Scottish Sanitary Survey Programme

Sanitary Survey Report

Production Area: Basta Voe Outer

SIN: SI 323 403 08

April 2012

Report Distribution – Basta Voe Outer

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I. Executive Summary

The sanitary survey at Basta Voe: Outer was undertaken due to the ranking of the area in a statistical assessment of potential deterioration in *E. coli* results. Basta Voe is located on the eastern side of the island of Yell in the northern Shetland Islands. The area is sparsely populated, with the four small settlements of Basta, Colvister, Sellafirth and Cunnister on the shoreline of Basta Voe.

The Basta Voe: Outer mussel fishery is a longline mussel farm consisting of seven long lines, each 200 m in length with 5 – 8 m droppers. The site is harvested all year round.

There are no large sewage discharges in the area surrounding Basta Voe and the shoreline immediately adjacent to the fishery is uninhabited. There are a number of small sewage discharges to soakaway or land from private houses, with one to directly into the voe, north-west and south west of the fishery. If these septic tanks are failing or poorly functioning they may contribute to background levels of faecal contamination in the outer voe. Overall sewage discharges are unlikely to impact significantly on the mussel fishery at Basta Voe.

The most significant source of faecal contamination reaching Basta Voe is from diffuse, livestock sources. There is the potential for livestock faeces to impact on the waters of the mussel farm, via both streams and rainfall dependent direct runoff from the north and southeast of the farm. Run-off due to rainfall will usually be higher during the autumn and winter months when rainfall is highest. Very large numbers of sheep are kept within the parish and livestock were observed grazing around most of the shoreline adjacent to the fishery. Direct deposition of livestock faeces on the intertidal shoreline will potentially contaminate the fishery waters independent of rainfall

Wildlife likely to contribute to background levels of faecal contamination includes marine mammals and seabirds. Large numbers of various birds were observed during the shoreline survey and many bird droppings were seen on the shore. The impacts from seabirds are most likely to be highest during the summer months, when birds are present on and near nests. Impacts from goose and other bird droppings deposited on shore are most likely to be higher where the mussel farm lies nearest the shore. These will provide a source of diffuse faecal contamination at the fishery when washed into the water.

Much of Basta Voe is relatively deep and any contamination will be subject to significant dilution before reaching the shellfishery, except for that arising from the shore immediately adjacent to the mussel farm. This contamination is more likely to affect the lower half of the farm and to be transported out of the loch on the outward-bound surface current. For the remaining mussel farm at

Basta Voe Outer, sources located further up the voe are more likely to contribute to levels of faecal contamination found in the mussels

<u>Recommendations</u>

Production area:
As the mussel farms at the north end of the current production area lie partly in both Basta Voe: Outer and Basta Voe: Cove production areas, it is recommended that the northern boundary of the Basta Voe: Outer production area is curtailed to exclude these farms, which will be included into the Basta Voe: Cove production area. The southern boundary was amended to bring the area in closer agreement with the designated SGW, however the western end of the boundary was set at Basta Ness, a more easily recognised feature. Therefore, the recommended boundary is described as the area bounded by lines drawn between HU 5263 9620 to HU 5193 9578 and between HU 5369 9380 and HU 5489 9488, extending to MHWS.

RMP:
As sources from the north and east are more likely to have an effect on water quality at the mussel farm, it is recommended the RMP be adjusted to HU 5294 9568, which lies at the northeast corner of the farm.

II. Sampling Plan

PRODUCTION AREA	Basta Voe Outer
SITE NAME	Outer
SIN	SI 323 403 08
SPECIES	Common mussels
TYPE OF FISHERY	Aquaculture
NGR OF RMP	HU 5294 9568
EAST	452940
NORTH	119568
TOLERANCE (M)	40
DEPTH (M)	1-3
METHOD OF SAMPLING	Hand
FREQUENCY OF SAMPLING	Monthly
LOCAL AUTHORITY	Shetlands Islands Council
AUTHORISED SAMPLER(S)	
LOCAL AUTHORITY LIAISON OFFICER	

III. Report

1. General Description

Basta Voe is located on the eastern side of the island of Yell in the northern Shetland Islands. The voe is approximately 5km in length and approximately 1.5km wide at its widest point, the mouth. The voe is sheltered and surrounded by moderately steep hills.

The sanitary survey at Basta Voe: Outer was undertaken due to the ranking of the area in a statistical assessment of potential deterioration in *E. coli* results. A map showing the location of the area is shown in Figure 2.1.

Figure 1.1 Location of Basta Voe

2. Fishery

The Basta Voe: Outer fishery has historically comprised three sites used for longline mussel aquaculture: Inner – Site 1 – Thomason, Outer, and Basta Ness. The Inner – Site 1 – Thomason site lies partly within the Basta Voe Cove production area, nearer the head of the voe. It was agreed with the Food Standards Agency in Scotland that due to the nature of the area, this site would be addressed when Basta Voe: Cove is surveyed and therefore it is not considered within this survey.

At the time of shoreline survey in 2011, the Basta Voe: Outer mussel fishery comprised a single longline mussel farm at the Outer site with seven lines, each 200 m in length with 5 – 8 m droppers. The Basta Ness site located southeast of the Outer site and near the entrance to the voe, has been sold to an aquaculture company who do not intend on using it to farm shellfish.

The production area boundary is defined as the area bounded by a line drawn between HU 5244 9700 and HU 5128 9771 to a line drawn between HU 5379 9300 and HU 5575 9523.

The nominal Representative Monitoring Point (RMP) is reported as HU 532 957, which lies 150 m north of the mussel lines. The site may be harvested at any time of year. The location of the Outer mussel farm was recorded during the shoreline survey and is shown mapped, together with the production area boundaries, RMP and lease areas, in Figure 2.1.

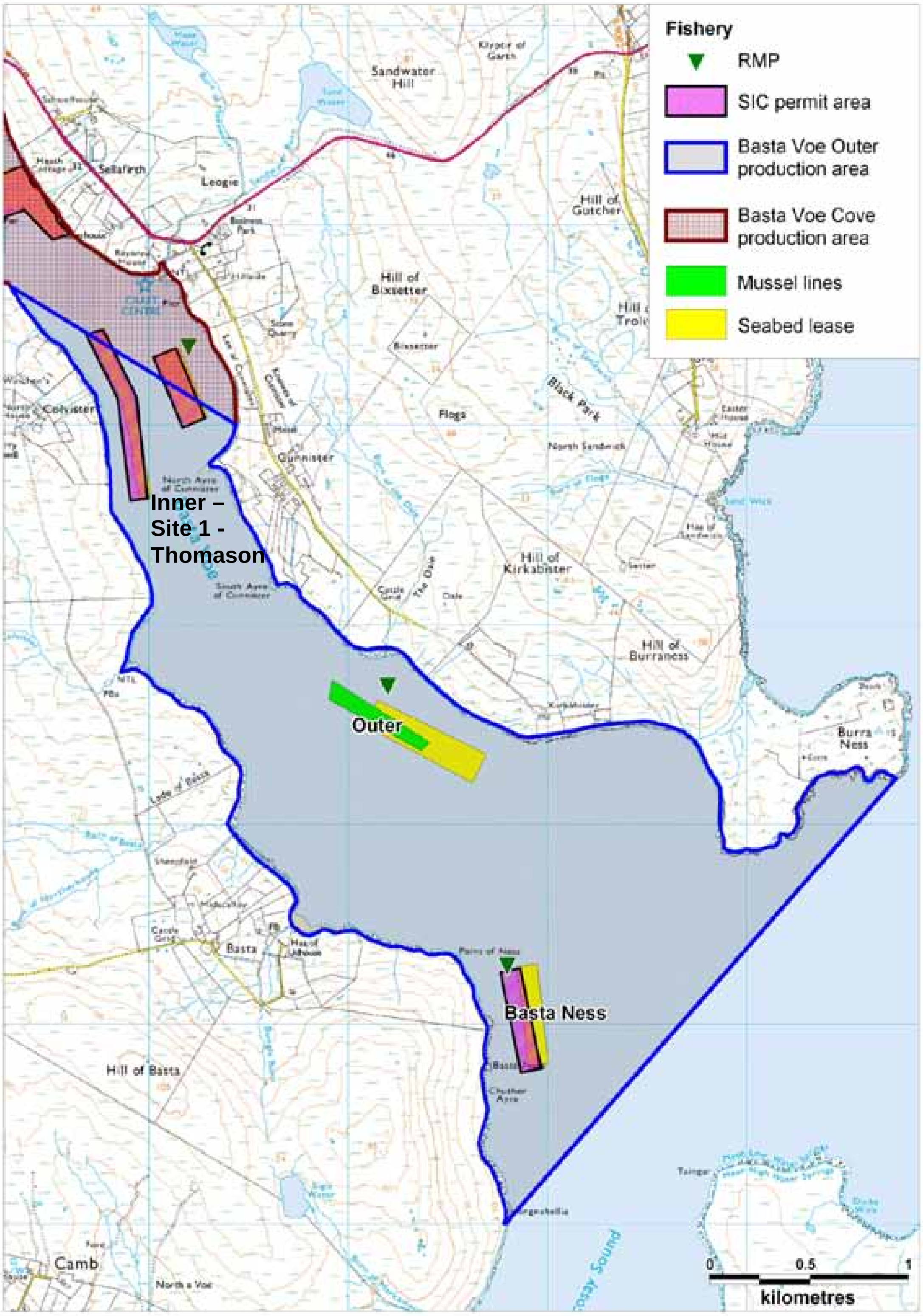
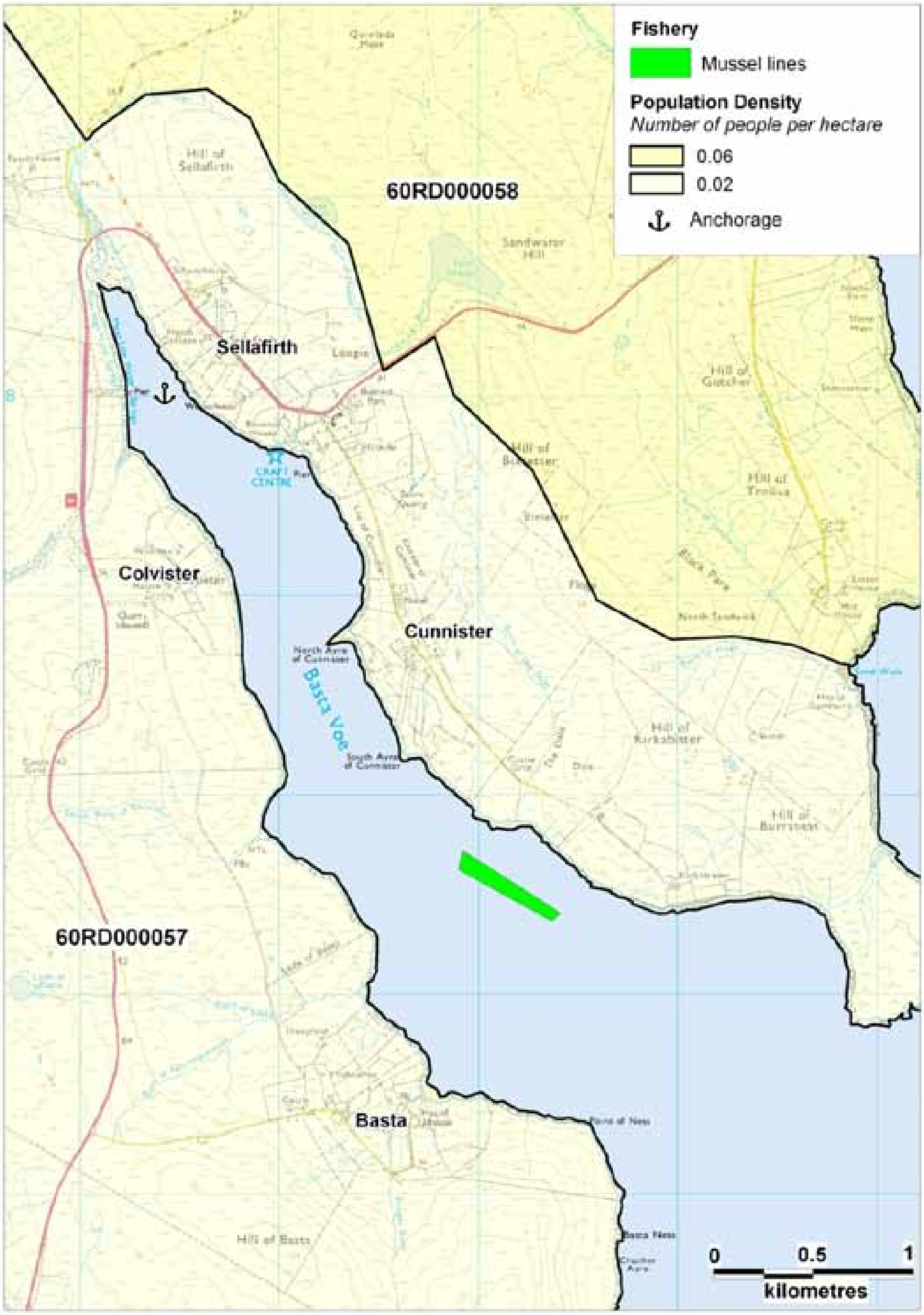


Figure 2.1 Basta Voe Outer Fishery

3. Human Population

Information on the human population of the area surrounding Basta Voe was obtained from the General Register Office for Scotland. Data was provided for the 2001 census by output area. The population density for the output areas nearest the fishery is shown thematically mapped in Figure 3.1.



 2001 Population Census Data, General Register Office, Scotland.

Figure 3.1 Population map of Basta Voe

Population density for the census output areas surrounding Basta Voe is low, indicating that overall the area surrounding the fishery is sparsely populated. The shoreline at Basta Voe is accessible via inland roads/tracks running along both sides of the voe. There are four small settlements along these roads, consisting primarily of farms or crofts, at Basta, Colvister, Sellafirth and Cunnister. The largest of these settlements is Sellafirth, near the head of the voe. The nearest dwelling to the mussel farm is just less than 1 km to the north and approximately 250 m from the shore. There are no dwellings along the shoreline adjacent to the mussel farm and one derelict farm house southeast of the mussel farm.

Table 3.1 Census output areas: Basta Voe Outer

Output area	Population
60RD000057	122
60RD000058	169
Total	**191**

There is a small pier located at Sellafirth. A boat was observed working on the mussel fishery on the second day of the shoreline survey. There is an anchorage at the northern end of the voe close to the settlement of Sellafirth.

The ferry route between Yell and Fetlar passes approximately 2 km east of the production area boundary. This ferry visits Fetlar (the terminal nearest the fishery) up to 10 times per day during summer, and less frequently in winter. Ferries are generally required to provide onboard treatment of sanitary wastes and would therefore only be expected to discharge treated waste overboard and then only greater than 3 nautical miles (5.6 km) from land (http://www.dft.gov.uk/mca/mcga-notice.htm?textobjid=66BA552FA1C46975, Accessed April 2012). Overboard discharge of treated wastes from the ferries is unlikely to contribute to faecal contamination at the fishery. Discharges of untreated wastes from other boat traffic, should they occur in the vicinity of the mussel farm, could cause high levels of contamination at the fishery, depending on the proximity and direction of any discharge relative to the mussel lines.

The motel identified on the OS map is the North Isles Motel, which has been abandoned. There are no known tourist facilities along Basta Voe and therefore no significant seasonal increase in human population is expected.

Overall, the impact from human population is likely to be very low within the outer part of the voe.

4. Sewage Discharges

Information on sewage discharges in the vicinity of the fishery was sought from Scottish Water and the Scottish Environment Protection Agency (SEPA). No Scottish Water community septic tanks or sewage discharges were identified for the area surrounding the Basta Voe fishery.

Discharge consents provided by SEPA are listed in Table 4.1. There are no intermittent discharges in the area. No information on consent conditions or size of discharge was provided.

Table 4.1 Discharge consents identified by SEPA

No.	Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented/ design PE	Discharges to
1	CAR/R/1039899	HU 52670 94440	Sewage (Private) Primary	Septic tank	-	Soakaway
2	CAR/R/1039912	HU 52350 94390	Sewage (Private) Primary	Septic tank	-	Soakaway
3	CAR/R/1039916	HU 52220 94470	Sewage (Private) Primary	Septic tank	-	Soakaway
4	CAR/R/1082094	HU 51080 99250	Sewage (Public) Primary	Septic tank	-	Soakaway
5	CAR/R/1009334	HU 51610 98270	Sewage (Private) Primary	Septic tank	-	Soakaway
6	CAR/R/1077854	HU 51828 97971	Sewage (Private) Primary	Septic tank	-	Soakaway
7	CAR/R/1046278	HU 51990 97757	Sewage (Private) Primary	Septic tank	-	Basta Voe
8	CAR/R/1089818	HU 52043 97833	Sewage (Private) Primary	Septic tank	-	Soakaway
9	CAR/R/1039538	HU 52120 97880	Sewage (Private) Primary	Septic tank	-	Land
10	CAR/R/1079161	HU 52310 97810	Sewage (Private) Primary	Septic tank	-	Soakaway
11	CAR/R/1039536	HU 52330 97540	Sewage (Private) Primary	Septic tank	-	Land
12	CAR/R/1039537	HU 52700 96780	Sewage (Private) Primary	Septic tank	-	Land
13	CAR/R/1037580	HU 52600 96580	Sewage (Private) Primary	Septic tank	-	Land
14	CAR/R/1039954	HU 52760 96450	Sewage (Private) Primary	Septic tank	-	Soakaway
15	CAR/R/1038770	HU 54710 97180	Sewage (Private) Primary	Septic tank	-	Soakaway
16	CAR/R/1036925	HU 54640 97030	Sewage (Private) Primary	Septic tank	-	Soakaway
17	CAR/R/1039547	HU 54820 96980	Sewage (Private) Primary	Septic tank	-	Land

No consent related to the business park at Sellafirth, and it is likely that there are other septic tanks in the area not included in Table 4.1. There are no large sewage discharges in the area surrounding Basta Voe and the shoreline immediately adjacent to the fishery is uninhabited. The majority of consents relate to private dwellings and all except one discharge either to land or to soakaway. Provided the systems are working properly, these discharges are unlikely to impact significantly on the mussel fishery at Basta Voe. One tank (Table 4.1, No. 7) discharges to Busta Voe approximately 2.3 km northwest of the mussel farm.

One pipe was observed during the shoreline survey, however it was not flowing and was not near any dwellings, therefore is not likely to have been associated with septic waste. No other outfall pipes, septic tanks or sanitary debris was observed during the shoreline survey.

Overall the impact of microbiological contamination of the fishery from sewage discharges will not be significant.

Figure 4.1 Map of discharges for Basta Voe Outer

5. Geology and Soils

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

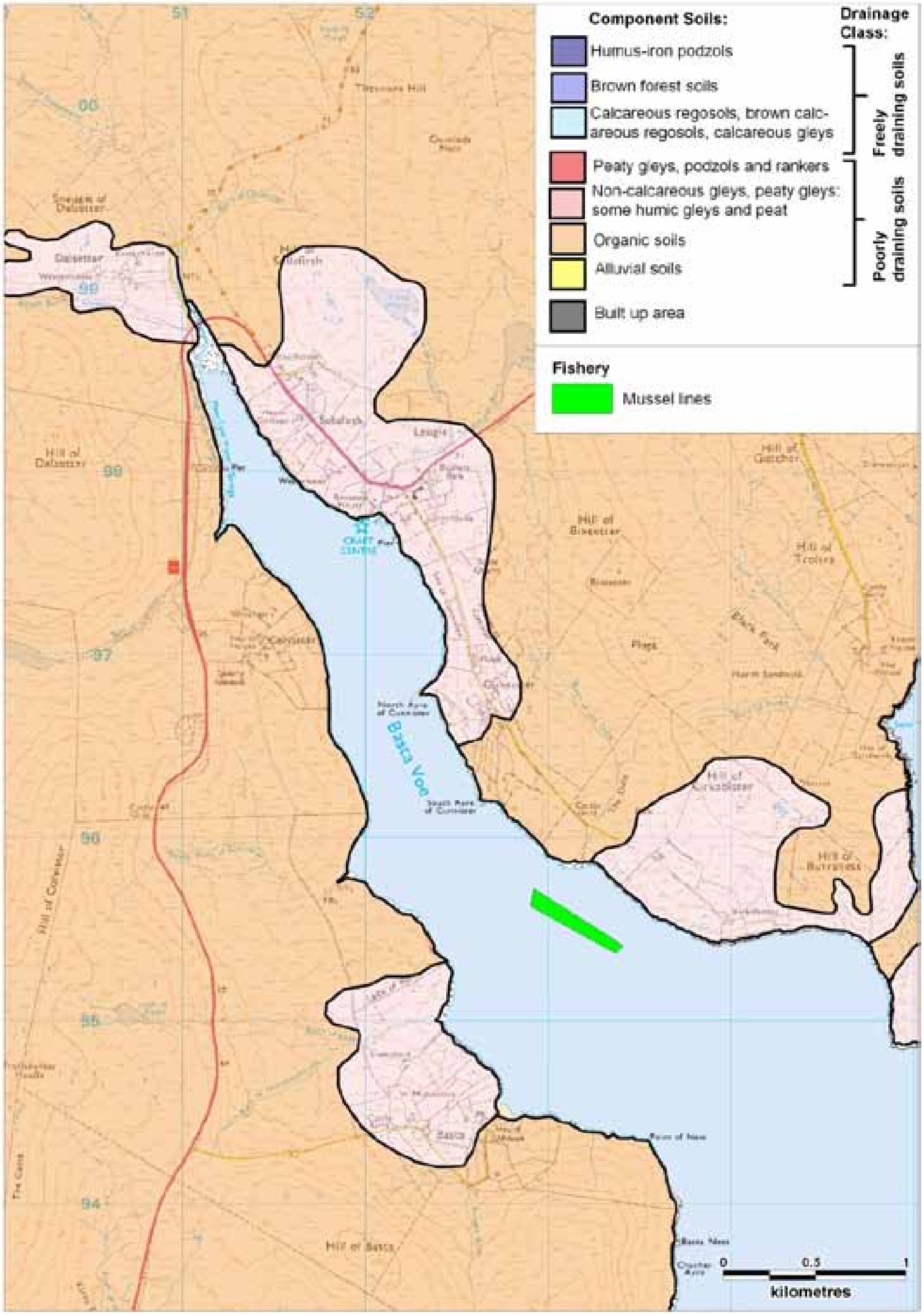


Figure 5.1 Component soils and drainage classes for Basta Voe

Two types of component soil are found in the vicinity of Basta Voe. The large majority of the area is composed of organic soils. Areas of non-calcareous gleys, peaty gleys, some humic gleys and peat are found in areas along the eastern shoreline, extending northwest from the head of the voe, and in a small area around Basta on the southwest shore. No areas have been identified as built up.

