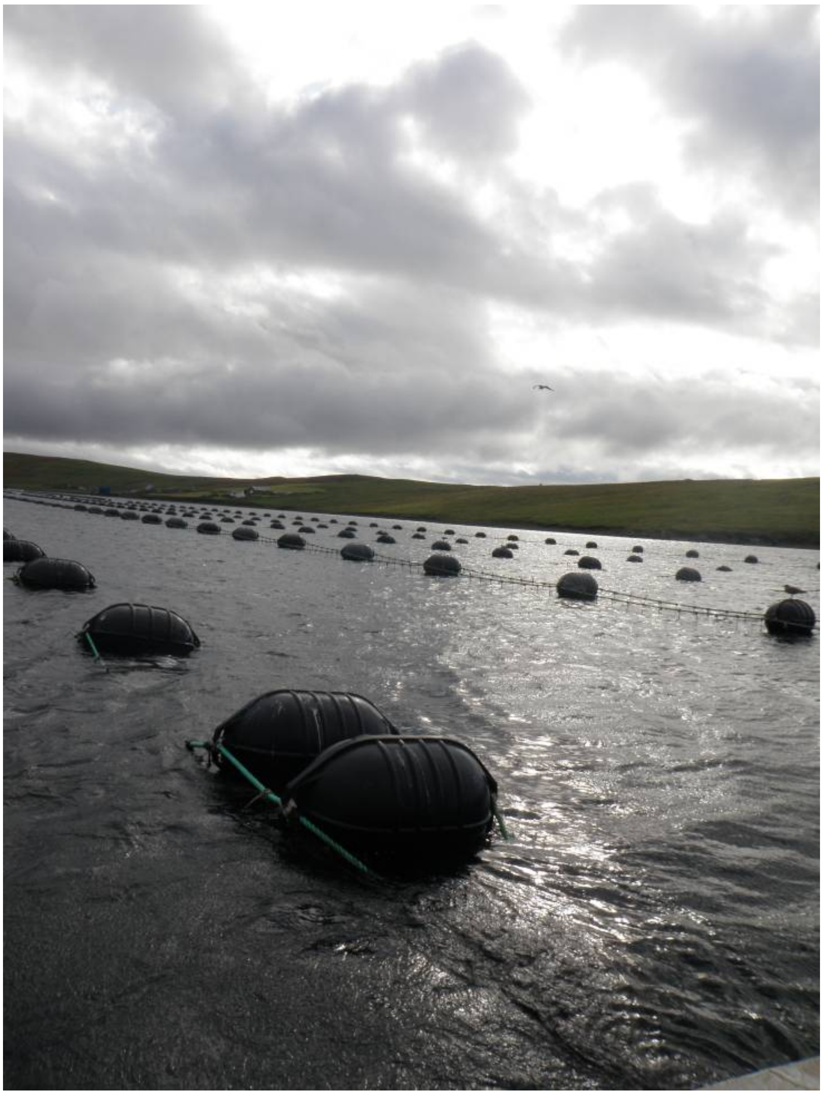
Scottish Sanitary Survey Project



Sanitary Survey Report

Lower Gruting Voe
Greenhead (SI 442)
Gruting Voe: Braewick Voe (SI 080)
Gruting Voe: Seli Voe (SI 084)

February 2010

Report Distribution – Lower Gruting Voe

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	Sean Williamson	Shetland Council
	A&C Tait	Harvester**
	Selivoe Shellfish	Harvester**

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

** Distribution of draft and final reports to harvesters in undertaken by the relevant local authority.

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1. General Description

Gruting Voe is located on the western side of the main island of Shetland. The southern half of Gruting Voe (termed Lower Gruting Voe in this report) runs approximately north-east to south-west, and is open to the Atlantic at the latter end. Lower Gruting Voe is approximately 3.5 km long (depending on the arbitrary split between the upper and lower voe) and between 0.4 and 1.0 km wide. It contains the main basin of the voe, which exceeds 30 m in depth. There are two side arms on the eastern side, the northernmost one of which is named Seli Voe and the southern one Olas Voe.

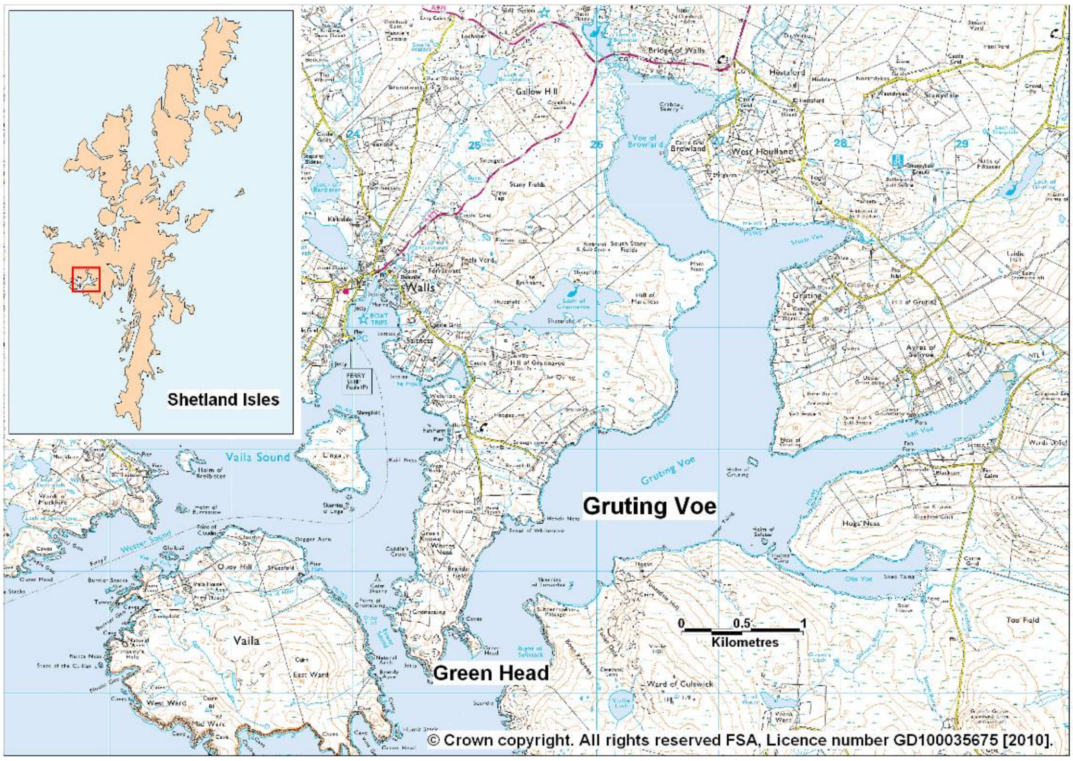

Figure 1.1 Location of lower Gruting Voe and Green Head

This sanitary survey was undertaken in response to an application for classification of North of Greenhead for common mussels. This site is located towards the mouth of Gruting Voe. There are existing classified mussel sites just to the north of this (Gruting Voe: Braewick Voe) and in Seli Voe (Gruting Voe: Seli Voe) and these were included in the same survey.

2. Fishery

The new fishery requiring classification at North of Green Head (SI 442 846 08) consists of a long line common mussel (*Mytilus* sp.) farm. The production area boundaries and RMP are yet to be assigned. An interim sampling point has been established at HU 2520 4710.

To the north of Greenhead are four currently classified production areas for common mussels in Gruting Voe. The two northernmost areas Browland Voe and Quilse were surveyed in 2008. The two production areas nearer to Greenhead at Braewick Voe and Seli Voe were surveyed included in the present survey. Both of the existing classified sites also comprise long line common mussel farms. The lower Gruting Voe production sites are listed in Table 2.1.

Table 2.1 Production sites in lower Gruting Voe

Production Area	Site	SIN	Species
Green Head	North of Green Head	SI 442 846 08	Common mussel
Gruting Voe: Braewick Voe	Heockness	SI 080 412 08	Common mussel
Gruting Voe: Seli Voe	Seli Voe	SI 084 360 08	Common mussel

The production area at Gruting Voe: Braewick Voe (SI 080 424 08) lies within lines drawn between HU 2645 4820 to HU 2747 4820 and HU 2745 4797 to HU 2762 4729 and HU 2760 4727 to HU 2746 4721 and HU 2613 4711 to HU 2550 4741. The RMP is at grid reference HU 260 480.

The production area at Gruting Voe: Seli Voe (SI 084 428 08) lies within lines drawn between HU 2745 4797 to HU 2762 4729 extending to MHWS. The RMP is at grid reference HU 281 481.

Figure 2.1 shows the relative positions of the mussel farms and the Shetlands Island Council (SIC) permit areas

At the time of the shoreline survey, the Seli Voe long line mussel farm consisted of one active site of 6 lines, three shorter than the others. All had droppers to 10 m depth. The Braewick Voe production area also had only one active site consisting of 6 lines with droppers approximately 8 m in length. The North of Green Head site had two long lines with droppers hung to a depth of 8-9 m. One line was nearly sinking and the other only had sizable mussels at one end.

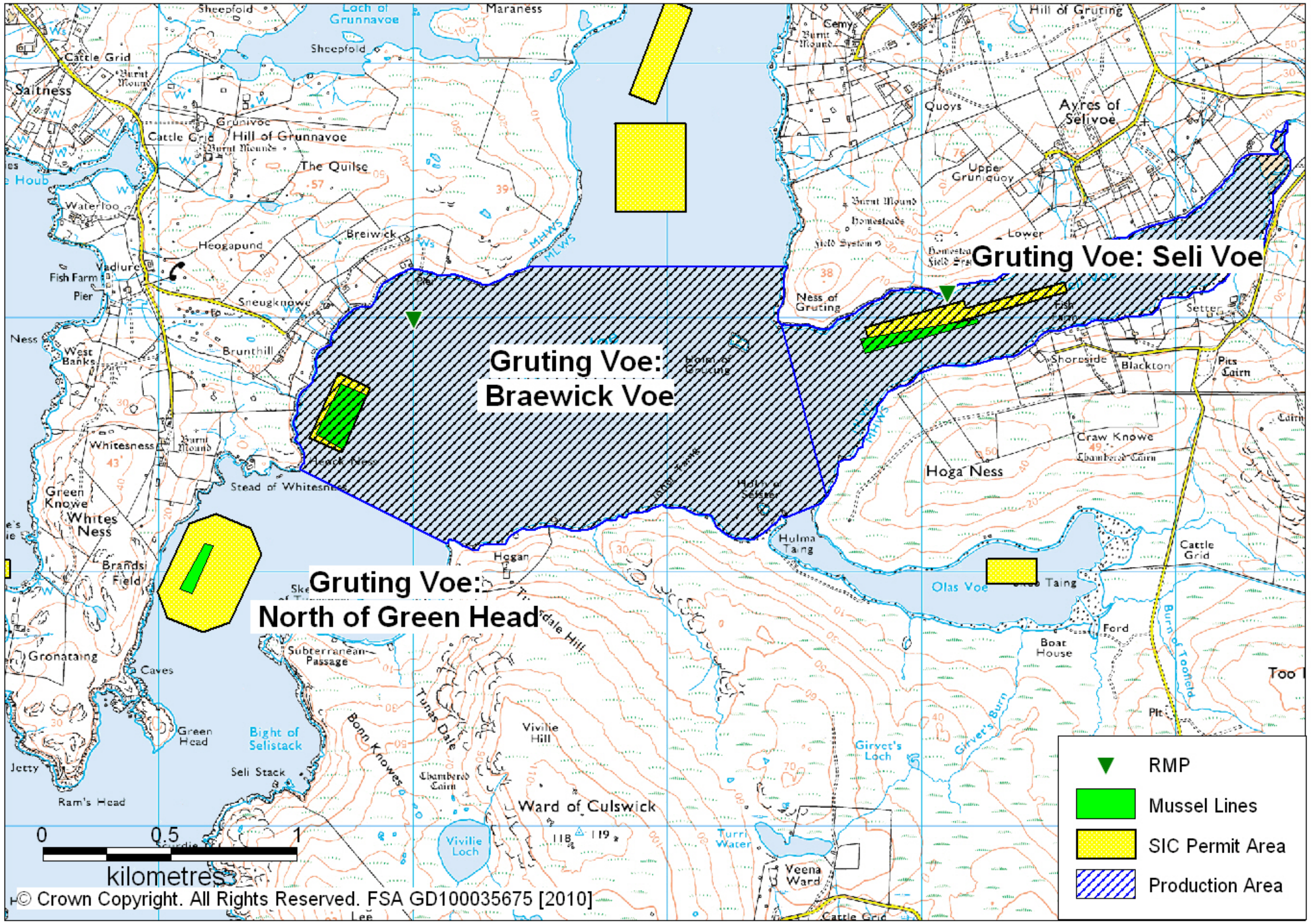

Figure 2.1 Lower Gruting Voe production areas

3. Human Population

Figure 3.1 shows information obtained from the General Register Office for Scotland on the population in the census output areas in the vicinity of lower Gruting Voe. The data relates to the 2001 census.

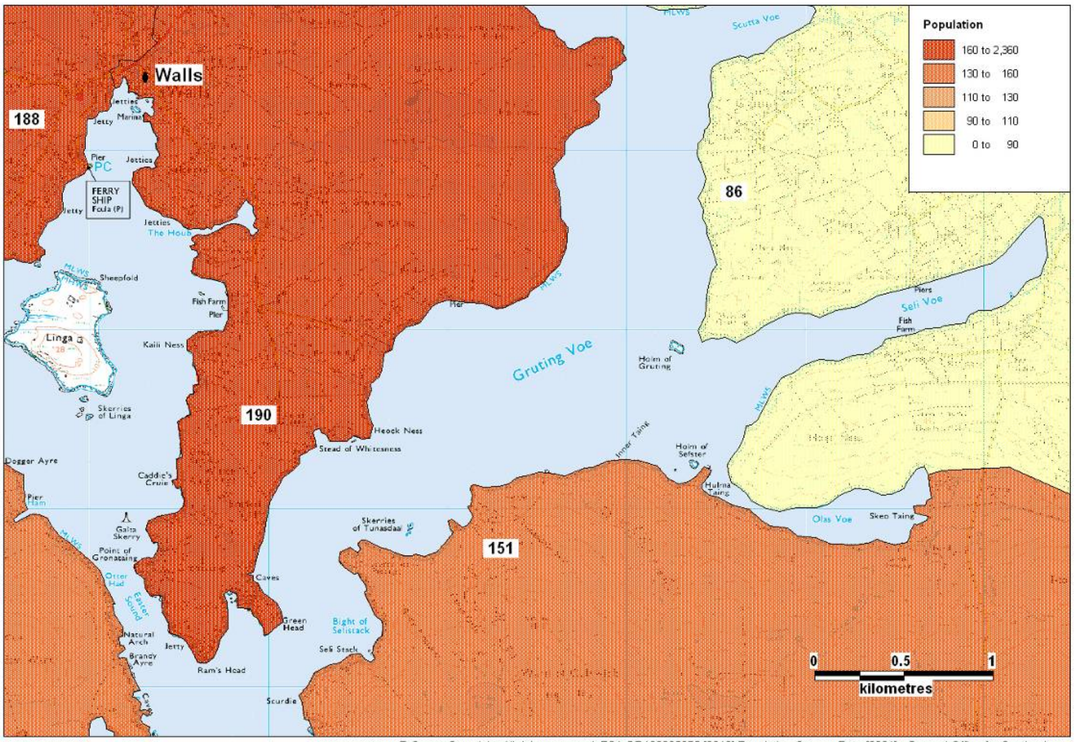

Figure 3.1 Human population surrounding Green Head

Lower Gruting Voe is surrounded by three census output areas (the full extent of the areas is not shown in the Figure. The population in the census areas to the west and south is greater than that for the census area surrounding Seli Voe. However, the census area to the west contains the village of Walls, which is on the edge of Vaila Sound rather than Gruting Voe, and the population of the rest of that area is low and dispersed. There are a small number of small villages (Bridge of Walls, West Houlland and Gruting) on the west side of Gruting Voe to the north of the present survey area and a few collections of dwellings within the survey area itself, principally around Seli Voe and the bay containing the Braewick Voe mussel site (see Figure 2.1). Any contamination from human sources is therefore likely to be relatively localised in these areas.

4. Sewage Discharges

No community septic tanks were identified by Scottish Water for Gruting Voe or North of Green Head. There is no mains sewerage in the area.

Two discharge consents were identified by SEPA for this area. One is for a discharge to land located approximately 1 km inland from the western shore of Gruting Voe and is not likely to impact water quality there. The second relates to a village hall near the head of Scutta Voe 2km north of the Braewick Voe production area boundary. The location of this discharge was confirmed in 2008 during the shoreline survey for the upper part of Gruting Voe. Detail of this consent is presented in Table 4.1. The design population equivalent is only 5 persons and, as a village hall, it could potentially be used by more than this on occasions and it is not known whether this could overcome the capacity of the septic tank and/or soakaway.

Table 4.1 Discharge consents provided by SEPA

Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consented/ design PE	Discharges to
CAR/R/1025329	HU 24200 48923	Continuous	Septic Tank	-	5	Land via soakaway
CAR/R/1037372	HU 2512 4877	Continuous	Septic Tank	-	5	Land via soakaway

Historically there was no requirement to register private sewage and septic tank discharges in Scotland, so there are likely to be further septic tanks or discharges in the area. A number of septic tanks and/or outfalls were recorded during the shoreline survey, confirming that SEPA consents only cover a proportion of discharges in the area. Details are presented in Table 4.2. As only the shoreline was walked in most areas, septic tanks with soakaways set back from the shore would not have been observed.

Table 4.2 Discharges and septic tanks observed during shoreline survey

No.	Date	Grid Reference	Observation
1	25-Aug-09	HU 28562 48241	House with septic tank and soakaway
2	26-Aug-09	HU 25324 47416	Pipe from septic tank
3	26-Aug-09	HU 28661 47879	Large house and shore base for salmon farm, area inaccessible, no septic pipes directly observed, septic tank presumed nearby
4	26-Aug-09	HU 28429 47860	Septic tank for house, faint odour, line of rocks running from shore but no apparent pipe
5	26-Aug-09	HU 29134 48091	White plastic discharge pipe, not flowing but active. Whitish-grey area on substrate below pipe
6	26-Aug-09	HU 29140 48095	Clay pipe underwater, no apparent discharge

The observed discharges in the area were for the most part related to small private septic tanks. The house and fish farm shorebase were located on the shoreline, however it was not possible to access the base area or shore adjacent to it due to fencing, equipment and pipework associated with the salmon operation. It has therefore been presumed that toilets associated with both the salmon operation and the home will be treated via a septic tank in the vicinity. Whether this discharges to soakaway or to the voe is not known.

Large well boats bring salmon to a jetty just off shore of the base here, from which they are pumped to buildings on the shore and transferred to tanker trucks for transport to market. These boats are presumed to also have onboard toilets for crew which could potentially be discharged anywhere in the voe. Likewise, boats serving the salmon cages in the southern part of the voe could impact on water quality in the vicinity of any overboard sewage discharges.

The mussel farm at Gruting Voe: Seli Voe is most likely to be impacted by sources located on either shore of Seli Voe itself and by any discharges from the salmon boats docking near point 4. The mussel farms at Gruting Voe: Braewick Voe and the new farm at North of Green Head are closest to the discharge from the private septic tank observed between the two. However, given the small size of the discharge and the distance from the two farms (at least 300 metres) it is not anticipated that this will cause measurable impact at either.

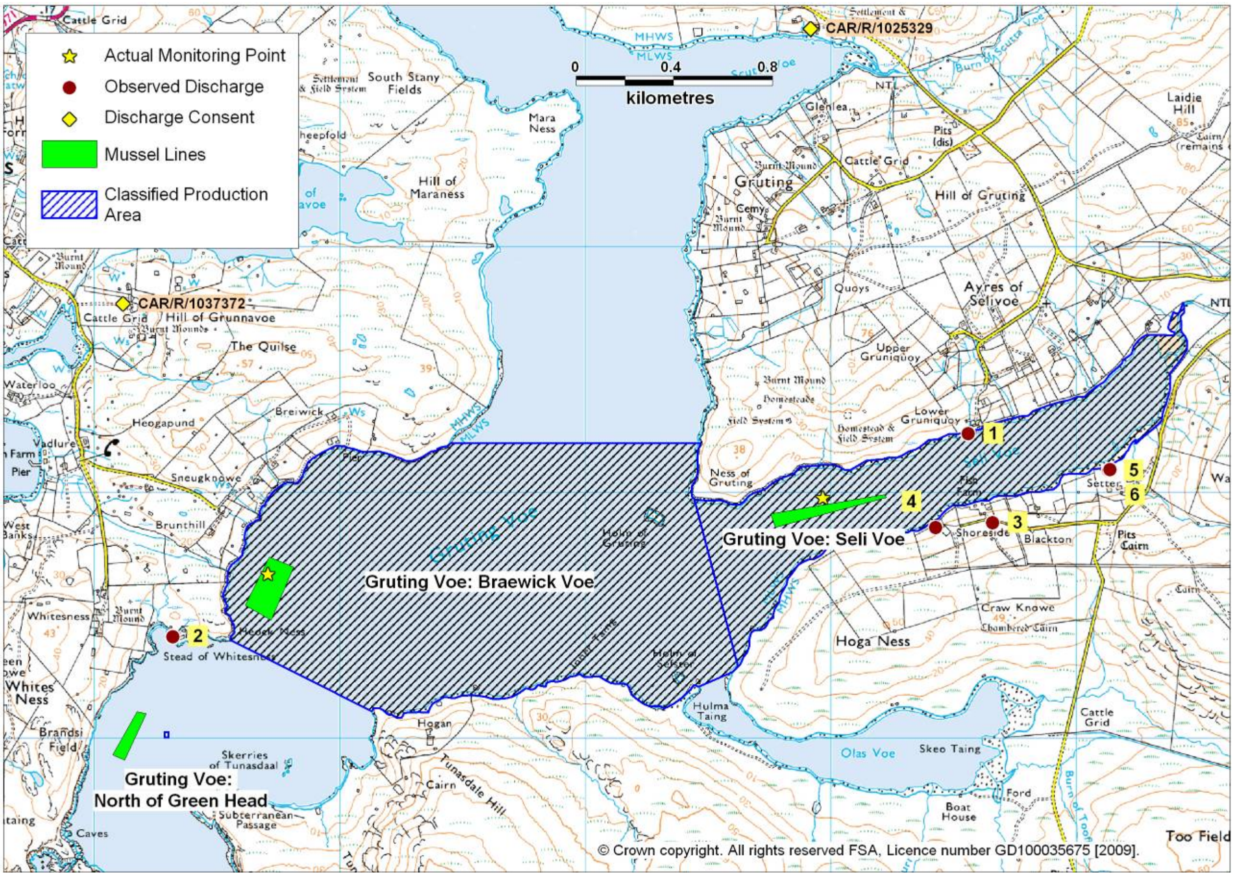

Figure 4.1 Discharges in lower Gruting Voe

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 and orange indicate poorly draining soils.

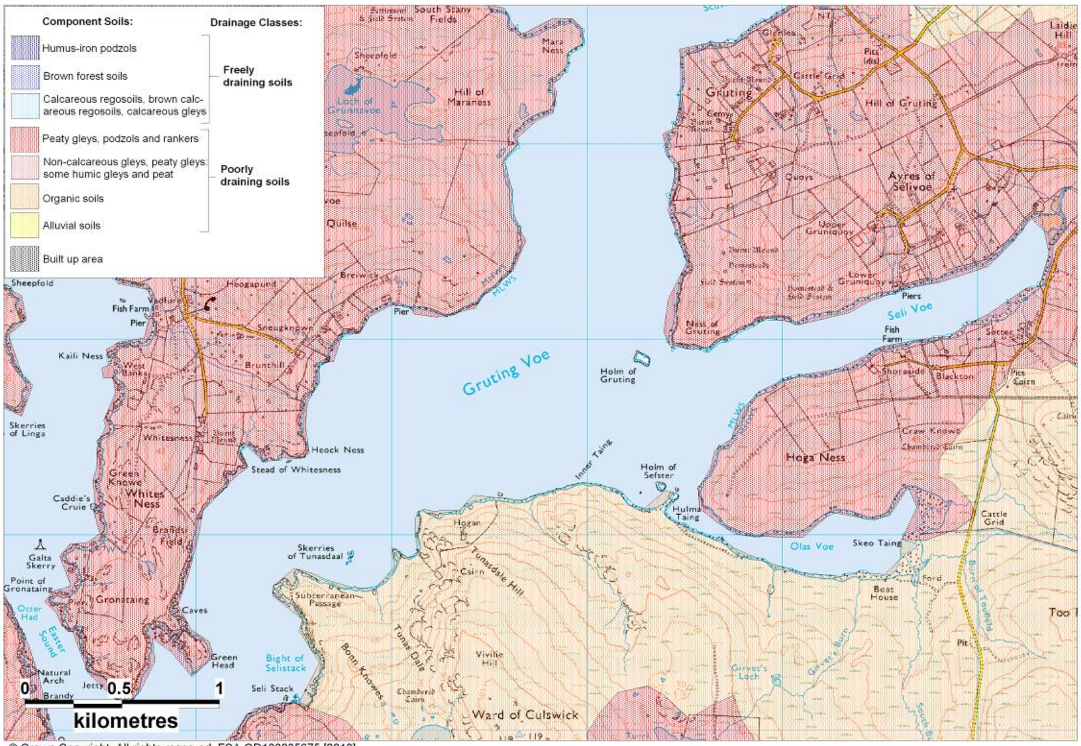

Figure 5.1 Component soils and drainage classes for lower Gruting Voe

Two types of component soils are present in the area: peaty gleys, podzols and rankers and organic soils. Both of these soils are poorly draining. Therefore, the potential for runoff contaminated with *E. coli* from human and/or animal waste is high for all the land surrounding lower Gruting Voe.

6. Land Cover

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

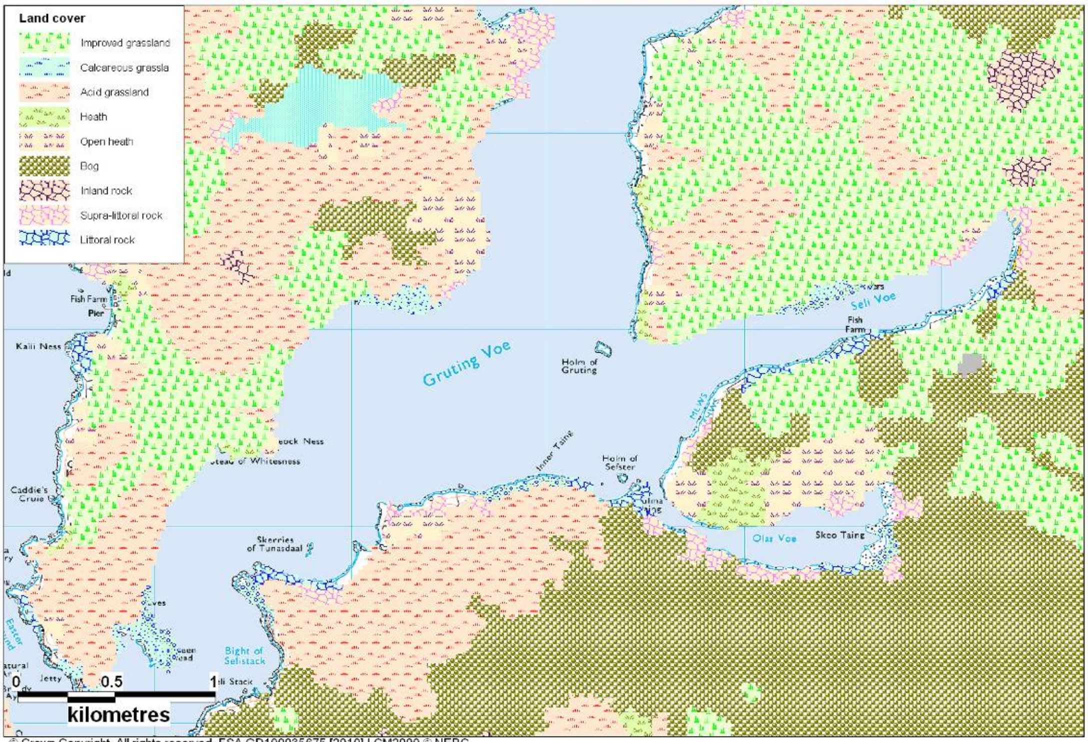

Figure 6.1 LCM2000 class land cover data for lower Gruting Voe

There are three main types of land cover shown in Figure 6.1: acid grassland, improved grassland and bog. Most of the land around Seli Voe is composed of improved grassland although there is some bog on the southern side. There are stretches of improved grassland amongst acid grassland on the western side of lower Gruting Voe, in the vicinity of the fisheries.

The faecal coliform contribution would be expected to be highest from developed areas (approx 1.2 – 2.8×10^9 cfu km^{-2} hr^{-1}), with intermediate contributions from the improved grassland (approximately 8.3×10^8 cfu km^{-2} hr^{-1}) and lowest from the other land cover types (approximately 2.5×10^8 cfu km^{-2} hr^{-1}) (Kay *et al*. 2008). The contributions from all land cover types would be expected to increase significantly after marked rainfall events, this being expected to be highest, at more than 100-fold, for the improved grassland.

There are no significant developed areas around the shore of lower Gruting Voe. The overall predicted contribution of contaminated runoff from the land cover types that are present would be low to intermediate, and would be expected to increase significantly following rainfall events. It is likely that the areas with the large areas of improved grassland around Seli Voe and the western side of Gruting Voe, adjacent to the fisheries, would be subject to higher levels of contamination.

