areas.

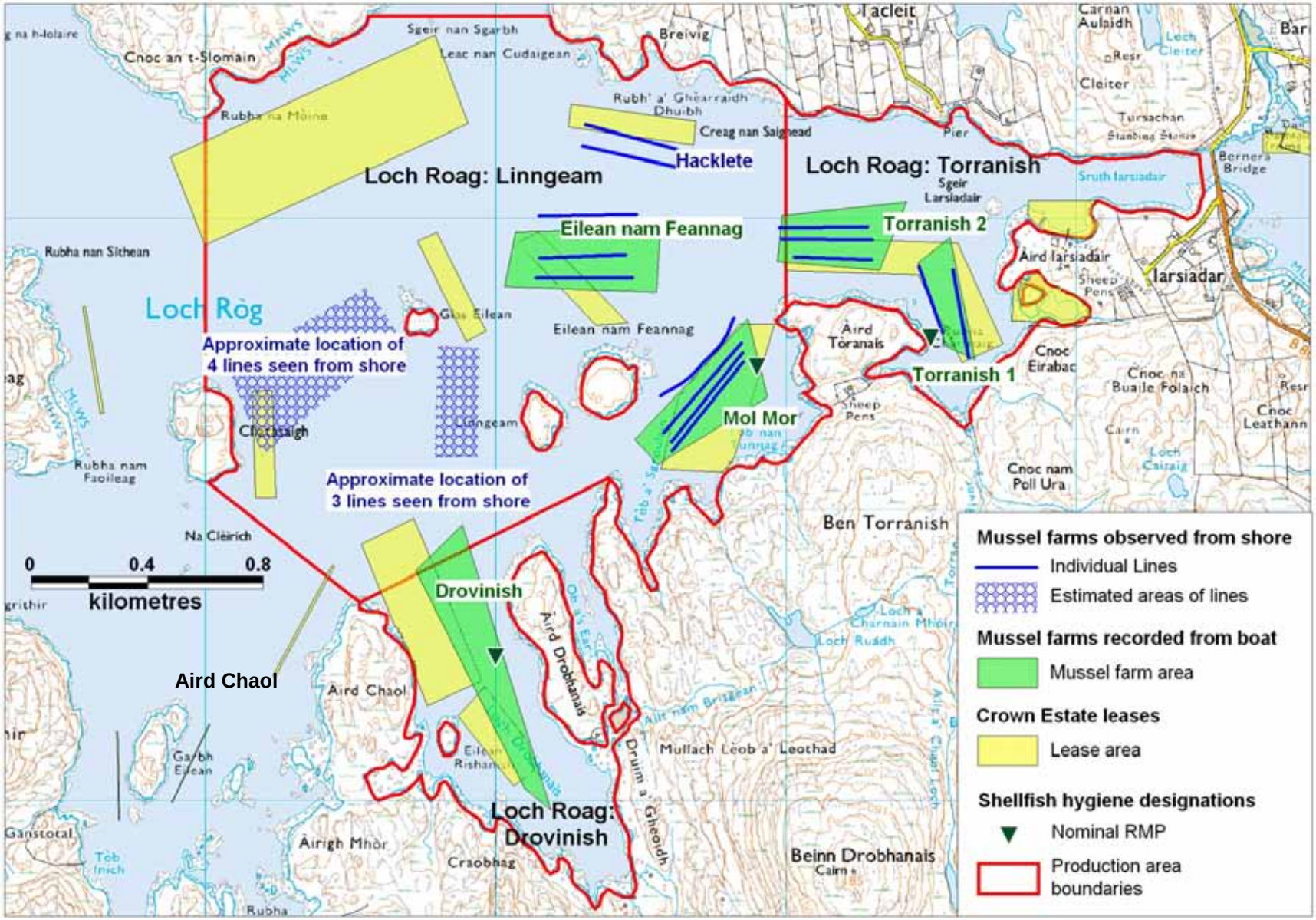

Figure 2.1 Loch Roag Linngeam, Drovinish and Torranish fisheries

3. Human Population

Figure 3.1 shows information obtained from the General Register Office for Scotland on the population within the census output areas in the vicinity of Loch Roag: Linngeam, Drovinish and Torranish fisheries. The last census was undertaken in 2001.

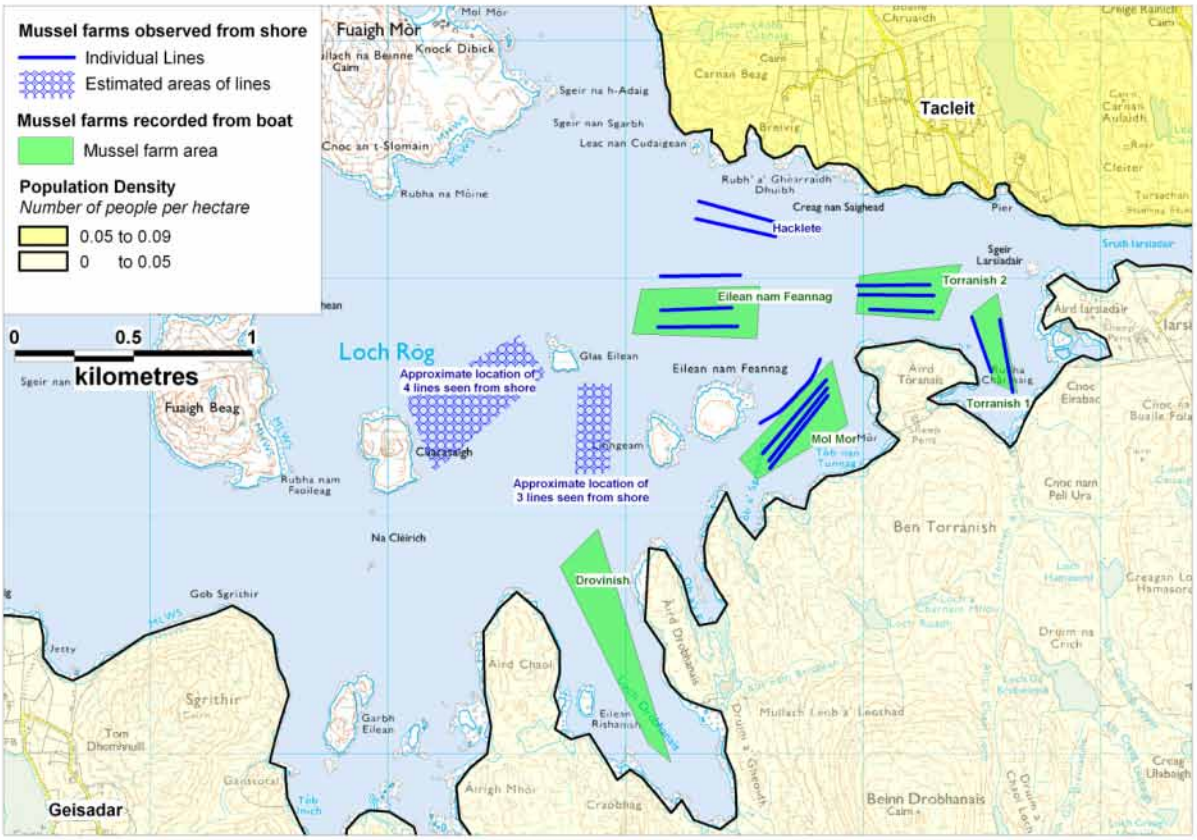

Figure 3.1 Population map of Loch Roag Linngeam, Drovinish and Torranish

Figure 3.1 shows that there is a low population density for the census output areas surrounding Loch Roag indicating that overall the area surrounding the fisheries is sparsely populated. There are two small settlements adjacent to the fishery. Tacleit lies north of the fishery and larsiadar is on the mainland west of the Bernera Bridge, east of the fishery. A mussel processing shed and shore base are located at Iarsiadar.

The population in the surrounding area is spread amongst two census output areas, listed in Table 3.1. The large majority of the population for these three areas is likely to be located along the main roads. The south-eastern shoreline is largely unpopulated except at its far eastern end at Iarsiadar.

No hotels or B&B's were observed in the area surrounding the fisheries during the shoreline survey, although it was observed that many of the homes in the area are in seasonal occupation. There is a picnic area at the northern end of the Bernera Bridge. It does not have toilet facilities.

Table 3.1 Census output areas: Loch Roag Linngeam, Drovinish and Torranish

Output area	Population
60RJ000061	66
60RJ000067	105
Total	**171**

Overall, the area is sparsely populated, with the majority of the human population in the vicinity of the fishery located along the northern shore and to the east of the Torranish production area. There was no human population adjacent to the Drovinish production area.

4. Sewage Discharges

Information on sewage discharges to the area was sought from Scottish Water and the Scottish Environment Protection Agency (SEPA). Only one Scottish Water discharge was located within 5km of the mussel farms. This is detailed in Table 4.1.

Table 4.1 Discharges identified by Scottish Water

Consent Ref No.	NGR of discharge	Discharge Name	Discharge Type	Level of Treatment	Consented flow m^3/day	Consented Design PE
NA	NB 1810 3420	Kirkibost dun Innes	Continuous	Septic tank	10.8	144

The Kirkibost dun Innes septic tank was observed during a shoreline survey undertaken in east Loch Roag during 2007. As it is a small tank, and over 2.5 km from the easternmost end of the surveyed mussel farms, it is not anticipated to have a substantial impact on water quality at the Torranish, Linngeam or Drovinish production areas.

SEPA provided information on a number of consented discharges, which are listed in Table 4.2. No information was provided regarding the consented flow or design Population Equivalent (PE) of these discharges. The majority appear to serve single homes and would therefore each discharge a relatively small volume of sewage.

Table 4.2 Discharge consents identified by SEPA

No.	Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Discharges to
1	CAR/R/1068536	NB 1472 3513	Sewage	Septic Tank	Soakaway
2	CAR/R/1063365	NB 1508 3472	Sewage	Septic Tank	Soakaway
3	CAR/R/1056225	NB 1516 3475	Sewage	Secondary	Soakaway
4	CAR/R/1055846	NB 1537 3465	Sewage	Septic Tank	Soakaway
5	CAR/R/1042802	NB 1545 3456	Sewage	Septic Tank	Soakaway
6	CAR/R/1067798	NB 1551 3459	Sewage	Septic Tank	Soakaway
7	CAR/R/1049570	NB 1540 3446	Sewage	Septic Tank	Soakaway
8	CAR/R/1063357	NB 1536 3436	Sewage	Septic Tank	Loch Roag
9	CAR/R/1047054	NB 1655 3483	Sewage	Septic Tank	Soakaway
10	CAR/R/1049534	NB 1674 3452	Sewage	Septic Tank	Soakaway
11	CAR/R/1061481	NB 1689 3458	Sewage	Septic Tank	Soakaway
12	CAR/R/1059996	NB 1690 3452	Sewage	Septic Tank	U/T of Loch Barraglom
13	CAR/R/1030323	NB 1725 3454	Sewage	Septic Tank	Soakaway
14	CAR/R/1077617	NB 1690 3360	Sewage	Septic Tank	Soakaway
15	CAR/R/1066509	NB 1671 3371	Sewage	Septic Tank	Soakaway
16	CAR/R/1087895	NB 1654 3397	Sewage	Secondary	Loch Roag
17	CAR/R/1044392	NB 1648 3393	Sewage	Septic Tank	Land
18	CAR/R/1064030	NB 1636 3405	Sewage	Septic Tank	Sruth Larsiadair
19	CAR/R/1040737	NB 1625 3386	Sewage	Septic Tank	Soakaway
20	CAR/L/1009011	NB 160 339	Other effluent-mussel tank	NA	Loch Roag
21	CAR/L/1002198	NB 1600 3396	Food processing waste	NA	Sruth Larsiadair

The two commercial effluent discharges relate to the mussel processing facility at Iarsiadar. Waste water from the mussel holding tanks may contain bacteria and/or viruses purged by mussels depurating in the facility. It is not clear whether toilets

provided for staff working at the facility discharge with the food processing waste or separately elsewhere.

Observations of sewage infrastructure recorded during the shoreline survey are listed in Table 4.3.

Table 4.3 Discharges and septic tanks observed during shoreline surveys

No.	Date	NGR	Description
1	20/07/2011	NB 16406 33981	Septic pipe (dribbling) to small watercourse
2	20/07/2011	NB 15998 33918	Small pipe, no flow plus mussel processing effluent discharge
3	20/07/2011	NB 15525 34353	New house with septic tanks
4	20/07/2011	NB 15598 34410	Septic tank with pipe heading toward road, no outlet found
5	20/07/2011	NB 14693 34765	Septic tank

Only a small number of discharges were directly observed. This was due in part to the relatively rough terrain and in part to the predominant use of soakaway systems. Two of the observed discharges (Nos. 1 and 2) correlated with consents identified in Table 4.3. One observation (No. 3) related to a home under construction and not yet occupied at the time of survey. The remaining two observed septic tanks may discharge to soakaway or land, however this was not clear. No associated discharge pipe was observed at the location identified for CAR/R/1063357 (No 8, Table 4.2), though algal growth was noted on the shoreline in the vicinity. A seawater sample collected a short distance to the west returned a result of no detectable *E. coli* in 100 ml. This location lies over 300 m from the nearest mussel line, at Torranish 2, therefore, it is not considered likely to significantly impact the mussel farms.

The greatest risk from human sewage to the fishery is from the settled areas along the shores of Great Bernera and at Iarsiadar, with the Torranish and Hacklete sites most likely to receive any impact from these.

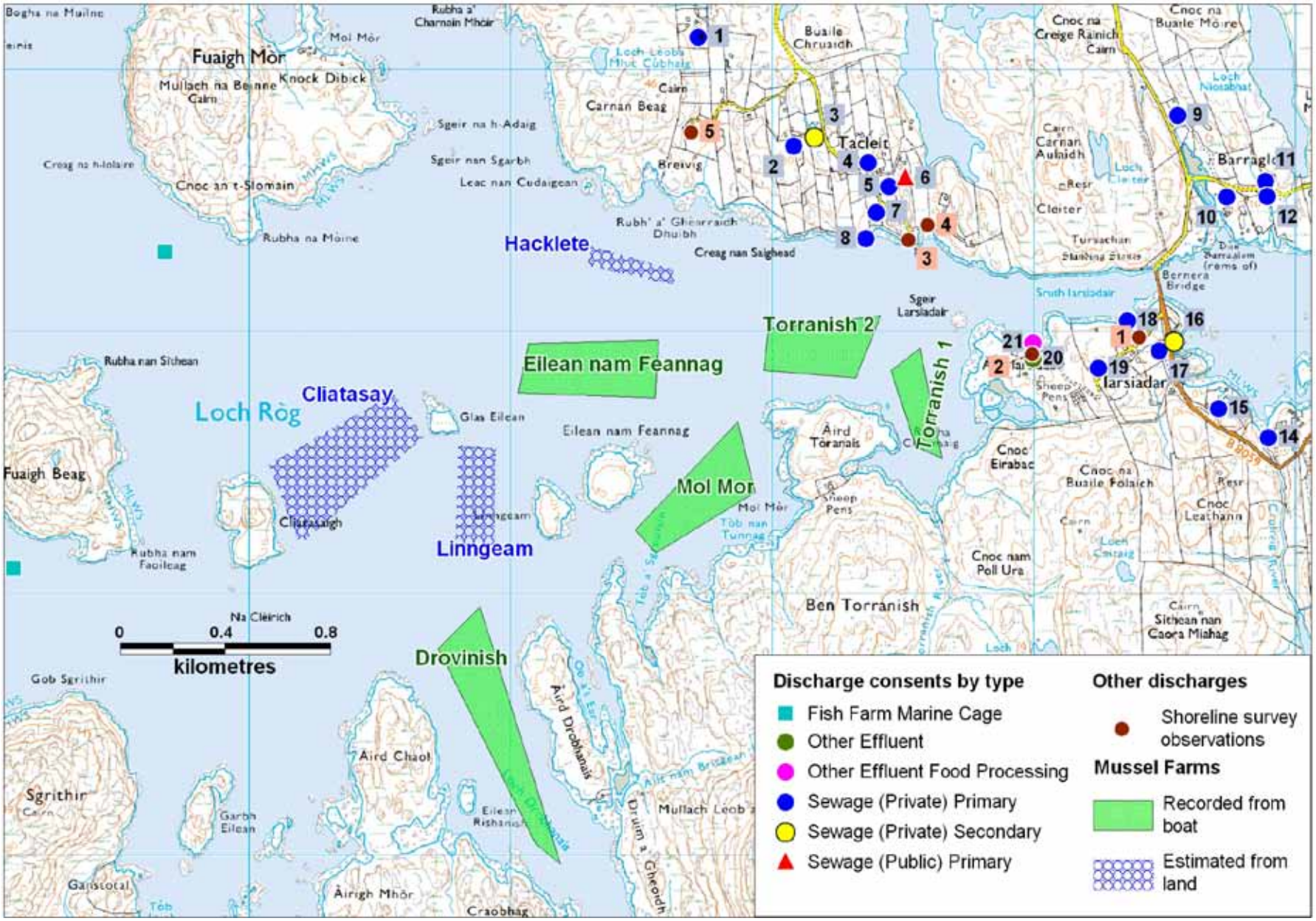

Figure 4.1 Map of discharges for Loch Roag Linngeam, Drovinish & Torranish

5. Geology and Soils

Geology and soil types were assessed following the method described in Appendix 2. A map of the resulting soil drainage classes is shown in Figure 5.1. Areas shaded red indicate poorly draining soils while areas shaded blue indicate more freely draining soils.

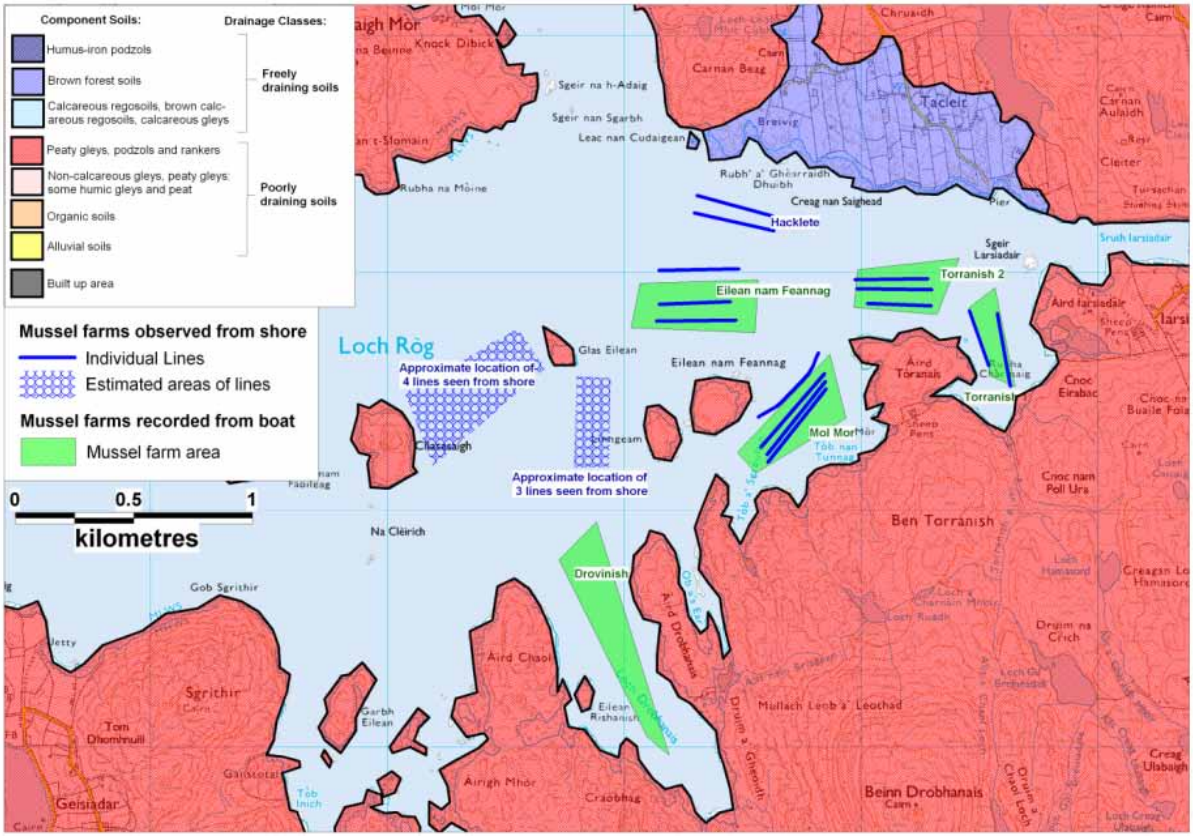

Figure 5.1 Component soils and drainage classes for Loch Roag Linngeam, Drovinish and Torranish

The predominant type of component soil found in this area is composed primarily of peaty gleys, podzols and rankers. This poorly draining soil type covers the majority of the land area immediately surrounding the western half of Loch Roag. A small area of freely-draining brown forest soils lies along the south shore of Bernera at Tacleit, to the north of the fishery. Not identified in the soil profile map are small areas of impermeable cover at Iarsiadar and Tacleit, where there are roads and other areas of hardstanding. These are very small relative to the overall area.

The potential for runoff contaminated with *E. coli* from human and/or animal wastes and due to soil drainage characteristics is therefore high along the majority of the coastline surrounding the fisheries. The exception is at Tacleit, north of the Hacklete and Torranish lines, where soils are more freely draining.

6. Land Cover

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

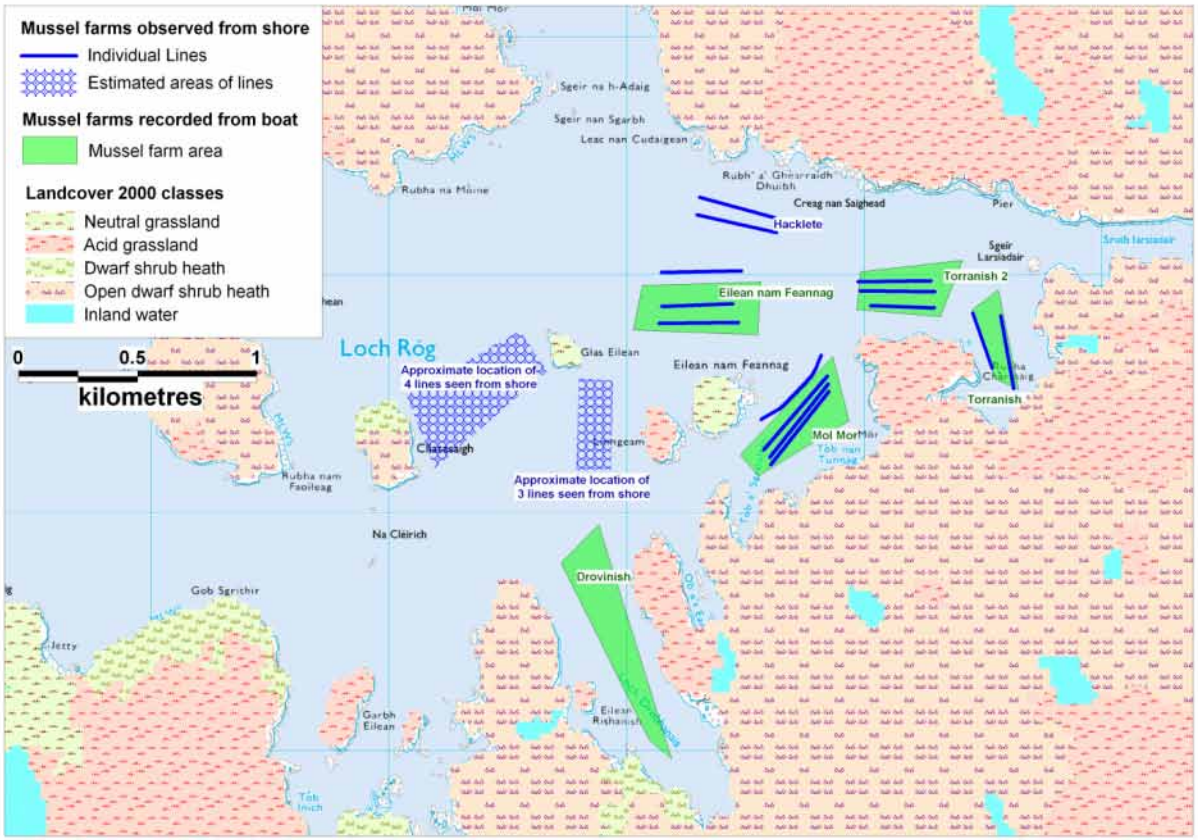

Figure 6.1 LCM2000 class land cover data for Loch Roag Linngeam, Drovinish & Torranish

The land immediately adjacent to the fisheries on the eastern side of Loch Roag is predominantly classed as open dwarf shrub heath and acid grassland with some areas of inland water. Open dwarf shrub heath is dominant on the south eastern shoreline and acid grassland is dominant on the north eastern shoreline. Areas of natural grassland are found along the shore further southwest of the fisheries. Most of the land cover types in the area are likely to be used to some extent for rough grazing.

Faecal indicator organism export coefficients for faecal coliform bacteria have been found to be approximately $8.3x10^{8}$ cfu km^{-2} hr^{-1} for areas of improved grassland and approximately $2.5x10^{8}$ cfu km^{-2} hr^{-1} for rough grazing (Kay et al. 2008). The contributions from all land cover types would be expected to increase significantly after rainfall events, however this effect would be particularly marked from improved grassland areas (roughly 1000-fold) (Kay et al. 2008).

There are no areas of improved grassland in close vicinity of the Loch Roag Linngeam, Drovinish and Torranish fisheries. However, much of the remaining area is used for rough grazing. Therefore, the potential for *E. coli*-contaminated runoff attributable to land cover is moderate for the area surrounding the mussel farms.

7. Farm Animals

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 Uig parish. Reported livestock populations for the parish in 2009 and 2010 are listed in Table 7.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data. Any entries which relate to less than five holdings, or where two or fewer holdings account for 85% or more of the information, are replaced with an asterisk.

Table 7.1 Livestock numbers in Uig parish 2009 - 2010

	Uig 567 km^2			
	2009		2010	
	Holdings	Numbers	Holdings	Numbers
Pigs	10	27	10	33
Poultry	59	639	63	663
Cattle	52	345	64	400
Sheep	330	26517	303	23914
Deer	0	0	0	0
Horses used in Agriculture	*	*	*	*
Other horses and ponies	12	19	10	15

The parish area is large, extending approximately 30 km North to South and nearly the same East to West at its widest points. Sheep were the predominant livestock animals kept in the parish and outnumber the human population within the same area by over 15 to 1, based on 2001 human census data. However, the data above do not give a clear picture of the spatial distribution of animals within the parish. The distribution of animals is unlikely to be even.

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.

Livestock counts taken during the shoreline survey relate only to the time of the site visit on 19 and 20 July 2011 and are dependent upon the viewpoint of the observer.

