Scottish Sanitary Survey Programme

Sanitary Survey Report

Production Area: Hamnavoe

SI 348

January 2012

Report Distribution – Hamnavoe

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I. Executive Summary

A sanitary survey at Hamnavoe has been undertaken as the area was first classified after 2006, when the requirement to conduct sanitary surveys under Regulation (EC) No. 854/2004 came into force. Hamnavoe is located at the southern end of the island of Yell in the Northern Shetland Islands. The area surrounding the fishery is sparsely populated, the only settlements being the small hamlets of Copister on the western shoreline and Hamnavoe, Houlland, Burravoe and Upper Neapback on the eastern shoreline.

The fishery at Hamnavoe is for mussels and uses a system supplied by Smart Farm AS consisting of 4 sets of 7 polyethylene pipes with rope collectors dropping to 2.2 m. Harvesting may be undertaken at any time of year. The current nominal Representative Monitoring Point (RMP) lies 40 m west of the mussel lines.

The principal sources of faecal contamination to the fishery are from the Hamnavoe septic tank and potentially from the smaller pipes which lie nearest to the fishery. Contaminants from these discharges would need to pass the mussel farm to exit the loch and as such impacts from these are most likely to affect the northern end of the mussel farm.

Historical monitoring showed that the underlying level of contamination appeared to be stable across the period of this assessment but, within individual years, there was a tendency for a peak in *E. coli* contamination in the latter half of the year. Further analysis showed higher levels in summer and autumn, with results in summer being significantly higher than in spring and winter. There was some correlation seen with water temperature and with rainfall prior to sampling. The general level of contamination of the mussels is low with intermittent, but ongoing, results greater than 230 *E. coli* MPN/100 g.

During the shoreline survey of the area, water samples taken from the watercourse discharging to the area indicated that the main concentration of contamination would tend to impact on the north-east end of the mussel lines.

Based on the animals observed during the shoreline survey, and the reported numbers for the agricultural parish, it is likely that a significant proportion of any faecal contamination impacting on the fishery is from diffuse, livestock sources. Direct deposition of droppings at the shoreline and in and around watercourses is likely to pose the greatest threat to water quality at the fishery. Direct runoff from the steep hillside to the west of the fishery may carry livestock faeces to the waters immediately west of the shellfish farm. Wildlife is likely to be present in modest numbers and will contribute to background levels of contamination at the fishery.

Overall the area receives some input of human sewage and agricultural diffuse pollution.

Recommendations

The recommended production area boundaries were changed slightly from the existing boundary. This was done to exclude the area nearest the head of the voe because contaminants there are likely to be more concentrated than at the fishery. The southern boundary locations were adjusted slightly to bring them in line with MHWS. The recommended production area boundaries are: the area bounded by lines drawn between HU 4900 7974 to HU 4900 7920 and HU 4835 8000 to HU 4889 8000, extending to MHWS.

It is recommended that the RMP be relocated to HU 4864 7950, which lies on the west side toward the southern end of the mussel farm.

Assessment of monitoring results from the last three years did not indicate that the area was suitable for reduced sampling frequency. Therefore, it is recommended that monthly monitoring be maintained.

As most of the potential sources of contamination to the head of the voe are likely to be found near the surface, it is recommended that the sampling depth be 1m. A 40 metre sampling tolerance is recommended to allow scope for locating a sampling rope or bag at a suitable place on the mussel farm and to allow for movement of the lines.

II. Sampling Plan

PRODUCTION AREA	Hamnavoe
SITE NAME	Copister
SIN	SI 348 736 08
SPECIES	Common Mussels
TYPE OF FISHERY	Aquaculture, longline
NGR OF RMP	HU 4864 7950
EAST	448640
NORTH	1179500
TOLERANCE (M)	40
DEPTH (M)	1
METHOD OF SAMPLING	Hand
FREQUENCY OF SAMPLING	Monthly
LOCAL AUTHORITY	Shetland Island Council
AUTHORISED SAMPLER(S)	
LOCAL AUTHORITY LIAISON OFFICER	

III. Report

1. General Description

A sanitary survey at Hamnavoe has been undertaken as the area was first classified after 2006, when the requirement to conduct sanitary surveys under Regulation (EC) No. 854/2004 came into force. Hamnavoe is located at the southern end of the island of Yell in the Northern Shetland Islands (see Figure 1.1). The voe is approximately 1.5 km in length and ranges in width from 300m at its head near Salt Ness to 700m at its mouth. The voe is oriented toward the southeast.

Figure 1.1 Location of Hamnavoe

2. Fishery

The Hamnavoe mussel fishery is a system supplied by Smart Farm AS consisting of 4 sets of 7 polyethylene pipes with rope collectors dropping to 2.2m. Harvesting may be undertaken at any time of year.

The current production area boundary is defined by lines drawn between HU 4901 7920 and HU 4901 7974 and HU 4891 8009 to HU 4864 8039, extending to MHWS. The nominal Representative Monitoring Point (RMP) is reported at HU 486 795, which lies 40 m west of the mussel lines. The actual sampling point reported by the official control sampling officer is HU 4871 7957.

The actual location of the mussel farm within the voe was recorded during the shoreline survey and is shown together with the production area boundaries, RMP and lease areas, in Figure 2.1. Both the Crown Estate lease area and the area reported by the Shetland Island Council planning department are depicted as there is some variation between them.

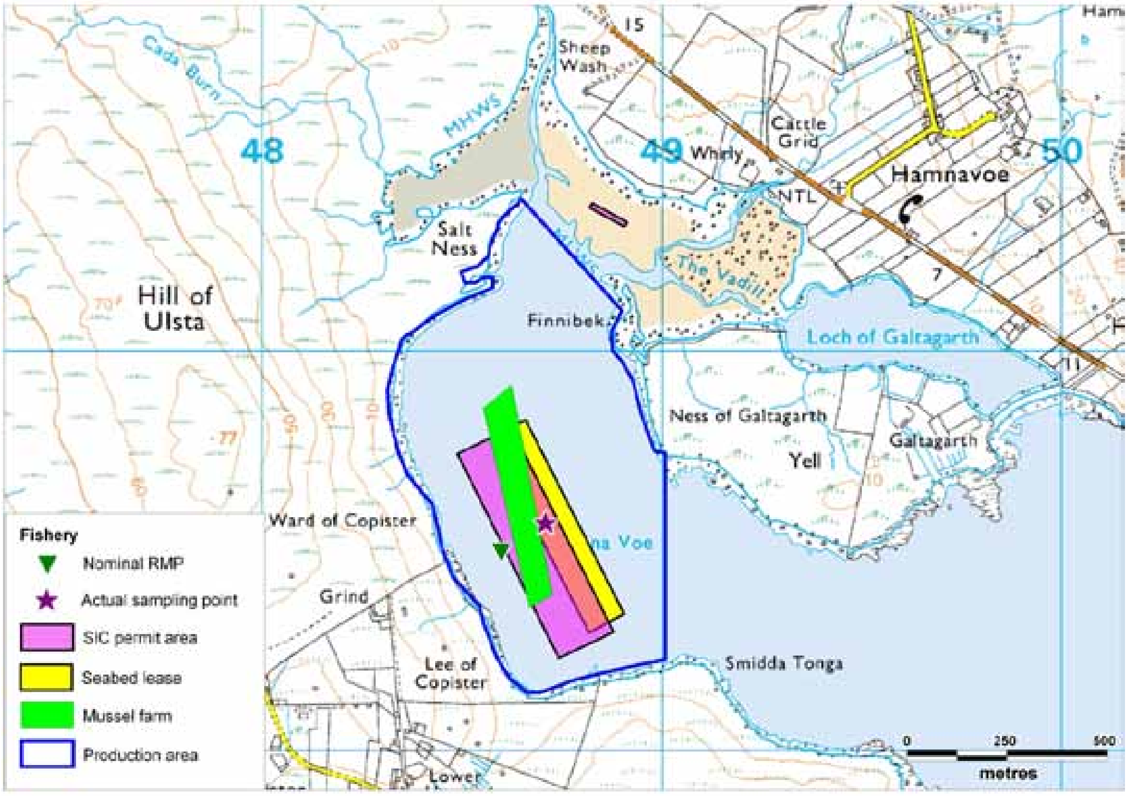

Figure 2.1 Hamnavoe Fishery

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 Hamnavoe. The last census was undertaken in 2001.

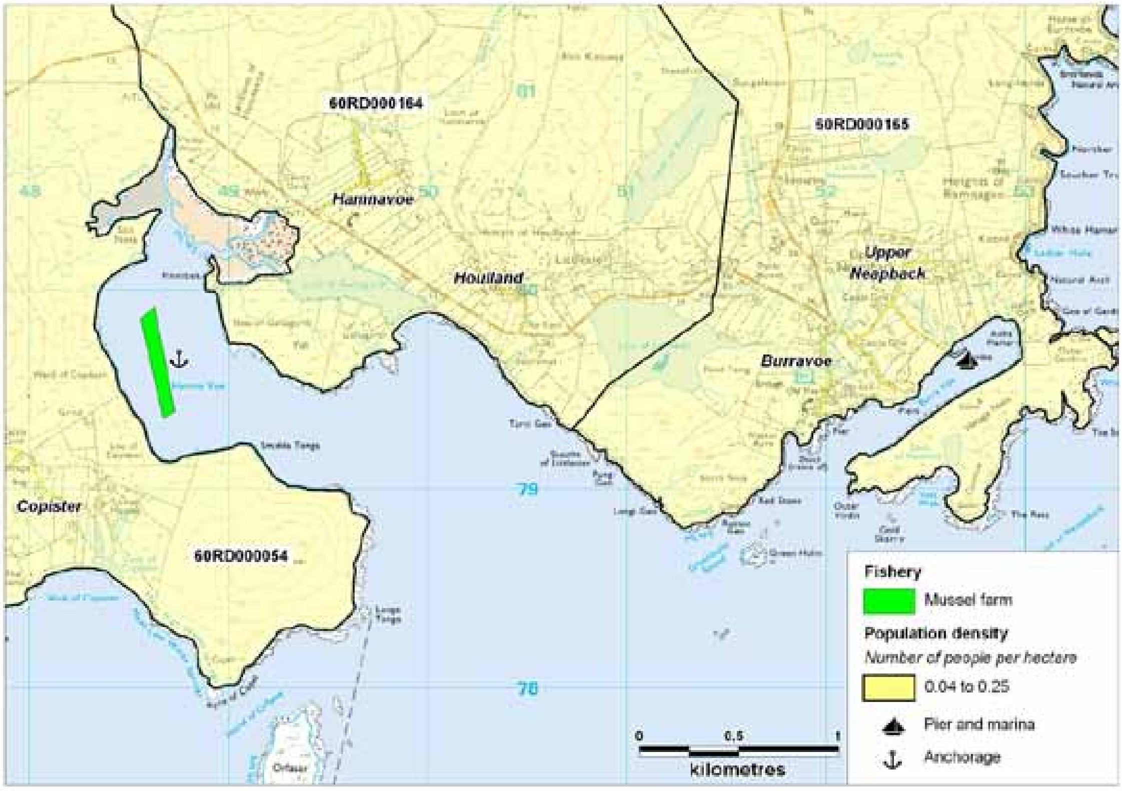

Figure 3.1 Population map of Hamnavoe

Figure 3.1 shows that the population density is low for the areas surrounding Hamnavoe. Settlement is in crofting townships along the shore, with Copister to the west of the fishery on the south side of the peninsula and Hamnavoe and Houlland along the eastern shore. Burravoe and Upper Neapback lie further to the east.

The population for each census area is listed in Table 3.1. Area 60RD000054, which includes Copister, extends nearly 11.5km northward to include four further townships and therefore only a small proportion of its population of 127 is likely to live near the Hamnavoe fishery.

Table 3.1 Census output areas: Hamnavoe

Output area	Population
60RD000054	127
60RD000164	51
60RD000165	133
Total	**311**

There is a pier and small marina at Burravoe approximately 4km east of the fishery. No hotels or B&B's were observed in the area surrounding the fishery during the shoreline survey. The island of Yell is popular with wildlife enthusiasts and walkers.

An anchorage was identified in the upper part of Hamnavoe, where the mussel farm is currently located (Clyde Cruising Club, 2003 with amendments to 2011). Although largely obstructed by the mussel farm, it may still be possible for small yachts to anchor to the south or east of the mussel farm. Any overboard discharges of waste in the vicinity could significantly affect water quality at the mussel farm. It is not known how often this anchorage is used, however the presence of the mussel farm in the most protected part of the voe would likely discourage most yachts from using the voe.

4. Sewage Discharges

Information on sewage discharges to the area was sought from Scottish Water and the Scottish Environment Protection Agency (SEPA). Scottish Water identified two septic tanks in the vicinity of Hamnavoe. A third septic tank was identified at Bay of Ulsta, which lies 2.2km west, overland, from the Hamnavoe mussel farm. However, the distance contaminants would need to travel between the two is over 6 km. These are identified in Table 4.1.

Table 4.1 Discharges identified by Scottish Water

Consent Ref No.	NGR of discharge	Discharge Name	Discharge Type	Level of Treatment	Consented flow m^3/day	Consented Design PE
CAR/L/1002263	HU 495 807	Hamnavoe ST	Continuous	Septic tank	NA	250
CAR/L/1002245	HU 518 792	Burravoe ST	Continuous	Septic tank	37.5	150
CAR/L/1002287	HU 464 795	Bay of Ulsta ST	Continuous	Septic tank	11.25	45

No sanitary or microbiological data were available for these discharges.

SEPA provided information on a small number of consented discharges, which are listed in Table 4.2. No information was provided regarding the consented flow or design Population Equivalent (PE) of these discharges. The majority appear to serve single homes and would therefore each discharge relatively very small volumes of sewage.

Table 4.2 Discharge consents identified by SEPA

No.	Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consented/ design PE	Discharges to
1	CAR/R/1078285	HU 4832 7891	Sewage (private)	Septic tank	-	-	Soakaway
2	CAR/L/1002263	HU 4960 8015	Sewage (Public)	Primary	-	-	Loch of Galtagarth, Yell
3	CAR/R/1076441	HU 5047 7992	Sewage (private)	Septic tank	-	-	Soakaway
4	CAR/R/1078610	HU 5078 7975	Sewage (private)	Septic tank	-	-	Soakaway
5	CAR/R/1069793	HU 5124 8004	Sewage (private)	Septic tank	-	-	Soakaway
6	CAR/R/1078708	HU 5410 8003	Sewage (private)	Septic tank	-	-	Soakawat
7	CAR/R/1078612	HU 5151 8015	Sewage (private)	Septic tank	-	-	Soakaway
8	CAR/R/1010061	HU 5156 8001	Sewage (private)	Septic tank	-	-	Soakaway
9	CAR/L/1002245	HU 5180 7220	Sewage (Public)	Primary	-	-	Burra Voe
10*	CAR/L/1002287	HU 464 795	Sewage (Public)	Untreated	-	-	Bay of Ulsta

* This discharge lies west-northwest of the mapped area in Figure 4.1.

In addition to the discharges identified above, two consents related to marine cage fish farms, which are identified for reference in Figure 4.1, though not listed in the table. One of these lies immediately adjacent to the mussel farm and most likely related to a previous use of the same site. These fish farms are not considered to be a significant source of faecal indicator bacteria though they discharge other types of contaminants to the marine environment. Sewage infrastructure recorded during the shoreline survey is listed in Table 4.3.

Table 4.3 Discharges and septic tanks observed during shoreline surveys

No.	Date	NGR	Description
1	18/08/2011	HU 49575 80179	Outfall pipe and septic tank leading from houses, end below water

The only sewage discharge observed during the shoreline survey relates to the Hamnavoe septic tank outfall, which lies approximately 40 metres NNW of the grid reference identified in the SEPA consent. A review of satellite imagery of the area suggested the outfall extends approximately 25 metres from the shore. A seawater sample taken from near this pipe returned a result of 4700 *E. coli* cfu/100 ml, confirming that the outfall was active at the time of survey. Although two other pipes were observed, these did not appear to carry sewage. A small flow observed from one of the pipes was sampled and found to contain a relatively low concentration of *E. coli* (50 cfu/100ml), suggesting that it may have been surface water drainage.

Discharges from the Hamnavoe septic tank and any potential discharges from the smaller pipes which lie nearest to the fishery and any contaminants arising from these sources would need to pass the mussel farm to exit the loch. Impacts from these are most likely to affect the northern end of the mussel farm. The Burravoe septic tank discharges outside Hamnavoe and therefore is less likely to impact on the water quality at the mussel farm, which is located well inside the voe.