7. Farm Animals

Regulation (EC) No. 854/2004 requires the competent authority to:

(a) make an inventory of the sources of pollution of human or animal origin likely to be a source of contamination for the production area;
(b) examine the quantities of organic pollutants which are released during the different periods of the year, according to the seasonal variations of both human and animal populations in the catchment area, rainfall readings, waste-water treatment, etc.

With regard to potential sources of pollution of animal origin, agricultural census data to parish level was requested from the Scottish Government. Agricultural census data was provided by the Rural Environment, Research and Analysis Directorate (RERAD) for the parishes of Sandsting to the East of Gruting Voe, and Walls to the West, encompassing a land area of 7,300 and 4,800 hectares respectively. Reported livestock populations for the parishes in 2007 and 2008 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, is replaced with an asterisk.

Table 7.1 Livestock Census for Sandsting

	2007		2008	
	Holdings	Numbers	Holdings	Numbers
Total pigs	*	*	*	*
Total poultry	19	242	16	234
Total cattle	11	200	11	250
Total sheep	88	18170	84	17028
Deer	0	0	0	0
Horses and Ponies	10	56	11	70

* Data withheld on confidentiality basis.

Table 7.2 Livestock Census for Walls

	2007		2008	
	Holdings	Numbers	Holdings	Numbers
Total pigs	*	*	*	*
Total poultry	9	149	8	145
Total cattle	10	175	11	170
Total sheep	62	14418	58	11437
Deer	0	0	0	0
Horses and Ponies	16	99	15	96

* Data withheld on confidentiality basis.

In general, the number of animals across the two parishes are broadly similar, There are large numbers of sheep in both parishes with somewhat more in Sandsting than Walls. Information on pig numbers was not available. Deer are not present in Sheltand as a whole. Due to large areas covered by the census data, this numbers do not provide information on the livestock in the area immediately surrounding Gruting Voe. The only information specific to the area near the shellfishery was therefore the shoreline survey (see Appendix), which only relates to the time of the site visit on 25-28 August 2009. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1. The shoreline survey confirmed that the area around Lower Gruting Voe is predominantly used for sheep grazing with significant numbers around much of Seli Voe and in the vicinity of the Gruting Voe: Braewick Voe site and to the north of the North of Green Head site. Some cattle were also observed a little inland at the latter location.

On the basis of those observations, it would be expected that the eastern end of the Gruting Voe: Seli Voe lines would be subject to impact from this source, as would the western side of the mussel lines at Gruting Voe: Braewick Voe. Impact on the North of Green Head site would be potentially less, with any effects being observed at the northern end. However, this assessment relates to the observed locations and does not take into account that the animals may move over time.

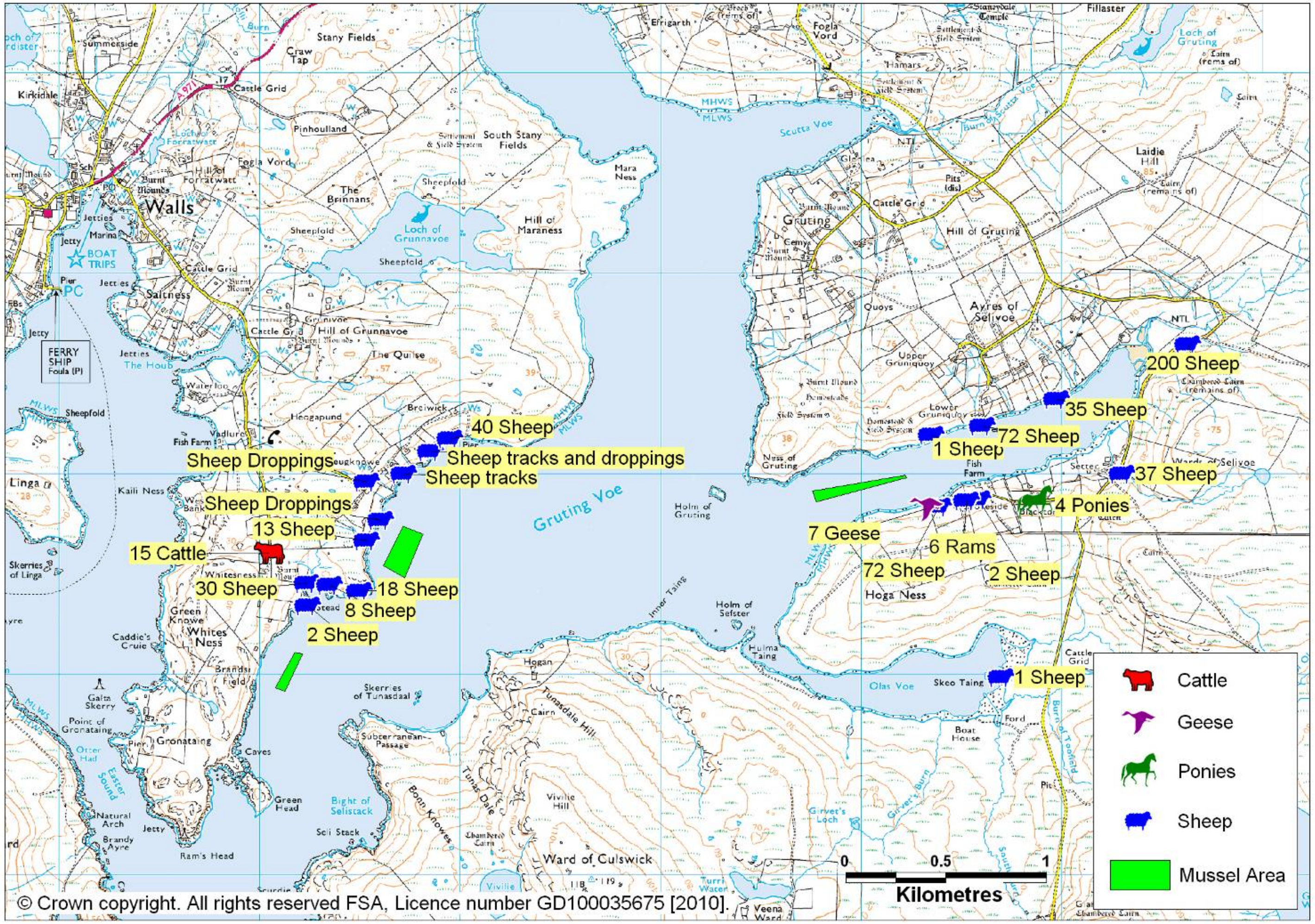

Figure 7.1 Shoreline Survey Livestock observations in lower Gruting Voe

8. Wildlife

Seals

Common seals surveys are conducted every 5 years and an estimate of minimum numbers is available through Scottish Natural Heritage. The Shetland-wide count in 2006 was 3021 harbour seals, though this was anticipated to be an underestimation of the total population (Sea Mammal Research Unit 2007). In the previous count (2001), three haulout sites were recorded towards the head of Gruting Voe, confirming their presence in the immediate area of the fishery. It is also likely that Grey Seals visit the area.

Whales and Dolphins

A variety of cetacean species are routinely observed near Shetland. It is highly likely that whales and dolphins will be found from time to time in the area, although the larger species are less likely to pass near the shore. As with seals, these are highly mobile animals and any impact from their presence is likely to be limited in duration and unpredictable.

Seabirds

A number of seabirds breed in Shetland. These were the subject of a detailed census starting in 1998 and completed in 2002. Total counts of all species in recorded within a 5km radius of the mussel lines are presented in table 8.1. Where counts were of occupied sites/nests/territories, actual numbers of birds breeding in the area will be higher.

Table 8.1 Seabird counts within 5km of the site.

Common name	Species	Count	Method
Northern Fulmar	*Fulmarus glacialis*	2065	Occupied sites
Arctic Tern	*Sterna paradisaea*	556	Individuals on Land/ Occupied Nests
Common Gull	*Larus canus*	115	Individuals on land/ Occupied nests and territory
Black-headed Gull	*Larus ridibundus*	90	Individuals on Land/Occupied Territory
Black Guillemot	*Cepphus grylle*	43	Individuals on land
Herring Gull	*Larus argentatus*	39	Individuals on land/Occupied territory
Kittiwake	*Rissa tridactyla*	20	Occupied nests
Arctic skua	*Stercorarius parasiticus*	12	Occupied territory
Razor Bill	*Alca torda*	10	Individuals on land
European Shag	*Phalacrocorax aristotelis*	7	Occupied nests
Great Black-backed Gull	*Larus marinus*	6	Occupied nests and territory

Large aggregations of Arctic Terns, totalling 215 individuals, were counted in three areas directly inland from the fisheries on the western side of lower Gruting Voe. Further south, a large count of 552 Northern Fulmar occupied sites, approximately 1.5km from the North of Green Head mussel lines.

Nesting occurs during the summer, following which many disperse (e.g. Arctic Terns migrate south during late July and August), so any impacts from faecal waste at nesting sites will be largely limited to this period of time. However gulls will be present in the area throughout the year.

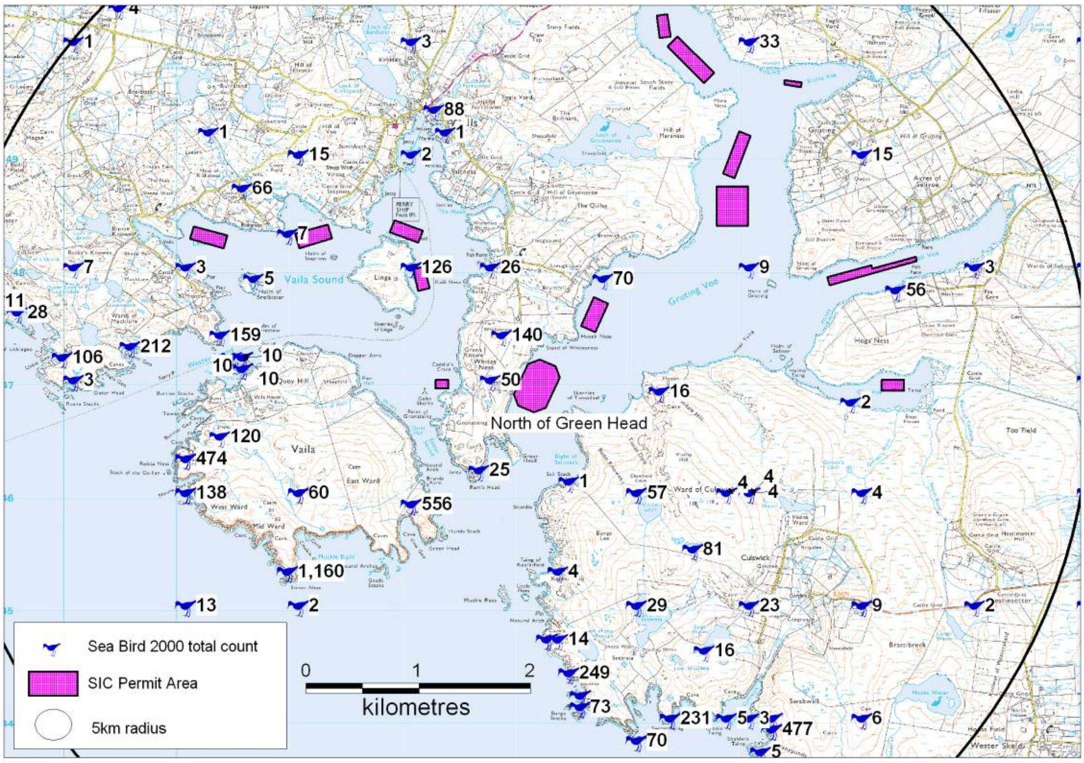

Figure 8.1 Seabird 2000 census data

Otters
Yell Sound to the northern side of Shetland is a designated Special Area of Conservation (SAC) for the otter and the common seal. The total population of otters on Shetland is 12% of the UK total, and is one of the most dense populations in Europe (Shetland Otters 2009). However, populations are still relatively small in relation to the bird and livestock populations, and are unlikely to be a significant source of contamination on the shellfishery.

Deer
There are no deer present in Shetland

Summary
Species potentially impacting on the lower Gruting Voe area include fulmars, gulls, terns and seals. The wild birds are widely distributed in the area and so are likely to impact all of the mussel sites. The occurrence of seals will be sporadic and will have an unpredictable affect on the microbiological status of the fisheries. be unpredictable, and deposition of faeces by wildlife is likely to be widely distributed around the area.

9. Meteorological data

The nearest weather station is located at Lerwick, approximately 20 km to the south-east of the fishery, for which rainfall and wind data is available for 2003-2008 inclusive. It is likely that overall wind patterns are broadly similar at the fishery and at Lerwick, but local topography may result in some differences, and conditions at any given instant may differ due to the distance between them. This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish within lower Gruting Voe.

9.1 Rainfall

High rainfall and storm events are commonly associated with increased faecal contamination of coastal waters through surface water run-off from land where livestock or other animals are present, and through sewer and waste water treatment plant overflows (e.g. Mallin et al, 2001; Lee & Morgan, 2003). Figures 9.1 and 9.2 present box and whisker plots summarising the distribution of individual daily rainfall values by year and by month. The grey box represents the middle 50% of the observations, with the median at the midline. The whiskers extend to the largest or smallest observations up to 1.5 times the box height above or below the box. Individual observations falling outside the box and whiskers are represented by the symbol *.

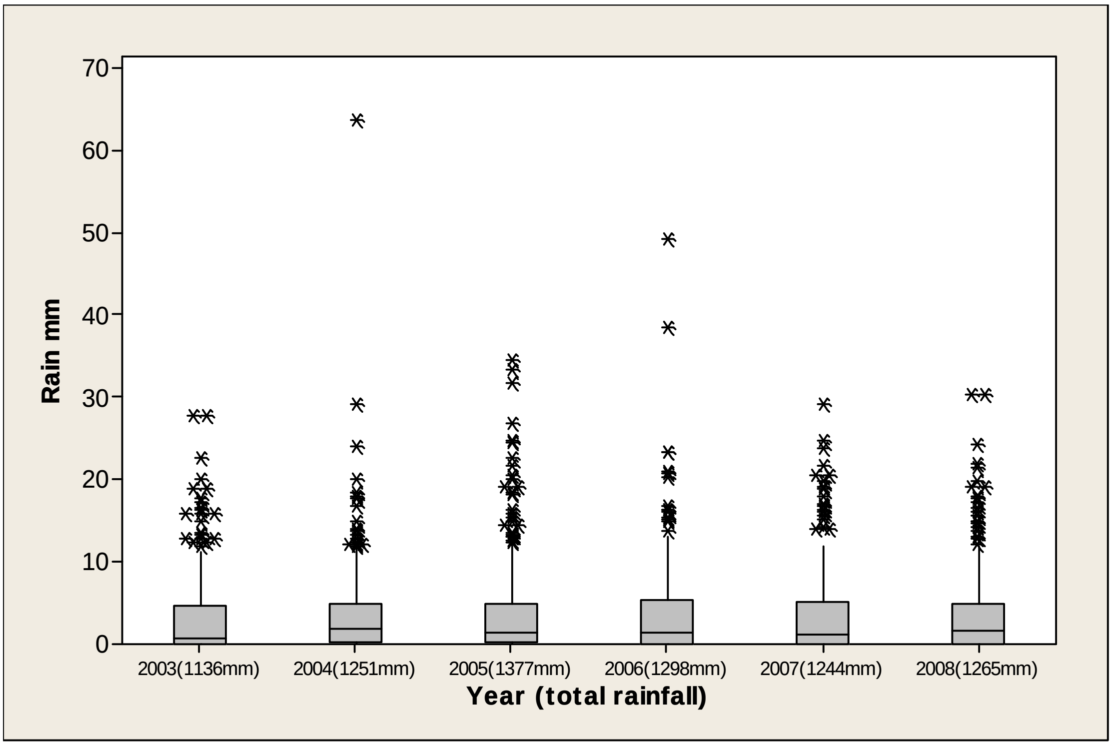

Figure 9.1 Box plot of daily rainfall values by year at Lerwick, 2003-2008

Figure 9.1 shows that rainfall patterns were generally similar for the years presented here although rainfall in 2003 was somewhat less than in the other years and extreme rainfall events (950 mm or above in 24 h) were seen on single occasions during 2004 and 2006.

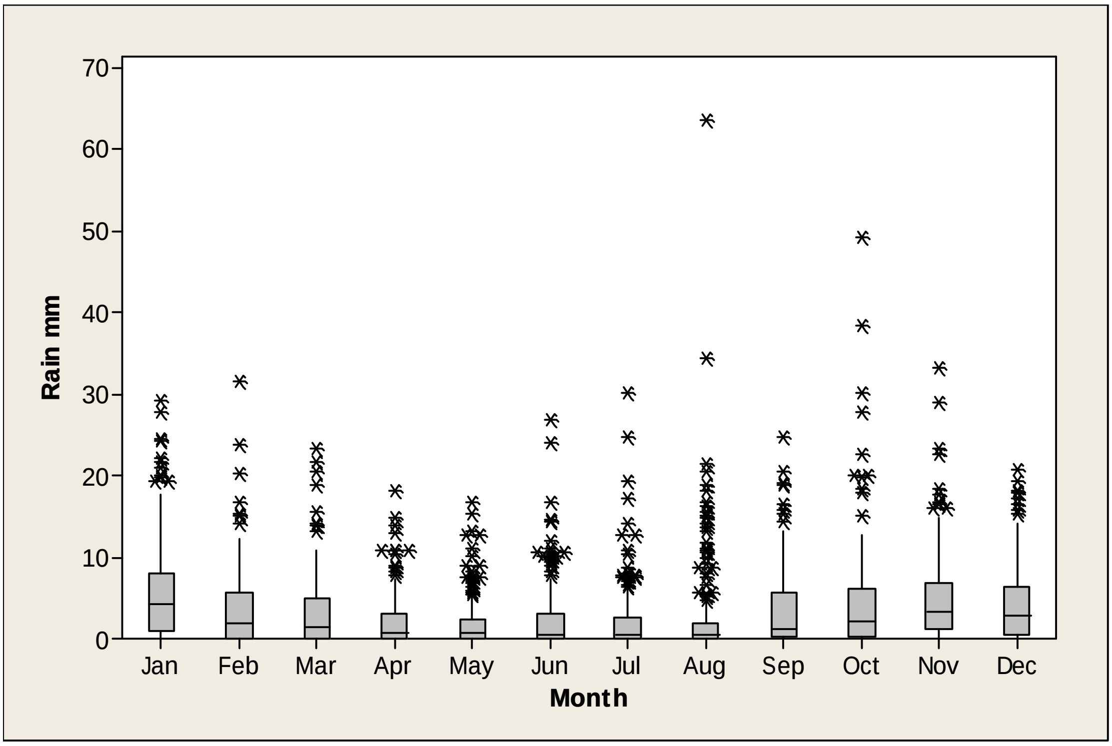

Figure 9.2 Box plot of daily rainfall values by month at Lerwick, 2003-2008

The wettest months were from September to February, and April to August were the driest months. The extreme rainfall events noted above for 2004 and 2006 occurred in August and October respectively. Days with high rainfall can occur at any time of the year. For the period considered here (2003-2008), 44% of days experienced rainfall less than 1 mm, and 9% of days experienced rainfall of 10 mm or more.

It can therefore be expected that levels of rainfall dependent faecal contamination entering the production area from these sources will be higher during the autumn and winter months. A build-up of faecal matter on pastures during the drier summer months when stock levels are at their highest may result in a ‘first flush’ of contaminated runoff following summer storms, or in the autumn at the onset of the wetter months although this could happen at any time of the year.

9.2 Wind

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

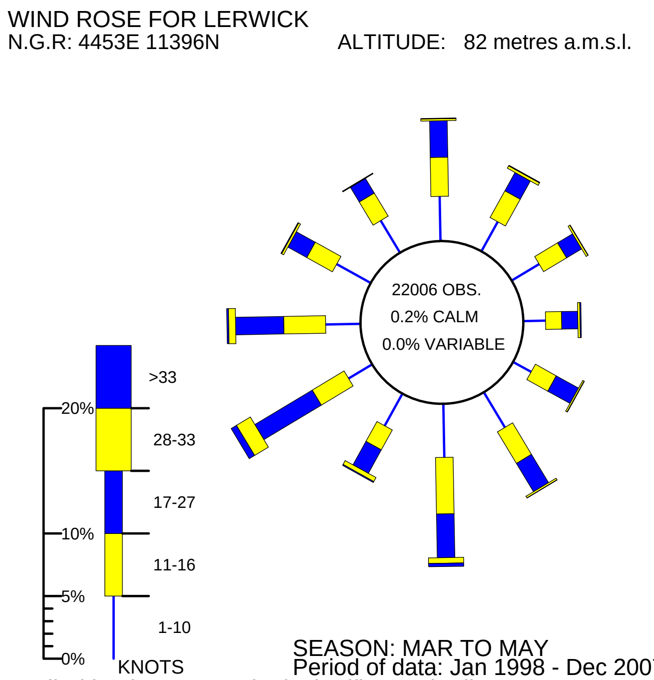

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Figure 9.3 Wind rose for Lerwick (March to May)

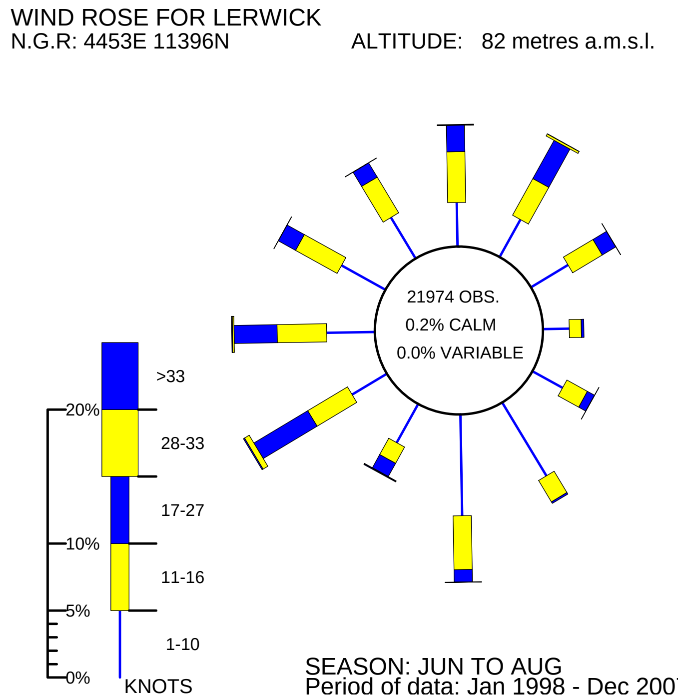

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Figure 9.4 Wind rose for Lerwick (June to August)

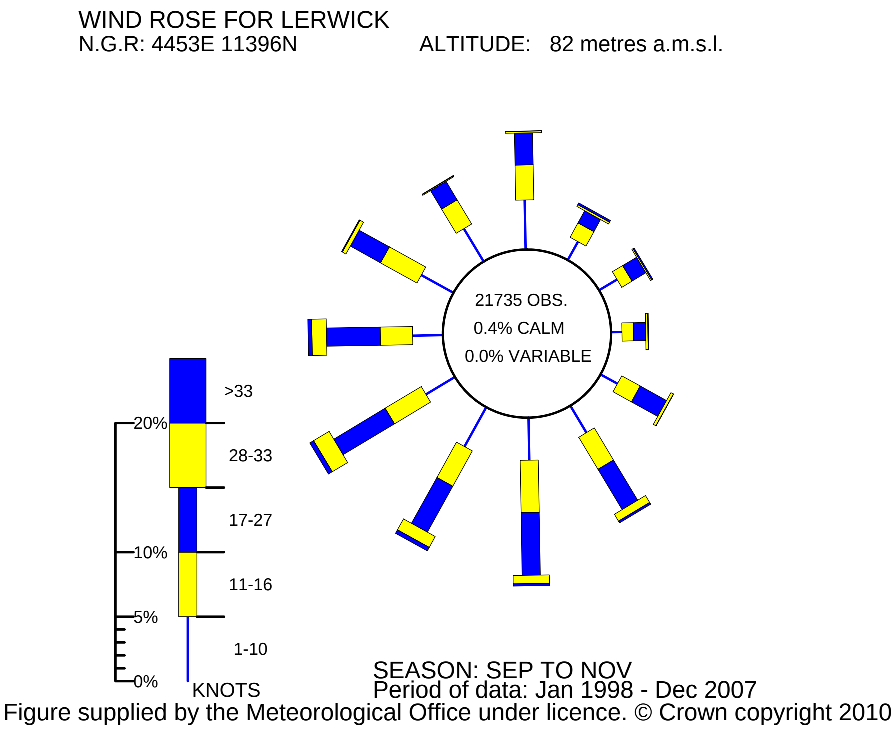


Figure 9.5 Wind rose for Lerwick (September to November)

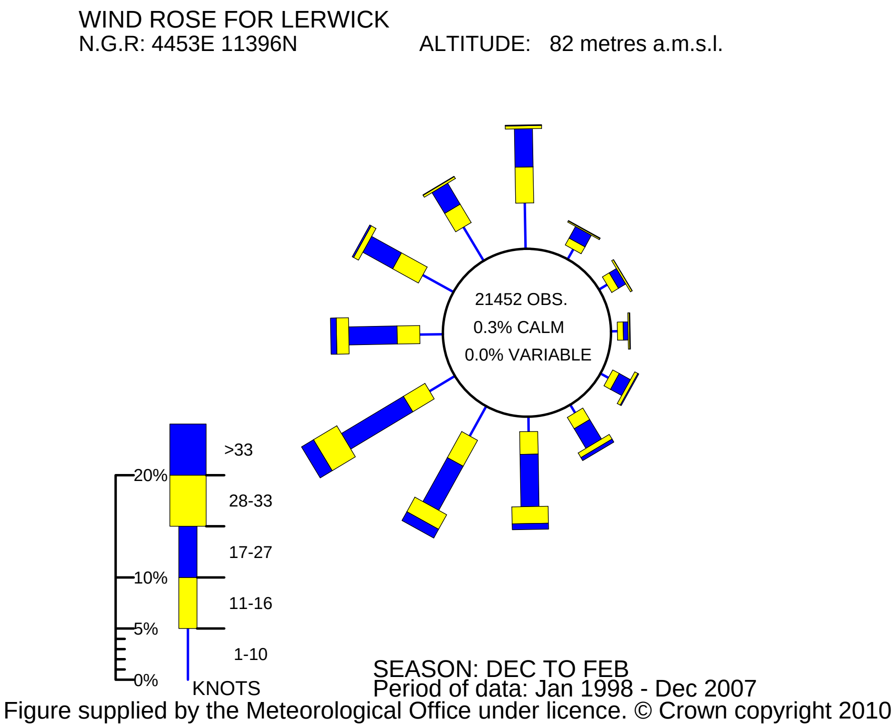


Figure 9.6 Wind rose for Lerwick (December to February)

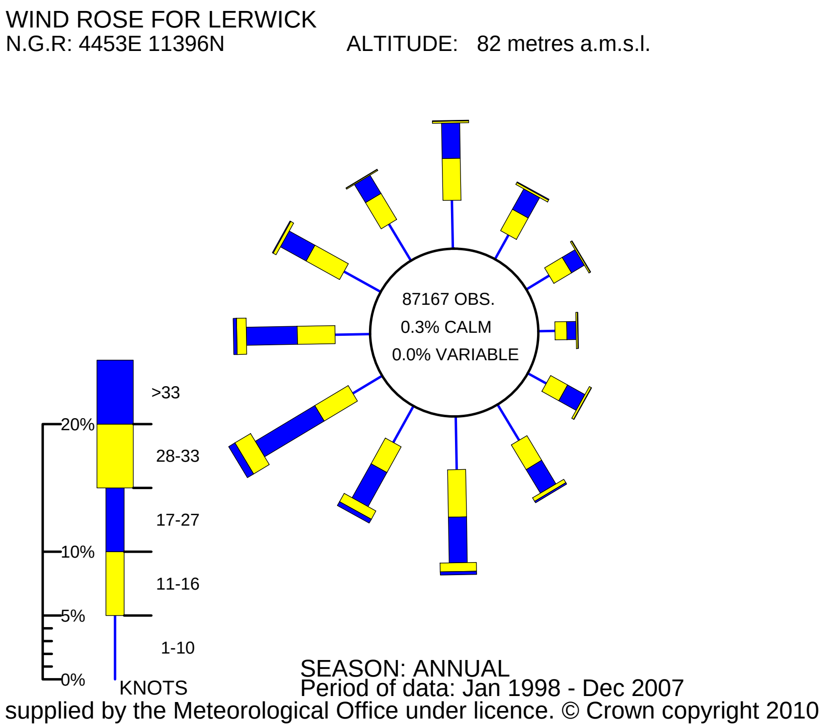


Figure 9.7 Wind rose for Lerwick (Annual)

Shetland is one of the more windy areas of Scotland with a much higher frequency of gales than the country as a whole. The wind roses show that the overall prevailing direction of the wind is from the south and west, and when it is blowing from this direction it is likely to be stronger than when blowing from other directions. Winds are generally lighter during the summer months and strongest in the winter.

Gruting Voe has a south-west to north-east aspect, with the surrounding land rising to over 100 m in places, and so is most exposed to winds from the south-west and to a lesser extent the north-east. Therefore, wind patterns here are likely to align more along this axis that they do at Lerwick. 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 (50 cm/s). Currents actually recorded in the area during light to moderate wind conditions varied from approximately 3 to 11 cm/s (see Section 13.2) and so there is the potential for tidal flows to be significantly modified at the surface during prolonged high winds. Such surface water currents create return currents which may travel along the bottom or sides of the water body depending on bathymetry. Strong winds will increase the circulation of water and hence dilution of contamination from point sources within the sound.

