Scottish Sanitary Survey Report

Sanitary Survey Report
Brindister Voe
SI 023
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Cefas

Food Standards Agency
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Report Distribution – Brindister Voe

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The hydrographic assessment and the shoreline survey and its associated report were undertaken by SSQC, Scalloway.

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I. Executive Summary

The sanitary survey at Brindister Voe was undertaken due to the risk ranking the area received amongst areas that had not yet been surveyed.

Brindister Voe is a narrow inlet on the western coast of Mainland Shetland opens to the Atlantic Ocean in the North and to the south meets the shallow, sheltered lagoons of The Vadills at Uni Firth.

Brindister Voe production area contains one long-line mussel farm. At the time of survey it consisted of three long-lines near to the east shore of the voe, one set on the north end of the seabed lease and two set on the southern end. To the north of the production area boundary, a farm consisting of 6 sets of long-lines is used for collection of spat. A small salmon and mussel shore base is located on the northwest shore of the voe.

Overall, the Brindister Voe production area is subject to relatively little faecal contamination. The main sources of contamination are varied diffuse sources along the western shoreline. Livestock, wildlife and a failing septic tank contribute to modest faecal contamination of watercourses discharging to the voe along much of the western shore and the head of the voe. A septic tank discharge from the shore base was the only direct discharge seen to the marine environment. There is a possibility of overboard discharges from boats, particular at the north end of the voe. A few watercourses also discharge to the east side of the voe. These drain steep, inaccessible terrain used for grazing sheep.

Contamination observed in mussels appears to be rainfall associated which is consistent with the observed diffuse, land-based sources. Due to its association with freshwater sources, it is anticipated that faecal contaminants may be more concentrated in lower salinity water at or near the surface.

Seasonal variation is seen in monitoring results, with lowest results are occurring from April to July. This corresponds with the trend in historical rainfall over the same period.

A significant correlation was found between historical monitoring results and rainfall, although this was driven by the number of very low results rather than by high results. Results exceeding 230 *E. coli* MPN/100 g occurred at low as well as high rainfall values, indicating that rainfall is a poor predictor of high results at this location.

Hydrographic analysis showed a consistent near surface flow from the head toward the mouth of the loch, which suggests that contamination carried into the loch via watercourses would move predominantly northward. Given this, it is likely that sources arising in the north of the voe from the shore station and adjacent burn would be taken out of the voe and therefore would be less likely to impact the mussel farm and spat farm to the south.

It is recommended that the production area boundaries be extended northward to cover the entire Brindister Voe waterbody and curtailed at the south end to exclude Uni Firth and the Vadills. The RMP should be relocated to a point on the southern end of the Brindister Voe site and bagged shellfish should be placed at that location to ensure consistency in sampling location.

Further details on the sampling plan and recommended boundaries can be found in tabular form overleaf and on page 78.

II. Sampling Plan and Recommended Production Area Boundaries

Production Area	Brindister Voe
Site Name	Brindister Voe
SIN	SI 023 406 08
Species	Common mussel
Type of Fishery	Long-line aquaculture
NGR of RMP	HU 2877 5649
East	428770
North	1156490
Tolerance (m)	40
Depth (M)	1
Method of sampling	Hand
Frequency of Sampling	Monthly
Local Authority	Shetland Islands
Authorised Sampler(s)	Sean Williamson Marion Slater Daniel Stone Vicki Smith
HMMH Liaison Officer	Sean Williamson
Production Area Boundaries	Area bounded by lines drawn between HU 2865 5630 and HU 2877 5640 and between HU 2827 5770 and HU 2858 5782 and extending to MHWS.

III. Report

1. General Description

Brindister Voe is an inlet on the western coast of Mainland Shetland. It is approximately 1.5 km long and 500 m wide. The voe opens to the Atlantic Ocean in the North and to the south meets The Vadills at Uni Firth.

The area around the Voe is very sparsely populated, with road access to the western shore only. A small number of farms and a shore base with pier are located along the road, and cattle grids are identified on the OS map.

The sanitary survey at Brindister Voe was undertaken due to the risk ranking the area received amongst areas that had not yet been surveyed. A map showing the location of the area is shown in Figure 1.1.

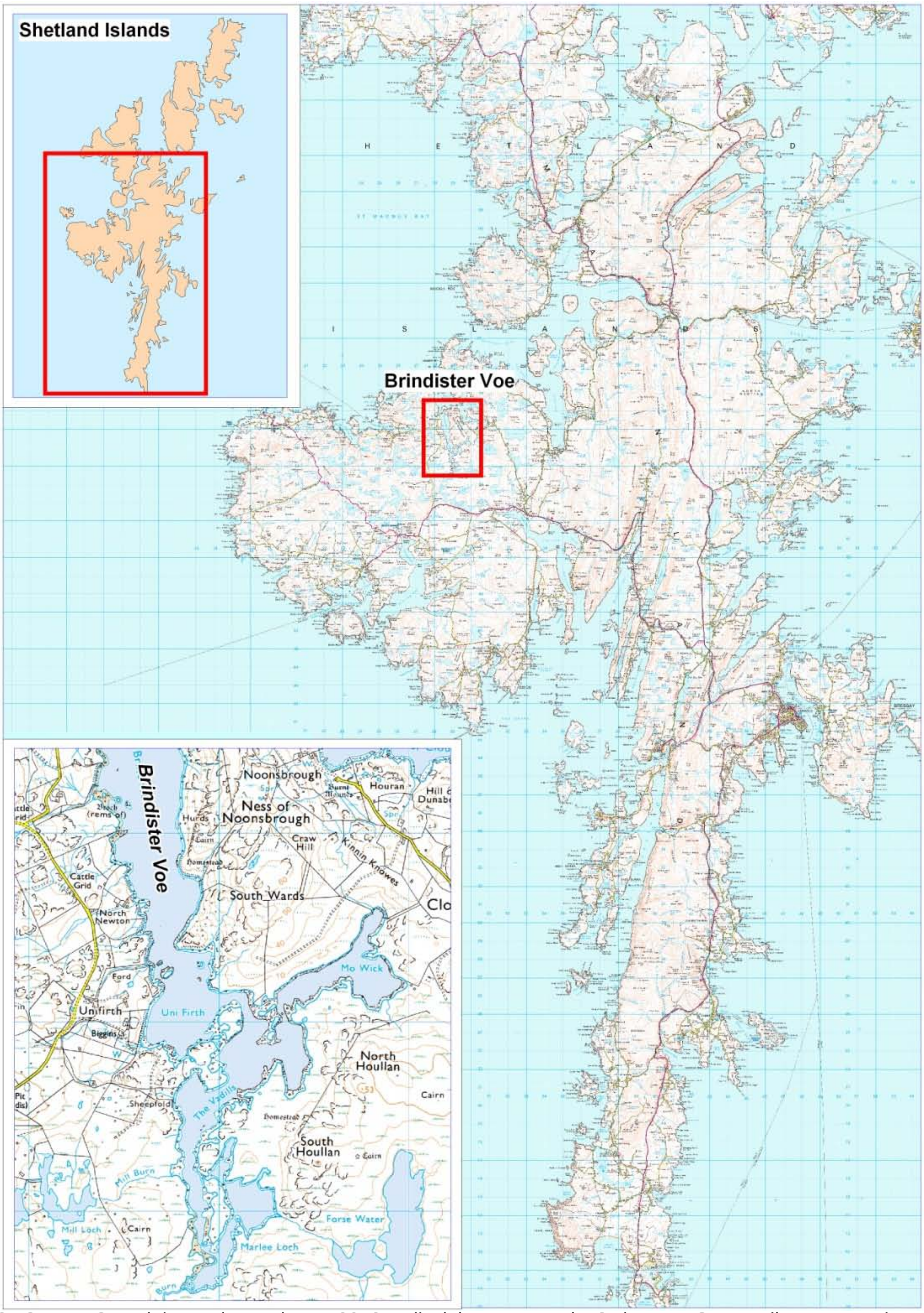


Figure 1.1 Location of survey area

2. Fishery

The currently classified fishery at Brindister Voe is comprised of a single mussel (*Mytilus edulis*) farm at site Brindister Voe (SIN SI-023-406-08) in two adjoining legs running parallel to the east shore of the voe. As the site and production area have the same name, the mussel farm itself will be referred to as Brindister Voe site.

At the time of the survey the target site consisted of three sets of double headed long lines: one on the northern leg and two on the southern leg. No stock was present as the site had been harvested off. The site typically has two lines per leg with 6m droppers, although the harvester has permission for up to four lines per leg.

A second mussel farm was identified near the northern mouth of the voe (currently no name or site identification number assigned) and it consisted of six double-headed long lines. Situated within the lease of a former salmon farm, this site falls outside the current production area. This site is reported to be used for spat collection only and at the time of survey the owner, Shetland Mussels, did not intend to apply for classification.

Boundaries for the current production area lie inshore of the following line: HU 2842 5714 to HU 2880 5714 extending to MHWS. The nominal representative monitoring point (RMP) is located at HU 2868 5705. This point lies north of the currently classified mussel farm.

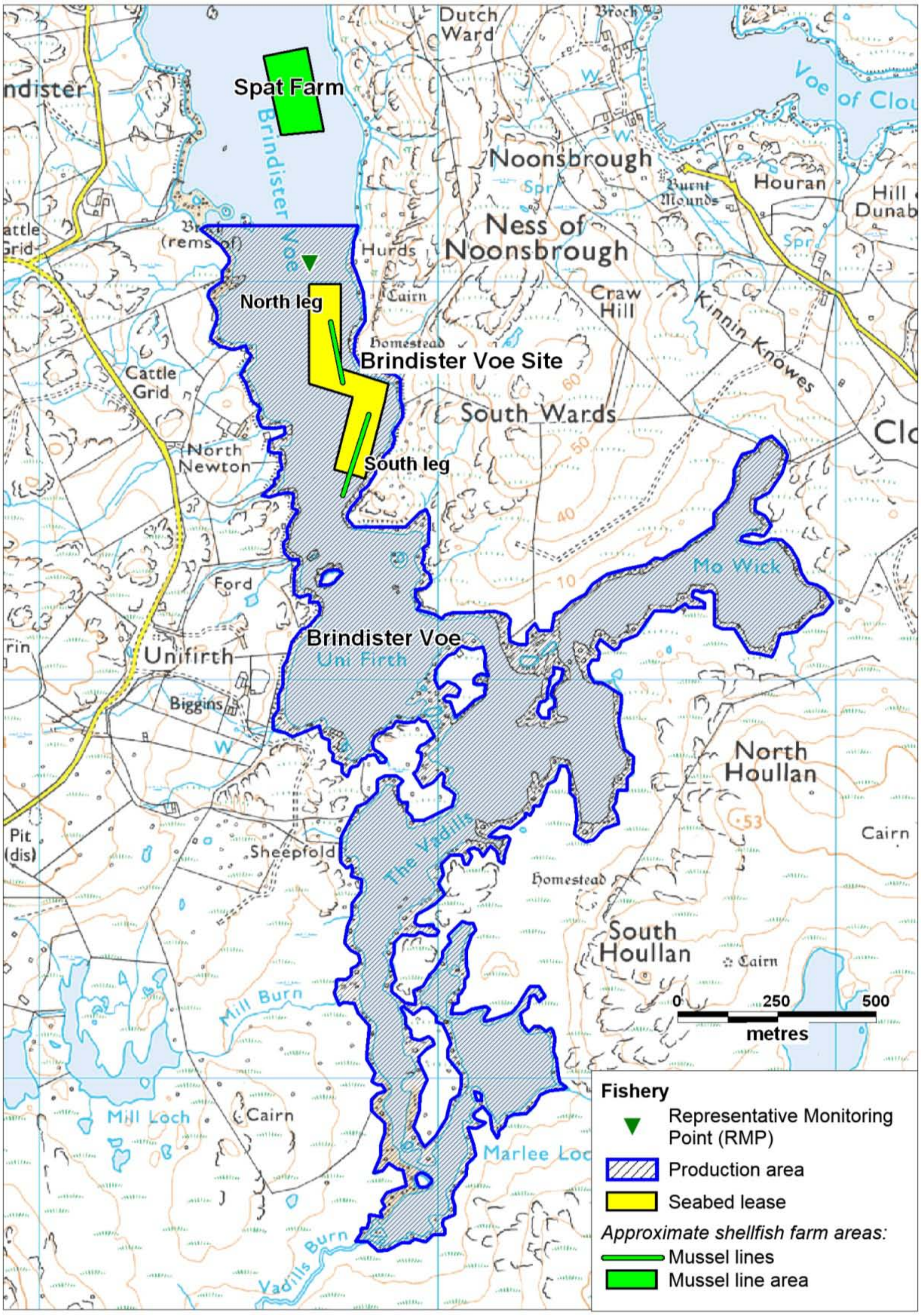


Figure 2.1 Brindister Voe Fishery

3. Human Population

Information was obtained from the General Register Office for Scotland on the population within the census output areas in the vicinity of Brindister Voe. The last census was undertaken in 2011. However, the 2011 census data was unavailable at the time of writing this report. Data presented below are from the 2001 census.

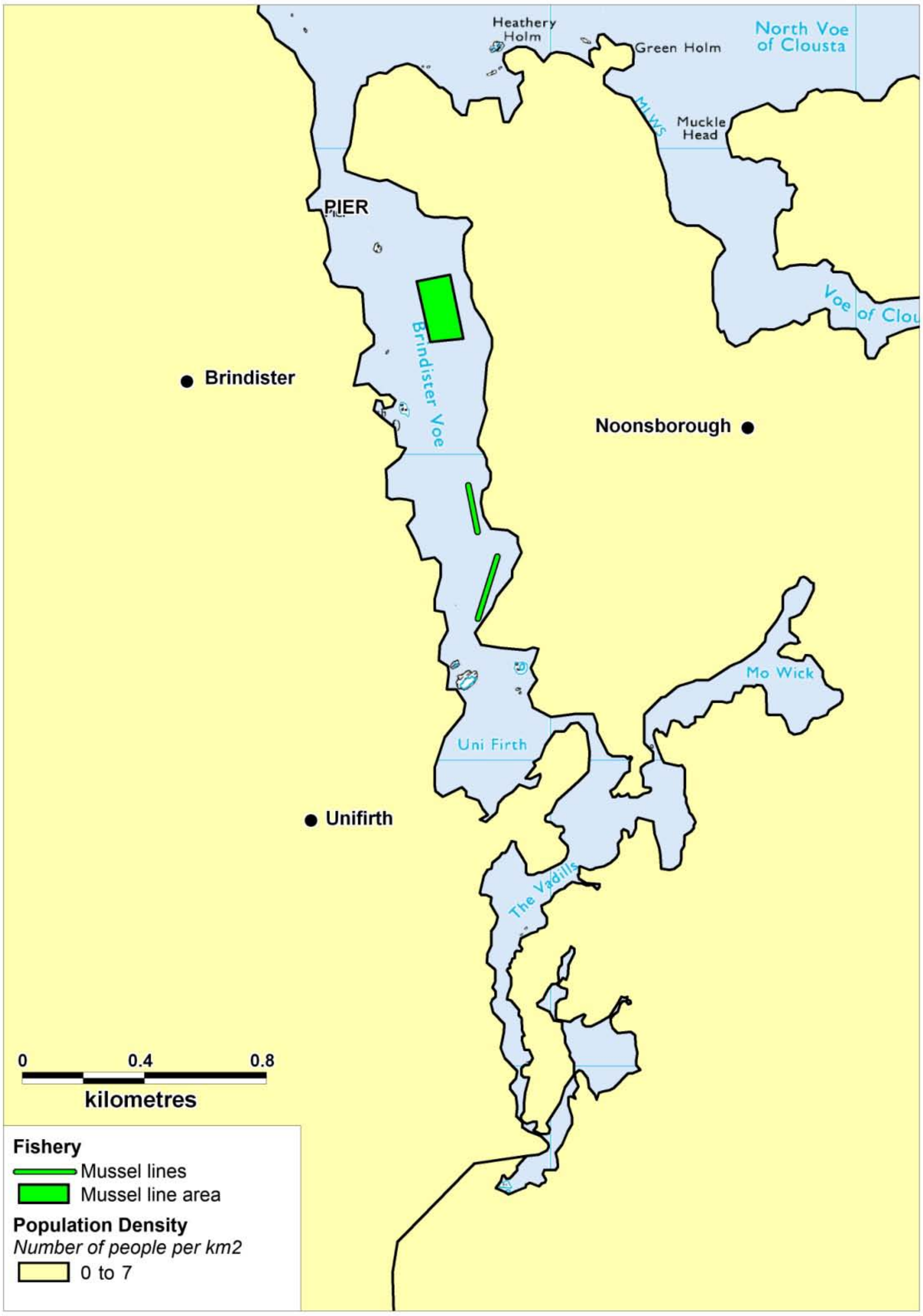


Figure 3.1 Population map of Brindister Voe

Figure 3.1 shows that population density is low for the census output areas representing Brindister Voe. The population surrounding Brindister Voe area is split between two census output areas, as listed in Table 3.1.

Table 3.1 Census output areas: Brindister Voe

No.	Output area	Population	Area (km^2)	Population Density (per km^2)
1	60RD000029	190	41.5	4.6
2	60RD000035	128	20.3	6.3
Total		318	61.8	

There are three tiny settlements (Brindister, Unifirth and Noonsborough) in the vicinity of the voe, each accommodating only a handful of dwellings. Noonsborough lies east of Brindister Voe and on the shore of Voe of Clousta. There are no roads along the east side of the Brindister Voe and no dwellings are identified on this side of the voe either on the OS map or in the shoreline survey report. A road runs along the west side of the voe and approaches within 500 metres of the shore from Unifirth to the north end of Brindister Voe. All occupied dwellings adjacent to the voe are scattered along this road. The road links a shore base for local salmon and mussel farms at its north end with the A971 further south.

There is no habitation around The Vadills and no known holiday accommodation in the area. There are no anchorages in the voe and boat traffic is expected to be only that associated with the finfish and shellfish aquaculture undertaken in vicinity.

Overall, there is likely to be relatively little impact to the water quality at the Brindister Voe fishery due the low human population in the area and the limited amount of boat traffic.

4. Sewage Discharges

No community septic tank discharges were identified by Scottish Water at Brindister Voe.

Two private septic tank discharges were registered with SEPA (Table 4.1). Discharge volumes are given in population equivalent (PE). No sanitary or microbiological data was available for these discharges.

Table 4.1 Discharge consents identified by SEPA

No.	Ref No.	NGR	Discharge Type	Level of Treatment	Flow (m^3/d)	PE	Discharges to
1	CAR/R/1014204	HU 2804 5784	Continuous	Septic Tank	-	5	Soakaway
2	CAR/R/1038804	HU 2850 5591	Continuous	Septic Tank	-	6	Soakaway

Both of these discharges are located on the western shore of Brindister Voe as shown in Figure 4.1. They are registered as land soakaways and therefore their efficiency will depend on the surrounding soil and function of the septic system itself. The low population equivalents given suggest these tanks serve single dwellings. No consents were received relating to the shore base or other dwellings present along the west side of the voe.

Sewage-related observations recorded during the shoreline survey are listed in Table 4.2.

Table 4.2 Discharges and septic tanks observed during shoreline survey

No.	Date	NGR	Description
1	06/11/2012	HU 2825 5777	Suspected Septic tank outlet, shore base
2	06/11/2012	HU 2849 5588	Concrete septic tank in poor condition, located adjacent to a stream. Leaks on side and along grass beneath, as well as effluent pooling in boggy grass further down (within 2-3 m of stream)
3	06/11/2012	HU 2869 5616	Septic tank with a soakaway, presumed inactive
4	06/11/2012	HU 2815 5788	Septic tank at property here, soakaway
5	06/11/2012	HU 2813 5770	Septic tank at house beside road

At the north end of the voe, a suspected septic tank was noted at the hard standing near the top of the pier at the Westside Salmon shore base, where a stagnant smell was also noted. The outfall for the tank discharged to sea and was submerged at the time. A seawater sample taken in the vicinity indicated very low *E.coli* levels (<1 cfu/100 ml). With the exception of the shore base outfall, there were no septic tank outfall pipes to sea or to the foreshore. Any overboard discharges from boats operating from this base may have a significant and localised impact in the immediate vicinity of any discharge.

At Biggins, a dilapidated concrete septic tank associated with a house and small farm was found to be leaking effluent from one side and pooling at the bottom of the grass slope below it. Due to its proximity, this is presumed to be the septic tank identified in Table 4.1, No 2. The observed tank lies within 3 metres of a small stream although no direct discharge to this was observed. Spot water samples showed elevated *E. coli* levels (300 cfu/100 ml) in this stream compared with a second stream to the south (70 cfu/100 ml). However, it is not possible to clearly identify the source of this contamination.

Dellings at North Newton were reported by the sampling officer to have been unoccupied for some time. Two further homes were seen between North Newton and the pier, east of Crooie Hill. Though no pipes or septic tanks were directly observed, these are likely to have had either a single or shared septic tank discharging to soakaway.

Only one of the discharge was observed to discharge directly to the marine environment at Brindister Voe. All other septic systems in the area appear to discharge to soakaway. Although soakaway systems would not be normally expected to contribute faecal contamination to the marine environment, malfunctioning systems such as that seen at Biggins may lead to overland flow that can be carried either directly or via nearby watercourses to the sea.

The overall potential impact from human sewage contamination to Brindister Voe is low. Greatest impacts are likely at the northern end of the voe, where the shore base and the majority of septic tanks area located. Contamination arising from the malfunctioning septic tank at Biggins is most likely to impact the west side of Uni Firth. Both mussel farms are located nearer the uninhabited east shore of the voe, therefore the potential for contamination arising from the west shore reaching the fisheries will be dependent on the predicted movement of contaminants (Section 13).

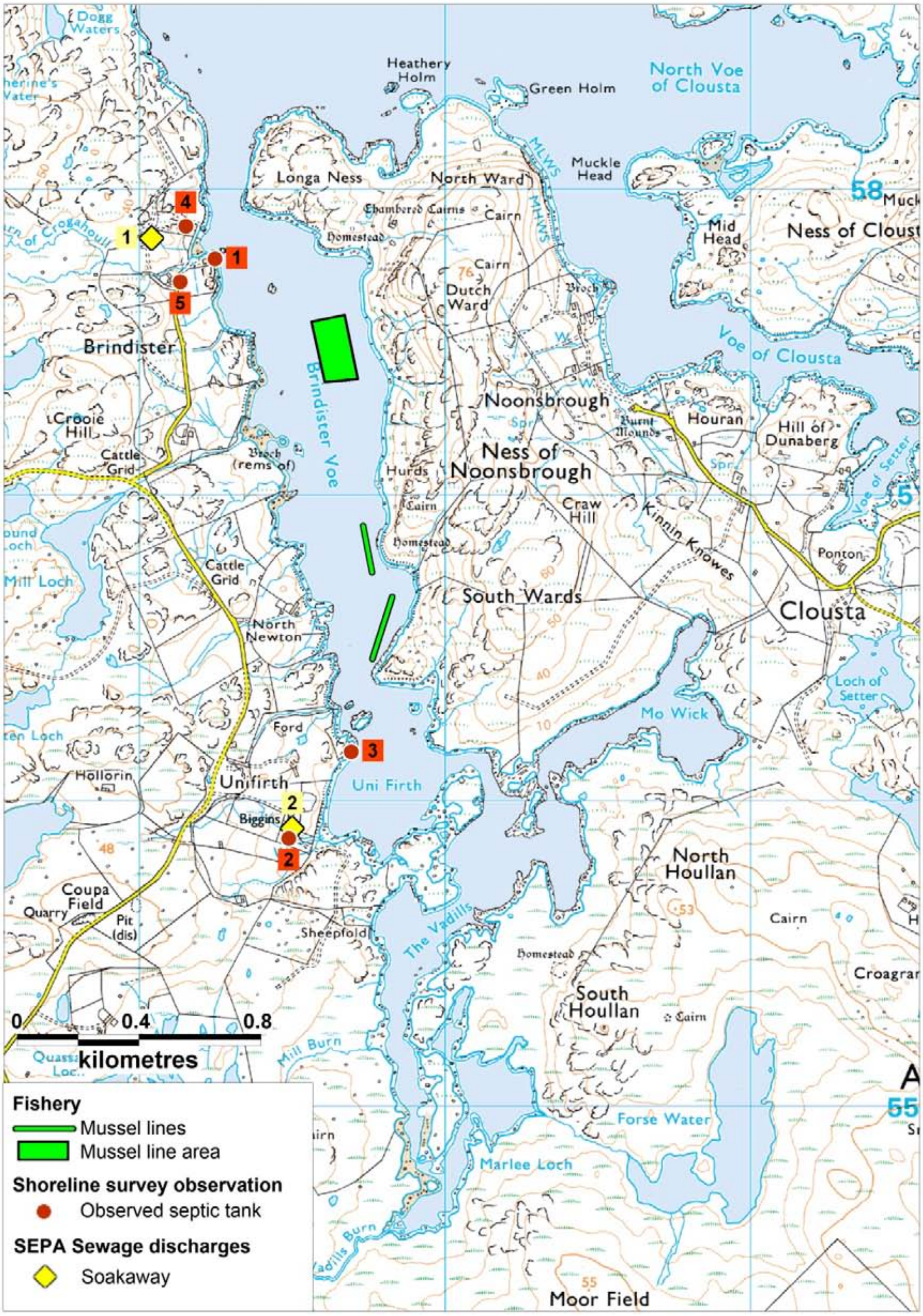


Figure 4.1 Map of sewage discharges at Brindister Voe.

5. Agriculture

Agricultural census data to parish level was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for the Aithsting parish. Reported livestock populations for the parish in 2012 are listed in Table 5.1. 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 5.1 Livestock numbers in the Aithsting parish 2012

	Aithsting	
	93 km^2	
	2012	
	Holdings	Numbers
Pigs	0	0
Poultry	14	171
Cattle	12	312
Sheep	71	18799
Other horses and ponies	7	20

Aithsting parish is located on the western mainland of Shetland (shown in the inset of Figure 5.1). Because the livestock census data relate to a large geographic area, it is not possible to determine the spatial distribution of the livestock relative to the fisheries in Brindister Voe. However, the information does give an idea of the total numbers of livestock over the broader area. The large majority of livestock kept in the area are sheep, with a rough average of 265 per holding. Cattle are also present, but in much lower numbers. There are no significant poultry farms in the area. The majority of the agricultural land use in the parish is rough grazing.

The only significant source of spatially relevant information on livestock population in the area was the shoreline survey (see Appendix 6), which only relates to the time of the site visit on the 6th November 2012. Observations made during the survey are dependent upon the viewpoint of the observer some animals may have been obscured by the terrain. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 5.1.

The land surrounding the production area was observed during the shoreline survey to used for mainly for rough grazing of sheep. Eleven sheep were observed on the hillside on the eastern side of the voe, although it was suspected that more sheep may have been grazing in the sheltered conditions of the lee of the hill. Sheep on this side of the voe were observed to be fenced away from the shore. Flocks of sheep with 20 to 30 animals were noted in fields around houses at the northern end of the voe. No sheep droppings were seen on the shoreline, though sheep had access to the shore along the west side of the voe. Although no ponies or horses were observed, hoof prints were observed on the western shoreline.

Table 5.2 Livestock observations during shoreline survey

No.	Date	Time	NGR	Livestock observation
1	06/11/2012	11:44	HU 2857 5583	Rough grazing along shore, with improved grassland above and below silage park. Sheep droppings noted on grass.
2	06/11/2012	12:23	HU 2862 5639	On the far side of the voe, 3 sheep observed on the hillside, sheep have access to the shoreline.
3	06/11/2012	12:46	HU 2856 5662	Now on the far side of the voe, 8 sheep observed.
4	06/11/2012	13:12	HU 2840 5711	Pony hoof prints.
5	06/11/2012	13:17	HU 2832 5716	25-30 sheep observed on the hillside fields around the houses.
6	06/11/2012	13:34	HU 2827 5752	26 sheep in the field beyond shore base, another 20 in an adjacent field. Field which the shore base is in previously cut for silage.