Therefore, due to poor soil permeability, the potential for runoff potentially contaminated with *E. coli* from human and/or animal waste is high along the entire coastline of Basta Voe.

6. Land Cover

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

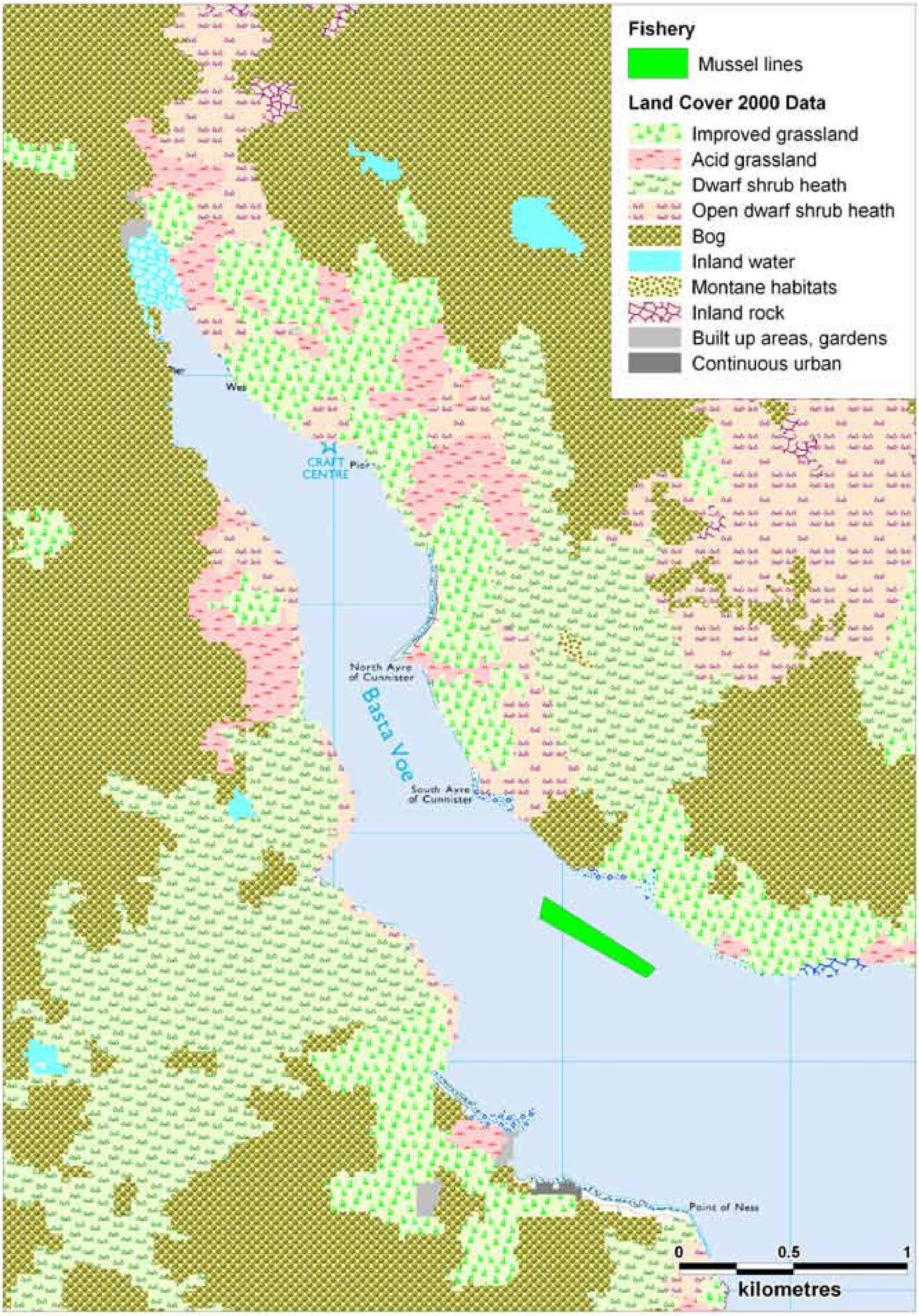


Figure 6.1 LCM2000 class land cover data for Basta Voe Outer

Much of the land around Basta Voe is covered by bog and heath, with a large area of bog around the head of the voe. Improved and acid grassland is found adjacent to the shoreline along much of the eastern side of the voe, including the land adjacent to the shellfish farm. The settlement of Basta, located opposite the shellfish farm on the southwest shoreline of the voe is represented by small patches of built up areas and continuous urban land use. The built up area roughly corresponds with two of the three croft houses at Basta. The continuous urban area corresponds with uninhabited shoreline and is therefore considered to be erroneously classified.

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 majority of land cover present around Basta Voe would fall into this category, as it is likely to be used for extensive sheep grazing. 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 potential for contribution of faecal coliform bacteria attributable to land cover type is greatest for the areas of improved grassland which lie adjacent to the shoreline along the eastern side of the voe, including that adjacent to the mussel farm, and on the western side of the voe to the southwest of the mussel farm.

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 for Yell parish from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD). 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, extending over 27 km north to south and including nearby smaller islands. The fishery lies in Basta Voe on northeast side 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 and 20th October 2011. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1. Observations were dependent upon the viewpoint of the observer, and some animals may have been obscured from view.

Approximately 60 sheep and 8 cattle were observed to the southwest of the fishery and 74 sheep were seen on the shore northeast of the fishery. Some livestock were fenced in fields and approximately half the sheep had access to the shoreline. Sheep droppings were abundant on both sides of the voe. The catchment for the area extends along a number of burns, and the areas away from the immediate shoreline were not viewed. Therefore, additional animals may have been present but not directly observed.

Figure 7.1 Livestock observations at Basta Voe Outer

Sheep populations in particular will be roughly double during the late spring and summer when lambs are present. Lambs are typically sent to market in autumn, after which the sheep population returns to pre-spring levels. The shoreline survey was undertaken in October, therefore the numbers observed would have most likely reflected winter population.

Some of the improved grassland area may be used for production of silage, in which case it may receive application of either slurry or dry farm yard manure. Based on publicly available satellite imagery, fields of improved grassland around Kirkabister and Cunnister, approximately 0.5 km to the east and north of the mussel farm, respectively, are the closest of these areas to the fishery.

There is also the potential for direct runoff of livestock wastes from the grazed hillsides adjacent to the fishery, particularly to the east and southeast of the mussel farm.

8. Wildlife

Wildlife may contribute to faecal contamination observed at shellfisheries. General information on the impacts of wildlife species can be found in Appendix 2. Wildlife species most likely to contribute to faecal contamination of the waters of Basta Voe include birds, seals and otters.

The Fetlar Special Protected Area (SPA) is located east of the Burra Ness headland. It is designated for a range of habitats and is important for breeding waders and seabirds (http://jncc.defra.gov.uk/page-1893, Accessed 20/03/2012). Also on Fetlar, the North Fetlar Special Area of Conservation (SAC) is designated for its habitats, with no special reference to animal species. Hascosay Island, located <1 km from the southern boundary of the production area, is a Special Area of Conservation (SAC) designated for primarily for blanket bog habitats, with otters (*Lutra lutra*) listed as a qualifying species. The East Mires and Lumbister SAC lies inland to the west of Basta Voe and is designated for blanket bog.

Seabirds

Seabird 2000 census data was queried for the area within a 5 km radius of the Basta Voe Outer 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 Basta Voe shellfish farm

Common name	Species	Count	Method
Arctic Tern	*Sterna paradisaea*	122	Individuals on land
Northern Fulmar	*Fulmarus glacialis*	1140	Occupied sites
Herring Gull	*Larus argentatus*	27	Occupied nests/ Individuals on land
Common Gull	*Larus canus*	117	Occupied nests or territory/ Individuals on land
Black Guillemot	*Cepphus grylle*	133	Individuals on land
Great Black-backed Gull	*Larus marinus*	58	Occupied nests or territory/ Individuals on land
Lesser Black-backed Gull	*Larus fuscus*	4	Occupied territory
Black-headed Gull	*Larus ridibundus*	24	Occupied territory or nests
Great Skua	*Stercorarius skua*	140	Occupied territory
European Shag	*Phalacrocorax aristotelis*	6	Occupied nests
Arctic skua	*Stercorarius parasiticus*	64	Occupied territory
European Storm Petrel	*Hydrobates pelagicus*	194	Occupied sites
Razorbill	*Alca torda*	11	Individuals on land

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

Seabird2000 census data records showed an estimated total 2040 seabirds within a 5km radius of the fishery.

During the breeding season, the Fetlar SPA area supports, on average, in excess of 20,000 individual seabirds, and an extension of the SPA to include waters extending 2km beyond the island has been proposed to allow for essential water habitat area required by some of the seabird species for maintenance activities (http://www.snh.org.uk/pdfs/directives/b269966.pdf, Accessed 12/04/2012).

Seabirds nesting at or near the fishery are most likely to contribute diffuse faecal contamination to the area, particularly after rainfall when guano can be washed from around nesting areas. Although some species, such as some gulls, are likely to be present year round, many of the seabirds will only be present near shore during the summer nesting season. Guano deposited around their nest areas is likely to wash off in rainfall over a longer period of time, however.

During the shoreline survey on the 18th and 20th October 2011, approximately 204 gulls and 1 cormorant were observed.

Wildfowl and wading birds

Fifteen geese were observed during the shoreline survey. Goose droppings were present on the shoreline in large numbers on both sides of the voe. No specific data were found on counts in the vicinity of Basta Voe, although the large areas of grassland are likely to be attractive to geese that feed on grass. Eider ducks are commonly found around Shetland and feed on mussels, therefore these animals are likely to be present in the area from time to time. Both ducks and geese may contribute faecal contamination to the waters around the fishery through direct deposition of droppings at or near the mussel farm, and through carriage of faecal material in rainfall runoff from land areas where they rest and/or feed. Given the large numbers of droppings observed, it is likely that geese contribute to the levels of faecal contamination found in land runoff and streams around the fishery.

Seals

Both grey seals (*Halichoerus grypus*) and common or harbour seals (*Phoca vitulina vitulina*) are recorded in Shetland, and are common around the coastline of Yell, especially in the Yell Sound Special Area of Conservation (SAC) located on the opposite side of the island. Harbour seal haulouts are recorded on both Fetlar and Hascosay and a survey undertaken in 2001 found 126 seals on these two islands. There is a grey seal breeding colony on Fetlar, though no count of the total population of grey seals likely to be present in the area was available. Given the proximity of Fetlar and Hascosay to Basta Voe, seals are likely to forage in the voe and therefore may contribute to background levels of contamination there. One seal was seen near the mussel farm during the shoreline survey.

Otters

Otters (*Lutra lutra*) have been recorded in Basta Voe in the past, however no recent records of otter numbers were found within the voe. Otters typically defecate in established latrines adjacent to freshwater courses. Otters forage mainly within the 10m depth curve and maintain their holts up fresh water streams from the coast. Basta Voe 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. The Hascosay SAC is secondarily designated for otters, although numbers on the island were not investigated. However, typical population densities of coastal otters are low and therefore any impact is expected to be minor. No otters were seen during the shoreline survey.

Cetaceans

Whales and dolphins are present around the Shetland Islands and these animals have been seen in the sound between Yell and Fetlar and two beached within Basta Voe in March 2012 (dead) and August 2011 (http://www.nature-shetland.co.uk/naturelatest/latestcetaceans.htm, accessed 13/04/2012). Common dolphins have been observed in Basta Voe suggesting that small cetacean species may be commonly found within the voe (http://www.nature-shetland.co.uk/naturelatest/archives/seamammalarchive07.htm). Although these animals are likely to be present in and around the fishery, their potential impact on water quality is poorly characterised. These animals are likely to contribute to background levels of contamination at the fishery when they are present.

Conclusions

Wildlife species likely to contribute to background contamination levels within Basta Voe include whales and dolphins, seals, seabirds, geese and eider ducks, and otters. Of these, the available information showed that seabirds were the most numerous. The impacts from seabirds are most likely to be highest during the summer months, when birds are present on and near nests. All of the species likely to be present may have a significant impact on faecal contamination at the fishery if they happen to defecate in close proximity to the mussel lines. However, there is no evidence to suggest whether any part of the fishery is more likely to be affected by this than another.

Impacts from goose droppings deposited on shore are most likely to be higher where the mussel farm lies nearest the shore.

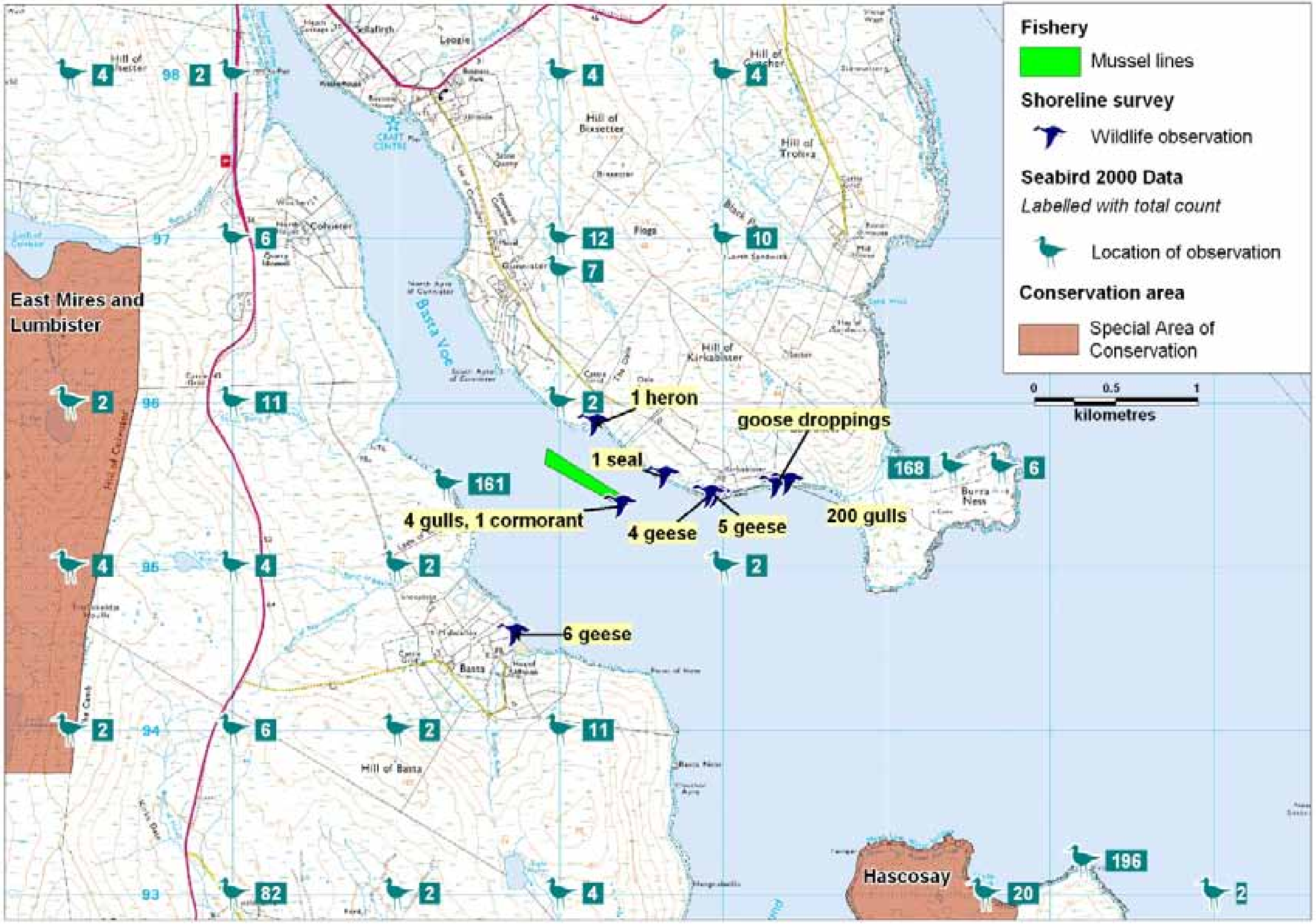


Figure 8.1 Map of seabird distributions

9. Meteorological data

The nearest weather station is located at Unst: Uyeasound No. 3, 8.4 km north east of the production area. Rainfall data was obtained for 2003-2010, however data was missing for the months of November and December 2010.

The nearest wind station is Sumburgh, which lies approximately 87 km to the south of the production area. Due to the distance and differences in topography between these locations, wind patterns at Basta Voe may differ significantly from Sumburgh. However, this data is still shown as it can be useful in identifying seasonal variation in wind patterns.

This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish at Basta Voe Outer.

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). The box and whisker plots in Figures 9.1 and 9.2, present a summary of the distribution of individual daily rainfall values by year and by month. The grey box represents the middle 50% of the observations, with the median 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 *.

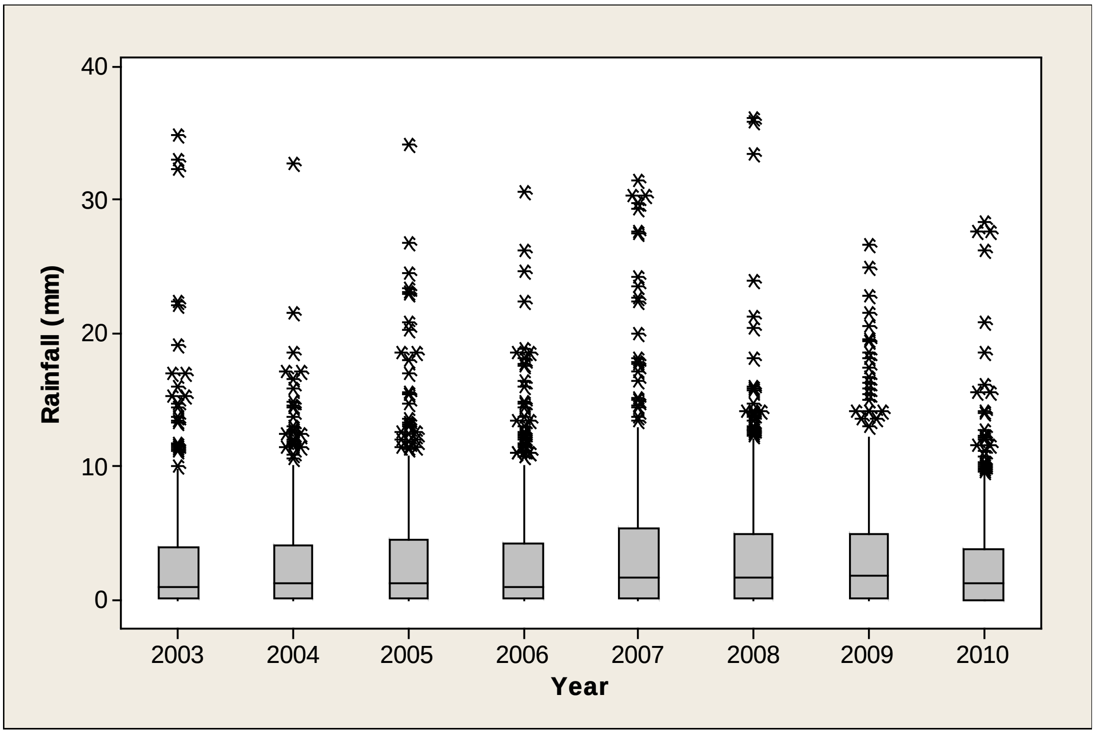


Figure 9.1 Daily rainfall values by year at Unst: Uyeasound No3 (2003 –2010)

Annual rainfall varied slightly over the years examined. The wettest year was 2007 and the driest 2006. Although 2010 appeared to be relatively dry, data for November and December were missing and therefore this year cannot be compared on the same terms with previous years.

