Scottish Sanitary Survey Project

Sanitary Survey Report

Vaila Sound and Vaila Sound: Riskaness

SI288 and SI289

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Cefas

FOOD STANDARDS AGENCY SCOTLAND

Buidheann Inbhe-Bìdhe an Alba

Report Distribution – Vaila Sound

Date	Name	Agency*
	Linda Galbraith	Scottish Government
	Judith White	Scottish Government
	Ewan Gillespie	SEPA
	Douglas Sinclair	SEPA
	Stephan Walker	Scottish Water
	Alex Adrian	Crown Estate
	Dawn Manson	Shetland Island Council
	Sean Williamson	Shetland Island Council
	North Atlantic Shellfish	Harvester**
	Demlane	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

Vaila Sound is located on the eastern coast of the Shetland Isles. The island of Vaila lies to the west and shelters the majority of the sound. The island of Linga is situated in the middle of the sound. The area of the sound, on the east side of the island of Linga is approximately 1.2 km wide and 1.3 km long and is between 10-20 m in depth. On the west side of the island of Linga the sound is narrower at 0.8 km but longer in length at about 1.9 km. Areas of this side of the sound reach up to 30 m in depth. South of the island of Linga, the sound narrows and runs between the island of Vaila and the mainland.

This sanitary survey was triggered by the risk matrix score achieved for Vaila Sound due to monitoring results outwith its classification. The production area of Vaila Sound: Riskaness was agglomerated due to its proximity.

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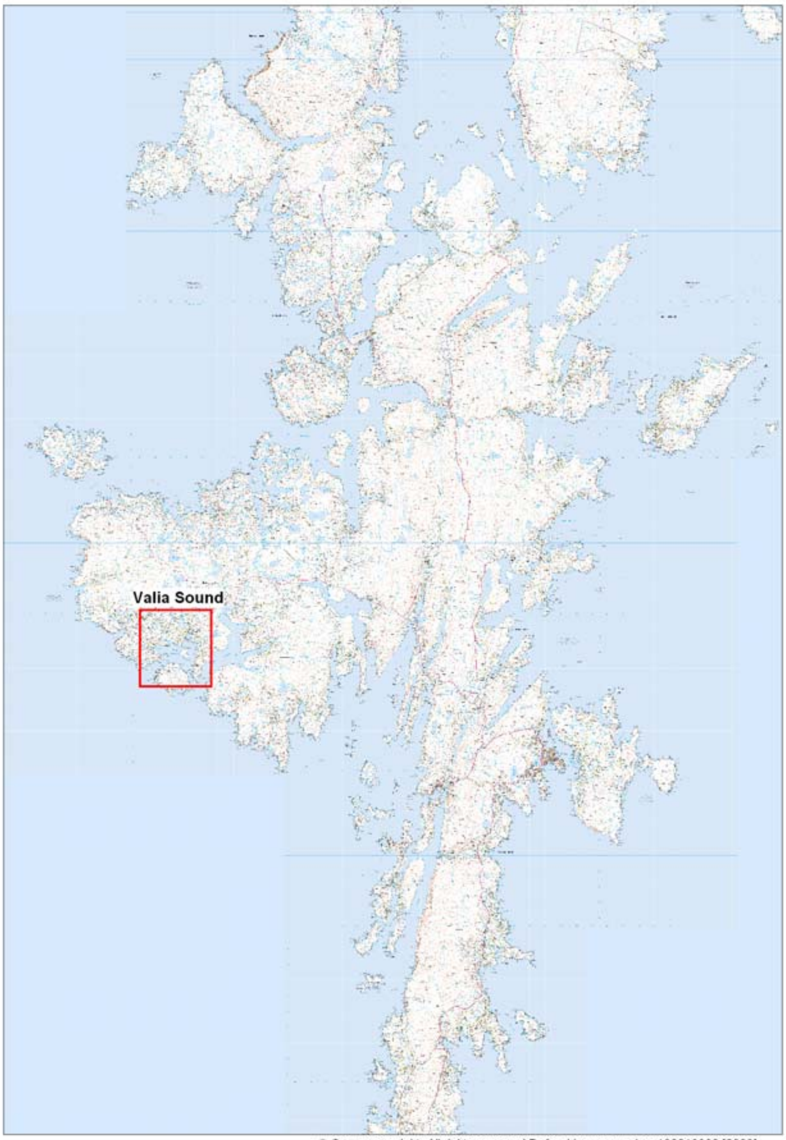

Figure 1.1 Location of Vaila Sound

2. Fishery

The fishery at Vaila Sound is composed of five long line common mussel fisheries (*Mytilus edulis*) as listed in Table 2.1 below:

Table 2.1 Vaila Sound shellfish farms

Production Area	Site	SIN	Species
Vaila Sound	Linga	SI 288 457 08	Mussels
Vaila Sound	Galtaskerry	SI 288 456 08	Mussels
Vaila Sound	East of Linga	SI 288 455 08	Mussels
Vaila Sound: Riskaness	Riskaness	SI 289 458 08	Mussels
Vaila Sound: Riskaness	Lera Voe	SI 289 805 08	Mussels

The current production area boundaries for Vaila Sound are given as the area bounded by lines drawn from HU 2358 4719 and HU 2387 4766 and between HU 2416 4620 and HU 2459 4620 (Rams Head) and from HU 2369 4840 to HU 2382 4832 extending to MHWS. There is currently one RMP located at HU 232 483, within the Linga site.

The current production area boundaries for Vaila Sound: Riskaness are given as the area bounded by lines drawn between HU 2369 4840 and HU 2382 4832 and between HU 2236 4750 and HU 2387 4766 extending to MHWS. There is currently one RMP located at HU 240 484, within the Riskaness site.

Vaila Sound: Linga consists of 6 float lines from which 8 m droppers are suspended. Vaila Sound Riskaness: Riskaness consists of 6 float lines from which 10 m droppers are suspended. These two sites are owned by Demlane, and are usually harvested between September and April, with the timing of harvest dependent on demand, biotoxin status, and the status of other sites under the same ownership.

Vaila Sound: East of Linga consists of 5 float lines from which 8 m droppers are suspended. Vaila Sound: Galtaskerry consists of 6 float lines from which 5 m droppers are suspended. Vaila Sound Riskaness: Lera Voe consists of 5 float lines from which 8 m droppers are suspended. These three sites are owned by North Atlantic Shellfish, and can be harvested at any time of year dependent on demand, biotoxin status, and the status of other sites under the same ownership.

Stock of a range of sizes, including harvestable size was present on all sites.

A detailed map showing the position of the RMPs, production areas, Crown Estates seabed leases and mussel lines are shown in Figure 2.1.

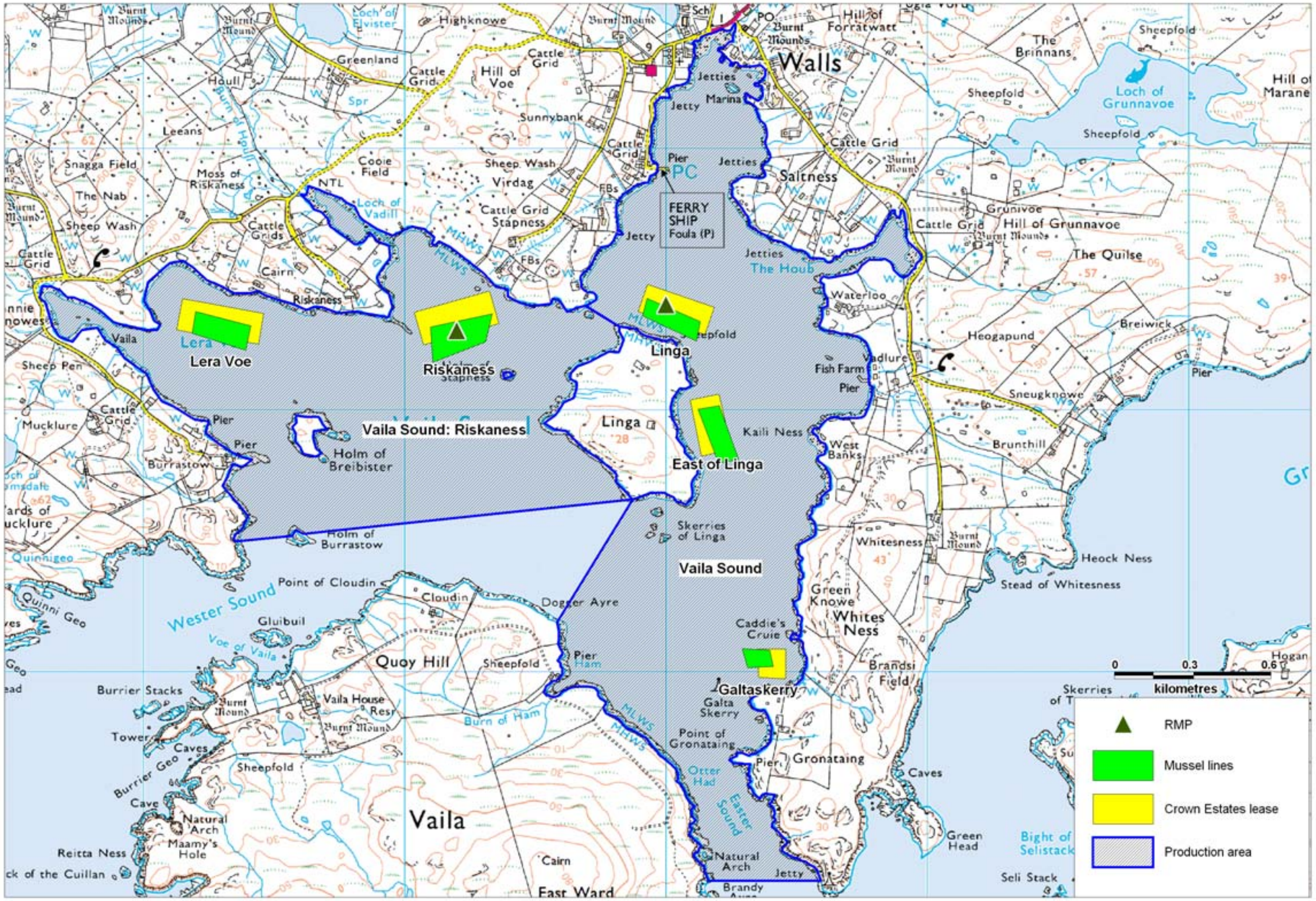

Figure 2.1 Vaila Sound Fishery

3. Human Population

The figure below shows information obtained from the General Register Office for Scotland on the population within the census output in the vicinity of Vaila Sound.

Figure 3.1 Population of Vaila Sound

The population for the three census output areas bordering immediately on Vaila Sound are:

60RD000134	147
60RD000028	188
60RD000029	190
Total	525

Apart from Walls on the north eastern coast of Vaila Sound, there are very few settlements and the majority of dwellings are sparsely scattered about. The majority of the population is therefore concentrated on the around the settlement of Walls and any associated faecal pollution from human sources is likely to be concentrated in this area. The islands of Linga and Holm of Breibister are uninhabited.

4. Sewage Discharges

Two community septic tanks and one emergency overflow were identified by Scottish Water for the area around Vaila Sound. They are listed in Table 4.1.

Table 4.1 Discharges identified by Scottish Water

NGR	Discharge Name	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consented / design pop	Q&S III Planned improvement?	SEPA Consent No.
HU 242 489	Saltness	Continuous	Septic tank	70	-	No	WPC-W-48877
HU 24234 49422	Walls East P/S EO	Intermittent	EO	Not stated	Not stated	No	WPC-W-48877
HU 2390 4880	Walls ST	Continuous	Septic tank	4	15	No	WPC-N-59410

No sanitary or microbiological data was available for these discharges. A number of discharge consents were issued by SEPA and are listed in Table 4.2. As there was historically no requirement to register private sewage and septic tank discharges in Scotland, this list will not include all the discharges that may be present in the area. The first three consents listed apply to the Scottish Water discharges listed in Table 4.1.

Table 4.2 Discharge consents held by SEPA

Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consented/ design PE	Discharges to
WPC-W-48877	HU 24200 48923	Domestic	Septic tank	70	-	Vaila Sound
WPC-W-48877	HU 24234 49422	Emergency overflow	None	-	-	Vaila Sound
WPC-N-59410	HU 2390 4880	Domestic	Septic tank	4	15	Vaila Sound
CAR/R/1018964	HU 2220 4767	Domestic	Septic tank	-	5	Soakaway
CAR/R/1010063	HU 2289 4962	Domestic	Septic tank	-	5	Soakaway

A number of septic tanks and/or outfalls were recorded during the shoreline survey. These are listed in Table 4.3.

The main concentration of population is at the settlement of Walls, at the northern end of the Vaila Sound production area. The Scottish Water Saltness septic tank, on the east shore, serves the majority of Walls. Associated with this is an emergency discharge from a pumping station that pumps wastewater to the Saltness septic tank. It is not known how frequently this emergency discharge operates, but the consent indicates that it should only operate in the event of electrical/mechanical failure or blockage, so presumably discharges from here are very infrequent. The Scottish Water Walls septic tank serves a few houses only and is located by the ferry pier.

An additional 10 private sewer pipes discharging to Vaila Sound from the settlement of Walls were recorded during the shoreline survey, but not all were flowing at the time. Assuming that each of these private discharges equate to a population of 5, and that the Saltness septic tank is equivalent to a maximum population of 311 (estimated using a per capita water use of 225 L/head/day), the total population equivalent discharging in the vicinity of Walls is about 381. Therefore, the site closest to Walls (Linga) is likely to be most heavily impacted by the discharges here.

Table 4.3 Discharges and septic tanks observed during shoreline survey

No.	Date	Grid Reference	Observation
1	22/07/2008	HU 23935 48882	Septic tank with 12cm cast iron pipe to underwater. Serves the pier toilets and about 7 houses. (Scottish Water Walls ST)
2	22/07/2008	HU 23887 48853	White 12cm plastic sewer pipe to underwater. Possibly redundant.
3	22/07/2008	HU 23807 48710	Septic tank with 12cm white plastic pipe to underwater. Probably serves about 3 or 4 houses.
4	22/07/2008	HU 23638 48471	Septic tank for 1 house. No overflow pipe seen.
5	22/07/2008	HU 21623 48355	Septic tank belonging to one house with channel cut in soil down to sea. Some odour.
6	22/07/2008	HU 21862 48245	Septic tank with 12cm orange plastic overflow to underwater. Serves 1 house.
7	22/07/2008	HU 21908 48187	Septic tank from 1 house. Orange 12cm plastic pipe buried, possibly discharging to very small stream.
8	23/07/2008	HU 24105 49390	10cm cast iron sewer pipe, nothing coming from end.
9	23/07/2008	HU 23949 49016	Septic tank with 12cm cast iron pipe to underwater. Grey water coming from end. Probably serves 3 or 4 houses.
10	23/07/2008	HU 23938 48952	12cm ceramic septic outfall to underwater, probably serves 1 house.
11	23/07/2008	HU 23941 48942	12cm ceramic septic outfall to beach, probably serves 1 house, not flowing but owners away.
12	23/07/2008	HU 24321 49314	White 12cm plastic sewer pipe to beach, dripping.
13	23/07/2008	HU 24378 49280	12cm metal sewer pipe to underwater
14	23/07/2008	HU 24360 49239	12cm orange plastic sewer pipe to underwater
15	23/07/2008	HU 24383 49039	15cm orange ceramic sewer pipe not flowing.
16	23/07/2008	HU 22824 48374	12cm orange plastic sewer pipe, flowing, toilet paper around end.
17	23/07/2008	HU 22650 48655	Septic tank in back garden about 50 m north, no pipe seen.
18	23/07/2008	HU 24681 48325	Septic tank, no overflow visible
19	23/07/2008	HU 24780 48128	2x15cm plastic pipes not flowing.
20	23/07/2008	HU 24781 48026	Septic tank with overflow pipe to beach not flowing.
21	23/07/2008	HU 24372 48918	Scottish water communal septic tank (Saltness). Outflow underwater and not visible. Probably serves majority of houses on east side of Walls.
22	24/07/2008	HU 24614 47875	Septic tank up hill by house, no overflow visible.

Outside of Walls, there are other areas of settlement on the shores of Vaila Sound, but these are much more scattered and less dense. A number of other private septic tanks or discharges were seen to the north shore near the Lera Voe and Riskaness sites, and around Vadlure on the east shore. Of these, four were septic tanks with no apparent overflow, two were septic tanks with overflows to watercourses, and four were pipes discharging to Vaila Sound. Therefore, the estimated population equivalent discharging to water outside of the settlement of Walls is about 30.

SEPA discharge consents indicate another two discharges (CAR/R/1018964 and CAR/R/1010063). These were not seen during the shoreline survey as they were some distance from the shore. Both are small private septic tanks discharging to soakaway so should have negligible impact.

While a few of the observed dwellings in the area may be holiday homes, there are no specific areas of interest to tourists and so no large fluctuations in population are expected during the summer months.

Boat traffic in Vaila Sound includes small pleasure craft, mussel and salmon farm boats, and the Foula ferry. There was a small marina at Walls, where a total of 18 small boats were tied up at the time of the shoreline survey. Other moorings or jetties were seen on Vaila (2 jetties and one small boat), at the North Atlantic Shellfish building (one jetty and mussel boat), and in Lera Voe (4 small boats on moorings, salmon jetty with 3 boats). The small Foula ferry sails twice weekly in winter, and three times weekly in summer from the pier in Walls. A large barge that was likely to have on-board toilets was moored next to the salmon farm just off Vaila at the time of shoreline survey. Therefore sporadic and unpredictable inputs from boat traffic may be expected in the general area.

In conclusion, it is likely that the area around Walls will receive the greatest inputs of human sewage, and this will probably not increase significantly during the summer months. Therefore, the Linga site is likely to be most affected by these discharges as it lies closest to Walls.

Figure 4.1 Discharges at Vaila Sound

5. Geology and Soils

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

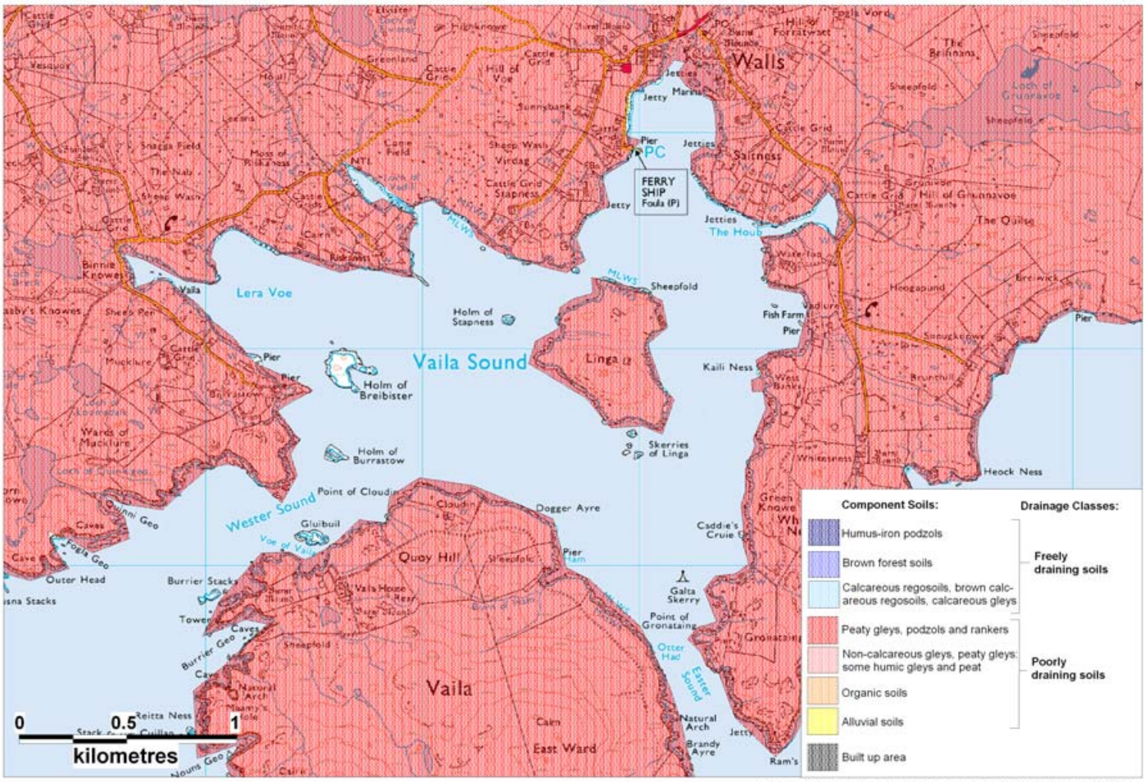

Figure 5.1 Component soils and drainage classes for Vaila Sound.

Only one type of component soil is present in this area: the peaty gleys, podzols and rankers. This is a poorly draining soil type. Therefore, the potential for runoff contaminated with *E. coli* from human and/or animal waste is high for all the land surrounding Vaila Sound.

6. Land Cover

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

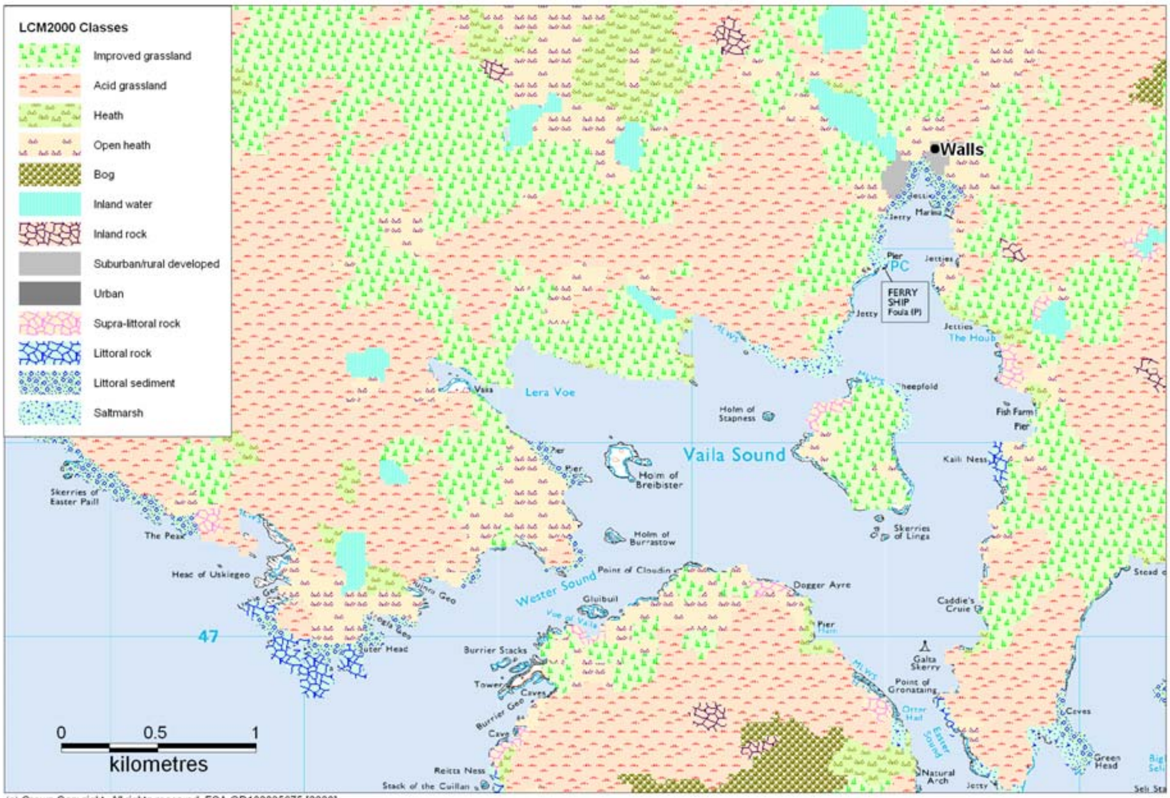

Figure 6.1 LCM2000 class land cover data for Vaila Sound

There are two main types of land cover shown in Figure 6.1: improved grassland and acid grassland. These two types of landcover form a patchwork covering most of the surrounding area. The settlement of Walls is shown as a small suburban/rural development. Many of the areas of improved grassland border on the sound.

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.

Therefore, the overall predicted contribution of contaminated runoff from these land cover types would be low to intermediate, and would be expected to increase significantly following rainfall events. There is no particular spatial pattern in land cover suggesting that any one site would be subjected to higher levels of contamination, apart from perhaps the Linga site is closest to the built up area at Walls, and there may be slightly more improved grassland around Lera Voe than in other places.

7. Farm Animals

Agricultural census data was provided by RERAD for the parish of Walls which surrounds the production area and includes the island of Vaila. Recorded livestock populations for the parish in 2007 and 2008 are presented in Table 7.1. RERAD withheld data for reasons of confidentiality where the small number of holdinmgs would have made it possible to discern individual farm data.

Table 7.1 Livestock numbers in Walls Parish

	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
Horses and ponies	16	99	15	96

* Data withheld on a confidentiality basis

Agriculture within this parish is dominated by sheep production. Due to the large area of the parish, this data does not provide information on the livestock numbers in the area immediately surrounding the production areas. The only significant source of local information was therefore the shoreline survey (see Appendix), which only relates to the time of the site visit on 22-24th July 2008. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1.

The shoreline survey confirmed that sheep grazed widely around the Vaila Sound coastline. Several cattle and three pigs were also observed on the nearby island of Vaila, although no pigs were reported by RERAD in the agricultural census on confidentiality grounds due to the small number of holdings. Sheep were fairly evenly spread around the shoreline of the two production areas. Geographical spread of contamination at the shores of the sound is therefore likely to fairly even.

Numbers of sheep will approximately double during May following the birth of lambs, and decrease in the autumn as they are sent to market. Therefore higher impacts from livestock may to be expected during this period.

Figure 7.1 Livestock observations at Vaila Sound

8. Wildlife

A variety of wildlife species can be found in the vicinity of Vaila Sound, and those most likely to have an impact on bacteriological water quality at the fishery are considered here. For further background information relating to the impact of wildlife-source contamination, please see Appendix 3. Seals, dolphins, seabirds, waterfowl (geese and ducks) and otters are those most likely to frequent the area surrounding the fishery.

Seals

Common seal 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). More detailed information from the previous count (2001) identified haulout sites for this species in Gruting Voe to the east, and in Wester Sound to the west, but not within either of the Vaila Sound production areas.

Minimum grey seal pup production in Shetland was estimated as 943 in 2004. Adult numbers are estimated to be 3.5 times the pup population (Callan Duck, Sea Mammal Research Unit, personal communication). No breeding colonies were reported for grey seals in Vaila Sound.

One seal was seen just off Vaila during the shoreline survey. Seals will hunt widely for food so it is likely they will feed near the mussel farms at some point in time. Seals have been observed lying between mussel floats in other parts of Shetland (R. Anderson, personal communication) so it is anticipated that there could be some impact to the fisheries. However, the population is highly mobile therefore it is likely that any impact will be unpredictable.

Dolphins

It is possible that dolphins may be found from time to time in the area, although the larger species are unlikely visit this area as it is fairly shallow and enclosed. Little is known about the bacterial content of dolphin excreta, however any impact due to their presence is likely to be fleeting and unpredictable.

Seabirds

A number of seabird species breed in Shetland. These were the subject of a detailed census carried out in sections during the late spring of 1999, 2000, 2001 and 2002. Total counts of all species recorded within 5km of the production area boundaries are presented in Table 8.2. Where counts were of occupied sites/nests/territories, actual numbers of birds breeding in the area were higher as each territory represented a breeding pair.

There is a high density of breeding seabirds in the general area. The highest concentrations of birds (mainly fulmars, together with a wide mix of lesser species) were recorded along the shores of Wester Sound along the west side of Vaila. Arctic terns and various gulls were quite widespread along the whole of the surrounding land, albeit at lower densities.

Table 8.2 Seabird counts within 5km of the production areas.

Common name	Species	Count	Qualifier
Northern Fulmar	*Fulmarus glacialis*	3960	Occupied sites
Arctic Tern	*Sterna paradisaea*	1253	Individuals on land/occupied nests
Black Guillemot	*Cepphus grylle*	806	Individuals on land
Common Guillemot	*Uria aalge*	405	Individuals on land
Common Gull	*Larus canus*	351	Occupied territory/nests/individuals on land
Great Black-backed Gull	*Larus marinus*	237	Occupied territory/nests/individuals on land
Black-headed Gull	*Larus ridibundus*	193	Occupied territory/nests/individuals on land
European Shag	*Phalacrocorax aristotelis*	183	Occupied nests
Herring Gull	*Larus argentatus*	149	Occupied territory/nests/individuals on land
Kittiwake	*Rissa tridactyla*	100	Occupied nests
Atlantic Puffin	*Fratercula arctica*	51	Individuals on land
Great Skua	*Stercorarius skua*	47	Occupied territory
Arctic skua	*Stercorarius parasiticus*	43	Occupied territory
Razorbill	*Alca torda*	10	Individuals on land
Lesser Black-backed Gull	*Larus fuscus*	2	Occupied territory
Common Tern	*Sterna hirundo*	2	Individuals on land

An aggregation of around 100 gulls was seen during the shoreline survey around the fish farm site just north of Vaila. Though many seabird species disperse following the summer breeding season, gulls will be present in the area throughout the year.

Waterfowl (ducks and geese) are present in Shetland at various times of the year. Geese tend to pass through the Shetlands during migrations but do not linger in very large numbers as they do further south. However, a total of about 100 geese were seen during the shoreline survey, suggesting that they may be breeding in the area. 60 of these were seen on the north shores of Vaila, and 40 were seen at Riskaness. Eider ducks feed on mussel lines and are present in the Shetlands throughout the year. None was seen during the shoreline survey, but they were seen feeding on mussel lines in nearby Gruting Voe in an earlier shoreline survey, so it is likely they frequent Vaila Sound on occasions.