10. Current and historical classification status

Of the three production areas considered in this report, Gruting Voe: Seli Voe and Gruting Voe: Braewick Voe are currently classified for the production of mussels. Until the end of 2003, these two areas were classified together under a larger production area encompassing Browlands Voe, Seli Voe and Braewick Voe. In 2004, this area was split to its current boundaries. The classification histories from 2004 on are presented in Tables 10.1 and 10.2. Green Head is yet to be classified. A map of these production areas can be found in Section 2, Figure 2.1.

Table 10.1 Classification history, Gruting Voe: Seli Voe, common mussels

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2004	A	A	A	A	A	A	B	B	B	A	A	A
2005	A	A	A	A	A	B	B	B	B	A	A	A
2006	A	A	A	A	A	A	A	A	A	A	A	A
2007	A	A	A	A	A	A	A	B	B	B	B	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	B	A
2010	A	A	A									

Gruting Voe: Seli Voe received seasonal A/B classifications in all years apart from in 2006 and 2008, when it received a year round A classification. Months of B classification varied slightly from year to year, but almost always fell in the second half of the year (the exception being June 2005).

Table 10.2 Classification history, Gruting Voe: Braewick Voe, common mussels

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2004	A	A	A	A	A	A	A	A	A	A	A	A
2005	A	A	A	A	A	A	A	A	A	A	A	A
2006	A	A	A	A	A	B	B	B	B	B	B	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									

Since 2004, Gruting Voe: Braewick Voe has held year round A classifications, apart from in 2006 when it received a seasonal A/B classification, with the B months extending from June to November.

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken Green Head, Gruting Voe: Seli Voe Gruting Voe: Braewick Voe from the beginning of 2002 up to the 29th September 2009 were extracted from the database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data.

Fourteen samples from Gruting Voe: Seli Voe were reported from HU 281 484, which falls 280 m outside the production area, so these samples were excluded from the analysis. One sample from Gruting Voe: Braewick Voe had an invalid laboratory test result so could not be used.

Nineteen samples from Gruting Voe: Braewick Voe, 24 samples from Gruting Voe: Seli Voe, and 3 samples from Green Head had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation.

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

11.2 Summary of microbiological results

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

Table 11.1 Summary of historical sampling and results

Sampling Summary					
Production area	Green Head	Gruting Voe: Braewick Voe	Gruting Voe: Braewick Voe	Gruting Voe: Seli Voe	Gruting Voe: Seli Voe
Site	North Of Green Head	Braewick Voe	Braewick Voe	Seli Voe	Seli Voe
Species	Common mussels	Common mussels	Common mussels	Common mussels	Common mussels
SIN	SI-442-846-08	SI-080-424-08	SI-080-424-08	SI-084-428-08	SI-084-428-08
Location	HU252471	HU257476	HU260480	HU279479	HU281481
Total no of samples	6	20	63	20	52
No. 2002	0	0	11	0	6
No. 2003	0	0	10	0	9
No. 2004	0	0	12	0	8
No. 2005	0	0	13	0	12
No. 2006	0	0	12	0	11
No. 2007	0	5	5	4	6
No. 2008	0	9	0	9	0
No. 2009	6	6	0	7	0
Results Summary					
Minimum	<20	<20	<20	<20	<20
Maximum	130	330	2200	790	1300
Median	25	20	20	20	40
Geometric mean	27.3	29.1	36.9	29.3	40.2
90 percentile	105	167	310	150	220
95 percentile	118	235	310	353	723
No. exceeding 230/100g	0 (0%)	1 (5%)	9 (14%)	2 (10%)	5 (10%)
No. exceeding 1000/100g	0 (0%)	0 (0%)	2 (3%)	0 (0%)	1 (2%)
No. exceeding 4600/100g	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
No. exceeding 18000/100g	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

11.3 Overall geographical pattern of results

Figure 11.1 presents a map showing geometric mean *E. coli* result by reported sampling locations, and Figure 11.2 presents a boxplot of the same data.

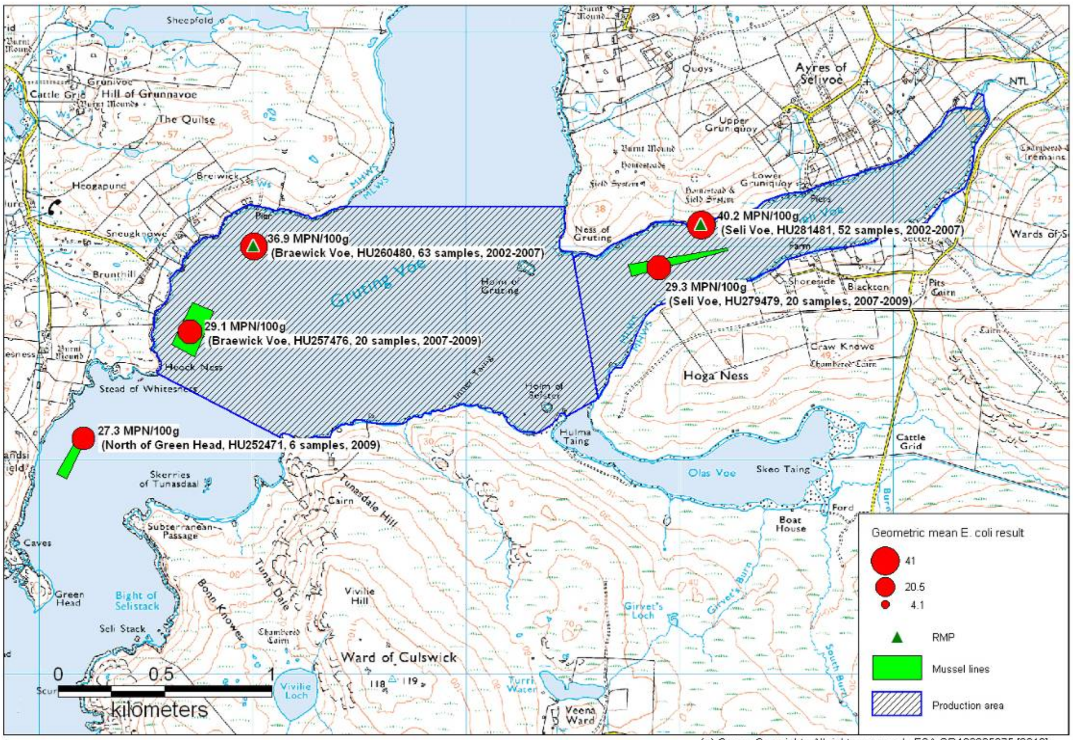


Figure 11.1 Map of sampling points and geometric mean result

Table 11.1 and Figure 11.2 show that geometric mean *E. coli* result and the proportion of results exceeding 230 *E. coli* MPN/100g were similar at all sampling locations. Figure 11.1 gives the impression that results increase very slightly with increasing longitude, or possibly with increasing distance from the mouth of Gruting Voe. However, mean results did not differ significantly between sampling locations (One-way ANOVA, p=0.811, Appendix 6) or between sites (One-way ANOVA, p=0.861 Appendix 6). Both Gruting Voe: Seli Voe and Gruting Voe: Browlands Voe were sampled on the same date, and hence under comparable environmental conditions on 34 occasions. A comparison of these results again revealed no significant difference (paired T-test, T=0.82, p=0.418). It was not possible to make statistical comparisons of proportions of results greater than 230 *E. coli* MPN/100g by sampling location or by site due to the low numbers of samples yielding such results in the paired data set. However, in the entire data set, results greater than 1,000 *E. coli* MPN/100 g were only seen at the northernmost Braewick Voe sampling point (HU 260 480; 2 occasions) and the easternmost Seli Voe sampling point (HU 281 481; 1 occasion) indicating that these locations may be occasionally exposed to higher levels of contamination than other locations sampled in the area.

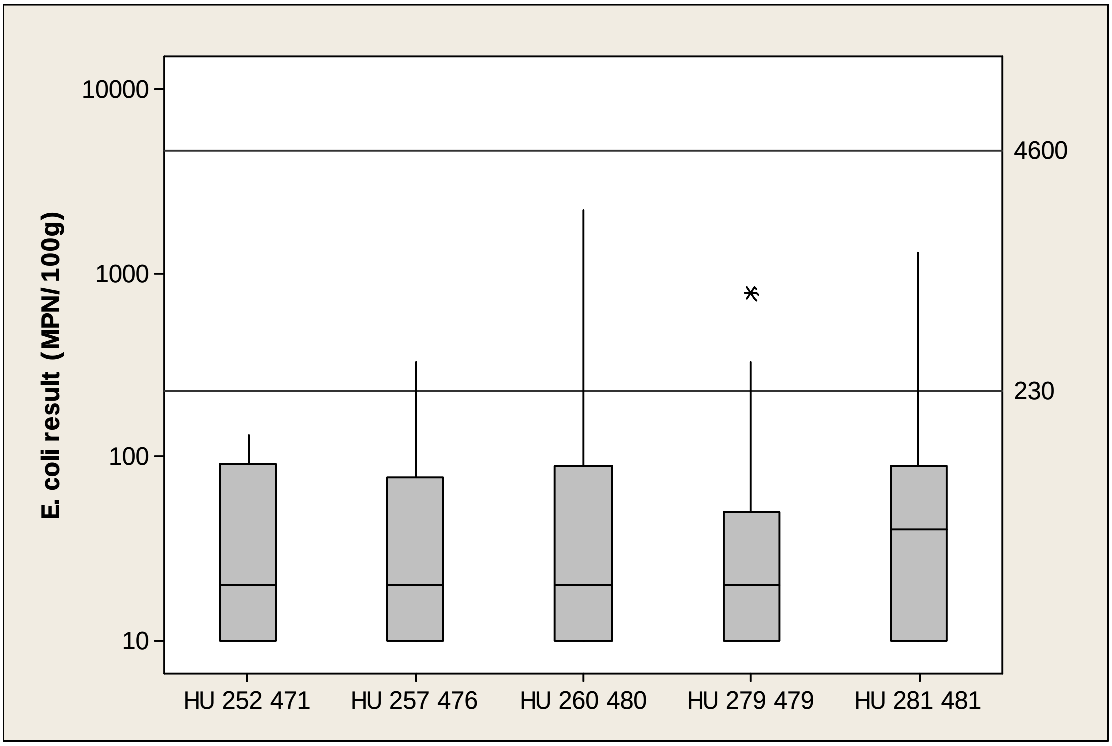


Figure 11.2 Boxplot of *E. coli* results by reported sampling location

11.4 Overall temporal pattern of results

Figures 11.3 and 11.4 present a scatter plots of individual results against date for Gruting Voe: Braewick Voe and Gruting Voe: Seli Voe. The points are fitted with trend lines calculated using two different techniques. These trend lines help to highlight any apparent underlying trends or cycles. There were insufficient samples from Green Head to investigate temporal trends in levels of contamination.

One of the trend lines joins the values representing the geometric mean of the previous 5 samples, the current sample and the following 6 samples and is referred to as a rolling geometric mean (black line). The other is a loess line (blue line), which stands for 'locally weighted regression scatter plot smoothing'. At each point in the data set an estimated value is fit to a subset of the data, using weighted least squares. The loess line 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 will be influenced more by the data close to it (in time) and less by the data further away.

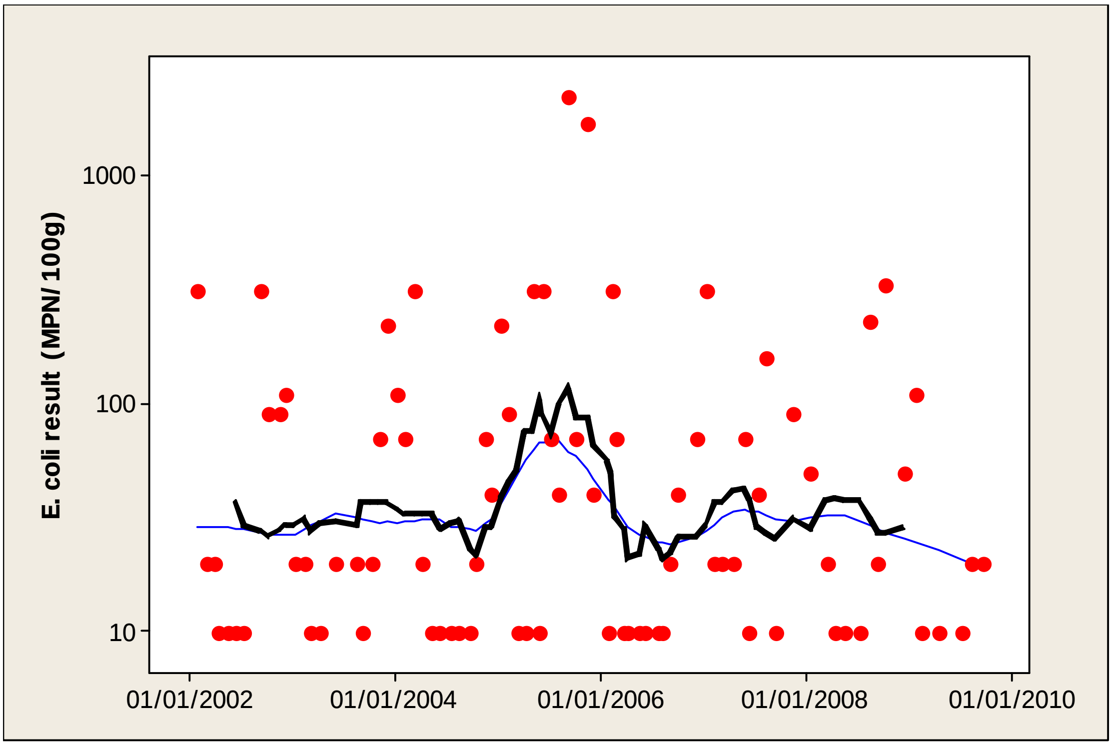


Figure 11.3 Scatterplot of *E. coli* results by date with rolling geometric mean (black line) and loess line (blue line) for Gruting Voe: Braewick Voe

Figure 11.3 shows that a peak in results occurred in 2005 at Gruting Voe: Braewick Voe. Results of <20 *E. coli* MPN/100 g tended to be seen mainly in the spring.

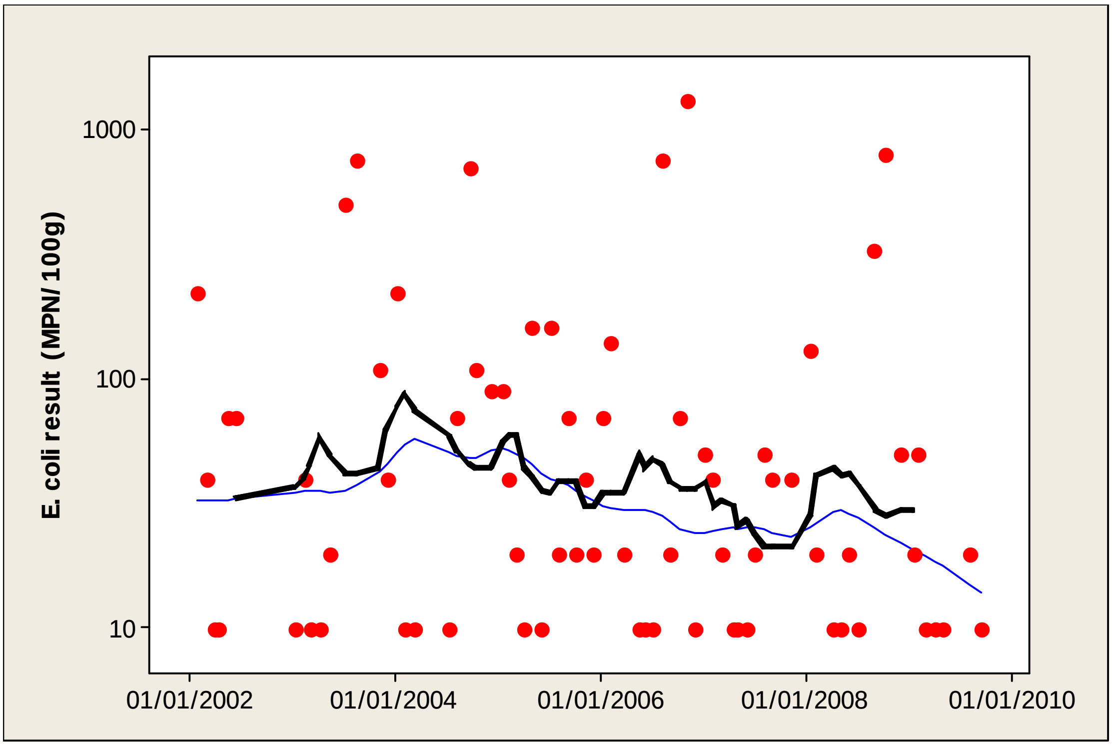


Figure 11.4 Scatterplot of *E. coli* results by date with rolling geometric mean (black line) and loess line (blue line) for Gruting Voe: Seli Voe

Figure 11.4 suggests a slight overall improvement in the average level of results occurred from 2005 to 2009 at Gruting Voe: Seli Voe. However, peak results approaching 1,000 *E. coli* MPN/100g have continued to occur.

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 11.5 and 11.6 present boxplots of *E. coli* result by month from Gruting Voe: Braewick Voe and Gruting Voe: Seli Voe respectively.

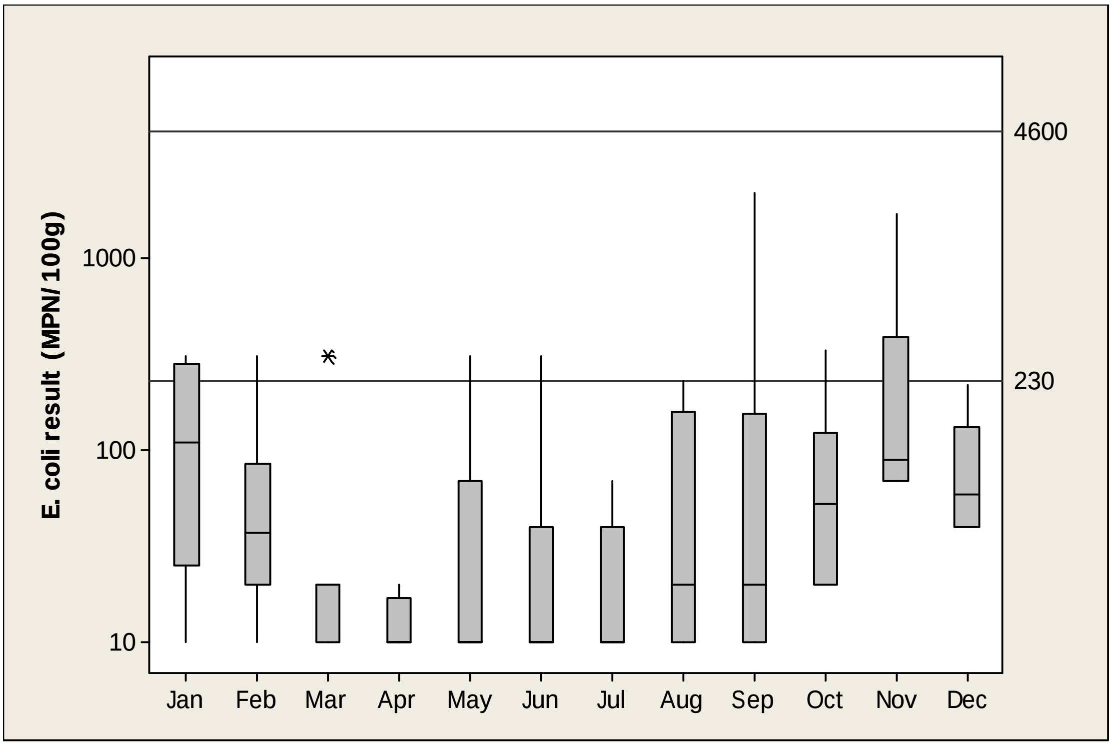


Figure 11.5 Boxplot of results by month (Gruting Voe: Braewick Voe)

Results were generally lowest in March and April, and highest from September to January. However, results exceeding 230 *E. coli* MPN/100 g were seen in most months in one or more of the years represented in the plot.

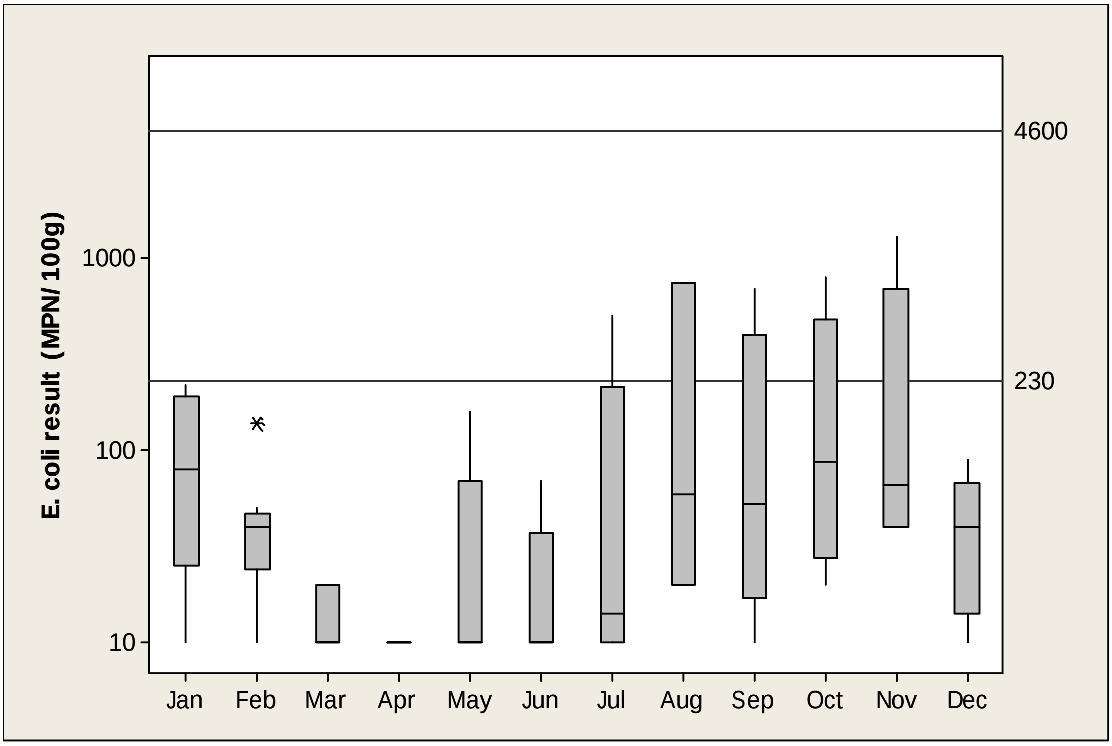


Figure 11.6 Boxplot of results by month (Gruting Voe: Seli Voe)

Higher results generally occurred from August to November, and lower results occurred from December to June. At this location, results only exceeded 230 *E. coli* MPN/100 g in one or more years during the period July to November.

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

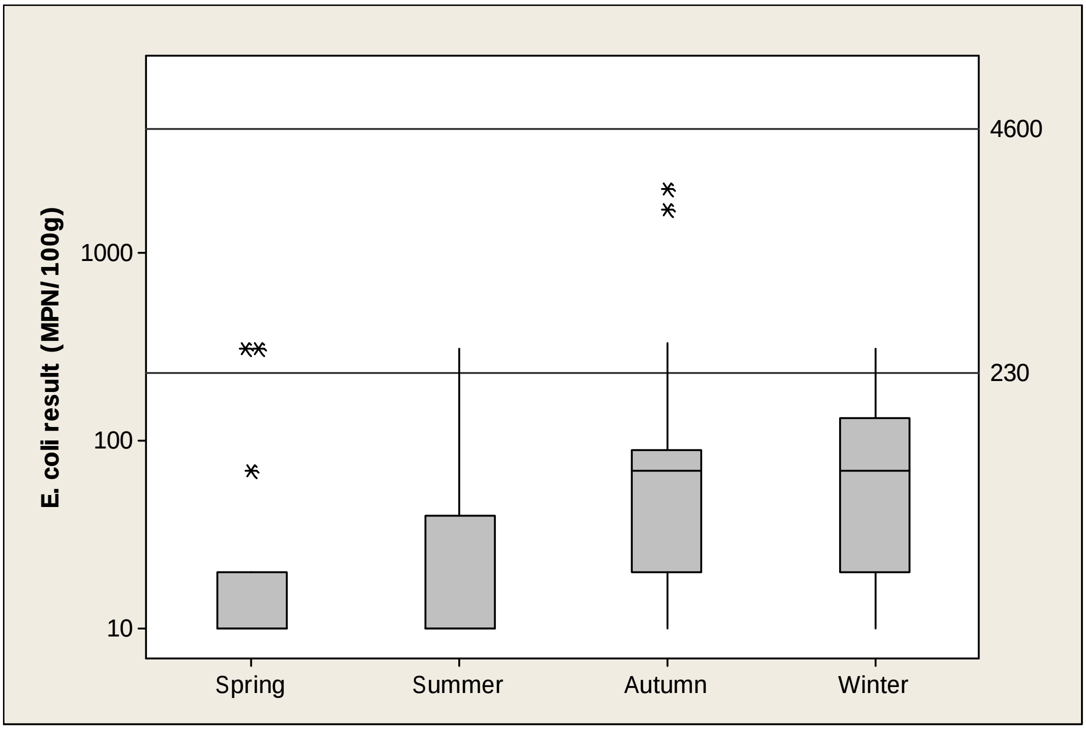


Figure 11.7 Boxplot of result by season (Gruting Voe: Braewick Voe)

A significant difference was found between results by season for Gruting Voe: Braewick Voe (One-way ANOVA, p=0.001, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicated that results were significantly higher for autumn and winter compared to spring, and significantly higher for winter compared to summer.

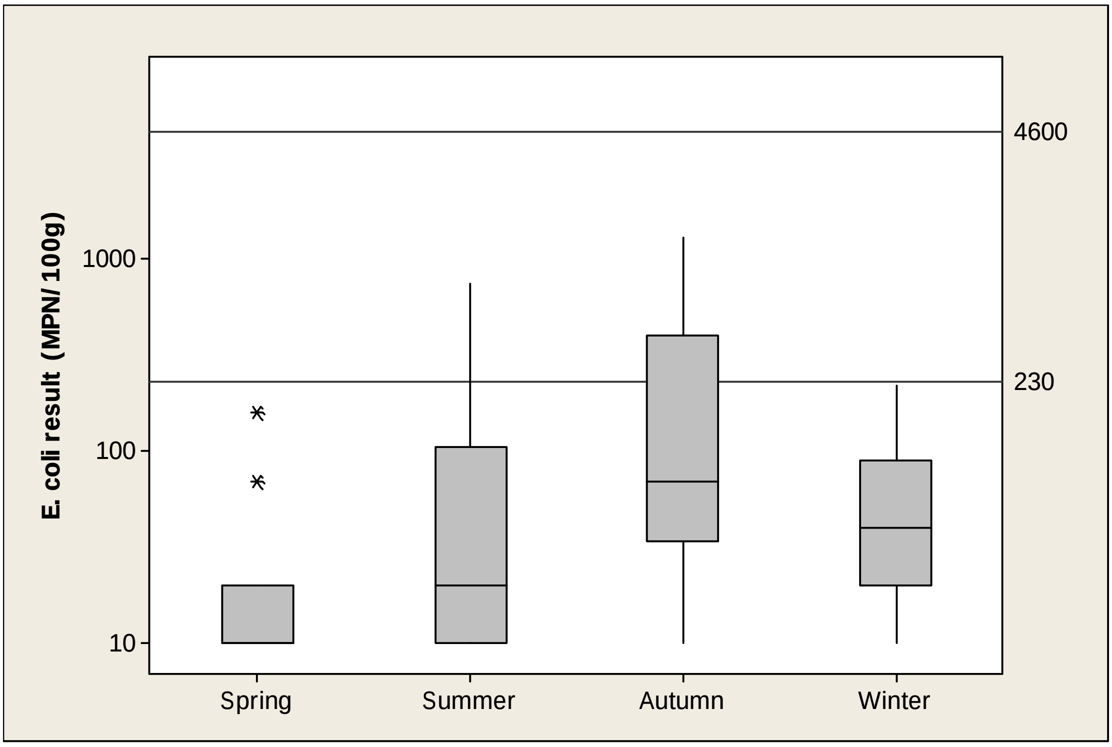


Figure 11.8 Boxplot of result by season (Gruting Voe: Seli Voe)

A significant difference was found between results by season for Gruting Voe: Seli Voe (One-way ANOVA, p=0.000, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicates that results for the autumn and winter were significantly higher than those in the spring.

11.6 Analysis of results against environmental factors

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

11.6.1 Analysis of results by recent rainfall

The nearest weather station is at Lerwick, approximately 20 km to the south-east of the fishery. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2008 (total daily rainfall in mm). Figure 11.9 presents a scatterplot of *E. coli* results against rainfall for Gruting Voe:

Braewick Voe and Figure 11.10 presents the same for Gruting Voe: Seli Voe. Spearman's Rank correlations were carried out between results and rainfall.

