Scottish Sanitary Survey Project

Sanitary Survey Report
East Burra Firth (SI 055)
Aith Voe: Sletta (SI 326)
February 2010

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

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Appendices

1. General Description

Aith Voe and East Burra Firth are located east of St. Magnus Bay on the western coast of mainland Shetland. East Burra Firth is roughly 0.2 km in width and 0.6 km in length, and forms a sidearm of Aith Voe, which is 3.4km long by 1.3 km at its widest point. East Burra Firth is shallow, with a large intertidal area at its head, while Aith Voe has depth of up to 49 m. The nearest settlement is the village Aith, at the head of Aith Voe. This sanitary survey was undertaken in response to an application for classification for common mussels at a site within East Burra Firth.

Figure 1.1 Location of Aith Voe and East Burra Firth

2. Fishery

There are three active longline mussel farms within Aith Voe and East Burra Firth, as listed in Table 2.1 below.

Table 2.1 East Burra Firth and Aith Voe shellfish sites

Production Area	Site	SIN	Species
East Burra Firth	Aith Voe (East Burra Firth)	SI 055 863 08 (SI 055 421 08)	Common mussels
Aith Voe: Sletta	Point of Sletta	SI 326 393 08	Common mussels
Aith Voe: Sletta	Slyde	SI 326 733 08	Common mussels

There are two sites within the Aith Voe: Sletta production area which is currently classified for the harvest of mussels. East Burra Firth was previously classified as SI 055 421 08 but was declassified in 2007. Although the sanitary survey was triggered by an application to harvest mussels at the site within East Burra Firth, the Aith Voe: Sletta production area is included in this sanitary survey as it is immediately adjacent to East Burra Firth. Another former mussel production area (Aith Voe: Ayres, SI 325) lies to the south of Aith Voe Sletta, and to the west of East Burra Firth. This area was declassified in 2009, and although there is a Crown Estates lease within this area, there is currently no tackle on the site. Therefore, this area will only be considered in terms of contamination sources of relevance to the active sites and its historical *E. coli* classification monitoring results.

The Aith Voe Sletta production area is an area bounded by lines drawn between HU 3558 5927 and HU 3377 5990 and HU 3377 5990 to HU 3500 5965 and HU 3522 5800 to HU 3385 5800. The nominal RMP for this production area is located at HU 348 586. A sample location at HU 342 588 , which lies on the Point of Sletta spat line, is now noted as dormant. The boundary of the former East Burra Firth production area is an area inshore of a line drawn between HU 352 580 and HU 351 574.

Figure 2.1 shows the relative positions of the mussel farms and the seabed lease areas in East Burra Firth and Aith Voe.

East Burra Firth (Aith Voe)
This site consisted of three mussel longlines with 6-8m droppers situated just inside the mouth of East Burra Firth. At the time of survey there was little harvestable stock present on this site. The name of the site has been changed from East Burra Firth to Aith Voe due to the application for reclassification being in the new name, although these two names and their associated SINs both represent the same site.

Aith Voe: Sletta (Slyde)
This site consisted of four mussel longlines with 6-8 m droppers, and was being harvested at the time of shoreline survey.

Aith Voe Sletta (Point of Sletta)

This site consists of a single longline that is used for the purpose of collecting spat only.

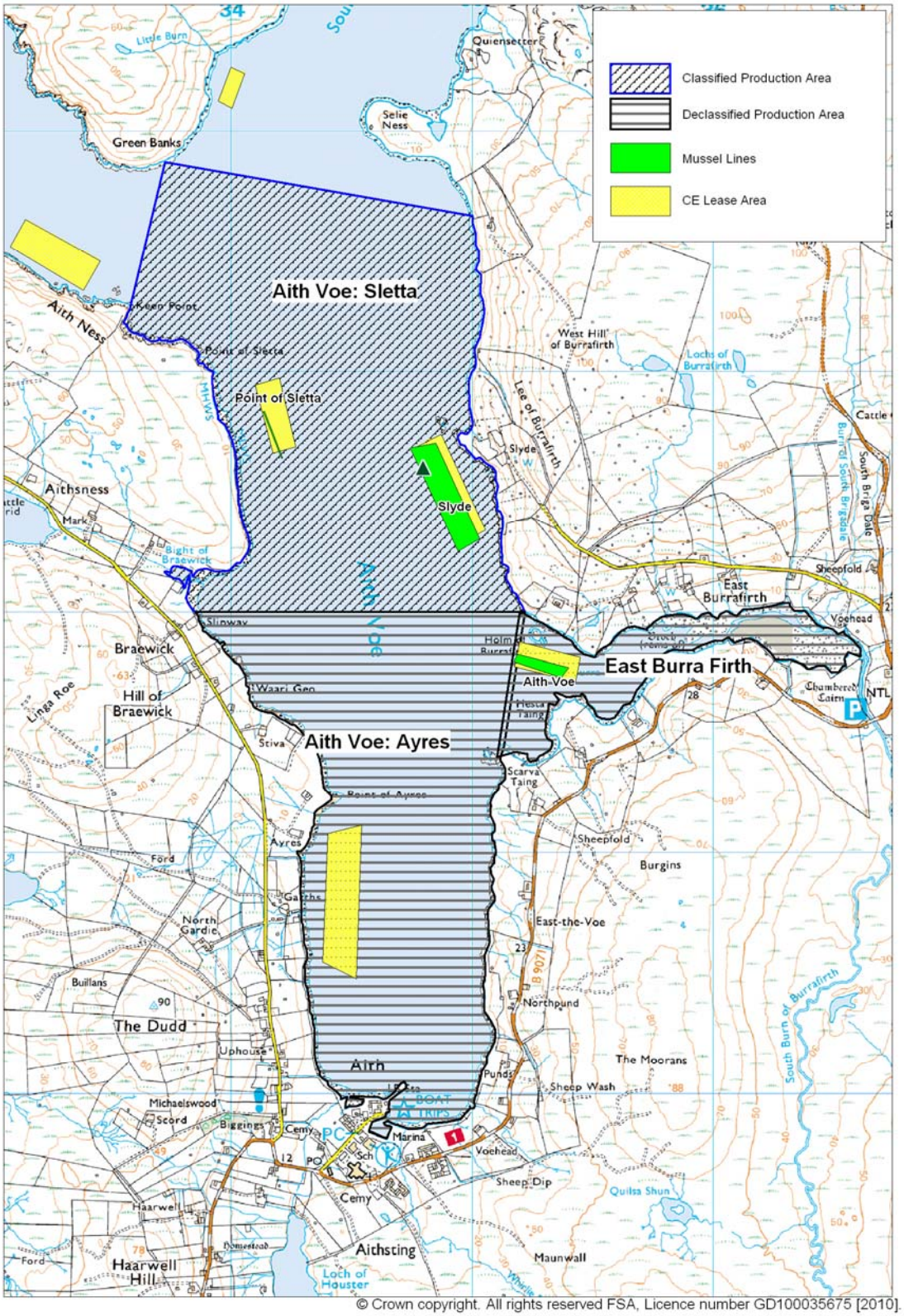

Figure 2.1 East Burra Firth and Aith Voe fisheries

3. Human Population

Figure 3.1 shows information obtained from the General Register Office for Scotland on the population within the census output areas in the vicinity of East Burra Firth and Aith Voe. The last census was undertaken in 2001.

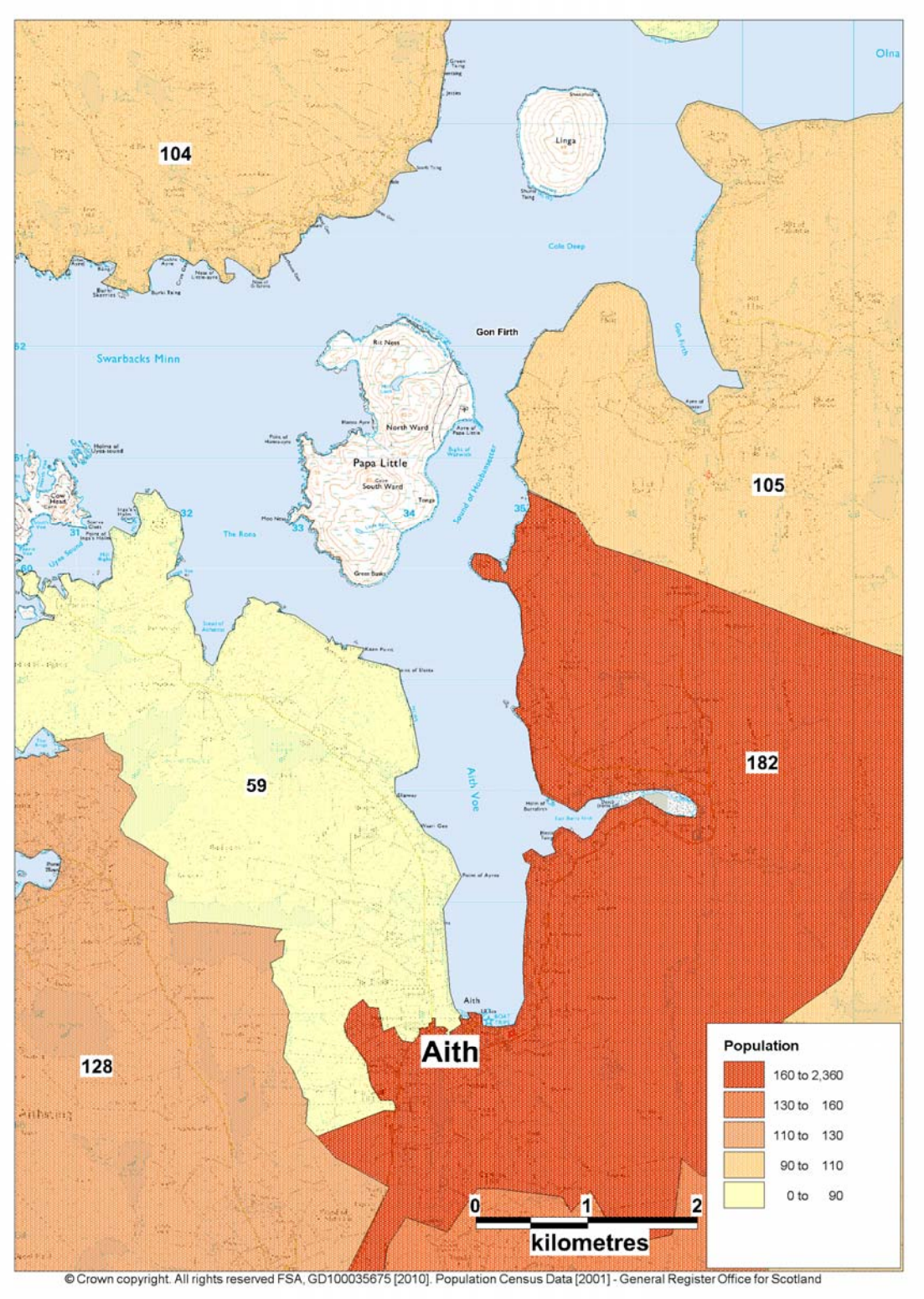

Figure 3.1 Human Population surrounding East Burra Firth and Aith Voe

The population immediately surrounding East Burra Firth is relatively small,, with a population of 182 for the entire census area. Population is centred around the settlement of Aith, at the head of Aith Voe, although there are dwellings spread around the shores of Aith Voe and East Burra Firth. Some dwellings in the area are believed to be holiday homes, and wildlife tours operate from the marina at Aith suggesting population may increase during the summer months. Therefore, inputs from human sewage are likely to be mainly found at Aith, and may be slightly higher during the summer months.

4. Sewage Discharges

One community septic tank was identified by Scottish Water for the area., This tank is consented to serve 300 people and discharges to Aith Voe about 300 m north of Aith and about 125 m off from the east shore of the voe, at a depth of just over 10 m. This system also has two emergency overflows to just below MHWS at Aith. Details are presented in Table 4.1.

Table 4.1 Discharges Identified by Scottish Water

SEPA Consent No.	NGR	Discharge Name	Discharge Type	Level of Treatment	Consented Flow (DWF)	Consented Design PE
S16C, S59B	HU 3457 5601	Aith West WWPS	EO only	None (8 hrs storage)	Not Stated	Not Stated
S16B, S59A	HU 3478 5587	Aith East WWPS	EO only	None (8 hrs storage)	Not Stated	Not Stated
S59X	HU 3495 5624	Aith	Continuous	Septic Tank	70 m^3/d	300

No sanitary or microbiological data is available for these discharges. Ten consented discharges in the area were listed by SEPA, details of which are presented in Table 4.2. The first three entries correspond to the discharges listed in Table 4.1.

Table 4.2 SEPA discharge consents

SEPA Consent No.	NGR of Discharge	Discharge Type	Level of Treatment	Discharges to	Consent Flow (DWF) m^3/d	Conse-nted Design PE
S16C, S59B	HU 3457 5601	Domestic	None (EO only)	Aith Voe	-	120
S16B, S59A	HU 3478 5587	Domestic	None (EO only)	Aith Voe	-	230
S59X	HU 3495 5624	Domestic	Septic tank	Aith Voe	70	300
CAR/R/1013090	HU 3522 5683	Domestic	Septic tank	Land	-	5
CAR/R/1014050	HU 3562 5760	Domestic	Septic tank	Aith Voe	-	5
CAR/R/1020320	HU 3623 5769	Domestic	Septic tank	Land	-	5
CAR/R/1039922	HU 3520 5698	Domestic	Septic tank	Land	-	5
CAR/R/1041943	HU 3531 5725	Domestic	Septic tank	Land	-	8
CAR/R/1039784	HU 3615 5774	Domestic	Septic tank	Land		5
CAR/R/1039870	HU 3602 5812	Domestic	Septic tank	Land		5

Of these, only the Scottish Water septic tank at Aith, and a private septic tank on the shouth shore of East Burra Firth discharge directly to coastal waters. The rest discharge to soakaway, and so are less likely to impact on water quality within the production areas if functioning properly. As there has not historically been a requirement to register septic systems in Scotland, this list is unlikely to cover all septic tanks in the area. A physical survey of the shoreline was undertaken and observations of septic tanks and/or outfalls present along the shoreline are presented in Table 4.3.

Table 4.3 Discharges and septic tanks observed during shoreline survey

No	**Date**	**NGR**	**Description**	**SEPA consent no.**
1	31-Aug-09	HU 34567 55924	Pumping station (Aith West)	S16C, S59B
2	31-Aug-09	HU 34560 55969	Pipe on shoreline running from Aith West pumping station. Ceramic in poor repair with major crack, no apparent flow. Seawater sample 6 by pipe (90 *E. coli* cfu/100ml)	S16C, S59B
3	31-Aug-09	HU 34295 56743	Discharge pipe flowing, sudsy. Flow could not be determined. Water sample 8 from discharge (1900 *E. coli* cfu/100ml)	
4	31-Aug-09	HU 34329 57064	Septic discharge pipe, completely dry, no green algae or other signs of septic input	
5	31-Aug-09	HU 34372 57246	Septic tank with no apparent discharge pipe. Foul water puddled around base with wet, overgrown ditch leading to shoreline. Odour and flies, but no apparent flow over shoreline.	
6	01-Sep-09	HU 33794 57899	Septic tank, concrete, presumably to soakaway	
7	01-Sep-09	HU 33860 57786	Septic tank downhill from road, presumably to soakaway	
8	01-Sep-09	HU 33930 57665	Septic tank below house, concrete, presumably to soakaway	
9	01-Sep-09	HU 33957 57622	Inspection hatch with nearby septic tank downhill, presumably to soakaway	
10	01-Sep-09	HU 34785 55821	Aith East pumping station	S16B, S59A
11	01-Sep-09	HU 34792 55842	Outfall pipe from Aith East pumping station, no odour apparent, seawater sample number 16 by end (4 *E. coli* cfu/100ml)	S16B, S59A
12	01-Sep-09	HU 34863 55855	Discharge pipe, flowing across sand. Water sample 17 from discharge (26000 *E. coli* cfu/100ml)	
13	01-Sep-09	HU 35010 55787	Septic tank downhill from road, presumably to soakaway	
14	01-Sep-09	HU 35330 58025	Septic tank, 1 house, presumably to soakaway	
15	01-Sep-09	HU 36302 58166	Septic tank, 1 house, presumably to soakaway	

Of these, observations 1, 2, 10 and 11 confirm the locations of the Scottish Water pumping stations at Aith. A further three private discharges to Aith Voe were identified. Two of these were on the west shore of Aith Voe, just to the south of Point of Ayres, one of which did not appear to have been in recent use at the time of survey (4), the other of which was flowing (3), but a water sample from this discharge had a low sanitary content. The third possible private discharge to Aith Voe (12) was at Aith, and was discharging water with some (albeit fairly dilute) sanitary content at the time of survey. In addition to these, a further 8 private septic tanks were noted, none of which had a discharge pipe to the shore, so it is presumed that these were all to

soakaway, and therefore should have no impact on water quality in Aith Voe assuming they were functioning correctly. However, one of these (5) at Point of Ayre did not appear to have an effective soakaway as waste water was observed puddled around its base, although it did not appear to be spilling directly to Aith Voe from there.

Figure 4.1 Sewage Discharges at East Burra Firth and Aith Voe

There is a marina at Aith, and a pier and lifeboat station. The shoreline survey recorded that the marina had space for 21 small boats on inshore side, 16 larger boats on other side. At the time, 9 of the boats moored there were of sufficient size to have had onboard toilets which could be discharged overboard. The lifeboat and another work boat were observed by the pier. There are 2 berths and associated facilities for visiting yachts at the marina, and additional berthing space at the public pier. A charter vessel with an on board toilet runs wildlife/sightseeing/angling trips from Aith.

In summary, the main human sewage input to Aith Voe is the Scottish Water septic tank at Aith, which is consented to serve 300 people and discharges to Aith Voe about 300 m north of Aith, and about 125 m off from the east shore of the voe. A discharge consent was issued by SEPA for a small private discharge to the south shore of East Burra Firth, about 280 m to the south west of the Aith Voe site which may cause a localised hotspot of contamination there, though the discharge was not directly observed during the shoreline survey. Three further small private discharges were identified during the shoreline survey, one of which was to Aith Voe at Aith, and two to the west shore of Aith Voe just to the south of the Point of Ayres, although only one of these latter two appeared to have been in recent use at the time of shoreline survey, and the other did not have a major sanitary content when sampled during the survey. Other SEPA discharge consents and other discharges noted during the shoreline survey were all to soakaway. Boat traffic is centred around Aith, and it is likely that several of the boats visiting/operating from here have onboard toilets which discharge to the sea. However, it is not known whether these boats actually discharge waste water within Aith Voe and if so, where and when.

5. Geology and Soils

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

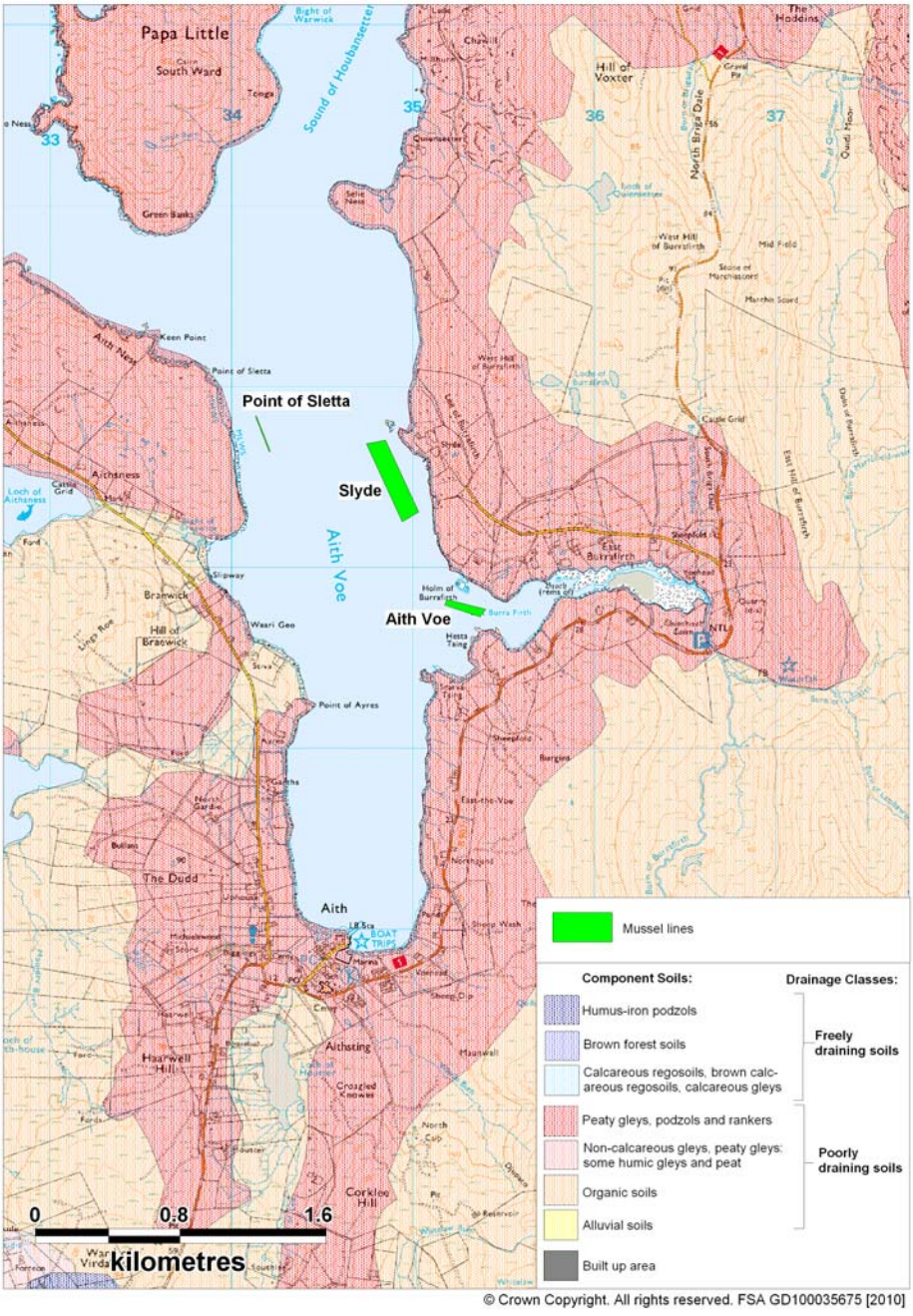

Figure 5.1 Component soils and drainage classes for East Burra Firth and Aith Voe

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

6. Land Cover

The Land Cover Map 2000 data on types of land cover for the area around Aith Voe and East Burra Firth is shown in Figure 6.1 below.

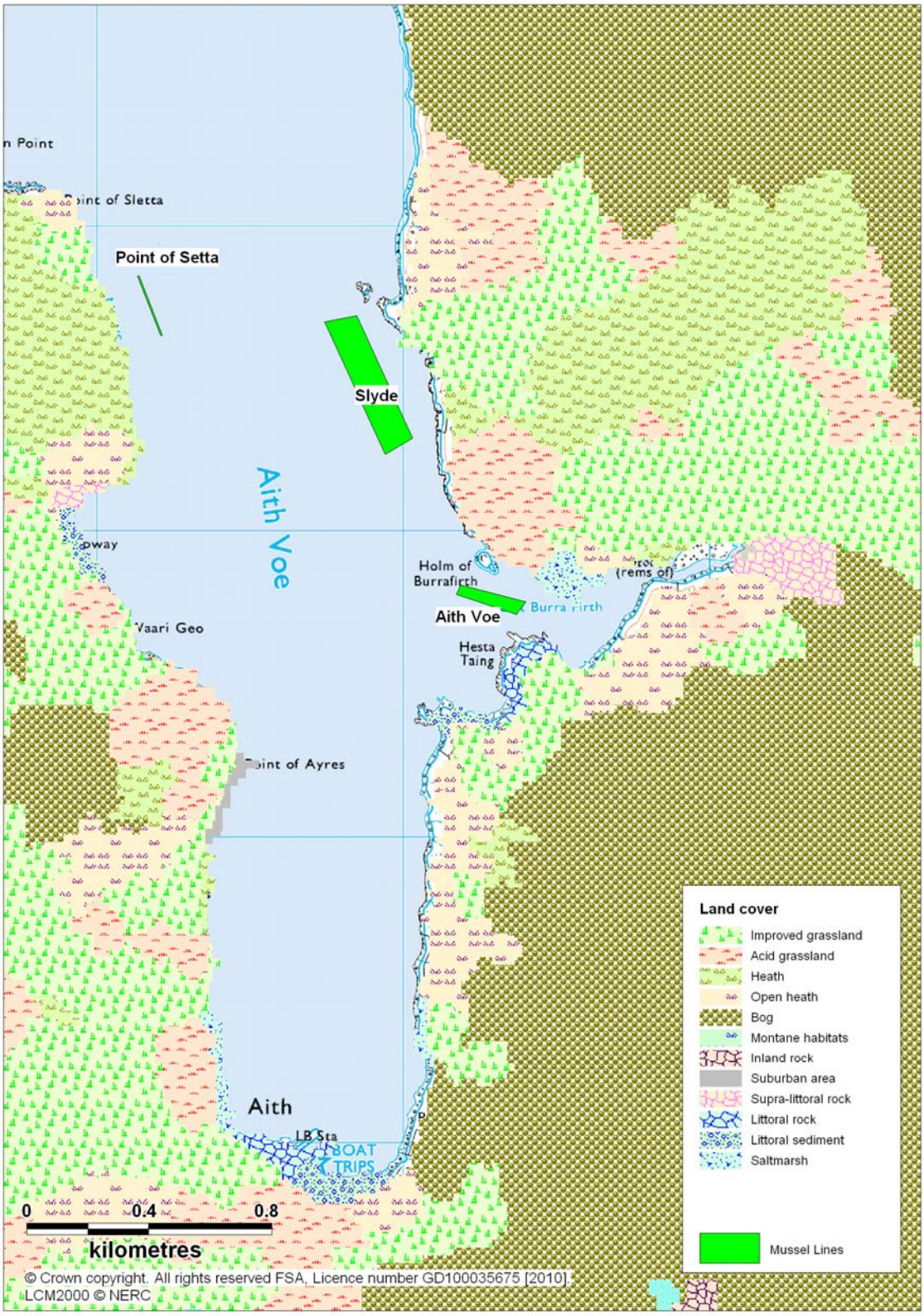

Figure 6.1 LCM2000 class land cover data for East Burra Firth

The land to the east of Aith Voe is predominantly bog inland with patches of improved grassland, acid grassland and heath along the shoreline. Two large areas of improved grassland are found along the northern shore of East Burra Firth and also further north along the east shore of Aith Voe. There are also small patches of supra-littoral rock, saltmarsh and littoral rock along the shoreline of East Burra Firth. The land to the west of Aith Voe also has some patches of bog, heath and acid grassland with large areas of improved grassland stretching northward from Aith.

Developed area is erroneously shown along the western shore south of the Point of Ayres and not shown around the settlement of Aith at the southern end of the voe. There is a paved road around East Burra Firth and the southern end of Aith Voe, providing additional impermeable surface area.

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.

The highest contribution of contaminated runoff is therefore expected to be associated with the developed area around Aith. The overall contribution from the other landcover types would be low to intermediate, and would be expected to increase significantly after rainfall. This is likely to be exacerbated by the presence of poorly drained soils in the area as described in Section 5. The mussel farms at Aith and Slyde both lie close to large areas of improved grassland and so may subject to rainfall-dependent contamination from these areas.

7. Farm Animals

With regard to potential sources of pollution of animal origin, agricultural census data to parish level was requested from the Scottish Government. Agricultural census data was provided by the Rural Environment, Research and Analysis Directorate (RERAD) for the parishes of Aithsting, encompassing a land area of 93 km^2. Reported livestock populations for the parishes in 2007 and 2008 are listed in Table 7.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data. Any entries which relate to less than five holdings, or where two or fewer holdings account for 85% or more of the information, are replaced with an asterisk.

Table 7.1 Livestock Numbers in Aithsting in 2007 and 2008

	2007		2008	
	Holdings	Numbers	Holdings	Numbers
Total pigs	0	0	*	*
Total poultry	17	248	15	215
Total cattle	13	404	12	302
Total sheep	74	21188	72	19764
Deer	0	0	0	0
Horses and Ponies	5	21	8	37

Sheep and cattle are the predominant types of livestock kept within Aisting parish. Due to the large geographic area covered by 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 (Appendix 8), which only relates to the time of the site visit on 31 August - 1 September, 2009. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1. This information is specific only to the survey dates and is dependent upon the point of view of the observer (some animals may have been obscured from view by the terrain).

The shoreline survey confirmed that livestock in the area is predominantly sheep and cattle, in reasonably high numbers. At the time of survey, animals were concentrated around the shores of East Burra Firth, and on the west shore of Aith Voe, so it is likely that streams draining these areas are subject to contamination by livestock. Direct deposition to the intertidal area may also be of significance where animals are not fenced off from the shore and sheep and their droppings were observed on and near the shoreline. Therefore, it is likely that a large proportion of contamination detected within shellfish here is of livestock origin.

Seasonal fluctuation in livestock populations are expected as the numbers of sheep and cattle increase in the spring following the birth of lambs and calves, and decrease in the autumn after they are sent to market.

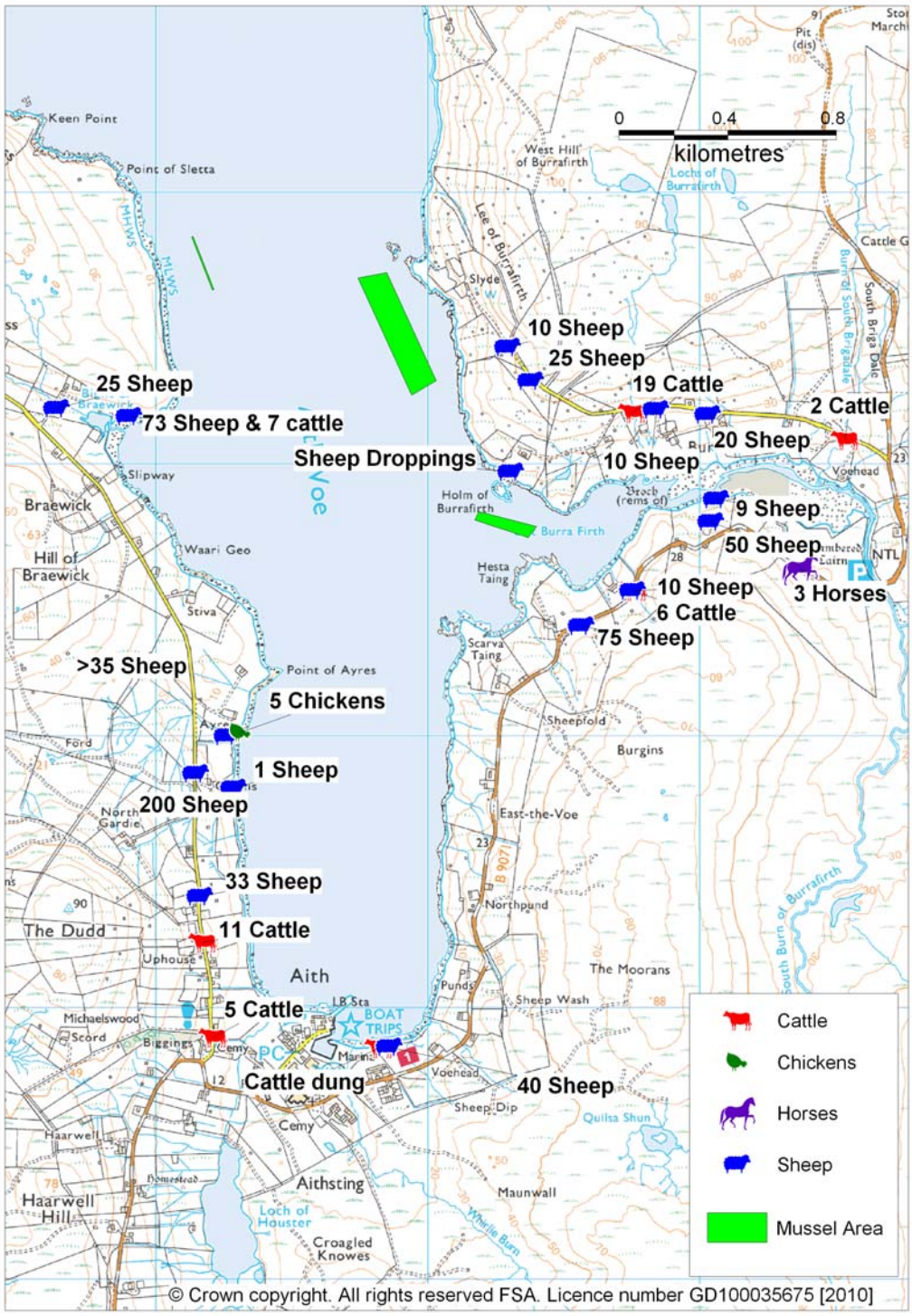

Figure 7.1 Livestock observations at Aith Voe and East Burra Firth

8. Wildlife

General information related to potential risks to water quality by wildlife can be found in Appendix 4. A number of wildlife species present or likely to be present at Aith Voe and East Burra Firth could potentially affect water quality around the fisheries.

