Scottish Sanitary Survey Project

Sanitary Survey Report
Dales Voe
SI 050, 501, 502, 503, 504
August 2010

Cefas

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Report Distribution – Dales Voe

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

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1. General Description

Dales Voe is one of two voes with the same name in Shetland. This sanitary survey report covers only the Dales Voe that is located on the north-east mainland of Shetland, aligned parallel to Colla Firth (Figure 1.1). For clarity, this production area will be referred to as Dales Voe: Scarvar Ayre. The voe is approximately 4.8 km in length and ranges in width from 370m near the head to 1km at West Taing at its mouth. The voe is sheltered to the east by the 'island' of Fora Ness, which is connected to the mainland by two narrow spits of land. The voe opens to the northeast, and the steep sides will tend to funnel winds from the south to southwest or north to northeast along the length of the voe.

The sanitary survey was prompted by an application for classification of four new sites (South Side, West Taing, West of Fora Ness, and Scarvar Ayre 2) near to the Dales Voe: Scarvar Ayre production area.

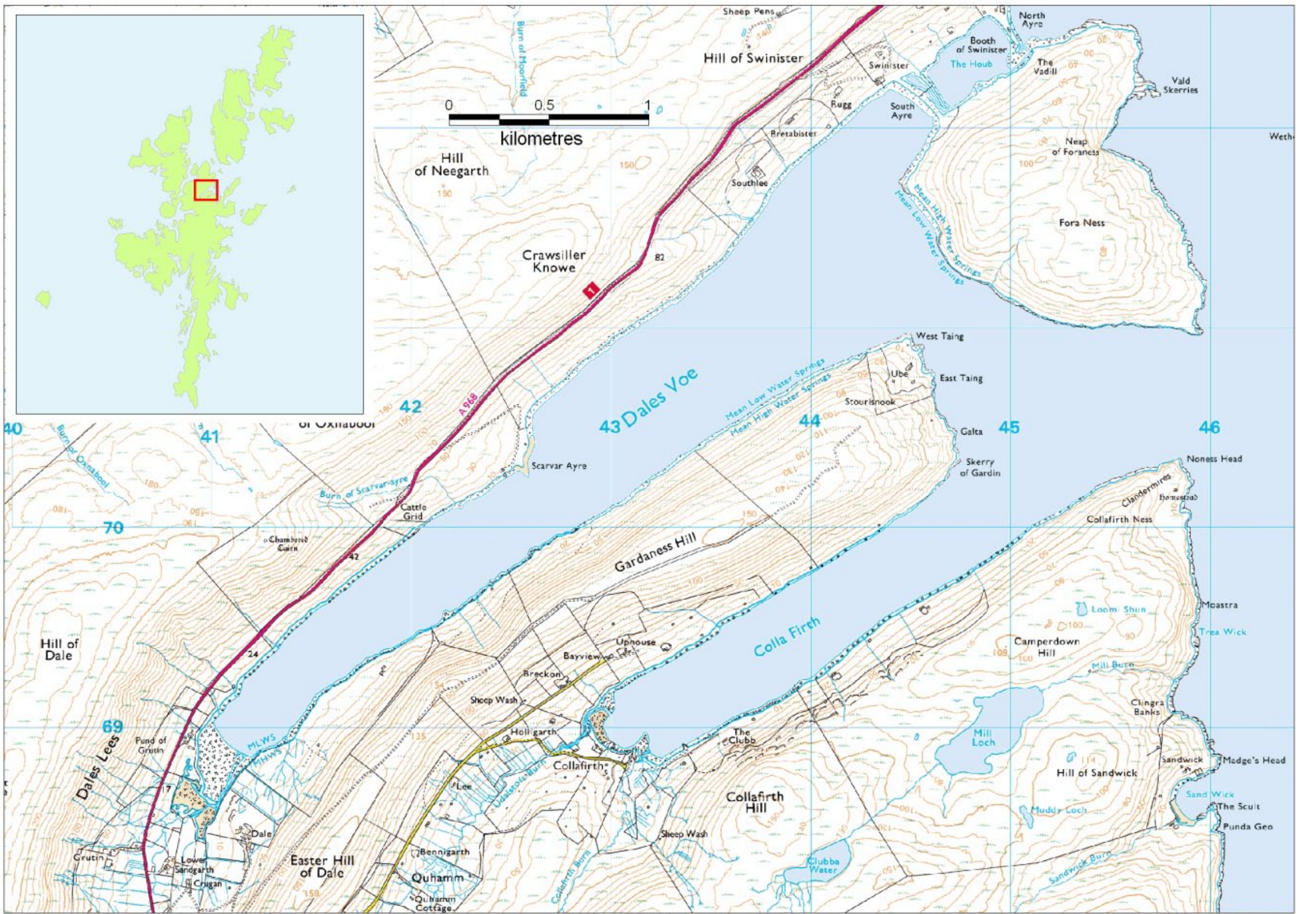


Figure 1.1 Location of Dales Voe

2. Fishery

The Dales Voe fishery consists of five separate longline mussel farms, one of which is currently classified and four of which are the subject of recent applications for classification. These sites are all operated by Hunter Shellfish and are listed in Table 2.1 below.

Table 2.1 Dales Voe shellfish farms

Production Area	Site	SIN	Species
Dales Voe	South Side	SI 501 868	Common mussels
Dales Voe 2	West Taing	SI 502 869	Common mussels
Dales Voe 3	West of Fora Ness	SI 503 870	Common mussels
Dales Voe 4	Scarvar Ayre 2	SI 504 871	Common mussels
Dales Voe: Scarvar Ayre	Scarvar Ayre	SI 050 420	Common mussels

The currently classified production area, Dales Voe: Scarvar Ayre, is defined as an area bounded by lines drawn between HU 4256 7030 and HU 4280 7000 and HU 4190 6990 and HU 4216 6953. The nominal Representative Monitoring Point (RMP) is reported at HU 423 700, which lies 98 m northeast of the mussel lines. The sampling point in use by the Official Control sampling officers is HU 4223 6992. The actual locations of all the mussel farms within the voe were recorded during the shoreline survey and are shown mapped, together with the production area boundaries, sampling points and lease areas, in Figure 2.1. The four new sites do not fall within the existing production area boundaries. The following site descriptions are based on observations made during the shoreline survey.

The South Side site (SI 501 868) consisted of four rows of double long lines with 8m deep droppers at the time of shoreline survey. The two lines closest to the shoreline are new and droppers were being installed at the time of the shoreline survey in June 2010. The other two lines were installed in 2008 and will be harvested this year.

The West Taing site (SI 502 869) consisted of five rows of double long lines with 8m deep droppers. The second line from the shore was put into place in 2010, while the remaining lines were placed in 2009. The harvester plans to commence harvesting in February 2012.

The West of Fora Ness (SI 503 870) site consisted of two rows of double long lines with 8m deep droppers. The lines were installed in 2008 and the harvester plans to harvest the site in February 2011.

The Scarvar Ayre 2 site (SI 504 871) consisted of four rows of double long lines with 8m deep droppers. The lines were installed in 2009 and the harvester plans to commence harvesting in February 2012.

The Scarvar Ayre 1 site consisted of 4 rows of double long lines with droppers to 8 meters.

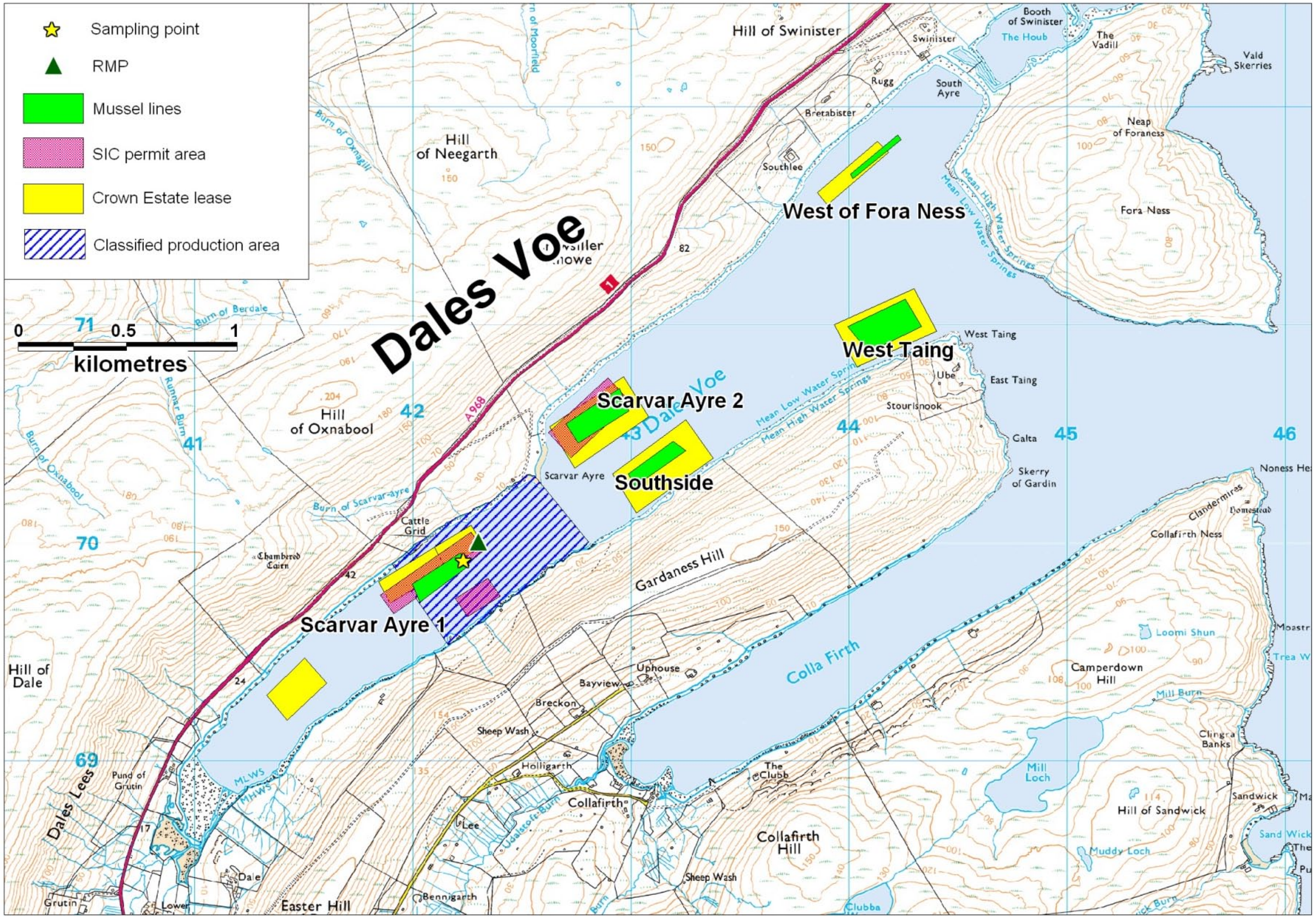
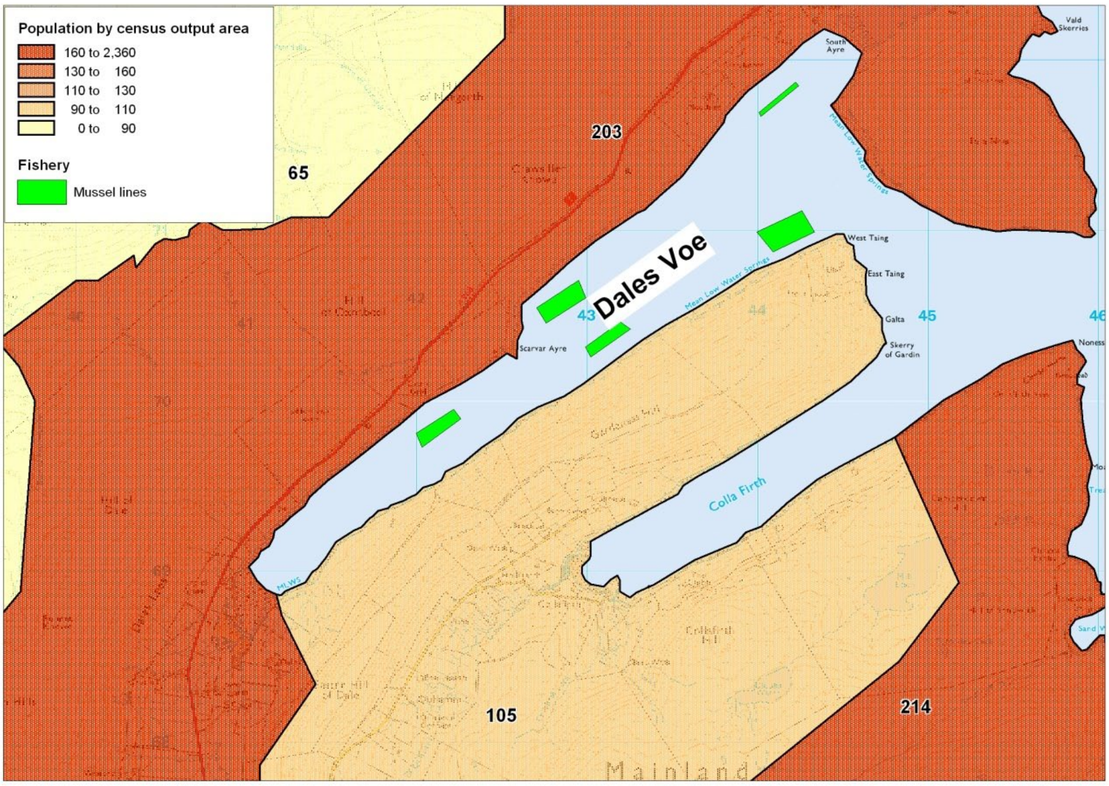


Figure 2.1 Dales Voe Fishery

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 Dales Voe: Scarvar Ayre at the time of last census (2001).



2001 Population Census Data, General Register Office, Scotland.

Figure 3.1 Population map for Dales Voe

The census output areas immediately bordering the voe had populations of 203 and 105, however both these areas are large and encompass communities over 5km away and outside the catchment area of the voe.

The population actually present around the voe is very low. During the shoreline survey, 9 homes and one farm were observed around the head of the voe. There were no occupied dwellings along either side of the voe with only a pier and outbuildings belonging to Hunter Shellfish present near Scarvar Ayre along the north side of the voe. Using the average household size for Shetland of 2.6 (Shetland Island Council 2000) for the 9 dwellings observed, the human population resident along the shores of the voe would be approximately 24.

Overall the faecal contribution from the human population will be low and any impacts will tend to be localised. Any impact from the population located at the head of the voe will be highest at the mussel farm nearest the head of the loch.

4. Sewage Discharges

Information on sewage discharges to Dales Voe or nearby waters was requested from Scottish Water and from the Scottish Environment Protection Agency (SEPA). A short glossary of common abbreviations used in describing sewage discharges follows at the end of this section.

No community sewage discharges were identified by Scottish Water for Dales Voe or Colla Firth. The nearest Scottish Water discharges were for Mossbank, which lies 6 km by sea to the north of Dales Voe. These are listed in Table 4.1.

Table 4.1 Discharge consents identified by Scottish Water

Consent Reference	NGR of Discharge	Discharge Name	Type	Level of Treatment	Consented Flow (DWF) m^3/d	Design PE
CAR/L/1002280	HU 4534 7542	Mossbank No. 1	Continuous	Septic tank	37.5	150
CAR/L/1002271	HU 4544 7510	Mossbank No. 2	Continuous	Septic tank	150	600

No sanitary or microbiological data was available for these discharges. In addition, SEPA provided consent information for the discharges listed in Table 4.2 below.

Table 4.2 Discharge consents identified by SEPA

No.	Ref No.	NGR of Discharge	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consented/ design PE	Discharges to
1	CAR/R/1067934	HU 4087 6891	Continuous	Septic tank	*	5	soakaway
2	CAR/R/1028313	HU 4052 6841	Continuous	Septic tank	*	5	unnamed watercourse
3	CAR/R/1043629	HU 4077 6828	Continuous	Septic tank	*	5	soakaway
4	CAR/R/1043632	HU 4080 6833	Continuous	Septic tank	*	5	soakaway
5	CAR/R/1048547	HU 4297 6914	Continuous	Septic tank	*	5	Colla Firth
6	CAR/R/1041264	HU 4250 7267	Continuous	Septic tank	*	5	soakaway
7	CAR/R/1022534	HU 4101 7332	Continuous	Septic tank	*	20	soakaway
8	CAR/R/1019825	HU 4501 7559	Continuous	Septic tank	*	6	land
9	CAR/R/1031889	HU 4494 7546	Continuous	Septic tank	*	5	soakaway
10	CAR/R/1037925	HU 4520 7551	Continuous	Septic tank	*	5	soakaway
11	CAR/L/1002271	HU 4542 7490	Continuous	Septic tank	*	*	Yell Sound
12	CAR/L/1002280	HU 4540 7530	Continuous	Septic tank	*	*	Yell Sound
13	CAR/R/1051275	HU 4600 6641	Continuous	Septic tank	*	6	land

*consent details not specified

Two of the above discharges, Nos. 11 and 12, relate to the Scottish Water community discharges at Mossbank. There was a discrepancy between the Scottish Water and SEPA information provided for the locations of the two discharges at Mossbank. As this are was not covered by the shoreline survey, the correct locations could not be verified.

Sewage infrastructure recorded during the shoreline survey is listed in Table 4.2.

Table 4.3 Discharges and septic tanks observed during shoreline surveys

No.	Date	NGR	Description
1	22/06/2010	HU 4093 6889	Pipe at shore near house – flowing lightly. Water sample 11 result 800 *E.coli* cfu/100ml. Flow 2.3 m3/day.

Only one discharge pipe was observed during the shoreline survey, and this was for the house nearest the shoreline. The location corresponded with discharge consent CAR/R/ 1067934 (Table 4.2, No. 1), however the consent is listed as being for a soakaway so the pipe observed may be for an overflow. The water sample taken from this flow indicated that it contained moderate faecal contamination at the time of sampling. This would equate to a loading of 1.8×10^7 *E.coli* per day into the receiving waters of the voe. However, it is likely that both the *E. coli* content and the flow through the pipe will both vary over time.

As there is no mains sewerage in the area, the remaining homes for which discharge consents were not available are presumed to be on private septic systems discharging either to the Burn of Sandgarth, which flows into the head of the voe, or to soakaway systems.

The most significant source of human sewage to the fishery within Dales Voe is the small area of homes at the head of the voe. Discharges from this source are most likely to impact the Scarvar Ayre 1 site, which lies nearest the head of the voe.

In 2006, Shetland Islands Council issued an information bulletin to warn members of the public not to collect or eat shellfish from the foreshore at Firths Voe, just south of Mossbank and north of the entrance to Dales Voe. This advisory was issued due to contamination of the area with raw sewage. While this covered an area outside the fishery, it is indicative of potentially serious episodes of sewage contamination nearby to the north. These could have an effect on water quality particularly in the outer part of the voe, depending upon the bathymetry and hydrodynamics of the area.

Glossary

DWF Dry Weather Flow
PE Population Equivalent

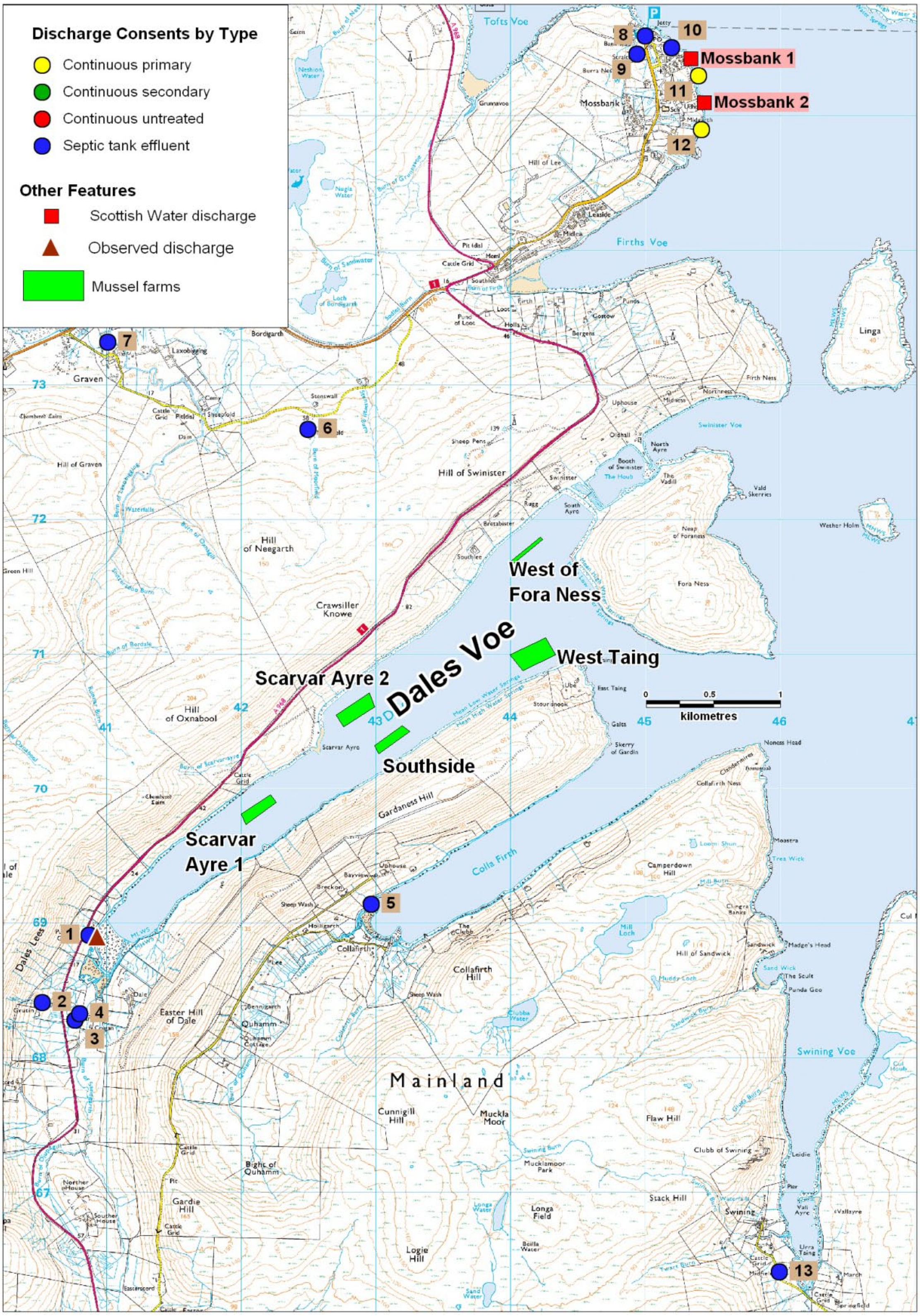


Figure 4.1 Map of discharges for Dales Voe: Scarvar Ayre

5. Geology and Soils

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

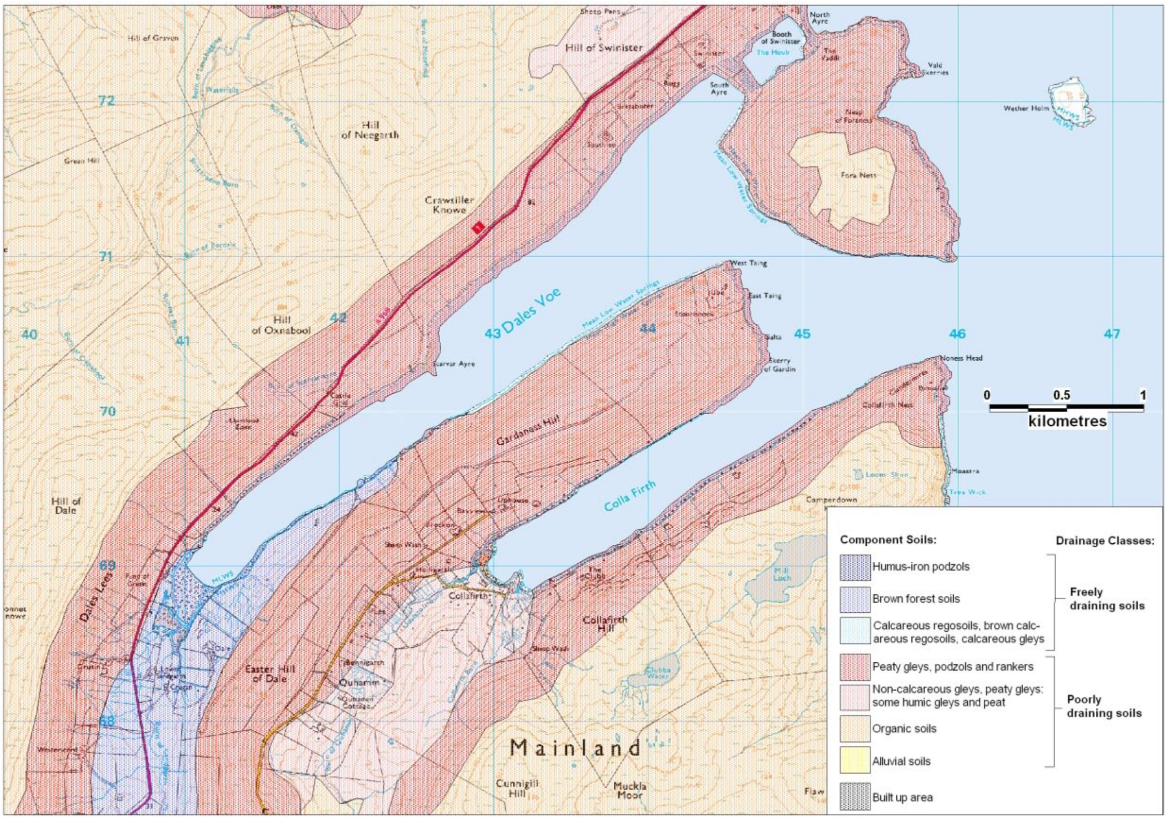


Figure 5.1 Component soils and drainage classes for Dales Voe Scarvar Ayre.