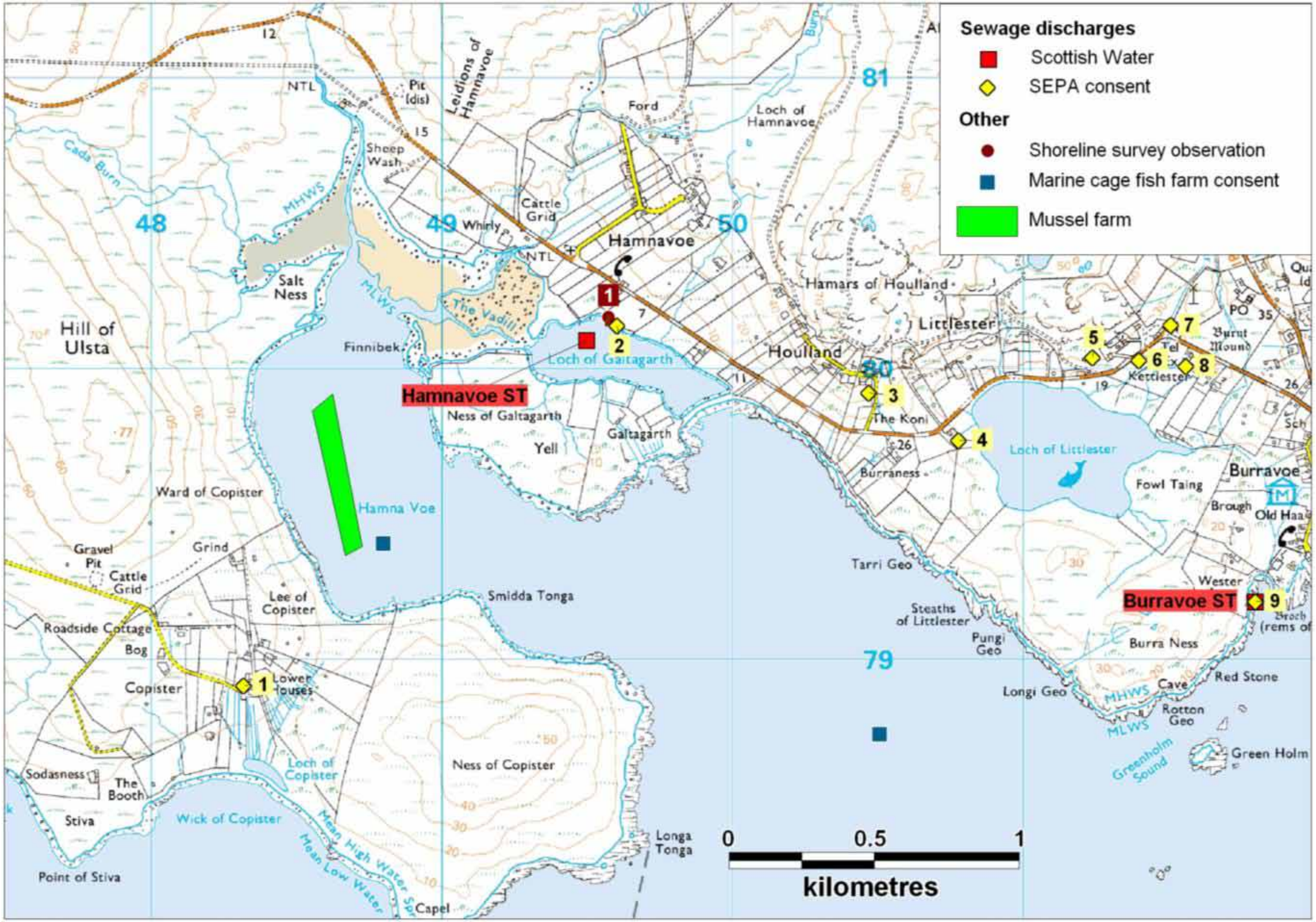

Figure 4.1 Map of discharges for Hamnavoe

5. Geology and Soils

Geology and soil types were assessed following the method described in Appendix 1. A map of the resulting soil drainage classes is shown in Figure 5.1. Areas shaded red, orange and pink indicate poorly draining soils.

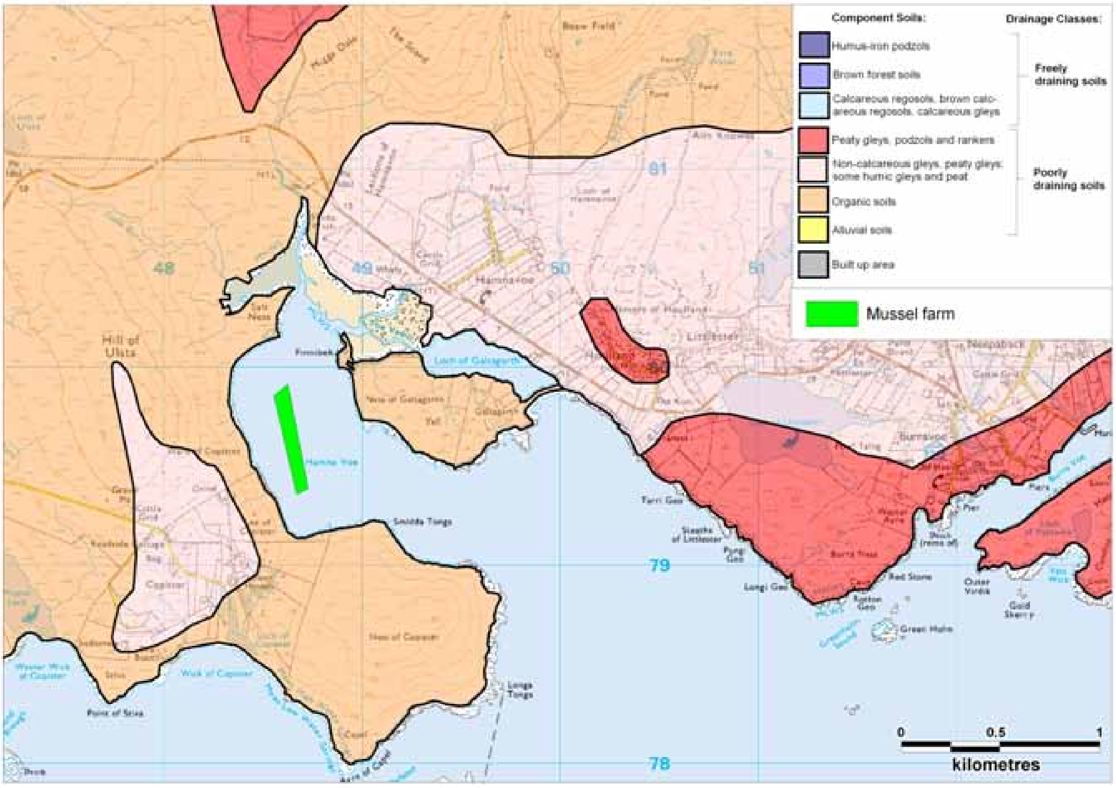

Figure 5.1 Component soils and drainage classes for Hamnavoe

Three types of component soils are found in this area, all of which are classed as poorly draining. Therefore, the potential for runoff contaminated with *E. coli* from human and/or animal waste is high along all coastal areas in the vicinity of the Hamnavoe mussel farm.

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6. Land Cover

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

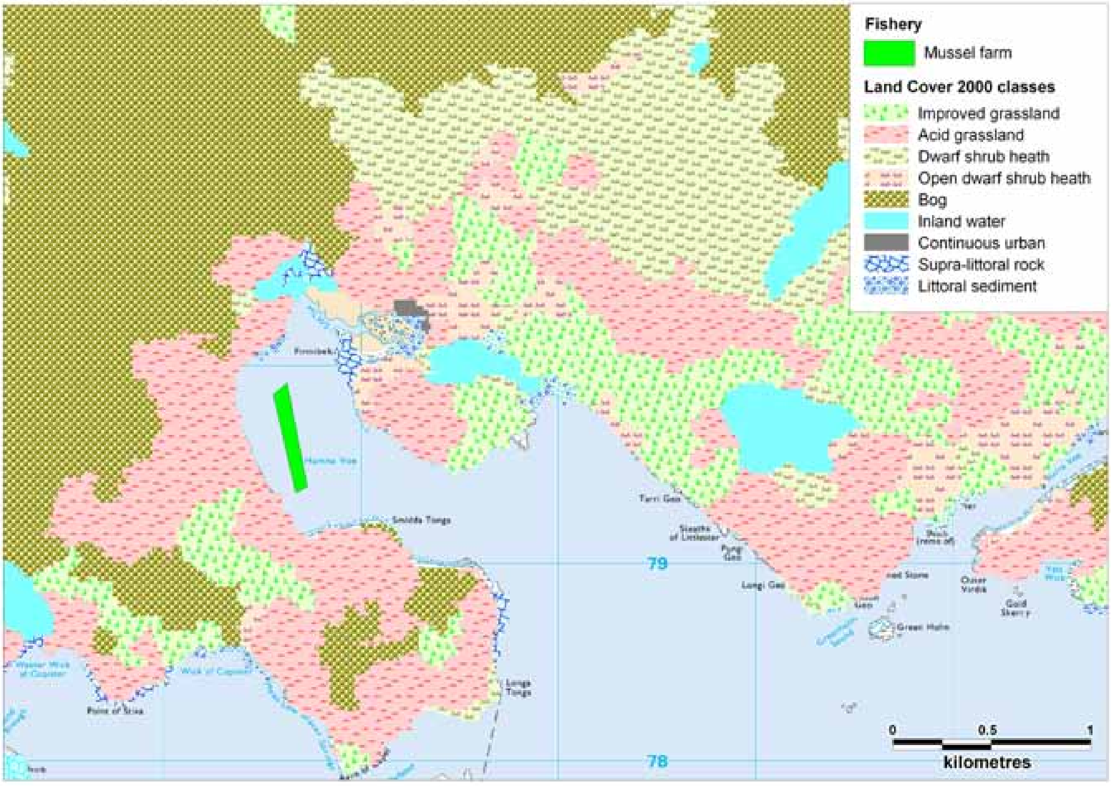


Figure 6.1 LCM2000 class land cover data for Hamnavoe

There are four main land cover types found along the shoreline adjacent to Hamnavoe. Acid grassland covers the majority of the shoreline directly adjacent to the farm. Improved grassland and heath are present in patches inland on the western shore and on the Ness of Galtagarth. Large areas of bog are found to the north and west of the voe. A small area of 'continuous urban' is shown on the shoreline north of the Ness of Galtagarth. This appears to relate to a church, cemetery and large car park at a road junction.

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 majority of land cover types adjacent to the voe are likely to be used to some extent for rough grazing. Areas of improved grassland around the west end of Ness of Galtagarth and north of Loch of Galtagarth may contribute more significantly to contamination levels draining from the loch to the head of Hamnavoe. The large paved areas next to the church would experience significant rainfall runoff containing any droppings deposited on the road or carparks.

7. Farm Animals

Information on the spatial distribution of animals on land adjacent to or near the fishery can provide an indication of the potential amount of organic pollution from livestock entering the shellfish production area. Agricultural census data to parish level was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for Yell parish. Reported livestock populations for the parish in 2009 and 2010 are listed in Table 7.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data. Any entries which relate to less than five holdings, or where two or fewer holdings account for 85% or more of the information, are replaced with an asterisk.

Table 7.1 Livestock numbers in Yell parish 2009 - 2010

	Yell 218 km^2			
	2009		2010	
	Holdings	Numbers	Holdings	Numbers
Pigs	0	0	*	*
Poultry	29	481	28	520
Cattle	19	277	18	267
Sheep	147	25248	143	24514
Horses used in Agriculture	*	*	0	0
Other horses and ponies	7	20	10	28

The Yell agricultural parish encompasses the entire island of Yell and nearby small islands, extending over 27 km north to south. The fishery lies along the southern shore of Yell. Very large numbers of sheep are kept within the parish, with the total sheep population being 26 times that of the total human population of the island which was 957 at the 2001 census. However, it is the number of animals kept within the catchment and near shore of the fishery that will be most likely to affect water quality there.

The only significant source of spatially relevant information was the shoreline survey (see Appendix 6), which only relates to the time of the site visit on 18th August 2011. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1.

Sheep were observed on rough grazing along the north and west shores of the voe as well as north and east of Ness of Galtagarth, where a large number of droppings were seen on the shoreline. In total, 140 sheep and 1 pony were seen. The catchment for the area extends northward along a number of burns, and these areas away from the immediate shoreline were not viewed.

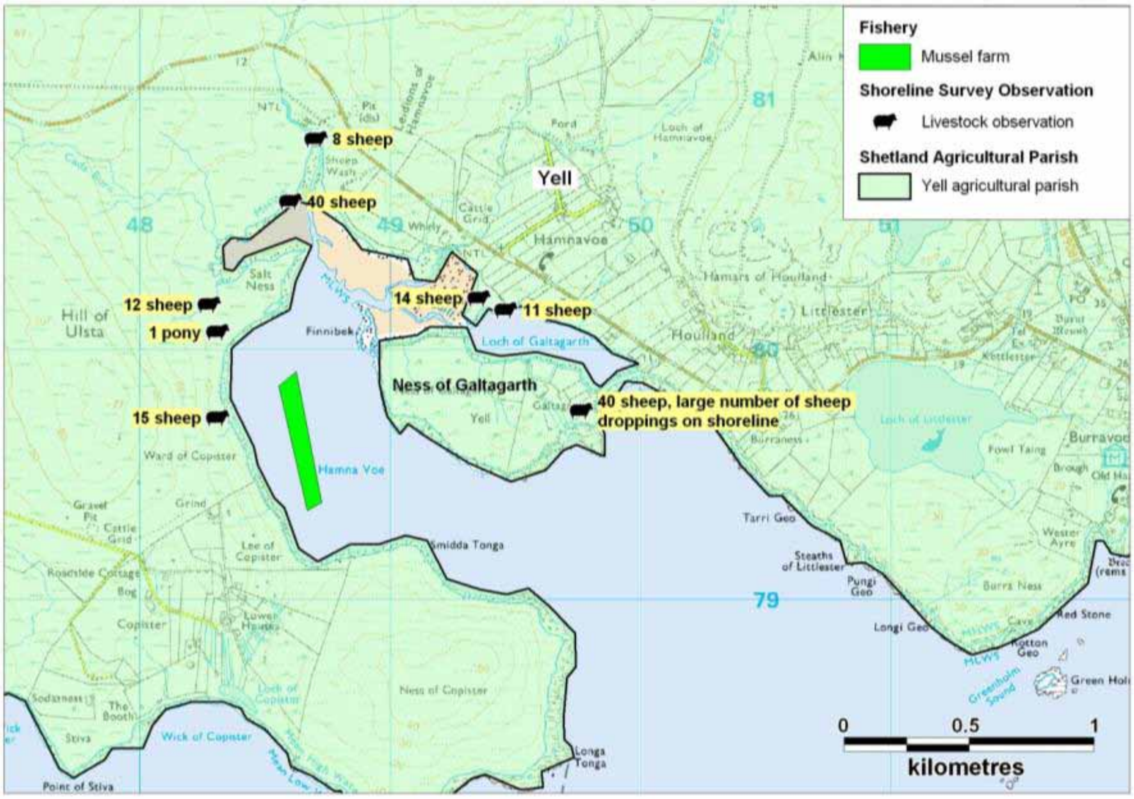


Figure 7.1 Livestock observations at Hamnavoe

Based on the animals observed during the shoreline survey, and the reported numbers for the agricultural parish, it is likely that a significant proportion of any faecal contamination reaching Hamnavoe is from diffuse, livestock sources. Direct deposition of droppings at the shoreline and in and around watercourses is likely to pose the greatest threat to water quality at the fishery. There is also the potential for direct runoff from the steep hillside to the west of the fishery to carry livestock faeces to the waters immediately west of the shellfish farm.

8. Wildlife

Wildlife may also contribute to faecal contamination observed at the fishery. General information on the impacts of wildlife species can be found in Appendix 2. The outermost, south western shore of Hamnavoe falls within the Yell Sound Coast Special Area of Conservation (SAC), designated for its population of otters (*Lutra lutra*) and common seals (*Phoca vitulina*) (http://jncc.defra.gov.uk/protectedsites/sacselection/sac.asp?EUCode=UK0012687). Wildlife species most likely to contribute to faecal contamination of the waters of Hamnavoe include birds, seals, and otters.

Birds

Seabird 2000 census data was queried for the area within a 5km radius of the Hamnavoe production area and is summarised in Table 8.1 below. This census, undertaken between 1998 and 2002, covered the 25 species of seabird that breed regularly in Britain and Ireland.

Table 8.1 Seabird counts within 5km of the site.

Common name	Species	Estimated No.*	Method
Arctic Tern	*Sterna paradisaea*	437	Individuals on land
Northern Fulmar	*Fulmarus glacialis*	1538	Occupied sites
Herring Gull	*Larus argentatus*	76	Individuals on land/Occupied territory or nests
Common Gull	*Larus canus*	71	Individuals on land/Occupied nests
Black Guillemot	*Cepphus grylle*	107	Individuals on land
Great Black-backed Gull	*Larus marinus*	175	Individuals on land/Occupied territory or nests
Lesser Black-backed Gull	*Larus fuscus*	4	Individuals on land/Occupied territory
Black-headed Gull	*Larus ridibundus*	4	Individuals on land
European Storm Petrel	*Hydrobates pelagicus*	542	Occupied sites
Great Skua	*Stercorarius skua*	99	Individuals on land/Occupied territory
European Shag	*Phalacrocorax aristotelis*	80	Occupied nests
Arctic skua	*Stercorarius parasiticus*	26	Occupied territory
Atlantic Puffin	*Fratercula arctica*	74	Individuals on land or sea
Common tern	*Sterna hirundo*	16	Individuals on land
Common Guillemot	*Uria aalge*	208	Individuals on land
Black-legged Kittiwake	*Rissa tridactyla*	246	Occupied nests
Razorbill	*Alca torda*	11	Individuals on land

* Counts for occupied sites, nests or territories were doubled to reflect the number of individuals

Records showed an estimated total 3700 seabirds within a 5km radius of the fishery. The majority of these birds will have little or no impact to the waters at the fishery. Those nesting nearest the fishery are most likely to contribute diffuse faecal contamination to the area, particularly after rainfall. Some species, such as gulls, are likely to be present year round. However, many of the seabirds will only be present near shore during the summer nesting season. Guano deposited around their nest areas, however, is likely to wash off in rainfall over a longer period of time. This is likely to have a greater impact at the southern end of the mussel farm where there is a larger number of nesting birds on the adjacent hillsides and the mussel lines lie closer to shore.

Wildfowl, such as geese and ducks, are likely to be present in the area though no specific data were found on populations in or near Hamnavoe.

Seals

Both grey seals (*Halichoerus grypus*) and common or harbour seals (*Phoca vitulina vitulina*) are recorded in Shetland, and the Yell Sound SAC was secondarily identified for its population of common seals. Populations of these animals, however, have declined sharply over the past decade. Surveys undertaken between 1991 and 2006 identified between 35 and 51 common seals at Orfasay, a short distance south of Hamnavoe. However, a further survey undertaken in 2009 found no seals at this location (Duck and Morris, 2010). The 2009 survey identified a total of 115 common seals and within the Yell Sound Coast SAC area, which encompasses 15.4km square of coastline and islands. Grey seals around the coasts of Yell numbered 94 during the same survey. No seals were seen during the shoreline survey.