Seals

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*). Scotland hosts significant populations of both species.

A survey conducted by the Sea Mammal Research Unit in 2001 estimated a population of 856 common seals in St Magnus Bay (SMRU, 2002). The closest haulout site identified during this survey was on the island of Papa Little, at the mouth of Aith Voe, where between 6 and 10 individuals were recorded.

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). The closest identified breeding colony was at Muckle Roe, about 5 km to the north of the mouth of Aith Voe. Pup production here was estimated at 23 in 2004.

Therefore it is likely that both species of seals regularly frequent the area. During the shoreline survey, 24 seals (species uncertain) were seen hauled out at Uyea Sound, about 3.5 km to the west of the mouth of Aith Voe, and one was seen in the water in the vicinity of Aith.

Whales/Dolphins

A variety of whales and dolphins are routinely observed near Shetland. It is possible that cetaceans will be found from time to time in the area, although the larger species will not visit this area as it is fairly shallow and enclosed. Any impact of their presence is likely to be fleeting and unpredictable.

Birds

A number of bird species are found around Aith Voe and East Burra Firth, but seabirds and waterfowl may be expected to occur around or near the fisheries. 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 and 2002 (Mitchell *et al*, 2004). Total counts of all species recorded within 5 km of the mussel lines are presented in Table 8.1. Where counts are of pairs of birds, the actual number of breeding adults will be

double. This data is also thematically mapped in Figure 8.1, and here each pair is represented as two birds.

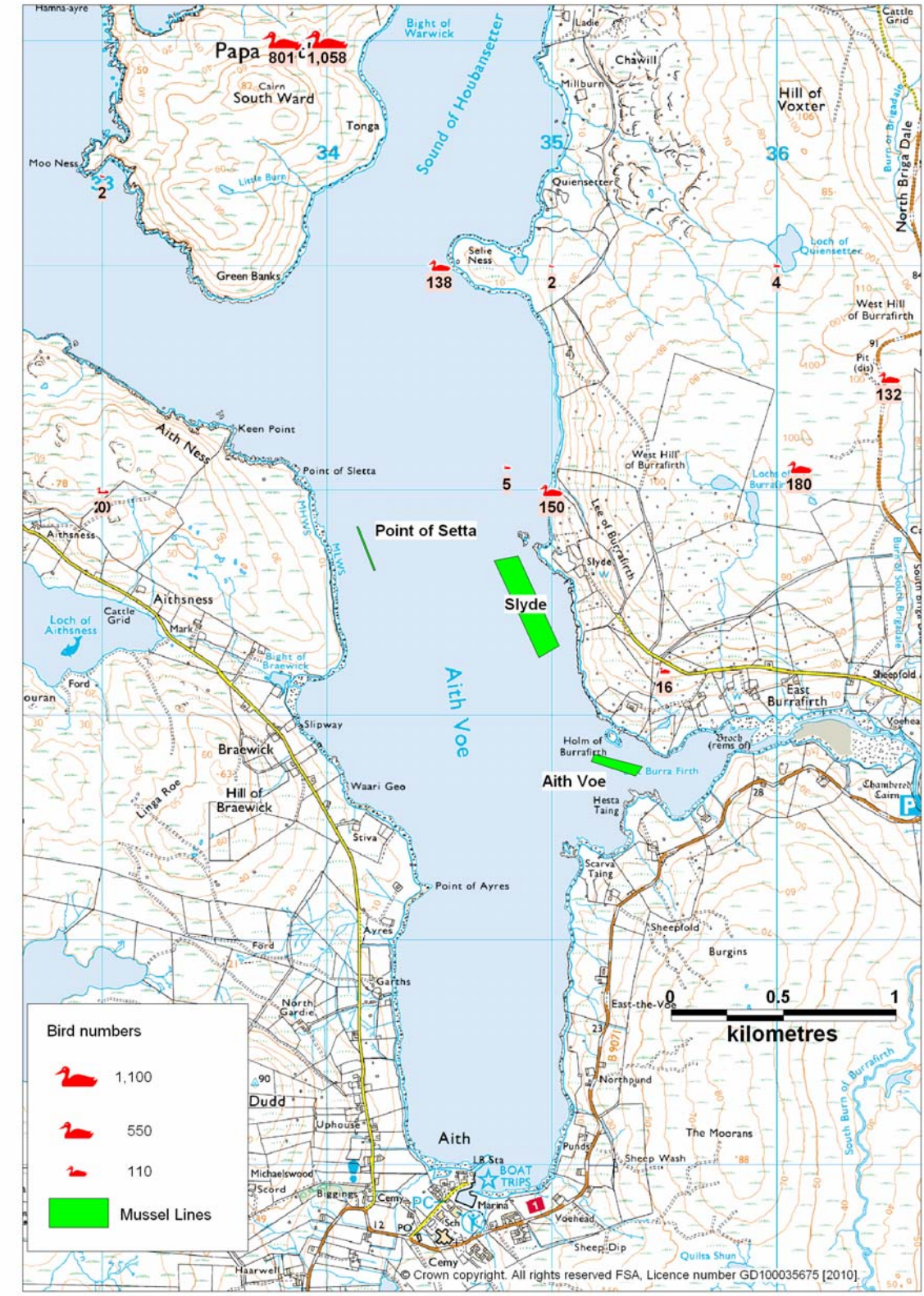

Figure 8.1 Spatial distribution of breeding seabirds near Aith Voe

Table 8.1 Counts of breeding seabirds within 5 km of the mussel sites

Common name	Species	Count	Method	Individual/pair
Northern Fulmar	*Fulmarus glacialis*	1180	Occupied sites	pairs
Arctic Tern	*Sterna paradisaea*	398	Occupied nests/territories	pairs
Herring Gull	*Larus argentatus*	170	Occupied nests/territories	pairs
Common Gull	*Larus canus*	139	Occupied nests/territories	pairs
Great Black-backed Gull	*Larus marinus*	95	Occupied nests/territories	pairs
Black Guillemot	*Cepphus grylle*	64	Individuals on land	individual
Black-headed Gull	*Larus ridibundus*	44	Occupied territory	pairs
Great Skua	*Stercorarius skua*	21	Occupied territory	pairs
Common Tern	*Sterna hirundo*	13	Occupied territory	pairs
Arctic skua	*Stercorarius parasiticus*	11	Occupied territory	pairs
Lesser Black-backed Gull	*Larus fuscus*	4	Occupied territory	pairs
European Shag	*Phalacrocorax aristotelis*	1	Occupied nests	pairs

The seabird census indicated a fairly high density of breeding seabirds in the general area, with several hundred pairs on the island of Papa Little at the mouth of Aith Voe (mainly gulls, terns and fulmars), and on Vementry to the west of Papa Little (mainly terns and fulmars). On the shores of Aith Voe, the highest concentrations were on the east shore, to the north of East Burra Firth. Along this stretch there were 77 pairs of gulls, 67 pairs of fulmars and a handful of other species recorded. Contamination of the production areas from these birds would be via direct deposition as they forage, and through runoff from streams draining the areas in which they nest. Therefore impacts from these species may be of most significance at the Slyde site during the summer breeding season, although of course these birds are highly mobile and direct deposition could occur anywhere and some species are likely to be resident throughout the year.

Waterfowl may be present in the area at various times, either to overwinter, or briefly during migration, or possibly to breed during the summer. No ducks or geese were seen during the course of the shoreline survey, but 5 swans were seen on Aith Voe, and they are believed to roost at Braewick.

Wading birds would be concentrated on intertidal areas, such as that found at the head of East Burra Firth, but no aggregations were noted during the shoreline survey.

Otters

A family of three otters were observed during the course of the shoreline survey, just offshore by the south end of the Slyde mussel lines. However, the typical population densities of coastal otters are low and their impacts on the shellfishery are expected to be very minor.

Summary

In summary, the main wildlife species potentially impacting on the production areas are seals and seabirds. There are significant seal colonies within St

Magnus Bay, and one individual was seen at Aith, so it is likely that they are a regular presence in the area. The main seabird breeding colonies were on Papa Little and Vementry, outside of Aith Voe, although there were significant numbers of breeding sites on the east shore of Aith Voe, to the north of East Burra Firth, so it is possible they impact more on the Slyde site during the breeding season. 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 fishery, for which rainfall and wind data is available for 2003-2008 inclusive. It is likely that overall wind patterns are broadly similar at the fishery and at Lerwick, but local topography may skew these patterns in different ways, and conditions on any given day may differ due to the distance between them. This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish within East Burra Firth and Aith Voe.

9.1 Rainfall

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

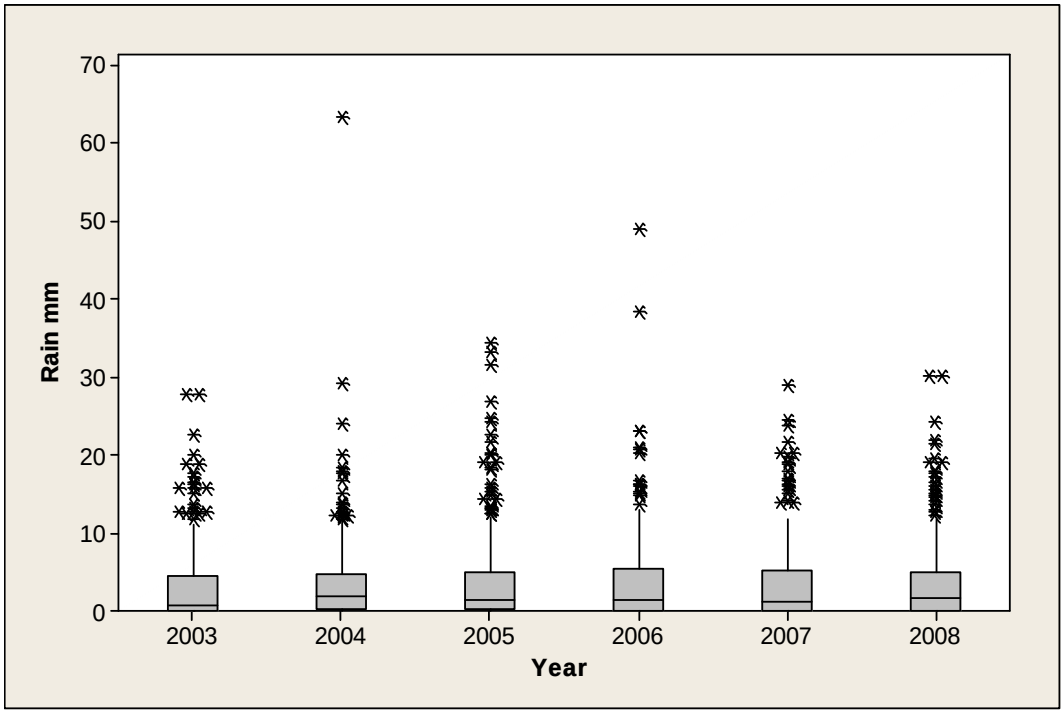

Figure 9.1 Box plot of daily rainfall values by year at Lerwick, 2003-2008

Figure 9.1 shows that daily rainfall patterns were similar between the years presented here, with the exception of marked high rainfall events in 2004 and 2006.

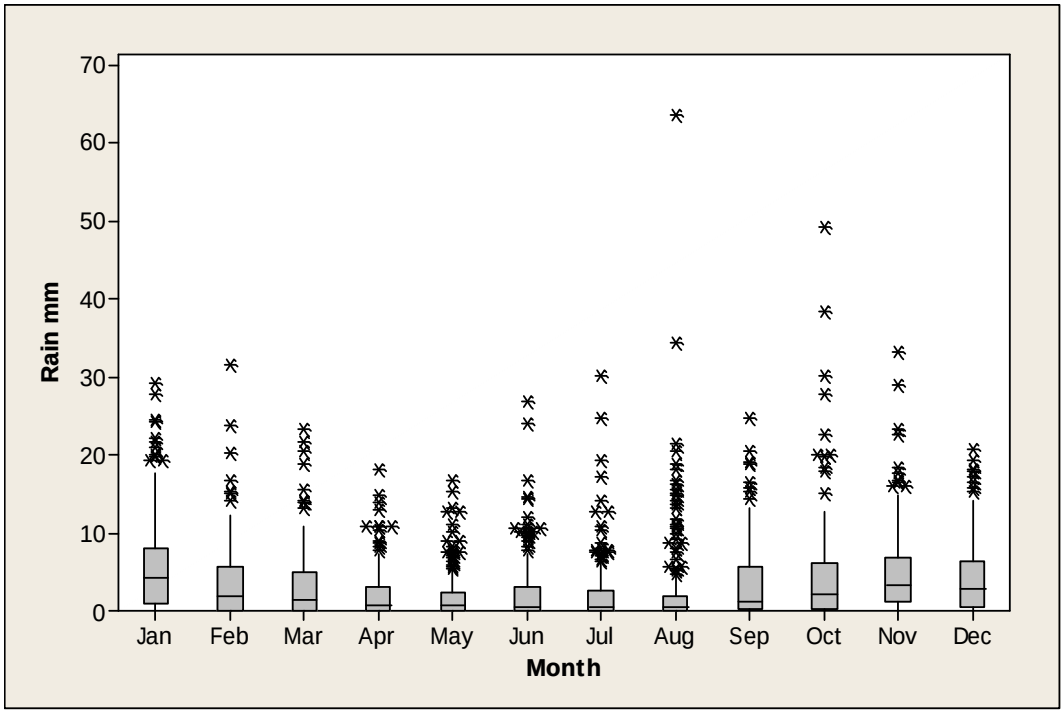

Figure 9.2 Box plot of daily rainfall values by month at Lerwick, 2003-2008

The wettest months were from September to February, and April to August were the driest months on average. Days with high rainfall can occur at any time of the year, although the very wettest days occurred in August (one of the driest months) and October. For the period considered here (2003-2008), 44% of days experienced rainfall less than 1 mm, and 9% of days experienced rainfall of 10 mm or more.

It can therefore be expected that levels of rainfall dependent faecal contamination entering the production area from these sources will be higher on average during the autumn and winter months. High rainfall events can occur at any time of year, perhaps with the exception of April and May, and these may result in a 'first flush' of highly contaminated runoff from pastures. This effect may be particularly acute during the summer, when livestock numbers are likely to be highest, and any preceding dry periods result in a buildup of faecal contamination on pastures.

9.2 Wind

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

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. There is a higher frequency of north easterly winds during the summer.

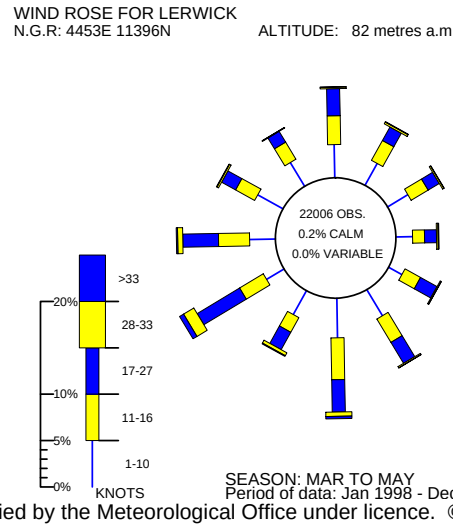

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Figure 9.3 Wind rose for Lerwick (March to May)

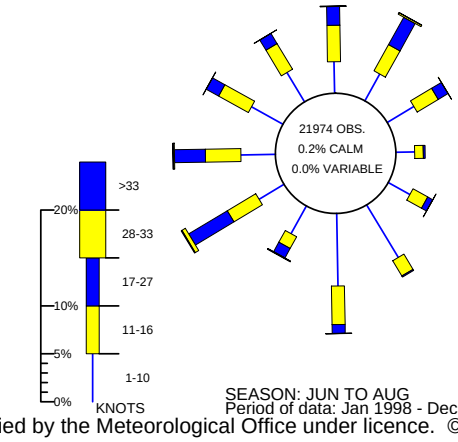

Figure supplied by the Meteorological Office under licence. ©Crown copyright 2010.

Figure 9.4 Wind rose for Lerwick (June to August)

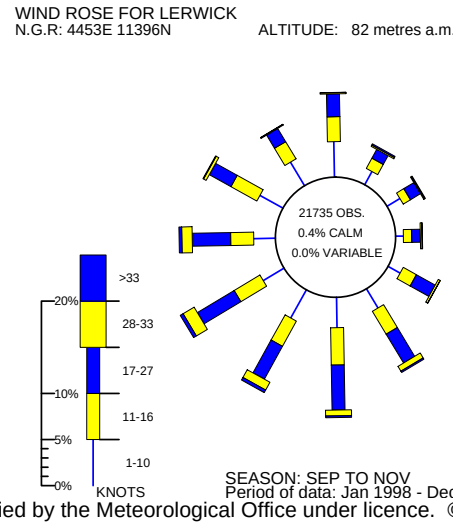

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Figure 9.5 Wind rose for Lerwick (September to November)

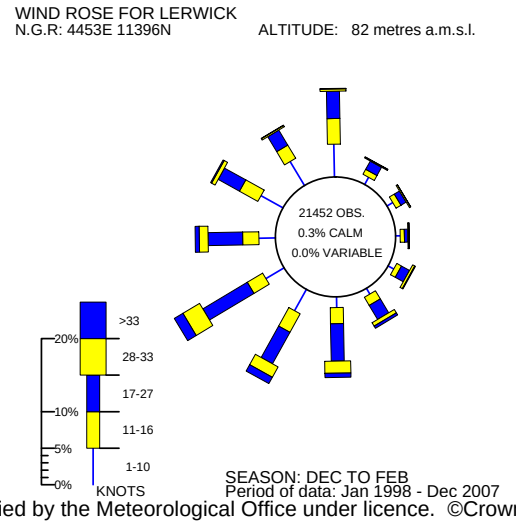

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Figure 9.6 Wind rose for Lerwick (December to February)

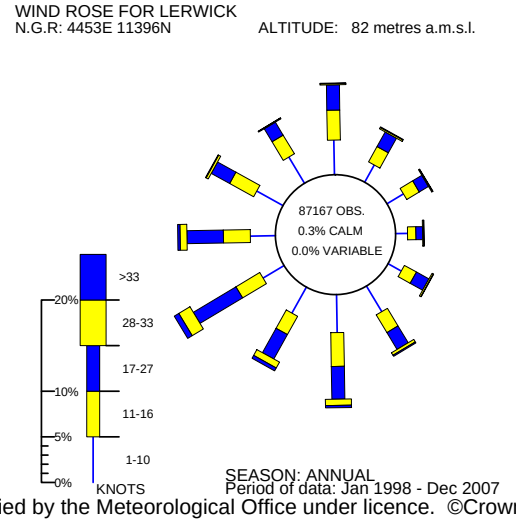

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Figure 9.7 Wind rose for Lerwick (Annual)

Aith Voe has a south-north aspect, with the surrounding land rising to 100 m in places, and so is most exposed to winds from the north, and to a lesser extent the south, so wind patterns may tend to align more along the north south axis. The site at East Burra Firth lies within a small sidearm of Aith Voe, and so is much more sheltered from winds from all directions. Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s. These surface water currents create return currents which may travel along the bottom or sides of the water body depending on bathymetry. Strong winds will increase the circulation of water and hence dilution of contamination from point sources within the sound. Winds from a southerly direction may transport contamination from the settlement of Aith towards the fisheries.

10. Current and historical classification status

Of the three production areas within the survey area, all have been classified for the production of mussels in recent years, but only Aith Voe Sletta is currently classified. Their classification histories are presented in Tables 10.1 to 10.3. A map of these production areas can be found in Section 2, Figure 2.1.

Table 10.1 Classification history, East Burra Firth, common mussels

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

East Burra Firth received seasonal A/B classifications in all years apart from in 2002, when it received a year round A classification. Months of B classification varied slightly from year to year, but always fell in the summer or autumn. The area was declassified in 2007.

Table 10.2 Classification history, Aith Voe Ayres, common mussels

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

Aith Voe Ayres received seasonal A/B classifications apart from in 2006, when it received a year round A classification. Months of B classification varied slightly between 2007 and 2008, but always fell in the summer or autumn. The area was declassified in 2009.

Table 10.3 Classification history, Aith Voe Sletta, common mussels

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

Aith Voe Sletta received seasonal A/B classifications in all years apart from in 2009, when it received a year round A classification. Months of B classification varied from year to year, but generally fell in the second half of the year.

Overall, classifications for the three production areas within the survey area have been generally similar, but not identical. The general pattern has been for any B months to fall within the summer or autumn.

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken East Burrafirth, Aith Voe Ayres and Aith Voe Sletta from the beginning of 2002 up to the 28th September 2009 were extracted from the database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data.

No samples were excluded from the analysis on the basis of geographical or sampling date discrepancies. One mussel sample had an invalid lab result and so could not be used in the analysis. A total of 60 samples had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation. Two samples had the result reported as >18000, and this was assigned a nominal value of 36000 for these purposes.

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

11.2 Summary of microbiological results

A summary of all sampling and results by location sampled are presented in Table 11.1. There are two sites identified within the East Burra Firth production area (East Burra Firth and Aith Voe), but they are actually one and the same. The site was declassified in 2007, and then sold on, and when the new owners applied for reclassification a different site name was used so a different SIN was assigned, although the site is still in the same location as it was when previously classified.

Table 11.1 Summary of historical sampling and results

Sampling Summary									
Production area	East Burra Firth	East Burra Firth	Aith Voe Ayres	Aith Voe Ayres	Aith Voe Sletta	Aith Voe Sletta	Aith Voe Sletta	Aith Voe Sletta	Aith Voe Sletta
Site	East Burra Firth	Aith Voe	Point of Ayres	Point of Ayres	Slyde	Slyde	Point of Sletta	Point of Sletta	Point of Sletta
Species	Common mussels	Common mussels	Common mussels	Common mussels	Common mussels	Common mussels	Common mussels	Common mussels	Common mussels
SIN	SI-055-421-08	SI-055-863-08	SI-325-392-08	SI-325-392-08	SI-326-733-08	SI-326-733-08	SI-326-393-08	SI-326-393-08	SI-326-393-08
Location	HU356578	HU353577	HU344569	HU344567	HU350583	HU348586	HU342588	HU341586	HU342585
Total no of samples	45	11	31	8	20	18	31	7	1
No. 2002	12	0	0	0	0	0	0	0	0
No. 2003	13	0	0	0	0	0	0	0	0
No. 2004	9	0	5	0	0	0	2	0	0
No. 2005	11	0	10	0	0	2	12	0	0
No. 2006	0	0	12	0	0	11	12	0	0
No. 2007	0	0	4	5	5	5	5	4	1
No. 2008	0	2	0	3	9	0	0	3	0
No. 2009	0	9	0	0	6	0	0	0	0
Results Summary									
Minimum	<20	<20	<20	<20	<20	<20	<20	<20	
Maximum	>18000	490	>18000	330	490	750	3500	200	
Median	40	<20	50	<20	20	<20	70	20	<20
Geometric mean	49.6	37.7	90.3	23.9	28.9	29.6	58.9	34.8	
90 percentile	310	230	1300	155	159	233	500		
95 percentile	660	360	3580	243	338	376	1580		
No. exceeding 230/100g	7 (16%)	1 (9%)	7 (23%)	1 (13%)	2 (10%)	2 (11%)	9 (29%)		
No. exceeding 1000/100g	2 (4%)	0 (0%)	4 (13%)	0 (0%)	0 (0%)	0 (0%)	2 (6%)		
No. exceeding 4600/100g	1 (2%)	0 (0%)	2 (6%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)		
No. exceeding 18000/100g	1 (2%)	0 (0%)	1 (3%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)		

11.3 Overall geographical pattern of results

Figure 11.1 presents a map showing geometric mean result by reported sampling location.

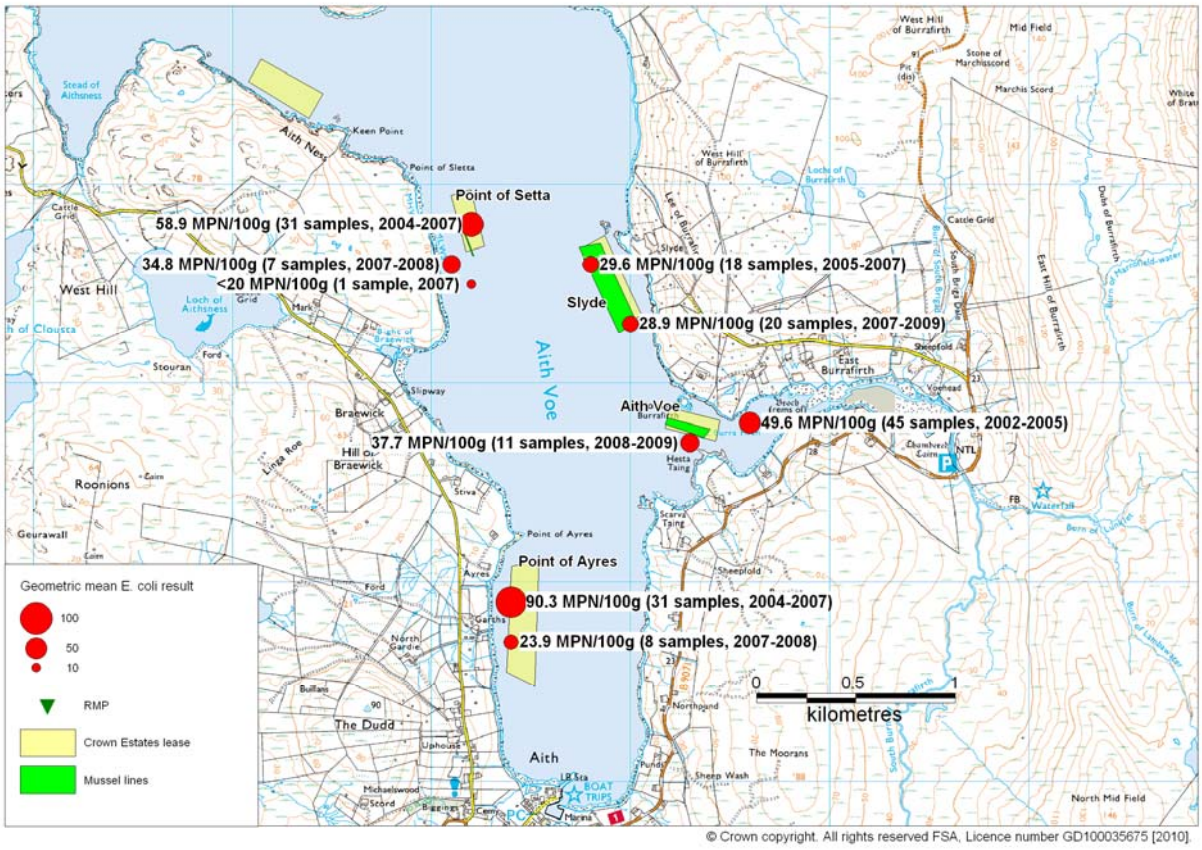

Figure 11.1 Map of sampling points and geometric mean result

No significant difference was found in mean result by reported sampling location (one way ANOVA, p=0.194). Figure 11.1 shows results were higher on average at the north end of the Point of Ayres site compared to its southern end. Results were also higher on average at the northern end of the Point of Sletta site compared to its southern end. Results were very similar at either end of the Slyde site. Within the East Burra Firth/Aith Voe site results were on average higher at the eastern end of the site. It must be noted that these differences in results within sites may equally be down to temporal rather than spatial differences in levels of contamination, and the accuracy of some of these sampling locations cannot be assured, and they do not all appear to strictly align with the current location of the fisheries. Of specific importance, the earlier sampling location at the east end of the Aith Voe may not necessarily have been to the east of the later sampling location at this site.

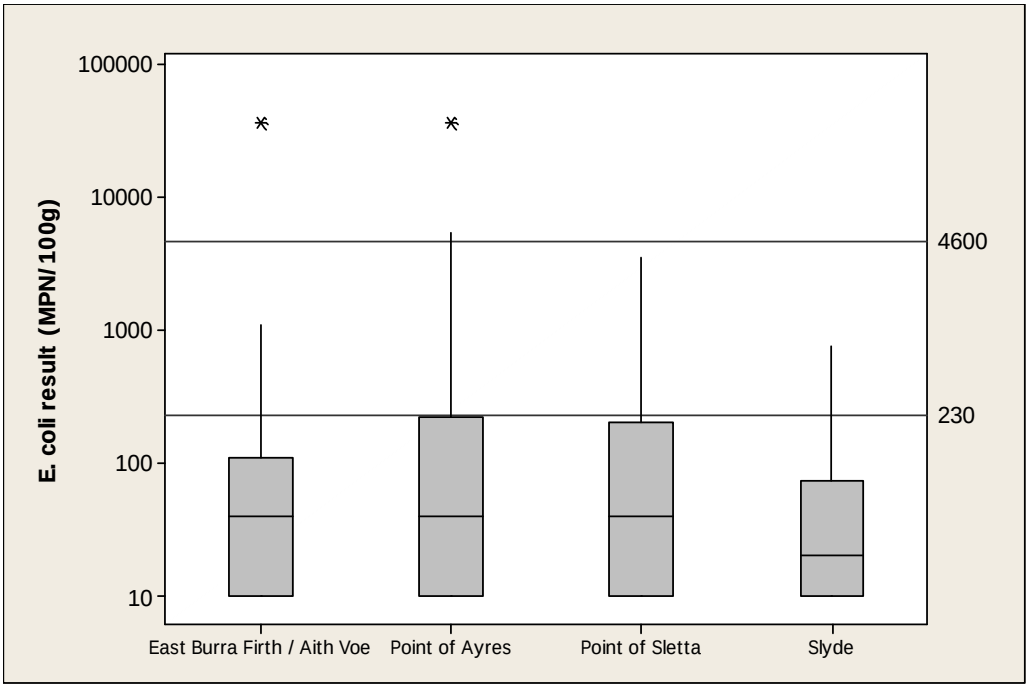

Figure 11.2 Boxplot of *E. coli* results by site

Geometric mean result was highest at Point of Ayres (68.7 *E. coli* MPN/100g), followed by Point of Sletta (51.2 *E. coli* MPN/100g) then East Burra Firth / Aith Voe (47.0 *E. coli* MPN/100g) then Slyde (29.2 *E. coli* MPN/100g). There was however no significant difference in mean results between these four sites (One-way ANOVA, p=0.155, Appendix 6) or in proportion of results of over 230 *E. coli* MPN/100g (Chi-square=2.284, p=0.516). Point of Ayres and Point of Sletta were both sampled on the same date, and hence under the same environmental conditions on a total of 14 occasions, allowing a more robust comparison of results between these two sites. There was no significant difference in mean result between these sites when only these paired results were considered (paired T-test, T=-0.47, p=0.648, Appendix 6). No other pairs of sites were sampled on the same day on more than four occasions, so no similar comparisons between other pairs of sites could be made. Results exceeding 4600 *E. coli* MPN/100g were found only at East Burra Firth/Aith Voe and Point of Ayres, which are the two southernmost sites which both lie closer to the largest identified sources of faecal contamination.