The majority of the soils around Dales Voe Scarvar Ayre are poorly draining, with the exception an area of freely-draining brown forest soils at the head of the voe. The poorly drained soils occur on relatively steep terrain (with slopes in excess of 0.55), particularly along the south shore of the voe, and will therefore have a higher tendency for rain to run off the surface. The well-drained soils follow the course of the Burn of Sandgarth, which discharges into the head of Dales Voe, and then stretch along the south shore for approximately 1.5 km.

The potential for runoff contaminated with *E. coli* from animal waste is high along the majority of the coastline of Dales Voe. However, the burn that discharges into the head of the voe flows through well-drained soils which would be less prone to carrying large amounts of runoff immediately following heavy rainfall (Beven, 1978)

6. Land Cover

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

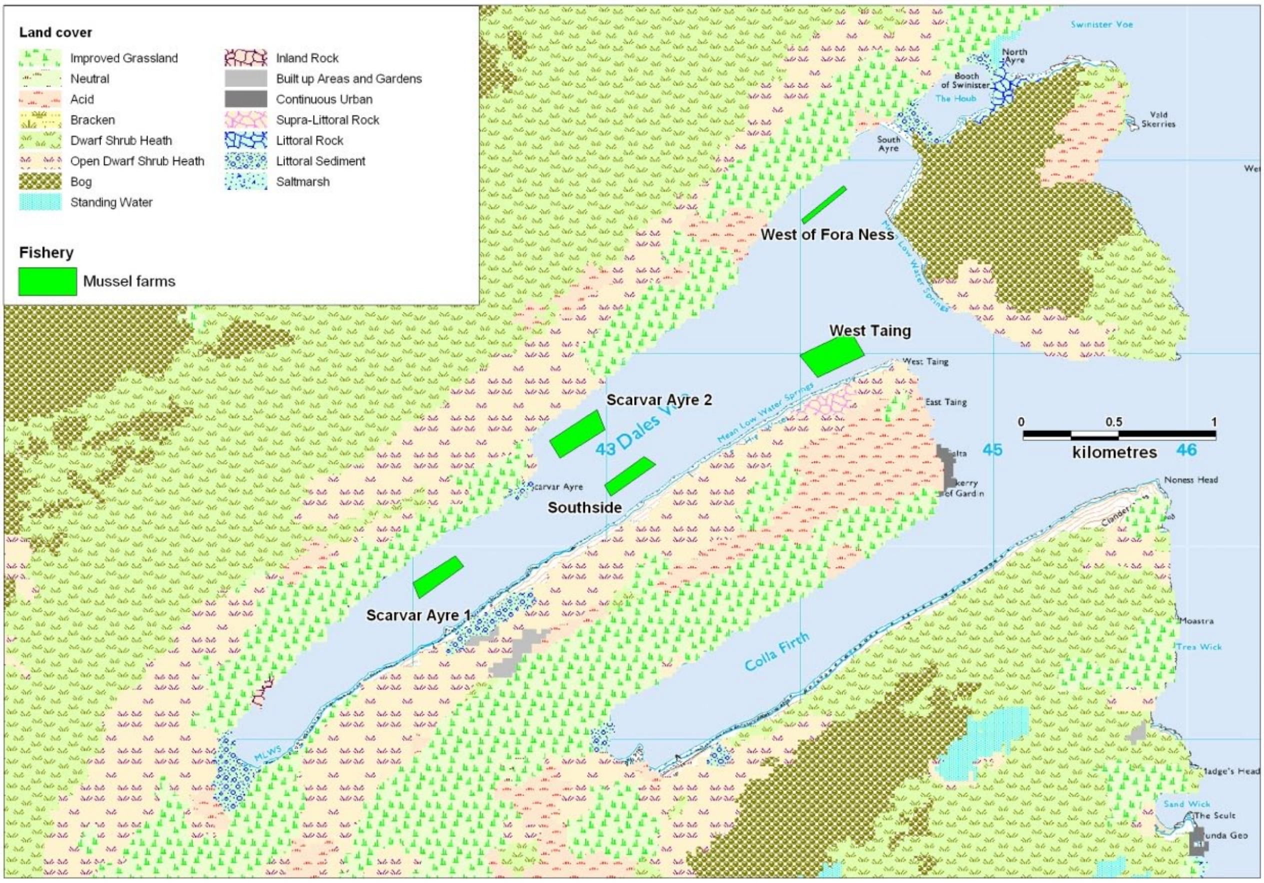


Figure 6.1 LCM2000 class land cover data for Dales Voe: Muckle Ayre

Landcover in the Dales Voe area is predominantly heath land and both acid and improved grassland, with substantial areas of bog. The improved grassland lines the northern shore of the voe, where poorly draining soils may add to the potential for runoff of faecal material deposited on the shore by livestock.

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.

Areas of improved grassland along the north shore and at the head of the voe would tend to contribute the higher levels of faecal contamination than other areas around the voe. Combined with the effects of soil permeability and slope identified in Section 5, the impact would be highest from the improved grassland along the north shore nearest sites Scarvar Ayre 1 and 2 and West of Fora Ness.

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 parish of Delting, encompassing a land area of 148 km^2. Reported livestock populations for the parishes in 2009 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 Delting parish 2008 - 2009

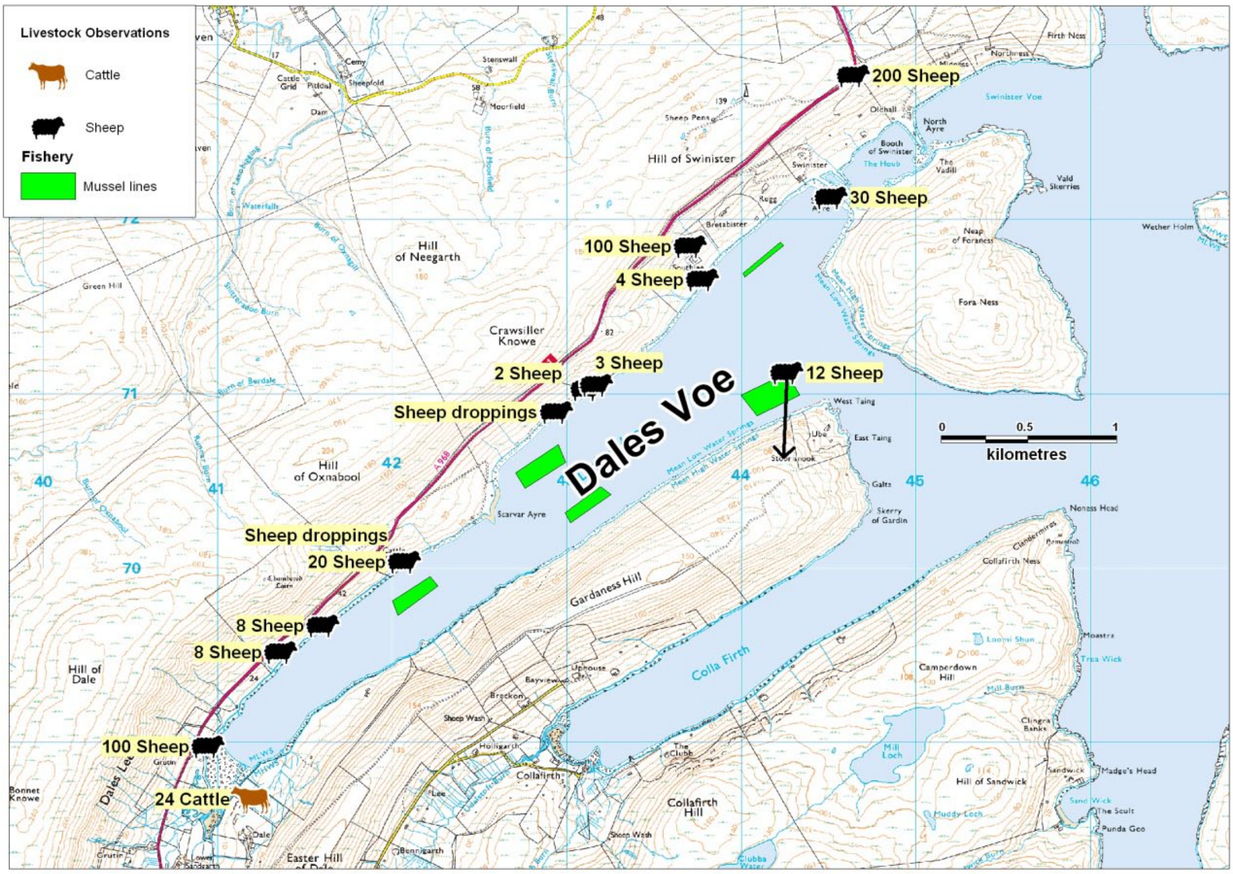
	Delting	
	2009	
	Holdings	Numbers
Pigs	*	*
Poultry	15	253
Cattle	12	371
Sheep	65	22,596
Horses and ponies	5	17

* Data withheld for reasons of confidentiality

The predominant farm animals within the parish are sheep. Due to the large area of the Delting parish and missing data for pig holdings, accurate information regarding the number of livestock on land immediately surrounding Dales Voe is only available from the shoreline survey (see section 15 and Appendix 7). The observations relate to the time of the site visit on 22nd – 23rd June 2010 only. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1.

Sheep and lambs were observed grazing along most of the shoreline surveyed. In most places livestock had access to the shoreline and fresh water courses discharging into the voe. Sheep and their droppings were often observed on the beach, especially around the South Ayre tombolo at the mouth of Dales Voe, where approximately 30 sheep and lambs were observed. Approximately 200 more sheep were observed grazing in fields on the hills above The Houb next to the road. An additional 12 sheep were observed on the connected island of Fora Ness and a further 104 were observed on the Hill of Swinister. Further towards the head of the voe at the bottom of the Hill of Oxnabool, another 36 sheep were observed. In addition to the flocks of sheep already mentioned, scattered pairs of sheep were observed. At the head of Dales Voe, on the side of Easter Hill, 20 cattle were observed grazing in a fenced field adjacent to the shoreline.

A sample taken from the stream that ran alongside the farm where 100 sheep were observed at the head of the voe had a high result of 6.6×10^3 *E. coli* cfu/100 ml, indicating significant microbial pollution to this freshwater input.



Produced by Cefas Weymouth Laboratory.

Figure 7.1 Livestock observations at Dales Voe

The livestock population observed around Dales Voe roughly 20 times that of the human population estimated in Section 3. Given that, depending on species, livestock excrete 2 to 10 times the amount of faecal coliform bacteria per day of humans, it is reasonable to presume that livestock will be the predominant source of faecal bacteria found in the voe. This faecal contamination will be delivered to the voe both via direct deposition at the shoreline and via freshwater runoff directly from land and via streams. The impact is likely to be highest during summer, when more livestock are present and will be presumed to be evenly spread along the north shore, where most of the animals were observed and where there is more land available for grazing.

8. Wildlife

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*). Shetland hosts significant populations of both species.

The 'island' of Fora Ness forms part of the Yell Sound Special Area of Conservation (SAC) which was designated for its populations of otters (*Lutra lutra*) and common seal (*Phoca vitulina*). However, no recent population data was available for this area. Annual surveys of seal populations are undertaken for the Natural Environment Research Council (NERC) Special Committee on Seals (SCOS). Information from the most recent SCOS main advice report indicated that seal populations surveyed in Shetland in 2006 had declined markedly since the previous survey in 2001 (SCOS 2009). The nearest grey seal breeding colonies to Dales Voe are at Whalsay and Out Skerries, more than 10 km to the east. Harbour seals are also reported to use the offshore islands to haulout and give birth.

Three seals were observed near the north shore of the voe during the shoreline survey, indicating that they do use the voe for foraging. However, their presence is likely to be widely distributed within the voe with no substantially higher impact to one part of the fishery over another.

Whales/Dolphins

Although various species of whales and dolphins (cetaceans) are found in the waters around Shetland, due to the narrow entrance and generally shallow waters of Dales Voe these animals are unlikely to be present in the voe and therefore are not considered to be a significant source of faecal contamination to the fishery there.

Birds

Seabirds were the subject of a detailed census carried out in the summer of 1999 (Mitchell *et al.*, 2004). Total counts of the most abundant species recorded near Dales Voe are recorded in Table 8.1. Where counts were of sites/nests/territories occupied by breeding pairs actual numbers of birds breeding in the area will be higher. Locations of records relative to the fishery are shown in Figure 8.1. Gulls and black guillemots were observed during the shoreline survey, with gulls seen resting on the mussel floats.

The Dales Voe Site of Special Scientific Interest (SSSI), which lies at the head of the voe, was designated for its salt marsh and intertidal sand and mud flats, which host locally significant populations of wading birds and arctic terns (*Sterna paradisaea*). The area is not, however, part of the Wetland Birds Survey site and so no records have been found of the numbers of wading birds present in this area. Likewise no records were found of numbers of birds present during the winter months.

Table 8.1 Seabird counts within 5km of the Dales Voe mussel fisheries

Common name	Species	Count	Method
Black Guillemot	*Cepphus grylle*	34	Individuals on land
Northern Fulmar	*Fulmarus glacialis*	241	Occupied sites
Storm Petrel	*Hydrobates pelagicus*	59	Occupied sites
Herring Gull	*Larus argentatus*	11	Occupied territory
Common Gull	*Larus canus*	7	Occupied territory
Great Black-backed Gull	*Larus marinus*	38	Occupied nests/Occupied territory
Arctic skua	*Stercorarius parasiticus*	4	Occupied territory
Great Skua	*Stercorarius skua*	12	Occupied territory
Arctic Tern	*Sterna paradisaea*	126	Occupied territory

The locations of recorded seabirds are mapped in Figure 8.1.

Otters

No otters were observed during the course of the shoreline survey. The Yell Sound SAC is listed for otters, and so they are expected to be present in the area. However, the typical population densities of coastal otters are low and their impacts on the shellfishery are expected to be very minor.

Deer

There are no deer present on Shetland.

Conclusions

The potential impact from wildlife on the bacteriological quality of water at the fishery is likely to from birds resting and feeding near to the mussel farms and seals foraging in the area. The impact from birds is likely to be highest during the summer breeding season, when seabirds are on nests near the head of the voe and northeast of Fora Ness. Although other waterfowl may be present during the winter, no information was found on their numbers. Gulls or other birds resting on mussel floats are likely to impact those lines directly under the floats most and this is likely to affect all the mussel farms to some extent.

Impacts from seals are likely to be scattered and unpredictable, as it is not known how many animals are likely to be present in the voe at any given time.

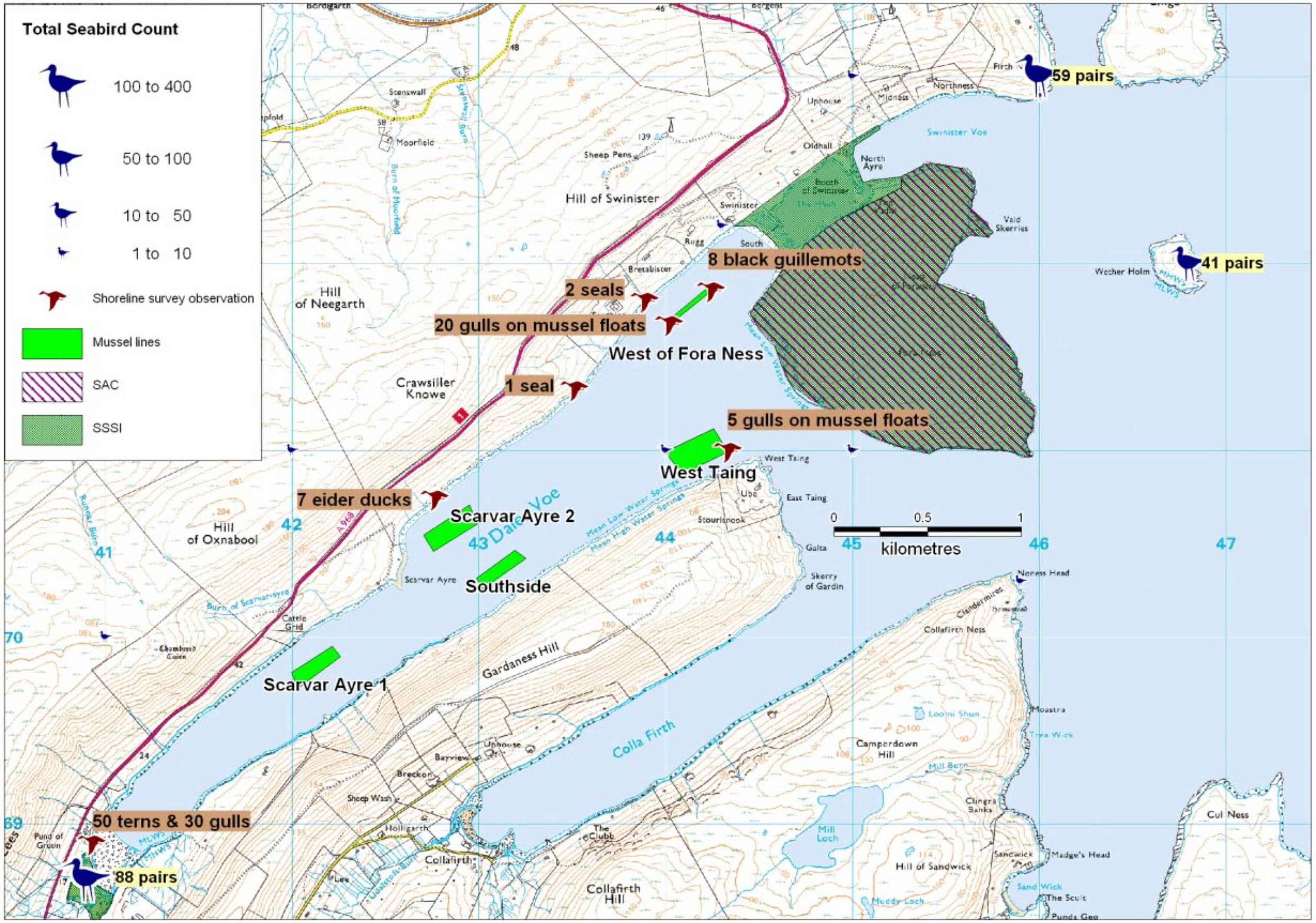


Figure 8.1 Map of seabird distributions (Seabird2000 data) and wildlife observed during the shoreline survey at Dales Voe.

9. Meteorological data

The nearest weather station is located at Lerwick, approximately 31 km south of the fishery, for which rainfall and wind data is available for 2004-2009 inclusive. Although larger-scale weather patterns influencing overall wind direction are likely to be broadly similar at the fishery and at Lerwick, differences in smaller scale wind patterns due to local topography and the significant distance between Lerwick and Dales Voe could be substantial. 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 shown as a line within the box. 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 *.

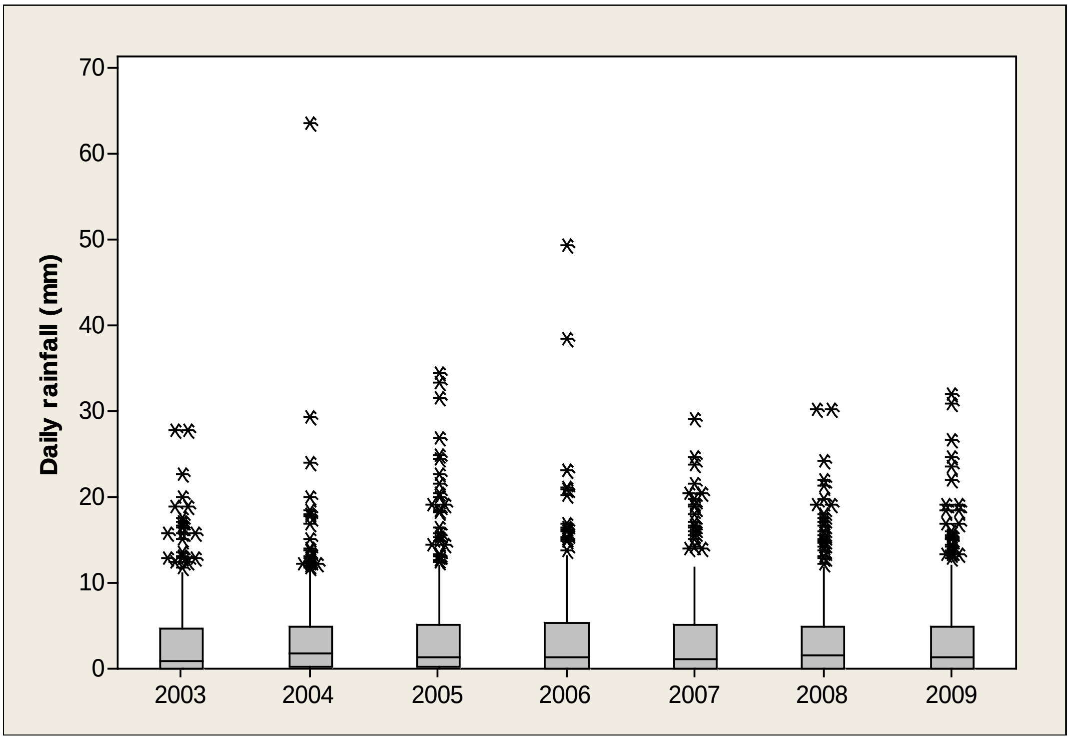


Figure 9.1 Box plot of daily rainfall values by year at Lerwick, 2003-2009

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.