There is a significant population of European Otters (*Lutra lutra*) present in Shetland, but none was seen during the shoreline survey. Overall densities of otters are very low relative to livestock and seabirds, so it is unlikely that otter faeces will be a significant source of contamination to the fishery.

In summary, the main wildlife species potentially impacting on the production areas are geese, seabirds and seals. However, as these animals are highly mobile, the impacts of these on the fishery will 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 production areas, for which uninterrupted rainfall data is available for 2003-2007 inclusive. It is likely that the rainfall patterns at Lerwick are similar but not identical to those on Vaila Sound and Vaila Sound: Riskaness and surrounding land due to their proximity, but it is not certain whether the local topography may result in differing wind patterns (Lerwick is on the east coast, the production areas are on the west coast). This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish within Vaila Sound and Vaila Sound: Riskaness.

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 summarise the pattern of rainfall at Lerwick by year and by month respectively.

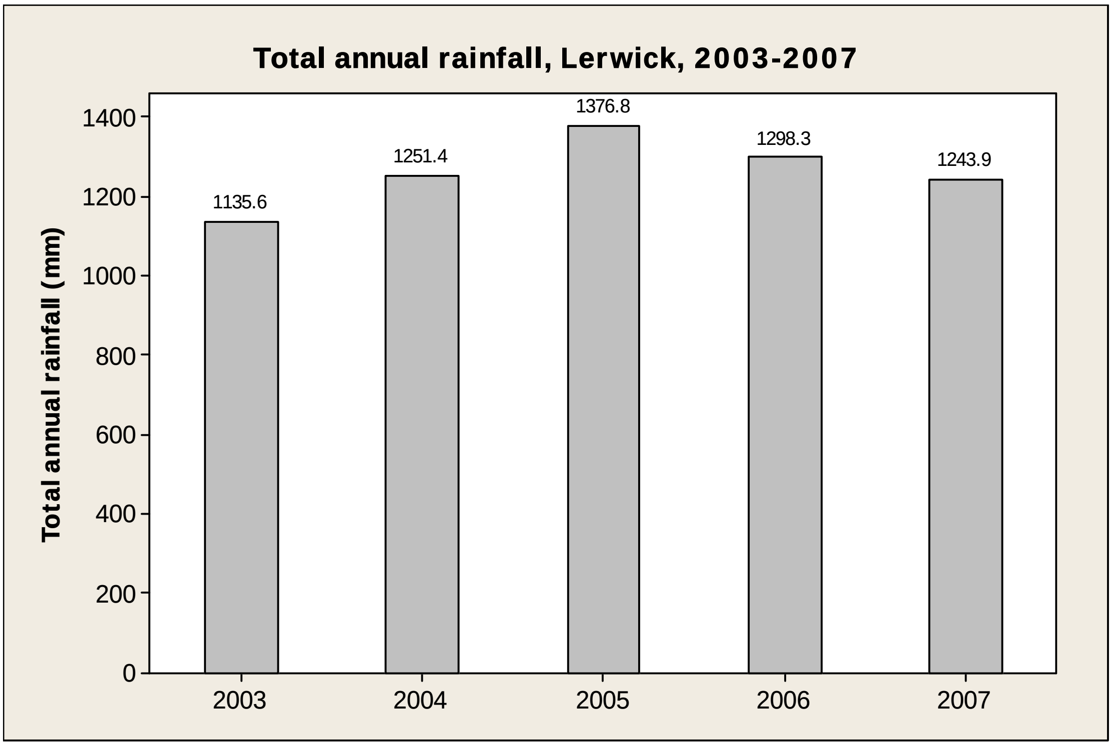

Figure 9.1 Bar chart of annual rainfall at Lerwick 2003-2007

Figure 9.1 shows that 2005 was the wettest of these years, and 2003 was the driest. Inter-annual variation in rainfall was not nearly as great as monthly variation shown in Figure 9.2.

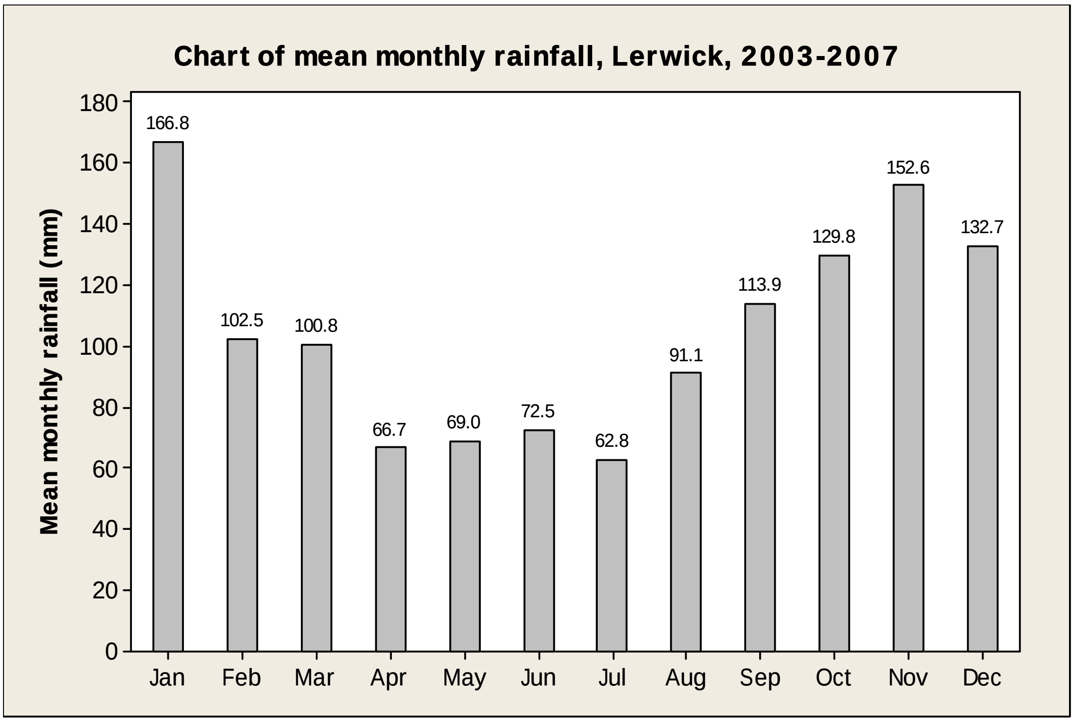

Figure 9.2 Bar chart of mean monthly rainfall at Lerwick 2003-2007

The wettest months were October, November, December and January with the latter being wettest of all. For the period considered here (2003-2007), 44.6% of days experienced rainfall of 1 mm or less, and 9.4% of days experienced rainfall of 10 mm or more.

A comparison of Lerwick rainfall data with Scotland average rainfall data for the period of 1970-2000 is presented in Table 9.3 (Data from Met Office website © Crown Copyright). This indicates that rainfall in Lerwick was lower than the average for the whole of Scotland for every month of the year, but there were fewer dry days in Lerwick than in Scotland on average during most of the year.

Table 9.1 Comparison of Lerwick mean monthly rainfall with Scottish average 1970-2000.

Month	Scotland rainfall (mm)	Lerwick rainfall (mm)	Scotland - days of rainfall >= 1mm	Lerwick - days of rainfall >= 1mm
Jan	170.5	135.4	18.6	21.3
Feb	123.4	107.8	14.8	17.8
Mar	138.5	122.3	17.3	19
Apr	86.2	74.2	13	14.4
May	79	53.6	12.2	10.1
Jun	85.1	58.6	12.7	11.3
Jul	92.1	58.5	13.3	11
Aug	107.4	78.3	14.1	12.5
Sep	139.7	115.3	15.9	17.4
Oct	162.6	131.9	17.7	19.4
Nov	165.9	152.4	17.9	21.5
Dec	169.6	150	18.2	22.2
Whole year	1520.1	1238.1	185.8	197.9

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. As there are few dry days, it is likely that a steady flow contaminated of runoff from pastures is to be expected throughout the wetter months. It is possible that there is a build-up of faecal matter on pastures during the drier summer months when stock levels are at their highest which results in a 'first flush' of contaminated runoff following summer storms, or in the autumn at the onset of the wetter months.

9.2 Wind

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

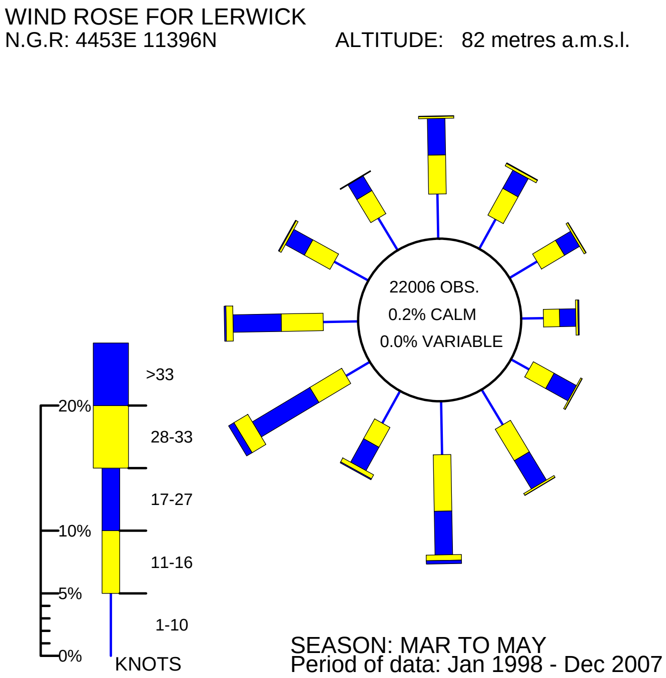

Figure 9.3 Wind rose for Lerwick (March to May)

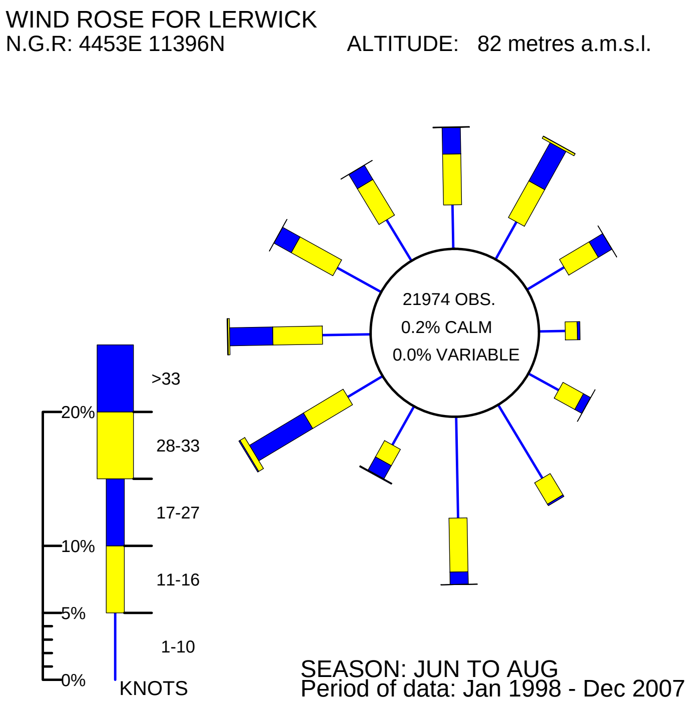

Figure 9.4 Wind rose for Lerwick (June to August)

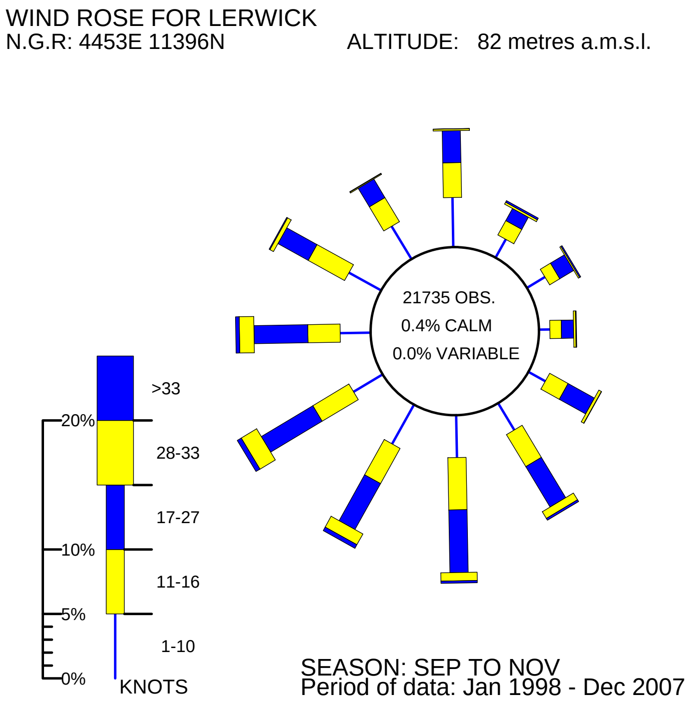

Figure 9.5 Wind rose for Lerwick (September to November)

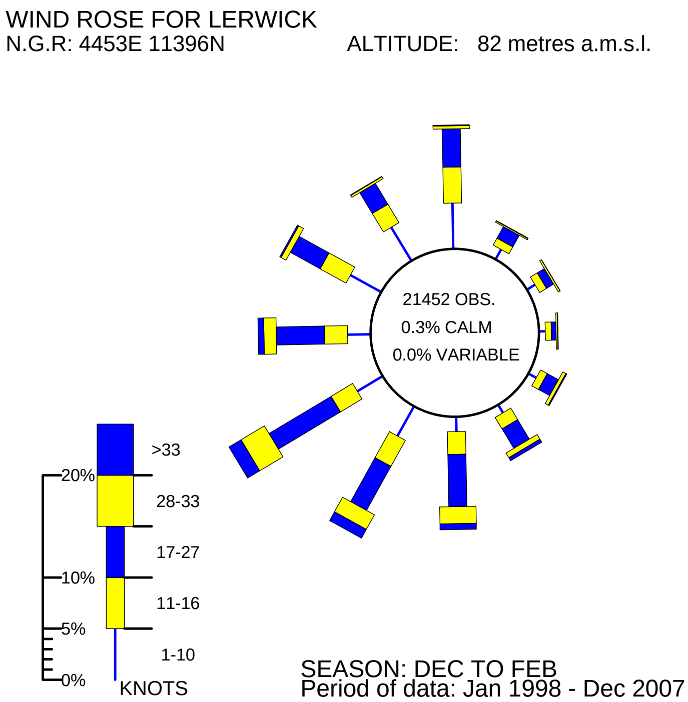

Figure 9.6 Wind rose for Lerwick (December to February)

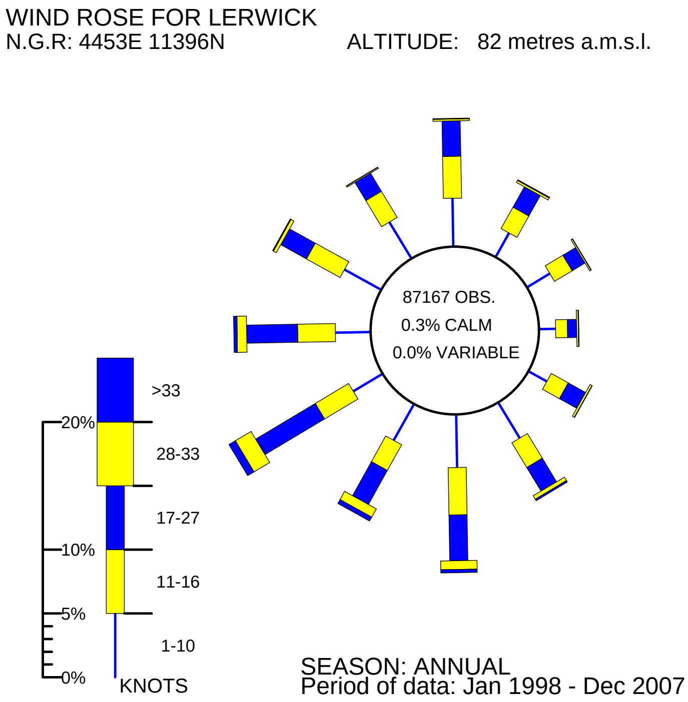

Figure 9.7 Wind rose for Lerwick (Annual)

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.

Vaila Sound and Vaila Sound: Riskaness are part of the same water body, which is essentially a south facing bay which is almost entirely sheltered from the open sea by the Island of Vaila which lies across its mouth.

A strong southerly wind combined with a spring tide may result in higher than usual tides which will carry accumulated faecal matter from livestock, above the normal high water mark, into the production area.

Wind effects are likely to cause significant changes in water circulation within the sound as tidally influenced movements of water are relatively weak. 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. These surface water currents create return currents which may travel along the bottom or sides of the water body depending on bathymetry. Exact effects will be difficult to predict given the complex shape of the sound. Strong winds will increase the circulation of water and hence dilution of contamination from point sources within the sound. Winds from a particular direction may facilitate the transport of contamination from point sources to the shellfish. Within Vaila Sound, a northerly wind may transport contamination from the settlement of Walls towards the Linga site.

10. Current and historical classification status

The survey area consists of two adjacent production areas: Vaila Sound and Vaila Sound: Riskaness (both currently classified for mussels). A map of the production areas is presented in Section 2, Figure 2.1.

Vaila Sound has been classified for the production of mussels under its current boundaries since 2002. The classification history is presented in Table 10.1. During the period of classification, it was classified as seasonal A/B from 2004 to 2007, and an A in other years.

Table 10.1 Classification history, Vaila Sound, mussels

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

Vaila Sound: Riskaness has been classified for the production of mussels under its current boundaries since 2001. The classification history is presented in Table 10.2. Throughout the period of classification, it has been classified as either an A or a seasonal A/B.

Table 10.2 Classification history, Vaila Sound: Riskaness, mussels

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

As classifications are based on previous monitoring results. These indicate that, in general, higher levels of contamination have occurred during the second half of the year. Vaila Sound received slightly more B months than Vaila Sound: Riskaness, suggesting that contamination levels have been slightly higher here.

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken from Vaila Sound and Vaila Sound: Riskaness from the beginning of 2002 up to the end of 2007 were extracted from the database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data.

One sample was rejected from the analysis as no grid reference was recorded.

26 samples from Vaila Sound and 11 from Vaila Sound: Riskaness had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation.

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

11.2 Summary of microbiological results by production area

A summary of all sampling and results by sampling location is presented in Table 11.1. No samples were submitted from the Vaila Sound Riskaness: Lera Voe site prior to the end of 2007.

Table 11.1 Summary of results from Vaila Sound and Vaila Sound: Riskaness by reported sampling location

Sampling Summary							
Production area	Vaila Sound: Riskaness	Vaila Sound	Vaila Sound	Vaila Sound	Vaila Sound	Vaila Sound	Vaila Sound
Site	Riskaness	All combined	Linga	Linga	Galtaskerry	Galtaskerry	East of Linga
Species	Common mussels	Common mussels	Common mussels	Common mussels	Common mussels	Common mussels	Common mussels
SIN	SI-289-458-8	SI 288	SI-288-457-8	SI-288-457-8	SI-288-456-8	SI-288-456-8	SI-288-455-8
Location	HU232483	All combined	HU240484	HU240483	HU244471	HU244470	HU242480
Total no of samples	68	123	61	4	34	11	13
No. 2002	11	19	10	0	0	4	5
No. 2003	12	20	12	0	5	3	0
No. 2004	14	26	13	0	9	4	0
No. 2005	11	22	10	0	12	0	0
No. 2006	10	22	10	0	8	0	4
No. 2007	10	14	6	4	0	0	4
Results Summary							
Minimum	<20	<20	<20	<20	<20	<20	<20
Maximum	3500	2400	2200	380	2400	130	310
Median	40	40	70	110	30	40	20
Geometric mean	45.9	56.5	75	150	47.3	36.4	25.7
90 percentile	205	318	310		430	110	98
95 percentile	388	500	500		500	120	190
No. exceeding 230/100g	7 (10%)	20 (16%)	12 (20%)		6 (17%)	0 (0%)	1 (7%)
No. exceeding 1000/100g	1 (1%)	3 (2%)	2 (3%)		1 (3%)	0 (0%)	0 (0%)
No. exceeding 4600/100g	0 (0%)	0 (0%)	0 (0%)		0 (0%)	0 (0%)	0 (0%)
No. exceeding 18000/100g	0 (0%)	0 (0%)	0 (0%)		0 (0%)	0 (0%)	0 (0%)

Figure 11.1 Map of sampling points and geometric mean *E. coli* result

11.3 Overall geographical pattern of results

Figure 11.2 presents a boxplot of results by site. Figure 11.1 presents a map showing geometric mean result by reported sampling locations (with OS grid reference, site, number of samples and sampling dates).

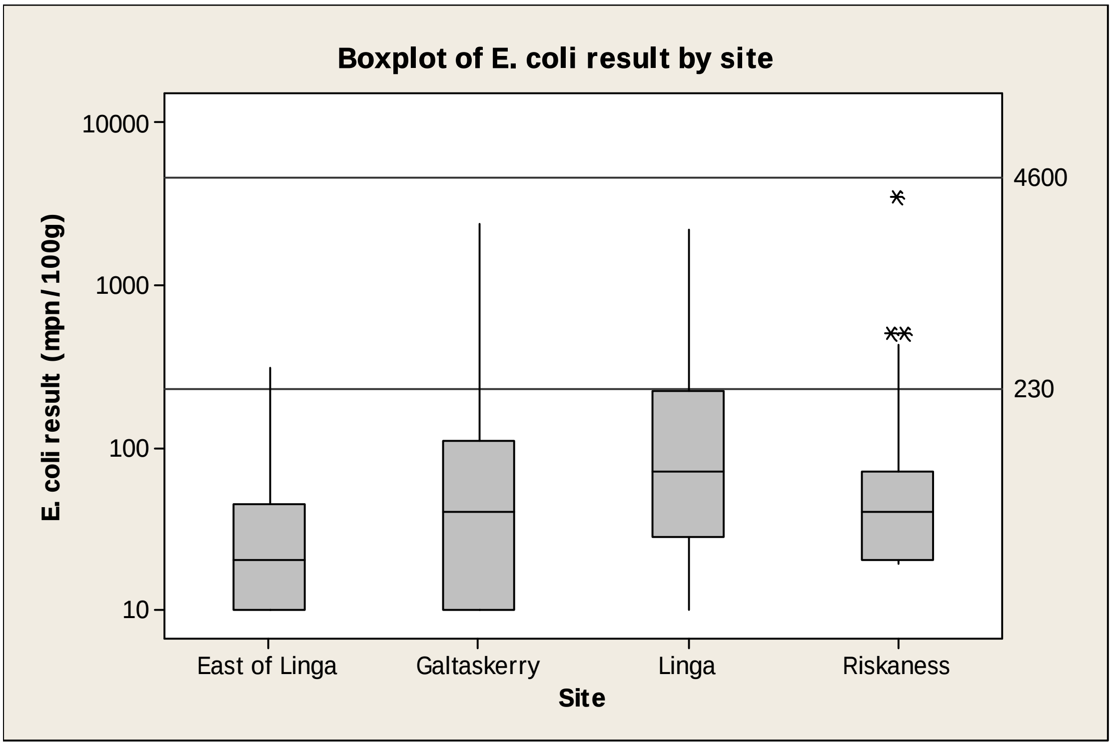

Figure 11.2 Boxplot of all *E. coli* results by site

On a number of occasions more than one site was sampled on the same day. These samples permit a robust comparison of results between sites, as they were collected under the same environmental conditions. Site comparisons are presented in Table 11.2 and include the p-value obtained from a paired T-test comparison of results by site and the number of samples from each site used in each analysis. Full details of the statisitical analyses can be found in Appendix 5.

Table 11.2 Results of paired T-tests with geometric mean *E. coli* results for all samples used in the analysis. Significant differences ($p<0.05$) are highlighted.

	Linga	Riskaness	Galtaskerry
Riskaness	**Linga > Riskaness P=0.007 n=64**		
Galtaskerry	**ND P=0.249 n=24**	**ND P=0.766 n=25**	
East of Linga	**Linga > East of Linga P=0.013 n=7**	**ND P=0.410 n=8**	**ND P=0.792 n=4**

ND = No significant difference found

Levels of contamination at Linga were highest, and were significantly higher than those at Riskaness and East of Linga, but not Galtaskerry. No significant differences were found between Riskaness, Galtaskerry and East of Linga, but sample numbers were low for some comparisons. Overall, contamination was highest at Linga, intermediate at Galtaskerry and Riskaness, and lowest at East of Linga. Lera Voe was not sampled.

No results over 4600 *E. coli* MPN/100g were reported from any of the sites. A total of 27 results of over 230 *E. coli* MPN/100g were reported from the two production areas. Proportions of these higher results occurring by site are presented in Table 11.3.

Table 11.3 Proportion of historic *E. coli* sampling result over 230 MPN/100g by site

	Riskaness	Linga	Galtaskerry	East of Linga
No. results > 230 MPN/100g	7 (10%)	13 (20%)	6 (13%)	1 (8%)
No. results < 230 MPN/100g	61	52	39	12

No significant difference was found in the proportion of results over 230 *E. coli* MPN/100g between the sites (Chi-Sq = 2.588, DF = 2, P-Value = 0.274, Appendix 5). The East of Linga site was not included in this analysis due to low sample numbers, although data from this site are presented in Table 11.3.

Table 11.4 Proportion of historic *E. coli* sampling result less than 50 MPN/100g by site

	Riskaness	Linga	Galtaskerry	East of Linga
No. results < 50 MPN/100g	43 (63%)	27 (42%)	26 (58%)	10 (77%)
No. results > 50 MPN/100g	25	38	19	3

A significant difference was found in the proportion of results less than 50 *E. coli* MPN/100g between the sites (Chi-Sq = 9.288, DF = 3, P-Value = 0.026, Appendix 5), with higher than expected numbers of results less than 50 *E. coli* MPN/100g at the Riskaness and East of Linga sites, and lower than expected numbers of result less than 50 *E. coli* MPN/100g at the other two sites.

As a consequence of the differences between results obtained from each site, they were considered separately in further analyses. Insufficient samples were collected from the East of Linga site (13) for more detailed analysis of results from this site.

11.4 Overall temporal pattern of results

Figures 11.3 to 11.5 present scatter plots of individual results against date for all mussel samples taken from the three sites for which sufficient data was available. They are fitted with Loess trend lines to help highlight any apparent underlying trends or cycles.