Table 7.2 Livestock observations from shoreline survey 2011

No.	Date	NGR	Description
1	19/07/2011	NB 14505 31729	Sheep droppings on shore adjacent to burn
2	19/07/2011	NB 14310 31871	Approximately 30 sheep being herded on western shore, sheep also seen on eastern shore
3	20/07/2011	NB 16435 34076	Approximately 15 sheep. No sheep visible on Bernera shore opposite this position
4	20/07/2011	NB 16390 33992	Sheep droppings and hoof prints on shore
5	20/07/2011	NB 16245 34028	3 sheep in view on Bernera shore opposite this position
6	20/07/2011	NB 16011 33916	5 sheep on opposite shore (Bernera)
7	20/07/2011	NB 15819 33952	12 sheep with access to shore
8	20/07/2011	NB 15796 33789	2 sheep on island
9	20/07/2011	NB 15841 33566	2 sheep
10	20/07/2011	NB 15669 33348	11 sheep (uphill from shore)
11	20/07/2011	NB 16254 33733	Sheep pens with approximately 200 sheep, these were being rounded up during the survey
12	20/07/2011	NB 15707 34372	14 sheep toward the shore from this position
13	20/07/2011	NB 15628 34420	25 sheep toward shore from this position
14	20/07/2011	NB 15555 34322	Dry sheep droppings
15	20/07/2011	NB 15317 34345	2 sheep uphill from this position
16	20/07/2011	NB 15251 34362	2 sheep

Relatively small numbers of animals were observed during the shoreline survey, and many of these were being rounded up from rough land. Sheep and droppings were observed at the head of Loch Drovinish and also along the shore of Great Bernera at Tacleit. However, the majority of animals were seen on the south shore of the fishery, in and around Iarsiadar. If these distributions of animals are presumed to be representative, then the areas of the fishery most likely to be impacted by livestock-source faecal contamination are Torranish 1 and 2, particularly the southern end of Torranish 1, and the southern end of Drovinish.

The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1.

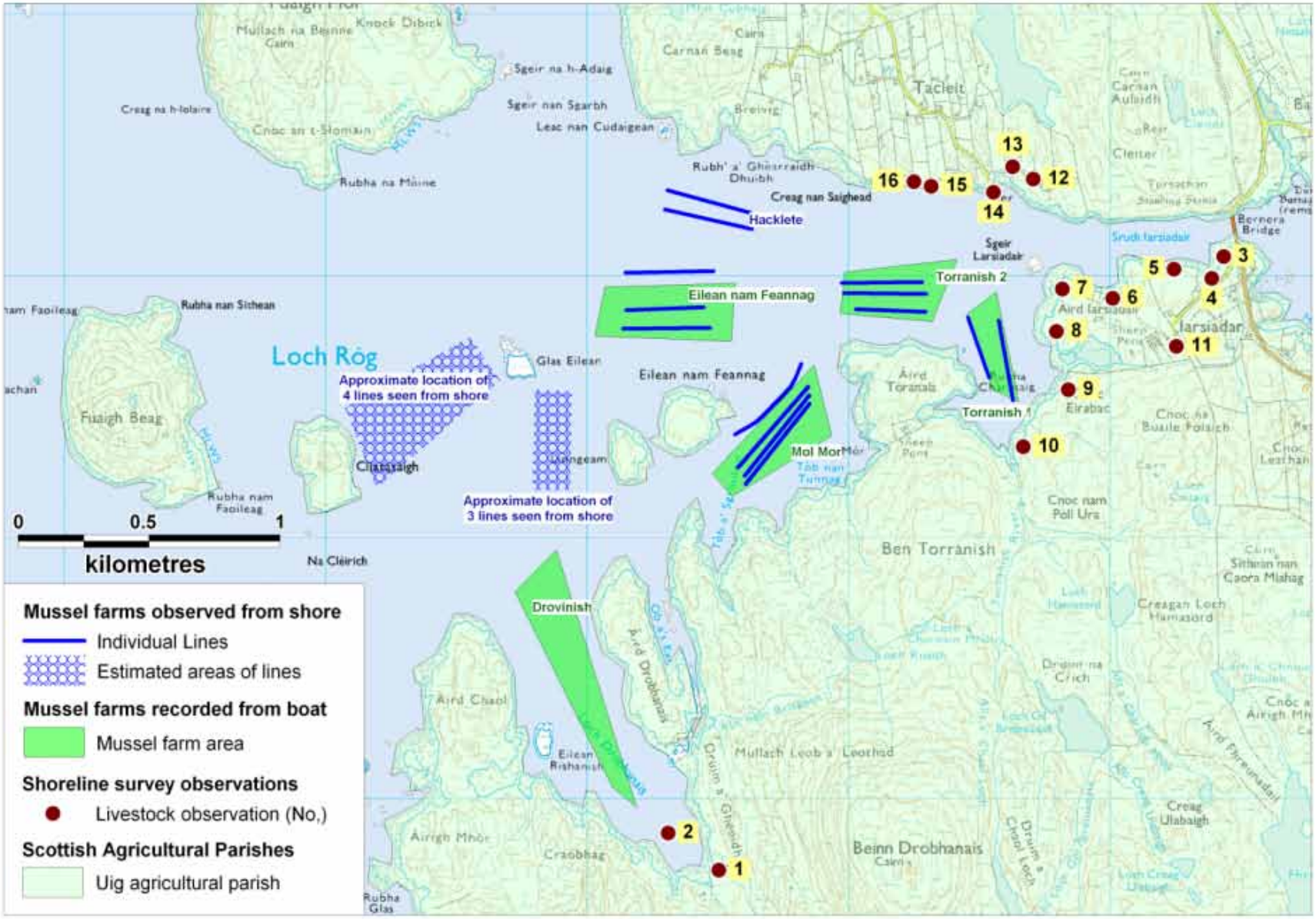

Figure 7.1 Livestock observations at Loch Roag Linngeam, Drovinish & Torranish

8. Wildlife

Wildlife is likely to be present in fishery areas and may contribute to the faecal bacterial load in a water body either via direct deposition of faeces or via diffuse runoff from land areas.

The Traigh na Berie Special Area of Conservation (SAC) is located to the northwest of the fishery area. The area was designated due to its machair habitat, which attracts a number of bird species, including geese. The Loch Roag Lagoons SAC lies on the north end of Great Bernera.

The following are considered most likely to be present at or near the fishery.

Seabirds
Results from the Seabird2000 census (Mitchell *et al*. 2004) were used to ascertain the likely distribution and numbers of seabirds at or near the Linngeam, Torranish and Drovinish production areas.. Records within 3 km of the mussel farms are listed in Table 8.1.

Table 8.1 Seabird counts within 5km of the site.

Common name	Species	Count	Method
Arctic Tern	*Sterna paradisaea*	293	Occupied nests
Herring Gull	*Larus argentatus*	1	Occupied nests
Common Gull	*Larus canus*	1	Occupied nests
Great Black-backed Gull	*Larus marinus*	1	Occupied nests
Black-headed Gull	*Larus ridibundus*	18	Occupied nests

Only a small number of gulls were noted during the shoreline survey.

Waders and Wildfowl
Little information was available on the presence, numbers and seasonal variation in the populations of waders and wildfowl in Loch Roag. Some information was available pertaining to Lewis and Harris more broadly. A document on the birds of the Outer Hebrides produced by the Western Isles Natural History Society identified that the moorland and machair on Lewis & Harris were important areas for breeding waders and other birds (http://www.thewesternisles.co.uk/outer-hebrides-birds-checklist.pdf). It also suggested that Lewis & Harris did not attract the same number of wintering waders that the more southerly islands did. Given that moorland is common around the loch, it should be presumed that wading birds will contribute to background levels of faecal contamination found within the loch, particularly during the summer months when they are present. A small flock of oystercatchers were observed near Iarsiadar during the shoreline survey.

In 2008, 1914 greylag geese were found on Lewis & Harris (Mitchell *et al*, 2010) Post-moult counts of Greylag geese undertaken in August 2008 in North and South Uist indicated a strong association of the birds with grassland feeding areas (Mitchell *et al*. 2010). A large proportion of land around the proposed fishery was recorded as heath and no arable fields were identified, therefore the presence of geese in the area is likely to be concentrated on areas of open grassland. These are found east of Drovinish, on the headland between Torranish1 and Mol Mor, and along the south

shore of Great Bernera, north of the Hacklete and Torranish 2 sites. There are also three islands in the loch with grassland cover. Geese and/or goose droppings were observed during the shoreline survey in and around Iarsiadar and along the shore south of Tacleit.

Seals

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.

Otters

Otters are known to be present on the island and 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.

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 15/08/2011).
No deer were seen during the shoreline survey.

Whales and Dolphins

Due to the shallow depths found within the area of the fishery (much less than 10 m in most areas) it is considered unlikely that even the smaller cetaceans such as porpoises and dolphins will frequent waters near the mussel farms.

Summary

Wildlife species in and around Loch Roag are likely to have a limited impact on bacteriological quality of water around the fishery due to the relatively small number of animals likely to be present compared with the large and open water area of the outer loch. Seals and seabirds may potentially directly deposit faeces to waters at the mussel farms, this is likely to be limited in extent and duration and relatively unpredictable. Other wildlife sources of faecal contamination are waterfowl and deer. Faecal material from both these sources is likely to be present in streams discharging to the loch. Therefore impacts may be higher near where streams and other freshwater runoff reach the loch. Waterfowl may also directly deposit droppings at or near the mussel lines anywhere within the fishery. Impacts from this source are likely to be higher nearer the surface of the lines.

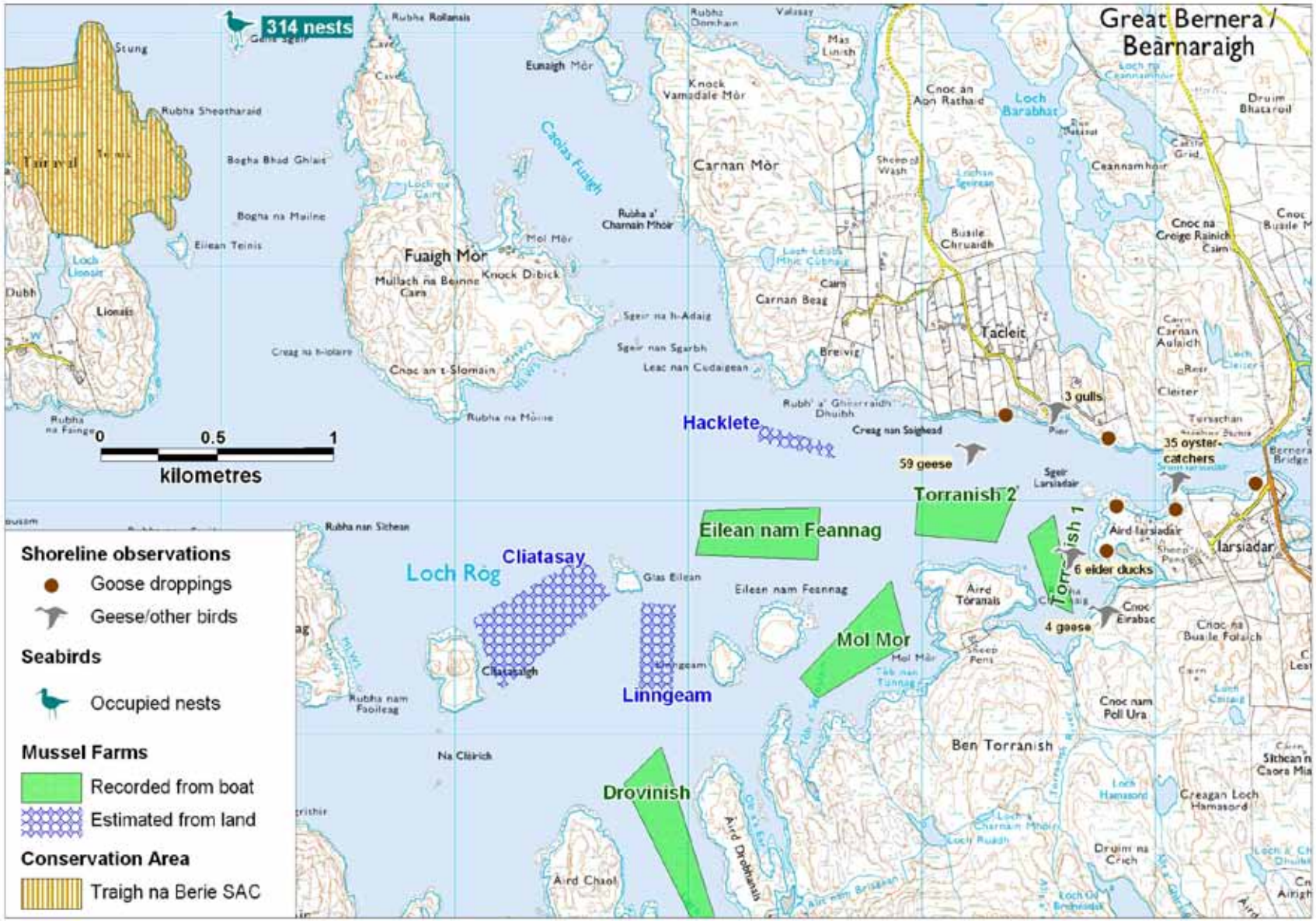

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Figure 8.1 Map of wildlife distributions at Loch Roag Linngeam, Drovinish & Torranish

9. Meteorological data

Both rainfall and wind data were available for Stornoway airport, approximately 32 km east of the fishery. Rainfall data was available for 2003-2009 inclusive. Rainfall data was also available for Lewis Creed, located 25 km east of the fishery. However, data was incomplete for September to December 2006, December and November, 2007 and June, 2004. Data for 2010 was complete and so this was used to supplement the Stornaway airport data set.

Data for the stations was purchased from the Meteorological Office. Unless otherwise identified, the content of this section (e.g. graphs) is based on further analysis 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: Linngeam, Torranish and Drovinish.

9.1 Rainfall

High rainfall and storm events are commonly associated with increased faecal contamination of coastal waters through surface water run-off from land where livestock or other animals are present, and through sewer and waste water treatment plant overflows (e.g. Mallin et al, 2001; Lee & Morgan, 2003). 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 *.

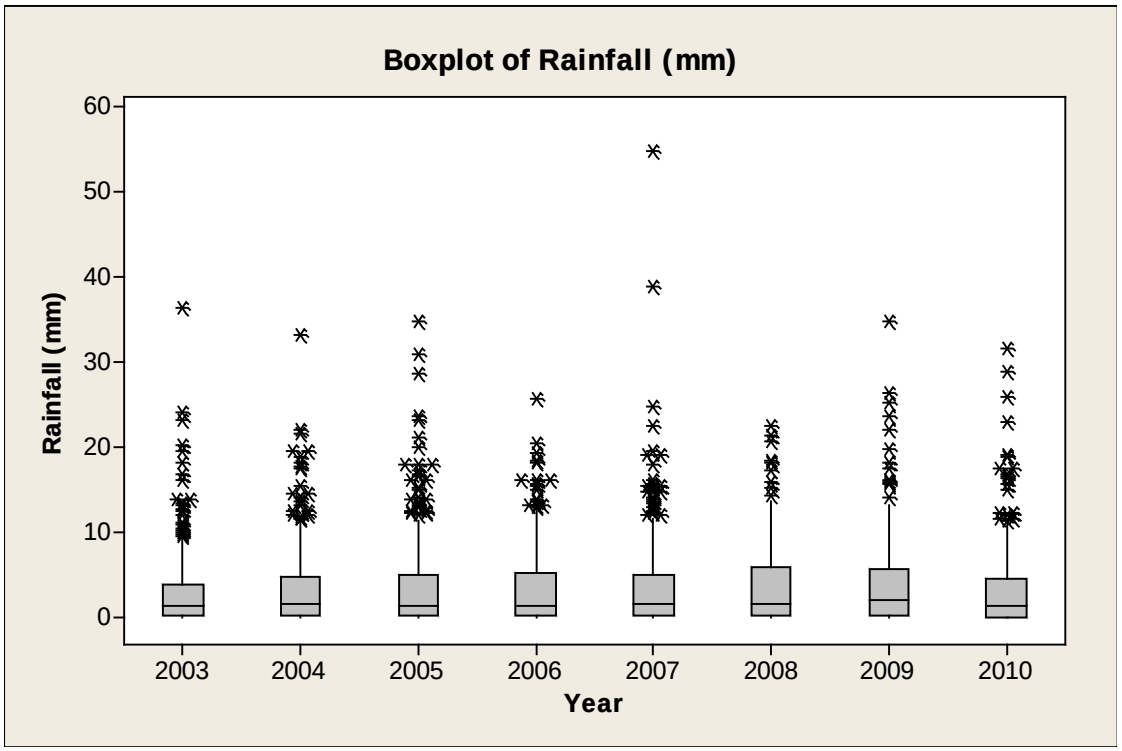

Figure 9.1 Box plot of daily rainfall values by year at Stornaway (2003 – 2009) and Lewis Creed (2010)

Figure 9.1 shows that rainfall levels were similar throughout the years with 2003 being the driest and 2008 the wettest.

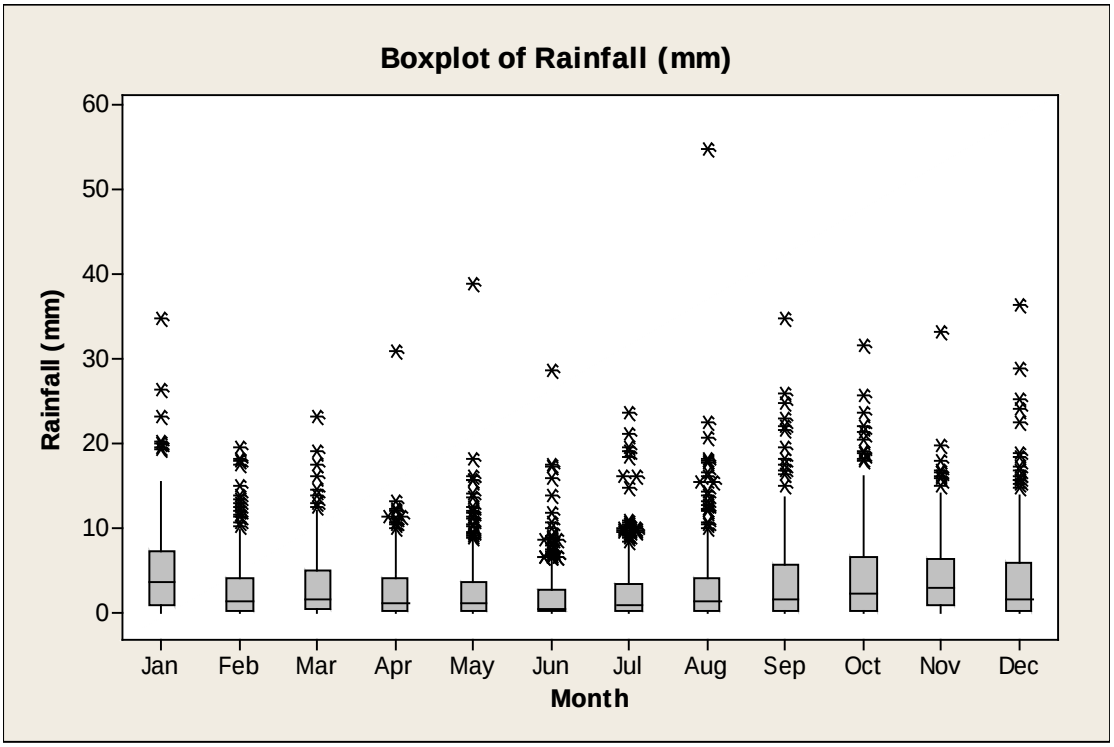

Figure 9.2 Box plot of daily rainfall values by month at Stornaway (2003 – 2009) and Lewis Creed (2010).

Figure 9.2 shows that monthly rainfall occurs at its highest through the months of January, October and November. More extreme rainfall events (>20mm in a day) occurred throughout all the months, with no obvious seasonal pattern. For the duration considered here (2003 – 2010), 41% of days experienced less than 1mm of rainfall and 7% of days experienced rainfall of 10mm or more.

It can therefore generally be expected that levels of run-off will be higher during the autumn and winter months. However, it is likely that associated faecal contamination entering the production area will be greatest when extreme rainfall events occur during summer or early autumn after a build-up of faecal matter on pastures during the drier summer months when stock levels are at their highest.

9.2 Wind

Wind data collected at the Stornaway weather station is summarised by month and presented in figures 9.3 and 9.4.

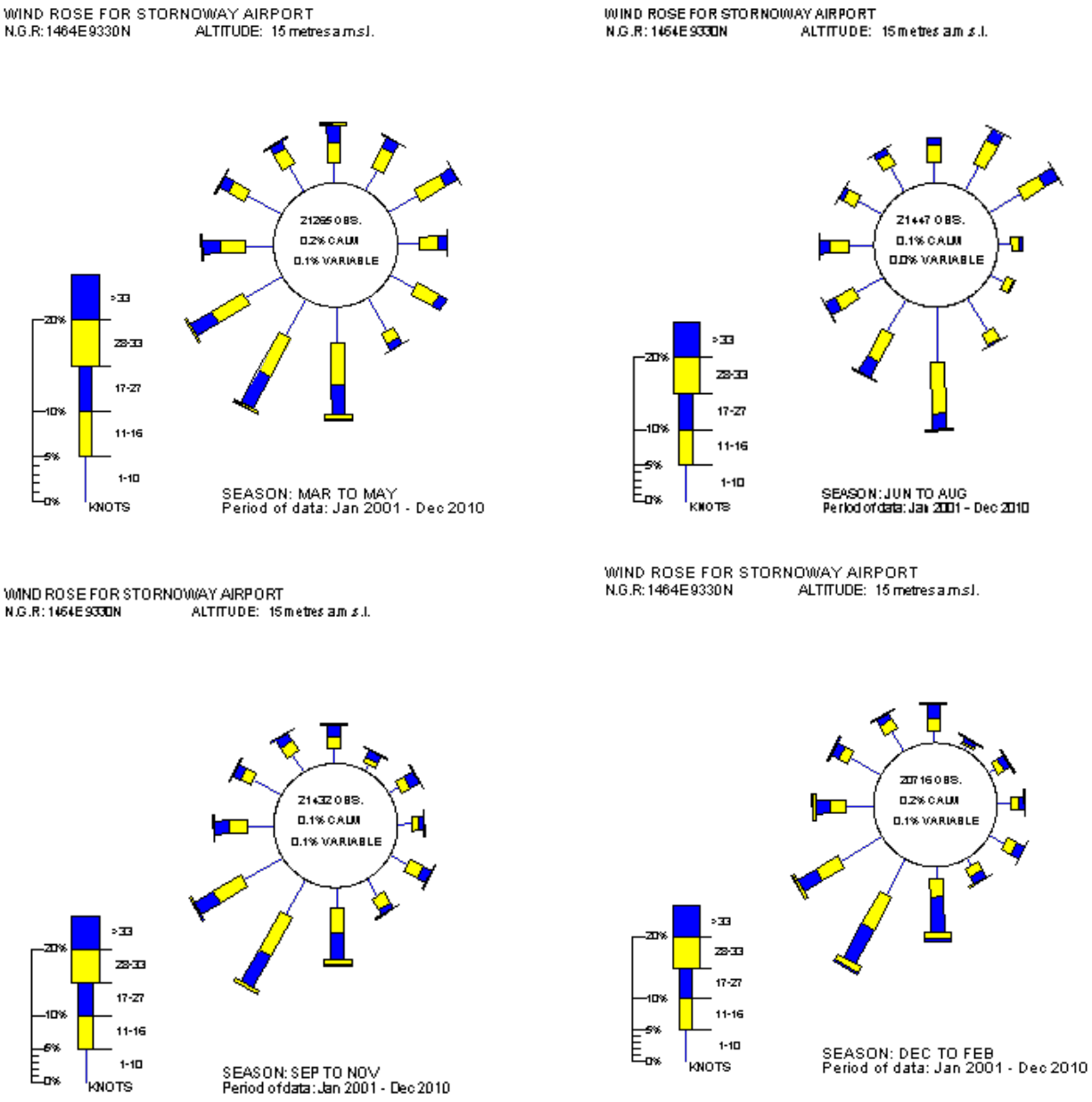

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Figure 9.3 Seasonal Wind Roses for Stornaway

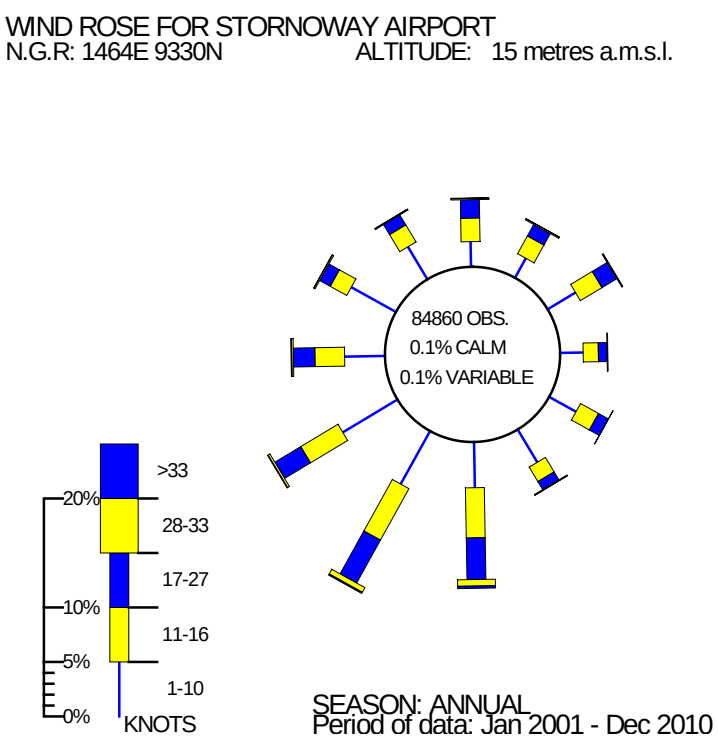

Figure 9.4 Wind Rose for Stornaway (Annual)

The prevailing wind direction at Stornaway is from the southwest. There is a higher occurrence of north easterly winds during the spring and summer. Winds are generally lightest in the summer and strongest in the winter. The terrain surrounding the Stornaway airport is relatively low lying and so the station is exposed to wind from all directions.

Winds typically drive surface water at about (3%) of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s. Therefore strong winds, particularly those from the directions to which it is most exposed will significantly alter the pattern of surface currents at within Loch Roag; Linngeam, Torranish and Drovinish. Strong winds may affect tide height depending on wind direction and local hydrodynamics. A strong wind combined with a spring tide may result in higher than usual tides, which will carry accumulated faecal matter from livestock, in and above the normal high water mark, into the production area.

10. Current and historical classification status

The historical and current classifications for the area are shown below in Tables 10.1, 10.2 and 10.3.

The 2003 classification listing had one entry for mussels in Loch Roag and the separate areas were not differentiated. In the 2004 classification listing, five separate areas were identified in Loch Roag, with Torranish and Drovinish both appearing. Linngeam appear as a new production area in the 2006 listing. The classifications from 2006 on are shown below.