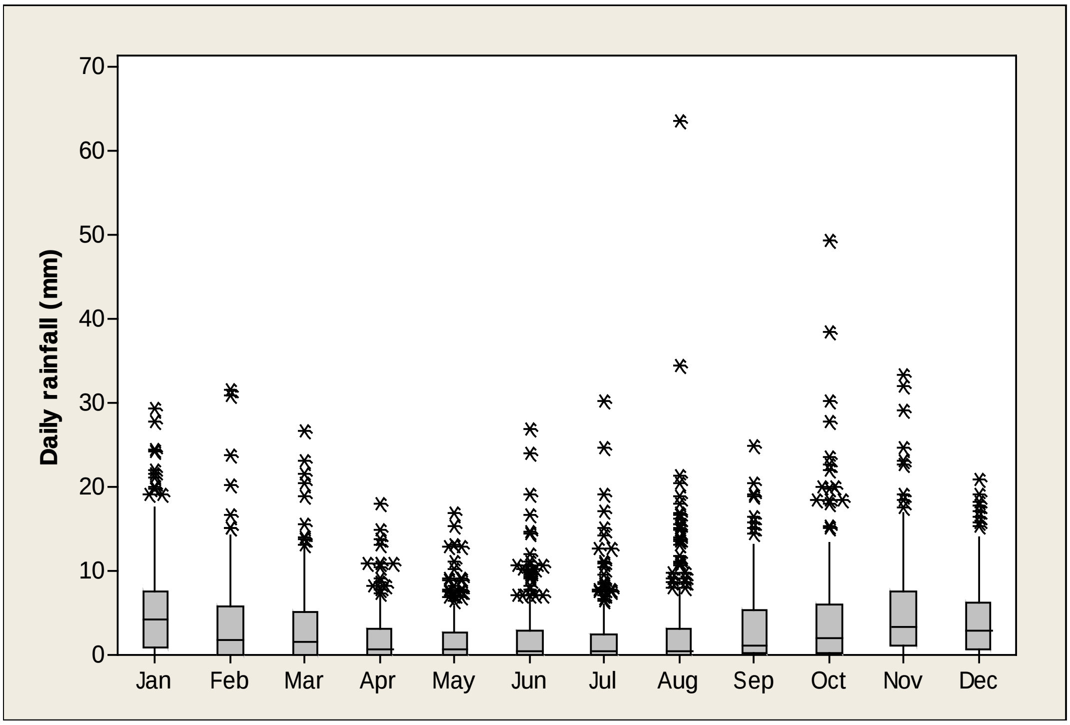


Figure 9.2 Box plot of daily rainfall values by month at Lerwick, 2003-2009

Weather was generally wetter from September through to March, with the wettest months being November and January. Days with very high rainfall (over 20 mm) have occurred in all months aside from April and May. For the period considered here, 44% of days experienced rainfall less than 1 mm, and 9% of days experienced rainfall of 10 mm or more.

In general, it is expected that levels of run-off associated with rainfall will be higher during the autumn and winter months. However, increases in faecal contamination carried into the voe via rainfall runoff may be higher after extreme rainfall events during summer when there is likely to be a larger ‘first-flush’ effect after periods of dry weather.

9.2 Wind

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

The prevailing wind direction at Lerwick is from the south and west, but wind direction often changes markedly from day to day with the passage of weather systems. There is a higher occurrence of north easterly winds during the summer. 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.

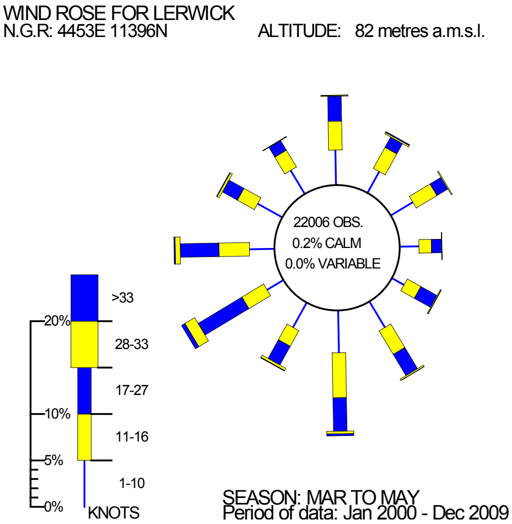


Figure 9.3Wind rose for Lerwick (March to May)

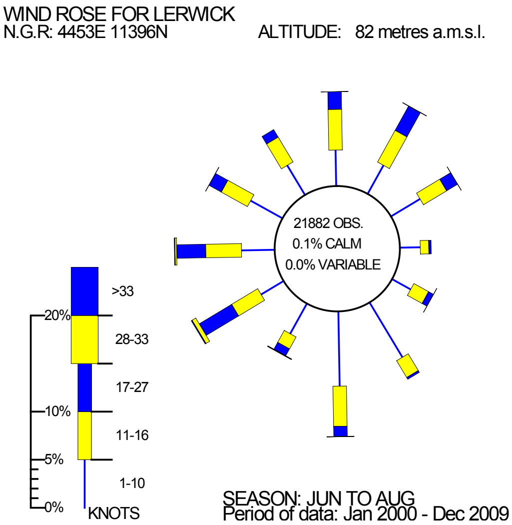


Figure 9.4 Wind rose for Lerwick (June to August)

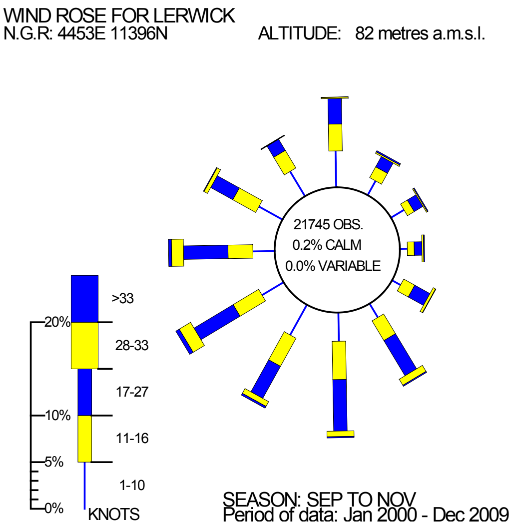


Figure 9.5 Wind rose for Lerwick (September to November)

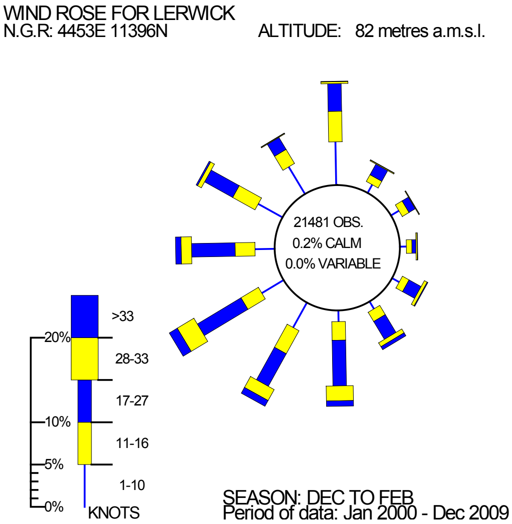


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Figure 9.6 Wind rose for Lerwick (December to February)

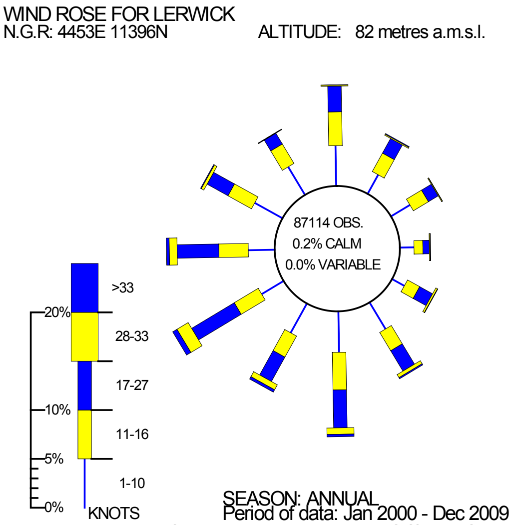

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Figure 9.7 Wind rose for Location (All year)

Dales Voe has a southwest to northeast aspect, with the surrounding land rising to over 200 m in places so wind patterns may tend to align more along this axis. 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. Winds from a southerly direction may transport contamination from the head of the voe towards the fisheries.

10. Current and historical classification status

Classification records for Dales Voe: Scarvar Ayre were available back to 2001, when it was first given a provisional classification.

Table 10.1 Classification history, Dales Voe: Scarvar Ayre

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	a	a	a	a	a	a	a	a	a	a	a	a
2002	A	A	A	A	A	A	A	A	B	B	B	B
2003	A	A	A	A	A	A	B	A	A	A	A	A
2004	A	A	A	A	A	A	A	A	A	A	A	A
2005	A	A	A	A	A	A	A	A	A	A	A	A
2006	A	A	A	A	A	A	A	A	A	A	A	A
2007	A	A	A	A	A	A	A	A	A	A	A	A
2008	A	A	A	A	A	A	A	A	A	A	A	A
2009	A	A	A	A	A	A	A	A	A	A	A	A
2010	A	A	A	A	A	A	A	A	A	A	A	A
2011	A	A	A									

Lower case denotes provisional classification

The area has been classified A year-round since 2004 and only received B classification in 5 months in 2002 and 2003.

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken Dales Voe: Scarvar Ayre from the beginning of 2002 up to the 16th April 2010 were extracted from the database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data.

All reported sampling locations fell within the production area, and all samples were received by the testing laboratory within two days of collection. One sample had an invalid test result and so could not be used, and 28 samples had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation.

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

11.2 Summary of microbiological results

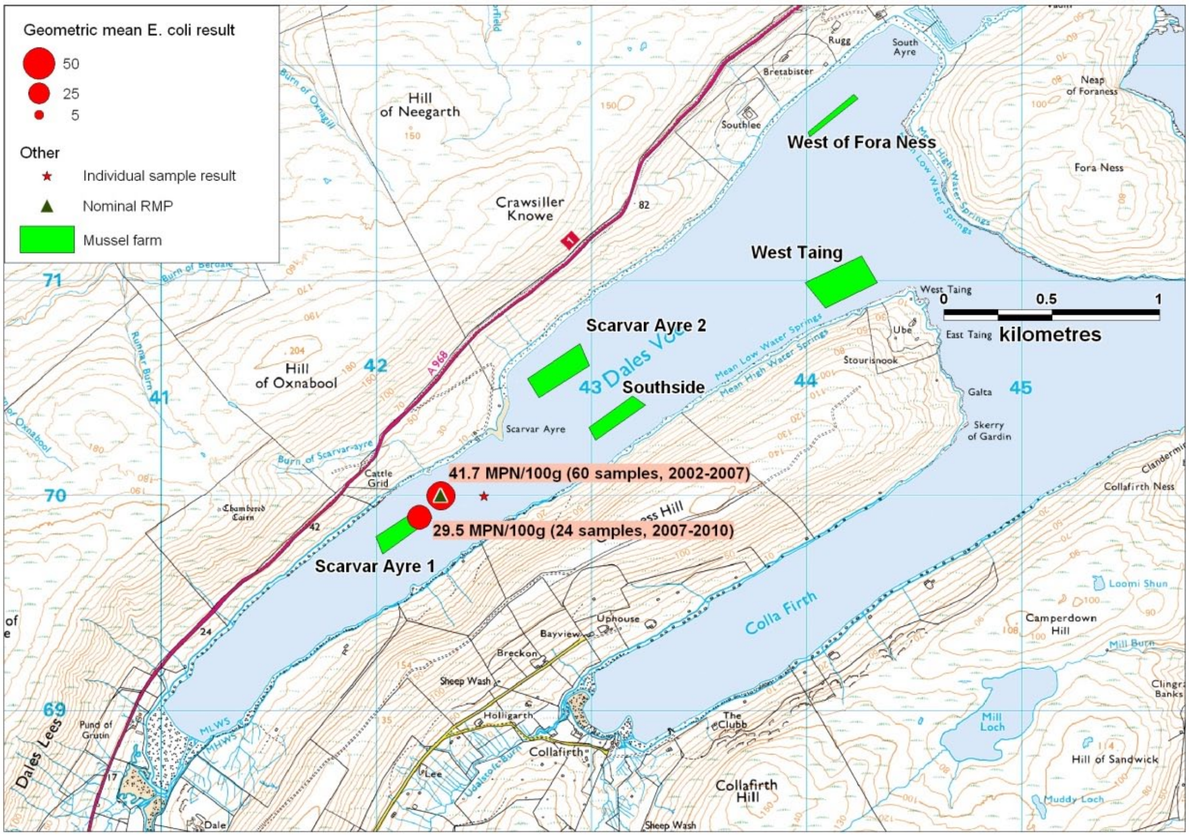
A summary of all sampling and results is presented in Table 11.1.

Table 11.1 Summary of historical sampling and results

Sampling Summary			
Production area	Dales Voe: Scarvar Ayre	Dales Voe: Scarvar Ayre	Dales Voe: Scarvar Ayre
Site	Scarvar Ayre	Scarvar Ayre	Scarvar Ayre
Species	Common mussels	Common mussels	Common mussels
SIN	SI-050-420-08	SI-050-420-08	SI-050-420-08
Location	HU423700	HU425700	HU422699
Total no of samples	60	1	24
No. 2002	11	0	0
No. 2003	12	0	0
No. 2004	12	0	0
No. 2005	10	1	0
No. 2006	9	0	0
No. 2007	6	0	4
No. 2008	0	0	9
No. 2009	0	0	9
No. 2010	0	0	2
Results Summary			
Minimum	<20		<20
Maximum	3500		490
Median	40	110	20
Geometric mean	41.7		29.5
90 percentile	257		250
95 percentile	500		327
No. exceeding 230/100g	7 (12%)		3 (13%)
No. exceeding 1000/100g	2 (3%)		0 (0%)
No. exceeding 4600/100g	0 (0%)		0 (0%)
No. exceeding 18000/100g	0 (0%)		0 (0%)

11.3 Overall geographical pattern of results

All sampling results are thematically mapped by sampling location in Figure 11.1.



Produced by Cefas Weymouth Laboratory. Ordnance Survey licence number [GD100035675]

Figure 11.1 Map of *E. coli* results by sampling location

Results were recorded against the nominal RMP from 2002-2007. This lay off the current fishery. In 2007, the reported sampling point was located at a point lying on the current fishery. No significant difference in mean result was found between the two main sampling locations (T-test, T=-1.09, p=0.281, Appendix 6), and the proportions of results over 230 *E. coli* MPN/100 g at these two locations were similar (Table 11.1). The maximum recorded result was higher at the older sampling point, as was the proportion of results exceeding 1000 *E. coli* MPN/100 g. One sample was reported as having been taken at a third location which did not lie on the current fishery: this may have been a clerical error as the location differed from that of the nominal RMP by one digit. It is not clear whether the actual sampling location changed with time. The locations were reported to 100 m accuracy and so it is not clear how close the actual sampling locations were.

11.4 Overall temporal pattern of results

Figures 11.2 presents a scatter plot of individual results against date for Dales Voe Scarvar Ayre, 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. These trend lines help to highlight any apparent underlying trends or cycles in the data.

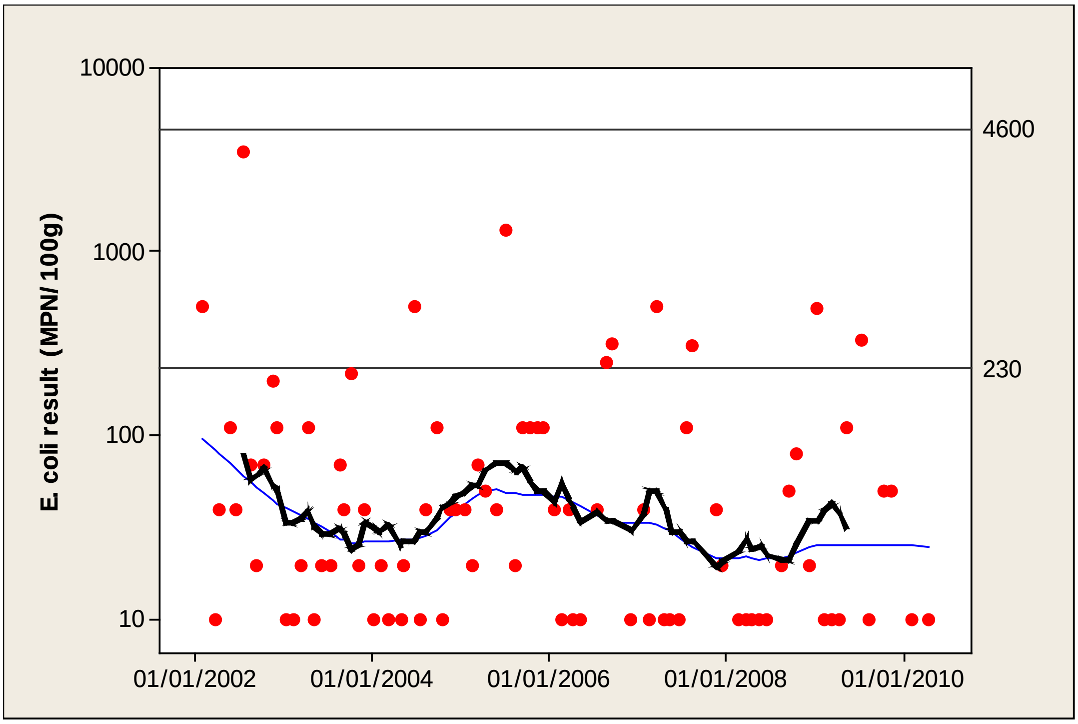


Figure 11.2 Scatter plot of *E. coli* results by date with rolling geometric mean (black line) and loess line (blue line)

Figure 11.2 suggests an overall improvement in results, and a gradual decline in peak levels over years, although a slight deterioration in results is evident in 2005, when higher low results and a peak result of >1000 MPN/100 g coincided.

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. Figure 11.3 presents a boxplot of *E. coli* result by month.

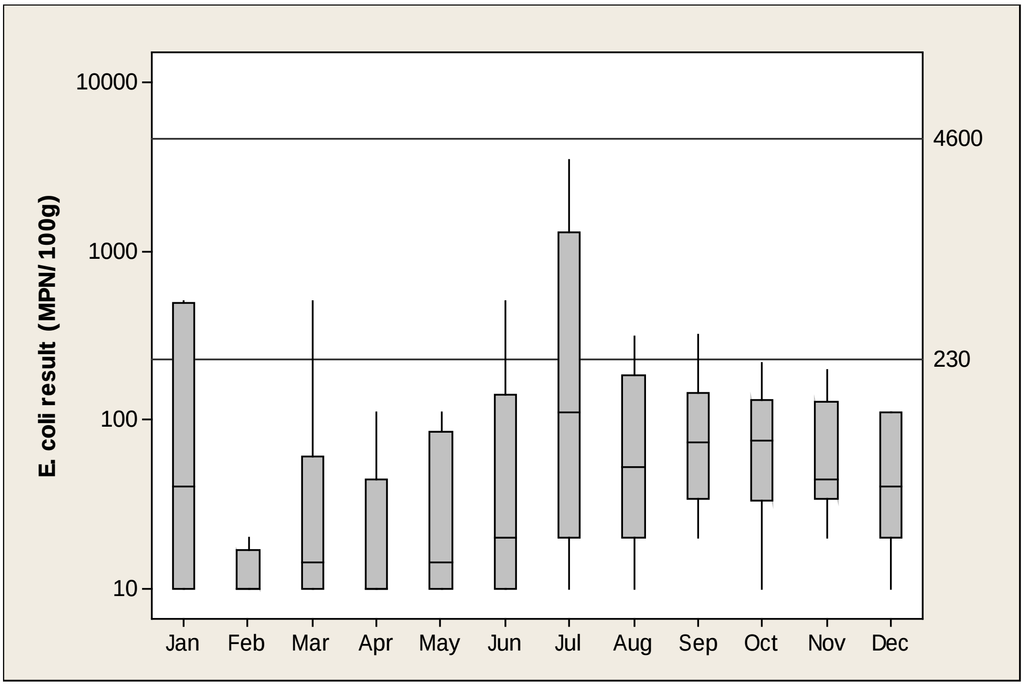


Figure 11.3 Boxplot of results by month

Between 5 and 9 samples were submitted for each month. Results were generally fairly low in the spring, and higher on average during the second half of the year, with a peak in July. Results greater than 230 *E. coli* MPN/100g occurred in January, March, and June through September. The highest results occurred during July while results were lowest in February.

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

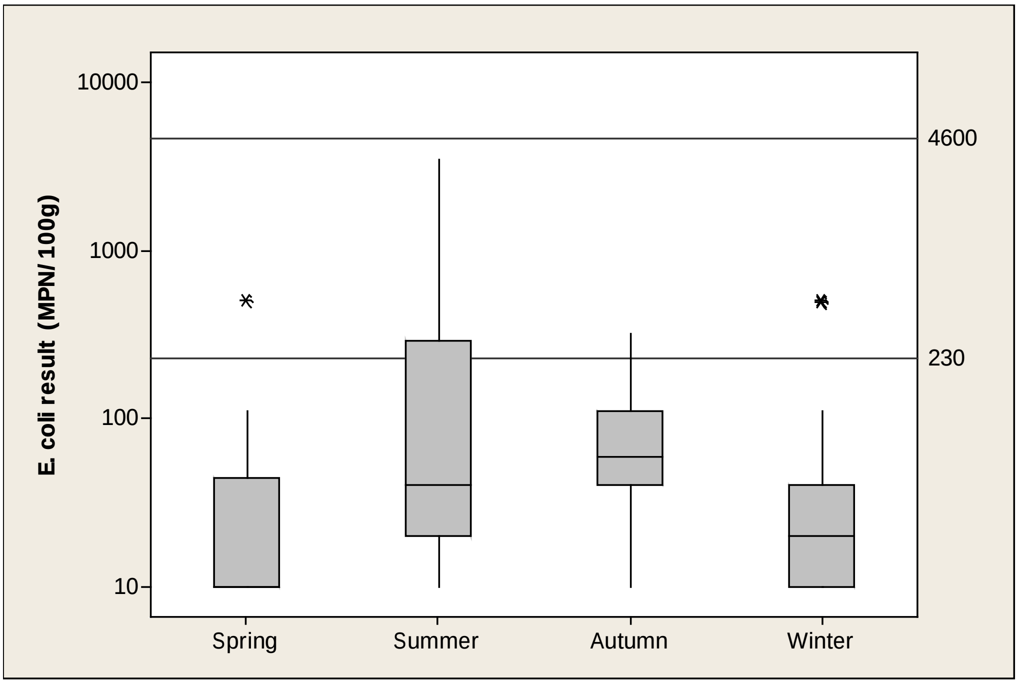


Figure 11.4 Boxplot of result by season

A significant difference was found between results by season (One-way ANOVA, p=0.007, Appendix 6). A post ANOVA test (Tukeys comparison, Appendix 6) indicates that results for the summer and autumn were significantly higher than those for the spring.