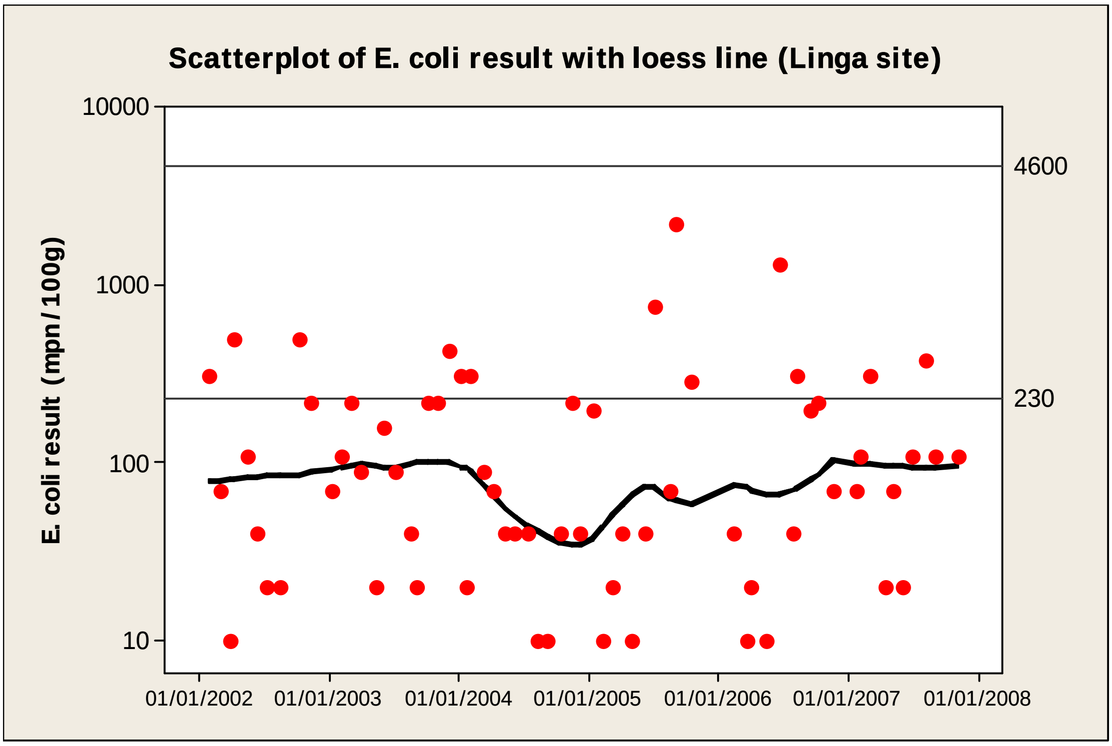

Figure 11.3 Scatterplot of *E. coli* results by date with loess smoother (Linga)

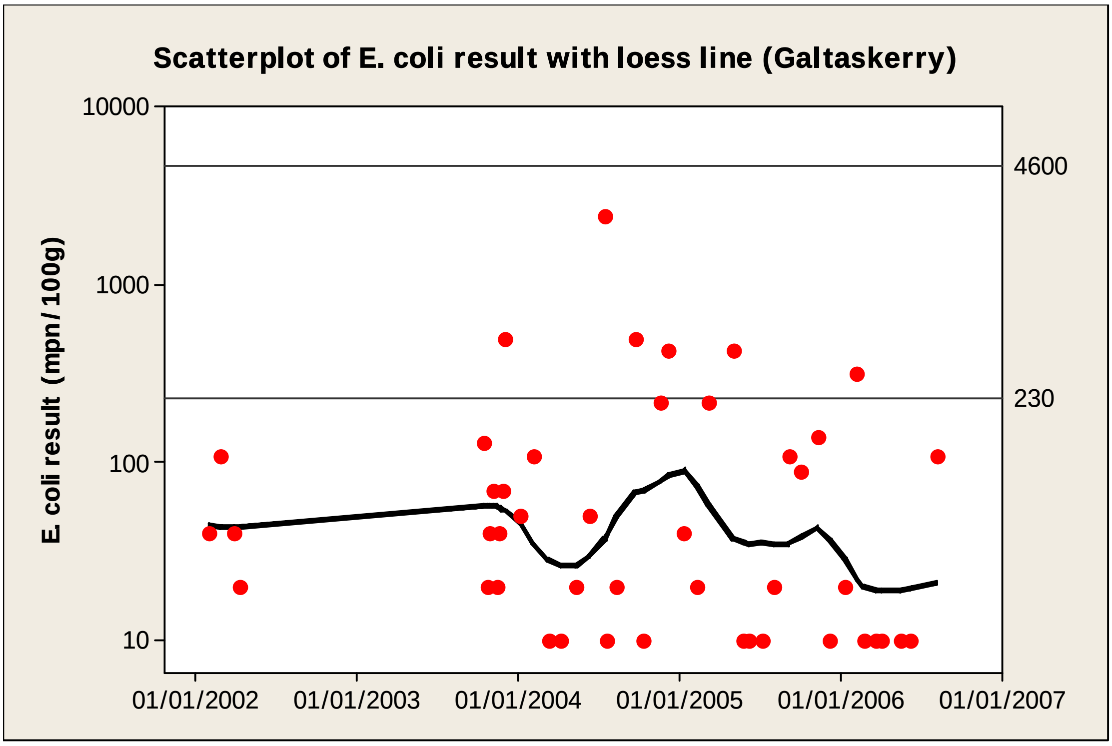

Figure 11.4 Scatterplot of *E. coli* results by date with loess smoother (Galtaskerry)

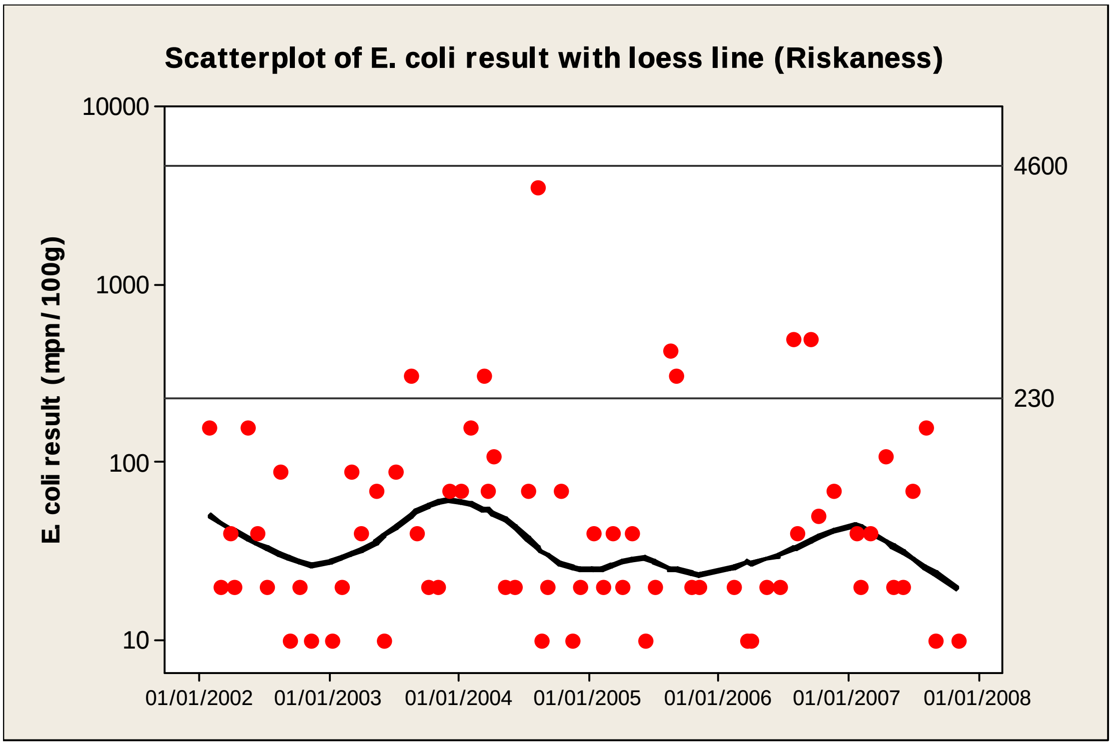

Figure 11.5 Scatterplot of *E. coli* results by date with loess smoother (Riskaness)

No obvious trends or cycles are apparent in Figures 11.3 – 11.5, aside from a possible tendency for higher results during the winter months at Galtaskerry. During 2004, peak results are Linga were lower than those observed at the other two sites.

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 11.6 to 11.8 present the geometric mean *E. coli* result by month (+ 2 times the standard error) for Linga, Galtaskerry and Riskaness respectively.

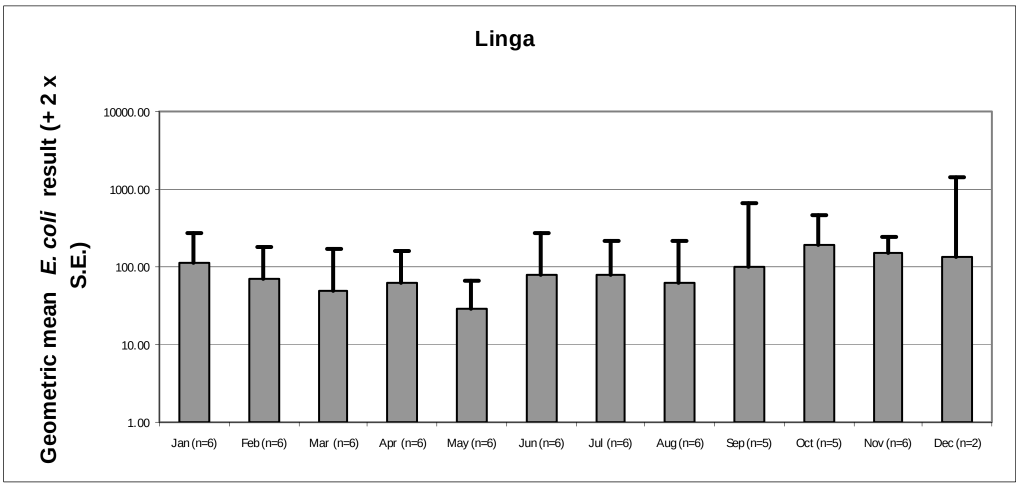

Figure 11.6 Geometric mean *E. coli* result by month (Linga)

At Linga, overall mean results were relatively stable, with highest mean results obtained during September to December and lowest results during May.

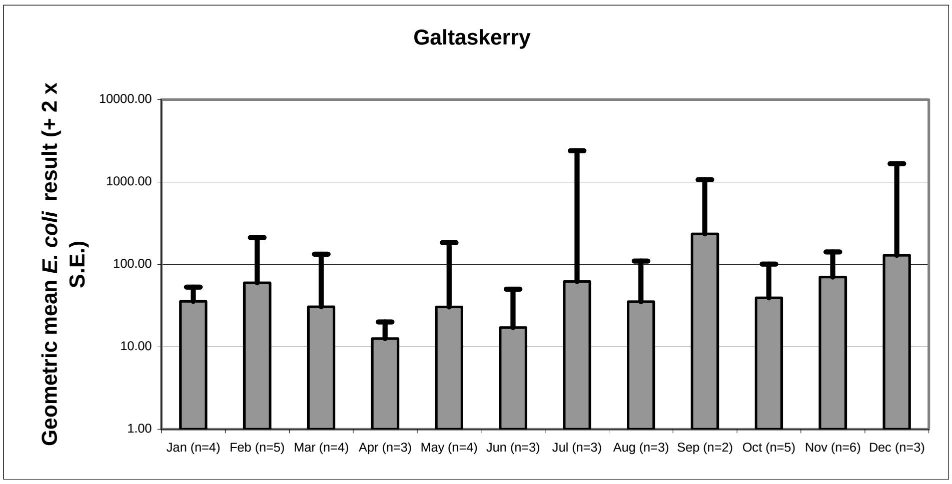

Figure 11.7 Geometric mean *E. coli* result by month (Galtaskerry)

At Galtaskerry, results were far more variable. While the highest mean results were obtained during September, the range of the standard error showed potential for higher peak results in July, September and December. The lowest mean result occurred during April.

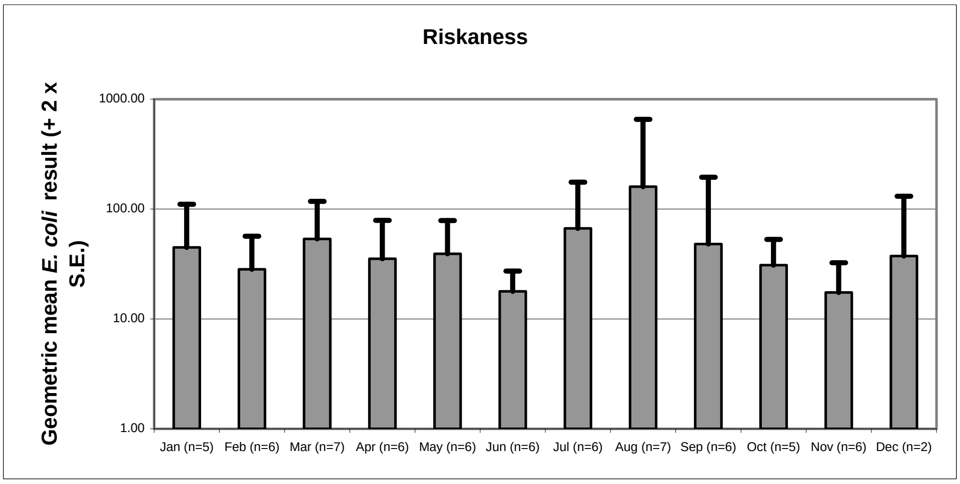

Figure 11.8 Geometric mean *E. coli* result by month (Riskaness)

At Riskaness, highest results were obtained during August, and lowest results during June and November. A clear rise is apparent during the summer months, declining again after the peak in August.

Of the three sites, only Riskaness showed an apparent seasonal pattern. At Linga and Galtaskerry, results varied rapidly from month to month.

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

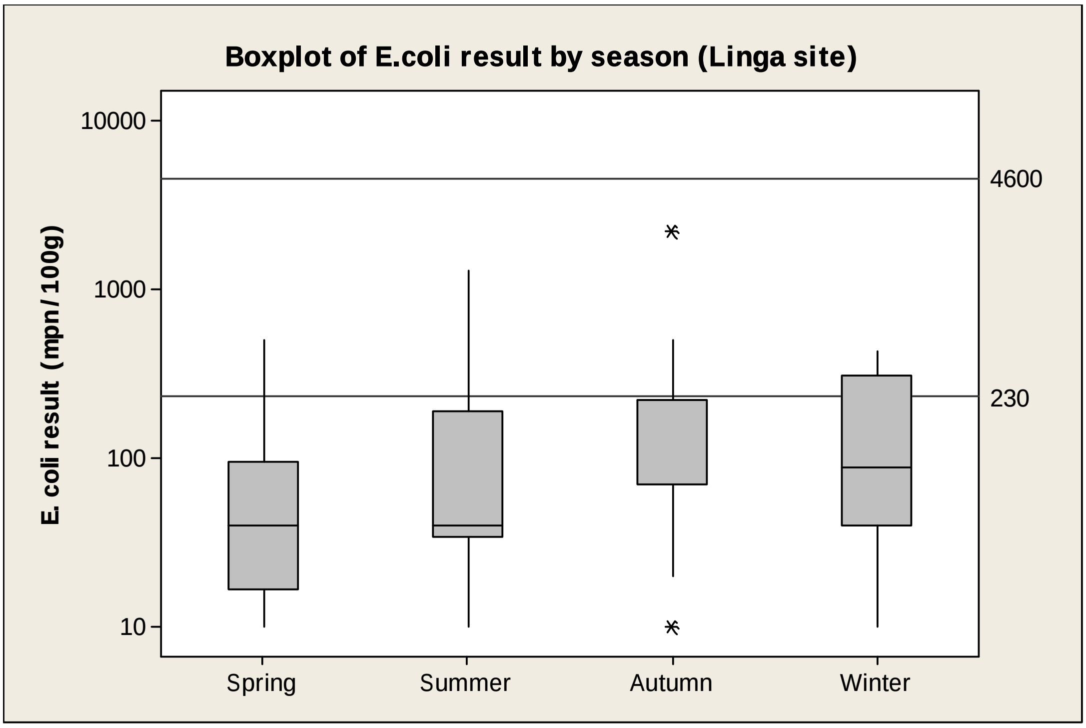

Figure 11.9 Boxplot of *E. coli* result by season (Linga)

For Linga, no significant difference was found between results by season (One-way ANOVA, p=0.067, Appendix 5).

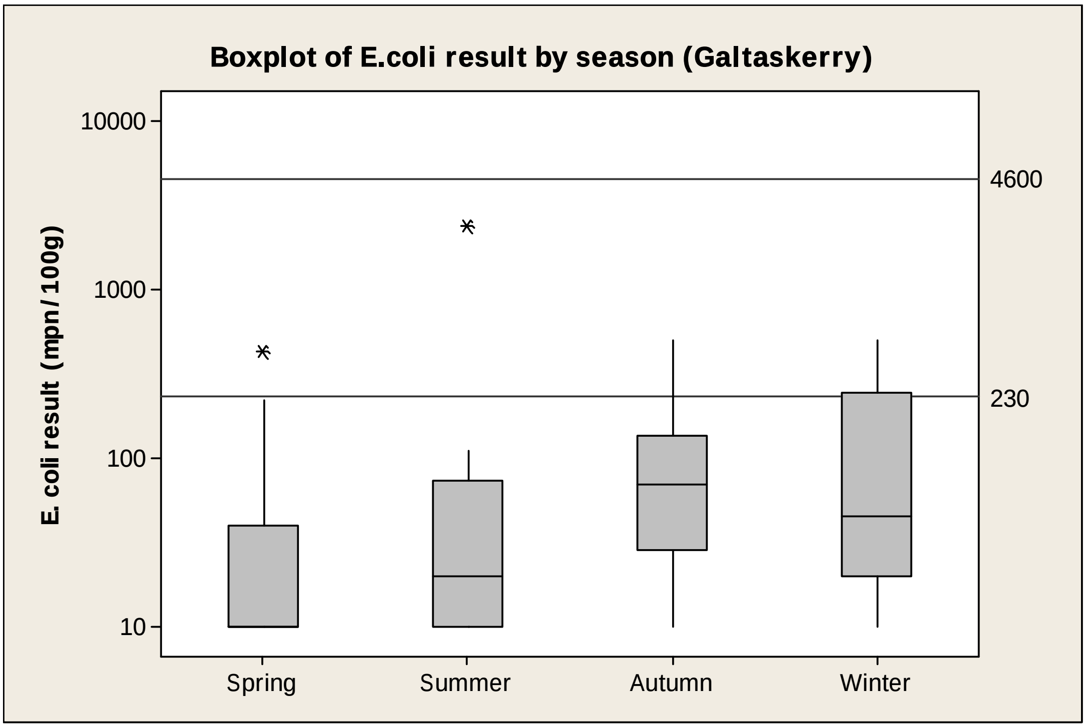

Figure 11.10 Boxplot of *E. coli* result by season (Galtaskerry)

For Galtaskerry, no significant difference was found between results by season (One-way ANOVA, p=0.243, Appendix 5).

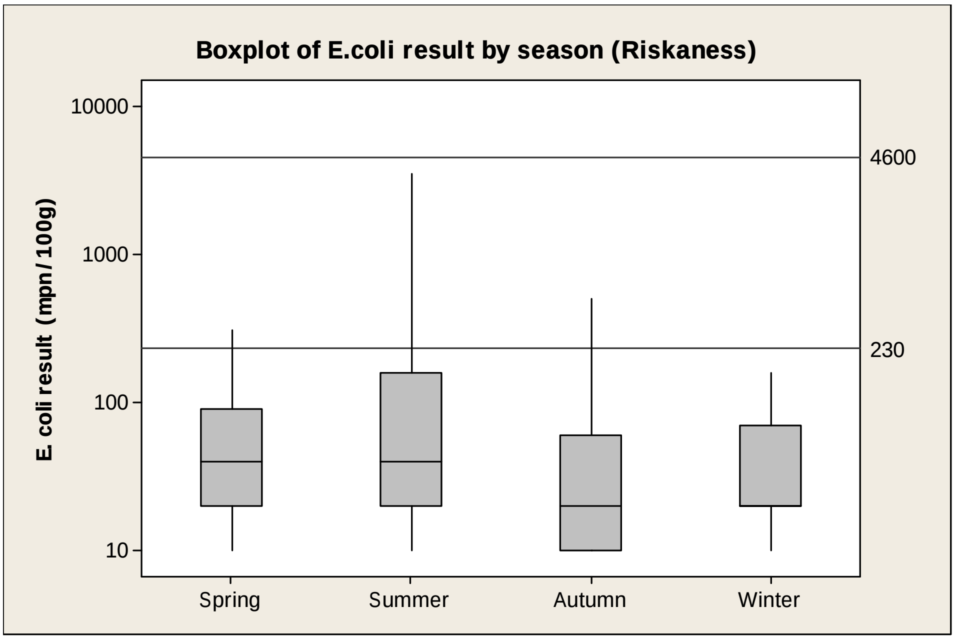

Figure 11.11 Boxplot of *E. coli* result by season (Riskaness)

For Riskaness, no significant difference was found between results by season (One-way ANOVA, p=0.324, Appendix 5). However, the range of results is higher in summer, with highest peak results occuring at this time.

Table 11.5 Proportion of historic *E. coli* sampling result over 230 MPN/100g by season (all four sites combined)

	Spring	Summer	Autumn	Winter
No. results > 230 MPN/100g	4 (8%)	9 (19%)	7 (15%)	7 (17%)
No. results < 230 MPN/100g	48	38	41	37

Although a lower proportion of results over 230 *E. coli* MPN/100g arose in the spring, no significant difference was found between the seasons (Chi-Sq = 2.874, DF = 3, P-Value = 0.412, Appendix 5). It was not possible to undertake this analysis on individual sites as sample numbers were too low.

11.6 Analysis of results against environmental factors

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

11.6.1 Analysis of results by recent rainfall

The nearest weather station is Lerwick, approximately 20 km to the south east of the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2007 (total daily rainfall in mm).

Figures 11.12, 11.13 and 11.14 present scatterplots of *E. coli* results against rainfall for the two days previous to sampling dates for each site. Rainfall and microbiological data was ranked, and a correlation was carried out using the ranked data.

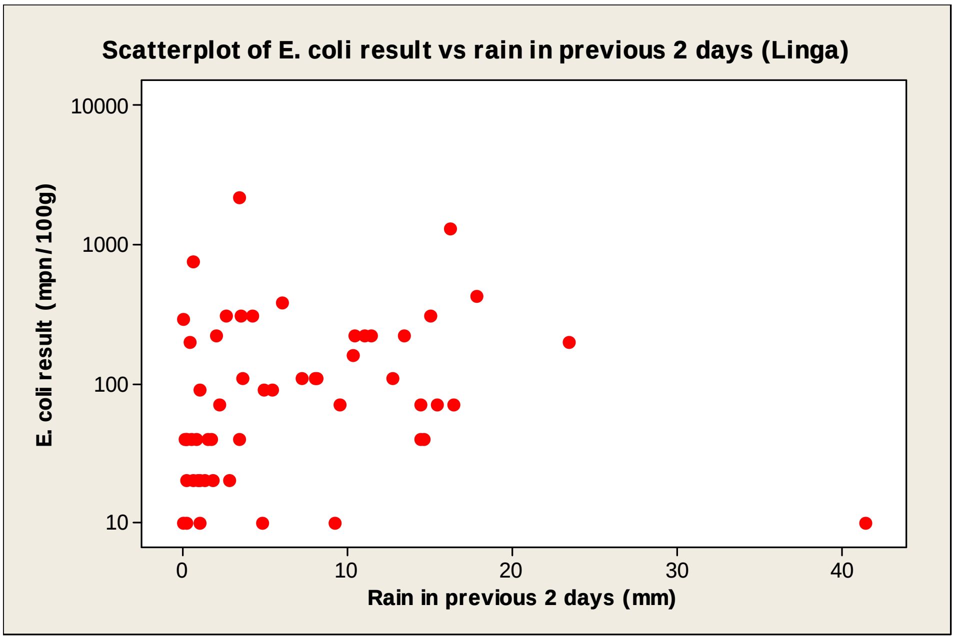

Figure 11.12 Scatterplot of *E. coli* result vs rainfall in previous 2 days (Linga)

A significant positive correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous two days for Linga (Spearman's Rank correlation=0.349, p=0.010, Appendix 5).

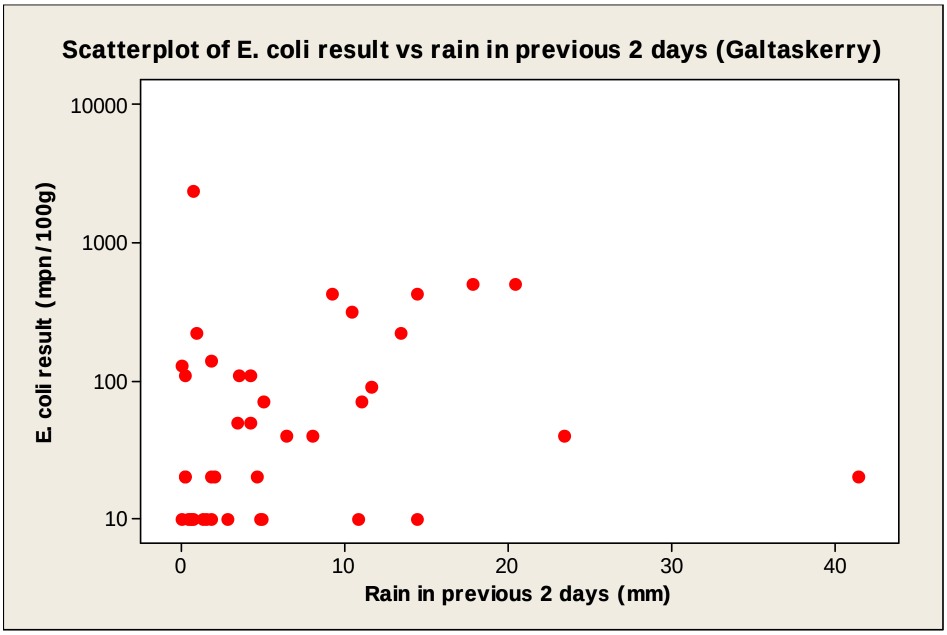

Figure 11.13 Scatterplot of *E. coli* result vs rainfall in previous 2 days (Galtaskerry)

A significant positive correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous two days for Galtaskerry (Spearman's Rank correlation=0.316, p=0.044, Appendix 5).

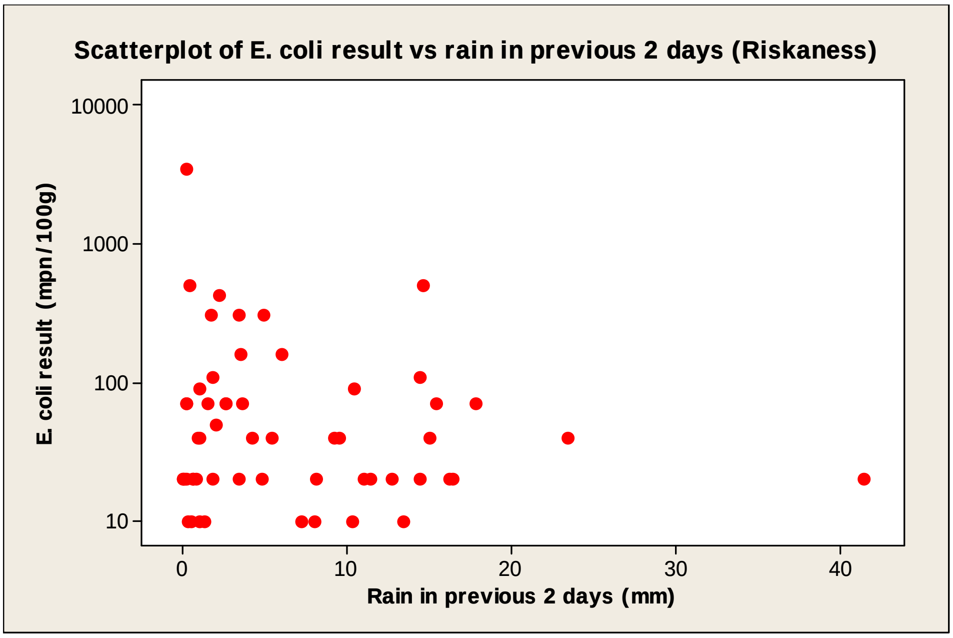

Figure 11.14 Scatterplot of *E. coli* result vs rainfall in previous 2 days (Riskaness)

No correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous two days for Riskaness (Spearman's Rank correlation=-0.002, p=0.988, Appendix 5).

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 for Vaila sound was investigated in an identical manner to the above.

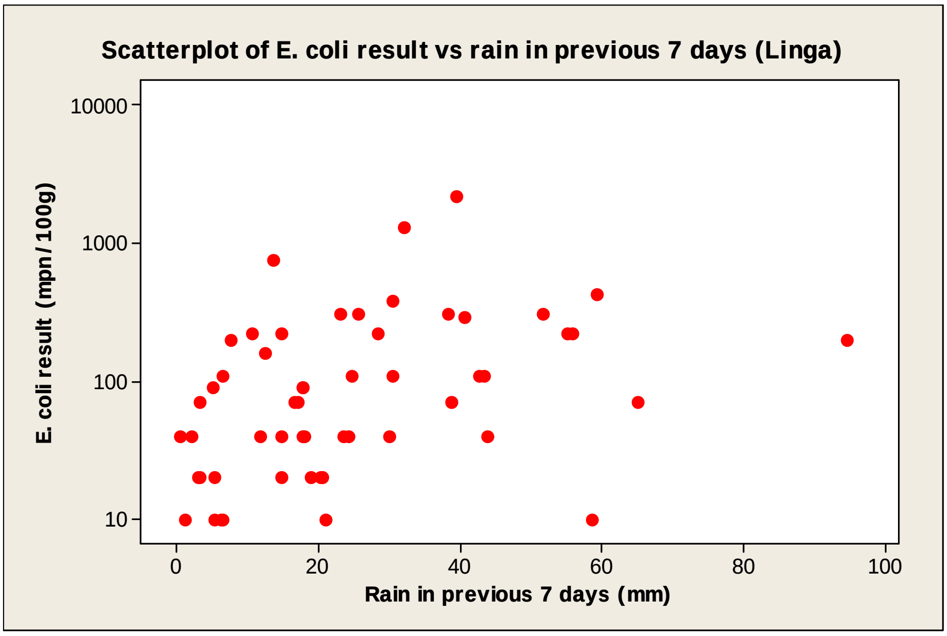

Figure 11.15 Scatterplot of *E. coli* result vs rainfall in previous 7 days (Linga)

A significant positive correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous seven days for Linga (Spearman's Rank correlation=0.454, p=0.001, Appendix 5).

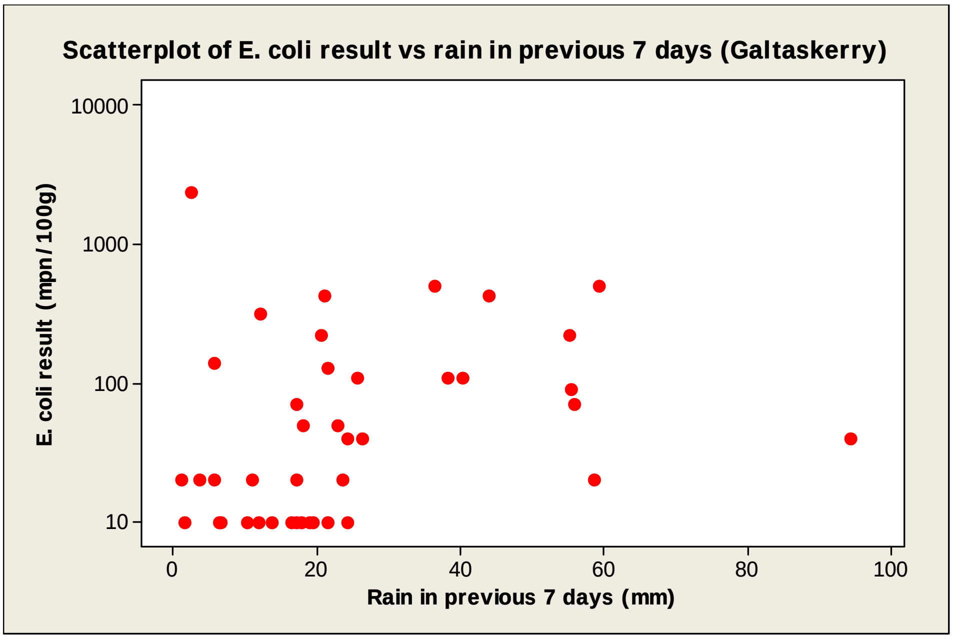

Figure 11.16 Scatterplot of *E. coli* result vs rainfall in previous 7 days (Galtaskerry)

A significant positive correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous seven days for Galtaskerry (Spearman's Rank correlation=0.398, p=0.010, Appendix 5).