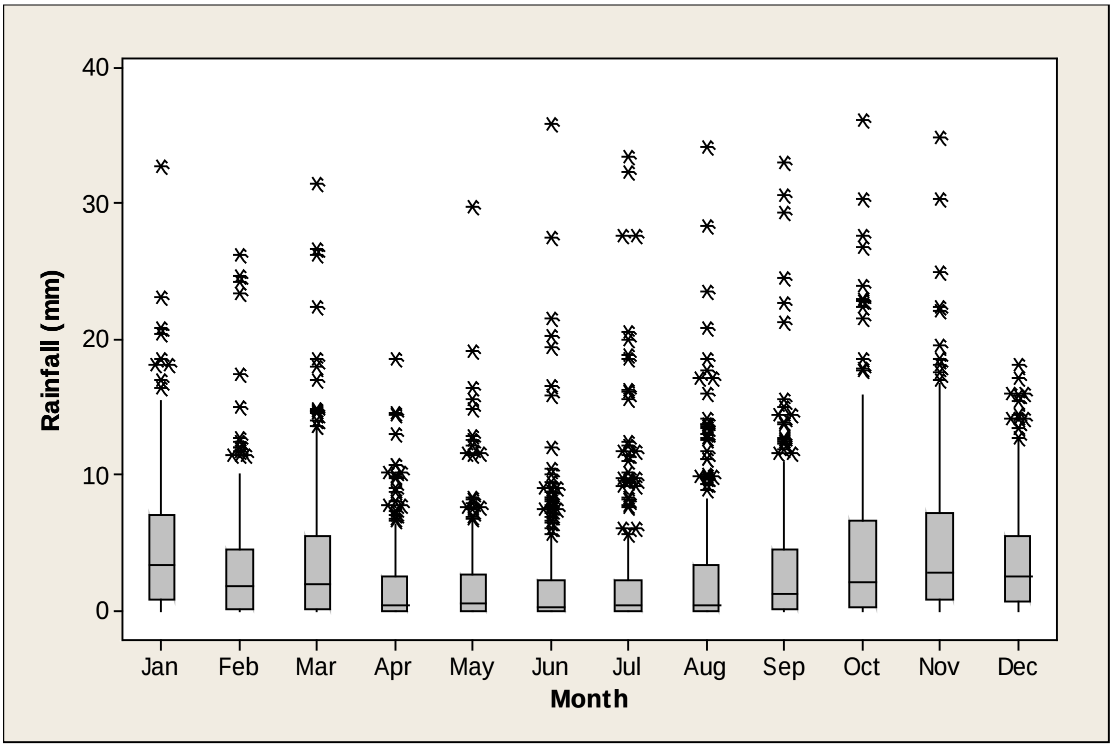


Figure 9.2 Daily rainfall values per month at Unst: Uyeasound No3 (2003 – 2010)

Daily rainfall was higher from October to January and in March. The driest months were April to July. Days with extreme rainfall events (>20 mm) occurred in all months except for April, May and December. However, caution should be used in interpreting the data for November and December, as no data was recorded for these months in 2010. For the period considered here, 45% of days experienced rainfall less than 1 mm and 8% of days experienced rainfall of 10mm or more.

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

9.2 Wind

Wind data collected at Sumbergh is summarised by seasonal wind roses as shown in Figure 9.3 and annually in Figure 9.4.

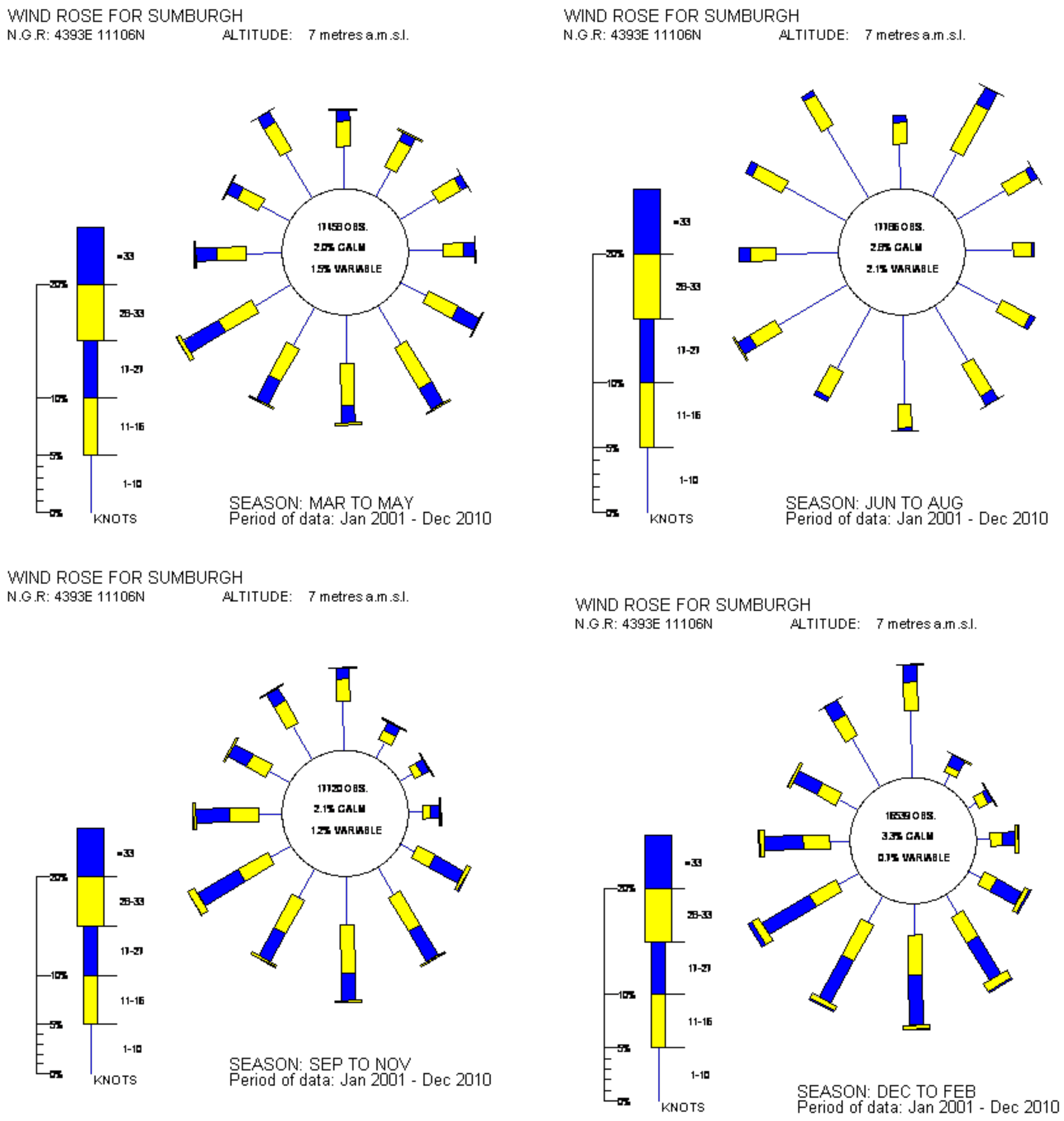


Figure 9.3 Seasonal wind roses for Sumburgh

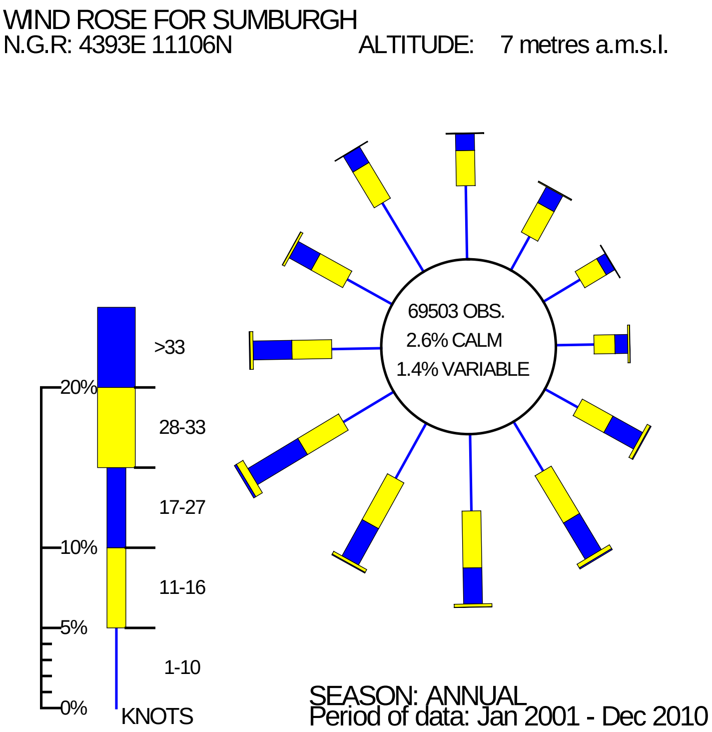


Figure 9.4 Annual wind rose for Sumburgh

Shetland is one of the more windy areas of Scotland with a much higher frequency of gales than the country as a whole. The wind roses show that the overall prevailing direction of the wind is from the south and west, and when it is blowing from this direction it is likely to be stronger than when blowing from other directions. Winds are generally lighter during the summer months and strongest in the winter.

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. Therefore strong winds may significantly alter the surface movement at Basta Voe Outer. Basta Voe lies roughly along a north-south axis, with the mouth of the voe opening to the south. Strong winds may affect tide height depending on wind direction and local hydrodynamics. A strong wind from the south combined with a spring tide may result in higher than usual tides, which will carry accumulated faecal matter deposited by livestock at and above the normal high water mark into the production area. Strong winds will increase the circulation of water and hence dilution of contamination from sources within the voe.

10. Current and historical classification status

Basta Voe Outer was first given a classification for Common Mussels (*Mytilus edulis)* in 2005. The historical and current classifications for the area are shown below in Table 10.1.

Table 10.1 Basta Voe Outer, Common Mussels

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	A	A	A	A	A	A	A	A	A	A	A	A
2006	A	A	A	A	A	A	A	A	A	A	A	A
2007	A	A	A	A	A	A	A	A	A	A	A	A
2008	A	A	A	A	A	A	A	A	A	A	A	A
2009	A	A	A	A	A	A	A	A	A	A	A	A
2010	A	A	A	A	A	A	A	A	A	A	A	A
2011	A	A	A	A	A	A	A	A	A	A	A	A
2012	A	A	A									

Basta Voe consistently held an A classification from 2005 to the present.

11. Historical *E. coli* data

11.1 Validation of historical data

The results for all samples assigned against Basta Voe Outer from 1st January 2007 up to the 31st December 2011 were extracted from the FSAS database in March 2012 and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. All *E. coli* results were reported as most probable number (MPN) per 100 g of shellfish flesh and intravalvular fluid.

Two samples were recorded on the database as “Rejected” and were deleted. All samples were reported as received in the laboratory within 24 hours. The reported coolbox temperatures were all ≤8°C. The locations given for all samples fell within the production area. Forty-one samples had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation. No sample had a result reported as >18000. One sample had a reported collection time less than one hour prior to the reported time of receipt at the laboratory. Given the location of the fishery, this transit time is considered unlikely. However, the sample has not been excluded on this basis. Six samples were associated with Inner – Site 1- Thomason. This site lies partly within the Basta Voe Cove production area nearer the head of the voe, and under agreement with FSAS will be considered as part of the survey undertaken at a future date at Basta Voe Cove. Therefore, these samples have not been included in the analysis for this survey.

11.2 Summary of microbiological results

Table 11.1 Summary of historical sampling and results

Sampling Summary		
Production area	Basta Voe Outer	
Site	Outer	Basta Ness
Species	Common mussels	Common mussels
SIN	SI 323 403 08	SI 323 396 08
Location	4 locations	HU 538 940 HU 538 943
Total no of samples	50	29
No. 2007	9	8
No. 2008	9	9
No. 2009	10	8
No. 2010	11	4
No. 2011	11	0
Results Summary		
Minimum	<20	<20
Maximum	5400	2400
Median	20	10
Geometric mean	30.3	22.4
90 percentile	221	62
95 percentile	418	122
No. exceeding 230/100g	4 (8%)	1 (3%)
No. exceeding 1000/100g	1 (2%)	1 (3%)
No. exceeding 4600/100g	1 (2%)	0
No. exceeding 18000/100g	0	0

11.3 Overall geographical pattern of results

Prior to December 2010, all sampling locations were recorded on the database to 100 m accuracy. After this time, sampling locations were recorded to 10 m accuracy. Over half the samples from Basta Voe Outer were recorded against HU 533 953. All samples from January 2011 onward were recorded against HU 5336 9537. It is likely that the samples from these two locations were actually taken from the same point, with the latter samples simply recorded to greater accuracy therefore no inference can be made regarding spatial differences between these two points.

The reported sampling locations are plotted on the map shown in Figure 11.1.

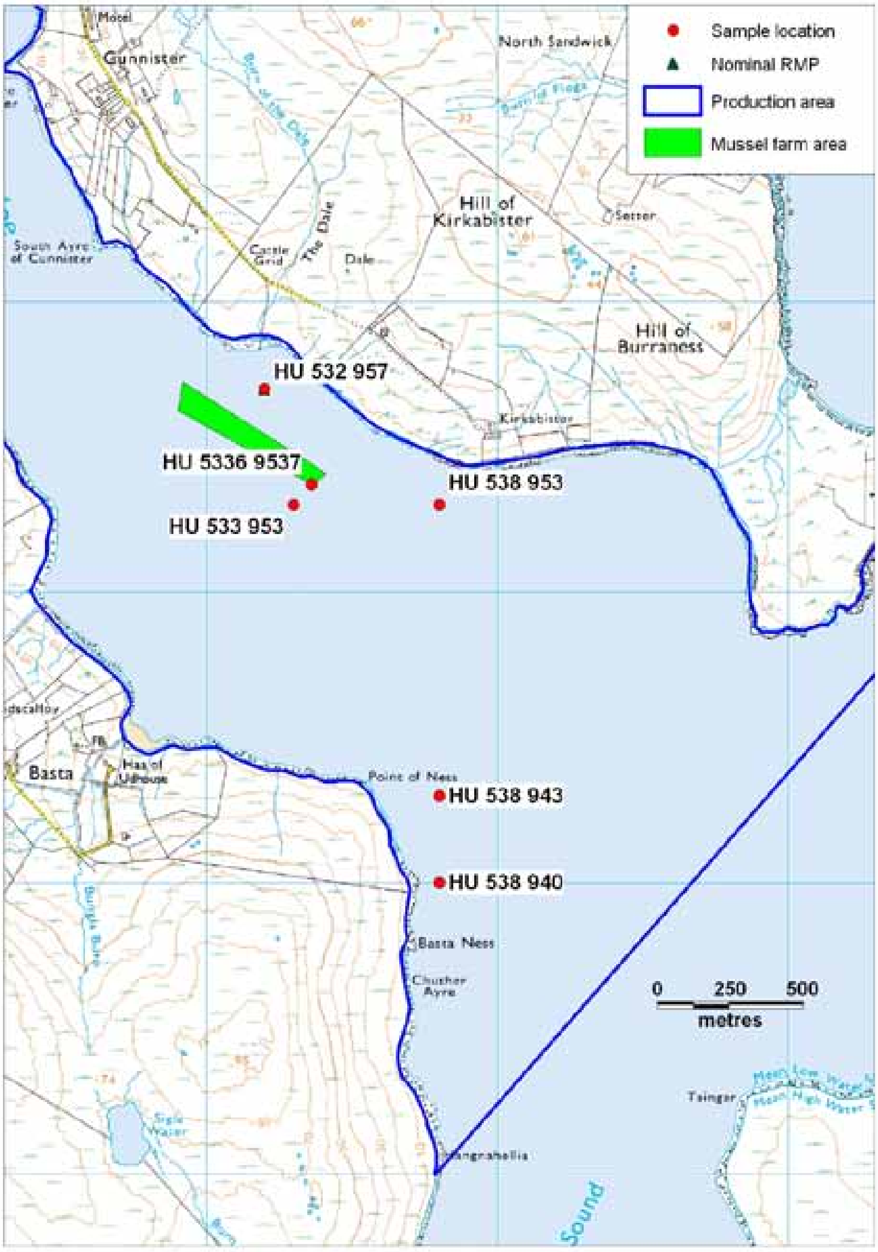


Figure 11.1 Sampling locations in Basta Voe Outer

The *E. coli* results reported against Outer and Basta Ness were compared to determine whether there were differences in results between the sites. A boxplot of *E. coli* results from the two production areas is shown in Figure 11.2.

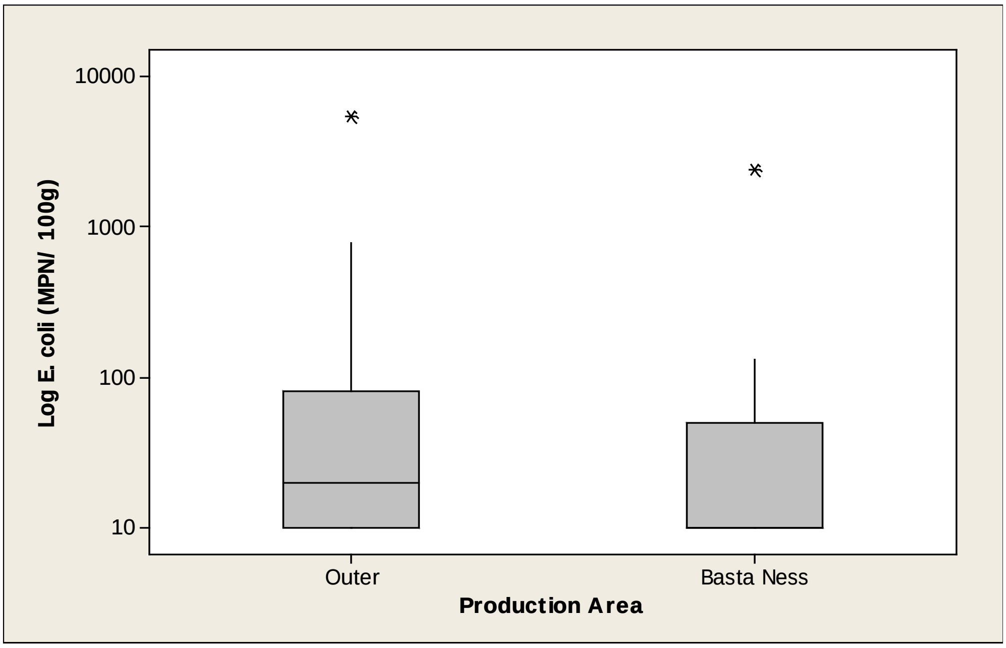


Figure 11.2 Boxplot of Log *E. coli* results by site

A one-way Analysis of Variance (ANOVA) showed no statistically significant difference between the mean $\log_{10}$ transformed results for the two areas (p=0.461; Appendix 4).

11.4 Overall temporal pattern of results

Figure 11.3 presents scatter plots of individual *E. coli* results against date, for each site, fitted with loess smoother lines. 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 smoother line helps to highlight any apparent underlying trends or cycles.