These numbers represent the number of animals hauled out on shore counted on a specific date. Therefore, it may be an underestimate of the total number of seals present, particularly of grey seals. These animals are present in the area year-round and forage widely for food. Therefore, they are presumed to be present in or around the waters of the fishery at least part of the time and are likely to contribute to background levels of faecal contamination in the areas where they are found.

Otters

The Yell sound population of European otters (*Lutra lutra*) was last reported as 180 in 2006, and at higher densities than other coastal otters (http://www.ukmpas.org/pdf/Sitebasedreports/Yell_Sound_Coast.pdf). Otters forage mainly within the 10m depth curve and maintain their holts up fresh water streams from the coast. Hamnavoe has a number of streams and burns that may host otters, and any faecal contamination from these animals is likely to be carried in the streams.

Conclusions

Overall, the wildlife species most likely to be present in or around Hamnavoe are likely to be present in modest numbers and will contribute to background levels of contamination at the fishery. Seabirds are most likely to be present during the summer months, and impacts may be higher at the southern end of the mussel lines. Gulls and cormorants may rest on the floats throughout the year. Seals are likely to be present in and around the Hamnavoe, and have been known to haul out on an island south of the entrance to the voe.

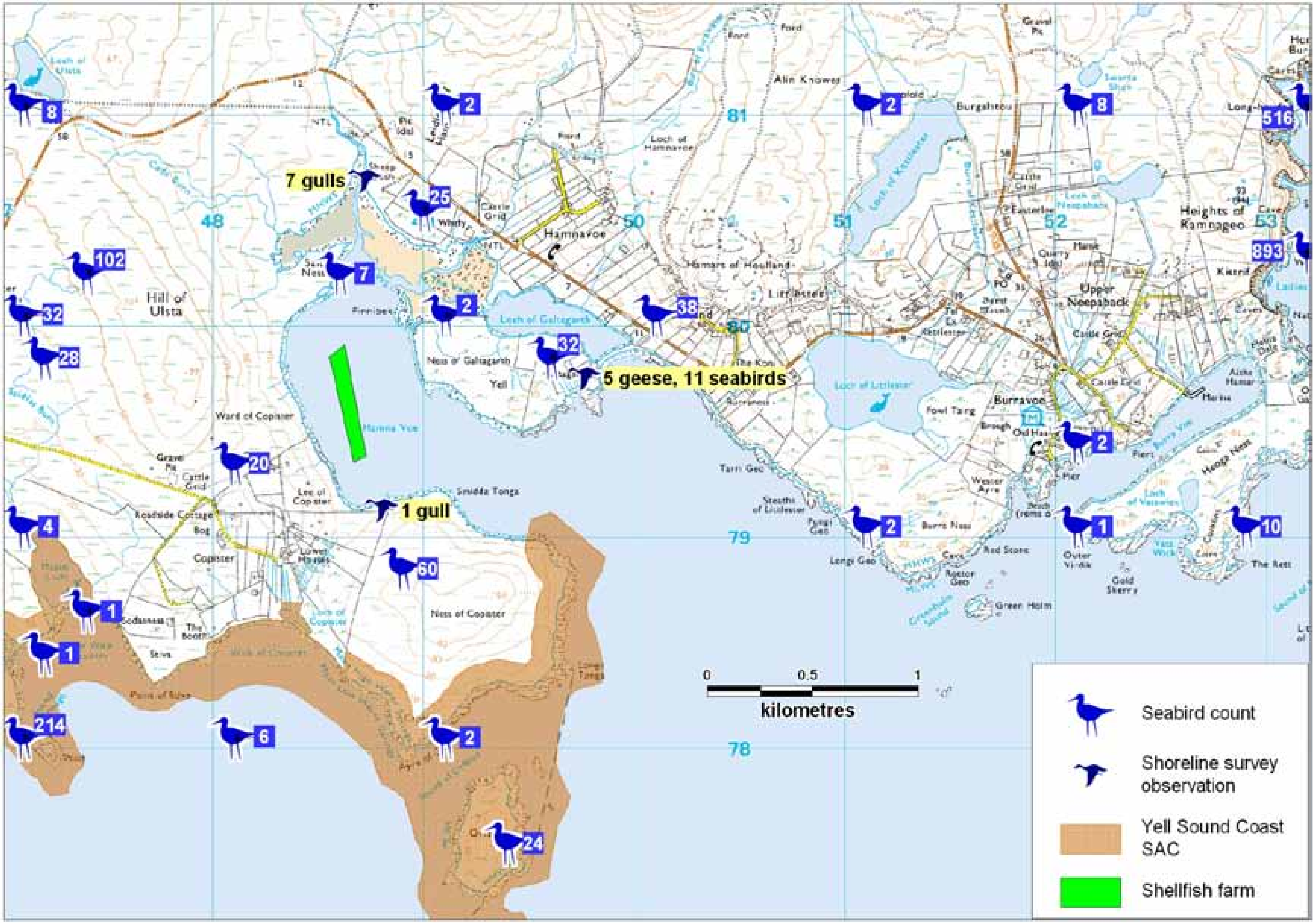


Figure 8.1 Map of wildlife counts and observations

9. Meteorological data

The nearest Meteorological Office rain station is located at Unst: Uyeasound, approximately 24km to the north of Hamnavoe. Uninterrupted rainfall data was available for 2003-2009. Data was missing for the months of November and December 2010. Windfall data was available from Sumburgh, located approximately 7 km to the south of the fishery.

Data from both 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 rain and wind patterns in the context of the bacterial quality of shellfish at Hamnavoe. In view of the distances between the rainfall and wind stations from the fishery, it is likely that patterns of both rainfall and wind direction and strength may vary from those experienced at Hamnavoe.

9.1 Rainfall

High rainfall and storm events are commonly associated with increased faecal contamination of coastal waters through surface water run-off from land where livestock or other animals are present, and through sewer and waste water treatment plant overflows (e.g. Mallin et al, 2001; Lee & Morgan, 2003).

Figures 9.1 and 9.2 are graphical representations showing box and whisker plots that summarise the distribution of daily rainfall by year and month. The grey box represents the middle 50% of the observations, with the median at the midline. The whiskers extend to the largest or smallest observations up to 1.5 times the box height above or below the box. Individual observations falling outside the box and whiskers are represented by the symbol *.

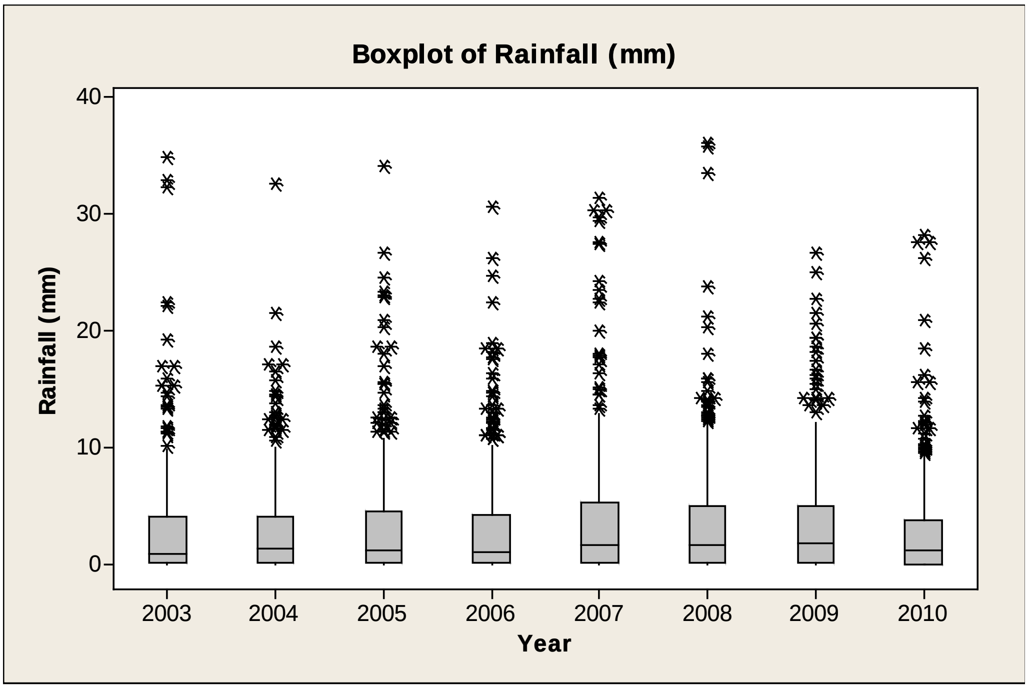


Figure 9.1 Box plot of daily rainfall values by year at Unst: Uyeasound (2003– 2010)

Rainfall varied somewhat from year to year for the period considered, with 2007 being wettest and 2003 driest.

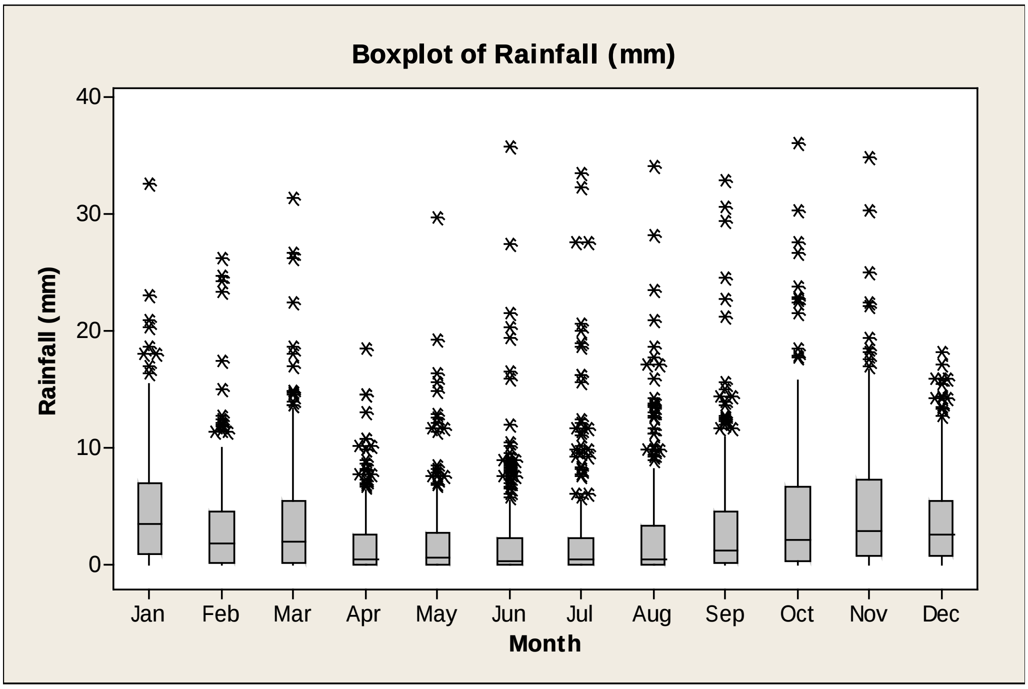


Figure 9.2 Box plot of daily rainfall values by month at Unst (2003 – 2010)

Weather was wettest in the period from October to January. The driest months were April, June and July. More extreme rainfall events (in which over 30mm fell in a day) occurred in most months. For the period considered here (2003-2010), 45% of days experienced rainfall less than 1mm, and 8% of days experienced rainfall of 10mm or more.

It is therefore expected that run-off due to rainfall will increase during the autumn and winter months, but it is important to note that faecal contamination entering the production area will occur during the summer and early autumn from the build up of faecal matter on pasture land over the drier period when stocking densities tend to be at their highest.

9.2 Wind

Wind data was collected at Sumburgh weather station and is characterised by seasonal wind roses, in Figure 9.3 and an annual summary presented in Figure 9.4.

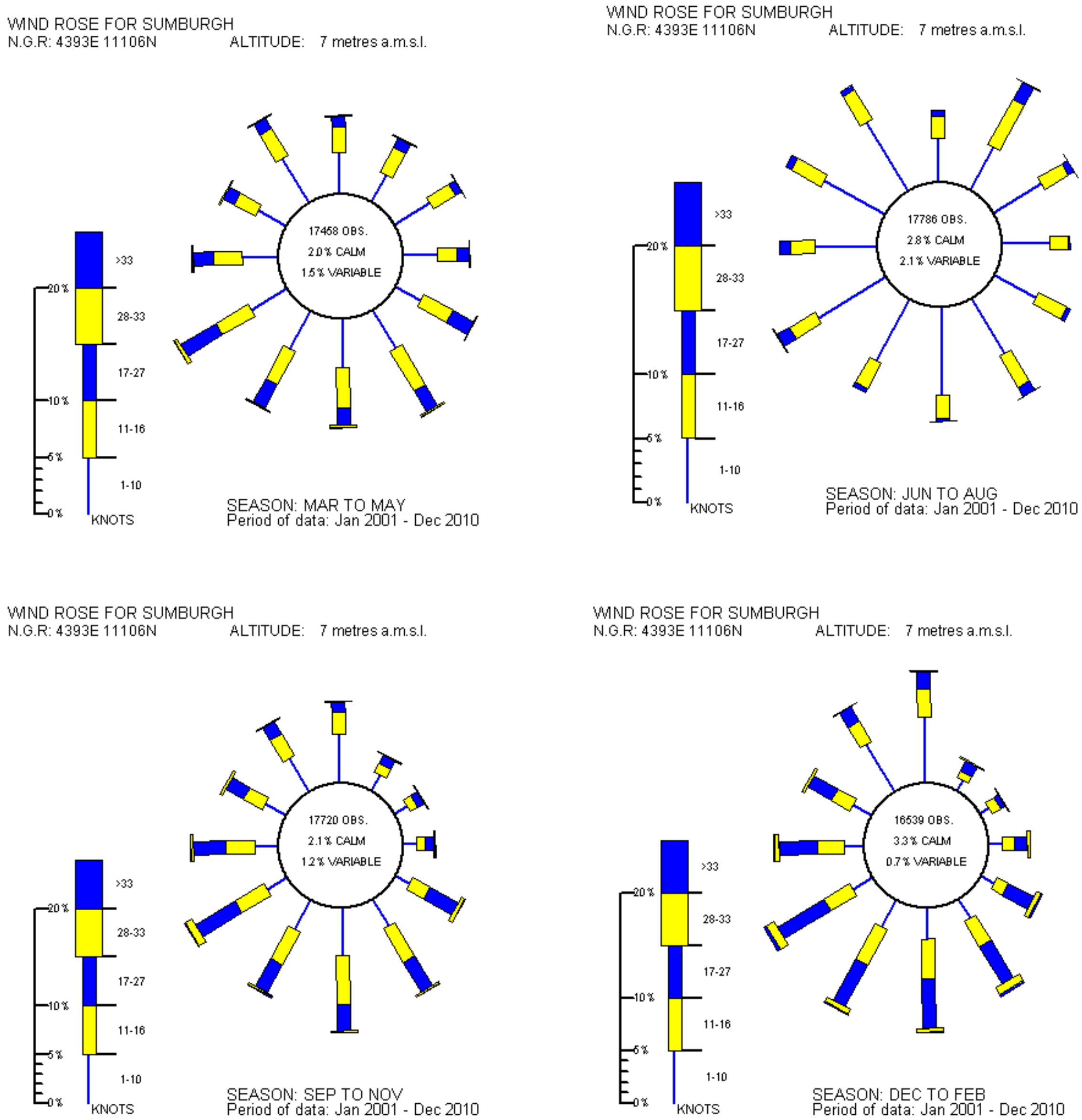
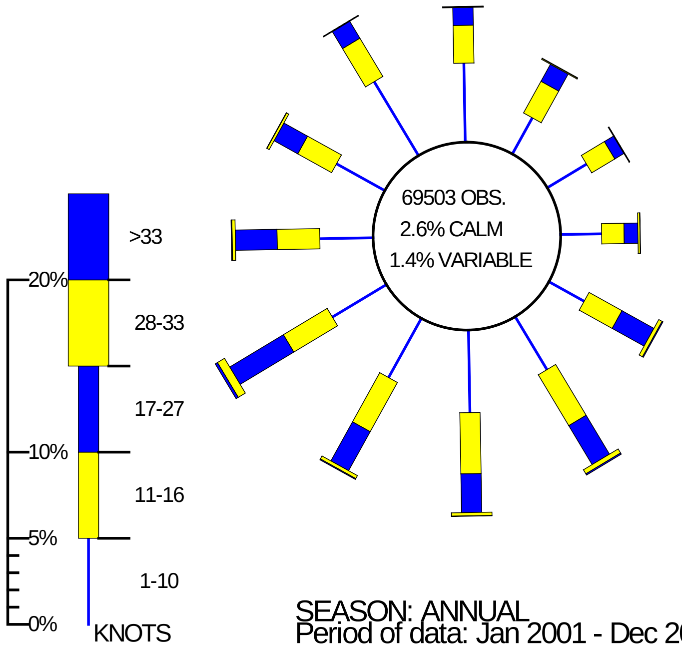


Figure 9.3 Seasonal wind rose for Sumburgh

WIND ROSE FOR SUMBURGH
N.G.R: 4393E 11106N ALTITUDE: 7 metres a.m.s.l.



SEASON: ANNUAL
Period of data: Jan 2001 - Dec 2010

Figure 9.4 Wind rose for Sumburgh (All year)

Overall, the wind direction at Sumburgh was predominantly stronger from the south and south west and weakest from the north east. This pattern was similar for all months except the summer months (June to August) where there was no clear direction. In general winds are stronger in the winter then in the summer and wind direction and strength has the potential to effect the movement of surface waters and associated contamination into a fishery, particularly if the fishery is exposed to the direction of the winds. Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s.

Strong winds may 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 accumulated faecal matter from livestock from above the normal high water mark into the production area.

10. Current and historical classification status

Hamnavoe was first given a classification for common mussels (*Mytilus edulis*) in April 2007. The historical and current classifications for the area are shown below in Table 10.1.

Table 10.1 Hamnavoe, common mussels

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

Prior to 2010, the area held a seasonal A/B classification with the B period being from August to January/March (this varied with year).

11. Historical *E. coli* data

11.1 Validation of historical data

The results for all mussel samples taken in Hamnavoe from 1 January 2007 up to the 18th August 2011 were extracted from the FSAS database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. The data was extracted from the database in November 2011 and no samples appeared to have been submitted in September or October 2011.