Table 10.1 Loch Roag: Torranish, mussels

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

Table 10.2 Loch Roag: Drovinish, mussels

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

Table 10.3 Loch Roag: Linngeam, mussels

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2006[1]	A	A	A	A	A	A	A	A	B	B	A	A
2007	A	A	A	A	A	A	A	A	A	A	A	A
2008	A	A	A	A	A	A	A	A	A	A	A	A
2009	A	A	A	A	A	A	A	A	A	A	A	A
2010	A	A	A	A	A	A	A	A	A	A	A	A
2011	A	A	A	A	A	A	A	A	A	A	A	A
2012	A	A	A									

Note: [1]For 2006, the classification listing actually states: 2006 = A - November to August B - September to October

In recent years, the mussels in these three production areas have therefore tended to hold year-round A classifications, except for Torranish, which held B classifications for the months of August to October in 2009 and 2011, and Linngeam, which held a B classification for the months of September and October in 2006.

11. Historical *E. coli* data

11.1 Validation of historical data

Data for all mussel samples taken from Loch Roag: Drovinish, Loch Roag: Linngeam and Loch Roag: Torranish from the beginning of 2006 up to the 12th September 2011 were extracted from the FSAS database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. All *E. coli* results are reported in most probable number per 100g of shellfish flesh and intravalvular fluid.

Drovinish

Four samples were noted as rejected by FSAS and were deleted from the data set. Twenty-three samples had a result of <20 *E. coli* MPN/100 g and were assigned a value of 10 for the purposes of statistical analysis and graphical representation. No sample had a result of >18000 *E. coli* MPN/100 g. None of the validated samples was received at the laboratory more than 48 hours after collection. The recorded coolbox temperatures were all 8°C or less.

Linngeam

Three samples were noted as rejected by FSAS and were deleted from the data set. Twenty-six samples had a result of <20 *E. coli* MPN/100 g and were assigned a value of 10 for the purposes of statistical analysis and graphical representation. No sample had a result of >18000 *E. coli* MPN/100 g. None of the validated samples was received at the laboratory more than 48 hours after collection. The recorded coolbox temperatures were all 8°C or less.

Torranish

Five samples were noted as rejected by FSAS and were deleted from the data set. Twenty-five samples had a result of <20 *E. coli* MPN/100 g and were assigned a value of 10 for the purposes of statistical analysis and graphical representation. No sample had a result of >18000 *E. coli* MPN/100 g. One of the validated samples was received at the laboratory more than 48 hours after collection. The recorded coolbox temperatures were all 8°C or less.

11.2 Summary of microbiological results

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

Table 11.1 Summary of historical sampling and results

Sampling Summary			
Production area	**Loch Roag: Drovinish**	**Loch Roag: Linngeam**	**Loch Roag: Torranish**
Site	Loch Drovinish	Cliatasay; Linngeam; Hacklete; Mol Mor; Aird Chaol	Loch Torranish
Species	Common Mussels	Common Mussels	Common Mussels
SIN	LH-186-121-08	LH-187-699-08; LH-187-698-08; LH-187-122-08; LH-187-710-08; LH-187-941-08	LH-189-124-08
Location	Various	Various	Various
Total no of samples	67	81	65
No. 2006	12	21	12
No. 2007	10	15	9
No. 2008	12	12	12
No. 2009	12	12	11
No. 2010	12	12	12
No. 2011	9	9	9
Results Summary			
Minimum	<20	<20	<20
Maximum	3500	500	3500
Median	20	20	40
Geometric mean	37	31	42
90 percentile	220	130	314
95 percentile	290	220	735
No. exceeding 230/100g	3 (4%)	3 (4%)	7 (11%)
No. exceeding 1000/100g	1 (1%)	0 (0%)	2 (3%)
No. exceeding 4600/100g	0 (0%)	0 (0%)	0 (0%)
No. exceeding 18000/100g	0 (0%)	0 (0%)	0 (0%)

11.3 Overall geographical pattern of results

All sampling locations in 2006 and 2007 were only recorded in the database to 100m accuracy. The Drovinish and Torranish production areas were sampled throughout the period from 1 January 2006 to 12th September 2011. In practice, the sampling locations varied around the areas. The same grid references (to 100 m accuracy) were given for samples taken up to and including April 2007: these locations were pre-printed on the sample submission forms and probably relate to nominal sampling locations. At Linngeam several of the named sites were sampled over time. During 2006 and 2007, samples were taken on the same day at Cliatasay, Mol Mor and Hacklete. Sampling at the Linngeam site started in April 2007. From January 2008 to July 2009, samples were taken at one or other of the sites on a single sampling occasion. One site would be sampled for a period of time before changing to another. From August 2009 to November 2010, only the Cliatasay site was sampled. Only the Linngeam site was sampled from December 2010 to May 2011. Cliatasay was sampled in June 2011 and then a new site, Aird Chaol, was sampled from July 2011.

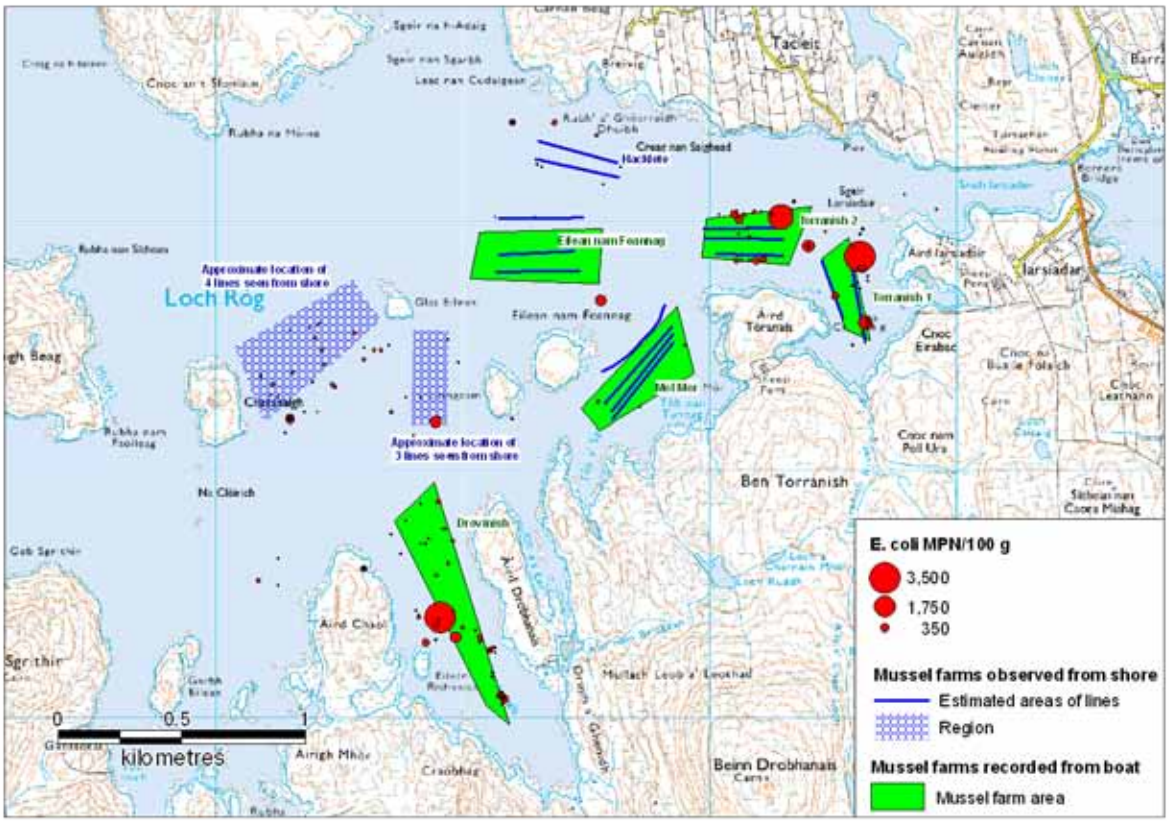

Figure 11.1 Map of individual E. coli results

The sampling locations are shown in Figure 11.1, thematically mapped by *E. coli* result. A map of interpolated *E. coli* results is shown in Figure 11.2. Both maps show that the highest results occur in the Torranish production area, on the north-eastern end, and in the Drovinish production area, on the western side of the middle of the current set of lines (going from north to south). In general, much lower results have been seen at all sites in the Linngeam production area.

The *E. coli* results for the three production areas were subjected to a one-way Analysis of Variance (ANOVA). There was no significant difference between the mean $\log_{10}$ transformed results for the three areas ($p=0.366$; Appendix 6). Boxplots of the results from the three production areas are shown in Figure 11.3.

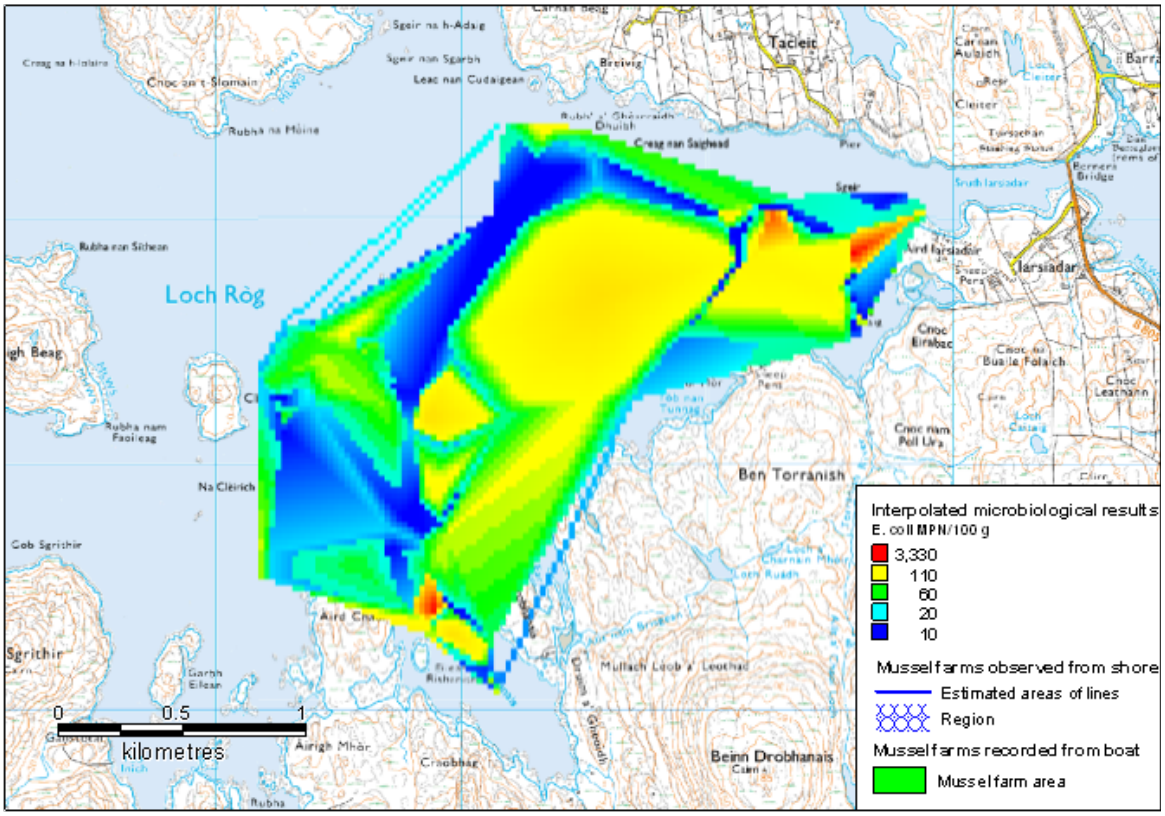

Figure 11.2 Map of interpolated *E. coli* results

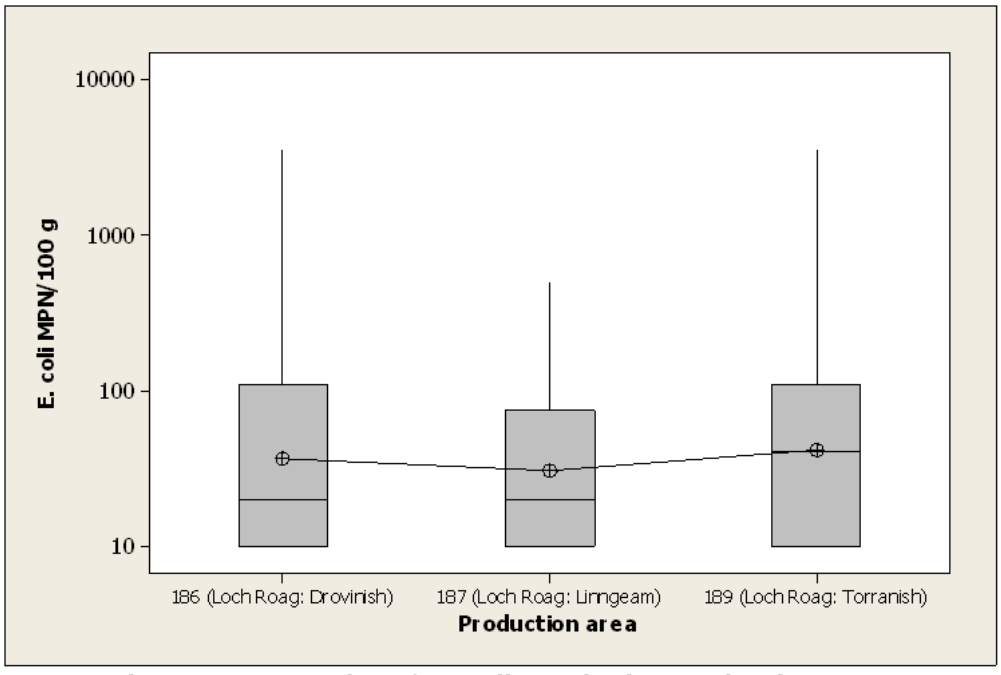

Figure 11.3 Boxplot of E. coli results by production area

11.4 Overall temporal pattern of results

Figures 11.4, 11.5 and 11.6 present scatter plots of individual *E. coli* results against date, for each of the three production areas, fitted with loess smoother lines. Loess stands for 'locally weighted regression scatter plot smoothing'. At each point in the data set an estimated value is fit to a subset of the data, using weighted least squares. The approach gives more weight to points near to the x-value where the estimate is being made and less weight to points further away. In terms of the monitoring data, this means that any point on the loess line is influenced more by the data close to it (in time) and less by the data further away. The smoother line helps to highlight any apparent underlying trends or cycles.

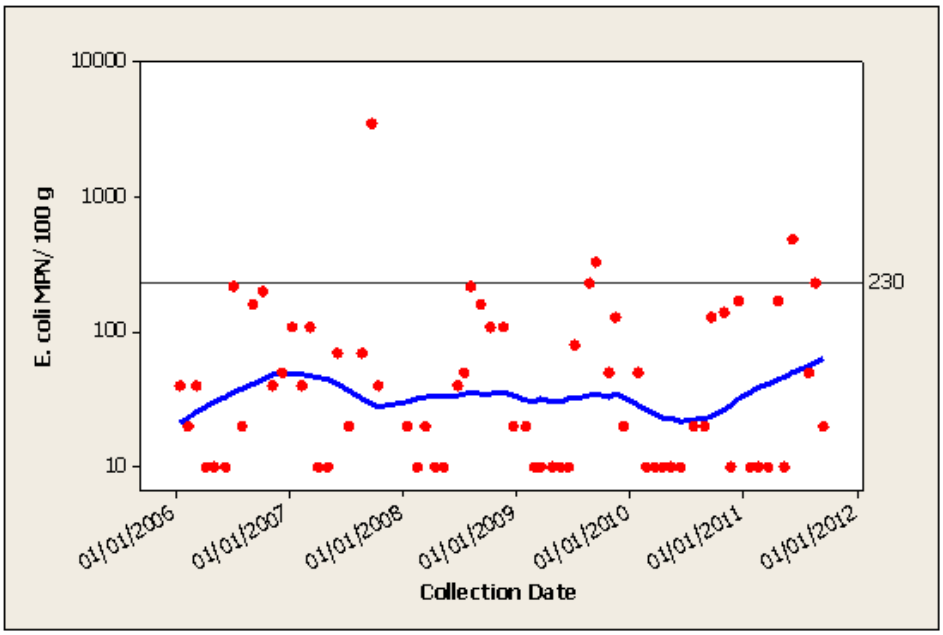

Figure 11.4 Loch Roag: Drovinish; Scatterplot of *E. coli* results by date

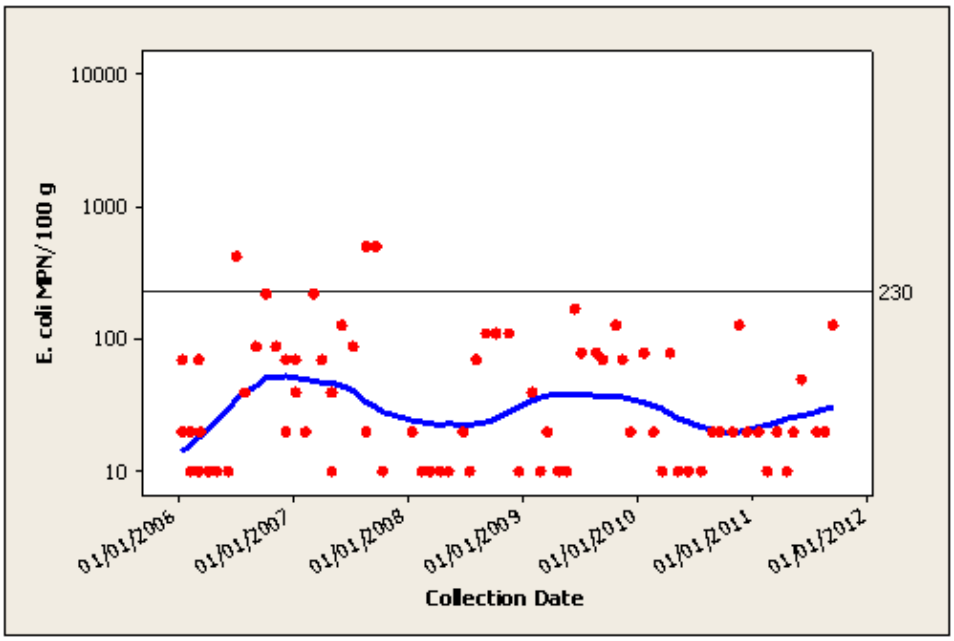

Figure 11.5 Loch Roag: Linngeam; Scatterplot of *E. coli* results by date

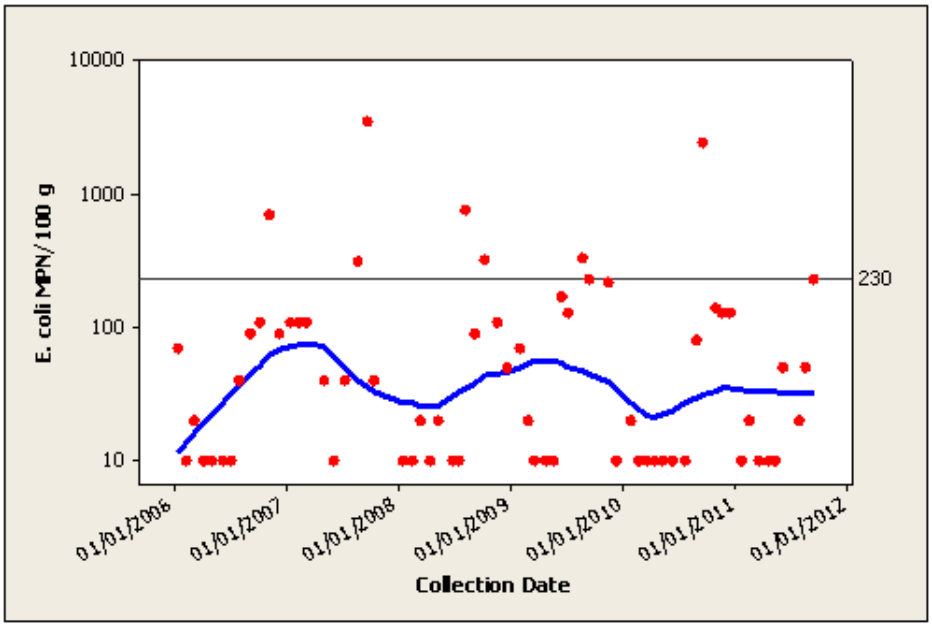

Figure 11.6 Loch Roag: Torranish; Scatterplot of *E. coli* results by date

The three figures suggest no overall change in results over the period since January 2007. The trend lines for Linngeam and Torranish do show that there is a tendency to higher results approximately every two years. However, the peak results at a site do not necessarily coincide with these periods.

11.5 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns of human occupation. All of these can affect levels of microbial contamination, and cause seasonal patterns in results. Figures 11.7, 11.8 and 11.9 present scatterplots of *E. coli* result by month for each of the three production areas, superimposed with loess smoother lines.

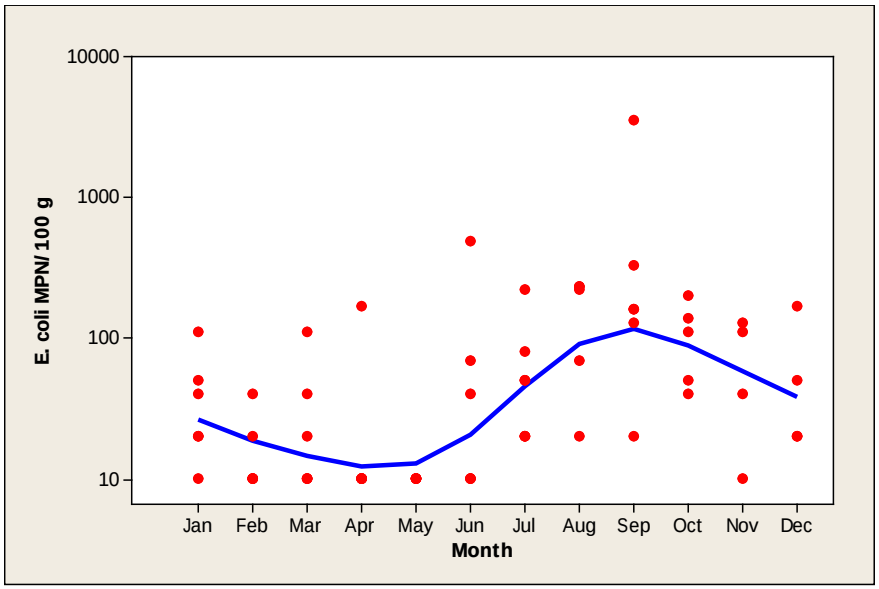

Figure 11.7 Loch Roag: Drovinish; Scatterplot of results by month

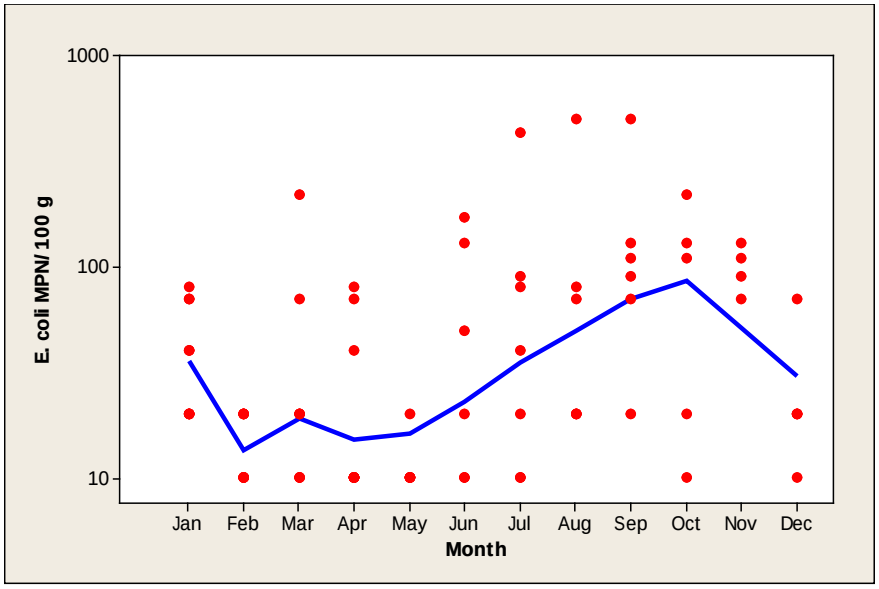

Figure 11.8 Loch Roag: Linngeam; Scatterplot of results by month

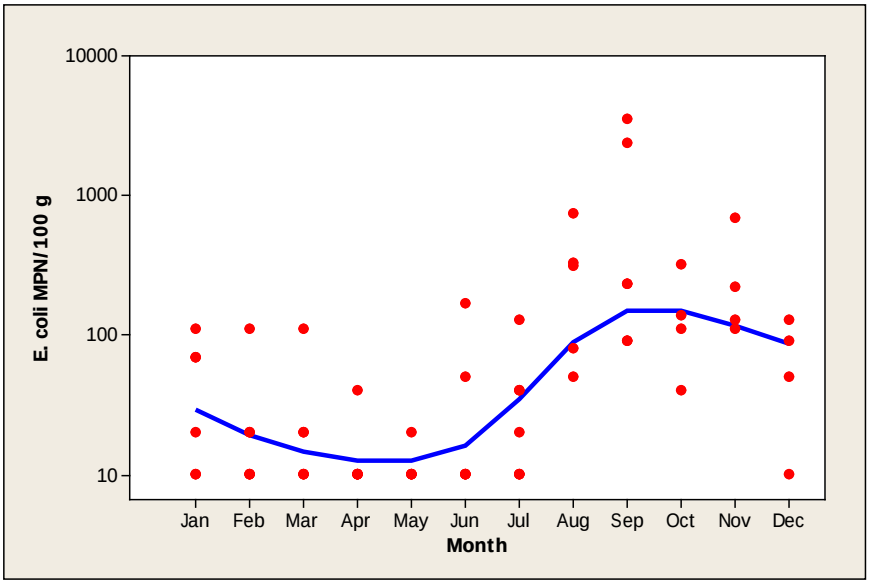

Figure 11.9 Loch Roag: Torranish; Scatterplot of results by month

In general, higher results were seen in the three production areas in summer and autumn.

For statistical evaluation, seasons were split into spring (March - May), summer (June - August), autumn (September - November) and winter (December - February). A boxplot of the results by season for each of the three areas is presented in Figures 11.10, 11.11 and 11.12.