11.6 Analysis of results against environmental factors

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

11.6.1 Analysis of results by recent rainfall

The nearest weather station is at Lerwick, which lies 31km to the south of the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2009 (total daily rainfall in mm). As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationships between rainfall in the previous 2 and 7 days and sample results were investigated and are presented below.

Two-day antecedent rainfall

Figure 11.5 presents a scatter plot of *E. coli* results against rainfall in the previous two days. A Spearman's Rank correlation was carried out between results and rainfall.

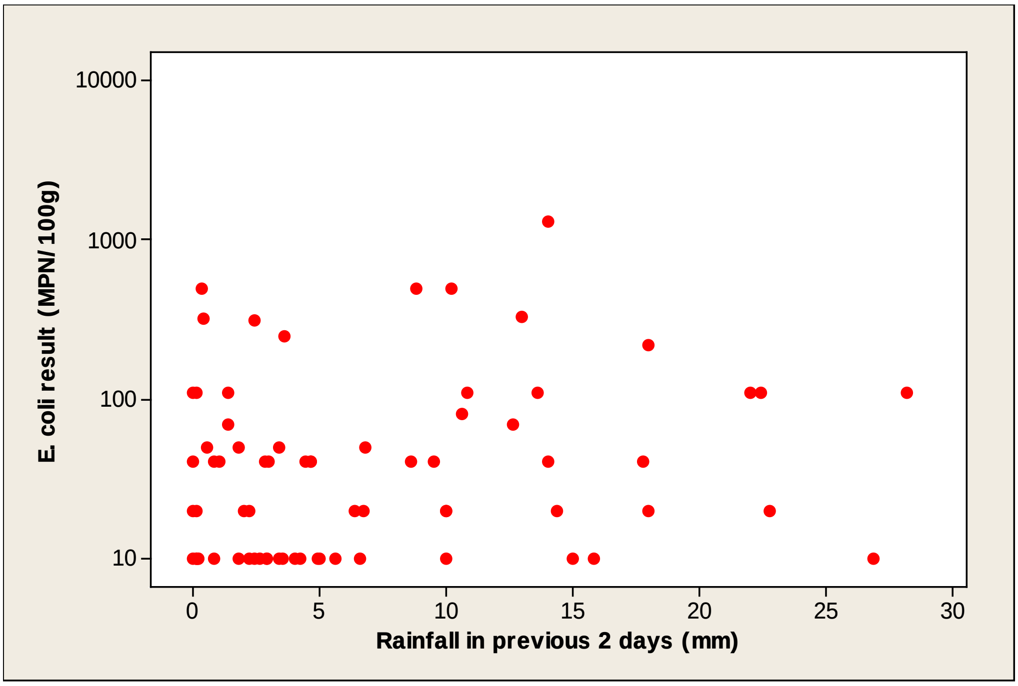


Figure 11.5 Scatter plot of result against rainfall in previous 2 days

No significant correlation was found between *E. coli* result and rainfall in the previous 2 days (Spearman's rank correlation=0.187, p>0.10, Appendix 6). There was no pattern apparent in Figure 11.5, and very low results were observed after both low and high rainfall.

Seven-day antecedent rainfall

Figure 11.6 presents a scatter plot of *E. coli* results against rainfall in the previous 7 days. As for two day rainfall, a Spearman's Rank correlation was carried out.

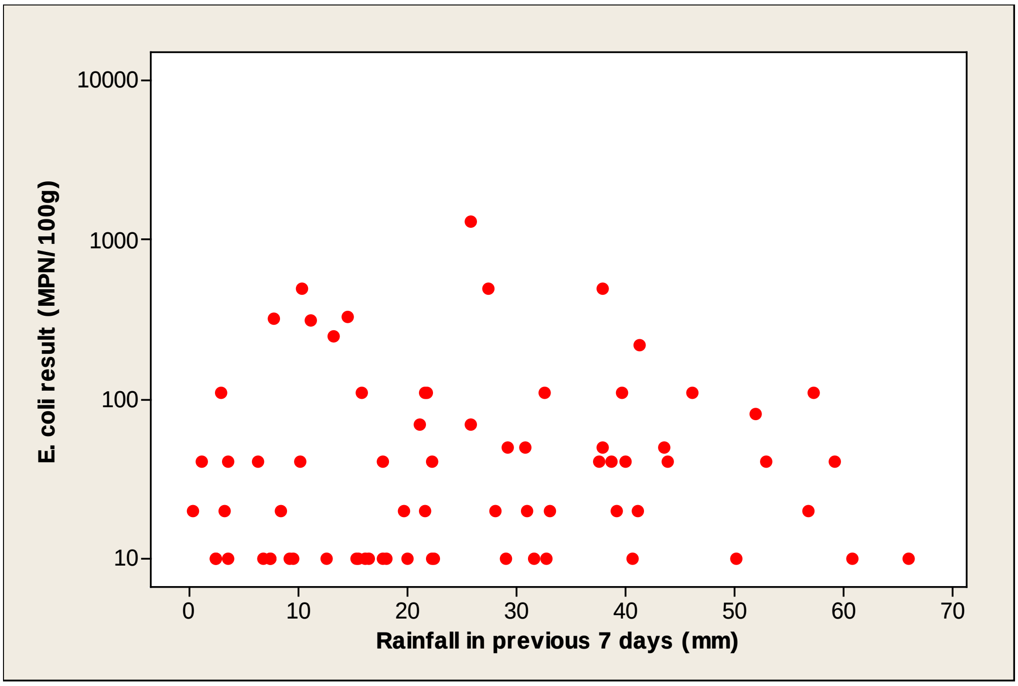


Figure 11.6 Scatter plot of result against rainfall in previous 7 days

No significant correlation was found between *E. coli* result and rainfall in the previous 7 days (Spearman's rank correlation= 0.153, p>0.10, Appendix 6).

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 area. Figure 11.7 presents a polar plot of $\log_{10}$ *E. coli* results on the lunar spring/neap tidal cycle. Full/new moons are located at 0º, and half moons at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of under 230 *E. coli* MPN/100 g are plotted in green, those between 230 and 1000 *E. coli* MPN/100 g are plotted in yellow, and those over 1000 *E. coli* MPN/100 g 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.

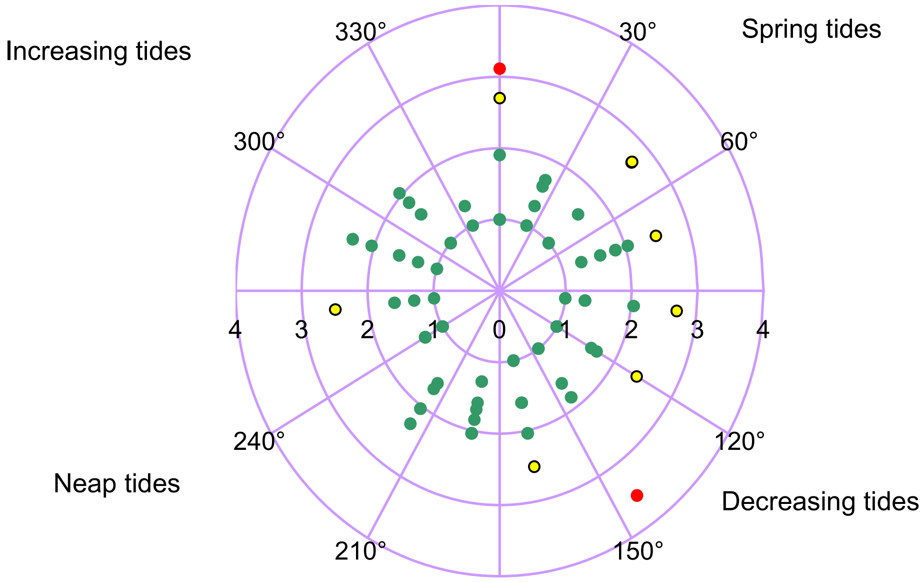


Figure 11.7 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle

No significant correlation was found between *E. coli* results and the spring/neap cycle (circular-linear correlation, r=0.094, p=0.486, Appendix 6).

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 at Dury Voe) was compared with *E. coli* results. Figure 11.8 presents a polar plot of $\log_{10}$ *E. coli* results on the lunar high/low tidal cycle. High water is located at 0º, and low water at 180º. Again, results of under 230 *E. coli* MPN/100 g are plotted in green, those between 230 and 1000 *E. coli* MPN/100 g are plotted in yellow, and those over 1000 *E. coli* MPN/100 g are plotted in red.

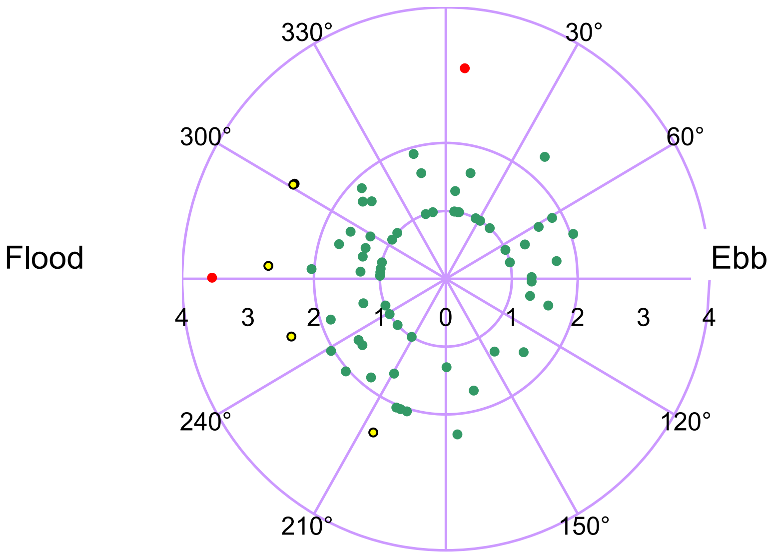


Figure 11.8 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle

A significant correlation was found between *E. coli* results and the high/low tidal cycle (circular-linear correlation, r=0.240, p=0.022, Appendix 6). Figure 11.8 suggests that higher results occurred when samples were taken during the flood tide.

11.6.3 Analysis of results by water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) and the feeding and elimination rates of shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. It is of course closely related to season, and so any correlation between temperatures and *E. coli* levels in shellfish flesh may not be directly attributable to temperature, but to other factors such as seasonal differences in livestock grazing patterns. Figure 11.9 presents a scatter plot of *E. coli* results against water temperature.

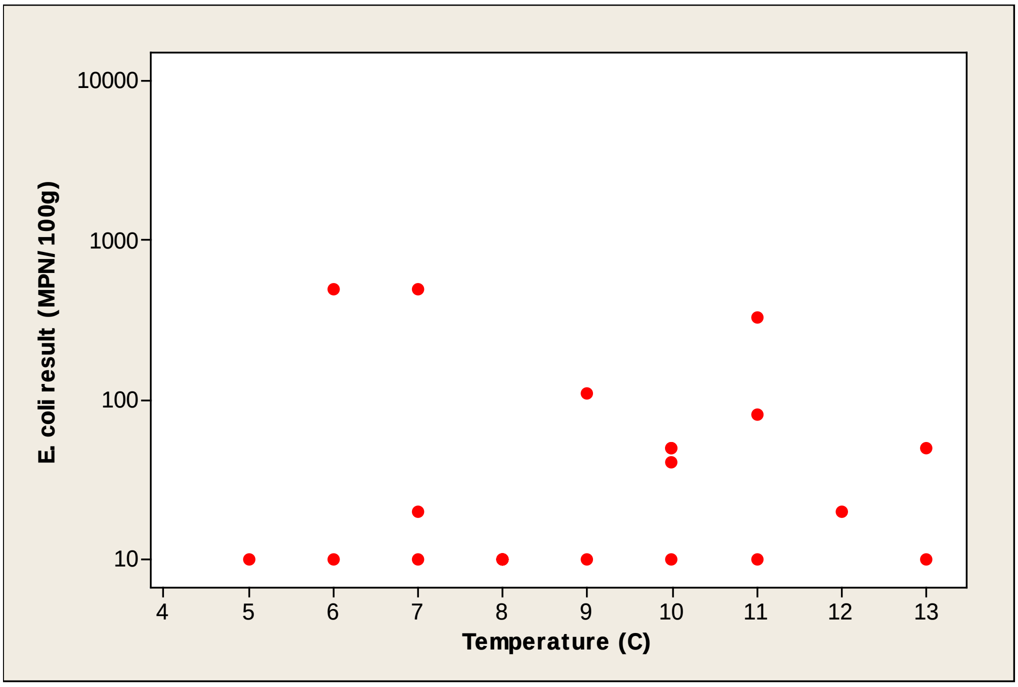


Figure 11.9 Scatter plot of result by water temperature

No significant correlation was found between *E. coli* result and water temperature (Spearman's rank correlation= 0.170, p>0.10, Appendix 6).

11.6.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater borne contamination at the site. Figure 11.10 presents a scatter plot of *E. coli* result against salinity.

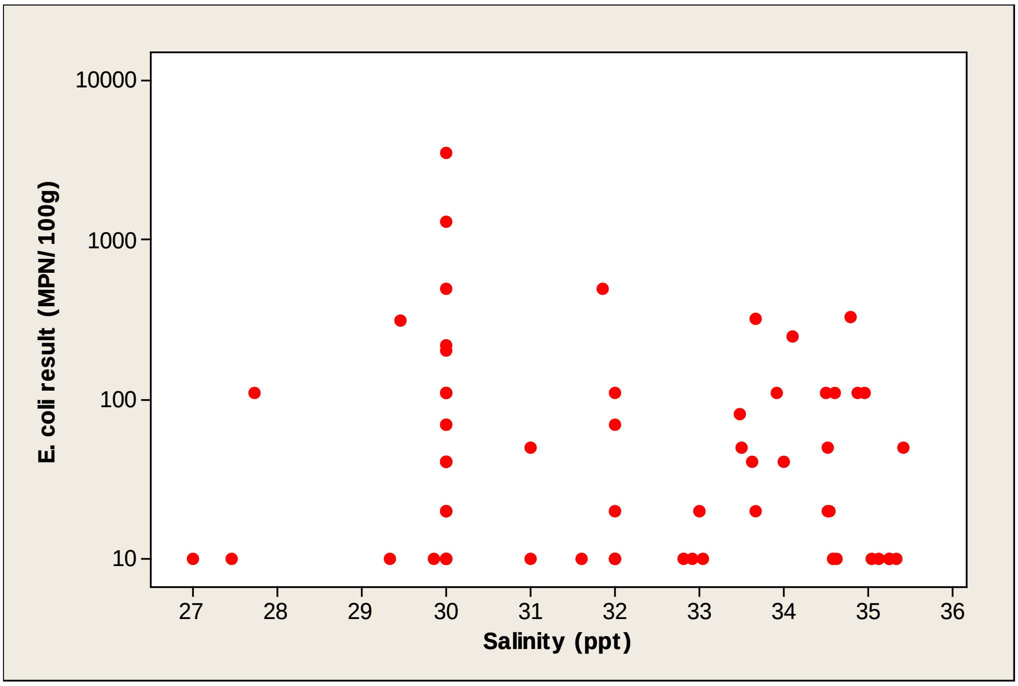


Figure 11.10 Scatter plot of result by salinity

No significant correlation was found between the *E. coli* result and salinity (Spearman's rank correlation= -0.078 p>0.10, Appendix 6).

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

Two samples gave a result of greater than 1000 *E. coli* MPN/100 g, details of which are presented in Table 11.2.

Table 11.2 Historic *E. coli* sampling results over 1000 *E. coli* MPN/100 g

Collection date	*E. coli* (MPN/100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tidal state (high/low)	Tidal state (spring/neap)
16/07/2002	3500	HU423700	*	*	*	30	high	Decreasing
06/07/2005	1300	HU423700	14	25.7	*	30	flooding	Spring

*Data unavailable

Both samples were reported as having been taken from the nominal RMP and both were taken during June. Both were taken at a salinities indicating minor freshwater influence (30 ppt), and the second sample was taken following moderately high rainfall. They were taken under differing tidal conditions.

11.8 Bacteriological Survey

Samples were collected from multiple sites within the voe between January and October 2010. Results for those samples collected on the same dates are summarised in Table 11.3.

Table 11.3 Bacteriological survey sampling 2010

Date	Scarvar Ayre 1	Scarvar Ayre 2	Southside	West Taing	West of Fora Ness
26-Jan	-	-	-	<20	-
9-Feb	<20	20	<20	-	-
23-Mar	-	-	-	<20	50
14-Apr	<20	<20	<20	-	-
20-Apr	-	-	-	<20	20
11-May	<20	<20	<20	-	-
19-May	-	-	-	1300	490
8-Jun	<20	<20	<20	-	-
15-Jun	-	-	-	130	80
13-Jul	490	1300	790	-	-
20-Jul	-	-	-	20	20
10-Aug	9200	16000	5400	-	-
17-Aug	-	-	-	-	50
14-Sep	490	340	490	-	-
21-Sep	-	-	-	<20	<20
12-Oct	<20	<20	<20	-	-

West Taing and West of Fora Ness were sampled on the same date 6 times, and the remaining three sites were sampled on the same date 8 times. All five sites were only sampled at the same time during the shoreline survey. Results from all sites over time are shown graphed in Figure 11.11.

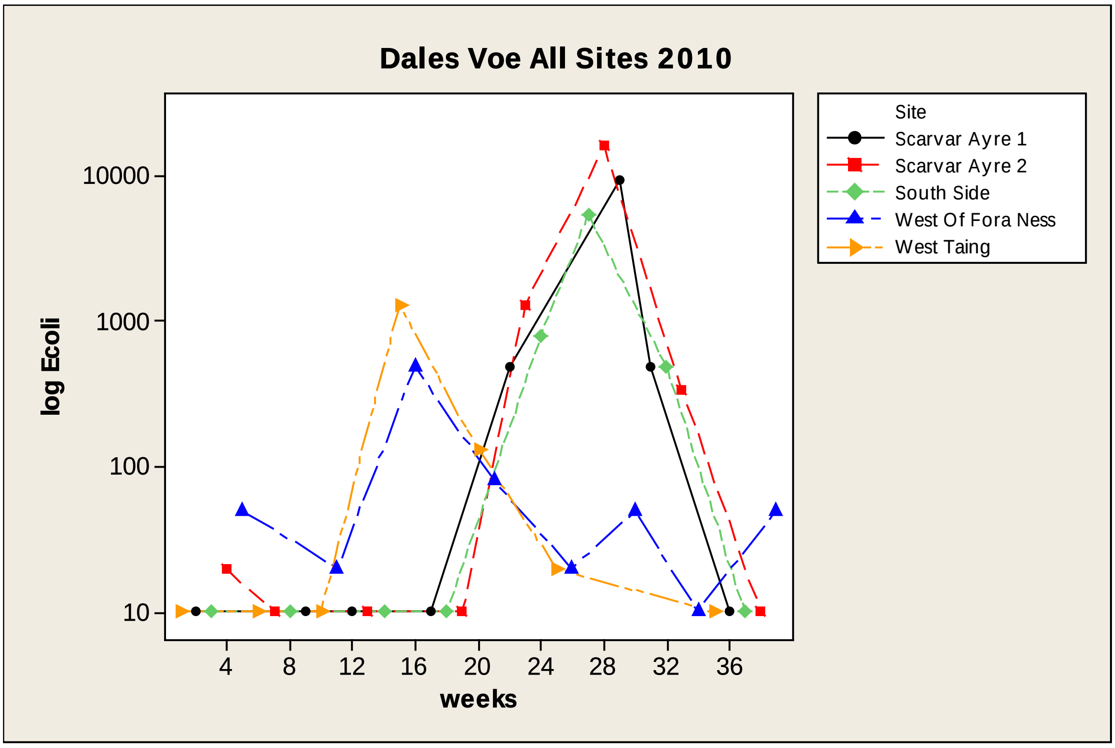


Figure 11.11 Bacteriological results for all sites 2010

The trend in results at the different sites shows two distinct patterns. At West of Fora Ness and West Taing, results peaked in May then tailed in June returning to pre-peak levels in July. At the other three sites, results were all below the limit of detection of the test used through June. In July, all three trended upward simultaneously, reaching a peak in August then falling back in September to return to pre-peak levels in October.

This seems to indicate that the three sites nearest the head of the voe (Scarvar Ayre 1 & 2 and Southside) may be subject to different contaminating sources and/or different environmental factors. Peak results were substantially higher at the inner three sites than at the outer two. These data should be treated with some caution, however, as samples at the two cohorts were taken during alternate weeks.

11.9 Summary

A seasonal pattern was observed in the classification monitoring history, with the highest results occurring in June. Results for the summer and autumn were significantly higher than those for the spring. No significant correlation was found between *E. coli* results and water temperature.

No significant correlation was found between *E. coli* results and rainfall in the previous 2 and 7 days or salinity at the time of sampling. No significant correlation was found between *E. coli* results and the spring/neap tidal cycle. A significant correlation was found with the high/low tidal cycle, with higher results generally arising on a flooding tide. This may indicate the influence of a contaminating source further toward the mouth of the voe from the sampling point.

Analysis of bacteriological survey sampling undertaken during 2010 indicated that the sites within the voe appeared to split into two distinct groups (inner voe and outer voe) with respect to contamination levels over time. Peak levels during this period were higher than were observed during earlier monitoring, and higher at the inner sites that at the outer 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.

11.10 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. As the Dales Voe: Scarvar Ayre has held the same classification for more than 3 years, a stability assessment was undertaken in accordance with the recommendations contained in the Good Practice Guide (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2010). Monitoring results taken from HU 422 699 were obtained for the period November 2007 to October 2010 are summarised in Table 11.3 below. Minimum, maximum and geometric mean results are in *E. coli* MPN/100 g.

Table 11.4 Summary of E. coli results for stability assessment

Dales Voe: Scarvar Ayre HU 422 699	
Year	No of samples
2007	2
2008	9
2009	9
2010	8
Total	28
Results	
Minimum	<20
Maximum	9200
Geometric mean	35

Of the 2010 results, 3 of 7 were greater than 230 *E. coli* MPN/100 g, with the highest result recorded at the site, 9200, occurring in August.

To qualify for reduced sampling frequency (less than monthly), the geometric mean for the last 3 years monitoring results (at least 24 samples) must be 13 or lower. As the geometric mean at Dales Voe: Scarvar Ayre was 35, it does not qualify for reduced sampling frequency at this time.

12. Designated Shellfish Growing Waters Data

Dales Voe has not historically been identified as a designated Shellfish Growing Water (SGW). The adjacent voe to the south, Colla Firth, was designated as a SGW between 2002 and 2009 during which time it failed to achieve the guideline standard for faecal coliforms in 2003, 2006 and 2007.

In 2009, the designation was rescinded from Colla Firth and Dales Voe was designated. As the classification monitoring results from Dales Voe will be used for SGW compliance under agreement between the Food Standards Agency in Scotland and SEPA, these results are already considered within this report and therefore will not be presented in this section.