11.4 Overall temporal pattern of results

Figures 11.3 to 11.6 present scatter plots of individual results against date for East Burra Firth/Aith Voe, Point of Ayres, Point of Sletta and Slyde, fitted with trend lines calculated using two different techniques. The first is a rolling geometric mean, with the line following the geometric mean of the previous 5 samples, the current sample and the following 6 samples. The second is a loess line which stands for 'locally weighted regression scatter plot smoothing'. At each point in the data set an estimated value is fit to a subset of the data, using weighted least squares. The approach gives more weight to points near to the x-value where the estimate is being made and less weight to points further away. In terms of the monitoring data, this means that any point on the loess line is influenced more by the data close to it (in time)

and less by the data further away. These trend lines help to highlight any apparent underlying trends or cycles. For each of the figures, the rolling geometric mean is plotted with a heavy black line and the Loess line is plotted as a fine blue line.

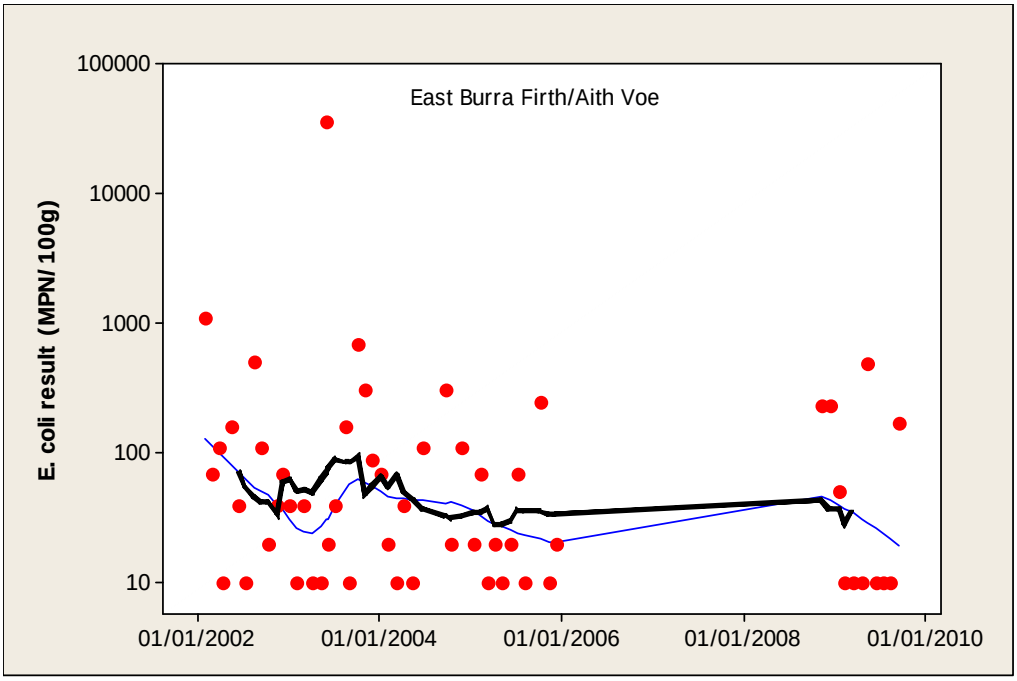

Figure 11.3 Scatterplot of *E. coli* results by date for East Burra Firth/Aith Voe

While monitoring at this site began far earlier than the other sites, there was a gap where no monitoring took place from 2006 through 2009, making comparison with the other sites more difficult. There does appear to be a trough in early 2003, followed by a peak later in the same year.

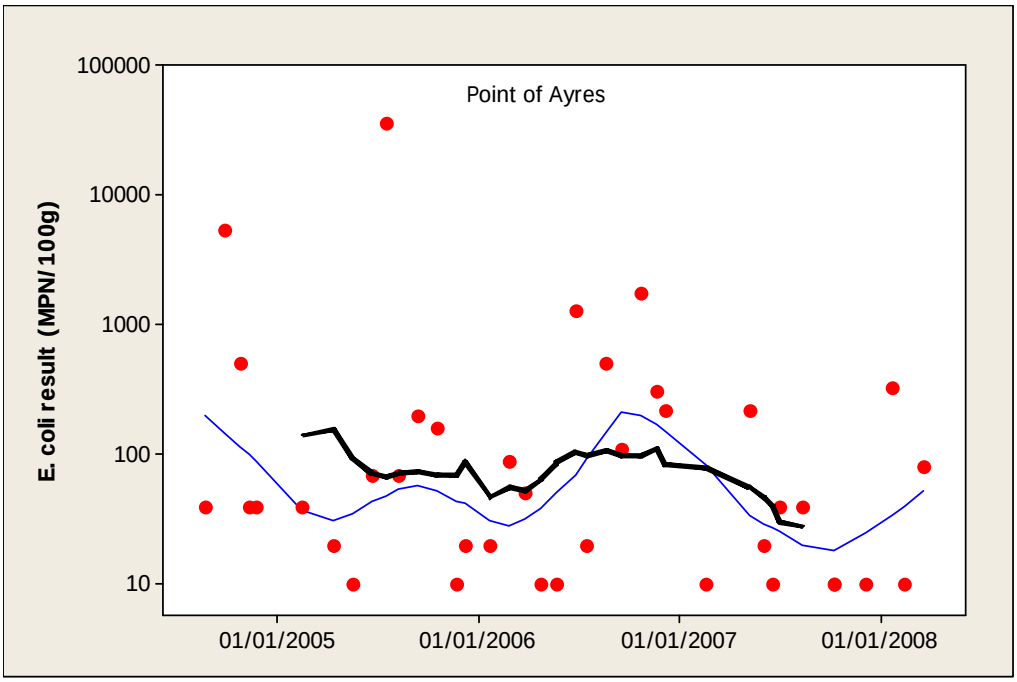

Figure 11.4 Scatterplot of *E. coli* results by date for Point of Ayres

Figure 11.4 suggests a marginal overall improvement in results may have occurred between 2005 and 2008, with peaks in results towards the latter half of 2005 and 2006.

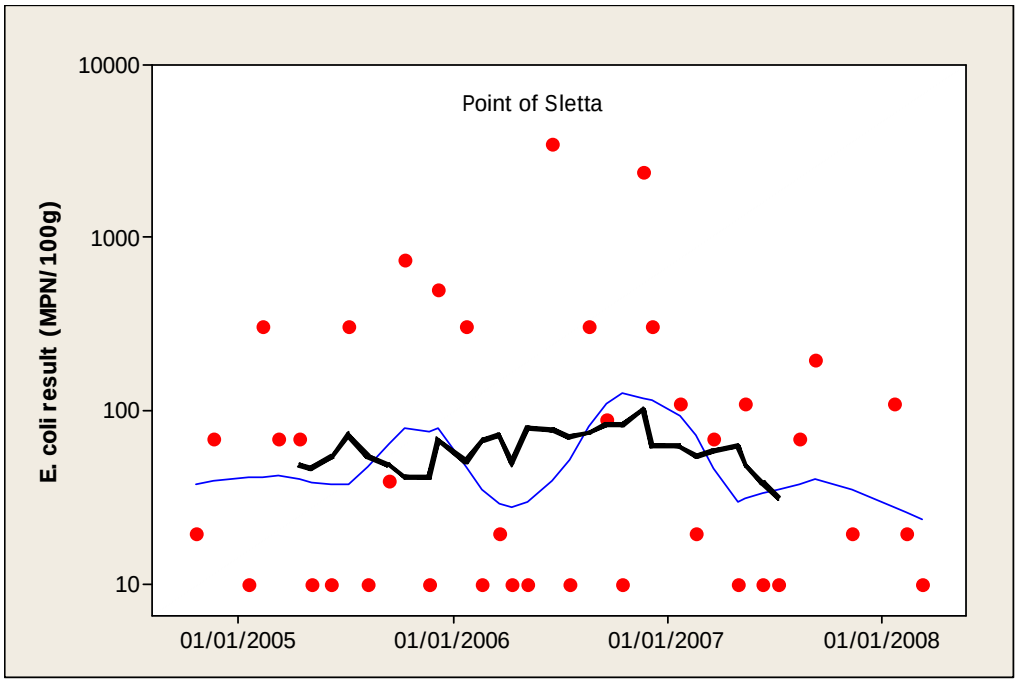

Figure 11.5 Scatterplot of *E. coli* results by date for Point of Sletta

Peaks in results at Point of Sletta occurred in the latter halves of 2005, 2006 and 2007, while troughs appeared in early 2006 and 2007.

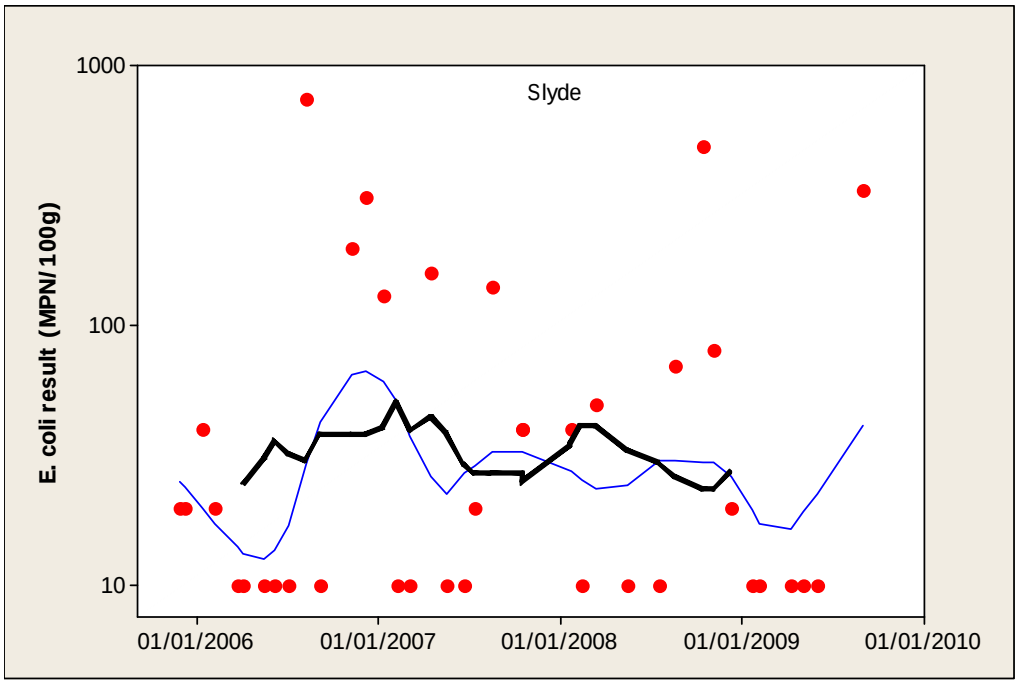

Figure 11.6 Scatterplot of *E. coli* results by date for Slyde

In Figure 11.6, results of <20 MPN/100g appear to cluster around the first half of the year, with the effect most pronounced in 2007 and 2009.

Analysis is complicated somewhat by the fact that not all sites were in operation at the same times. However, generally it appears that higher results tended to occur during the second half of the year at most of the 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 11.7, 11.8, 11.9 and 11.10 present boxplots of *E. coli* result by month for East Burra Firth/Aith Voe, Point of Ayres, Point of Sletta and Slyde respectively. The number of samples submitted for some months was very low, so the number of samples on which the analysis is based is noted next to the month in each graph.

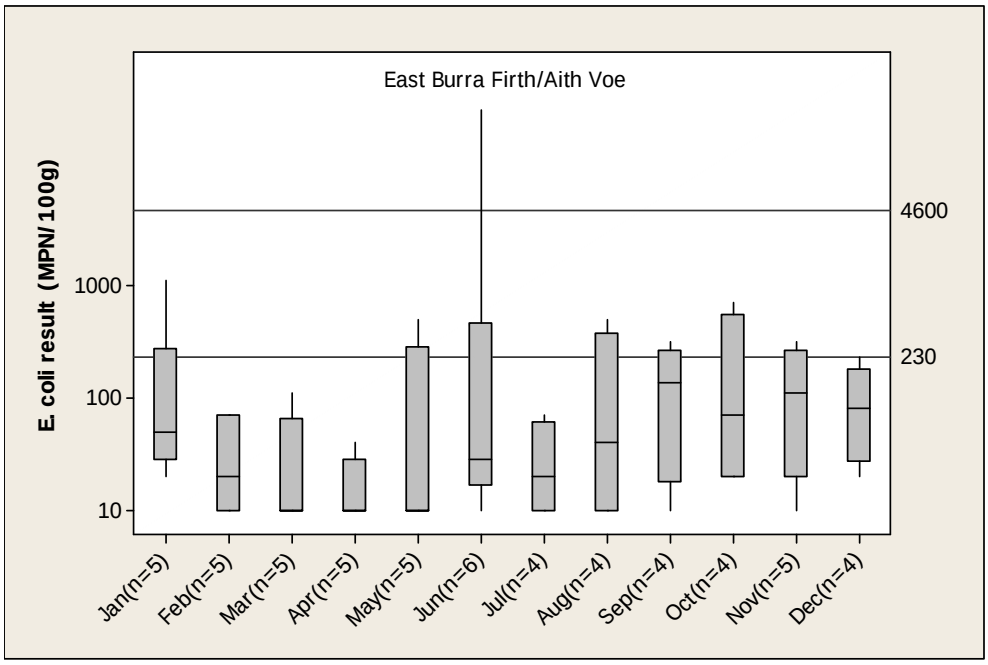

Figure 11.7 Boxplot of results by month (East Burra Firth / Aith Voe)

No strong seasonal effect is apparent in Figure 11.7, although results were consistently lower during February to April and in July, with the highest individual result occuring in June.

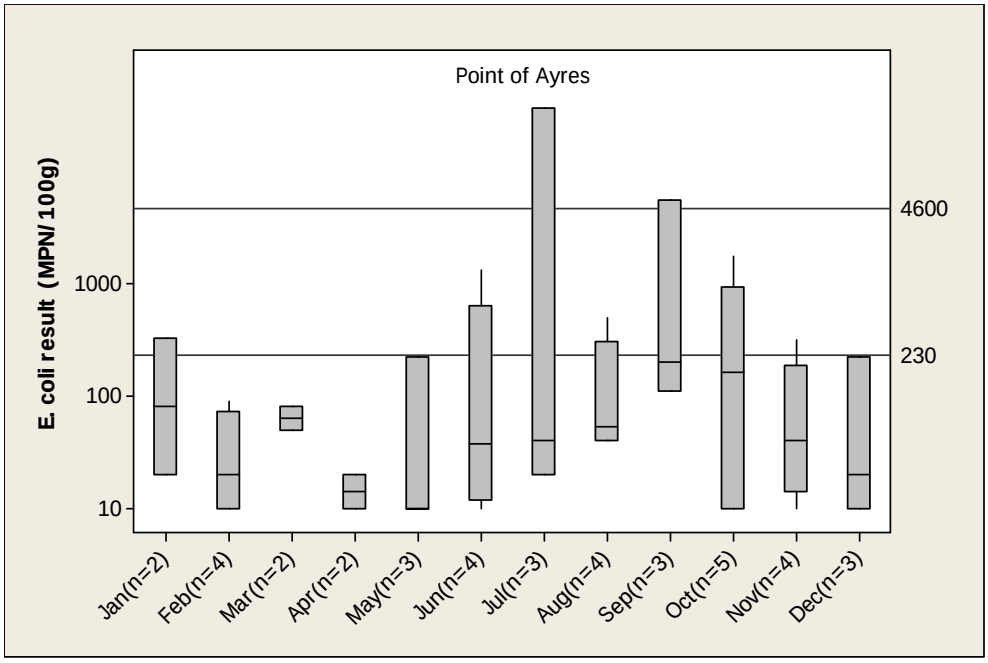

Figure 11.8 Boxplot of results by month for Point of Ayres

Higher results occurred from June through October, and lower results occurred from February to April. However, only two samples were submitted in both March and April.

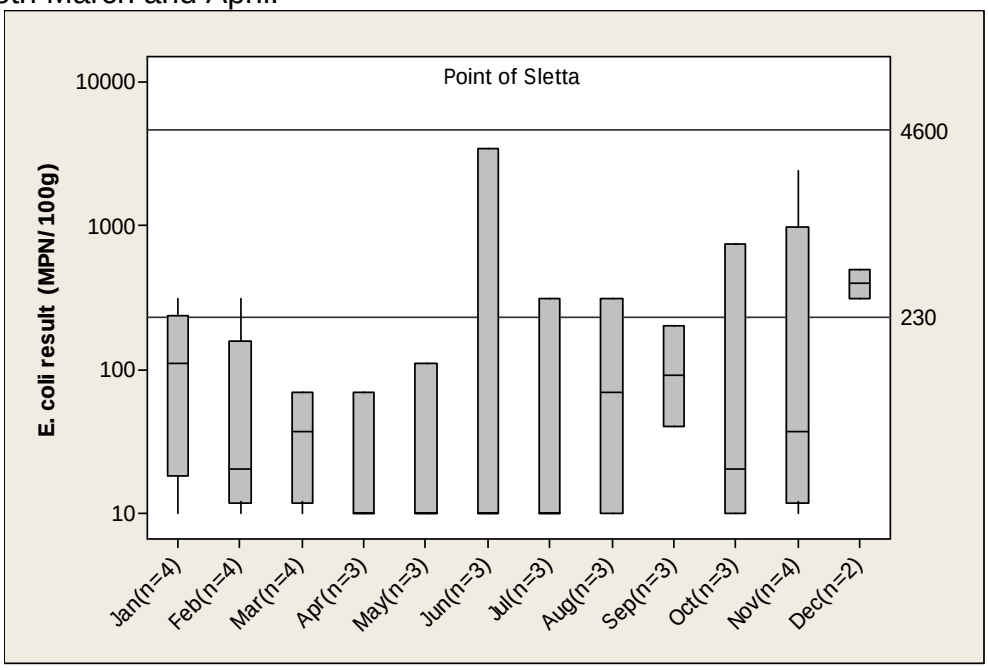

Figure 11.9 Boxplot of results by month for Point of Sletta

Results were consistently below 230 *E. coli* MPN/100g from March to May, and in September. Results greater than 230 *E. coli* MPN/100g occurred in all months except the four mentioned above and in December both samples submitted were greater.

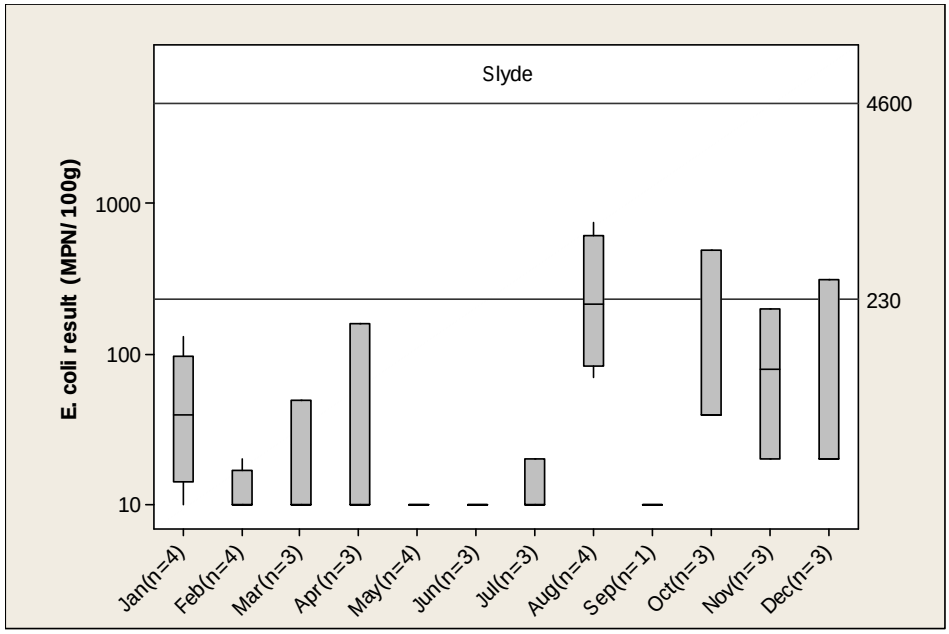

Figure 11.10 Boxplot of results by month for Slyde

Highest results occurred from August to December. Only one sample was submitted in September. The only results greater than 230 *E. coli* MPN/100g occurred in August, October and December. No samples had more than 1000 *E. coli* MPN/ 100g, indicating that this was the cleanest overall of the four sites.

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

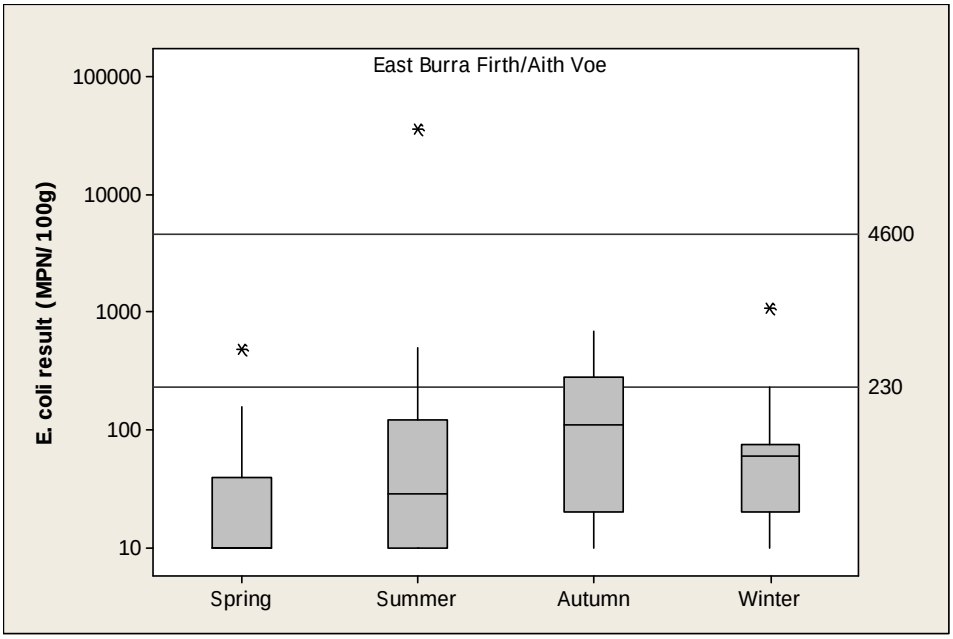

Figure 11.11 Boxplot of result by season for East Burra Firth / Aith Voe

No significant difference was found between results by season for Aith Voe / East Burra Firth (One-way ANOVA, p=0.191, Appendix 6).

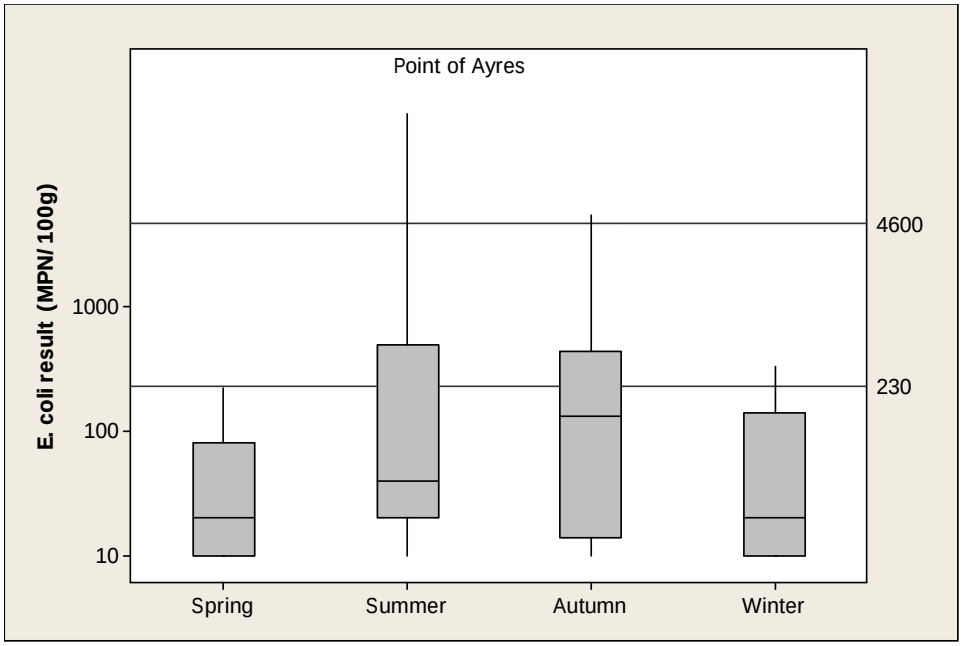

Figure 11.12 Boxplot of result by season for Point of Ayres

No significant difference was found between results by season for Point of Ayres (One-way ANOVA, p=0.264, Appendix 6).

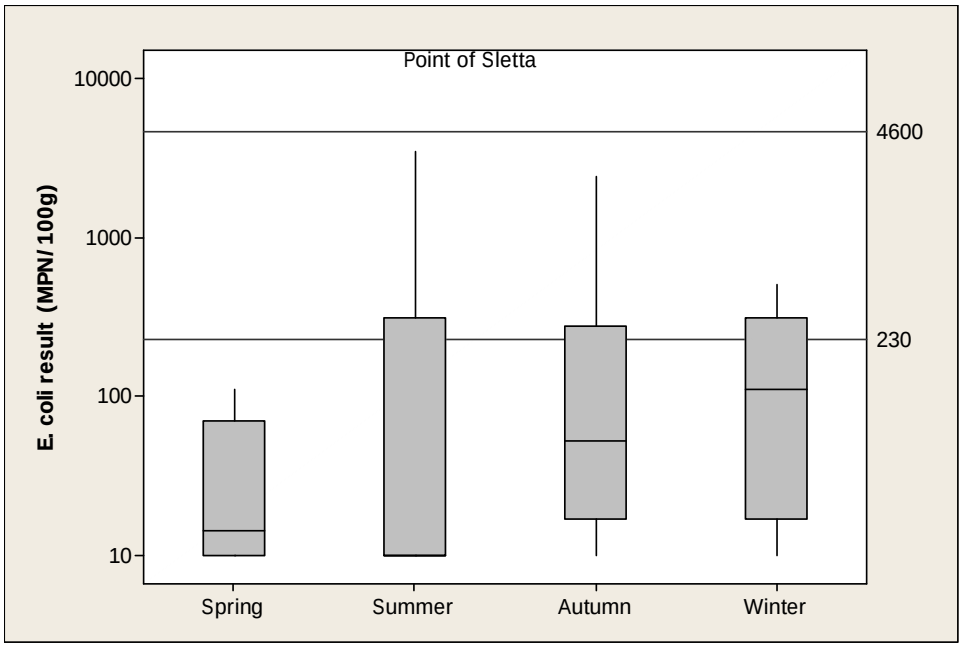

Figure 11.13 Boxplot of result by season for Point of Sletta

No significant difference was found between results by season for Point of Sletta (One-way ANOVA, p=0.417, Appendix 6).

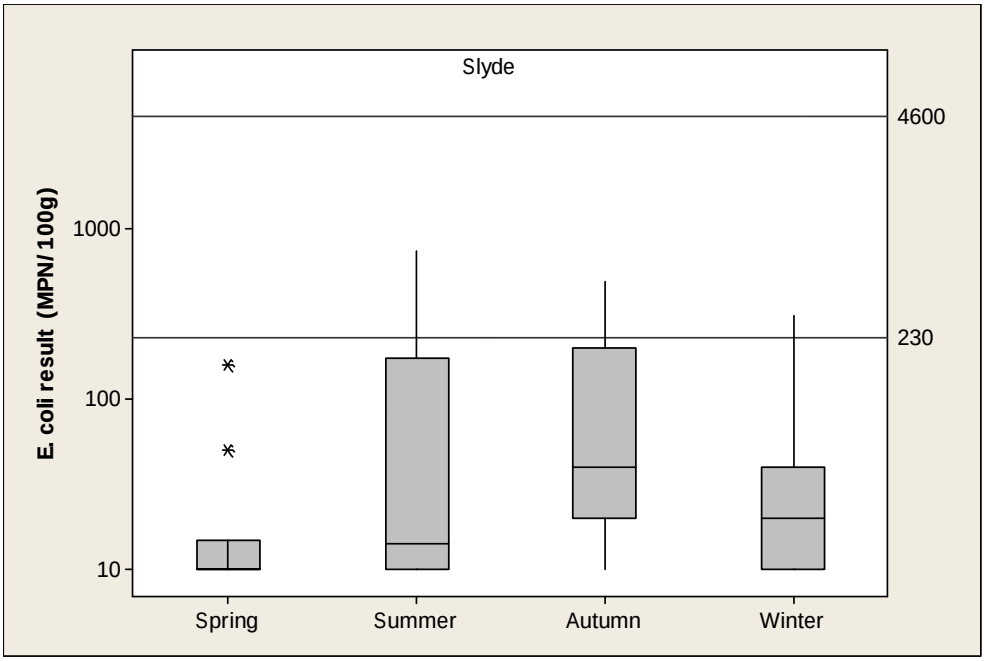

Figure 11.14 Boxplot of result by season for Slyde

No significant difference was found between results by season for Slyde (One-way ANOVA, p=0.203, Appendix 6).

11.6 Analysis of results against environmental factors

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

11.6.1 Analysis of results by recent rainfall

The nearest weather station is at Lerwick, approximately 20 km to the south-east of the fishery. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2008 (total daily rainfall in mm). Figures 11.15, 11.16, 11.17 and 11.18 present scatterplots of *E. coli* results against rainfall for East Burra Firth/Aith Voe, Point of Ayres, Point of Sletta and Slyde respectively. Spearman's Rank correlations were carried out between results and rainfall.