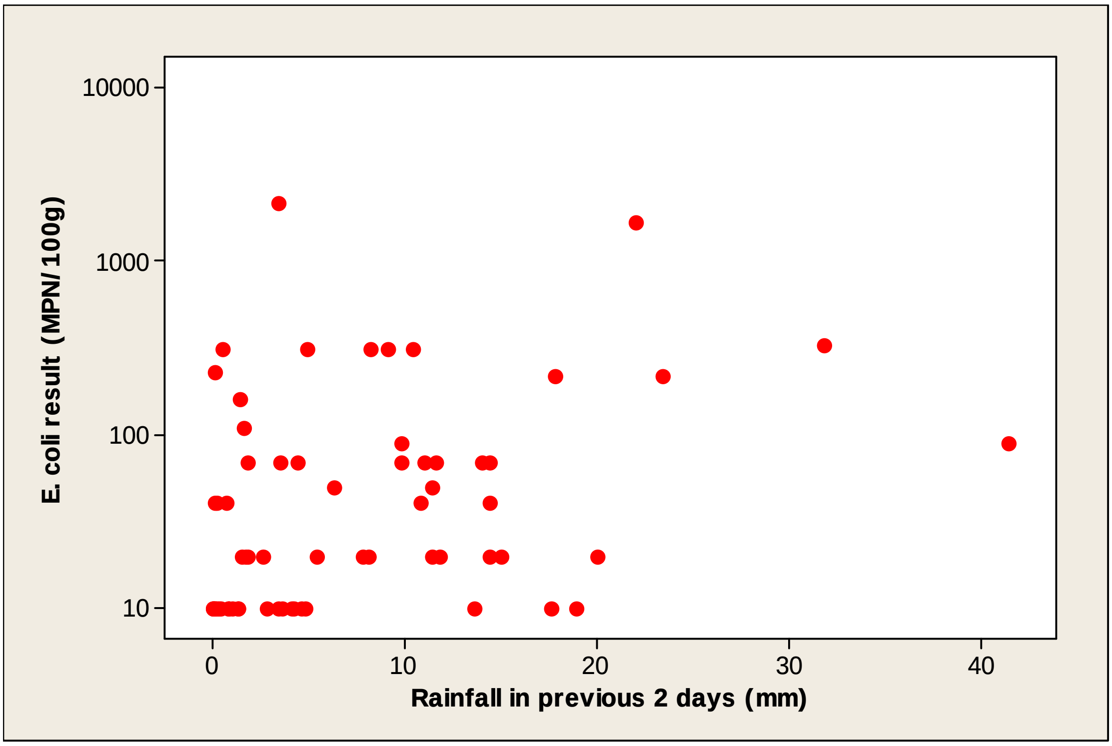


Figure 11.9 Scatterplot of result against rainfall in previous 2 days (Gruting Voe: Braewick Voe)

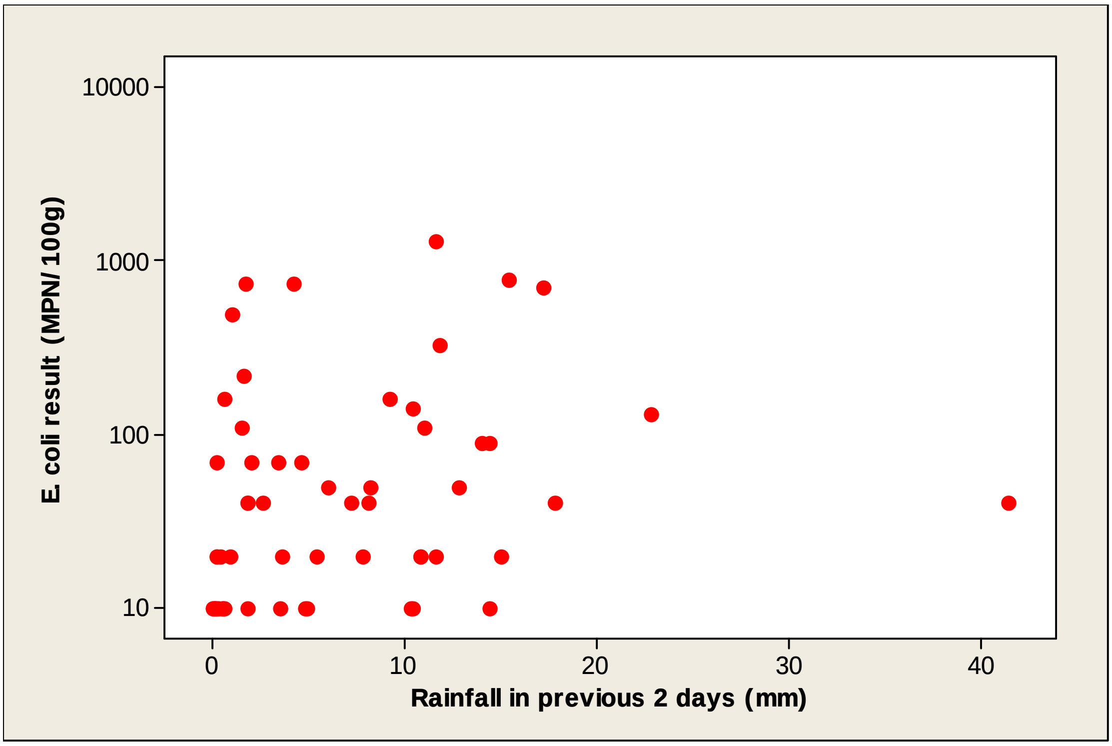


Figure 11.10 Scatterplot of result against rainfall in previous 2 days (Gruting Voe: Seli Voe)

A positive correlation was found between *E. coli* result at Gruting Voe: Braewick Voe and rainfall in the previous 2 days (Spearman's rank correlation=0.387, p=0.001, Appendix 6). However, the two highest results, both <1,000 *E. coli* MPN/100 g, were seen following widely differing amounts of rainfall prior to sampling, and the highest level of rain (>40 mm in 2 days) preceeding sampling was associated with a relatively low result of 90 *E. coli* MPN/100 g.

A positive correlation was also found between *E. coli* result at Gruting Voe: Seli Voe and rainfall in the previous 2 days (Spearman's rank correlation=0.411, p=0.001, Appendix 6). However, a number of results in the vicinity of 1,000 *E. coli* MPN/100 g were associated with a range of rainfall values (from 1 mm upwards) and the highest rainfall value (> 40 mm in 2 days) was associated with a low result of 40 *E. coli* MPN/100 g.

As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationship between rainfall in the previous 7 days and sample results was investigated in an identical manner to the above.

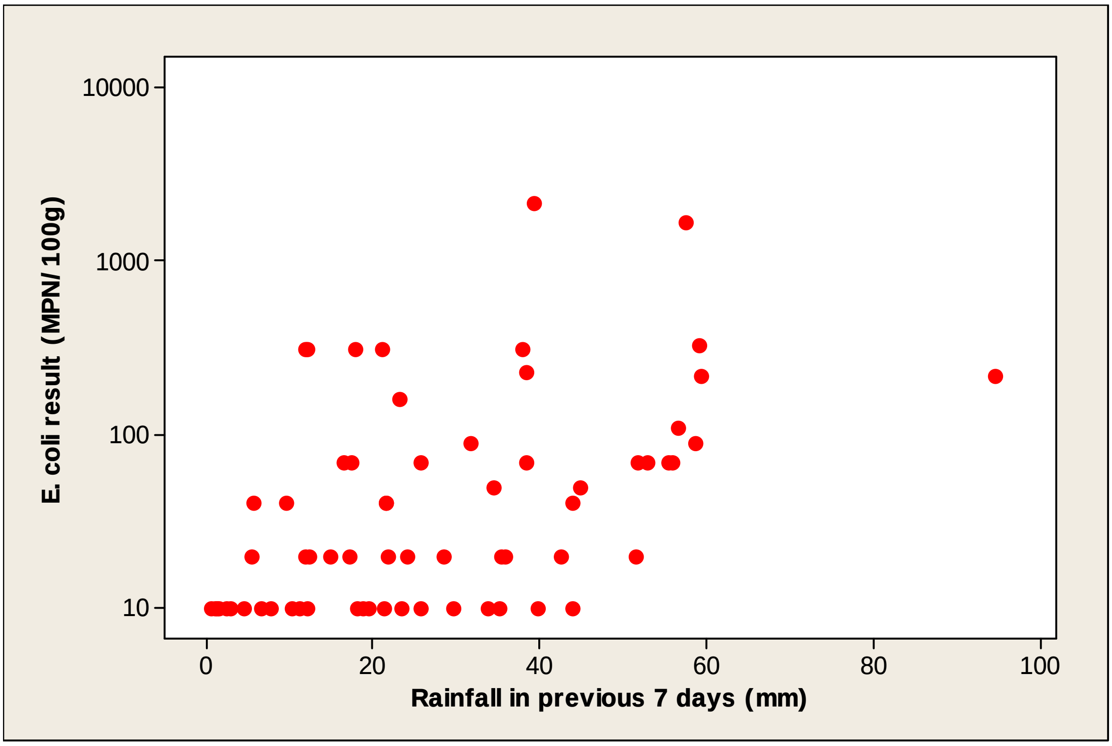


Figure 11.11 Scatterplot of result against rainfall in previous 7 days (Gruting Voe: Braewick Voe)

A positive correlation was found between *E. coli* result at Gruting Voe: Braewick Voe and rainfall in the previous 7 days (Spearman's rank correlation=0.508, p=0.000, Appendix 6).

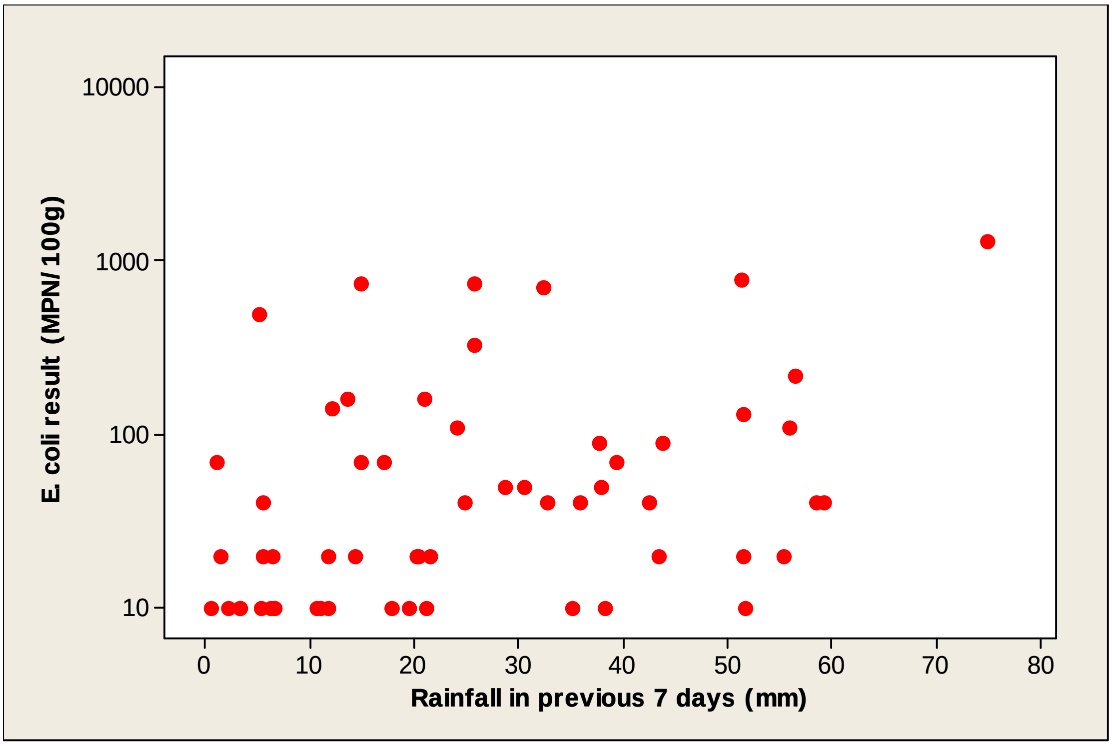


Figure 11.12 Scatterplot of result against rainfall in previous 7 days (Gruting Voe: Seli Voe)

A positive correlation was found between *E. coli* result at Gruting Voe: Seli Voe and rainfall in the previous 7 days (Spearman's rank correlation= 0.395, p=0.002, Appendix 6).

At Braewick Voe, a clear pattern was seen between *E. coli* result and 7 day rainfall, with no results greater than 100 *E. coli* MPN/100 g occurring at rainfall values of less than 10 mm and the two highest E. coli results occurring at rainfall values of 40 mm or more. At Seli Voe, the pattern with regard to high results was less clear and although

11.6.2 Analysis of results by tidal height and state

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 loch. Figures 11.13 and 11.14 present polar plots of $\log_{10}$ *E. coli* results on the lunar spring/neap tidal cycle for Braewick Voe and Seli Voe respectively. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of under 230 *E. coli* MPN/100g are plotted in green, those between 230 and 1000 *E. coli* MPN/100g are plotted in yellow, and those over 1000 *E. coli* MPN/100g are plotted in red. It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account.

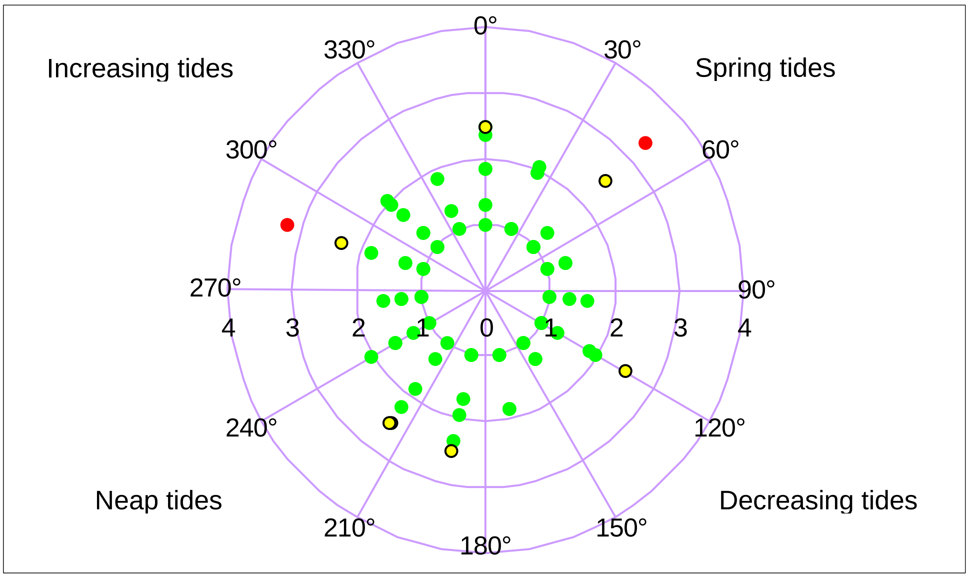


Figure 11.13 Polar plot of $\log_{10}$ E. coli results on the spring/neap tidal cycle (Braewick Voe)

No correlation was found between *E. coli* results and the spring/neap cycle for Braewick Voe (circular-linear correlation, r=0.125, p=0.289, Appendix 6) and no pattern in results is apparent in Figure 11.13.

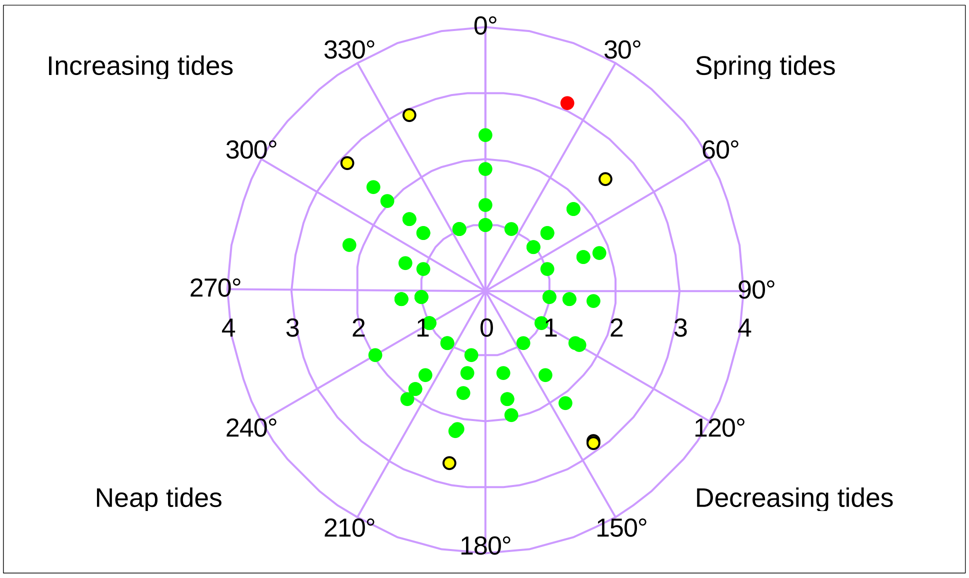


Figure 11.14 Polar plot of $\log_{10}$ E. coli results on the spring/neap tidal cycle (Seli Voe)

No correlation was found between *E. coli* results and the spring/neap cycle for Seli Voe (circular-linear correlation, r=0.092, p=0.555, Appendix 6), and no pattern in results is apparent in Figure 11.14.

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As *E. coli* levels in some shellfish species can respond within a few hours or less to changes in

E. coli levels in water, tidal state at time of sampling (hours post high water) was compared with *E. coli* results. Figures 11.15 and 11.16 present polar plots of log_{10} *E. coli* results on the lunar high/low tidal cycle for Braewick Voe and Seli Voe respectively. High water is at 0º, and low water is at 180º. Again, results of under 230 *E. coli* MPN/100g are plotted in green, those between 230 and 1000 *E. coli* MPN/100g are plotted in yellow.

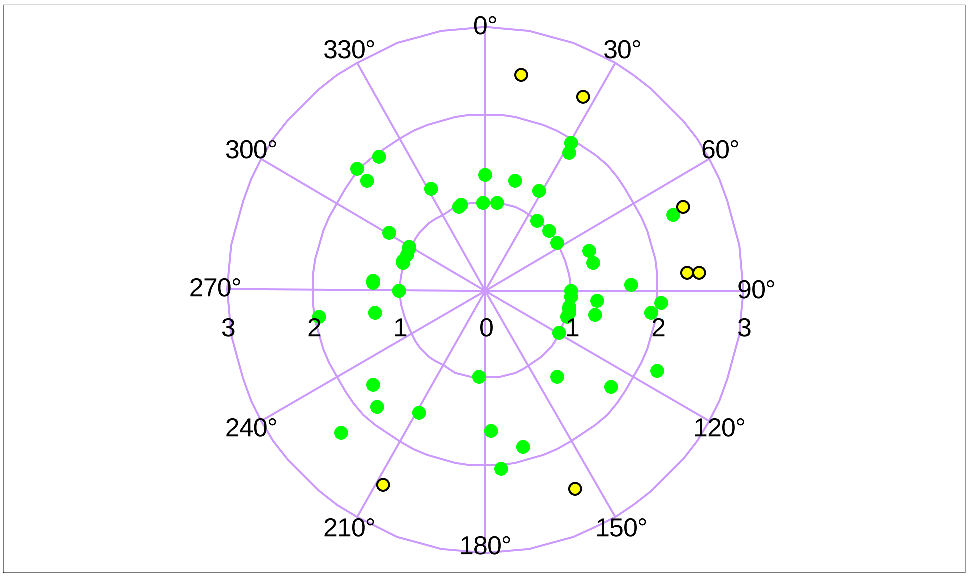


Figure 11.15 Polar plot of log_{10} *E. coli* results on the high/low tidal cycle (Braewick Voe).

A very weak correlation was found between *E. coli* results and the high/low tidal cycle for the Braewick Voe (circular-linear correlation, r=0.230, p=0.045, Appendix 6). Figure 11.15 shows some tendency for higher results to generally occur on the ebb tide.

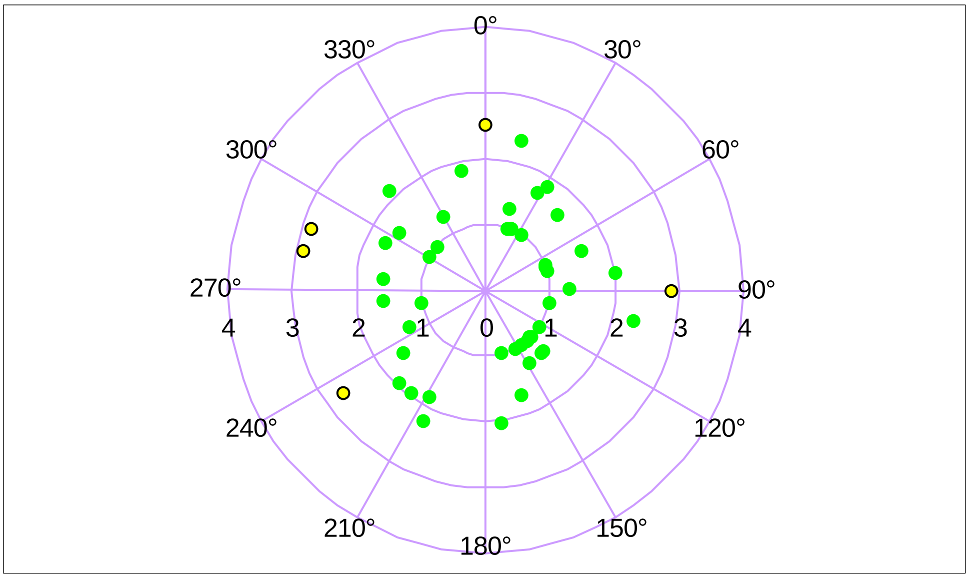


Figure 11.16 Polar plot of log_{10} *E. coli* results on the high/low tidal cycle (Seli Voe).

A weak correlation was found between *E. coli* results and the high/low cycle for Seli Voe (circular-linear correlation, r=0.311, p=0.010, Appendix 6). Results appear to be lower on average during the second half of the ebb tide.

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. Figures 11.17 and 11.18 present scatterplots of *E. coli* results against water temperature for Gruting Voe: Braewick Voe and Gruting Voe: Seli Voe respectively.

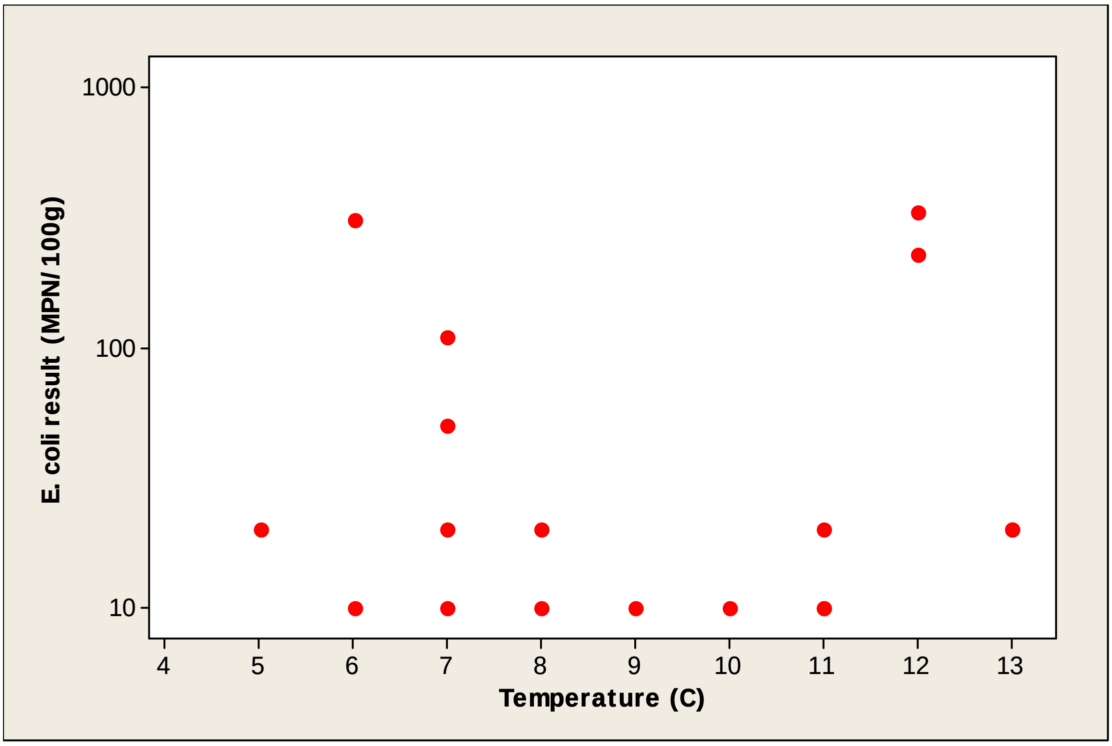


Figure 11.17 Scatterplot of result by water temperature (Gruting Voe: Braewick Voe)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and water temperature at Gruting Voe: Braewick Voe (Adjusted R-sq=0.0%, p=0.850, Appendix 6).

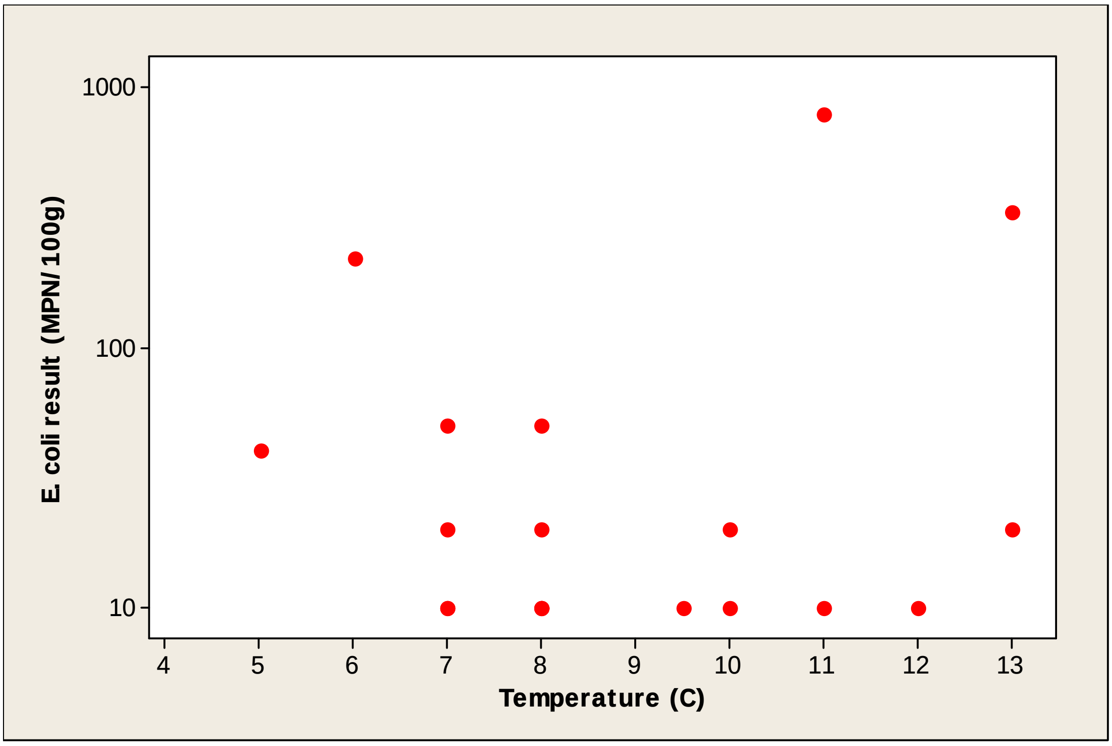


Figure 11.18 Scatterplot of result by water temperature (Gruting Voe: Seli Voe)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and water temperature at Gruting Voe: Seli Voe (Adjusted R-sq=0.0%, p=0.616, Appendix 6).

11.6.4 Analysis of results by wind direction

Wind speed and direction are likely to change water circulation patterns within the production area. However, the nearest wind station for which records were available was Lerwick, approximately 20 km to the south-east of the fishery. Given the differences in local topography and distance between the two it is likely that the overall patterns of wind direction differ, and that the wind strength and direction may differ significantly at any given time. Therefore it was not considered appropriate to compare *E. coli* results at Gruting Voe with wind readings taken at Lerwick.

11.6.5 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater borne contamination at the site. Figures 11.19 and 11.20 present a scatter plot of *E. coli* result against salinity. Five salinity readings from Gruting Voe: Braewick Voe and four from Gruting Voe: Seli Voe were over 36 ppt, and so fell outside the expected range of salinities and were not used in the analysis. In general,

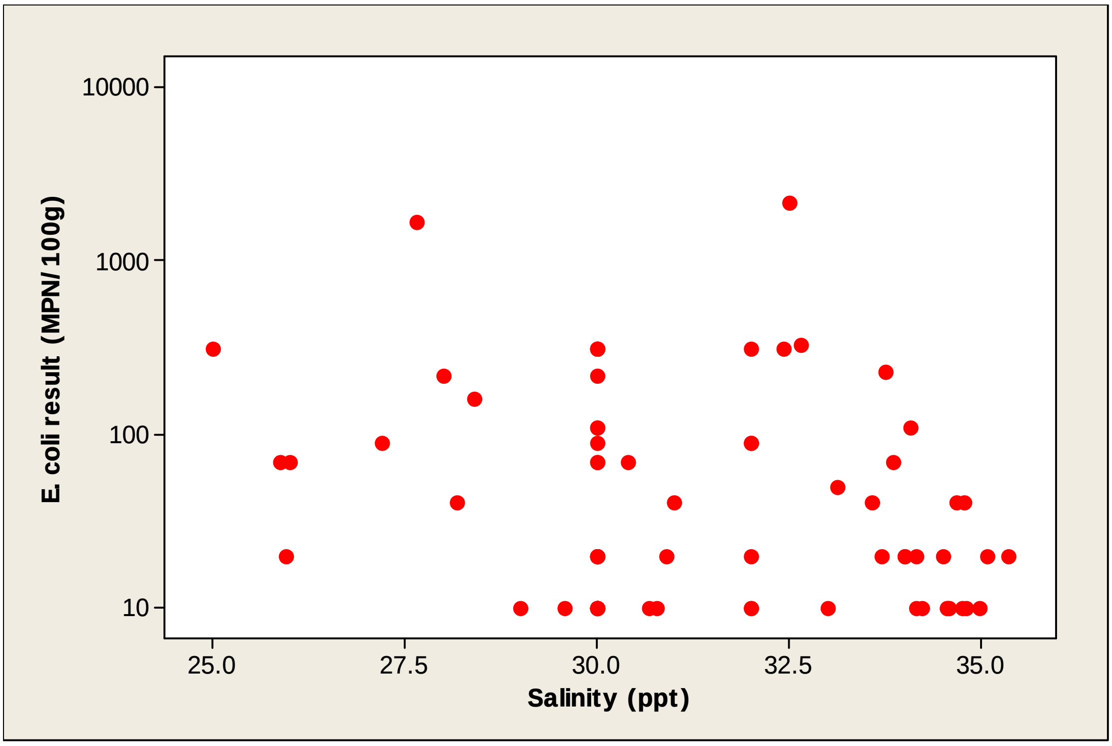


Figure 11.19 Scatterplot of result by salinity (Gruting Voe: Braewick Voe)

The coefficient of determination indicates that there was a weak positive relationship between the *E. coli* result at Gruting Voe: Braewick Voe and salinity (Adjusted R-sq=5.5%, p=0.023, Appendix 6).