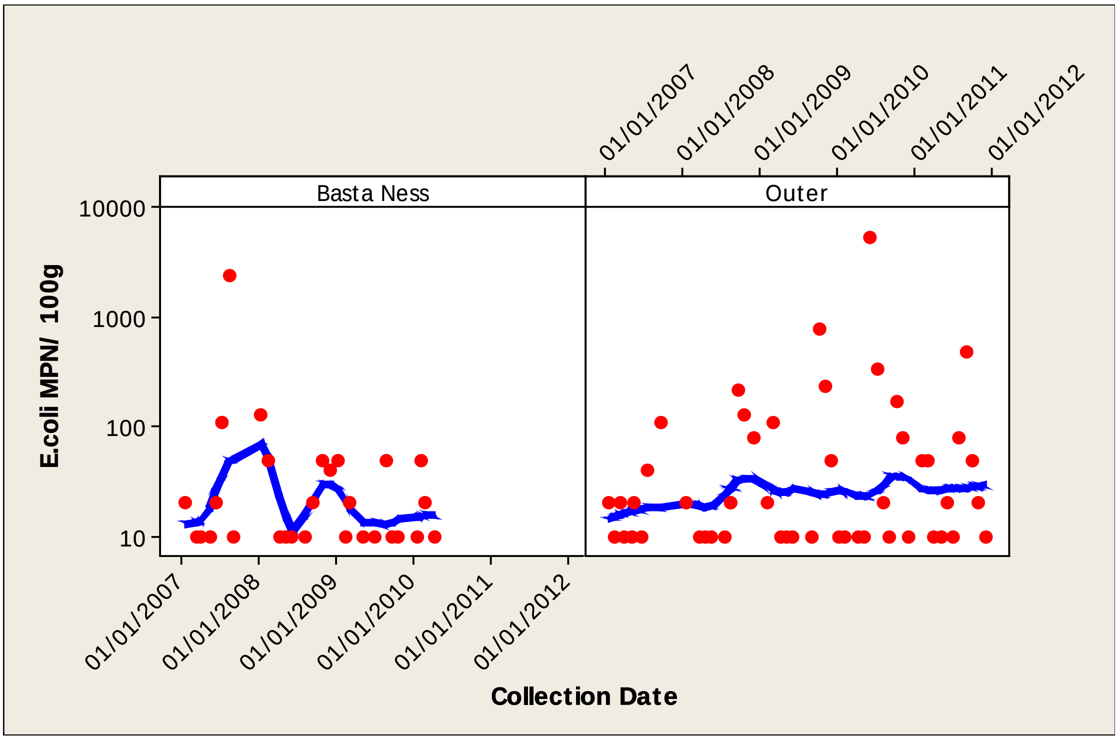


Figure 11.3 Scatterplot of *E. coli* results by date

Basta Ness was only monitored until early 2010. During this period, results were generally low, with most results falling below 100 *E. coli* MPN/100 g. There appeared to be a spike in results peaking around mid-2008 after which results fell to below the limit of detection of the MPN test for a short period before returning to a mix of results all below 100 *E. coli* MPN/100 g. Results from Outer appeared to show a very slight upward trend, with all results≥230 *E. coli* MPN/100 g occurring from after September 2009. Both sites showed a lack of very low results during late 2007- early 2008 and late 2008.

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 11.5 presents scatterplots of *E. coli* result by month for each of the two sites, superimposed with Loess smoother lines.

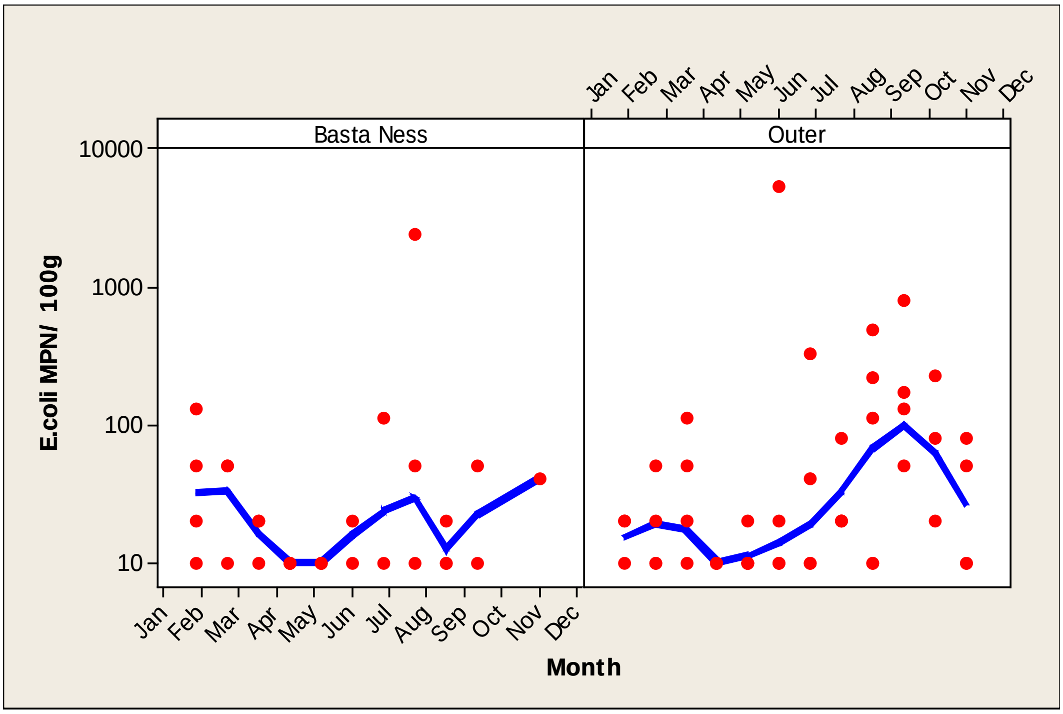


Figure 11.4 Scatterplot of *E. coli* results by month

Lowest results occurred at both areas during April and May. Results were highest in January, July and August at Basta Ness. However, it should be noted that no samples were taken in November and only one sample was taken in December.

At Outer, although the highest result occurred in June there was an overall peak in contamination in September and October.

For statistical evaluation, seasons were split into spring (March - May), summer (June - August), autumn (September - November) and winter (December - February). Boxplots of the results by season for each of the three areas is presented in Figure 11.6.

A two-way ANOVA was undertaken of $\log_{10}$ *E. coli* against season and production area using general linear modelling. A significant difference was found between results by season (Two-way ANOVA, $p<0.00$, Appendix 4). The interaction between season and site was not significant ($p = 0.64$). A post ANOVA test (Tukey's comparison, Appendix 4) indicated that results were significantly lower in spring than in summer and winter.

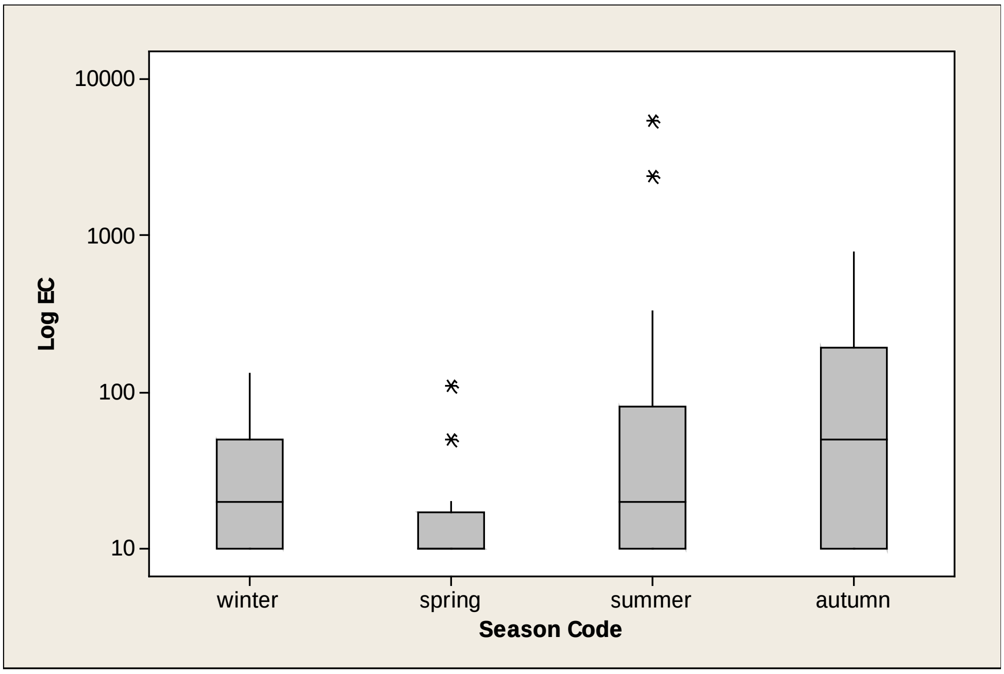


Figure 11.5 Box plot of results by season

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 Meteorological Office weather station is at Unst: Uyea Sound No. 3, which lies approximately 3 km north of the production area. Rainfall data was purchased for the period up to 31/10/2010 (total daily rainfall in mm). Daily rainfall data was not available for the remaining two months (November and December) 2010.

Two-day antecedent rainfall

Figure 11.6 presents scatterplots for each site of *E. coli* against rainfall in the previous two days. A Spearman's rank correlation was carried out between results and rainfall. No statistically significant association was found between two-day rainfall and *E. coli* results for either Outer (Spearman's rank correlation = 0.222, p = 0.187) or Basta Ness (Spearman's rank correlation = 0.168, p = 0.382). Previous rainfall data was not available for two samples taken in 2010 at Outer.

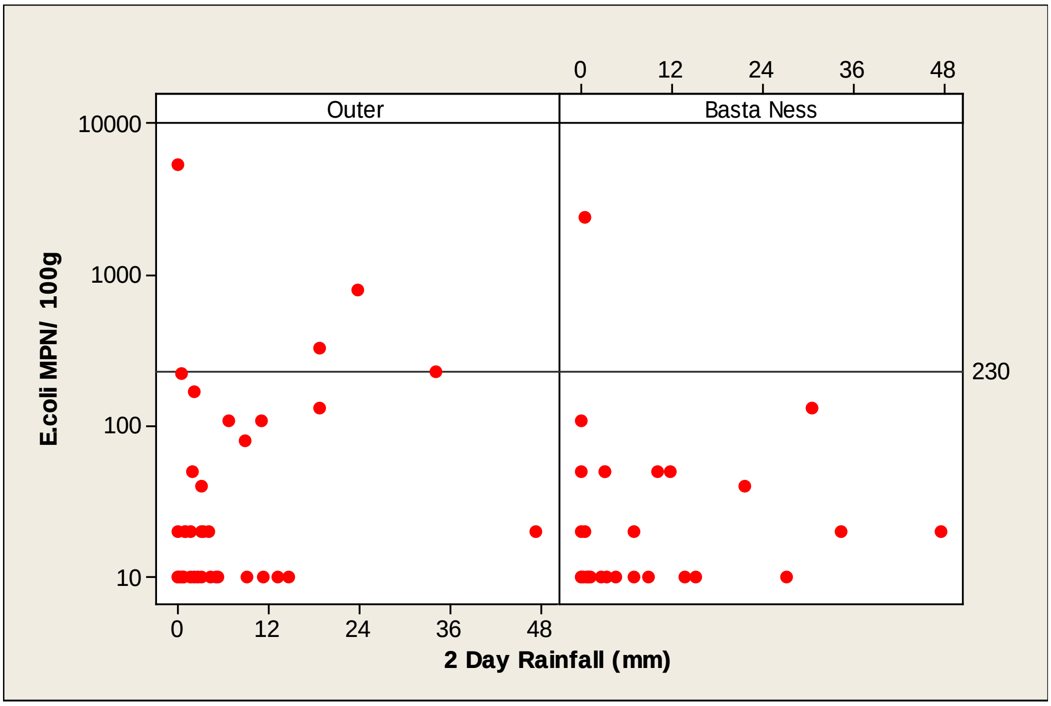


Figure 11.6 Scatterplot of result against rainfall in previous 2 days

Seven-day antecedent rainfall

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. Scatterplots of *E. coli* results against rainfall in the previous 7 days are presented in Figure 11.7 for each of the two sites.

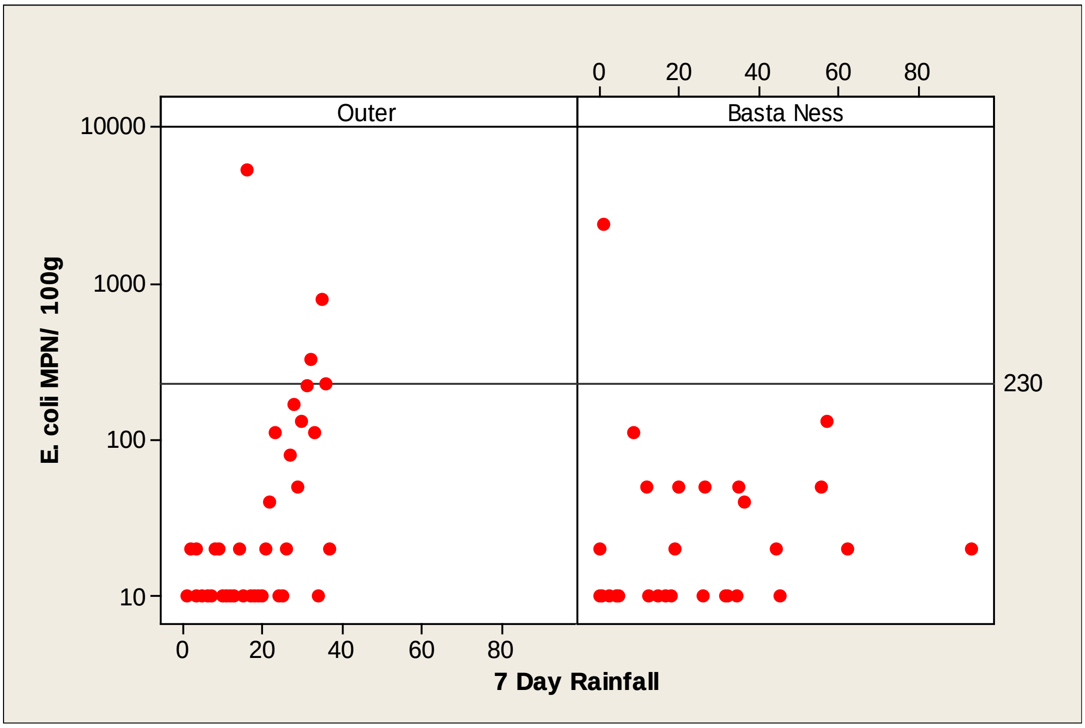


Figure 11.7 Scatterplot of result against rainfall in previous 7 days

A statistically significant positive correlation was found between *E. coli* result and rainfall during the previous 7 days for Outer (Spearman's rank correlation = 0.553, p = 0.000). No statistically significant correlation was found between *E. coli* result and rainfall in the previous 7 days for either Basta Ness (Spearman's rank correlation = 0.265, p = 0.165).

11.6.2 Analysis of results by tidal height and state

Spring/Neap Cycle

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. Figures 11.8 and 11.9 present polar plots of $\log_{10}$ *E. coli* results for the two sites in relation to 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 these are not taken into account.

Spring/Neap Cycle

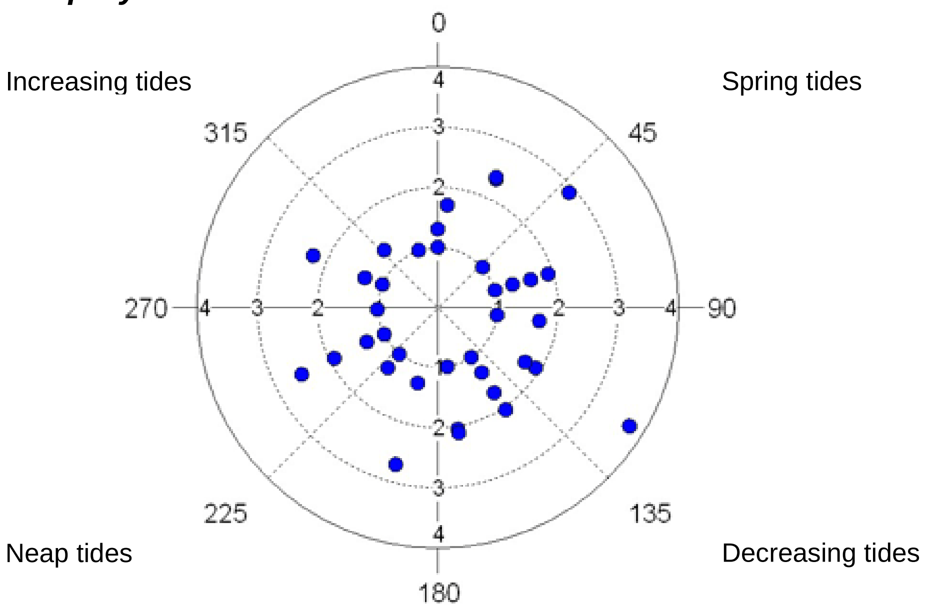


Figure 11.8 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle – Outer

A statistically significant correlation was found between *E. coli* results and the spring/ neap tidal cycle for Outer (circular linear correlation= 0.295,p = 0.017). The highest results were seen at and just after spring tide and lower results tended to be seen on the last part of the increasing tide.

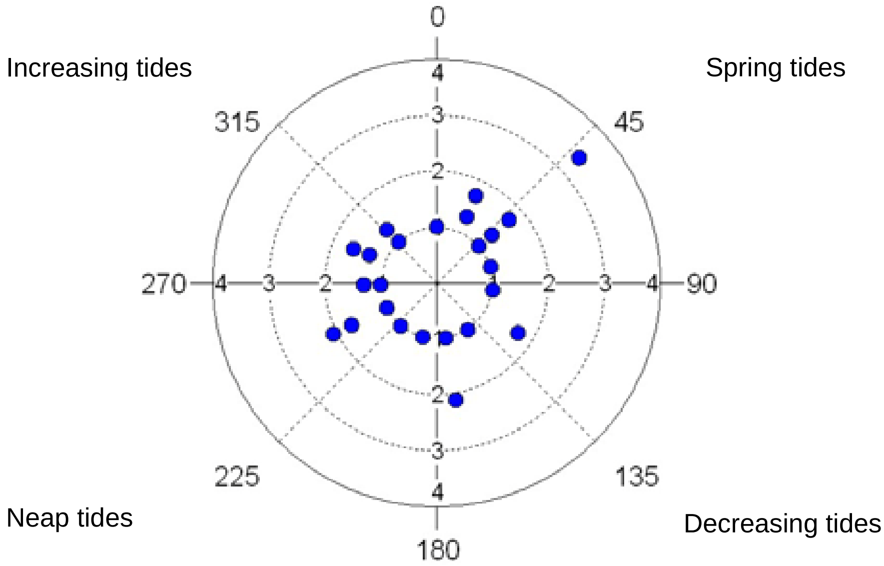


Figure 11.9 Polar plot of log_{10} *E. coli* results on the spring/neap tidal cycle – Basta Ness

No statistically significant correlation was found between *E. coli* results and the spring/neap tidal cycle for Basta Ness (circular linear correlation = 0.213, p = 0.306), although the highest result was seen at spring tide.

High/Low Cycle

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As *E. coli* levels in some shellfish species can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (hours post high water) was compared with *E. coli* results. Figures 11.10 and 11.11 present polar plots of log_{10} *E. coli* results on the lunar high/low tidal cycle. High water is located at 0º, and low water at 180º.

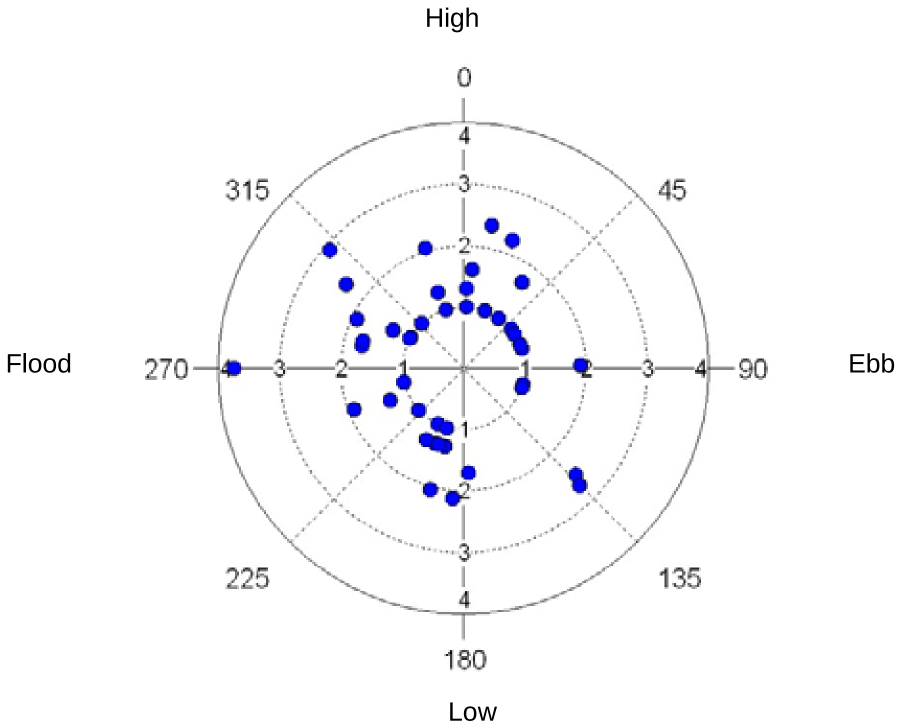


Figure 11.10 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle – Outer

No significant correlation was found between *E. coli* and the high/ low tidal cycle for Basta Voe Outer (Circular linear correlation = 0.172, p = 0.279).