13. River Flow

There are no gauging stations on burns or streams along the Dales Voe coastline. Dales Voe has a catchment area 10 km^2, with very steep hill sides. The largest watercourse flowing into the voe is Burn of Sandgarth, which discharges into the head of the voe. The much smaller Burn of Scarvar Ayre discharges part way along the north shore, to within 200 m of the mussel farm Scarvar Ayre 1.

The watercourses listed in Table 13.1 were measured and sampled during the shoreline survey. The locations are shown on the map presented in Figure 13.1. 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.

A number of land drains were observed during the shoreline survey but these were dry at the time. A number of other water courses are shown on the south-east side of the voe on the OS map but these could not be accessed during the shoreline survey due to the steep terrain. There had been some light showers in the week preceding the survey and light rain was noted for part of the survey period.

Table 13.1 Stream loadings for Dales Voe

No	Sample number	Grid Ref	Description	Width (m)	Depth (m)	Flow (m/s)	Flow in m^3/day	*E.coli* (cfu/ 100ml)	Loading (*E.coli* per day)
1	Dales Voe FW1	HU 4260 7061	Stream	0.04	0.02	0.703	49	20	9.7×10^6
2	Dales Voe FW2	HU 4265 7064	Stream	0.25	0.02	0.254	3	<10	$<3.0 \times 10^5$
3	Dales Voe FW3	HU 4369 7154	Stream	0.10	0.05	0.085	47	30	1.4×10^7
4	Dales Voe FW4	HU 4388 7179	Stream	0.15	0.07	0.150	136	50	6.8×10^7
5	Dales Voe FW5	HU 4438 7222	Stream	0.02	-	350ml/20 secs[1]	1.5	<10	$<1.5 \times 10^5$
6	Dales Voe FW6	HU 4221 7013	Burn of Scarvar Ayre	0.65	0.10	0.100	562	110	6.2×10^8
7	Dales Voe FW7	HU 4128 6943	Stream	0.06	0.18	0.137	128	400	5.1×10^8
8	Dales Voe FW8	HU 4109 6920	Stream	0.24	0.10	0.513	1064	<10	$<1.1 \times 10^8$
9	Dales Voe FW9	HU 4102 6910	Stream	0.15	0.15	0.224	435	300	1.3×10^9
10	Dales Voe FW10	HU 4094 6897	Stream	0.60	0.05	0.155	402	6.6×10^3	2.7×10^{10}
11	Dales Voe FW12	HU 4095 6858	Burn of Sandgarth	2.0	0.08	0.241	3332	1.3×10^3	4.3×10^{10}

[1]Too small to measure with a flow meter. Approximate time taken to fill a measured volume.

A general trend toward decreasing loadings with distance from the head of the voe was observed in the data. The two watercourses with the highest loadings were number 10 and number 11. A third stream (number 9) also had a relatively high loading. These were all located towards the head of the voe and would be expected to impact principally on the Scarvar Ayre 1 site. However, streams 1, 4 and 6 would potentially have a greater effect on the mussel farms in their vicinity as, although the loadings are less, they are much closer to the lines.

The loadings of all of the streams would be expected to increase significantly following moderate to heavy rainfall and thus their potential effects on the microbiological quality of the mussels would also increase. The dry land drains would be expected to flow under such conditions. Given the steep sided nature of the land around the sounds, there is also the potential for direct run-off after rainfall. All of these would be potential pathways for contamination from animal faeces to enter the voe.

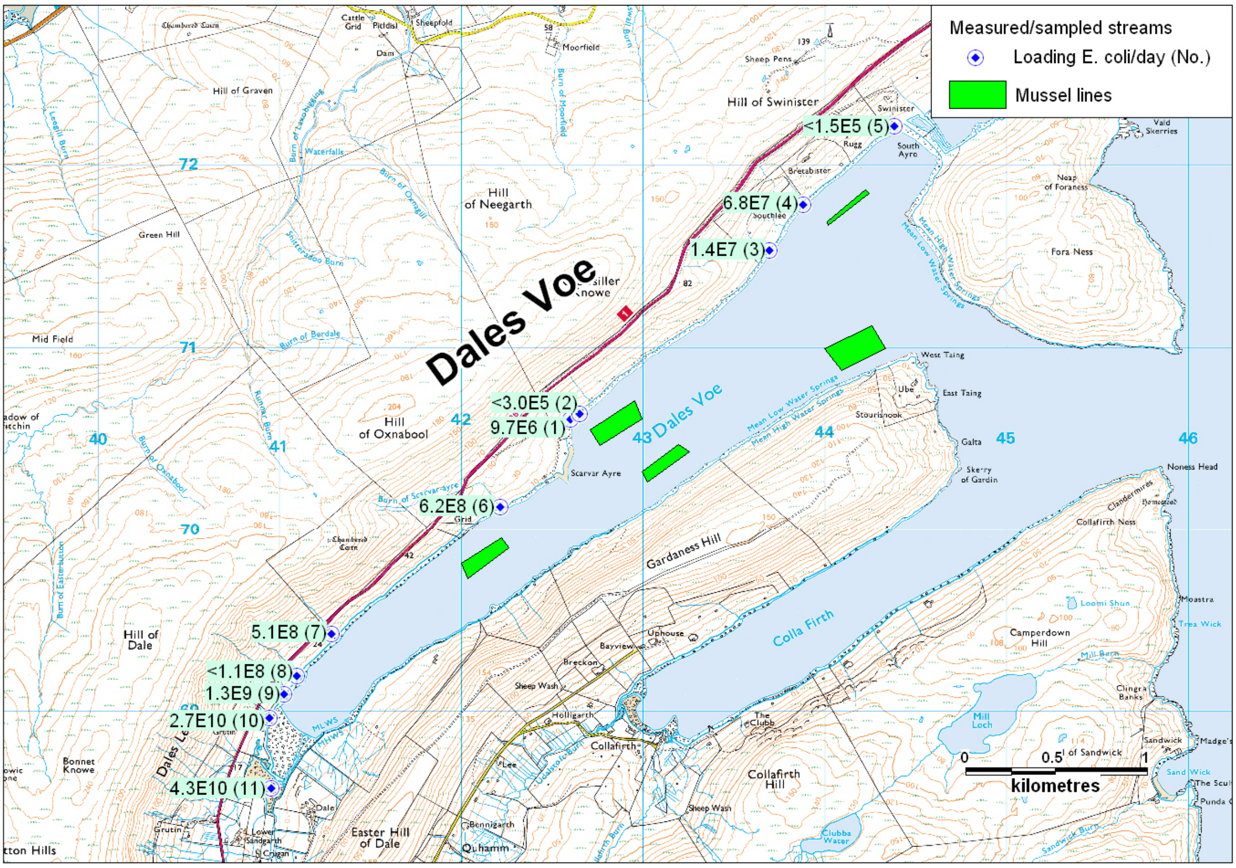


Figure 13.1 Map of stream loadings at Dales Voe

14. Bathymetry and Hydrodynamics

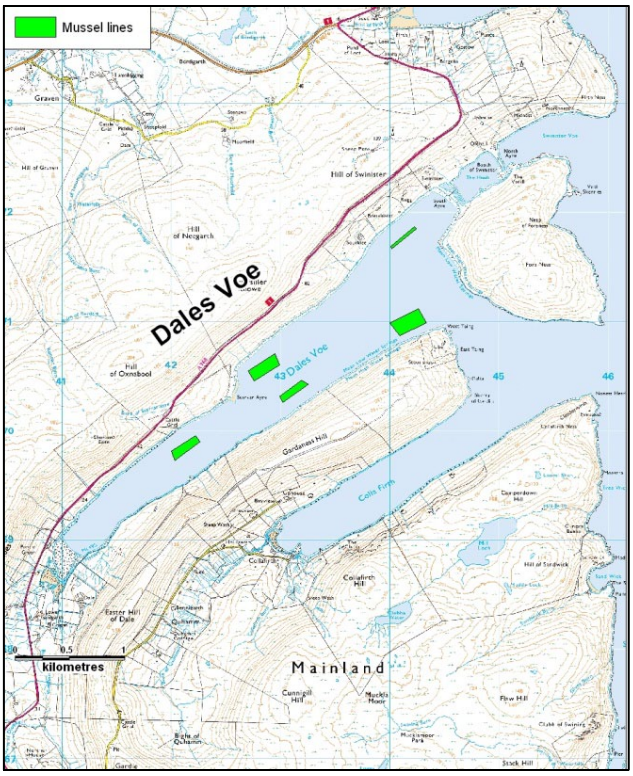


Figure 14.1 OS map of Dales Voe

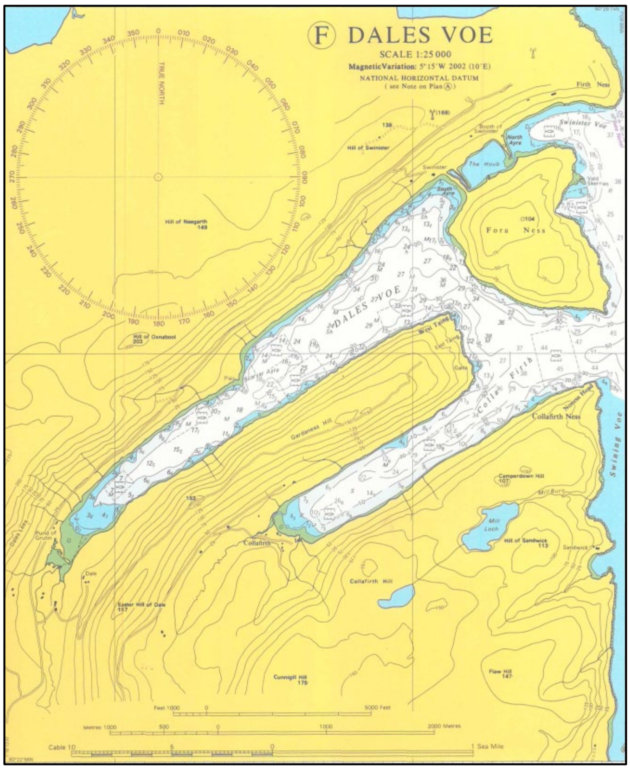


Figure 14.2 Bathymetry at Dales Voe

Dales Voe is approximately 4.7 km long and between 0.35 km and 1 km wide. It lies in an approximately WSW to ENE direction with the entrance at the upper end. Fora Ness lies across most of the entrance and restricts flow into and out of the voe. Most of Dales Voe is relatively deep, mostly greater than 10 m, with a maximum depth of 34 m. The OS map (Figure 14.1) and Hydrographic Chart (Figure 14.2) show that there is a small drying area at the head of the voe. There are no basins in the voe, flushing times are relatively slow (6 days) and there is very little freshwater input with a calculated salinity reduction of 0.1 ppt (Edwards & Sharples, 1986).

14.1 Tidal Curve and Description

The two tidal curves below are for Sullom Voe, a straight line distance of approximately 4 km from Dales Voe, but approximately 21 km by sea. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 BST on 22/06/10 and the second is for seven days beginning 00.00 BST on 29/06/10. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle, including the dates of the shoreline survey.

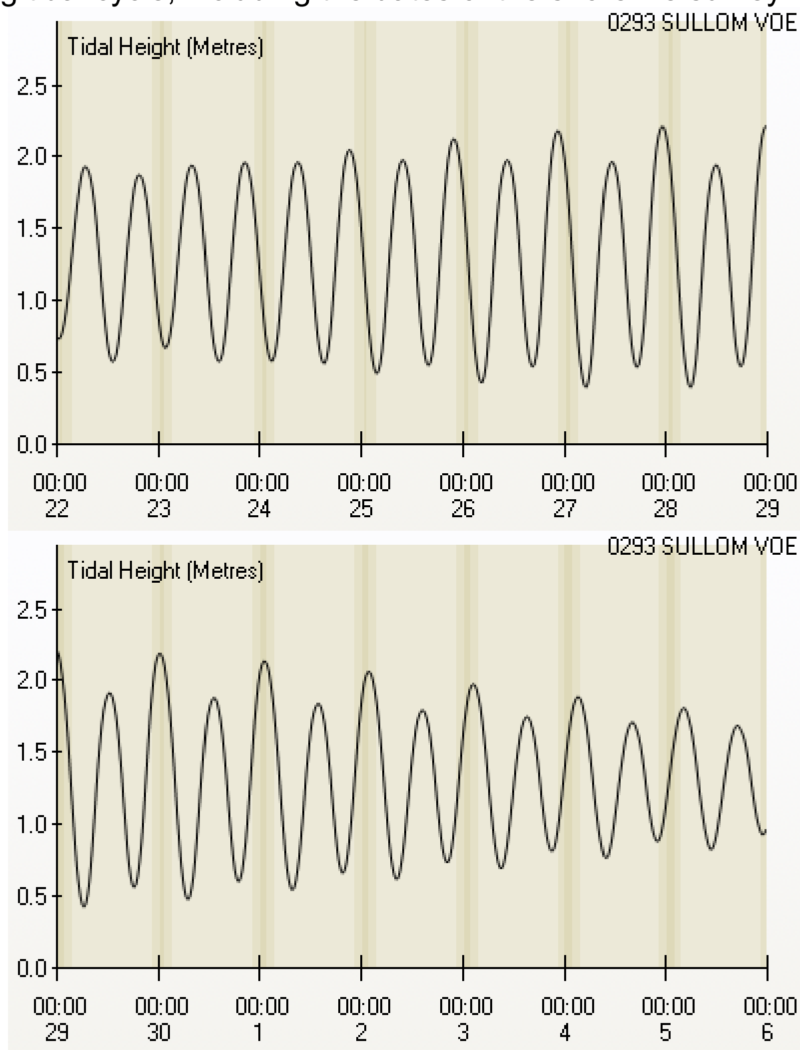


Figure 14.3 Tidal curves for Sullom Voe

The following is the summary description for Sullom Voe from TotalTide:

0293 SULLOM VOE is a Standard Harmonic port. The tide type is Semi-Diurnal.

HAT	2.8 m
MHWS	2.3 m
MHWN	1.8 m
MSL	1.39 m
MLWN	0.9 m
MLWS	0.4 m
LAT	0.0 m

Predicted heights are in metres above Chart Datum. The tidal range at spring tide is 1.9 m, and at neap tide 0.9 m, and so tidal ranges in the area are relatively small.

14.2 Currents

Given the importance of shipping for the oil terminal at Sullom Voe, there is a significant amount of tidal stream information for that area, including in Yell Sound, to the north-west of Dales Voe. None of these tidal stream stations actually lie within Dales Voe. The locations of the two tidal stream stations closest to Dales Voe, together with the tidal streams for peak flood and ebb tide, are presented in Figures 14.4 and 14.5, and their tidal diamonds are presented in Tables 14.1 and 14.2.

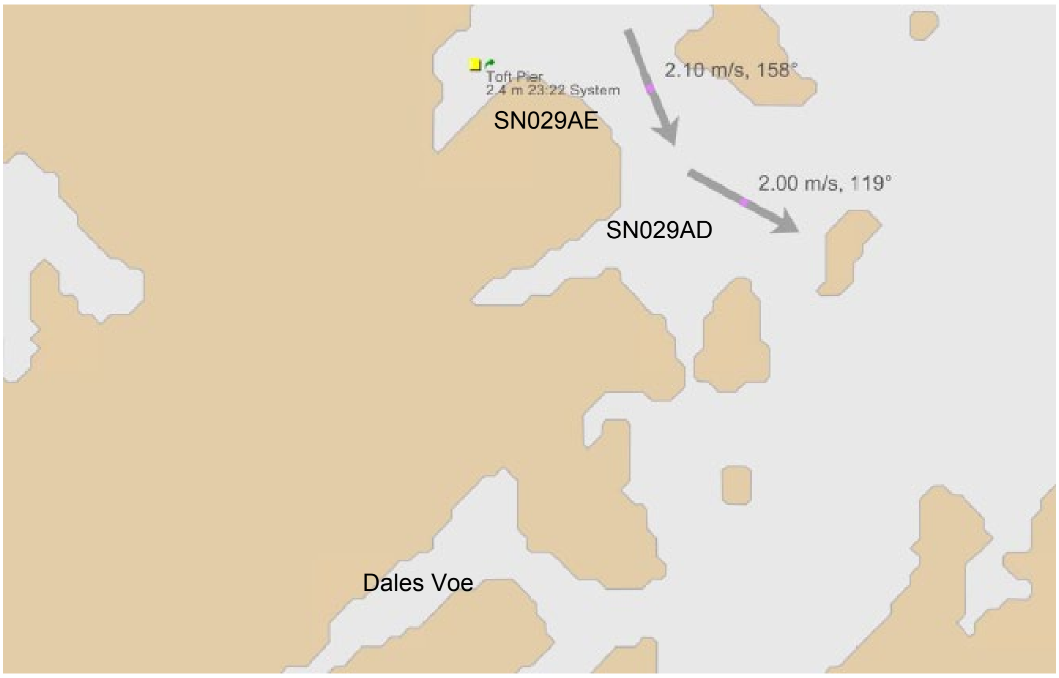


Figure 14.4 Spring flood tide in Yell Sound

Figure 14.5 Spring ebb tide in Yell Sound

Table 14.1 Tidal streams for station SN029AE (60°27.87'N 1°10.12'W) (taken from TotalTide)

Time	Direction	Spring rate	Neap Rate
-06h	160°	0.93 m/s	0.46 m/s
-05h	160°	1.70 m/s	0.87 m/s
-04h	157°	2.20 m/s	1.10 m/s
-03h	158°	2.20 m/s	1.10 m/s
-02h	154°	1.80 m/s	0.93 m/s
-01h	170°	0.67 m/s	0.36 m/s
HW	020°	0.87 m/s	0.46 m/s
+01h	025°	2.20 m/s	1.10 m/s
+02h	027°	2.70 m/s	1.30 m/s
+03h	029°	2.70 m/s	1.40 m/s
+04h	030°	2.30 m/s	1.20 m/s
+05h	028°	1.50 m/s	0.77 m/s
+06h	135°	0.41 m/s	0.21 m/s

Table 14.2 Tidal streams for station SN029AD (60°27.27'N 1°09.12'W) (taken from TotalTide)

Time	Direction	Spring rate	Neap Rate
-06h	113°	0.31 m/s	0.15 m/s
-05h	120°	1.50 m/s	0.77 m/s
-04h	118°	2.20 m/s	1.10 m/s
-03h	119°	2.10 m/s	1.00 m/s
-02h	120°	1.90 m/s	0.98 m/s
-01h	130°	0.46 m/s	0.26 m/s
HW	155°	0.15 m/s	0.10 m/s
+01h	270°	0.21 m/s	0.10 m/s
+02h	025°	0.10 m/s	0.05 m/s
+03h	300°	0.05 m/s	0.05 m/s
+04h	303°	0.31 m/s	0.15 m/s
+05h	030°	0.15 m/s	0.10 m/s
+06h	090°	0.15 m/s	0.10 m/s

Shetland Seafood Quality Control had undertaken a number of current meter studies in the nearby sounds to provide information in support of applications to SEPA to discharge from marine cage fish farms. Three were immediately relevant to the Dales Voe survey. All three had been undertaken on behalf of Hunter Salmon Ltd. The Foraness site is now operated by Hjaltland Seafarms Ltd. Data from the studies were provided to Cefas with the agreement of the companies.

The locations at which the current meters were deployed are shown in Figure 14.6. The survey periods were as given in Table 14.3.

Table 14.3 Survey periods for the fish farm current meter studies

Location	NGR	Survey period
Dales Voe Site 1	HU 4405 7099	10/01/2001 - 26/01/2001
Dales Voe Site 2	HU 4372 7125	15/02/2001 - 04/03/2001
Foraness	HU 4428 7144	10/10/2001 – 26/10/2001

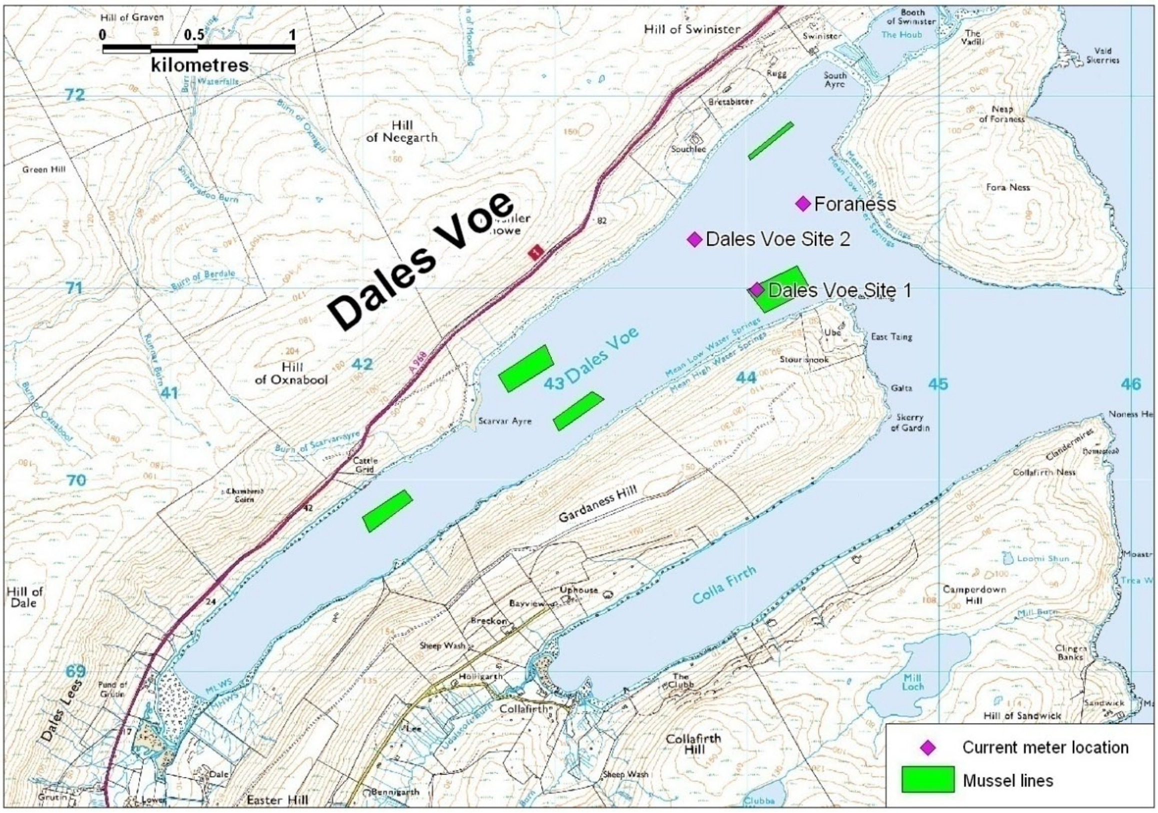


Figure 14.6 Current meter locations in Dales Voe

Unfortunately, the deployment locations were all at the head of the voe and thus there is no data directly relevant to the sites located in the middle of the voe. Plots of the current directions and speeds at the three locations, together with the wind direction and speeds over the relevant periods, are shown in Figure 14.7.