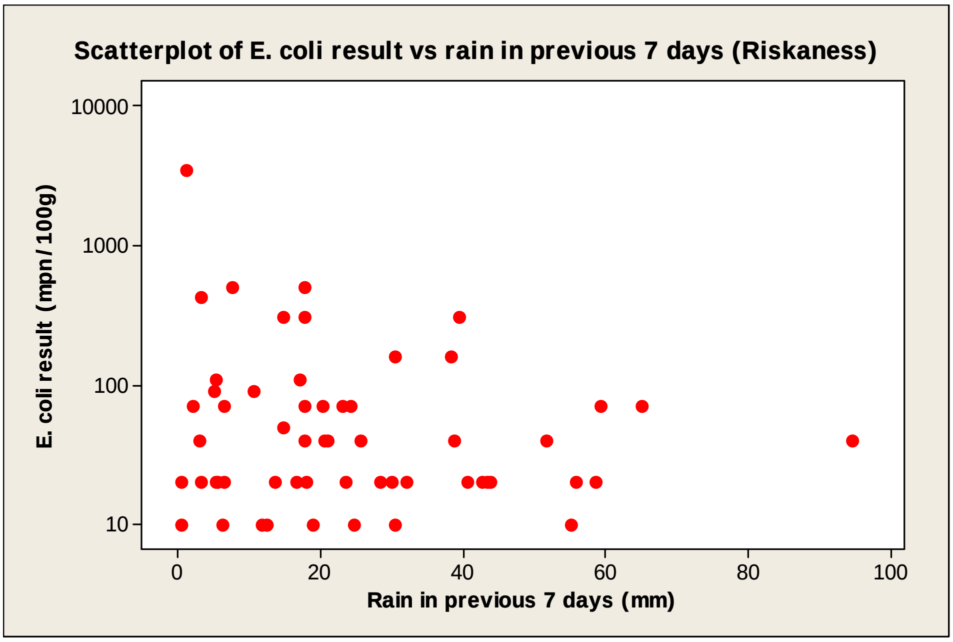

Figure 11.17 Scatterplot of *E. coli* result vs rainfall in previous 7 days (Riskaness)

No correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous seven days for Riskaness (Spearman's Rank correlation=-0.112, p=0.410, Appendix 5).

11.6.2 Analysis of results by tide height and state

With spring tides, 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.

In order to determine whether *E. coli* levels in mussels at the three sites were related to the spring/neap tidal cycle, regression analysis was conducted comparing historical E. coli results and the predicted height of the previous high water in metres above chart datum at Scalloway (predictions from Neptune tidal prediction software). Figures 11.21 to 11.23 present scatterplots of *E. coli* results by the predicted tidal height.

It should be noted that local meteorological conditions such as wind and barometric pressure can influence the height of tides and this is not taken into account.

In the case of all three sites, no relationship was found between *E. coli* results and the spring/neap tidal cycle.

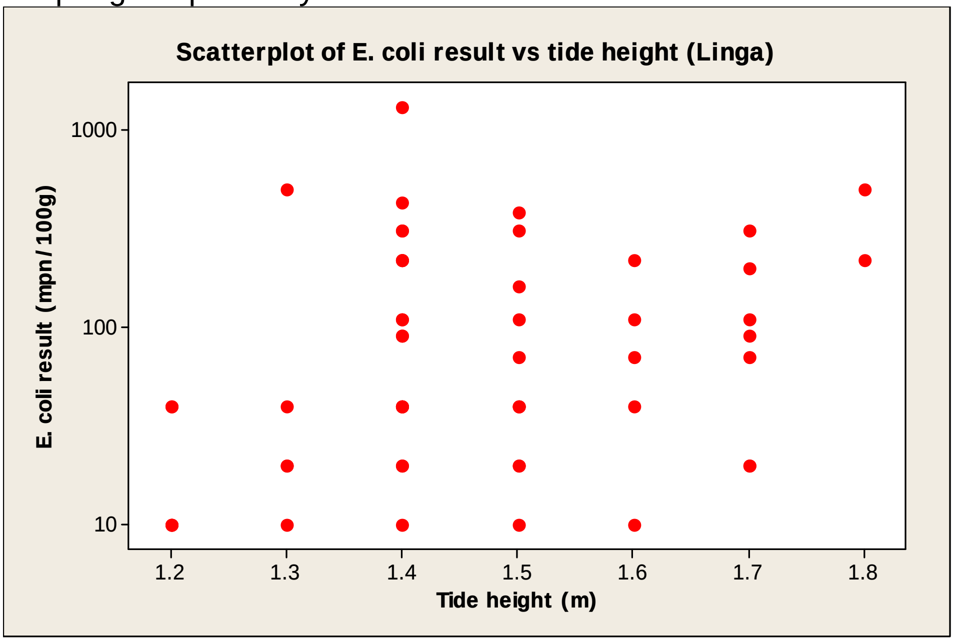

Figure 11.21 Scatterplot of *E. coli* result by tide height (Linga)

The coefficient of determination (R squared) indicates that there was no relationship between the *E. coli* result and predicted height of the previous tide for Linga (Adjusted R-sq=6.7%, p=0.034, Appendix 5).

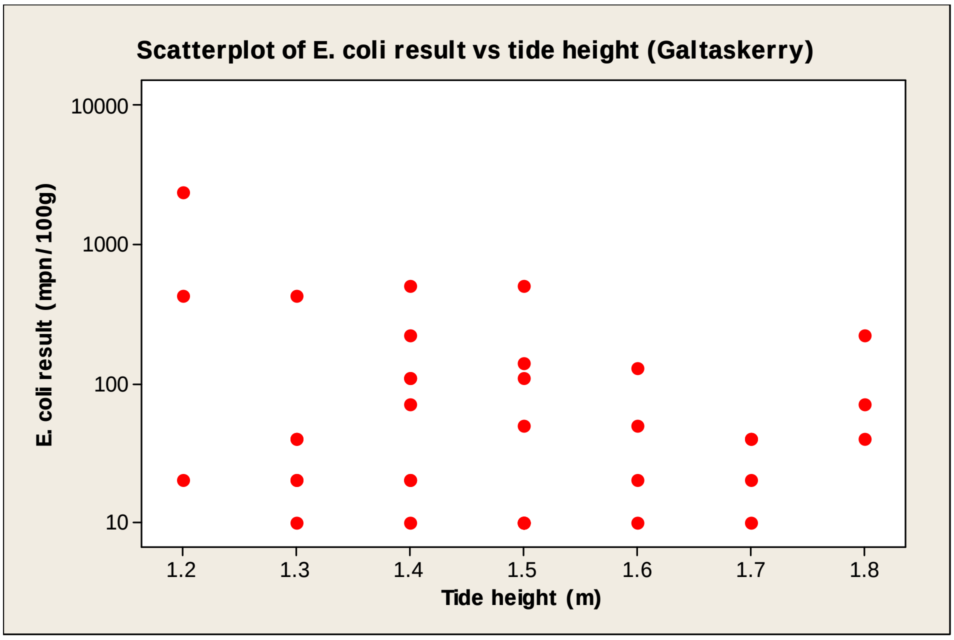

Figure 11.22 Scatterplot of *E. coli* result by tide height (Galtaskerry)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and predicted height of the previous tide for Galtaskerry (Adjusted R-sq=1.0%, p=0.252, Appendix 5).

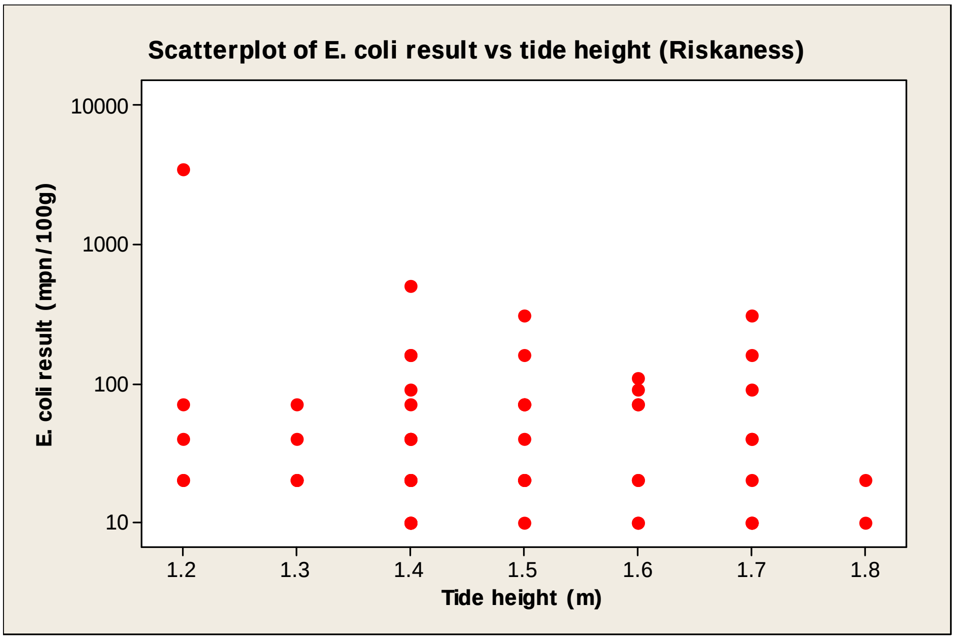

Figure 11.23 Scatterplot of *E. coli* result by tide height (Riskaness)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and predicted height of the previous tide for Riskaness (Adjusted R-sq=0.3%, p=0.281, Appendix 5).

Direction and strength of flow around the production areas will change according to tidal state within the ebb/flood cycle. 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 mussels 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 11.24 to 11.26 present polar plots of log10 *E. coli* results across the tidal cycle. High water is at 0°, and low water is at 180°.

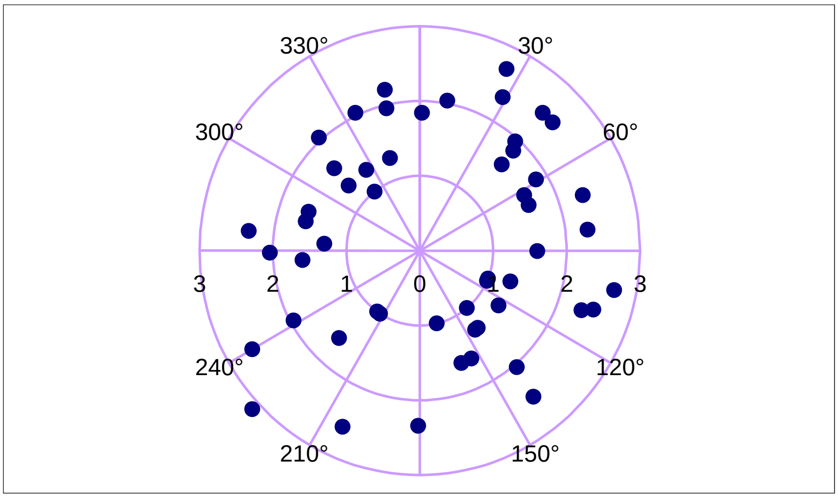

Figure 11.24 Polar plot of log10 *E. coli* result by tidal state (Linga)

No significant correlation was found between tidal state and *E. coli* result at Linga (circular-linear correlation, r=0.147, p=0.341, Appendix 5)

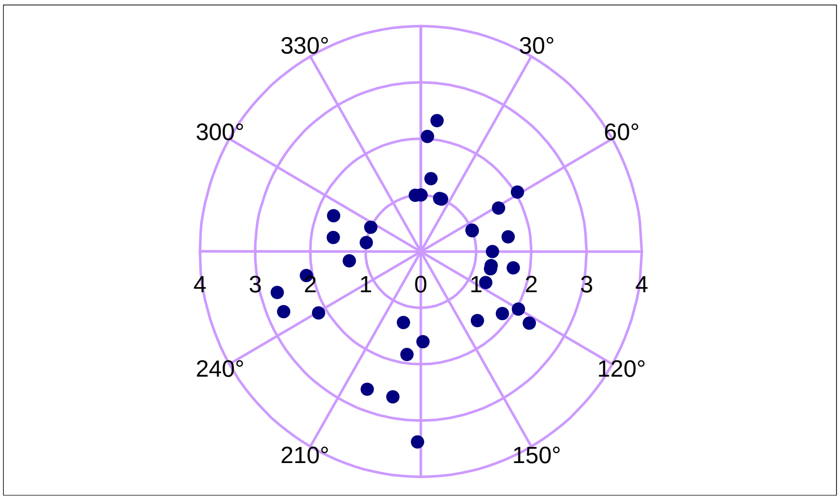

Figure 11.25 Polar plot of log10 *E. coli* result by tidal state (Galtaskerry)

A significant correlation was found between tidal state and *E. coli* result at Galtaskerry (circular-linear correlation, r=0.53, p<0.0001, Appendix 5). Results were highest on the first half of the flooding tide.

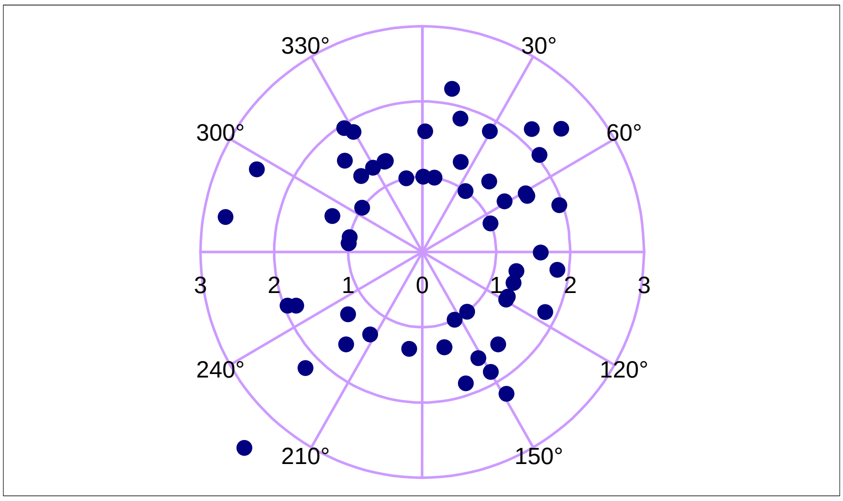

Figure 11.26 Polar plot of log10 *E. coli* result by tidal state (Riskaness)

No significant correlation was found between tidal state and *E. coli* result at Riskaness (circular-linear correlation, r=0.103, p=0.571, Appendix 5)

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.

Records of water temperature at time of sampling were only available for a total of 16 samples, so no investigation of the relationship between water temperature and *E. coli* result could be undertaken.

11.6.4 Analysis of results by wind direction

Wind speed and direction are likely to change water circulation patterns in the production areas. Mean wind direction for the 7 days prior to each sample being collected was calculated from wind data recorded at the Lerwick weather station, and mean result by mean wind direction in the previous 7 days is plotted for each site in Figures 11.27 to 11.29. Neither wind speeds or variability in wind direction during the 7 day period prior to sampling were taken into account during this analysis. It must also be noted that wind direction as recorded at Lerwick may not be representative of local wind directions within Vaila Sound.

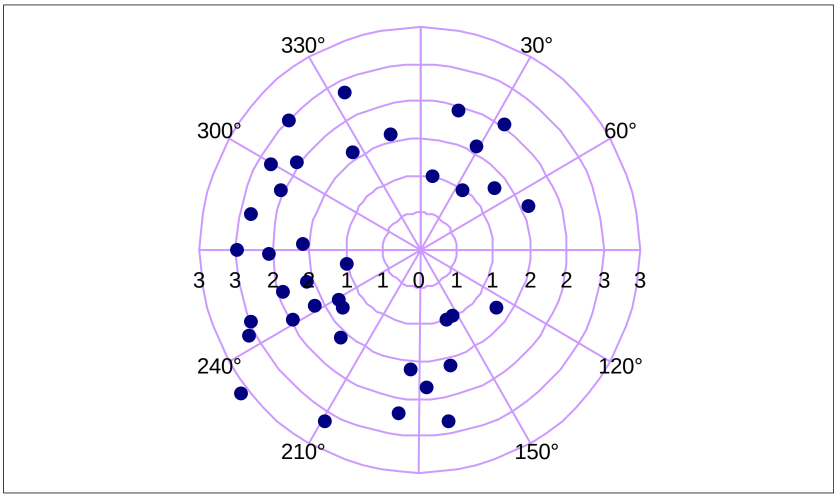

Figure 11.27 Polar plot of log10 *E. coli* result by wind direction (Linga)

A significant correlation was found between wind direction and *E. coli* result for Linga (circular-linear correlation, r=0.428, p=0.002, Appendix 5), with higher results occurring when the wind was blowing from the west.

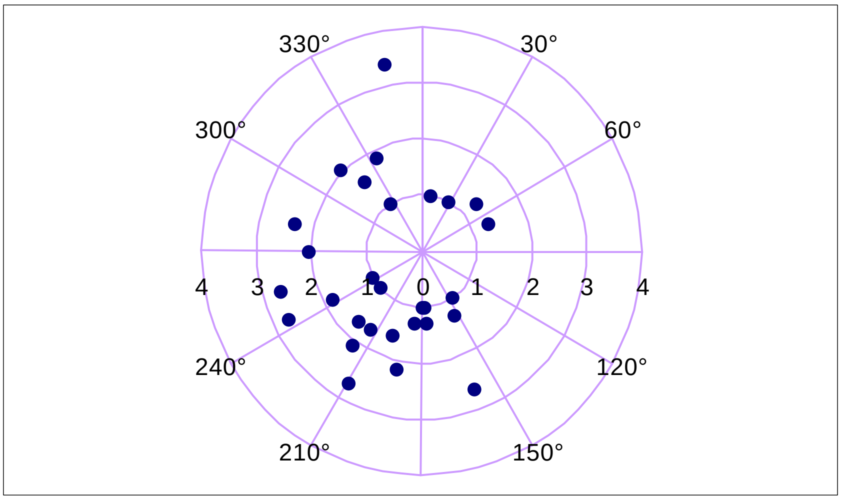

Figure 11.28 Polar plot of log10 *E. coli* result by wind direction (Galtaskerry)

A significant correlation was found between wind direction and *E. coli* result for Galtaskerry (circular-linear correlation, r=0.391, p=0.018, Appendix 5), with higher results occurring when the wind was blowing from the western quarters.

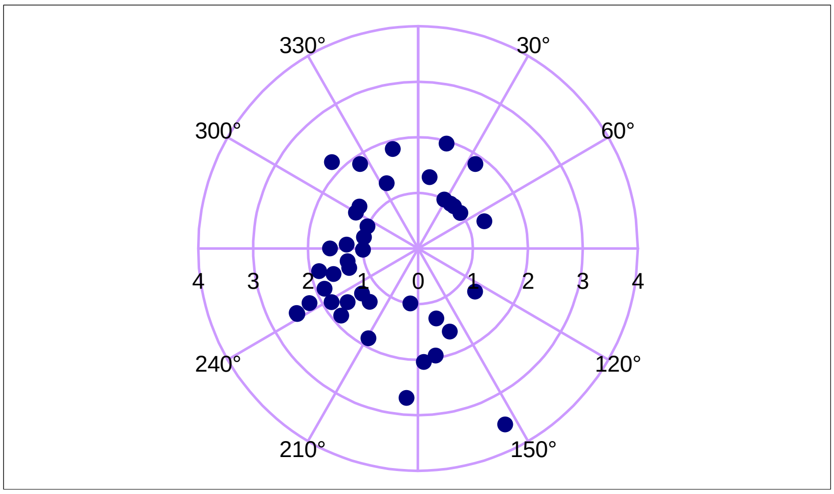

Figure 11.29 Circular histogram of geometric mean *E. coli* result by wind direction (Riskaness)

A significant correlation was found between wind direction and *E. coli* result for Riskaness (circular-linear correlation, r=0.361, p=0.007, Appendix 5), with highest results occurring when the wind was blowing from the south.

11.7 Evaluation of peak results

No sample results of greater than 4600 *E. coli* MPN/100g were recorded. A total of 4 samples exceeded 1000 *E. coli* MPN/100g and these are presented in Table 11.4.

Table 11.6 Historic *E. coli* sampling results over 1000 MPN/100g

Collection date	*E. coli* result (MPN/100g)	Location sampled	Area	2 day rain quartile	7 day rain quartile	7 day wind direction	Previous tide height	Time since high water
13/07/2004	2400	HU244471	Galtaskerry	Q1	Q1	348	1.2	06:17
09/08/2004	3500	HU232483	Riskaness	Q1	Q1	153	1.2	07:44
05/09/2005	2200	HU240484	Linga	Q2	Q4	213	*	*
19/06/2006	1300	HU240484	Linga	Q4	Q3	231	1.4	07:53

* Time of collection not recorded

All samples were collected during the summer or the early autumn. No particular geographic pattern or association with specific weather conditions is apparent. Where collection time was recorded, the samples were collected around or just after low water on smaller (neap) tides.

11.8 Summary and conclusions

Historical microbiological data was only available for four of the five sites within the two production areas (Linga, East of Linga, Galtaskerry and Riskaness, but not Lera Voe). Overall, levels of contamination were highest at Linga, intermediate at Galtaskerry and Riskaness, and lowest at East of Linga. No significant difference between sites in the proportion of the samples giving results of over 230 *E. coli* MPN/100g was found, although the

East of Linga site could not be included in this test or in the more detailed site by site analysis as too few samples (13) were submitted from here.

A significant difference in the proportion of results under 50 *E. coli* MPN/100g was found, with higher than expected numbers of these results found at the Riskaness and East of Linga sites, while fewer than expected results under 50 *E. coli* MPN/100g were found at the Linga and Galtaskerry sites. This may be indicative of lower background levels of contamination in waters at the Riskaness and East of Linga sites. Higher levels of contamination at the Linga site were consistent with its location closest to the main population centre at Walls.

No overall improvement or deterioration in results was seen for Linga, Galtaskerry or Riskaness from 2002-2007.

Correlations investigated between E. coli results and various environmental parameters are summarised in Table 11.7 below.

Table 11.7 Summary of correlations by site

	Linga	**Galtaskerry**	**Riskaness**
2 day rainfall	Positive	Positive	nc
7 day rainfall	Positive	Positive	nc
Season	nc	nc	nc*
Wind direction	Positive West	Positive West	Positive South
Spring/neap tide	nc	nc	nc
High/low tide	nc	Positive 1st half flood	nc
Peak results	June, Sept	July	Aug

nc = no correlation found
* range of results higher and broader in summer

No statistically significant seasonal or monthly pattern in mean results was identified for any of the sites, or in the proportion of samples (all sites combined) giving results of over 230 *E. coli* MPN/100g. However, peak results at Riskaness were highest in summer and the monthly geometric mean result also showed an upward trend from June to the peak in August, followed by a gradual decline toward the winter months. The four highest results occurred between June and September. A common pattern observed in Shetland mussel fisheries is for higher results during the summer and autumn, and there are no obvious reasons why a clearer seasonal pattern was not observed at all the Vaila Sound sites.

Positive correlations were found between *E. coli* results and rainfall in the previous two and seven days at the Linga and Galtaskerry, but not at Riskaness. The reasons for these differences are not immediately apparent, but are presumably related to the size and proximity of freshwater inputs relative to the sites, and water circulation patterns within the sound.

A significant correlation between tidal state (on the high/low cycle) was found for Galtaskerry only, with higher results occurring on the early flood tide. The reasons for this are unclear.

Significant correlations between wind direction and *E. coli* results were found for all three sites investigated, with winds from the west most commonly correlated with higher *E. coli* results. It is not clear whether this was a direct effect of the wind itself or coincidental with other environmental parameters.

12. Designated Shellfish Growing Waters Data

The area considered in this report is also a shellfish growing water which was designated in 2000. The growing water encompasses a similar but not identical area to 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

Monitoring results for faecal coliforms in shore mussels from 2000 to the end of 2007 have been provided by SEPA. These results are presented in Table 12.1. Until early 2003, samples were taken from the Vaila Sound RMP, so were presumably rope grown mussels. After this, samples were taken from by the pier at Vadlure, and so were presumably shore mussels taken from the intertidal zone. Both of these sampling locations fall within the Vaila Sound production area.

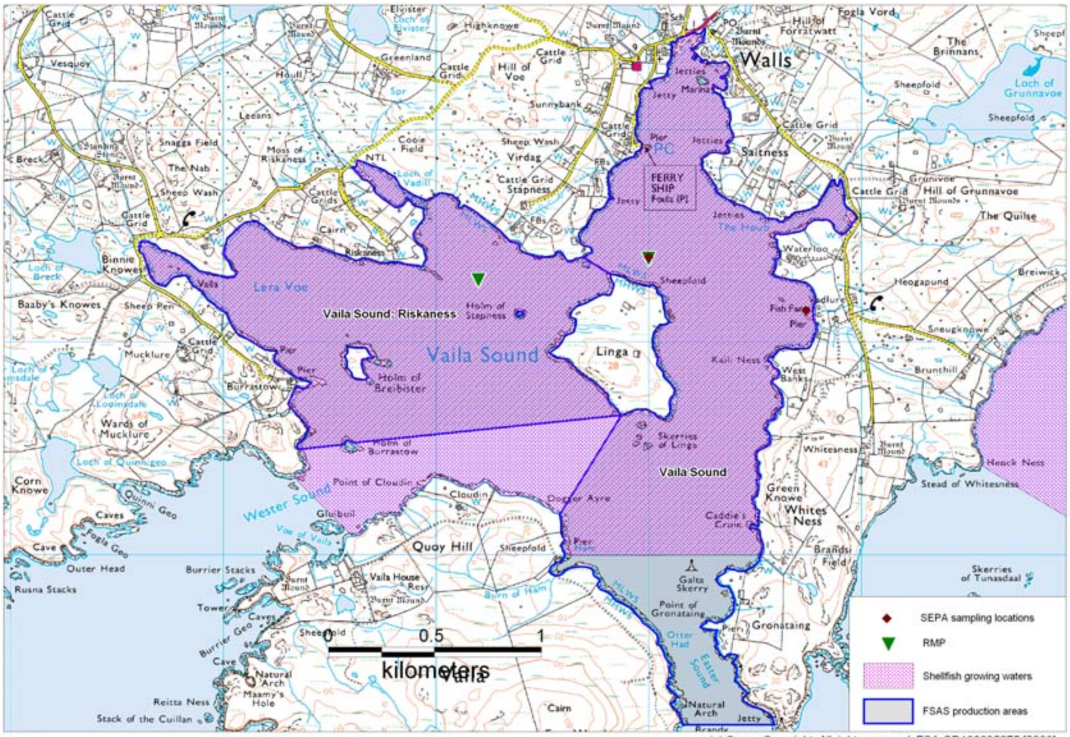

Figure 12.1 Shellfish growing waters and mussel sampling locations

Results were reported by calendar quarter, and no information was available regarding dates of sampling. Further analysis of these results against environmental parameters was therefore not possible.

Table 12.1 SEPA faecal coliform results (MPN/100g) for mussels gathered from Vaila Sound.

	Site	Vaila Sound	Vaila Sound
	OS Grid Ref.	HU 240 484	HU 2474 4815
2000	Q1		
	Q2	110	
	Q3	110	
	Q4	90	
2001	Q1	70	
	Q2	160	
	Q3	9100	
	Q4	160	
2002	Q1	<20*	
	Q2	40	
	Q3	20	
	Q4	220	
2003	Q1	40	
	Q2		
	Q3		110
	Q4		40
2004	Q1		20
	Q2		110
	Q3		90
	Q4		310
2005	Q1		<20*
	Q2		40
	Q3		16000
	Q4		90
2006	Q1		40
	Q2		<20*
	Q3		220
	Q4		310
2007	Q1		200
	Q2		20
	Q3		220
	Q4		50

* Assigned a nominal value of 10 for the calculation of the geometric mean.

The geometric mean result of all mussel samples from HU 240 484 was 102 faecal coliforms / 100g. Results ranged from <20 to 9100 faecal coliforms/100g. The geometric mean result of all mussel samples from HU 2474 4815 was 91 faecal coliforms / 100g. Results ranged from <20 to 16000 faecal coliforms/100g. There was no significant difference in mean result between sampling locations (T-Test, T=0.18, p=0.860, Appendix 5).

A significant difference in results between quarters was found (One-way ANOVA, p=0.023, Appendix 5). A post ANOVA test (Tukeys comparison, Appendix 5) indicated that results for quarter 3 were significantly higher than those for quarter 1. This difference was driven largely by two very high results obtained in Q3 2001 and Q3 2005.

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.

Results for the physical and chemical parameters monitored by SEPA are not presented in this report.

13. Bathymetry and Hydrodynamics

Figure 13.1 OS map of Vaila Sound

Figure 13.2 Bathymetry of Vaila Sound

The chart above shows that both production areas are in relatively shallow water, with maximum depths of just over 20 m. Vaila Sound is connected to the Atlantic Ocean to the south via Wester Sound (west of Vaila) and Easter

Sound (east of Vaila). The island of Linga lies in the middle of the sound, as well as a few other much smaller islands.

13.1 Tidal Curve and Description

The two tidal curves below 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 GMT on 14/07/08 and the second is for seven days beginning 00:00 GMT on 20/07/08. 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.