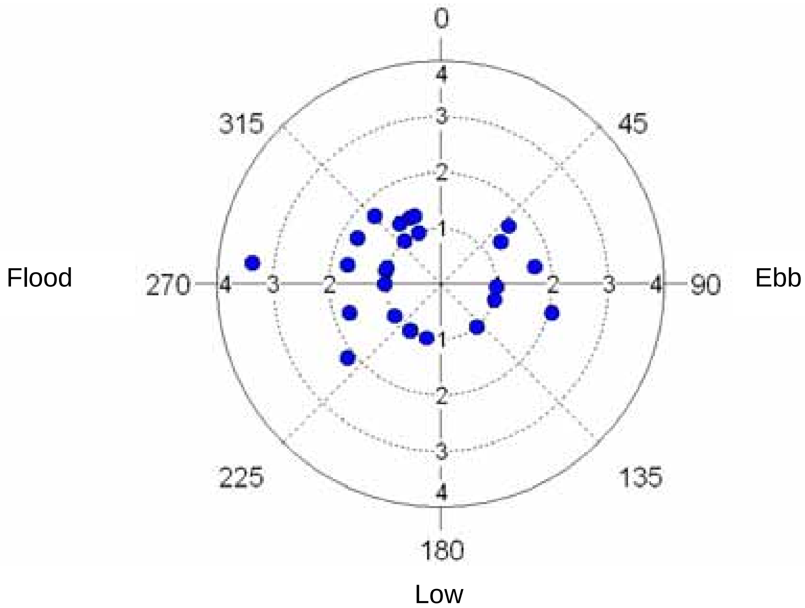


Figure 11.11 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal – Basta Ness

No significant correlation was found between *E. coli* and high/low tidal cycle for Basta Ness (Circular linear correlation = 0.132, p = 0.683).

11.6.3 Analysis of results by water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) and the feeding and elimination rates of shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. It is of course closely related to season, and so any correlation between temperatures and *E. coli* levels in shellfish flesh may not be directly attributable to temperature, but to other factors such as seasonal differences in livestock grazing patterns. Figure 11.12 presents scatterplots of *E. coli* results against water temperature for both sites.

Seawater temperature was recorded for 40 of the 49 mussel sampling occasions for the Outer site and 21 out of 29 samples for the Basta Ness site.

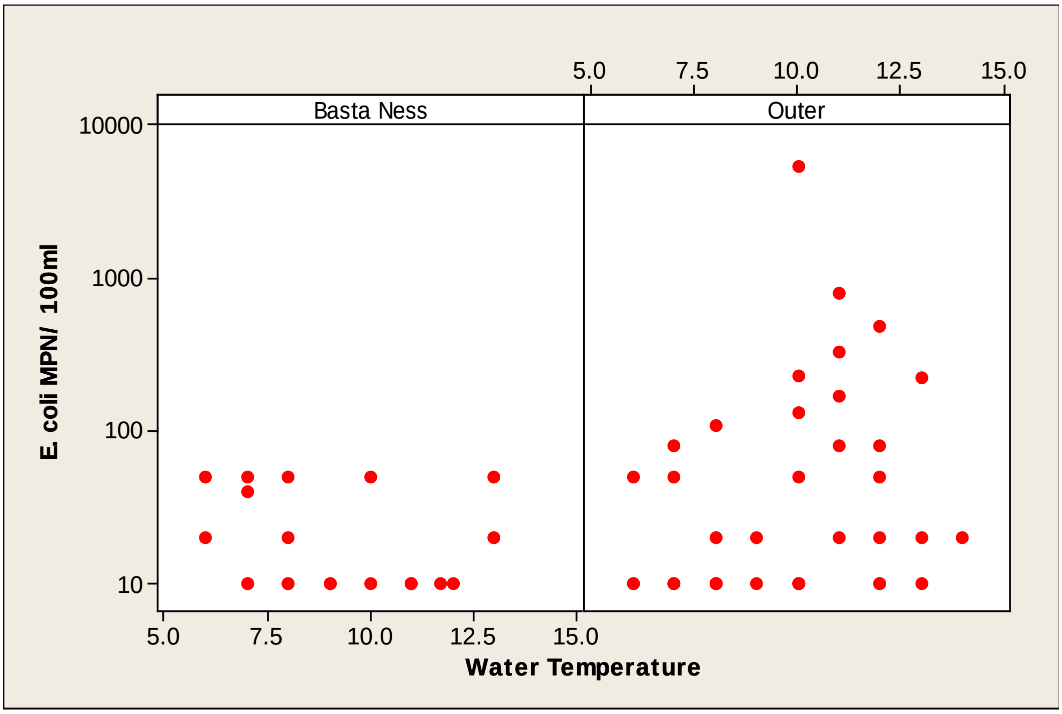


Figure 11.12 Scatterplot of result by water temperature

A statistically significant correlation was found between *E. coli* result and water temperature for Outer (Spearman's rank correlation = 0.0330, p = 0.037). Higher results were associated with higher water temperatures, however very low results were found across the range of recorded temperatures. No significant correlation between *E. coli* result and water temperature was found for Basta Ness (Spearman's rank correlation = -0.237, p = 0.300).

11.6.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater-borne contamination at the site. Figure 11.13 presents a scatter plot of *E. coli* result against salinity.

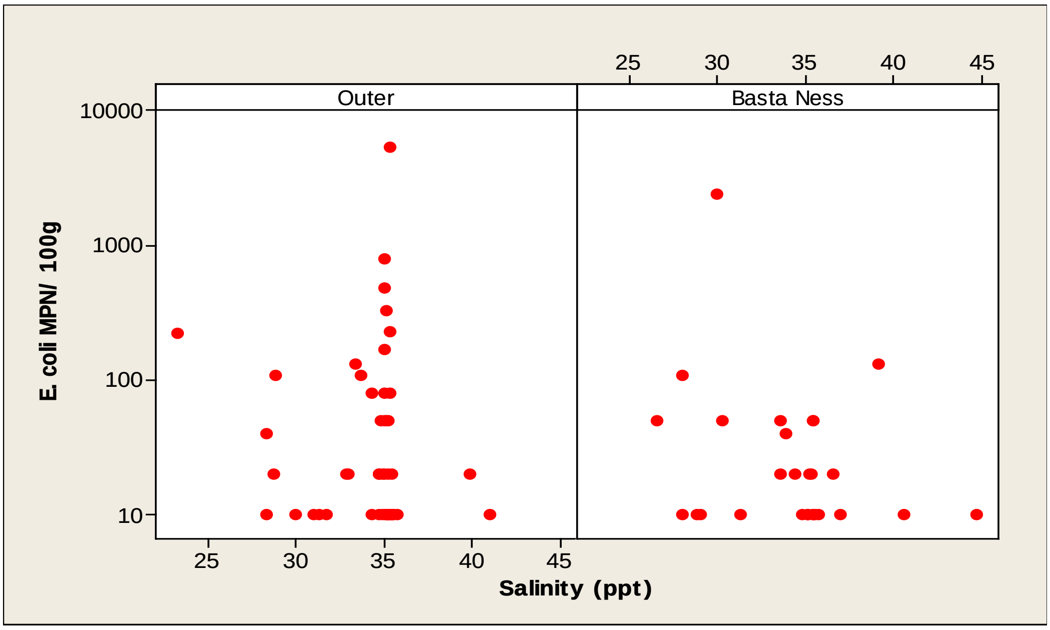


Figure 11.13 presents a scatter plot of *E. coli* result against salinity

No significant correlation was found between *E. coli* result and salinity for the either Outer (Spearman's rank correlation = -0.173, p = 0.230) or Basta Ness (Spearman's rank correlation = -0.218, p = 0.255).

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

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

Collection date	*E. coli* (MPN/ 100 g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tidal state (high/low)	Tidal state (spring/ neap)
14/08/2007	2400	HU 538 940	0.6	1.0	-	30	flood	spring
06/10/2009	790	HU 533 953	23.8	35.0	11	35	flood	spring
01/06/2010	5400	HU 533 953	0.0	16.0	10	35	flood	decreasing tide
06/07/2010	330	HU 533 953	18.8	32.0	11	35	ebb	increasing tide
06/09/2011	490	HU 5336 9537	-	-	12	35	ebb	decreasing tide

- Data not available

One of the results in Table 11.2, taken 14/08/2007, was from the Basta Ness site. All remaining results were from the Outer site. The samples were taken between June and October, after varying amounts of rainfall. Rainfall data were not available for 2011. Water temperature was recorded for all but the Basta Ness sample, and were roughly in the middle of the range observed for all samples from this site. Salinity was recorded for all samples, and only the Basta Ness sample had a salinity slightly below that of full strength sea water.

The highest results were all taken at around mid-flood, though the most recent two results coincided with latter half of the ebb tide. Although two samples were taken at spring tides, the remainder were taken between spring and neap tides.

11.8 Summary and conclusions

Monitoring results were not significantly different between the two sites overall, however the association of monitoring results with environmental factors differed between the sites. A summary of associations with environmental factors is presented in Table 11.3.

Table 11.3 Summary of environmental factors vs *E. coli* results

Parameter	Basta Ness	Outer
Season	Lower results in spring	Lower results in spring
2-day rain	n.s.	n.s.
7-day rain	n.s.	Positive
Spring/Neap cycle	n.s.	Lower results latter part of increasing tides, higher results just after spring tides
High/Low cycle	n.s.	n.s.
Salinity	n.s.	n.s.
Temperature	n.s.	Positive

n.s.= not significant

Seasonal effects were the same at both sites. A review of *E. coli* result by month showed that both sites had lower results in April and May. There was a slightly later peak in results at Outer than at Basta Ness, however both sites appeared to experience higher results from late summer through winter.

At the Outer site, higher *E. coli* results were associated with higher levels of rainfall over the 7 days prior to sampling, which suggests that this site may be more influenced by rainfall-dependent sources of contamination than the Basta Ness site. A positive association was also seen with sea temperature, however as higher results tended to occur during the summer and autumn it is not clear whether this is related to other seasonally associated factors, such as increased rainfall or increased animal populations. A further association was found with the spring/neap tidal cycle with higher *E. coli* results tending to correspond with the decreasing tides.

Over the longer period of time assessed, results showed slightly different trends between the two sites however both experienced periods of very low results during late 2007 to early 2008 and again in late 2008. Overall contamination levels appeared to be higher at Outer, though no statistically significant association was found.

11.9 Sampling frequency

When a production area holds a non-seasonal classification, and where at least 24 results are available over the past 3 years, and the geometric mean of those results falls within a certain range, consideration can be given to reducing the sampling frequency from monthly to bimonthly. For Basta Voe Outer, 44 results were available for the 3-year period from January 2009 to December 2011. The geometric mean of these results was 28.9. This is greater than the class A limit of 13 given in the EURL Good Practice Guide and so it is not recommended that the sampling frequency be reduced.

12. Designated Shellfish Growing Waters Data

The production area at Basta Voe Outer coincides with the Basta Voe designated shellfish growing water, extending approximately 400-600 m beyond the southern boundary of the SGW. The area was designated under the European Community Shellfish Waters Directive (2006/113/EC) in 2002. SEPA is responsible for ensuring that monitoring is undertaken for a variety of parameters, including faecal coliforms in mussels.

Results of shellfish monitoring to 2007 were provided by SEPA and are presented in Table 12.1. The relative positions of the SGW boundary, the Basta Voe Outer production area, and the SGW monitoring points are shown in Figure 12.1. Since 2007, SEPA have obtained shellfish classification monitoring results (*E. coli*) under an agreement with FSAS for the purposes of SGW monitoring.

Table 12.1 SEPA monitoring results for shore mussels – Basta Voe

Year	Quarter	Faecal coliform results (FC/100g)	
		HU 518 972	HU 513 980
2002	Q4	70	-
2003	Q1	40	-
	Q2	-	-
	Q3	-	2400
	Q4	-	310
2004	Q1	-	20
	Q2	-	220
	Q3	-	<20
	Q4	-	110
2005	Q1	-	20
	Q2	-	70
	Q3	-	110
	Q4	-	1300
2006	Q1	-	160
	Q2	-	<20
	Q3	-	1700
	Q4	-	380
2007	Q1	-	1300

- No result reported

Mussel samples were taken for faecal coliform analysis from two points within the growing water. The first point sampled was located close to the northern boundary of the Basta Voe Outer production area and this was sampled on only two occasions. The second sampling point is located near the pier at the northern end of the voe and within the Basta Voe Cove production area. Samples from this location are more likely to reflect contamination levels present within Basta Voe Cove and therefore may not be representative of conditions at the outer loch.

Although levels of faecal coliforms are usually correlated to levels of *E. coli* at a ratio of roughly 1:1, the ratio depends on a number of factors, such as environmental conditions and the source of contamination. The results shown above suggest that the sampling location is subject to moderate levels of faecal contamination.

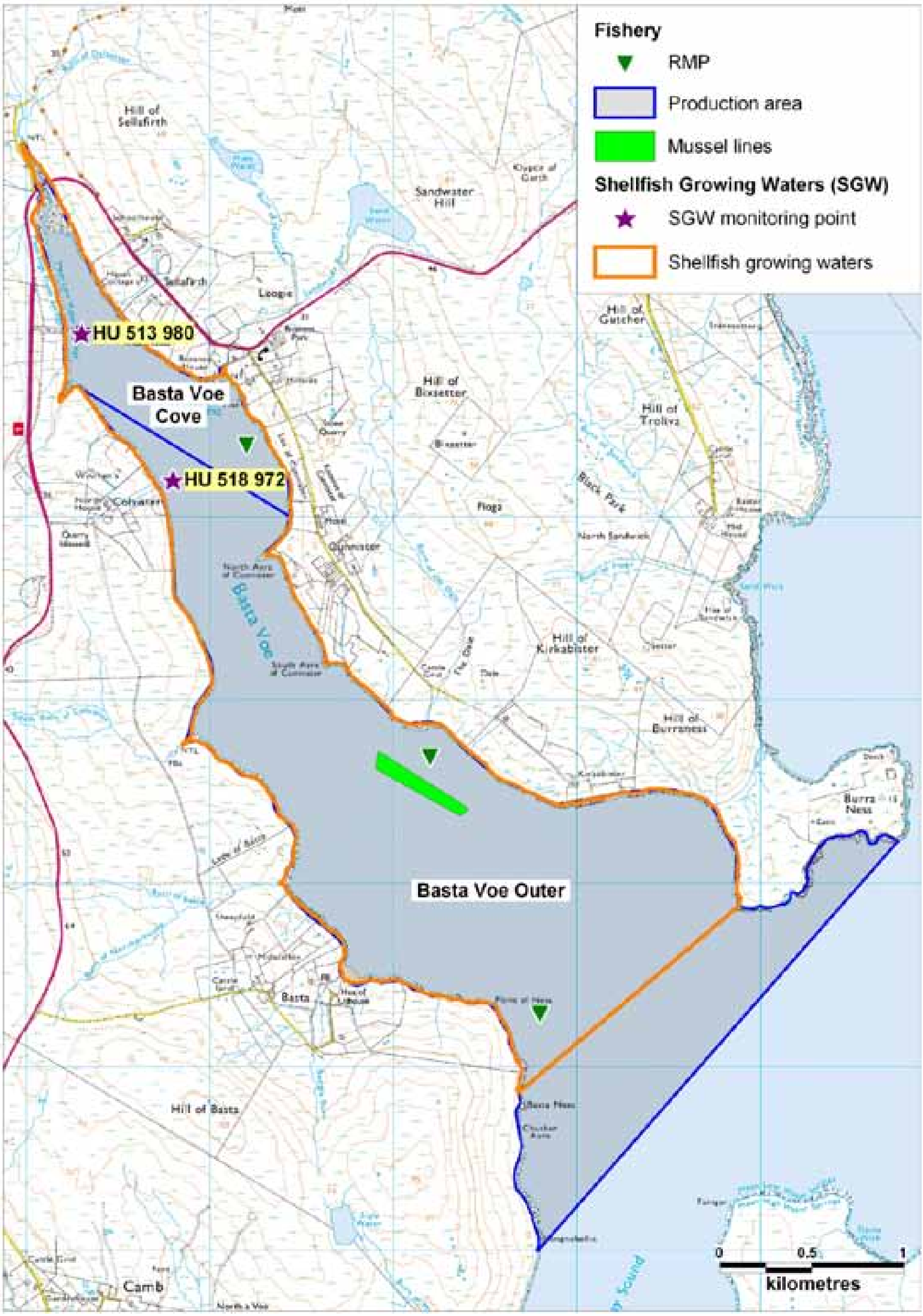


Figure 12.1 Designated shellfish growing water – Basta Voe

13. River Flow

There are no river gauging stations on watercourses within Basta Voe. The burns and streams listed in Table 13.1 were measured and sampled during the shoreline survey. These represent the freshwater inputs to the voe in the vicinity of the Basta Voe Outer fishery. There was light rain during the first part of the shoreline survey and no rain during the second half, though there was heavy rain the day before the survey. The locations, together with the calculated loadings, are shown in Figure 13.2.

Table 13.1 River (or stream) loadings for Basta Voe Outer

No	Grid Ref	Description	Width (m)	Depth (m)	Flow (m/s)	Flow in m^3/day	*E. coli* (cfu/100 ml)	Loading (*E. coli* per day)
1	HU 52716 94470	Bungla Burn	2	0.17	0.135	3966	290	1.2×10^{10}
2	HU 52536 94812	Stream	0.25	0.05	0.143	154	30	4.6×10^{7}
3	HU 52446 94892	Stream	0.15	0.05	0.462	299	20	6.0×10^{7}
4	HU 52358 94969	Burn of Basta	1.3	0.44	0.491	24266	100	2.4×10^{10}
5	HU 52848 94450	Stream	0.25	0.05	0.488	527	80	4.2×10^{8}
6	HU 52943 94444	Stream	0.14	0.14	0.329	557	600	3.3×10^{9}
7	HU 53245 94362	Stream	0.25	0.1	0.261	564	180	1.0×10^{9}
8	HU 53417 95711	Stream	0.1	0.05	0.48	207	30	6.2×10^{7}
9	HU 53609 95550	Stream	0.15	0.06	0.119	93	240	2.2×10^{8}
10	HU 53772 95482	Stream	0.12	0.05	0.149	77	610	4.7×10^{8}
11	HU 54087 95457	Stream	0.12	0.04	0.432	179	4700	8.4×10^{9}
12	HU 54255 95487	Stream	0.2	0.07	0.334	404	50	1.7×10^{5}
13	HU 54544 95487	Stream	0.17	0.06	0.474	418	80	3.8×10^{5}
14	HU 53141 95847	Burn of the Dale	1	0.05	0.386	1668	70	2.7×10^{5}
15	HU 52951 95971	Stream	0.25	0.05	0.181	195	14	2.5×10^{4}
16	HU 52867 96046	Stream	0.1	0.04	0.405	140	40	1.6×10^{5}
17	HU 52733 96184	Stream	0.11	0.03	0.379	108	18	6.8×10^{4}

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

The watercourses identified as 1-7 in the table and map were sampled and measured on the 18/10/11 during light rain showers, with heavy rain the previous day and those identified as 8-17 were sampled and measured on 20/10/11, during dry weather with heavy rain showers the previous day. Flows were slightly lower during the second half of the survey.

Figure 13.1 Map of river/stream loadings at Basta Voe Outer

Only one of the watercourses, located south of Kirkabister yielded *E. coli* results indicating marked faecal contamination with a water sample result of 4700 *E. coli* (cfu/100 ml). The highest calculated loadings were seen at the two burns (1 - Bungla Burn and 4 – Burn of Basta) on the shoreline opposite the fishery, south of the settlement of Basta. Loadings in the streams would be expected to increase significantly after rainfall. There are streams identified on the OS map between the location of streams 3 - 4 and 8 - 14 but, although parts of the area were waterlogged, no streams were observed and there was no evidence of dry stream beds.

Estimated loadings from the watercourses located nearest to the present mussel farm were all low to moderate but would be expected to pose the most immediate source of faecal contamination to the fishery from freshwater sources. They would be expected to be lower than estimated after a period of dry weather.

14. Bathymetry and Hydrodynamics

Figure 1 shows the bathymetry at Basta Voe Outer.