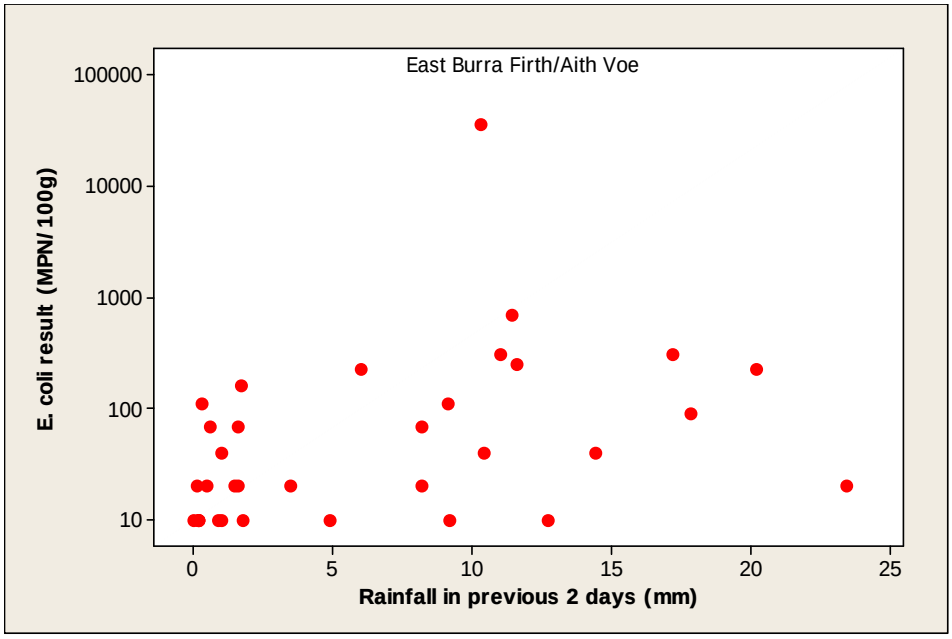

Figure 11.15 Scatterplot of result against rainfall in previous 2 days (East Burra Firth / Aith Voe)

A positive correlation was found between *E. coli* result for East Burra Firth / Aith Voe and rainfall in the previous 2 days (Spearman's rank correlation=0.498, p=0.003, Appendix 6).

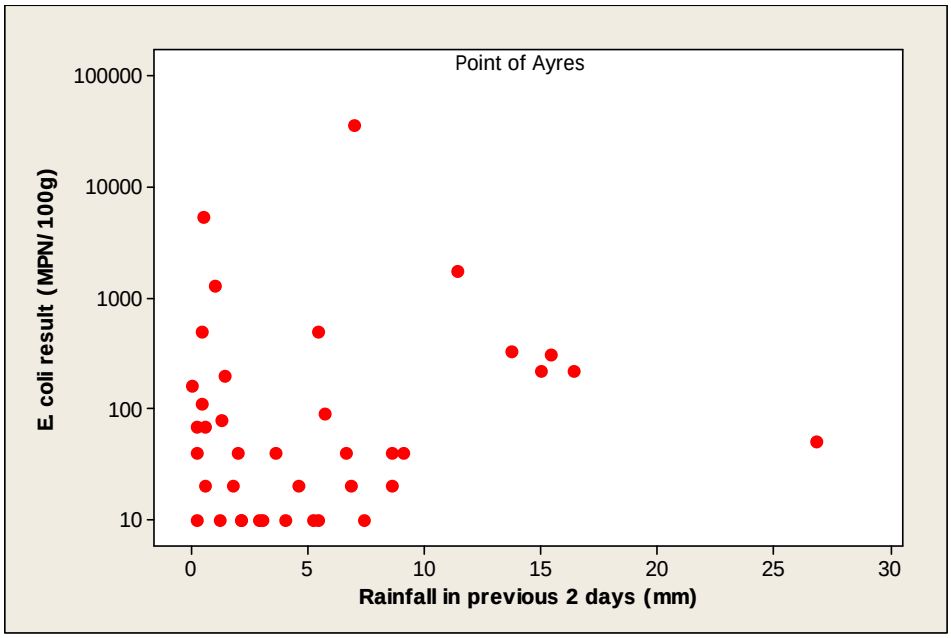

Figure 11.16 Scatterplot of result against rainfall in previous 2 days (Point of Ayres)

No correlation was found between *E. coli* result for Point of Ayres and rainfall in the previous 2 days (Spearman's rank correlation=0.091, p=0.583, Appendix 6).

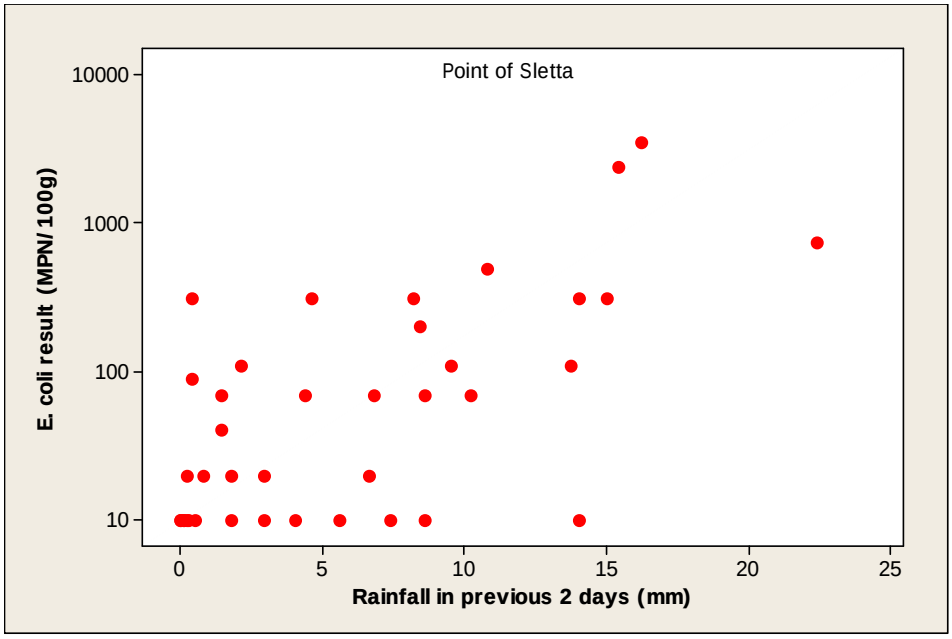

Figure 11.17 Scatterplot of result against rainfall in previous 2 days (Point of Sletta)

A positive correlation was found between *E. coli* result for Point of Sletta and rainfall in the previous 2 days (Spearman's rank correlation=0.592, p=0.000, Appendix 6).

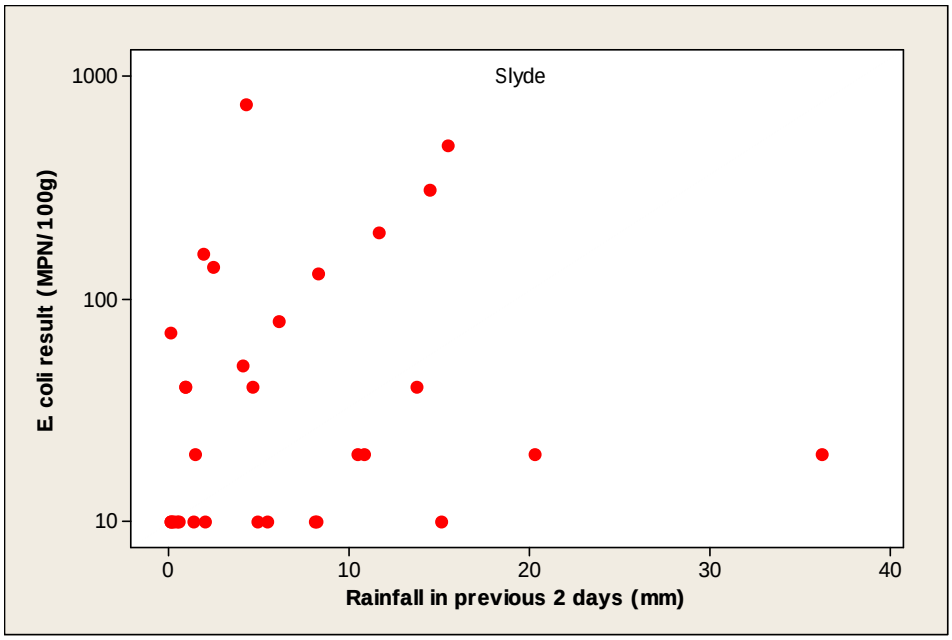

Figure 11.18 Scatterplot of result against rainfall in previous 2 days (Slyde)

No correlation was found between *E. coli* result for Slyde and rainfall in the previous 2 days (Spearman's rank correlation=0.325, p=0.070, Appendix 6).

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

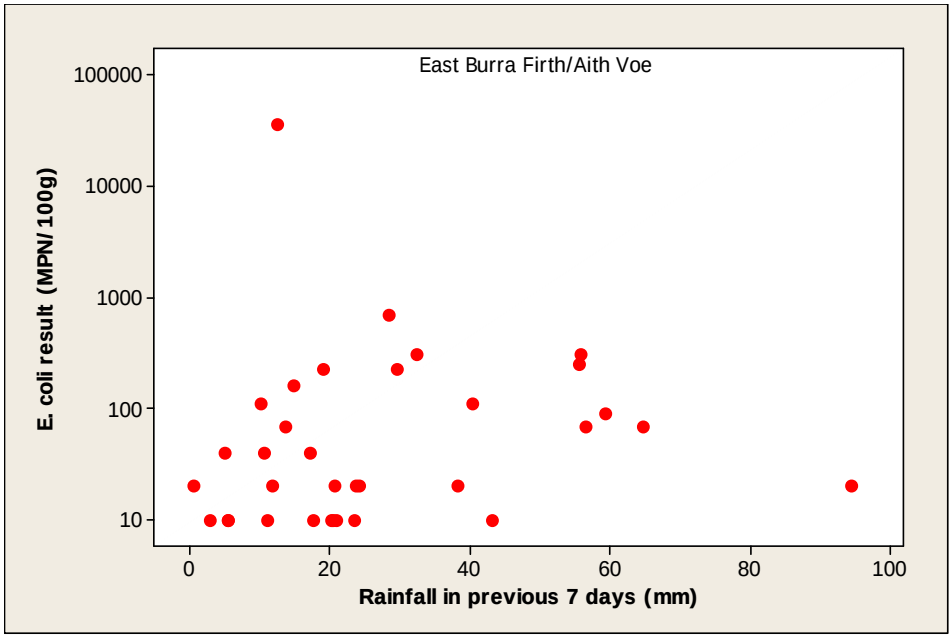

Figure 11.19 Scatterplot of result against rainfall in previous 7 days (East Burra Firth / Aith Voe)

No correlation was found between *E. coli* result for East Burra Firth / Aith Voe and rainfall in the previous 7 days (Spearman's rank correlation=0.307, p=0.077, Appendix 6).

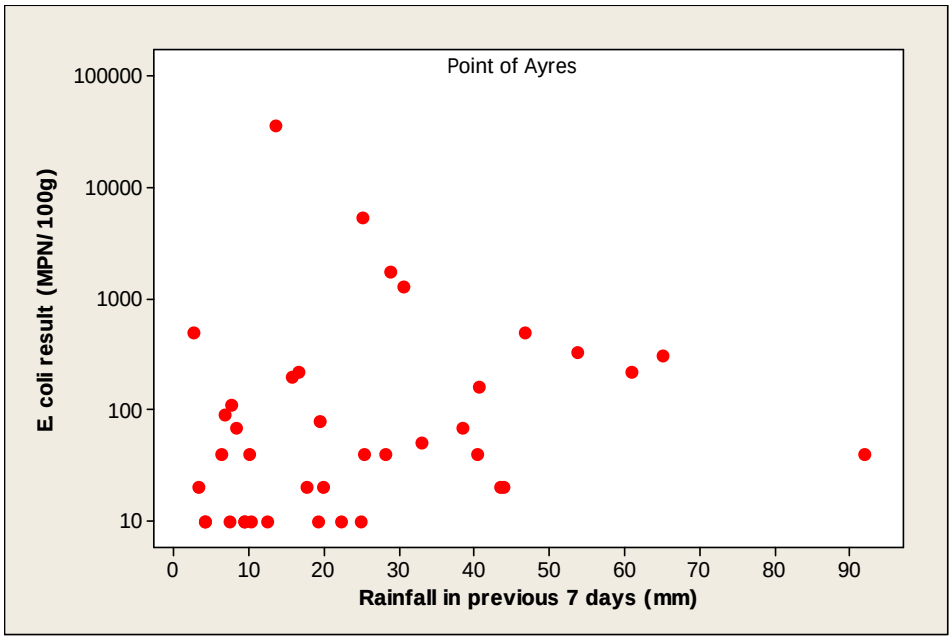

Figure 11.20 Scatterplot of result against rainfall in previous 7 days (Point of Ayres)

A weak positive correlation was found between *E. coli* result for Point of Ayres and rainfall in the previous 7 days (Spearman's rank correlation=0.334, p=0.037, Appendix 6).

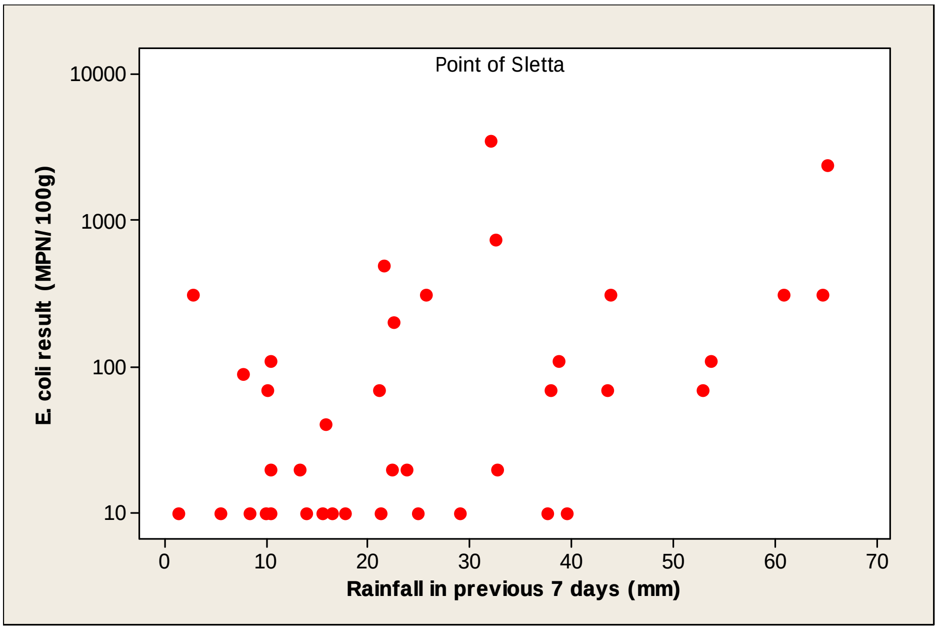

Figure 11.21 Scatterplot of result against rainfall in previous 7 days (Point of Sletta)

A positive correlation was found between *E. coli* result for Point of Sletta and rainfall in the previous 7 days (Spearman's rank correlation=0.427, p=0.007, Appendix 6).

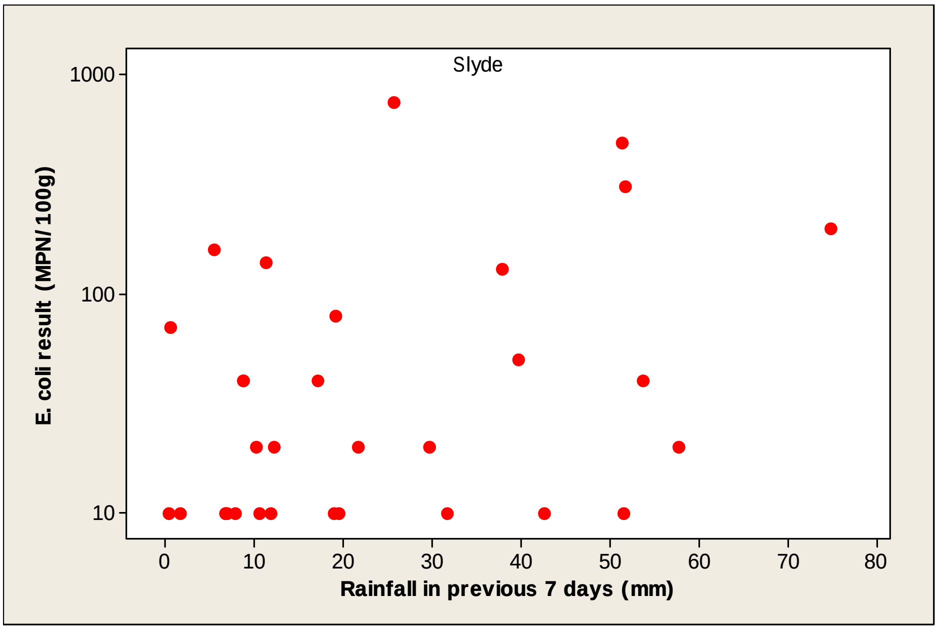

Figure 11.22 Scatterplot of result against rainfall in previous 7 days (Slyde)

No correlation was found between *E. coli* result for Slyde and rainfall in the previous 7 days (Spearman's rank correlation=0.325, p=0.069, Appendix 6). Correlations for all sites are summarised in Table 11.2 below.

Table 11.2 Summary of rainfall correlations for all sites organised geographically

	South - North			
Rainfall	Point of Ayres	E Burra Firth/Aith	Slyde	Point of Sletta
Previous 2 days	✘	✓ +	✘	✓ +
Previous 7 days	✓ +	✘	✘	✓ +

There does not appear to be a clear geographic trend between correlations. The site at East Burra Firth lies near to where the Burn of Burrafirth discharges and is likely to be heavily influenced when the burn is in spate, which is consistent with the observed correlation with 2-day rainfall. The other correlations, however, did not appear to clearly coincide with identified freshwater sources.

11.6.2 Analysis of results by tidal height and state

When the larger (spring) tides occur every two weeks, circulation of water and particle transport distances will increase, and more of the shoreline will be covered at high water, potentially washing more faecal contamination from livestock into the voe. Figures 11.23 to 11.26 present polar plots of log-10 *E. coli* results on the lunar spring/neap tidal cycle for East Burra Firth/Aith Voe, Point of Ayres, Point of Sletta and Slyde respectively. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of under 230 *E. coli* MPN/100g are plotted in green, those between 230 and 1000 *E. coli* MPN/100g are plotted in yellow, and those over 1000 *E. coli* MPN/100g are plotted in red. It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account.

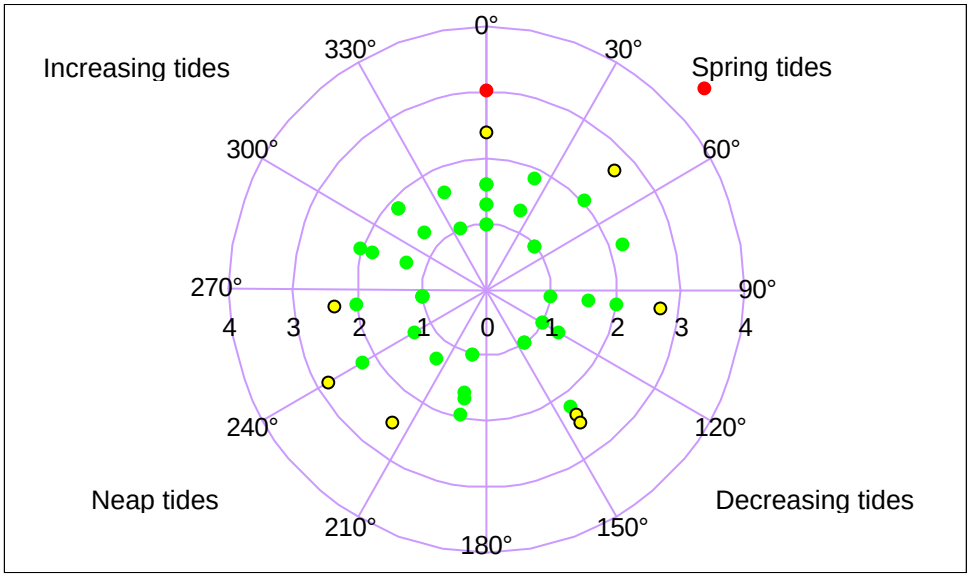

Figure 11.23 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle (East Burra Firth / Aith Voe)

No correlation was found between *E. coli* results and the spring/neap cycle for East Burra Firth / Aith Voe (circular-linear correlation, r=0.134, p=0.385, Appendix 6).

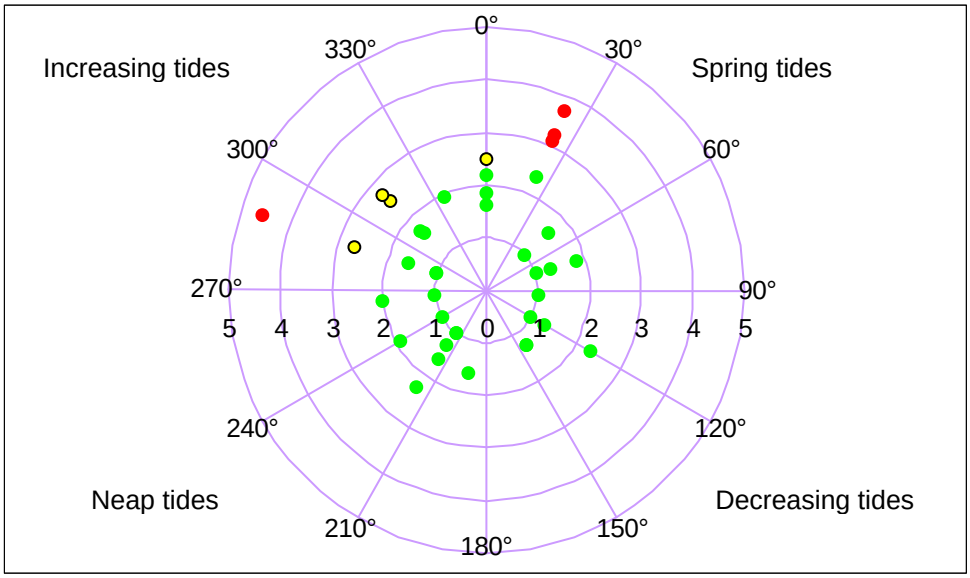

Figure 11.24 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle (Point of Ayres)

A correlation was found between *E. coli* results and the spring/neap cycle for Point of Ayres (circular-linear correlation, r=0.451, p<0.001, Appendix 6), with higher results occurring as the tides increased to springs.

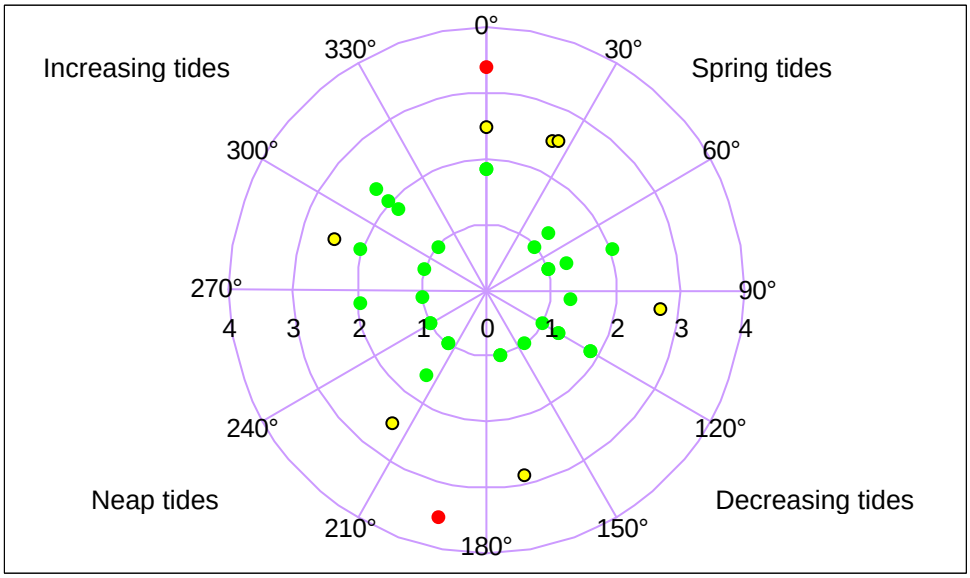

Figure 11.25 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle (Point of Sletta)

No correlation was found between *E. coli* results and the spring/neap cycle for Point of Sletta (circular-linear correlation, r=0.234, p=0.139, Appendix 6).

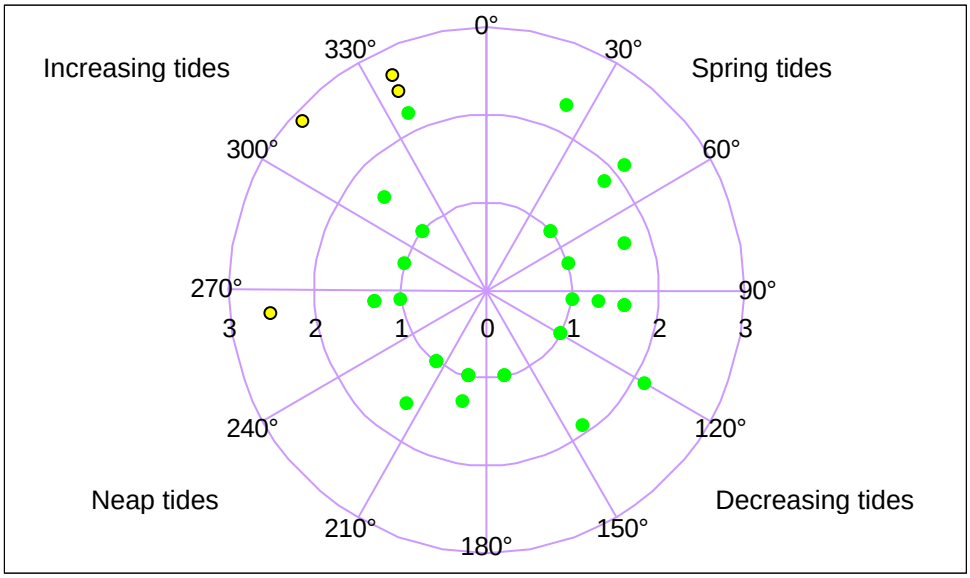

Figure 11.26 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle (Slyde)

A correlation was found between *E. coli* results and the spring/neap cycle for Slyde (circular-linear correlation, r=0.491, p<0.001, Appendix 6). Highest results occurred as the tide size was increasing towards spring tides.

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As *E. coli* levels in some shellfish species can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (hours post high water) was compared with *E. coli* results. Figures 11.26 to 11.29 present polar plots of $\log_{10}$ *E. coli* results on the lunar high/low tidal cycle for East Burra Firth/Aith Voe, Point of Ayres, Point of Sletta and Slyde respectively. High water is at 0º, and low water is at 180º. Again, results of under 230 *E. coli* MPN/100g are plotted in green, those between 230 and 1000 *E. coli* MPN/100g are plotted in yellow, and those over 1000 *E. coli* MPN/100g are plotted in red.

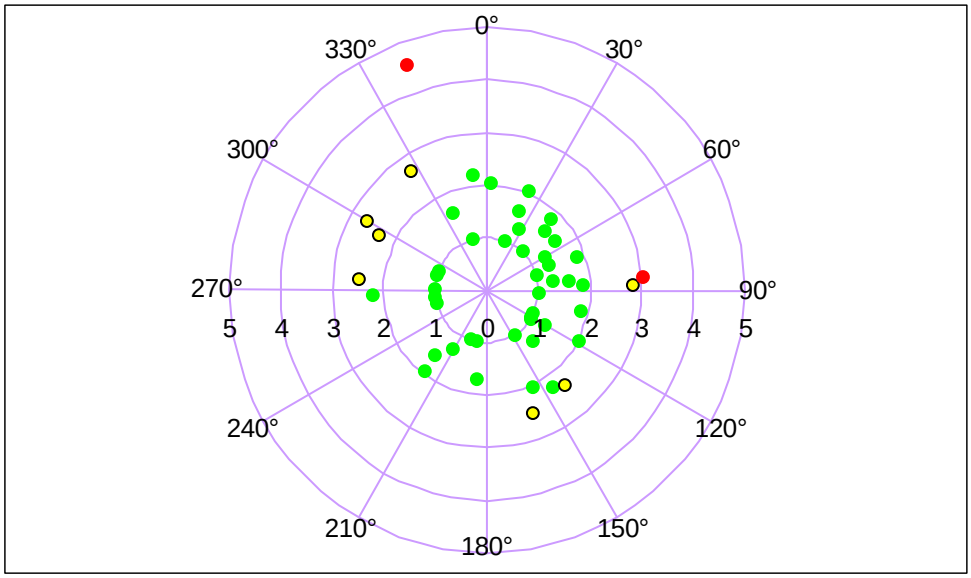

Figure 11.27 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle (East Burra Firth / Aith Voe)

No correlation was found between *E. coli* results and the high/low tidal cycle was found for East Burra Firth / Aith Voe (circular-linear correlation, r=0.186, p=0.191, Appendix 6).

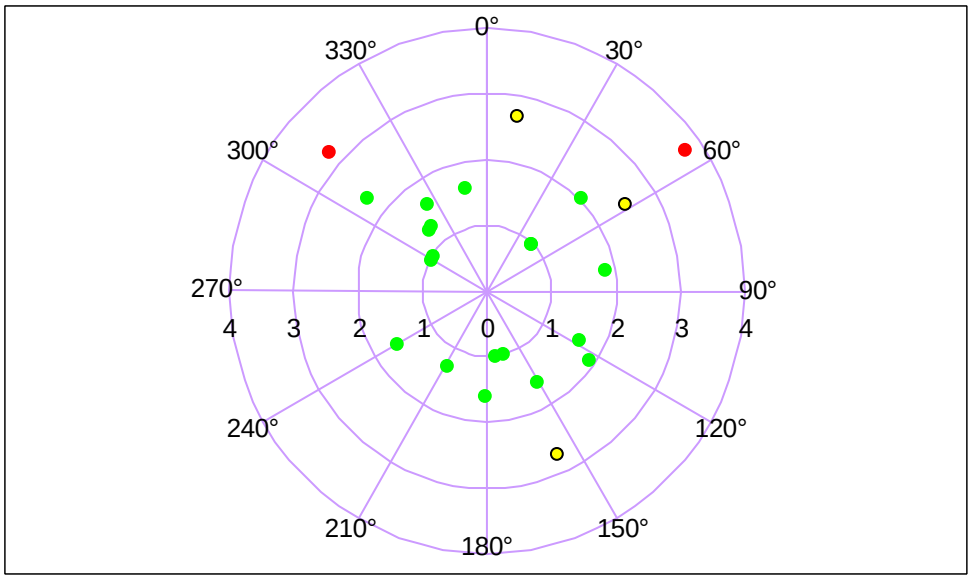

Figure 11.28 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle (Point of Ayres)

No correlation was found between *E. coli* results and the high/low tidal cycle was found for Point of Ayres (circular-linear correlation, r=0.313, p=0.127, Appendix 6).