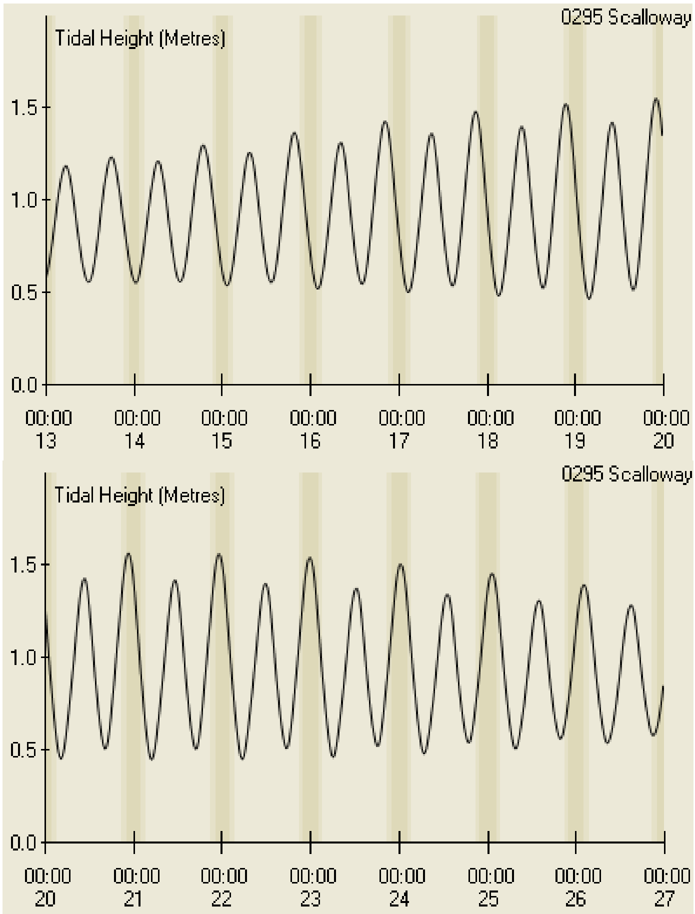

Figure 13.3 Tidal curves for Scalloway

The following is the summary description for Scalloway from TotalTide:

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

Predicted 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.

13.2 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 exchange of water is likely to be weak. The complex shape and bathymetry of Vaila Sound make predictions of tidally driven flow patterns difficult. Currents are likely to be strongest in Easter and Wester Sounds, and will of course be stronger on the larger spring tides.

Vaila Sound is sheltered from southerly winds by the island of Vaila, which rises to almost 100 m. To the north, the land is more low lying, although it does rise to between 60 and 70 m in places. Therefore, Vaila Sound receives some shelter from winds if all directions. Nevertheless, given the relatively weak tidal currents, wind driven currents have the potential to significantly alter flows around the production areas. Winds will create surface currents travelling in the direction of the wind. The path of associated return currents will be difficult to predict given the complex shape of the Sound.

The majority of streams discharge along the north shore of Vaila Sound. The catchment area is relatively small (estimated to be around 20 km^2), so under normal conditions little freshwater influence within Vaila Sound would be expected. On 22/7/2008, the North Atlantic Fisheries College (NAFC) took salinity profiles at the five mussel culture sites within the two Vaila Sound production areas. Salinity at selected depths is presented in Table 13.1, and the locations of these salinity profiles are presented in Figure 13.4.

Table 13.1 Salinity at selected depths at the five Vaila Sound mussel sites

Station No.	1	2	3	4	5
Location	HU 24111 48365	HU 24393 47099	HU 24228 47944	HU 23312 48358	HU 22420 48286
Area and site	Vaila Sound: Linga	Vaila Sound: Galtaskerry	Vaila Sound: East of Linga	Vaila Sound Riskaness: Riskaness	Vaila Sound Riskaness: Lera Voe
Time	13:36	15:02	15:23	14:20	14:00
Depth sounding	17.3 m	15.3 m	19.6 m	12.5 m	14.4 m
Salinity at 1m depth (ppt)	33.2	33.8	34.4	35.3	33.8
Salinity at 2m depth (ppt)	33.4	34.5	34.5	35.4	33.9
Salinity at 3m depth (ppt)	33.3	34.6	34.6	35.3	34.1
Salinity at 5m depth (ppt)	33.7	34.7	34.7	35.3	34.3
Salinity at 7m depth (ppt)	34.0	34.8	34.8	35.4	34.5
Salinity at 10m depth (ppt)	34.2	34.9	34.9	35.4	34.6
Salinity at 15m depth (ppt)	-	-	35.1	-	-

Surface salinity readings indicated salinity reductions ranging from 0 to nearly 2 ppt below standard Atlantic seawater salinity of 35ppt. Salinities at Riskaness were nearly constant at all depths and slightly higher than 35ppt, indicating no fresh water influence at the time they were recorded. All of the other sites showed some level of freshwater mixing with lower salinities at the surface that increased with depth. Although this was indicative of some freshwater input, there was no clear halocline, therefore, freshwater (density) driven flows would have been of little importance at the time of survey. Conditions at the time of survey were relatively dry, so it is possible that freshwater (density) driven currents may be of greater significance following heavy rainfall. These would create a net seaward flow of fresh water at the surface of the Sound, possibly with return currents of more saline water at depth.

Also coinciding with the shoreline survey, NAFC deployed two fixed current meters at locations indicated on Figure 13.4 (Current 1 and Current 2) for a period of 5 days, recording speed and direction of the current at various depths at 10-minute intervals. A weather station was simultaneously deployed which recorded hourly wind speed and direction. In addition to this, the NAFC provided similar data from a series of six studies to assess movement of water around potential salmon cage farm sites within Vaila Sound. These were carried out on separate occasions from 2002 to 2007, and therefore under differing environmental conditions. The studies involved the deployment of a fixed current meter for periods of around 2 weeks, therefore covering a full spring/neap tidal cycle. Locations of these six fish farm study sites are also shown in Figure 13.4.

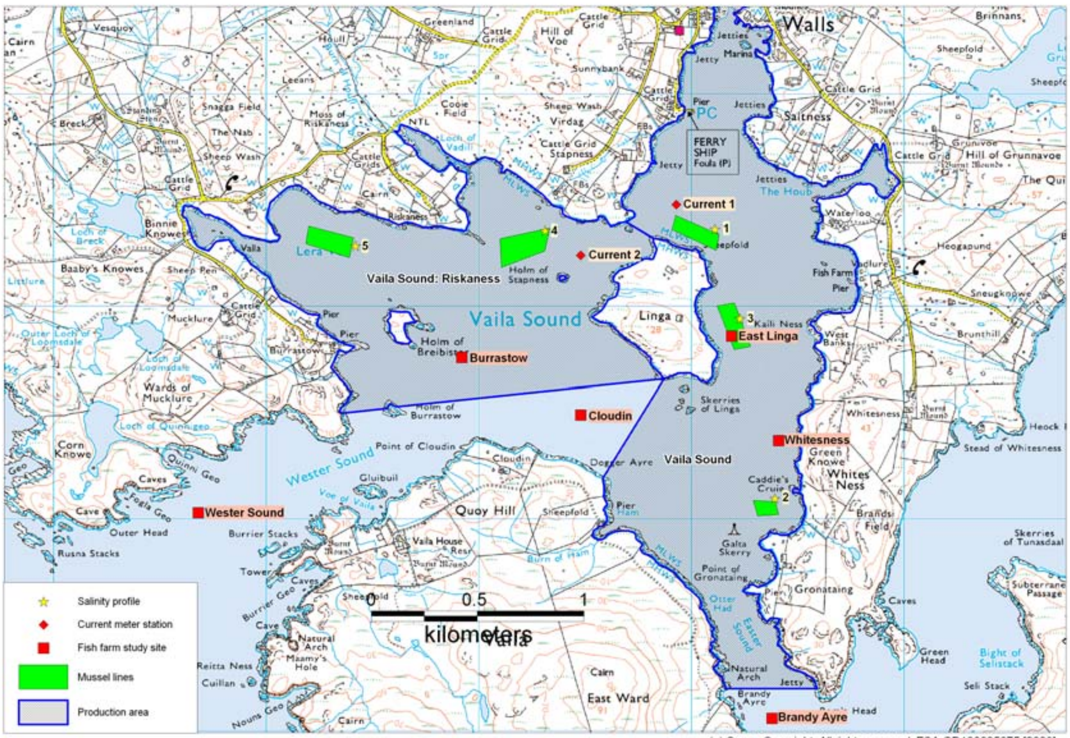

Figure 13.4 Location of salinity profiles, current meter stations and fish farm study sites.

To present the data generated by the current meters, polar plots of tidal direction and velocity readings near the top (surface) and bottom, with polar plots of simultaneous wind recordings are presented in Figure 13.5 for the two current meter recordings coinciding with the shoreline survey, and in Figure 13.6 for the six fish farm study sites. 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 as quiescent.

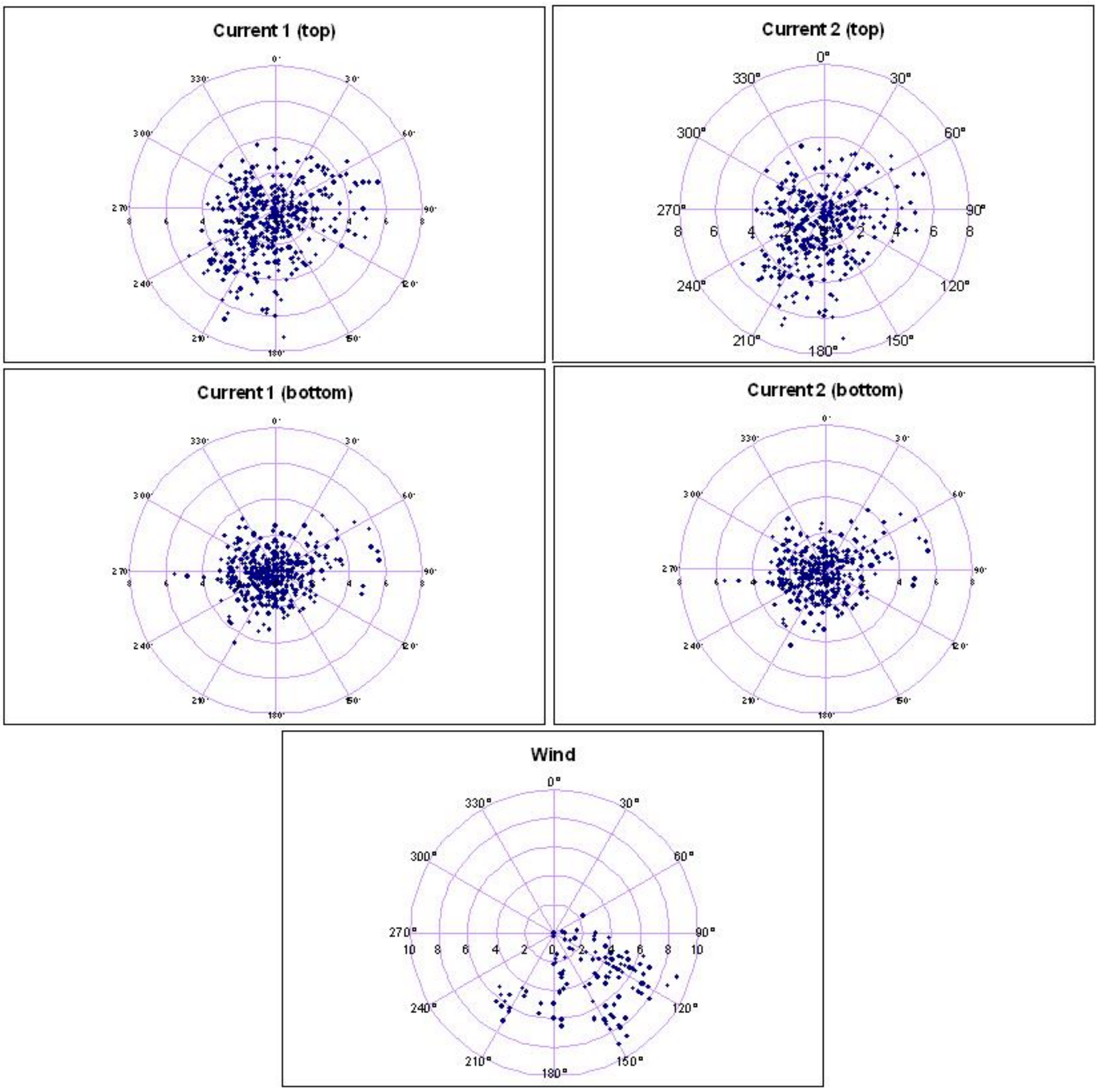

Figure 13.5 Polar plots of tidal direction and velocity readings near the top (surface) and bottom for the two current meter sites coinciding with the shoreline survey, with polar plots of simultaneous wind recordings.
Current velocity is in cm/s, and wind speed is in m/s.

Both stations showed very similar overall patterns in terms of flow direction and speed. Flows were on average quiescent, with a mean current speed near the surface of 2.4 cm/s at station 1, and 3.0 cm/s at station 2, and of 1.7 cm/s near the bottom at station 1, and 2.6 cm/s at station 2. Flows were quite evenly spread in terms of direction at both the top and the bottom. Wind was predominantly from the southeast, and of light to moderate strength.

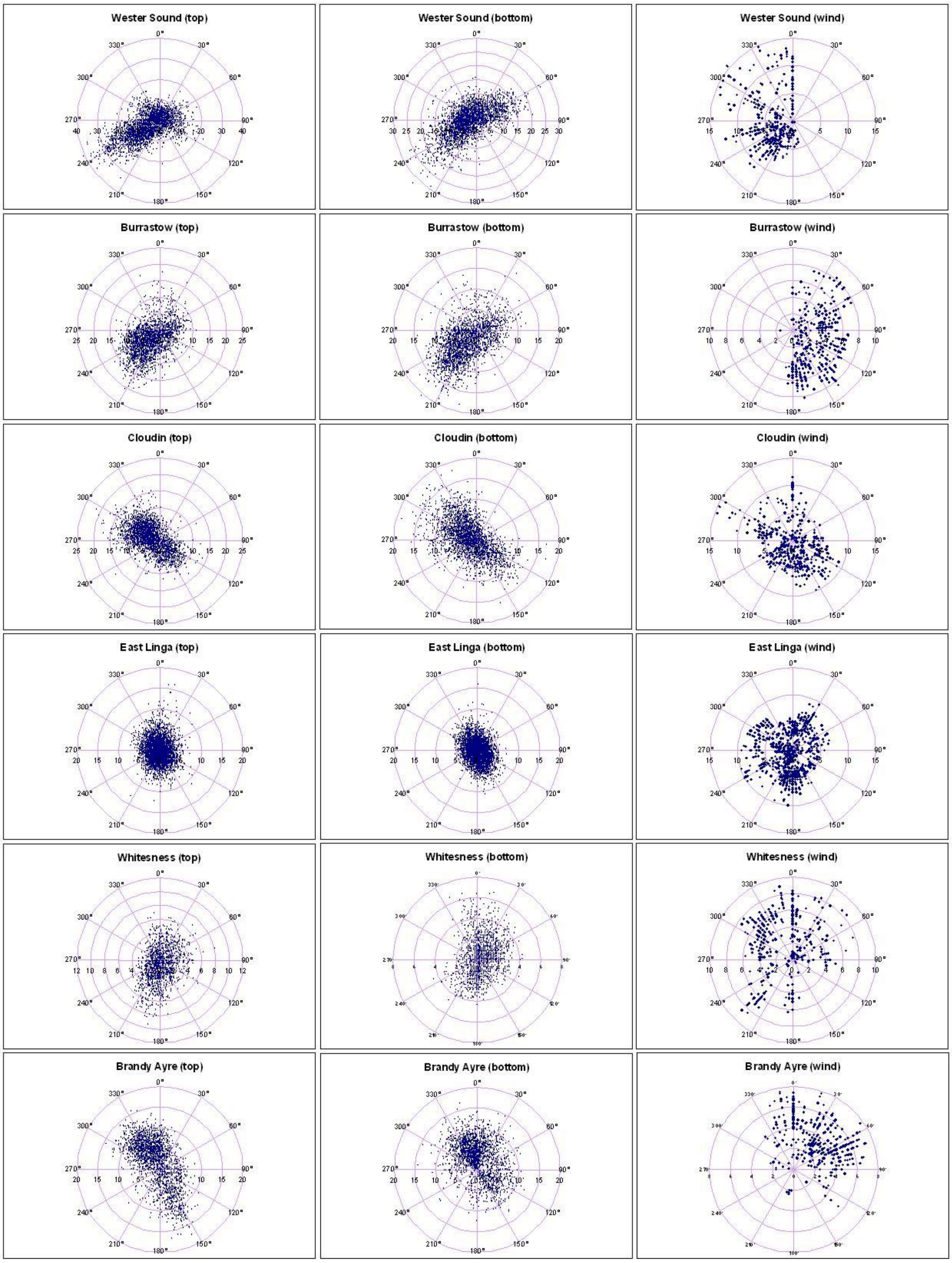

Figure 13.6 Polar plots of tidal direction and velocity readings near the top (surface) and bottom for the six historical fish farm study sites, with polar plots of simultaneous wind recordings.

Current velocity is in cm/s, and wind speed is in m/s.

At Wester Sound, flows were on average strong at the top, and moderate near the bottom, with a mean current speed near the surface of 10.9 cm/s, and 8.2 cm/s at the bottom. There was a tidally driven bidirectional pattern of flows along Wester Sound, although this was slightly skewed in a south westerly direction at the surface. Wind was from the west, and quite strong at times, and this presumably influenced the flow pattern recorded at the surface, although westerly winds may be expected to skew the flow pattern in the opposite direction to that observed.

At Burrastow, flows were moderate on average, with a mean current speed near the surface of 6.7 cm/s, and 6.4 cm/s at the bottom. There was a tidally driven bidirectional pattern along the southwest-northeast axis. Wind was from the east, and light to moderate. This appeared to influence the flow pattern recorded at the surface, skewing flow directions in the same direction as the wind.

At Cloudin, flows were moderate on average, with a mean current speed near the surface of 5.6 cm/s, and 5.1 cm/s at the bottom. There was a tidally driven bidirectional pattern along the northwest-southeast axis. Wind was fairly evenly spread in terms of direction, and generally light to moderate in strength, and did not appear to excerpt a major influence the flow pattern recorded at the surface.

At East Linga, flows were weak/quiescent on average, with a mean current speed near the surface of 3.0 cm/s, and 3.0 cm/s at the bottom. Current direction was fairly evenly spread, with a vague bidirectional tendency along the north-south axis apparent at the bottom. Wind was evenly spread in direction, and ranged from light to moderate in strength, and appeared to have slightly influenced flow patterns at the surface.

At Whitesness, flows were quiescent on average, with a mean current speed near the surface of 2.6 cm/s, and 2.0 cm/s at the bottom. There was a tidally driven bidirectional pattern along the north-south axis. Wind was evenly spread in direction, and ranged from light to moderate in strength, and did not appear to have significantly influenced flow patterns at the surface.

At Brandy Ayre, flows were moderate on average, with a mean current speed near the surface of 6.4 cm/s, and 5.7 cm/s at the bottom. There was a tidally driven bidirectional pattern along the northwest-southeast axis. Wind was consistently from the northeast, and generally light in strength and did not appear to have significantly influenced flow patterns at the surface.

Overall, the current meter records show that bidirectional tidally driven currents generally of a moderate strength predominate through Wester Sound, along the north shore of Vaila, and through Easter Sound. Towards the north shore of Vaila Sound, and around the island of Linga, where four of the five mussel sites are located, currents are weak or quiescent, and generally do not exhibit a marked bidirectional tendency. At these sites, surface currents tended to mirror the bottom currents, exhibiting little influence from wind driven flow for the most part.

13.3 Conclusions

Circulation around the sound will be driven primarily by tide and winds, and, possibly by fresh water inputs at times. Tidal currents are strongest through Wester Sound, along the north shore of Vaila, and through Easter Sound, and weaker around Linga and the north shore of Vaila Sound. Where tidal currents were stronger, they followed a bidirectional alongshore pattern. Contamination originating from the settlement of Walls may be expected to travel slowly south towards the Linga site on an ebbing tide, then around the east and northwest shores of Linga potentially impacting on the East of Linga and possibly the Riskaness sites depending upon conditions. Due to the very slow current speeds observed, it could be expected that little flushing would occur in the upper parts of the sound and that contaminants may tend to persist near to where they were discharged for more than one tidal cycle.

Superimposed on this, wind driven currents are likely to alter circulation within Vaila Sound, particularly near the surface, depending on wind strength and direction. The complex shape of Vaila Sound makes the exact effects of wind on currents difficult to accurately predict, although generally they will be expected to drive a surface current in the same direction of wind flow though return currents and eddies are likely to form around the complex coastline and islands. Following heavy rainfall, any large influx of freshwater is likely to form a density driven surface current of fresh water flowing slowly in a seaward direction until it is mixed with the underlying seawater by wind-driven or tidal processes. However, density driven flows are not expected to play a major role in the movement of contaminants within Vaila Sound.

14. River Flow

There are no gauging stations on streams draining to Vaila Sound. The following streams were measured and sampled during the shoreline survey. These represent the largest freshwater inputs into Vaila Sound and are likely to be the principal pathways by which diffuse contamination from livestock will be carried into the production areas.

Table 14.1 Stream loadings for Vaila Sound

No	Grid Ref	Description	Width (m)	Depth (m)	Flow (m/s)	Flow in m^3/day	*E.coli* (cfu/ 100ml)	Loading (*E.coli* per day)
1	HU 23545 46881	Stream	0.62	0.15	0.085	683	130	$8.9x10^8$
2	HU 23340 48530	Stream	0.10	0.03	0.259	67.1	6000	$4.0x10^9$
3	HU 21577 48468	Stream	0.95	0.05	0.142	583	30	$1.7x10^8$
4	HU 21572 48485	Stream	0.60	0.05	0.136	353	40	$1.4x10^8$
5	HU 22268 47648	Stream	0.44	0.06	0.113	258	780	$2.0x10^9$
6	HU 24099 49395	Stream	4.30	0.08	0.073	2170	10	$2.2x10^8$
7	HU 24258 49458	Stream	1.70	0.12	0.088	1550	180	$2.8x10^9$
8	HU 24323 49318	Stream	0.15	0.02	0.214	55.5	70	$3.9x10^7$
9	HU 24349 48869	Stream	0.13	0.03	0.052	17.5	7000	$1.2x10^9$
10	HU 24910 48760	Stream	0.80	0.15	0.141	1460	30	$4.4x10^8$
11	HU 22113 48561	Stream	0.26	0.03	0.062	41.8	200	$8.4x10^7$
12	HU 22582 48810	Stream	1.60	0.07	0.313	3030	330	$1.0x10^{10}$
13	HU 24790 48065	Stream	0.27	0.03	0.156	109	50	$5.5x10^7$
14	HU 24529 46962	Stream	0.09	0.07	0.125	68.0	300	$2.0x10^8$

Water levels in the streams at the time of the shoreline survey appeared to be relatively low. Some of the smaller streams marked on the Ordnance Survey map, although wetted in places, had negligible flow. All streams drain areas of pasture, and had widely varying levels of *E. coli* (10-7000 cfu/100ml) at the time of survey. Two of the smaller streams (2 and 9) had high levels of *E. coli* (6000 and 7000 cfu/100ml) but the reason for this was uncertain.

The highest overall *E. coli* loadings were from streams 12 and 2, both of which discharge near the Riskaness site and contributed 64% of the loadings measured during the shoreline survey. Streams 3, 4 and 11 discharge near the Lera Voe site, and stream 14 discharges near the Galtaskerry site, so these three sites may be expected to be most affected by heavy rainfall. The total loading contributed by all these streams at the time of survey was 2.2×10^{10} *E. coli* per day, roughly equivalent to a discharge of septic tank treated wastewater from a population of 2. Following heavy rain, however, the loadings contributed by these streams would be expected to increase significantly.

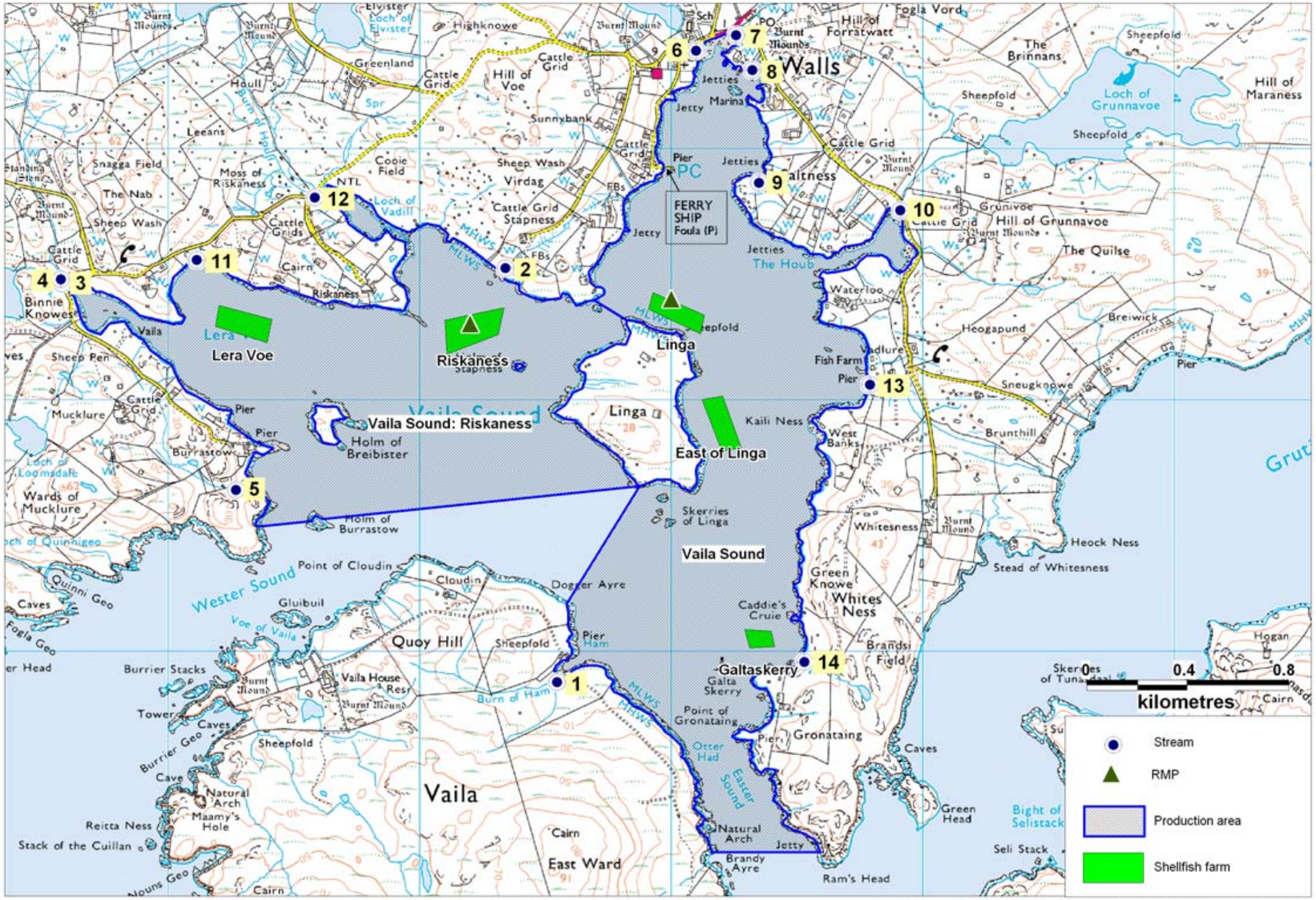

Figure 14.1 Streams at Vaila Sound

15. Shoreline Survey Overview

The shoreline survey was conducted on the 22nd to the 24th July 2008.

Within the Vaila Sound production area, there were three active mussel sites – Linga (owned by Demlane), East of Linga (owned by North Atlantic Shellfish) and Galtaskerry (owned by North Atlantic Shellfish). Within the Vaila Sound: Riskaness production area there were two active mussel sites – Riskaness (owned by Demlane) and Lera Voe (owned by North Atlantic Shellfish). All sites were longline sites, with stock of a range of sizes present, including those of a harvestable size. The two sites owned by Demlane are usually harvested between September and April, with the timing of harvest dependent on demand, biotoxin status, and the status of other sites under the same ownership. The three sites owned by North Atlantic Shellfish can be harvested at any time of year dependent on demand, biotoxin status, and the status of other sites under the same ownership.

The main population centre in the area is the village of Walls, at the eastern head of the sound. Here there were two communal septic tanks with outfalls into the sound, and a further 10 pipes believed to be private sewage discharges. Around the rest of the mainland shore, houses are spread out at a low density, and a further 11 septic tanks were seen associated with these, although only six of them had visible overflows to either Vaila Sound or nearby watercourses. A small number of the dwellings seen on the shoreline survey are believed to be holiday homes. No septic tanks were seen on Vaila Island, although there were 2 houses here. The island of Linga is uninhabited. Boat traffic in Vaila Sound includes small pleasure craft, mussel and salmon farm boats, and the Foula ferry. A marina and boat club were observed at Walls, where a total of 20 small boats were tied up. Other moorings or jettys were seen on Vaila (2 jettys and one small boat), at the North Atlantic Shellfish building (one jetty and a mussel boat), and in Lera Voe (4 small boats on moorings, salmon jetty with 3 boats). The small Foula ferry sails twice weekly in winter, and three times weekly in summer from the pier in Walls. A large barge that is likely to have an on-board toilet was moored next to the salmon farm just off Vaila.

The land surrounding the production area is pasture which is grazed by sheep, with over 350 sheep noted during the survey. Sheep had access the shoreline around most areas. In addition to the sheep, a total of 12 cows, 3 pigs, 2 ponies and 4 semi-domesticated geese were recorded. No sheep were seen on Linga, but the sampling co-ordinator advised that 50 sheep are usually left on the island during the summer months. Rabbits were present on all pasture land, but were not observed in great numbers during the survey. A seal was seen just off Vaila island. A total of approximately 100 wild geese were seen during the course of the survey on the north shore of Vaila and on pasture at Riskaness. About 100 seagulls were seen around the salmon farm just north of Vaila island.