Numbers of sheep will be approximately double during May following the birth of lambs, and decrease in the autumn as they are sent to market. Therefore larger amounts of livestock droppings will be deposited during this period, though it may not impact the fishery until washed into the sea during and/or after rainfall unless deposited directly on the shoreline.

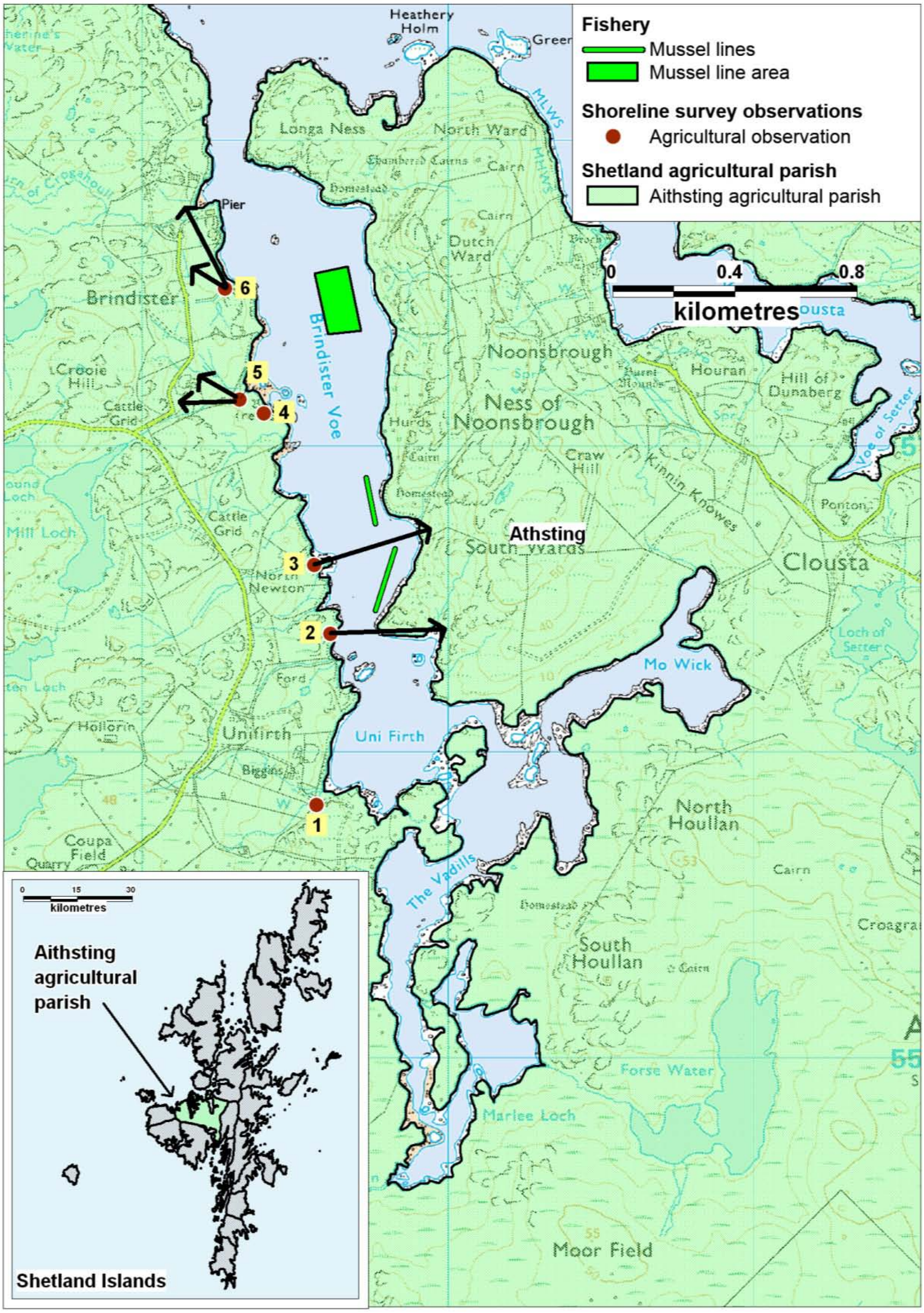


Figure 5.1 Agricultural parish boundary and livestock observations at Brindister Voe

6. Wildlife

Pinnipeds

The common/harbour seal (*Phoca vitulina*) and the grey seal (*Halichoerus grypus*) are commonly found in waters around Brindister Voe.

The total number of grey and common seals in Shetland is estimated to be between 3,000 and 3,500 (NAFC Marine Centre 2012), but there are no specific population counts for Brindister Voe.

The sheltered habitat at Brindister Voe has been shown to support common seals (NAFC Marine Centre 2012). Areas identified as important habitat for common seals are shown in Figure 6.1. Three main areas are indentified within the Brindister Voe area: one immediately north of the voe, one within the voe and a smaller area just inside the Vadills. The identified area within Brindister Voe includes the entirety of the classified mussel farm (both north and south legs). Seals forage widely for food and may be present anywhere within the voe, however it is not clear how much of the time they may be present within the identified areas.

During the shoreline survey, two seals were observed swimming adjacent to the western shoreline, opposite the southernmost mussel lines. Seals present in the area are likely to contribute to background levels of faecal contamination within the voe. It is likely that their presence on areas of foreshore may be seasonal, with seals more likely to spend time hauled out on the shore when they moult in August (Scottish Natural Heritage, 2000). However, not enough is known about the numbers of animals, extent of presence in the voe, and typical FIO concentrations excreted by seals to determine whether this contributes to the observed *E. coli* concentrations in mussels at Brindister Voe site.

Birds

Seabird Census 2000 records are shown in Table 6.1 and the Shetland Bird Report 2010 shown in Table 6.2.

Table 6.1 Seabird counts within 5km of Brindister Voe taken from Seabird Census 2000.

Common name	Species	Count*	Method
Great Black-backed Gull	*Larus marinus*	10	Individuals on land/Occupied territory
Common gull	*Larus canus*	41	Occupied nests/Individuals on land
European Herring Gull	*Larus argentatus*	4	Occupied nests/Individuals on land
Northern Fulmar	*Fulmarus glacialis*	36	Occupied sites
Arctic tern	*Sterna paradisaea*	6	Individuals on land

* All counts adjusted to number of individual birds not including offspring

Table 6.1 identifies Northern Fulmar and common gulls as the most numerous breeding seabirds around Brindister Voe. The number of reported breeding seabirds in the area is modest.

During the shoreline survey, evidence of geese, ducks and other birds was found on the shoreline.. The most commonly observed birds were geese, with 30 seen during the survey. Goose droppings were observed along the entire western shoreline. It must be noted, however, that as the eastern shoreline was not walked it cannot be directly inferred that no droppings were present on the eastern shore. Graylag geese, a common visitor and now breeding goose on Shetland, feeds preferentially on grasses and would be more likely found on the improved grassland on the west side of the voe. Other commonly observed birds included gulls and eider ducks, with one oyster catcher and one crow also present.

Eider ducks may be present at the mussel lines when feeding and duck droppings containing mussel shell were observed during the survey. Droppings from birds can affect the fishery in two ways: direct deposition in the near vicinity of the mussels and via diffuse runoff from land where the birds have been. Recorded locations of breeding seabirds and observations from the shoreline survey, including the presence of suitable feeding habitat for geese, suggest that input from avian-source faecal contamination may be higher on the west side of the voe. There is no compelling reason to suggest that one mussel farm, or part of a mussel farm, may be more impacted than another.

Otters

No important otter habitat areas were identified within Brindister Voe in the Shetland Marine Atlas. Otters are present throughout much of Shetland, and may be present in Brindister Voe. However, they are unlikely to be present in large numbers and therefore are not considered likely to contribute significant loadings of faecal contaminants to the waters around the fishery.

Overall

No large concentrations of wild mammals are known to be present around Brindister Voe. Wildlife species most likely to contribute to background levels of faecal contamination in the voe are geese, seabirds, and seals. While there may be some seasonal variation in the presence and numbers of most of these animals there is insufficient information on which to base a clear assessment of seasonal impact. Although the middle part of the voe has been identified as important seal habitat, it is not clear whether this would result in higher levels of faecal indicator bacteria at the Brindister Voe farm as opposed to the new farm to the north.

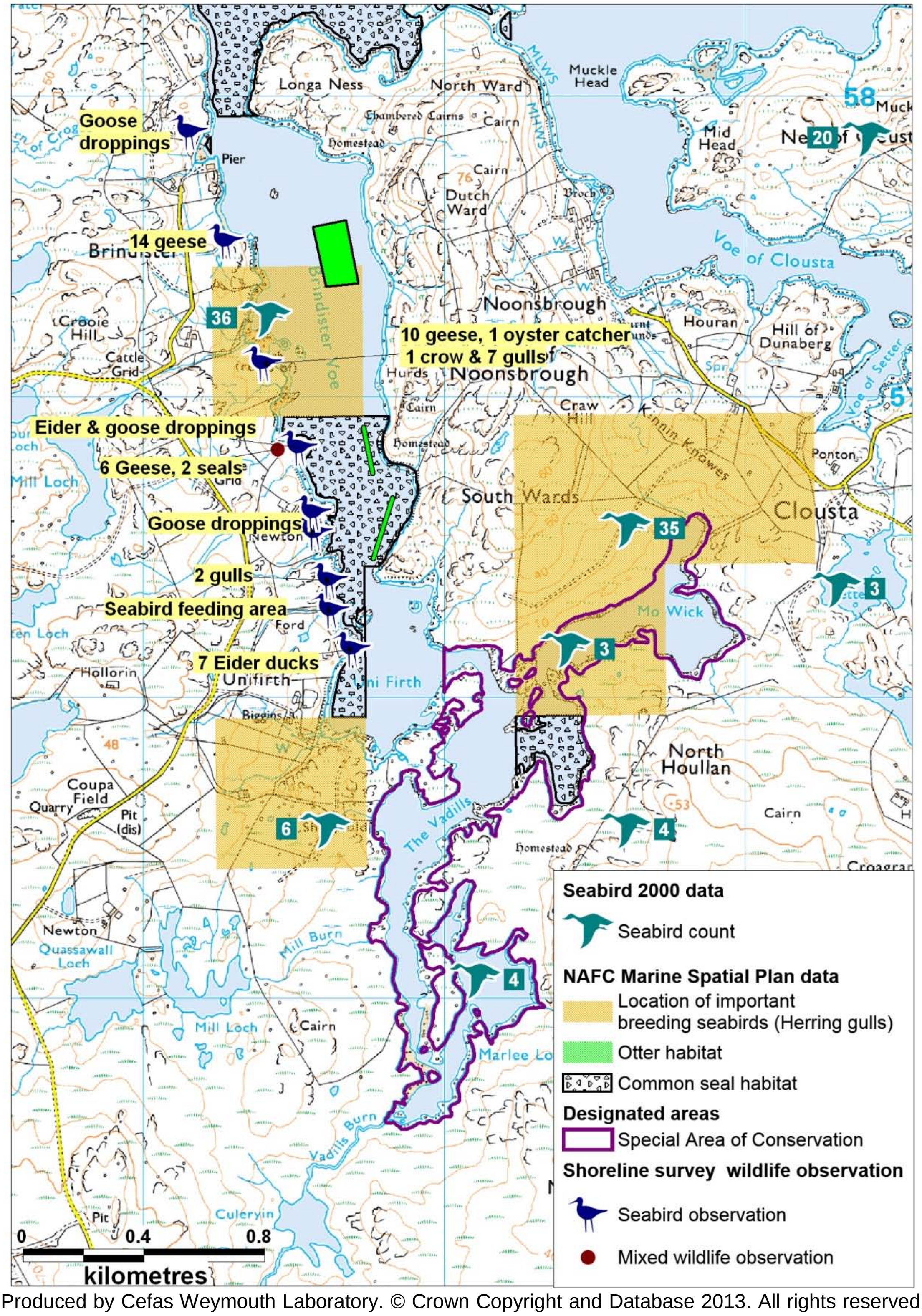


Figure 6.1 Map of wildlife identified and observed during the shoreline survey at Brindister Voe.

7. Land Cover

The Land Cover Map 2007 data for the area is shown in Figure 6.1 below:

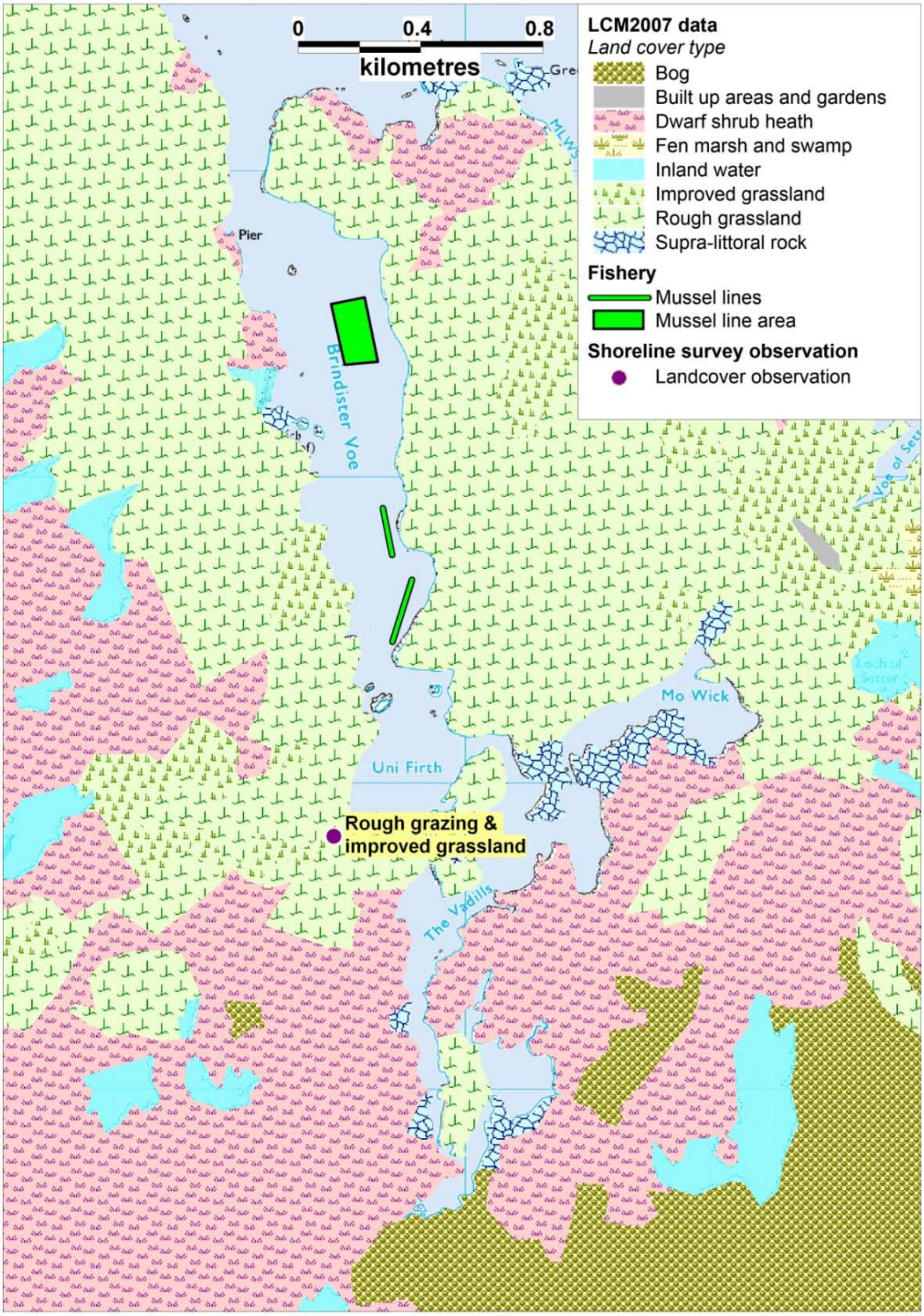


Figure 7.1 LCM2007 land cover data for Brindister Voe

Rough grassland, improved grassland and dwarf shrub heath are the predominant land cover types adjacent to the Brindister Voe shoreline. South of The Vadills there are large areas of bog. Areas of improved grassland are found along the shore opposite the Brindister Voe mussel farm and to the south of Uni Firth. Although the LCM2007 data indicates there is built up area to the northeast of Mo Wick, there are no known built up areas in the vicinity of Brindister Voe. During the shoreline survey, it was observed that on the western shoreline adjacent to Uni Firth there was an area of rough grazing along the shore, with improved grazing behind. These observations coincide with the Land Cover 2007 data as shown in Figure 6.1. Review of satellite imagery of the area shows areas that appear to be additional areas improved grassland further north along the west side of the voe, around the area of the pier.

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

The highest potential contribution of contaminated runoff to the Brindister Voe shellfish farm is from areas of improved grassland along the west side of the voe. Areas utilised for rough grazing all around the shoreline would be expected to contribute significantly to faecal contaminant loading carried in watercourses and overland flow draining the area during and immediately after periods of wet weather.

8. Watercourses

There are no river gauging stations on watercourses discharging to Brindister Voe.

Numerous areas of land drainage were observed during the shoreline survey. Spot samples and flow measurements were taken at 9 watercourses. The location only was recorded for a further 6 areas of drainage and/or very small watercourses. Although the weather was dry on the day of survey, heavy rain had fallen during the previous night. Table 8.1 lists those watercourses for which samples and flows were recorded.

Table 8.1 Watercourse loadings to Brindister Voe

No.	NGR	Description	Width (m)	Depth (m)	Flow (m/s)	Flow (m^3/d)	*E. coli* (cfu/100 ml)	Loading *E. coli* per day)
1	HU 2891 5676	Small burn on east shore	-	-	4 l/s*	350	190	5.6×10^8
2	HU 2858 5584	Stream	0.25	0.25	0.679	3670	70	2.6×10^9
3	HU 2859 5587	Stream that passes septic tank	0.55	0.10	0.276	1310	300	3.9×10^9
4	HU 2862 5629	Stream w/overland flow nearby	0.50	0.22	0.520	4940	50	2.5×10^9
5	HU 2855 5645	Stream	0.15	0.09	0.381	440	90	4.0×10^8
6	HU 2856 56615	Stream at North Newton	0.22	0.13	0.950	2350	60	1.4×10^9
7	HU 2845 5702	Stream	0.30	0.13	0.328	1100	26	2.9×10^8
8	HU 2832 5716	Outlet from Mill Loch	0.50	0.25	0.313	3380	24	8.1×10^8
9	HU 2816 5775	Burn of Crogahoull	0.50	0.30	0.766	9930	42	4.2×10^9

- No reading taken as flow was collected in bucket
* Units in litres/second

The watercourses sampled were found to be only lightly to moderately contaminated. The majority of the watercourses were observed on the western shoreline of Brindister Voe, with only one watercourse surveyed on the eastern shore, directly adjacent to the mussel lines. This was due to the inaccessibility of the shoreline along this side of the voe. From the OS map, it appears that other minor watercourses are present on the east shore adjacent to the spat farm at the northern end of the voe.

Due to the heavy rain overnight and the saturated state of the ground, flows recorded are considered to be representative of wet weather conditions and therefore should be at the high end of their range. None of the flows was particularly high. Loadings were calculated based on the spot measurements and samples. These showed that at the time of sampling, Burn of Grogahoull at the north end of the voe carried the highest *E. coli* loading of all the measured watercourses, although a number of others (2,3,4 & 6 in Table 8.1) had loadings that approached that of Burn of Crogahoull. These watercourses were located along the western shore. As the *E. coli* concentration was not particularly high, the loading was driven largely by the estimated daily discharge. The discharge volume of Burn of Crogahoull was over twice that of any of the other watercourses sampled at this site. This burn flows through an area of improved grassland used for silage and past an occupied dwelling. A septic tank presumed to be associated with this dwelling was situated approximately 40 m south of the burn. Faecal contamination to this burn could come from a mix of domestic, livestock and wildlife sources.

The next highest loading, however, came from one of the smaller recorded streams, No. 2 in Table 8.1. This stream ran adjacent to a failing septic tank observed at Biggins. A spot water sample taken from this stream returned a result of 300 *E. coli* cfu/100 ml. A similar sample taken from an adjacent stream a short distance to the south was found to have 70 *E. coli* cfu/100 ml. This suggests that the failing septic tank may have been impacting water quality in Stream 2. Due to large differences in the discharge of these streams, however, the calculated loadings were similar.

The watercourse observed on the east shore of the voe was sampled and measured due to its close proximity to the Brindister Voe site. This had a moderate *E. coli* result of 190 cfu/100 ml but a very low volume. Although this is the nearest watercourse to the fishery, it is unlikely to cause significant contamination problems due to its small volume and catchment. Any faecal contamination to this stream is likely to have come from sheep or wildlife present on the hills above the shore.

Overall, watercourses around Brindister Voe were found during the survey to be relatively lightly contaminated considering the wet weather conditions. One stream at the south end of the voe appeared to receive some contamination at the time from a failing septic tank.

The greatest impacts based on observations during the survey are likely to be at the northwest end of the voe and in Uni Firth. The stream adjacent to the mussel farm on the east shore carries only a very low volume and would be most likely to impact the very near shore.

Figure 8.1 Map of watercourse loadings at Brindister Voe.

Where the bacterial loading is labelled on the map, the scientific notation is written in digital format, as this is the only format recognised by the mapping software. So, where normal scientific notation for 1000 is 1×10^3, in digital format it is written as 1E+3.

9. Meteorological data

The nearest weather station for which rainfall data was available is located at Lerwick, situated approximately 25 km to the south east of the production area. Rainfall data was available for January 2007 – July 2012. At the time of writing this report rainfall data for August 2012 onwards, had not been supplied. The nearest wind station is also situated in Lerwick, located 25 km south east of the production area. Conditions may differ between this station and the fisheries due to the distances between them. However, this data is still shown as it can be useful in identifying seasonal variation in wind patterns.

Data for these stations was purchased from the Meteorological Office. Unless otherwise identified, the content of this section (e.g. graphs) is based on further analysis of this data undertaken by Cefas. This section aims to describe the local rain and wind patterns in the context of the bacterial quality of shellfish at Brindister 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 and Morgan 2003)). The box and whisker plots in Figures 9.1 and 9.2, present a summary of the distribution of individual daily rainfall values by year and by month. The grey box represents the middle 50% of the observations, with the median represented by 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 *.

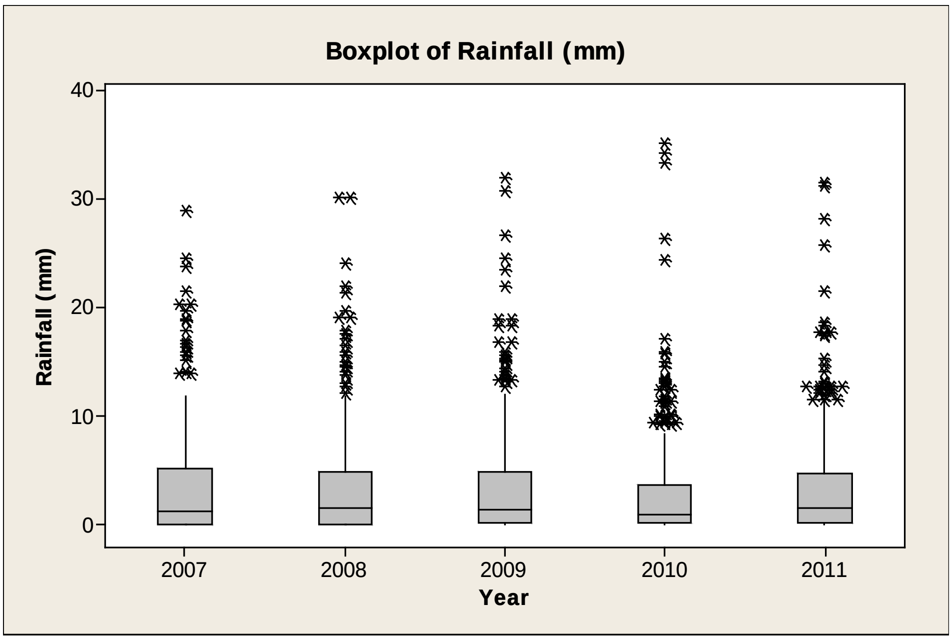


Figure 9.1 Box plot of daily rainfall values by year at Lerwick (2007 – 2011)

Daily rainfall values varied little from year to year, with 2010 being slightly drier than the other years. Rainfall data for 2012 was omitted from the analysis due to data only being available for half the year.

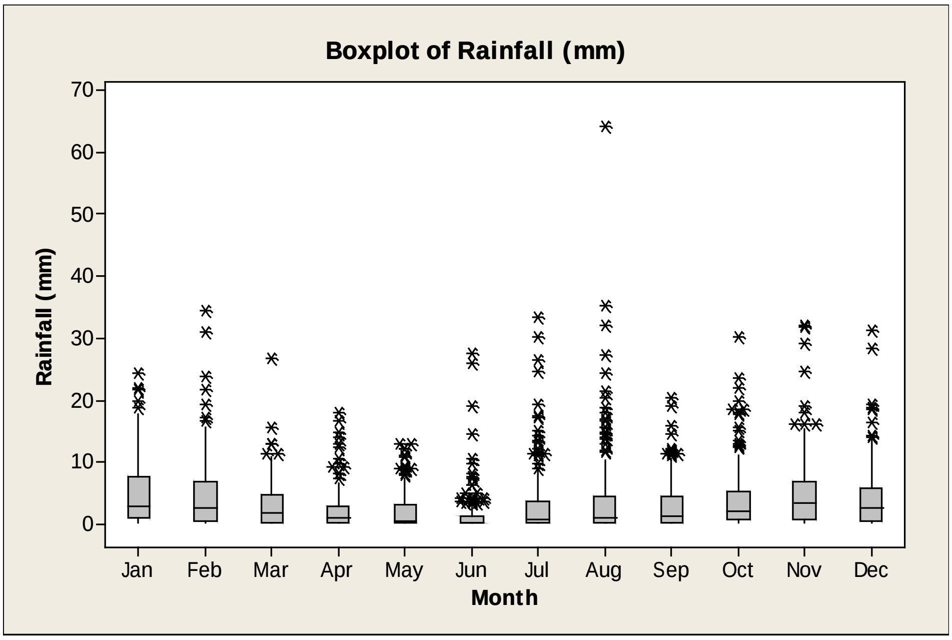


Figure 9.2 Box plot of daily rainfall values by month at Lerwick (2007 – 2012)

Daily rainfall values were higher during the autumn and winter. Rainfall increased from August onward and was highest in January and February. The driest months were April to June. Rainfall greater than 20 mm did not occur in April and May, and only once in March.

For the period considered here (2007 – 2012) 44% of days received daily rainfall of less than 1 mm and 9% of days received rainfall of over 10 mm.

It is therefore expected that run-off due to rainfall will be higher during the autumn and winter months. However, extreme rainfall events leading to episodes of high runoff can occur in most months and when these occur during generally drier periods in summer and early autumn, they are likely to carry higher loadings of faecal material that has accumulated on pastures when greater numbers of livestock were present.

9.2 Wind

Wind data was collected from Lerwick and summarised in seasonal wind roses in Figure 9.3 and annually in Figure 9.4.