All samples were received by the testing laboratory within one day of collection. The reported coolbox temperatures were all <8°C. One sample, dated 16/10/07, was recorded on the database as "Rejected" and was deleted. This sample appeared to be a duplicate of a valid entry. All samples were recorded against one of 3 sampling locations, all of which were located relatively close together and all of which fell within the classified production area. Prior to December 2010, all grid references were reported to 100m accuracy. The grid reference reported since then appeared to be a more accurate estimate of the location that had been reported since July 2007.

Seventeen samples had the result reported as <20 *E. Coli* MPN/100g, and were assigned a nominal value of 10 for statistical assessment and graphical presentation.

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

11.2 Summary of microbiological results

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

Table 11.1 Summary of historical sampling and results

Sampling Summary	
Production area	Hamnavoe
Site	Copister
Species	Common mussels
SIN	SI-348-736-08
Location	3 locations
Total no of samples	40
No. 2007	8
No. 2008	9
No. 2009	7
No. 2010	10
No. 2011	6
Results Summary	
Minimum	<20
Maximum	9200
Median	20
Geometric mean	37
90 percentile	240
95 percentile	454
No. exceeding 230/100g	4 (10%)
No. exceeding 1000/100g	2 (5%)
No. exceeding 4600/100g	1 (2.5%)
No. exceeding 18000/100g	0

11.3 Overall geographical pattern of results

Of the 40 samples included in the analyses 33, taken up to November 2010, were reported to 100m accuracy and against 2 different locations. The 7 samples taken since December 2010 were reported to an accuracy of 10m. All three locations plotted close to each other and, given the limited accuracy of the positions given for most of the samples, a spatial analysis of the magnitude of the *E. coli* result by location was not undertaken.

Figure 11.1 Map of reported sampling locations

11.4 Overall temporal pattern of results

Figure 11.2 presents a scatter plot of individual *E. coli* results against date, fitted with a loess trend line. Loess stands for 'locally weighted regression scatter plot smoothing'. At each point in the data set an estimated value is fit to a subset of the data, using weighted least squares. The approach gives more weight to points near to the x-value where the estimate is being made and less weight to points further away. In terms of the monitoring data, this means that any point on the loess line is influenced more by the data close to it (in time) and less by the data further away. The trend line helps to highlight any apparent underlying trends or cycles.

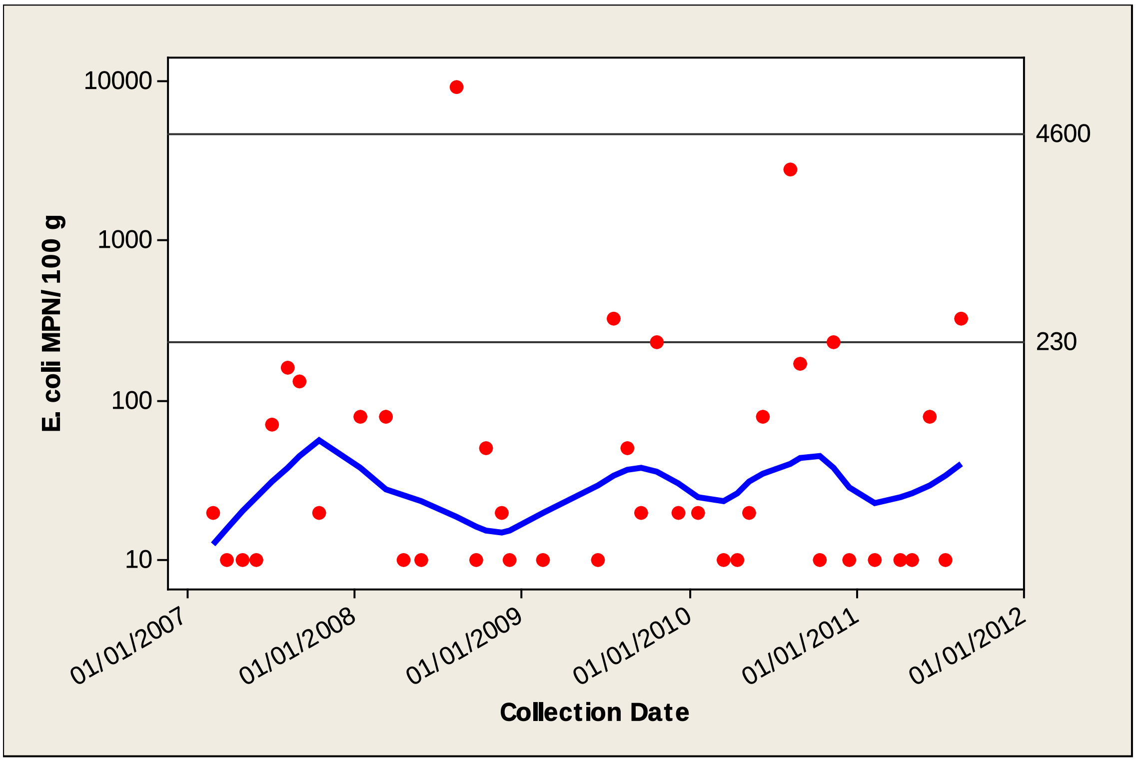


Figure 11.2 Scatterplot of *E. coli* results by date with loess line

The general level of contamination of the mussels is low with intermittent, but ongoing, results greater than 230 *E. coli* MPN/100 g. The underlying level of contamination appears to be stable across the period of this assessment but, within individual years, there is a tendency for a peak in *E. coli* contamination in the latter half of the year. This increase was not seen in 2009.

11.5 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns of human occupation. All of these can affect levels of microbial contamination, and cause seasonal patterns in results. Figure 11.3 presents a scatterplot of *E. coli* result by month, overlaid with a loess line to highlight any trends.

A marked peak in results is seen in August. This is due to the only two results greater than 1000 *E. coli* MPN/100 g occurring during that month.

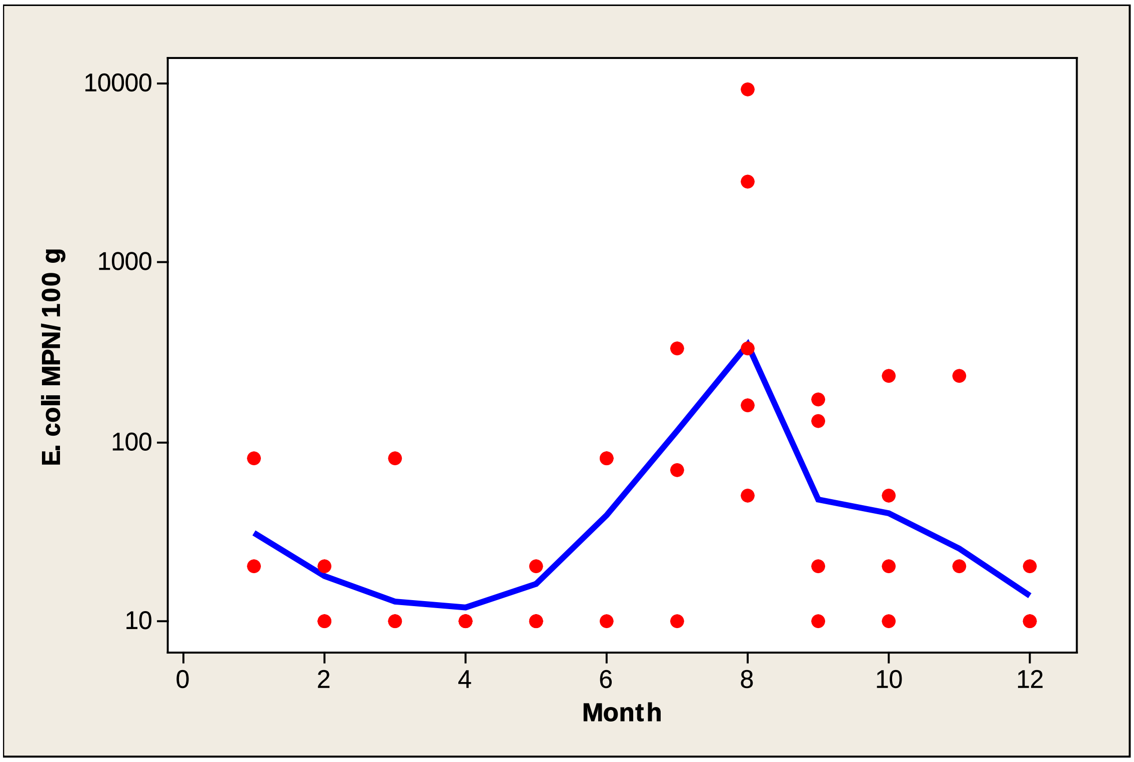


Figure 11.3 Scatterplot of results by month

For statistical evaluation, seasons were split into spring (March - May), summer (June - August), autumn (September - November) and winter (December - February). Boxplots of results by season are shown in Figure 11.4.

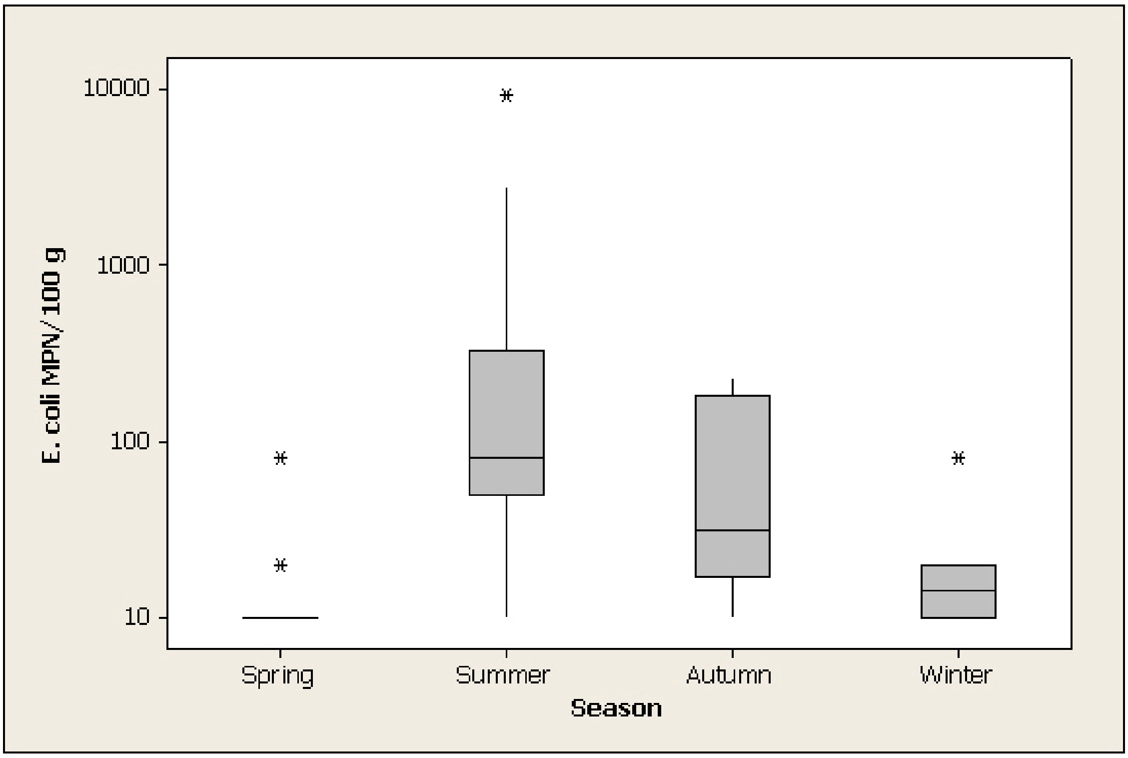


Figure 11.4 Boxplot of result by season

A significant difference was found between results by season (One-way ANOVA, p=0.001, Appendix 6). A post-ANOVA analysis (Tukey's method) showed that the results in spring and winter were significantly lower than those in summer.

11.6 Analysis of results against environmental factors

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

11.6.1 Analysis of results by recent rainfall

The nearest weather station for which rainfall was available was at Uyeasound on Unst, approximately 24 km to the north-north-east of the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2002 to 31/12/2010 (total daily rainfall in mm). Data was extracted from this for the period 1/1/2007 to 31/12/2010. Figure 11.5 presents a scatterplot of E. coli results against total rainfall recorded on the two days prior to sampling. A Spearman's Rank correlation was carried out between the results and the two day rainfall.

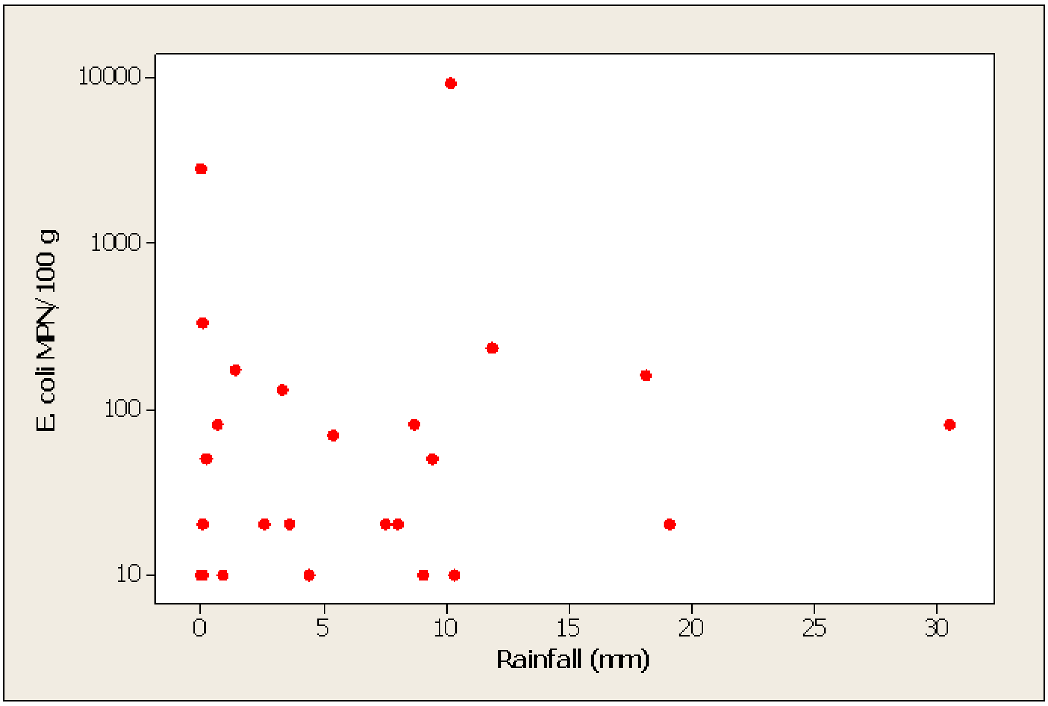


Figure 11.5 Scatterplot of result against rainfall in previous 2 days

A weak but significant correlation was found between E. coli result and rainfall in the previous 2 days (Spearman's rank correlation=0.394, p=0.026).

As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationship between rainfall in the previous 7 days and sample results was investigated in an identical manner to the above. Figure 11.6 presents a scatterplot of E. coli results against total rainfall recorded on the seven days prior to sampling.

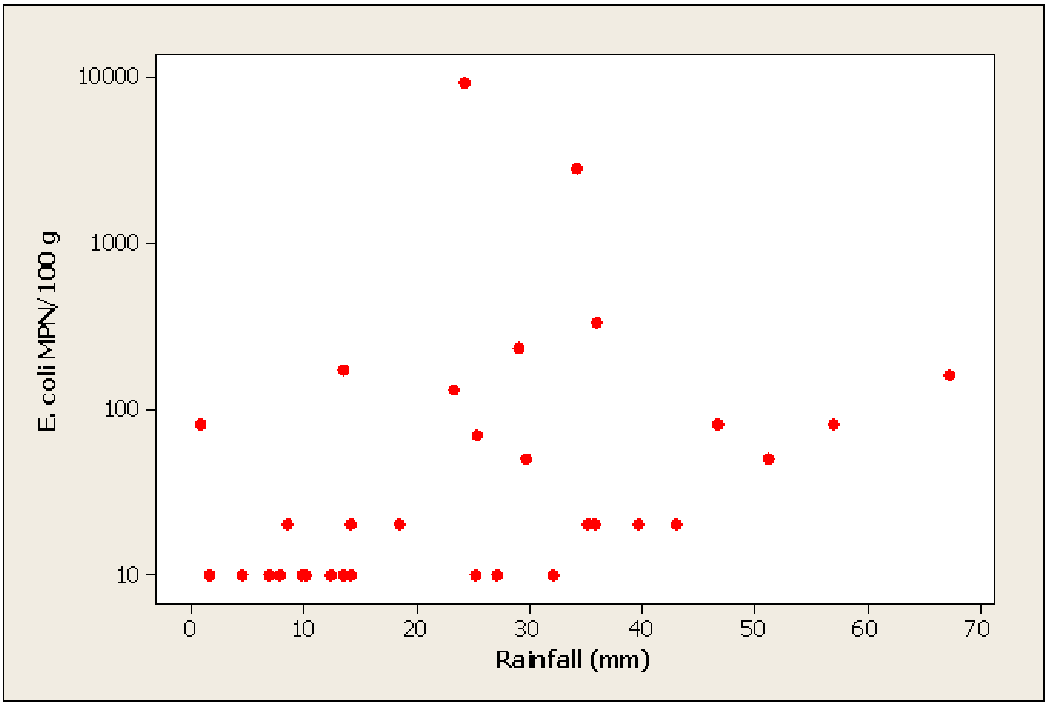


Figure 11.6 Scatterplot of result against rainfall in previous 7 days

A significant correlation was found between E. coli result and rainfall in the previous 7 days (Spearman's rank correlation= 0.486, p=0.005). However, the highest results occurred after moderate levels of rainfall.

11.6.2 Analysis of results by tidal height and state

When the larger (spring) tides occur every two weeks, circulation of water and particle transport distances will increase, and more of the shoreline will be covered at high water, potentially washing more faecal contamination from livestock into the area. Figure 11.7 presents a polar plot of log10 E. coli results on the lunar spring/neap tidal cycle. Full/new moons are located at 0º, and half moons at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account.