A few streams discharge into the sound and these drain areas of pasture. Water samples were taken, and discharge estimated for these, although water levels were low, and some of the smaller streams marked on the Ordnance Survey map, although wetted in places, had negligible flow and could not be sampled. Water samples from these streams contained levels of *E. coli* between 10-7000 cfu/100ml.

Rope mussel samples had *E. coli* concentrations ranging from <20 to 170 MPN/100g. The highest 5 results came from the Lera Voe site, and results from here were significantly higher that at all the other sites (One-way ANOVA with Tukeys comparison, p=0.001, Appendix 5).

At all but one site sampled, mussel samples taken from the shallowest depth contained *E. coli* concentrations equal to or higher than those found on samples taken from deeper depths.

Surface seawater samples taken at the Linga, East of Linga and Riskaness sites all seawater sample results were <1 *E. coli* cfu/100ml, and for Galtaskerry the one seawater sample gave a result of 1 *E. coli* cfu/100ml. At the Lera Voe site, results of 2 and 9 *E. coli* cfu/100ml were reported, reflecting the pattern observed with the mussel samples.

Of seawater samples taken from the shore, highest results (4100, 4000, 780 and 700 *E. coli* cfu/100ml) were obtained at selected points on the north and west shores, away from the main settlement of Walls. Other samples taken in this area yielded lower results. This suggests that there are localised sources here causing these high results, but the sources here (livestock on the shoreline, streams, private septic tanks) are similar in nature to those found in other areas which did not show such high levels of contamination in the seawater, so it is not certain why these high results arose. Currents in this area are weak, so it is possible that contamination is flushed more slowly from here.

E. coli results were on average slightly higher for mussel samples taken at the surface than those taken at greater depths, but differences between results by depth sampled were not statistically significant (One-way ANOVA, p=0.545, Appendix 5). Surface salinity measurements taken during the survey showed salinities all approaching that of full strength seawater (35 ppt).

Figure 15.1 Summary of shoreline survey findings for Vaila Sound

16. Overall Assessment

Human sewage impacts

The main concentration of population is at the settlement of Walls, at the northern end of the Vaila Sound production area. A large proportion of the village is served by two Scottish Water septic tanks, the larger of which is on the east shore. An additional 10 private sewer pipes discharging to Vaila Sound from the settlement of Walls were recorded during the shoreline survey. An estimate of the total population equivalents of these discharges is 381. It is likely that the Linga site is most impacted by these discharges as it is closest.

Outside of Walls, a total of 11 other private septic tanks or discharges were seen, on the north shore near the Riskaness and Lera Voe sites, and at Vadlure on the east shore. Of these, six discharged direct to Vaila Sound or to nearby watercourses. Therefore, an estimate of the total population equivalent discharging to water from areas outside of Walls is about 30.

Boat traffic in Vaila Sound includes small pleasure craft, mussel and salmon farm boats, and the Foula ferry. The ferry route passes by the farms at Linga and East of Linga, and any discharge from the onboard toilets whilst in the vicinity would affect these two sites. However, it is not known whether or how often this might occur. Other potential sources from boats moored at Walls and Lera Voe are mostly likely to impact the Linga and Lera Voe sites respectively. As the currents in the vicinity of the mussel farms are generally weak, contaminants from boating sources are most likely to impact near to where they are discharged.

The vast majority of faecal contamination of human origin enters Vaila Sound in the area of Walls, and its impacts are likely to be greatest at the Linga site, which lies closest to the town. Lesser impacts from small private discharges and a small number of boats may also affect Lera Voe and Riskaness.

Agricultural impacts

Agricultural census data identified that agriculture within the surrounding parish is dominated by sheep production. The shoreline survey confirmed that sheep grazed widely around the Vaila Sound coastline. No sheep were seen on Linga, but the local sampling co-ordinator advises that usually 50 sheep are left on the island during the summer months. Several cattle and three pigs were also observed on the nearby island of Vaila.

Sheep populations appeared to be evenly distributed along the shores of the mainland, so no particular geographic patterns in the levels of contamination of livestock origin are expected. However, a seasonal pattern is likely due to the presence of lambs and calves during the late spring and summer months, leading to an approximate doubling of the livestock population in the area.

Wildlife impacts

The main wildlife species potentially impacting on the production areas are geese, seabirds and seals.

No common seal haulout sites or grey seal breeding colonies were reported in Vaila Sound, though one seal was seen just off Vaila during the shoreline survey. Therefore, it is likely that seals may be present close to the mussel farms at times, but their presence and impacts are likely to be fleeting and unpredictable.

The seabirds 2000 survey indicated a high density of breeding seabirds along Wester Sound, to the southwest of the mussel fisheries. Terns and various gulls were quite widespread along the whole of the surrounding land, albeit at lower densities. Again, patterns of impacts to the mussel fisheries are difficult to predict, although it is likely that overall numbers in the area will be higher during the spring/summer breeding season.

A total of about 100 geese were seen during the shoreline survey, suggesting that they may be breeding in the area. 60 of these were seen on the north shores of Vaila, and 40 were seen at Riskaness, but almost all of the shoreline of Vaila Sound has suitable pastures for geese to graze and so the impact of faecal deposition from geese will be presumed to be even across the fisheries.

The overall impact of wildlife sources of faecal bacteria to the fisheries will be assumed to be evenly distributed, with the potential for higher background levels of contamination occurring in summer when more birds are present in the area.

Seasonal variation

No statistically significant seasonal pattern was observed in historical *E. coli* monitoring results for any of the three sites with sufficient monitoring history to be investigated (Linga, Galtaskerry and Riskaness), though highest results were recorded during June to September. A seasonal difference in shellfish growing waters monitoring results was found, with results significantly higher in quarter 3 (July-September) compared to quarter 1 (January-March).

The amount of diffuse pollution contributed by livestock and wildlife is likely to be higher during the summer months, when animal populations around the shoreline are at their highest levels.

Weather is both wetter and windier during the winter months (in particular between September and February) so there is a greater likelihood of rainfall-dependent contamination particularly at the onset of the rainy season. However, contamination carried by runoff from streets, sewers and pastures may occur after a heavy rainfall at any time of the year.

Seasonal differences in levels of contamination contributed from livestock and wildlife sources and in weather patterns are expected, with higher contributions during the summer months and higher rainfall occuring during the autumn and winter months increasing the amount of contamination carried via runoff from land areas. As harvesting may occur at any time of the year, it is reasonable to anticipate that seasonal variation in results will continue to be observed in the future.

Rivers and streams

Streams are important pathways by which diffuse contamination from livestock will be carried into the production areas. Streams were measured and sampled during the shoreline survey, which took place during the summer when water levels appeared relatively low. The streams drained areas of pasture and had widely varying levels of *E. coli* (10-7000 cfu/100ml) at the time of survey. Following heavy rain, the loadings contributed by these streams would be expected to increase significantly, particularly given that the local soils are poorly draining.

The majority of the observed streams discharge to the north shores of the sound, so the Riskaness and Lera Voe sites, which are closest to this shore, may be more affected by them than other sites. Additionally, a small stream discharges in close proximity to the Galtaskerry site.

Meteorology, hydrology, and movement of contaminants

The weather is wetter and windier during the autumn and winter months, and the prevailing wind direction is from the south west. Many of the streams supplying fresh water to the area were found to be dry during the shoreline survey, indicating that fresh water flows to the area are only likely to occur after significant rain. Diffuse pollution from the surrounding land is most likely to be transported to the fishery via this route and so is expected to be higher after rainfall.

Weak tidal flows in the northern end of the sound mean that movement of contaminants here is likely to be predominantly wind-driven.

Positive correlations were found between *E. coli* results and rainfall in the previous two and seven days at the Linga and Galtaskerry, but not at Riskaness. The reasons for this are unclear. The Riskaness site is located near the two streams with the highest loadings measured during the shoreline survey, and there are no significant streams discharging close to the Linga site.

There was insufficient historic *E. coli* monitoring data to fully assess the effects of environmental variables (rain, wind and tides) on the East of Linga and Lera Voe sites.

Significant correlations between wind direction and *E. coli* results were found for all sites investigated. For the Linga and Galtaskerry sites, results were higher when the wind was blowing from the west, and for Riskaness results were higher when the wind was blowing from the south. However, wind conditions were measured at Lerwick and local wind directions in Vaila Sound may have differed.

Contamination originating from the settlement of Walls may be expected to travel slowly south towards the Linga site on an ebbing tide. Due to the very slow current speeds observed, it could be expected that little flushing would occur in the upper parts of the sound and that contaminants may tend to persist for more than one tidal cycle near to where they were discharged.

Superimposed on this, wind driven currents are likely to alter circulation within Vaila Sound, particularly near the surface, depending on wind strength and direction. Following heavy rainfall, any density-driven surface currents of fresher water will flow slowly in a seaward direction, with contaminants carried in a surface layer of fresher water until wind- or tidally-driven mixing occurs.

Temporal and geographical patterns of sampling results

No overall improvement or deterioration in historical monitoring data was seen for the Linga, Galtaskerry or Riskaness sites from 2002-2007. There was insufficient data from the East of Linga and Lera Voe sites to assess if any temporal changes had occurred at these sites.

Levels of contamination at Linga were found to be statistically significantly higher than those at Riskaness and East of Linga. The proportion of results under 50 *E. coli* MPN/100g greater at the Riskaness and East of Linga sites and lower at the Linga and Galtaskerry sites. This implies that background levels of contamination may be slightly higher Linga and Galtaskerry.

Overall, historic *E. coli* monitoring results indicate that results for all four sites were quite similar in terms of the proportion of results falling within the classification thresholds. A comparison of mean results suggests that the Linga site may be considered separately from the Riskaness and East of Linga sites. However, sites which show a similar level of contamination, as indicated by *E. coli*, may be subject to different polluting sources and so these results need to be considered in conjunction with other elements of the assessment.

Seawater samples collected during the shoreline survey at Linga, East of Linga, Riskaness and Galtaskerry all returned results of 1 or <1 *E. coli* cfu/100ml. Contamination levels were found to be higher at the Lera Voe site, from which results of 2 and 9 *E. coli* cfu/100ml were reported.

Mussel samples collected from the long-line farms contained *E. coli* concentrations ranging from <20 to 170 MPN/100g, with significantly higher results coming from the Lera Voe site, reflecting the pattern observed with the seawater samples. The reason for higher levels of contamination here is not clear, but may be related to the low levels of water circulation in this part of the sound. Although contamination levels at the Lera Voe site were higher at the time of shoreline survey, there were no historical *E. coli* monitoring to confirm that this is the usual pattern.

Results were on average slightly higher for mussel samples taken at the surface, but differences between results by depth sampled were not statistically significant. Surface salinity measurements taken during the survey showed salinities all approaching that of full strength seawater (35 ppt), but at times of higher freshwater inputs higher levels of contamination may be experienced in a layer of fresher water at the surface.

Differences in mussel samples taken from both ends of the sites were small, and only three samples were taken from each end, but the geometric mean result was higher at the eastern end of the Lera Voe site (83.3 MPN/100g) compared to its western end (73.2 MPN/100g), and the geometric mean result was higher at the western end of Riskaness (29.2 MPN/100g) compared to its eastern end (20.0 MPN/100g).

These differences were small, and therefore need to be considered in conjunction with other information when determining the location of the RMPs. Differences in geometric mean result between the ends was even smaller at Linga and East of Linga, and only one location was sampled at the smaller Galtaskerry site.

17. Recommendations

As analysis has indicated differences in both observed and expected spatial patterns of contamination within Vaila Sound, it is recommended that the production areas be reorganised to reflect these.

Differences in historic *E. coli* monitoring results between sites and in mussel sampling results obtained during the shoreline survey support the division of the two current production areas into three separate areas as listed below.

<u>Vaila Sound: Linga</u>

It is recommended that a separate production area be established for the Linga mussel site, which formerly fell within the Vaila Sound production area. This should be classified separately from the two adjacent sites (East of Linga and Riskaness) on the basis of significant differences in historic *E. coli* monitoring results and its proximity to the settlement of Walls.

The boundaries should be sufficiently large to permit movement of the apparatus in the tide, and expansion of the site to fill its seabed lease boundaries, but should exclude the bay to the north where the settlement of Walls is located. Therefore, the recommended boundaries are lines drawn between HU 2382 4832 and HU 2382 4858 and between HU 2382 4858 and HU 2432 4858 and between HU 2432 4858 and HU 2432 4824 and between HU 2432 4824 and HU 2405 4824 extending to MHWS.

The RMP should be set at the northern extremity of the site, to best capture any contamination originating from the settlement of Walls. The recommended RMP is therefore HU 2393 4842. Sampling tolerance should be 20 m to allow for the lines to shift in the wind and tides. A sampling depth of 1 m is recommended to capture higher levels of contamination which may arise at times of high freshwater input in a layer of fresher water at the surface. It is recommended that monthly monitoring be undertaken due to recent seasonal classification.

<u>Vaila Sound: East of Linga and Galtaskerry</u>

It is recommended that this production area should include the East of Linga and Galtaskerry sites, which formerly fell within the Vaila Sound production area. Historical monitoring results were significantly higher at Linga than at Galtaskerry, and as Linga lies much closer to the settlement of Walls is Likely to be more impacted by human sewage than the East of Linga and Galtaskerry sites. Although they are likely to be affected by slightly different sources of contamination, no significant difference was found in historic *E. coli* results or for samples collected during the shoreline survey between these two adjacent sites apart from differing proportions of results over *E. coli* 50 MPN/100g. The sites are less than 1 km apart, lending support to their continued classification together.

The recommended boundaries are lines drawn between HU 2480 4809 and HU 2409 4812 and between HU 2388 4766 and HU 2433 4689 extending to MHWS. Of the two sites, the RMP should be set at the Galtaskerry site as it is closer to an inhabited shoreline along which contamination may be carried on the tide, and also has a small stream discharging in close proximity.

Historic *E. coli* monitoring results were on average marginally higher at Galtaskerry. The RMP should be set at the eastern extremity of the site to best capture any contamination arising from the stream, and from other sources along the east shore of Vaila Sound. The recommended RMP is therefore HU 2440 4703. Sampling tolerance should be 20 m to allow for the lines to shift in the wind and tides. A sampling depth of 1 m is recommended to capture higher levels of contamination which may arise at times of high freshwater input in a layer of fresher water at the surface. It is recommended that monthly sampling be undertaken as this area has exhibited seasonal variation in historic results.

<u>Vaila Sound: Riskaness</u>

It is recommended that the production area boundaries be curtailed to exclude areas that lie nearer to contaminating sources while still including both mussel sites. Therefore, the recommended production area boundaries are lines drawn between HU 2290 4848 and HU 2317 4862 and between HU 2342 4842 and HU 2360 4800 and between HU 2360 4800 and HU 2214 4800 and between HU 2214 4800 and HU 2204 4831 extending to MHWS.

Mussel samples taken from the Lera Voe and Riskaness sites during the shoreline survey showed significantly higher levels of contamination at Lera Voe, though all samples contained fewer than 230 *E.coli* MPN / 100 g. Even though the results from Lera Voe still fell within the A class range at the time of shoreline survey, it is conceivable that following significant rainfall events for example, this site may be more likely to obtain results in the Class B range than the Riskaness site.

Both sites are subject to broadly the same contaminating influences and quiescent seawater conditions. Nevertheless, the difference in sampling results lends support to monitoring of the Lera Voe site separately to determine whether the difference observed during the shoreline survey is coincidental or indicative of higher overall levels of contamination at Lera Voe. Therefore, it is recommended that parallel monitoring be undertaken monthly at both the Riskaness and Lera Voe sites for 1 year to determine whether these sites should be monitored separately.

The RMP at Riskaness should be set towards the north western corner of the site, as this places it closest to a stream and a private septic tanks, and slightly higher results were obtained at its western end during the shoreline survey. At Lera Voe, although slightly higher results were obtained at its eastern end during the shoreline survey, the most significant sources of contamination (streams and septic tanks) lie to its west around the head of the voe. Therefore, the recommended parallel monitoring points are HU 2312 4831 at Riskaness and HU 2221 4831 at Lera Voe.

In both locations, sampling tolerance should be 20 m to allow for the lines to shift in the wind and tides. A sampling depth of 1 m is recommended to capture higher levels of contamination which may arise at times of high freshwater input in a layer of fresher water at the surface.

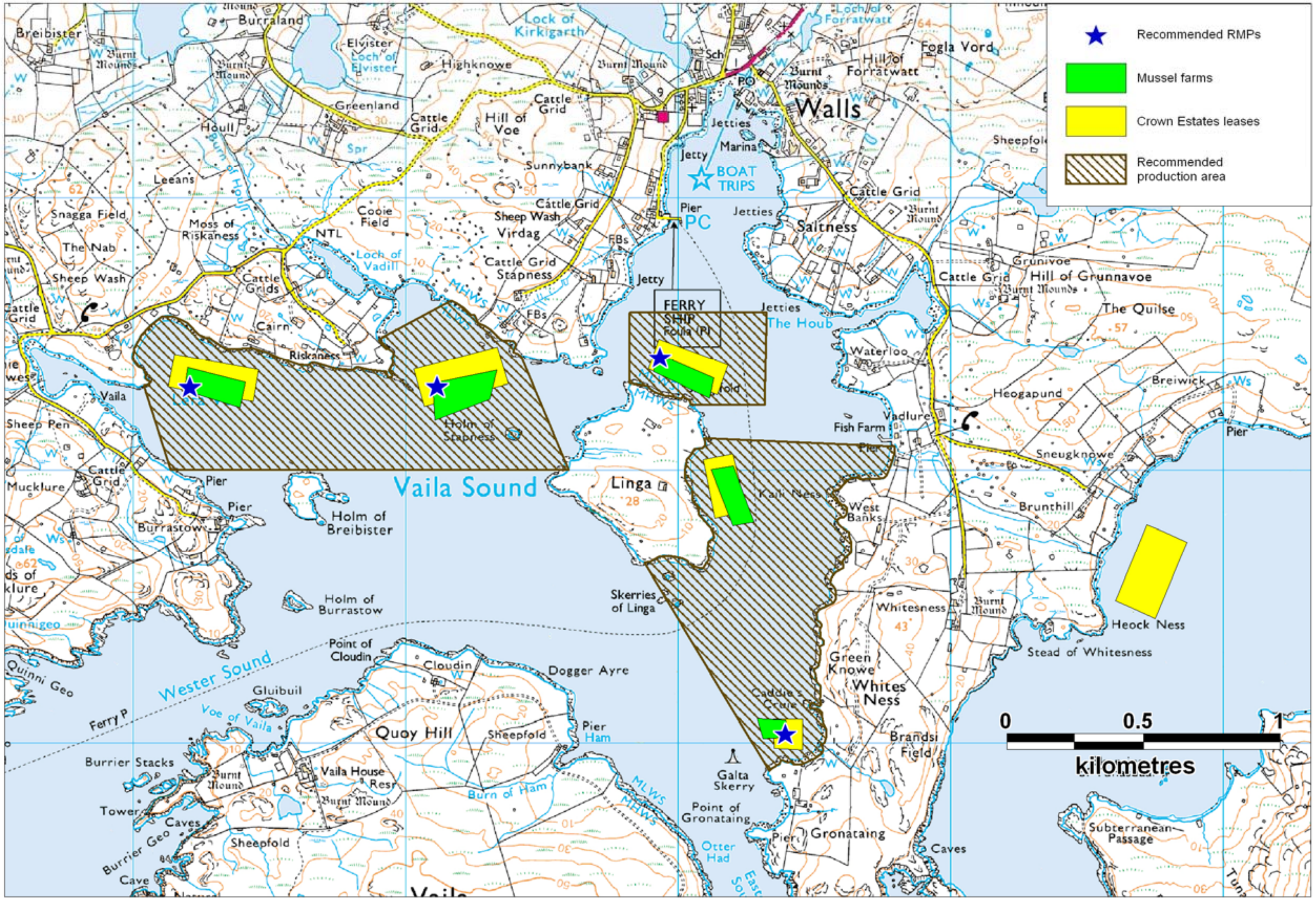

Figure 17.1 Map of recommendations at Vaila Sound

18. References

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

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

Edwards, A. and F. Sharples. (1986) Scottish sea lochs: a catalogue. Scottish Marine Biological Association, Oban. 250pp.

Kay, D, Crowther, J., Stapleton, C.M., Wyler, M.D., Fewtrell, L., Anthony, S.G., Bradford, M., Edwards, A., Francis, C.A., Hopkins, M. Kay, C., McDonald, A.T., Watkins, J., Wilkinson, J. (2008). Faecal indicator organism concentrations and catchment export coefficients in the UK. *Water Research* 42, 442-454.

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

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

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

Sea Mammal Research Unit (2002). Surveys of harbour (common) seals in Shetland and Orkney, August 2001. Scottish Natural Heritage Commissioned Report F01AA417 .

Sea Mammal Research Unit (2007). The status of British common seal populations. Special Committee on Seals Briefing paper 07/3.

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Sampling Plan for Vaila Sound Production Areas

PRODUCTION AREA	SITE NAME	SIN	SPECIES	TYPE OF FISHERY	NGR OF RMP	EAST	NORTH	TOLERANCE (M)	DEPTH (M)	METHOD OF SAMPLING	FREQ OF SAMPLING	LOCAL AUTHORITY	AUTHORISED SAMPLER(S)	LOCAL AUTHORITY LIAISON OFFICER
Vaila Sound: Linga	Linga	SI 288	Mussels	Rope	HU 2393 4842	423930	1148420	20	1	Hand	Monthly	Shetland Islands	Sean Williamson George Williamson Kathryn Winter Marion Slater	Dawn Manson
Vaila Sound: Galtaskerry	East of Linga and Galtaskerry	TBA	Mussels	Rope	HU 2440 4703	424400	1147030	20	1	Hand	Monthly	Shetland Islands	Sean Williamson George Williamson Kathryn Winter Marion Slater	Dawn Manson
Vaila Sound: Riskaness	Riskaness	SI 289	Mussels	Rope	HU 2312 4831	423120	1148310	20	1	Hand	Monthly	Shetland Islands	Sean Williamson George Williamson Kathryn Winter Marion Slater	Dawn Manson
	Lera Voe		Mussels	Rope	HU 2221 4831	422210	1148310	20	1	Hand	Monthly for 1 year	Shetland Islands	Sean Williamson George Williamson Kathryn Winter Marion Slater	Dawn Manson

Comparative Table of Boundaries and RMPs

New Production Area	Species	Old PA/SIN	Existing Boundary	Existing RMP	New Boundary	New RMP	Comments
Vaila Sound: Linga SI 288	Common mussels	Vaila Sound Linga SI 288 457 08	Area bounded by lines drawn from HU 2358 4719 and HU 2387 4766 and between HU 2416 4620 and HU 2459 4620 (Rams Head) and from HU 2369 4840 to HU 2382 4832 extending to MHWS	HU 232 483	Area bounded by lines drawn between HU 2382 4832 and HU 2382 4858 and between HU 2382 4858 and HU 2432 4858 and between HU 2432 4858 and HU 2432 4824 and between HU 2432 4824 and HU 2405 4824 extending to MHWS	HU 2393 4842	Established as separate production area due to geographical variation in historical results and in sources of contamination
Vaila Sound: Galtaskerry SI TBD	Common mussels	Vaila Sound Galtaskerry SI 288 456 08	Area bounded by lines drawn from HU 2358 4719 and HU 2387 4766 and between HU 2416 4620 and HU 2459 4620 (Rams Head) and from HU 2369 4840 to HU 2382 4832 extending to MHWS	New area	Area bounded by lines drawn between HU 2480 4809 and HU 2409 4812 and between HU 2388 4766 and HU 2433 4689 extending to MHWS	HU 2440 4703	Established as separate production area due to geographical variation in historical results and in sources of contamination
		East of Linga SI 288 455 08					
Vaila Sound: Riskaness SI 289	Common mussels	Vaila Sound: Riskaness Riskaness SI 289 458 08	Area bounded by lines drawn between HU 2369 4840 and HU 2382 4832 and between HU 2236 4750 and HU 2387 4766 extending to MHWS	HU 240 484	Area bounded by lines drawn between HU 2290 4848 and HU 2317 4862 and between HU 2342 4842 and HU 2360 4800 and between HU 2360 4800 and HU 2214 4800 and between HU 2214 4800 and HU 2204 4831 extending to MHWS	HU 2312 4831	Boundaries restricted to exclude areas nearest freshwater sources
		Vaila Sound: Riskaness Lera Voe SI 289 805 08				HU 2221 4831	Extended bacteriological survey (1 year) to evaluate relative levels of contamination and determine final RMP

Geology and Soils Assessment

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

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

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

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

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

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

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

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

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

Glossary of Soil Terminology

Calcareous: Containing free calcium carbonate.

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

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

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

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

General Information on Wildlife Impacts

Pinnipeds

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

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

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

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

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

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

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

Cetaceans

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

During 2001-2002, there were confirmed sightings of the following species (Shetland Sea Mammal Group 2003):

Table 1 Cetacean sightings near Shetland by species.

Common name	**Scientific name**	**No. sighted***
Minke whale	*Balaenoptera acutorostrata*	28
Humpback whale	*Megaptera novaeangliae*	1
Sperm whale	*Physeter macrocephalus*	3
Killer whale	*Orcinus orca*	183
Long finned pilot whale	*Globicephala melas*	14
White-beaked dolphin	*Lagenorhynchus albirostris*	399
Atlantic white-sided dolphin	*Lagenorhynchus acutus*	136
Striped dolphin	*Stenella coeruleoalba*	1
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.

Little is known about the volume or bacterial composition of cetacean faeces. It is presumed that their guts will contain commensal bacteria normal to mammals, including *Escherichia coli*.