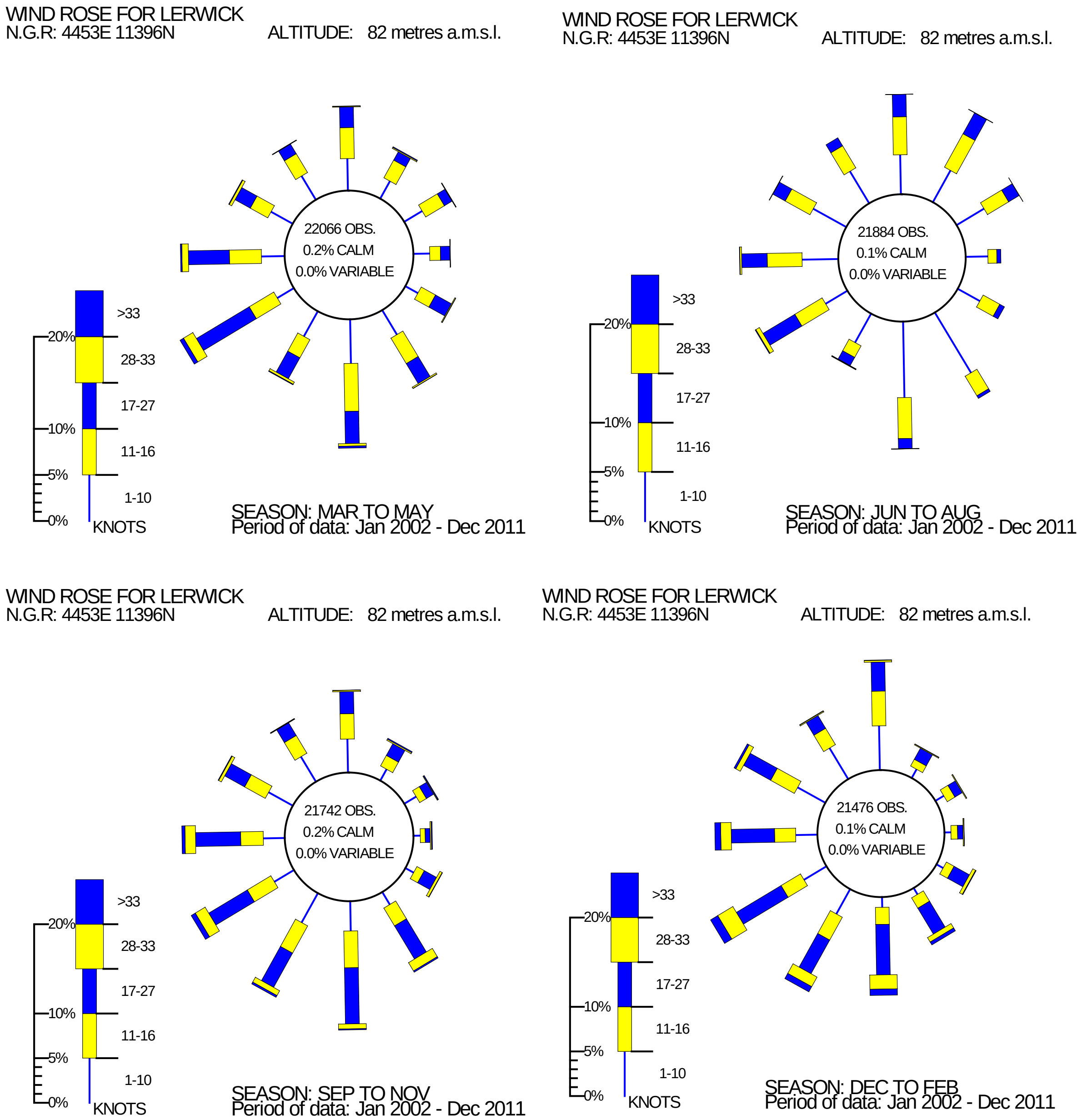


Figure 9.3 Seasonal wind roses for Lerwick

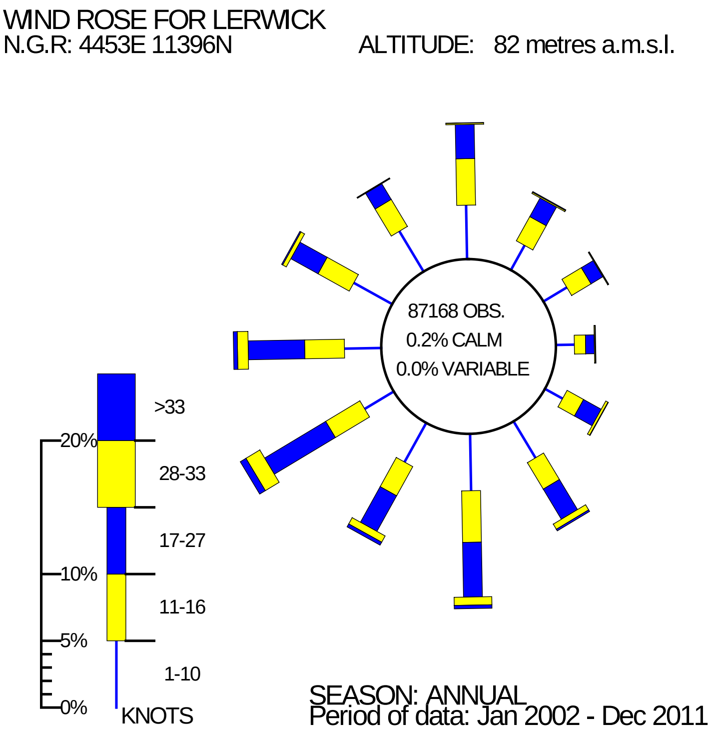


Figure 9.4 Annual wind rose for Lerwick

Overall the annual wind direction showed that wind was stronger when coming from the west than the east, and winds from the southerly direction were stronger than those from the north. There was no marked change in wind direction throughout the months; however winds were much stronger in the winter months than in the summer months.

Wind is an important factor in the spread of contamination as it has the ability to drive surface water at about (3%) of the wind speed (Brown 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s. Therefore strong winds can significantly alter the pattern of surface currents. Strong winds also have the potential to affect tide height depending on wind direction and local hydrodynamics of the site. A strong wind combined with a spring tide may result in higher than usual tides, which will carry any accumulated faecal matter at and above the normal high water mark into the production area.

10. Classification Information

The area was first classified for mussel production prior to 2007, however only the classification status from 2007 onward is presented in Table 10.1 below.

Table 10.1 Brindister Voe (common mussel) classification history

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007	B	B	A	A	A	A	A	A	A	A	B	B
2008	B	B	A	A	A	A	A	A	A	B	B	A
2009	A	A	A	A	A	A	A	B	B	B	B	A
2010	A	A	A	A	A	A	A	A	A	A	A	A
2011	A	A	A	A	A	A	A	A	A	A	A	A
2012	A	A	A	A	A	A	A	A	A	A	A	A
2013	A	A	A									

Currently the area is classified as A year round. Historically the area was classified as A/B in 2007 to 2009 with classification improving to A year round from 2010 onward. Months classified as B occurred from late summer to winter.

11. Historical E. coli data

11.1 Validation of historical data

Results for all samples assigned against Brindister Voe from the 8th January 2007 to the 3rd September 2012 were extracted from the FSAS database in October 2012 and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. All *E. coli* results were reported as most probable number (MPN) per 100 g of shellfish flesh and intravalvular fluid.

Two samples were recorded in the database as ‘rejected’ and were deleted from analysis. All samples were collected and delivered to the laboratory within the 48hr limit, and all box temperatures were <8°C. Twenty samples had an *E. coli* result of <20, so were assigned nominal values of 10 *E. coli* MPN/100 g for the purposes of statistical analysis and graphical representation.

11.2 Summary of microbiological results

Table 11.1 Summary of historical sampling and results.

Sampling Summary	
Production area	Brindister Voe
Site	Brindister Voe
Species	Common mussels
SIN	SI-023-406-08
Location	various
Total no. of samples	59
No. 2007	9
No. 2008	9
No. 2009	10
No. 2010	12
No. 2011	11
No. 2012	8
Results Summary	
Minimum	10
Maximum	330
Median	20
90 Percentile	230
95 Percentile	230
No. exceeding 230/100g	2 (3%)
No. exceeding 1000/100g	0
No. exceeding 4600/100g	0
No. exceeding 18000/100g	0

Overall, monitoring results have been low, with only two results >230 *E. coli*/100 g.

11.3 Overall geographical pattern of results

Locations of samples included in this analysis are shown mapped in Figure 11.1 below. All samples are attributed to the Brindister Voe production area. Where more than one sample was attributed to a location, the geometric mean *E. coli* result is shown.

Figure 11.1 Map of reported *E. coli* sampling locations

Not all sample locations coincided with the recorded location of the mussel lines, and a large number of sample locations were only recorded to 100 metre accuracy. Due to the level of uncertainty with respect to the reported sampling locations, it is not possible to undertake a spatial analysis of this data.

11.4 Overall temporal pattern of results

A scatterplot of individual *E. coli* results against date is presented in Figure 11.2. The dataset is fitted with a lowess trend line. Lowess trendlines allow for locally weighted regression scatter plot smoothing. At each point in the dataset an estimated value is fitted 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 lowess line is influenced more by the data close to it (in time) and less by the data further away. The trend line helps to highlight any apparent underlying trends or cycles.

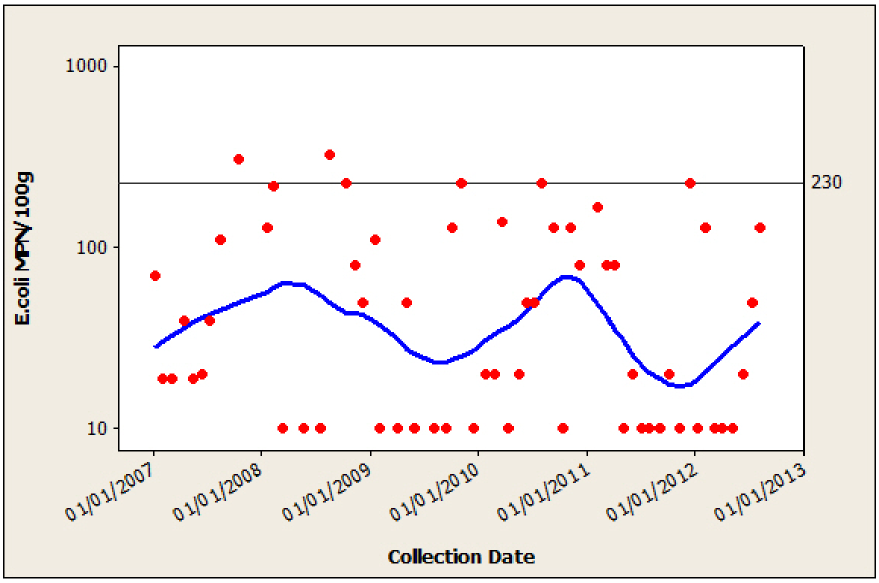


Figure 11.2 Scatterplot of *E. coli* results by date with a lowess line.

Across all years of sampling the vast majority of *E. coli* results were ≤ 230 *E. coli* MPN/100 g. Two results >230 *E. coli* MPN/100 g occurred in 2007 and 2008. The trend line suggests cyclical variation in results, with the period of the cycle varying with time.

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 in human distribution. All of these can affect levels of microbial contamination, causing seasonal patterns in results. Figure 11.3 presents *E. coli* results by month, overlaid with a lowess line to highlight trends.

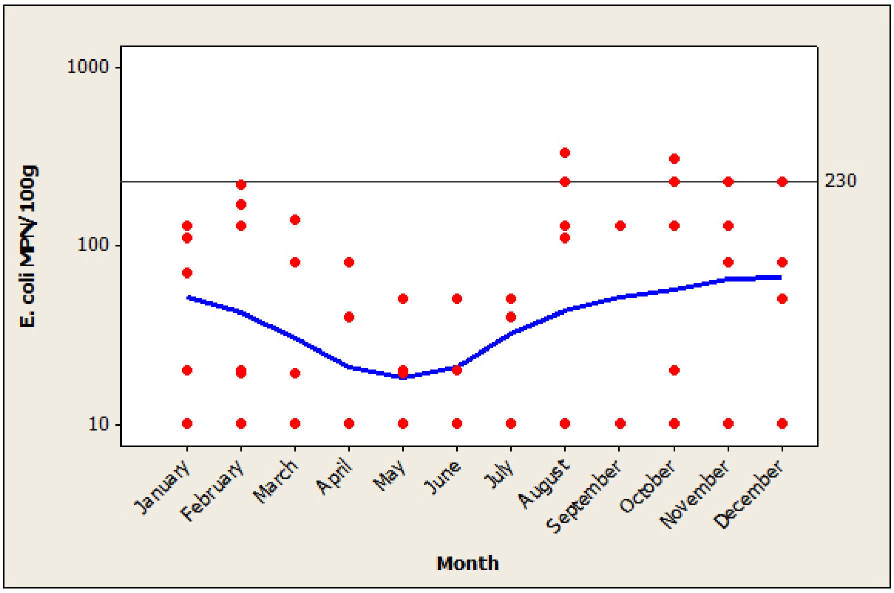


Figure 11.3 Scatterplot of *E. coli* results by month, fitted with a lowess line.

A dip occurs in the trend line between April and July, associated with lower levels of contamination during these months. Sample results≥230 *E. coli* MPN/100 g occurred mainly from August to December.

For statistical evaluation, seasons were split into spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). Figure 11.4 presents a boxplot of *E. coli* results by season.

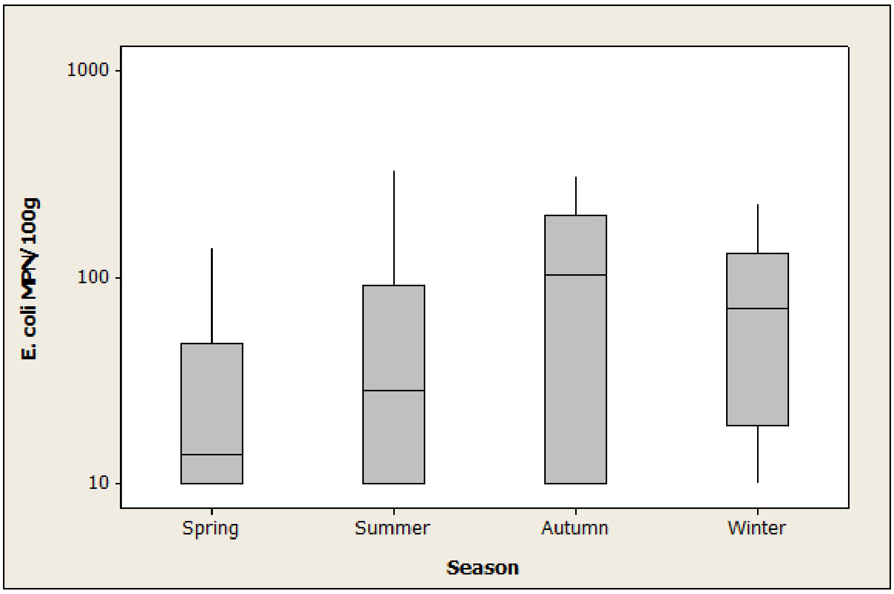


Figure 11.4 Boxplot of *E. coli* results by season.

No significant difference was found between results by season (one-way ANOVA, p = 0.117, Appendix 4). A post-ANOVA analysis (Tukey's method) showed that the results between seasons did not vary significantly. The median result was higher in autumn and winter than in spring and summer, and fewer very low results occurred in winter than in other seasons.

11.6 Analysis of results against environmental factors

Environmental factors such as rainfall, tides, wind, sunshine and temperature can all influence the flux of faecal contamination into growing waters ((Mallin, et al. 2001)(Lee and 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 with available rainfall data was at Lerwick, approximately 25 km SE of the production area. Rainfall data was purchased from the Meteorological Office for the period of 01/01/2007-12/09/2012 (total daily rainfall in mm). Data was extracted from this for common mussels between 08/01/2007-06/08/2012.

11.6.1.1 Two-day rainfall

The scatterplot in Figure 11.5 presents individual *E. coli* results against total rainfall recorded on the two days prior to sampling.

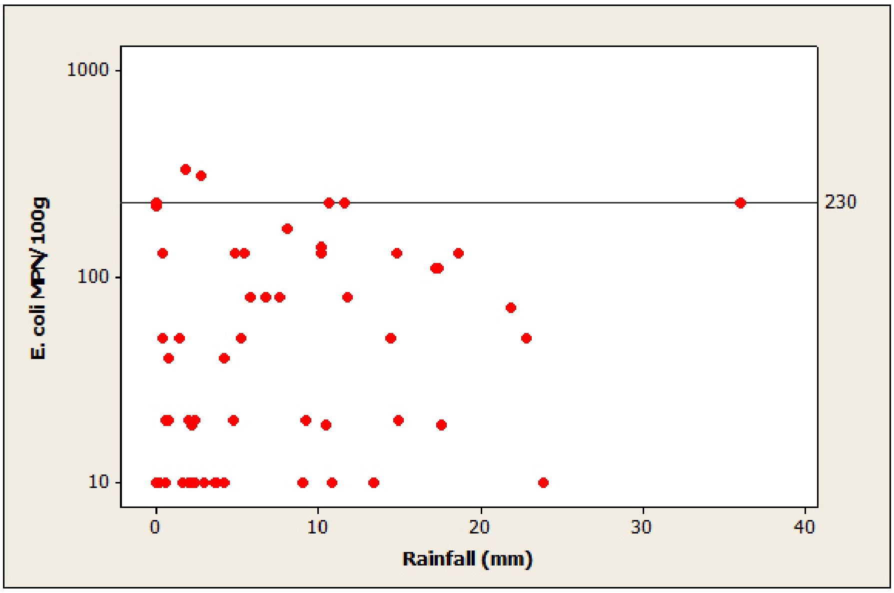


Figure 11.5 Scatterplot of *E. coli* results against rainfall in the previous two days.

A significant correlation was found between the results and the previous two day rainfall (Spearman's rank correlation r = 0.312, p = 0.016). A single result of 230 MPN/100 g at between 30 and 40mm rainfall, together with a cluster of very low results at 0-5mm rainfall are driving the correlation. However, the two results > 230 *E. coli* MPN/100 g coincided with rainfall of <5mm, and results <20 occurred across most recorded rainfall values. Therefore, the correlation is not significant in terms of predicting exceedance of the 230 *E.coli* MPN/100 g standard in this case.

11.6.1.2 Seven-day rainfall

The effects of heavy rainfall may take differing amounts of time to be reflected in shellfish sample results in different system, the relationship between rainfall in the previous seven days and sample results was investigated in an identical manner to the above. A scatterplot presents common mussel *E. coli* results against total rainfall recorded for the seven days prior to sampling.

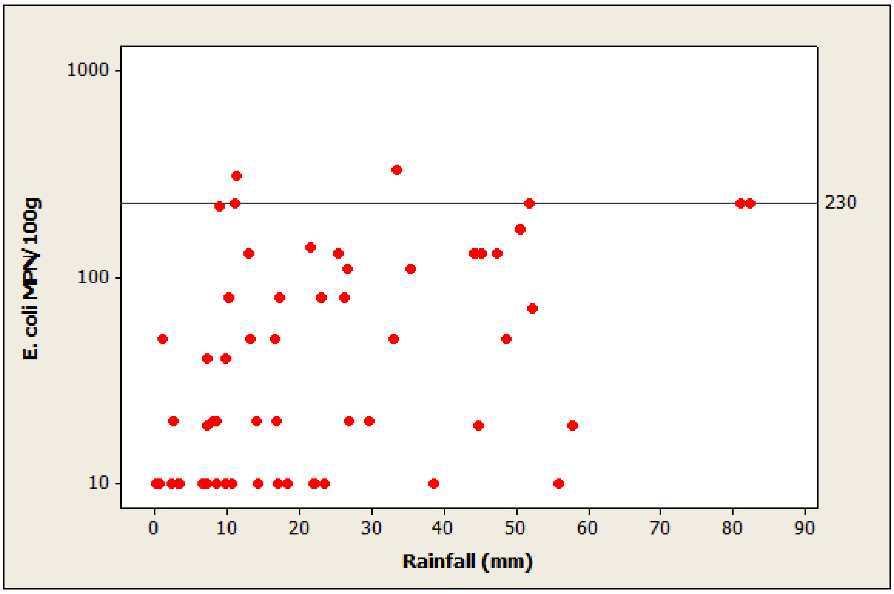


Figure 11.6 Scatterplot of *E. coli* results against rainfall in the previous seven days.

A significant correlation was found between the results and the previous seven day rainfall (Spearman's rank correlation r = 0.458, p = 0.000). As was seen in the analysis against 2-day rainfall, correlation appears to be largely driven by a cluster of very low results at low rainfall levels and a pair of higher results to the far right of the graph at exceptionally high rainfall. Sample results appear widely distributed across recorded rainfall values and results exceeding 230 *E. coli* MPN/100 g occurred after as little as 10mm rainfall in the 7 days prior to sampling.

11.6.2 Analysis of results by tidal height

11.6.2.1 Tidal state spring/neap

Spring tides are large tides that occur fortnightly and are influenced by the state of the lunar cycle. They reach above the mean high water mark and therefore increase circulation and particle transport distances from potential contamination sources on the shoreline. The largest Spring tides occur approximately two days after the full moon about 45°, then decreases to the smallest neap tides at about 225°, before increasing back to spring tides 0°. Polar plots are presented below showing *E. coli* results against the lunar cycle**.** It should be noted local meteorological conditions (e.g. wind strength and direction) can also influence tide height, but is not taken into account in this section.

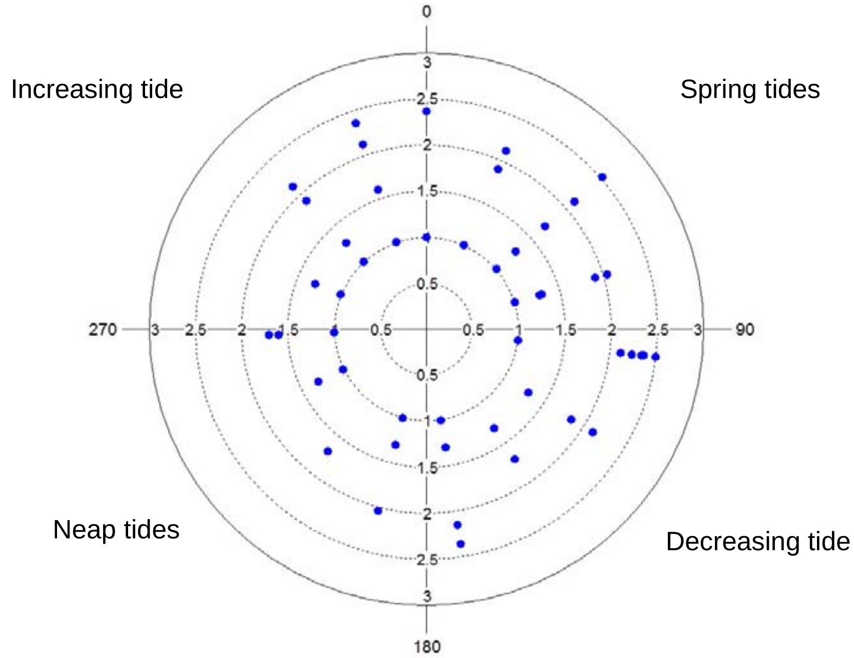


Figure 11.7 Polar plot of Log_{10} *E. coli* results on the spring/neap tidal cycle.

A significant correlation was found between $\log_{10}$ *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r = 0.331, p = 0.002).

Results were lower for samples taken at neap tides as shown in Figure 11.7

11.6.2.2 Tidal state by high/low water

Tidal state (high/low tide) changes the direction and strength of water flow around production areas. Depending on the location of contamination sources, tidal state may cause marked changes in water quality near the vicinity of the farms. Shellfish species response time to *E. coli* levels can vary from within an hour to a few hours. Polar plots present *E. coli* results against lunar tidal cycle, where high water is at 0° and low water at 180°. High and low water data from Sullom Voe was extracted from POLTIPS-3 in October 2012. This site was the closest to the production area and it is assumed that tidal flow will be very similar between sites.

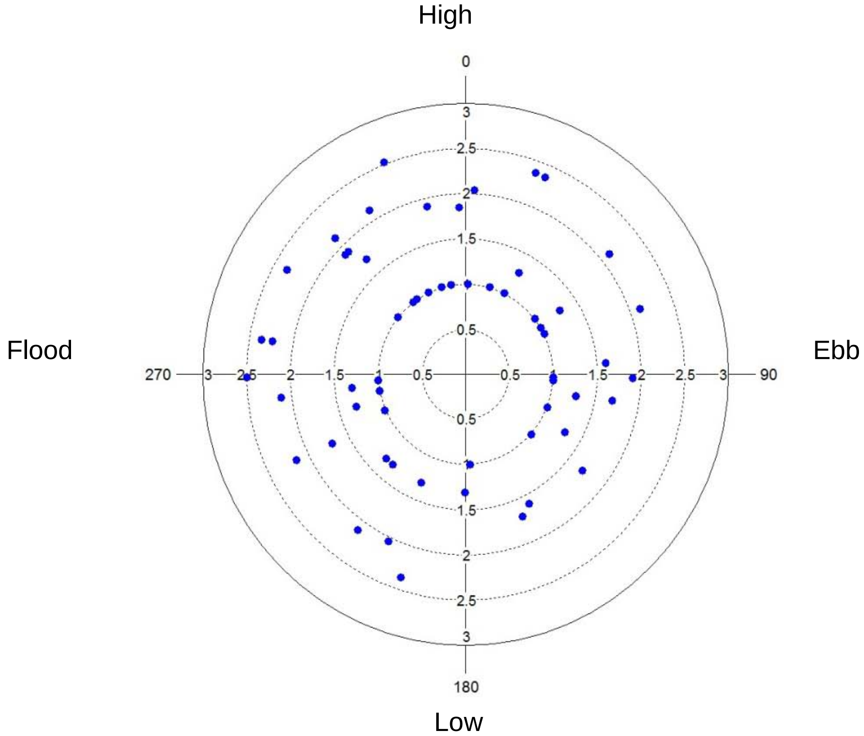


Figure 11.8 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle.

A significant correlation was found between $\log_{10}$ *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.238, p = 0.042). Higher results appeared to occur on the flood tide and results were lower overall on the later half of the ebb.

11.6.3 Analysis of results by water temperature

Water temperature can affect survival time of bacteria in seawater (Burkhardt, et al. 2000). It can also affect the feeding and elimination rates in shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. Water temperature is obviously closely related to season. Any correlation between temperatures and *E. coli* levels in shellfish flesh may therefore not be directly attributable to temperature, but to the other factors e.g. seasonal differences in livestock grazing patterns. Figure 11.9 presents *E. coli* results against water temperature, with water temperature recorded for forty nine of the fifty nine samples.

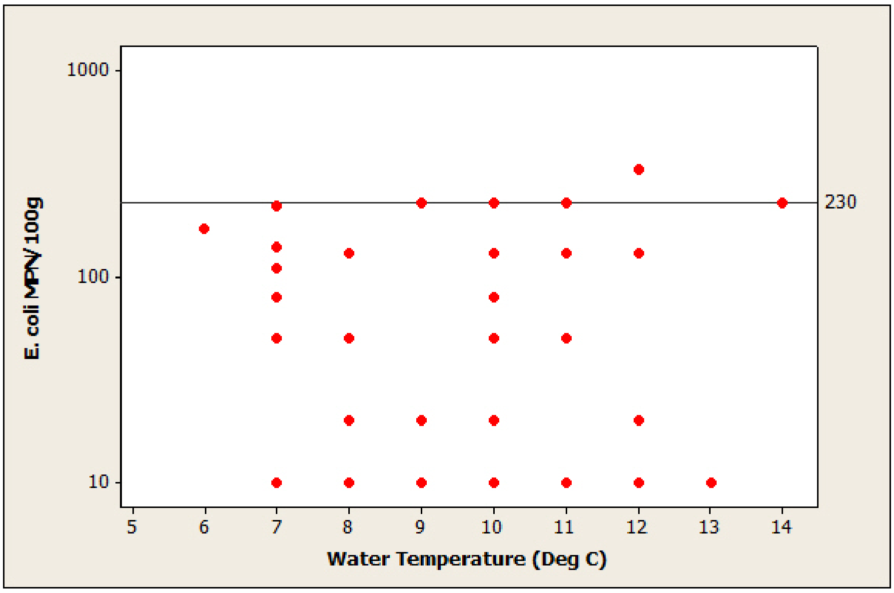


Figure 11.9 Scatterplot of *E. coli* results against water temperature.

No significant correlation was found between *E. coli* results and water temperature (Spearman's rank correlation r = -0.061, p = 0.677). Recorded water temperatures ranged from 6 to 14°C.