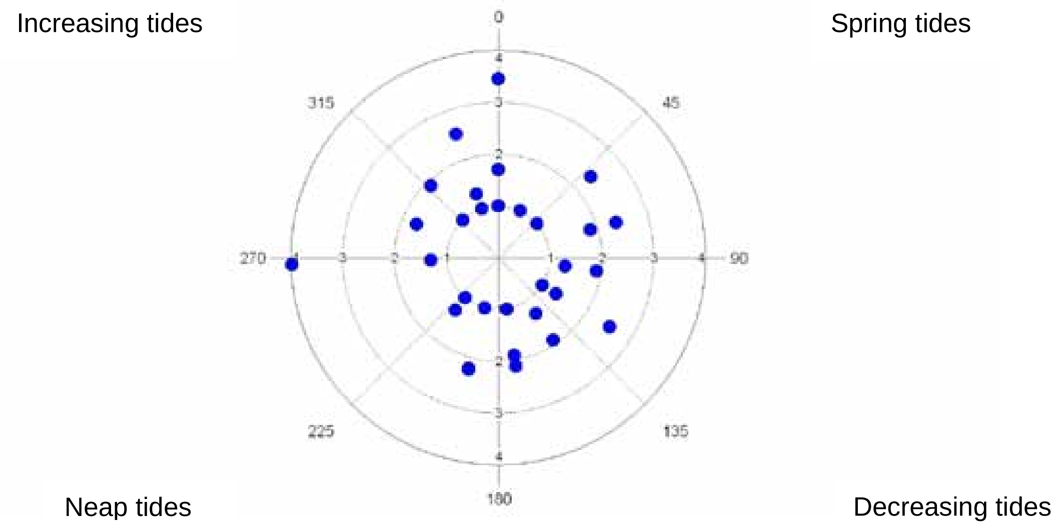


Figure 11.7 Polar plot of log10 E. coli results on the spring/neap tidal cycle

No significant correlation was found between log10 E. coli results and the spring/neap cycle (circular-linear correlation, r=0.121, p=0.584).

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As E. coli levels in some shellfish species can respond within a few hours or less to changes in E. coli levels in water, tidal state at time of sampling (hours post high water) was compared with E. coli results. Figure 11.8 presents a polar plot of log10 E. coli results on the lunar high/low tidal cycle. High water is located at 0º, and low water at 180º.

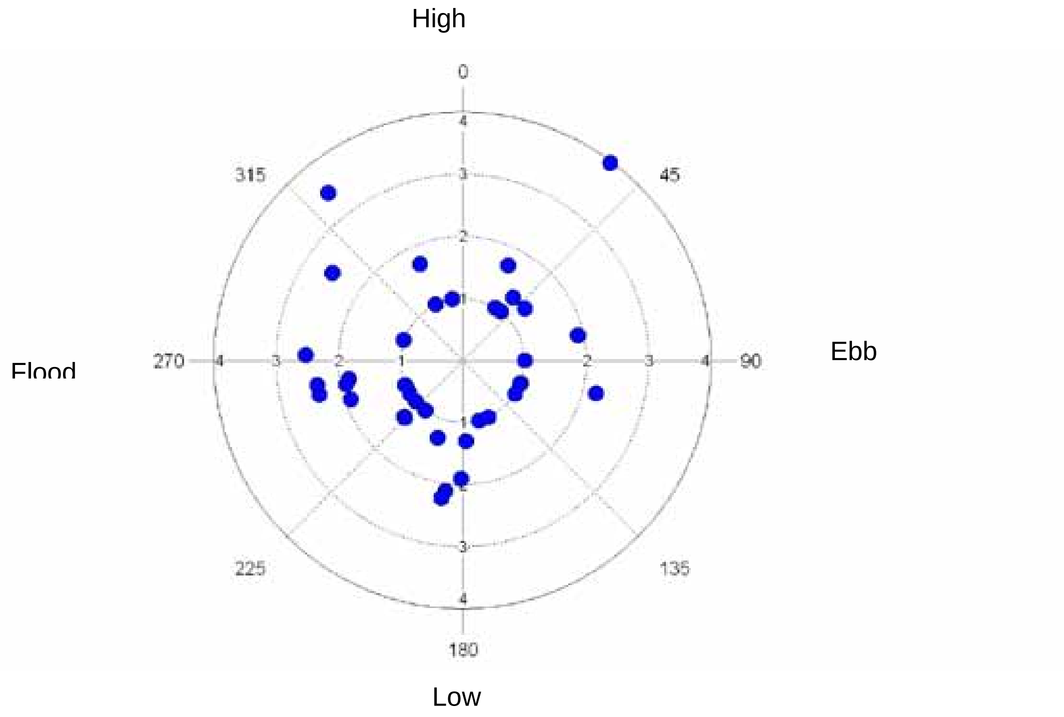


Figure 11.8 Polar plot of log10 E. coli results on the high/low tidal cycle

Although the higher E. coli values appear to occur around the time of high water, no significant correlation was found between E. coli results and the high/low tidal cycle (circular-linear correlation, r=0.28, p=0.064).

11.6.3 Analysis of results by water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) and the feeding and elimination rates of shellfish, and therefore may be an important predictor of *E. coli* levels in shellfish flesh. It is of course closely related to season, and so any correlation between temperatures and *E. coli* levels in shellfish flesh may not be directly attributable to temperature, but to other factors such as seasonal differences in livestock grazing patterns. Water temperature was recorded against only 31 of the mussel sampling occasions. Figure 11.9 presents a scatterplot of *E. coli* results against water temperature recorded at the time of sampling.

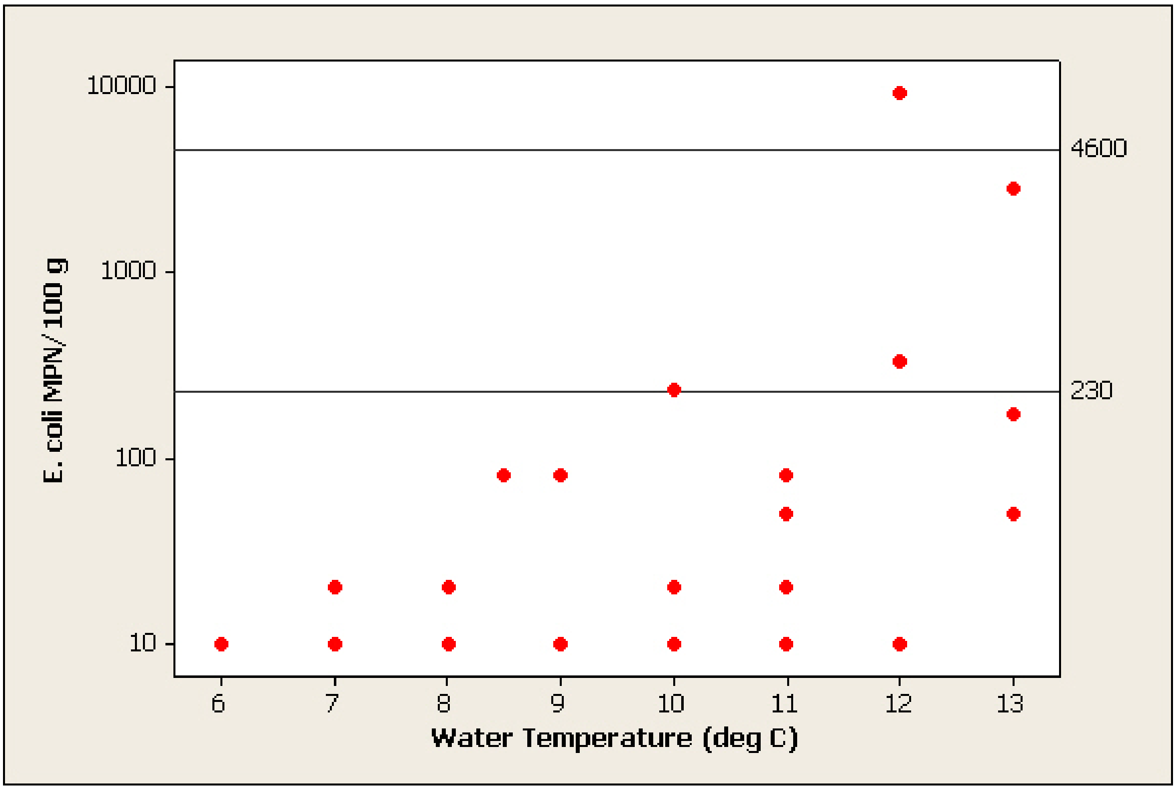


Figure 11.9 Polar plot of $\log_{10}$ *E. coli* results against water temperature

A highly significant correlation was found between *E. coli* result and water temperature (Spearman's rank correlation= 0.574, p=0.001).

11.6.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater borne contamination at the site. Salinity was recorded for 39 of the 40 mussel sampling occasions for the data analysed. No significant correlation was found between *E. coli* result and salinity (Spearman's rank correlation= -0.101, p=0.542).

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

Of the mussel samples, four gave results of over 230 *E. coli* MPN/100g. Details of these samples 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/ 100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tidal state (high/low)	Tidal state (spring/neap)
12/08/2008	9200	HU 487 795	10.2	24.2	12	16.74	Flood	Increasing
21/07/2009	330	HU 487 795	0.1	36	12	34.39	Flood	Increasing
10/08/2010	2800	HU 487 795	0	34.2	13	0	Flood	Increasing
10/08/2011	330	HU 4871 7957	*	*	12	35.4	Flood	Decreasing

*Data not available

Samples were collected in either July or August. For the samples for which rainfall data was available, two of the three high results occurred after little or no rain in the preceding two days but moderate amounts of rain had fallen over the preceding seven days. All of the samples giving these high results were taken around on a flood tide and three of the four, including the two exceeding 1000 E. coli/100 g, were taken as the tidal range increased towards springs.

11.7 Summary and conclusions

All samples had been taken from three reported locations close to each other and therefore a spatial analysis of the results was not undertaken. The general level of contamination has stayed the same over the period considered in this section. A seasonal effect was seen with results in summer being significantly higher than in spring and winter. All results greater than 230 *E. coli* MPN/ 100 g occurred in samples taken in July or August. This was reflected in a significant correlation with water temperature. No significant correlation was seen with salinity. Significant correlations were seen with rainfall over the two days and seven days prior to sampling although the highest results did not necessarily coincide with high rainfall on the two days prior to sampling. No significant correlation was seen with either the spring/neap or high/low tidal cycle. However, all samples giving a result greater than 230 *E. coli* MPN/100 g were taken on a flood tide and three of the four were taken as the tidal range increased towards springs.

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

11.8 Sampling frequency

When a production area holds a non-seasonal classification and the geometric mean of the results falls within a certain range, the EURL Good Practice Guide (GPG) recommends that consideration be given to the sampling frequency being decreased from monthly to bimonthly. The production area currently holds a year-round A classification although it was a seasonal A/B in 2009. However, the geometric mean of the 29 results obtained between 1/09/2008 and 18/08/2011 is 33.4 *E. coli* MPN/100g. This is higher than the upper limit of 13 *E. coli*/100 g given in the GPG for class A stability assessment.

12. Designated Shellfish Growing Waters Data

The waters of Hamnavoe are not currently designated under the either the European Community Shellfish Waters Directive (2006/113/EC) or the EC Bathing Water Directive (2006/7/EC).

13. River Flow

There are no river gauging stations on watercourses along the Hamnavoe coastline.

Five watercourses were observed during the shoreline survey. One of the watercourses was too large to measure. Watercourses on the western side of the voe were not covered in the shoreline survey. There were light rain showers on the afternoon of the survey.

Table 13.1 Stream loadings for Hamnavoe

No	Grid Ref	Description	Width (m)	Depth (m)	Flow (m/s)	Flow in m^3/day	*E.coli* (cfu/ 100ml)	Loading (*E.coli* per day)
1	HU 50314 79696	Unnamed watercourse	0.12	0.02	1.936	401	70	2.8×10^8
2	HU 49757 80073	Unnamed watercourse	1.1	0.12	0.059	673	180	1.2×10^9
3	HU 49284 80398	Burn of Hamnavoe	2.74	0.25	0.103	6096	130	7.9×10^9
4	HU 48705 80841	Burn of Arisdale	Unable to measure due to size				30	N/A
5	HU 48293 80451	Cada Burn	0.15	0.17	0.043	95	50	4.7×10^7

None of the watercourses yielded *E. coli* results indicating marked faecal contamination. The highest calculated loadings were seen at the two streams (2 and 3) on the eastern side of the voe nearest to Hamnavoe. One of these discharged into the Loch of Galtagarth. Despite the low *E. coli* concentration seen in the sample from stream 4, the loading would be expected to be at least as great as that of streams 2 and 3, due to its large size. Loadings in the streams would be expected to increase significantly after rainfall. There are streams marked on the map between the location of stream 5 and Smidda Tonga but, although parts of the area were boggy, no streams were seen and there was no evidence of dry stream beds.

The main concentration of contamination from the observed watercourses would be towards the north east of the mussel farm and would tend to impact most on that end of the mussel lines. During heavy rainfall, direct run-off from the western shore may carry faecal contamination from animal droppings into the sea near to the mussel lines.

Figure 13.1 Map of stream loadings at Hamnavoe

14. Bathymetry and Hydrodynamics

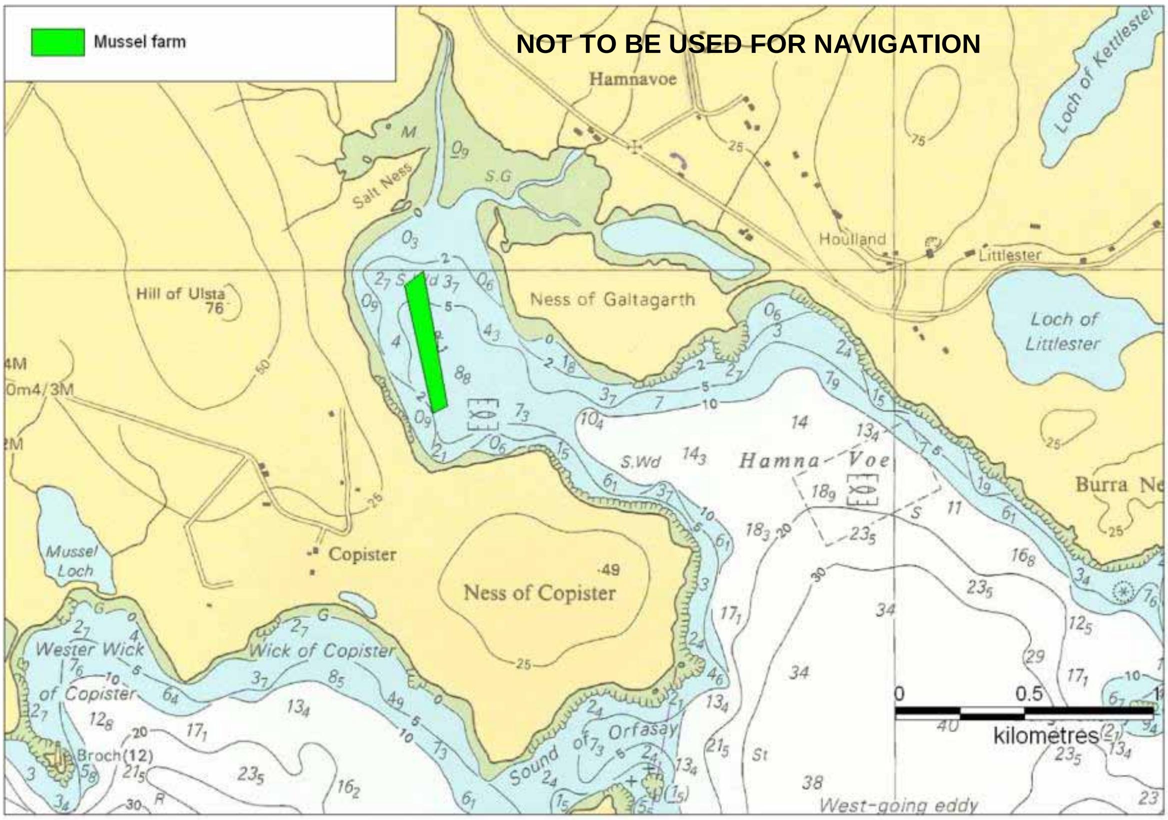


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Figure 14.1 Bathymetry at Hamnavoe

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Figure 14.1 shows that the mussel farm is located in approximately 2 to 9 m of water at chart datum in narrows approximately 500 m wide between the main island and the Ness of Galtagarth. South of the Ness, the voe broadens to approximately 1 km wide and deepens to more than 30 m at the mouth. There is a drying area around the voe which is most extensive at the head and on the north side of the Ness of Galtagarth. The Loch of Galtagarth, on the north-east side of the Ness, is an area of brackish water.

14.1 Tidal Curve and Description

The two tidal curves below (Figure 14.2) are for Burra Voe, approximately 3.5 km from Hamnavoe. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 BST on 18/08/11 and the second is for seven days beginning 00.00 BST on 25/08/11. This two-week period covers the date of the shoreline survey. Together the curves show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

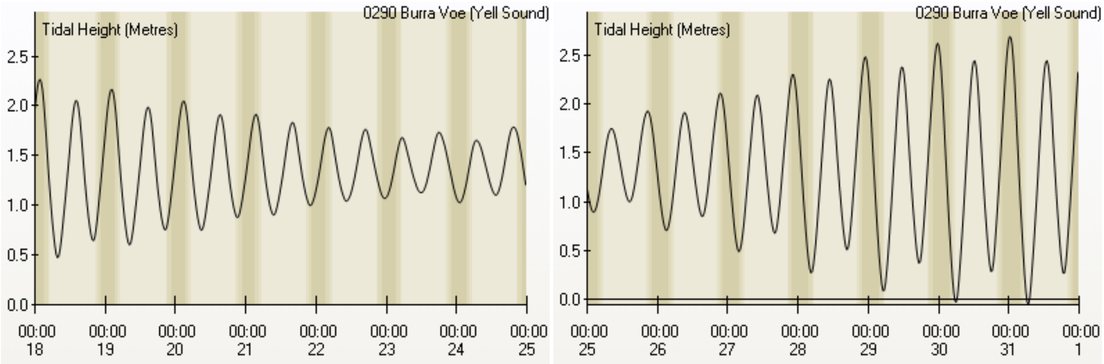


Figure 14.2 Tidal curves for Burra Voe

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

0290 Burra Voe (Yell Sound) is a Secondary Non-Harmonic port.
The tide type is Semi-Diurnal.

HAT	2.8 m
MHWS	2.3 m
MHWN	1.8 m
MSL	1.32 m
MLWN	0.9 m
MLWS	0.4 m
LAT	-0.2 m

Predicted heights are in metres above chart datum. The tidal range at spring tide is 1.9m and at neap tide 0.9m and so the area is microtidal (tidal ranges are relatively small).