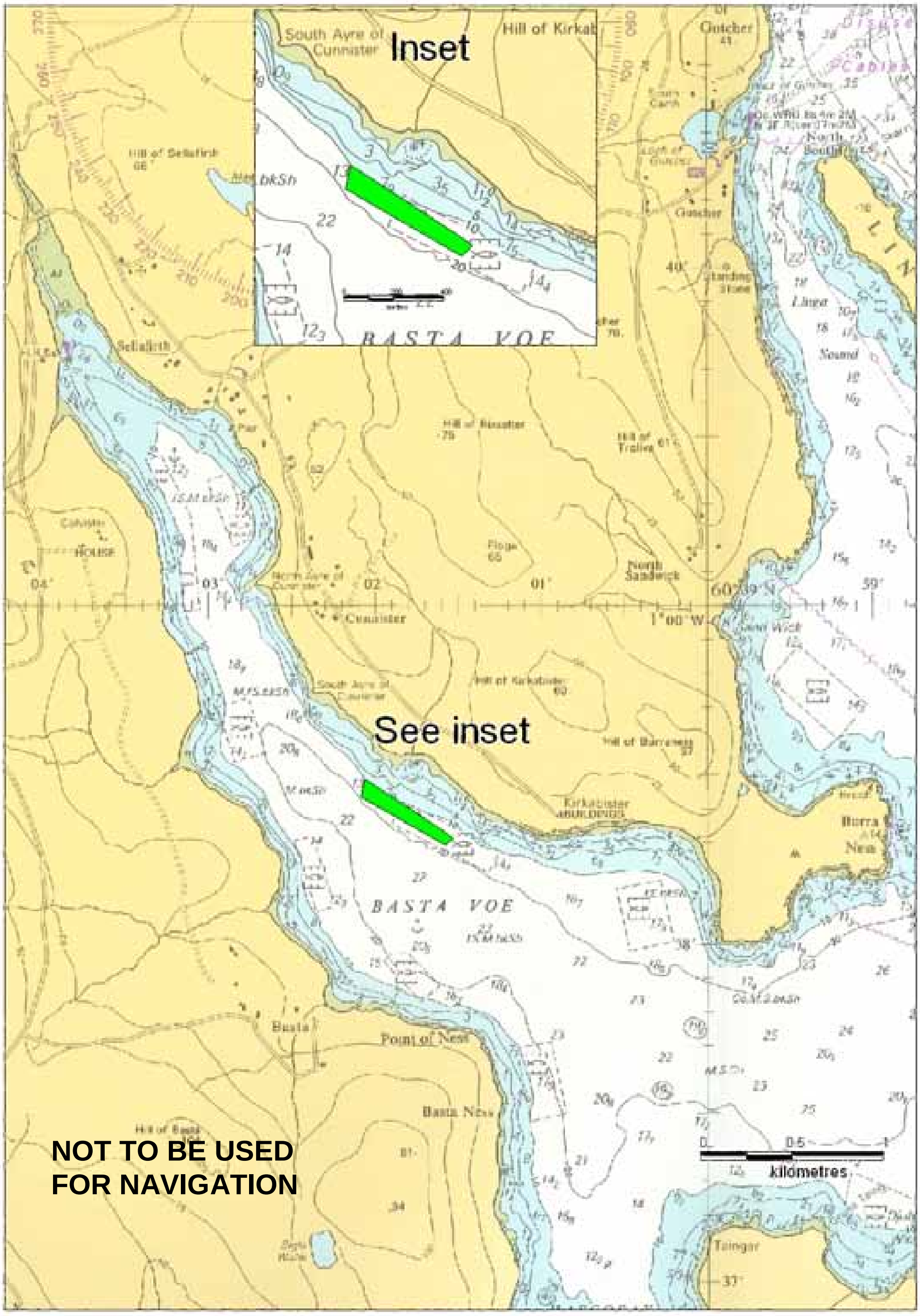


Figure 14.1 Bathymetry at Basta Voe

Basta Voe is located on the east cost of Yell. It lies in a north-west to south-east direction. It is approximately 5 km in length. It is approximately 1.5 km wide at the moth and 0.5 km wide towards the head. There is a moderately-sized drying area at the head of the voe but a limited extent of drying area around the rest of the shore. Around much of the voe, the depth reaches 10 m within 10 to 15 m of the shore. The maximum depth in the outer voe is shown as 23 m. Both the Outer and Basta Ness mussel sites lie in 10 to 20 m of water.

The island of Hascosay lies approximately 1 km off the southern side of the mouth of Basta Voe. Hascosay Sound runs between that island and Yell.

14.1 Tidal Curve and Description

The two tidal curves shown in Figure 14.2 are for Mid Yell, 3 km southwest of the southern extent of the Basta Voe production area boundary. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 GMT on 18/11/11 and the second is for seven days beginning 00.00 GMT on 25/11/11. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

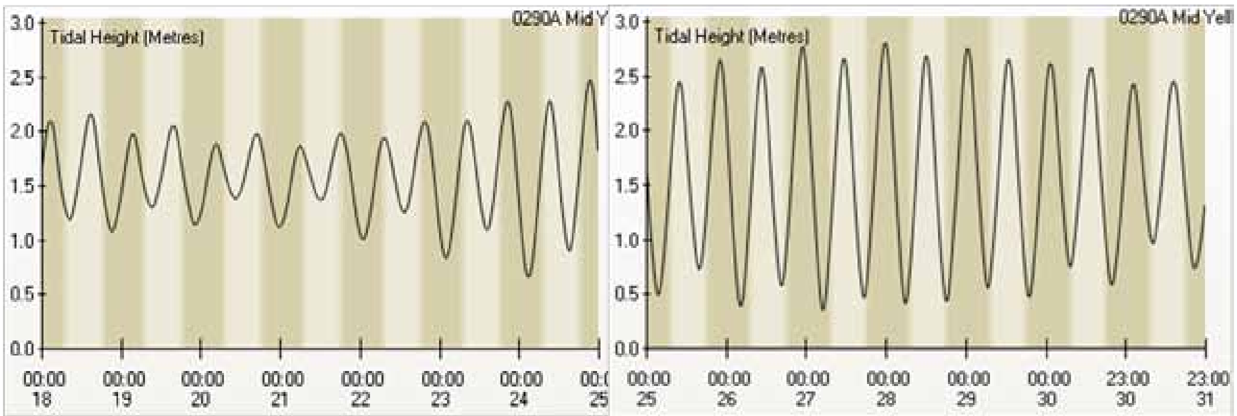


Figure 14.2 Tidal curves for Mid Yell

The following is the summary description for Mid Yell from TotalTide:

0290A Mid Yell is a Secondary Non-Harmonic port.
The tide type is Semi-Diurnal.

HAT	2.9 m
MHWS	2.4 m
MHWN	1.9 m
MSL	1.52 m
MLWN	1.1 m
MLWS	0.6 m
LAT	0.0 m

Predicted heights are in metres above chart datum. The average tidal range at spring tide is 1.8 m and at neap tide 0.8 m. The area is therefore microtidal (small tidal range).

14.2 Currents

Edwards & Sharples (1991) calculated that the voe had a flushing time of 5 days. There is no tidal stream information for the vicinity of Basta Voe. Shetland Seafood Quality Control (SSQC) had undertaken seven current meter studies in the area in support of discharge consent applications for fish farms. The data was made available to Cefas with the consent of the current owners (Basta Voe North, Basta Voe South, Bastaness, Djubawick & Bow of Hascosay: Northern Isles Salmon Ltd.; Basta Voe & North Sandwick: John Wilson). The positions are shown on the map in Figure 14.3 and the locations and survey periods are given in Table 14.1. Plots of the current directions and speeds, together with the wind direction and speeds over the relevant period, are shown in Figure 14.4 and 14.5.

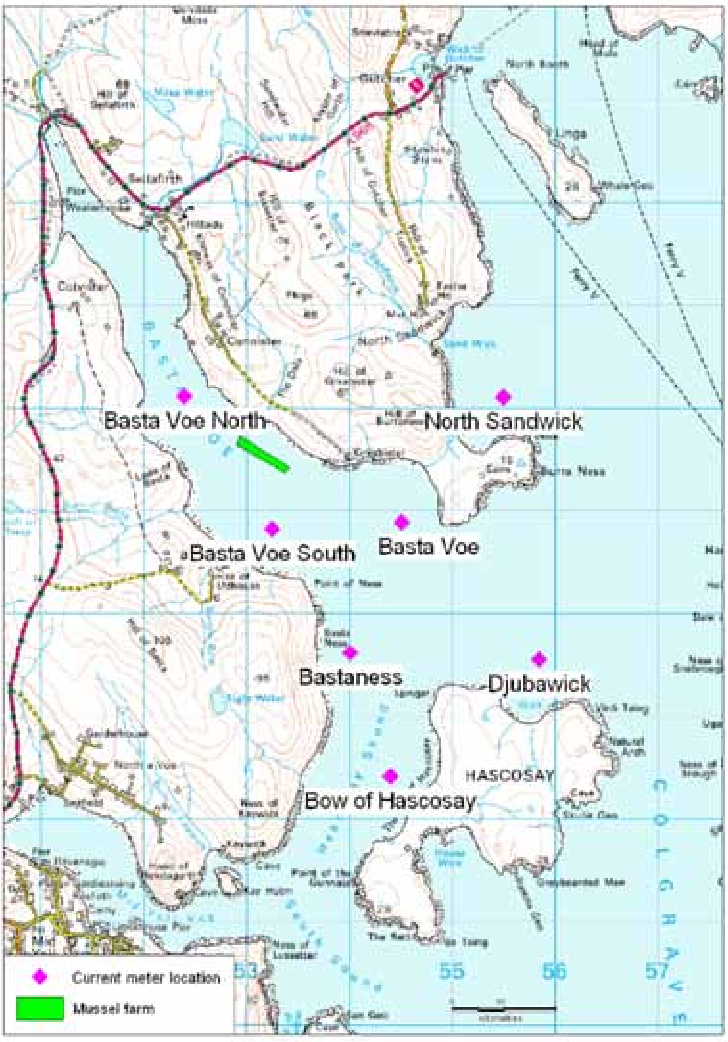


Figure 14.3 Current meter locations

Table 14.1 Survey period for the current meter studies

Location	NGR	Survey period
Basta Voe North	HU 5239 9611	23/03/2001 - 10/04/2001
Basta Voe South	HU 5325 9482	09/04/2011 - 20/04/2011
Basta Voe	HU 5451 9488	14/10/2008 - 29/10/2008
Bastaness	HU 5401 9362	12/01/2011 - 27/01/2011
Bow of Hascosay	HU 5440 9241	01/05/2011 - 16/05/2011
Djubawick	HU 5585 9355	12/01/2009 - 27/01/2009
North Sandwick	HU 5550 9610	07/06/2002 - 28/06/2002

Currents speeds shown in Figures 14.4 and 14.5 are measured in cm/s. Wind speeds are 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 true.

Basta Voe North

Currents were strongly bimodal, particularly at mid-depth and near-bottom and flowed in a roughly north-north-westerly and south-south-easterly direction (i.e. along the line of the voe). At near-bottom, the currents to the north-north-west predominated and at the surface the currents to the south-south-east predominated. There appeared to be no observable effect of wind on the near surface-currents during the period of the survey.

Basta Voe South

Flows at this site were complex. At near-bottom, currents flowed predominantly to the west. At mid-depth, they flowed over a wide range for directions from west-north-west, through south, to east-south-east. Near-surface, they flowed predominantly towards the south east. There appeared to be no observable effect of wind on the near surface-currents during the period of the survey.

Basta Voe

Flows at this site were approximately bimodal, running approximately west-south-west and east-north-east (at an angle to the main channel). The currents at near-surface were more variable than at other depths, with more southerly components to the flows. However, the predominant winds during the survey period were from the south and thus wind does not appear to have been the cause of this effect.

Bastaness

Flows at this site were essentially unimodal, flowing due south (along the line of the channel) at all three depths. Winds during the survey period were predominantly from the north to north-west so an effect of wind on the observed currents cannot be ruled out.

Bay of Hascosay
Flows were only given for near-bottom and near-surface. Currents were strongly bimodal, flowing north-north-east and south-south-west (Along the line of the channel). At depth, flows to the north-north-east were strongest. Winds during the study period were from the south-east and do not appear to have had any effect on the observed currents.

Djubawick

Current directions were quite variable at all three depths and ranged from north-west, through south, to south-east. The flows towards the north-west and west were the strongest.

North Sandwick
Currents were bimodal at all three depths, flowing approximately north-westerly and south-easterly (approximately along the axis of the outer edge of the bay). Although flows ran to the south-east for much of the time, the currents in the opposite direction were stronger.

Overall, currents tend to follow the main channels. Within Basta Voe, flows up the voe predominate near the bottom and flows down the voe predominate near the surface. At the mouth of the voe, and at the sides outside of it, there is much less of a difference in currents with depth. There is an indication that, outside of the voe, currents flow from off Burra Ness down through Hascosay Sound over much of the tidal cycle, although this is not conclusively seen at all sites and the return currents may be stronger, although flowing for a shorter period.

The median and maximum current speeds at the sites are shown in Table 14.2. Current speeds within the voe are low while they are much higher at the mouth and outside.

Current flows at the Basta Voe North and Basta Voe South sites are most relevant to the current mussel farm. Within the voe, a maximum current speed of 18 cm/s (0.18 m/s; 0.35 kt) would be expected to carry contamination a distance of approximately 2.5 km over a flood or neap tide, ignoring any effects of dispersion and dilution. Most of the time, current speeds, and therefore transport distances, would be less than this.

Table 14.2 Median and maximum current speeds

Site	Depth	Current speed (cm/s)	
		Median	Maximum
Basta Voe North	Near-bottom	2.5	11.0
	Mid-depth	2.5	9.2
	Near-surface	2.3	8.9
Basta Voe South	Near-bottom	4.9	18.2
	Mid-depth	3.6	14.0
	Near-surface	3.9	13.8
Basta Voe	Near-bottom	11.8	47.7
	Mid-depth	11.4	49.2
	Near-surface	12.2	44.9
Basta Ness	Near-bottom	10.7	31.6
	Mid-depth	11.1	32.3
	Near-surface	10.7	33.1
Bay of Hascosay	Near-bottom	26.9	62.2
	Mid-depth	-	-
	Near-surface	29.6	75.0
Djubawick	Near-bottom	13.1	58.8
	Mid-depth	14.6	67.7
	Near-surface	14.5	67.7
North Sandwick	Near-bottom	9.9	65.4
	Mid-depth	10.2	69.0
	Near-surface	10.4	67.9

14.3 Salinity

Edwards & Sharples (1991) estimated a salinity reduction of 0.2 ppt at Basta Voe, indicating little freshwater influence. However, this estimate relates to the whole voe and does not preclude greater freshwater impacts at specific locations. One salinity profile was recorded during the shoreline survey (at the Outer mussel site). The details are shown in Table 14.2 and the location is shown in Figure 14.4.

Table 14.3 Salinity profile at Basta Voe

Profile	Date	Time	Position	Depth (m)	Salinity (ppt)	Temperature ˚C
1	18/10/2011	10:45	HU 52921 95722	Surface	36.2	10.5
				1	36.2	10.5
				2	36.2	10.5
				3	36.2	10.4
				4	36.2	10.3
				5	35.4	10.2

The profile showed no measurable impact of freshwater and no stratification. Two spot samples taken at the mussel farm during the shoreline survey gave results of 35.0 and 35.2 ppt.

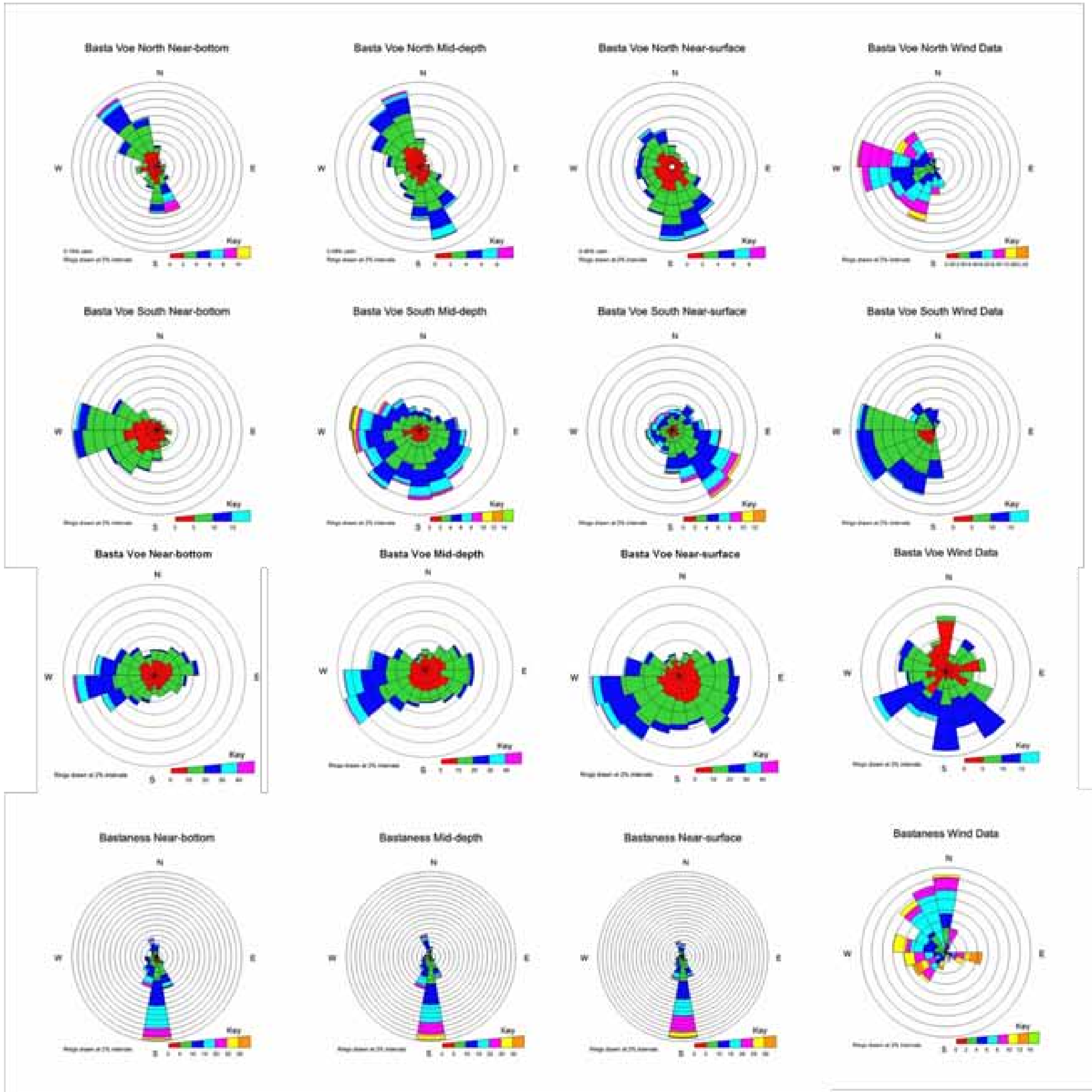


Figure 14.4 Current plots for Basta Voe Outer

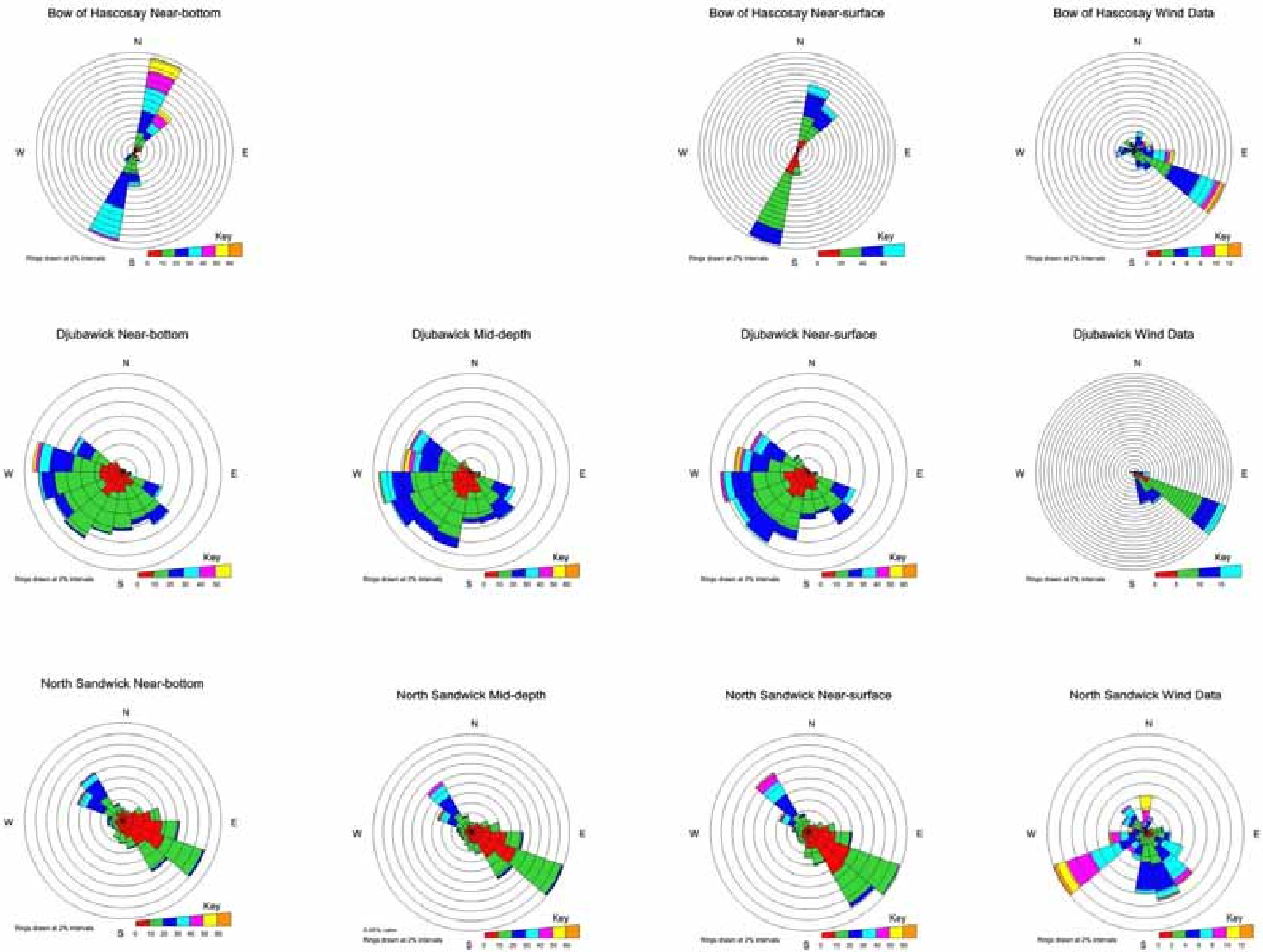


Figure 14.5 Current plots for Basta Voe Outer

Figure 14.6 Salinity profile location

14.4 Conclusions

Much of Basta Voe is relatively deep and any contamination will be subject to significant dilution before reaching the shellfishery, except for that arising from the shore immediately adjacent to the mussel farm.