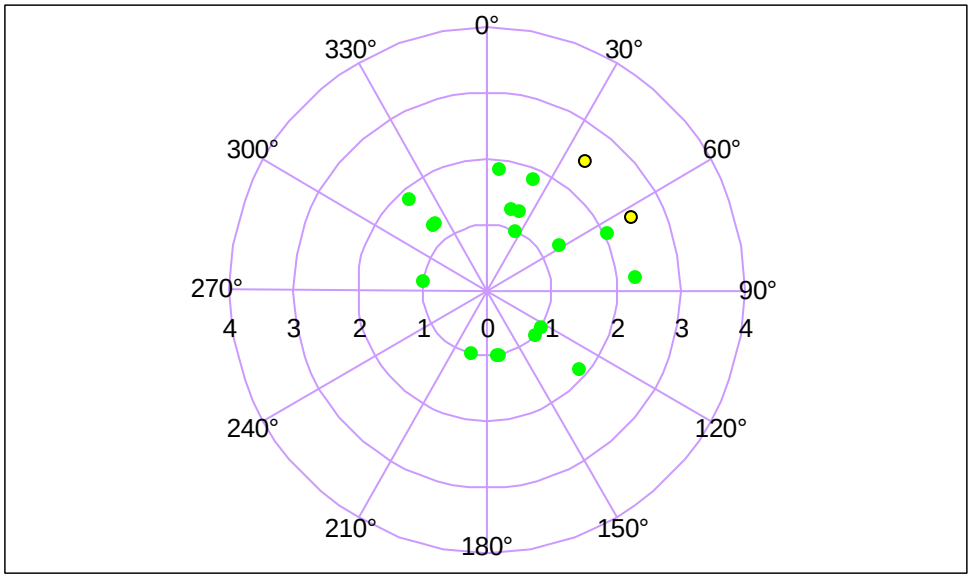

Figure 11.29 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle (Point of Sletta)

A correlation was found between *E. coli* results and the high/low tidal cycle was found for Point of Sletta (circular-linear correlation, r=0.589, p=0.002, Appendix 6), with highest results occurring just after high water.

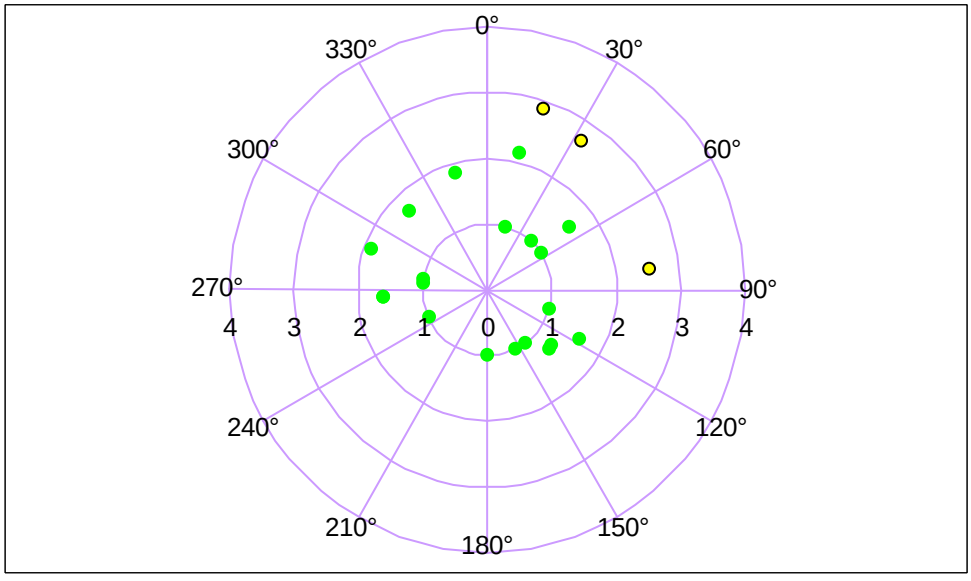

Figure 11.30 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle (Slyde)

A correlation was found between *E. coli* results and the high/low tidal cycle for Slyde (circular-linear correlation, r=0.516, p=0.004, Appendix 6), with highest results occurring just after high water.

11.6.3 Analysis of results by water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) and the feeding and elimination rates of shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. It is of course closely related to season, and so any correlation between temperatures and *E. coli* levels in shellfish flesh may not be directly attributable to temperature, but to other factors such as seasonal differences in livestock grazing patterns. Figure 11.30 to 11.31 present a scatterplots of *E. coli* results against water temperature for East Burra Firth / Aith Voe and Slyde. Water temperature was only recorded on 5 sampling occasions for Point of Ayres and 2 occasions for Point of Sletta, so it was not possible to investigate the relationship between water temperature and *E. coli* results at these sites in a meaningful way.

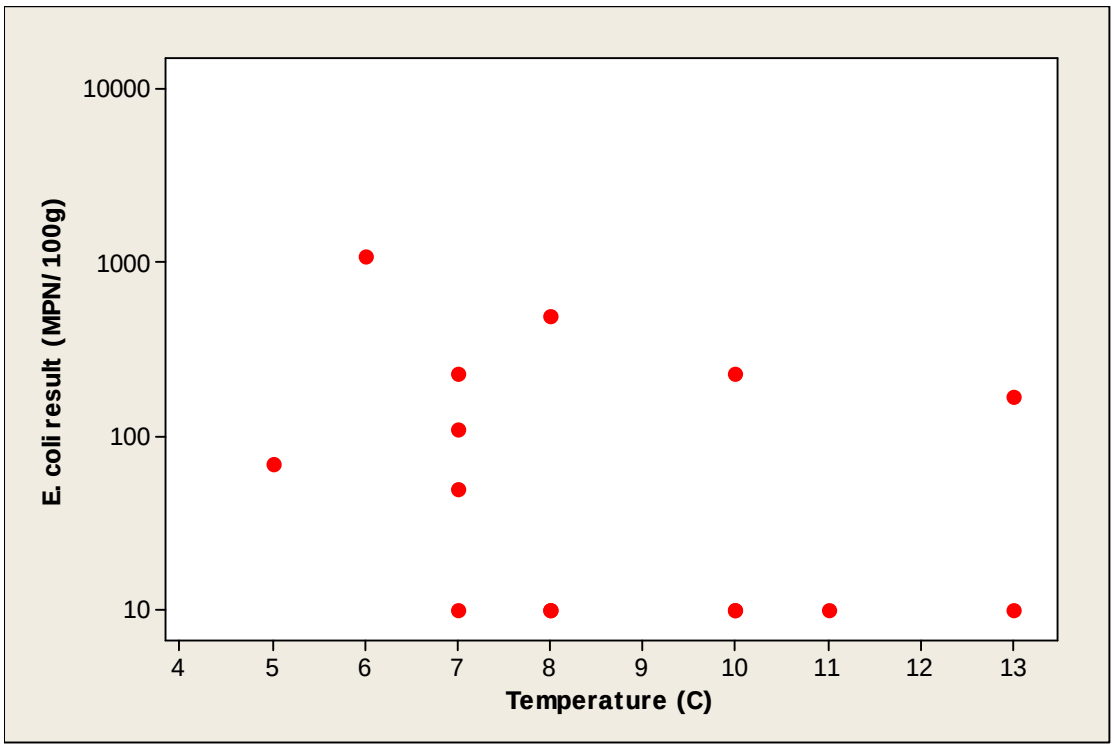

Figure 11.31 Scatterplot of result by water temperature (East Burra Firth / Aith Voe)

The coefficient of determination indicates that there was no relationship between the *E. coli* result and water temperature for East Burra Firth / Aith Voe (Adjusted R-sq=2.8%, p=0.259, Appendix 6)

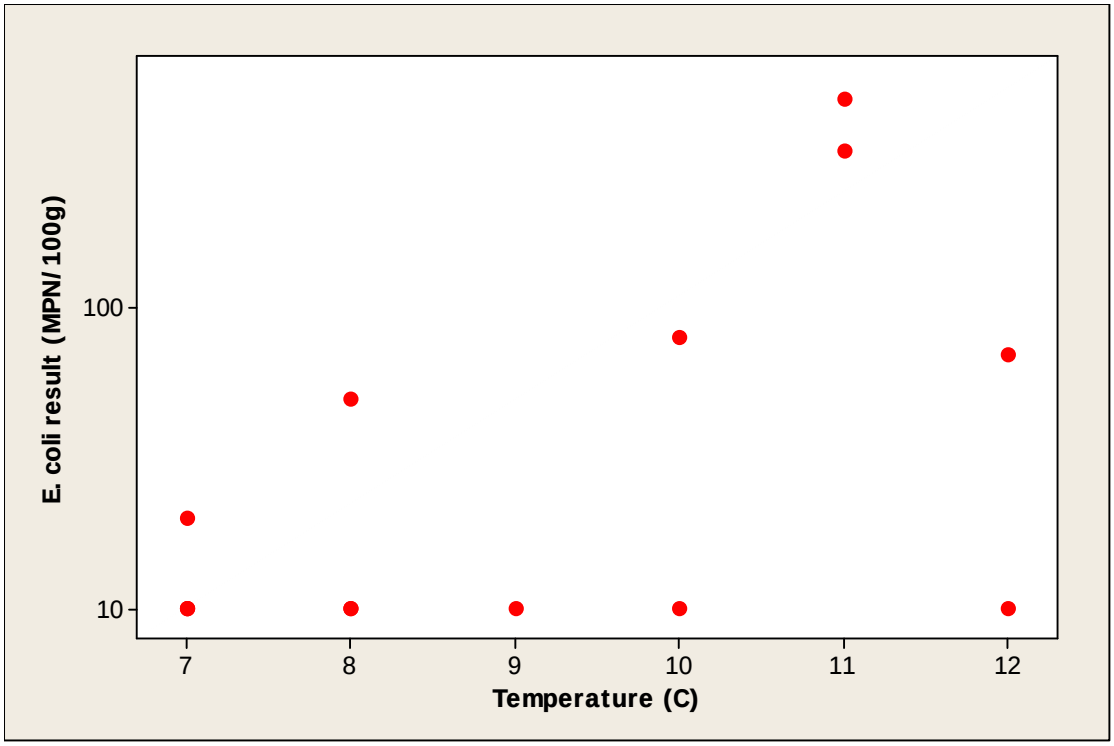

Figure 11.32 Scatterplot of result by water temperature (Slyde)

The coefficient of determination indicates that there was a weak positive relationship between the *E. coli* result and water temperature for Slyde (Adjusted R-sq=23.9%, p=0.044, Appendix 6).

11.6.4 Analysis of results by wind direction

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

11.6.5 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater borne contamination at the site. Figure 11.32 to 11.35 present scatter plots of *E. coli* result against salinity for East Burra Firth/Aith Voe, Point of Ayres, Point of Sletta and Slyde respectively.

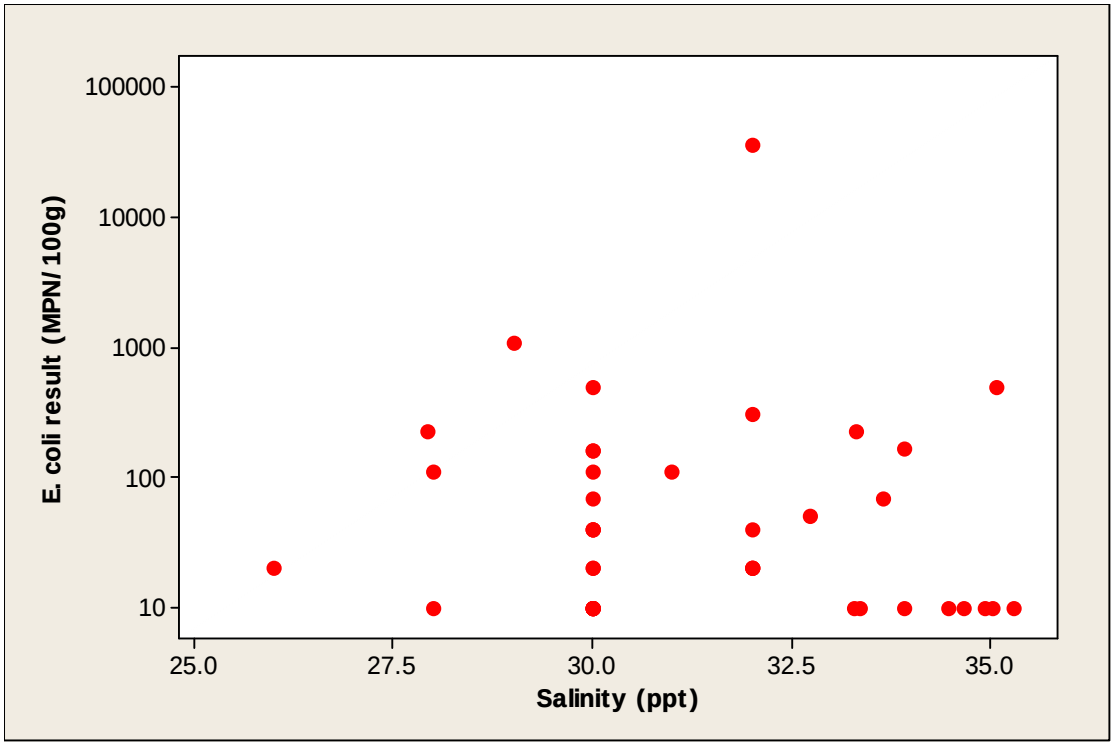

Figure 11.33 Scatterplot of result by salinity (East Burra Firth / Aith Voe)

The coefficient of determination indicates that there was no relationship between the *E. coli* result for East Burra Firth / Aith Voe and salinity (Adjusted R-sq=0.0%, p=0.575, Appendix 6).

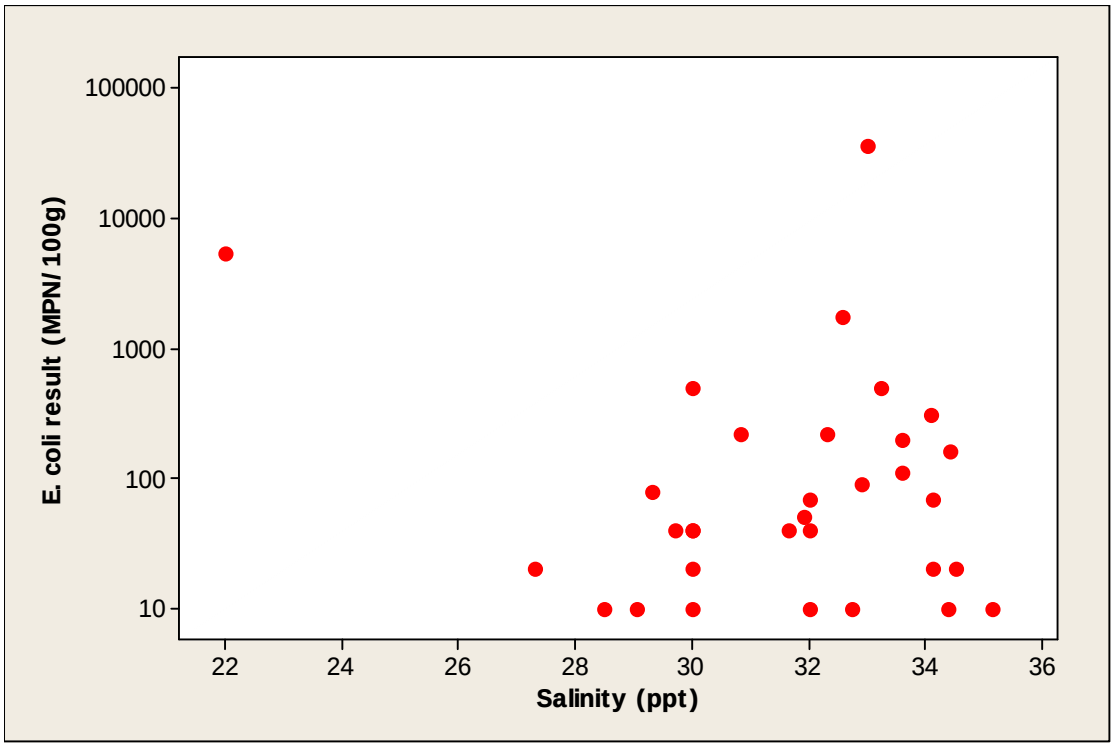

Figure 11.34 Scatterplot of result by salinity (Point of Ayres)

The coefficient of determination indicates that there was no relationship between the *E. coli* result for Point of Ayres and salinity (Adjusted R-sq=0.0%, p=0.523, Appendix 6).

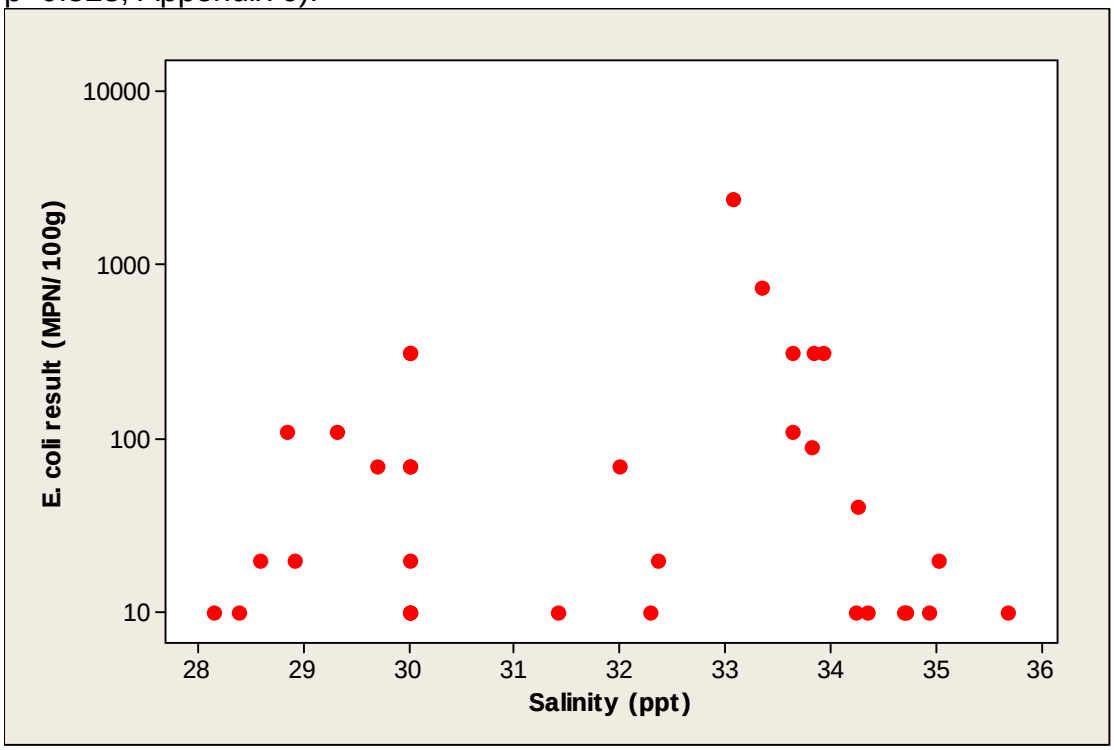

Figure 11.35 Scatterplot of result by salinity (Point of Sletta)

The coefficient of determination indicates that there was no relationship between the *E. coli* result for Point of Sletta and salinity (Adjusted R-sq=0.0%, p=0.823, Appendix 6).

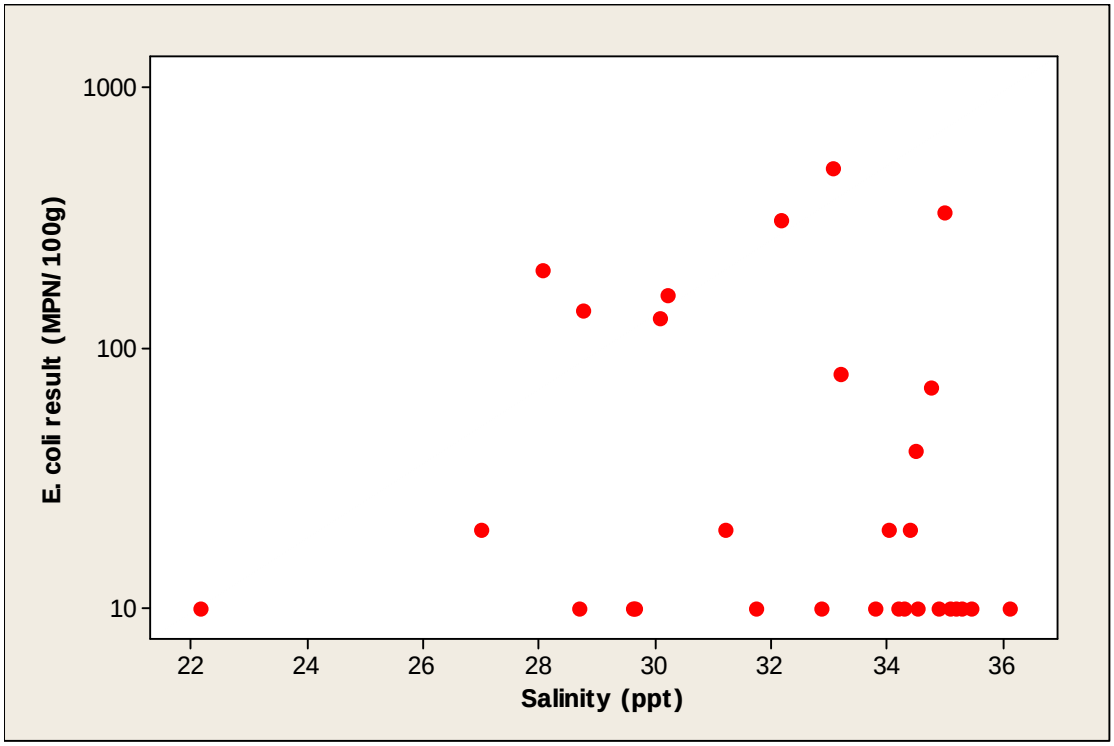

Figure 11.36 Scatterplot of result by salinity (Slyde)

The coefficient of determination indicates that there was no relationship between the *E. coli* result for Slyde and salinity (Adjusted R-sq=0.0%, p=0.534, Appendix 6).

11.7 Evaluation of peak results

Details of samples with results of over 1000 *E. coli* MPN/100g are presented in Tables 11.3.

Table 11.3 Sample details for results of over 1000 *E. coli* MPN/100g

Collection date	Site	Grid Reference	*E. coli* (MPN/ 100g)	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tide (spring/ neap)	Tide (high/ low)
28/01/2002	East Burra Firth/Aith Voe	HU 356 578	1100	*	*	6	29	Spring	Ebb
02/06/2003	East Burra Firth/Aith Voe	HU 356 578	>18000	10.3	12.5	*	32	Spring	High
29/09/2004	Point of Ayres	HU 344 569	5400	0.5	25.1	*	22	Spring	Ebb
18/07/2005	Point of Ayres	HU 344 569	>18000	7	13.5	*	33.01	Increasing	*
19/06/2006	Point of Sletta	HU 342 588	3500	16.2	32	*	*	Neap	*
26/06/2006	Point of Ayres	HU 344 569	1300	1	30.6	*	*	Spring	*
23/10/2006	Point of Ayres	HU 344 569	1750	11.4	28.8	11	32.59	Spring	Flood
20/11/2006	Point of Sletta	HU 342 588	2400	15.4	65	*	33.06	Spring	*

Of these samples, one was collected in January, three in June, and one each in July, September, October and November. Two originated from East Burra Firth / Aith Voe, four from Point of Ayres, two from Point of Sletta and none from Slyde, with the two very highest results originating from Aith Voe and Point of Ayres, although these were the only sites sampled on these days, so they are not directly comparable with any results from the other sites. They arose following a range of rainfalls, although never under particularly dry conditions. Six of eight were taken on spring tides.

11.8 Summary and conclusions

In terms of geometric mean *E. coli* result, the sites were ranked as follows: Point of Ayres (68.7 *E. coli* MPN/100g) > Point of Sletta (51.2 *E. coli* MPN/100g) > East Burra Firth / Aith Voe (47.0 *E. coli* MPN/100g) > Slyde (29.2 *E. coli* MPN/100g). These differences between the sites were not statistically significant either in terms of mean result or proportion of results exceeding 230 *E. coli* MPN/100g. The highest individual results came East Burra Firth / Aith Voe and Point of Ayres, however of these only East Burra Firth is currently an active site. Both of these sites are located nearer to the head of the voe than the other two. No significant difference was found in mean *E. coli* result by reported sampling location either. Results were higher on average at the north end of the Point of Ayres site compared to its southern end. Results were also higher on average at the northern end of the Point of Sletta site compared to its southern end. Results were very similar at either end of the Slyde site. Within the East Burra Firth/Aith Voe site results were on average higher at the more easterly reported sampling location,

although whether the samples were actually taken from the eastern end of this site is uncertain. It must be noted that these differences in results may equally be down to temporal rather than spatial differences in levels of contamination, and the accuracy of some of these sampling locations cannot be verified.

Overall, a marginal improvement may have occurred between 2002 and 2009 at East Burra Firth / Aith Voe. A marginal overall improvement in results at Point of Ayres may have occurred between 2005 and 2008, with a peak in results towards the end of 2006. No overall temporal trends were identified at either Point of Sletta or Slyde. No strong seasonal patterns were identified at any of the four sites, although results were on average lower during the spring at all four sites. A weak positive relationship between *E. coli* results and temperature was found at Slyde but not at East Burra Firth / Aith Voe. There was insufficient data to investigate relationships between these two variables at either of the other sites. The majority of results over 1000 *E. coli* MPN/100g (7 of 8) occurred from June to November.

For East Burra Firth / Aith Voe, a positive correlation was found between *E. coli* results and rainfall in the previous 2 days, but not the rainfall in the previous 7 days. For Point of Ayres, a positive correlation was found between *E. coli* results and rainfall in the previous 7 days, but not the rainfall in the previous 2 days. Positive correlations were found between *E. coli* results and rainfall in both the previous 2 and 7 days at Point of Sletta. No correlation between *E. coli* result and recent rainfall were found at Slyde. No relationship between *E. coli* results and salinity was found at any of the four sites.

A correlation between *E. coli* results and the spring/neap tidal cycle was found at Slyde and Point of Ayres, with higher results generally occurring on spring tides and those increasing in size towards spring tides at both these sites. A correlation was found between *E. coli* results and the high/low tidal cycle was found at Point of Sletta and Slyde, with higher results occurring just after high water at both sites.

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

11.9 Sampling frequency

When a production area has held the same (non-seasonal) classification for 3 years, and the geometric mean of the results falls within a certain range it is recommended that the sampling frequency be decreased from monthly to bimonthly (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2007). Of these production areas, only Aith Voe Sletta is currently classified, and it is not appropriate for this production area as it has held a seasonal classification within the last three years.

12. Designated Shellfish Growing Waters Data

The survey area does not coincide with a designated shellfish growing water.

13. Rivers and streams

The following rivers and streams were measured and sampled during the shoreline survey. These represent the most significant freshwater inputs into the production area. The survey was undertaken under relatively dry conditions, although heavy rain had fallen about 4 days previously.

Table 13.1 River loadings for Aith Voe and East Burra Firth

No.	Position	Width (m)	Depth (m)	Flow (m/s)	Discharge (m^3/d)	*E. coli* (cfu/100 ml)	*E. coli* loading (cfu/day)
1	HU 34467 55962	1.2	0.08	0.634	4930	420	$2.1x10^{10}$
2	HU 34307 56616	-	-	-	2.6	1800	$4.7x10^{7}$
3	HU 34264 56992	0.8	0.18	0.049	610	1600	$9.8x10^{9}$
4	HU 34347 57146	0.2	0.04	Not measured	-	280	-
5	HU 33721 58182	0.53	0.12	0.551	3028	1600	$4.8x10^{10}$
6	HU 34723 55833	1.4	0.56	0.198	13412	20	$2.7x10^{9}$
7	HU 34938 55855	0.8	0.09	0.2305	1434	1300	$1.9x10^{10}$
8	HU 35021 55932	0.3	0.3	0.47	3655	Not sampled	-
9	HU 36588 57848	12	0.2	0.806	167132	700	$1.2x10^{12}$
10	HU 36310 57786	0.2	0.1	0.12	207	1200	$2.5x10^{9}$
11	HU 36263 57789	Not measured	Not measured	Not measured	-	1000	-

Stream 2 was measured by timed collection of the flow using a graduated vessel. Flow was could not be measured for stream 3 due to its small size. No sample was taken for stream 8. No measurements could be taken for stream 11 as it was percolating through rocks. These four streams were all relatively small, and none was particularly close to any of the fisheries, and so are likely to be of relatively minor impact.

The points where streams were measured and sampled are shown in Figure 14.1 together with the calculated loadings. Where the bacterial loading is labelled on the map, the scientific notation is written in digital format, as this is the only format recognised by the mapping software. So, where normal scientific notation for 1000 is 1×10^3, in digital format it is written as 1E+3.

Streams discharging into the survey area drain areas of bog, rough grassland and improved pastures. Water samples from these stream inputs showed low to moderate concentrations of *E. coli*, ranging from 20 to 1800 *E. coli* cfu/100 ml, with the majority containing over 500 cfu/100 ml, suggestive of inputs from livestock. The largest loading was for stream 9, which contributed 91% of the total measured stream loadings. It discharges at the head of East Burra Firth, and so it is likely that there is higher freshwater influence and hence higher levels of freshwater-borne contamination within East Burra Firth, particularly towards its head. On this basis, the eastern end of the Aith Voe site may be more impacted by contamination from this source than the western end. With a discharge of almost 2 m^3/s at the time of survey, this

stream is likely to cause a significant salinity reduction in the waters towards the head of East Burra Firth, which may be of significance to the hydrography of the area. This stream will also contribute to some extent to background levels of contamination within Aith Voe as a whole.

Other streams may create minor hotspots of contamination where they discharge. Several smaller streams discharge at Aith, but these carried relatively minor loadings relative to that which may be expected from the sewage discharge at Aith at the time of shoreline survey. Stream 5 is likely to cause a small hotspot of contamination within the small embayment where it discharges, and may have minor impacts primarily at the Point of Sletta site. Stream loadings are expected to increase significantly following heavy rainfall events, particularly those with high densities of livestock within their catchment areas.