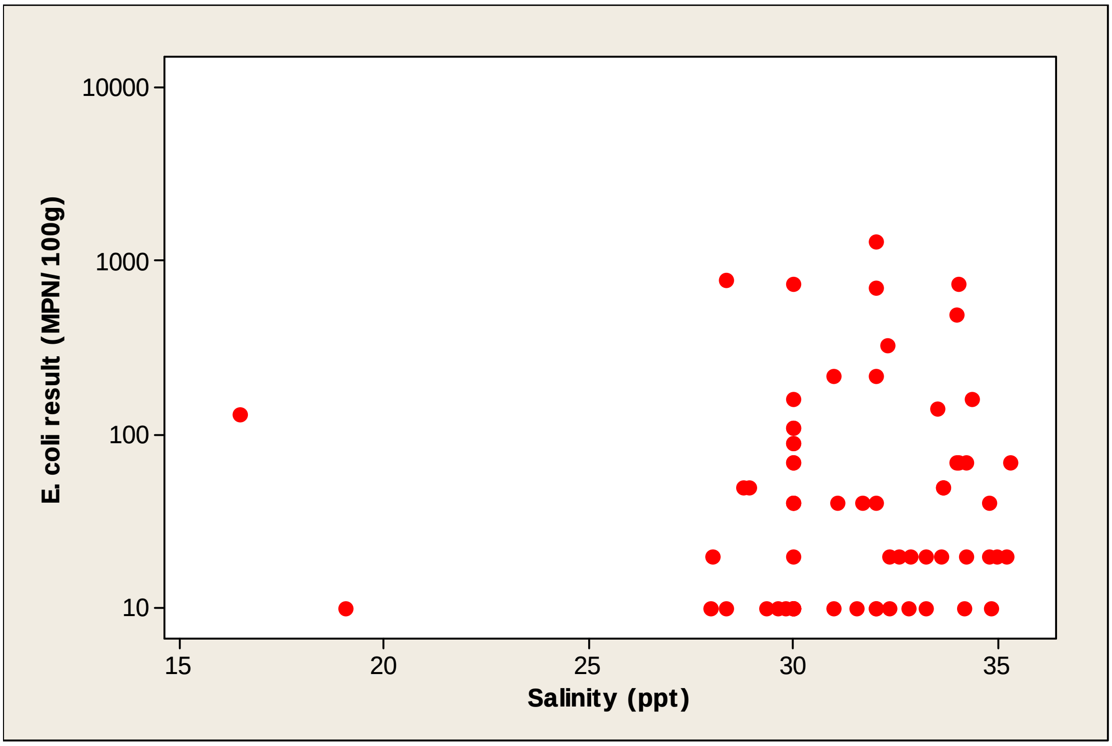


Figure 11.20 Scatterplot of result by salinity (Gruting Voe: Seli Voe)

The coefficient of determination indicates that there was no relationship between the *E. coli* result at Gruting Voe: Seli Voe and salinity (Adjusted R-sq=0.0%, p=0.723, Appendix 6). The two low salinity values recorded at Gruting Voe: Seli Voe were not associated with high *E. coli* results.

11.7 Evaluation of results of 500 *E. coli* MPN/100g or above

A total of 8 samples gave a result of 500 *E. coli* MPN/100g or higher, and these are listed in Table 11.2.

Table 11.2 Historic *E. coli* sampling results of 500 *E. coli* MPN/100g or higher

Collection date	*E. coli* (MPN/ 100g)	Site	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tidal state (high/low)	Tidal state (spring/neap)
07/07/2003	500	Seli Voe	HU281481	1	5	*	34	Flood	Neap
18/08/2003	750	Seli Voe	HU281481	1.7	14.8	*	30	Flood	Decreasing to neap
20/09/2004	700	Seli Voe	HU281481	17.2	32.4	*	32	Flood	Decreasing to neap
05/09/2005	2200	Braewick Voe	HU260480	3.4	39.3	*	33	*	Spring
14/11/2005	1700	Braewick Voe	HU260480	22	57.3	*	28	*	Increasing to spring
07/08/2006	750	Seli Voe	HU281481	4.2	25.6	*	34	*	Increasing to spring
06/11/2006	1300	Seli Voe	HU281481	11.6	74.8	*	32	*	Spring
13/10/2008	790	Seli Voe	HU279479	15.4	51.3	11	28	Ebb	Increasing to spring

* Data unavailable

Of these results, 6 of 8 occurred at Seli Voe, although the two highest results arose at Braewick Voe. The 8 high results occurred in July (1), August (2), September (2), October (1) and November (2) and therefore all fell within the summer/autumn period. They results arose under a range of salinities and tidal states. However, they all occurred after rainfall and, for 7 of the 8, the preceding 7-day rainfall exceeded 10 mm.

11.8 Summary and conclusions

No significant difference was found in average *E. coli* results between any of the sampling locations within the survey area, although the Figure 11.1 gave the very tentative impression of increasing levels of contamination with increasing longitude. Low sample numbers (6) prevented further analysis of results from Green Head. High results greater than 1,000 *E. coli* MPN/100 g were only seen at one of the two sampling locations in Braewick Voe and one of the two sampling locations in Seli Voe.

A peak in results occurred in 2005 at Braewick Voe. A slight overall improvement in results was seen between 2005 and 2009 at Seli Voe. Similar seasonal effects were found at Braewick Voe and Seli Voe. At Braewick Voe, results were significantly higher for autumn and winter compared to spring, and significantly higher for winter compared to summer. At Seli Voe, results for the autumn and winter were significantly higher than those in the spring. No relationship between *E. coli* results and water temperature was found at either of these sites however.

Positive correlations between both 2 and 7 day rainfall and *E. coli* result were found for both Braewick Voe and Seli Voe. This indicates that *E. coli* results are influenced by rainfall. High *E. coli* results tended to be seen over a wide range of preceding rainfall values, and an obvious association of high rainfall and peak E. coli results was only seen with the 7 day rainfall values at Braewick Voe. A weak relationship between *E. coli* results and salinity was found at Braewick Voe only.

No correlations between *E. coli* result tidal state on the spring/neap tidal cycle were found at either Braewick Voe or Seli Voe. Weak correlations between tidal state on the high/low cycle were found at Braewick Voe and Seli Voe, although no strong tidally influenced pattern in levels of contamination was apparent when these data were plotted.

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

11.9 Sampling frequency

When a production area has held the same (non-seasonal) classification for 3 years, and the geometric mean of the results falls within a certain range it is recommended that the sampling frequency be decreased from monthly to bimonthly. Gruting Voe: Seli Voe has not held a non-seasonal classification for the last three years. However, Gruting Voe: Braewick Voe has been class A for the last three years. The geometric mean for the samples taken at Braewick Voe over the period 2007 to 2009 ,and included in the analyses in this section, was 31.7 *E. coli* MPN/ 100g. The upper limit recommended for consideration of a reduced sampling frequency for class A areas is 13. Therefore, Braewick Voe does not comply with this requirement and so is not suitable for reduced sampling frequency.

12. Designated Shellfish Growing Waters Data

The area considered in this report coincides in part with a shellfish growing water which was designated in 2002. The growing water encompasses a larger area than the two production areas covered by this report. The extent of the growing water is shown on Figure 12.1.

The monitoring requires the following testing:

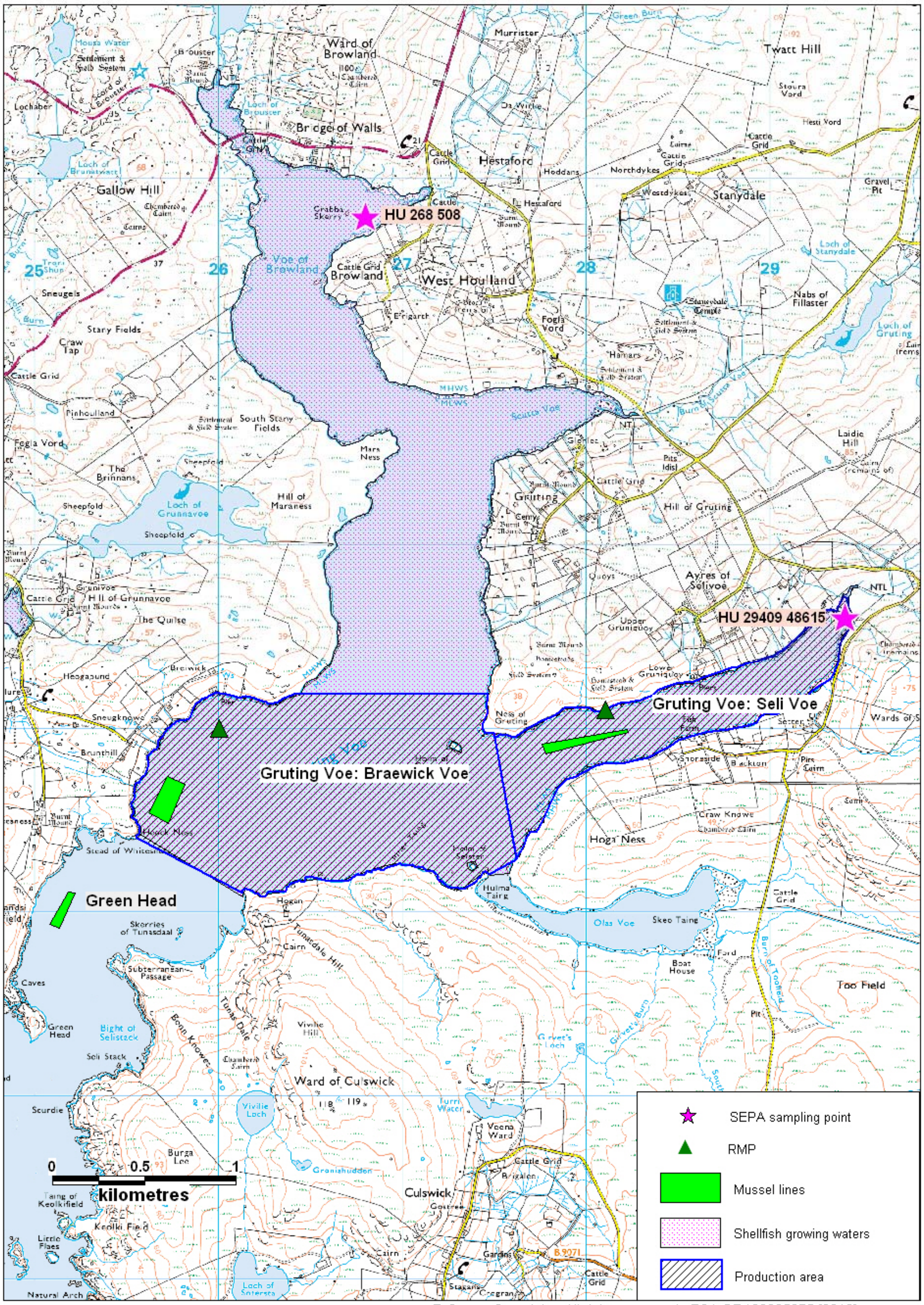
- Quarterly for salinity, dissolved oxygen, pH, temperature, visible oil
- Twice yearly for metals in water
- Annually for metals and organohalogens in mussels
- Quarterly for faecal coliforms in mussels

There are two designated monitoring points within the growing water indicated on the map. One is located at the head of Seil Voe, within the Gruting Voe: Seli Voe production area. The other falls outside of the area considered in this report (only two samples were taken from that location). Results are presented in Table 12.1. It should be noted that from early 2007, SEPA started to use FSAS *E. coli* data for SGW compliance reporting purposes.

Table 12.1 SEPA Faecal coliform results (faecal coliforms/100g) for shore mussels gathered from Gruting Voe.

	Site	Gruting Voe	Gruting Voe
	OS Grid Ref.	HU 268 508	HU 29409 48615
2002	Q1		
	Q2		
	Q3		
	Q4	40	
2003	Q1	<20	
	Q2		
	Q3		5400
	Q4		500
2004	Q1		160
	Q2		9100
	Q3		310
	Q4		50
2005	Q1		40
	Q2		750
	Q3		>18000*
	Q4		515
2006	Q1		40
	Q2		320
	Q3		1300
	Q4		9100
2007	Q1		130
	Q2		
	Q3		
	Q4		

* Assigned a nominal value of 36000 for the calculation of the geometric mean.



Production areas, RMPs and mussel lines are shown for lower Gruting Voe only

Figure 12.1 Shellfish growing waters and monitoring points

The geometric mean result of all SEPA shore mussel samples from HU 29409 48615 was 614 faecal coliforms / 100g. Results ranged from 40 to >18000 faecal coliforms/100g. High results (>1,000 *E. coli* MPN/100 g) were seen in quarters 2, 3 and 4 but not quarter 1. However, differences between results by quarter were not significant (One-way ANOVA, p=0.068, Appendix 6). The quarters used in the SEPA monitoring differ from those used in the analysis of classification data elsewhere in this report and so it is not possible to directly compare the seasonal effects.

Levels of faecal coliforms are usually closely correlated to levels of *E. coli* often at a ratio of approximately 1:1. The ratio depends on a number of factors, such as environmental conditions and the source of contamination and as a consequence the results presented in Table 12.1 are not directly comparable with other shellfish testing results presented in this report. However, the peak faecal coliform results from the wild mussel samples taken at the head of Seli Voe were higher than the peak levels seen in the aquaculture mussels in lower Gruting Voe, including the lines in the mouth of Seli Voe. This suggests that they have been exposed to a higher level of faecal contamination.

13. Rivers and streams

There are no river gauging stations on rivers or burns along the coastline in lower Gruting Voe.

The rivers and streams listed in Table 13.1 were measured and sampled during the shoreline survey. These represent the largest freshwater inputs into the survey area. There was no rainfall on the days of the survey during which the streams were measured and sampled.

Table 13.1 Stream loadings for lower Gruting Voe

No	Grid Reference	Width (m)	Depth (m)	Flow (m/s)	Flow in m^3/day	*E.coli* (cfu/ 100ml)	Loading (*E.coli* per day)
1	HU 29451 48763	3.3	0.35	0.064	6390	200	1.3×10^{10}
2	HU 29232 48179	1	0.085	0.1	3	85	2.6×10^{6}
3	HU 28754 46885	1.5	0.11	0.22	47	1300	6.1×10^{8}
4	HU 28687 46706	1.3	0.213	0.05	1480	1000	1.5×10^{10}
5	HU 28921 47130	1.2	0.22	0.216	5070	340	1.7×10^{10}

A stream located on the western shore of lower Gruting Voe, just to the north of the Braewick Voe site, yielded a result of 1600 *E. coli* cfu/100 ml (see Figure 3 of the shoreline survey report). The flow at the time of the shoreline survey was too small to measure and therefore a loading could not be calculated. In addition, two streams were observed that were too small to measure and sample and two dry stream beds were noted. Some dry drainage ditches were also seen.

It was noted that the lower portion of stream 1 was tidal. A local crofter reported that the flow in stream 2 increased markedly after rain.

The points where the streams were measured and sampled are shown in Figure 13.1 together with the calculated loadings. Two of the streams with the largest loadings were located in Olas Voe and one was located at the head of Seli Voe. No measurable freshwater inputs were observed in the close vicinity of any of the mussel farm sites.

Other burns and streams are shown on the Ordnance Survey map. It is likely that these only run in wet weather and thus these may represent additional sources of potential contamination during periods of wet weather.

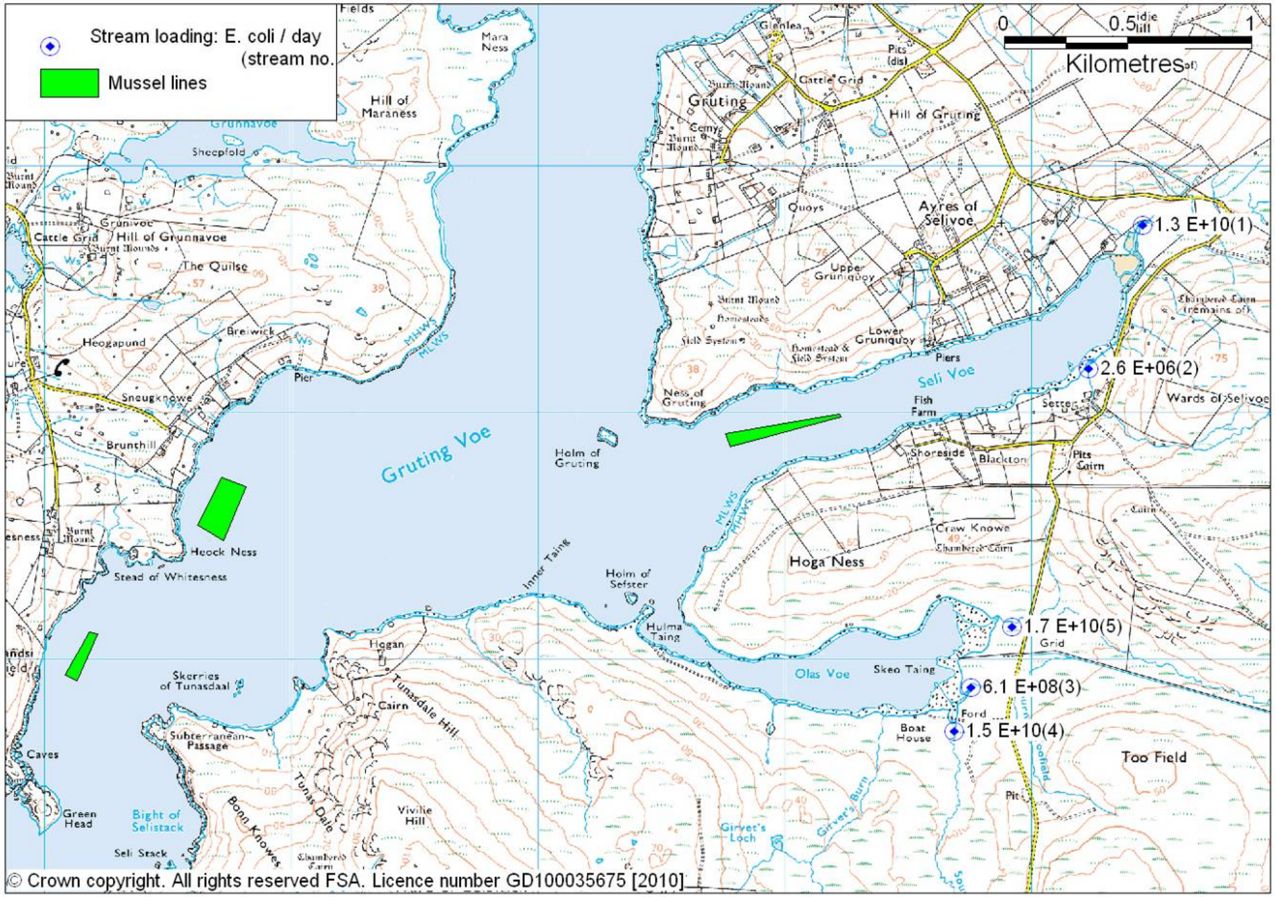


Figure 13.1 Map of river/stream loadings in lower Gruting Voe

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. Where normal scientific notation for 1000 is 1×10^3, in this case it would be written as 1E+3.

14. Bathymetry and Hydrodynamics

Currents in coastal waters and estuaries are driven by a combination of tide, wind and freshwater inputs. This section aims to make a simple assessment of water movements around the area. Figure 14.1 shows the OS map of lower Gruting Voe (including Seli Voe) and Figure 14.2 shows the bathymetry of the same area.

Gruting Voe as a whole is approximately 7km long and runs in a generally north to south direction, although the mouth where it joins the Atlantic is angled to the south-west. It is approximately 1 km wide in the vicinity of the fisheries. The voe has two sills (Edwards & Sharples, 1991). One sill is located in the north part of the voe, at Mara Ness (not shown in the figures) The other is located at Green Head, immediately to the south of the fisheries being considered here. The mussel farm sites considered in this report are located in the bottom half of the voe. Seli Voe is actually an arm off of Gruting Voe, running east-north-east to west-south-west, and is approximately 2 km long and 0.3 km wide (in the vicinity of the fishery).

Figure 14.2 shows that the Braewick Voe and Seli Voe lines lie in a depth of between 5 and 20 m, while the North of Green Head site lies in a depth of between 20 and 30 m.

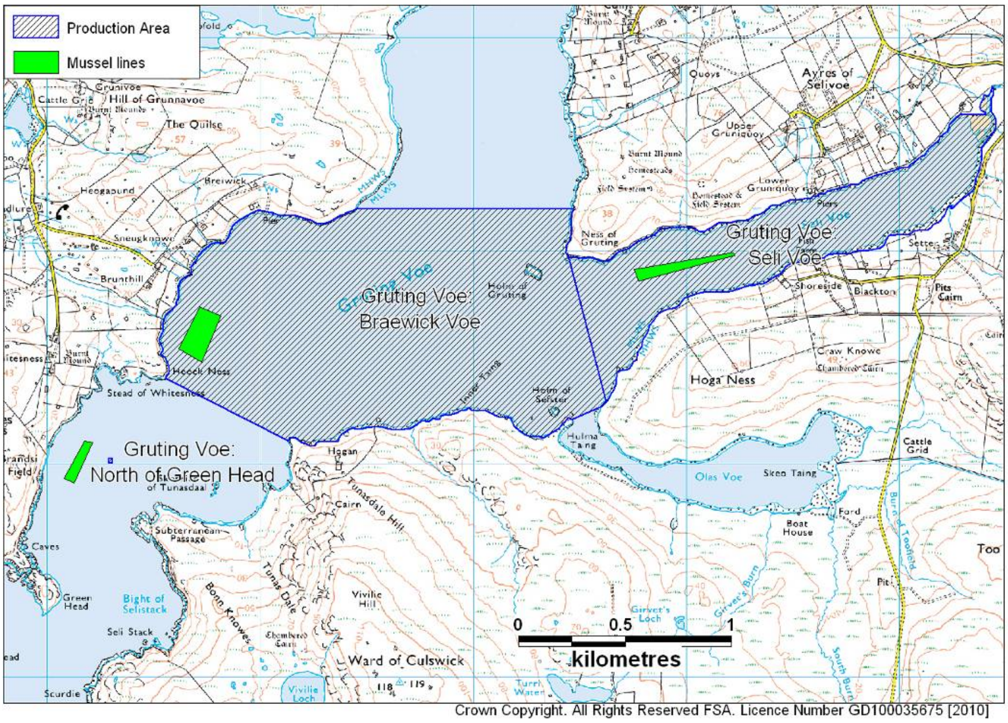


Figure 14.1 OS map of Lower Gruting Voe

Figure 14.2 Bathymetry of Lower Gruting Voe

14.1 Tidal Curve and Description

The two tidal curves shown in Figure 14.3 are for Scalloway, the closest port for which tidal predictions are available. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 BST on 25/08/09 and the second is for seven days beginning 00.00 BST on 01/09/09. This two-week period covers the date of the shoreline survey. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

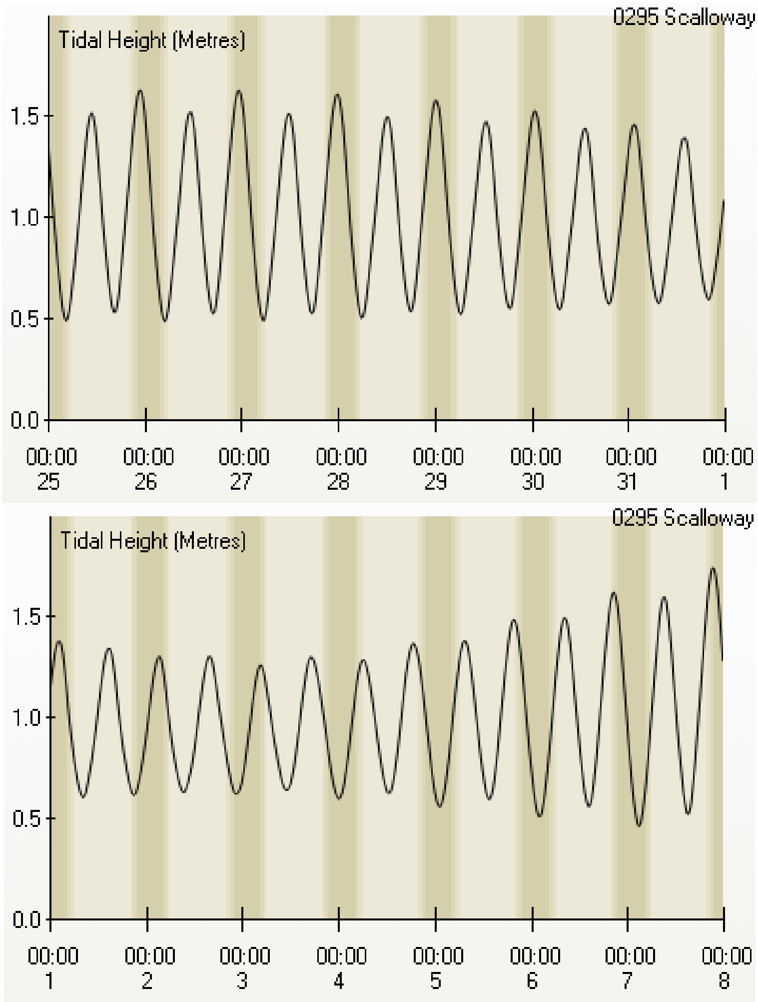


Figure 14.3 Tidal curves at Scalloway

The following is the summary description for Scalloway from TotalTide:

0295 Scalloway is a Secondary Non-Harmonic port.
The tide type is Semi-Diurnal.

HAT	1.9 m
MHWS	1.6 m
MHWN	1.3 m
MLWN	0.6 m
MLWS	0.5 m

The heights are in metres above chart datum. The tidal range at spring tide is therefore approximately 1.1 m and at neap tide 0.7 m, so tidal ranges here are small.

14.2 Currents

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. The tidal range here is small, so tidally driven exhange of water is likely to be weak. This is reflected in the relatively lengthy calculated flushing time of 9 days for the whole voe (Edwards and Sharples, 1986). Each basin will have its own local flushing characteristics, with some deep waters exchanging more slowly than this. Tidally driven currents within the voe would be expected to move in a northerly direction on the flood tide, and a southerly direction on the ebb tide. Contamination from sources along the shore would tend to hug the shoreline. Currents will be faster over the sills than in areas of deeper water, and greater mixing will occur around the sills. Tidally driven currents will be faster on the larger spring tides and the distance of transport of contaminants will be expected to be greater.

The land surrounding the production areas is low lying, and the voe has a north south aspect, so will be fairly exposed to winds from all directions, particularly southerly winds, which would be funnelled up the voe, and to a lesser extent northerly winds which would be funnelled in the other direction. Given the relatively weak tidal currents, wind driven currents have the potential to significantly alter flows around the production areas.

The catchment area of Gruting Voe is about 52 km^2, which is large for Shetland. An average salinity reduction of 0.5 ppt was calculated on the basis of tidal and freshwater inflows (Edwards and Sharples, 1986) although this is likely to fluctuate greatly depending on rainfall. Salinity profiles taken at the mussel lines during the course of the shoreline survey indicated very low freshwater influence. Surface salinities ranged from 35.0 to 35.3 ppt, and readings taken at 10 m depth ranged from 35.4 to 35.6 ppt.

The best available source of real data on the movement of water around the area was from a series of five studies carried out by the North Atlantic Fisheries College, Scalloway (NAFC) to assess movement of water around potential salmon cage farm sites withing Gruting Voe. These were carried out on separate occasions, therefore under differing environmental conditions. The studies involved the deployment of a fixed current meter for periods of around 2 weeks, recording average speed and direction of the current at various depths at 10-minute intervals. A weather station was deployed simultaneously which recorded wind speed and direction hourly. Locations of these five current meter stations are shown in Figure 14.4. Polar plots of current velocity and direction readings near the surface and near the bottom and wind data for each of the five locations are presented in Figure 14.5.