14.2 Currents

There is no tidal stream information for the immediate vicinity of Hamnavoe: the nearest tidal diamond is in Yell Sound south of Samphrey. Shetland Seafood Quality Control had undertaken a current meter study at the Ness of Copister in Hamnavoe in support of an application to SEPA for a consent for a discharge from a marine caged fish farm. The study had been undertaken on behalf of Northern Isles Salmon Ltd. and the data was released to Cefas with the permission of the company. Summary information on the site is given in Table 14.1 and the position is shown on the map in Figure 14.3. Plots of the current directions and speeds, together with the wind direction and speeds over the relevant period, are shown in Figure 14.4.

Figure 14.3 Current meter location

Table 14.1 Survey period for the current meter study

Location	NGR	Survey period
Ness of Copister	HU 50342 78985	17/11/2010 – 02/12/2010

The plots in Figure 14.4 show that the currents near the bottom predominantly flowed in a south-easterly direction. A completely different pattern was seen at mid-depth with the currents flowing over a range of directions between north and east. The latter pattern was modified at near-surface with a single direction of east-north-east being more frequent than the others in the north to east range. None of the current directions appeared to relate to the wind directions seen during the survey: these were predominantly from the north and east-south-east. Median and maximum current speeds at the three depths are shown in Table 14.2.

Table 14.2 Median and maximum current speeds

Depth	Current speed (cm/s)	
	Median	Maximum
Near-bottom	5.4	17.4
Mid-depth	6.6	21.7
Near-surface	7.1	23.6

At a maximum current speed of 24cm/s, the distance that contaminants would be transported over an ebb or flood tide is approximately 3.5km. In general, the distance would be expected to be significantly less than this.

However, the current data may not be directly relevant to the situation at the mussel lines. The current direction at depth may also be predominantly to the southeast. However, given the more enclosed aspect and the presence of a drying area at the head of the voe, it would be expected that on the flood tide there would be a more general movement sweeping around from the gap between the Ness of Copister and the Ness of Galtagarth, over the lines and northward towards the drying area. The opposite would be the case on the ebb tide.

14.3 Conclusions

The dilution of contaminants would be expected to be much greater at the southern end of the mussel lines than at the northern end due to the greater depth at the southern end. Currents within the voe are expected to be generally weak and the distances over which contaminants will be transported are limited. Available information indicates that currents at the seabed tend to flow out of the voe for most of the tidal cycle whereas they flow northeast at mid-depth and near the surface. However, this may not hold at the mussel lines, where the flows may run more generally towards and away from the head of the voe.

The most important sources of faecal contamination will therefore be those within the voe itself and potentially the greatest contamination will be seen towards the bottom of the lines at the northern end of the mussel farm.

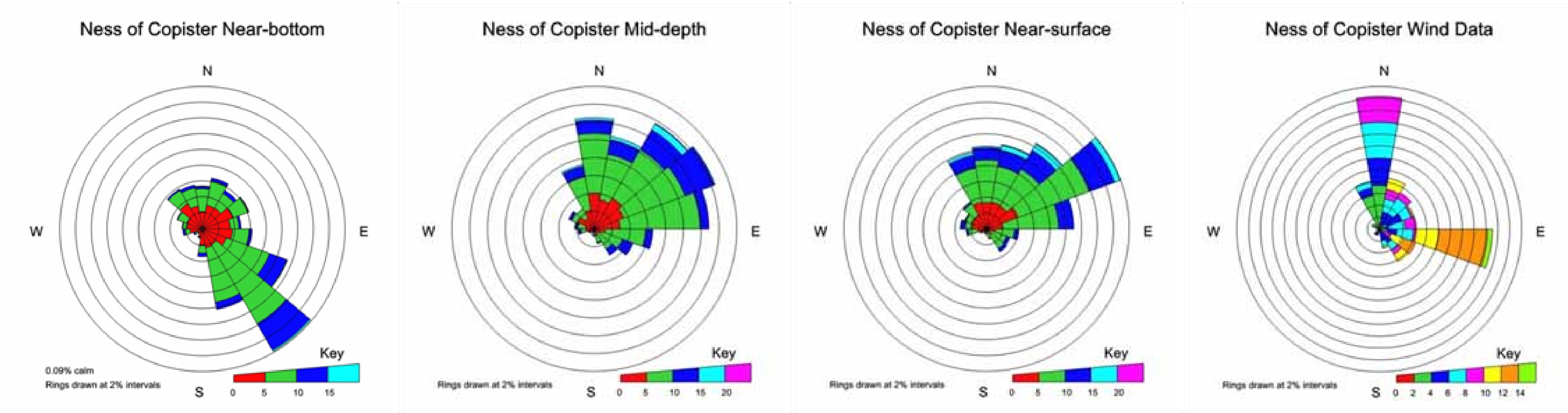


Figure 14.4 Current and wind plots for the Ness of Copister current meter study

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

15. Shoreline Survey Overview

The shoreline survey was conducted on the 18th August 2011 under mainly dry and calm weather conditions.

The fishery was visited on the day of the shoreline survey. The fishery consists of a smart farm system consisting of 4 sets of 7 polyethylene-pipes with 2.2 m rope droppers. The fishery had sufficient stock on site for sampling during the survey.

The area surrounding the Hamnavoe fishery is sparsely populated. During the shoreline survey a few dwellings were observed on the far eastern coast at the settlements of Hamnavoe and Houlland. Between the settlements of Hamnavoe and Houlland three outfall pipes and one septic tank was observed. One of the outfall pipes had a small flow and a fresh water sample collected had a result of 50 *E. coli* cfu/100 ml. A sea water sample close to the end of an outfall pipe flowing into the sea had a high result of 4700 *E. coli* cfu/100 ml.

Livestock were observed grazing along the shoreline adjacent to the northern extent of the shellfish farm and on the Ness of Galtagarth. In total 140 sheep and a single pony were observed. Livestock were able to access the shoreline and freshwater streams.

In total 8 gulls, 5 geese and 11 additional seabirds were observed in the area surrounding the shellfish farm on the day of the survey.

Sea water samples taken in the close vicinity of the fishery contained little *E. coli* (<1-7 cfu/100 ml) in all cases. Salinity profiles taken close to the mussel fishery indicated little or no significant freshwater influence at the time.

Fresh water samples and discharge measurements were taken at four streams draining into the survey area. A stream discharging into the northern end of the voe was too large to measure safely. Fresh water samples taken at all five streams had low levels of *E. coli* contamination (30-180 *E. coli* cfu/100 ml) in all cases. Mussel samples were collected from both ends of the mussel fishery. The mussel sample taken from the northern end of the pipes at a depth of 2m had a result of 130 *E. coli* MPN/100 g. Two mussel samples were collected at the southern end of the pipes. The mussel sample collected near the surface had a result of 80 *E. coli* MPN/100 g and the mussel sample taken at a depth of 2m had a result of 230 *E. coli* MPN/100 g.

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

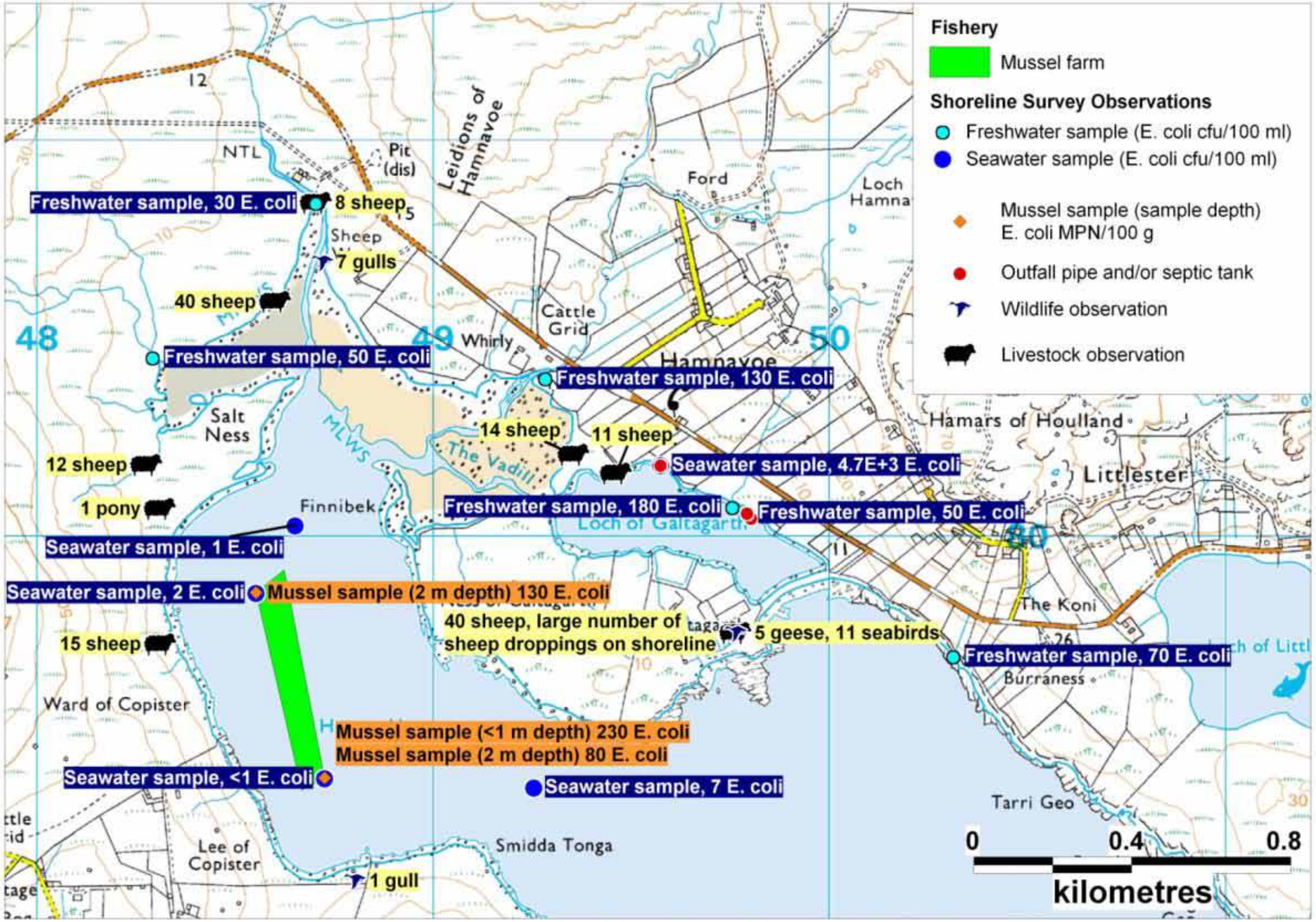


Figure 15.1 Summary of shoreline survey findings for Hamnavoe

16. Overall Assessment

Human sewage impacts

Discharges from the Hamnavoe septic tank and any potential discharges from the smaller pipes which lie nearest to the fishery and any contaminants arising from these sources would need to pass the mussel farm to exit the loch. Impacts from these are most likely to affect the northern end of the mussel farm. The Burravoe septic tank discharges outside Hamnavoe and therefore is less likely to impact on the water quality at the mussel farm, which is located well inside the voe.

Agricultural impacts

It is likely that a significant proportion of any faecal contamination reaching Hamnavoe is from diffuse, livestock sources. Direct deposition of droppings at the shoreline and in and around watercourses is likely to pose the greatest threat to water quality at the fishery. There is also the potential for direct runoff from the steep hillside to the west of the fishery to carry livestock faeces to the waters immediately west of the shellfish farm.

Wildlife impacts

Overall, the wildlife species most likely to be present in or around Hamnavoe are likely to be present in modest numbers and will contribute to background levels of contamination at the fishery. Seabirds are most likely to be present during the summer months and higher numbers have been recorded on the hills adjacent to the southern end of the fishery. Gulls and cormorants may rest on the floats throughout the year. Seals are likely to be present in and around Hamnavoe, and have been known to haul out on an island south of the entrance to the voe. However, any wildlife-source contamination is likely to be relatively minor compared to other identified sources such as livestock.

Seasonal variation

Significant seasonal variation is likely to occur in livestock population numbers, as sheep production is prevalent in the area and the number of sheep would roughly double during the summer months when lambs are present. Significant seasonal variation was also observed in rainfall, with higher rainfall generally occurring during the autumn and winter. However, significant rainfall events during summer may have a higher impact on the fishery due to the first flush effect of accumulated livestock droppings being washed to the fishery via area watercourses.

Rivers and streams

The main concentration of contamination from the observed watercourses would be towards the north east of the mussel farm and would tend to impact most on that end of the mussel lines. During heavy rainfall, direct run-off from the western shore may carry faecal contamination from animal droppings into the sea near to the mussel lines.

Movement of contaminants

The dilution of contaminants would be expected to be much greater at the southern end of the mussel lines than at the northern end due to the greater depth at the southern end. Currents within the voe are generally weak and the distances over which contaminants will be transported are limited.

At the mussel lines, flows on the flood tide would be expected to move from the Ness of Copister over the lines and northward towards the head of the voe, reversing direction on the ebb tide.

The most important sources of faecal contamination will therefore be those within the voe itself and potentially the greatest contamination will be seen at the northern end of the mussel farm.

Temporal and geographical patterns of sampling results

All samples had been taken from three reported locations close to each other and therefore a spatial analysis of the results was not undertaken. The general level of contamination has stayed the same over the period considered in this section. A seasonal effect was seen with results in summer being significantly higher than in spring and winter. All results greater than 230 *E. coli* MPN/ 100 g occurred in samples taken in July or August. This was reflected in a significant correlation with water temperature. No significant correlation was seen with salinity. Significant correlations were seen with rainfall over the two days and seven days prior to sampling although the highest results did not necessarily coincide with high rainfall on the two days prior to sampling. No significant correlation was seen with either the spring/neap or high/low tidal cycle. However, all samples giving a result greater than 230 *E. coli* MPN/100 g were taken on a flood tide and three of the four were taken as the tidal range increased towards springs.

Conclusions

Considering the results and observations obtained from the shoreline survey, and the patterns of water circulation suggested by the current meter study summarised in Section 14, there would appear to be two principal sources of contamination acting on the fishery. Both point-source and diffuse faecal pollution affect the Loch of Galtagarth, which in turn discharges to the head of Hamnavoe, which is very shallow, on the dropping tide.. This, combined with diffuse faecal pollution carried via the Burn of Arisdale, will affect water quality most at the head of the voe and hence toward the northern end of the mussel farm, where there has been less chance for any contaminants to dilute out.

Contamination arising to the southeast of the fishery is also expected to affect water quality at the mussel farm. Large numbers of sheep droppings were observed in this area during the shoreline survey, and the current meter study suggested that surface flows predominantly move northeast, toward the shore near the entrance to the voe. When this flow reaches land, it is likely that it will split and part will flow north along the shore. This flow would tend to carry contaminants arising from the southeast of the production area toward the mussel farm. All historical sampling results >230 *E. coli* coincided with a flooding tide, suggesting that higher levels of contamination arising from the southeast. This may in part be due to the location sampled, however during the shoreline survey the highest sample result also came from the southern end of the mussel farm. Contamination from this direction may either be arising from sources to the southeast of the fishery or be concentrating due to the predicted limited tidal excursion from the head of the loch.

17. Recommendations

Production area

The recommended production area boundaries are: The area bounded by lines drawn between HU 4900 7974 to HU 4900 7920 and HU 4835 8000 to HU 4889 8000, extending to MHWS. This represents a small change to the existing boundary that excludes the area nearest the head of the voe as contaminants there will receive less dilution than at the fishery. The southern boundary locations were adjusted slightly to bring them in line with MHWS.

RMP

It is recommended that the RMP be relocated to HU 4864 7950, which lies on the western side of the current mussel farm, toward the southern end. This lies within the southern half of the lines, which may receive inputs from sources arising both from the north and southeast.