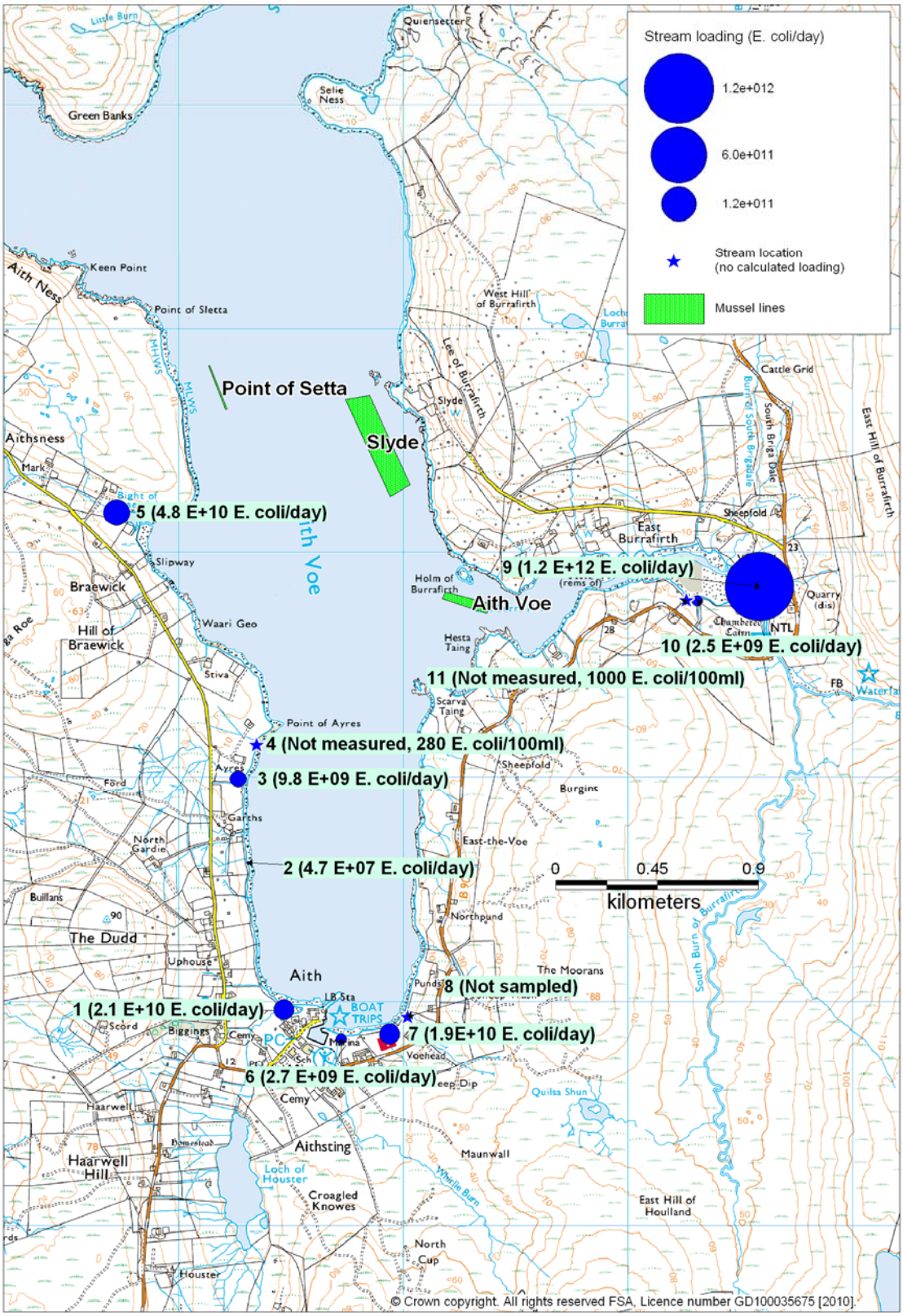

Figure 13.1 Stream loadings for Aith Voe and East Burra Firth

14. Bathymetry and Hydrodynamics

Currents in coastal waters and estuaries are driven by a combination of tide, wind and freshwater inputs. This section aims to make a simple assessment of water movements around the area. Figure 14.1 shows the OS map of Aith Voe (including East Burra Firth) and Figure 14.2 shows the bathymetry of the same area. Both maps also show the location of the mussel lines and of the fish farm hydrographic study sites (see section 14.2)

Aith Voe is approximately 4 km long, just under 1 km wide, and runs in a south to north direction. The island of Papa Little lies in its mouth. East Burra Firth forms a small side arm off Aith Voe just over 1 km in length with an east-west apect. The maximum depth within Aith Voe is 55 m near its mouth. East Burra Firth is shallower, with a maximum depth of about 20 m at its mouth, and a large intertidal area at its head. There are no sills within either Aith Voe or East Burra Firth. The mussel lines at Slyde lie in mainly within the 20 to 30 m depth band, while the Point of Sletta and Aith Voe sites lie mainly in the 10 to 20 m depth band. The Aith Voe site lies in the mouth of East Burra Firth just to the west of a small constriction in East Burra Firth.

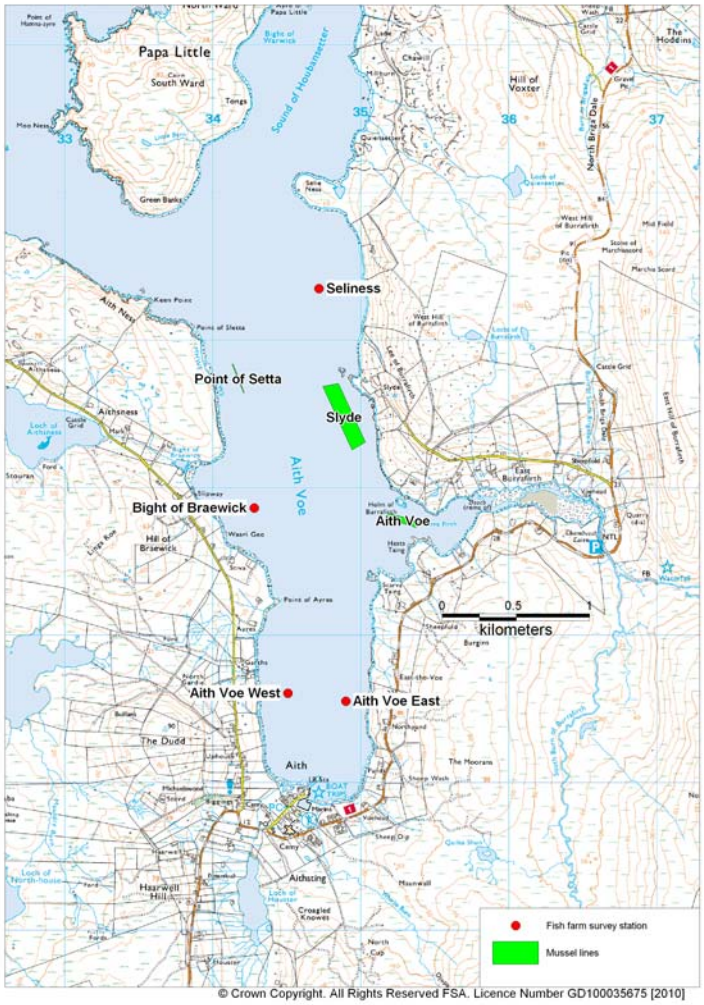

Figure 14.1 OS map of Aith Voe

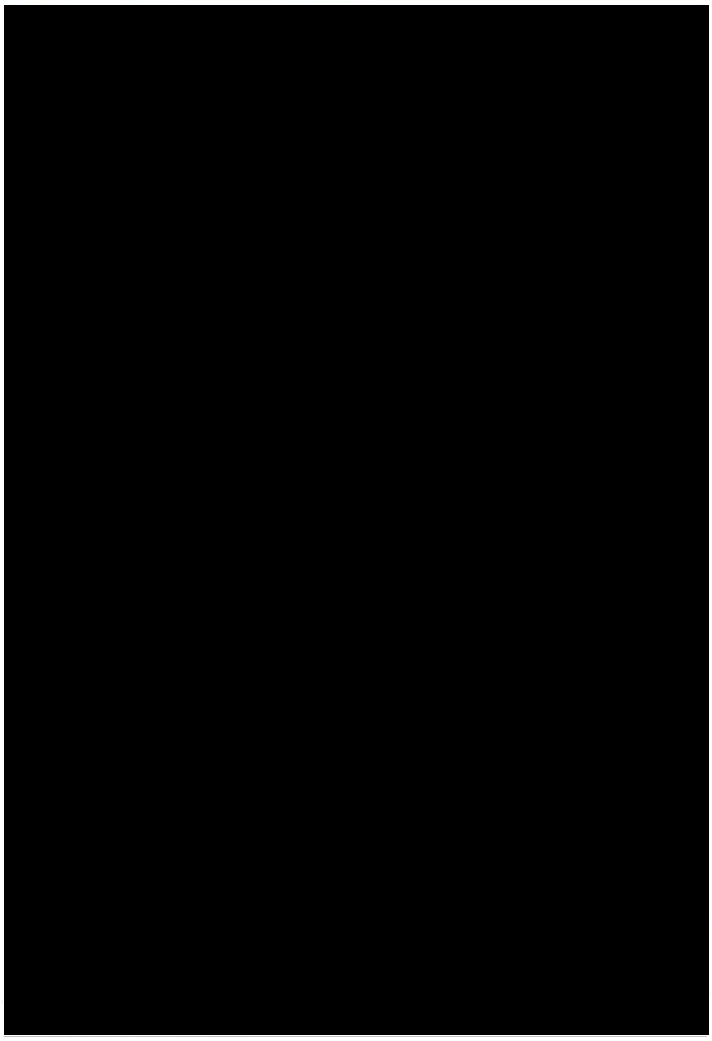

Figure 14.2 Bathymetry of Aith Voe

14.1 Tidal Curve and Description

The two tidal curves below are for Hillswick which lies within St Magnus Bay about 20 km to the north of Aith Voe and is the closest port for which tidal predictions are available. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 BST on 31/08/09 and the second is for seven days beginning 00.00 BST on 08/09/09. This two-week period covers the date of the shoreline survey. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

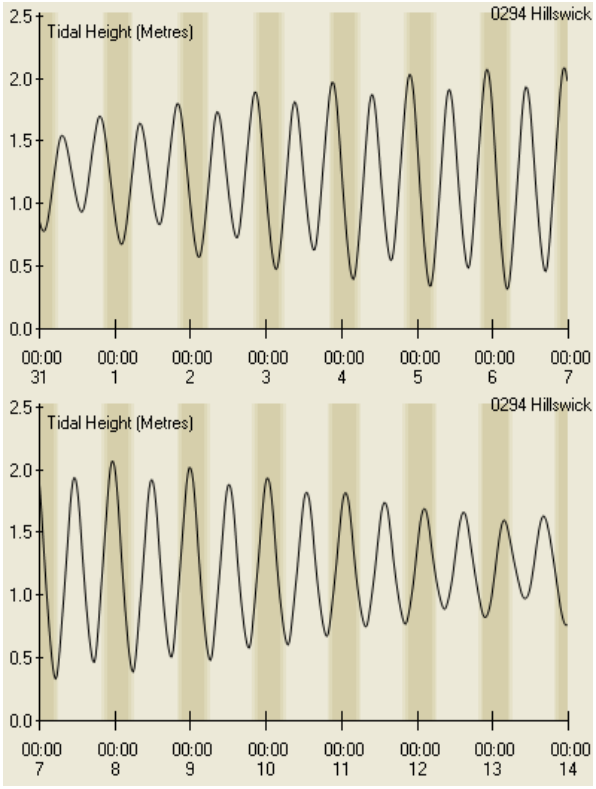

Figure 14.3 Tidal curves for Hillswick

The following is the summary description for Hillswick from TotalTide:
0294 Hillswick is a Secondary Non-Harmonic port. The tide type is Semi-Diurnal.

HAT	2.4 m
MHWS	2.0 m
MHWN	1.6 m
MLWN	0.8 m
MLWS	0.4 m

The heights are in metres above chart datum. The tidal range at spring tide is therefore approximately 1.6 m and at neap tide 0.8 m, so tidal ranges here are relatively small.

14.2 Currents

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. The tidal range here is small, so tidally driven exhange of water is likely to be weak. This is reflected in the relatively lengthy calculated flushing time of 10 days for the whole voe (Edwards and Sharples, 1986). Tidally driven currents within Aith Voe would be expected to move in a northerly direction on the flood tide, and a southerly direction on the ebb tide, and in an east-west direction in East Burra Firth. Contamination from sources along the shore would tend to hug the shoreline. Currents are likely to be faster in shallower areas. Tidally driven currents will be faster on the larger

spring tides and the distance of transport of contaminants is be expected to be greater at these times. Flows may be more complicated at the site in the mouth of East Burra Firth, but water from the north would be expected to flow across it on the flood tide, and water from the south and east would be expected to flow across it on the ebb tide. There may be some differences between the two ends of this site in terms of the flow of water over it during the ebb tide.

The surrounding land rises to 120 m in places, and Aith Voe has south north aspect. The island of Papa Little which rises to 80 m partially obscures its mouth. Therefore, it is most exposed to north and south winds, which will tend to be funnelled up or down the voe, although it will derive some shelter from the surrounding land. East Burra Firth has an east west aspect and is generally more sheltered than Aith Voe itself. It is most exposed to winds from a westerly direction. The East Hill of Burrafirth, at its head, rises steeply to 120 m providing some shelter to the head of the firth from easterly winds. Given the relatively weak tidal currents, wind driven currents have the potential to cause large changes to flows around the area.

The catchment area of Aith Voe is about 35 km^2, and the main freshwater input to the water body is at the head of East Burra Firth. An average salinity reduction of 0.3 ppt was calculated on the basis of tidal and freshwater inflows (Edwards and Sharples, 1986) although this is likely to fluctuate greatly depending on rainfall. Salinity profiles taken at the mussel lines during the course of the shoreline survey indicated that at the time, there was no freshwater influence or stratification. At times of high rainfall, greater freshwater influence may be expected within East Burra Firth compared to Aith Voe, so the mussel farm at East Burra Firth may be expected to experience higher levels of contamination from runoff than either Point of Sletta or Slyde. During historical *E. coli* monitoring surface salinities were often recorded at the time of sampling at the four sites discussed in Section 11 of this report. Although these salinities were not recorded at each site on the same occasions and therefore under the same conditions, they give a useful impression of the range of salinities experienced at these sites and are presented as a boxplot in Figure 14.4.

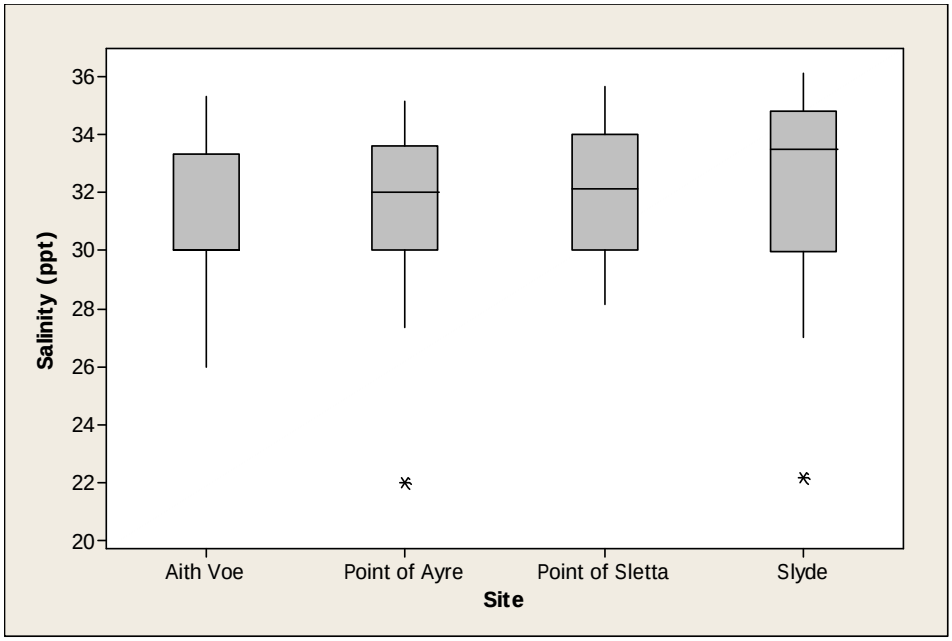

Figure 14.4 Boxplot of salinities recorded by site during historic *E. coli* monitoring

Figure 14.4 indicates that salinities are generally approaching that of full strength seawater most of the time at all sites, although readings of less than 30 ppt were recorded about 25% of the time, and readings as low as 22 ppt were recorded on two occasions (only one site was sampled on both occasions where these exceptionally low salinities arose). There was little difference between the sites (One-Way ANOVA, p=0.430, Appendix 6). Mean salinity was highest at Slyde (32.33 ppt) and lowest at Aith Voe (31.32 ppt).

The best available source of real data on the movement of water around the area was from a series of four studies carried out by the North Atlantic Fisheries College, Scalloway (NAFC) to assess movement of water around potential salmon cage farm sites within Aith Voe. These were carried out on separate occasions, therefore under differing environmental conditions. The studies involved the deployment of a fixed current meter for periods of around 2 weeks, recording average speed and direction of the current at various depths at 10-minute intervals. A weather station was simultaneously deployed which recorded wind speed and direction hourly. Locations of these five current meter stations are shown in Figures 14.1 and 14.2. Polar plots of current velocity and direction readings near the surface and near the bottom and wind data for each of the four locations are presented in Figure 14.5.

Figure 14.5 Polar plots of tidal direction and velocity readings and wind recordings. Current velocity is in cm/s, and wind speed is in m/s.

The study sites were located within Aith Voe, and none was within East Burra Firth. The stations were in varying depths of water (10-40 m) between 100 and 300 m from the shore. They could therefore be considered broadly representative of the sites at Slyde and Point of Sletta, but possibly less so for the Aith Voe site, which lies at the mouth of the East Burra Firth sidearm. The NAFC classed average current speeds of greater than 10 cm/s as strongly flushed, between 5 and 10 cm/s as moderately flushed, between 3 cm/s and

less than 5 cm/s as weakly flushed and less than 3 cm/s are classed as quiescent. Currents of 5 cm/s and 10 cm/s will result in particle transport distances of 1.125 and 2.25 km during a flood or an ebb tide.

At Seliness, flows were weak on average, with a mean current speed near the surface of 4.6 cm/s, and 3.0 cm/s at the bottom. Flows were quite evenly spread in terms of direction at both the top and the bottom, with a very vague north-south bi-directional tendency. Wind was from a variety of directions, although when it was in the westerly half it was generally stronger, possibly due in part to the greater shelter afforded by the nearby land. A total of 67.9 mm of rain fell at Lerwick during the 15 day survey period.

At Bight of Braewick, flows were moderate on average, with a mean current speed near the surface of 6.1 cm/s, and 5.6 cm/s at the bottom. Flows were skewed to the north east at both the top and the bottom. Wind was from a variety of directions, although there was a period of strong south westerly winds, which was presumably responsible for the north east skew in current records. Outside of these periods, the overall pattern of flows was very similar to that observed at Seliness. Rainfall data was unavailable for the survey dates (late December 2002).

At Aith West, flows were strong on average, with a mean current speed of 10.3 cm/s at both the surface and the bottom. Flows were fairly evenly spread in terms of direction at both the top and the bottom, although they appear skewed in a northerly direction at the surface. Wind was primarily from the south, which was presumably responsible for the skew in current records at the surface. Rainfall data was unavailable for the survey dates (late November/ early December 2000).

At Aith East, flows were strong on average, with a mean current speed near the surface of 3.3 cm/s, and 4.1 cm/s at the bottom. Flows were quite evenly spread in terms of direction at the surface, with a north-south bi-directional tendency at the bottom. Wind was from a variety of directions, although when it was in the westerly half it was generally stronger, possibly due in part to the greater shelter afforded by the nearby land. A total of 98.2 mm of rain fell at Lerwick during the 16 day survey period.

Taken together, these records indicate that tidally driven currents in Aith Voe are generally fairly weak, not strongly bi-directional, and can be heavily influenced by wind at times.

14.3 Conclusions

Circulation around the voe will be driven by tide, winds, and, at times, possibly freshwater inputs. The tidal range in the voe is small and tidal currents are fairly weak, and only vaguely bidirectional. Superimposed on this, wind driven currents are likely to significantly alter circulation within the area, depending of course on wind strength and direction. There is no evidence for stratification in either East Burra Firth or in Aith Voe. In general, due to the expected weak currents, significant impact of contaminants will be seen from sources close to the fisheries.

15. Shoreline Survey Overview

The shoreline survey was conducted on the 31st August to 1st September 2009 under mixed conditions. Heavy rain had fallen about 4 days before the start of the survey.

The fishery consisted of three active longline mussel sites, two within the Aith Voe: Sletta production area (Slyde and Point of Sletta), and one within the East Burra Firth declassified production area (Aith Voe). The Slyde site consisted of 4 longlines with 6-8 m droppers, and was being harvested at the time of survey. The Point of Sletta site consisted of a single longline that was used for spat collection only, which may be transferred for growing on at any other of the many sites under the same ownership (Blueshell Mussels). The Aith Voe site consisted of three longlines with 6-8 m droppers, and at the time of survey there was little stock of a harvestable size on this site.

The main sewage input to the survey area was the Scottish Water septic tank serving the village of Aith, at the head of Aith Voe. There were two pumping stations with overflow discharges associated with this septic tank. A number of private septic tanks were observed further north along the shoreline of Aith Voe and also along the shores of East Burra Firth. For 8 of these, no discharge pipe was identified and so these tanks are believed to discharge to soakaway. Three private discharges direct to Aith Voe were identified. Two of these were on the west shore of Aith Voe, just to the south of Point of Ayres, one of which did not appear to have been in recent use at the time of survey, the other of which was flowing, but a water sample from this pipe had a low sanitary content relative to that expected from a sewage discharge (1900 *E. coli* cfu/100 ml). The third possible private discharge to Aith Voe was at Aith, and was discharging water with a sanitary content at the time of survey (26000 *E. coli* cfu/100 ml). The marina at Aith contained 37 boats at the time of survey, 9 of which were of sufficient size to contain on-board toilets. A lifeboat station and a further workboat were present outside the marina itself and a further workboat was observed harvesting on the mussel farm at Slyde. It is likely that human population in the area is slightly higher during the summer, as some houses in the area are believed to be holiday homes, and a wildlife watching charter boat operates out of Aith.

Crofts and farms lined the west shore of Aith Voe and the north shore of East Burra Firth. Farms were also present around the settlement of Aith and also at Slyde, though the latter appeared to be in seasonal occupation. Sheep, cattle and horses were observed on the crofts with sheep being the most numerous. 24 seals (species uncertain) were seen hauled out at Uyea Sound, about 3.5 km to the west of the mouth of Aith Voe, and one was seen in the water in the vicinity of Aith, so it is likely that there is a significant seal presence within the survey area. A family of otters was seen by the Slyde site. No significant aggregations of birds were recorded.

Seawater samples taken during the survey generally contained low levels of *E. coli*. Of the five samples taken within the mussel sites, results ranged from

<1 to 6 *E. coli* cfu/100 ml. Three seawater samples were taken from the shore. Two of these contained low levels of *E.coli* (one at Point of Ayres contained 7 cfu/100 ml, one at Aith contained 4 cfu/100 ml), whereas another sample taken at Aith contained 90 *E. coli* cfu/100 ml. Salinity profiles taken at the mussel sites all indicated that there was no freshwater influence or stratification at the time, with all measurements indicative of full strength seawater. No salinity measurements were taken within East Burra Firth however, which has the main freshwater input to the area at its head.

Freshwater samples and discharge measurements were taken at most streams draining into the survey area. These streams contained light to moderate levels of contamination (20-1800 *E. coli* cfu/100 ml). Most were small and drained areas of moorland and/or pasture. The most significant of these in terms of both discharge and loading was located at the head of East Burra Firth.

Shellfish samples were taken from the Slyde site and the Aith Voe site. At Slyde, paired samples were taken at the top and bottom of the lines from either end of the site. Results were higher at the top of the lines (790 and 1700 *E. coli* MPN/100 g) compared to the bottom (80 and 330 *E. coli* MPN/100 g), and were higher at the south end of the lines (1700 and 330 *E. coli* MPN/100 g) compared to the north end (790 and 80 *E. coli* MPN/100 g). At the Aith Voe site, samples were taken from the top and bottom at the east end, and at the top at the west end. The two samples taken at the top had the same level of *E. coli* (790 MPN/100 g) and the sample taken at the bottom of the lines had a lower level of *E. coli* (490 MPN/100 g). The overall highest result came from the surface at the southern end of the Slyde site (1700 *E. coli* MPN/100 g). A periwinkle sample taken from the west shore of Aith voe, about 800 m north of Aith contained 330 *E. coli* MPN/100 g.

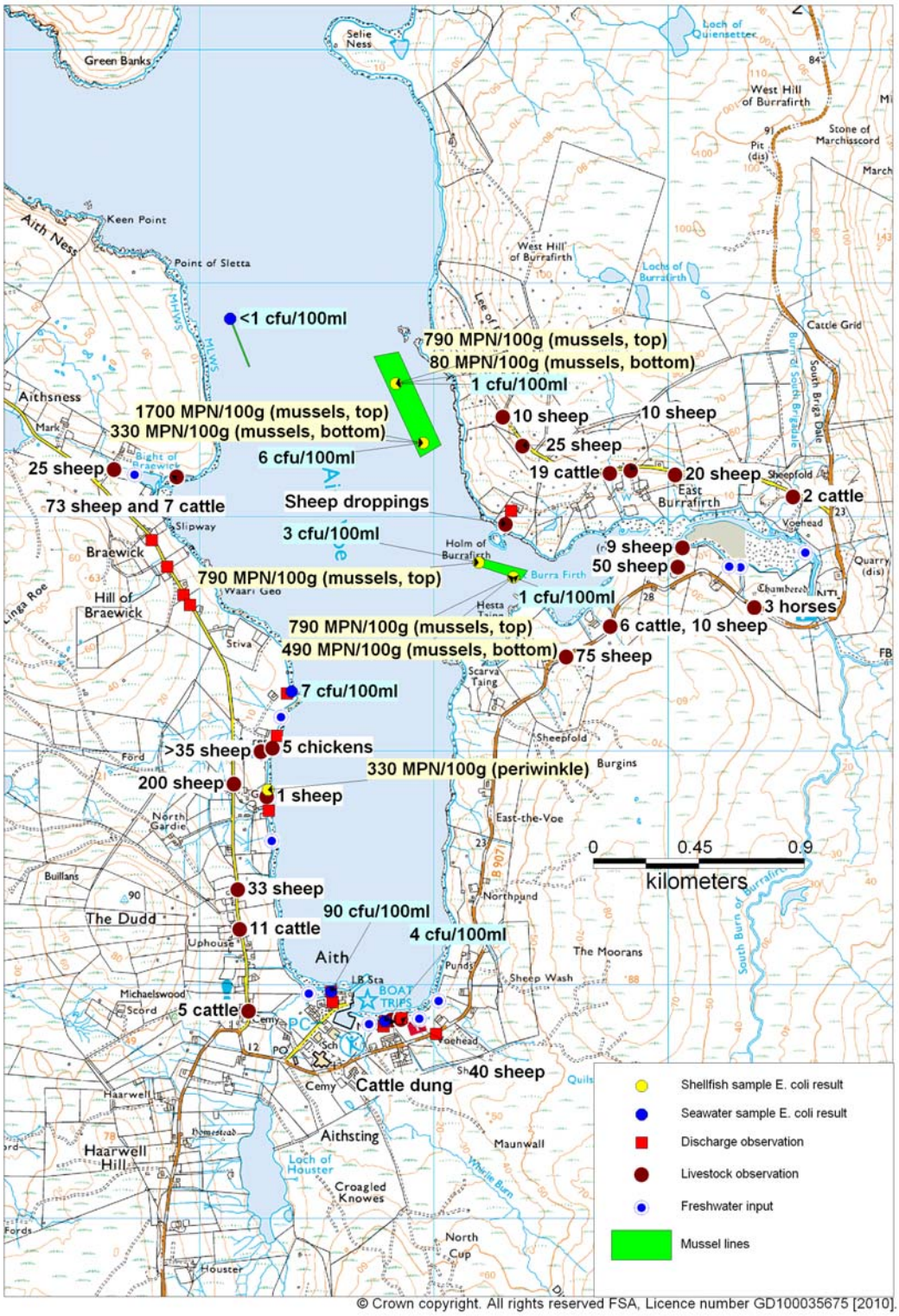

Figure 15.1 Summary of shoreline observations

16. Overall Assessment

Human sewage impacts

The main human sewage input to Aith Voe is the Scottish Water septic tank at Aith, which is consented to serve 300 people and discharges to Aith Voe about 300 m north of Aith, and about 125 m off from the east shore of the voe at a depth of just over 10 m. There are also two overflows associated with this discharge, but as these are emergency overflows they should only discharge if power cuts or other failures occur, and not during times of high rainfall. Properties outside of Aith are served by private septic tanks, the majority of which are believed to discharge to soakaway, and should therefore have no effect on water quality within the survey area. Four private discharges to either Aith Voe or East Burra Firth have been identified. One is to the south shore of East Burra Firth: this was identified by a SEPA discharge consent but not confirmed during the shoreline survey. The other three were recorded on the shoreline survey. Two of these were on the west shore of Aith Voe, just to the south of Point of Ayres, one of these appeared disused, and the other was flowing but had very little sanitary content. The third was at Aith, and was discharging water with fairly dilute sanitary content at the time of survey. Based on these observations, the general impact of these latter three discharges should be minmal.

Discharges from boating traffic may make a minor contribution to general levels of contamination within Aith Voe although there could be more significant local effects. Boat traffic is centred around the marina at Aith, and it is likely that several of the boats visiting/operating from here have onboard toilets which discharge to the sea. Nine vessels that were of a sufficient size to discharge overboard were recorded at Aith marina during the shoreline survey. It is uncertain however if, when and where these boats discharge waste water within Aith Voe.

Agricultural impacts

The surrounding land is a mixture of unimproved and improved grassland and bog. The main areas of improved grassland are around the north shore of East Burra Firth and along the north east end shore of Aith Voe, and along the south west shore of Aith Voe. The shoreline survey confirmed that livestock in the area is predominantly sheep at quite high densities, with some cattle. At the time of survey they were concentrated around the shores of East Burra Firth, and on the west shore of Aith Voe, approximately in alignment with the location of the areas of improved pastures. It is likely that streams draining these pastures are subject to contamination by livestock, and this will be the primary pathway by which this contamination is carried into coastal waters here, although direct deposition to intertidal areas may also be of importance where animals are not excluded from the shoreline. Contamination from livestock will certainly be of significance to general levels of contamination within the survey area, and given the locations recorded on the shoreline

survey, it is possible that there may be slightly greater impacts at the Aith Voe site compared to the other two sites. Shoreline observations only relate to the day of survey however, and it is likely that the animals are moved around from time to time.

Wildlife impacts

The main potential wildlife impacts to the fisheries within Aith Voe and East Burra Firth are seals and seabirds. There are significant seal colonies within St Magnus Bay, and one individual was seen at Aith during the shoreline survey, so it is likely that they are a regular presence in the area. The main seabird breeding colonies in the area are on Papa Little and Vementry, to the north and north west of Aith Voe, although there were significant numbers of breeding sites on the east shore of Aith Voe, to the north of East Burra Firth, so it is possible they impact more on the Slyde site. 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.

Seasonal variation

It is likely that human population in the area is slightly higher during the summer, as although there is little in the way of attractions in the immediate area, some houses are believed to be holiday homes. It is also likely that most of the yachts that visit the area do so during the summer. Therefore, minor increases in human inputs may be expected during the summer months.

Livestock numbers will be higher in the summer, and they are likely to access watercourses to drink more frequently during warmer weather. Therefore, inputs from these will be higher during the summer, particularly following high rainfall events.

The weather is generally wetter and windier in the winter months, so levels of rainfall dependent faecal contamination entering the production area from these sources is likely to be higher on average during the autumn and winter months. High rainfall events can however occur at any time of year, and these may result in a ‘first flush’ of highly contaminated runoff from pastures. This effect may be particularly acute during the summer, when livestock numbers are likely to be highest, and any preceding dry periods result in a buildup of faecal contamination on pastures.