Currents within the voe are weak and the maximum expected transport distance for contaminants means that only sources within the voe itself are likely to be of significance. The current directions differ with depth. Those most relevant to the mussel lines are the near-surface and mid-depth currents. At the surface, currents tend to move predominantly out of the voe. At mid-depth, they are bidirectional, although the flows towards the voe mouth are less bimodal than those in the middle of the voe. This means that the tops of the lines will be mainly exposed to contamination arising from towards the head of the voe, while the bottoms of the lines will be exposed to contamination arising from both up and down the voe. Other current components will mean that during parts of the tidal cycle, some flow will occur towards the lines from the adjacent shore.

15. Shoreline Survey Overview

The shoreline survey was conducted on the 18th and 20th October 2011 under variable weather conditions.

The Basta Voe Outer: Outer mussel fishery is a longline mussel farm consisting of seven long lines, each 200 m in length with 5 – 8 m droppers. The fishery had sufficient stock on site for sampling at the time of the shoreline survey and is harvested all year round. There is a second site called Basta Ness further towards the entrance of the voe has been sold to an aquaculture company who do not intend on using it as a shellfish farm.

The area surrounding Basta Voe is sparsely populated and there are no large settlements along the coastline of the voe. On the south west shoreline opposite the shellfish farm is the small settlement of Basta. There are two small settlements of Gunnister and Sellafirth situated on the north east coast of the voe. There is a small pier near Sellafirth. The shoreline immediately adjacent to the fishery is uninhabited. A single pipe was observed next to a field drain on the shoreline north of the settlement of Basta, although this was not flowing at the time of the shoreline survey. No other outfall pipes, septic tanks or sanitary debris was observed.

Livestock were observed grazing most of the shoreline adjacent to the fishery. On the south west shoreline of the voe approximately 69 sheep in total were observed scattered along the coastline. On the north east shoreline of the voe approximately 84 sheep were observed in total. Half of the sheep observed were located in fenced off fields and the remaining had access to the shoreline. Sheep droppings were in abundance and found on the shoreline on both sides of the voe.

On the north east shoreline of the voe a total of nine geese, approximately 200 gulls and one seal were observed. Four gulls and one cormorant were observed on the mussel lines. On the south west shoreline of the voe, one heron and six geese were observed. Goose droppings were present on the shoreline in large numbers on both sides of the voe.

Sea water samples were taken in the vicinity of the mussel farm and contained <1 and 1 *E. coli* (cfu/100 ml).

Freshwater samples and discharge measurements were taken at 17 of the streams draining into the survey area. The streams were of varying size and drained areas of improved grassland, bog and acid grassland. Fresh water samples taken from the streams contained varying levels of *E. coli* contamination. The highest fresh water result of 4700 *E. coli* (cfu/100 ml) was taken from a stream <1 km east of the shellfish farm.

Mussel samples were collected at two depths from both ends of the mussel lines. At the eastern end of the lines mussel samples collected at depths of <1 and 8 m both returned results of <20 *E. coli* MPN/100 g. At the western end of the lines a mussel sample collected at <1 m depth returned are result of <20 *E. coli* MPN/100 g a sample collected at 5 m depth had 50 *E. coli* MPN/100g.

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

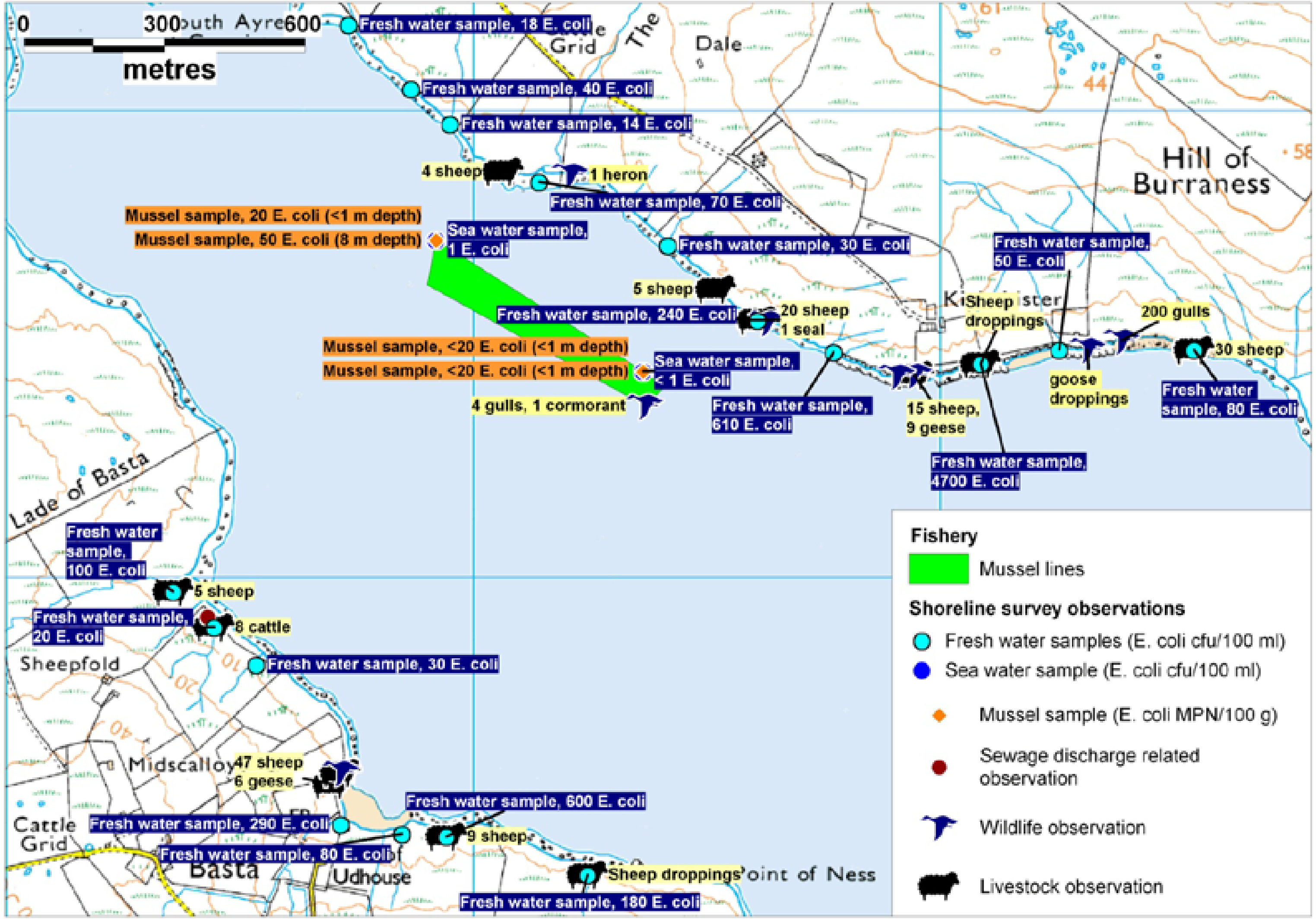


Figure 15.1 Summary of shoreline survey findings for Basta Voe Outer

16. Overall Assessment

Human sewage impacts

No large sewage discharges are present in the area surrounding the Basta Voe Outer fishery and the shoreline immediately adjacent to the fishery is uninhabited. The majority of consented sewage discharges in the area relate to small private dwellings which discharge either to land or to soakaway. These are all located in areas which have soils classed as poorly-draining, and therefore if not adequately maintained may lead to overland runoff of septic waste during wet weather. The nearest of these discharges lies approximately 600m north of the mussel farm.

Only one septic tank discharges to Basta Voe, approximately 2 km north of the mussel farm. Overall, the impact to the fishery of microbiological contamination from sewage discharges is expected to be minimal.

The ferry route between Yell and Fetlar passes approximately 2 km east of the production area boundary. Overboard discharge of treated wastes from the ferries is unlikely to contribute to faecal contamination at the fishery. Potential discharges of untreated wastes from other boat traffic using Basta Voe could cause high levels of contamination at the fishery, depending on the proximity and direction of any discharge relative to the mussel lines. Due to the large number of marine cage fish farms in the outer part of the voe, the amount of boat traffic is expected to be moderate.

Agricultural impacts

Sheep and cattle are grazed on both sides of the voe. During the shoreline survey, similar numbers of animals were observed on the shore east of the mussel farm and around Basta, to the southwest of the mussel farm. Based on the animals observed during the shoreline survey, and the presence of improved grassland, a significant proportion of any faecal contamination reaching the mussel farm at Basta Voe: Outer is expected to come from diffuse agricultural sources. These are likely to arise both to the north and the southeast of the mussel farm and would be largely rainfall dependent, with streams and direct runoff from the hillsides adjacent to the fishery likely to carry livestock faeces to the waters of the mussel farm. Direct deposition of livestock faeces on the intertidal shoreline will potentially contaminate the fishery waters independent of rainfall.

Wildlife impacts

Wildlife, including marine mammals and seabirds, are likely to contribute to background contamination levels within Basta Voe. Little information was available on the numbers of most animals likely to be present at or near the fishery. The greatest impact from seabirds is likely to be during the summer months, when a large number of birds nest in the area. Impacts from goose and other bird droppings deposited on shore are most likely to be higher where the mussel farm lies nearest the shore.

All of the species likely to be present could have a significant impact on faecal contamination at the fishery if they happen to defecate in close proximity to the mussel lines. However, there is no evidence to suggest whether any part of the fishery is more likely to be affected in this way than another.

Seasonal variation

Seasonal variation is likely to occur in livestock and wildlife populations, rainfall, prevailing wind direction and strength. There is little human population around the voe, and little in the way of tourist facilities in the immediate area therefore a large seasonal increase in human impacts is not expected.

Livestock, particularly sheep, populations are likely to roughly double during the late spring and summer when lambs are present. Lambs are typically sent to market in autumn, after which the sheep population returns to pre-spring levels. The shoreline survey was undertaken in October, therefore the numbers observed would have most likely reflected winter populations and the summer population would be higher.

The impacts from seabirds are most likely to be highest during the summer months, when birds are present on and near nests.

Daily rainfall has generally been higher in late autumn and winter. It is therefore expected that run-off due to rainfall will be higher during these months. However, extreme rainfall events occurring outside this period, and especially following periods of dry weather, may lead to episodes of high runoff and can contribute high loadings of faecal organisms to the voe via runoff to streams and overland flow to the shore.

Analysis of historical monitoring data showed that *E. coli* results in the spring were significantly lower in comparison to the other seasons. Evaluation of results by month showed a tendency toward higher results from July to November, though the highest result overall occurred in June. Results exceeding 230 *E. coli* MPN/100 g all occurred during the months of June to October.

Rivers and streams

Several small streams and burns were observed during the shoreline survey on both shores of the production area. The majority of these were relatively lightly contaminated. Those carrying the highest calculated spot loadings were located along the eastern shore, toward the southeast end of the mussel farm and along the opposite shore to the south of the mussel farm. The streams along the nearest shore would have been affected by livestock-source contamination as there are no occupied dwellings along this shore. Streams discharging to the opposite shore, south of the mussel farm, may also carry diffuse contamination from septic discharges in addition to mainly livestock-source faecal contamination. All loadings would be expected to be lower than estimated after a period of dry weather.

Movement of contaminants

Much of Basta Voe is relatively deep and any contamination will be subject to significant dilution before reaching the shellfishery, except for that arising from the shore immediately adjacent to the mussel farm.

Currents within the voe are weak and only sources within the voe itself are likely to be of significance. Water movement differs with depth. The tops of the mussel downlines will be mainly exposed to contamination arising from sources up-voe, while the bottoms of the lines will be exposed to any contamination carried at depth from both up- and down-voe. Some flow will occur towards the lines from the adjacent shore. The nearest potential sources to the fishery are along the adjacent shore, and as they are likely to be rainfall dependent will be present toward the surface of the water as they are transported toward the mussel farm and southeastward out of the voe. Sources arising from shore to the north and northwest of the fishery are therefore more likely to impact mussel farm as they are transported outward by surface currents. Any contamination arriving at the fishery is likely to have arisen very near the mussel farm.

Analysis of historical monitoring data showed correlation between *E. coli* results and the spring/neap tidal cycle, with lower results during the latter half of the neap tide (approaching springs) and highest results at or just after spring tides. Two potential reasons for this are increased transport distance and increased wetted shoreline area. Higher tidal flows during spring tides would be expected to transport contamination further from surface sources nearer the head of the voe, and therefore these may be more likely to impact at the mussel farm during spring tides. Alternatively, or in addition, faecal material deposited at or above the mean high water line may be washed into the voe on the higher spring tides, thereby adding to faecal contamination at the fishery.

Temporal and geographical patterns of sampling results

Scatterplots of the historical *E. coli* monitoring results from the two sites suggested that there may be slightly lower levels of contamination at the Basta Ness site, which lies nearer the mouth of the loch. However, no statistically significant difference was found in levels of contamination. Sampling at Basta Ness ceased in 2010, however, and the site is no longer used for mussel production. There appeared to be a very slight upward trend in contamination levels at the Outer site. There have been episodes of moderately high levels of faecal contamination, with one sample exceeding 4600 *E. coli* MPN/100 g. This is supported by the Shellfish Growing Water monitoring results. Overall, however, the monitoring results have generally shown low to very low levels of contamination.

Conclusions

The Basta Voe Outer mussel fishery is likely to be affected primarily by diffuse source faecal contamination, mainly of agricultural origin, but also from wildlife. Failing or poorly functioning septic systems located further up the voe may also contribute to background levels of faecal contamination in the outer voe. For the remaining mussel farm at Outer, sources located further up the voe are more likely to contribute to levels of faecal contamination found in the mussels. Sources arising from the adjacent shore, east of the mussel farm, may also contribute, though these are more likely to affect the lower half of the farm and to be transported out of the loch on the outward-bound surface current.

17. Recommendations

Production area

As the mussel farms at the north end of the current production area lie partly in both Basta Voe: Outer and Basta Voe: Cove production areas, it is recommended that the northern boundary of the Basta Voe: Outer production area is curtailed to exclude these farms. The southern boundary was amended to bring the area in closer agreement with the designated SGW, however the western end of the boundary was set at Basta Ness, a more easily recognised feature. Therefore, the recommended boundary is described as the area bounded by lines drawn between HU 5263 9620 to HU 5193 9578 and between HU 5369 9380 and HU 5489 9488, extending to MHWS.

RMP

As sources from the north and east are more likely to have an effect on water quality at the mussel farm, it is recommended the RMP be adjusted to HU 5294 9568, which lies at the northeast corner of the farm.

Depth of sampling

Sampling depth is recommended to be between 1 and 3 meters, as it is likely that contaminants arising from the near shore and at the fishery will be more concentrated near the surface.

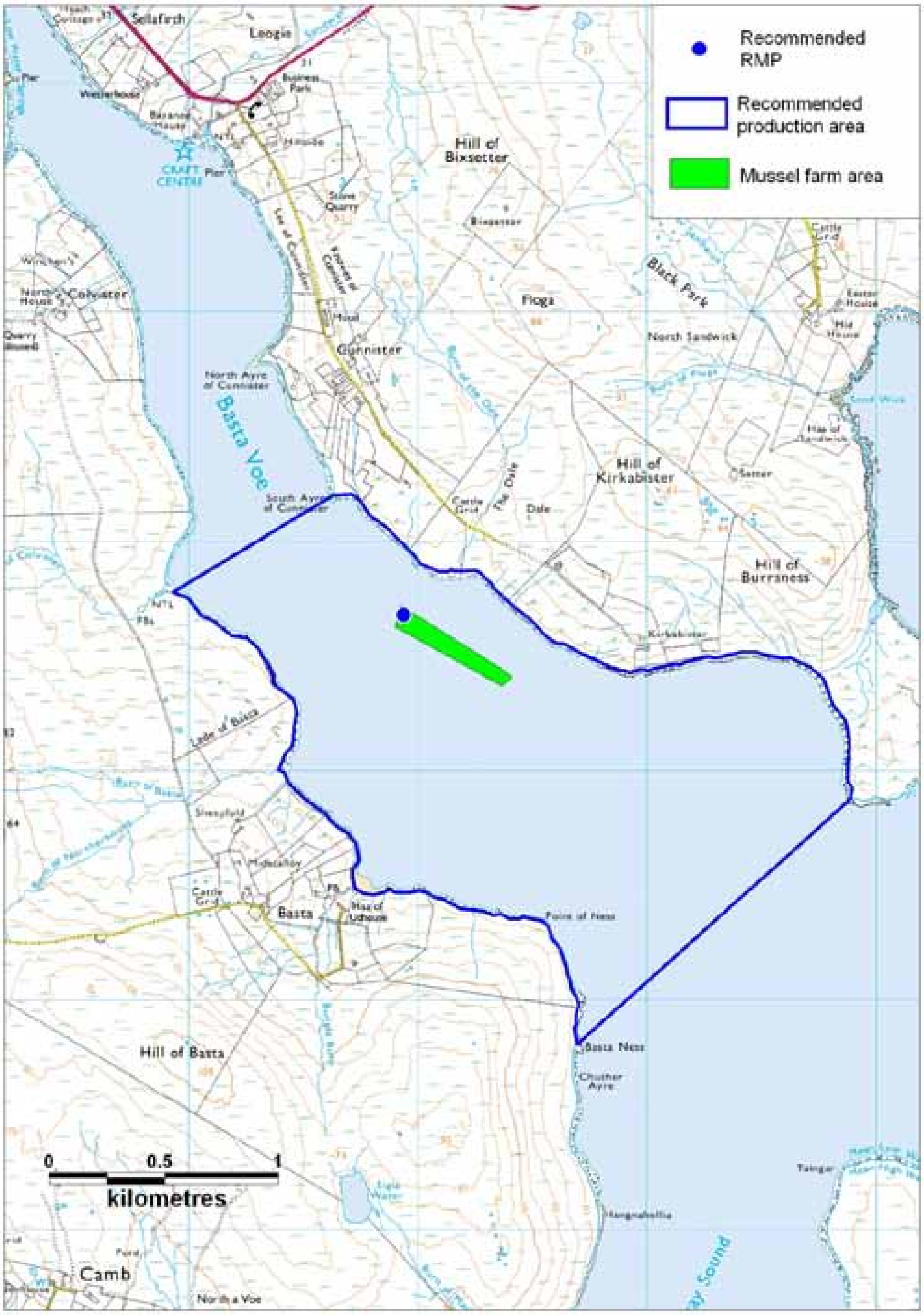
Tolerance

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

Frequency

An assessment of sampling results for stability did not suggest the area was suitable for reduced sampling frequency, therefore the recommended sampling frequency is monthly.

The locations of the recommended production area, RMP and the mussel farm are shown in Figure 17.1.