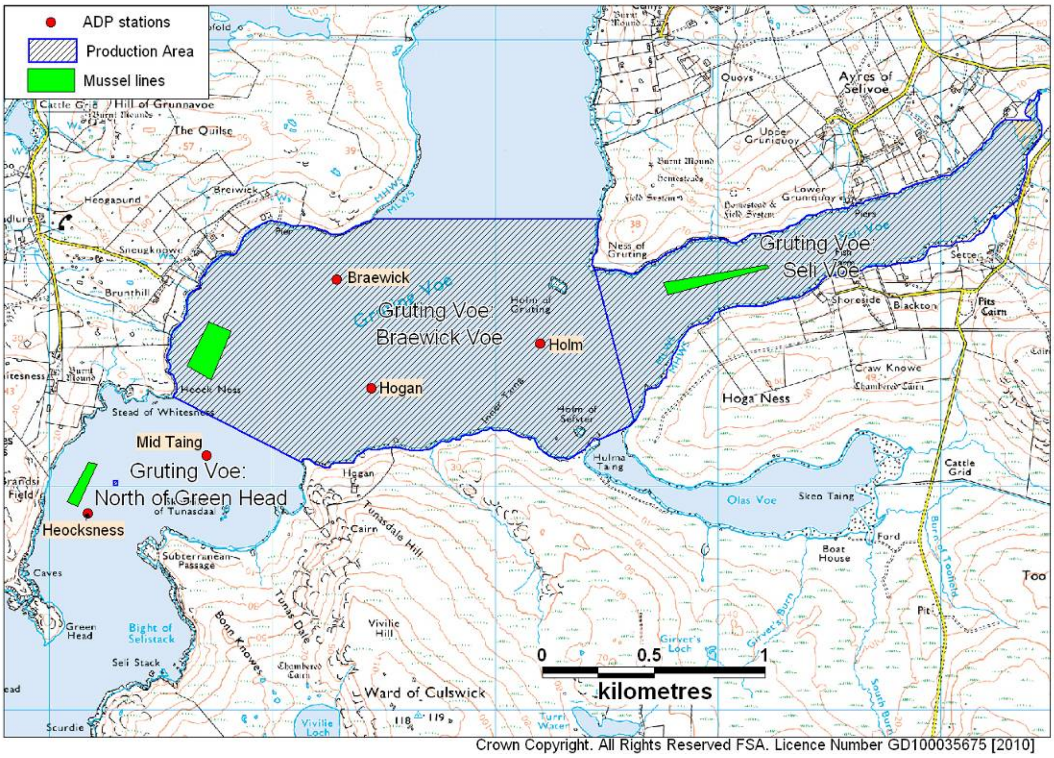


Figure 14.4 Location of the fish farm study sites

The study sites were located within the existing Gruting Voe: Braewick Voe production area and the vicinity of the new Gruting Voe: North of Green Head mussels lines. The Holm station was located just outside the mouth of Seli Voe. The results are thus relevant to the mussel lines being considered in this report. All stations were in similar depth of water (20-30 m) in a fairly uniform area. The NAFC classed current speeds of greater than 10 cm/s as strongly flushed, between 5 and 10 cm/s as moderately flushed, between 3 cm/s and less than 5 cm/s as weakly flushed and less than 3 cm/s are classed as quiescent.

At Braewick, flows were weak on average, with a mean current speed near the surface of 3.5 cm/s, and 3.4 cm/s at the bottom. Flows were quite evenly spread in terms of direction at both the top and the bottom, with slightly more records indicating a northeasterly flow at the top. Wind was predominantly from the southwest, and quite strong at times, and this would account for the flow directions recorded at the surface. Rainfall data was unavailable for the survey dates (late March 2002).

At Holm, flows were again weak on average, with a mean current speed near the surface of 3.5 cm/s, and 2.7 cm/s at the bottom. Flows were evenly spread in terms of direction at both the top and the bottom. Wind was light to moderate in strength, and mainly from the southeast or southwest. A total of 69.7 mm of rain fell during the 25 day survey period.

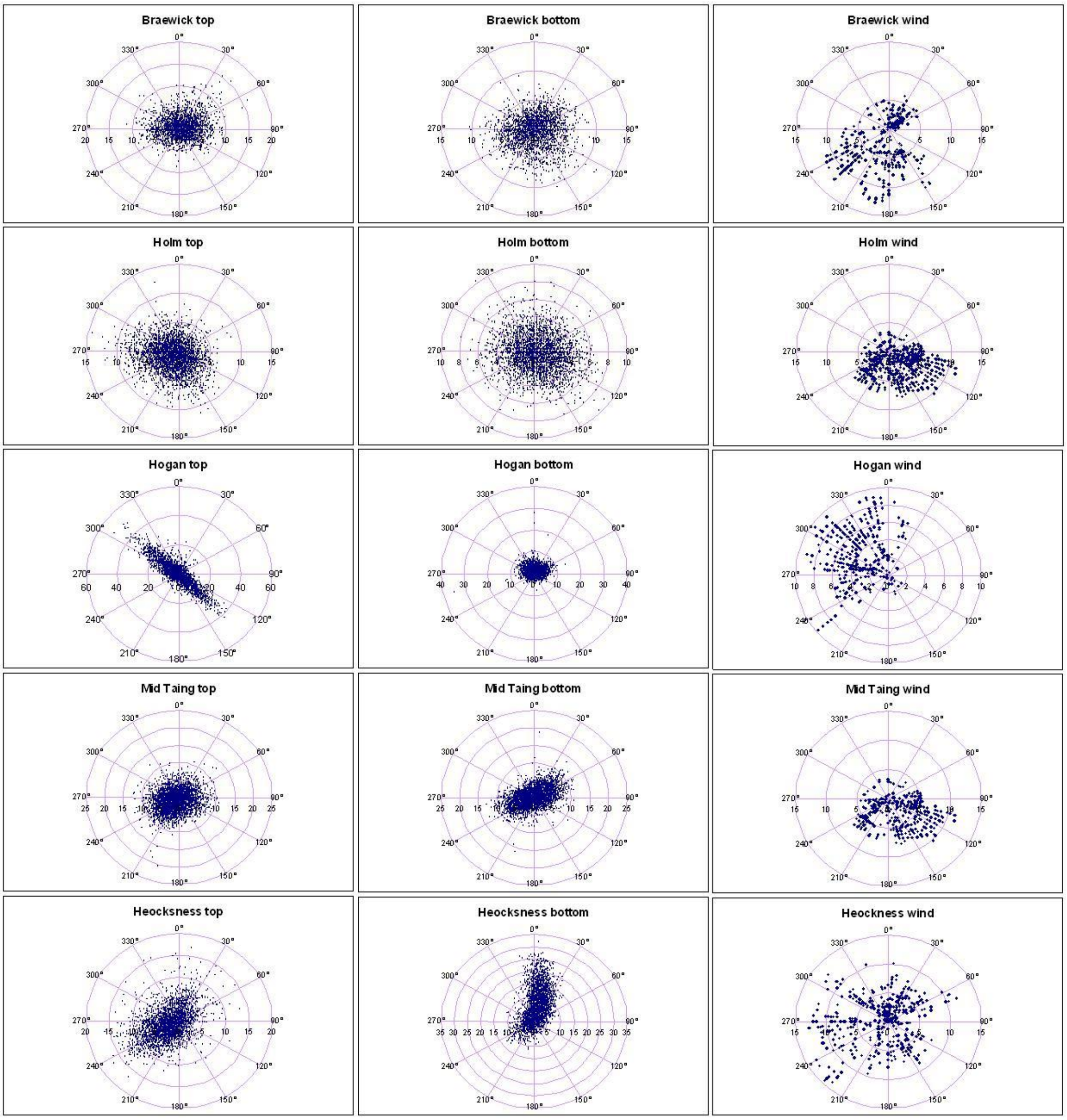


Figure 14.5 Polar plots of tidal direction and velocity readings near the top (surface) and bottom for the fish farm study sites, with polar plots of simultaneous wind recordings.
Current velocity is in cm/s, and wind speed is in m/s.

At Hogan, flows were on average strong at the top, and weak at the bottom, with a mean current speed near the surface of 11.2 cm/s, and 3.2 cm/s at the bottom. Flows at the surface appeared to be strongly bidirectional, a feature generally associated with tidally driven flows. Closer examination of the data indicated that the changes in current directions did not align with the tidal cycle, but were characterised by rapid shifts from one direction to the other. The pattern emerged within 10 m of the bottom and strengthened towards the surface. Generally bidirectional tidally driven currents would be expected to flow along the shore, which would be along the northeast-southwest axis, rather than along the northwest-southeast axis as seen in Figure 14.5. Wind records show that the wind was persistently blowing from the northwest at light to moderate strengths, and it is likely that this will have influenced flows at the surface. A total of 41.9 mm of rain fell during the 18 day survey period.

At Mid Taing, flows were weak on average, with a mean current speed near the surface of 4.1 cm/s, and 3.9 cm/s at the bottom. A vague bidirectional tendency along the southwest-northeast axis was apparent, and this pattern was stronger near the bottom, where tidally driven currents are less disrupted by wind effects. Wind was light to moderate in strength, and mainly from the southeast. A total of 69.7 mm of rain fell during the 25 day survey period.

At Heocksness, flows were on average weak at the surface, and moderate at the bottom, with a mean current speed near the surface of 4.7 cm/s, and 8.7 cm/s at the bottom. As this station was located in a slight constriction, and close to a sill, higher current speeds were not unexpected. At the surface a vague bidirectional tendency was seen along the southwest-northeast axis at the surface, although there was more of a tendency for the current to move in a southwesterly direction. At the bottom, there was a strong tendency for northerly flows. These may represent return flows created by seaward moving surface waters, which could either be wind or density (freshwater) driven. Wind blew from a wide spread of directions, but was strongest when blowing from the southwest, approaching gale force at times. This may have represented density-driven flow patterns but rainfall data was unavailable for the survey dates (early March 2002) and thus it was not possible to determine whether there was significant freshwater input at that time.

In summary, the fish farm study data confirms that tidally driven currents are weak within the voe, and can be heavily influenced by wind.

14.3 Conclusions

Circulation around the voe will be principally driven by tide and winds. The tidal range in the voe is small and tidal currents are weak, and vaguely bidirectional. Superimposed on this, wind driven currents are likely to significantly alter circulation within the voe, depending on wind strength and direction. There is the potential, following heavy rainfall, for density driven surface currents of fresher water to flow slowly in a seaward direction although no direct evidence was obtained for this. The sills will tend to limit the movement of contaminants, the most significant with regard to this assessment is the one at Green Head. In general, due to the expected low currents, significant impact of contaminants will be seen from sources close to the fisheries.

15. Shoreline Survey Overview

The shoreline survey was undertaken between the 25 and 28 August 2009. Conditions were overcast but dry during the first three days but with rain and gales on the 28 August.

Each of the three production areas covered by this survey (two currently classified : Gruting Voe: Seli Voe and Gruting Voe: Braewick Voe; one new area: Green Head) contained one active site of long-line mussel production.

Figure 15.1 shows the most significant findings from the shoreline survey. The seawater results have been omitted for the sake of clarity (the seawater results can be found in Figure 3 of the shoreline survey report).

Population in the area is sparse and there was no evidence of camp sites, etc, that could lead to potential seasonal increases. No community sewage discharges were observed in the area. Three septic tank outlets were seen, one of which was not flowing at the time.

A large number of sheep were seen in the area with approximately 500 counted on the day of observation. A small number of cattle were also seen. Some large groups of gulls were seen, with over 100 observed on a field on the south shore of Seli Voe. Large numbers of goose droppings and some domestic geese were also observed along this shoreline. One seal was noted during the survey.

Seven streams were recorded during the survey although only six of these had sufficient flow to measure and sample. A small number of dry stream beds were also recorded. None of the *E. coli* concentrations obtained from the streams that were sampled was particularly high, with the maximum being 1,300 *E. coli* cfu/100 ml.

Seawater samples taken during the shoreline survey gave results varying from <1 to 240 *E. coli* cfu/100 ml. In general, higher results were obtained from samples taken from the shore rather than in the vicinity of the mussel lines. However, the highest result of 240 *E. coli* cfu/100 ml was obtained offshore in the vicinity of the salmon farm shore base (see Figure 3 in the shoreline survey report).

Mussel samples taken during the shoreline survey gave results varying from 20 to 2,400 *E. coli* MPN /100 g. The highest results were obtained from the lines in Seli Voe.

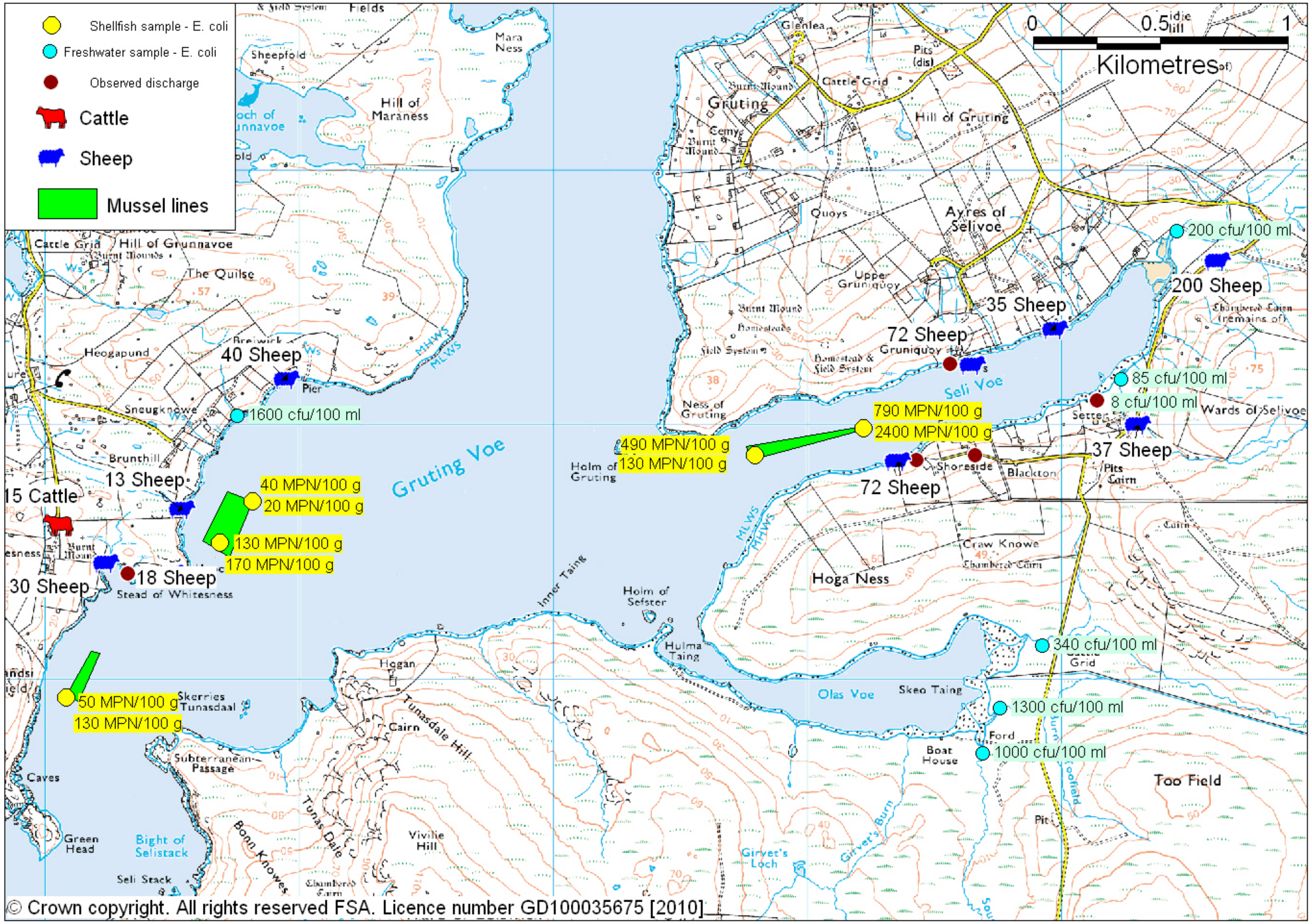


Figure 15.1 Summary of shoreline survey findings for lower Gruting Voe

16. Overall Assessment

Human sewage impacts

No community discharges were identified to the areas under consideration. There were two small community discharges to soakaway some distance away – under normal operating conditions these should not impact on water quality in lower Gruting Voe. Six presumed septic tank outlets were identified during the shoreline survey and these could cause local deterioration in water quality. Five of these were located on the shores of Seli Voe, one on the north shore and four on the south shore. One of the latter was associated with the salmon farm and associated house and so could serve more people than the others. All of the five were further up the voe than the fishery. The sixth observed discharge was located on the western shore of Gruting Voe between the two mussel sites there. In general, the risk of contamination from human sources would be greater for the mussel lines within Seli Voe and, within that area, to the eastern end of those lines.

Agricultural impacts

In Seli Voe, sheep were located around the upper two thirds of the voe. The droppings of these could impact on the water quality in the voe and effects would tend to be greater at the eastern end of the mussel lines.

Sheep were observed on the western side of lower Gruting Voe all around the vicinity of the Braewick Voe site and to the north of the North of Green Head site. A small number of cattle were observed inland of the headland between the two sites. The main potential impact would therefore be on the Braewick Voe site although the northern end of the North of Green Head site could also be affected.

Wildlife impacts

Information available from published sources and the observations made during the shoreline survey indicated that the predominant impact on water quality arising from wildlife would be due to relatively large numbers of water birds. The predominant wildlife are seabirds and these occur throughout the area – from the information available it is not possible to determine any potential spatial effect. It is expected that seabird numbers will be greatest during the summer period.

Seasonal variation

No significant variation is expected in faecal sources of human origin as there is no noteworthy tourist activity in the area. The impact of both farm and wild animals is expected to be greater during the summer period. Diffuse pollution due to rainfall would be expected to be highest in the autumn when faecal material that has accumulated during the summer months is washed off the ground by autumn rains. However, this effect may occur at other times if major rainfall events occur after a period of dry weather.

Rivers and streams

At the time that the shoreline survey was undertaken, the only significant inputs from streams was at the head of Seli Voe and the head of Olas Voe. It is unlikely that the streams within Olas Voe would impact on the microbiological quality of the present shellfisheries in lower Gruting Voe. A stream located to the north-west of the Braewick Voe site returned a high *E. coli* result but the flow was too small to measure. The loading from this stream could become a significant potential source of *E. coli* following rainfall. Some dry stream beds were observed at the time of the shoreline survey and a number of streams are marked on the OS map, although these were not running at the time of the visit. There is thus the potential for additional freshwater sources to impact on the shellfisheries after heavy rainfall.

Meteorology, hydrology, and movement of contaminants

The wettest months in the area are from September to February, and the driest are from April to August. It would therefore be expected that contamination associated with run-off would occur in the autumn and winter periods. It would also be expected that the level of contamination would be greatest when rainfall occurred after a dry period during which faecal material had built up on the ground, i.e. in autumn. However, high rainfall events can occur at any time of the year, not just during the wetter months. Significant correlations were obtained of *E. coli* against rainfall for both the Braewick Voe and Seli Voe sites and therefore there is a tendency towards higher results with increasing rainfall. However, it should be noted that while all shellfish results above 500 *E. coli* MPN/100 g occurred after at least some rainfall, the range of rainfall occurring prior to those sampling occasions was wide and therefore relatively high *E. coli* results (for the area) can be seen after commonly encountered levels of rain.

Circulation around the voe will be driven by tide, winds, and, at times, freshwater inputs. The tidal range in the voe is small and tidal currents are weak, and vaguely bidirectional. The general tendency will be up and down lower Gruting voe and within Seli Voe, parallel to the shore. In an analysis of historical shellfish data relative to tides, no association was seen between the E. coli resylts and the spring/neap cycle but weak correlations were seen with the high/low tidal cycle. For Braewick Voe, higher results tended to be seen on the ebbing tide while for Seli Voe lower results were seen during the second half of the ebbing tide. This would suggest that sources north of Braewick Voe were influencing the microbiological quality of the mussels and that impacting sources within Seli Voe were located local to the fishery.

The prevailing wind in Shetland is from the south and west and there is a high frequency of gales. Gruting Voe is most exposed to winds from the south-west and to a lesser extent the north-east. Strong winds and possibly density driven flows will tend to modify weak tidal currents – surface currents produced by winds would tend to be accompanied by return currents at depth. The sills in Gruting Voe itself will tend to limit the movement of contaminants between basins although there may be increases in transport in the upper layer due to increased flow. Increased mixing, and therefore an increase in dilution, may occur in the vicinity of sills. The most significant of the sills is at Green Head. In general, due to the expected low currents, significant impact of contaminants will be seen from sources close to the fisheries.

Temporal and geographical patterns of sampling results

At Braewick Voe, apart from two unusually high results in 2005, the general level of contamination of the mussels appeared to be relatively constant from 2002 to 2009. In Seli Voe, the average level of contamination appears to have decreased slightly over that period, although the occurrence of high results seems stayed relatively constant. With respect to season, results were generally higher in the autumn and winter periods and lowest in the spring.

The average level of *E. coli* in shellfish did not differ significantly between the Braewick Voe and Seli Voe sites. Both had also returned small numbers of results greater than 1,000 *E. coli* MPN/100 g. Only 6 samples had been taken at Green Head in the period assessed for this survey and so it was not possible to compare the data with those from the presently classified sites. The wild mussels sampled by SEPA at the head of Seli Voe up to 2007 showed the presence of high levels of faecal coliforms on occasions – this is consistent with the influence of the stream at the head of the voe.

Seven shellfish samples were taken during the shoreline survey. These were taken at surface and depth at each end of the lines in Braewick Voe and Seli Voe and the southern end of the lines at Green Head (animals of sufficient size were not present at the other end). Highest results were seen at the eastern end of the lines in Seli Voe (790 and 2400 *E. coli* MPN/100 g). Results at the northern end of the Braewick Voe line (20 and 40 *E. coli* MPN/100 g) were slightly lower than those at the southern end (130 and 170 *E. coli* MPN/100 g) and at Green Head (50 and 130 *E. coli* MPN/100 g). There was no consistent difference between the surface and depth samples.

The seawater samples taken during the shoreline survey in the vicinity of the mussel lines were all relatively low (<1 to 13 *E. coli* cfu/100 ml). The highest result was obtained at the eastern end of the Seli Voe mussel lines, thus agreeing with the pattern seen in the shellfish samples taken at that time. Higher results (30 and 200 *E. coli* cfu/100 ml) were obtained in two samples taken from the shore on the western side of lower Gruting Voe indicating the influence of local sources. The highest seawater result, 240 *E. coli* cfu/100 ml, was obtained slightly offshore in the vicinity of the fish farm in Seli Voe, probably indicating the influence of a local source there as a sample taken from the shore higher up the voe returned a markedly lower result.

Conclusions

Local sources of contamination are likely to be the most important source of *E. coli* in the mussels in all three areas. The number of septic tank outlets in lower Gruting Voe is small but mainly concentrated within Seli Voe. Contamination from farm animals and wildlife is likely to be a significant factor with both direct deposition and land run-off via streams impacting on water quality. A number of separate strands of evidence identifies that contamination within Seli Voe may be higher towards the eastern end. There may also be a separate local source in the vicinity of the fish farm. The evidence with respect to the Braewick Voe and Green Head sites is less apparent – assessment of the potential sources of pollution would indicate that the north-western end of Braewick Voe would be impacted to a slightly greater extent although samples taken at the time of the shoreline survey showed slightly higher contamination towards the south. Given the conflicting evidence for these two sites, the assessment of the potential sources should take priority over the limited data from the shoreline survey.

Although the historical levels of *E. coli* in Seli Voe and Braewick Voe have been similar, different sources of both human and animal origin will affect the microbiological quality of the mussels with these two areas and thus it is relevant for them to continue to be maintained as separate production areas and therefore monitored separately. On the other hand, the mussel lines at Braewick Voe and Green Head are influenced by the same sources, although possibly to slightly different extents, and it would be pertinent for them to be combined in one production area with a single RMP.

17. Recommendations

Production area

Gruting Voe: Braewick Voe: A revised boundary is recommended to include the Green Head site, to exclude the area adjacent to Seli Voe, which is subject to different sources of contamination.

The area lying within lines drawn between HU 2644 4819 to HU 2544 4676 and between HU 2544 4676 and HU 2493 4676 and extending to MHWS.

Gruting Voe: Seli Voe: The eastward extent of the production area should be limited to exclude the potentially more contaminated areas further up the voe. The production area would then become:

The area lying within lines drawn between HU 2745 4797 to HU 2762 4729 and between HU 2834 4817 and HU 2834 4785 and extending to MHWS.

RMP

Gruting Voe: Braewick Voe: The recommended RMP is HU 2572 4768. This lies towards the north-west corner of the current Braewick Voe lines and will be potentially impacted by the identified contamination sources – it is approximately in the location from which more recent samples have been taken. This will also represent the lines at North of Green Head.

Gruting Voe: Seli Voe: The recommended RMP is HU 2818 4798. This is towards the eastern end of the lines which is expected to be exposed to the contamination arising from higher up the voe.

Depth

The recommended depth for sampling is from 1 to 3 m given that there was no evidence of a consistent difference in the extent of contamination with depth.

Tolerance

The recommended tolerance for both RMPs is 20 m. Given that these are aquaculture sites, it should be possible to access stock within this tolerance. However, it allows for some variation in accessing animals of sufficient size and drift of the lines themselves. If either of these factors presents a problem with regard to sampling within the recommended tolerance, consideration should be given to placing a bag of shellfish at the recommend location and depth specifically for sampling purposes. If this is done, shellfish should be placed in situ for at least two weeks prior to sampling to ensure that they have taken on the microbiological quality of the RMP.

Frequency

A stability assessment undertaken for Braewick Voe showed that it did not comply with the recommendations for a reduced sampling frequency. A stability assessment for Seli Voe was not appropriate as this site had held a seasonal classification within the last three years. Given the variation in results and seasonal effects seen in both presently classified areas, it is recommended that a monthly sampling frequency be maintained.

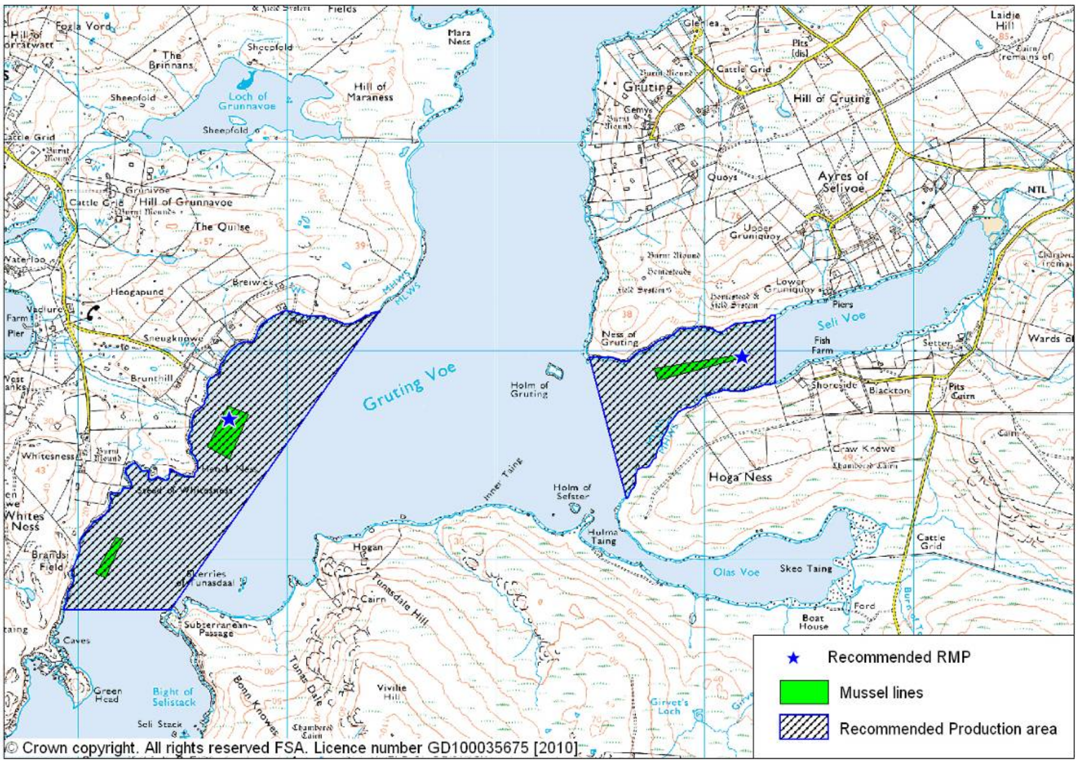


Figure 17.1 Map of recommendations for lower Gruting Voe

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5. **Tables of Typical Faecal Bacteria Concentrations**
6. **Statistical Data**
7. **Hydrographic Methods**
8. **Shoreline Survey Report**

Sampling Plan for Lower Gruting Voe

Production Area	Site name	SIN	Species	Type of Fishery	NGR of RMP	Eastings	Northings	Tolerance (m)	Depth (m)	Method of sampling	Frequency of sampling	Local Authority (LA)	Authorised sampler(s)	LA Liaison Officer
Gruting Voe: Braewick Voe	Heockness	SI 080 412 08	Common Mussel	Mussel lines	HU 2572 4768	425720	1147680	30	1-3	Hand	Monthly	Shetland Island Council	Sean Williamson George Williamson Kathryn Winter Marion Slater	Dawn Manson
Gruting Voe: Seli Voe	Seli Voe	SI 084 360 08	Common Mussel	Mussel lines	HU 2818 4798	428180	1147980	30	1-3	Hand	Monthly	Shetland Island Council	Sean Williamson George Williamson Kathryn Winter Marion Slater	Dawn Manson

Table of Proposed Boundaries and RMPs

Production Area	Species	SIN	Existing Boundary	Existing RMP	New Boundary	New RMP	Comments
Gruting Voe: Braewick Voe	Common mussel	SI 080 412 08 SI 442 846 08	Lines drawn between HU 2645 4820 to HU 2747 4820 and HU 2745 4797 to HU 2762 4729 and HU 2760 4727 to HU 2746 4721 and HU 2613 4711 to HU 2550 4741	HU 260 480	HU 2644 4819 to HU 2544 4676 and between HU 2544 4676 and HU 2493 4676 and extending to MHWS	HU 2572 4768	Braewick Voe production area revised to include the Green Head site
Gruting Voe: Seli Voe	Common mussel	SI 084 360 08	HU 2745 4797 to HU 2762 4729 extending to MHWS	HU 281 481	HU 2745 4797 to HU 2762 4729 and between HU 2834 4817 and HU 2834 4785 and extending to MHWS	HU 2818 4798	Eastward extent of production area removed to exclude potential areas of contamination

Geology and Soils Assessment

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

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

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

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

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

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

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

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

These component soils were classed broadly into two groups based on whether they are freely or poorly draining. Drainage classes were created based on information obtained from the both the Macaulay Institute website and personal communication with Dr. Alan Lilly. GIS map layers were created for each class with poorly draining classes shaded red, pink or orange and freely draining classes coloured blue or grey. These maps were then used to assess the spatial variation in soil permeability across a survey area and it's potential impact on runoff.