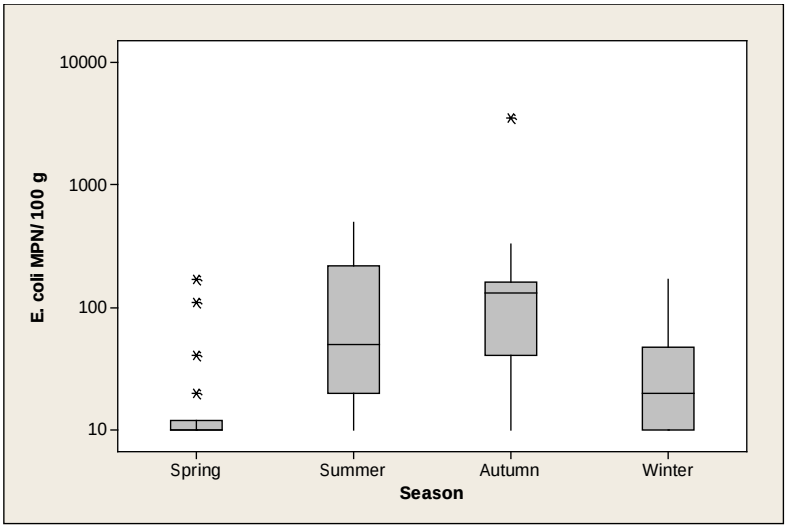

Figure 11.10 Loch Roag: Drovinish; Boxplot of results by season

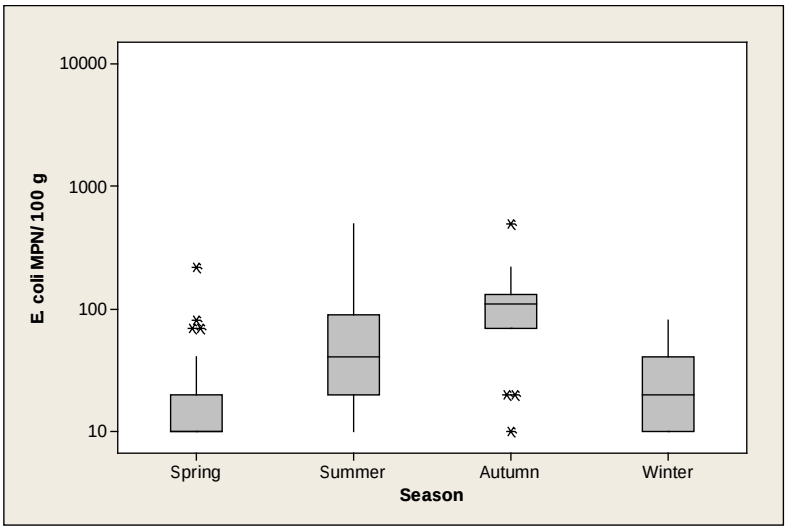

Figure 11.11 Loch Roag: Linngeam; Boxplot of results by season

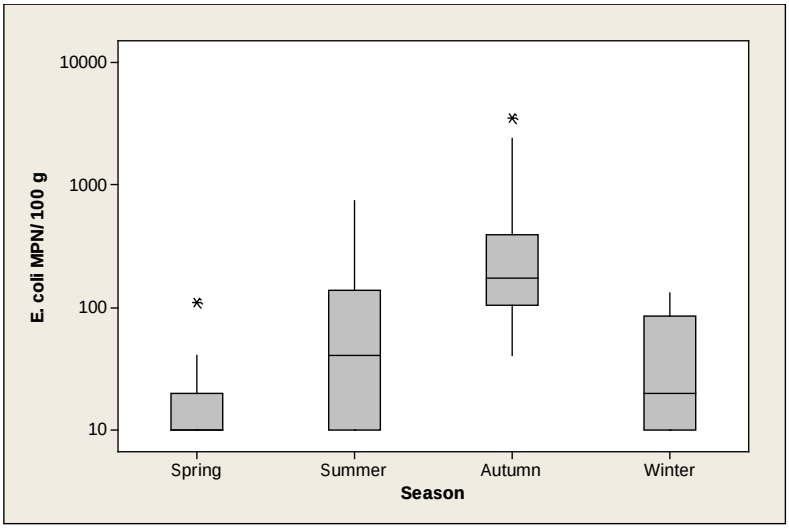

Figure 11.12 Loch Roag: Torranish; Boxplot of results by season

A significant difference was found between results by season for each of the three production areas (One-way ANOVA, p<0.001, Appendix 4). A post ANOVA test (Tukey's comparison, Appendix 4) indicated that:

- Drovinish and Linngeam: The mean $\log_{10}$ *E. coli* results for autumn were significantly higher than those for spring and winter. The mean $\log_{10}$ *E. coli* results for summer were significantly higher than those for spring.

- Torranish: The mean $\log_{10}$ *E. coli* results for autumn were significantly higher than those for spring, summer and winter. The mean $\log_{10}$ *E. coli* results for summer were significantly higher than those for spring.

11.6 Analysis of results against environmental factors

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

11.6.1 Analysis of results by recent rainfall

The nearest Meteorological Office weather station to Loch Roag: Linngeam, Drovinish and Torranish is at Lewis: Creed Bridge, approximately 28 km to the east of the production area. However, more complete data was available for the station at Stornoway Airport, a further 6 km to the east, Rainfall data was purchased from the Meteorological Office for the period up to 31/12/2010 (total daily rainfall in mm). Daily rainfall data was not available for just one day during the period 1/01/2007 to 31/12/2010.

Two-day antecedent rainfall

Figure 11.13 presents scatterplots for each of the three production areas of *E. coli* results against rainfall in the previous two days. A Spearman's Rank correlation was carried out between results and rainfall. No significant correlation was found between *E. coli* result and rainfall in the previous 2 days for any of the three production areas (Drovinish: Spearman's rank correlation=0.209, p=0.116; Linngeam: Spearman's rank correlation=0.036, p=0.762; Torranish: Spearman's rank correlation=0.101, p=0.459).

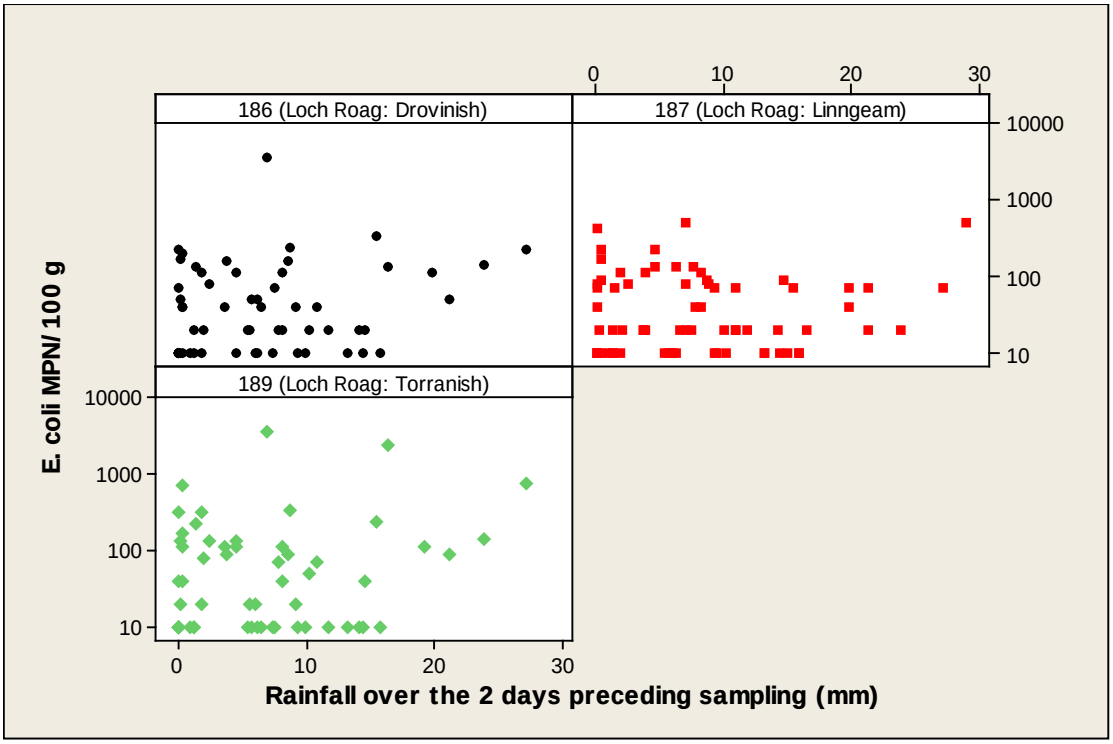

Figure 11.13 Scatterplot of result against rainfall in previous 2 days

As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationship between rainfall in the previous 7 days and sample results was investigated in an identical manner to the above. However, there were no very low results at either Drovinish or Torranish at rainfall values above 18 mm.

Seven-day antecedent rainfall

Scatterplots of *E. coli* results against rainfall for each of the three production areas are presented in Figure 11.14. A significant positive correlation was found between *E. coli* result and rainfall in the previous 7 days for Drovinish (Spearman's rank correlation= 0.368, p=0.005). and Torranish (Spearman's rank correlation= 0.318, p=0.017) but not for Linngeam (Spearman's rank correlation= 0.214, p=0.071).

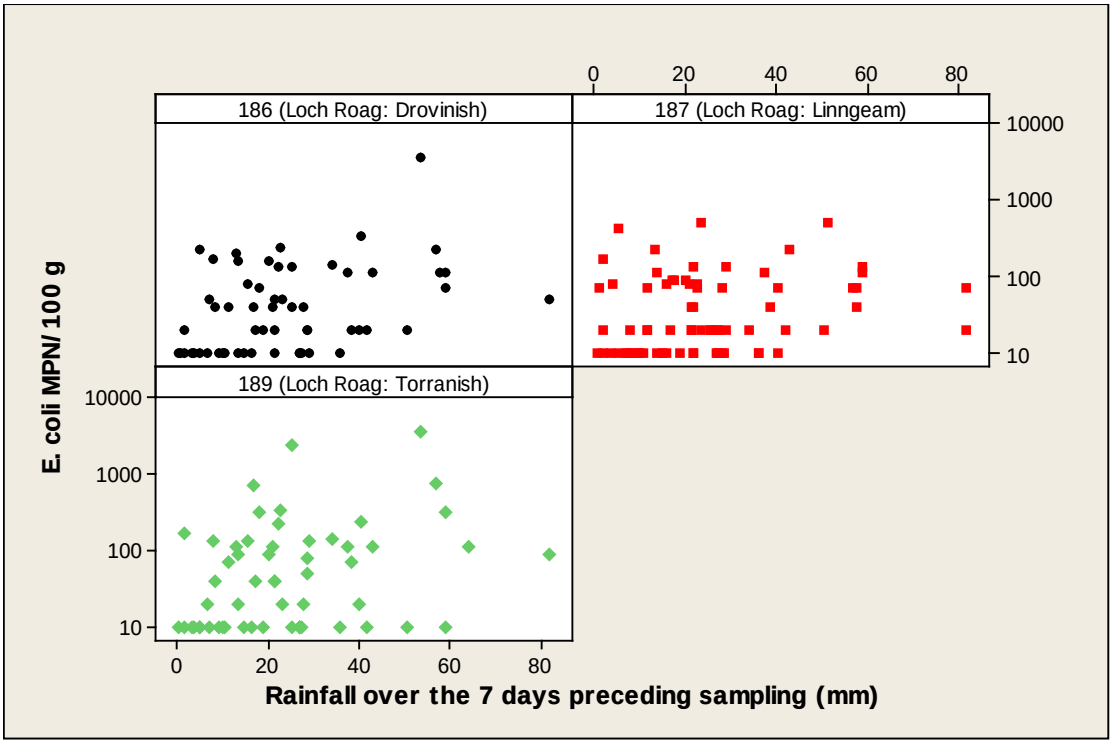

Figure 11.14 Scatterplot of result against rainfall in previous 7 days

11.6.2 Analysis of results by tidal height and state

Spring/Neap Cycle

When the larger (spring) tides occur every two weeks, circulation of water and particle transport distances will increase, and more of the shoreline will be covered at high water, potentially washing more faecal contamination from livestock into the area. Figures 11.15, 11.16 and 11.17 present polar plots of $\log_{10}$ *E. coli* results for the three production areas in relation to the lunar spring/neap tidal cycle. Full/new moons are located at 0º, and half moons at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account.

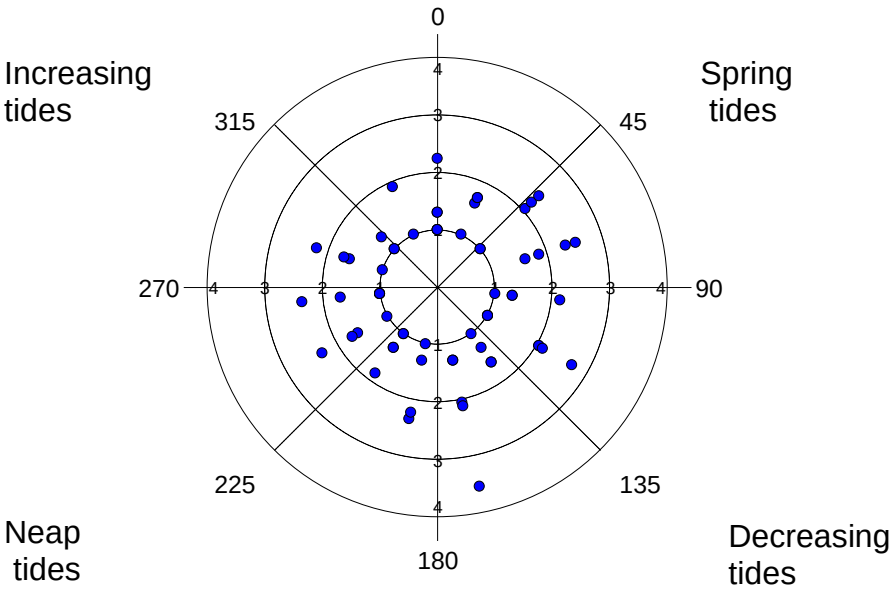

Figure 11.15 Polar plot of log_{10} *E. coli* results at Drovinish on the spring/neap tidal cycle

A low but significant correlation was found between log_{10} *E. coli* results and the spring/neap cycle at Drovinish (circular-linear correlation, r=0.243, p=0.023). The highest results all occurred when sampling was undertaken as tides decreased from springs to neaps.

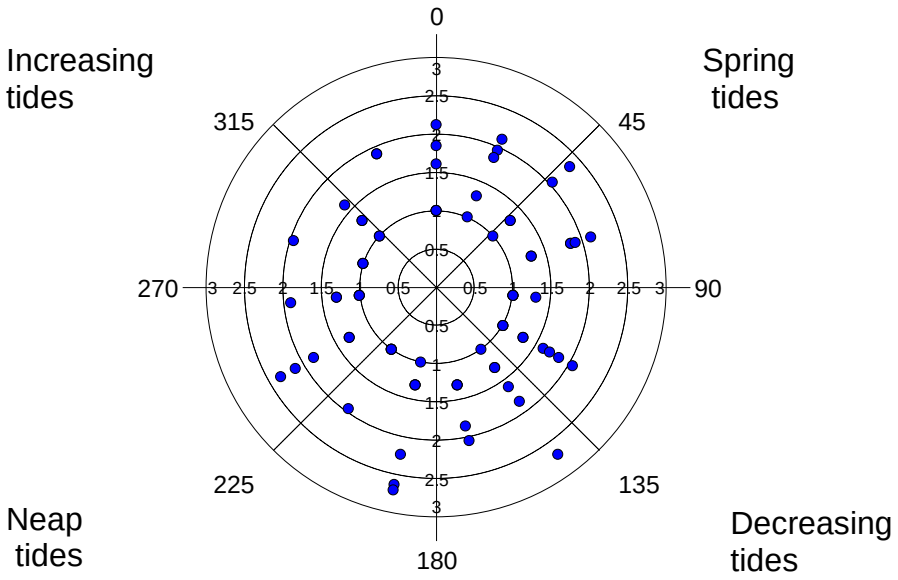

Figure 11.16 Polar plot of log_{10} *E. coli* results at Linngeam on the spring/neap tidal cycle

No significant correlation was found between log_{10} *E. coli* results and the spring/neap cycle at Linngeam (circular-linear correlation, r=0.087, p=0.554).

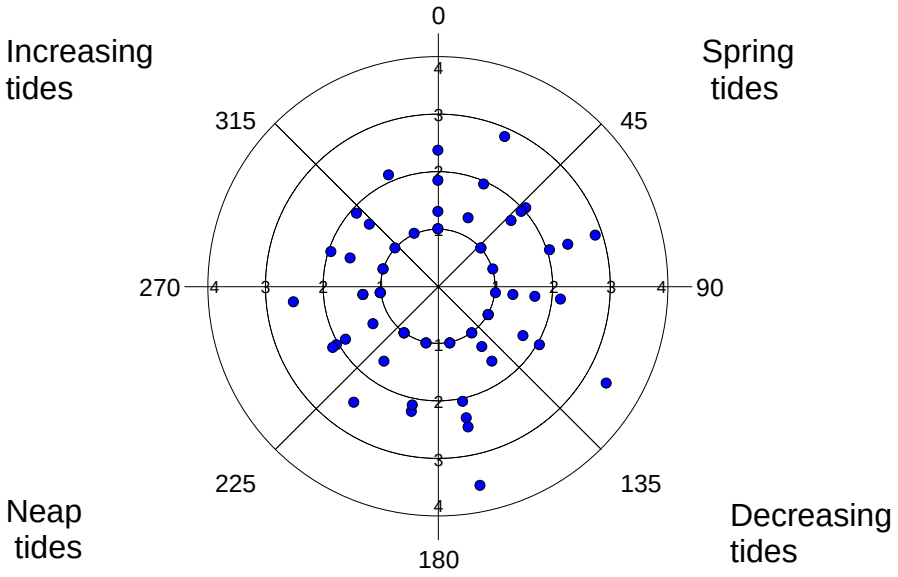

Figure 11.17 Polar plot of log_{10} *E. coli* results at Torranish on the spring/neap tidal cycle

No significant correlation was found between log_{10} *E. coli* results and the spring/neap cycle at Torranish (circular-linear correlation, r=0.144, p=0.274).

High/Low Cycle

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As *E. coli* levels in some shellfish species can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (hours post high water) was compared with *E. coli* results. Figures 11.18, 11.19 and 11.20 present polar plots of log_{10} *E. coli* results on the lunar high/low tidal cycle for the three production areas. High water is located at 0º, and low water at 180º.

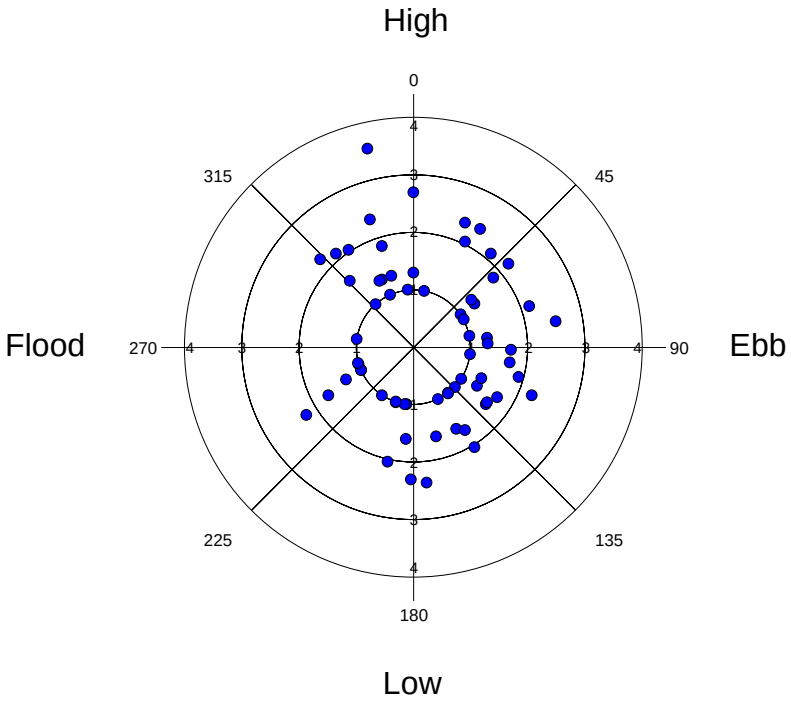

Figure 11.18 Polar plot of log_{10} *E. coli* results at Drovinish on the high/low tidal cycle

A significant correlation was found at Drovinish between *E. coli* results and the high/low tidal cycle (circular-linear correlation, r=0.266, p=0.011). There is a tendency towards higher results between late flood tide and low water.

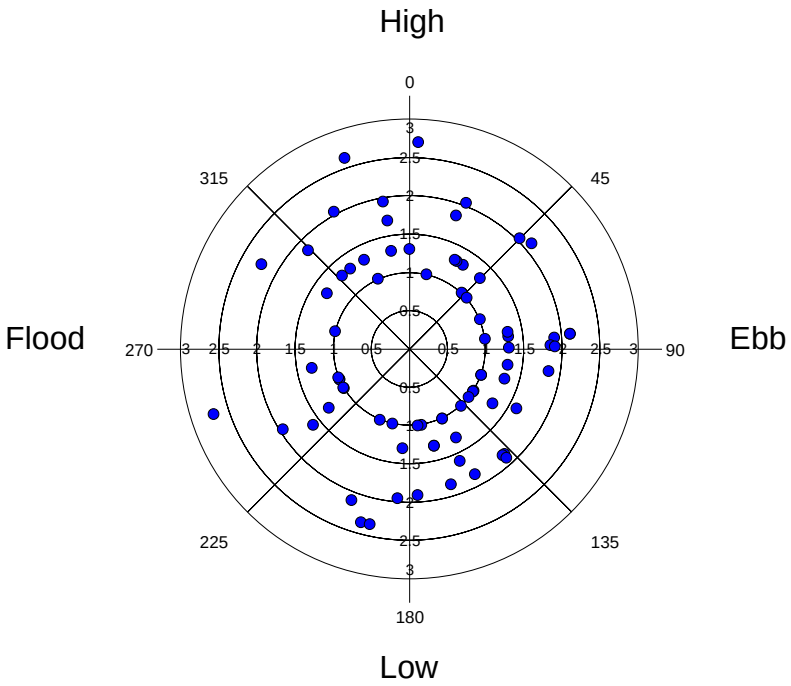

Figure 11.19 Polar plot of log_{10} *E. coli* results at Linngeam on the high/low tidal cycle

No significant correlation was found at Linngeam between *E. coli* results and the high/low tidal cycle (circular-linear correlation, r=0.134, p=0.253).

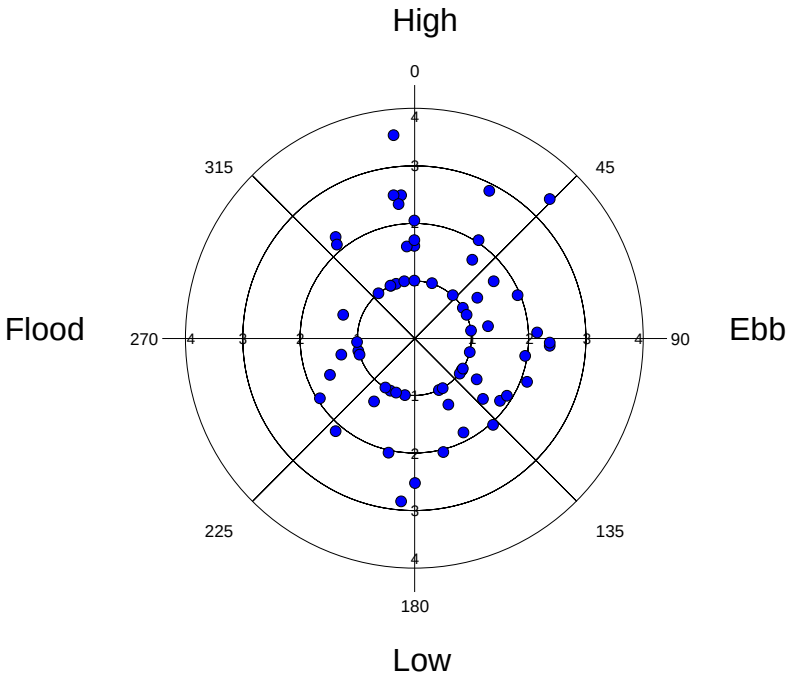

Figure 11.20 Polar plot of log_{10} *E. coli* results at Torranish on the high/low tidal cycle

No significant correlation was found at Torranish between *E. coli* results and the high/low tidal cycle (circular-linear correlation, r=0.181, p=0.130).

11.6.3 Analysis of results by water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) and the feeding and elimination rates of shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. It is of course closely related to season, and so any correlation between temperatures and *E. coli* levels in shellfish flesh may not be directly attributable to temperature, but to other factors such as seasonal differences in livestock grazing patterns. Figure 11.21 presents scatterplots of *E. coli* results against water temperature for the three production areas.

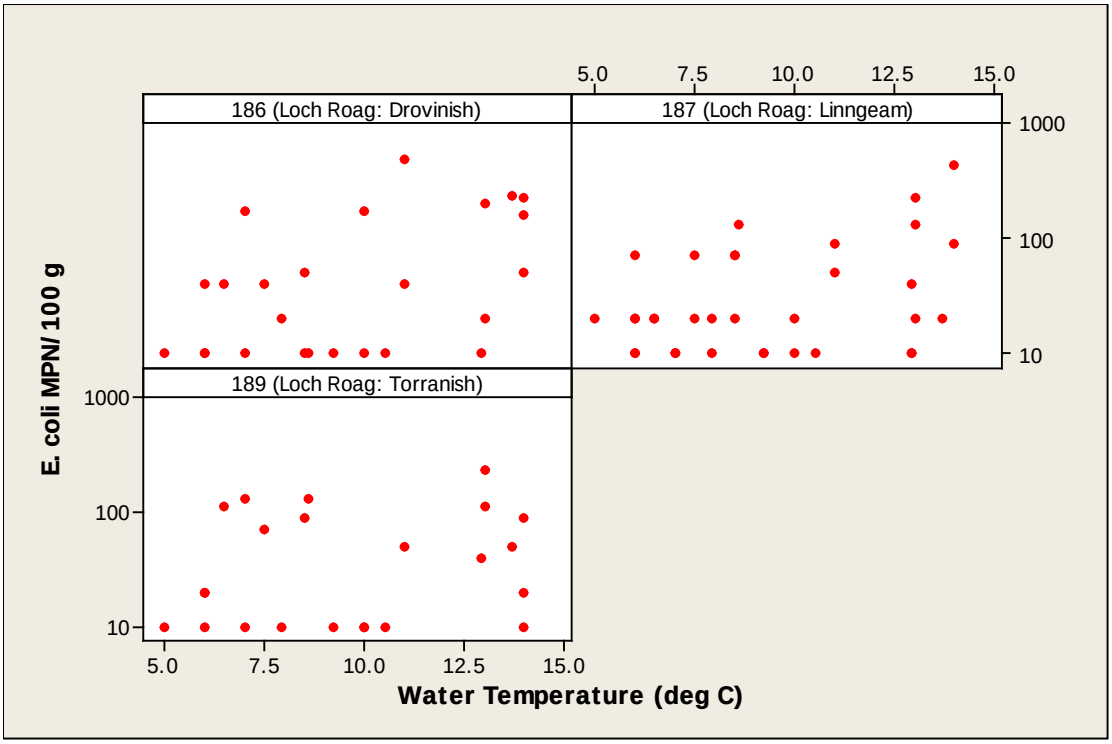

Figure 11.21 Scatterplot of result by water temperature

Water temperature was recorded for 82 of the 213 samples across the three production areas. A significant correlation was seen between *E. coli* results and water temperature at Drovinish (Spearman's rank correlation= 0.480, p=0.015) but not at Linngeam (Spearman's rank correlation= 0.318, p=0.067) or Torranish (Spearman's rank correlation= 0.168, p=0.442).