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

Figure 17.1 Map of recommendations at Basta Voe Outer

18. References

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19. List of Figures and Tables

Appendices

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

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

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

Cetaceans

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

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

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

Birds

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

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

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

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

Deer

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

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

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

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

Other

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

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

References:

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

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

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

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

Tables of Typical Faecal Bacteria Concentrations

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

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

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

Overall geographical pattern of results

```
One-way ANOVA: Log E Outer, Log E Basta Ness

Source  DF      SS     MS     F      P
Factor   1   0.199  0.199  0.55  0.461
Error   71  25.722  0.362
Total   72  25.921

S = 0.6019   R-Sq = 0.77%   R-Sq(adj) = 0.00%


                                      Individual 95% CIs For Mean Based on
                                      Pooled StDev
Level              N    Mean   StDev  -----+---------+---------+---------+--
--
Log E Outer       50  1.4818  0.6207              (-----------*----------)
Log E Basta Ness  23  1.3693  0.5579  (---------------*----------------)
                                      -----+---------+---------+---------+--
--
                                         1.20      1.35      1.50      1.65

Pooled StDev = 0.6019
```

Seasonal patterns of results

```
General Linear Model: Log EC versus Site, Season

Factor  Type   Levels  Values
Site    fixed       2  Basta Ness, Outer
Season  fixed       4  autumn, spring, summer, winter


Analysis of Variance for Log EC, using Adjusted SS for Tests

Source       DF   Seq SS   Adj SS  Adj MS     F      P
Site          1   0.3207   0.3721  0.3721  1.32  0.255
Season        3   4.3675   3.0915  1.0305  3.65  0.017
Site*Season   3   2.1457   2.1457  0.7152  2.53  0.064
Error        71  20.0674  20.0674  0.2826
Total        78  26.9013


S = 0.531639   R-Sq = 25.40%   R-Sq(adj) = 18.05%


Unusual Observations for Log EC

Obs   Log EC      Fit   SE Fit  Residual  St Resid
 33  3.73239  1.58001  0.15347   2.15238      4.23 R
 57  3.38021  1.63166  0.20094   1.74855      3.55 R

R denotes an observation with a large standardized residual.


Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Log EC
All Pairwise Comparisons among Levels of Season
Season = autumn  subtracted from:

Season    Lower   Center     Upper  ------+---------+---------+---------+
spring  -0.9458  -0.4710  0.003800  (-------*-------)
summer  -0.4758   0.0233  0.522411          (-------*--------)
winter  -0.6738  -0.1798  0.314277       (-------*-------)
                                    ------+---------+---------+---------+
```

```
                                    -0.60      0.00      0.60      1.20


Season = spring  subtracted from:

Season    Lower  Center   Upper  ------+---------+---------+---------+
summer   0.0499  0.4943  0.9387                 (------*-------)
winter  -0.1475  0.2912  0.7300              (------*------)
                                 ------+---------+---------+---------+
                                    -0.60      0.00      0.60      1.20


Season = summer  subtracted from:

Season    Lower   Center   Upper  ------+---------+---------+---------+
winter  -0.6680  -0.2031  0.2618       (-------*------)
                                  ------+---------+---------+---------+
                                     -0.60      0.00      0.60      1.20
```

```
Tukey Simultaneous Tests
Response Variable Log EC
All Pairwise Comparisons among Levels of Season
Season = autumn  subtracted from:

        Difference       SE of           Adjusted
Season    of Means  Difference  T-Value   P-Value
spring     -0.4710      0.1805   -2.609    0.0527
summer      0.0233      0.1897    0.123    0.9993
winter     -0.1798      0.1878   -0.957    0.7740


Season = spring  subtracted from:

        Difference       SE of           Adjusted
Season    of Means  Difference  T-Value   P-Value
summer      0.4943      0.1690    2.926    0.0234
winter      0.2912      0.1668    1.746    0.3080


Season = summer  subtracted from:

        Difference       SE of           Adjusted
Season    of Means  Difference  T-Value   P-Value
winter     -0.2031      0.1767   -1.149    0.6607
```

```
Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Log EC
All Pairwise Comparisons among Levels of Site
Site = Basta Ness  subtracted from:

Site     Lower  Center   Upper  -------+---------+---------+---------
Outer  -0.1069  0.1449  0.3968  (----------------*---------------)
                                -------+---------+---------+---------
                                     0.00      0.15      0.30
```

```
Tukey Simultaneous Tests
Response Variable Log EC
All Pairwise Comparisons among Levels of Site
Site = Basta Ness  subtracted from:

       Difference       SE of           Adjusted
Site     of Means  Difference  T-Value   P-Value
Outer      0.1449      0.1263    1.147    0.2551
```

Residual Plots for Log EC

Hydrographic Methods

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

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

Background processes

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

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

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

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

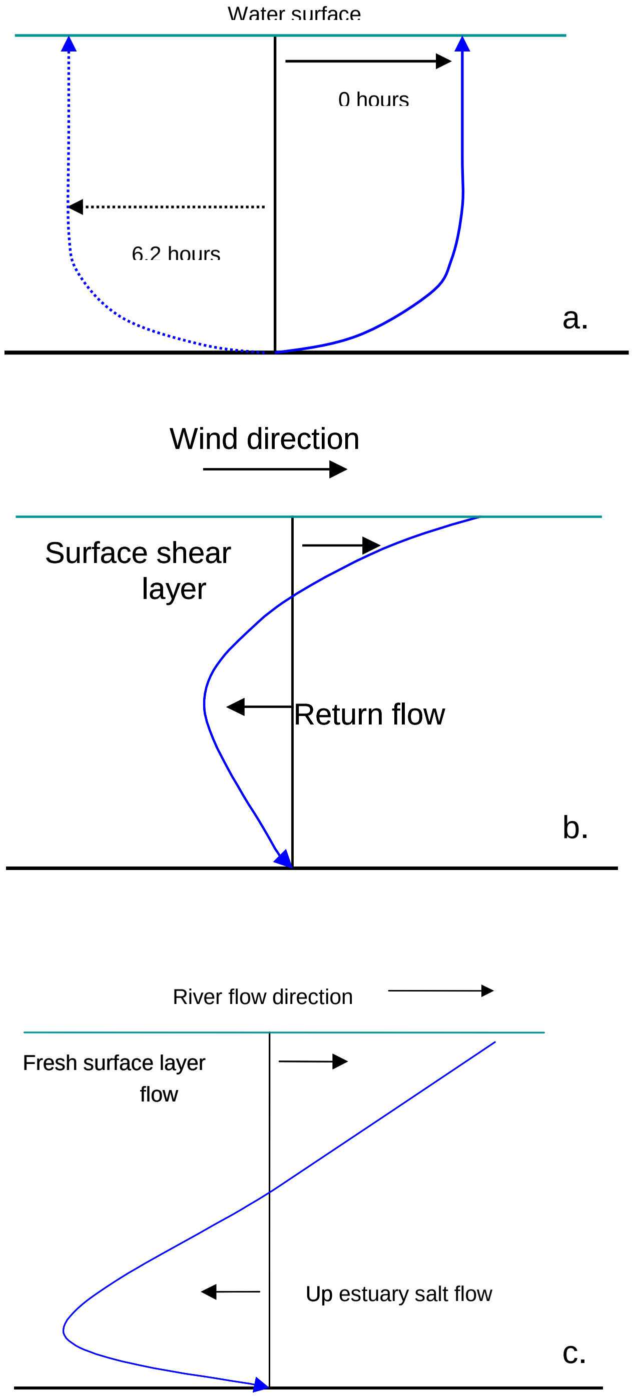

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

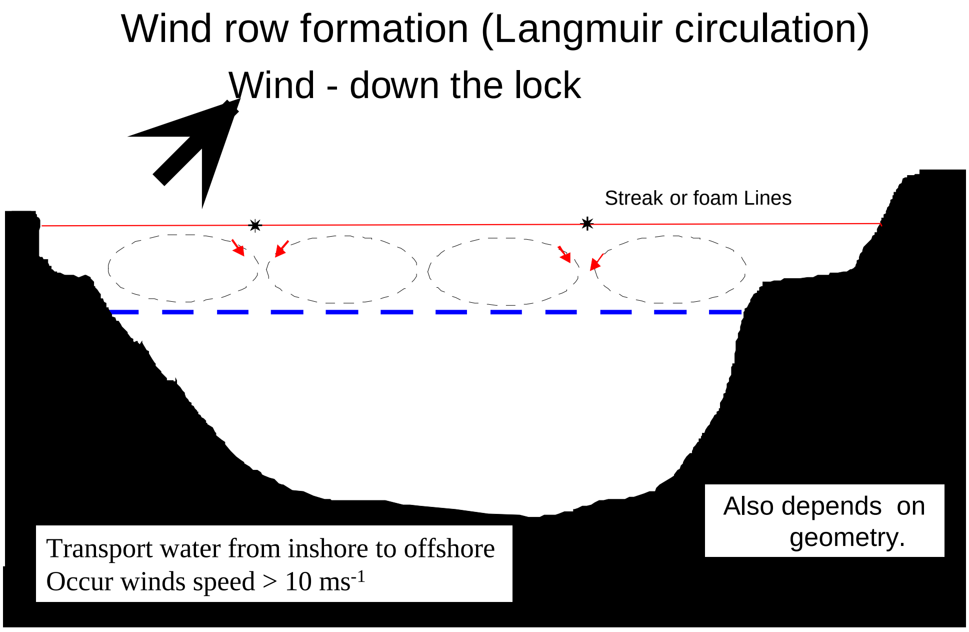

Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Non-modelling Assessment

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

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

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

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

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

References

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

Glossary

The following technical terms may appear in the hydrographic assessment.

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

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

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

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

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

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

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

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

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

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

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

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

Shoreline Survey Report

Production area:	Basta Voe Outer
Site name:	Outer
SIN:	SI 323 403 08
Species:	Common mussels
Harvester:	Christopher Thomason (C & A Thomason)
Local Authority:	Shetland Islands Council
Status:	Existing site
Date Surveyed:	18th and 20th October 2011
Surveyed by:	Jessica Larkham – Cefas Sean Williamson – NAFC
Nominal RMP:	HU 532 957
Sampling Point:	HU 533 953
Area Surveyed:	See Figure 1.

Weather observations

18/10/2011 – Cloudy with light rain showers in the morning and calm and dry in the afternoon. Wind 2.2 knots, 8.7˚C. Heavy rain previous day.

20/10/2011 - Calm and dry, slightly overcast. Wind 1.1 knots, 11˚C. Heavy sleet and rain previous day.

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 Basta Voe Outer: Outer mussel fishery is a longline mussel farm consisting of seven long lines, each 200 m in length with 5 – 8 m droppers. The fishery had sufficient stock on site for sampling at the time of the shoreline survey and the site is harvested all year round. There is a second site called Basta Ness further towards the entrance of the voe, however the site has been sold to an aquaculture company who do not intend on using it as a mussel farm.

Sewage/Faecal Sources

Human

There are no large settlements in the area surrounding Basta Voe. On the south west shoreline of the voe opposite the shellfish farm is the small settlement of Basta. A further two small settlements, Gunnister and Sellafirth are located on the north east coast further up the voe. There is a small pier at Sellafirth. The shoreline immediately adjacent to the fishery is uninhabited. A single pipe was observed next to a field drain along the coastline north of the settlement of Basta, although this was not flowing at the time of the shoreline survey. No other outfall pipes, septic tanks or sanitary debris was observed during the shoreline survey.

Livestock
Livestock were observed grazing around most of the shoreline adjacent to the fishery. On the south west shoreline of the voe approximately 61 sheep in total were observed scattered along the coastline, either side of the settlement of Basta. A further 8 cattle were also observed fenced off in a field adjacent to the shoreline north of Basta. On the north east shoreline of the voe approximately 74 sheep were observed in total. Half of the sheep observed were located in fenced off fields and the remaining often had access to the shoreline. Sheep droppings were in abundance and found on the shoreline of both sides of the voe.

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. However both are located at the south end of the island away from the fishery. There is a small pier located at Sellafirth. A boat was observed working on the mussel fishery on the second day of the shoreline survey.

Land Use
The majority of the land on both sides of the voe was rough grassland with boggy areas, mainly used for rough grazing.

Wildlife/Birds
During the shoreline survey on the north eastern side of the voe, east of the fishery a total of 9 geese, approximately 200 gulls and 1 seal were observed. Approximately 4 gulls and 1 cormorant were observed on the mussel lines. On the south west shoreline of the voe, 1 heron and 6 geese were observed. Goose droppings were present on the shoreline in large number on both sides of the voe.

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	18/10/2011	10:42	HU 52577 96048	452577	1196048	Figure 4		Fish farm
2	18/10/2011	10:45	HU 52921 95722	452921	1195722	Figure 5	BVOSW1, BVOMUSSEL1, BVOMUSSEL2	Corner of mussel farm. Location of seawater sample BVOSW1 (10:46) and mussel samples BVOMUSSEL1 (<1 m depth) and BVOMUSSEL2 (8 m depth). Salinity profile 5 m 35.41/10.2C, 4 m 36.22/10.3C, 3 m 36.24/10.4C, 2 m 36.22/10.5C, 1 m 36.21/10.5C, <1 m 36.19/10.5C
3	18/10/2011	10:57	HU 53364 95441	453364	1195441		BVOSW2, BVOMUSSEL3, BVOMUSSEL4	Corner of mussel farm. Location of seawater sample BVOSW2 (10:58) and mussel samples BVOMUSSEL3 (<1 m depth) and BVOMUSSEL4 (4 m depth) Droppers actually 8 m depth but too heavy to lift.
4	18/10/2011	11:03	HU 53410 95406	453410	1195406			Far end of second line in
5	18/10/2011	11:04	HU 53368 95367	453368	1195367	Figure 6		Corner of mussel lines, 4 gulls & 1 cormorant on the lines. Note the long line closest to the shore has no droppers on yet
6	18/10/2011	11:07	HU 52902 95626	452902	1195626			Corner of mussel farm
7	18/10/2011	12:14	HU 52716 94470	452716	1194470	Figures 7 & 8	BVOFW1	Stream, leading down from houses, sheep droppings all along the shore. Stream width 2.0 m, depth 0.17 m, flow 0.135 m/sec, standard deviation 0.019, location of freshwater sample BVOFW1 (12:14)
8	18/10/2011	12:21	HU 52700 94556	452700	1194556			19 sheep
9	18/10/2011	12:30	HU 52536 94812	452536	1194812		BVOFW2	Stream, width 0.25 m, depth 0.05 m, flow 0.143 m/s, location of freshwater sample BVOFW2 (12:31)
10	18/10/2011	12:40	HU 52446 94892	452446	1194892	Figure 9	BVOFW3	Approx 8 cattle in a field, fenced off from shoreline. Stream running through cattle field, width 0.15 m, depth 0.05 m, flow 0.462 m/s, standard deviation 0.005, location of freshwater sample BVOFW3 (12:40)
11	18/10/2011	12:45	HU 52432 94916	452432	1194916			Pipe, with no flow, next to small field drain
12	18/10/2011	12:50	HU 52358 94969	452358	1194969	Figure 10	BVOFW4	Burn of Basta, width 1.3 m , depth 0.44 m, flow 0.491 m/s, standard deviation 0.087, location of freshwater sample BVOFW4, 5 sheep in field. Fishing boat working on

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								mussel farm.
13	18/10/2011	13:10	HU 52716 94581	452716	1194581	Figure 11		6 geese and lots of goose dropping along the shoreline, approximately 28 sheep fenced off in field next to shoreline.
14	18/10/2011	13:17	HU 52848 94450	452848	1194450		BVOFW5	Stream, width 0.25 m, depth 0.05 m, flow 0.488 m/s, standard deviation 0.005, location of freshwater sample BVOFW5 (13:17)
15	18/10/2011	13:22	HU 52943 94444	452943	1194444		BVOFW6	Approx 9 sheep on shoreline. Stream, width 0.14 m, depth 0.14 m, flow 0.329 m/s, standard deviation 0.005, location of freshwater sample BVOFW6 (13:29)
16	18/10/2011	13:33	HU 53245 94362	453245	1194362		BVOFW7	Stream, lots of sheep droppings close by, width 0.25 m, depth 0.10 m, flow 0.261 m/s, standard deviation 0.078, location of freshwater sample BVOFW7 (13:34)
17	20/10/2011	09:36	HU 53208 95862	453208	1195862			1 heron
18	20/10/2011	09:41	HU 53417 95711	453417	1195711		BVOFW8	Stream, width 0.10 m, depth 0.05 m, flow 0.480 m/s, standard deviation 0.006, freshwater sample BVOFW8 (09:41)
19	20/10/2011	09:48	HU 53520 95617	453520	1195617	Figure 12		5 sheep on the beach
20	20/10/2011	09:50	HU 53609 95550	453609	1195550		BVOFW9	Approx 20 sheep in a field next to the shoreline. Stream, width 0.15 m, depth 0.06 m, flow 0.119 m/s, standard deviation 0.007, location of freshwater sample BVOFW9 (09:51)
21	20/10/2011	09:58	HU 53772 95482	453772	1195482		BVOFW10	Stream, width 0.12 m, depth 0.05 m, flow 0.149 m/s, standard deviation 0.004, location of freshwater sample BVOFW10 (09:58)
22	20/10/2011	10:05	HU 53944 95433	453944	1195433			Derelict house with adjacent field with approx 15 sheep and 5 geese
23	20/10/2011	10:09	HU 54087 95457	454087	1195457		BVOFW11	Stream, width 0.12 m, depth 0.04 m, flow 0.432 m/s, standard deviation 0.005, location of freshwater sample BVOFW11 (10:09). Sheep droppings all along the shoreline
24	20/10/2011	10:16	HU 54255 95487	454255	1195487	Figure 13	BVOFW12	Stream, width 0.20 m, depth 0.07 m, flow 0.334 m/s,

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								standard deviation 0.009, location of freshwater sample BVOFW12 (10:16)
25	20/10/2011	10:20	HU 54316 95488	454316	1195488			Goose droppings
26	20/10/2011	10:22	HU 54363 95501	454363	1195501			Field drain
27	20/10/2011	10:22	HU 54389 95506	454389	1195506			Approx 200 gulls
28	20/10/2011	10:27	HU 54544 95487	454544	1195487		BVOFW13	Stream, width 0.17 m, depth 0.06 m, flow 0.474 m/s, standard deviation 0.008, location of freshwater sample BVOFW13 (10:27). Approx 30 sheep in field behind
29	20/10/2011	10:57	HU 53907 95431	453907	1195431			4 geese
30	20/10/2011	11:03	HU 53630 95546	453630	1195546			1 seal
31	20/10/2011	11:16	HU 53141 95847	453141	1195847	Figure 14	BVOFW14	Stream (leading straight onto mussel lines and next to abandoned salmon cages on shoreline) width 1. m, depth 0.05 m, flow 0.386 m/s, standard deviation 0.009, location of freshwater sample BVOFW14 (11:16)
32	20/10/2011	11:21	HU 53064 95869	453064	1195869	Figure 15		4 sheep on shoreline
33	20/10/2011	11:25	HU 52951 95971	452951	1195971		BVOFW15	Small stream, width 0.25 m, depth 0.05 m, flow 0.181 m/s, standard deviation 0.030, location of freshwater sample BVOFW15 (11:25)
34	20/10/2011	11:30	HU 52867 96046	452867	1196046		BVOFW16	Stream, width 0.10 m, depth 0.04 m, flow 0.405 m/s, standard deviation 0.003, location of freshwater sample BVOFW16 (11:30)
35	20/10/2011	11:39	HU 52733 96184	452733	1196184		BVOFW17	Stream, width 0.11 m, depth 0.03, flow 0.379 m/s, standard deviation 0.040, location of freshwater sample BVOFW17 (11:39)

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	SUSW1	18/10/2011	HU 52921 95722	Seawater	1	35.02
2	SUSW2	18/10/2011	HU 53364 95441	Seawater	<1	35.15
3	BVOFW1	18/10/2011	HU 52716 94470	Freshwater	290	
4	BVOFW2	18/10/2011	HU 52536 94812	Freshwater	30	
5	BVOFW3	18/10/2011	HU 52446 94892	Freshwater	20	
6	BVOFW4	18/10/2011	HU 52358 94969	Freshwater	100	
7	BVOFW5	18/10/2011	HU 52848 94450	Freshwater	80	
8	BVOFW6	18/10/2011	HU 52943 94444	Freshwater	600	
9	BVOFW7	18/10/2011	HU 53245 94362	Freshwater	180	
10	BVOFW8	20/10/2011	HU 53417 95711	Freshwater	30	
11	BVOFW9	20/10/2011	HU 53609 95550	Freshwater	240	
12	BVOFW10	20/10/2011	HU 53772 95482	Freshwater	610	
13	BVOFW11	20/10/2011	HU 54087 95457	Freshwater	4.7×10^3	
14	BVOFW12	20/10/2011	HU 54255 95487	Freshwater	50	
15	BVOFW13	20/10/2011	HU 54544 95487	Freshwater	80	
16	BVOFW14	20/10/2011	HU 53141 95847	Freshwater	70	
17	BVOFW15	20/10/2011	HU 52951 95971	Freshwater	14	
18	BVOFW16	20/10/2011	HU 52867 96046	Freshwater	40	
19	BVOFW17	20/10/2011	HU 52733 96184	Freshwater	18	

Table 3. Shellfish sample *E. coli* results

No.	Sample Ref.	Date	Position	Species	Depth (m)	*E. coli* MPN/100 g
1	BVOMUSSEL1	18/10/2011	HU 52921 95722	Common mussels	<1 (Surface)	20
2	BVOMUSSEL2	18/10/2011	HU 52921 95722	Common mussels	5	50
3	BVOMUSSEL3	18/10/2011	HU 53364 95441	Common mussels	<1 (Surface)	<20
4	BVOMUSSEL4	18/10/2011	HU 53364 95441	Common mussels	8	<20

Table 4. Salinity profiles

Profile	Date	Time	Position	Depth (m)	Salinity (ppt)	Temperature ˚C
1	18/10/2011	10:45	HU 52921 95722	Surface	36.19	10.5
				1	36.21	10.5
				2	36.22	10.5
				3	36.24	10.4
				4	36.22	10.3
				5	35.41	10.2

Figure 2. Water sample results

Figure 3. Shellfish sample results

Photographs

Figure 4. Fish farm in Basta Voe Outer

Figure 5. Basta Voe Outer: Outer mussel farm

Figure 6. Gulls on the mussel lines

Figure 7. Stream leading down from houses, location of freshwater sample BVOFW1

Figure 8. Sheep dropping all along the shoreline

Figure 9. Approx. 8 cattle in field fenced off from shoreline

Figure 10. Burn of Basta, location of freshwater sample BVOFW4

Figure 11. Approx. 28 sheep in total fenced off in field next to shoreline

Figure 12. Approx. 5 sheep on the beach

Figure 13. Stream, location of freshwater sample BVOFW12