Frequency

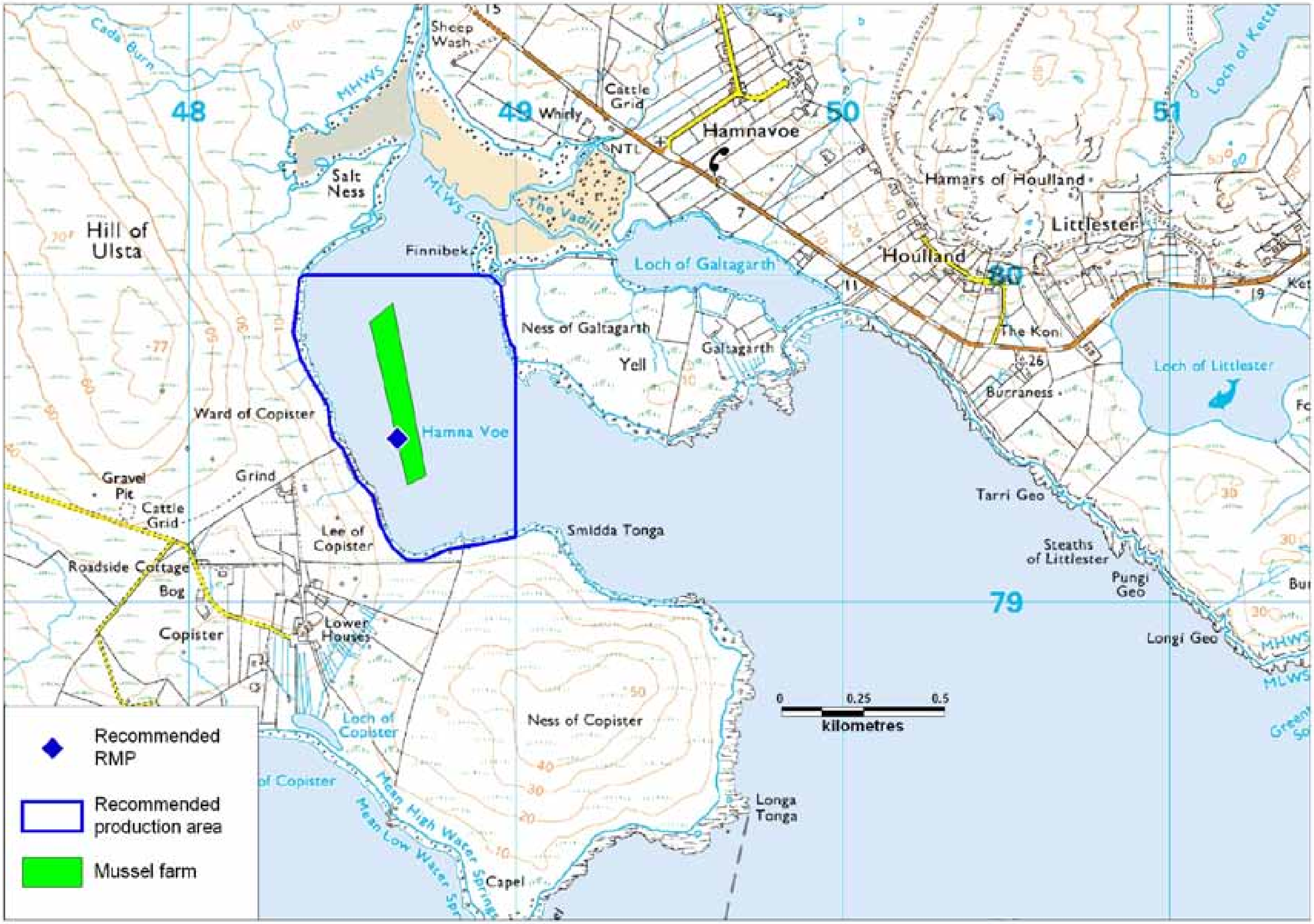
A stability assessment of the last three years monitoring results did not indicate that the area was suitable for reduced sampling frequency. Therefore, it is recommended that monthly monitoring be maintained.

Depth of sampling

As most of the potential sources of contamination to the head of the voe are likely to be found near the surface, and where samples were taken at the surface and depth showed higher contamination levels nearer the surface, it is recommended that the sampling depth be 1m.

Tolerance

A 40 metre sampling tolerance is recommended to allow scope for locating a sampling rope or bag at a suitable place on the mussel farm and to allow for movement of the lines.



Produced by Cefas Weymouth Laboratory.

Figure 16.1 Map of recommendations at Hamnavoe

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1. **Geology and Soils Assessment Method**
2. **General Information on Wildlife Impacts**
3. **Tables of Typical Faecal Bacteria Concentrations**
4. **Statistical Data**
5. **Hydrographic Methods**
6. **Shoreline Survey Report**

Geology and Soils Assessment Method

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

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

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

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

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

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

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

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

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

Glossary of Soil Terminology

Calcareous: Containing free calcium carbonate.

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

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

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

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

General Information on Wildlife Impacts

Pinnipeds

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

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

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

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

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

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

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

Cetaceans

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

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

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

Birds

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

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

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

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

Deer

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

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

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

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

Other

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

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

References:

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Tables of Typical Faecal Bacteria Concentrations

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

Indicator organism	Base-flow conditions				High-flow conditions			
Treatment levels and specific types: Faecal coliforms	n^c	Geometric mean	Lower 95% CI	Upper 95% CI	n^c	Geometric mean	Lower 95% CI	Upper 95% CI
Untreated	252	1.7×10^{7} * (+)	1.4×10^{7}	2.0×10^{7}	282	2.8×10^{6} * (-)	2.3×10^{6}	3.2×10^{6}
Crude sewage discharges	252	1.7×10^{7} * (+)	1.4×10^{7}	2.0×10^{7}	79	3.5×10^{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	1.0×10^{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	3.3×10^{5} * (-)	2.9×10^{5}	3.7×10^{5}	184	5.0×10^{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	2.8×10^{5} * (-)	2.2×10^{5}	3.5×10^{5}	93	5.1×10^{5} * (+)	3.1×10^{5}	8.5×10^{5}
Oxidation ditch	35	2.0×10^{5}	1.1×10^{5}	3.7×10^{5}	5	5.6×10^{5}		
Trickling/sand filter	11	2.1×10^{5}	9.0×10^{4}	6.0×10^{5}	8	1.3×10^{5}		
Rotating biological contactor	80	1.6×10^{5}	1.1×10^{5}	2.3×10^{5}	2	6.7×10^{5}		
Tertiary	179	1.3×10^{3}	7.5×10^{2}	2.2×10^{3}	8	9.1×10^{2}		
Reedbed/grass plot	71	1.3×10^{4}	5.4×10^{3}	3.4×10^{4}	2	1.5×10^{4}		
Ultraviolet disinfection	108	2.8×10^{2}	1.7×10^{2}	4.4×10^{2}	6	3.6×10^{2}		

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

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

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

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

Statistical Data

One-way ANOVA: Log_EC versus Season

```
Source  DF      SS     MS     F      P
Season   3   7.495  2.498  7.18  0.001
Error   36  12.528  0.348
Total   39  20.023

S = 0.5899   R-Sq = 37.43%   R-Sq(adj) = 32.22%


                            Individual 95% CIs For Mean Based on
                            Pooled StDev
Level    N    Mean   StDev  -----+---------+---------+---------+----
Autumn  10  1.6670  0.5553             (------*-------)
Spring  11  1.1095  0.2783  (------*------)
Summer  11  2.1820  0.9110                        (-------*------)
Winter   8  1.2258  0.3116   (--------*-------)
                            -----+---------+---------+---------+----
                               1.00      1.50      2.00      2.50

Pooled StDev = 0.5899


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

Individual confidence level = 98.93%


Season = Autumn subtracted from:

Season    Lower   Center   Upper  --------+---------+---------+---------+-
Spring  -1.2519  -0.5575  0.1369       (------*------)
Summer  -0.1794   0.5150  1.2095                  (------*------)
Winter  -1.1951  -0.4412  0.3126        (-------*------)
                                  --------+---------+---------+---------+-
                                       -1.0       0.0       1.0       2.0


Season = Spring subtracted from:

Season    Lower  Center   Upper  --------+---------+---------+---------+-
Summer   0.3949  1.0726  1.7502                         (------*------)
Winter  -0.6222  0.1163  0.8548             (------*-------)
                                 --------+---------+---------+---------+-
                                      -1.0       0.0       1.0       2.0


Season = Summer subtracted from:

Season    Lower   Center    Upper  --------+---------+---------+---------+-
Winter  -1.6947  -0.9563  -0.2178   (------*-------)
                                   --------+---------+---------+---------+-
                                        -1.0       0.0       1.0       2.0
```

One-way ANOVA: Log_EC versus Season

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Season   3   7.495  2.498  7.18  0.001
Error   36  12.528  0.348
Total   39  20.023

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```

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                            Individual 95% CIs For Mean Based on
                            Pooled StDev
Level    N    Mean   StDev  -----+---------+---------+---------+----
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                            -----+---------+---------+---------+----
                               1.00      1.50      2.00      2.50

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All Pairwise Comparisons among Levels of Season

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Winter  -1.1951  -0.4412  0.3126        (-------*------)
                                  --------+---------+---------+---------+-
                                       -1.0       0.0       1.0       2.0


Season = Spring subtracted from:

Season    Lower  Center   Upper  --------+---------+---------+---------+-
Summer   0.3949  1.0726  1.7502                       (------*------)
Winter  -0.6222  0.1163  0.8548             (------*-------)
                                 --------+---------+---------+---------+-
                                      -1.0       0.0       1.0       2.0


Season = Summer subtracted from:

Season    Lower   Center    Upper  --------+---------+---------+---------+-
Winter  -1.6947  -0.9563  -0.2178   (------*-------)
                                   --------+---------+---------+---------+-
                                        -1.0       0.0       1.0       2.0
```

Hydrographic Methods

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

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

Background processes

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

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

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

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

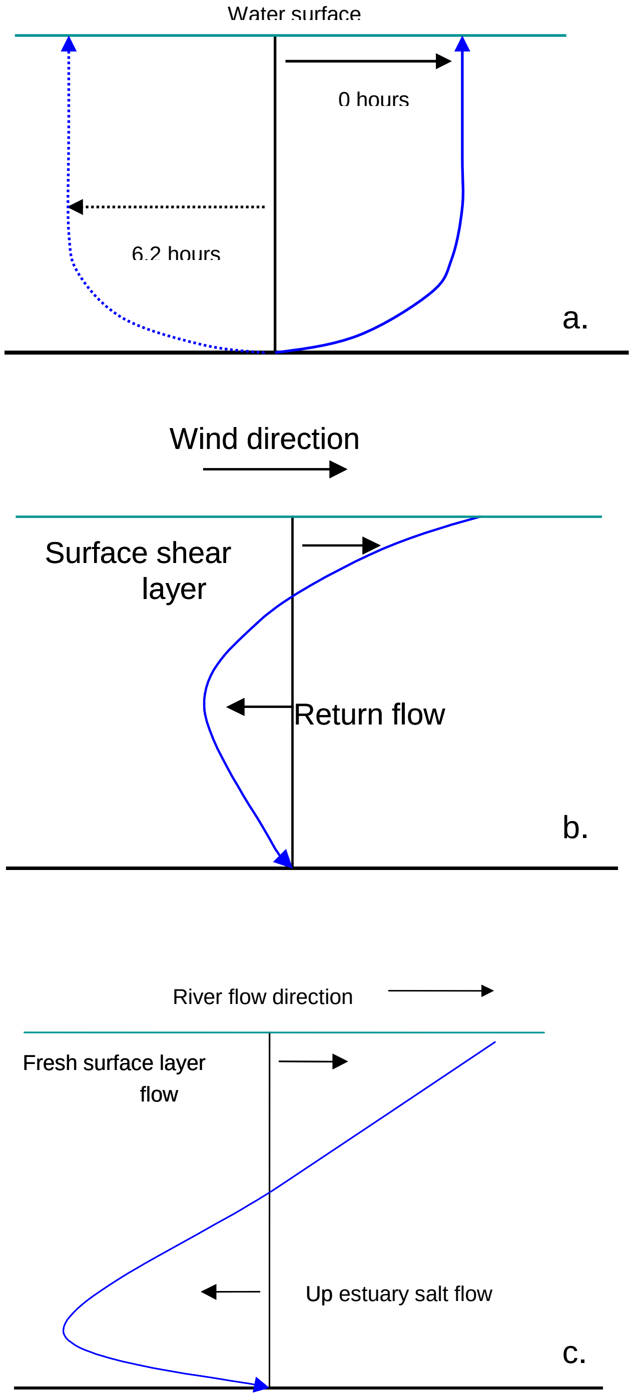

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

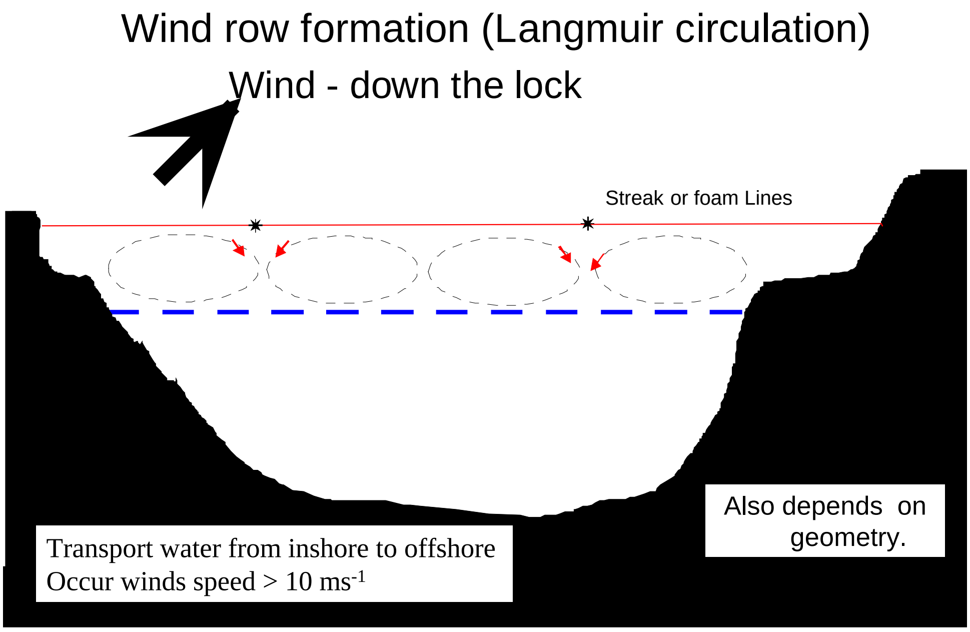

Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

<u>Non-modelling Assessment</u>

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

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

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

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

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

References

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

Glossary

The following technical terms may appear in the hydrographic assessment.

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

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

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

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

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

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

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

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

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

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

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

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

Shoreline Survey Report

Production area:	Hamnavoe
Site name:	Copister
SIN:	SI 348 736 08
Species:	Common mussels
Harvester:	Christopher Thomason
Local Authority:	Shetland Islands Council
Status:	Existing site
Date Surveyed:	18/08/2011
Surveyed by:	Jessica Larkham – Cefas Sean Williamson – NAFC
Existing RMP:	HU 486 795
Area Surveyed:	See Figure 1.

Weather observations
18/08/2011 – Calm and dry, slightly overcast in morning, light rain showers in the afternoon. Wind 1.2 knots, 14.9˚C.

Site Observations

Specific observations made on site are mapped in Figure 1 and listed in Table 1. Water and shellfish samples were collected at sites marked on Figures 2 and 3. Bacteriology results are given in Tables 2 and 3. Salinity profiles are presented in Table 4. Photographs are presented in Figures 4 – 15.

Fishery
The Hamnavoe mussel fishery is a smart farm system consisting of 4 sets of 7 PE-pipes with 2.2 m ropes. The fishery had sufficient stock on site for sampling at the time of the shoreline survey and the site is harvested all year round.

Sewage/Faecal Sources

Human
There are no large settlements in the area surrounding Hamnavoe. Several dwellings were observed on the shoreline northeast of the mussel farm belonging to the hamlets of Hamnavoe and Houlland. Three outfall pipes and one septic tank were observed leading down from houses between Hamnavoe and Houlland. No houses were observed on the small island of Yell to the east of the fishery or the shoreline to the west of the fishery. A freshwater hatchery was located at the mouth of the river, directly north of the fishery. There were several pipes from the hatchery freshwater tanks flowing directly into the river.

Livestock
Livestock were observed grazing around most of the shoreline surrounding Hamnavoe. Approximately 40 sheep were observed grazing on the eastern shoreline of the small island of Yell, although it was observed that they had

access to the whole island. Approximately 33 sheep in total were observed grazing along the shoreline between Houlland and the freshwater hatchery and approximately 67 sheep in total were observed grazing along the western shoreline adjacent to the fishery. In addition, a pony was observed grazing on the shoreline directly adjacent to the fishery on the western shoreline.

Seasonal Population

No hotels or B&B's were observed in the area surrounding the fishery. The island of Yell is popular with wildlife enthusiasts and walkers so there is likely to be holiday accommodation available elsewhere on the island.

Boats/Shipping

There is a daily ferry service from the Shetland mainland (Toft) to Yell (Ulsta), which runs all year round. There is a small marina on Yell close to the ferry terminal.

Land Use

The majority of the land adjacent to Hamnavoe is rough grassland with boggy areas.

Wildlife/Birds

During the shoreline survey approximately 5 geese and 11 seabirds were observed on the small island of Yell adjacent to the fishery. A further 7 gulls were observed near to the freshwater hatchery and a single gull was observed on the shoreline south of the fishery.

General observations

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

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

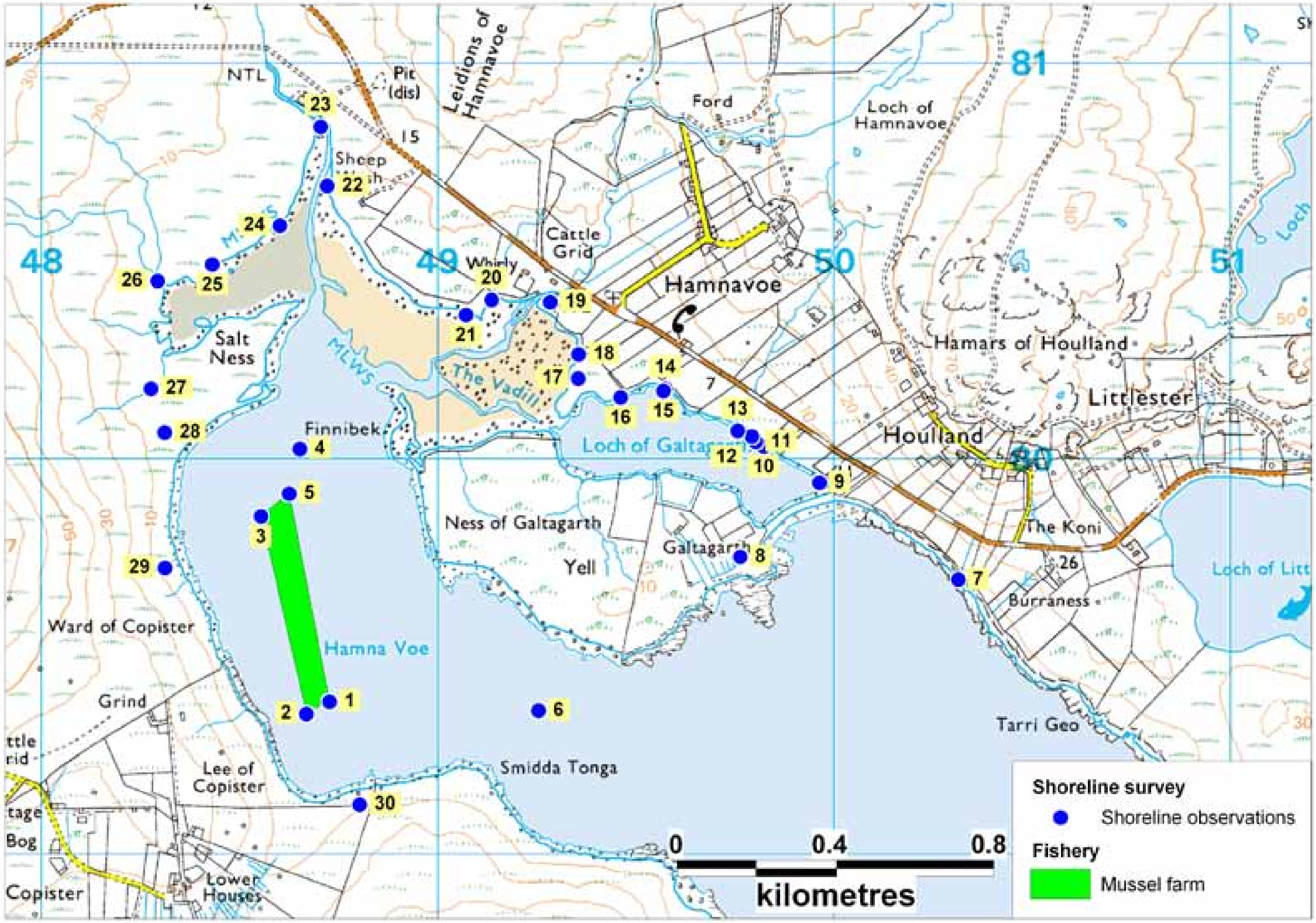

Figure 1. Shoreline Observations

Table 1 Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	18/08/2011	10:32	HU 48727 79388	448727	1179388	Figure 4	HVMUSSEL1, HVMUSSEL2, HVSW1	Corner of Hamnavoe mussel farm, SMART system, 4 sets of 7 lines 100 m in length, with 2.2 m long droppers. Location of mussel samples HVMUSSEL1 (2 m depth), HVMUSSEL2 (Surface) and seawater sample HVSW1, Salinity profile 5 m 36.4 ppt, 12.3˚C, 4 m 36.4 ppt, 12.2˚C, 3 m 36.4 ppt, 12.2˚C, 2 m 36.4 ppt, 12.2˚C, 1 m 36.4 ppt, 12.4˚C, Surface 35.7 ppt, 12.4˚C
2	18/08/2011	10:44	HU 48669 79357	448669	1179357			Corner of Hamnavoe mussel farm
3	18/08/2011	10:48	HU 48554 79856	448554	1179856		HVMUSSEL3, HVSW2	Corner of Hamnavoe mussel farm, location of mussel sample HVMUSSEL3 (2 m) and seawater sample HVSW2, Salinity profile 5 m 36.3 ppt, 12.2˚C, 4 m 36.3 ppt, 12.2˚C, 3 m, 36.3 ppt, 12.3˚C, 2 m 36.3 ppt, 12.3˚C, 1 m 36.2 ppt, 12.5˚C, Surface 36.2 ppt, 12.7˚C
4	18/08/2011	10:59	HU 48652 80027	448652	1180027		HVSW3	Location of seawater sample HVSW3A & HVSW3B
5	18/08/2011	11:02	HU 48625 79914	448625	1179914			Corner of Hamnavoe mussel farm
6	18/08/2011	11:10	HU 49255 79365	449255	1179365		HVSW4	Location of seawater sample HVSW4, no sheep observed on Papa Little
7	18/08/2011	12:27	HU 50314 79696	450314	1179696	Figure 5	HVFW1	Stream, Width 0.12 m, Depth 0.02 m, Flow 1.936 m/secs, Standard Deviation 0.017, location of freshwater sample HVFW1
8	18/08/2011	12:46	HU 49764 79754	449764	1179754	Figure 6		Approx 40 sheep on shore side of small island. 5 geese, 11 seabirds and lots of sheep droppings on shoreline
9	18/08/2011	12:54	HU 49964 79941	449964	1179941			Field drain
10	18/08/2011	12:58	HU 49823 80033	449823	1180033			3 houses next to the shoreline
11	18/08/2011	12:59	HU 49803 80045	449803	1180045	Figure 7		Outfall pipe, not flowing
12	18/08/2011	13:01	HU 49793 80058	449793	1180058	Figure 8	HVFW2	Outfall pipe, small flow, location of freshwater sample HVFW2
13	18/08/2011	13:07	HU 49757 80073	449757	1180073	Figure 9	HVFW3	Stream, Width 1.10 m, Depth 0.12 m, Flow 0.059 m/sec, Standard Deviation 0.005, location of freshwater sample HVFW3
14	18/08/2011	13:14	HU 49575 80179	449575	1180179	Figures 10 & 11	HVSW5	Outfall pipe and septic tank leading from houses. Location

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								of seawater sample HVSW5
15	18/08/2011	13:20	HU 49570 80174	449570	1180174			Field drain
16	18/08/2011	13:23	HU 49462 80157	449462	1180157			Approx 11 sheep
17	18/08/2011	13:25	HU 49355 80205	449355	1180205			Approx 14 sheep
18	18/08/2011	13:27	HU 49356 80266	449356	1180266			Field drain
19	18/08/2011	13:34	HU 49284 80398	449284	1180398	Figure 12	HVFW4	Stream, Width 2.74 m, Depth 0.25 m, Flow 0.103 m/sec, Standard Deviation 0.070, location of freshwater sample HVFW4
20	18/08/2011	13:46	HU 49136 80404	449136	1180404			Field drain
21	18/08/2011	13:48	HU 49072 80365	449072	1180365			Field drain
22	18/08/2011	13:56	HU 48721 80691	448721	1180691			Approx 7 gulls
23	18/08/2011	13:58	HU 48705 80841	448705	1180841	Figure 13	HVFW5	Freshwater hatchery, pipes flowing into river next to it. River too big to measure flow. Location of freshwater sample HVFW5. Approx 8 sheep.
24	18/08/2011	14:14	HU 48602 80591	448602	1180591			Approx 40 sheep on shoreline
25	18/08/2011	14:17	HU 48431 80493	448431	1180493			Field drain
26	18/08/2011	14:21	HU 48293 80451	448293	1180451	Figure 14	HVFW6	Stream, Width 0.15 m, Depth 0.17 m, Flow 0.043 m/sec, Standard Deviation 0.002, location of freshwater sample HVFW6
27	18/08/2011	14:28	HU 48277 80179	448277	1180179			Approx 12 sheep
28	18/08/2011	14:32	HU 48311 80068	448311	1180068	Figure 15		Pony grazing on the beach adjacent to mussel lines
29	18/08/2011	14:38	HU 48312 79726	448312	1179726			Approx 15 sheep
30	18/08/2011	14:53	HU 48803 79128	448803	1179128			1 gull

Photographs referenced in the table can be found attached as Figures 4 – 15.

Sampling

Water and shellfish samples were collected at sites marked on the maps in Figures 2 and 3 respectively. Bacteriology results follow in Tables 2 and 3. Samples were transferred to a cool box with ice packs after sampling then delivered by hand on the same day to the SSQC laboratory at the NAFC Marine College in Scalloway. Samples were then processed the day after sampling.

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

Table 2. Water sample *E. coli* results

No.	Sample Ref.	Date	Position	Type	*E. coli* (cfu/100 ml)	Salinity (g/L)
1	HVSW1	18/08/2011	HU 48727 79388	Seawater	<1	35.4
2	HVSW2	18/08/2011	HU 48554 79856	Seawater	2	34.1
3	HVSW3	18/08/2011	HU 48652 80027	Seawater	1	35.4
4	HVSW4	18/08/2011	HU 49255 79365	Seawater	7	35.0
5	HVSW5	18/08/2011	HU 49575 80179	Seawater	4.7×10^3	33.2
6	HVFW1	18/08/2011	HU 50314 79696	Freshwater	70	
7	HVFW2	18/08/2011	HU 49793 80058	Freshwater	50	
8	HVFW3	18/08/2011	HU 49757 80073	Freshwater	180	
9	HVFW4	18/08/2011	HU 49284 80398	Freshwater	130	
10	HVFW5	18/08/2011	HU 48705 80841	Freshwater	30	
11	HVFW6	18/08/2011	HU 48293 80451	Freshwater	50	

Table 3. Shellfish sample *E. coli* results

No.	Sample Ref.	Date	Position	Species	Depth (m)	*E. coli* MPN/100 g
1	HVMUSSEL1	18/08/2011	HU 48727 79388	Common mussels	2	80
2	HVMUSSEL2	18/08/2011	HU 48727 79388	Common mussels	Surface	230
3	HVMUSSEL3	18/08/2011	HU 48554 79856	Common mussels	2	130

Table 4. Salinity profiles

Profile	Date	Time	Position	Depth (m)	Salinity (ppt)	Temperature ˚C
1	18/08/2011	10:32	HU 48727 79388	Surface	35.7	12.4
				1	36.4	12.4
				2	36.4	12.2
				3	36.4	12.2
				4	36.4	12.2
				5	36.4	12.3
2	18/08/2011	10:38	HU 48554 79856	Surface	36.2	12.7
				1	36.2	12.5
				2	36.3	12.3
				3	36.3	12.3
				4	36.3	12.2
				5	36.3	12.2

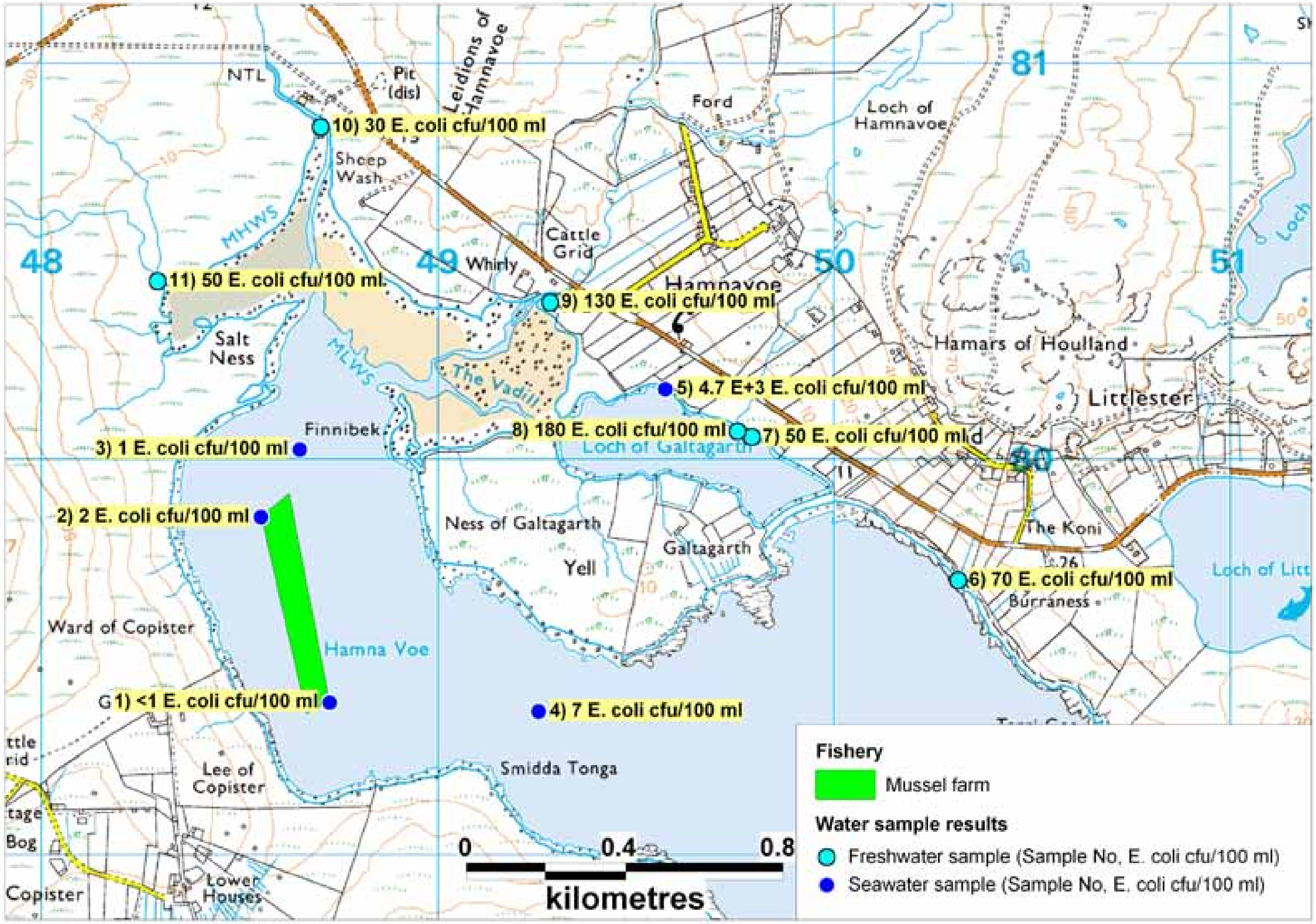

Figure 2. Water sample results

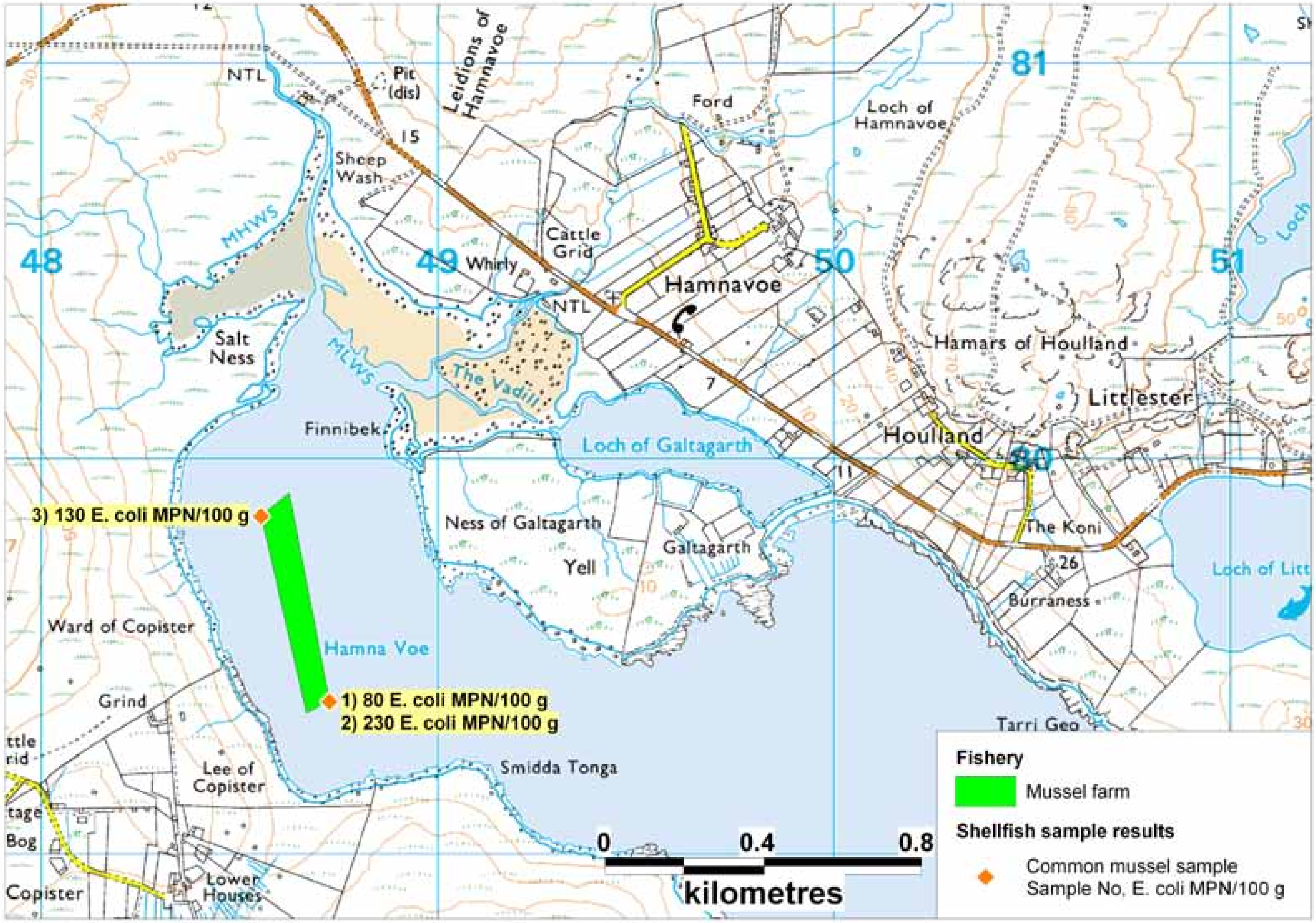

Figure 3. Shellfish sample results

Photographs

Figure 4. Hamnavoe mussel farm

Figure 5. Stream, location of freshwater sample HVFW1

Figure 6. Approx 40 sheep in field on small island of Yell

Figure 7. Outfall pipe, not flowing

Figure 8. Outfall pipe, small flow, location of freshwater sample HVFW2

Figure 9. Stream, location of freshwater sample HVFW3

Figure 10. Outfall pipe leading down from houses, location of seawater sample HVSW5

Figure 11. Septic tank joined on to outfall pipe shown in Figure 10

Figure 12. Stream, location of freshwater sample HVFW4

Figure 13. Freshwater Hatchery, pipes flowing into the river, location of freshwater sample HVFW6

Figure 14. Stream, location of freshwater sample HVFW6

Figure 15. Pony grazing on the beach adjacent to mussel lines