11.6.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence and hence freshwater borne contamination at a site. Due to problems with salinity analysis at the testing laboratory during the period considered in this report, and consequent uncertainty regarding some of the recorded salinity values, assessment of results against salinity was not undertaken.

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

In the data examined, only two results exceeded 230 *E. coli* MPN/100 g. These are presented in Table 11.2.

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

Collection Date	E. coli (MPN/ 100 g)	Location	Two day rainfall (mm)	Seven day rainfall (mm)	Water Temp (°C)	Salinity (ppt)	Tidal State (high/low)	Tidal state (spring/neap)
15/10/2007	310	HU287565	2.8	11.2	-	40.22	Low	Ebb
18/08/2008	330	HU287565	1.8	33.4	12	34.64	Increasing	Spring

(-) Data not available.

Both samples were only slightly over the threshold, and both were reported against the same nominal sampling location, but in different years. Both occurred in late summer/autumn. Both occurred after low rainfall in the two days prior to sampling. Rainfall in the 7 days prior to sampling was moderate for one and high for the other. Recorded salinity was very high for the 2007 sample, which is likely due to technical problems at the laboratory and not an accurate reflection of the water salinity at the time of sampling. There was no discernible pattern in any of the other recorded environmental variables with regard to these samples.

11.8 Summary and conclusions

Only one sample was recorded against the nominal RMP, which lies over 100 metres north of the recorded mussel lines at Brindister Voe. Due to uncertainty regarding the sampling locations, it was not possible to examine the data for any spatial variation in *E. coli* results.

More than 96% of samples considered in this analysis had results ≤ 230 *E. coli* MPN/100 g. Only two samples exceeded this value. Although there was no statistically significant variation in results by season, there did appear to be variation across months, with lowest results occurring from April to July.

Although statistically significant correlations were found between results and both 2-day and 7-day antecedent rainfall, the graphs did not appear to show any clear trends. Highest *E. coli* results occurred at low to moderate rainfall values.

A statistically significant correlation was found between *E. coli* results and both the spring/neap tidal cycle and the high/low tidal cycle. Results were lower for samples taken at neap tides and on the later half of the ebb tide. Higher results appeared to occur on the flood tide.

There was no correlation between water temperature and *E. coli* results.

12. Designated Shellfish Growing Water Data

Brindister Voe is not a designated Shellfish Growing Water (SGW) under the European Community Shellfish Waters Directive (2006/113/EC). The nearest designated SGW is in the Voe of Clousta, which is a water body located to the north east of Brindister Voe (shown in Figure 12.1). The Voe of Clousta has been monitored since 2002.

This area is not contiguous with Brindister Voe, and is likely to be subject to different specific sources of faecal contamination. Therefore, monitoring results from the Voe of Clousta SGW are not considered likely to be representative of conditions at the Brindister Voe fishery and these results will not be considered further here.

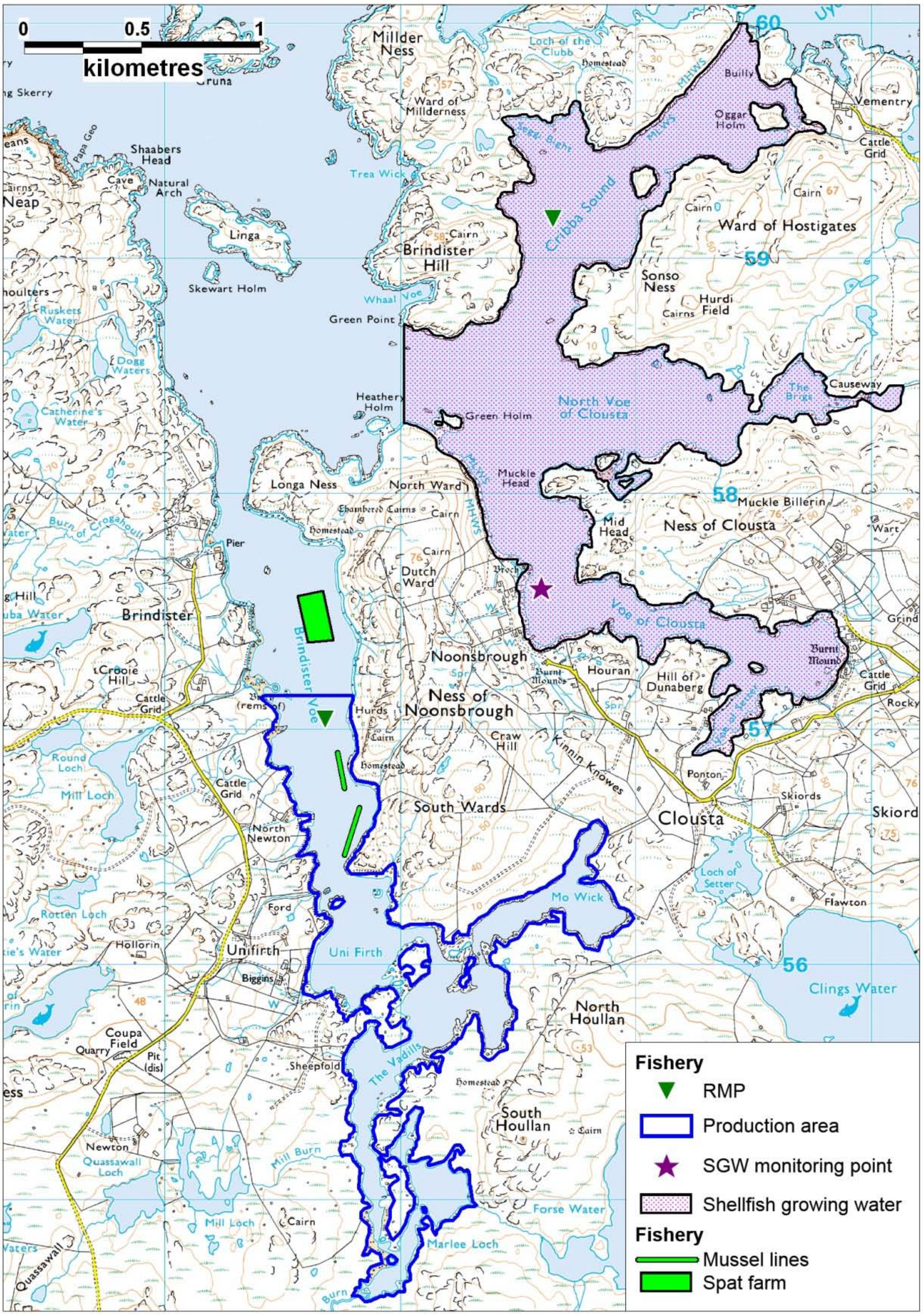


Figure 12.1 Designated shellfish growing water – Voe of Clousta

13. Bathymetry and Hydrodynamic Assessment

Brindister Voe and The Vadills

13.1 Introduction

The study area comprises all waters south of a line drawn between HU 28203 58234 and HU 28406 58234, namely Brindister Voe and The Vadills. The voe is located on the west Shetland mainland and is an inlet on the convoluted southern coastline of St. Magnus Bay. The voe is relatively shallow and orientated roughly north – south with an average width of 0.3 km over its 2.3 km length.

At the head of the voe a narrow channel connects to The Vadills, an area of interconnected basins designated as a Special Area of Conservation (Marine SAC) to protect unique coastal lagoon habitats.

13.2 Bathymetry

As can be seen from the Admiralty chart extract presented in Figure 13.1 no information concerning water depth exists for the study area.

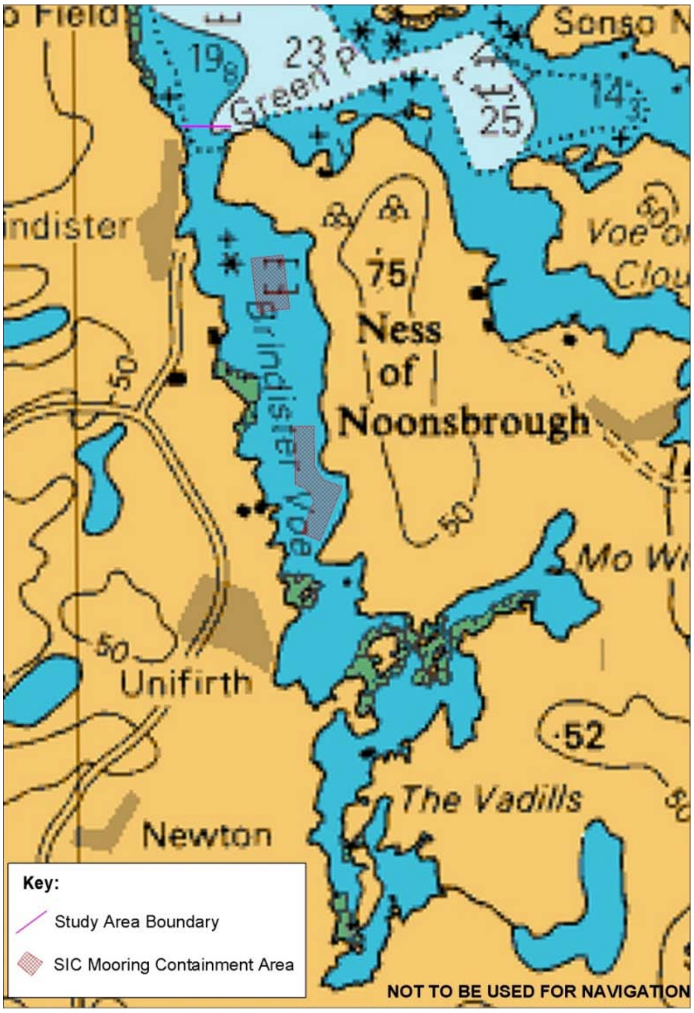
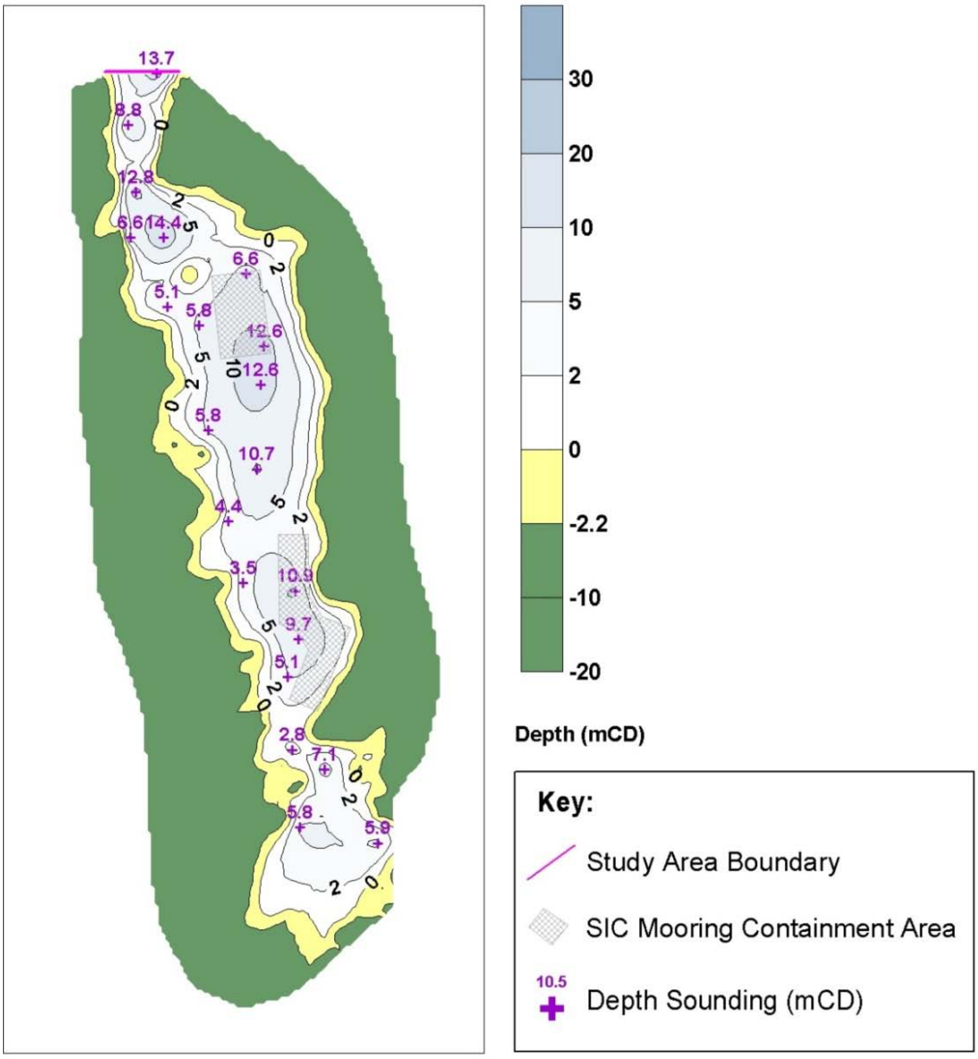


Figure 13.1 Admiralty chart extract for Brindister Voe

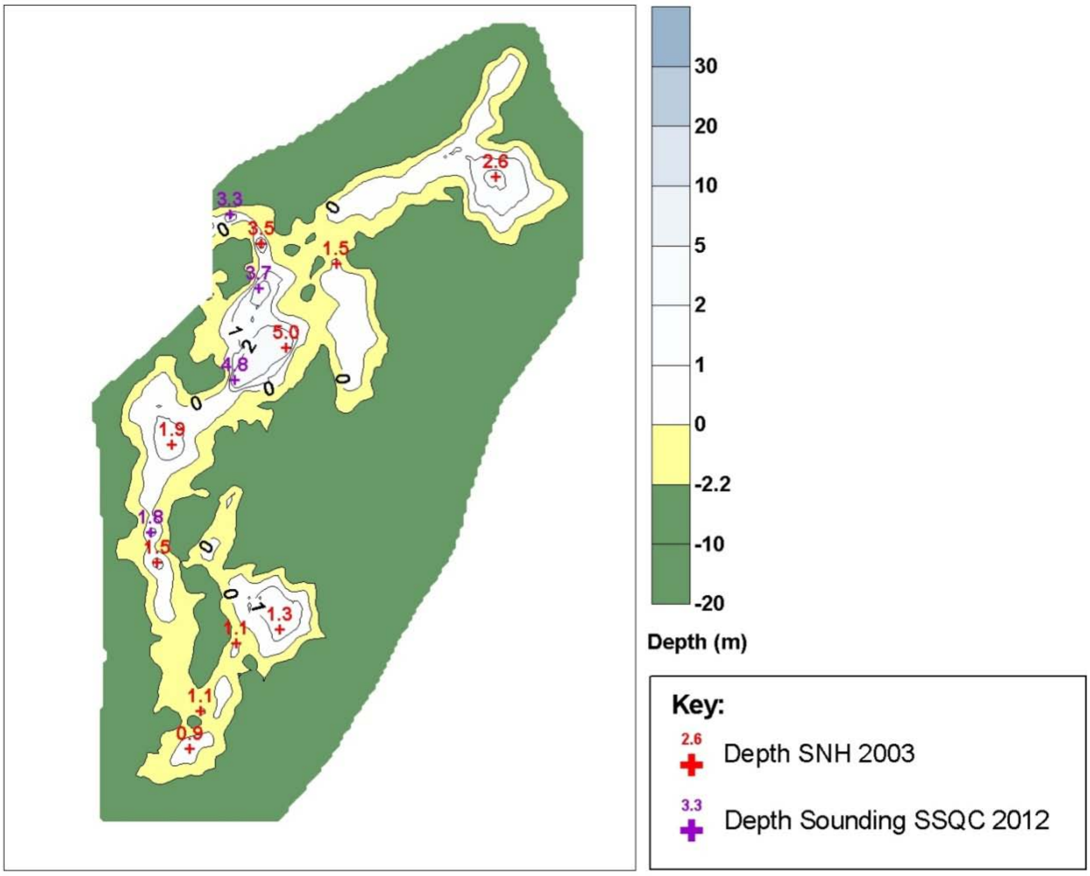
Accordingly a bathymetric survey consisting of five replicate spot depth soundings collected at 26 locations throughout the system was undertaken on the 12 November 2012 by SSQC Ltd. Soundings were corrected to chart datum (CD) by subtracting the local tide height extracted from the Admiralty TotalTide prediction for West Burra Firth, the closest port to Brindister Voe. Soundings are tabulated in Appendix 1 and are plotted on Figure 13.2.

Shallow depths at The Vadills precluded a detailed study of the lagoons however it was possible to derive some data from a Site Condition monitoring report of the SAC undertaken on behalf of Scottish Natural Heritage in 2003 (ERT (Scotland) Ltd., 2006). Here divers swam along a 100 m transect laid from the shoreline into the numerous basins and across the major channels that comprise The Vadills. A total of 10 additional depth points were derived from the known positions of these transects. The authors made no attempt to correct for the tidal state, citing a lack of data and the influence of the many rapids and narrow channels on the normal tidal rise and fall. For consistency the same approach was used with the soundings collected on the 12 November 2012 and are plotted in Figure 13.3.



Depths corrected to metres chart datum. MLWS and MHWS data extracted from Ordnance Survey Explore Sheet 467

Figure 13.2 Bathymetry at Brindister Voe



MLWS and MHWS data extracted from Ordnance Survey Explore Sheet 467

Figure 13.3 Bathymetry of The Vadills

These data were combined with data extracted from Ordnance Survey Explorer sheet 467 by manually digitising the MHWS and MLWS boundaries and contouring the vector data using Golden Software Surfer 8. Brindister Voe and The Vadills are contoured separately on account of the fact that soundings for the former are corrected to chart datum. The boundary between the voe and The Vadills follows that defined for the SAC, between HU 29000 56162 and HU 29000 56031.

The survey data highlights the presence of sills which divide Brindister Voe into a number of basins, illustrating the potential for restricting exchange at depth. Two sills are identified where the width of the voe is constricted by topography at the mouth of the voe and at Unifirth. A third larger sill is present at the northern end of the broader central part of the voe where water depth shoals to approximately five metres either side of a skerry which is exposed at low tide. The two shellfish production sites in the voe are located to the south of this sill.

Grid volume computations in Surfer allow for the estimation of the surface area and volume of each area. Positional information is related to the British National Grid to give Eastings as the “x” coordinate and Northings as the “y” coordinate in a three dimensional grid. The values presented in Table 13.1 represent the area and volume at chart datum by defining the surface “z” as zero.

Table 13.1 Brindister Voe area and volume estimations using Surfer

Parameter*	Brindister Voe
Area (km^2)	0.641
Volume (Mm^3)	2.697
Mean depth (m)	4.21
Maximum depth (m)	14.4

* All values at chart datum

As soundings for The Vadills have not been related to chart datum it is not possible to reliably estimate volume using this technique. However, as the MLWS contour is defined this area can be estimated at 0.413 km^2 (for comparison the area of the MLWS contour in Brindister Voe is calculated as 0.703 km^2).

13.3 Field Data

Historically there have been a total of six field studies in the area which give an insight into the current flow patterns and salinity levels within Brindister Voe and beyond. Four of these were conducted at marine cage fish farms to provide the required baseline information in support of applications to SEPA and Shetland Islands Council for planning and water use licence purposes, including one survey at the former fish farm at Brindister Voe which is presently a shellfish production site. Two Star-Oddi DST CTD (conductivity, temperature and depth) meters were deployed in the voe to support the sanitary survey process in 2012. Summary information of the deployments is given in Table 13.2 while their locations are illustrated in Figure 13.4.

Table 13.2 Survey Locations

Sitename	NGR	Survey Period	Equipment
Shetland Mussels shore base	HU 28273 57775	12/11/12 – 26/11/12	Star-Oddi DST CDT no. 5884
The Vadills Approaches	HU 28957 56101	12/11/12 – 26/11/12	Star-Oddi DST CDT no. 5885
Brindister Voe	HU 28486 57574	09/05/00 – 25/05/00	Nortek 500 kHz ADCP
Linga (Skewart Holm)	HU 28182 58611	13/07/01 – 01/08/01	Nortek 500 kHz ADCP
Linga (Skewart Holm)	HU 28234 58761	05/06/07 – 03/07/07	Aquadopp 600 kHz ADP
Brindister Crossroads	HU 29400 58600	16/10/98 – 03/11/98	Sensordata SD6000

Of the two surveys at Skewart Holm the earlier deployment at the site is disregarded from further study in favour of the higher precision, longer duration survey conducted in 2007.

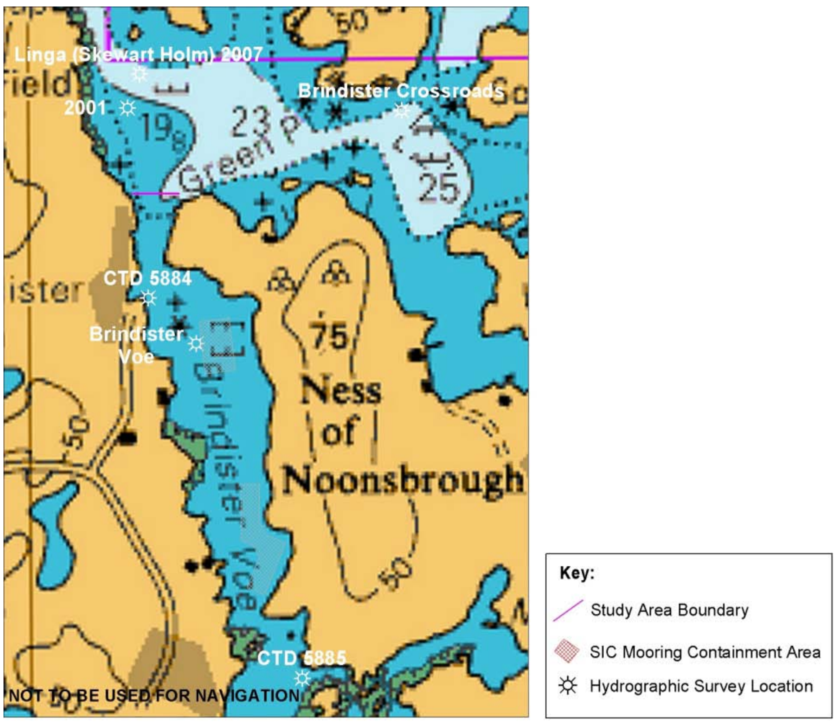


Figure 13.4 Surveys in the Brindister Voe region

13.4 Tidal Information

Information pertaining to predicted tide height is derived from the UKHO TotalTide prediction for West Burra Firth, a secondary port in the next inlet to Brindister Voe (approximately 7 km west by sea). Figures 13.5 and 13.6 show tidal curves for a fifteen day period starting on the 31 October 2012 and therefore includes the date of the shoreline survey (6 November 2012).

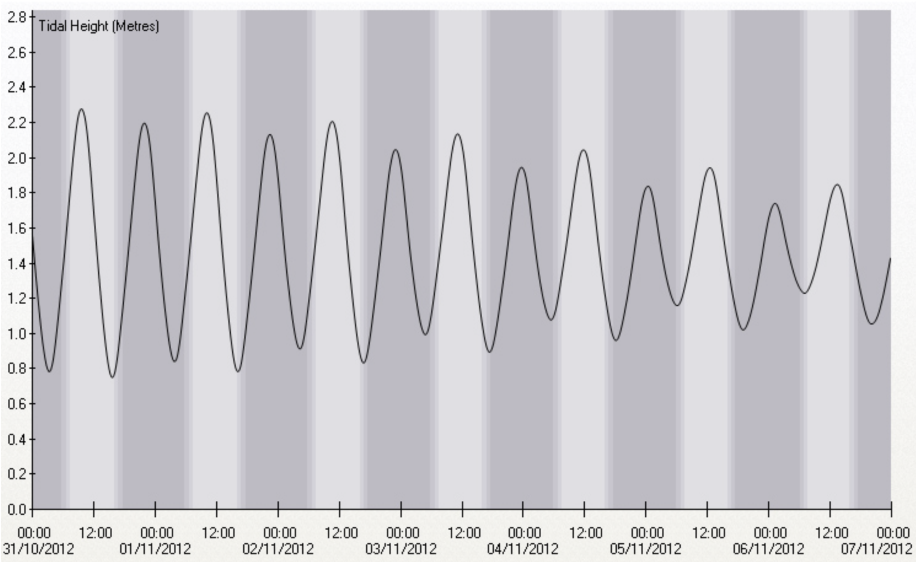


Figure 13.5 Tidal Curve West Burra Firth; 31 October to 7 November 2012

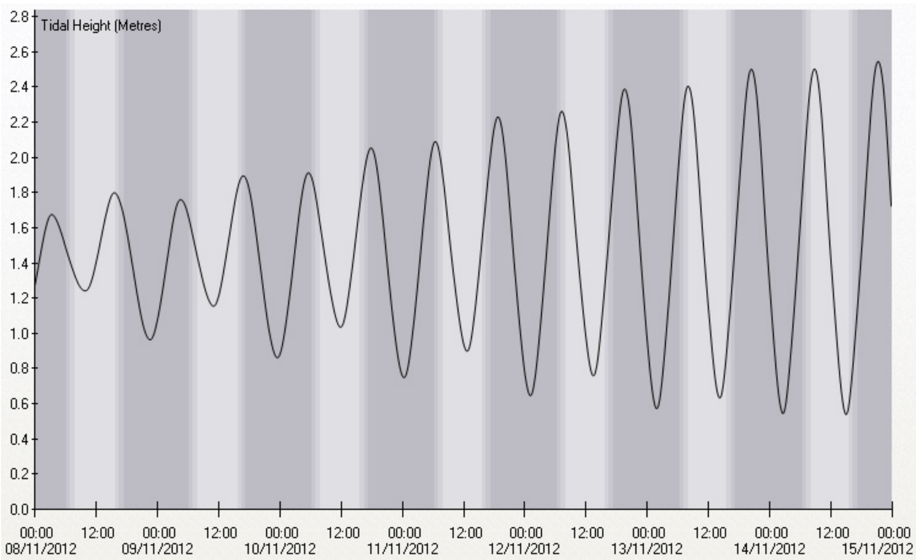


Figure 13.6 Tidal Curve West Burra Firth; 8 to 15 November 2012

Tide level information from TotalTide is summarised below. Predicted heights are in metres above chart datum.
0294A West Burra Firth is a Secondary Non-Harmonic port.
The tide type is Semi-Diurnal.

HAT	2.7 m
MHWS	2.2 m
MHWN	1.7 m
MSL	1.39 m
MLWN	1.0 m
MLWS	0.6 m
LAT	0.1 m

Based on the above West Burra Firth would be classified as micro-tidal with a low tidal range of 1.6 m for springs and 0.7 m for neaps. Comparable conditions are likely to be found at Brindister Voe on account of similar topography and geographic proximity. Limited validation of this assumption is possible through pressure data collected from *in situ* measurements at five locations in the area, described in detail in Section 3.

13.4.1 Timing

Figure 13.7 plots the first six days of the pressure record of the current meter survey deployment in May 2000. The times of high and low water for the West Burra Firth TotalTide prediction for the same period are also shown and it is apparent that the timing of these of the tidal states in the voe is consistent with the prediction. This was also observed in data collected by the Star ODDI sensors deployed in the voe in 2012, which also showed that there is no discernible difference between the timing of a high or low water event at either end of Brindister Voe.