11.6.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater borne contamination at the site. Figure 11.22 presents scatter plots of *E. coli* result against salinity for the three production areas. No significant correlation was found between the *E. coli* result and salinity for any of the production areas (Spearman's rank correlation; Drovinish r=0.008, p=0.959; Linngeam r=0.205, p=0.144; Torranish r=-0.114, p=0.407).

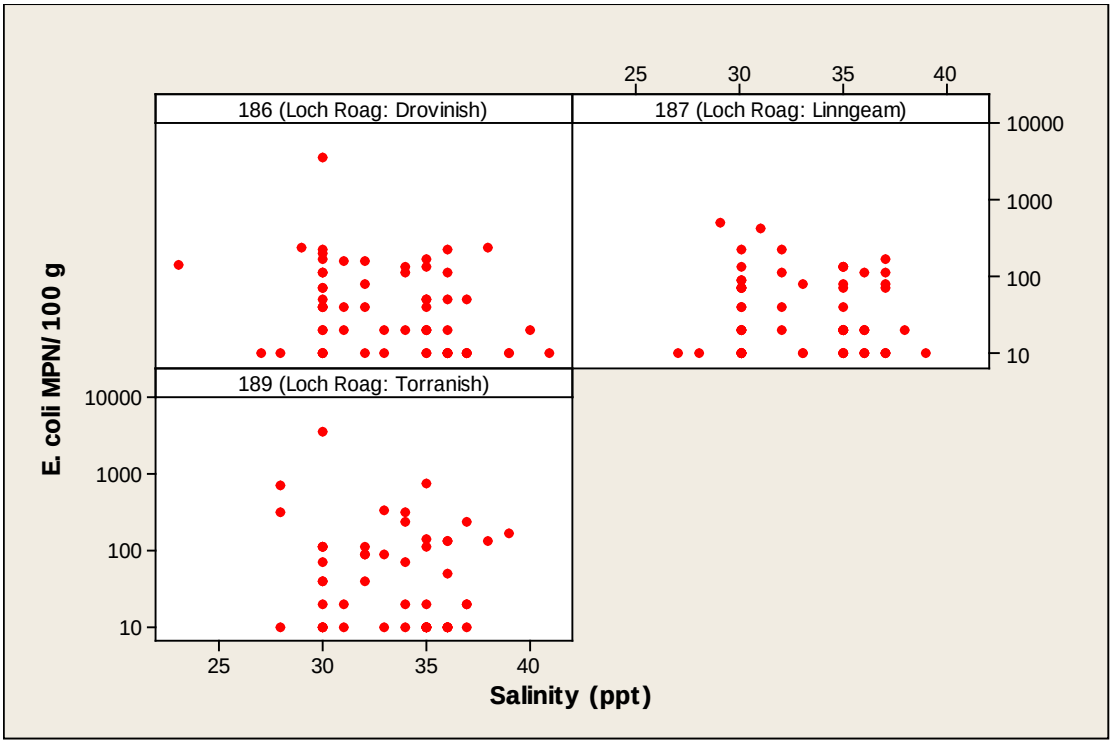

Figure 11.22 Scatterplot of result by salinity

11.7 Evaluation of results over 230 *E. coli* MPN/100g

A total of 13 samples gave a result of over 230 *E. coli* MPN/100g, details of which are presented in Tables 11.2, 11.3 and 11.4.

The greatest number of results exceeding 230 *E. coli* MPN/100 g was seen at Torranish. All of the high results were seen in summer or autumn. Significant levels of rainfall had occurred in the 7 days prior to sampling in most cases. Water temperature data was only available for two of the samples. The samples were taken under a range of water salinities. There did not appear to be a pattern with respect to the spring/neap or high/low tidal cycles.

Table 11.2 Historic *E. coli* sampling results over 230 *E. coli* MPN/100g –Drovinish

Drovinish								
Collection date	*E. coli* (MPN/100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tidal state (high/low)	Tidal state (spring/neap)
18/09/2007	3500	NB 139 324	7.0	53.6	*	30	High	Decreasing
07/09/2009	330	NB 1417 3207	15.4	40.4	*	*	Ebbing	Spring
06/06/2011	490	NB 1397 3232	*	*	11	*	High	Decreasing

* Data unavailable

Table 11.3 Historic *E. coli* sampling results over 230 *E. coli* MPN/100g - Linngeam

Linngeam								
Collection date	*E. coli* (MPN/100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tidal state (high/low)	Tidal state (spring/neap)
03/07/2006	430	NB 133 332[1]	0.1	5.2	14	31	Flooding	Neap
20/08/2007	500	NB 138 331[1]	7.0	23.2	*	29	High	Neap
17/09/2007	500	NB 145 336[2]	29.0	51.1	*	*	Flooding	Decreasing

[1]Cliatasay [2]Mol Mor * Data unavailable

Table 11.4 Historic *E. coli* sampling results over 230 *E. coli* MPN/100g - Torranish

Torranish								
Collection date	*E. coli* (MPN/100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tidal state (high/low)	Tidal state (spring/neap)
06/11/2006	700	NB 154 339	0.3	17.0	*	28	Low	Spring
21/08/2007	310	NB 156 338	0.1	18.1	*	28	High	Neap
18/09/2007	3500	NB 156 338	7.0	53.6	*	30	High	Decreasing
04/08/2008	750	NB 1563 3359	27.2	57.0	*	35	Ebbing	Spring
06/10/2008	320	NB 1512 3401	1.9	59.1	*	34	High	Decreasing
17/08/2009	330	NB 1510 3403	8.8	22.6	*	33	Low	Increasing
13/09/2010	2400	NB 1529 3402	16.4	25.4	*	*	Ebbing	Decreasing

* Data unavailable

11.8 Summary and conclusions

There are two areas where higher results tend to occur. One is on the western side of the present mussel lines at Drovinish, approximately midway along the lines with respect to the north-south direction. The other is on the north-eastern side of the lines at Torranish. Torranish has shown the greatest number of results exceeding 230 *E. coli* MPN/100g. However, *E. coli* levels in the three areas were not significantly different.

The time trend graphs showed that, at Linngeam and Torranish, there was a trend to higher results approximately every two years. There was no overall change in the extent of contamination at any of the three areas over the period in question. Results in summer and autumn tend to be higher than in winter and spring. A significant correlation was seen between *E. coli* results and rainfall in the 7 days prior to sampling at Drovinish and Torranish (but not Linngeam). No significant correlation was seen with rainfall in the 2 days prior to sampling. A low but significant correlation was found between *E. coli* results and the spring/neap tidal cycle at Drovinish (but not Linngeam or Torranish). There was also no significant correlation between *E. coli* results and the high/low tidal cycle in any of the three production areas.

The relatively small amount of data precluded the assessment of the effect of interactions between environmental factors on the *E. coli* concentrations in shellfish.

11.9 Sampling frequency

When a production area holds a non-seasonal classification, and where at least 24 results are available over the past 3 years, and the geometric mean of those results falls within a certain range, consideration can be given to reducing the sampling frequency from monthly to bimonthly.

The classification at Torranish has been a seasonal A/B within the past 3 years and so this area was not investigated further.

Both Drovinish and Linngeam have held year-round A classifications over the last 3 years. At Drovinish, 67 samples had been taken over the 3 year period from October 2008 to September 2011. The geometric mean of the results was 33.0 *E. coli* MPN/100 g. At Linngeam, 36 samples had been taken over the same period and the geometric mean of the results was 29.4 *E. coli* MPN/100 g. Both of the geometric mean values are greater than the class A limit of 13 given in the EURL Good Practice Guide and so it is not recommended that the sampling frequency be reduced.

12. Designated Shellfish Growing Waters Data

The Linngeam, Torranish and Drovinish production areas all fall within the Loch Roag designated shellfish growing water. The area was redesignated in 2002 and a full monitoring regime implemented in 2005. SEPA is responsible for ensuring that monitoring is undertaken for a variety of parameters, including faecal coliforms in shore mussels. The sampling point used for SGW monitoring at Loch Roag was NB 16000 34000. This lies near the Bernera Bridge and the mussel processing facility. The relative positions of the SGW boundaries, mussel farms and SGW monitoring point are shown in Figure 12.1.

Since 2007, SEPA have obtained shellfish classification monitoring results (*E. coli*) under an agreement with FSAS for the purposes of SGW monitoring. Those results have been used in the analysis in Section 11 of this report and so are not repeated here.

Table 12.1 SEPA monitoring results for shore mussels - Loch Roag

Year	Quarter	Faecal coliform results (FC/100g)
2003	Q1	-
	Q2	-
	Q3	200
	Q4	110
2004	Q1	20
	Q2	40
	Q3	290
	Q4	70
2005	Q1	<20
	Q2	<20
	Q3	18000
	Q4	50
2006	Q1	-
	Q2	70
	Q3	20
	Q4	-

- No result reported

All samples were collected from the same location. The geometric mean result for all samples is 77 FC/100 g. The majority of results ranged between <20 and 290 faecal coliforms/100 g, indicating relatively low levels of faecal contamination. However, one result of 18000 faecal coliforms/100 g was obtained in quarter 3 of 2005, indicating that episodically high results may occur at the sampling location.

Although levels of faecal coliforms are usually correlated to levels of *E. coli* at a ratio of roughly 1:1, the ratio depends on a number of factors, such as environmental conditions and the source of contamination. Comparison is further complicated by differences in accumulation between the different species of shellfish. Consequentially, the results presented in Table 12.1 are not directly comparable with the other shellfish testing results presented in this report.

Overall, the results indicate that while generally the level of contamination observed in shore mussels taken from the SEPA monitoring point is low, there is potential for episodes of very high levels of contamination.

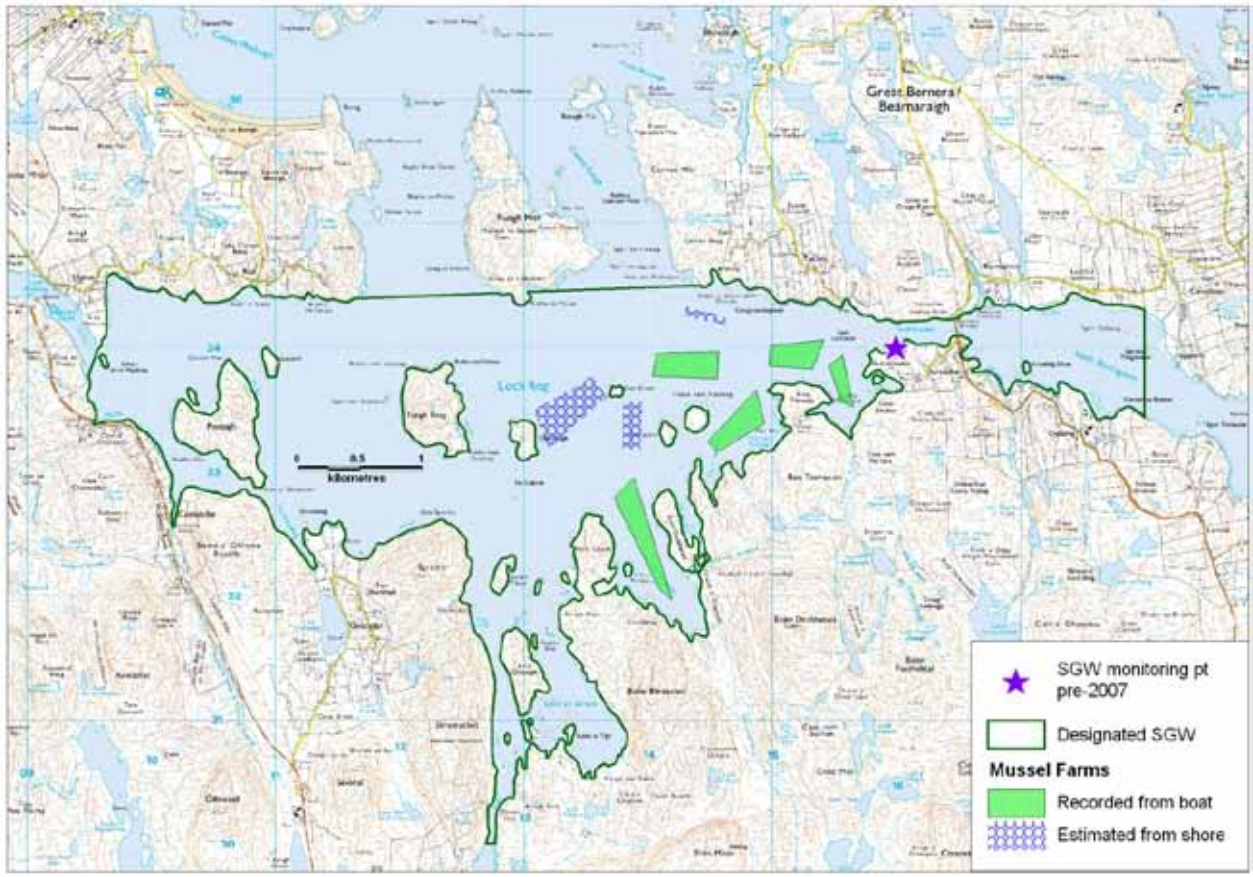

Figure 12.1 Designated shellfish growing water – Loch Roag

13. River Flow

There are no gauging stations on watercourses along the Loch Roag coastline.

The watercourses were listed in Table 13.1 were the most significant observed during the shoreline survey and were measured and sampled. The locations, together with the calculated loadings, are shown in Figure 13.1. There had been heavy rain overnight and on the day prior to the first day of the shoreline survey and there were showers on the second day. Where the bacterial loading is labelled on the map, the scientific notation is written in digital format, as this is the only format recognised by the mapping software. So, where normal scientific notation for 1000 is 1 x 10^3, in digital format it is written as 1E+3

Table 13.1 Watercourse loadings for Loch Roag: Linngeam, Torranish, and Drovinish

No.	Grid Ref	Description	Width (m)	Depth (m)	Flow (m/s)	Flow in m^3/day	*E.coli* (cfu/ 100ml)	Loading (*E.coli* per day)
1	NB 14505 31729	Drovinish River	2.5	0.13[1]	0.691[1]	25500[2]	<100	$<2.5x10^{10}$
2	NB 16404 33987	Stream	0.22	0.08	0.023	35	1700	$5.9x10^8$
3	NB 16078 33655	Stream	0.40	0.05	0.098	170	<100	$<1.7x10^8$
4	NB 15653 33230	River Torranish	1.06	0.29[1]	0.221[1]	3750[2]	100	$3.7x10^9$

[1]Average of two measurements
[2]Calculated from the measurements for separate sections

The observed watercourses were all located on the southern shore of the loch. The loadings given in Table 13.1 are relatively low, and some streams that had very low flows were observed, despite the heavy rain that occurred at the time of the survey.

Three small streams that were too small to sample and measure, and areas of land seepage/run-off were also observed along the shore (the details of these are in the shoreline survey report). Therefore, although the watercourses included in Table 13.1 represent the most significant potential freshwater sources in the area, other run-off may cause very localised deteriorations in water quality. Overall, the rivers Drovinish and Torranish will pose the greatest potential sources of waterborne contamination to the fisheries, and would have greatest impact on the southern ends of the lines closest to them.

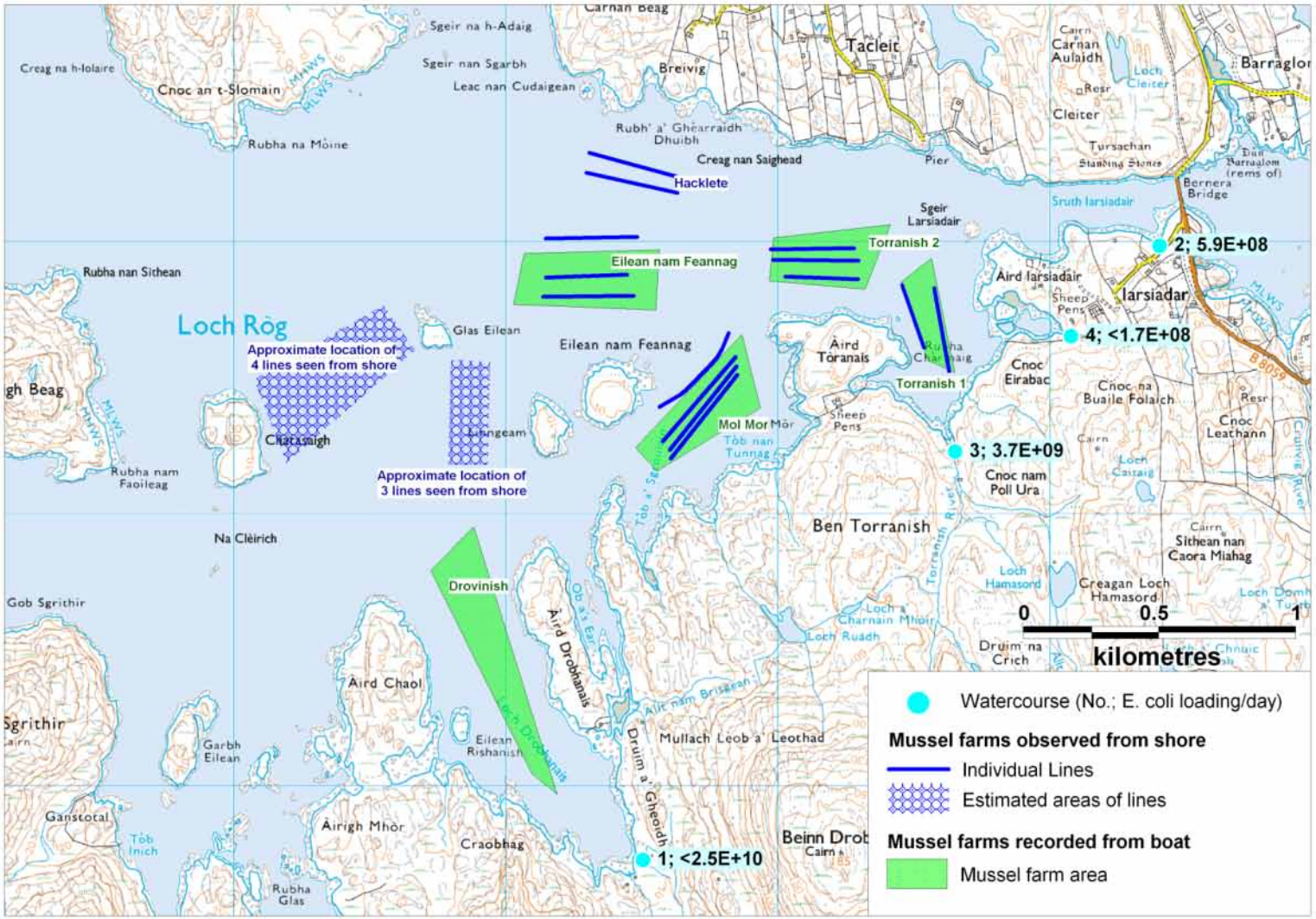

Figure 13.1 Map of watercourse loadings at Loch Roag: Linngeam, Torranish, and Drovinish

14. Bathymetry and Hydrodynamics

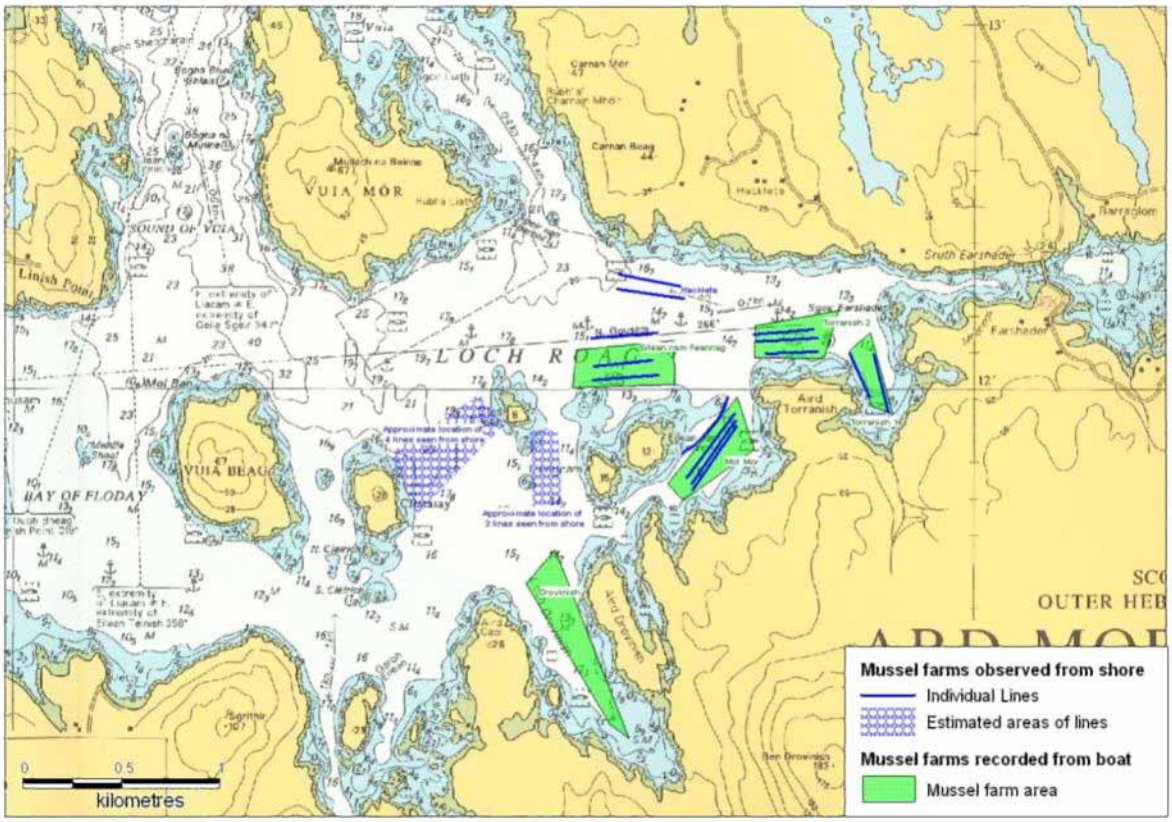

Figure 14.1 Bathymetry at Loch Roag: Linngeam, Torranish and Drovinish

Loch Roag is a large, complex sea loch situated on the western coast of the Isle of Lewis. It opens to the sea to the north. For the purposes of this report, the three areas within the broader water body will be referred to as Loch Roag West, Loch Roag and Loch Roag East. West and East Loch Roag lie either side of Great Bernera island. West Loch Roag and Loch Roag lie either side of Vuia Mòr while Loch Roag and East Loch Roag are connected by a strait between Great Bernera and the mainland of Lewis. The basin identified as Loch Roag on the chart is often included in the broader West Loch Roag term. There are a large number of islands and inlets within Loch Roag: a number of the latter are named as separate lochs. The mussel farms that are the subject of the present report lie principally in the area of Loch Roag between Lewis and Great Bernera, west of the Bernera bridge.

Depths in the vicinity of the mussel lines vary from between 8 to more than 20 metres. It should be noted that the depths on the chart are based on an Admiralty leadline survey undertaken in 1902. The extent of drying areas tends to be limited around the rocky shore but is greater in some of the inlets and between some of the islands.

14.1 Tidal Curve and Description

The two tidal curves below are for Little Bernera, located on the north side of Great Bernera. The tidal curves have been output from UKHO TotalTide. The first is for

seven days beginning 00.00 BST on 18/07/11 and the second is for seven days beginning 00.00 BST on 25/07/11. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle and cover the period during which the shoreline survey was undertaken.

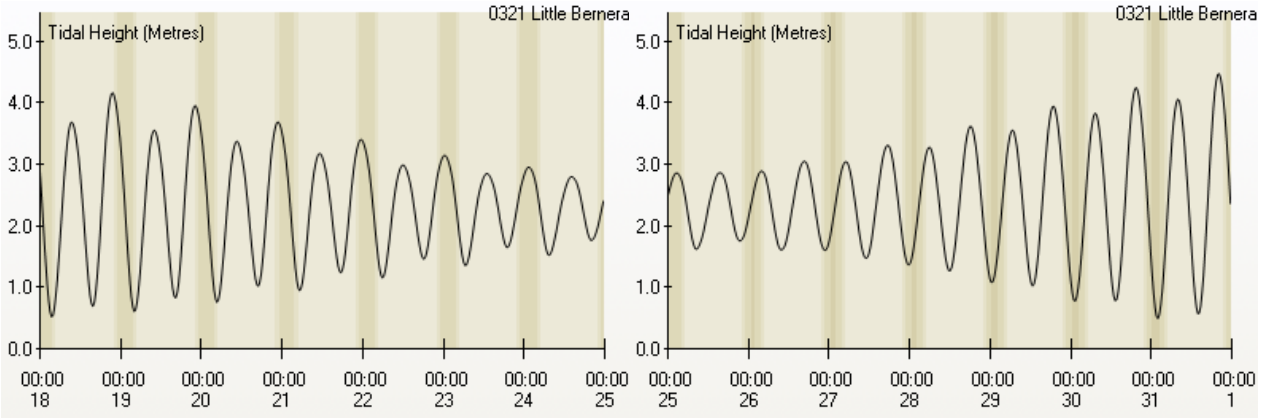

Figure 14.2 Tidal curves for Little Bernera

The following is the summary description for Little Bernera from TotalTide:

0321 Little Bernera is a Secondary Non-Harmonic port.
The tide type is Semi-Diurnal.

HAT	5.2 m
MHWS	4.3 m
MHWN	3.1 m
MLWN	1.6 m
MLWS	0.5 m
LAT	-0.1 m

Predicted heights are in metres above chart datum. The average tidal range at spring tide is 3.8 m and at neap tide 2.6 and so tidal ranges at this location are moderate (mesotidal).

14.2 Currents

Tidal stream arrows on the hydrographic chart indicate that the flood tide stream in the main channel between Great Bernera and Aird Torranish reaches 0.7 knots (approximately 0.35 m/s), flowing along the channel towards the bridge. They also indicate that the ebb tide stream reaches the same speed but flows west-north-west towards the channel between Vuia Mòr and Great Bernera. Flood and Ebb tide streams in the latter channel are shown as reaching 0.4 knots (approximately 0.2 m/s) flowing south-south-east on the flood and north-north-east on the ebb.

SEPA provided current meter study data for three locations within Loch Roag. The locations are shown in Figure 14.3. The survey periods were as given in Table 14.1.

Unfortunately, none of the locations were in close vicinity to the mussel farms. However, the data will inform the general assessment of current movements within Loch Roag.