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

Birds

Seabird populations were surveyed all over Britain as part of the SeaBird 2000 census. These counts are investigated using GIS to give the numbers observed within a 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 x 10^5 faecal coliforms per faecal deposit and ring-billedgulls (*Larus delawarensis*) approximately 1.77 x 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 Paired T-test comparison of results from Linga and Riskaness when sampled on the same day

```
Paired T for Linga - Riskaness
             N    Mean   StDev  SE Mean
Linga       64  1.9028  0.5649   0.0706
Riskaness   64  1.6370  0.5245   0.0656
Difference  64  0.2658  0.7590   0.0949

95% CI for mean difference: (0.0762, 0.4554)
T-Test of mean difference = 0 (vs not = 0): T-Value = 2.80  P-Value = 0.007
```

Section 11.3 Paired T-test comparison of results from Linga and Galtaskerry when sampled on the same day

```
Paired T for Linga - Galtaskerry
              N   Mean  StDev  SE Mean
Linga        24  1.830  0.620    0.126
Galtaskerry  24  1.639  0.588    0.120
Difference   24  0.191  0.793    0.162

95% CI for mean difference: (-0.143, 0.526)
T-Test of mean difference = 0 (vs not = 0): T-Value = 1.18  P-Value = 0.249
```

Section 11.3 Paired T-test comparison of results from Linga and East of Linga when sampled on the same day

```
Paired T for Linga - East of Linga
               N   Mean  StDev  SE Mean
Linga          7  1.981  0.643    0.243
East of Linga  7  1.407  0.411    0.155
Difference     7  0.575  0.432    0.163

95% CI for mean difference: (0.175, 0.974)
T-Test of mean difference = 0 (vs not = 0): T-Value = 3.52  P-Value = 0.013
```

Section 11.3 Paired T-test comparison of results from Riskaness and Galtaskerry when sampled on the same day

```
Paired T for Riskaness - Galtaskerry
              N    Mean  StDev  SE Mean
Riskaness    25   1.608  0.562    0.112
Galtaskerry  25   1.659  0.584    0.117
Difference   25  -0.051  0.851    0.170

95% CI for mean difference: (-0.403, 0.300)
T-Test of mean difference = 0 (vs not = 0): T-Value = -0.30  P-Value = 0.766
```

Section 11.3 Paired T-test comparison of results from Riskaness and East of Linga when sampled on the same day

```
Paired T for Riskaness - East of Linga
               N   Mean  StDev  SE Mean
Riskaness      8  1.544  0.408    0.144
East of Linga  8  1.394  0.382    0.135
Difference     8  0.151  0.486    0.172

95% CI for mean difference: (-0.256, 0.557)
T-Test of mean difference = 0 (vs not = 0): T-Value = 0.88  P-Value = 0.410
```

Section 11.3 Paired T-test comparison of *E. coli* results from Galtaskerry and East of Linga when sampled on the same day

Paired T for Galtaskerry - East of Linga

	N	Mean	StDev	SE Mean
Galtaskerry	4	1.637	0.305	0.152
East of Linga	4	1.561	0.428	0.214
Difference	4	0.075	0.522	0.261

95% CI for mean difference: (-0.755, 0.905)
T-Test of mean difference = 0 (vs not = 0): T-Value = 0.29 P-Value = 0.792

Section 11.3 Chi-square test on numbers of *E. coli* results over 230 MPN/100g by site

Expected counts are printed below observed counts
Chi-Square contributions are printed below expected counts

	Riskaness	Linga	Galtaskerry	Total
1	7	13	6	26
	9.93	9.49	6.57	
	0.866	1.294	0.050	
2	61	52	39	152
	58.07	55.51	38.43	
	0.148	0.221	0.009	
Total	68	65	45	178

Chi-Sq = 2.588, DF = 2, P-Value = 0.274

Section 11.3 Chi-square test on numbers of *E. coli* results less than 50 MPN/100g by site

Expected counts are printed below observed counts
Chi-Square contributions are printed below expected counts

	iskaness	Linga	Galtaskerry	E of Linga	Total
1	43	27	26	10	106
	37.74	36.07	24.97	7.21	
	0.734	2.282	0.042	1.075	
2	25	38	19	3	85
	30.26	28.93	20.03	5.79	
	0.915	2.846	0.053	1.341	
Total	68	65	45	13	191

Chi-Sq = 9.288, DF = 3, P-Value = 0.026

Section 11.5 ANOVA comparison of *E. coli* results by season (Linga)

Source	DF	SS	MS	F	P
Season	3	2.250	0.750	2.51	0.067
Error	61	18.207	0.298		
Total	64	20.458			

S = 0.5463   R-Sq = 11.00%   R-Sq(adj) = 6.62%

```
                                 Individual 95% CIs For Mean Based on
                                 Pooled StDev
Level   N    Mean   StDev  ----+---------+---------+---------+-----
1      18  1.6434  0.5359  (--------*-------)
2      18  1.8678  0.5818          (-------*--------)
3      15  2.1565  0.5662                  (---------*--------)
4      14  1.9666  0.4868            (---------*--------)
                           ----+---------+---------+---------+-----
                             1.50      1.80      2.10      2.40
Pooled StDev = 0.5463
```

Section 11.5 ANOVA comparison of *E. coli* results by season (Galtaskerry)

```
Source  DF      SS     MS     F      P
Season   3   1.585  0.528  1.45  0.243
Error   41  14.959  0.365
Total   44  16.544

S = 0.6040   R-Sq = 9.58%   R-Sq(adj) = 2.97%

                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  ------+---------+---------+---------+---
1      11  1.3800  0.5853  (-----------*-----------)
2       9  1.5247  0.7859     (-------------*------------)
3      13  1.8303  0.4665                  (----------*----------)
4      12  1.7855  0.6016                (-----------*----------)
                           ------+---------+---------+---------+---
                               1.20      1.50      1.80      2.10
Pooled StDev = 0.6040
```

Section 11.5 ANOVA comparison of *E. coli* results by season (Riskaness)

```
Source  DF      SS     MS     F      P
Season   3   0.959  0.320  1.18  0.324
Error   64  17.312  0.271
Total   67  18.271

S = 0.5201   R-Sq = 5.25%   R-Sq(adj) = 0.81%

                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev   -+---------+---------+---------+--------
1      19  1.6283  0.4046         (--------*---------)
2      19  1.7832  0.6862               (--------*---------)
3      17  1.4699  0.5112   (---------*---------)
4      13  1.5468  0.3774    (-----------*----------)
                            -+---------+---------+---------+--------
                           1.25      1.50      1.75      2.00
Pooled StDev = 0.5201
```

Section 11.5 Chi-square test on numbers of *E. coli* results over 230 MPN/100g by season

```
Expected counts are printed below observed counts
Chi-Square contributions are printed below expected counts

       Spring  Summer  Autumn  Winter  Total
    1       4       9       7       7     27
         7.35    6.64    6.79    6.22
        1.527   0.835   0.007   0.098

    2      48      38      41      37    164
        44.65   40.36   41.21   37.78
        0.251   0.138   0.001   0.016

Total      52      47      48      44    191

Chi-Sq = 2.874, DF = 3, P-Value = 0.412
```

Section 11.6.1 Pearson correlation of ranked *E. coli* result and ranked 2 day rainfall (Linga)

```
Pearson correlation of logres rain ranked and 2 day rain ranked = 0.349
P-Value = 0.010
```

Section 11.6.1 Pearson correlation of ranked *E. coli* result and ranked 2 day rainfall (Galtaskerry)

```
Pearson correlation of logres rain ranked and 2 day rain ranked = 0.316
P-Value = 0.044
```

Section 11.6.1 Pearson correlation of ranked *E. coli* result and ranked 2 day rainfall (Riskaness)

```
Pearson correlation of logres rain ranked and 2 day rain ranked = -0.002
P-Value = 0.988
```

Section 11.6.1 Pearson correlation of ranked *E. coli* result and ranked 7 day rainfall (Linga)

```
Pearson correlation of logres rain ranked and 7 day rain ranked = 0.454
P-Value = 0.001
```

Section 11.6.1 Pearson correlation of ranked *E. coli* result and ranked 7 day rainfall (Galtaskerry)

```
Pearson correlation of logres rain ranked and 7 day rain ranked = 0.398
P-Value = 0.010
```

Section 11.6.1 Pearson correlation of ranked *E. coli* result and ranked 7 day rainfall (Riskaness)

```
Pearson correlation of logres rain ranked and 7 day rain ranked = -0.112
P-Value = 0.410
```

Section 11.6.2 Regression analysis – *E. coli* result vs height of previous tide (Linga)

```
The regression equation is
logres linga = 0.327 + 1.02 tide height Linga

Predictor            Coef  SE Coef     T      P
Constant           0.3271   0.6918  0.47  0.638
tide height Linga  1.0194   0.4692  2.17  0.034

S = 0.530646   R-Sq = 8.5%   R-Sq(adj) = 6.7%

Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   1.3289  1.3289  4.72  0.034
Residual Error  51  14.3608  0.2816
Total           52  15.6897

Unusual Observations

       tide
     height  logres
Obs   Linga   linga     Fit  SE Fit  Residual  St Resid
  4    1.30  2.6990  1.6523  0.1067    1.0466      2.01R
 46    1.40  3.1139  1.7543  0.0792    1.3597      2.59R

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

Section 11.6.2 Regression analysis – *E. coli* result vs height of previous tide (Galtaskerry)

```
The regression equation is
logres galtaskerry = 2.73 - 0.698 tide height galtaskerry

Predictor                   Coef  SE Coef      T      P
Constant                  2.7349   0.8913   3.07  0.004
tide height galtaskerry  -0.6980   0.5992  -1.16  0.252

S = 0.611729   R-Sq = 3.8%   R-Sq(adj) = 1.0%

Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.5078  0.5078  1.36  0.252
Residual Error  34  12.7232  0.3742
Total           35  13.2311

Unusual Observations

     tide height       logres
Obs  galtaskerry  galtaskerry    Fit  SE Fit  Residual  St Resid
 19         1.20        3.380  1.897   0.195     1.483     2.56R

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

Section 11.6.2 Regression analysis – *E. coli* result vs height of previous tide (Riskaness)

```
The regression equation is
logres riskaness = 2.28 - 0.470 tide height riskaness

Predictor                 Coef  SE Coef      T      P
Constant                2.2801   0.6441   3.54  0.001
tide height riskaness  -0.4698   0.4316  -1.09  0.281

S = 0.513495   R-Sq = 2.1%   R-Sq(adj) = 0.3%

Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.3125  0.3125  1.19  0.281
Residual Error  54  14.2386  0.2637
Total           55  14.5510

Unusual Observations

     tide height     logres
Obs    riskaness  riskaness     Fit  SE Fit  Residual  St Resid
 26         1.70     2.4914  1.4814  0.1158    1.0100     2.02R
 32         1.20     3.5441  1.7163  0.1404    1.8278     3.70R
 49         1.40     2.6990  1.6223  0.0776    1.0767     2.12R

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

Section 11.6.2 Circular linear correlation for tidal state and *E. coli* result (Linga)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 31 July 2008 16:39:56

Variables (& observations) r p
Angles & Linear (53) 0.1470.341

Section 11.6.2 Circular linear correlation for tidal state and *E. coli* result (Galtaskerry)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 31 July 2008 16:42:12

Variables (& observations)r p
Angles & Linear (36) 0.537.16E-05

Section 11.6.2 Circular linear correlation for tidal state and *E. coli* result (Riskaness)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 31 July 2008 16:35:04

Variables (& observations) r p
Angles & Linear (56) 0.1030.571

Section 11.6.4 Circular linear correlation for 7 day wind direction and *E. coli* result (Linga)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 31 July 2008 17:03:43

Variables (& observations) r p
Angles & Linear (38) 0.4280.002

Section 11.6.4 Circular linear correlation for 7 day wind direction and *E. coli* result (Galtaskerry)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 01 August 2008 10:20:03

Variables (& observations) r p
Angles & Linear (29) 0.391 0.018

Section 11.6.4 Circular linear correlation for 7 day wind direction and *E. coli* result (Riskaness)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 31 July 2008 16:56:32

Variables (& observations) r p
Angles & Linear (41) 0.3610.007

Section 12 T-test comparison of SEPA monitoring results by sampling location

```
Two-sample T for HU 240 484 vs HU 2474 4815

               N   Mean  StDev  SE Mean
HU 240 484    12  2.008  0.731     0.21
HU 2474 4815  18  1.960  0.735     0.17

Difference = mu (HU 240 484) - mu (HU 2474 4815)
Estimate for difference:  0.049
95% CI for difference:  (-0.516, 0.613)
T-Test of difference = 0 (vs not =): T-Value = 0.18  P-Value = 0.860  DF =
23
```

Section 12 ANOVA comparison of SEPA sampling results by quarter

```
Source   DF      SS     MS     F      P
Quarter   3   4.544  1.515  3.74  0.023
Error    26  10.533  0.405
Total    29  15.076

S = 0.6365   R-Sq = 30.14%   R-Sq(adj) = 22.08%

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level  N    Mean   StDev  ---------+---------+---------+---------+
Q1     7  1.5216  0.4687  (--------*---------)
Q2     7  1.6846  0.4385     (---------*---------)
Q3     8  2.5233  1.0166                    (--------*---------)
Q4     8  2.0923  0.3437            (--------*--------)
                          ---------+---------+---------+---------+
                                1.50      2.00      2.50      3.00
Pooled StDev = 0.6365

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

Individual confidence level = 98.91%

Quarter = Q1 subtracted from:

Quarter    Lower  Center   Upper  -------+---------+---------+---------+--
Q2       -0.7704  0.1630  1.0964          (---------*--------)
Q3        0.0979  1.0016  1.9054                   (--------*--------)
Q4       -0.3330  0.5707  1.4745               (--------*--------)
                                  -------+---------+---------+---------+--
                                      -1.0       0.0       1.0       2.0
Quarter = Q2 subtracted from:

Quarter    Lower  Center   Upper  -------+---------+---------+---------+--
Q3       -0.0651  0.8387  1.7424                 (--------*--------)
Q4       -0.4960  0.4078  1.3115             (--------*--------)
                                  -------+---------+---------+---------+--
                                      -1.0       0.0       1.0       2.0
Quarter = Q3 subtracted from:

Quarter    Lower   Center   Upper  -------+---------+---------+---------+--
Q4       -1.3040  -0.4309  0.4422      (--------*-------)
                                   -------+---------+---------+---------+--
                                       -1.0       0.0       1.0       2.0
```

Section 15 ANOVA comparison of shoreline survey mussel sampling results by site

```
Source  DF      SS      MS     F      P
Site     4  2.3518  0.5879  6.83  0.001
Error   21  1.8083  0.0861
Total   25  4.1601

S = 0.2934   R-Sq = 56.53%   R-Sq(adj) = 48.25%

                                  Individual 95% CIs For Mean Based on
                                  Pooled StDev
Level          N    Mean   StDev  ---------+---------+---------+---------+
East of Linga  6  1.3075  0.3810           (------*------)
Galtaskerry    3  1.1003  0.1738  (---------*----------)
Lera Voe       6  1.8925  0.3414                            (------*------)
Linga          5  1.0602  0.1346   (-------*-------)
Riskaness      6  1.3835  0.2707             (-------*------)
                                  ---------+---------+---------+---------+
                                        1.05      1.40      1.75      2.10

Pooled StDev = 0.2934
```

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

Individual confidence level = 99.28%

Site = East of Linga subtracted from:

Site            Lower   Center   Upper  --------+---------+---------+--------
Galtaskerry  -0.8249  -0.2072  0.4105          (------*-------)
Lera Voe      0.0807   0.5850  1.0894                     (-----*------)
Linga        -0.7763  -0.2473  0.2817          (------*------)
Riskaness    -0.4284   0.0760  0.5803               (-----*-----)
                                        --------+---------+---------+--------
                                             -0.80      0.00      0.80

Site = Galtaskerry subtracted from:

Site          Lower   Center   Upper  --------+---------+---------+---------+
Lera Voe    0.1745   0.7922  1.4099                      (-------*-------)
Linga      -0.6781  -0.0401  0.5978            (------*-------)
Riskaness  -0.3345   0.2832  0.9009                (-------*------)
                                      --------+---------+---------+---------+
                                           -0.80      0.00      0.80      1.60

Site = Lera Voe subtracted from:

Site         Lower   Center    Upper  --------+---------+---------+---------+
Linga      -1.3613  -0.8323  -0.3034   (------*-----)
Riskaness  -1.0134  -0.5090  -0.0047       (------*-----)
                                      --------+---------+---------+---------+
                                            -0.80      0.00      0.80    1.60

Site = Linga subtracted from:

Site          Lower  Center   Upper  --------+---------+---------+---------+-
Riskaness  -0.2057  0.3233  0.8523                (------*------)
                                     --------+---------+---------+---------+-
                                          -0.80      0.00      0.80      1.60
```

<u>Section 15 ANOVA comparison of shoreline survey mussel sampling results by depth (top, middle and bottom)</u>

```
Source  DF     SS     MS     F      P
BMT      2  0.214  0.107  0.62  0.545
Error   23  3.946  0.172
Total   25  4.160

S = 0.4142   R-Sq = 5.14%   R-Sq(adj) = 0.00%

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level  N    Mean   StDev  ---------+---------+---------+---------+
B      8  1.3556  0.3507    (--------------*--------------)
M      9  1.2975  0.4490  (-------------*-------------)
T      9  1.5090  0.4291            (-------------*-------------)
                          ---------+---------+---------+---------+
                                1.20      1.40      1.60      1.80

Pooled StDev = 0.4142
```

Hydrographic Methods

Introduction

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. This document collects together information common to all hydrographic assessments avoiding the repetition of information in each individual report.

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.

The regulations require an appreciation of the hydrography and currents within a region classified for shellfish production.

Background processes

This section gives an overview of the hydrographic processes relevant to sanitary surveys.

Movement in the estuarine and coastal waters is generally driven by one of three mechanisms: 1) Tides, 2) Winds, 3) Density differences. Unless tidal flows are weak they usually dominate over the short term (~12 hours) and move material over the length of the tidal excursion. The tidal residual flow acts over longer time scales to give a net direction of transport. 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.

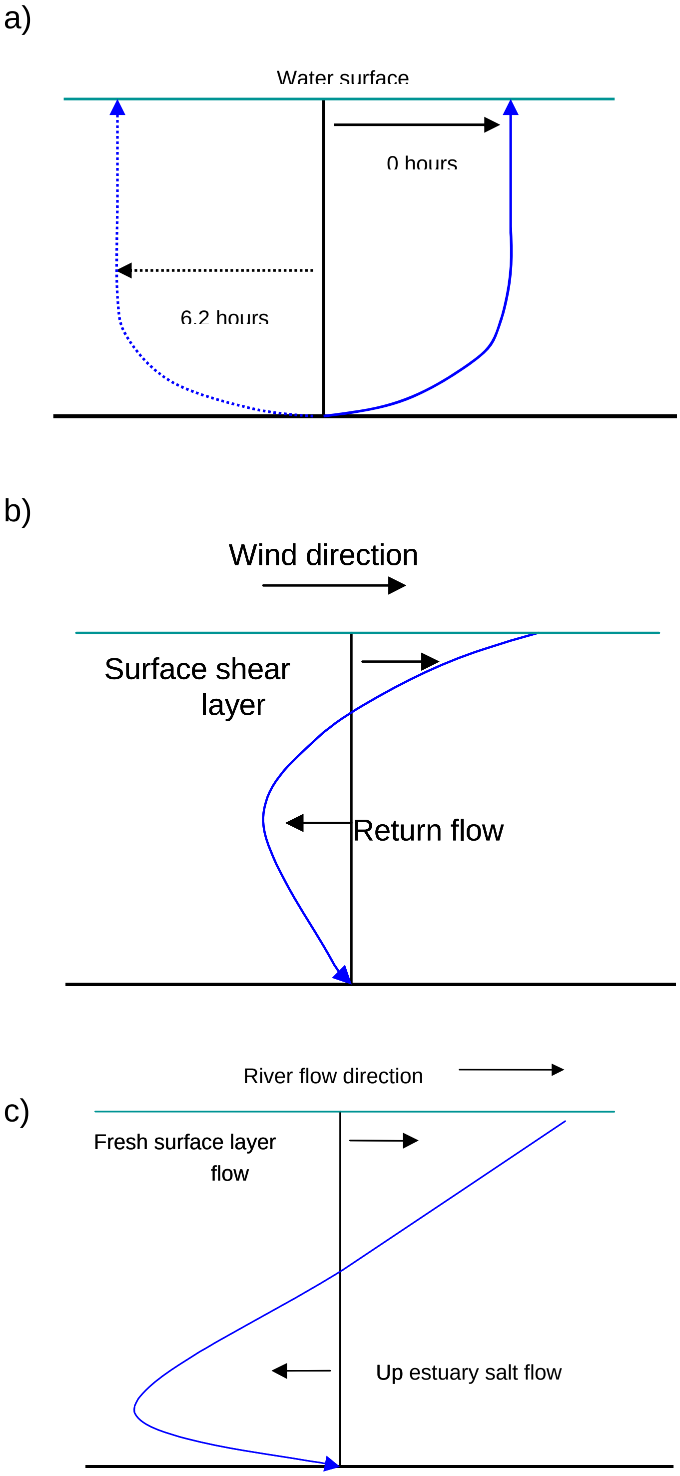

Figure 1 Typical vertical profiles for water currents.

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

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

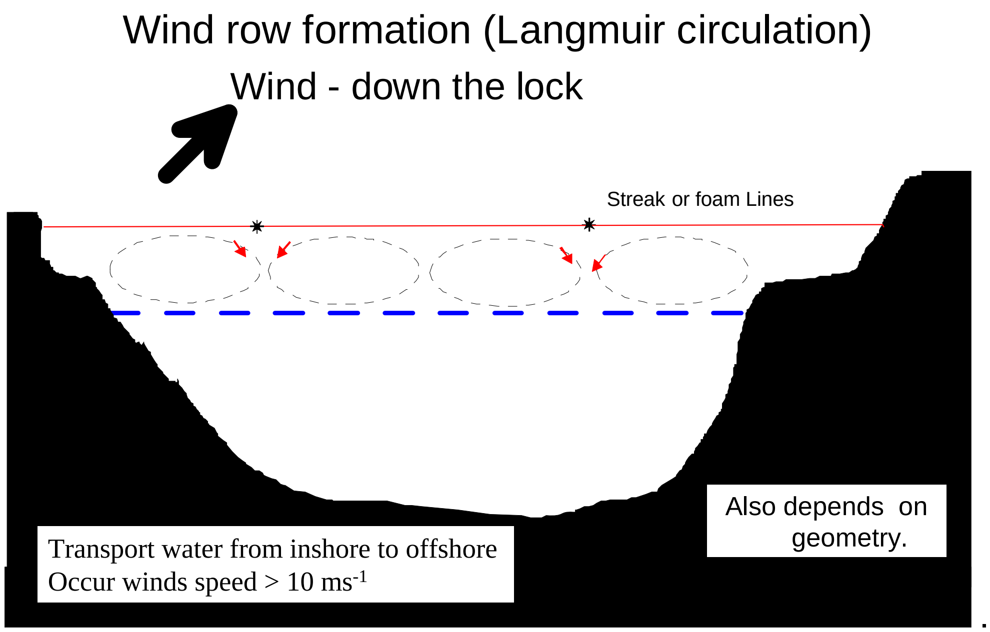

Figure 2 Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Shoreline Survey Report

Vaila Sound (SI 288) and Vaila Sound: Riskaness (SI 289)

Scottish Sanitary Survey Project

Shoreline Survey Report

Production Areas:

Production Area	Site	SIN	Species
Vaila Sound	Linga	SI 288 457 08	Mussels
Vaila Sound	Galtaskerry	SI 288 456 08	Mussels
Vaila Sound	East of Linga	SI 288 455 08	Mussels
Vaila Sound: Riskaness	Riskaness	SI 289 458 08	Mussels
Vaila Sound: Riskaness	Lera Voe	SI 289 805 08	Mussels

Harvesters: Lera Voe, Galtaskerry and East of Linga sites – North Atlantic Shellfish
Linga and Riskaness sites – Demlane
Status: Both production areas are currently classified for harvest.
Date Surveyed: 22/7/08 to 24/7/08
Surveyed by: Sean Williamson, Alastair Cook
Existing RMPs: HU 240484, HU 232483
Area Surveyed: See Figure 1.

Weather observations

22/7/08 Wind 20 Km/h Westerly, 12 ºC, overcast with occasional light showers
23/7/08 Wind 16 Km/h Westerly, 14 ºC, overcast
24/7/08 Wind 22 Km/h Westerly, 16 ºC, sunny

Site Observations

Specific observations made on site are mapped in Figure 1 and listed in Table 1. Water and shellfish samples were collected at sites marked on Figures 2 and 3. Bacteriology results are given in Tables 2 and 3. Photographs are presented in Figures 4-25.

Fishery

Vaila Sound: Linga (SI 288 457 08) consists of 6 float lines from which 8 m droppers are suspended. Vaila Sound Riskaness: Riskaness (SI 289 458 08) consists of 6 float lines from which 10 m droppers are suspended. These two sites are owned by Demlane, and are usually harvested between September and April, with the timing of harvest dependent on demand, biotoxin status, and the status of other sites under the same ownership.

Vaila Sound: East of Linga (SI 288 455 08) consists of 5 float lines from which 8 m droppers are suspended. Vaila Sound: Galtaskerry (SI 288 456 08) consists of 6 float lines from which 5 m droppers are suspended. Vaila Sound Riskaness: Lera Voe (SI 289 805 08) consists of 5 float lines from which 8 m droppers are suspended. These three sites are owned by North Atlantic

Shellfish, and can be harvested at any time of year dependent on demand, biotoxin status, and the status of other sites under the same ownership.

Stock of a range of sizes, including harvestable size was present on all sites.

Sewage/Faecal Sources

Human – The main population centre in the area is the village of Walls, at the eastern head of the voe. Here there are two communal septic tanks with outflows into the voe, and a further 10 pipes believed to be private sewage discharges. Around the rest of the mainland shore, houses are spread at a low density, and a further 10 septic tanks were seen associated with these. Not all houses had a visible septic tank, and not all septic tanks had an overflow pipe to the voe. No septic tanks were seen on Vaila Island, although there were 2 houses here. The island of Linga is uninhabited.

Livestock – The entire area surrounding the production area is pasture which is grazed by sheep. A total of over 350 sheep were recorded during the survey. Droppings were present in most areas. Sheep had access the shoreline around most of the voe. In addition to the sheep, a total of 12 cows, 3 pigs, 2 ponies and 4 domestic geese were recorded. The geese are believed to be feral. No sheep were seen on Linga, but the sampling co-ordinator advised that 50 sheep are usually left on the island during the summer months.

A few streams discharge into the voe and these drain areas of pasture. Water samples were taken, and discharge estimated where the streams were of sufficient size for flow to be measured. It must be noted that water levels were low, and some of the smaller streams marked on the Ordnance Survey map, although wetted in places, had negligible flow. Stream inputs had levels of *E. coli* between 10-7000 cfu/100ml.

For the Linga, East of Linga and Riskaness sites all seawater sample results were <1 *E. coli* cfu/100ml, and for Galtaskerry the one sample gave a result of 1 *E. coli* cfu/100ml. At the Lera Voe site, results of 2 and 9 *E. coli* cfu/100ml were reported. Of seawater samples taken from the shore, highest results (4100, 4000, 780 and 700 *E. coli* cfu/100ml) were obtained at selected points on the north and west shores, away from the main settlement of Walls. Other samples taken in this area yielded lower results.

Rope mussel samples contained *E. coli* concentrations ranging from <20 to 170 MPN/100g. The highest 5 results came from the Lera Voe site.

Surface salinity measurements taken during the survey showed salinities all approaching that of full strength seawater (35 ppt).

Seasonal Population

A small number of the dwellings seen on the shoreline survey are believed to be holiday homes.

Boats/Shipping

Boat traffic in Vaila Sound includes small pleasure craft, mussel and salmon farm boats, and the Foula ferry. A marina was observed at Walls, where a total of 18 small boats were tied up. Next to the marina was a boat club, where two small boats were tied up. Other moorings or jettys were seen on Vaila (2 jettys and one small boat), at the North Atlantic Shellfish building (one jetty and mussel boat), and in Lera Voe (4 small boats on moorings, salmon jetty with 3 boats). The small Foula ferry sails twice weekly in winter, and three times weekly in summer from the pier in Walls. A large barge that is likely to have on board toilets was moored next to the salmon farm just off Vaila.

Land Use

Aside from the houses and their gardens, the land surrounding the production areas is pasture, some of which appeared to be improved, with the majority unimproved. All pasture is grazed by sheep.

Wildlife/Birds

Rabbits are present on all pasture land, but were not observed not in great numbers during the survey. A seal was seen just off Vaila island. A total of approximately 100 wild geese were seen during the course of the survey. About 100 seagulls were seen around the salmon farm just off Vaila island.

General observations

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.

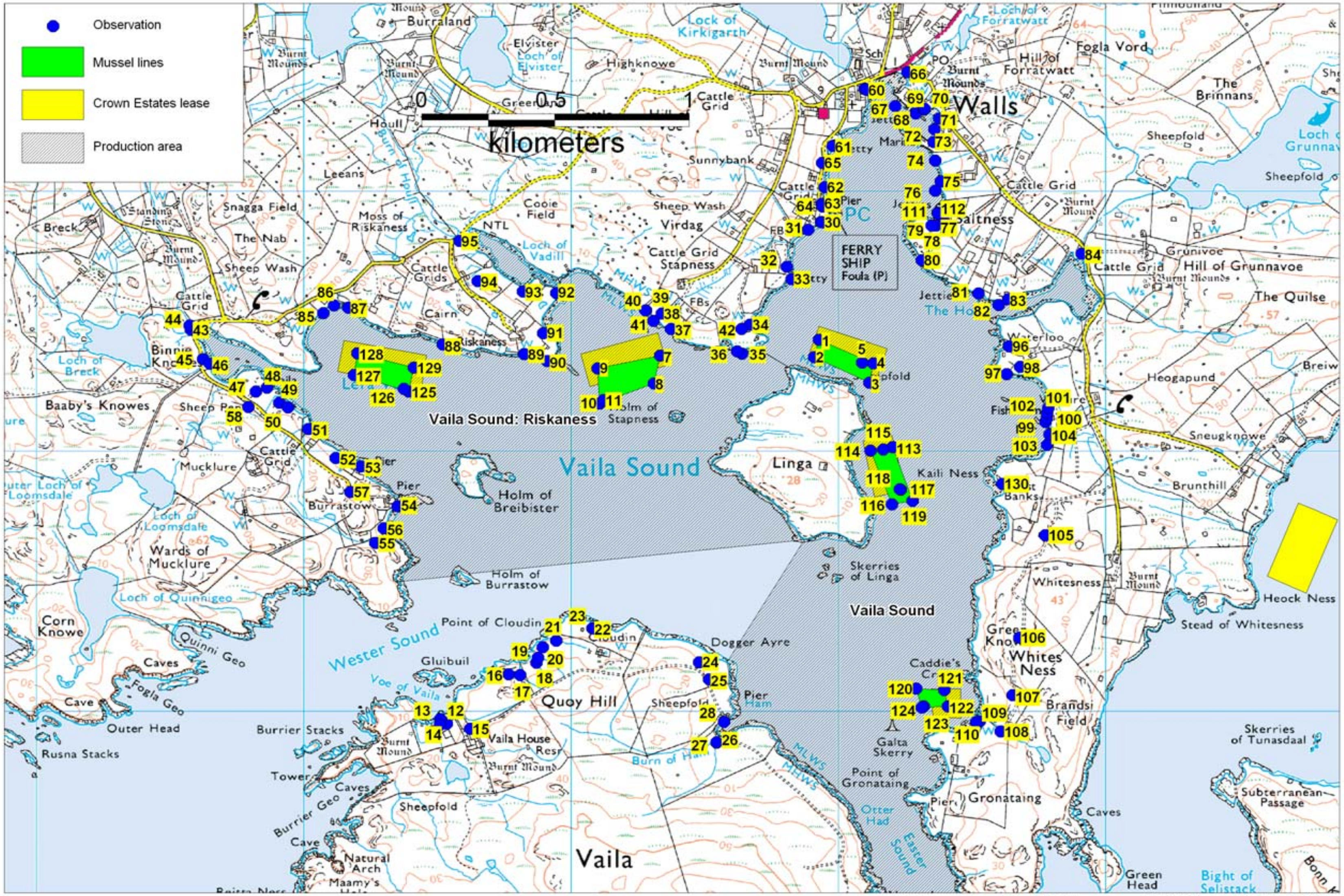

Figure 1. Map of Shoreline Observations

Table 1. Shoreline observations

No.	Date	Position	Photograph	Description
1	22-JUL-08 9:40:56AM	HU 23927 48429		Corner of lines
2	22-JUL-08 9:41:36AM	HU 23909 48362		Corner of lines. Seawater sample 1 34ppt. Mussel sample 1 (Bottom), 2 (middle), 3 (top). 8m droppers
3	22-JUL-08 10:01:45AM	HU 24116 48265		Corner of lines
4	22-JUL-08 10:02:37AM	HU 24131 48339		Corner of lines
5	22-JUL-08 10:04:46AM	HU 24090 48342		Seawater sample 2 35ppt. Mussel samples 4 (bottom) 5 (middle) 6 (top). 8m droppers
6	22-JUL-08 10:19:10AM	HU 23334 48369		Corner of lines
7	22-JUL-08 10:19:10AM	HU 23334 48369		No recorded observation
8	22-JUL-08 10:20:25AM	HU 23310 48262		Corner of lines. Seawater sample 3 34ppt. Mussel sample 7 (Bottom), 8 (middle), 9 (top). 10m droppers
9	22-JUL-08 10:35:17AM	HU 23099 48319		Corner of lines
10	22-JUL-08 10:36:42AM	HU 23107 48184		Corner of lines
11	22-JUL-08 10:38:11AM	HU 23121 48198		Seawater sample 4 34ppt. Mussel samples 10 (bottom) 11 (middle) 12 (top). 10m droppers
12	22-JUL-08 11:02:20AM	HU 22535 46954		Pier with one boat
13	22-JUL-08 11:11:54AM	HU 22511 46972		Seawater 5 35 ppt. Seal in bay
14	22-JUL-08 11:14:58AM	HU 22509 46949		Disused house and shed, large house.
15	22-JUL-08 11:19:29AM	HU 22623 46934	Figure 4	3 pigs
16	22-JUL-08 11:26:26AM	HU 22767 47144	Figure 5	5 cattle, possibly more behind hill
17	22-JUL-08 11:27:10AM	HU 22809 47141		Very small stream
18	22-JUL-08 11:29:31AM	HU 22870 47188		Very small stream
19	22-JUL-08 11:29:47AM	HU 22876 47208		Very small stream
20	22-JUL-08 11:31:42AM	HU 22894 47247		20 geese disturbed
21	22-JUL-08 11:33:58AM	HU 22945 47273		Very small stream
22	22-JUL-08 11:36:16AM	HU 23079 47321	Figure 6	Salmon farm with barge about 200m off shore
23	22-JUL-08 11:36:52AM	HU 23088 47319	Figure 6	20 geese disturbed. Approx 100 seagulls around fish farm
24	22-JUL-08 11:42:55AM	HU 23479 47190		20 geese on water about 200m off shore