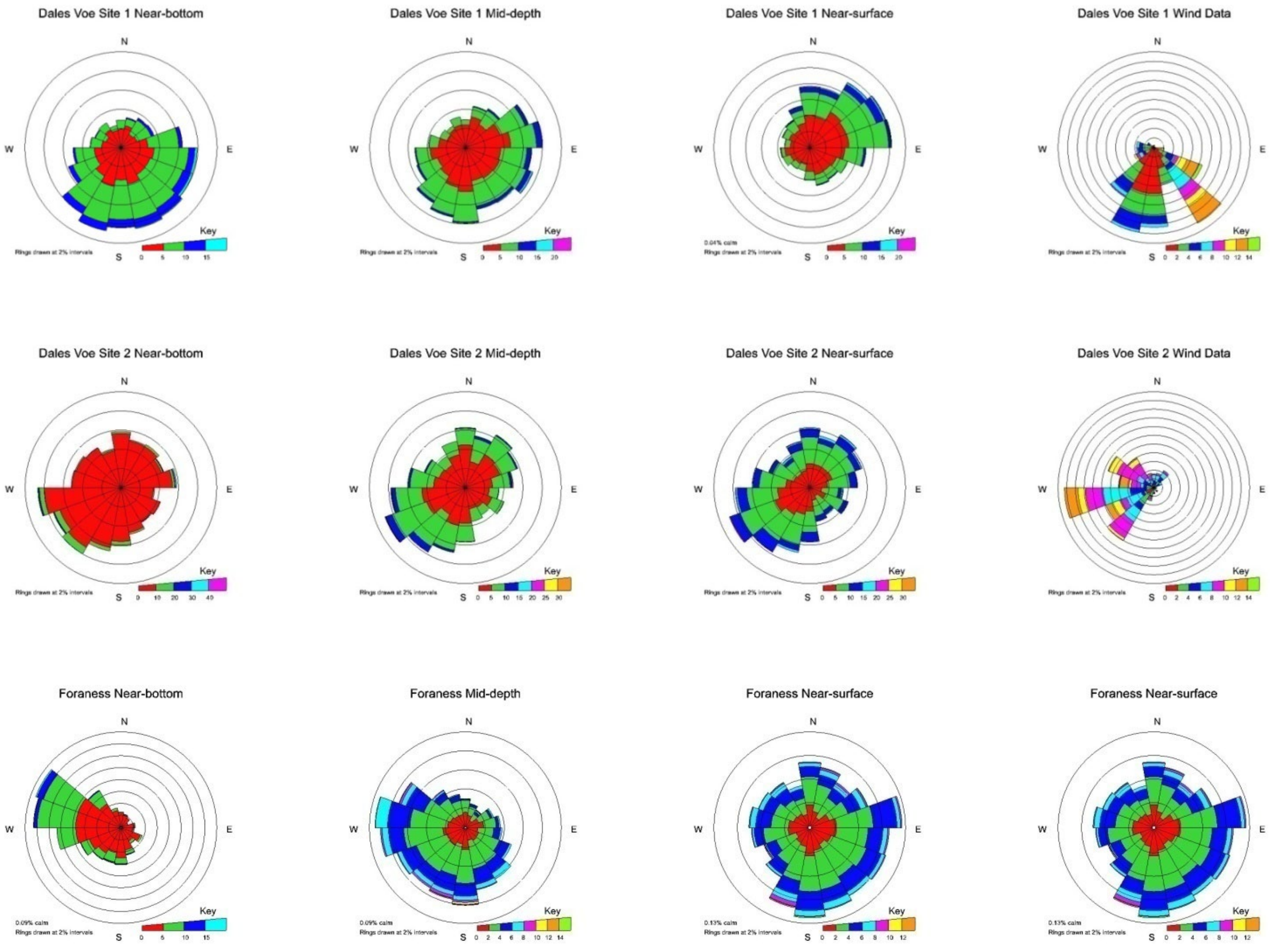


Figure 14.7 Current and wind plots for the Dales Voe sites 1 & 2 and Foraness fish farm surveys

Currents measured in cm/s. Wind measured in m/s. As per convention, currents are plotted against the direction towards which they are travelling while winds are plotted against the direction from which they are travelling. The length of each segment in a plot relates to the proportion of observations lying in that direction. The speed relates to the colour key beneath each plot. The proportion that each colour takes up in an individual segment relates to the proportion of observations in that direction having speed in that range.

The current meter data only shows a clear predominant directional component at Foraness, and there only near the sea bed. At this location, the predominant current was approximately WNW and indicates movement arcing around from the entrance of the voe on the Fora Ness side towards the main part of the voe. At the other locations and depths, the current directions were more variable and simple comparison with the wind data plots suggests that the currents are appreciably influenced by that environmental variable.

The maximum recorded currents at the entrance to the voe were in the order of 20 to 50 cm/s (0.2 to 0.5 m/s), depending on location and depth. This is markedly less than the peak rate given in TotalTide for Yell Sound. The mean recorded current speeds in Dales Voe were in the order of 3 to 6 cm/s (0.03 to 0.06 cm/s). These are very low. It is assumed that the current speeds, but not necessarily directions, will be similar in the middle of the voe. The direction there is likely to be more closely aligned with the general direction of the voe itself, although the generally low current speeds will mean that any winds that are not blowing along the voe will tend to shift the current direction.

Given the maximum recorded current, the distance travelled by contaminants on the flooding or ebbing tide could be as much as approximately 7 km, ignoring any dispersion and dilution. However, at the mean current speed of 6 cm/s, this would reduce to less than 1 km.

14.3 Salinity profiles

The salinities shown in Table 14.4 were recorded during the shoreline survey.

Table 14.4 Salinity profiles recorded during the 2010 shoreline survey

Profile	Position	Depth (m)	Salinity (ppt)
1	HU 4402 7167	<1	37.23
		3	37.22
		5	37.23
		10	37.24
2	HU 4433 7099	<1	35.15
		3	36.94
		5	37.01
		10	37.09
3	HU 4299 7032	<1	37.26
		3	37.25
		5	37.38
		10	37.29
4	HU 4299 7060	<1	37.27
		3	37.29
		5	37.26
		10	37.27
5	HU 4200 6981	<1	37.20
		3	37.22
		5	37.23
		10	37.21

In general the salinities at the five locations were similar. There was only evidence of a freshwater layer at the surface with profile 2. This profile was taken at the south-east corner of the West Taing site nearest to the entrance of the voe, but also close to land. At this location there was almost a 2 ppt difference in salinity between surface and 10 m. The salinity readings at all depths were also slightly lower than those recorded elsewhere in the voe. These results indicate some freshwater influence but there is no permanent stream on the shoreline at that location and, as the weather was fine during the survey, there was no direct land run-off at the time.

14.4 Conclusions

Currents within Dales Voe are generally weak and appreciably influenced by the wind. At the mussel lines at the mouth of the voe the current direction is markedly variable and thus contamination from sources in a number of directions from the lines may be significant. It is assumed that the current direction will be less variable at the mussel lines within the voe itself and these will tend to be influenced more by contamination arising on the shore near the lines. Both the depth of the voe, which will cause significant dilution of contamination, and the generally short distance of transport due to the weak currents, will mean that only nearby sources of contamination will generally be of significance. There is no indication of general stratification within the voe but the salinity profile taken at the south-east corner of the West Taing site indicates a localised freshwater influence.

15. Shoreline Survey Overview

The shoreline survey was conducted on the 22nd and 23rd June 2010 under mostly dry and calm weather conditions.

Five mussel farm sites were observed and boundaries recorded with assistance from the harvester during the shoreline survey. Dales Voe: South Side consisted of four double-headed long lines, with 8 m droppers. The two lines closest to the shoreline had recently been laid and droppers were being installed on these two lines at the time of the shoreline survey. Dales Voe: West Taing consisted of five double-headed long lines, with 8 m droppers. The second line in from the shore was new and was put in place this year. Dales Voe: West of Fora Ness consisted of two double-headed long lines, with 8 m droppers. Dales Voe: Scarvar Ayre 2 consisted of four double-headed long lines, with 8 m droppers. Dales Voe: Scarvar Ayre (currently classified for common mussels) consisted of four double-headed long lines, with 8 m droppers.

A single outfall pipe was observed from a house next to a farm. No other sewage pipes, septic tanks or sanitary debris were observed. There were nine occupied houses spread out at the head of the voe, as well as a small farm with outbuildings. There were no further dwellings along either side of the voe.

Livestock was observed grazing along most of the shoreline surveyed and were able to access the shoreline and fresh water streams. Sheep and their droppings were observed on the shore, and 30 sheep were seen at the South Ayre tombolo. On the side of Easter Hill, at the head of the voe, 20 cattle were observed grazing in a fenced field adjacent to the shore. The majority of livestock were found along the northern shore of the voe between the head and Fora Ness.

Approximately 115 seabirds were observed, with the largest concentrations near the head of the voe. Seals were reported to frequent the area, and three were observed in the outer part of the voe during the course of the survey.

Sea water samples taken in the vicinity of the mussel lines contained no detectable *E. coli* (<1 cfu/100ml) in all cases. Salinity profiles taken at the mussel sites indicated no significant freshwater influence at the time, though observed salinities were slightly lower at the East Taing site.

Freshwater samples and discharge measurements were taken at most of the streams draining into the survey area. The streams were small and drained areas of rough grassland with some areas of improved pasture. Streams contained varying levels of contamination (<10 to 6.6×10^3 *E. coli* cfu/100ml). The three streams with the highest *E. coli* loadings were all located at the head of the voe. Mussel samples were collected from each of the five fisheries in Dales Voe and all returned low results of <20 *E. coli* MPN/100 g.

Figure 15.1 shows a summary map of the most significant findings from the shoreline survey.

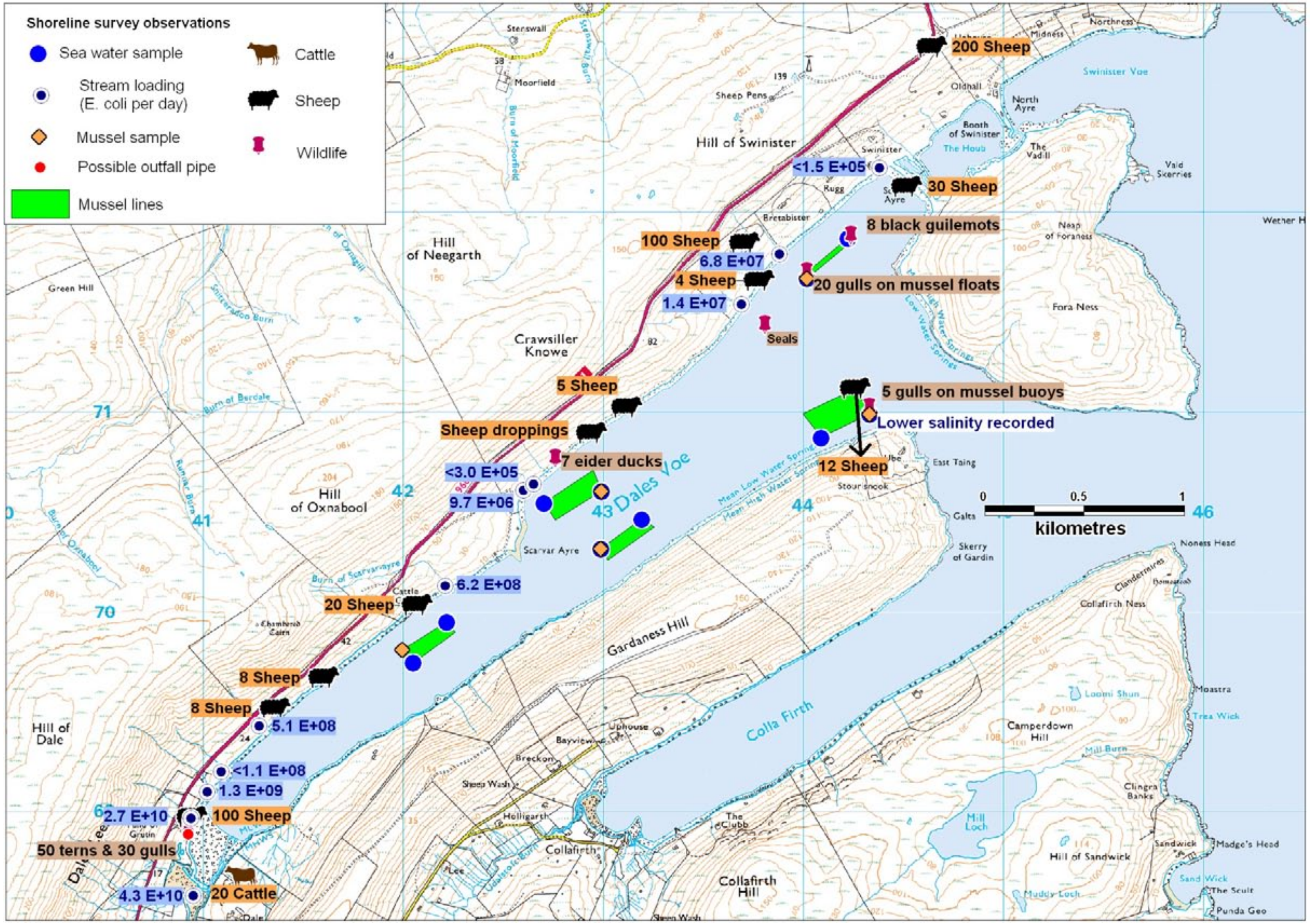


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Figure 15.1 Summary of shoreline survey findings for Dales Voe: Scarvar Ayre

16. Overall Assessment

Human sewage impacts

Overall, there will be very little impact from human sewage to the fishery. Only nine occupied dwellings and a farm were observed along the shores of Dales Voe, and all near the head of the voe. Only one discharge pipe was observed to discharge directly to the sea, approximately 1.5 km west of the nearest mussel farm.

Water samples taken from streams at the head of the voe contained relatively high concentrations of *E. coli*, indicating that these were subject to faecal contamination at the time of sampling. However, it is not known what proportion of the contamination might have come from human versus animal sources.

Contamination from the limited human sewage sources would be likely to be substantially diluted before reaching the nearest fishery, at Scarvar Ayre 1, and any impact is likely to be highest at the southwestern end of this site.

Agricultural impacts

A farm is situated at the head of the voe, and livestock were observed along both shores of the voe though the majority were seen on the north shore. Animals and droppings were observed on the shoreline, particularly on the tombolo at Fora Ness, where direct deposition into the sea is likely to occur. Animals grazed on improved pasture along the north shore and the head of the voe are likely to have a significant impact to water quality in the area, particularly where streams carrying land-runoff discharge into the sea and in areas where animals directly access the shore. Therefore, the mussel farms along the northern shore are at greater risk from agricultural sources of contamination.

Wildlife impacts

Seabirds, wading birds, seals and small mammals such as otters and rabbits are likely to deposit faecal material either directly into the voe or onto land within the catchment of local streams. A significant number of birds were observed at the head of the voe during the shoreline survey, and a conservation area there is noted for nesting birds. Therefore, there is likely to be a some impact from bird faeces at and near the head of the voe during the nesting season. Gulls were observed on the mussel floats from which they are likely to directly deposit faeces to the fishery, which would occur year-round. Three seals were observed in the outer voe, and seals are reported to be normally present in the area. Overall, impacts from either seals or birds are likely to be spatially variable across the fishery, with no one site likely to be more significantly impacted than another. Impacts from the nesting area at the head of the voe are more likely to affect the Scarvar Ayre 1 site during the summer breeding season, although some birds may be present in the area year-round.

Seasonal variation

The human population in the area is low and there is no evidence to suggest a large seasonal influx of visitors or residents to the area. There will be seasonal patterns to livestock management in the area, with animals generally allowed to graze more widely during the summer months than during winter. Lambs are generally born between April and June, leading to an increase in numbers of livestock present until they are sent off to market in October. There is some evidence to suggest that seabirds are more likely to be present in larger numbers at nest sites near the head of the loch during the summer months.

Examination of variation in historical *E. coli* monitoring results showed a seasonal trend to higher results in summer and autumn (June - November). This did not directly coincide with seasonal variation in rainfall, which was generally higher in autumn and winter. However, it does roughly coincide with the onset of higher peak rainfall after dry months in April and May. It also coincides with a seasonal increase in the numbers of livestock likely to be present around the voe.

Rivers and streams

While there were streams along much of the northern shoreline of the voe, there were fewer observed along the southern shoreline and the largest of these in terms of flow and *E. coli* loading were located near the head of the voe. Smaller streams were located closer to the mussel lines, however, at the southern end of the West of Fora Ness and Scarvar Ayre 2 sites, and near the northern end of the Scarvar Ayre 1 site. The Scarvar Ayre 1 site is also most likely to be affected by contamination arising from stream discharges to the head of the voe.

Although few streams were observed at the southeastern shore of the voe, a very small decrease in salinity was observed at the West Taing site during the shoreline survey, which indicated that there was a source of freshwater nearby.

Hydrography and movement of contaminants

The voe is relatively deep, which should allow for significant dilution of contaminants. There is relatively little in the way of tidal flushing of the voe, so contaminants entering the inner voe would be likely to persist until diluted by wind-driven mixing. As prevailing winds recorded at Lerwick are from the south and west, and the voe has a southwest – northeast aspect, prevailing winds may drive contaminants from the head of the voe northeastward toward the mussel farms. This would be most likely to affect the site at Scarvar Ayre 1. At the other sites, streams discharging near to the mussel lines, and direct deposition of faeces on the shoreline by livestock, are likely to be more important sources of faecal contamination to the shellfish. However, analysis of historical *E. coli* data showed a significant association of higher results with the flooding tide. This would indicate a source towards the mouth of the voe from the fishery.

Temporal and geographical patterns of sampling results

Over the monitoring history examined at the classified production area, there appeared to be a general trend toward improvement in peak results. However, subsequent analysis of bacteriological survey results from all sites for 2010 showed a substantial peak in results occurred during August at the classified production area and in June at the sites in the outer voe. Comparison of results for all sites over 2010 suggested that the Scarvar Ayre 1, Scarvar Ayre 2, and Southside sites may be subject to different sources of contamination than the West Taing and West of Scarvar Ayre sites. Peak results were also highest at the inner three sites, with the highest result to date, 16000 *E. coli* MPN/100 g, occurring at the Scarvar Ayre 2 site.

Conclusions

Dales Voe has little in the way of human sewage input, with the most likely primary source of faecal contamination being livestock present along the sides of the voe. The main route of contamination is likely to be via streams and land runoff. Monitoring results show a that higher results are generally seen in summer and autumn, with peak results falling in July and August.

The main sources of contamination appear to be concentrated at the head of the voe, as indicated by calculated *E. coli* loadings in the streams there. However, under most conditions these sources are less likely to affect the nearest mussel farm, which lies approximately 1 km away. Monitoring results at the site nearest the head of the voe, Scarvar Ayre 1, indicate that results are affected by a source to the east of the mussel farm. The nearest watercourse to the site lies less than 200 m to the northeast of the eastern end of the mussel lines, and though the loading calculated for this stream was less than that of the streams at the head of the voe, it was still sufficiently high to constitute an important local source of contamination.

There is some evidence to suggest that there may be spatial variation between sites in the inner and outer voe, possibly due to differences in local contaminating sources.

17. Recommendations

Production area

Due to differences observed in both timing and extent of peak results in 2010, it is recommended that existing Dales Voe: Scarvar Ayre production area be extended to encompass the Scarvar Ayre 1, Scarvar Ayre 2 and Southside sites and that a separate production area be established for the West of Fora Ness and West Taing sites.

Dales Voe: Scarvar Ayre
It is recommended that the Dales Voe: Scarvar Ayre production area be defined as the area bounded by lines drawn between HU 4175 6978 to HU 4210 6949 and between HU 4342 7038 to HU 4300 7094 extending to MHWS. Boundaries are extended to cover the full extent of the seabed lease area underlying the Scarvar Ayre 1 site, but still avoid the area at the head of the voe where contamination levels may be higher.

Dales Voe: Fora Ness
The recommended boundaries for the production area at Dales Voe: West of Fora Ness are described by the area bounded by lines drawn between HU 4331 7114 to HU 4395 7072 and between HU 4448 7095 to HU 4464 7141 and between HU 4448 7173 to HU 4414 7201 extending to MHWS. Boundaries are drawn to encompass both sites, but exclude the area nearest the South Ayre of Fora Ness, where there may be higher contamination levels due to the presence of livestock on the shore. A buffer area was left between the two production areas so that they are clearly delineated.

RMP

Dales Voe: Scarvar Ayre
As monitoring results have indicated that results were significantly affected by a source or sources east of the Scarvar Ayre 1 site, it is felt that the current monitoring point (in use since 2007) is sufficiently representative for this area. However, the RMP should be restated in FSAS records to reflect the actual sampling location of HU 4223 6992. The recommended tolerance is 20 m to allow for movement of the lines.

Dales Voe: Fora Ness
The limited monitoring history available on these two sites does not clearly suggest higher contamination levels at one over another. However, the West of Fora Ness site does lie closer to identified sources of faecal contamination, therefore it is recommended that the RMP be placed on this site at HU 4405 7171. This is located toward the west end of the mussel lines, nearer to several streams identified just west of the mussel farm. The recommended tolerance is 20 m to allow for movement of the lines.

Frequency

Due to the seasonal variation in results observed, and the failure of the classified site to meet the stability criteria for reduced sampling frequency, it is recommended that monthly monitoring be continued at both production areas.

Depth of sampling

Due to the water depth and likely sources of contamination being carried in surface water, it is recommended that samples be taken from a depth of 1 meter at both production areas.

A map identifying the location of the recommended production area boundaries and RMPs is provided in Figure 17.1 overleaf.