Glossary of Soil Terminology

Calcareous: Containing free calcium carbonate.

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

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

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

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

Wildlife

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

A variety of cetacean species are routinely observed around the west coast of Scotland.

Table 8.1 Cetacean sightings in 2007 – Western Scotland.

Common name	Scientific name	No. sighted*
Minke whale	*Balaenoptera acutorostrata*	28
Killer whale	*Orcinus orca*	183
Long finned pilot whale	*Globicephala melas*	14
Bottlenose dolphin	*Tursiops truncatus*	369
Risso's dolphin	*Grampus griseus*	145
Common dolphin	*Delphinus delphis*	6
Harbour porpoise	*Phocoena phocoena*	>500

*Numbers sighted are based on rough estimates based on reports received from various observers and whale watch groups. Source: Hebridean Whale and Dolphin Trust.

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 5km 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 per faecal deposit and ring-billedgulls (*Larus delawarensis*) approximately 1.77×10^8 FC per faecal deposit to a local reservoir (Alderisio and DeLuca, 1999). 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 and birds are known to carry *Salmonella*.

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.

Tables of Typical Faecal Bacteria Concentrations

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

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

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

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

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

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

Statistical data

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

Section 11.3 One-way ANOVA comparison of results by sampling location

```
Source    DF      SS     MS     F      P
GridRef    4   0.535  0.134  0.40  0.811
Error    156  52.602  0.337
Total    160  53.137

S = 0.5807   R-Sq = 1.01%   R-Sq(adj) = 0.00%


                              Individual 95% CIs For Mean Based on
                              Pooled StDev
Level      N    Mean   StDev   -+---------+---------+---------+--------
HU252471   6  1.4365  0.5051   (------------------*------------------)
HU257476  20  1.4642  0.5129            (----------*---------)
HU260480  63  1.5671  0.6040                     (-----*----)
HU279479  20  1.4668  0.5347            (----------*---------)
HU281481  52  1.6044  0.5986                      (-----*------)
                               -+---------+---------+---------+--------
                              1.00      1.25      1.50      1.75

Pooled StDev = 0.5807
```

Section 11.3 One-way ANOVA comparison of results by site

```
Source   DF      SS     MS     F      P
Site      2   0.101  0.050  0.15  0.861
Error   158  53.036  0.336
Total   160  53.137

S = 0.5794   R-Sq = 0.19%   R-Sq(adj) = 0.00%



Level                 N    Mean   StDev
Braewick Voe         83  1.5423  0.5820
North Of Green Head   6  1.4365  0.5051
Seli Voe             72  1.5662  0.5812

                     Individual 95% CIs For Mean Based on
                     Pooled StDev
Level                 -+---------+---------+---------+--------
Braewick Voe                            (----*----)
North Of Green Head   (-----------------*------------------)
Seli Voe                                (-----*----)
                      -+---------+---------+---------+--------
                     1.00      1.25      1.50      1.75

Pooled StDev = 0.5794
```

Section 11.3 Paired T-test comparison of same day results from Gruting Voe: Seli Voe and Gruting Voe: Braewick Voe

```
Paired T for sameday Braewick - sameday seli

                   N   Mean  StDev  SE Mean
sameday Braewick  34  1.627  0.600    0.103
sameday seli      34  1.524  0.549    0.094
Difference        34  0.103  0.735    0.126


95% CI for mean difference: (-0.153, 0.360)
```

```
T-Test of mean difference = 0 (vs not = 0): T-Value = 0.82  P-Value = 0.418
```

Section 11.5 One way ANOVA comparison of *E. coli* results by season (Gruting Voe: Braewick Voe)

```
Source  DF      SS     MS     F      P
Season   3   5.369  1.790  6.31  0.001
Error   79  22.408  0.284
Total   82  27.777

S = 0.5326   R-Sq = 19.33%   R-Sq(adj) = 16.27%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  ------+---------+---------+---------+---
1      22  1.2424  0.4537  (------*-------)
2      20  1.3505  0.5017     (-------*-------)
3      19  1.7941  0.6952                  (-------*-------)
4      22  1.7990  0.4681                  (-------*-------)
                           ------+---------+---------+---------+---
                               1.20      1.50      1.80      2.10

Pooled StDev = 0.5326


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

Individual confidence level = 98.96%


Season = 1 subtracted from:

Season    Lower  Center   Upper  --------+---------+---------+---------+-
2       -0.3236  0.1081  0.5397             (-------*--------)
3        0.1141  0.5517  0.9893                     (--------*--------)
4        0.1354  0.5566  0.9779                      (-------*--------)
                                 --------+---------+---------+---------+-
                                     -0.50      0.00      0.50      1.00


Season = 2 subtracted from:

Season    Lower  Center   Upper  --------+---------+---------+---------+-
3       -0.0040  0.4436  0.8912                   (--------*--------)
4        0.0169  0.4486  0.8802                   (--------*--------)
                                 --------+---------+---------+---------+-
                                     -0.50      0.00      0.50      1.00


Season = 3 subtracted from:

Season    Lower  Center   Upper  --------+---------+---------+---------+-
4       -0.4326  0.0049  0.4425           (--------*--------)
                                 --------+---------+---------+---------+-
                                     -0.50      0.00      0.50      1.00
```

Section 11.5 One way ANOVA comparison of *E. coli* results by season (Gruting Voe: Seli Voe)

```
Source  DF      SS     MS     F      P
Season   3   5.701  1.900  7.07  0.000
Error   68  18.283  0.269
Total   71  23.984

S = 0.5185   R-Sq = 23.77%   R-Sq(adj) = 20.41%
```

```
                              Individual 95% CIs For Mean Based on
                              Pooled StDev
Level   N    Mean   StDev  ---+---------+---------+---------+------
1      20  1.1627  0.3242  (-----*------)
2      17  1.6027  0.6834              (------*------)
3      14  1.9683  0.6516                       (-------*-------)
4      21  1.6528  0.4059                (-----*------)
                           ---+---------+---------+---------+------
                            1.05      1.40      1.75      2.10

Pooled StDev = 0.5185


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

Individual confidence level = 98.95%


Season = 1 subtracted from:

Season    Lower  Center   Upper  ----+---------+---------+---------+-----
2       -0.0099  0.4401  0.8900               (------*-------)
3        0.3304  0.8056  1.2809                     (------*-------)
4        0.0640  0.4901  0.9163                (------*------)
                                 ----+---------+---------+---------+-----
                                  -0.60      0.00      0.60      1.20


Season = 2 subtracted from:

Season    Lower  Center   Upper  ----+---------+---------+---------+-----
3       -0.1267  0.3656  0.8578             (-------*-------)
4       -0.3949  0.0501  0.4951        (-------*------)
                                 ----+---------+---------+---------+-----
                                  -0.60      0.00      0.60      1.20


Season = 3 subtracted from:

Season    Lower   Center   Upper  ----+---------+---------+---------+-----
4       -0.7861  -0.3155  0.1551   (-------*-------)
                                  ----+---------+---------+---------+-----
                                   -0.60      0.00      0.60      1.20
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 2 day rainfall (Gruting Voe: Braewick Voe)

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.387
P-Value = 0.001
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 2 day rainfall (Gruting Voe: Seli Voe)

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.411
P-Value = 0.001
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 7 day rainfall (Gruting Voe: Braewick Voe)

```
Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.508
P-Value = 0.000
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 7 day rainfall (Gruting Voe: Seli Voe)

```
Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.395
P-Value = 0.002
```

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the spring/neap cycle (Gruting Voe: Braewick Voe)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 19 November 2009 11:20:11

Variables (& observations)	r	p
Angles & Linear (83)	0.125	0.289

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the spring/neap cycle (Gruting Voe: Seli Voe)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 19 November 2009 11:28:29

Variables (& observations)	r	p
Angles & Linear (72)	0.092	0.555

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the high/low cycle (Gruting Voe: Braewick Voe)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 19 November 2009 11:20:58

Variables (& observations)	r	p
Angles & Linear (62)	0.23	0.045

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the high/low cycle (Gruting Voe: Seli Voe)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 19 November 2009 11:36:03

Variables (& observations)	r	p
Angles & Linear (50)	0.311	0.01

Section 11.6.3 Regression analysis – *E. coli* result vs water temperature (Gruting Voe: Braewick Voe)

```
The regression equation is
log e coli for temperature = 1.35 + 0.0100 temperature


Predictor       Coef  SE Coef     T      P
Constant      1.3494   0.4905  2.75  0.014
temperature  0.01000  0.05217  0.19  0.850


S = 0.559378   R-Sq = 0.2%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF      SS      MS     F      P
Regression       1  0.0115  0.0115  0.04  0.850
Residual Error  16  5.0065  0.3129
```

```
Total           17  5.0180


Unusual Observations

                   log e coli
                          for
Obs  temperature  temperature    Fit  SE Fit  Residual  St Resid
  1          6.0        2.491  1.409   0.207     1.082     2.08R
 11         12.0        2.519  1.469   0.202     1.049     2.01R

R denotes an observation with a large standardized residual.
```

Section 11.6.3 Regression analysis – *E. coli* result vs water temperature (Gruting Voe: Seli Voe)

```
The regression equation is
log e coli for temperature = 1.15 + 0.0308 temperature


Predictor       Coef  SE Coef     T      P
Constant      1.1458   0.5514  2.08  0.053
temperature  0.03082  0.06025  0.51  0.616


S = 0.593194   R-Sq = 1.5%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF      SS      MS     F      P
Regression       1  0.0920  0.0920  0.26  0.616
Residual Error  17  5.9819  0.3519
Total           18  6.0740


Unusual Observations

                   log e coli
                          for
Obs  temperature  temperature    Fit  SE Fit  Residual  St Resid
 11         11.0        2.898  1.485   0.187     1.413     2.51R

R denotes an observation with a large standardized residual.
```

Section 11.6.5 Regression analysis – *E. coli* result vs salinity (Gruting Voe: Braewick Voe)

```
The regression equation is
log e coli for salinity = 3.49 - 0.0619 salinity


Predictor      Coef  SE Coef      T      P
Constant     3.4922   0.8375   4.17  0.000
salinity   -0.06188  0.02669  -2.32  0.023


S = 0.579034   R-Sq = 6.8%   R-Sq(adj) = 5.5%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   1.8017  1.8017  5.37  0.023
Residual Error  74  24.8108  0.3353
Total           75  26.6125


Unusual Observations
```

```
                 log e coli
Obs  salinity  for salinity     Fit  SE Fit  Residual  St Resid
 42      32.5        3.3424  1.4805  0.0741    1.8619      3.24R
 44      27.6        3.2304  1.7819  0.1176    1.4486      2.55R
 46      25.0        2.4914  1.9459  0.1805    0.5455      0.99 X

R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large leverage.
```

Section 11.6.5 Regression analysis – *E. coli* result vs salinity (Gruting Voe: Seli Voe)

```
The regression equation is
log e coli for salinity = 1.34 + 0.0083 salinity


Predictor     Coef  SE Coef     T      P
Constant    1.3393   0.7343  1.82  0.073
salinity   0.00832  0.02339  0.36  0.723


S = 0.596372   R-Sq = 0.2%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.0451  0.0451  0.13  0.723
Residual Error  64  22.7622  0.3557
Total           65  22.8073


Unusual Observations

                 log e coli
Obs  salinity  for salinity     Fit  SE Fit  Residual  St Resid
 12      30.0        2.8751  1.5891  0.0789    1.2860      2.18R
 20      32.0        2.8451  1.6057  0.0755    1.2394      2.10R
 39      34.0        2.8751  1.6226  0.0982    1.2524      2.13R
 42      32.0        3.1139  1.6058  0.0756    1.5081      2.55R
 52      16.4        2.1139  1.4762  0.3539    0.6377      1.33 X
 58      28.4        2.8976  1.5755  0.0995    1.3221      2.25R
 63      19.0        1.0000  1.4977  0.2951   -0.4977     -0.96 X

R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large leverage.
```

Section 12 One-way ANOVA comparison of shellfish growing waters results by season

```
Source   DF      SS     MS     F      P
quarter   3   5.492  1.831  3.17  0.068
Error    11   6.359  0.578
Total    14  11.851

S = 0.7603   R-Sq = 46.34%   R-Sq(adj) = 31.71%


                          Individual 95% CIs For Mean Based on Pooled StDev
Level  N    Mean   StDev    +---------+---------+---------+---------
Q1     4  1.8805  0.3237    (--------*-------)
Q2     3  3.1131  0.7556               (---------*---------)
Q3     4  3.4735  0.8819                    (--------*-------)
Q4     4  2.7672  0.9254             (--------*-------)
                            +---------+---------+---------+---------
                          1.0       2.0       3.0       4.0

Pooled StDev = 0.7603
```

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.

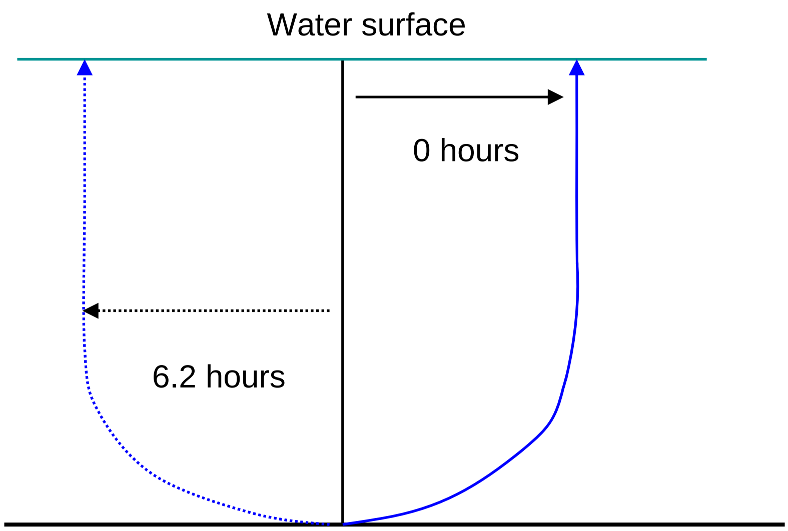
The hydrography at most sites will be assessed on the basis of bathymetry and tidal flow software only and is not discussed in any detail in this document. Selected sites will be assessed in more detail using either: 1) a hydrodynamic model, or 2) an extended consideration of sources, available field studies and expert assessment. This document will focus on this more detailed hydrographic assessment 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.

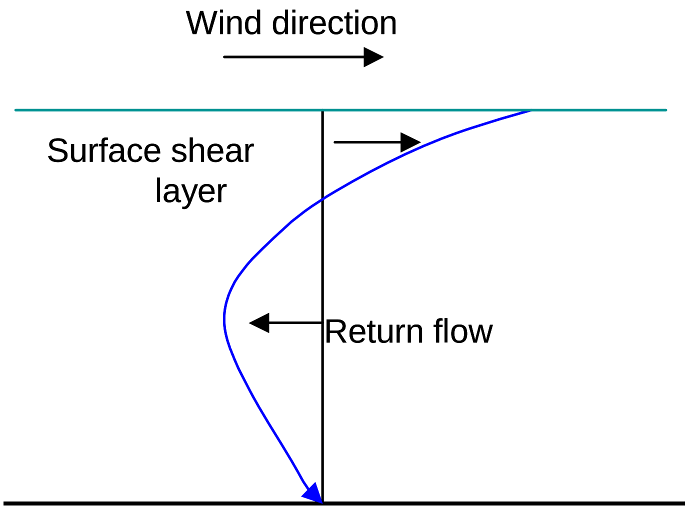
Tidal flows often dominate water movement over the short term (approximately 12 hours) and move material over the length of the *tidal excursion*. Tides move water back and forth over the tidal period often leading to only a small net movement over the 12 hours tidal cycle. This small net movement is 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.

a)



b)



c)

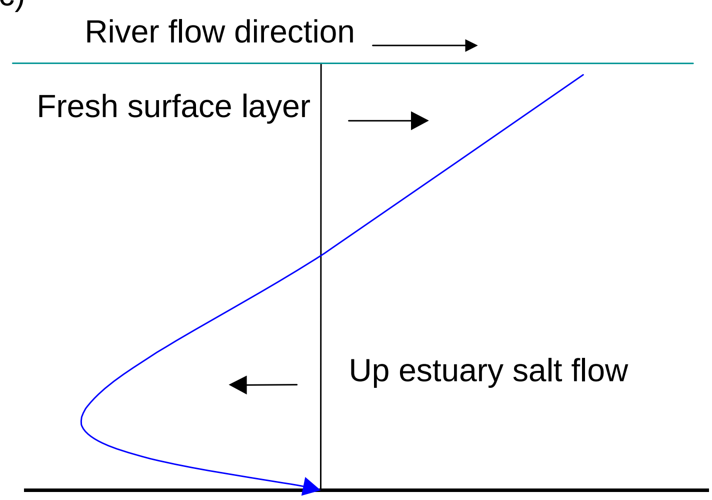


Figure 1 Typical vertical profiles for currents generated by different mechanisms. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main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

In sea lochs, currents associated with *windrows* can transport contaminated water near the shore to production areas further offshore. Windrows are often generated by winds directed along the main length of the loch. Figure 2 illustrates the water movements associated with this. As can be seen the water circulates in a series of cells that draw material across the loch at right angles to the wind direction. This is a particularly common situation for lochs with high land on either side as these tend to act as a steering mechanism to align winds along the water body.

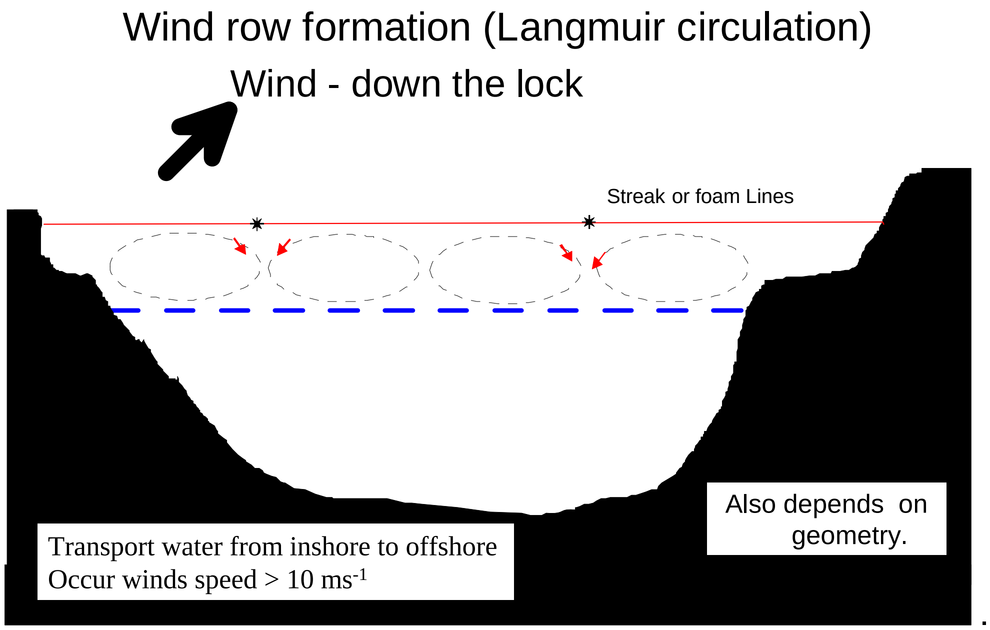


Figure 2 Schematic of wind driven 'wind row' currents. View is down the loch.The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Shoreline Survey Report

Green Head (SI442)
Gruting Voe: Seli Voe (SI84)
Gruting Voe: Braewick Voe (SI80)

Scottish Sanitary Survey Project

Shoreline Survey Report

Areas surveyed:

Production Area	Site	SIN	Species	Harvester
Green Head	North of Green Head	SI 442 846 08	Common mussel	A&C Tait
Gruting Voe: Braewick Voe	Braewick Voe	SI 080 424 08	Common mussel	A&C Tait
Gruting Voe: Seli Voe	Seli Voe	SI 084 428 08	Common mussel	Selivoe Shellfish

Local Authority: Shetland Islands Council
Status: New/Existing
Date Surveyed: 25-28 August 2009
Surveyed by: M. Price-Hayward, S. Williamson, D. Manson, L. Moar
RMPs:

Area	Nominal RMP	Sample location
Gruting Voe: Braewick Voe	HU 260 480	HU 2571 4767
Gruting Voe: Seli Voe	HU 281 481	HU 2797 4798

Weather observations
Overcast to partly cloudy, Winds S F3-4, T to 16C. Rain and gales on 28 August.

Site Observations

Fishery

Gruting Voe: Seli Voe

There was only one active site in this production area. The Seli Voe long line mussel farm consisted of 6 lines, three shorter than the others. All had droppers to 10 m depth.

Braewick Voe

The Braewick Voe production area also had only one active site, located along the west side of Gruting Voe, to the north of the point at Hoeck Ness. On this site was a longline mussel farm consisting of 6 lines with droppers approximately 8 m in length.

North of Green Head

This mussel farm was located approximately 600 m southwest of the Braewick Voe mussel farm. Two long lines were deployed with droppers hung to a depth of 8-9 m. One line was nearly sinking and the other only had growth suitable for sampling at one end.

Sewage/Faecal Sources

No community septic tanks were found within the area surveyed. A number of homes and farms were observed. Only 3 septic pipes were seen, one of which was dry. The population in the area is sparse.
Sheep were observed in large numbers with over 500 counted on the day of survey. In addition, cattle were observed, though in much smaller numbers with only 19 observed.

Seasonal Population
No campsites or other tourist accommodation were observed in the area.

Boats/Shipping
A number of boats were present in both Seli Voe and Gruting Voe during the time of survey. A number of salmon cages are present in Gruting Voe and a large facility for offloading fish from well boats was present on the south side of Seli Voe, approximately 500 m east of the end of the mussel farm there. In addition to the well boat, 2 barges used to service the salmon farms were present in Gruting Voe as well as a second ship and a few very small boats. Overall, the majority of the boat traffic in the area appeared to be associated with either the salmon or mussel farms. No marinas were present within the surveyed area.

Land Use
Land use around the Seli Voe and the west shore of Gruting Voe was predominantly agricultural, with crofts and associated pastures lining the shores. Grains or silage were grown along the south shore of Seli Voe and along the western side of Gruting Voe. Sheep were grazed widely around the area and some cattle and ponies were also kept.

Wildlife/Birds
Some large aggregations of gulls were observed, with over 100 observed on a field on the south shore of Seli Voe. Large numbers of goose droppings and some domestic geese were also observed along this shoreline.

One seal was observed, and a local crofter reported that otters and seals were frequently spotted in the water nearby (Table 1, No. 59) and that the otters were thought to have a holt up the stream here.

Recorded observations apply to the date of survey only. Animal numbers were recorded on the day from the observer's point of view. This does not necessarily equate to total numbers present as natural features may obscure individuals and small groups of animals from view.

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

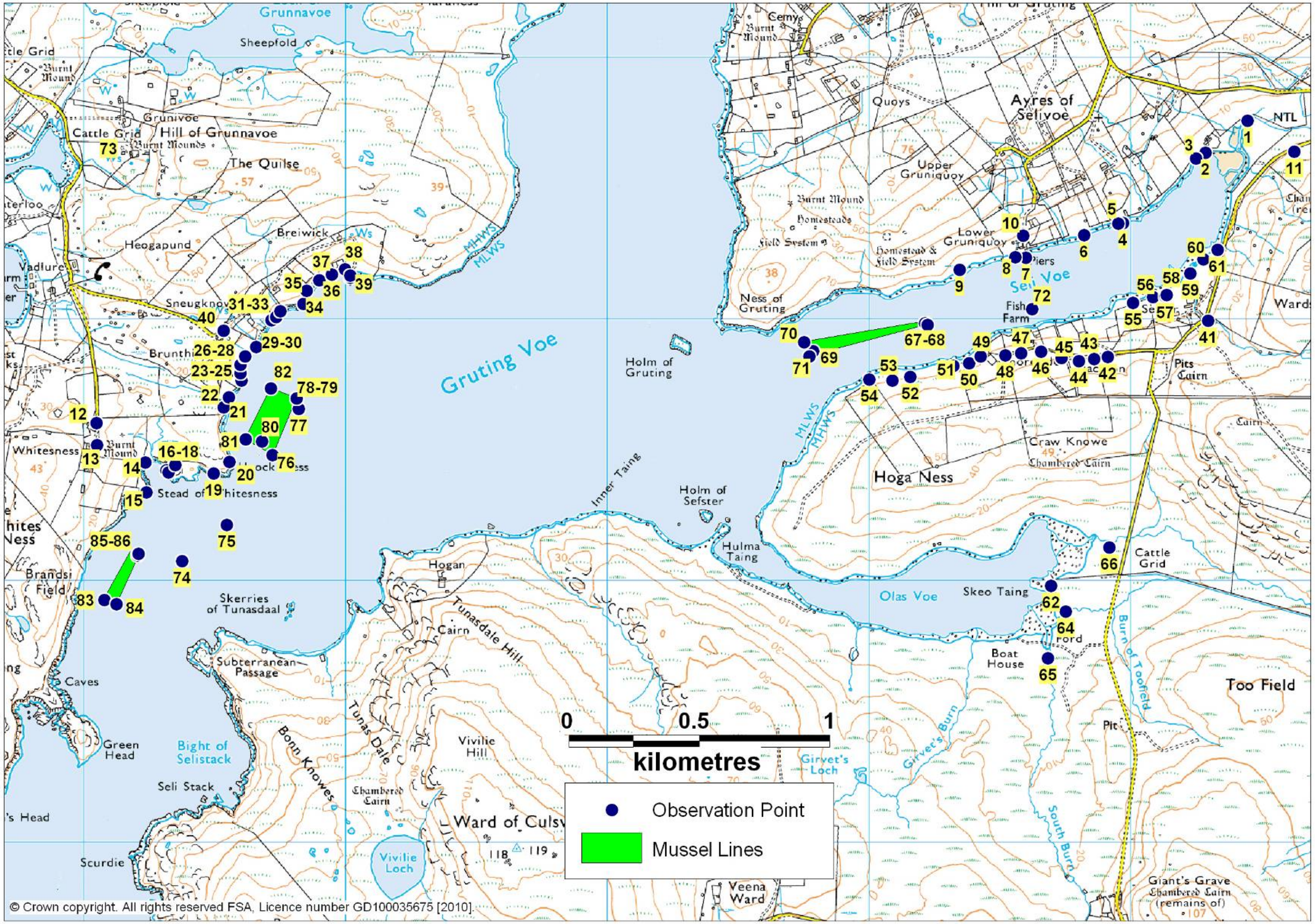


Figure 1 Map of Shoreline Observations

Table 1 Shoreline Observations

No	Date	T i m e	Grid Ref	East	North	Associated Photograph	Note
1	25/08/2009	15:10:05	HU 29451 48763	429451	1148763		Stream, tidal for lower part. Width 3.3 m, depth 35cm, flow 0.064 m/s. Water sample 1
2	25/08/2009	15:22:03	HU 29289 48641	429289	1148641		Houses near here are ruins, unoccupied
3	25/08/2009	15:23:33	HU 29254 48618	429254	1148618		Beach, very little litter here
4	25/08/2009	15:33:34	HU 28973 48371	428973	1148371	Figure 6	7 occupied dwellings up hill away from shore, 2 unoccupied dwellings. 35 sheep
5	25/08/2009	15:35:47	HU 28955 48369	428955	1148369		Bit more rubbish on shore from this point on
6	25/08/2009	15:38:40	HU 28825 48324	428825	1148324		2 small sailboats, 60 sheep, rabbit droppings and dead rabbit
7	25/08/2009	15:53:13	HU 28603 48238	428603	1148238	Figure 7	Small pier and farm belonging to Selivoe harvester, 2 work boats, larger jetty 40 m to west, farm and work sheds behind. Well boat just offshore of this point. Arable field beyond sheds with silage bales. Across the voe are 7 arable fields already cut, 72 sheep in fenced field, ~100 gulls on field adjacent shore (see 42 and 43, don't count twice)
8	25/08/2009	16:02:23	HU 28562 48241	428562	1148241		Drainage runoff, concrete pipe, dry at time. Harvester confirms house has septic tank with soakaway.
9	25/08/2009	16:14:10	HU 28349 48192	428349	1148192		1 sheep. Marshy area with some standing water, large ship across water at salmon shore base
10	25/08/2009	16:21:22	HU 28592 48323	428592	1148323		Drainage ditch along driveway
11	25/08/2009	16:30:24	HU 29628 48645	429628	1148645		200 sheep looking north from this point spread out around hills
12	26/08/2009	09:03:57	HU 25049 47605	425049	1147605		Area of silage bales, 30 sheep and 15 cattle
13	26/08/2009	09:06:37	HU 25050 47521	425050	1147521		Farm, silage bales
14	26/08/2009	09:11:02	HU 25236 47454	425236	1147454		2 sheep on beach, 3 very small boats on shore
15	26/08/2009	09:13:45	HU 25239 47341	425239	1147341	Figure 8	8 sheep, 7 gulls, view of new mussel site, two lines, 1 mature one moved from Breiwick, 1 new line, appears heavy
16	26/08/2009	09:21:27	HU 25315 47425	425315	1147425	Figure 9	Septic tank for large house
17	26/08/2009	09:22:31	HU 25324 47416	425324	1147416	Figure 10	Pipe from septic tank, rabbit, Water sample 2
18	26/08/2009	09:28:33	HU 25350 47445	425350	1147445		18 sheep
19	26/08/2009	09:31:55	HU 25496 47413	425496	1147413		13 sheep, area low grass and rocks
20	26/08/2009	09:36:04	HU 25556 47456	425556	1147456	Figure 11, Figure 12	View of Braewick Voe mussel lines, 2 large ships and 2 barges beyond. Harvesting boat at mussel farm, 1 seal, 25 ducks. Photo along shoreline adjacent to mussel farm.
21	26/08/2009	09:45:05	HU 25535 47665	425535	1147665		Fence, sheep droppings with shells
22	26/08/2009	09:47:08	HU 25554 47705	425554	1147705		Rocky beach with broken fence, 12 birds perched on mussel boat
23	26/08/2009	09:49:49	HU 25604 47768	425604	1147768		More rocky foreshore with no fence, sheep trails but no droppings apparent