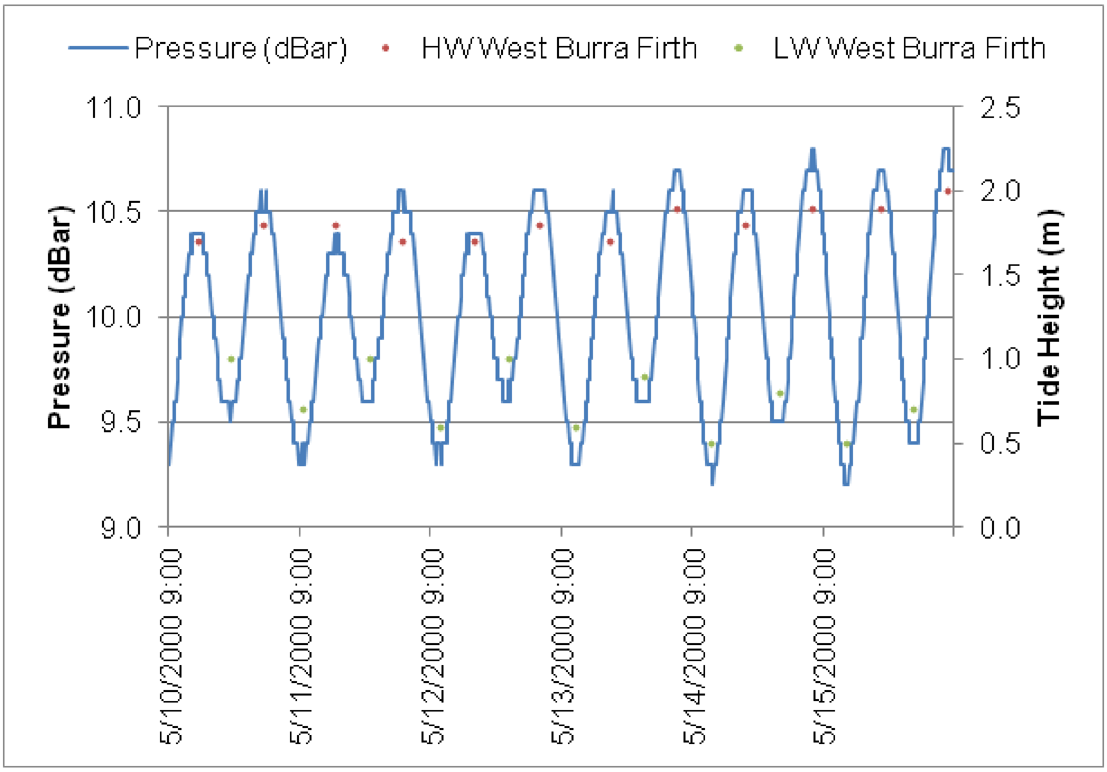


Figure 13.7 Brindister Voe 2000 pressure record compared to the TotalTide prediction for West Burra Firth.

13.4.2 Range

The average tidal range of the pressure record during the period illustrated above was 1.17 dBar. This is comparable to the average range predicted at West Burra Firth (1.05 m) for the same period. Over the entire fifteen day survey period the pressure observed was between 9.2 and 10.8 dBar equating to a range of 1.6 dBar, again comparable to the predicted springs range. A similar pattern was also observed in the Star ODDI data with an observed range of 2.1 m at the entrance to The Vadills and 2.2 m at the Shetland Mussels shore base near the mouth of the voe, compared to a predicted range of 2.0 at West Burra Firth.

13.4.3 Tidal Volume

The volume of water entering and leaving Brindister Voe on each tide is estimated by two methods. The first is a simple box model based on a “tidal prism” method (Edwards and Sharples, 1986):

$$T_f \text{ (days)} = 0.52V/0.7A.R$$

where V is the volume of the loch basin (m^3), A is the surface area of the loch (m^2) and R is the spring tidal range (m). The factor 0.52 is the number of days per tidal cycle, and the factor 0.7 approximates the mean tidal range from the spring tidal range, R. As the spring tidal range is used, inputs for volume and area pertain to those calculated for MLWS. Based on this method estimates of flushing time (T_f) and flushing rate (Q) are given below in Table 13.3

Table 13.3 Estimate of flushing rate and tidal volume at Brindister Voe using the tidal prism method.

Input:		
Volume of Voe (V)	m^3	3,101,447
Area of Voe (A)	m^2	702,628
Tidal range (R)	m	1.6
Output:		
Flushing Time (T_f)	days	2.04
Flushing Rate (Q)	m^3/year	552,373,563
Flushing Rate (Q)	m3/day	1,512,316
Flushing Rate (Q)	m^3/tidal cycle	786,405

The tidal prism method indicates that 25 % of the low water volume of the voe is exchanged during each tidal cycle and that total exchange would take two days.

The second method again utilises Surfer grid computations to estimate the volume of the voe at different tidal states by defining the “z” surface according to the tidal level and subtracting low water from high water (Table 13.4).

Table 13.4 Estimate of flushing rate and tidal volume at Brindister Voe using Surfer grid volume calculation.

Tide	**Z (m)**	**Volume (m^3)**
MLWS	0.6	3,101,447
MHWS	2.2	4,325,044
Difference (spring tide)		1,223,597
MLWN	1.0	3,359,927
MHWN	1.7	3,922,729
Difference (Neap tide)		562,802
Average		**893,200**

Both estimations of the exchange rate given should be interpreted cautiously as both employ a gross simplification of hydrodynamic properties in topographically complex area. Sill and basin features will restrict exchange at depth and lead to longer residency times while wind forcing may serve to enhance or compound exchange depending on the direction. Brindister Voe is not typical of a semi-enclosed loch system for which the tidal prism calculation is suited as the voe is the recipient and source of the tidal exchange at The Vadills. Such interactions are beyond the scope of simple box modelling techniques.

13.5 Currents

Admiralty charts provide no tidal stream information relevant to the study area.

Hydrographic studies conducted in the area related to marine fish farming are detailed in Table 3.1. Data from these studies were provided to Cefas by SEPA which archive information concerning fish farm licencing on their Public Register. Collected over a period fourteen years these data have been evaluated and re-processed to the requirements outlined by SEPA in the *Regulation and Monitoring of Marine Cage Fish Farming (Scotland) Attachment VIII* (v2.7 2008) to standardise analysis. Summary statistics for each survey are presented in Tables 5.1 to 5.3.

The tidal major axis is the long axis of the predominant tidal direction. Amplitude anisotropy is a measure of the relative scale of the currents along the tidal major axis relative to those across it. Residual speed and direction represent the net transport away from survey position during the fifteen-day assessment period and this is resolved over the three layers in the value reported as vector averaged residual. Finally the tidal excursion is an estimate based on the amplitude of tidal currents along the tidal major axis.

In summary tidal currents are not very well represented in the data from the three current meter surveys assessed. There is limited evidence for the classic tidal signature along a single linear axis typical of a location where the tide has a significant influence. In cases where one tide may be well represented in the data record, the evidence for the counter tidal flow is weak, potentially as a result of local influences (i.e. wind forcing, topography). In addition the poor quality of the data (described below) is likely to contribute to uncertainty in this interpretation.

Currents within Brindister Voe demonstrate the highest average speeds of the three locations. Close to the surface the ebb tide flows NW with a potential for transport beyond the voe while the flood tide is less clearly defined. In this instance a predominantly southerly airflow combined with the greatest fetch in this direction potentially enhanced the northerly flow at the surface and supressed the flood tide. Close to the seabed there is evidence for a counter current towards the head of the voe. Beyond the voe the area is less enclosed defined by a series of straits and open areas between islands, largely sheltered from the open sea. Generally the ebb flows to the west through the system while the flood flows to the east, although at Linga there was little evidence for the latter potentially as a result of the shelter provided by the islets adjacent to the survey location. At both locations the tidal patterns are less clearly defined at depth. With weak current speeds at all depths there is potential for wind forcing to influence currents, with some evidence for this present at Linga where a predominantly north easterly airflow appeared to result in south westerly flow on occasion.

Figure 13.8 illustrates the frequency of currents by vector and the pertinent summary statistics for near surface waters for each of the three surveys in the context of a chart of the surrounding area.

13.5.1 Data quality Assessment

The quality of the data collect is assessed against Attachment VIII to determine if each survey suitably represents the hydrographic conditions at each site. At Brindister Voe the statistics must be interpreted with care as the set up parameters of the instrument were not suited to the conditions encountered, resulting in a standard deviation of the velocity measurements (= velocity precision) which estimated to be around 0.045 m/s, or over half of the mean velocity. This affects the reliability of both the vector and velocity data returned and leads to a potentially unrepresentative “spikey” data set.

The Brindister Crossroads survey in 1998 was conducted with an array of three instruments which have a measuring threshold of 0.014 m/s, above which the measuring rotor will begin to rotate reliably. With 74% of the observations within a range of 0 to 0.03 m/s and a mean speed of 0.028 m/s the effectiveness of this type of instrument to suitably represent the low current speeds observed at the site must be questioned.

The 2007 survey at Linga (Skewart Holm) produces data that is considered acceptable to the standards defined in Attachment VII. However, while velocity precision predicted to be 0.017 m/s, below the 0.02 m/s threshold required by these standards, this still represents a predicted standard deviation which is greater than half of the observed mean speed. Once again, reliability of the data will be affected.

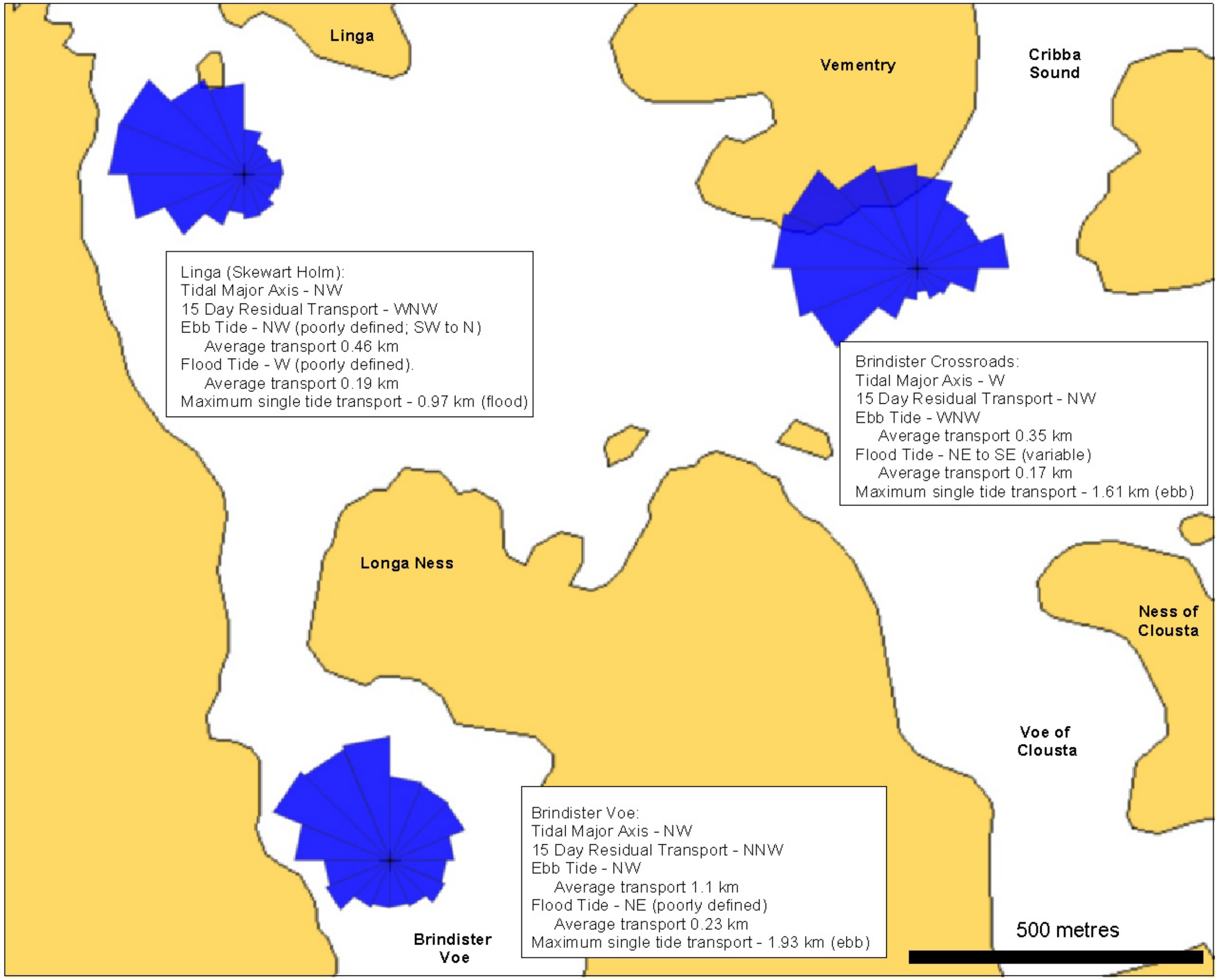


Figure 13.8 Near surface current direction frequency (bin size 22.5°) for the three surveys assessed at Brindister Voe, Linga (Skewart Holm) and Brindister Crossroads including a summary of residual and tidal transport at each location.

13.5.2 Brindister Voe

Summary statistics derived through analysis of the hydrographic data collected at Brindister Voe during May 2000 are presented in Table 13.5. Rose plots illustrating the frequency of current speeds observed against direction are given in Figure 13.9 alongside meteorological data collected during the same period.

Table 13.5 Brindister Voe summary statistics

Brindister Voe		Near Surface	Mid depth	Near Bottom
Mean speed	m/s	0.087	0.078	0.079
Tidal major axis	°Grid	315	300	140
Amplitude anisotropy	-	1.14	1.09	1.04
Residual speed	m/s	0.025	0.006	0.014
Residual direction	°Grid	335	28	114
Vector averaged residual	-	0.008 m/s at 11 °Grid		
Tidal excursion	km	1.46	1.32	1.29

The survey at the Brindister Voe marine cage fish farm in May 2000 is located on the western boundary of what is presently a mussel farm operated by Shetland Mussels. An amplitude anisotropy of below two indicates that tidal currents have a weak influence at this location. Tidal currents moving to the north have a stronger influence at the surface and mid depth than those near to the seabed, although with an anisotropy close to one very little tidal influence is present at this depth. This is consistent with the location of the deployment close to the sill which defines the northern end of the largest basin in the voe.

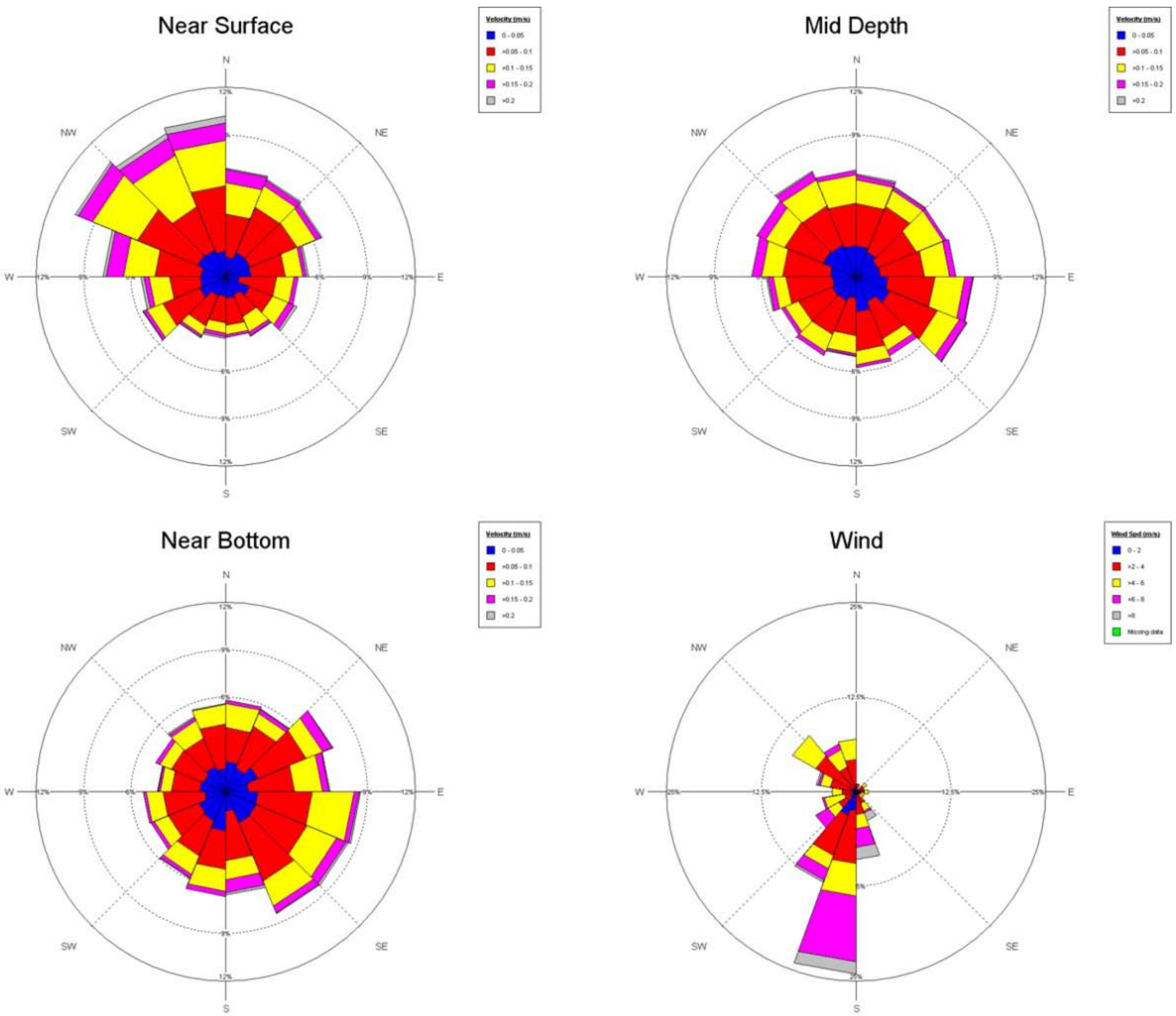


Figure 13.9 Rose plots of current and wind speed and direction for Brindister Voe.

Notes: Current direction is presented as the flow vector while for meteorological data wind measurements are recorded as the direction from where the airflow originates. The frequency of current velocity measurements for each direction segment (bin size 22.5°) is represented by the length of the segment, while within each segment the proportion of readings within a given velocity range is represented by the size each coloured division according to the legend.

Analysis of a two day period around the spring tide, when the tidal cycle is expected to have a greater influence, indicates that currents associated with the northerly flowing ebb tide can be expected to be marginally stronger than those associated with the flood tide. At depth the directionality of the tide is less well defined, although northerly currents are more likely to be encountered during the ebb tide. For near surface waters current data for each ebb and flood tide was isolated by identifying the time in the record of high and low water at West Burra Firth. Each tide was analysed independently to estimate the total transport between each tidal event (i.e. high and low water). For all ebb tides the vector averaged transport in near surface waters was 1.1 km to the NW while for flood tides 0.23 km to the NE. Maximum excursion on a single tide was 1.93 km and 1.23 km for the ebb and flood tides respectively. While it is possible to assess the current meter data according to the state of the tide it is not possible to attribute transport observed during this period solely to tidal influence. It is clear from these statistics that the classic single axis signature typical of a strongly tidal location is absent. Net movement away from the site to the north is indicated by the residual flow while the tidal excursion illustrates the potential for transport beyond the voe. Transport away from the survey position for each successive 24 hour interval during the fifteen day analysis period is illustrated for each layer in Figure 13.10.

Maximum fetch length is defined as the length of open water between the survey position and the farthest line-of-sight shoreline boundary, in this instance the shoreline at Unifirth to the SSE. With a fetch of around 1.6 km there is potential for wind forcing to influence surface currents however during the survey there were no instances of unidirectional flow persisting over the duration of a tidal cycle or longer. Maximum wind speeds encountered were Beaufort Force 4/5 predominantly from the south.

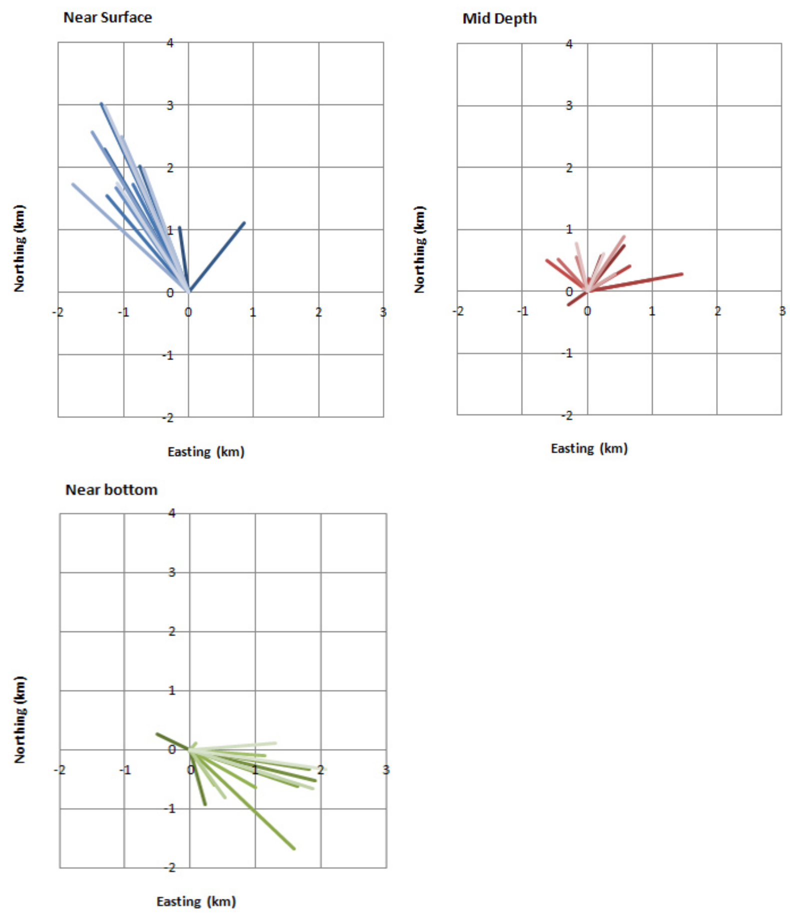


Figure 13.10 24 hour transport from the survey location at Brindister Voe

13.5.3 Linga (Skewart Holm)

Summary statistics derived through analysis of the hydrographic data collected at Linga (Skewart Holm) during June 2007 are presented in Table 13.6. Rose plots illustrating the frequency of current speeds observed against direction are given in Figure 13.11 alongside meteorological data collected during the same period.

Table 13.6 Linga (Skewart Holm) summary statistics

Linga (Skewart Holm)		Near Surface	Mid depth	Near Bottom
Mean speed	m/s	0.033	0.033	0.031
Tidal major axis	°Grid	315	135	285
Amplitude anisotropy	-	1.20	1.38	1.22
Residual speed	m/s	0.015	0.01	0.011
Residual direction	°Grid	287	189	272
Vector averaged residual	-	0.009 m/s at 263 °Grid		
Tidal excursion	km	0.55	0.61	0.53

The survey at Linga (Skewart Holm) was conducted 0.5 km north of Brindister. Topographically, the area is not similar to the study area with the greatest degree of exposure to the south east and is relatively sheltered from the north by the small islands from which the site takes its name. Current velocities are low with a tidal axis aligned NW/SE corresponding to shoreline topography. The tide has a weak influence indicated by an amplitude anisotropy of less than two and a smaller excursion than that indicated at Brindister Voe. Residual transport shows a net movement away from this location to the west towards the channel between the islands and the shoreline at Neeans. This could indicate either the stronger influence of the tide flowing along the NW or the influence of the longest fetch to the SE (~2.3 km), or a combination of these two factors. Transport away from the survey position for each successive 24 hour interval during the fifteen day analysis period is illustrated for each layer in Figure 13.12.

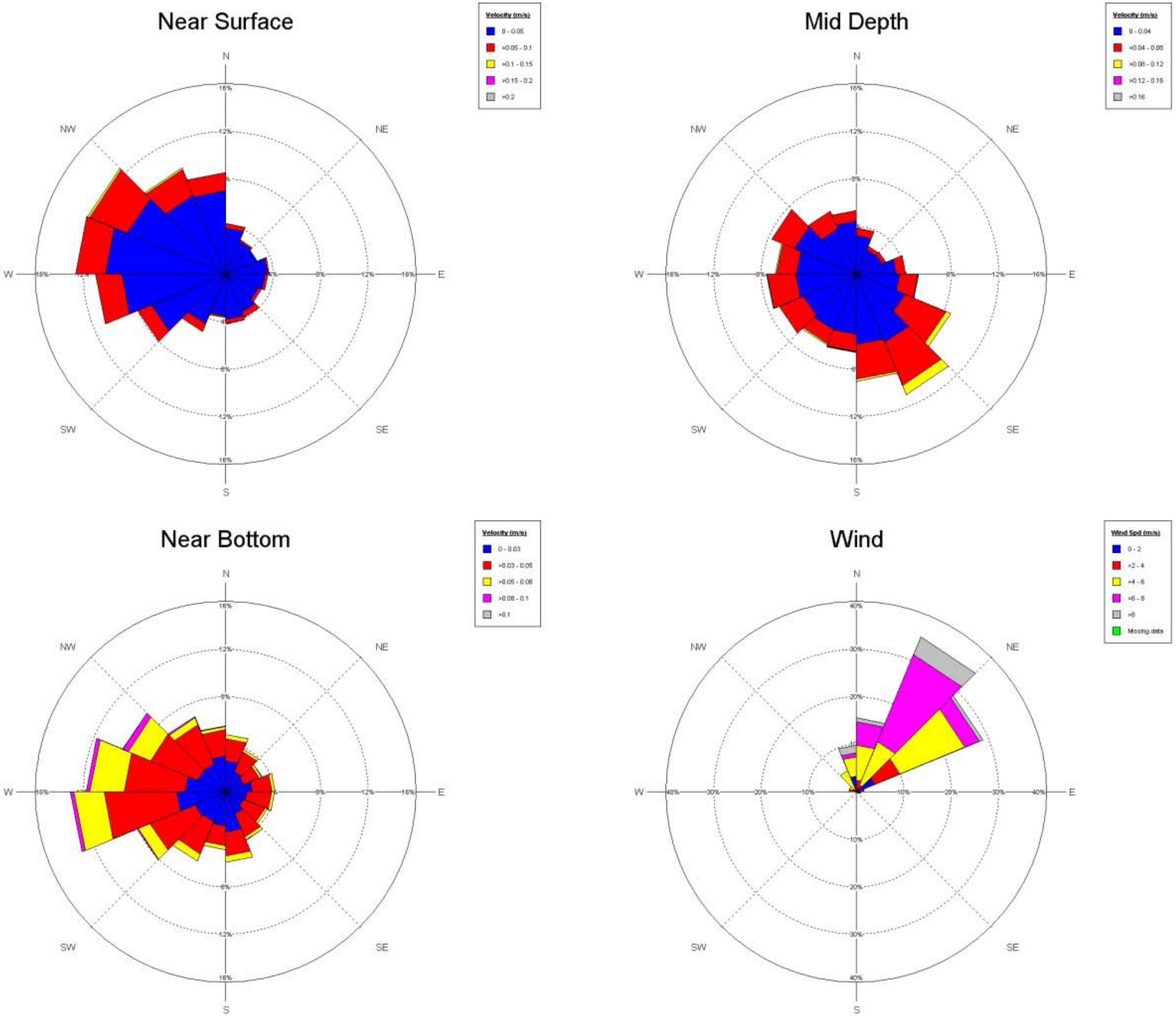


Figure 13.11 Rose plots of current and wind speed and direction for Linga (Skewart Holm).