Table 14.1 Survey periods for the fish farm current meter studies

Location	NGR	Survey period
Gousam	NB 11227 33758	07/07/2009-22/07/2009
Vuia Beag	NB 12109 32983	07/07/2009-22/07/2009
Kyles Vuia	NB 13514 35413	06/05/2004-03/06/2004

Polar plots of the current directions and speeds at the three locations, together with the wind direction and speeds over the relevant periods, are shown in Figure 14.4. Currents are presented in cm/s. Wind speeds are presented in m/s. As per convention, currents are plotted against the direction towards which they are travelling. The length of each segment in a plot relates to the proportion of observations lying in that direction. The speed relates to the colour key beneath each plot. The proportion that each colour takes up in an individual segment relates to the proportion of observations in that direction having speed in that range. Clear areas at the centre of each plot are proportional to the amount of data showing no, or negligible, current. Directions are in degrees magnetic.

The plots show that there were no or imperceptible currents at both Gousam and Vuia Beag over a large proportion of the monitoring period, with the proportions being greater at mid-depth and near-surface at Gousam than Vuia Beag. At Gousam, there is some directional component at mid-depth and near-surface but this differs between the two depths. Current speeds at the two locations were all <15 cm/s (0.15 m/s; 0.3 knots).

In contrast, the plots for Kyles Vuia show a marked bidirectional current, the directions of which coincide with that of the channel and the tide stream arrows on the hydrographic chart. Maximum current speeds were in the region of 40 cm/s (0.4 m/s; 0.8 knots). This is a little larger than the 0.4 knots indicated on the hydrographic chart.

Currents flowing through the narrows by Bernera Bridge will be faster than in the broader channels. However, the severe restriction at the bridge means that the volume of water exchanged through that route will be much less than that exchanged with the rest of Loch Roag to the west.

At the maximum current speed of 0.4 m/s, contaminants would be expected to be taken a distance of approximately 6 km over a flood or ebb tide, ignoring any effects of dilution or dispersion. However, most currents within the area are much lower than this and transport distances would be expected to be more in the order of 1 to 2 km.

It has been calculated that the flushing time for West Loch Roag (including the Loch Roag basin) is approximately 8 tidal cycles (4 days) (Tyrer & Bass, 2005). This is a moderate flushing time: that calculated for other lochs varies between 0 and 14 days (Edwards & Sharples, 1991). Tyrer and Bass calculated the mean daily water exchange in West Loch Roag as 248 million m^3/day.

Figure 14.3 Current meter locations

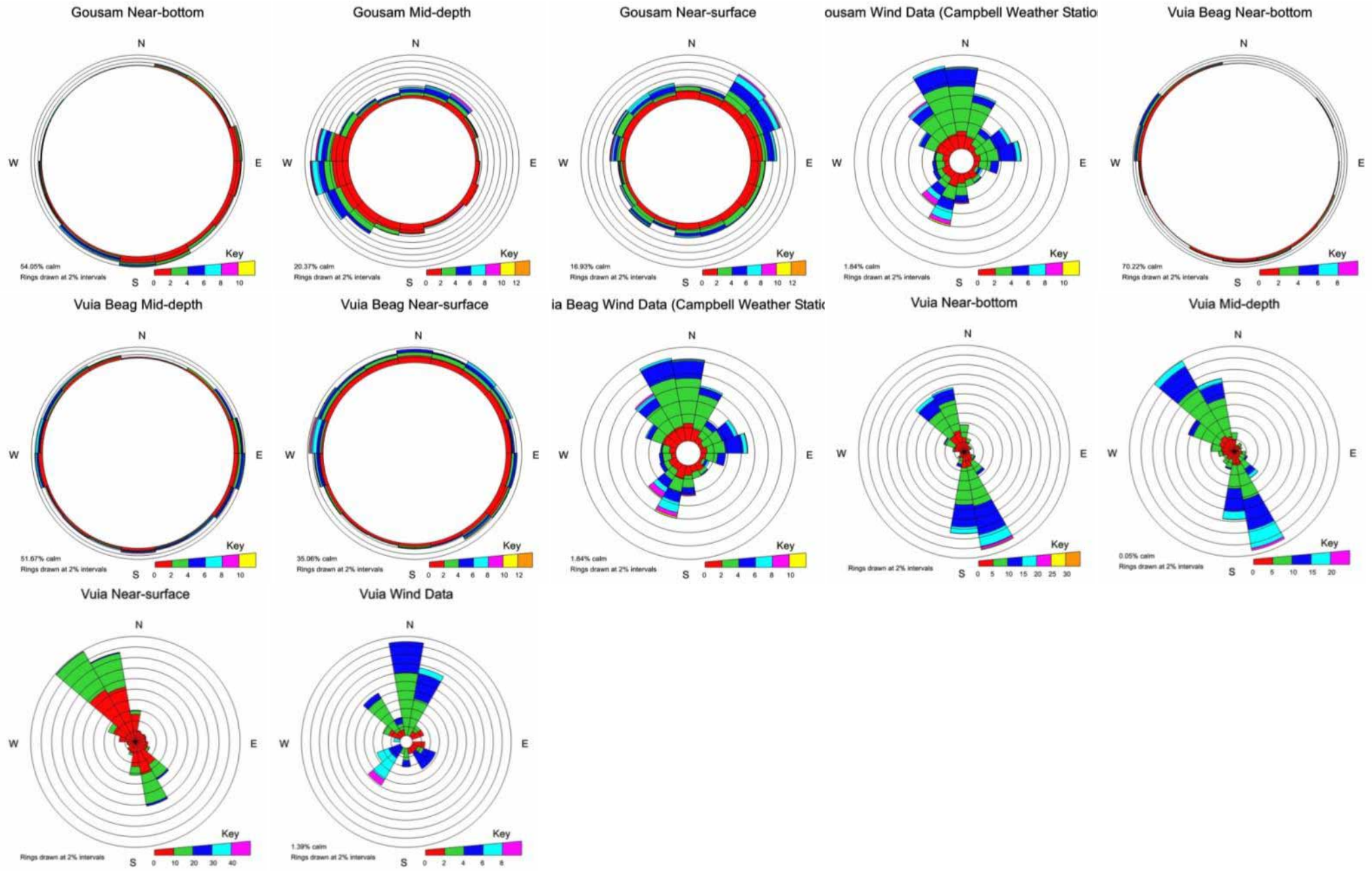

Figure 14.4 Current plots for Loch Roag

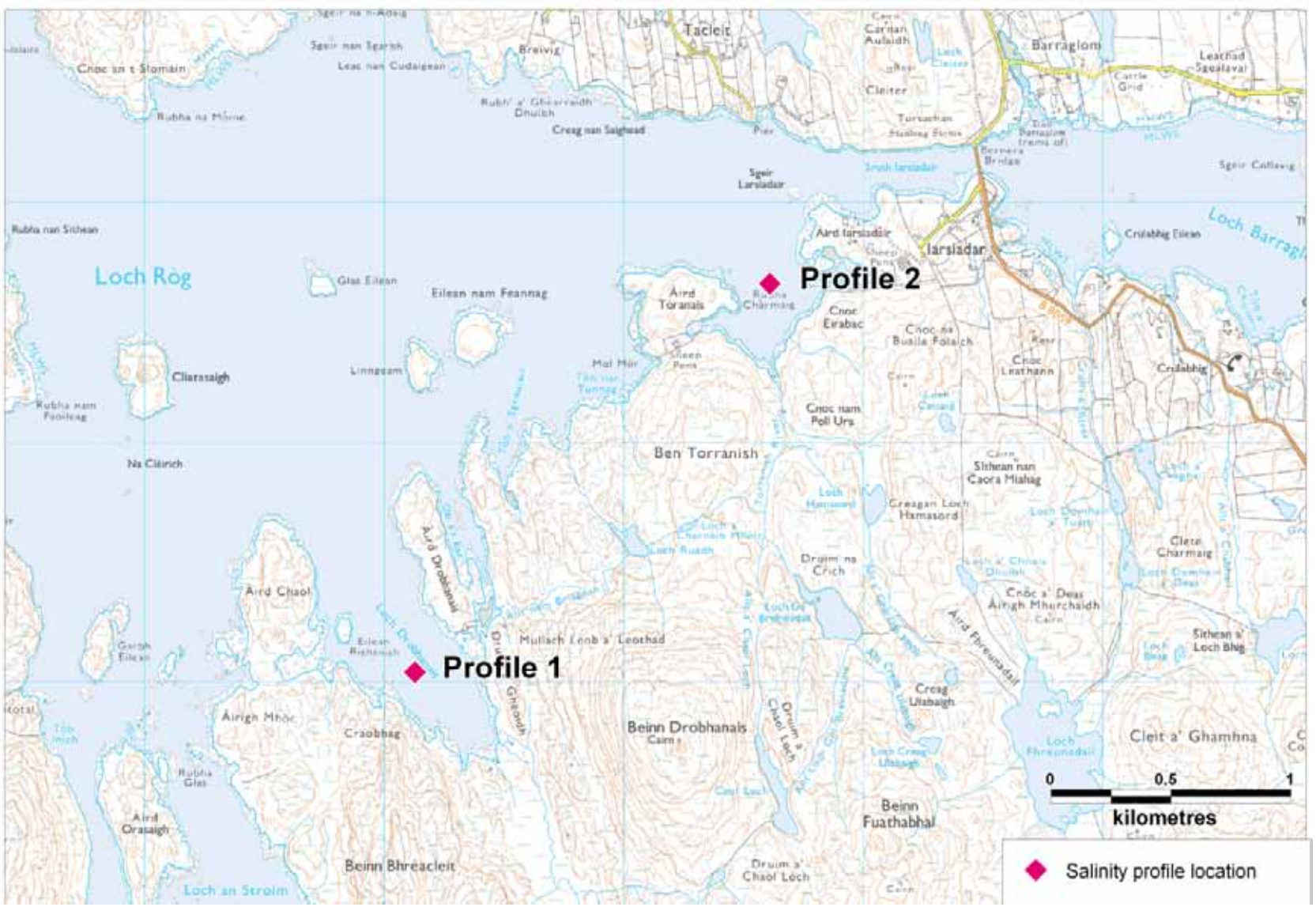

Figure 14.5 Salinity profile locations

14.3 Salinity effects

Two salinity profiles were recorded during the shoreline survey. The locations are shown in Figure 14.5 and the results are given in Table 14.2.

Table 14.2 Salinity profile results

Profile	Date and time	Position	Depth (m)	Salinity (ppt)	Temperature (°C)
1	19/07/2011 10:52:49	NB 1413 3204	0	25.5	12.9
			1	28.3	13.9
			3	35.5	13.8
			5	35.5	13.7
2	19/07/2011 11:31:51	NB 1561 3366	0	28.6	13.0
			1	34.6	13.6
			3	35.4	13.6
			5	35.5	13.5

The profiles indicate that there are significant surface freshwater effects at the two locations, with that at Drovinish being more marked than at Torranish. Both locations were in the vicinity of freshwater inputs. Salinity results (from laboratory analyses) for spot seawater samples taken during the survey gave results that ranged from 25.1 to 37.1 ppt.

14.4 Conclusions

Currents within the area are generally weak: in the eastern part of the area they will tend to follow the main channels. Given the generally low current speeds, there is the potential for wind-driven flows to be significant: in particular, southerly winds blowing across the area from Drovinish towards Vuia Mòr. There was no indication of wind effects in the current data analyses. There is also the possibility of density driven flows in those parts of the loch showing significant freshwater influence.

Drovinish and Torranish 1 will be impacted by any contamination arising from within those inlets on the ebb tide and may be exposed to contamination from outside the inlets on the flood tide. The southern end of the lines located to the west of Linngeam may be impacted by contamination arising in the Drovinish area during the ebb tide. At the Torranish 2 and Mol Mòr sites, the lines may be impacted by contamination being taken along the channels. As Mol Mor lies closer to the shore, it may also receive direct impacts from the shore during times of heavy rainfall. The lines at Eilean nam Feannag are probably sufficiently far from land-based sources of contamination that they will not be significantly impacted by contamination transported in the current through the main channel. The ends of the lines located between Glas Eilean and Cliatasay closest to those islands may receive some direct run-off during heavy rainfall though otherwise are unlikely to be impacted by land-based contamination.

15. Shoreline Survey Overview

A shoreline survey was conducted on the 19th and 20th of July 2011 under predominantly rainy conditions.

The mussel farms were observed by boat under misty and rainy conditions, and then again from shore under clear conditions. A large number of mussel farms were present in this area. Therefore, the area was surveyed from land and positions of the fisheries estimated. Some lines were reportedly used only for spat collection, though some of these clearly had a large number of floats on, indicating considerable weight on the lines.

Few discharges to water were observed. The harvester's processing base is located on the south shore of the loch, toward the east end of the production area. Mussels were being cleaned and sorted on the days of survey, and the processing discharge was observed in flow. No separate septic discharge pipe was clearly identified. Work boats were present at the shorebase and a small number of open boats were observed moored near other jetties around the loch. Homes along the shore at Tacleit and around the mussel base all have septic tanks but no discharge pipes were observed.

Of the farm animals observed around the area, sheep had most frequent access to the shoreline and their hoof prints and droppings were evident along much of the shore. Wild geese and eider ducks were observed, and goose droppings were observed in large numbers on the shoreline. Just under 50 geese were observed near the western edge of the production area. Though no seals were observed, they were reportedly sometimes present. Small numbers of gulls and wading birds were observed throughout the area.

Two rivers, two streams and three watercourses that were too small to measure or sample were observed along the southern shore of the fishery. Evidence of overland runoff or seepage was observed primarily along the southern shoreline but also in one location along the northern shore. On the day shellfish were sampled, the surface seawater at the Torranish and Drovinish fisheries was tea-coloured, indicating freshwater influence in these areas. Salinity profiles taken in these areas indicated higher fresh-water influence at the surface.

Water samples taken from watercourses and the loch returned results ranging from <1 to 1700 *E. coli*/100 ml. One seawater sample, taken from the same location on the Torranish 1 site as the salinity profile, had a result of 200 *E. coli*/100 ml, indicating significant faecal contamination in the seawater at this location. As the sample was taken near the surface, it is likely to have contained a higher concentration of faecal contaminants carried via freshwater sources to the site. The highest freshwater result (1700 *E. coli*/100 ml) came from a small stream east of Iarsiadar.

Mussel samples were taken where possible, as few of the sites visited by boat had sufficient mature stock on for sampling. Results ranged from 20 to 330 *E. coli* MPN/100 g, with the highest result found in the sample taken at the Drovinish site.

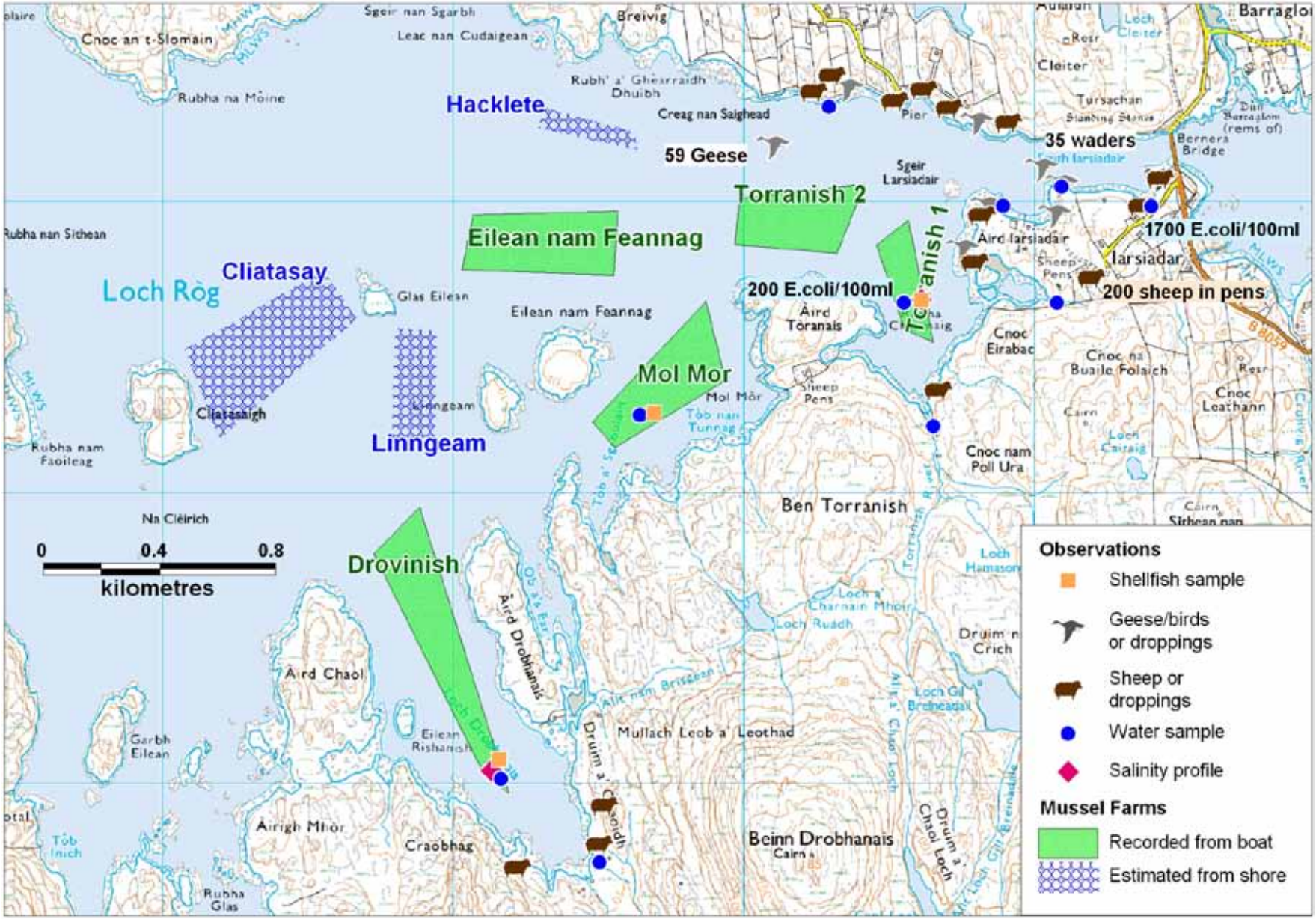

Figure 15.1 Summary of shoreline survey findings for Loch Roag: Linngeam, Torranish, and Drovinish

16. Overall Assessment

Human sewage impacts

There is little direct impact of human sewage on the fishery. The nearest community discharge, Kirkibost dun Innes, lies over 2.5 km east of the Torranish 1 mussel farm. It has a relatively small consented flow, which is likely to be substantially diluted within the water volume available and therefore is considered unlikely to substantially impact water quality at the Torranish production areas, which lies nearest the discharge.

The greatest risk from human sewage to the fishery is from the settled areas along the shores of Great Bernera and at Iarsiadar, with the Torranish and Hacklete sites lying in closest proximity to these.

Agricultural impacts

There is no arable agriculture in the vicinity of the fishery. Reported agricultural practices, as outlined in Section 7, suggest that livestock are likely to be kept in or near areas with crofts. During the shoreline survey, sheep were observed along the eastern shores of the area, with the majority of animals seen near Iarsiadar and Tacleit. However, it was noted that animals were being rounded up at the time and the largest number of sheep were observed at the pens outside Iarsiadar. Some sheep were seen on rough grazing at the head of Loch Drovinish, suggesting that the animals are grazed more widely in this area than is reportedly normal practice for the island. Sheep in the area have access to the shoreline and to watercourses. Therefore contamination from faeces will occur both by direct deposition to the intertidal shore and through rainfall runoff from the land around the fishery.

Based on the distribution of animals seen during the shoreline survey, the most likely impacts are to the waters adjacent the crofts at Tacleit, near Iarsiadar and to Loch Drovinish. However, sheep are likely to wander across much of the land area, particularly along the southern shore. The burns at Torranish and Drovinish are likely to carry faecal contamination from sheep across the wider area to the fishery. Therefore, the Drovinish and Torranish sites, and potentially the Hacklete site, are most likely to be impacted.

Wildlife impacts

Potential wildlife sources of faecal contamination are geese, other water birds, seals and deer. Geese and their droppings were observed in significant numbers during the shoreline survey, and they are likely to contribute to levels of faecal contamination carried in streams and direct runoff from land. They may also deposit faeces directly to the water at or near the fisheries, though the timing and location of this type of impact is not predictable. Though neither seals nor deer were observed during the survey, they are known to be present in the area. Deer droppings are likely to be carried via fresh-water runoff from land, and so are likely to contribute to the faecal indicator bacteria

loads found in local watercourses. Seal colonies are located outside the area, to the north of the loch and therefore due to weak tidal flows in the area are not likely to contribute significantly to faecal bacteria found at the fisheries. However, as seals are found within production area waters from time to time, they may contribute faecal bacteria to the waters when present.

Contributions of faecal bacteria from wildlife sources are likely to be highest near where geese are present, along or near the shorelines where grassland can be found on the islands within the loch and along the Tacleit and Iarsiadar shores.

Seasonal variation

There is likely to be some increase in human population during the summer holiday months though this is not quantified. There is also likely to be an increase in livestock populations, with larger numbers of sheep present from lambing until animals are sent off to market in the autumn. While geese are present year-round, their numbers may be higher in winter. Numbers of seabirds are likely to be higher in summer, when they are on nests and close to shore.

Rainfall varies with season, with higher rainfall observed in winter. However, extreme rainfall events were found in all months and these events after periods of dry weather, as is more likely to occur in summer and autumn, are most likely to result in higher levels of contamination in runoff. Wind direction was also found to vary seasonally, with lighter winds overall and a higher incidence of north-easterly winds occurring during spring and summer. Wind-driven circulation may be significant and north-easterly winds may tend to drive contaminants arising from the southern shoreline against the shore.

An assessment of historical microbiological monitoring data indicated significant seasonal variation in *E. coli* results, with results generally higher in summer and autumn, and particularly in autumn.

Rivers and streams

The rivers Torranish and Drovinish were found to be the largest potential sources of waterborne faecal contamination to the fisheries. All observed watercourses were located along the southern shore of the loch. Smaller watercourses and areas of land seepage may also lead to localised deterioration in water quality. All of these sources are most likely to impact the areas of mussel lines located closest to the shoreline or mouths of watercourses.

Movement of contaminants

Maximum tidal flow rates for the channel west of the bridge are reported to be 0.7 knots, or 0.36 metres/second, decreasing to around half that rate as the channel widens toward Vuia Mor to the northwest. This suggests that the most significant sources of contamination are likely to be very localised and

that likely particle transport distances are low and possibly more influenced by wind-driven flow. The easternmost side of the Torranish 1 site lies closest to Iarsiadar and therefore is most likely to be affected by contamination from sources arising there, particularly on an ebb tide. The southern end of the Drovinish site lies closest to the mouth of the Drovinish River and is likely to be more affected by that source than other locations on the fishery.

For all other sites, the parts of the mussel lines nearest either shore or islands will be most likely to receive impacts from land run-off contaminated with wildlife or livestock faeces.

Temporal and geographical patterns of sampling results

An analysis of historical *E. coli* results identified that there was no statistically significant variation in results between production areas, though the highest number of results exceeding 230 *E. coli*/100 g in shellfish flesh were found at Torranish. Sampling was found to have been rotated amongst the shellfish farms. From July 2011, samples for the Linngeam production area were taken from a new site, Aird Chaol, which does not lie within the current production area boundaries.

Time trend graphs showed a trend to higher results at Linngeam and Torranish approximately every two years, however this trend was not apparent at Drovinish.

Highest individual sampling results occurred along the western side of the Loch Drovinish site and from the north-eastern ends of the Drovinish 1 and Drovinish 2 sites. In general, lower results were seen for the Linngeam production area.

Conclusions

Contamination levels overall were relatively low in particular for the Linngeam production area. Of the three areas, Drovinish is the most likely to receive any impact from human sewage sources. The most likely sources of faecal contamination to the majority of the fishery are from diffuse agricultural sources and wildlife. There was a clear seasonal increase in *E. coli* results obtained in mussels, with summer and autumn seeing the highest contamination levels.

Although no statistically significant difference was found in overall results between the three production areas, there were differences in seasonality and spatial variation in results between the three. Linngeam was less affected by the identified potential sources of contamination than the other two production areas. Torranish was more likely to be affected by human and agricultural sources of faecal contamination. Therefore, there is insufficient basis for combining the areas.

17. Recommendations

It is recommended that the three production areas be retained due to differences in peak contamination levels and sources of contamination. Specific recommendations for each production area follow:

Torranish

Production area

It is recommended that the production area boundaries be amended to curtail the eastern boundary as contamination levels adjacent to sources at Iarsiadar may be higher. In addition, the boundary has been curtailed to exclude the inlet south of Iarsiadar, which receives runoff from the area where the sheep pens were in use. The western boundary has been adjusted to extend beyond the end of the Torranish 2 mussel lines as recorded during the survey.

The recommended boundaries are the area bounded by lines drawn between NB 1584 3422 to NB 1583 3400 and between NB 1576 3376 to NB 1584 3363 and between NB 1497 3366 to NB 1480 3446 and extending to MHWS.

RMP

It is recommended that the RMP be relocated to the north-eastern part of the Torranish 1 mussel farm, which historically has reflected the highest levels of contamination at the site. The recommended RMP is therefore NB 1556 3384.

Frequency

The classification at Torranish has been a seasonal A/B within the past 3 years and therefore continued monthly sampling is recommended.

Depth of sampling

As the sources of contamination are likely to arise from shore and be carried in freshwater near the surface, it is recommended that samples be taken from within 1 metre of the surface.

Tolerance

A sampling tolerance of 40 metres is recommended to allow for movement of the lines on the anchors.

Linngeam

Production area

It is recommended that the eastern boundary of the production area be adjusted to match that of the adjacent Torranish production area. The southern boundary has been amended to exclude the northern part of the

Loch Drovinish mussel farm, which overlapped the boundary. The northern and western boundaries have been retained unchanged.

Therefore, the recommended production area is the area bounded by lines drawn between NB 1497 3366 to NB 1480 3446 and between NB 1439 3311 to NB 1300 3309 and between NB 1300 3342 to NB 1300 3435 and between NB 1356 3470 to NB 1419 3470 and extending to MHWS.

RMP

It is recommended that the RMP be established at the Mol Mor site, near to the shore at NB 1462 3323.

Frequency

As the area did not meet the stability requirements for reduced sampling, continued monthly sampling is recommended.

Depth of sampling

As the sources of contamination are likely to arise from shore and be carried in freshwater near the surface, it is recommended that samples be taken from within 1 metre of the surface.

Tolerance

A sampling tolerance of 40 metres is recommended to allow for movement of the lines on the anchors.

Drovinish

Production area

As the mussel farm at Loch Drovinish overlaps the current production area boundaries, it is recommended that the production area boundaries be extended to the north to coincide with the amended Linngeam boundary. Although the Aird Chaol site to the west of Drovinish had been sampled for the Linngeam production area, geographically it is better placed within the Drovinish production area. Therefore, it is also recommended that the production area boundary be expanded to the west to include the Aird Chaol site.