An analysis of historic *E. coli* monitoring data identified no strong seasonal patterns at any of the four sites, although results were on average lowest during the spring at all four sites. A weak positive relationship between *E. coli* results and temperature was found at Slyde but not at East Burra Firth / Aith Voe. There was insufficient data to investigate relationships between these two variables at either of the other sites. The majority of results over 1000 *E. coli* MPN/100 g occurred from June to November. Generally, historical

classifications have been seasonal A/Bs with any B months arising in the summer and autumn.

In conclusion, there is likely to be more contamination of livestock origin during the summer months, as livestock numbers are higher at these times and they are more likely to access streams to drink. Analysis of historical *E. coli* monitoring data suggests lower average levels of contamination within shellfish during the spring, although this was a weak effect and not statistically significant.

Rivers and streams

Several streams drain into the survey area, and the most significant of these were sampled and measured during the shoreline survey to give an estimate of their *E. coli* loading. The survey was undertaken under relatively dry conditions, although heavy rain had fallen about 4 days before. Streams discharging into the area drain bog, rough grassland and improved pastures. Water samples from these stream inputs showed low to moderate concentrations of *E. coli*, ranging from 20 to 1800 *E. coli* cfu/100ml suggesting the majority carry inputs from livestock.

The largest loading was for the stream which discharges to the head of East Burra Firth, which contributed 91% of the total measured stream loadings. It is likely that there is higher freshwater influence and hence levels of freshwater borne contamination within East Burra Firth, particularly towards its head. On this basis, the eastern end of the Aith Voe site may be more impacted by contamination from this source than the eastern end. This stream will also contribute to some extent to background levels of contamination within Aith Voe. Other streams may create minor hotspots of contamination where they discharge. Several smaller streams discharge at Aith, but these carried relatively minor loadings relative to that which may be expected from sewage discharges at Aith at the time of shoreline survey. A stream discharges to the west shore about 800 m to the south of the Point of Sletta site, where it may have some localised impact.

Meteorology, hydrology, and movement of contaminants

Circulation around the area will be driven by tide, winds, and possibly freshwater inputs at times. Tidal influences are fairly weak, as reflected by the lengthy calculated flushing time of 10 days for Aith Voe. Tides will cause a vaguely bidirectional flow of water along the shore as the tide floods and ebbs, creating a region of impact to either side of sources discharging to the shore, with greater impacts closer to the source. As tidal currents are fairly weak, sources close to the fishery will be of greatest impact. Sources on the opposite shore will be of little relative importance as dilution effects will predominate over dispersion effects, reducing *E. coli* concentrations. A correlation between historic *E. coli* monitoring results and the spring/neap tidal cycle was found at Slyde and Point of Ayres, with higher results generally occurring on spring tides and those increasing in size towards spring tides at both these sites. This suggests that either significant sources these two sites

lie some distance from the sites, thereby having the greatest impacts when circulation is greater, and/or possibly that direct deposition of faeces by livestock in the intertidal areas may be of significance. No similar correlation was found for Aith Voe or Point of Sletta. A correlation was found between *E. coli* results and the high/low tidal cycle was found at Point of Sletta and Slyde only, with higher results occurring just after high water at both sites. This implies that these sites are exposed to more contaminated water on a flooding tide, which is unexpected as the main identified potential sources apart from possibly the seabird colonies on Papa Little lie to the south of these sites.

Superimposed on tidal effects, wind driven currents can alter circulation within the area, driving surface currents in the same direction as the wind. Aith Voe is most exposed to northerly and to a lesser extent southerly winds. East Burra Firth is most exposed to winds from a westerly direction. Given the relatively weak tidal currents, wind driven currents have the potential to cause large changes to flows around the area.

Immediately following heavy rainfall, freshwater borne contamination may tend to float in a surface layer over denser seawater in and around East Burra Firth. Very limited evidence of this effect was seen during the shoreline survey, where mussel samples taken from near the surface showed higher levels of contamination than those further down the water column at both the Aith Voe and Slyde sites. Although no evidence of stratification was found in the salinity profiles taken at the time, the higher levels of contamination in shellfish towards the surface may have been a consequence of heavy rain that had fallen 4 days previously. Surface salinities taken at the four sites within the area alongside the historic *E. coli* monitoring indicated that salinities were generally approaching that of full strength seawater most of the time at all sites, although readings of less than 30 ppt were recorded about 25% of the time, showing that some limited stratification occurs on occasion. There was very little difference in range and average salinity between the four sites.

For East Burra Firth / Aith Voe, a positive correlation was found between historic *E. coli* monitoring results and rainfall in the previous 2 days, but not the rainfall in the previous 7 days, which is consistent with the small rapidly draining catchment area of the stream draining to the head of East Burra Firth. For Point of Ayres, a positive correlation was found between *E. coli* results and rainfall in the previous 7 days, but not the rainfall in the previous 2 days. Positive correlations were found between *E. coli* results and rainfall in both the previous 2 and 7 days at Point of Sletta, suggesting the stream discharging at Braewick, 600 m south of the site may be a significant source at times. No correlation between *E. coli* result and recent rainfall were found at Slyde. Presumably these relationships are driven by the proximity and size of streams, and the density of livestock in their catchment areas, although they do not always completely align with what may be expected on the basis of shoreline observation on these streams. No relationship between *E. coli* results and salinity was found at any of the four sites.

Temporal and geographical patterns of sampling results

Historical *E. coli* monitoring samples were reported from 9 individual locations over four longline mussel sites. In terms of geometric mean *E. coli* result, the sites were ranked as follows: Point of Ayres > Point of Sletta > Aith Voe > Slyde. These differences between the sites were not statistically significant either in terms of mean result or proportion of results exceeding 230 *E. coli* MPN/100 g. No significant difference was found in mean *E. coli* result by reported sampling location either. Results were higher on average at the northern end of the Point of Ayres site compared to its southern end. Results were also higher on average at the northern end of the Point of Sletta site compared to its southern end. Results were very similar at either end of the Slyde site. Within the Aith Voe site results were on average higher at the eastern end of the site, although it is doubtful that one of these reported sampling locations is accurate. It must be noted that all these differences in results (none of which are statistically significant) may equally be down to temporal rather than spatial differences in levels of contamination. Highest individual results by some margin arose at the Aith Voe and Point of Ayers sites, both of which were located nearer to larger contamination sources than the other two sites. Overall, a marginal improvement in historic *E. coli* monitoring results may have occurred between 2002 and 2009 at Aith Voe. A marginal overall improvement in results at Point of Ayres may have occurred between 2005 and 2008, with a peak in results towards the end of 2006. No overall temporal trends were identified at either Point of Sletta or Slyde.

Seawater samples were taken during the shoreline survey showed low levels of contamination at the mussel lines at Aith Voe, Point of Sletta and Slyde had low levels of E. coli (<1 to 6 cfu/100 ml). Of the three seawater samples taken from the shore, two contained low levels of *E.coli* (7 and 4 cfu/100 ml), and one (taken at Aith) contained 90 *E. coli* cfu/100 ml. Shellfish samples were taken from the Slyde site and the Aith Voe site during the shoreline survey. Where samples were taken from the top and bottom of the lines, the samples near the surface always contained higher levels of *E. coli*. Samples taken at the surface gave the same result at either end of the Aith Voe site (790 *E. coli* MPN/100 g). At the Slyde site, results were higher at the southern end, and surface sample results were higher on average than at the Aith Voe site.

Overall conclusions

Two main point sources of contamination were identified, both of which are likely to cause localised decreases in water quality, as well as making significant contributions to background levels of contamination within the voe. The sewage discharge at Aith, likely to result in fairly constant hotspot of contamination near the head of Aith Voe, centred at the discharge point towards its eastern shore, moving as the strength and direction of currents fluctuate in the area. It is closest to the Aith Voe site (approximately 1.6 km) and farthest from the Point of Sletta site (approximately 2.5 km), so might possibly impact more on the Aith Voe site, although it is not particularly close to any of these sites so these differences are not expected to be large. The stream which discharges to the head of East Burra Firth is likely to cause a

gradient in levels of contamination from the head to the mouth of East Burra Firth which is likely to drop off very rapidly where it opens up into Aith Voe. The slope of this gradient, and how far any influence extends into Aith Voe will vary significantly depending on recent rainfall, as well as numbers and location of livestock within the catchment area. Given the locations of the active mussel sites, it is expected that this source may impact on the Aith Voe site more than the other two, and possibly more so at its eastern end. Other sources of potential relevance relevence to the fisheries include a private septic tank discharge about 280 m to the south west of the Aith Voe site, and a stream discharging just over 600 m to the south of the Point of Sletta site. It is unlikely that these sources are of sufficient size to create a noticeable gradient in levels of contamination across these fisheries, but they will probably make some minor contribution to levels of contamination found there. Also of note, there are fairly high densities of livestock in the area, apart from the shore between Aith and East Burra Firth where no livestock was recorded during the shoreline survey, and there are significant colonies of breeding seabirds on Papa Little to the north during the summer months.

Based on the location of the main sources of contamination it may be expected that the Aith Voe site is subject to higher levels of contamination than the other two sites in the area. However, the fairly comprehensive *E. coli* monitoring history, and samples taken during the shoreline survey indicate the location of these sources in relation to the fishery sites does not appear to result in any consistent or significant differences in levels of contamination either between or within the sites. In fact, some analyses of historic *E. coli* monitoring results in relation to environmental variables actually contradict these predicted differences to some degree. For example, an analysis of historic *E. coli* monitoring results in relation to recent rainfall suggests that levels of contamination are most heavily influenced by recent rainfall at the Point of Sletta site, although significant effects were also found at the Aith Voe and Point of Ayres site. Also, higher results arose at Point of Sletta and Slyde just after high water, implying that sources to the north of these are most important to levels of contamination here.

Therefore, there is little firm basis for the separate classification of the three sites, and they should all be classified together. Although the Point of Sletta site is only currently used for the collection of spat, there are no grounds for excluding it from the classified area, and including it within the classified area would allow harvesting to restart here without the requirement for further sanitary assessment and monitoring. Production area boundaries may be restricted to exclude contamination hotspots which may exist around the Aith discharge, and the head of East Burra Firth where there is likely to be significantly higher levels of contamination arising from the stream which discharges there.

The highest recorded historic *E. coli* monitoring result arose at the Aith Voe site, and as speculated geographical variation in impacts from the various identified sources predict highest levels of contamination here, it is recommended that the RMP for this production area be set at the eastern end of the Aith Voe site.

Mussel samples taken at different depths during the shoreline survey consistently showed higher levels of contamination towards the surface, salinity records from the *E. coli* monitoring history showed some salinity reduction at times, and the bathymetry and hydrography of the area suggest there is little scope for mixing. Therefore, it is believed that limited stratification may occur at times, and levels of contamination are likely to be highest in the fresher water at the surface at these times, so the RMP should be set at the surface to capture this effect.

17. Recommendations

Production Area

Recommended production area boundaries are lines drawn between HU 3392 5900 and HU 3500 5900 and between HU 3442 5722 and HU 3512 5738 and between HU 3542 5764 and HU 3551 5782 and between HU 3400 5818 and HU 3400 5780 extending to MHWS. Based on contamination sources from both the head of East Burra Firth and the head of Aith Voe, and given that they are not currently in use for shellfish production, these areas have been excluded from the production area boundaries. In addition, the small bay at Bight of Braewick on the west side of Aith Voe was excluded as this area receives higher levels of contamination due to runoff. The northern boundary has been redrawn to more closely encompass the area within which production is currently occurring. Should any of these excluded areas come into production in the future, the report should be reviewed and the sampling plan reevaluated in accordance with any changes.

Representative Monitoring Point

It is recommended that the RMP be located at HU 3539 5777, on the east side of the mussel farm where levels of contamination are generally expected to be the highest. Samples should be taken from a depth of 1 m as the shoreline survey showed samples from the tops of the lines were more highly contaminated than those from deeper within the water column. I

Sampling Tolerance

A sampling tolerance of 20 m is recommended to allow for some movement of the lines. As stock is rotationally harvested, it may be necessary to place a dedicated sampling bag at this RMP location. If a sampling bag is used, replenished stock should be in place for at least two weeks prior to sampling.

Frequency

Some potential seasonality was identified in sources, and although no statistically significant seasonal effects were detected in the historical *E. coli* monitoring data, former classifications in the area have generally been seasonal, so monthly monitoring should be continued.

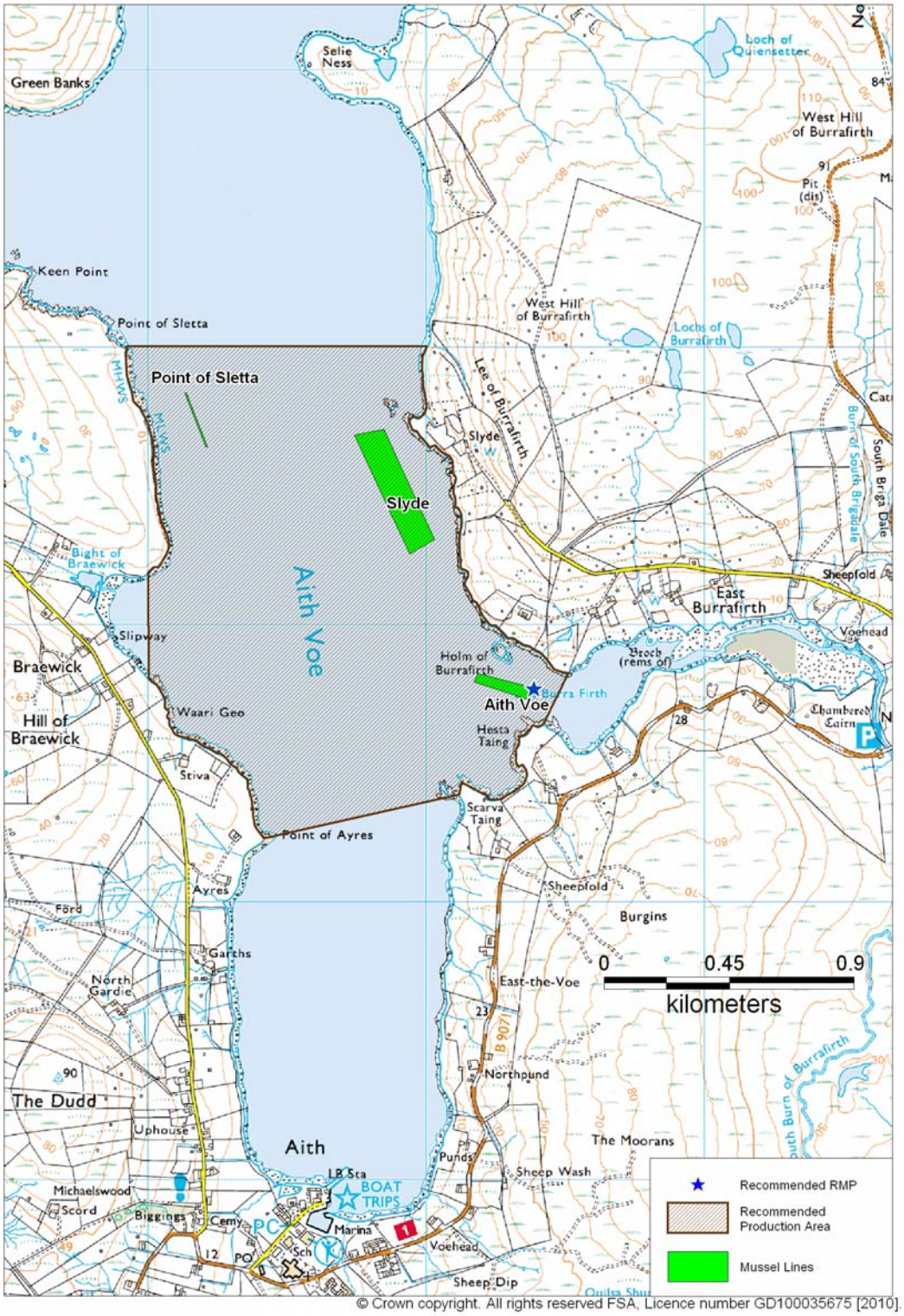

Figure 17.1 Recommendations for Aith Voe and East Burra Firth

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Sampling Plan for Aith Voe/East Burra Firth

PRODUC-TION AREA	SITE NAME	SIN	SPECIES	TYPE OF FISH-ERY	NGR OF RMP	EAST	NORTH	TOLER-ANCE (M)	DEPTH (M)	METHOD OF SAMPLING	FREQ OF SAMPL-ING	LOCAL AUTH-ORITY	AUTHORISED SAMPLER(S)	LOCAL AUTHORITY LIAISON OFFICER
Aith Voe/East Burra Firth	Aith Voe Slyde Point of Sletta	SI 055 863 08 SI 326 733 08 SI 326 393 08	Common mussels	Longline	HU 3539 5777	435390	1157770	20	1	Hand	Monthly	Shetland Islands Council	Sean Williamson George Williamson Kathryn Winter Marion Slater	Sean Williamson

Table of Proposed Boundaries and RMPs

Production Area	Species	SIN	Existing Boundary	Existing RMP	New Boundary	New RMP	Comments
Aith Voe	Common mussels	SI 326	Area bounded by lines drawn between HU 3558 5927 and HU 3377 5990 and HU 3377 5990 to HU 3500 5965 and HU 3522 5800 to HU 3385 5800	HU 348 586	Area bounded by lines drawn between HU 3392 5900 and HU 3500 5900 and between HU 3442 5722 and HU 3512 5738 and between HU 3542 5764 and HU 3551 5782 and between HU 3400 5818 and HU 3400 5780 extending to MHWS	HU 3539 5777	Existing Aith Voe: Sletta production area extended to include Aith Voe site at the mouth of East Burra Firth, which was formerly classified separately. RMP moved to the east end of the Aith Voe site.
East Burra Firth	Common mussels	SI 055	Formerly an area inshore of a line drawn between HU 352 580 and HU 351 574	None assigned			

Geology and Soils Information

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.

References

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General Information on Wildlife Impacts

Pinnipeds

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

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

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

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

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

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

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

Cetaceans

As mammals, whales and dolphins would be expected to have resident populations of *E. coli* and other faecal indicator bacteria in the gut. Little is known about the concentration of indicator bacteria in whale or dolphin faeces, in large part because the animals are widely dispersed and sample collection difficult.

A variety of cetacean species are routinely observed 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. As mammals, it can be safely assumed that their guts will contain an unknown concentration of normal commensal bacteria, 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 5 km radius of the production area. This gives a rough idea of how many birds may be present either on nests or feeding near the shellfish farm or bed.

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

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

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

Deer

There are no deer on Shetland.

Otters

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

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

References:

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Tables of Typical Faecal Bacteria Concentrations

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

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

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

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

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

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

Statistical data

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

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

```
Source    DF      SS     MS     F      P
GridRef    8   5.798  0.725  1.41  0.194
Error    163  83.571  0.513
Total    171  89.369

S = 0.7160   R-Sq = 6.49%   R-Sq(adj) = 1.90%


                            Individual 95% CIs For Mean Based on
                            Pooled StDev
Level      N    Mean   StDev  -----+---------+---------+---------+----
HU341586   7  1.5414  0.5198                  (-----*------)
HU342585   1  1.0000       *  (-----------------*----------------)
HU342588  31  1.7702  0.7711                        (--*--)
HU344567   8  1.3780  0.5783                 (-----*-----)
HU344569  31  1.9557  0.8607                          (--*---)
HU348586  18  1.4717  0.6303                    (---*----)
HU350583  20  1.4605  0.5391                    (---*---)
HU353577  11  1.5766  0.7007                    (-----*----)
HU356578  45  1.6955  0.7129                         (-*--)
                            -----+---------+---------+---------+----
                               0.00      0.80      1.60      2.40

Pooled StDev = 0.7160
```

Section 11.3 One-way ANOVA comparison of results by site

```
Source   DF      SS     MS     F      P
Site      3   2.734  0.911  1.77  0.155
Error   168  86.635  0.516
Total   171  89.369

S = 0.7181   R-Sq = 3.06%   R-Sq(adj) = 1.33%



Level                     N    Mean   StDev
East Burra Firth / Aith  56  1.6721  0.7058
Point of Ayres           39  1.8372  0.8380
Point of Sletta          39  1.7094  0.7305
Slyde                    38  1.4658  0.5760

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level                      -+---------+---------+---------+--------
East Burra Firth / Aith             (-------*------)
Point of Ayres                           (--------*---------)
Point of Sletta                     (--------*--------)
Slyde                       (---------*--------)
                           -+---------+---------+---------+--------
                          1.25      1.50      1.75      2.00

Pooled StDev = 0.7181
```

Section 11.3 Chi squared comparison of proportion of results over 230 *E. coli* MPN/100g by site

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

       EBF/AV    PoS    PoA  Slyde  Total
    1      46     30     31     34    141
        45.91  31.97  31.97  31.15
        0.000  0.122  0.029  0.261

    2      10      9      8      4     31
        10.09   7.03   7.03   6.85
        0.001  0.553  0.134  1.185

Total      56     39     39     38    172

Chi-Sq = 2.284, DF = 3, P-Value = 0.516
```

Section 11.3 Paired T-test comparison of same day results from Point of Ayres and Point of Sletta

```
Paired T for Point of Ayres - Point of Sletta

                  N    Mean  StDev  SE Mean
Point of Ayres   14   1.767  0.626    0.167
Point of Sletta  14   1.839  0.705    0.188
Difference       14  -0.071  0.573    0.153

95% CI for mean difference: (-0.402, 0.259)
T-Test of mean difference = 0 (vs not = 0): T-Value = -0.47  P-Value = 0.648
```

Section 11.5 One way ANOVA comparison of *E. coli* results by season (East Burra Firth / Aith Voe)

```
Source  DF      SS     MS     F      P
Season   3   2.368  0.789  1.64  0.191
Error   52  25.028  0.481
Total   55  27.396

S = 0.6938   R-Sq = 8.64%   R-Sq(adj) = 3.37%

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev   -+---------+---------+---------+--------
1      15  1.3627  0.5499   (---------*---------)
2      14  1.7251  0.9738             (---------*----------)
3      13  1.9311  0.6203                  (----------*----------)
4      14  1.7101  0.5443            (----------*---------)
                           -+---------+---------+---------+--------
                          1.05      1.40      1.75      2.10

Pooled StDev = 0.6938
```

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

```
Source  DF      SS     MS     F      P
Season   3   2.830  0.943  1.38  0.264
Error   35  23.857  0.682
Total   38  26.687

S = 0.8256   R-Sq = 10.60%   R-Sq(adj) = 2.94%
```

```
                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev  ---+---------+---------+---------+------
1       7  1.4636  0.5310  (-----------*------------)
2      11  2.0425  1.0366               (---------*---------)
3      12  2.0764  0.8871                (---------*--------)
4       9  1.5577  0.5877    (----------*----------)
                          ---+---------+---------+---------+------
                           1.00      1.50      2.00      2.50
Pooled StDev = 0.8256
```

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

```
Source  DF      SS     MS     F      P
Season   3   1.560  0.520  0.97  0.417
Error   35  18.716  0.535
Total   38  20.276

S = 0.7313   R-Sq = 7.70%   R-Sq(adj) = 0.00%

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev  -------+---------+---------+---------+--
1      10  1.3878  0.4490  (-----------*----------)
2       9  1.7080  0.9436        (------------*-----------)
3      10  1.8560  0.7969             (----------*-----------)
4      10  1.8858  0.6719             (-----------*-----------)
                          -------+---------+---------+---------+--
                               1.20      1.60      2.00      2.40
Pooled StDev = 0.7313
```

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

```
Source  DF      SS     MS     F      P
Season   3   1.534  0.511  1.62  0.203
Error   34  10.742  0.316
Total   37  12.276

S = 0.5621   R-Sq = 12.49%   R-Sq(adj) = 4.77%

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev  ------+---------+---------+---------+---
1      10  1.1903  0.4185  (---------*---------)
2      10  1.5686  0.7232            (----------*---------)
3       7  1.7714  0.5796                (------------*-----------)
4      11  1.4284  0.4943         (---------*---------)
                          ------+---------+---------+---------+---
                              1.05      1.40      1.75      2.10
Pooled StDev = 0.5621
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 2 day rainfall (East Burra Firth / Aith Voe)

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.498
P-Value = 0.003
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 2 day rainfall (Point of Ayres)

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.091
P-Value = 0.583
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 2 day rainfall (Point of Sletta)

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.592
P-Value = 0.000
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 2 day rainfall (Slyde)

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.325
P-Value = 0.070
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 7 day rainfall (East Burra Firth / Aith Voe)

```
Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.307
P-Value = 0.077
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 7 day rainfall (Point of Ayres)

```
Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.334
P-Value = 0.037
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 7 day rainfall (Point of Sletta)

```
Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.427
P-Value = 0.007
```

Section 11.6.1 Spearmans rank correlation for *E. coli* result and 7 day rainfall (Slyde)

```
Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.325
P-Value = 0.069
```

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the spring/neap cycle (East Burra Firth / Aith Voe)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 27 November 2009 11:31:15

Variables (& observations)	r	p
Frank & Linear (56)	0.134	0.385

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 14 January 2010 14:18:57

Variables (& observations)	r	p
Angles & Linear (39)	0.451	5.86E-04

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 27 November 2009 11:34:41

Variables (& observations)	r	p
Frank & Linear (39)	0.234	0.139

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 27 November 2009 11:26:52

Variables (& observations)	r	p
Angles & Linear (38)	0.491	1.84E-04

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the high/low cycle (East Burra Firth / Aith Voe)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 27 November 2009 11:30:16

Variables (& observations)	r	p
Linear & Linear (51)	0.186	0.191

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 27 November 2009 11:32:29

Variables (& observations)	r	p
Frank & Linear (24)	0.313	0.127

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 27 November 2009 11:34:02

Variables (& observations)	r	p
Frank & Linear (20)	0.589	0.002

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 27 November 2009 11:27:33

Variables (& observations)	r	p
Angles & Linear (23)	0.516	0.004

Section 11.6.3 Regression analysis – *E. coli* result vs water temperature (East Burra Firth / Aith Voe)

```
The regression equation is
log e coli for temperature = 2.50 - 0.0946 temperature

Predictor        Coef  SE Coef      T      P
Constant       2.5043   0.7183   3.49  0.004
temperature  -0.09457  0.08004  -1.18  0.259

S = 0.721838   R-Sq = 9.7%   R-Sq(adj) = 2.8%

Analysis of Variance

Source          DF      SS      MS     F      P
Regression       1  0.7274  0.7274  1.40  0.259
Residual Error  13  6.7737  0.5211
Total           14  7.5011
```

Section 11.6.3 Regression analysis – *E. coli* result vs water temperature (Slyde)

```
The regression equation is
log e coli for temperature = - 0.146 + 0.173 temperature

Predictor       Coef  SE Coef      T      P
Constant     -0.1459   0.7115  -0.21  0.841
temperature  0.17323  0.07688   2.25  0.044

S = 0.526685   R-Sq = 29.7%   R-Sq(adj) = 23.9%

Analysis of Variance

Source          DF      SS      MS     F      P
Regression       1  1.4082  1.4082  5.08  0.044
Residual Error  12  3.3288  0.2774
Total           13  4.7370

Unusual Observations
                   log e coli
                         for
Obs  temperature  temperature    Fit  SE Fit  Residual  St Resid
  4         12.0        1.000  1.933   0.266    -0.933     -2.05R

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

Section 11.6.5 Regression analysis – *E. coli* result vs salinity (East Burra Firth / Aith Voe)

```
The regression equation is
log e coli for salinity = 2.56 - 0.0296 salinity

Predictor      Coef  SE Coef      T      P
Constant      2.561    1.647   1.56  0.128
salinity   -0.02964  0.05244  -0.57  0.575

S = 0.759569   R-Sq = 0.8%   R-Sq(adj) = 0.0%

Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.1843  0.1843  0.32  0.575
Residual Error  40  23.0778  0.5769
Total           41  23.2621
```

```
Unusual Observations
                 log e coli
Obs  salinity  for salinity    Fit  SE Fit  Residual  St Resid
 16      32.0         4.556  1.612   0.123     2.944      3.93R
 22      26.0         1.301  1.790   0.303    -0.489     -0.70 X

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

Section 11.6.5 Regression analysis – *E. coli* result vs salinity (Point of Ayres)

```
The regression equation is
log e coli for salinity = 3.05 - 0.0369 salinity

Predictor      Coef  SE Coef      T      P
Constant      3.046    1.813   1.68  0.103
salinity   -0.03694  0.05717  -0.65  0.523

S = 0.852229   R-Sq = 1.4%   R-Sq(adj) = 0.0%

Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.3033  0.3033  0.42  0.523
Residual Error  30  21.7888  0.7263
Total           31  22.0921

Unusual Observations
                 log e coli
Obs  salinity  for salinity    Fit  SE Fit  Residual  St Resid
  1      22.0         3.732  2.233   0.569     1.499      2.36RX
  9      33.0         4.556  1.826   0.171     2.730      3.27R

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

Section 11.6.5 Regression analysis – *E. coli* result vs salinity (Point of Sletta)

```
The regression equation is
log e coli for salinity = 1.26 + 0.0113 salinity

Predictor     Coef  SE Coef     T      P
Constant     1.265    1.603  0.79  0.436
salinity   0.01133  0.05020  0.23  0.823

S = 0.680039   R-Sq = 0.2%   R-Sq(adj) = 0.0%

Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.0236  0.0236  0.05  0.823
Residual Error  32  14.7985  0.4625
Total           33  14.8221

Unusual Observations
                 log e coli
Obs  salinity  for salinity    Fit  SE Fit  Residual  St Resid
 22      33.1         3.380  1.639   0.131     1.741      2.61R

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

Section 11.6.5 Regression analysis – *E. coli* result vs salinity (Slyde)

```
The regression equation is
log e coli for salinity = 2.12 - 0.0213 salinity
```

```
Predictor      Coef  SE Coef      T      P
Constant      2.122    1.099   1.93  0.064
salinity   -0.02129  0.03382  -0.63  0.534

S = 0.584107   R-Sq = 1.4%   R-Sq(adj) = 0.0%

Analysis of Variance

Source          DF      SS      MS     F      P
Regression       1  0.1351  0.1351  0.40  0.534
Residual Error  28  9.5531  0.3412
Total           29  9.6882

Unusual Observations
                 log e coli
Obs  salinity  for salinity    Fit  SE Fit  Residual  St Resid
 22      33.1         2.690  1.418   0.109     1.272      2.22R
 27      22.2         1.000  1.651   0.360    -0.651     -1.42 X
 30      35.0         2.519  1.377   0.140     1.141      2.01R

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

Section 14.2 One way ANOVA comparison of salinities by site

```
Source   DF      SS    MS     F      P
Site      3   18.95  6.32  0.93  0.430
Error   134  913.78  6.82
Total   137  932.73