No.	Date	Position	Photograph	Description
25	22-JUL-08 11:44:19AM	HU 23516 47125		Very small stream
26	22-JUL-08 11:49:07AM	HU 23545 46881		Stream 62cmx15cmx0.085 m/s. Freshwater sample 6.
27	22-JUL-08 11:53:11AM	HU 23545 46882		No recorded observation
28	22-JUL-08 11:57:07AM	HU 23572 46961		Seawater sample 7 35ppt. Jetty and boatshed.
29	22-JUL-08 12:36:42PM	HU 23935 48882	Figures 7 and 8	Septic tank with 12cm cast iron pipe to underwater. Serves the pier toilets and about 7 houses.
30	22-JUL-08 12:40:37PM	HU 23940 48881		Seawater sample 8 33ppt.
31	22-JUL-08 12:45:38PM	HU 23887 48853	Figure 9	White 12cm plastic sewer pipe to underwater. Possibly redundant.
32	22-JUL-08 12:49:49PM	HU 23807 48710	Figure 10	Septic tank with 12cm white plastic pipe to underwater. Serves one house.
33	22-JUL-08 12:53:36PM	HU 23825 48663		Seawater sample 9 35 ppt.
34	22-JUL-08 1:00:17PM	HU 23669 48488		Dung on shoreline
35	22-JUL-08 1:04:52PM	HU 23639 48376		2 rabbits. Seawater sample 10 35ppt.
36	22-JUL-08 1:07:29PM	HU 23621 48385		29 sheep
37	22-JUL-08 1:14:30PM	HU 23373 48471		very small stream. House with pony behind.
38	22-JUL-08 1:17:39PM	HU 23340 48530		Stream 10cmx3cmx0.259m/s. Freshwater sample 11.
39	22-JUL-08 1:21:13PM	HU 23280 48543		No recorded observation
40	22-JUL-08 1:21:18PM	HU 23279 48542		21 sheep
41	22-JUL-08 1:23:06PM	HU 23308 48502		Seawater sample 12 33ppt.
42	22-JUL-08 1:33:16PM	HU 23638 48471	Figure 11	Septic tank for 1 house. No overflow pipe seen.
43	22-JUL-08 2:05:22PM	HU 21577 48468		Stream 95cmx5cmx0.142m/s. Freshwater sample 13.
44	22-JUL-08 2:08:44PM	HU 21572 48485		Stream 60cmx5cmx0.136m/s. Freshwater sample 14.
45	22-JUL-08 2:12:20PM	HU 21623 48355	Figure 12	Septic tank belonging to one house with channel cut in soil down to sea. Some odour. 4 small boats on moorings
46	22-JUL-08 2:15:10PM	HU 21648 48337		Seawater sample 15 35ppt.
47	22-JUL-08 2:22:22PM	HU 21820 48230		19 sheep in field
48	22-JUL-08 2:24:09PM	HU 21862 48245	Figure 13	Septic tank with 12cm orange plastic overflow to underwater. Serves one house.
49	22-JUL-08 2:26:30PM	HU 21908 48187	Figure 14	Septic tank from one house. Orange 12cm plastic pipe buried, possibly discharging to very small stream.

No.	Date	Position	Photograph	Description
50	22-JUL-08 2:28:50PM	HU 21941 48170		5 sheep
51	22-JUL-08 2:31:47PM	HU 22017 48087		Very small stream
52	22-JUL-08 2:36:10PM	HU 22119 47975		Salmon cages about 100m offshore
53	22-JUL-08 2:38:21PM	HU 22213 47942		Salmon shed, 3 boats, jetty
54	22-JUL-08 2:44:25PM	HU 22351 47790		Big house, sheds, no septic tank seen. 5 sheep, 2 ponies.
55	22-JUL-08 2:52:56PM	HU 22268 47648		Stream 44cmx6cmx0.113m/s. Freshwater sample 16
56	22-JUL-08 2:57:53PM	HU 22299 47705		Seawater sample 17 35ppt.
57	22-JUL-08 3:04:09PM	HU 22174 47844	Figure 15	Livestock shed/pen.
58	22-JUL-08 3:12:30PM	HU 21793 48171	Figure 16	Sheep pen.
59	23-JUL-08 10:07:48AM	HU 24099 49395		Stream 430cmx8cmx0.073m/s. Freshwater sample 18.
60	23-JUL-08 10:12:33AM	HU 24105 49390	Figure 17	10cm cast iron sewer pipe, nothing coming from end.
61	23-JUL-08 10:21:15AM	HU 23980 49175		Seawater sample 19 32 ppt.
62	23-JUL-08 10:28:16AM	HU 23949 49016	Figure 18	Septic tank with 12cm cast iron pipe to underwater. Grey water coming from end. Probably serves 3 or 4 houses.
63	23-JUL-08 10:36:31AM	HU 23938 48952	Figure 19	12cm ceramic septic outfall to underwater, probably serves 1 house.
64	23-JUL-08 10:37:37AM	HU 23941 48942	Figure 19	12cm ceramic septic outfall to beach, probably serves 1 house, not flowing but owners away.
65	23-JUL-08 10:41:27AM	HU 23940 49109		12 sheep in field behind road.
66	23-JUL-08 10:52:27AM	HU 24258 49458		Stream 170cmx12cmx0.088m/s. Freshwater sample 20
67	23-JUL-08 10:58:31AM	HU 24212 49328		Seawater sample 21 33 ppt.
68	23-JUL-08 11:02:59AM	HU 24290 49300		Boat club, jetty, 2 dinghys tied up.
69	23-JUL-08 11:05:15AM	HU 24321 49314	Figure 20	White 12cm plastic sewer pipe to beach, dripping.
70	23-JUL-08 11:06:07AM	HU 24323 49318	Figure 20	Stream through concrete pipe under road, 15mcx2cmx0.214m/s. Freshwater sample 22.
71	23-JUL-08 11:10:30AM	HU 24378 49280		12cm metal sewer pipe to underwater
72	23-JUL-08 11:11:48AM	HU 24360 49239	Figure 21	12cm orange plastic sewer pipe to underwater
73	23-JUL-08 11:13:49AM	HU 24357 49190	Figure 22	Marina with 18 small boats tied up.
74	23-JUL-08 11:16:05AM	HU 24362 49118		Field of 45 sheep
75	23-JUL-08 11:18:58AM	HU 24383 49039		15cm orange ceramic sewer pipe not flowing.

No.	Date	Position	Photograph	Description
76	23-JUL-08 11:20:26AM	HU 24362 49003		Seawater sample 36 33ppt
77	23-JUL-08 11:24:09AM	HU 24392 48901		7 cattle
78	23-JUL-08 11:25:10AM	HU 24365 48869		Very small stream
79	23-JUL-08 11:25:39AM	HU 24349 48869		Stream 13cmx3cmx0.052m/s. Freshwater sample 23
80	23-JUL-08 11:31:51AM	HU 24312 48735		Very small stream
81	23-JUL-08 11:36:24AM	HU 24524 48607		Very small stream
82	23-JUL-08 11:38:30AM	HU 24600 48563		Seawater sample 24 32ppt.
83	23-JUL-08 11:41:20AM	HU 24636 48586		51 sheep
84	23-JUL-08 11:47:46AM	HU 24910 48760		Stream 80cmx15cmx0.141m/s. Freshwater sample 25
85	23-JUL-08 12:27:40PM	HU 22073 48532		Seawater sample 27 34ppt
86	23-JUL-08 12:30:58PM	HU 22113 48561		Stream 26cmx3cmx0.062m/s. Freshwater sample 26
87	23-JUL-08 12:32:33PM	HU 22166 48553		15 sheep
88	23-JUL-08 12:39:25PM	HU 22520 48411		18 sheep
89	23-JUL-08 12:46:21PM	HU 22824 48374	Figure 23	12cm orange plastic sewer pipe, flowing, toilet paper around end. 40 geese disturbed.
90	23-JUL-08 12:52:13PM	HU 22910 48348		Seawater sample 28 34ppt.
91	23-JUL-08 12:57:14PM	HU 22896 48454		15 sheep
92	23-JUL-08 1:01:54PM	HU 22945 48609		Seawater sample 29 35ppt
93	23-JUL-08 1:07:09PM	HU 22820 48615		25 sheep
94	23-JUL-08 1:10:15PM	HU 22650 48655		Septic tank in back garden about 50m north, no pipe seen.
95	23-JUL-08 1:24:37PM	HU 22582 48810		Stream 160cmx7cmx0.313m/s. Freshwater sample 30
96	23-JUL-08 1:38:31PM	HU 24639 48404		Disused septic tank no overflow.
97	23-JUL-08 1:41:25PM	HU 24630 48298		4 domestic geese
98	23-JUL-08 1:44:09PM	HU 24681 48325		Septic tank, no overflow visible
99	23-JUL-08 1:53:54PM	HU 24775 48113		North Atlantic Shellfish depot, jetty, 1 boat. Seawater sample 31 34ppt.
100	23-JUL-08 1:57:11PM	HU 24780 48128		2x15cm plastic pipes not flowing.
101	23-JUL-08 1:57:44PM	HU 24782 48149		12 cm orange plastic pipe and 30cm black pipe both flowing quickly (seawater wash?)
102	23-JUL-08 1:58:50PM	HU 24786 48168		10 sheep on beach
103	23-JUL-08 2:11:13PM	HU 24781 48026		Septic tank with overflow pipe to beach not flowing.

No.	Date	Position	Photograph	Description
104	23-JUL-08 2:13:30PM	HU 24790 48065		Stream (through black pipe under road) 27cmx3cmx0.156m/s. Freshwater sample 32.
105	23-JUL-08 2:22:14PM	HU 24774 47678		13 sheep
106	23-JUL-08 2:27:08PM	HU 24678 47284		6 sheep
107	23-JUL-08 2:28:49PM	HU 24652 47063		59 sheep
108	23-JUL-08 2:31:53PM	HU 24607 46924		5 sheep (all buildings near Galtaskerry shoreline are abandoned)
109	23-JUL-08 2:36:56PM	HU 24529 46962		Stream 9cmx7cmx0.125m/s. Freshwater sample 33
110	23-JUL-08 2:39:01PM	HU 24515 46960		Seawater sample 34 34ppt.
111	23-JUL-08 3:04:29PM	HU 24372 48918	Figure 24	Scottish water communal septic tank. Outflow underwater and not visible. Serves most houses on this side of the voe.
112	23-JUL-08 3:07:18PM	HU 24373 48915		Seawater sample 35 34 ppt.
113	24-JUL-08 9:27:04AM	HU 24203 48017		Corner of lines.
114	24-JUL-08 9:27:52AM	HU 24121 48003		Corner of lines
115	24-JUL-08 9:30:35AM	HU 24168 48008		Seawater sample 37 35ppt. Mussel samples 13 (bottom) 14 (middle) 15 (top). 8m droppers.
116	24-JUL-08 9:40:54AM	HU 24201 47797		Corner of lines
117	24-JUL-08 9:42:50AM	HU 24234 47853		No recorded observation
118	24-JUL-08 9:43:41AM	HU 24230 47855		Seawater sample 38 35ppt. Mussel samples 16 (bottom) 17 (middle) and 18 (top). 8m droppers
119	24-JUL-08 9:52:58AM	HU 24278 47811		Corner of lines
120	24-JUL-08 9:57:29AM	HU 24291 47089		Corner of lines
121	24-JUL-08 9:58:21AM	HU 24396 47083		Corner of lines
122	24-JUL-08 9:59:14AM	HU 24410 47021		Corner of lines
123	24-JUL-08 10:00:24AM	HU 24320 47020		Seawater sample 39 35ppt. Mussel samples 19 (bottom) 20 (middle) and 21 (top). 5m droppers
124	24-JUL-08 10:07:30AM	HU 24312 47016		Corner of lines
125	24-JUL-08 10:19:24AM	HU 22392 48230		Corner of lines
126	24-JUL-08 10:19:59AM	HU 22375 48241		Seawater sample 40 34ppt. Mussel samples 22 (bottom) 23 (middle) 24 (top). 9m droppers.

No.	Date	Position	Photograph	Description
127	24-JUL-08 10:31:21AM	HU 22187 48295		Corner of lines. Seawater sample 41 34ppt. Mussel samples 25 (bottom) 26 (middle) 27 (top). 9m droppers.
128	24-JUL-08 10:38:41AM	HU 22200 48378		Corner of lines
129	24-JUL-08 10:40:05AM	HU 22411 48323		Corner of lines
130	24-JUL-08 11:08:04AM	HU 24614 47875	Figure 25	10 sheep. Septic tank up hill by house, no overflow visible.

Table 2. Water sample *E. coli* results

Sample ID	Date and time collected	Grid reference	Type	*E. coli* (cfu/100ml)	Salinity (ppt)
Vaila 1	22-JUL-08 9:41:36AM	HU 23909 48362	Seawater	<1	34.4
Vaila 2	22-JUL-08 10:04:46AM	HU 24090 48342	Seawater	<1	31.7
Vaila 3	22-JUL-08 10:20:25AM	HU 23310 48262	Seawater	<1	33.9
Vaila 4	22-JUL-08 10:38:11AM	HU 23121 48198	Seawater	<1	33.8
Vaila 5	22-JUL-08 11:11:54AM	HU 22511 46972	Seawater	8	33.5
Vaila 6	22-JUL-08 11:49:07AM	HU 23545 46881	Freshwater	130	
Vaila 7	22-JUL-08 11:57:07AM	HU 23572 46961	Seawater	1	33.3
Vaila 8	22-JUL-08 12:40:37PM	HU 23940 48881	Seawater	22	33.3
Vaila 9	22-JUL-08 12:53:36PM	HU 23825 48663	Seawater	3	33.8
Vaila 10	22-JUL-08 1:04:52PM	HU 23639 48376	Seawater	<1	34.0
Vaila 11	22-JUL-08 1:17:39PM	HU 23340 48530	Freshwater	6000	
Vaila 12	22-JUL-08 1:23:06PM	HU 23308 48502	Seawater	700	30.6
Vaila 13	22-JUL-08 2:05:22PM	HU 21577 48468	Freshwater	30	
Vaila 14	22-JUL-08 2:08:44PM	HU 21572 48485	Freshwater	40	
Vaila 15	22-JUL-08 2:15:10PM	HU 21648 48337	Seawater	780	33.8
Vaila 16	22-JUL-08 2:52:56PM	HU 22268 47648	Freshwater	780	
Vaila 17	22-JUL-08 2:57:53PM	HU 22299 47705	Seawater	4000	33.8
Vaila 18	23-JUL-08 10:07:48AM	HU 24099 49395	Freshwater	10	
Vaila 19	23-JUL-08 10:21:15AM	HU 23980 49175	Seawater	6	32.0
Vaila 20	23-JUL-08 10:52:27AM	HU 24258 49458	Freshwater	180	
Vaila 21	23-JUL-08 10:58:31AM	HU 24212 49328	Seawater	40	20.7
Vaila 22	23-JUL-08 11:06:07AM	HU 24323 49318	Freshwater	70	
Vaila 23	23-JUL-08 11:25:39AM	HU 24349 48869	Freshwater	7000	
Vaila 24	23-JUL-08 11:38:30AM	HU 24600 48563	Seawater	6	31.3
Vaila 25	23-JUL-08 11:47:46AM	HU 24910 48760	Freshwater	30	
Vaila 26	23-JUL-08 12:30:58PM	HU 22113 48561	Freshwater	200	
Vaila 27	23-JUL-08 12:27:40PM	HU 22073 48532	Seawater	9	33.4
Vaila 28	23-JUL-08 12:52:13PM	HU 22910 48348	Seawater	18	33.7
Vaila 29	23-JUL-08 1:01:54PM	HU 22945 48609	Seawater	4100	33.3
Vaila 30	23-JUL-08 1:24:37PM	HU 22582 48810	Freshwater	330	
Vaila 31	23-JUL-08 1:53:54PM	HU 24775 48113	Seawater	<1	33.4
Vaila 32	23-JUL-08 2:13:30PM	HU 24790 48065	Freshwater	50	
Vaila 33	23-JUL-08 2:36:56PM	HU 24529 46962	Freshwater	300	
Vaila 34	23-JUL-08 2:39:01PM	HU 24515 46960	Seawater	<1	33.5
Vaila 35	23-JUL-08 3:07:18PM	HU 24373 48915	Seawater	2	33.6
Vaila 36	23-JUL-08 11:20:26AM	HU 24362 49003	Seawater	4	31.8
Vaila 37	24-JUL-08 9:30:35AM	HU 24168 48008	Seawater	<1	34.0
Vaila 38	24-JUL-08 9:43:41AM	HU 24230 47855	Seawater	<1	33.7
Vaila 39	24-JUL-08 10:00:24AM	HU 24320 47020	Seawater	1	34.0
Vaila 40	24-JUL-08 10:19:59AM	HU 22375 48241	Seawater	9	34.1
Vaila 41	24-JUL-08 10:31:21AM	HU 22187 48295	Seawater	2	33.8

Table 3. Mussel sample *E. coli* results

Sample ID	Date	Position	Depth (m)	***E. coli* (MPN/100g)**
Vaila 1	22-JUL-08 9:41:36AM	HU 23909 48362	8	<20
Vaila 2	22-JUL-08 9:41:36AM	HU 23909 48362	4	<20
Vaila 3	22-JUL-08 9:41:36AM	HU 23909 48362	1	<20
Vaila 4	22-JUL-08 10:04:46AM	HU 24090 48342	8	IC (0,0,1)*
Vaila 5	22-JUL-08 10:04:46AM	HU 24090 48342	4	<20
Vaila 6	22-JUL-08 10:04:46AM	HU 24090 48342	1	20
Vaila 7	22-JUL-08 10:20:25AM	HU 23310 48262	10	20
Vaila 8	22-JUL-08 10:20:25AM	HU 23310 48262	5	20
Vaila 9	22-JUL-08 10:20:25AM	HU 23310 48262	1	20
Vaila 10	22-JUL-08 10:38:11AM	HU 23121 48198	10	50
Vaila 11	22-JUL-08 10:38:11AM	HU 23121 48198	5	<20
Vaila 12	22-JUL-08 10:38:11AM	HU 23121 48198	1	50
Vaila 13	24-JUL-08 9:30:35AM	HU 24168 48008	8	<20
Vaila 14	24-JUL-08 9:30:35AM	HU 24168 48008	4	20
Vaila 15	24-JUL-08 9:30:35AM	HU 24168 48008	1	70
Vaila 16	24-JUL-08 9:43:41AM	HU 24230 47855	8	50
Vaila 17	24-JUL-08 9:43:41AM	HU 24230 47855	4	<20
Vaila 18	24-JUL-08 9:43:41AM	HU 24230 47855	1	<20
Vaila 19	24-JUL-08 10:00:24AM	HU 24320 47020	5	<20
Vaila 20	24-JUL-08 10:00:24AM	HU 24320 47020	2.5	<20
Vaila 21	24-JUL-08 10:00:24AM	HU 24320 47020	1	20
Vaila 22	24-JUL-08 10:19:59AM	HU 22375 48241	9	20
Vaila 23	24-JUL-08 10:19:59AM	HU 22375 48241	4.5	170
Vaila 24	24-JUL-08 10:19:59AM	HU 22375 48241	1	170
Vaila 25	24-JUL-08 10:31:21AM	HU 22187 48295	9	70
Vaila 26	24-JUL-08 10:31:21AM	HU 22187 48295	4.5	70
Vaila 27	24-JUL-08 10:31:21AM	HU 22187 48295	1	80

*Invalid result.

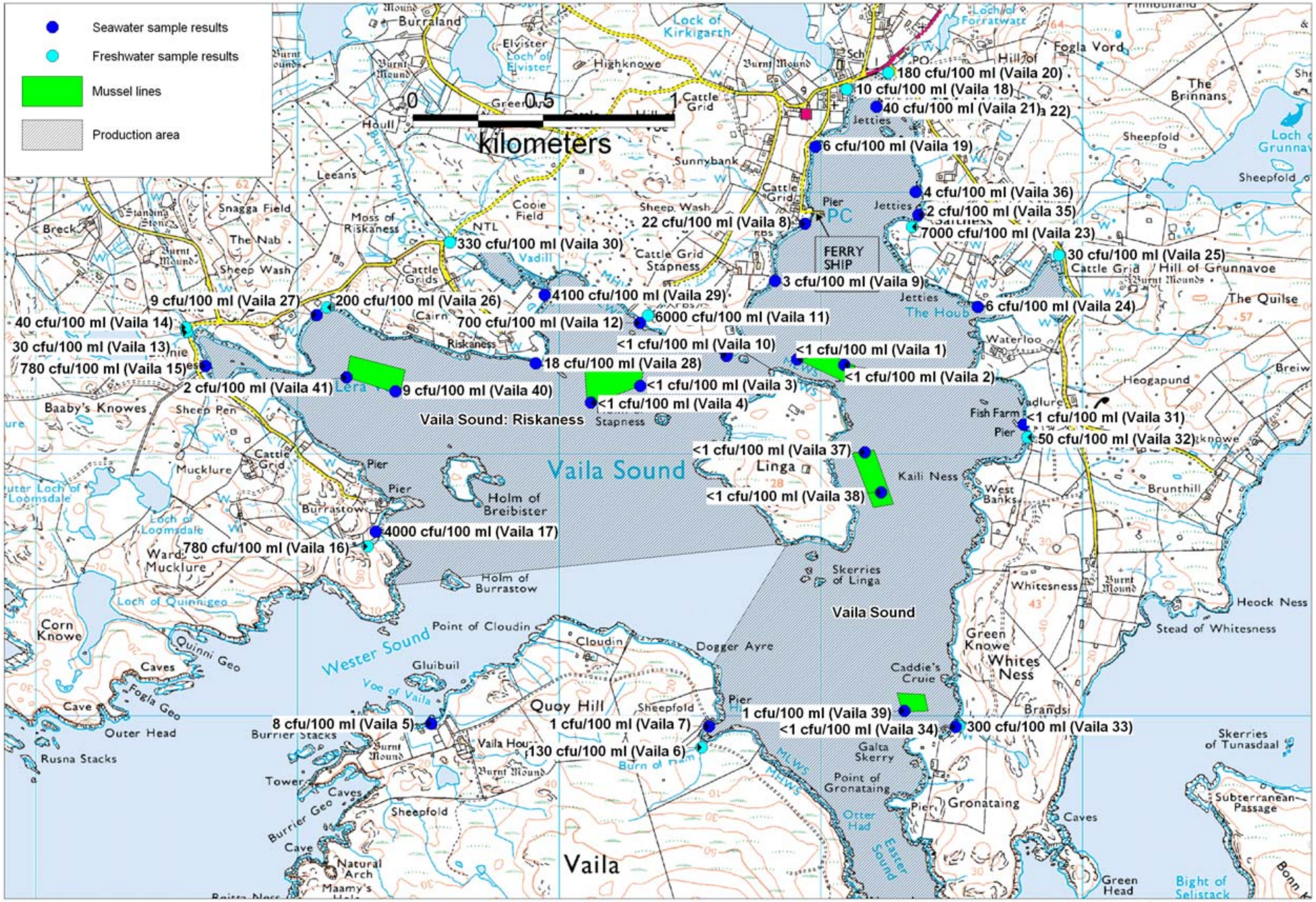

Figure 2 Water sample results map

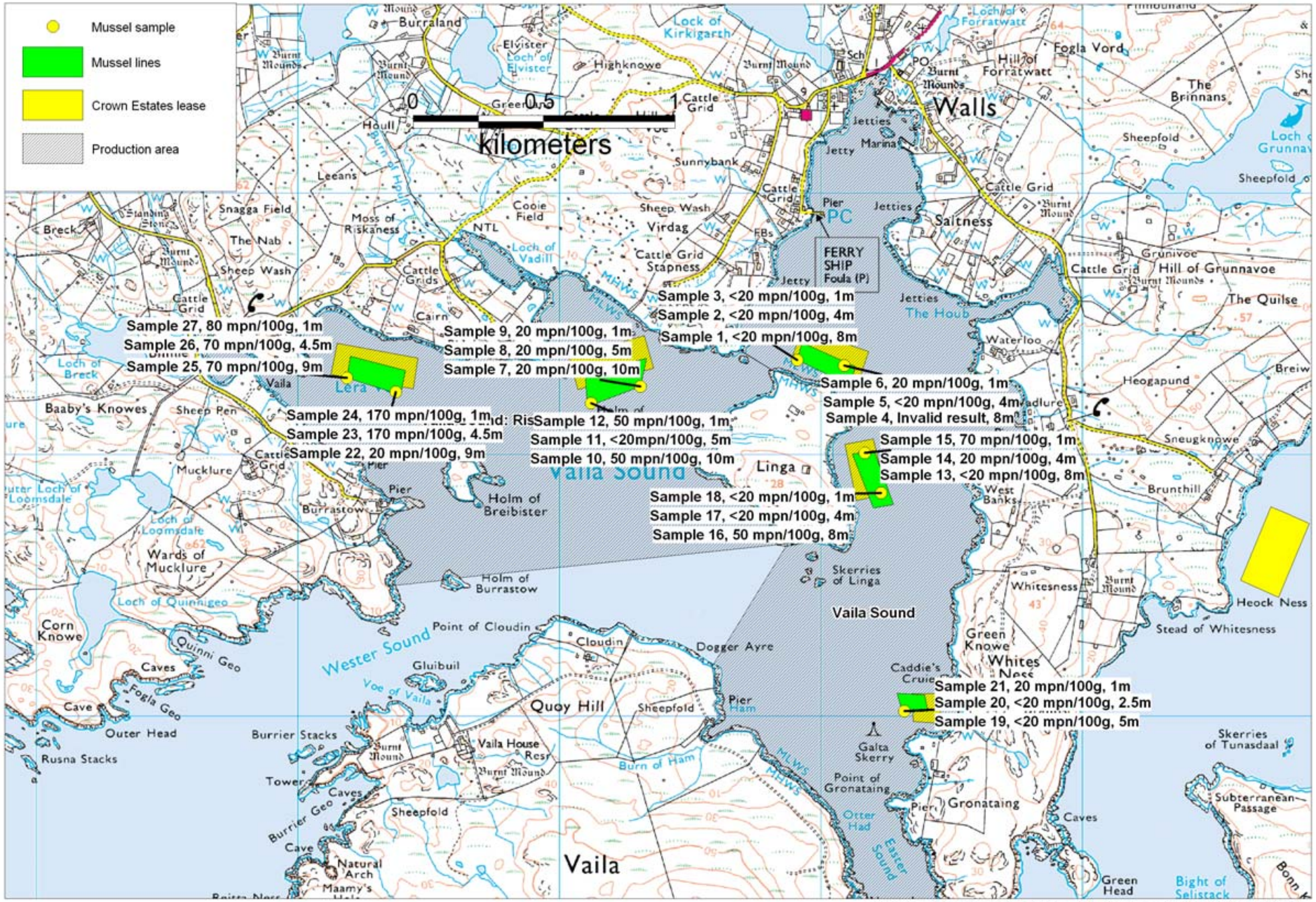

Figure 3 Shellfish sample results map

Figure 4 Pigs on Vaila

Figure 5 Cattle on Vaila

Figure 6 Geese and salmon farm and barge just off Vaila

Figure 7 Communal septic tank outfall

Figure 8 Communal septic tank

Figure 9 Private septic outfall

Figure 10 Private septic outfall

Figure 11 Private septic tank

Figure 12 Private septic tank

Figure 13 Private septic tank

Figure 14 Private septic tank

Figure 15 Livestock pen

Figure 16 Livestock pen

Figure 17 Private septic outfall

Figure 18 Private septic outfall

Figure 19 Private septic outfalls

Figure 20 Private septic outfall and stream

Figure 21 Private septic outfall

Figure 22 Walls marina

Figure 23 Private septic outfall

Figure 24 Communal septic tank

Figure 25 Private septic tank