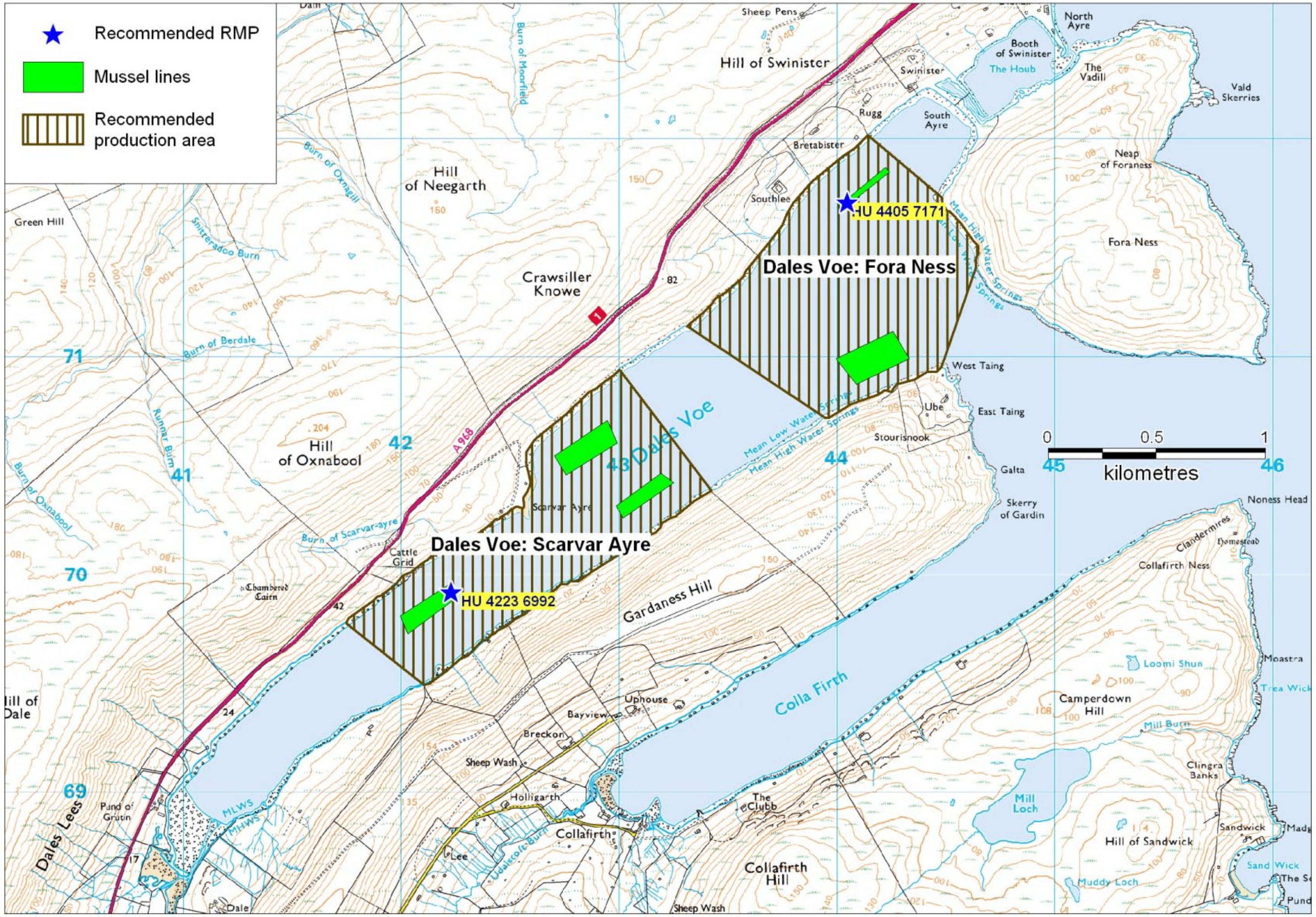

Figure 17.1 Map of recommendations at Dales Voe: Scarvar Ayre and Fora Ness

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Sampling Plan for Dales Voe: Scarvar Ayre and Fora Ness

PRODUCTION AREA	Dales Voe: Scarvar Ayre	Dales Voe: Fora Ness
SITE NAME	Scarvar Ayre 1	West of Fora Ness
SIN	SI 050 420 08	SI 503 870 08
SPECIES	Common mussel	Common mussel
TYPE OF FISHERY	Aquaculture, longline	Aquaculture, longline
NGR OF RMP	HU 4223 6992	HU 4405 7171
EAST	442230	444050
NORTH	1169920	1171710
TOLERANCE (M)	20	20
DEPTH (M)	1	1
METHOD OF SAMPLING	Hand	Hand
FREQUENCY OF SAMPLING	Monthly	Monthly
LOCAL AUTHORITY	Shetland Island Council	Shetland Island Council
AUTHORISED SAMPLER(S)	Sean Williamson George Williamson Kathryn Winter Marion Slater	Sean Williamson George Williamson Kathryn Winter Marion Slater
LOCAL AUTHORITY LIAISON OFFICER	Dawn Manson	Dawn Manson

Table of Proposed Boundaries and RMPs

PRODUCTION AREA	Dales Voe: Scarvar Ayre	Dales Voe: Fora Ness
SPECIES	Common mussels	Common mussels
SIN	SI 050 420 08	SI 503 870 08
EXISTING BOUNDARY	Area bounded by lines drawn between HU 4256 7030 and HU 4280 7000 and HU 4190 6990 and HU 4216 6953	Not yet defined
EXISTING RMP	HU 4223 6992	Not yet defined
RECOMMENDED BOUNDARY	Area bounded by lines drawn between HU 4175 6978 to HU 4210 6949 and between HU 4342 7038 to HU 4300 7094 extending to MHWS	Area bounded by lines drawn between HU 4331 7114 to HU 4395 7072 and between HU 4448 7095 to HU 4464 7141 and between HU 4448 7173 to HU 4414 7201 extending to MHWS
RECOMMENDED RMP	HU 4223 6992	HU 4405 7171
COMMENTS	Production area extended to cover seabed lease at Scarvar Ayre 1 and two new sites at Scarvar Ayre 2 and Southside. RMP retained at Scarvar Ayre 1.	New production area to encompass West of Fora Ness and West Taing sites, RMP established at West of Fora Ness.

Geology and Soils Assessment

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

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

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

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

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

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

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

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

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

Glossary of Soil Terminology

Calcareous: Containing free calcium carbonate.

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

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

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

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

General Information on Wildlife Impacts

Pinnipeds

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

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

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

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

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

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

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

Cetaceans

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

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

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

Birds

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

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

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

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

Deer

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

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

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

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

Other

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

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

References:

Alderisio, K.A. and N. DeLuca (1999). Seasonal enumeration of fecal coliform bacteria from the feces of Ring-billed gulls (*Larus delawarensis*) and Canada geese (*Branta canadensis*). *Applied and Environmental Microbiology*, 65:5628-5630.

Bedard, J. and Gauthier, G. (1986) Assessment of faecal output in geese. *Journal of Applied Ecology*, 23:77-90.

Lisle, J.T., Smith, J.J., Edwards, D.D., andd McFeters, G.A. (2004). Occurrence of microbial indicators and *Clostridium perfringens* in wastewater, water column samples, sediments, drinking water and Weddell Seal feces collected at McMurdo Station, Antarctica. *Applied and Environmental Microbiology*, 70:7269-7276.

Scottish Natural Heritage. http://www.snh.org.uk/publications/on-line/wildlife/otters/biology.asp. Accessed October 2007.

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 T-test comparison of results by sampling location

```
Two-sample T for Log E coli

GridRef    N   Mean  StDev  SE Mean
HU422699  24  1.470  0.558     0.11
HU423700  60  1.620  0.592    0.076

Difference = mu (HU422699) - mu (HU423700)
Estimate for difference:  -0.150
95% CI for difference:  (-0.426, 0.127)
T-Test of difference = 0 (vs not =): T-Value = -1.09  P-Value = 0.281  DF =
44
```

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

```
Source  DF      SS     MS     F      P
Season   3   3.890  1.297  4.27  0.007
Error   81  24.577  0.303
Total   84  28.467

S = 0.5508   R-Sq = 13.66%   R-Sq(adj) = 10.47%

                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  -----+---------+---------+---------+----
1      25  1.3510  0.4801  (--------*--------)
2      20  1.8253  0.7487                   (---------*---------)
3      18  1.8093  0.3890                  (---------*----------)
4      22  1.4403  0.5265     (---------*--------)
                           -----+---------+---------+---------+----
                              1.25      1.50      1.75      2.00

Pooled StDev = 0.5508

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

Individual confidence level = 98.96%

Season = 1 subtracted from:

Season    Lower  Center   Upper  -------+---------+---------+---------+--
2        0.0408  0.4743  0.9078                  (-------*--------)
3        0.0116  0.4583  0.9050                 (--------*--------)
4       -0.3332  0.0893  0.5117          (--------*-------)
                                 -------+---------+---------+---------+--
                                     -0.50      0.00      0.50      1.00
Season = 2 subtracted from:

Season    Lower   Center   Upper  -------+---------+---------+---------+--
3       -0.4855  -0.0160  0.4535         (---------*--------)
4       -0.8315  -0.3850  0.0614  (--------*--------)
                                  -------+---------+---------+---------+--
                                      -0.50      0.00      0.50      1.00

Season = 3 subtracted from:

Season    Lower   Center   Upper  -------+---------+---------+---------+--
4       -0.8283  -0.3690  0.0903  (---------*--------)
                                  -------+---------+---------+---------+--
                                      -0.50      0.00      0.50      1.00
```

Section 11.6.1 Spearman's rank correlation for *E. coli* result and 2 day rainfall

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.187
```
n=72, p>0.05

Section 11.6.1 Spearman's rank correlation for *E. coli* result and 7 day rainfall

```
Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.153
```
n=72, p>0.10

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 21 May 2010
10:58:54

Variables (& observations)	r	p
Angles & Linear (85)	0.094	0.486

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

CIRCULAR-LINEAR CORRELATION
Analysis begun: 10 June 2010 14:42:21

Variables (& observations)	r	p
Angles & Linear (69)	0.24	0.022

Section 11.6.3 Spearman's rank correlation for *E. coli* result and water temperature

```
Pearson correlation of ranked temperature and ranked E coli for temperature
= 0.170
```
n=23, p>0.10

Section 11.6.5 Spearman's rank correlation for *E. coli* result and salinity