S = 2.611   R-Sq = 2.03%   R-Sq(adj) = 0.00%

                                    Individual 95% CIs For Mean Based on
                                    Pooled StDev
Level             N    Mean  StDev  ----+---------+---------+---------+-----
Aith Voe         42  31.320  2.262  (----------*----------)
Point of Ayre    32  31.596  2.677    (------------*------------)
Point of Sletta  34  31.854  2.358        (------------*------------)
Slyde            30  32.330  3.207              (-------------*------------)
                                    ----+---------+---------+---------+-----
                                     30.80     31.50     32.20     32.90
Pooled StDev = 2.611
```

Hydrographic Methods

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

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

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

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

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

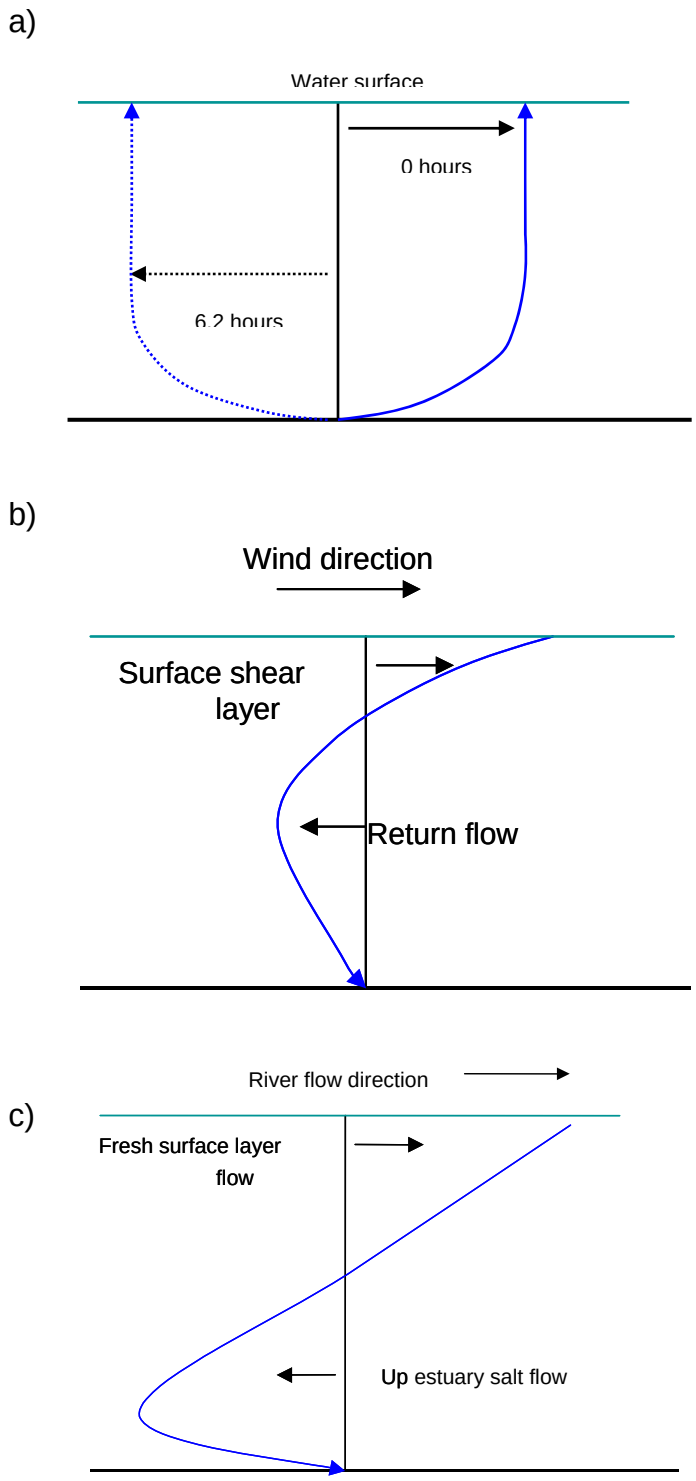

Figure 1. Typical vertical profiles for currents generated by different mechanisms. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main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

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

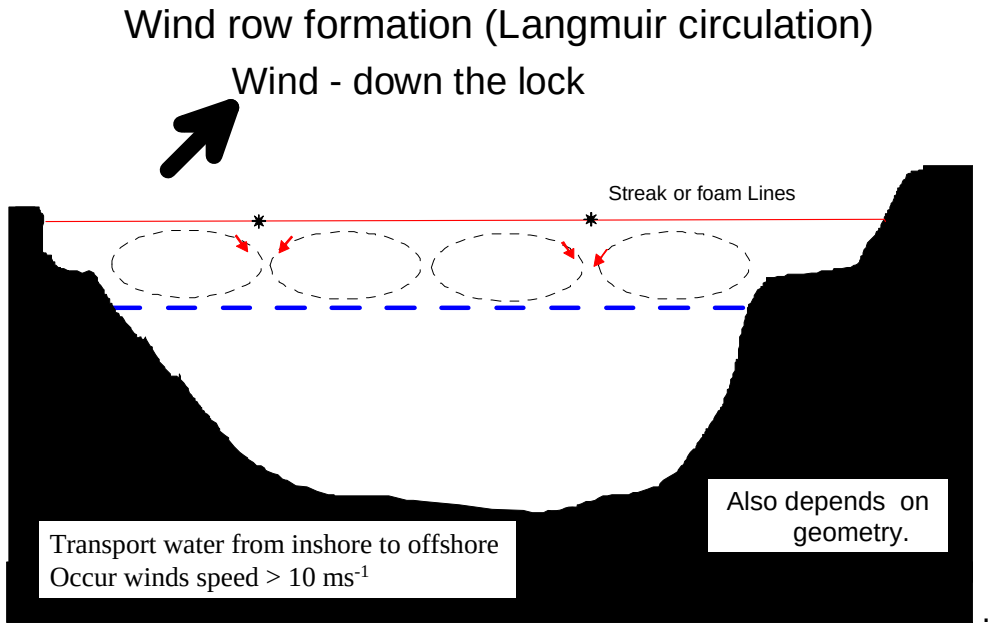

Figure 2: Schematic of wind driven 'wind row' currents. View is down the loch.The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Shoreline Survey Report

East Burra Firth SI 055
& Aith Voe SI 326

Scottish Sanitary Survey Project

Shoreline Survey Report

Survey Sites:

Production Area	Site	SIN	Species	Harvester
East Burra Firth	Aith Voe	SI 055 863 08	Common mussels	North Atlantic Shellfish
Aith Voe: Sletta	Point of Sletta	SI 326 393 08	Common mussels	Blueshell Mussels
Aith Voe: Sletta	Slyde	SI 326 733 08	Common mussels	North Atlantic Shellfish

Local Authority: Shetland Islands Council
Status: New application and existing sites
Date Surveyed: 31 August - 1 September, 2009
Surveyed by: M. Price Hayward, S. Williamson
Existing RMP:

Site	Nominal RMP	Sampling Point
Aith Voe	Unassigned	HU 3532 5779
Point of Sletta	HU 342 588	HU 3419 5863
Slyde	HU 348 586	HU 3502 5833

Weather observations
31 August: Dry, overcast. Temperature 15C, Wind SW F4. Rain previous weekend. Local resident reported that the Burn of Burrafirth had run high on 28 August after heavy rain then had returned to lower flow by 30 August. Winds over 29-30 August were reported to have been N-NE F7-8.

1 September: Intermittent rain, overcast. Temperature 15C, Wind SSW F2.

Site Observations

Fishery

East Burra Firth
One long line mussel farm was located just inside the entrance to East Burra Firth that consisted of three long lines with 6-8m droppers. Little growth of sufficient size for sampling was present, so one of the three samples collected came from the dedicated sampling basket hung at HU 35191 57804.

Aith Voe Sletta
Within this classified production area, there was one long line mussel farm located along the east side of the voe that consisted of 4 long lines with 6-8m droppers. The site was being harvested at the time of survey.

There is a single line located off the point of sletta that is used for collecting spat only. Consequently, no mussel sample was taken from this line.

Sewage/Faecal Sources
A sewage pumping station and outfall pipe were observed at the settlement of Aith, approximately 2 km south of the mussel farms. A small marina, lifeboat station and leisure centre were located at the southern end of Aith Voe. The

lifeboatman noted that the town was on a relatively new sewerage system that served the majority of the population along the southern shores of the voe and that water quality appeared to be much improved. A pumping station and overflow pipe were found just east of the jetty, however the the pipe was dry and in poor repair so may no longer have been active. The pumping station and outfall for the main sewage discharge was found to further to the east. A little beyond this outfall was another discharge pipe flowing across the sand, which was found to contain 26000 *E. coli* (cfu/100 ml).

A number of septic tanks were observed further north along the shoreline of Aith Voe and also along the shores of East Burra Firth. In most cases, no discharge pipe was identified and so these tanks were presumed to discharge to soakaway. One tank on the west shore of Aith Voe was observed to have no discharge pipe but evidence of leakage was present around the base of the tank. One discharge pipe was observed to be flowing, and contained 1900 *E. coli* (cfu/100ml).

Seasonal Population
A poster advertising wildlife watching tours by boat was seen near the marina, indicating that there may be at least some tourism to the area. In addition, some of the homes observed were reported to be summer homes, indicating seasonal increase in population during the summer.

Boats/Shipping
The marina at Aith contained 37 boats at the time of survey, 9 of which were of sufficient size to contain on-board toilets. A lifeboat station and a further workboat were present outside the marina itself and a further workboat was observed harvesting on the mussel farm at Slyde.

Land Use
Crofts and farms lined the west shore of Aith Voe and the north shore of East Burra Firth. Farms were also present around the settlement of Aith and also at Slyde, though the latter appeared to be in seasonal occupation. Sheep, cattle and horses were observed on the crofts with sheep being the most numerous.

Wildlife/Birds
No significant aggregations of birds was observed on the day. A large group of seals was seen to the west of Aith voe, off the map in Figure 1. No seals were observed within Aith Voe. Three otters were seen on the shoreline adjacent to the Slyde shellfish farm. No other wildlife were observed in the area.

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

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

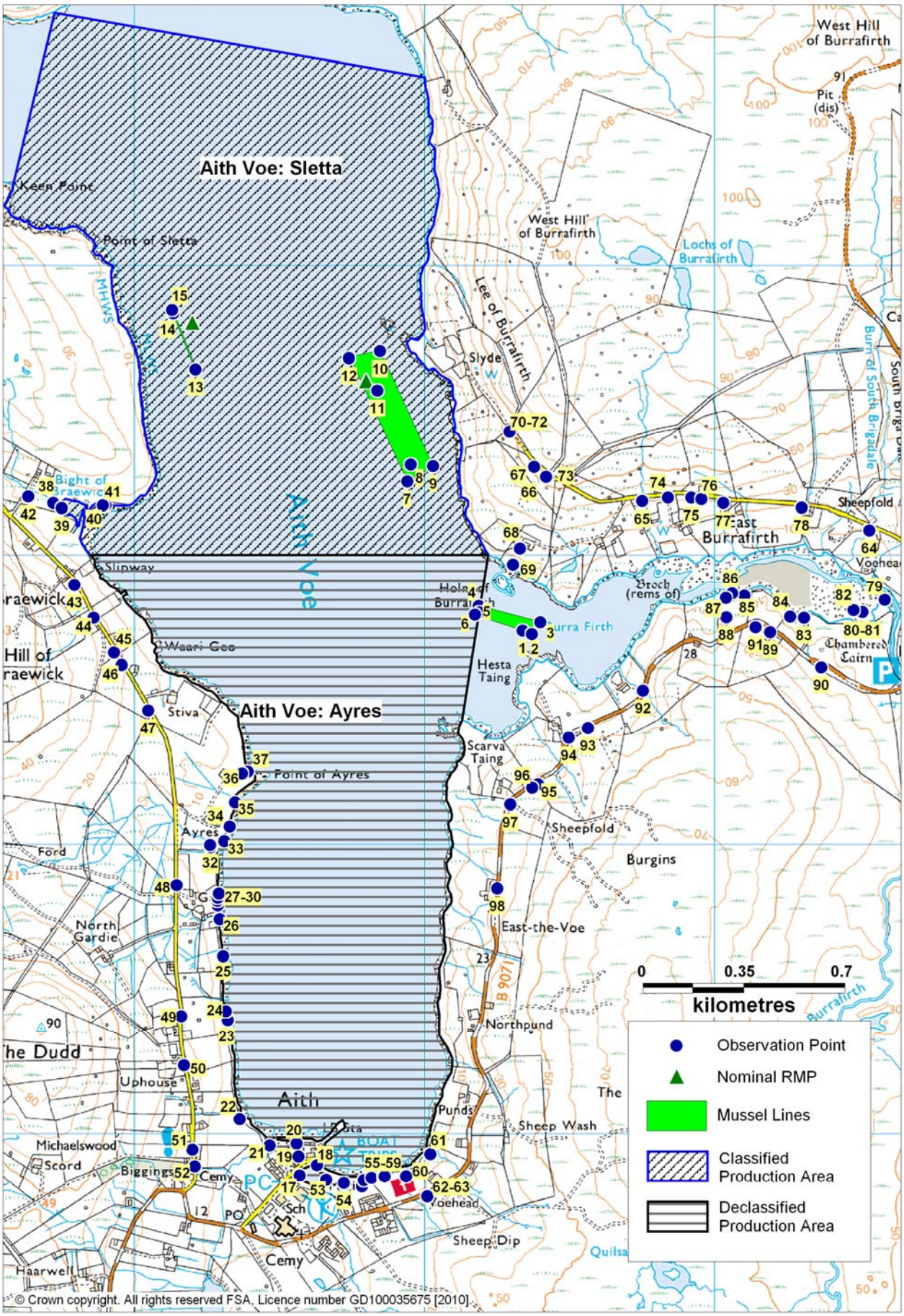

Figure 1. Map of Shoreline Observations

Table 1. Shoreline Observations

Obs No.	Date	Time	Grid Ref	East	North	Way-point	Associated Photograph	Note
1	31/08/2009	08:44:26	HU 35339 57741	435339	1157741	129	Figure 4	Depth of lines 6-8m. Mussel sample 1 taken from bottom of line (6-8 m depth), mussel sample 2 from top 1m. Seawater sample 1
2	31/08/2009	08:54:19	HU 35371 57728	435371	1157728	130		Corner of lines
3	31/08/2009	08:55:04	HU 35401 57769	435401	1157769	131	Figure 5	Corner of lines
4	31/08/2009	08:56:50	HU 35188 57826	435188	1157826	132		Corner of lines
5	31/08/2009	08:57:23	HU 35191 57804	435191	1157804	133		Mussel sample 3 taken from RMP basket at 1m depth, insufficient growth on lines. Seawater sample 2.
6	31/08/2009	09:02:31	HU 35175 57796	435175	1157796	134		Corner of lines
7	31/08/2009	09:04:47	HU 34941 58256	434941	1158256	135		Corner of lines
8	31/08/2009	09:14:19	HU 34954 58315	434954	1158315	136		Mussel sample 4 taken from bottom of line, mussel sample 5 from top (1m). Seawater sample 3.
9	31/08/2009	09:21:38	HU 35031 58309	435031	1158309	137		Corner of lines
10	31/08/2009	09:24:19	HU 34847 58706	434847	1158706	138		Corner of lines
11	31/08/2009	09:26:32	HU 34838 58570	434838	1158570	139	Figure 6	Harvesting boat working on site. Mussel samples taken from harvesting boat - sample 6 from the bottom of the line, and 7 from the top. Seawater sample 4.
12	31/08/2009	09:44:38	HU 34740 58682	434740	1158682	140		Corner of lines
13	31/08/2009	09:46:56	HU 34211 58643	434211	1158643	141		End of spat line
14	31/08/2009	09:48:21	HU 34134 58836	434134	1158836	142		End of spat line
15	31/08/2009	09:48:27	HU 34130 58847	434130	1158847	143		Seawater sample 5.
16	31/08/2009	10:15:44	HU 31120 60400	431120	1160400	144		24 seals hauled out on beach
17	31/08/2009	11:24:00	HU 34571 55858	434571	1155858	145	Figure 7	Marina with space for 21 small boats on inshore side, 16 larger boats on other side. 9 of these could have marine heads (see also 180)
18	31/08/2009	11:39:11	HU 34630 55893	434630	1155893	146	Figure 8	Slip way, Lifeboat station and boat, 1 other workboat. Lifeboat engineer informs that town of Aith on new sewerage from red house across voe around to his home on this side of the voe. Feels water quality much improved, indicated discharge is supposed to be clean.
19	31/08/2009	11:42:45	HU 34567 55924	434567	1155924	147	Figure 9	Pumping station
20	31/08/2009	11:45:34	HU 34560 55969	434560	1155969	148	Figure 10	Pipe on shoreline running from pumping station. Ceramic in poor repair with major crack, no apparent flow. Water sample 6

Obs No.	Date	Time	Grid Ref	East	North	Way-point	Associated Photograph	Note
21	31/08/2009	11:51:35	HU 34467 55962	434467	1155962	149	Figure 11	Stream, 1.2 m wide. 10cm and 5 cm deep. Flow at 10cm 0.634 m/s. Water sample 12. Green algae on either side of stream
22	31/08/2009	12:00:43	HU 34363 56054	434363	1156054	150		Dry field drain, bright green on shore, large barn with silage bales above shoreline, 1 seal.
23	31/08/2009	12:16:28	HU 34323 56396	434323	1156396	151		Red house at end of mains sewerage on shore opposite this point.
24	31/08/2009	12:19:43	HU 34316 56427	434316	1156427	152	Figure 12	Green patch on shore where land dips, this happens all along shore here. Land above used for growing silage and for grazing.
25	31/08/2009	12:26:17	HU 34307 56616	434307	1156616	153		Drainage from land running down bank at ~30ml/sec.Water sample 7
26	31/08/2009	12:33:54	HU 34295 56743	434295	1156743	154	Figure 13	Discharge pipe flowing, sudsy. Flow could not be determined. Dog on bank above shore. Water sample 8
27	31/08/2009	12:38:25	HU 34288 56791	434288	1156791	155		Another field drain with no apparent flow, green algae on shore
28	31/08/2009	12:39:41	HU 34287 56807	434287	1156807	156		1 sheep on shoreline
29	31/08/2009	12:40:19	HU 34288 56817	434288	1156817	157		Field drain
30	31/08/2009	12:53:08	HU 34292 56832	434292	1156832	158		Winkle sample taken from over approx 20m of shoreline here.
31	31/08/2009	13:01:24	HU 34264 56992	434264	1156992	159		Stream, 0.8m wide x 18cm deep, flow 0.049 m/s. Water sample 9
32	31/08/2009	13:04:34	HU 34262 57000	434262	1157000	160	Figure 14	More than 35 sheep (some obscured by other sheep) farmhouse, barn and silage bales
33	31/08/2009	13:08:34	HU 34311 57014	434311	1157014	161		5 chickens on shoreline
34	31/08/2009	13:10:23	HU 34329 57064	434329	1157064	162	Figure 15	Septic discharge pipe, completely dry, no green algae or other signs of septic input
35	31/08/2009	13:14:13	HU 34347 57146	434347	1157146	163		Stream flowing over rocks, foam at bottom. 20 cm wide x 4cm deep, water sample 10
36	31/08/2009	13:22:11	HU 34372 57246	434372	1157246	164	Figure 16	Septic tank with no apparent discharge pipe. Foul water puddled around base with wet, overgrown ditch leading to shoreline. Odour and flies, but no apparent flow over shoreline.
37	31/08/2009	13:27:03	HU 34392 57253	434392	1157253	165		Seawater sample 11 taken offshore of ditch
38	01/09/2009	08:31:26	HU 33721 58182	433721	1158182	166		Stream, 53cm wide x 12 cm deep, flow 0.551 m/s. Water sample 13
39	01/09/2009	08:40:49	HU 33749 58165	433749	1158165	167		Swan roost and droppings, feathers. 5 swans observed swimming out into Voe on approach from road.
40	01/09/2009	08:45:49	HU 33891 58174	433891	1158174	168		Field drain, dripping lightly but no flow

Obs No.	Date	Time	Grid Ref	East	North	Way-point	Associated Photograph	Note
41	01/09/2009	08:52:38	HU 33901 58174	433901	1158174	169		2 large houses and farm buildings, improved pasture cut for silage on opposite shore to this point. 8 sheep in field to right of buildings, 7 cattle above buildings, 65 sheep to left of buildings. 4 further houses continuing along shore to left, 1 to right that appears unoccupied
42	01/09/2009	09:03:48	HU 33634 58204	433634	1158204	170		2 houses, 25 sheep in view up stream from where it enters voe.
43	01/09/2009	09:22:27	HU 33794 57899	433794	1157899	171	Figure 17	Septic tank, concrete, downhill from road
44	01/09/2009	09:24:40	HU 33860 57786	433860	1157786	172		Septic tank downhill from road
45	01/09/2009	09:25:45	HU 33930 57665	433930	1157665	173		Septic tank below house, concrete
46	01/09/2009	09:27:07	HU 33957 57622	433957	1157622	174		Inspection hatch with nearby septic tank downhill
47	01/09/2009	09:27:54	HU 34048 57465	434048	1157465	175		Occupied dwelling toward shoreline
48	01/09/2009	09:29:18	HU 34146 56861	434146	1156861	176		3 farm houses, 200 sheep
49	01/09/2009	09:31:19	HU 34162 56409	434162	1156409	177		33 sheep
50	01/09/2009	09:32:32	HU 34171 56239	434171	1156239	178		11 cattle
51	01/09/2009	09:33:33	HU 34200 55948	434200	1155948	179		silage bales, mown field below with over 100 gulls on it
52	01/09/2009	09:34:23	HU 34209 55889	434209	1155889	180		5 cattle
53	01/09/2009	09:59:23	HU 34662 55843	434662	1155843	181	Figure 18	Marina (same as previously noted), water sample number 14
54	01/09/2009	10:02:16	HU 34723 55833	434723	1155833	182	Figure 19	Stream 1.4m wide. 55cm depth, flow 0.247m/s. 57 cm depth, 0.149 m/s, water sample 15
55	01/09/2009	10:09:46	HU 34785 55821	434785	1155821	183		Aith outfall pumping station
56	01/09/2009	10:11:17	HU 34792 55842	434792	1155842	184		Outfall pipe, seawater sample number 16, no odour apparent
57	01/09/2009	10:15:53	HU 34819 55850	434819	1155850	185		Cattle dung on shore (large)
58	01/09/2009	10:17:12	HU 34859 55854	434859	1155854	186		40 sheep on shoreline
59	01/09/2009	10:17:47	HU 34863 55855	434863	1155855	187	Figure 20	Discharge pipe, flowing across sand. Water sample 17
60	01/09/2009	10:23:57	HU 34938 55855	434938	1155855	188		Stream, w 0.8m, d 8cm, 10cm flow 0.248, 0.213. Water sample 18
61	01/09/2009	10:32:08	HU 35021 55932	435021	1155932	189		Stream, coffee coloured, w 30cm, d 30cm flow 0.470m/s.
62	01/09/2009	11:05:15	HU 35010 55787	435010	1155787	190		Septic tank downhill from road, should be on mains here
63	01/09/2009	11:05:33	HU 35010 55786	435010	1155786	191		Blank
64	01/09/2009	11:15:26	HU 36535 58088	436535	1158088	192	Figure 21	2 cattle on bank of stream
65	01/09/2009	11:18:12	HU 35752 58188	435752	1158188	193		19 cattle along stream
66	01/09/2009	11:20:06	HU 35426 58270	435426	1158270	194	Figure 22	Above mussel farm
67	01/09/2009	11:31:34	HU 35379 58306	435379	1158306	195		25 sheep
68	01/09/2009	11:37:34	HU 35330 58025	435330	1158025	196		Septic tank/house
69	01/09/2009	11:39:00	HU 35306 57970	435306	1157970	197		Many sheep droppings on field

Obs No.	Date	Time	Grid Ref	East	North	Way-point	Associated Photograph	Note
70	01/09/2009	11:56:47	HU 35295 58429	435295	1158429	198		No apparent pipes behind homes
71	01/09/2009	11:57:07	HU 35295 58429	435295	1158429	199		3 otters
72	01/09/2009	11:57:10	HU 35295 58429	435295	1158429	200		Holiday house at spit of land, occupied 1 week/year. 10 sheep
73	01/09/2009	11:59:48	HU 35421 58272	435421	1158272	201		Remark top of drive to house with septic tank
74	01/09/2009	12:01:16	HU 35841 58200	435841	1158200	202		House and 10 sheep
75	01/09/2009	12:02:25	HU 35921 58200	435921	1158200	203		House
76	01/09/2009	12:02:42	HU 35956 58195	435956	1158195	204		House
77	01/09/2009	12:03:02	HU 36031 58182	436031	1158182	205		Farm, 20 sheep
78	01/09/2009	12:04:16	HU 36302 58166	436302	1158166	206		Silage, house, septic tank at end of garden
79	01/09/2009	12:20:37	HU 36588 57848	436588	1157848	207		Burn, w 12m, d 20cm, flow 0.707 amd 0.905m/s. Water sample 19
80	01/09/2009	12:29:02	HU 36511 57803	436511	1157803	208		Seabed raked or ploughed in furrows, unknown purpose
81	01/09/2009	12:30:13	HU 36511 57805	436511	1157805	209		Edge of ploughed area
82	01/09/2009	12:30:56	HU 36481 57812	436481	1157812	210		End of ploughed area
83	01/09/2009	12:36:36	HU 36310 57786	436310	1157786	211		Field drain running through grass, no stream bed. W 20cm, d 10cm flow 0.120 m/s. Water sample 20
84	01/09/2009	12:43:01	HU 36263 57789	436263	1157789	212		Another stream, seems to come through rocks rather than over, unsuitable for flow measurement. Water sample 21
85	01/09/2009	12:54:10	HU 36104 57863	436104	1157863	213		Water seepage across gravel shore
86	01/09/2009	12:55:57	HU 36062 57870	436062	1157870	214		9 sheep
87	01/09/2009	12:57:18	HU 36041 57854	436041	1157854	215		Trickling drain off fields
88	01/09/2009	13:03:18	HU 36042 57787	436042	1157787	216		50 sheep
89	01/09/2009	13:07:22	HU 36193 57735	436193	1157735	217		House and shed, under construction
90	01/09/2009	13:10:46	HU 36370 57614	436370	1157614	218		3 horses, 1 house at head of firth. Winds now to F6
91	01/09/2009	13:18:55	HU 36143 57753	436143	1157753	219		New home
92	01/09/2009	13:20:42	HU 35754 57533	435754	1157533	220		6 cattle, 1 farm, 10 sheep
93	01/09/2009	13:22:10	HU 35565 57403	435565	1157403	221		Approx 75 sheep
94	01/09/2009	13:22:36	HU 35499 57370	435499	1157370	222		Farm
95	01/09/2009	13:23:14	HU 35392 57209	435392	1157209	223		New building site
96	01/09/2009	13:23:35	HU 35373 57197	435373	1157197	224		House
97	01/09/2009	13:23:53	HU 35297 57140	435297	1157140	225		Self catering accomodation
98	01/09/2009	13:25:08	HU 35252 56849	435252	1156849	226		Farm house

Referenced photographs can be found attached as Figures 11-22.

Sampling

Water and shellfish samples were collected at sites marked on the map. All samples were placed in a coolbox with icepacks and then transported to Shetland Seafood Quality Control in Scalloway and submitted for *E. coli* analysis. Bacteriology results follow in Tables 2 and 3.

Salinity and temperature profiles were taken at four locations on the fishery using a handheld electronic salinity meter with 30m cable (YSI Incorporated). These results are presented in Table 4. Recorded values varied by only 0.1ppt for salinity and 0.2 °C, both of which fall within the range of error of the instrument.

Table 2. Water Sample Results

No.	Date	Sample	Grid Ref	Type	*E. coli* (cfu/ 100ml)
1	31/08/2009	EBF 1	HU 35339 57741	Sea water	1
2	31/08/2009	EBF 2	HU 35191 57804	Sea water	3
3	31/08/2009	EBF 3	HU 34954 58315	Sea water	6
4	31/08/2009	EBF 4	HU 34838 58570	Sea water	1
5	31/08/2009	EBF 5	HU 34130 58847	Sea water	<1
6	31/08/2009	EBF 6	HU 34560 55969	Sea water	90
7	31/08/2009	EBF 7	HU 34307 56616	Freshwater	1800
8	31/08/2009	EBF 8	HU 34295 56743	Freshwater	1900
9	31/08/2009	EBF 9	HU 34264 56992	Freshwater	1600
10	31/08/2009	EBF 10	HU 34347 57146	Freshwater	280
11	31/08/2009	EBF11	HU 34392 57253	Sea water	7
12	31/08/2009	EBF 12	HU 34467 55962	Freshwater	420
13	01/09/2009	EBF 13	HU 33721 58182	Freshwater	1600
14	01/09/2009	EBF 14	HU 34662 55843	Seawater	Sample lost
15	01/09/2009	EBF 15	HU 34723 55833	Freshwater	20
16	01/09/2009	EBF 16	HU 34792 55842	Sea water	4
17	01/09/2009	EBF 17	HU 34863 55855	Freshwater	26000
18	01/09/2009	EBF 18	HU 34938 55855	Freshwater	1300
19	01/09/2009	EBF 19	HU 36588 57848	Freshwater	700
20	01/09/2009	EBF 20	HU 36263 57789	Freshwater	1200
21	01/09/2009	EBF 21	HU 36104 57863	Freshwater	1000

Table 3. Shellfish Sample Results

No.	Date	Sample	Depth	Grid Ref	Type	*E. coli* (mpn/100g)
1	31/08/2009	EBFM 1	7m	HU 35339 57741	Mussels	490
2	31/08/2009	EBFM 2	1m	HU 35339 57741	Mussels	790
3	31/08/2009	EBFM 3	1m	HU 35191 57804	Mussels	790
4	31/08/2009	EBFM 4	7m	HU 34954 58315	Mussels	330
5	31/08/2009	EBFM 5	1m	HU 34954 58315	Mussels	1700
6	31/08/2009	EBFM 6	7m	HU 34838 58570	Mussels	80
7	31/08/2009	EBFM 7	1m	HU 34838 58570	Mussels	790
8	31/08/2009	W1	na	HU 34292 56832	Periwinkle	330

Table 4. Salinity and Temperature Profiles

Profile No.	Grid Ref	Depth (m)	Salinity (ppt)	Temp (°C)
1	HU 35339 57741	10	36.0	12.8
		5	36.0	12.8
		1	36.0	12.9
2	HU 35191 57804	10	36.0	13.0
		5	36.0	12.9
		1	36.0	12.9
3	HU 34954 58315	10	36.0	12.9
		5	36.0	12.9
		1	36.0	12.9
4	HU 34838 58570	10	36.0	12.9
		5	36.0	12.9
		1	35.9	12.9

Figure 2 Water sample results map

Figure 3 Shellfish sample results map

Photographs

Figure 4. Mussel lines at East Burra Firth with farm and cattle in background.

Figure 5. East Burra Firth mussel farm looking across Aith Voe.

Figure 6. Mussel farm west of Slyde, Aith Voe: Sletta.

Figure 7. Marina at Aith.

Figure 8. Slipway adjacent to the lifeboat station at Aith.

Figure 9. Aith - Rotten Shun sewage pumping station.

Figure 10. Discharge pipe running from pumping station across shore.

Figure 11. Stream at shore west of Aith.

Figure 12. Algal growth on shoreline.

Figure 13. Discharge pipe, west shore of Aith Voe.

Figure 14. Sheep on field above shoreline.

Figure 15. Dry pipe from septic tank.

Figure 16. Septic tank with no discharge pipe, leaking at base.

Figure 17. Septic tank amongst sheep, west shore of Aith Voe.

Figure 18. Seawater sample site at Aith Marina

Figure 19 Stream near Aith

Figure 20 Discharge pipe at Aith

Figure 21 Cattle along stream bank

Figure 22 View looking south across East Burra Firth mussel lines toward Aith