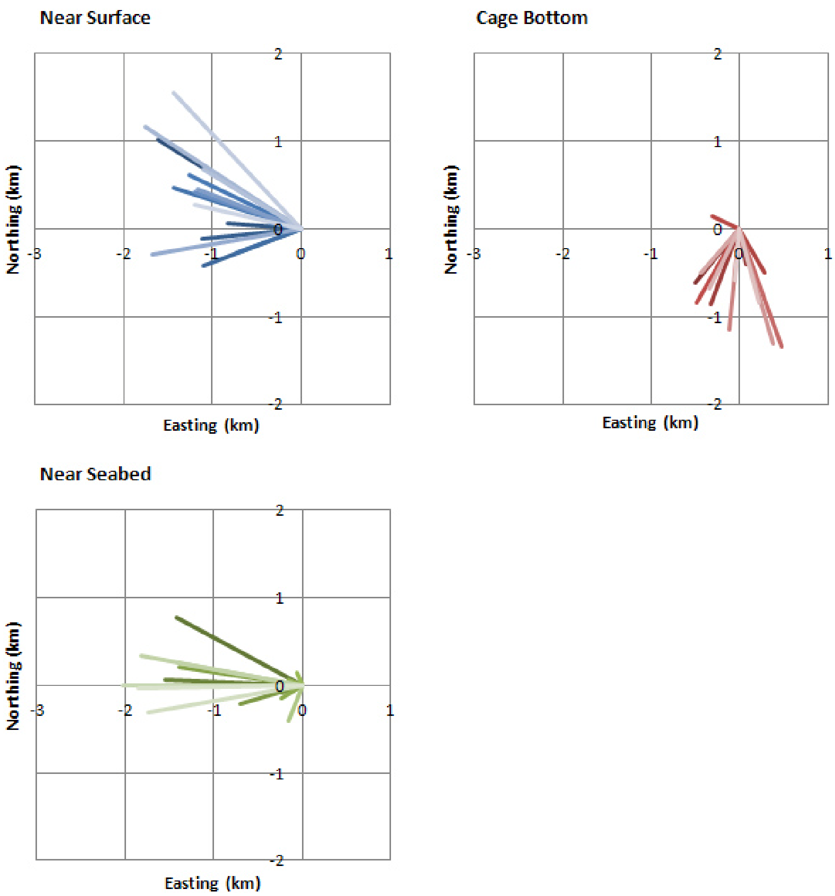


Figure 13.12 24 hour transport from the survey location at Linga (Skewart Holm).

With respect to patterns of tidal movement there appears to considerable variation with depth observed in a three day period examined around a spring tide. In general terms movement to the NW is associated with the ebb tide, although in near surface and mid depth layers this can be from SW to N on successive tides. In near seabed currents there is little directionality to the tidal currents; what might be a pattern on one tide is not necessarily repeated on subsequent tides, possibly as a result of the seabed topography associated with the proximity to the islands to the north of the survey location. The same is true of near seabed velocity, where there is little variation over the tidal cycle. Higher in the water column a pattern is present, with the highest speeds expected during or near the end of the ebb tide in near surface waters while at mid depth a stronger pulse is present at the start of the flood tide. In near surface waters analysis of individual tides indicates a vector averaged transport during ebb tides of 0.46 km to the WNW while for flood tides this would be 0.19 km to the west. Maximum transport on a single tide is 0.89 km and 0.97 km for the ebb and flood tides respectively. As with Brindister Voe there is little evidence for bidirectional tidal currents along a single axis.

Data collected during a spring tide compared to that collected during a neap tide indicates very little difference in current patterns during the lunar cycle. The exception to this are currents in the near surface layer where the effect of wind forcing cannot be ruled out as a contributing factor to small variations between spring and neap tides.

Meteorological data shows that during the survey winds were predominantly from the NE with low speeds, F4 or below. Comparing the cumulative vector plots for the wind flow and the near surface current data shows a tendency for water movement to be influenced by airflow from the NE, resulting in net transport to the SW on two occasions during the survey period. However wind transport may not be well represented in this instance, possibly because the site is sheltered from the direction from which the majority of the wind flow occurred during the survey.

13.5.4 Brindister Crossroads

Summary statistics derived through analysis of the hydrographic data collected at Brindister Crossroads during October 1998 are presented in Table 13.7. Rose plots illustrating the frequency of current speeds observed against direction are given in Figure 13.13 alongside meteorological data collected during the same period.

Table 13.7 Brindister Crossroads summary statistics

Brindister Crossroads		Near Surface	Mid depth	Near Bottom
Mean speed	m/s	0.024	0.025	0.035
Tidal major axis	°Grid	260	110	125
Amplitude anisotropy	-	1.55	1.91	3.17
Residual speed	m/s	0.007	0.003	0.024
Residual direction	°Grid	313	098	129
Vector averaged residual	-	0.006 m/s at 123 °Grid		
Tidal excursion	km	0.47	0.54	0.91

Brindister Crossroads is located at the confluence of three distinct water bodies; the Voe of Clousta to the south, the North Voe of Clousta to the east and Cribba Sound (between the island of Vementry and the Mainland) to the north. This area extends west towards Vementry Sound and the approaches to Brindister Voe. As such the site is moderately exposed with a fetch present in all four main cardinal directions. Current velocities are again low, and an amplitude anisotropy of less than two in the near surface and mid layers indicates limited tidal influence. A higher amplitude anisotropy in the near seabed data is thought to be a misrepresentation; “flat-line” data present between periods of high activity is indicative of a problem with the instruments rotor not turning freely at lower velocities leading to an over-representation of tidal currents. There is no clearly defined tidal axis common to all layers. Overall residual transport is to the SE.

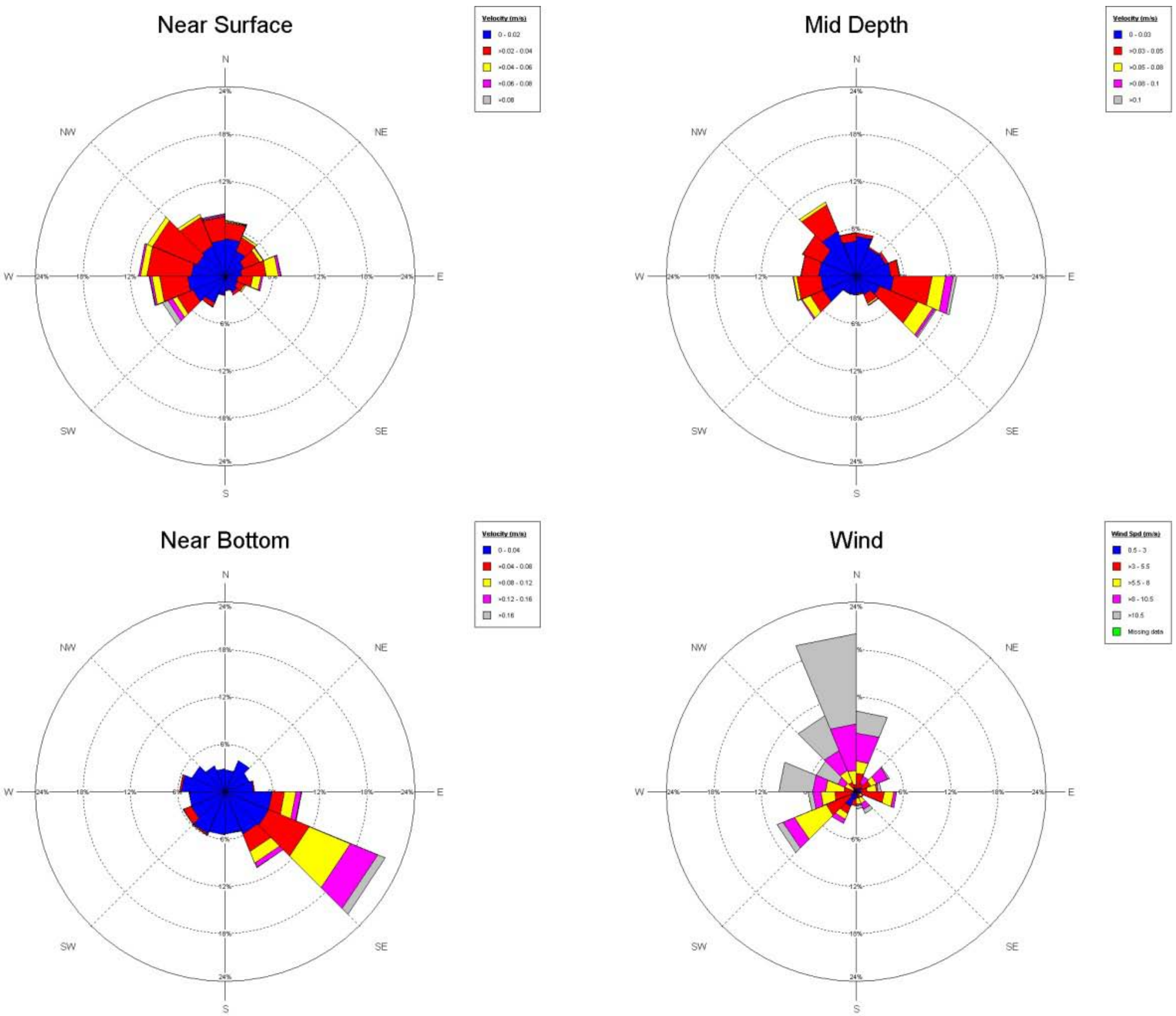


Figure 13.13 Rose plots of current and wind speed and direction for Brindister Crossroads.

Transport away from the survey position for each successive 24 hour interval during the fifteen day analysis period is illustrated for each layer in Figure 13.14

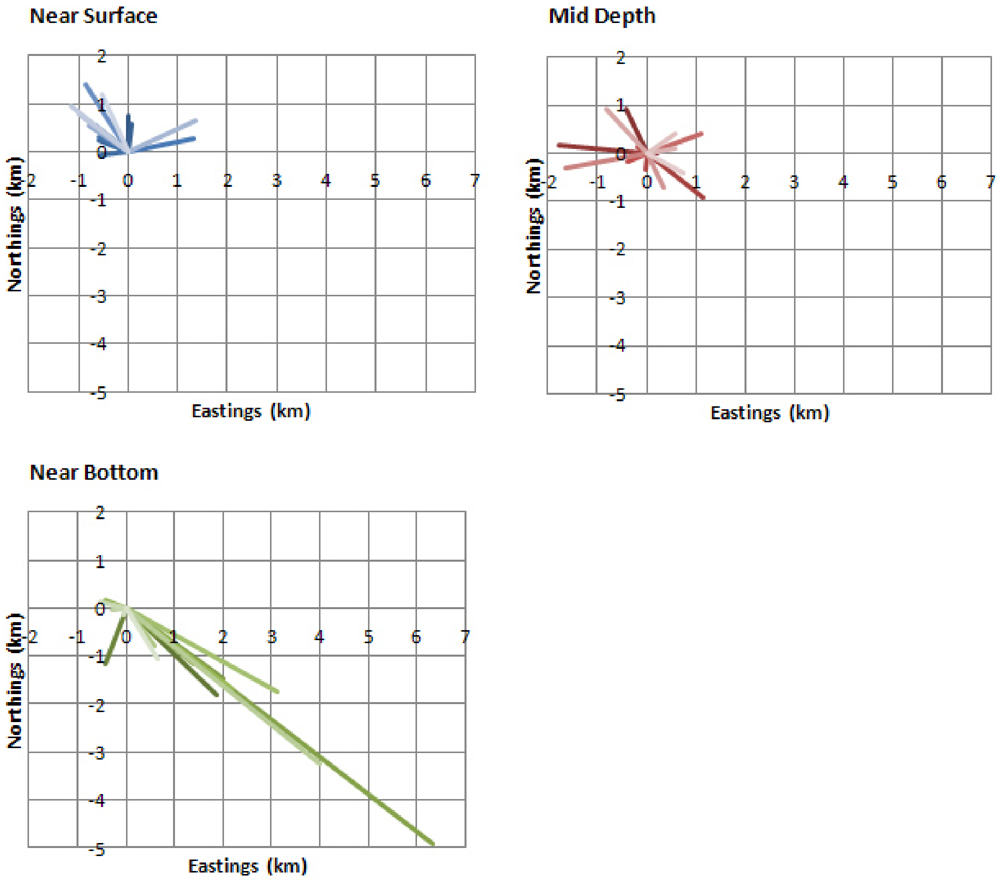


Figure 13.14 24 hour transport from the survey location at Brindister Crossroads

The tidal cycle is discernible in the time series of the current data for each layer, although data would imply that there is little consistency throughout the water column. In near surface waters the ebb tide demonstrates a general flow to the west with peak velocities in this layer often, but not always, present from the middle of the ebb to low water. The flood tide shows a more variable pattern of movement that can be between NE and SE with the strongest currents observed in the early part of this tide. In the middle and near seabed layers the peak in velocity occurs during the flood tide, and in the case of the deeper layer this appears to persist beyond high water into the ebb. In terms of direction the pattern is generally easterly for the flood and westerly for the ebb, although there is considerable variation in flow at any given stage in the cycle. In near surface waters analysis of individual tides indicates a vector averaged transport during ebb tides of 0.35 km to the WNW while for flood tides this would be 0.17 km to the NE. Maximum excursion on a single tide is 1.61 km and 0.74 km for the ebb and flood tides respectively. At this location there is more evidence for bidirectional tidal currents along a single axis.

Winds during the survey period varied with frequent peaks in Beaufort Force 6 interspersed with lows of F2/3. The majority of the stronger periods of wind forcing originated from a northerly direction, however with a net movement to the north in near-surface current record there is little evidence of wind driven transport. In addition there are no instances of unidirectional flow persisting over multiple tidal cycles.

13.6 Salinity

Salinity profiles were collected during the shoreline survey in November 2012 using a YSI Pro Plus meter with CT probe (accuracy 0.35 ppt). These measurements indicate the influence of freshwater input with lower readings in near surface waters. Nearer the mouth of the voe a change of around 0.7 or 0.8 ppt was observed over the 10m profile while towards the head of the voe profiling indicated a more uniform salinity with depth, although salinity readings were depressed compared to full strength seawater (33.4 ppt profile average).

Two Star-Oddi DST CDT loggers (accuracy 1 psu) were deployed as seabed moored installations at the northern end of the voe near the Shetland Mussels shore base and to the south near the entrance to The Vadills. The raw data demonstrate variability in salinity both spatially along the voe and temporally during the tidal cycle. This difference is greater at the entrance to The Vadills where salinity ranged from 33.51 to 34.79 psu (range = 1.28 psu) compared to the pier (34.42 to 35.33 psu, range 0.91 psu). When the accuracy of the instrument is considered the values must be reported to zero decimal places which means that a range of 34 to 35 psu is observed at both locations within the voe. While the actual salinity may be within 1 psu of the value recorded by the instrument, as both instruments were calibrated prior to the initiation of data collection it remains possible to have confidence that the spatial and temporal patterns evident in the raw data correspond to actual patterns in the voe.

Near to The Vadills at the seabed salinity levels closest to normal seawater are observed to be relatively stable for approximately three hours after local high water, after which there is a drop to the levels at the lower end of the range over a period of two to four hours. This is an indication that basins within The Vadills themselves are reduced salinity and that this water is ebbing from the system at this time. At local low water salinity begins to return to higher levels over a period of approximately three hours.

At the shore base salinity levels typical of full salinity seawater are present from local low water to approximately two hours after high water. At low water full salinity returns abruptly which is not unexpected given the proximity to the mouth of Brindister Voe and the potential for the waters beyond to readily exchange with open seawater.

The range between minimum and maximum observed salinity decreased during the six days the instruments were recording. This indicates a link to the spring-neap tidal cycle, with more water movement at the start of the survey resulting in lower salinity water at the surface getting closer to the sensors on the lower spring tides (Figure 13.15).

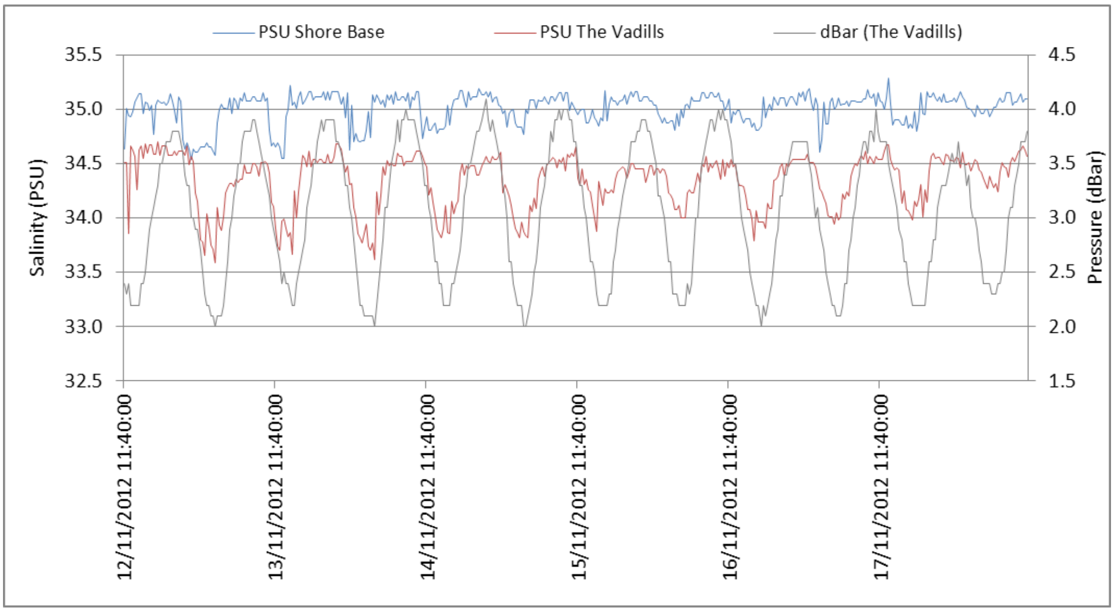


Figure 13.15 Salinity readings at The Vadills channel and the Brindister Voe shore base relative to tide height.

Note: As there is no discernible difference in the timing of the tide here or at the shore base this illustrates the pattern at both locations.

Precipitation data was supplied by Shetland Islands Council Roads department which operate a weather station at Sandness (HU 2092 5602, 7.7 km west). No direct link is evident with the highest daily rainfall totals being coincidental with the smallest ranges of salinity recorded during a tide (Table 13.7, Figure 13.16).

Table 13.8 Total daily precipitation at the Sandness road weather station compared to the observed salinity range at Brindister Voe

Date	Total daily precipitation (mm)	Salinity (psu) (accuracy 1 psu)					
		The Vadills channel			Shore base		
		Min.	Max.	Range	Min	Max	Range
11/11/2012	2.5	-	-	-	-	-	-
12/11/2012	1.2	-	-	-	-	-	-
13/11/2012	1.7	33.59	34.70	1.11	34.54	35.14	0.60
14/11/2012	2.0	33.62	34.68	1.06	34.55	35.22	0.67
15/11/2012	2.6	33.82	34.62	0.80	34.73	35.19	0.46
16/11/2012	1.3	33.88	34.65	0.77	34.81	35.17	0.36
17/11/2012	6.5	33.79	34.59	0.80	34.61	35.19	0.58
18/11/2012	6.0	33.98	34.67	0.69	34.80	35.29	0.49

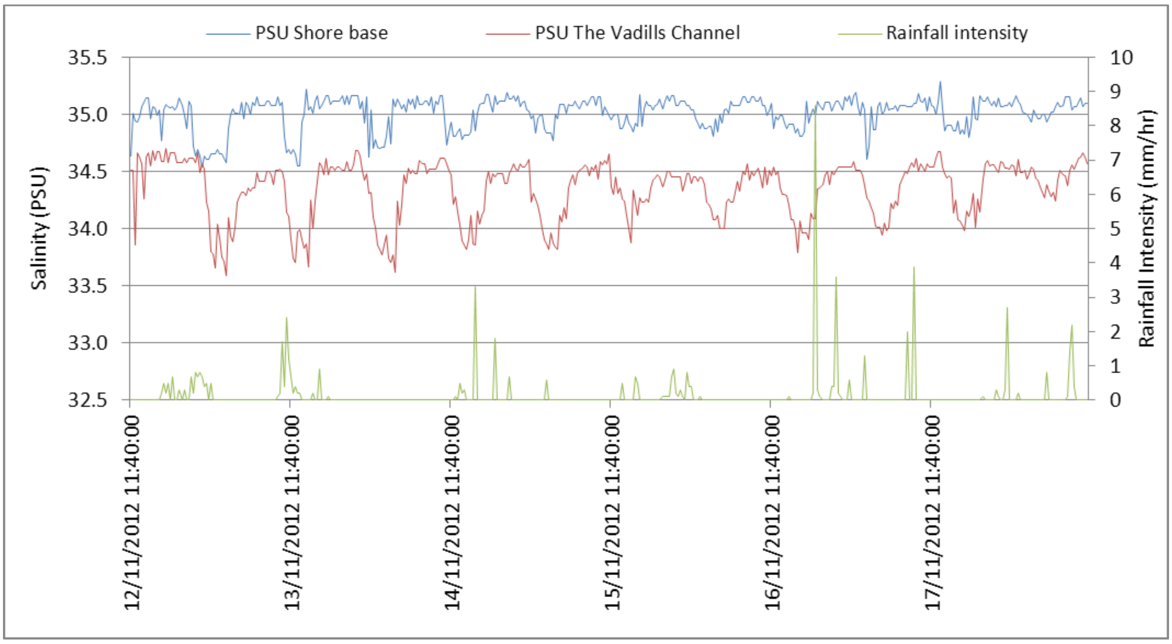


Figure 13.16Salinity readings at The Vadills channel and the Brindister Voe shore base relative to rainfall intensity at Sandness.

Regarding salinity within The Vadills system the SNH commissioned Site Condition monitoring report of the SAC (ERT (Scotland) Ltd., 2006) describes that two distinct lagoon habitats are covered by the Marine SAC designation; lagoonal inlets with regular tidal seawater exchange and where salinity is usually high, and silled lagoons where water is impounded at different states of the tide, retained by a barrier of rock where salinity may vary from full salinity through brackish to fresh water. In silled lagoons there may be season variation in salinity although in the summer readings taken during the 2003 all readings were approximate to full salinity. Freshwater enters the system from numerous streams and its influence to intertidal habitats was noted to be restricted to these locations. The authors also noted that while a large range in observed salinity might have been expected given the topography the habitats recorded were typical of extremely sheltered marine conditions rather than those associated with low salinity.

13.7 Summary

The surface area of Brindister Voe is relatively high compared to the average depth, and considering the tidal range observed there appears to be potential for the tidal exchange to represent a large proportion of the volume of the voe.

Evidence from shoreline survey, the CTD deployments and The Vadills 2003 site condition monitoring survey would indicate that there appears to be potential for surface runoff from the numerous streams entering Brindister Voe and The Vadills to measurably lower the salinity of surface waters with this influence extending at least to the seabed in a depth of five metres near the mouth of the voe. However rainfall intensity data from the region indicates that the highest daily input does not correspond to the greatest range in salinity readings measured in the voe. The first potential reason for this could be that the rainfall data from Sandness simply does not represent the rainfall at Brindister Voe. Secondly salinity measurements were collected at some distance from the source of the influence. At The Vadills rainfall is likely to have the greatest influence on salinity due to the low the volume of the system and the numerous streams entering this area. There were no readings collected directly from within this area during the CTD deployments to correlate to the rainfall data. In addition there was no direct measurement of the near surface water using the CTDs where it is expected that freshwater influence is likely to be more readily detected.

Profiles collected at both shellfish production sites during the shoreline survey recorded reduced salinity near to the surface with these profiles collected during the early part of the flood tide. There is a risk therefore that denser, full salinity water entering the voe during the flood tide will not fully mix with less dense lower salinity water near the surface, leading to the potential for contaminants carried within to persist over numerous tidal cycles.

There is not enough data to quantify the extent of mixing near the surface at the mouth of the voe. Ideally this would be in the form of salinity profiles collected throughout a tidal cycle or a CTD deployment targeting near surface water. As surface runoff has a measurable influence on the salinity of the voe it is expected that annual rainfall patterns will have a corresponding influence. Figure 7.1 illustrates the monthly total rainfall and the 24 hour average rainfall from the Lerwick Meteorological Office from 2007 to 2012. Shoreline survey and CTD deployments took place during November which typically has one of the highest rainfall rates. Seasonal variation in surface salinity could be qualified through corresponding measurements during late spring when lower rainfall would be expected.

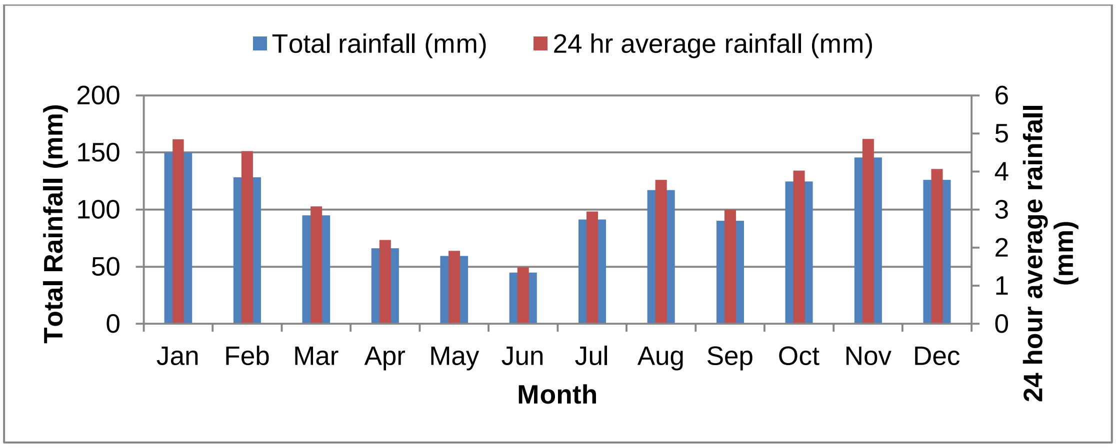


Figure 13.17 Total monthly and mean 24 hour rainfall for the period 2007 to 2012

Tidal currents within the voe follow a pattern defined by the topography with the ebb tide flowing towards the mouth of the voe with its marginal dominance over the flood tide contributing to an overall net movement in this direction. At The Vadills there are numerous narrows and shoals which serve to concentrate tidal flow producing tidal rapids. Indeed the strength of the current at the entrance to the system precluded deployment of the CTD directly in this channel. These will serve to facilitate mixing throughout the water column. Beyond Brindister Voe the flood tide appears to show a general movement west to east with the ebb tide flowing counter to this. This follows the topography of the overall area and it appears that the flood tide transports fresh seawater from St. Magnus Bay via Vementry Sound to Brindister Voe and the neighbouring inlets.

14. Shoreline Survey Overview

The shoreline survey was undertaken on Tuesday 6th November 2012 under dry, overcast conditions and breezy conditions. Heavy rainfall was reported overnight prior to the survey. Figure 14.1 shows a summary map of the significant findings from the shoreline survey at Brindister Voe.

The fishery consisted of two sites. The target site at (SI-023-406-08) was harvested at the time of the survey. The farm consisted of two adjoining lines running parallel to the shoreline. On the northern end, a single line of floats without droppers closed the lines. On the southern end there were two lines with only a few floats remaining. The harvester has permission for up to four lines on each leg, though currently only sets two on each leg.

A second site nearer to the mouth of the Voe was observed, consisting of six double headed long lines used by Shetland Mussels for spat production. This site was previously a salmon farm, but was converted to mussels approximately 1.5 years ago. The harvester did not intend to apply for classification of this site. No mature stock was present at the time of survey and a seawater sample was taken at the site which returned a result of 2 *E. coli* cfu/100 ml.

The area was sparsely populated, with only scattered dwellings present on the western shore. The eastern shore of the voe was uninhabited. Some of these private septic tanks were noted to discharge close to streams that led into Brindister Voe. One failing septic tank was observed at Biggins. With the exception of the Shetland Mussels shore base outfall there were no septic tank outfall pipes to sea or to the foreshore with the majority to soakaways where identified. Several boats were observed during the survey and were associated with the aquaculture ventures within and outside the Voe.

Sheep were observed on the western shoreline and appeared to have unrestricted access to the shoreline, though droppings were found on the shoreline. Sheep grazing on rough land on the eastern side of the voe appeared to fenced away from the shore. Land surrounding the production area is used for rough grazing for sheep and ponies, with some production of silage on the western side of the voe. Evidence of recent silage cutting was seen in fields at the north and south end of the west shore.

Geese and goose droppings were observed along the western shore, particularly where there were grassy areas. Small numbers of other birds, including eider ducks, were also seen. Two seals were observed near the western shoreline.

From the previous nights heavy rainfall evidence of surface water runoff was noted and higher flow in rivers was evident from flattened grass along river banks. Seawater salinity profiles showed a significant reduction in salinity at all depths within the vicinity of the Brindister Voe site. At the southernmost end of the mussel lines, there was almost no difference in salinity with depth, whereas at the other two locations there was a marked increase between 5 and 10 metres depth. At the new site, salinities were on the order of 1 ppt higher, and equivalent to full strength seawater by 10 metres depth.