```
Pearson correlation of ranked salinity and ranked e coli for salinity = -
0.078
```
n=73, p>0.10

Hydrographic Methods

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

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

Background processes

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

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

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

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

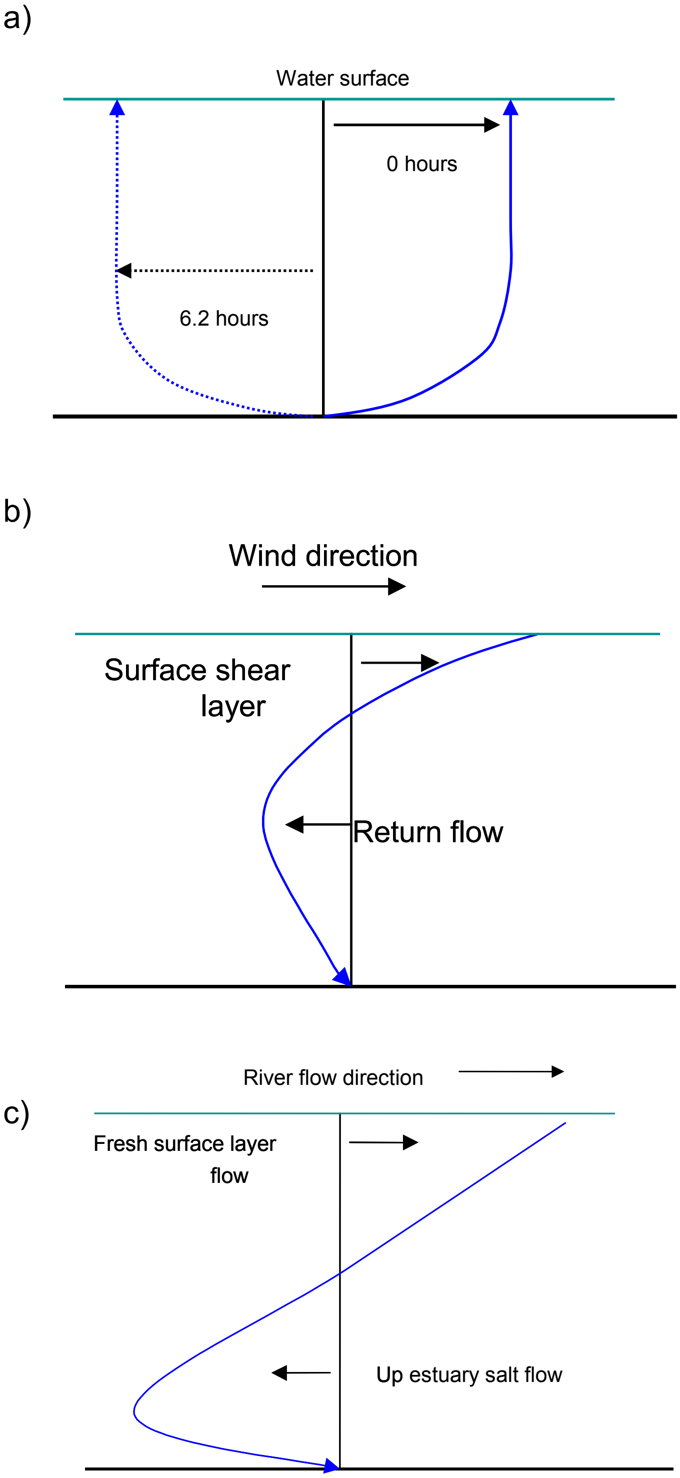


Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

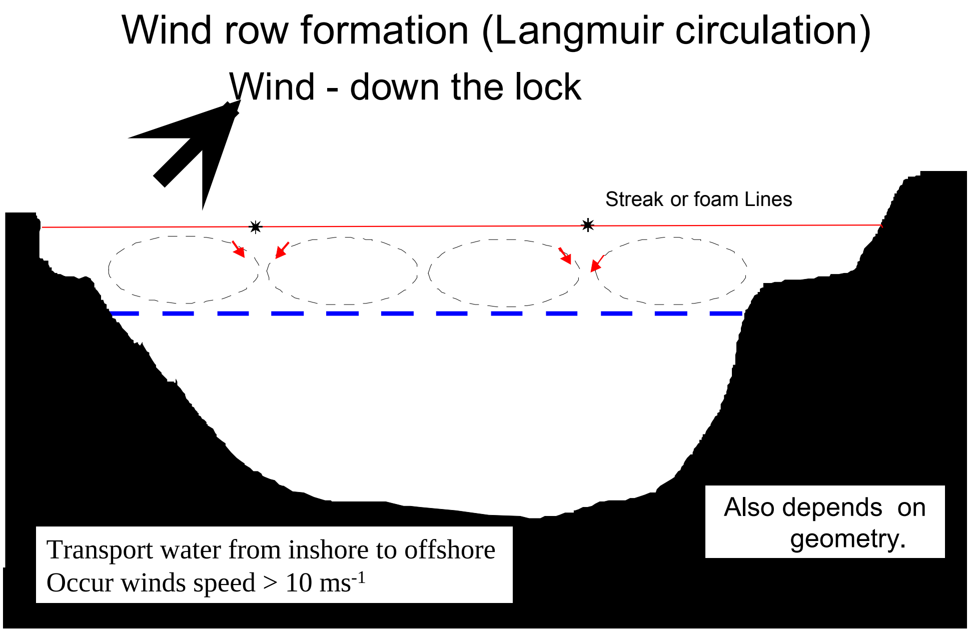


Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Non-modelling Assessment

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

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

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

The catalogue of Scottish Sea Loch produced by the SMBA is used to quantify sills, volume fluxes and likely flow velocities. Because the flow is so constrained by the rapidly varying bathymetry, care has to be used in the extrapolation of direct measurements of current flow. Mean flow velocities can be estimated at the sills by using estimates of the sill area and the volume change through a tidal cycle. This in turn can be used to estimate the maximum distance travelled in a tidal cycle in the sill area. Away from the sill area, tidal velocities are general low and transport events are dominated by wind or density effects. Sea Lochs generally have a surface layer of fresher water; the extent of this depends on freshwater input, sill depth and quantity of mixing.

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

References

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

Glossary

The following technical terms may appear in the hydrographic assessment.

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

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

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

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

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

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

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

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

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

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

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

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

Shoreline Survey Report

Production Areas:

Production Area	Site	SIN	Species
Dales Voe	South Side	SI 501 868 08	Mussels
Dales Voe	West Taing	SI 502 869 08	Mussels
Dales Voe	West of Fora Ness	SI 503 870 08	Mussels
Dales Voe	Scarvar Ayre 2	SI 504 871 08	Mussels
Dales Voe	Scarvar Ayre	SI 050 420 08	Mussels

Harvester: Derek Hunter (Hunter Shellfish)
Status: New application
Date Surveyed: 22/06/2010 & 23/06/2010
Surveyed by: Sean Williamson, Jessica Larkham, Frances Hockley
Area Surveyed: See Figure 1.

Monitoring Points:

Site	Nominal RMP	Sampling Point
Dales Voe: South Side		HU 430 702
Dales Voe: West Taing		HU 439 709
Dales Voe: West of Fora Ness		HU 442 718
Dales Voe: Scarvar Ayre 2		HU 428 706
Dales Voe: Scarvar Ayre	HU 423 700	

Weather

22/06/10 Some clouds, otherwise sunny, slight breeze, light rain in the afternoon
23/06/10 Overcast, slight breeze

The weather had been cold and windy (with some light scattered showers on Sunday) in the week preceding the survey.

Specific observations made on site are mapped in Figure 1 and listed in Table 1. Water and shellfish samples were collected at sites marked on Figures 2 and 3. Bacteriology results are given in Tables 2 and 3. Salinity profiles are presented in Table 4. Photographs are presented in Figures 4-20.

Fishery

Dales Voe: South Side (SI 501 868 08). This site consisted of four rows of double long lines, with 8 m droppers. The two lines closest to the shoreline are new and have only been put in place during the last month. Droppers were being installed on these two lines at the time of the shoreline survey. The two remaining lines were installed in 2008 and the harvester intends to commence harvesting this year. This site is within a Crown Estate (CE) lease area.

Dales Voe: West Taing (SI 502 869 08). This site consisted of five rows of double long lines, with 8 m droppers. The second line in from the shore is new and was put in place this year. The remaining lines have been in place since 2009 and the harvester wishes to commence harvesting early 2012. This site is within a CE lease area.

Dales Voe: West of Fora Ness (SI 503 870 08). This site consisted of two rows of double long lines, with 8 m droppers. The lines were installed in 2008 and the harvester plans to commence harvesting early 2011. This site is within a CE lease area.

Dales Voe: Scarvar Ayre 2 (SI 504 871 08). This site consisted of four rows of double long lines, with 8 m droppers. The lines were installed in 2009 and the harvester plans to commence harvesting early 2012. This site is within a CE lease area.

Dales Voe: Scarvar Ayre (SI 050 420 08). This site is currently classified as a class A for common mussels. The production area is defined as an area bounded by lines drawn between HU 4256 7030 and HU 4280 7000 and HU 4190 6990 and HU 4216 6953. This site is within a CE lease area.

Sewage/Faecal Sources

Human – There are no large settlements in the area surrounding Dales Voe. There are nine occupied houses spread out at the head of the voe. There is also a small farm with outbuildings close to the head of the voe. There are no dwellings on either side of the voe. There is a pier, with two outbuildings belonging to Hunter Shellfish half way down the voe. No septic tanks or sanitary debris were observed during the shoreline survey. An outfall pipe was observed running down from a house next to the farm.

Livestock – The land surrounding Dales Voe was mainly rough grassland, with some areas of improved pastures. At the head of the voe is an area of intertidal mud and sand and a small area of reed bed. Sheep and lambs were grazing along most of the shoreline surveyed. In most places livestock did have access to the shoreline and fresh water streams. Sheep and their droppings were often observed on the beach, especially at the South Ayre tombolo at the end of Dales Voe, where approximately 30 sheep and lambs were observed. At the end of the voe on the hills above The Houb next to the road approximately 200 more sheep were observed grazing in fields. An additional 12 sheep were observed on the connected island of Fora Ness and a further 104 were observed on the Hill of Swinister. Further towards the head of the voe at the bottom of the Hill of Oxnabool, another 36 sheep were observed. In addition to the flocks of sheep stated, scattered pairs of sheep were also observed. At the head of Dales Voe, on the side of Easter Hill a further 20 cattle were observed grazing in a fenced off field adjacent to the shoreline.

Several streams, which drain the improved pasture and grassland, were recorded discharging into Dales Voe. The largest input of freshwater to the voe was the Burn of Sandgarth, which discharges into the head of the voe. A fresh water sample was taken from the burn and returned a high result of $1.3x10^3$ *E. coli* cfu/100 ml. Another significant fresh water input to the voe, was a stream that ran alongside the farm. A freshwater sample taken from this stream returned the highest result of $6.6x10^3$ *E. coli* cfu/100 ml. A further nine burns and streams were observed discharging into the surveyed side the voe. These were also measured and sampled. There were also a lot of field drains leading from the fields into Dales Voe, these were recorded but not sampled or measured. It is likely that land runoff is an important pathway for moving contamination from livestock into Dales Voe. The OS map indicates additional streams on the other side of the voe but these were not accessible during the shoreline survey due to the steep terrain.

E. coli levels in sea water samples taken offshore in the vicinity of the mussel lines were low (<1 *E. coli* cfu/100ml in all cases). No additional sea water samples were taken from the shore.

The five common mussel samples taken from sampling baskets or straight from the long lines, where available, all gave *E. coli* results of <20 MPN/100 g. Salinity measurements taken during the survey indicated that there was little freshwater influence on the water body at the time, with salinities all around that of full strength seawater with very little or no stratification.

Seasonal Population

There are no hotels or B&BS in the area however the whole of Shetland is a popular tourist destination. The main attractions are wildlife watching and outdoor pursuits. Therefore the population is likely to be slightly higher during the summer months.

Boats/Shipping

Boat traffic in Dales Voe is very light and limited to small fishing boats, mussel and salmon boats and possibly small pleasure boats and yachts. During the shoreline survey a mussel boat was present placing droppers onto some of the new long lines. There is a small pier half way down the voe, which is used by the Hunter Shellfish mussel boat.

Land Use

The land surrounding Dales Voe was mainly rough grassland, with some areas of improved pastures. At the head of the voe is an area of intertidal mud and sand and a small area of reed bed.

Wildlife/Birds

Dales Voe is a designated SSSI salt marsh habitat and is an important breeding area for the nesting wing plover and the Arctic Tern. During the shoreline survey, approximately 50 Arctic Terns and 20 gulls were present in the area.

Individual gulls, eider ducks and black guillemots were also observed during the survey. Rabbits were observed along the shoreline. Seals are reported to frequent the area, three were observed during the course of the survey.

General

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 sound.

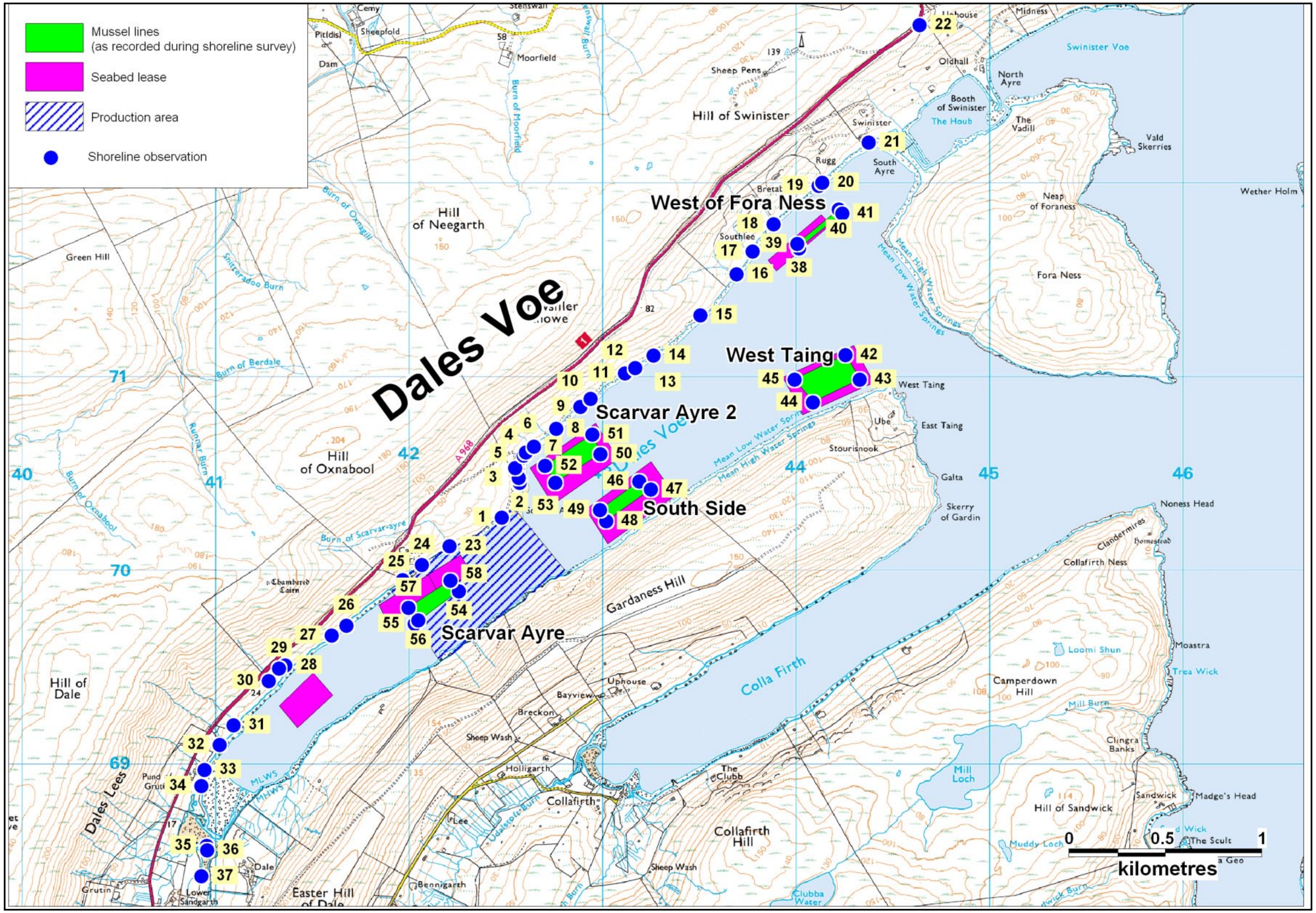


Figure 1. Shoreline Observations at Dales Voe

Table 1. Shoreline observations

No.	Date	Time	Position	Photograph	Associated sample	Observation
1	22/06/2010	09:01	HU 42480 70277	Figures 4 & 5		Pier, Hunter Shellfish workshop. New lines, ready to be laid out.
2	22/06/2010	09:06	HU 42571 70456			Field burn
3	22/06/2010	09:07	HU 42567 70482			Field burn
4	22/06/2010	09:08	HU 42548 70532	Figure 6		Pipe running under road
5	22/06/2010	09:11	HU 42592 70597			Field burn, oil on shoreline
6	22/06/2010	09:13	HU 42604 70613		Dales Voe FW1	Stream, Dales Voe FW1, W 0.04, D 0.02, Flow 0.703
7	22/06/2010	09:20	HU 42645 70644	Figure 7	Dales Voe FW2	Stream, Dales Voe FW2, W 0.25, D 0.02, Flow 0.254. Slight sewage smell, orange fungus.
8	22/06/2010	09:26	HU 42760 70735			7 eider ducks
9	22/06/2010	09:32	HU 42885 70850			Small burn, green algae
10	22/06/2010	09:35	HU 42938 70891			Sheep droppings on the shoreline
11	22/06/2010	09:44	HU 43115 71021	Figure 8		Sheep & young lamb on beach
12	22/06/2010	09:48	HU 43169 71049			3 sheep on the shoreline. Burn, green algae on the beach.
13	22/06/2010	09:48	HU 43169 71050			Small burn, green algae
14	22/06/2010	09:52	HU 43264 71114			Small burn, green algae. 3 gulls nesting.
15	22/06/2010	10:02	HU 43507 71321	Figure 9		1 seal
16	22/06/2010	10:10	HU 43694 71535	Figure 10	Dales Voe FW3	Burn, Dales Voe FW 3, W 0.10, D 0.05, Flow 0.085.
17	22/06/2010	10:17	HU 43776 71653			4 sheep
18	22/06/2010	10:21	HU 43884 71793		Dales Voe FW4	Dead sheep. Burn, Dales Voe FW 4, W 0.15, D 0.07, Flow 0.150. Approximately 100 sheep on hill above shoreline. 2 seals.
19	22/06/2010	10:33	HU 44117 71992			2 rabbits, field drain
20	22/06/2010	10:34	HU 44137 72008	Figure 11		End of Dales Voe. Approximately, 30 sheep on connecting beach. Derelict croft building. Small burn.
21	22/06/2010	10:45	HU 44376 72216		Dales Voe FW5	Stream, Dales Voe FW5, W 0.02, Jug flow 350 ml/ 20 seconds.
22	22/06/2010	11:08	HU 44639 72822	Figure 12		Approximately 200 sheep in field at the top of the hill, next to the road.
23	22/06/2010	15:25	HU 42210 70129		Dales Voe FW6	Stream, Dales Voe FW6, W 0.65, D 0.10, Flow 0.100
24	22/06/2010	15:32	HU 42067 70032			Sheep droppings. Approximately 20 sheep.
25	22/06/2010	15:36	HU 41967 69953			Burn, green algae on shoreline.
26	22/06/2010	15:44	HU 41677 69718			Burn.
27	22/06/2010	15:47	HU 41600 69668			8 sheep
28	22/06/2010	15:52	HU 41359 69513			8 sheep
29	22/06/2010	15:53	HU 41328 69496			Field burn

No.	Date	Time	Position	Photograph	Associated sample	Observation
30	22/06/2010	15:55	HU 41275 69432		Dales Voe FW7	Stream, Dales Voe FW7, W 0.06, D 0.18, Flow 0.137
31	22/06/2010	16:04	HU 41091 69204		Dales Voe FW8	Stream, Dales Voe FW8, W 0.24, D 0.10, Flow 0.513
32	22/06/2010	16:09	HU 41020 69101		Dales Voe FW9	Stream, Dales Voe FW9, W 0.15, D 0.15, Flow 0.224
33	22/06/2010	16:15	HU 40941 68973	Figure 13	Dales Voe FW10	Farm, approximately 100 sheep. Stream flowing onto shoreline next to the farm. Dales Voe FW 10, W 0.60, D 0.05, Flow 0.155
34	22/06/2010	16:22	HU 40925 68889	Figure 14	Dales Voe FW11	Pipe, small flow. House behind pipe. Dales Voe FW 11, Jug flow, 1 3/4 pints/ 30 seconds. Approximately 50 Arctic Terns & 30 gulls
35	22/06/2010	16:28	HU 40954 68581	Figure 15	Dales Voe FW12	Stream, Dales Voe FW12, W 2.00, D 0.08, Flow 0.241
36	22/06/2010	16:32	HU 40957 68557			Approx. 20 cattle on opposite shoreline.
37	22/06/2010	16:35	HU 40927 68423			Burn, orange fungi.
38	23/06/2010	11:44	HU 44016 71668		Dales Voe Mussel 1, Dales Voe SW1	End of West of Fora Ness mussel lines. Dales Voe Mussel 1 (from sampling basket), Dales Voe SW1. Salinity profile, <1m 37.23/11.1'C, 3m 37.22/10.9'C, 5m 37.23/10.5'C, 10m 37.24/10.4'C. Approx 20 gulls on mussel buoys.
39	23/06/2010	11:50	HU 44007 71691			Corner of West of Fora Ness mussel lines
40	23/06/2010	11:52	HU 44221 71868		Dales Voe SW2	Corner of West of Fora Ness mussel lines, Dales Voe SW2
41	23/06/2010	11:54	HU 44239 71848			Corner of West of Fora Ness mussel lines, 8 black guillemots
42	23/06/2010	11:59	HU 44257 71116			Corner of West Taing mussel lines, 12 sheep on adjacent shoreline
43	23/06/2010	12:01	HU 44331 70990	Figures 16 & 17	Dales Voe SW3, Dales Voe Mussel 2	Corner of West Taing mussel lines, Dales Voe SW3, Dales Voe Mussel 2. Salinity profile <1m 35.15/10.7'C, 3m 36.94/10.4'C, 5m 37.01/10.3'C, 10m 37.09/10.2'C. 5 gulls on mussel buoys.
44	23/06/2010	12:08	HU 44088 70873		Dales Voe SW4	Corner of West Taing mussel lines, Dales Voe SW4. Second line in from shoreline is brand new.
45	23/06/2010	12:10	HU 43994 70990			Corner of West Taing mussel lines.
46	23/06/2010	12:16	HU 43191 70464	Figures 18 & 19	Dales Voe SW5	Corner of South Side mussel lines, Dales Voe SW5. Two lines closest to shore are brand new.
47	23/06/2010	12:18	HU 43251 70422			Corner of South Side mussel lines. Four lines in total, older two lines installed in 2008.
48	23/06/2010	12:21	HU 43019 70258			Corner of South Side mussel lines.
49	23/06/2010	12:22	HU 42987 70316		Dales Voe SW6, Dales Voe Mussel 3	Corner of South Side mussel lines, Dales Voe SW6, Dales Voe Mussel 3 (from sampling basket). Salinity profile, <1m 37.26/10.5'C, 3m 37.25/10.2'C, 5m 37.28/10.2'C, 10m 37.29/9.9'C
50	23/06/2010	12:29	HU 42990 70604		Dales Voe SW7, Dales Voe	Corner of Scarvar Ayre 2 mussel lines, Dales Voe SW7, Dales Voe Mussel 4. Salinity profile <1m 37.27/10.6'C, 3m 37.29/10.3'C, 5m

No.	Date	Time	Position	Photograph	Associated sample	Observation
					Mussel 4	37.26/10.2'C, 10m 37.27/9.9'C. Total of four double lines
51	23/06/2010	12:35	HU 42947 70707	Figure 20		Corner of Scarvar Ayre 2 mussel lines
52	23/06/2010	12:37	HU 42702 70545		Dales Voe SW8	Corner of Scarvar Ayre 2 mussel lines, Dales Voe SW8
53	23/06/2010	12:39	HU 42756 70457			Corner of Scarvar Ayre 2 mussel lines
54	23/06/2010	12:43	HU 42258 69896			Corner of Scarvar Ayre mussel lines. Four double long lines in total, two middle lines are brand new.
55	23/06/2010	12:46	HU 42030 69728			Corner of Scarvar Ayre mussel lines
56	23/06/2010	12:47	HU 42048 69745		Dales Voe SW9	Dales Voe SW9
57	23/06/2010	12:49	HU 41996 69810		Dales Voe Mussel 5	Corner of Scarvar Ayre mussel lines. Salinity profile <1m 37.20/10.3, 3m 37.22/10.3, 37.23/10.1'C, 10m 37.21/9.9'C. Dales Voe mussel 5
58	23/06/2010	12:55	HU 42214 69951		Dales Voe SW10	Corner of Scarvar Ayre mussel lines. Dales Voe SW10.

Sampling

Water and shellfish samples were collected at sites marked on the maps in Figures 2 and 3 respectively. Bacteriology results follow in Tables 2 and 3.

Samples of seawater were tested for salinity by the laboratory using a salinity meter under controlled conditions. These results are shown in Table 2, given in units of grams salt per litre of water. Note that this is equivalent to ppt.

Table 2. Water sample *E. coli* results

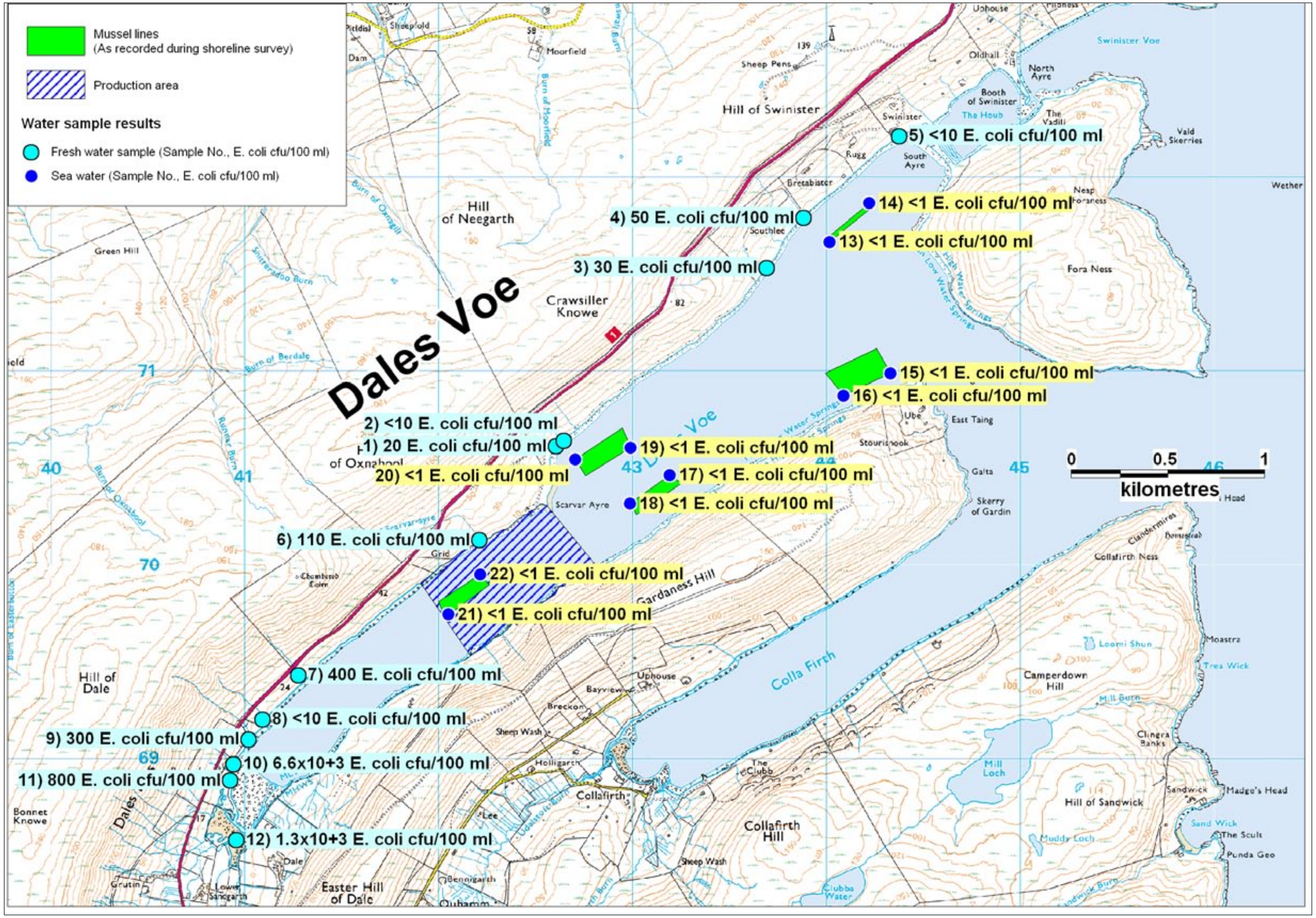
No.	Sample Ref.	Date	Position	Type	*E. coli* (cfu/100 ml)	Salinity (g/L)
1	Dales Voe FW1	22/06/2010	HU 4260 7061	Fresh water	20	NA
2	Dales Voe FW2	22/06/2010	HU 4265 7064	Fresh water	<10	NA
3	Dales Voe FW3	22/06/2010	HU 4369 7154	Fresh water	30	NA
4	Dales Voe FW4	22/06/2010	HU 4388 7179	Fresh water	50	NA
5	Dales Voe FW5	22/06/2010	HU 4438 7222	Fresh water	<10	NA
6	Dales Voe FW6	22/06/2010	HU 4221 7013	Fresh water	110	NA
7	Dales Voe FW7	22/06/2010	HU 4128 6943	Fresh water	400	NA
8	Dales Voe FW8	22/06/2010	HU 4109 6920	Fresh water	<10	NA
9	Dales Voe FW9	22/06/2010	HU 4102 6910	Fresh water	300	NA
10	Dales Voe FW10	22/06/2010	HU 4094 6897	Fresh water	$6.6x10^3$	NA
11	Dales Voe FW11	22/06/2010	HU 4093 6889	Fresh water	800	NA
12	Dales Voe FW12	22/06/2010	HU 4095 6858	Fresh water	$1.3x10^3$	NA
13	Dales Voe SW1	23/06/2010	HU 4402 7167	Sea water	<1	35.4
14	Dales Voe SW2	23/06/2010	HU 4422 7187	Sea water	<1	35.4
15	Dales Voe SW3	23/06/2010	HU 4433 7099	Sea water	<1	35.4
16	Dales Voe SW4	23/06/2010	HU 4409 7087	Sea water	<1	35.4
17	Dales Voe SW5	23/06/2010	HU 4319 7046	Sea water	<1	35.4
18	Dales Voe SW6	23/06/2010	HU 4299 7032	Sea water	<1	35.4
19	Dales Voe SW7	23/06/2010	HU 4299 7060	Sea water	<1	35.4
20	Dales Voe SW8	23/06/2010	HU 4270 7055	Sea water	<1	35.4
21	Dales Voe SW9	23/06/2010	HU 4205 6975	Sea water	<1	35.4
22	Dales Voe SW10	23/06/2010	HU 4221 6995	Sea water	<1	35.4

Table 3. Shellfish sample *E. coli* results

No.	Sample Ref.	Date	Position	Site	Species	Depth	Result (*E. coli* MPN/100 g)
1	Dales Voe Mussel 1	23/06/2010	HU 44012 7167	West of Fora Ness	Mussels	Sampling basket (3 - 4 m)	<20
2	Dales Voe Mussel 2	23/06/2010	HU 4431 7099	West Taing	Mussels	Sampling basket (3 – 4m)	<20
3	Dales Voe Mussel 3	23/06/2010	HU 4299 7032	South Side	Mussels	Sampling basket (3 – 4m)	<20
4	Dales Voe Mussel 4	23/06/2010	HU 4299 7060	Scarvar Ayre 2	Mussels	Surface (<1m)	<20
5	Dales Voe Mussel 5	23/06/2010	HU 4200 6981	Scarvar Ayre	Mussels	Surface (<1 m)	<20

Table 4. Salinity profiles

Profile	Date	Time	Position	Depth (m)	Salinity (ppt)
1	23/06/2010	11:44	HU 4402 7167	<1	37.23
				3	37.22
				5	37.23
				10	37.24
2	23/06/2010	12:01	HU 4433 7099	<1	35.15
				3	36.94
				5	37.01
				10	37.09
3	23/06/2010	12:22	HU 4299 7032	<1	37.26
				3	37.25
				5	37.38
				10	37.29
4	23/06/2010	12:29	HU 4299 7060	<1	37.27
				3	37.29
				5	37.26
				10	37.27
5	23/06/2010	12:49	HU 4200 6981	<1	37.20
				3	37.22
				5	37.23
				10	37.21



Produced by Cefas Weymouth Laboratory.

Figure 2. Water sample results - Dales Voe

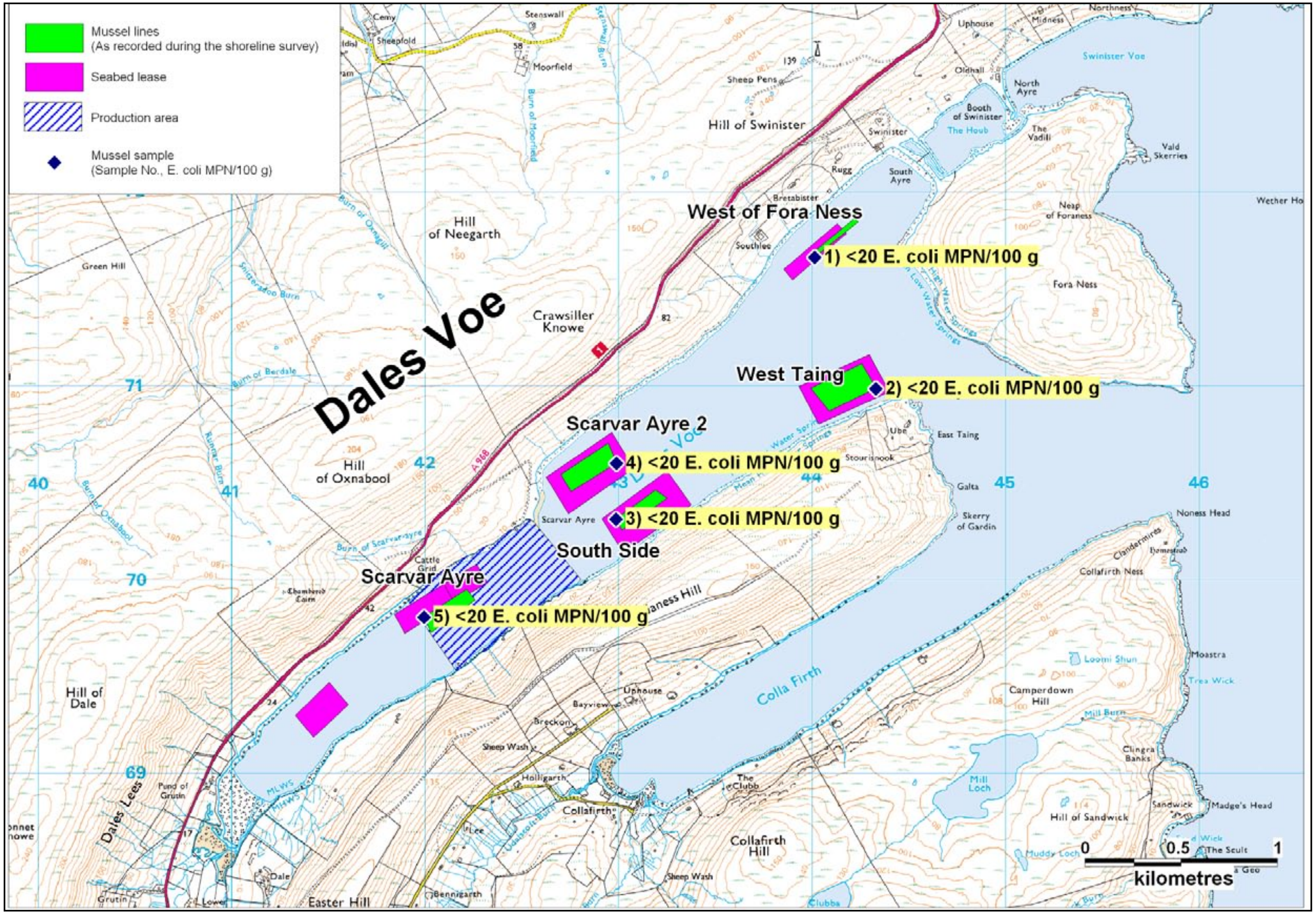


Figure 3. Shellfish sample results – Dales Voe

Photographs

Figure 4. Hunter Shellfish workshop and pier

Figure 5. New mussel lines ready to be laid out

Figure 6. Pipe running under road

Figure 7. Location of fresh water sample Dales Voe FW2

Figure 8. Sheep on beach

Figure 9. Seal

Figure 10. Location of fresh water sample Dales Voe FW3

Figure 11. Approximately 30 sheep on connecting beach

Figure 12. Approximately 200 sheep in field at the top of the hill, next to road

Figure 13. Stream next to farm. Location of fresh water sample Dales Voe FW 10

Figure 14. Pipe. Location of fresh water sample Dales Voe FW11

Figure 15. Location of fresh water Dales Voe FW12

Figure 16. West Taing mussel lines

Figure 17. West Taing mussel lines from adjacent hillside

Figure 18. South Side mussel lines

Figure 19. New droppers being installed on new South Side mussel lines

Figure 20. Scarvar Ayre mussel lines