The recommended production area is the area bounded by lines drawn between NB 1439 3311 and NB 1300 3309 and between NB 1300 3309 to NB 1291 3233 and between NB 1291 3233 to NB 1338 3239 and extending to MHWS.

RMP

It is recommended that the RMP be established at the Loch Drovinish site, near to the shore at NB 1397 3231.

Frequency

As the area did not meet the stability requirements for reduced sampling, continued monthly sampling is recommended.

Depth of sampling

As the sources of contamination are likely to arise from shore and be carried in freshwater near the surface, it is recommended that samples be taken from within 1 metre of the surface.

Tolerance

A sampling tolerance of 40 metres is recommended to allow for movement of the lines on the anchors.

A map identifying the recommended boundaries and RMPs is shown in Figure 17.1.

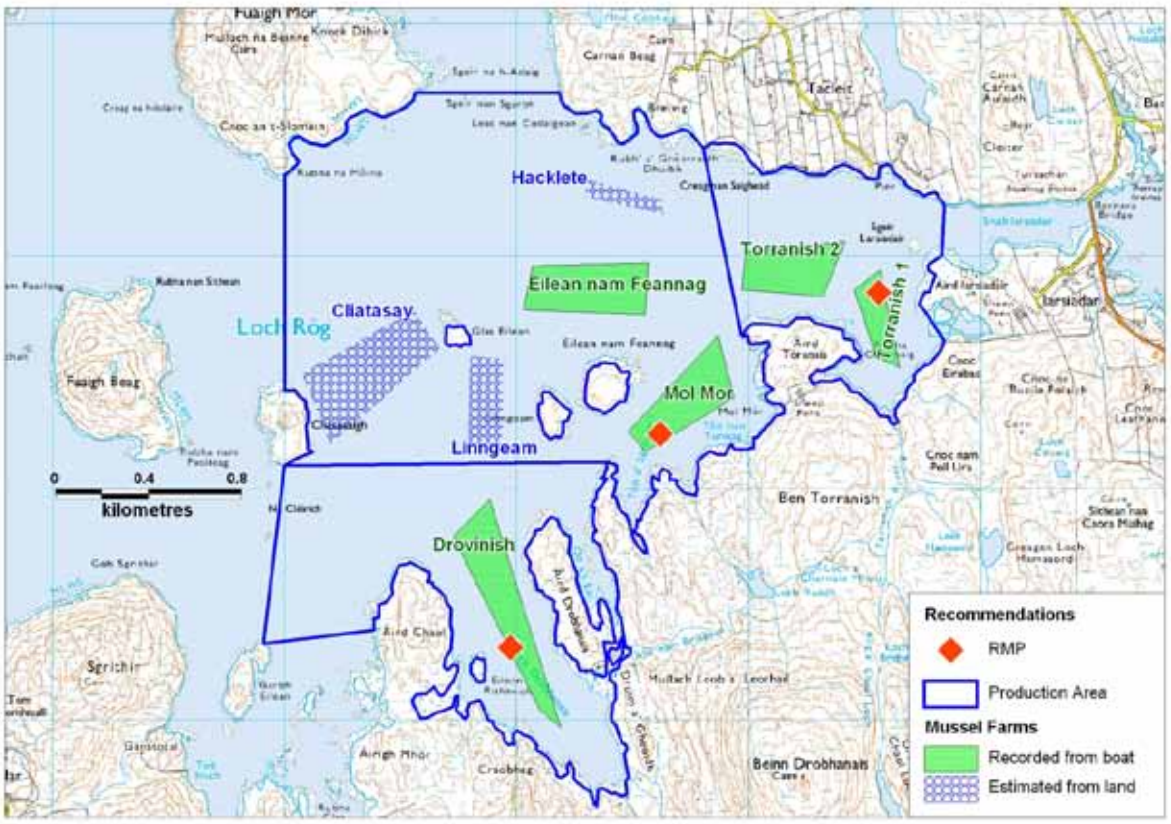

Figure 17.1 Map of recommendations at Loch Roag Linnegeam, Drovinish and Torranish

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19. List of Figures and Tables

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2. **General Information on Wildlife Impacts**
3. **Tables of Typical Faecal Bacteria Concentrations**
4. **Statistical Data**
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Geology and Soils Assessment Method

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

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

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

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

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

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

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

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

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

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

Glossary of Soil Terminology

Calcareous: Containing free calcium carbonate.

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

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

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

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

General Information on Wildlife Impacts

Pinnipeds

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

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

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

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

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

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

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

Cetaceans

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

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

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

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

Birds

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

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

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

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

Deer

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

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

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

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

Other

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

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

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Tables of Typical Faecal Bacteria Concentrations

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

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

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

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

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

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

Statistical Data

Results for: LTD combined

One-way ANOVA: Log_EC versus Production_area

```
Source            DF      SS     MS     F      P
Production_area    2   0.638  0.319  1.01  0.366
Error            210  66.278  0.316
Total            212  66.917

S = 0.5618   R-Sq = 0.95%   R-Sq(adj) = 0.01%
```

Results for: Drovinish

One-way ANOVA: Log_EC versus Season

```
Source  DF      SS     MS     F      P
Season   3   6.801  2.267  9.96  0.000
Error   63  14.340  0.228
Total   66  21.141

S = 0.4771   R-Sq = 32.17%   R-Sq(adj) = 28.94%

                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level    N    Mean   StDev  ---+---------+---------+---------+------
Autumn  15  2.0289  0.5832                          (------*------)
Spring  18  1.1764  0.3828  (------*-----)
Summer  18  1.7164  0.5356                 (-----*-----)
Winter  16  1.3987  0.3839        (------*------)
                           ---+---------+---------+---------+------
                            1.05      1.40      1.75      2.10

Pooled StDev = 0.4771

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

Individual confidence level = 98.95%

Season = Autumn subtracted from:

Season    Lower   Center    Upper   --+---------+---------+---------+-------
Spring  -1.2924  -0.8525  -0.4126   (-------*------)
Summer  -0.7523  -0.3124   0.1275            (-------*------)
Winter  -1.0824  -0.6302  -0.1779       (------*-------)
                                   --+---------+---------+---------+-------
                                  -1.20     -0.60      0.00      0.60

Season = Spring subtracted from:

Season    Lower  Center   Upper   --+---------+---------+---------+-------
Summer   0.1206  0.5401  0.9595                          (------*------)
Winter  -0.2100  0.2223  0.6547                    (-------*------)
                                 --+---------+---------+---------+-------
                                -1.20     -0.60      0.00      0.60


Season = Summer subtracted from:

Season    Lower   Center   Upper   --+---------+---------+---------+-------
Winter  -0.7501  -0.3177  0.1146            (-------*------)
                                   --+---------+---------+---------+-------
                                  -1.20     -0.60      0.00      0.60
```

Results for: Linngeam

One-way ANOVA: Log_EC versus Season

```
Source  DF      SS     MS     F      P
Season   3   5.088  1.696  9.99  0.000
Error   77  13.073  0.170
Total   80  18.161

S = 0.4120   R-Sq = 28.02%   R-Sq(adj) = 25.21%

                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level    N    Mean   StDev  ----+---------+---------+---------+-----
Autumn  15  1.9139  0.4283                      (------*------)
Spring  24  1.2392  0.3843  (----*-----)
Summer  19  1.6362  0.5364            (------*-----)
Winter  23  1.3458  0.2961     (-----*-----)
                           ----+---------+---------+---------+-----
                             1.20      1.50      1.80      2.10
Pooled StDev = 0.4120

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

Individual confidence level = 98.95%

Season = Autumn subtracted from:

Season    Lower   Center    Upper    -+---------+---------+---------+--------
Spring  -1.0304  -0.6746  -0.3189    (-------*------)
Summer  -0.6510  -0.2776   0.0957            (------*-------)
Winter  -0.9268  -0.5681  -0.2093      (-------*------)
                                    -+---------+---------+---------+--------
                                  -1.00     -0.50      0.00      0.50

Season = Spring subtracted from:

Season    Lower  Center   Upper    -+---------+---------+---------+--------
Summer   0.0651  0.3970  0.7289                       (------*------)
Winter  -0.2088  0.1066  0.4220                  (-----*-----)
                                    -+---------+---------+---------+--------
                                 -1.00     -0.50      0.00      0.50

Season = Summer subtracted from:

Season    Lower   Center   Upper    -+---------+---------+---------+--------
Winter  -0.6255  -0.2904  0.0447            (------*------)
                                    -+---------+---------+---------+--------
                                  -1.00     -0.50      0.00      0.50
```

Results for: Torranish

One-way ANOVA: Log_EC versus Season

```
Source  DF      SS     MS      F      P
Season   3  12.038  4.013  16.39  0.000
Error   61  14.938  0.245
Total   64  26.977

S = 0.4949   R-Sq = 44.63%   R-Sq(adj) = 41.90%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level    N    Mean   StDev  --+---------+---------+---------+-------
Autumn  14  2.3710  0.5485                        (----*-----)
Spring  17  1.1498  0.2891  (----*----)
Summer  18  1.6131  0.6251           (---*----)
Winter  16  1.4652  0.4507        (----*----)
                           --+---------+---------+---------+-------
                           1.00      1.50      2.00      2.50

Pooled StDev = 0.4949


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

Individual confidence level = 98.96%


Season = Autumn subtracted from:

Season    Lower   Center    Upper  ----+---------+---------+---------+-----
Spring  -1.6935  -1.2212  -0.7489  (------*-----)
Summer  -1.2243  -0.7579  -0.2915         (-----*------)
Winter  -1.3847  -0.9058  -0.4268      (------*------)
                                  ----+---------+---------+---------+-----
                                   -1.40     -0.70      0.00      0.70


Season = Spring subtracted from:

Season    Lower  Center   Upper  ----+---------+---------+---------+-----
Summer   0.0207  0.4633  0.9059                          (------*-----)
Winter  -0.1404  0.3154  0.7712                       (------*-----)
                                 ----+---------+---------+---------+-----
                                  -1.40     -0.70      0.00      0.70


Season = Summer subtracted from:

Season    Lower   Center   Upper  ----+---------+---------+---------+-----
Winter  -0.5975  -0.1479  0.3018                 (------*-----)
                                  ----+---------+---------+---------+-----
                                   -1.40     -0.70      0.00      0.70
```

Hydrographic Methods

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

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

<u>Background processes</u>

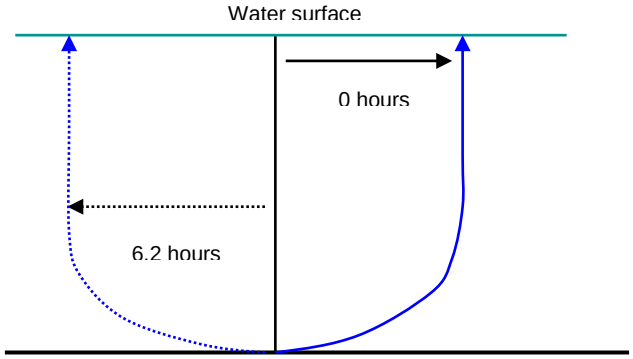
Currents in estuarine and coastal waters are generally driven by one of three mechanisms: 1) Tides, 2) Winds, 3) Density differences.

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

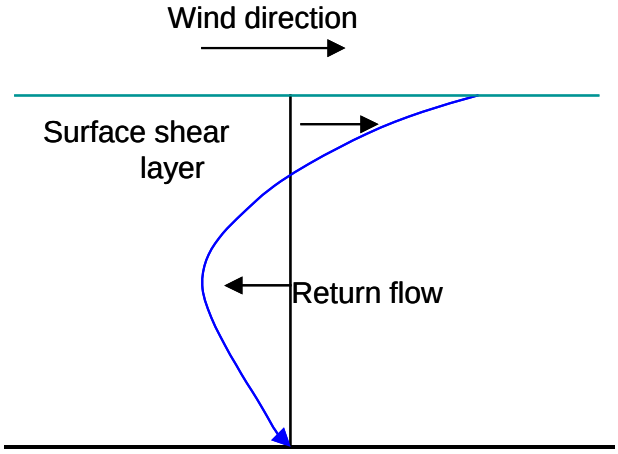
Wind and density driven current also lead to persistent movement of water and are particular important in regions of relatively low tidal velocities characteristic of many of the water bodies in Scottish waters. Whilst tidal flows generally move material in more or less the same direction at all depths,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

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

a)



b)



c)

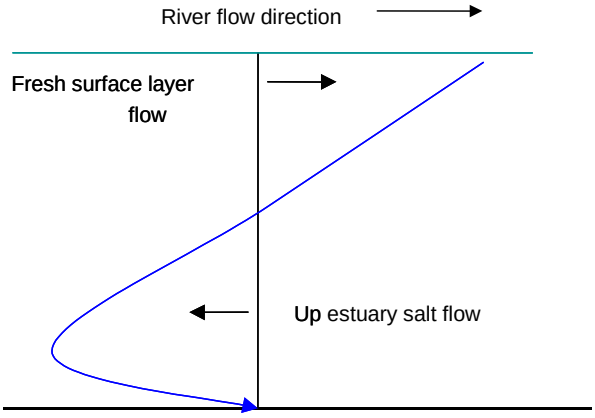


Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

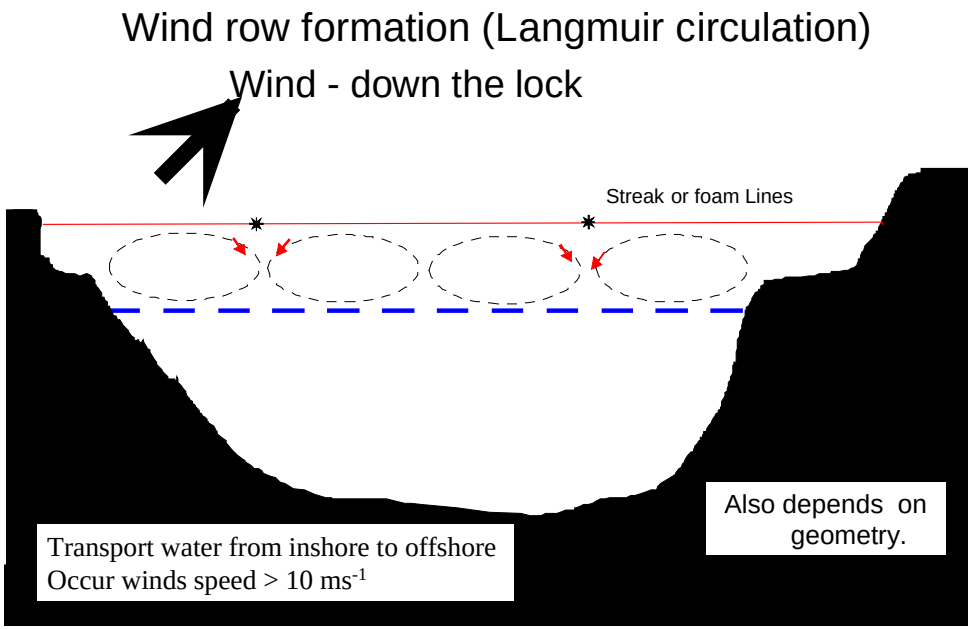


Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Non-modelling Assessment

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

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

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

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

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

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

References

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

Glossary

The following technical terms may appear in the hydrographic assessment.

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

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

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

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

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

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

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

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

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

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

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

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

Shoreline Survey Report

Prod. area: Loch Roag: Linngeam, Torranish and Drovinish
Site name: Various (see table below)
Species: Common mussel
Harvester: See table below
Local Authority: Comhairle nan Eilean Siar
Status: Existing
Date Surveyed: 19-20 July 2011
Surveyed by: Michelle Price-Hayward, Ron Lee
Nominal RMP: See table below
Area Surveyed: Iarsiadar to Torranish River, Tacleit, Loch Drovinish

Table 1. Production areas covered by survey

Production Area	Site Name	SIN	Harvester	RMP
Loch Roag: Linngeam	Cliatasay	LH 187 699 08	C. Mackenzie	NB 133 332
	Hacklete	LH 187 698 08	C. Mackenzie	
	Linngeam	LH 187 122 08	C. Mackenzie	
	Mol Mor	LH 187 710 08	David Smith	
Loch Roag: Torranish	Loch Torranish	LH 189 124 08	C. Mackenzie	NB 155 336
Loch Roag: Drovinish	Loch Drovinish	LH 186 121 08	C. Mackenzie	NB 140 329

Weather observations
19 July. Cloudy/misty, rain, winds N to NW F3-4, Temp 13C. Heavy rain overnight and previous day.
20 July. Overcast, dry with scattered light showers. Winds N F3, Temp 12C.

Fishery
There were a large number of mussel farms in this area, only some of which were visited by boat. Therefore, the area was surveyed from land and positions of the remaining fisheries estimated using photographs, bearings, and satellite imagery. Some lines were reportedly used only for spat collection, though some of these clearly had a large number of floats on, indicating considerable weight on the lines. Harvest at all active sites is reported to be year-round, in accordance with market demand.

The Linngeam production area consisted of five separate mussel farms, only two of which (Mol Mor and Eilean nam Feannag) were recorded by boat. The Haclete site consisted of 2 sets of long lines and was seen from the boat, though the harvester indicated that these lines were now only used for spat collection. The Mol Mor site was being harvested at the time of survey, and the harvester provided a sample from the stock that had just come off the lines. Much of the stock had been harvested from Eilean nam Feannag, leaving stock suitable for sampling at only one end of the lines.

Two additional sites were observed in passing and later recorded from the shore. One of these consisted of 4 sets of long lines lying between the islands of Cliatasaigh and Glas Eilean, the other consisted of 3 sets of long lines lying to the south of Glas Eilean and east of Linngeam. These are presumed to be the Cliatasay and Linngeam sites.

The Torranish fishery consisted of 5 double-headed long-lines with 8 metre droppers. Two of these were oriented north to south and three were oriented east to west and lay to the north of the other two.
The Drovinish fishery consisted of two double-headed longlines with 8 metre droppers, situated along the length of Loch Drovinish.

Sewage/Faecal Sources
There are no community sewage discharges in the area and few discharges to water were observed. The majority of homes are presumed to be on septic tanks discharging to soakaway systems. The harvester's processing base is located on the south shore of the loch, toward the east end of the production area. Mussels were being cleaned and sorted on the days of survey, and the processing discharge was observed in flow. No separate septic discharge pipe was clearly identified, though two other dry discharge pipes were observed. Homes along the shore at Tacleit and around the mussel base all have septic tanks, and no discharge pipes were observed. Sheep and sheep droppings were observed on both shores of the production area. Goose droppings were also observed in large numbers on the shoreline, and just under 50 geese were observed near the western edge of the production area.

Farming and livestock
Farming in the area is limited primarily to livestock production. Sheep, cattle and a small number of other livestock such as poultry, ducks, and horses were observed in the area. Of these, sheep had most frequent access to the shoreline and their hoof prints and droppings were evident along much of the shore.

Seasonal Population
Many of the homes in the area are in seasonal occupation. There is a picnic area at the northern end of the Bernera Bridge. This does not have toilet facilities.

Boats/Shipping
Boats were present at Iarsiadar, at a shorebase for the mussel farming operations in the loch. A small number of open boats were observed moored near other jetties around the loch.

Land Use
Land in the area is used for extensive livestock rearing and crofting. A significant number of the dwellings in the area are used for holiday accommodation.

Watercourses
Two rivers, two streams and three watercourses that were too small to measure or sample were observed along the southern shore of the fishery. Evidence of overland runoff or seepage was observed primarily along the southern shoreline but also in one location along the northern shore. On the day shellfish were sampled, the surface seawater at the Torranish and Drovinish fisheries was tea-coloured, indicating freshwater influence in these areas.

Wildlife/Birds
Wild geese and eider ducks were observed, and their droppings seen along much of the shoreline. The harvester reported that seals are sometimes present, though none were

observed during the survey. Small numbers of gulls and wading birds were observed throughout the area, numbers and locations were not specifically recorded.

Observations are listed in Table 2 and mapped in Figures 1 and 2.