The largest observed stream enters the Voe at the northwest shore, near the Shetland Mussels shore base. Freshwater from watercourses along the western shoreline had low *E. coli* levels of between 24 and 300 *E. coli* cfu/100 ml. One sample was taken on the eastern shoreline with a result of 190 *E. coli* cfu/100 ml. Loadings were relatively modest, with the

Seawater samples were taken at shellfish sample points and along the shoreline at near the outfall from the shorebase. Seawater samples had low *E. coli* levels between <1 to 4 *E. coli* cfu/100 ml.

Shellfish samples were taken from the southern mussel farm within the production area boundaries. Two mussel samples were taken from mussel bags at the northern end of the fishery and had results of 130 and 20 *E. coli* MPN/100 g for the surface and at 6 m respectively. At the other end of this line samples gave results of 140 and 330 *E. coli* MPN/100 g (surface and bottom respectively). Two samples were also taken from the southern lines and gave results of 490 and 230 *E. coli* MPN/100 g (surface and bottom respectively). Average levels at both locations increased from north to south towards the head of the Voe and the Vadills.

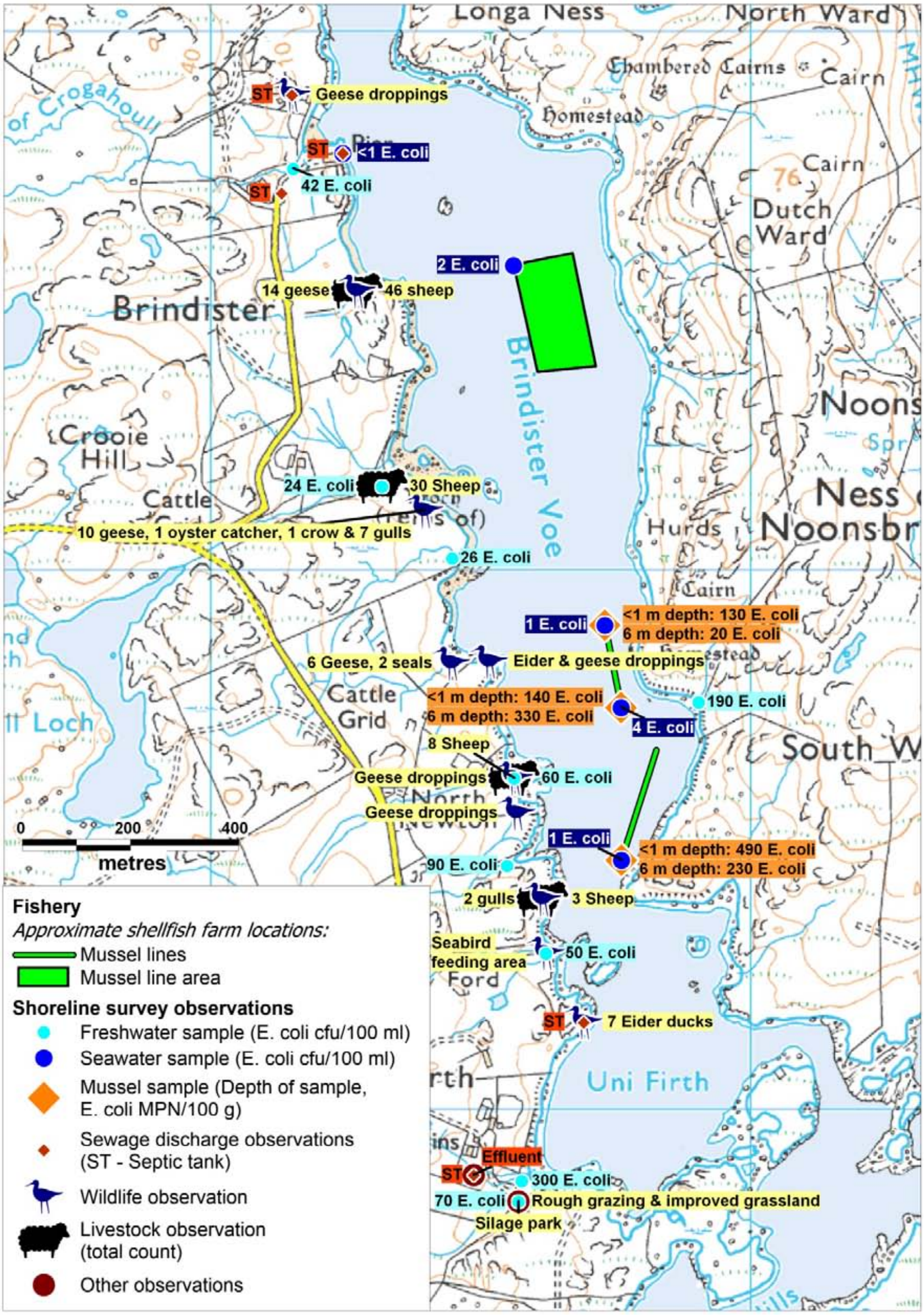


Figure 14.1 Summary of shoreline survey findings for Brindister Voe

15. Overall Assessment

Human sewage impacts

There is very little in the way of human population around the voe, with the majority of that inshore along the west side. There are no roads along the eastern side of the voe. There is no public sewerage provision in the area, and only two private septic tanks were registered with SEPA. Of these, one was observed to be in poor condition during the shoreline survey. This may have been impacting an adjacent stream. The water sample taken from this stream during the shoreline survey was the most contaminated of all the water samples taken that day.

A shore base serving the salmon and mussel farms in the voe was situated at the north end of the voe, on the western shore. A suspected outfall was observed near the jetty, though a seawater sample taken from this location did not indicate any faecal contamination.

Both mussel farms lie near the eastern shore of the voe, away from human habitation. Overall the risk of sewage contamination to the mussel farms is low as long as boats working on the site do not discharge sewage overboard in the vicinity.

Agricultural impacts

Land surrounding the production area is predominantly rough grazing. On the western shore, observed livestock were concentrated around the area of Unifirth, in the south, and on land around the shore base at the north end of the voe. Small numbers of sheep were observed across the voe on the eastern side, and these animals appeared to have access to the shore. However, as it is rough grazing, sheep are likely to move around the area and therefore impacts to the east side of the voe are likely to be relatively evenly spread.

Overall the risk of contamination from agricultural sources is low to medium, based on the presence of sheep on croft land to the west of the fishery and rough grazing areas to the east.

Wildlife impacts

Despite the remoteness of the area, relatively modest numbers of wild animals are recorded in Brindister Voe. The area is noted as important habitat for harbour seals, particularly in the central part of the voe around the Brindister Voe site. However, seals forage widely and are likely to be present throughout the voe, therefore any impacts Seals, geese and a small number of sea birds were observed in the voe during the shoreline survey. Goose droppings were observed along the western shoreline, particularly in grassy areas, where they are likely to feed. These were mainly located at Biggins, directly across from the fishery at North Newton, and near the mouth of the voe. Watercourses and overland flow of rainfall runoff will carry contamination from this source to the western side of the voe.

Seasonal variation

Little seasonal variation in human population around the voe is anticipated. Seasonal variation is expected in agricultural practices, with sheep present in higher numbers in summer and silage fields harvested in autumn and fertilised in spring.

Seasonal variation was observed in recorded rainfall at Lerwick, with drier conditions prevailing from April to June. Although there was no statistically significant variation in *E. coli* monitoring results when analysed by season, this may have been due to the bins used to split months. A trend was apparent across months, with lower results occurring from April to July. This coincided with the period of lower rainfall, suggesting that rainfall may be a significant driver of faecal contamination in the voe.

Rivers and streams

A large number of small streams and areas of land drainage are found along the shores of the voe. The largest freshwater input is to the north end of the voe, near the pier and shorebase. None of the streams observed was large, and with the possible exception of the stream adjacent to the septic tank at Biggins, none were found to have particularly high concentrations of *E. coli* at the time of sampling. However, salinity profiles taken at the fishery suggest that there is sufficient freshwater input to reduce seawater salinity to at least 10m depth around the Brindister Voe site. This effect was much smaller at the new site in the north of the voe.

Movement of contaminants

There appears to be potential for surface runoff from the numerous streams entering Brindister Voe and The Vadills to measurably lower the salinity of surface waters with this influence extending at least to the seabed in a depth of five metres near the mouth of the voe.

There is a risk therefore that denser, full salinity water entering the voe during the flood tide will not fully mix with less dense lower salinity water near the surface, leading to the potential for contaminants carried within to persist over numerous tidal cycles.

Annual and seasonal variation in rainfall may therefore be significant, though insufficient data exist on dry-weather salinity within the voe.

Tidal currents within the voe follow a pattern defined by the topography with the ebb tide flowing towards the mouth of the voe with its marginal dominance over the flood tide contributing to an overall net movement northward out of the voe.

Tidal currents recorded in the voe were generally weak, and surface currents did not show a clear bi-directional tendency, indicating that wind driven flow may have a significant effect on water movement at the surface. Particles may move on average up to 1.1 km to the NW on an ebb tide and 230 metres to the NE on the flood tide.

Due to the predicted net movement northward, sources arising to the south of the fishery may have a stronger influence over contamination levels found there than those to the north.

A statistically significant correlation was found between *E. coli* results and both the spring/neap tidal cycle and the high/low tidal cycle. Results were lower for samples taken at neap tides and on the later half of the ebb tide. Higher results appeared to occur on the flood tide. Given the uncertainty surrounding some of the sampling locations, however, it is not possible to speculate what significance this these correlations have with regard to spatial impact at the fishery. Likely particle transport distances would be lower at or near neap tides and it is possible that faecal contaminants do not reach the mussel farm during these periods. Transport at the surface is also predicted to be roughly toward the mouth of the voe but slower on the flood tide, and this doesn't seem to explain the higher results seen at this state of tide.

Temporal and geographical patterns of sampling results

Due to limitations with the recorded locations of historical samples, it was not possible to asses geographical variation in results from this dataset. Results of shellfish samples taken during the shoreline survey were higher at the south end of the lines and lowest at the north end. Samples taken from two locations, at the northern and southern extents of the farm, showed higher results at the surface than at depth. A pair of samples taken from nearer the middle of the fishery showed higher results at depth.

Although only two historical monitoring samples had results >230 *E. coli* MPN/100 g, two of the samples taken during the shoreline survey exceeded this value. These came from the middle and south end of the mussel farm.

From 2007 to 2012, there appeared to be a cyclical trend in results over the years though the cycle period varied and the underlying cause is not clear. Results were trending upward at the end of 2012.

Statistically significant relationships were found between *E. coli* results and rainfall during two and seven days prior to sampling. These correlations appeared to be driven by clusters of very low results at lower rainfall values and one or two results of 230 *E. coli* MPN/100 g after extremely high rainfall. Graphical presentation of the results showed that highest *E. coli* results occurred after low rainfall and very low results occurred across the range of recorded rainfall values. Therefore, although there is a link between rainfall and results, it is not useful in predicting compliance with the Class A shellfish standard.

There was no correlation between water temperature and *E. coli* results. Assessment of results by recorded salinity values was not undertaken due to uncertainties regarding reported salinity values during the period of assessment.

Conclusions

Overall, the Brindister Voe production area is subject to relatively little faecal contamination. The large majority of this is diffuse in origin, and may arise from human, livestock and wildlife sources though the latter two are expected to predominate.

Contamination observed in mussels appears to be rainfall associated and correlated with reductions in surface salinity in the voe, which is consistent with the observed diffuse, land-based sources. Results from mussel samples taken at different depths during the shoreline survey were mixed, showing higher results in samples taken from near the surface at two of three locations. Salinity profiles taken at the same time showed a reduction in salinity to at least 10 metres depth. Therefore any freshwater-born contamination may have been present at both sampled depths.

Seasonal variation is seen in monitoring results, as shown in the trend in *E. coli* results by month. Lowest results are seen from April to July, which also corresponds with the trend in historical rainfall over the same period.

However, much of the correlation between results and rainfall was driven by the number of very low results rather than by high results. Results exceeding 230 *E. coli* MPN/100 g occurred at low as well as high rainfall values, indicating that rainfall is a poor predictor of high results at this location.

Hydrographic analysis showed a consistent near surface flow from the head toward the mouth of the loch, which suggests that contamination carried into the loch via watercourses would move predominantly northward. Given this, it is likely that sources arising in the north of the voe from the shore station and adjacent burn would be taken out of the voe and therefore would be less likely to impact the mussel farm and spat farm to the south.

Overall Risk Table

Risk	Level
Sewage discharges	Low
Rainfall-dependent diffuse sources	Low
Wildlife sources	Low
Seasonal variability	Low

16. Recommendations

Production area

As the current production area boundaries do not include the full extent of the Brindister Voe farm, it is recommended that the boundary be adjusted northward to the mouth of the voe to include the area in which the new site is located.

The southern boundary should be restricted to exclude Uni Firth and The Vadills, as this area is not in use as part of the fishery and due to very shallow depths is not likely to be in the future. It is therefore recommended that the production area boundaries be amended to the area bounded by lines drawn between HU 2865 5630 and HU 2877 5640 and between HU 2827 5770 and HU 2858 5782 and extending to MHWS.

RMP

As the new site is not currently used for production of mussels for the table, it is recommended that the RMP be maintained at the Brindister Voe site. From samples taken during the shoreline survey, there appeared to be increasing levels of contamination toward the southern end of the site. Therefore it is recommended that the RMP be relocated to the southern end of the lines at HU 2877 5649.

As there was no stock of suitable size for sampling at this location at the time of shoreline survey, it is further recommended that bagged shellfish be placed within the recommended tolerance (below) for this location at least 2 weeks prior to sampling to ensure that the shellfish are as representative as possible of conditions at that location.

Frequency

A standard monthly sampling frequency is recommended.

Depth of sampling

Due to the possibility of contaminants being carried in lower salinity surface waters, the recommended sampling depth is 1m.

Tolerance

A sampling tolerance of 40 metres is recommended to allow for some movement of the mussel lines.

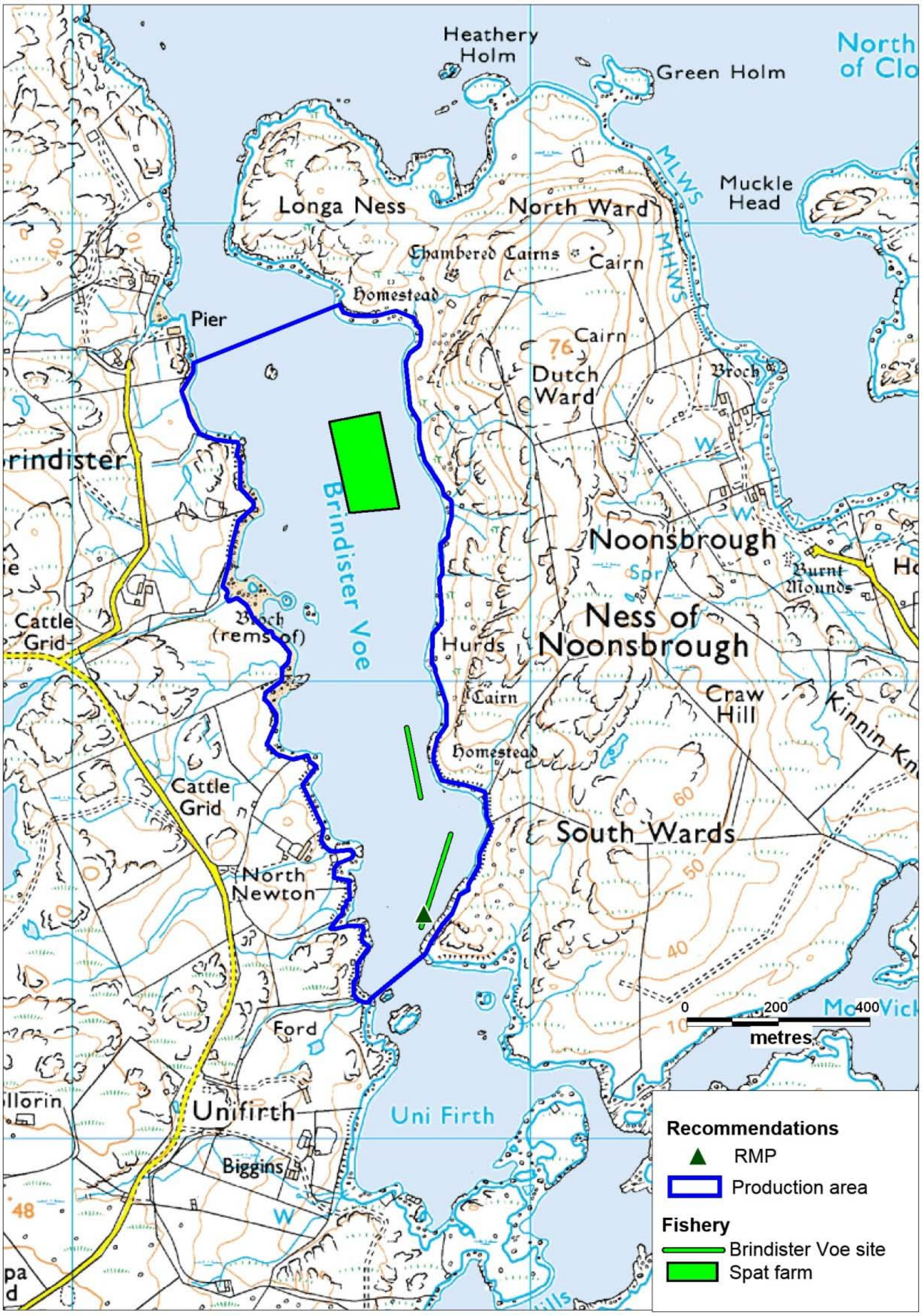


Figure 16.1 Map of recommendations at Brindister Voe

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18. List of Figures and Tables

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2. **Tables of Typical Faecal Bacteria Concentrations**
3. **Statistical Data**
4. **Hydrographic Methods Glossary**
5. **Shoreline Survey Report**

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 50-170 kg. 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 x 10^4 CFU (colony forming units) *E. coli* per gram dry weight of faeces (Lisle *et al* 2004).

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

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

Cetaceans

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

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

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

Birds

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

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

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

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

Deer

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

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

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

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

Other

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

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

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Tables of Typical Faecal Bacteria Concentrations

Summary of faecal coliform concentrations (cfu 100ml-1) for different treatment levels and individual types of sewage-related effluents under different flow conditions: geometric means (GMs), 95% confidence intervals (Cis), and results of t-tests comparing base- and high-flow GMs for each group and type. Source: (Kay, et al. 2008)

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		
Reed bed/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		

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: (Gauthier and Bedard 1986)

Statistical Data

Descriptive Statistics: Ecoli

Variable	Year	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3
Ecoli	2007	9	0	71.9	31.5	94.4	19.0	19.0	40.0	90.0
	2008	9	0	118.9	38.9	116.8	10.0	10.0	80.0	225.0
	2009	10	0	58.0	23.9	75.5	10.0	10.0	10.0	115.0
	2010	12	0	74.2	20.1	69.5	10.0	20.0	50.0	130.0
	2011	11	0	59.1	22.9	75.8	10.0	10.0	20.0	80.0
	2012	8	0	46.3	18.9	53.4	10.0	10.0	15.0	110.0

Variable	Year	Maximum	Mode	N for Mode
Ecoli	2007	310.0	19	3
	2008	330.0	10	3
	2009	230.0	10	6
	2010	230.0	20	3
	2011	230.0	10	5
	2012	130.0	10	4

Descriptive Statistics: Ecoli

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
Ecoli	59	0	71.3	10.7	82.1	10.0	10.0	20.0	130.0	330.0

```
                N for
Variable  Mode   Mode
Ecoli       10     20
```

One-way ANOVA: Log EC versus Season

```
Source  DF      SS     MS     F      P
Season   3   1.582  0.527  2.05  0.117
Error   55  14.116  0.257
Total   58  15.698

S = 0.5066   R-Sq = 10.08%   R-Sq(adj) = 5.17%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  -------+---------+---------+---------+--
1      16  1.3195  0.4007  (---------*---------)
2      16  1.5399  0.5114          (----------*---------)
3      12  1.7301  0.6154                (-----------*-----------)
4      15  1.7021  0.5084                 (---------*----------)
                           -------+---------+---------+---------+--
                                1.25      1.50      1.75      2.00

Pooled StDev = 0.5066



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       -0.2546  0.2204  0.6953           (--------*---------)
3       -0.1024  0.4106  0.9236              (---------*---------)
4       -0.1002  0.3826  0.8654              (---------*--------)
                                 ----+---------+---------+---------+-----
                                  -0.50      0.00      0.50      1.00


Season = 2 subtracted from:

Season    Lower  Center   Upper  ----+---------+---------+---------+-----
3       -0.3228  0.1902  0.7032          (---------*---------)
4       -0.3205  0.1623  0.6451          (--------*---------)
                                 ----+---------+---------+---------+-----
                                  -0.50      0.00      0.50      1.00


Season = 3 subtracted from:

Season    Lower   Center   Upper  ----+---------+---------+---------+-----
4       -0.5482  -0.0279  0.4923     (---------*----------)
                                  ----+---------+---------+---------+-----
```

```
-0.50      0.00      0.50      1.00
```

GM 36.3108 90%230 95% 230

```
Pearson correlation of ranked salinity and ranked EC = -0.332
P-Value = 0.014


Pearson correlation of ranked water temp and ranked EC = -0.061
P-Value = 0.677
```

Variables (& observations)	r	p
Degrees since full moon & LogEC (59)	0.331	0.002

Variables (& observations)	r	p
Degrees since HW & LogEC (59)	0.238	0.042

```
Pearson correlation of ranked 2day and ranked EC = 0.312
P-Value = 0.016


Pearson correlation of Ranked 7d and ranked EC = 0.458
P-Value = 0.000
```

Statistical Data

One-way ANOVA: Log EC versus Season

Source	DF	SS	MS	F	P
Season	3	1.582	0.527	2.05	0.117
Error	55	14.116	0.257		
Total	58	15.698			

S = 0.5066   R-Sq = 10.08%   R-Sq(adj) = 5.17%

```
                        Individual 95% CIs For Mean Based on
                        Pooled StDev
Level   N    Mean   StDev  -------+---------+---------+---------+--
1      16  1.3195  0.4007  (---------*---------)
2      16  1.5399  0.5114        (----------*---------)
3      12  1.7301  0.6154             (-----------*-----------)
4      15  1.7021  0.5084              (---------*----------)
                        -------+---------+---------+---------+--
                            1.25      1.50      1.75      2.00
```

Pooled StDev = 0.5066

Grouping information using Tukey method

Season	N	Mean	Grouping
1	16	1.3195	A
2	16	1.5399	A
3	12	1.7301	A
4	15	1.7021	A

Means that do not share a letter are significantly different.

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.

Appendix 4: Details of soundings obtained from Brindister Voe and The Vadills

Sounding no.	Date	Time (UT)	Easting	Northing	Latitude	Longitude	Raw depth (m)	Tide height (m)	Corrected depth (m)
1	12/11/2012	09:47	428839	1155266	60°16.834'N	01°28.823'W	1.8	-	-
2	12/11/2012	10:07	429057	1156146	60°17.307'N	01°28.579'W	3.3	-	-
3	12/11/2012	10:11	429136	1155941	60°17.197'N	01°28.495'W	3.7	-	-
4	12/11/2012	10:15	429071	1155689	60°17.061'N	01°28.568'W	4.8	-	-
5*	12/11/2012	10:27	428957	1156101	60°17.284'N	01°28.688'W	7.3	1.4	5.9
6	12/11/2012	10:34	428742	1156144	60°17.308'N	01°28.921'W	7.2	1.4	5.8
7	12/11/2012	10:36	428811	1156305	60°17.394'N	01°28.844'W	8.5	1.4	7.1
8	12/11/2012	10:38	428721	1156359	60°17.424'N	01°28.942'W	4.2	1.4	2.8
9	12/11/2012	10:40	428708	1156560	60°17.532'N	01°28.954'W	6.4	1.3	5.1
10	12/11/2012	10:42	428739	1156664	60°17.588'N	01°28.919'W	11.0	1.3	9.7
11	12/11/2012	10:43	428729	1156798	60°17.660'N	01°28.929'W	12.2	1.3	10.9
12	12/11/2012	10:46	428585	1156821	60°17.673'N	01°29.085'W	4.8	1.3	3.5
13	12/11/2012	10:49	428545	1156991	60°17.765'N	01°29.127'W	5.7	1.3	4.4

(continued…)

(Appendix 4 continued)

14	12/11/2012	10:51	428623	1157135	60°17.842'N	01°29.041'W	12.0	1.3	10.7
15	12/11/2012	10:53	428488	1157243	60°17.901'N	01°29.187'W	7.1	1.3	5.8
16	12/11/2012	10:55	428634	1157368	60°17.968'N	01°29.027'W	13.9	1.3	12.6
17	12/11/2012	10:57	428643	1157475	60°18.025'N	01°29.017'W	13.9	1.3	12.6
18	12/11/2012	10:59	428593	1157675	60°18.133'N	01°29.069'W	7.8	1.2	6.6
19	12/11/2012	11:02	428463	1157533	60°18.057'N	01°29.212'W	7.0	1.2	5.8
20	12/11/2012	11:03	428376	1157584	60°18.085'N	01°29.306'W	6.3	1.2	5.1
21	12/11/2012	11:05	428364	1157775	60°18.188'N	01°29.317'W	15.6	1.2	14.4
22	12/11/2012	11:06	428287	1157902	60°18.257'N	01°29.400'W	14.0	1.2	12.8
23	12/11/2012	11:08	428267	1158086	60°18.356'N	01°29.420'W	10.0	1.2	8.8
24	12/11/2012	11:10	428345	1158230	60°18.433'N	01°29.334'W	14.9	1.2	13.7
25	12/11/2012	11:11	428260	1158355	60°18.501'N	01°29.425'W	8.6	1.2	7.4
26[†]	12/11/2012	11:21	428273	1157775	60°18.188'N	01°29.416'W	7.7	1.1	6.6

*Location where CTD meter (Ser no. 5885) was deployed

[†]Location where CTD meter (Ser no. 5884) was deployed

Shoreline Survey Report

Production Area:	Brindister Voe
Site Name:	Brindister Voe
SIN:	SI-023-406-08
Species:	Common Mussel
Harvester:	Angus Walterson
Local Authority:	Shetland Islands Council
Status:	Existing area
Date surveyed:	6 November 2012
Surveyed By:	Michelle Price-Hayward (Cefas) Frank Cox (Cefas, observer) Sean Williamson (Hall Mark Meat Hygiene Ltd.) Vicki Smith (SSQC Ltd.) Alan Harpin (SSQC Ltd.) We are grateful to Shetland Mussels for providing a boat and to Mr. Walterson for his assistance during the marine survey work.
Existing RMP:	HU 2868 5705

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 4-17

Weather

Tuesday 6 November – Initially overcast, improving with some breaks in the cloud cover early in the shoreline walk. Cool F5 northerly breeze, easing through the day.

Preceding the survey – Sunday was mostly dry with some scattered showers and an SE–E F2/3 winds which backed NW during Monday, strengthening overnight and accompanied by heavy rain showers in the early hours.

Fishery

The location of the mussel lines are mapped in Figure 1. The fishery at the target site at Brindister Voe (SI-023-406-08) was harvested out at the time of the fieldwork. Lines are moored in a lease area with a shape consisting of two adjoining "legs" running parallel to the shoreline (Figure 4). At the northern end of the site there was a single line of floats for double headed long lines, although no droppers were present. At the southern end there were two lines, although on the inshore line the majority of the floats had been removed. Normally the harvester uses droppers with a length of 6m to 6.5m. The harvester has permission for four lines on each leg of the lease area, although currently he equips the site with just two on each leg.

The site nearer the mouth of the voe (presently with no assigned name or SI) was established approximately 1.5 years ago and consists of 6 no. double headed long lines (Figure 6). Shetland Mussels use this site for spat production on a one year turn around basis and have intimated that they presently have no intention to apply for a classification of this site. Previously a salmon farm, this site lies outwith the production area as it is presently defined although reconsideration of the boundary could occur during the sanitary survey process.