No	Date	Time	Grid Ref	East	North	Associated Photograph	Note
24	26/08/2009	09:51:15	HU 25599 47797	425599	1147797		Derelict buildings uphill of observation point, junked cars and equipment, silage bales
25	26/08/2009	09:52:52	HU 25600 47828	425600	1147828		Field drainage ditch with trickle, not enough flow to measure. Some algal growth on rocks
26	26/08/2009	09:55:43	HU 25616 47859	425616	1147859		Pile of rubbish
27	26/08/2009	09:56:47	HU 25617 47860	425617	1147860		Dry drainage ditch, black corrugated culvert pipe uphill
28	26/08/2009	09:59:33	HU 25659 47897	425659	1147897		Rabbit
29	26/08/2009	10:04:30	HU 25718 48000	425718	1148000		Farm house uphill, 1 ram, sheep track with droppings
30	26/08/2009	10:05:54	HU 25721 48002	425721	1148002		Dry drainage ditch
31	26/08/2009	10:06:28	HU 25736 48011	425736	1148011		Arable field, has been cut
32	26/08/2009	10:07:42	HU 25751 48034	425751	1148034	Figure 13	Ruin of old watermill on tiny stream, too shallow to measure, house upstream of mill, no pipes seen, Water sample 3
33	26/08/2009	10:14:54	HU 25841 48061	425841	1148061		Rusty remains of 3 or more vehicles on shore
34	26/08/2009	10:18:02	HU 25853 48112	425853	1148112	Figure 14	40 sheep behind fence, many droppings on shore
35	26/08/2009	10:20:29	HU 25901 48152	425901	1148152		Large group of ducks on water, >100
36	26/08/2009	10:22:32	HU 25948 48174	425948	1148174	Figure 14	Mussel lines and floats laid out in field, 37 sheep, 2 rabbits, 4 ponies
37	26/08/2009	10:25:27	HU 25999 48195	425999	1148195		Stagnant field ditch, no flow
38	26/08/2009	10:27:28	HU 26018 48170	426018	1148170		Pier, no pipes apparent
39	26/08/2009	10:29:15	HU 26018 48162	426018	1148162		Water sample 4, seawater near pier
40	26/08/2009	10:42:59	HU 25534 47960	425534	1147960		2 sheep
41	26/08/2009	11:36:58	HU 29300 47998	429300	1147998		Farm with shelds, silage bales and 2 houses, 6 rams
42	26/08/2009	11:44:03	HU 28915 47859	428915	1147859		Mown fields between road and shore (7 fields)
43	26/08/2009	11:45:25	HU 28864 47850	428864	1147850		72 sheep uphill of road behind fence
44	26/08/2009	11:46:45	HU 28806 47842	428806	1147842		43 gulls on field adjacent shoreline
45	26/08/2009	11:48:00	HU 28739 47854	428739	1147854		Arable fields either side of road here
46	26/08/2009	11:49:15	HU 28661 47879	428661	1147879	Figure 15	Large house and shore base for salmon farm, 2 large ships, 1 smaller fishing boat, 1 smaller house
47	26/08/2009	11:50:49	HU 28584 47872	428584	1147872		Arable fields either side of road, 7 domestic geese on field adjacent shore
48	26/08/2009	11:52:05	HU 28524 47865	428524	1147865		Farm, arable fields, silage bales, 1 sheep
49	26/08/2009	11:57:22	HU 28429 47860	428429	1147860		Septic tank for house, faint odour, line of rocks running from shore but no apparent pipe
50	26/08/2009	12:00:03	HU 28385 47834	428385	1147834		Dry ditch, 4 sheep in field
51	26/08/2009	12:02:03	HU 28326 47825	428326	1147825		Sheep droppings on shore, also many goose droppings, stretch of shoreline with no fence begins here

No	Date	T i m e	Grid Ref	East	North	Associated Photograph	Note
52	26/08/2009	12:05:45	HU 28161 47782	428161	1147782		Dry stream bed, line of thin blue piping in water just off shore, mussel lines further offshore
53	26/08/2009	12:08:35	HU 28093 47769	428093	1147769		Large numbers of rabbit droppings, also droppings with crushed mussel shell in
54	26/08/2009	12:11:16	HU 28003 47772	428003	1147772	Figure 16	Dry ditch, salmon cages visible beyond mussel farm
55	26/08/2009	12:36:39	HU 29013 48065	429013	1148065		Shingle beach with many shells, cockles, topshells, clams, whelks, horse mussels, urchins
56	26/08/2009	12:40:52	HU 29089 48088	429089	1148088	Figure 17	Iron pipe, dry.
57	26/08/2009	12:43:07	HU 29134 48091	429134	1148091	Figure 18	White plastic discharge pipe, not flowing but active. Whitish-grey area on substrate below pipe, Water sample 5 - seawater (3 small bottles)
58	26/08/2009	12:45:29	HU 29140 48095	429140	1148095	Figure 19	Clay pipe underwater, no apparent discharge
59	26/08/2009	12:52:48	HU 29232 48179	429232	1148179		Stream, 1m wide, 8.5 cm deep, flow 0.1 m/s. Water sample 6. Local crofter reports this stream runs much more after rain. Otters regularly observed in area, may have holt up stream. Seals also often seen.
60	26/08/2009	13:16:20	HU 29282 48232	429282	1148232	Figure 20	Dry stream, runs under road
61	26/08/2009	13:18:24	HU 29336 48269	429336	1148269		Stream with barely a trickle, too dry to measure
62	27/08/2009	14:51:11	HU 28698 46982	428698	1146982	Figure 21	Very low lying grass and peat, blanketed in sheep droppings - impossible to set notebook down without touching one. Broch just off shore here.
63	27/08/2009	14:54:28	HU 28755 46886	428755	1146886		Blank, GPS malfunctioning
64	27/08/2009	14:55:32	HU 28754 46885	428754	1146885	Figure 22	Stream, 1.5m wide, 11 cm depth, flow 0.22m/s, Water sample 7
65	27/08/2009	15:05:48	HU 28687 46706	428687	1146706	Figure 23	Stream, 1.3m wide, 10 cm depth at bank flow 0.01m/s, 24cm depth at centre flow 0.06m/s, 30cm depth at other bank flow 0.08 m/s. Water sample 8
66	27/08/2009	15:25:34	HU 28921 47130	428921	1147130		Stream, 1.2m wide. 20cm depth 0.14m/s, 24cm depth 0.291m/s. Water sample 9
67	28/08/2009	09:03:10	HU 28216 47987	428216	1147987	Figure 24	Mussel sample 1 (bottom of line), 2 (top of line). Water sample 10. Sal 10m 35.5, 5m 35.5, 1m 35.0. Temp 10m 12.8, 5m 13.1, 1m 13.6. 3 long sets of lines, 3 shorter sets of lines, droppers 10m.
68	28/08/2009	09:21:40	HU 28226 47981	428226	1147981		Corner of lines, 5 arctic terns, 8 gulls, 1 arctic skua
69	28/08/2009	09:29:49	HU 27788 47881	427788	1147881		Mussel sample 3 (bottom) and 4 (top). Water sample 11. Sal 10m 35.6, 5m 35.5, 1m 35.3. Temp 10m 12.8, 5m 13.2, 1m 13.6
70	28/08/2009	09:43:12	HU 27754 47915	427754	1147915		Corner of lines
71	28/08/2009	09:44:29	HU 27774 47860	427774	1147860		Corner of lines
72	28/08/2009	09:49:55	HU 28626 48042	428626	1148042		Seawater sample 12 , taken off salmon shore base where well boats offload
73	28/08/2009	10:16:08	HU 24177 48523	424177	1148523		4 cattle on hill to east, viewed from boat
74	28/08/2009	10:40:38	HU 25376 47078	425376	1147078		5 sheep on hill above mussel farm

No	Date	Time	Grid Ref	East	North	Associated Photograph	Note
75	28/08/2009	10:42:01	HU 25547 47215	425547	1147215		10 sheep on point, small field below ruin just off end of mussel lines
76	28/08/2009	10:43:59	HU 25721 47484	425721	1147484		Corner (approx 10m from float)
77	28/08/2009	10:45:21	HU 25822 47660	425822	1147660		5 cormorants, 3 gulls
78	28/08/2009	10:46:26	HU 25813 47703	425813	1147703		Corner of lines
79	28/08/2009	10:49:05	HU 25813 47699	425813	1147699		Mussel sample 5 (bottom) and 6 (top). Water sample 13. Sal 10m 35.6, 5m 35.3, 1m 35.3. Temp 10m 12.9, 5m 13.7, 1m 13.7
80	28/08/2009	11:04:29	HU 25681 47535	425681	1147535	Figure 25	Mussel sample 7 (top) and 8 (bottom). Water sample 14. Sal 10m 35.6, 5m 35.3, 1m 35.3. Temp 10 13.1, 5m 13.7, 1m 13.7. Two sets of long lines, one nearly sinking, the other with growth only at one end. Droppers 8-9m
81	28/08/2009	11:30:58	HU 25619 47543	425619	1147543		Corner of lines
82	28/08/2009	11:34:17	HU 25715 47738	425715	1147738		Corner of lines
83	28/08/2009	11:43:48	HU 25078 46928	425078	1146928	Figure 26	Corner of lines. Mussel samples 9 (bottom) and 10 (top). Water sample 15. Sal 10m 35.4, 5m 35.4, 1m 35.3. Temp 10m 13.6, 5m 13.6, 1m 13.7
84	28/08/2009	12:06:53	HU 25125 46913	425125	1146913		Corner of lines
85	28/08/2009	12:09:46	HU 25205 47100	425205	1147100		Corner of lines
86	28/08/2009	12:16:03	HU 25210 47105	425210	1147105		Water sample 16. Sal 10m 35.4, 5m 35.4, 1m 35.3. Temp 10m 13.6, 5m 13.6, 1m 13.6

Photos referenced in the table can be found attached as Figures 6-26.

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

Salinity and temperature profiles were taken using a YSI handheld salinity meter.

Table 2 Water Sample Results

No.	Date	Sample	Grid Ref	Type	*E. coli* (cfu/100 ml)	Salinity (ppt)
1	26/08/2009	LGV 1	HU 29451 48763	Freshwater	200	
2	26/08/2009	LGV 2	HU 25324 47416	Seawater	200	
3	26/08/2009	LGV 3	HU 25751 48034	Freshwater	1600	
4	26/08/2009	LGV 4	HU 26018 48162	Seawater	30	
5	26/08/2009	LGV 5	HU 29134 48091	Seawater	8	
6	26/08/2009	LGV 6	HU 29232 48179	Freshwater	85	
7	27/08/2009	LGV 7	HU 28754 46885	Freshwater	1300	
8	27/08/2009	LGV 8	HU 28687 46706	Freshwater	1000	
9	27/08/2009	LGV 9	HU 28921 47130	Freshwater	340	
10	28/08/2009	LGV 10	HU 28216 47987	Seawater	13	35.0
11	28/08/2009	LGV 11	HU 27788 47881	Seawater	2	35.3
12	28/08/2009	LGV 12	HU 28626 48042	Seawater	240	
13	28/08/2009	LGV 13	HU 25813 47699	Seawater	<1	35.3
14	28/08/2009	LGV 14	HU 25681 47535	Seawater	<1	35.3
15	28/08/2009	LGV 15	HU 25078 46928	Seawater	5	35.3
16	28/08/2009	LGV 16	HU 25210 47105	Seawater	1	35.3

Table 3 Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	*E. coli* (mpn/100g)	Depth (m)
1	28/08/2009	LGV1	HU 28216 47987	Mussel	790	1
2	28/08/2009	LGV2	HU 28216 47987	Mussel	2400	10
3	28/08/2009	LGV3	HU 27788 47881	Mussel	130	10
4	28/08/2009	LGV4	HU 27788 47881	Mussel	490	1
5	28/08/2009	LGV5	HU 25813 47699	Mussel	20	10
6	28/08/2009	LGV6	HU 25813 47699	Mussel	40	1
7	28/08/2009	LGV7	HU 25681 47535	Mussel	130	1
8	28/08/2009	LGV8	HU 25681 47535	Mussel	170	10
9	28/08/2009	LGV9	HU 25078 46928	Mussel	130	10
10	28/08/2009	LGV10	HU 25078 46928	Mussel	50	1

Table 4 Salinity and Temperature Profiles

Profile No.	Grid Ref	Depth (m)	Salinity (ppt)	Temp (°C)
1	HU 28216 47987	10	35.5	12.8
		5	35.5	13.1
		1	35.0	13.6
2	HU 27788 47881	10	35.6	12.8
		5	35.5	13.2
		1	35.3	13.6
3	HU 25813 47699	10	35.6	12.9
		5	35.3	13.7
		1	35.3	13.7
4	HU 25681 47535	10	35.6	13.1
		5	35.3	13.7
		1	35.3	13.7
5	HU 25078 46928	10	35.4	13.6
		5	35.4	13.6
		1	35.3	13.7
6	HU 25210 47105	10	35.4	13.6
		5	35.4	13.6
		1	35.3	13.6

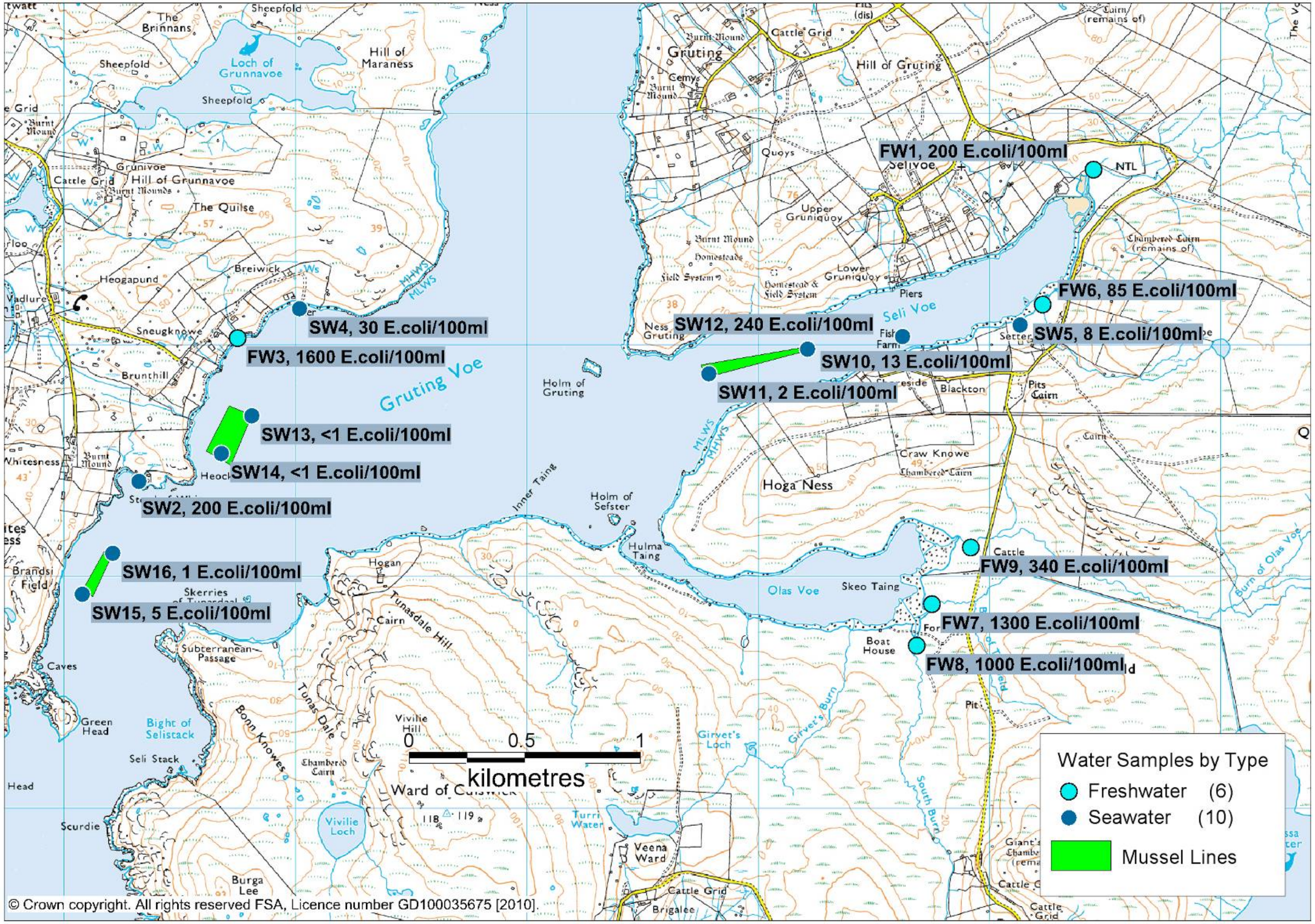


Figure 3 Water sample results map

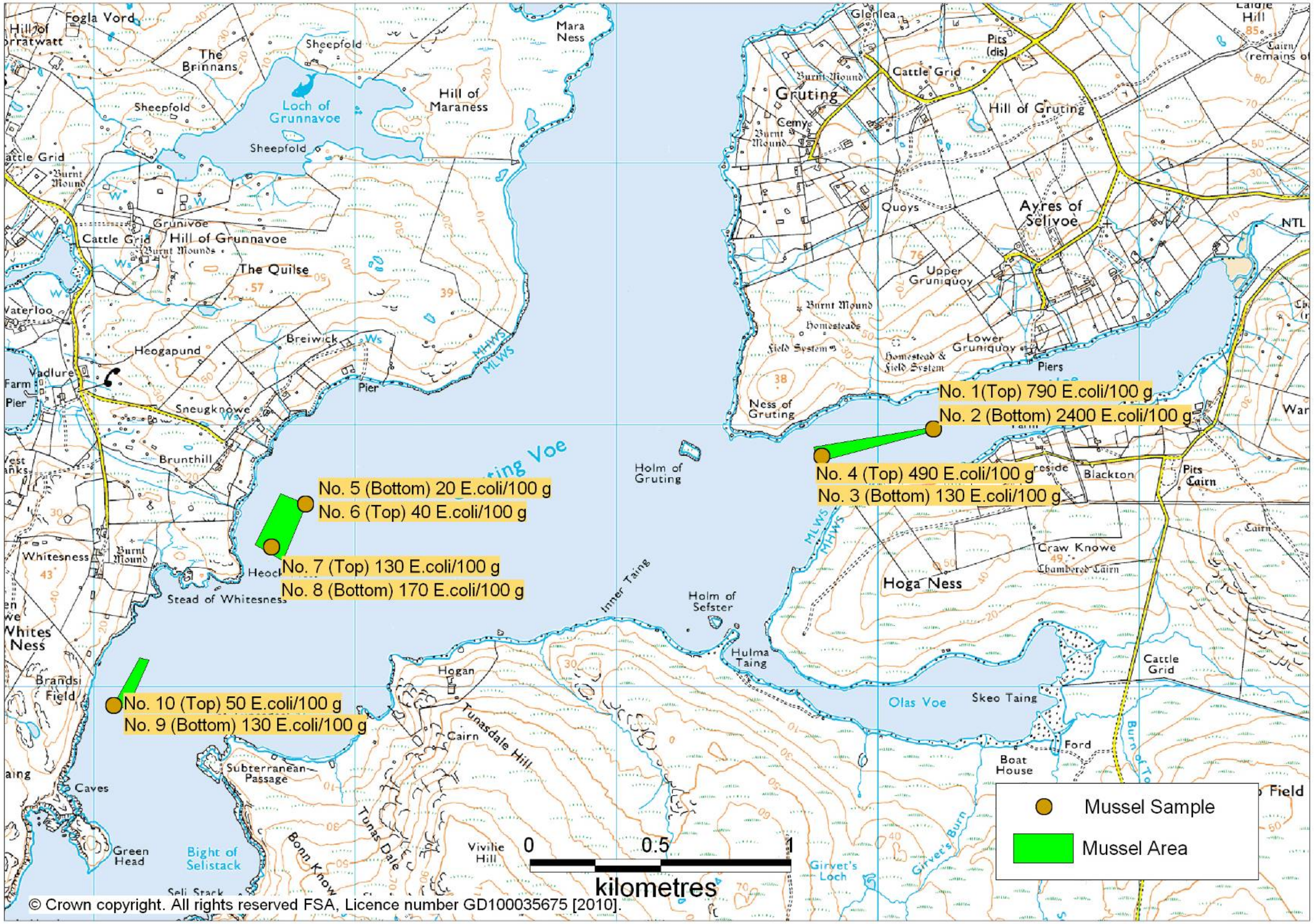


Figure 4 Shellfish sample results map

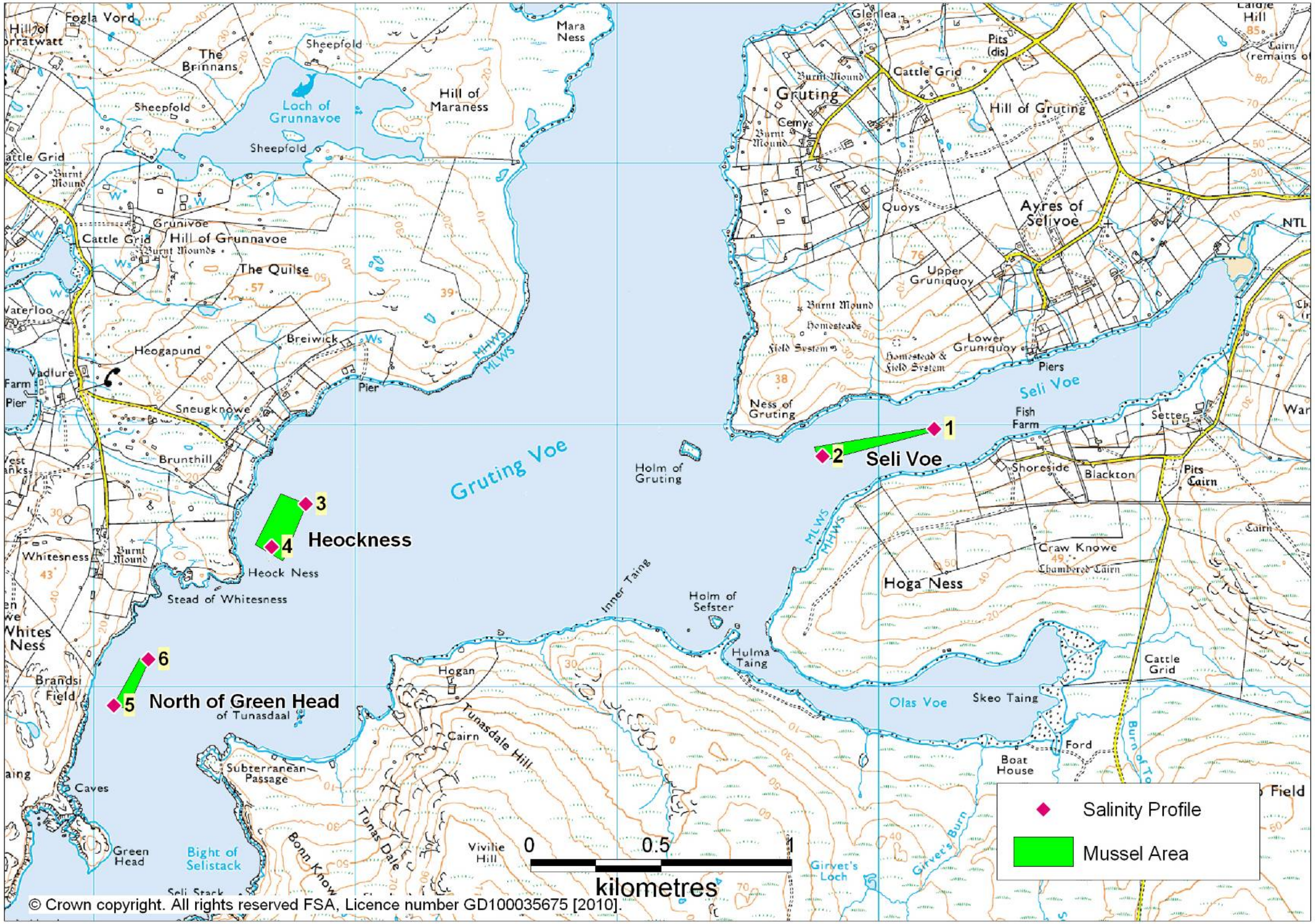


Figure 5 Salinity profile locations

Photographs

Figure 6 Dwellings and sheep uphill from from shoreline, north shore Seli Voe

Figure 7 Well boat and shore base, south shore Seli Voe

Figure 8 View of North of Green Head mussel farm from shore

Figure 9 House and septic tank

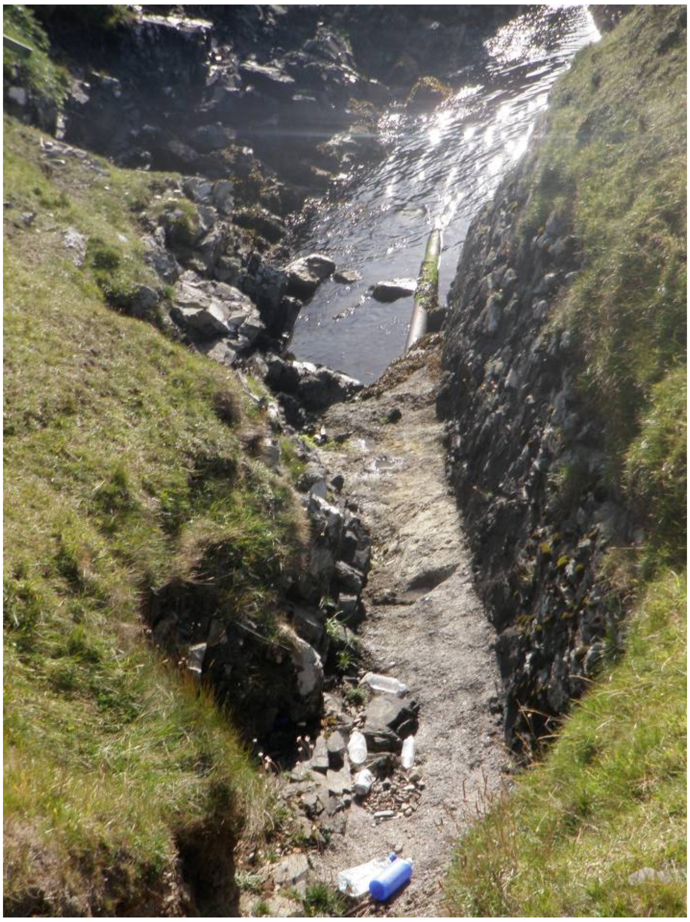


Figure 10 Discharge pipe from septic tank in Figure 9.

Figure 11 View of Braewick Voe mussel farm


Figure 12 Looking northward along shoreline adjacent to Braewick Voe site


Figure 13 Culvert pipe above drainage ditch, dry at time of survey

Figure 14 Stream below house and old mill

Figure 15 Shoreline looking north-eastward from observation point 33

Figure 16 Ships at salmon shore base.

Figure 17 Iron pipe

Figure 18 Active discharge pipe, Seli Voe south shore

Figure 19 Clay pipe underwater

Figure 20 Dry stream bed under road

Figure 21 Sheep droppings at Olas Voe

Figure 22 Burn of Toofield at Olas Voe

Figure 23 South Burn, Olas Voe

Figure 24 Mussel lines at Seli Voe

Figure 25 Sampling at Braewick Voe mussel farm

Figure 26 Sampling at North of Green Head