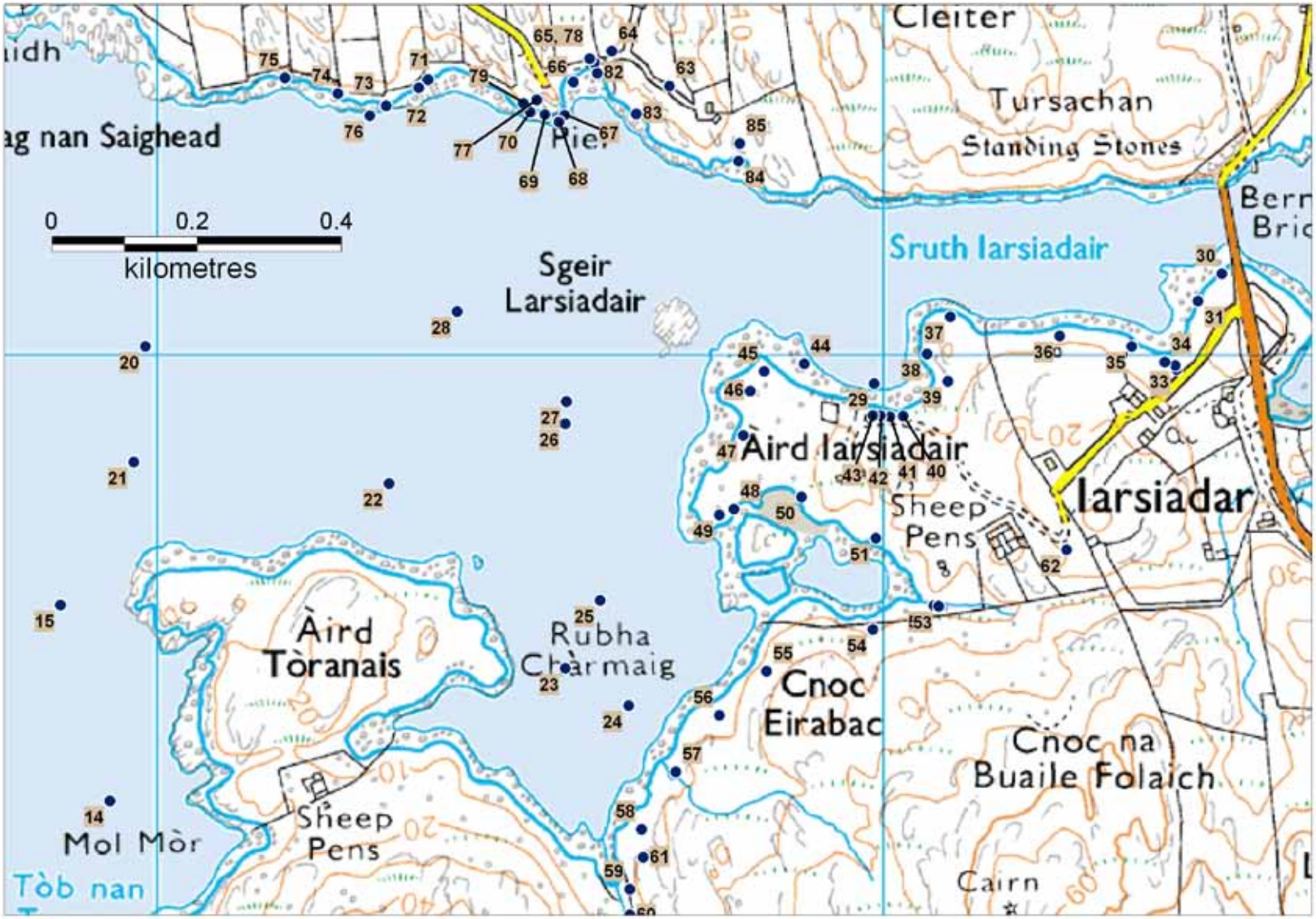


Figure 1. Map of Shoreline Observations- East side of fishery

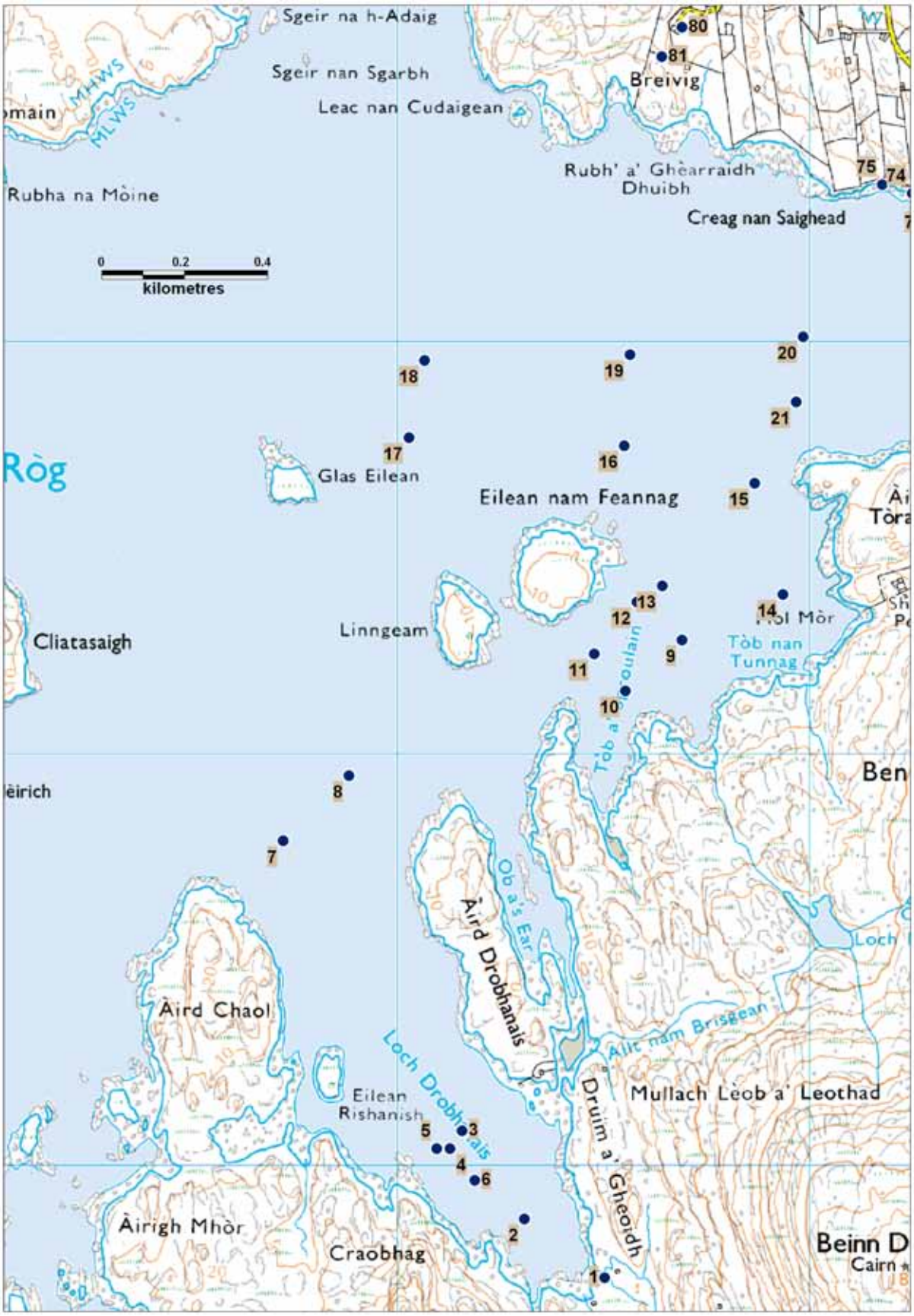


Figure 2. Map of Shoreline Observations – West side of fishery

Table 2. Shoreline Observations

No.	Date	Time (GMT)	NGR	East	North	Associated photograph	Description
1	19/07/2011	10:35:46	NB 14505 31729	114505	931729	Figure 5	Drovinish River: section 1 - 1.7 m x 18 cm, flow 0.852 m/s, SD 0.027. section 2 - 80 cm x 8 cm, flow 0.530 m/s, SD 0.067. Water sample LRDW1. Sheep droppings on shore adjacent to burn
2	19/07/2011	10:44:25	NB 14310 31871	114310	931871		Approximately 30 sheep being herded on western shore. Sheep also seen on eastern shore
3	19/07/2011	10:46:08	NB 14159 32086	114159	932086		Drovinish mussel sample 1. Seawater sample LRDW2
4	19/07/2011	10:52:49	NB 14130 32043	114130	932043		Salinity profile 1: 5m - 35.5 ppt/13.7C. 3m - 35.5 ppt/13.8C. 1m - 28.3 ppt/13.9C. Surface - 25.5 ppt/12.9C. Water at surface tea-coloured
5	19/07/2011	10:54:53	NB 14098 32042	114098	932042		Corner of Drovinish mussel farm. 2 double-headed longlines inner, 3 double-headed long lines outer, all with 8 m droppers
6	19/07/2011	10:56:14	NB 14190 31966	114190	931966		Corner of Drovinish mussel farm
7	19/07/2011	10:58:16	NB 13725 32790	113725	932790		Corner of Drovinish mussel farm. Outer part of site, central line, being harvested now
8	19/07/2011	10:59:36	NB 13884 32949	113884	932949		Corner of Drovinish mussel farm
9	19/07/2011	11:09:00	NB 14692 33276	114692	933276		Mol Mor site - owned/harvested by David Smith, who was on site checking lines with a researcher from Aberdeen. Site being harvested. 4 double-headed longlines. Mussel sample. Water sample LRLing 1
10	19/07/2011	11:12:41	NB 14556 33155	114556	933155		Corner of Mol Mor mussel farm, marked at end of floats rather than at anchors
11	19/07/2011	11:13:25	NB 14479 33242	114479	933242		Corner of Mol Mor mussel farm
12	19/07/2011	11:14:27	NB 14583 33368	114583	933368		End of line
13	19/07/2011	11:14:53	NB 14645 33408	114645	933408		Float marking sampling point - approximately 30m behind this point
14	19/07/2011	11:17:09	NB 14937 33387	114937	933387		Corner of Mol Mor mussel farm
15	19/07/2011	11:18:51	NB 14869 33657	114869	933657		Corner of Mol Mor mussel farm
16	19/07/2011	11:20:29	NB 14553 33748	114553	933748		Corner of Eilean nam Feannag mussel farm
17	19/07/2011	11:22:47	NB 14030 33768	114030	933768		Corner of Eilean nam Feannag mussel farm
18	19/07/2011	11:23:49	NB 14068 33956	114068	933956		Corner of Eilean nam Feannag mussel farm
19	19/07/2011	11:25:06	NB 14566 33969	114566	933969		Corner of Eilean nam Feannag mussel farm, Haclete site in view - used now for spat collection only. Location not recorded
20	19/07/2011	11:26:59	NB 14986 34013	114986	934013		Torranish - corner of E-W oriented lines
21	19/07/2011	11:27:53	NB 14970 33854	114970	933854		Corner Torranish - this line slack and curved
22	19/07/2011	11:29:09	NB 15321 33824	115321	933824		Level to end of line
23	19/07/2011	11:29:57	NB 15564 33570	115564	933570		Torranish, corner of N-S oriented lines, 16 sheep on west bank, 6 on east

No.	Date	Time (GMT)	NGR	East	North	Associated photograph	Description
24	19/07/2011	11:30:53	NB 15651 33518	115651	933518		Torranish, corner of farm
25	19/07/2011	11:31:51	NB 15612 33663	115612	933663	Figure 6	Torranish, mussel sample and seawater sample. Salinity profile 2: 5m - 35.5 ppt/13.5C. 3m - 35.4 ppt/13.6C. 1m - 34.6 ppt/13.6C. Surface - 28.6 ppt/13.0C. Water tea-coloured at surface
26	19/07/2011	11:41:38	NB 15564 33907	115564	933907		Corner
27	19/07/2011	11:41:49	NB 15566 33937	115566	933937		Corner
28	19/07/2011	11:43:06	NB 15415 34061	115415	934061		Corner
29	19/07/2011	11:44:47	NB 15989 33962	115989	933962		Shorebase
30	20/07/2011	07:50:58	NB 16468 34113	116468	934113		Start walk at Bernera Bridge, current flowing strongly in an easterly direction
31	20/07/2011	07:53:29	NB 16435 34076	116435	934076		Approximately 15 sheep, goose droppings, some cockle and clam shells. No sheep visible on Bernera shore opposite
32	20/07/2011	07:59:24	NB 16406 33981	116406	933981		Septic pipe (dribbling) to small watercourse
33	20/07/2011	08:05:18	NB 16404 33987	116404	933987	Figure 7	Stream: 22 cm x 8 cm, flow 0.023 m/s, SD 0.004 Water sample LRTW2
34	20/07/2011	08:08:13	NB 16390 33992	116390	933992		Sheep droppings and hoof prints on shore
35	20/07/2011	08:10:08	NB 16344 34013	116344	934013		Land seep
36	20/07/2011	08:15:08	NB 16245 34028	116245	934028		3 sheep in view on Bernera shore opposite
37	20/07/2011	08:26:38	NB 16094 34054	116094	934054		Seawater sample LRTW3, approx 35 oystercatchers in flight, 1 house visible up hill
38	20/07/2011	08:32:21	NB 16062 34003	116062	934003	Figure 8	Mussel shore base, only one boat on mooring at this time
39	20/07/2011	08:35:28	NB 16091 33965	116091	933965		Low wet ground, many goose droppings, thick layer of mussel shells in tideline, other fishing debris
40	20/07/2011	08:39:36	NB 16029 33917	116029	933917		Very small watercourse, not measured or sampled. Green algae on shore, storage for empty tanks, mussel floats. 1 large storage tank (empty) with outfall pipe
41	20/07/2011	08:43:20	NB 16011 33916	116011	933916		Brown plastic pipe - no flow or evidence of recent flow. 5 sheep on opposite shore (Bernera)
42	20/07/2011	08:45:28	NB 15998 33918	115998	933918		Small pipe, no flow
43	20/07/2011	08:46:22	NB 15988 33918	115988	933918		Mussel processing effluent discharge
44	20/07/2011	08:54:29	NB 15893 33989	115893	933989		Stone groin, seawater sample LRTW4
45	20/07/2011	08:59:01	NB 15838 33979	115838	933979		Large concentration of goose droppings, some eider duck droppings
46	20/07/2011	09:01:54	NB 15819 33952	115819	933952		12 sheep with access to shore
47	20/07/2011	09:04:59	NB 15809 33891	115809	933891		Small bay - fishing debris in tideline
48	20/07/2011	09:08:50	NB 15796 33789	115796	933789		2 sheep on island, large numbers of goose droppings here
49	20/07/2011	09:11:18	NB 15776 33781	115776	933781	Figure 9	Photo of Torranish mussel farm from shore, 2 eider ducks with 4 chicks near lines
50	20/07/2011	09:16:38	NB 15889 33806	115889	933806		Abandoned raft parts and floats - large amount of debris on shore

No.	Date	Time (GMT)	NGR	East	North	Associated photograph	Description
51	20/07/2011	09:20:28	NB 15992 33749	115992	933749	Figure 10	More wreckage along shore
52	20/07/2011	09:24:55	NB 16072 33656	116072	933656		Accidental record - no observation
53	20/07/2011	09:26:54	NB 16078 33655	116078	933655		Stream: 40 cm x 5 cm, flow 0.098 m/s, SD 0.004. Water sample LRTW5
54	20/07/2011	09:34:28	NB 15988 33623	115988	933623		Small stream through rocks, not measured or sampled
55	20/07/2011	09:41:15	NB 15841 33566	115841	933566		2 sheep
56	20/07/2011	09:44:12	NB 15776 33505	115776	933505		Land drain, fishing debris on shore, 4 geese
57	20/07/2011	09:47:56	NB 15716 33427	115716	933427		Land runoff, not measured or sampled
58	20/07/2011	09:50:11	NB 15669 33348	115669	933348		11 sheep away from shore
59	20/07/2011	09:52:50	NB 15653 33265	115653	933265		Land drainage
60	20/07/2011	09:55:42	NB 15653 33230	115653	933230		River Torranish. Section 1, 70 cm x 27 cm, flow 0.162 m/s, SD 0.046. Section 2, 36 cm x 30 cm, flow 0.118 m/s, SD 0.011. Water sample LRTW6
61	20/07/2011	10:03:42	NB 15671 33309	115671	933309	Figure 11	Photo across Torranish lines toward Bernera
62	20/07/2011	10:23:45	NB 16254 33733	116254	933733		Sheep pens with approximately 200 sheep, these were being rounded up during the survey
63	20/07/2011	11:17:10	NB 15707 34372	115707	934372		Start of walk, 14 sheep toward the shore from this position
64	20/07/2011	11:19:53	NB 15628 34420	115628	934420		25 sheep toward shore
65	20/07/2011	11:20:47	NB 15604 34404	115604	934404		Large amount of fishing debris on shore
66	20/07/2011	11:23:26	NB 15575 34378	115575	934378		Land drainage
67	20/07/2011	11:25:51	NB 15563 34332	115563	934332		Small pier, 1 small open boat and crab/lobster pots
68	20/07/2011	11:28:00	NB 15555 34322	115555	934322		Dry sheep droppings
69	20/07/2011	11:29:32	NB 15536 34333	115536	934333		Land drainage
70	20/07/2011	11:30:32	NB 15516 34336	115516	934336		New house. Land cover in area grass and rock
71	20/07/2011	11:38:25	NB 15375 34381	115375	934381		Small stream, not measured or sampled
72	20/07/2011	11:40:42	NB 15362 34370	115362	934370		Heavy algal growth, goose droppings on grass
73	20/07/2011	11:43:10	NB 15317 34345	115317	934345		2 sheep up hill from observation point with house beyond
74	20/07/2011	11:45:17	NB 15251 34362	115251	934362		2 sheep
75	20/07/2011	11:47:19	NB 15178 34383	115178	934383	Figure 12	59 geese in water between shore and Hacklete mussel farm
76	20/07/2011	11:59:13	NB 15295 34331	115295	934331	Figure 12	Seawater sample LRTW7. 2 sets of lines near shore (Hacklete) 1 with large number of floats (visible in Figure 12)
77	20/07/2011	12:09:59	NB 15525 34353	115525	934353		New house with septic tanks
78	20/07/2011	12:12:10	NB 15598 34410	115598	934410		Septic tank with pipe heading toward road, no outlet found
79	25/07/2011	09:26:41	NB 15506 34348	115506	934348	Figure 13	Bearings taken from this point to the mussel farms
80	25/07/2011	09:59:05	NB 14693 34765	114693	934765		Septic tank

No.	Date	Time (GMT)	NGR	East	North	Associated photograph	Description
81	25/07/2011	10:03:40	NB 14644 34694	114644	934694	Figure 14	Bearings taken from this point to the mussel farms. Harvesting barge on site between islands.
82	25/07/2011	10:49:17	NB 15608 34390	115608	934390		Fishing debris and 1 small boat. 3 gulls on pier. Land drainage
83	25/07/2011	10:55:09	NB 15662 34334	115662	934334		Land drainage, dry
84	25/07/2011	11:00:02	NB 15803 34269	115803	934269		Almost dry stream bed, house above. Goose droppings plentiful
85	25/07/2011	11:03:13	NB 15804 34293	115804	934293		Fishing debris, large floats well above tide line

Photographs referenced in the table can be found attached as Figures 5-14.

Sampling

Water and shellfish samples were collected at sites marked on the map. Samples were transferred to either Biotherm 25 or Biotherm 10 boxes with ice packs and shipped to Glasgow Scientific Services on the day collected for *E. coli* analysis. In all cases, samples were received and analysed on the day following collection. Sample temperatures on arrival ranged between 2.3 and 9.4 C, with samples taken on 19 July arriving above the recommended temperature range of 2-8C. Investigations undertaken by the National Reference Laboratory (NRL) have shown no significant effect on sample *E. coli* concentrations with up to 48 hours' storage at temperatures ≤10ºC. Sample results have been included in Tables 3 and 4.

Seawater samples were tested for salinity by the laboratory and results reported in mg Cloride per litre. These results have been converted to parts per thousand (ppt), and are shown in Table 3.

Salinity and temperature were recorded at the surface, 1 meter, 3 meters and 5 meters depth at two locations using a YSI ProPlus CT probe. The resulting profiles are reported in Table 5.

Table 3. Water Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (cfu/100ml)	Salinity (ppt)
1	19/07/2011	LRDW1	NB 1451 3173	Fresh	<100	-
2	19/07/2011	LRDW2	NB 1416 3209	Sea	<100	25.1
3	19/07/2011	LRMM1	NB 1469 3328	Sea	6	36.3
4	19/07/2011	LRTW1	NB 1561 3366	Sea	200	29.6
5	20/07/2011	LRTW2	NB 1640 3399	Fresh	1700	-
6	20/07/2011	LRTW3	NB 1609 3405	Sea	4	36.5
7	20/07/2011	LRTW4	NB 1589 3399	Sea	26	36.0
8	20/07/2011	LRTW5	NB 1608 3365	Fresh	<100	-
9	20/07/2011	LRTW6	NB 1565 3323	Fresh	100	-
10	20/07/2011	LRTW7	NB 1530 3433	Sea	0	37.1

- not recorded

Table 4. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (MPN/100g)
1	19/07/2011	LRMOLMOR	NB 1469 3328	Common mussel	80
2	19/07/2011	LRTORRAN	NB 1561 3366	Common mussel	20
3	19/07/2011	LRDROV1	NB 1416 3209	Common mussel	330

Table 5. Salinity profiles

Profile	Date and time	Position	Depth (m)	Salinity (ppt)	Temperature (°C)
1	19/07/2011 10:52:49	NB 1413 3204	0	25.5	12.9
			1	28.3	13.9
			3	35.5	13.8
			5	35.5	13.7
2	19/07/2011 11:31:51	NB 1561 3366	0	28.6	13.0
			1	34.6	13.6
			3	35.4	13.6
			5	35.5	13.5

Water and shellfish sampling locations are shown mapped in Figure 3, whilst the salinity profile locations and observed shellfish farms are shown in Figure 4.

Figure 3. Water and shellfish sample results map

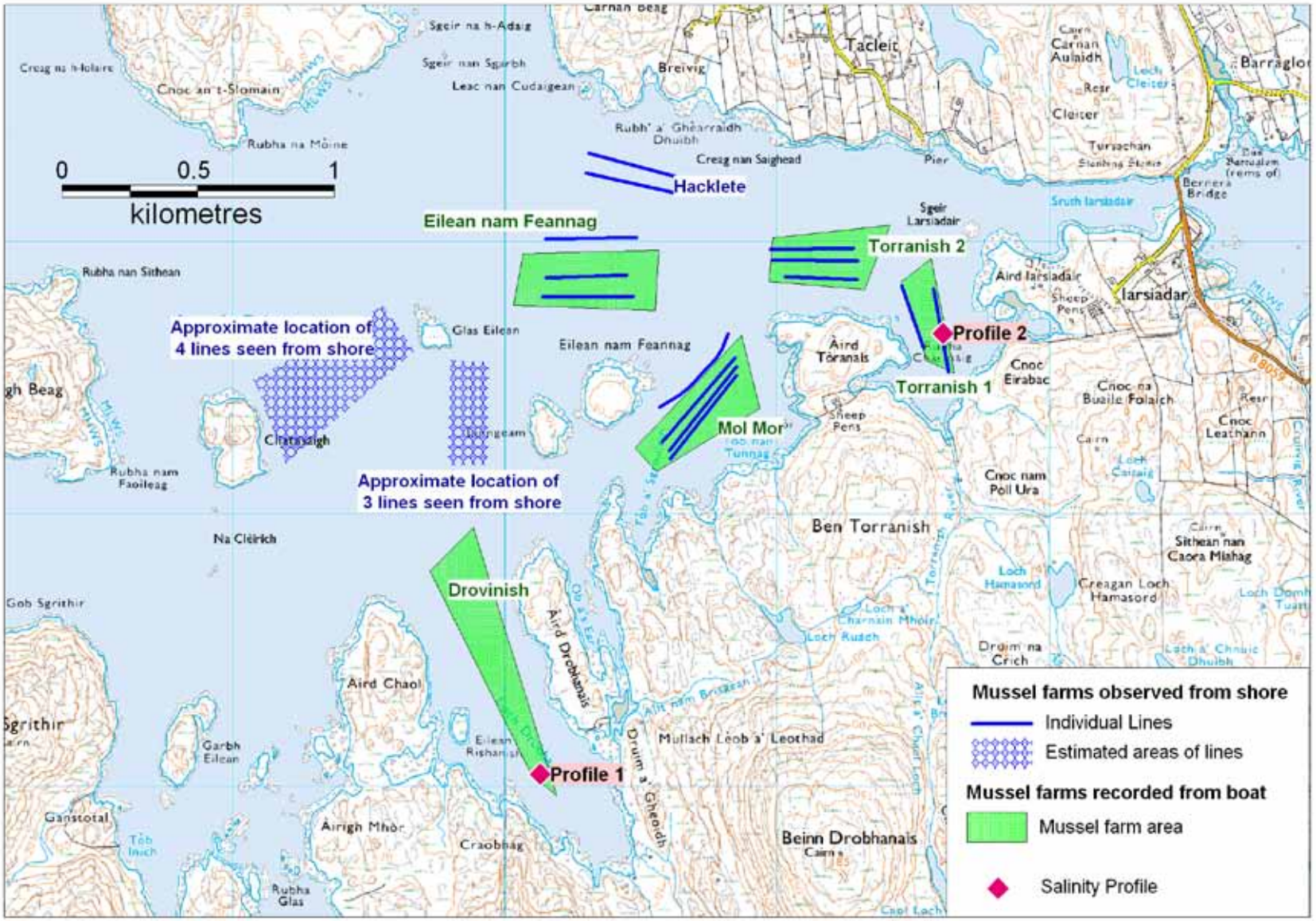


Figure 4. Fishery observations and salinity profile locations

Photographs

Figure 5. Drovinish River

Figure 6. Mussel line at Torranish

Figure 7. Small stream

Figure 8. Shore base for mussel operation

Figure 9. Torranish mussel lines from shore

Figure 10. Some of the debris found on shore south of Iarsiadar

Figure 11. View across Torranish lines toward Great Bernera.

Figure 12. View of mussel farms from shore looking southwest, geese and Hacklete lines at far right.

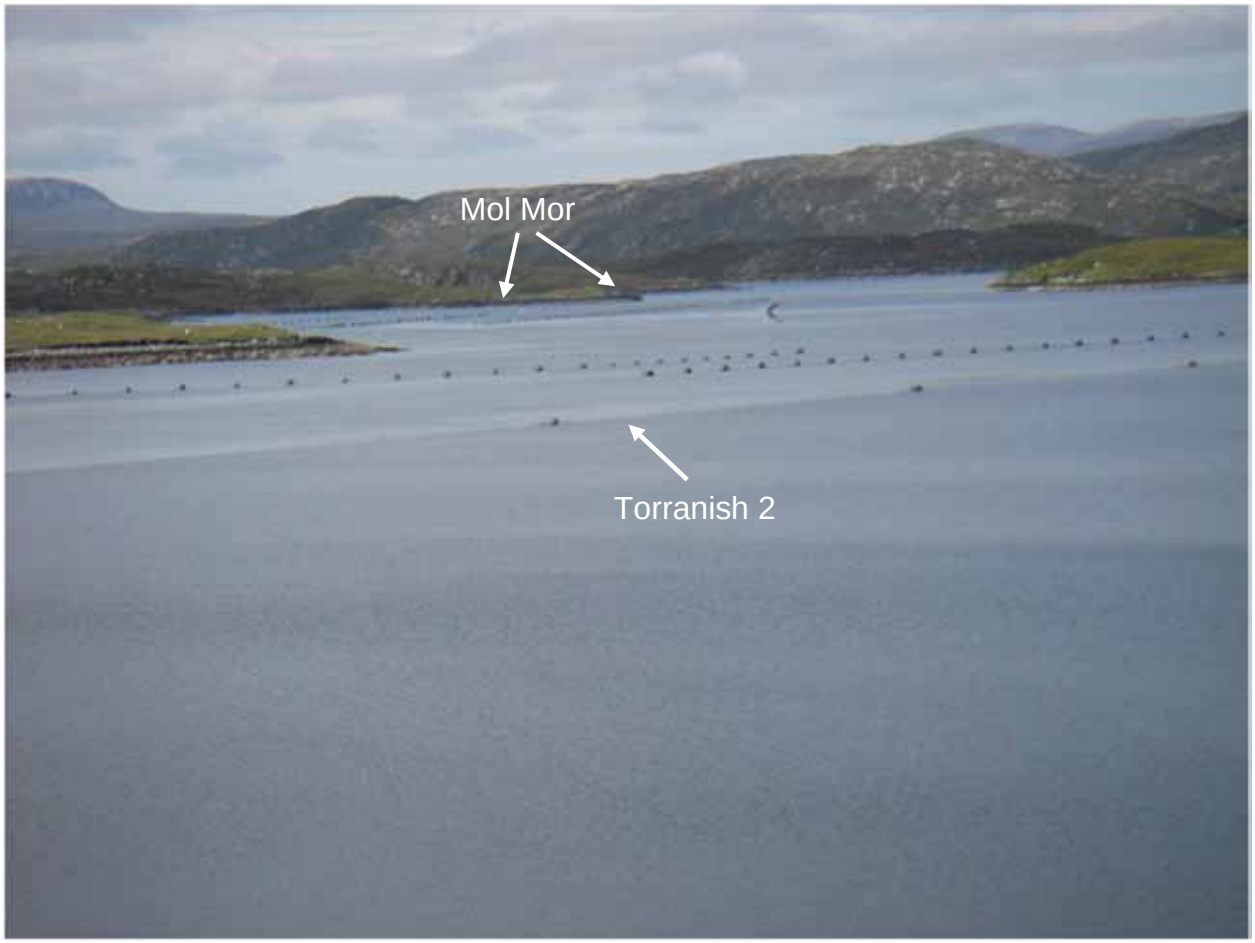


Figure 13. Torranish and Mol Mor from vantage point on shore looking south.

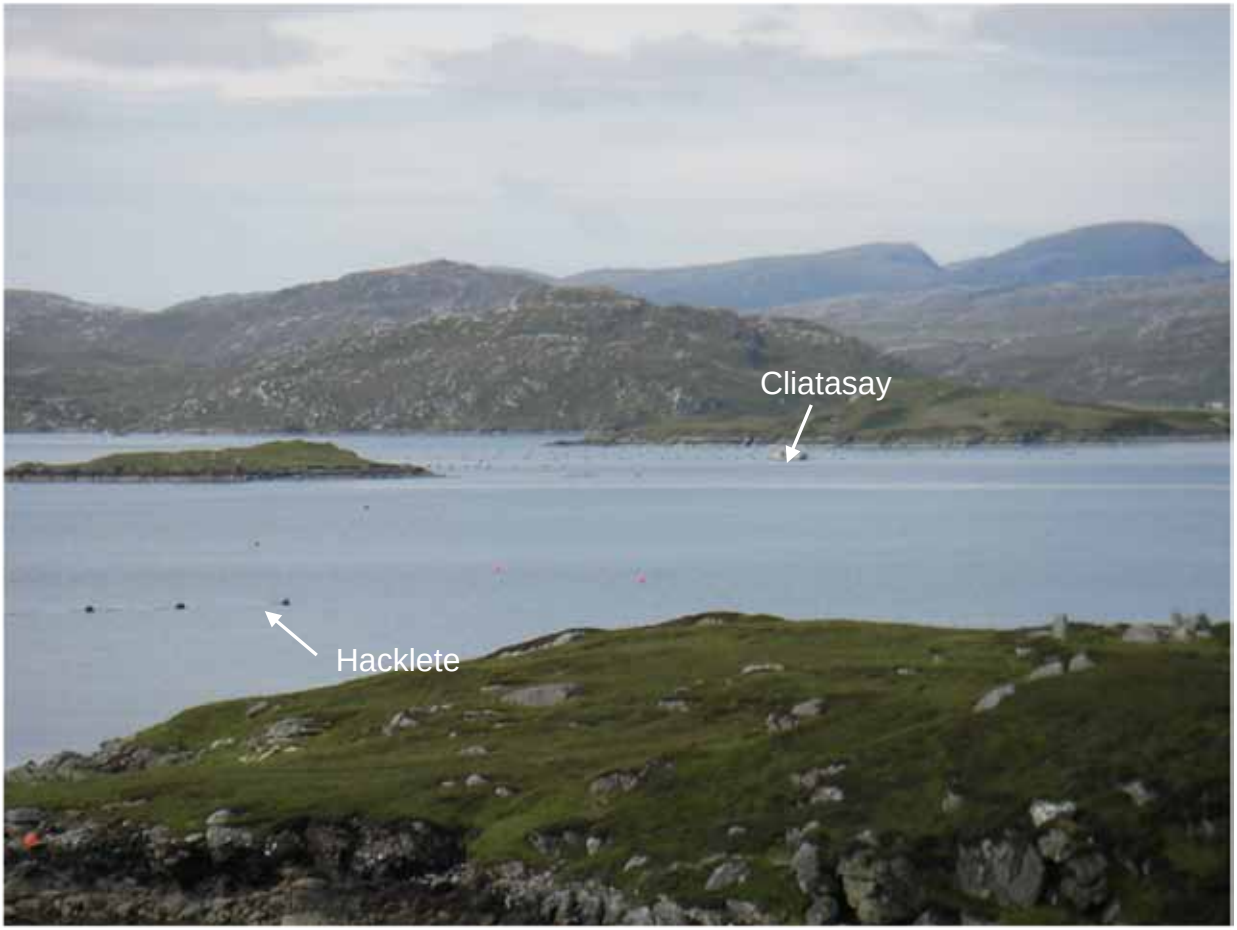


Figure 14. View to SW from vantage point, end of Hacklete in foreground and barge on lines at Cliatasay beyond.