Sewage sources

Human; there are no large settlements at Brindister. The western shore has scattered dwellings, two of which have been vacant for a number of years (S.Williamson) while the eastern shore of the voe is uninhabited with no road access.

At Biggins there is a house and a small farm. A dilapidated concrete septic tank associated with this property had effluent leaking from one side to the grass below which was pooling at the bottom of the slope (Figure 8). This tank is within 2 or 3 metres of a small stream although no direct discharge to this was observed. Water sampling showed higher *E.coli* levels (300 cfu/100 ml) than a second stream (70 cfu/100 ml) which joined with this watercourse prior to entering the voe. The catchment of the second stream is to the south of the stream adjacent to the septic tank.

Sample Analysis

Freshwater sampling from watercourses at 6 additional locations along the western shore had low *E.coli* levels of between 24 to 90 cfu/100 ml. On the eastern shore a single sample returned a result of 190 *E.coli* cfu/100 ml; more than double the average of the western shore samples although a relatively low level and within the range observed on this shore.

Most properties are located away from the shore on the hillside nearer the road, at the end of which is the Westside Salmon Ltd. (a partnership between Shetland Mussels Ltd. and Hjaltland Seafarms Ltd.). Here a suspected septic tank was noted at the hard standing near the top of the pier where a stagnant smell was also present. The outfall for the tank discharged to sea and was submerged at the time (2 hours prior to HW) (Figure 7). A seawater sample indicated very low *E.coli* levels (<1 cfu/100 ml). With the exception of the Shetland Mussels shore base outfall there were no septic tank outfall pipes to sea or to the foreshore with the majority to soakaways where identified.

E. coli levels in the four sea water samples taken in the vicinity of the mussel lines at both sites were low, between 1 and 4 *E. coli* cfu/100 ml.

At the northern end of the Brindister Voe mussel site two mussel samples taken from bags provided for the sanitary survey gave results of 130 and 20 *E.coli* MPN/100g for the surface and at 6 metres respectively. Near the other end of this line the levels were 140 and 330 *E.coli* MPN/100g (top and bottom respectively). At the southern end of the second line moderate levels were observed at 490 and 230 *E.coli* MPN/100g (top and bottom respectively). Average levels at each location increased from north to south, towards the head of the voe and The Vadills.

Salinity profiles collected indicate the influence of freshwater input with lower readings in near surface waters. The YSI Pro Plus meter with CT probe used have an accuracy of ± 0.35 ppt. The salinity change from 10 metres to surface was greatest in the two northernmost profiles (0.7-0.8 ppt) while at the southernmost sample the profile was more uniform, although salinity was below full strength seawater (33.4 ppt profile average). Salinities of sea water samples analysed at the lab showed a similar pattern. Temperature profiles indicated cooler waters near the surface than at 10 m depth in all cases.

At the Westside Salmon shore base outfall, near to the mouth of the voe, normal salinity levels were present in the sea water sample.

Seasonal Population

There are no guest houses or self-catering accommodation in the Brindister area. The population is unlikely to fluctuate seasonally.

Boats/Shipping

Boat traffic in Brindister Voe is light and largely associated with shore base activities which also serves aquaculture sites beyond the voe. Here a large workboat and smaller open workboats were moored. Further south along this shore Mr Walterson operates a smaller shore base with open workboats moored to pontoons (Figure 15). Navigation buoys at the northern mussel farm mark a channel of deeper water for larger vessels to approach this site.

Farming and Livestock

The land surrounding the production area is predominantly rough grazing for sheep and ponies. While no droppings were observed on the foreshore itself they were noted on the grass above at the southern extent of the shore indicating that animals have access to the beach. Indeed there was no evidence that sheep were restricted from accessing the foreshore along the entire western shoreline. On the uninhabited eastern shore of the voe 8 sheep were observed on the hillside although it was considered likely that more were grazing in more sheltered conditions in the lee of the hill. Flocks of sheep with 20 to 30 animals were noted in each of three fields around houses in the northern extent of the survey area.

Land Use and Land Cover

The rough grassland on the eastern shore of the voe is characterised by an undulating landscape of rocky outcrops and small areas of heather (Figure 13). The open grazing is not entirely unmanaged with fencing present.

On the western shore rough grassland with some areas of improved grazing is divided into smaller fields. Silage cutting was evident in fields at the northern and southern extent of the survey area.

Watercourses

All streams and drains encountered were noted to be in spate as a result of heavy rainfall overnight. Grass along the banks was flattened indicating that recently levels were greater and that this flow responds rapidly to rainfall input (Figure 9). The largest stream enters the voe near the end of the road at the Shetland Mussels shore base (Figure 16). A single small stream on the eastern shoreline identified in the survey plan was sampled (Figure 5).

Wildlife/Birds

Eider ducks, gulls, geese, oyster catchers, and crows were recorded during the shoreline walk. Shells and crab fragments indicated that the larger promontories were used by seabirds as feeding areas (Figure 12). Two seals were observed on the western shore during the shoreline walk. Goose droppings were observed near North Newton and to the north of the shore base along the western shore of the loch.

General observations

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

Dimensions and flows of watercourses are estimated at the most convenient point of access and not necessarily at the point at which the watercourse enters the voe.

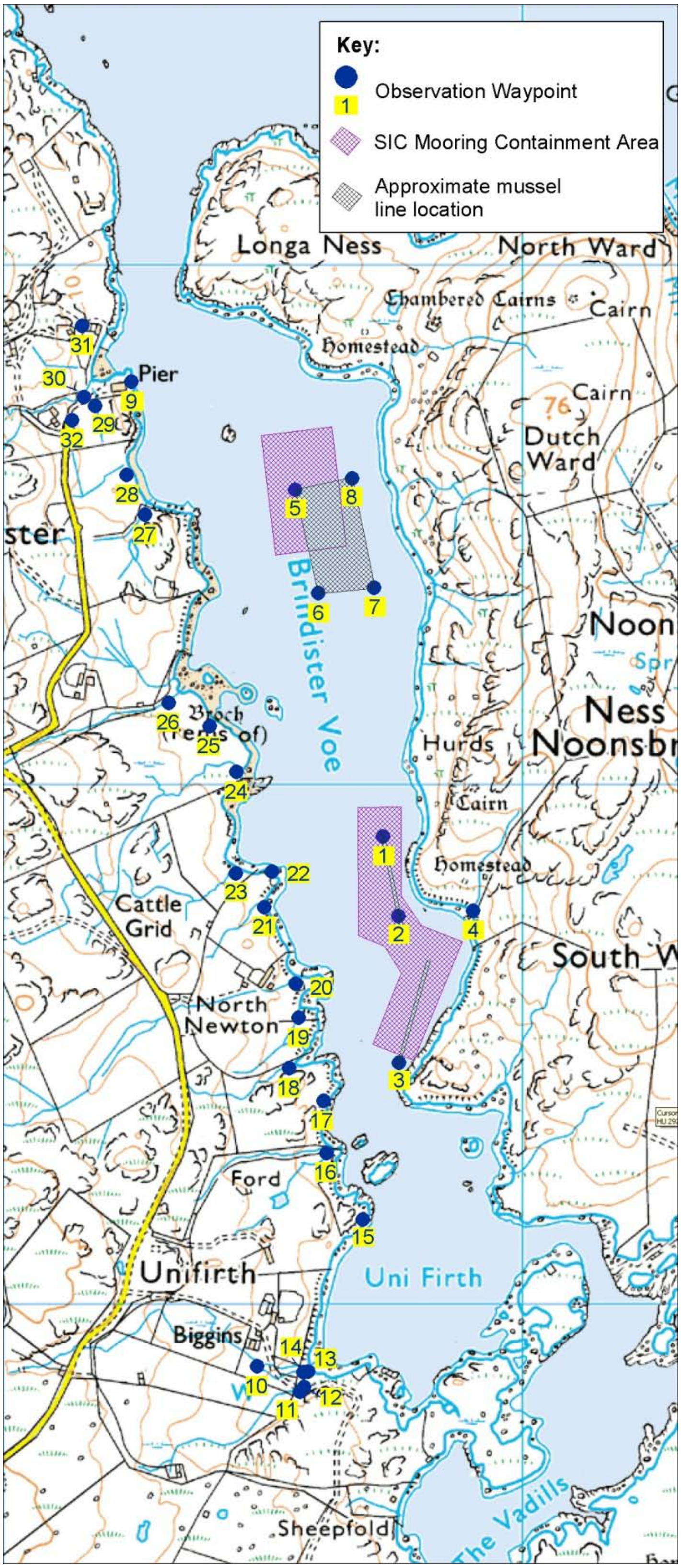

Figure 1 Map of Shoreline Observations

Table 1 Shoreline observations

No.	Date/Time (UT)	NGR	Easting	Northing	Associated Photograph	Associated Sample	Description
1	06/11/2012 09:30	HU 28732 56899	428732	1156899	Figure 4	BRI MUSS01 (top), BRI MUSS02 (bottom), BRI SW01	At northernmost end of the Brindister Voe site. Salinity profile 1 collected (ppt/°C): 10m 34.49/9.2, 5m 33.64/8.5, 3m 33.59/8.2, surface 33.59/8.4. Mussels collected (0935) from two mesh bags provided for this purpose. 1 bag at the surface and 1 at 6m depth. Seawater sample collected (0940)
2	06/11/2012 09:54	HU 28762 56746	428762	1156746		BRI MUSS03 (bottom), BRI MUSS04 (top), BRI SW02	Still at northern part of the site; approx. 1/5 along from southern end of this line. Salinity profile 2 collected (ppt/°C): 10m 34.31/9.0, 5m 33.70/8.5, 3m 33.53/8.4, surface 33.50/8.3. Mussels collected from two bags at same depths. Seawater sample collected
3	06/11/2012 10:10	HU 28763 56463	428763	1156463		BRI MUSS05 (top), BRI MUSS06 (bottom), BRI SW03	At southernmost extent of the site. Salinity profile 3 collected (ppt/°C): 10m 33.40/8.3, 5m 33.45/8.3, 3m 33.36/8.2, surface 33.35/8.2. Mussels collected from two bags at same depths. Seawater sample collected
4	06/11/2012 10:26	HU 28906 56756	428906	1156756	Figure 5	BRI FW01	Freshwater sample collected from the small burn where it meets eastern shore. Flow measured with 7 litre bucket at cascade above high water line. Time to fill bucket 1.7/1.5/1.9 seconds.
5	06/11/2012 10:40	HU 28563 57566	428563	1157566	Figure 6	BRI SW04	NW corner of northernmost site (6x double header long lines. Converted to mussel farming licence 1.5 yrs previous).Salinity profile 4 collected (ppt/°C): 10m 35.41/9.1, 5m 34.38/9.1, 3m 34.18/8.9, surface 34.13/8.8. Water sample collected.
6	06/11/2012 10:49	HU 28607 57368	428607	1157368			SW corner
7	06/11/2012 10:50	HU 28715 57378	428715	1157378			SE corner
8	06/11/2012 10:52	HU 28672 57588	428672	1157588			NE corner

9	06/11/2012 11:12	HU 28247 57774	428247	1157774	Figure 7	BRI SW05	At Westside Salmon shore base suspected septic tank, nr. the rock armouring at the top of the jetty. Stagnant smell, outfall to sea but could not see the end. Seawater sample collected from sea adjacent.
10	06/11/2012 11:37	HU 28489 55879	428489	1155879	Figure 8		At the house at Biggins. Concrete septic tank in poor condition, located adjacent to a stream. Effluent leaks on side and along grass beneath, as well as slurry pooling in boggy grass further down (within 2-3m of stream)
11	06/11/2012 11:44	HU 28572 55830	428572	1155830		BRI FW02	Rough grazing along shore, with improved graving above and silage park above. Two streams converge on the beach below here, the one mentioned at WP10 and a second to the south. Sheep droppings noted on grass. Water sample collected after culvert that takes it under track.
12	06/11/2012 11:50	HU 28580 55839	428580	1155839			Southern stream; width 25 cm, depth 25 cm, Flow 0.679 m/s st. dev. 0.011 m/s. Heavy rainfall previous night.
13	06/11/2012 11:55	HU 28588 55869	428588	1155869	Figure 9		Flow characterised for second stream, that passes septic tank in WP10. Width 55cm, Depth 10cm Flow 0.276m/s st. dev. 0.018 m/s. All streams noted to be running high with flattened grass on either bank, in some cases actively flowing over this grass.
14	06/11/2012 11:56	HU 28578 55868	428578	1155868		BRI FW03	Water sample collected upstream.
15	06/11/2012 12:09	HU 28693 56162	428693	1156162	Figure 10 Figure 11		Photographs. 7 Eider ducks disturbed from shoreline. Between here and waypoint 16 Dilapidated house at Unifirth vacant for a number of years (SW). Septic tank with a soak away, presumed inactive
16	06/11/2012 12:16	HU 28623 56290	428623	1156290		BRI FW04	Stream. Width 50cm, Depth 22cm Flow 0.52 m/s st. dev. 0.017 m/s. Water sample collected. 10 m prior to this (south) encountered a stream, too shallow and too slow to sample - overland flow

							likely as a result of rainfall. Ponded with rocks at the waters edge on the shore. Brackish pool above. Grass above the shore has shell and crab detritus indicating seabird feeding area.
17	06/11/2012 12:23	HU 28617 56390	428617	1156390			Overland flow after rain, draining marshy area. Sheep have access to the shore. On the far side of the voe, 3 sheep observed on the hillside. Appears to be a fence running parallel to the shore. 2 gulls flying up-voe.
18	06/11/2012 12:33	HU 28551 56453	428551	1156453		BRI FW05	South of property at North Newton, indicated sampling point. Width 15cm, Depth 9cm Flow 0.381 m/s st. dev. 0.10 m/s. Water sample collected.
19	06/11/2012 12:39	HU 28569 56550	428569	1156550			At North Newton. Very small stream present. Numerous geese droppings and closely grazed grass. Dwelling here has been vacant for approximately 2 years (SW). No sampling.
20	06/11/2012 12:46	HU 28564 56615	428564	1156615		BRI FW06	Moved to a stream below the house for sampling. Geese droppings. Width 22cm, Depth 13cm Flow 0.950 m/s st. dev. 0.018 m/s. Water sample collected. Now on the far side of the voe, 8 sheep observed.
21	06/11/2012 12:51	HU 28503 56763	428503	1156763			Moved north of N.Newton property. Boggy area near to the shore, draining to the sea.
22	06/11/2012 12:55	HU 28518 56831	428518	1156831	Figure 12 Figure 13		Small promontory. Eider and geese droppings, shell and crab detritus. Photographs taken, and one of far shore.
23	06/11/2012 12:58	HU 28448 56828	428448	1156828			Stream below this promontory. Width 30cm, Depth 13cm Flow 0.328 m/s st. dev. 0.013 m/s. No water sample. 6 Geese observed in flight. 2 seals swimming
24	06/11/2012 13:06	HU 28449 57023	428449	1157023	Figure 14	BRI FW07	At indicated sampling position south of the broch. Width 13cm, Depth 40cm Flow 0.303 m/s st. dev. 0.03 m/s.
25	06/11/2012 13:12	HU 28398 57111	428398	1157111			10 geese observed in flight. Oyster catcher. Crow, 7 gulls. Pony hoof prints.

26	06/11/2012 13:17	HU 28319 57156	428319	1157156		BRI FW08	At indicated sampling position adjacent to the broch, below two houses. Salmon pen floatation rings ashore. Large stream. Width 50cm, Depth 25cm Flow 0.313 m/s st. dev. 0.027 m/s. Water sample collected. 25-30 sheep observed on the hillside fields around the houses.
27	06/11/2012 13:34	HU 28273 57518	428273	1157518	Figure 15		At small jetties - Angus Walterson's shore base for the Brindister Voe mussel farm. 14 geese took flight. Drainage ditch at shore base - No sampling, no suitable point for flow measurement. Approx. 26 sheep in the field beyond shore base, another 20 in an adjacent field. Field which the shore base is in previously cut for silage.
28	06/11/2012 13:37	HU 28238 57595	428238	1157595			Drainage ditch. No sampling
29	06/11/2012 13:43	HU 28177 57728	428177	1157728			Boggy area behind Westside Salmon shore base.
30	06/11/2012 13:47	HU 28155 57745	428155	1157745	Figure 16	BRI FW09	Stream near shore base (indicated sampling position). Width 50cm, Depth 30cm Flow 0.766 m/s st. dev. 0.037 m/s. Water sample collected.
31	06/11/2012 13:58	HU 28152 57882	428152	1157882	Figure 17		Near the mouth of the voe. Septic tank at property here, soak away (also shed and abandoned property below). Field below (adjacent to the shore) cut for silage. Geese droppings.
32	06/11/2012 14:12	HU 28133 57700	428133	1157700			Septic tank at house beside road, taken from the road adjacent to the tank, approximately 2 m away to the right.

Sampling

Water and shellfish samples were collected at the locations indicated in Figures 2 and 3. As well as those defined in the survey plan one additional seawater sample was collected from the shellfish farm at the northern end of the voe and one additional freshwater sample was collected during the shoreline walk. All samples were transported initially by a cool backpack and then in a cool box to SSQC Ltd. for analysis on the same day.

Bacteriology results are present in Table 2 and 3 and mapped in Figures 2 and 3.

Seawater samples were also tested for salinity at SSQC Ltd. In the field salinity profiles were collected using a YSI Professional Plus handheld meter and CT probe which had an accuracy of (± 0.35 ppt). Results are presented in Table 4.

Table 2 Water sample *E. coli* results

No.	Sample Ref.	Date/Time	Position	Type	*E.coli* (cfu/100ml)	Salinity*
1	BRI SW01	06/11/2012 09:30	HU 28732 56899	Sea Water	1	34.23
2	BRI SW02	06/11/2012 09:54	HU 28762 56746	Sea Water	4	34.17
3	BRI SW03	06/11/2012 10:10	HU 28763 56463	Sea Water	1	33.90
4	BRI FW01	06/11/2012 10:26	HU 28906 56756	Fresh Water	190	-
5	BRI SW04	06/11/2012 10:40	HU 28563 57566	Sea Water	2	34.77
6	BRI SW05	06/11/2012 11:12	HU 28247 57774	Sea Water	<1	35.04
7	BRI FW02	06/11/2012 11:44	HU 28572 55830	Fresh Water	70	-
8	BRI FW03	06/11/2012 11:56	HU 28578 55868	Fresh Water	300	-
9	BRI FW04	06/11/2012 12:16	HU 28623 56290	Fresh Water	50	-
10	BRI FW05	06/11/2012 12:33	HU 28551 56453	Fresh Water	90	-
11	BRI FW06	06/11/2012 12:46	HU 28564 56615	Fresh Water	60	-
12	BRI FW07	06/11/2012 13:06	HU 28449 57023	Fresh Water	26	-
13	BRI FW08	06/11/2012 13:17	HU 28319 57156	Fresh Water	24	-
14	BRI FW09	06/11/2012 13:47	HU 28155 57745	Fresh Water	42	-

*Practical Salinity Scale 1978 (PSS-78)

Table 3 Shellfish sample *E. coli* results

No.	Sample Ref.	Date/Time	Position	Type	Depth	*E.coli* (MPN/100g)
1	BRI MUSS01	06/11/2012 09:30	HU 28732 56899	Common Mussel	Top	130
2	BRI MUSS02	06/11/2012 09:30	HU 28732 56899	Common Mussel	Bottom	20
3	BRI MUSS03	06/11/2012 09:54	HU 28762 56746	Common Mussel	Bottom	330
4	BRI MUSS04	06/11/2012 09:54	HU 28762 56746	Common Mussel	Top	140
5	BRI MUSS05	06/11/2012 10:10	HU 28763 56463	Common Mussel	Top	490
6	BRI MUSS06	06/11/2012 10:10	HU 28763 56463	Common Mussel	Bottom	230

Table 4 Salinity profiles

Profile	Date/Time	Position	Depth (m)	Salinity (ppt) (± 0.35 ppt)	Temperature (°C)
1	06/11/2012 09:30	HU 28732 56899	surface	33.59	8.4
			3	33.59	8.2
			5	33.64	8.5
			10	34.49	9.2
2	06/11/2012 09:54	HU 28762 56746	surface	33.50	8.3
			3	33.53	8.4
			5	33.70	8.5
			10	34.31	9.0
3	06/11/2012 10:10	HU 28763 56463	surface	33.35	8.2
			3	33.36	8.2
			5	33.45	8.3
			10	33.40	8.3
4	06/11/2012 10:40	HU 28563 57566	surface	34.13	8.8
			3	34.18	8.9
			5	34.38	9.1
			10	35.41	9.1

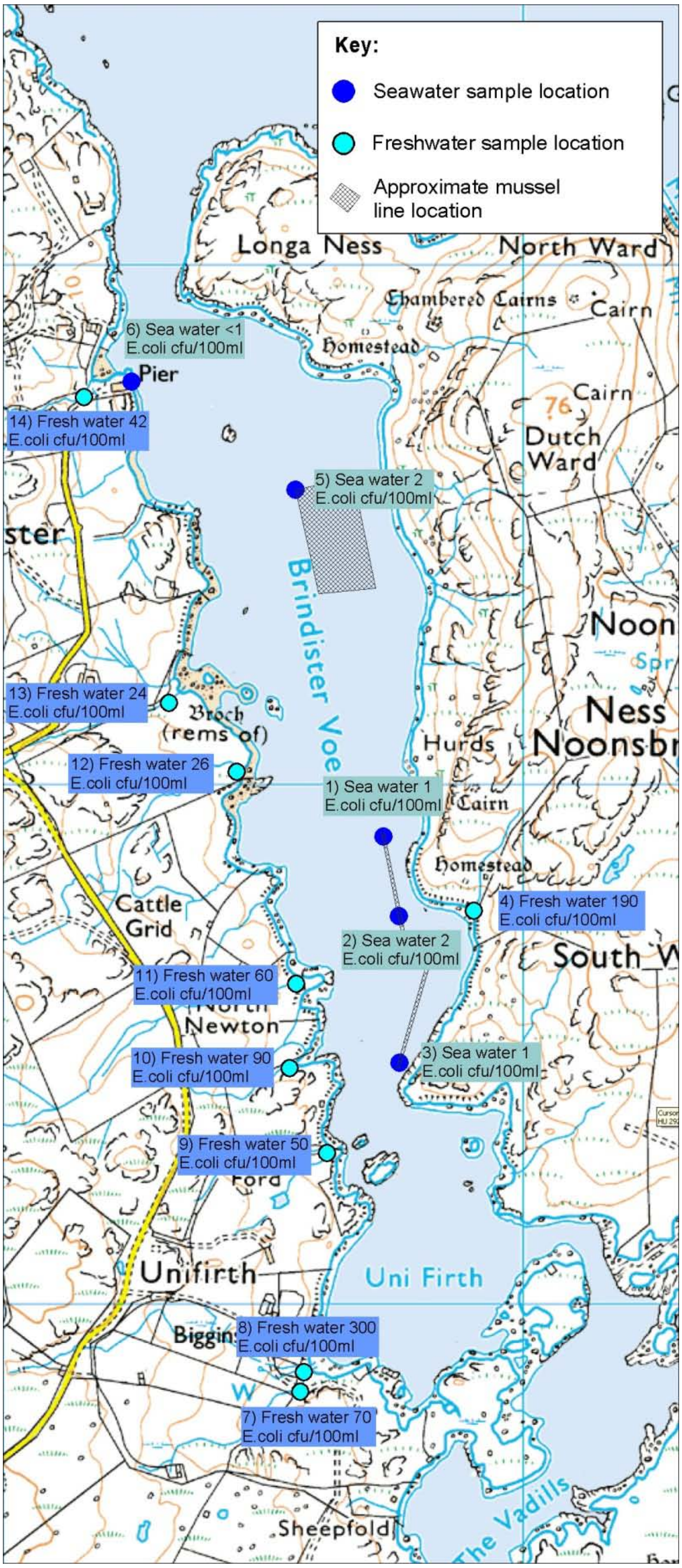

Figure 2. Map of water sample results

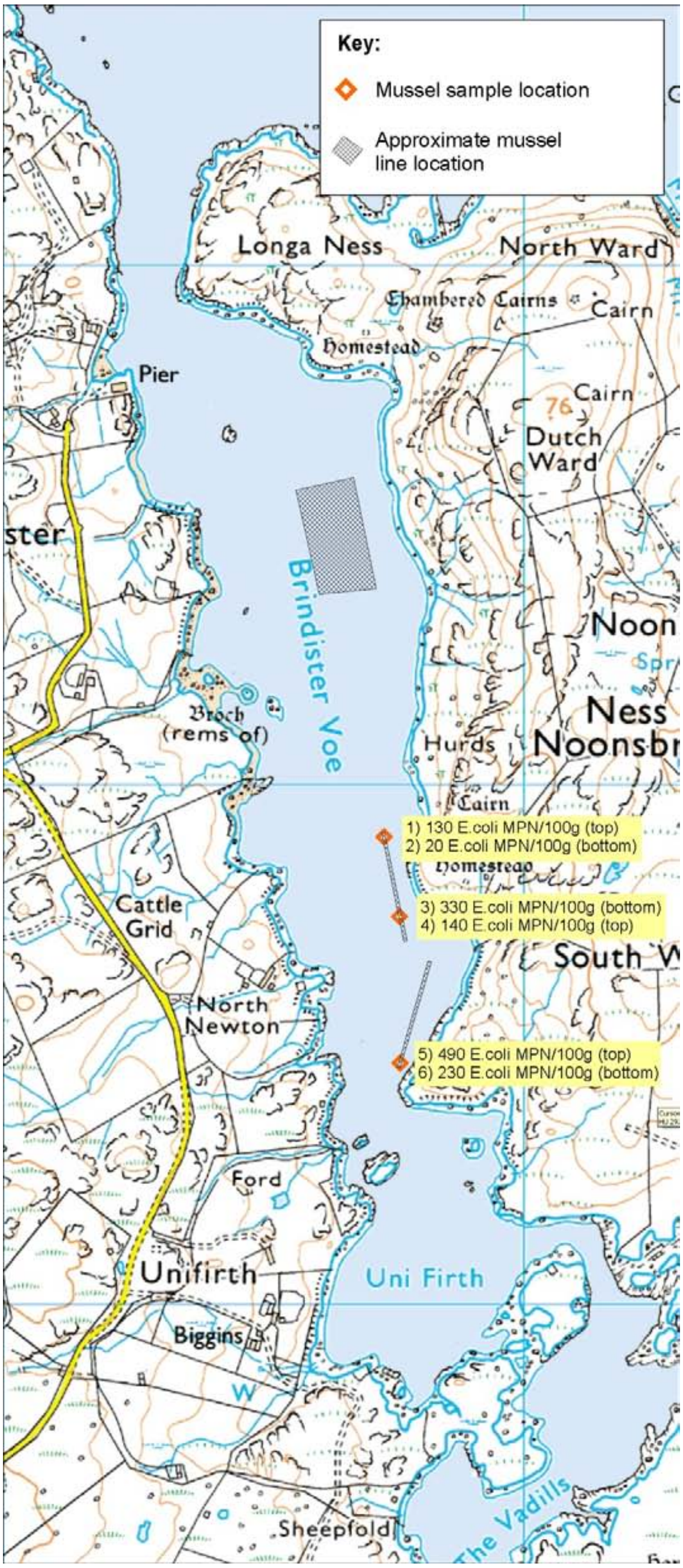

Figure 3. Map of Shellfish sample results

Photographs

Figure 4 – Lines at Brindister Voe

Figure 5 – Stream at South Wards (eastern shore)

Figure 6 – Lines at the northern site (formally a salmon farm)

Figure 7 – Outfall at Westside Salmon shore base

Figure 8 – Septic tank at Biggins

Figure 9 – Small stream with flattened grass

Figure 10 – Towards The Vadills

Figure 11 – Brindister Voe looking north

Figure 12 – Shell debris on promontory

Figure 13 – Eastern shore of Brindister Voe

Figure 14 – Flow measurements

Figure 15 – Angus Walterson's shore base pontoons

Figure 16 – Stream near Westside Salmon shore base

Figure 17 – Septic tank at the last house on the western shore.

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