Scottish Sanitary Survey Report

Sanitary Survey Report
Busta Voe Lee South
SI 328
March 2013

Cefas

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Report Distribution – Busta Voe Lee South

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Partner Organisations

The hydrographic assessment and the shoreline survey and its associated report were undertaken by Shetland Seafood Quality Control, Scalloway.

Table of Contents

Appendices

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

I. Executive Summary

A sanitary survey was undertaken at the Busta Voe Lee South production area based on its placement in a risk-based ranking of active production areas that had not yet received sanitary surveys.

The production area is located on the west side of mainland Shetland, around the uninhabited island of Linga. The surrounding area is sparsely populated, with the majority of human habitation along the western boundary of the production area, on the island of Muckle Roe.

The fishery at Busta Voe Lee South is comprised of three separate mussel farm sites: two adjacent to Muckle Roe on the western side of the production area and one east of Linga, on the east side of the production area. All three produce common mussels on double-headed long-lines, with droppers to approximately 10-15 metres.

The main potential sources of faecal contamination to the fishery are:

- Human contamination sources arising from inhabited areas of shoreline adjacent to the fishery, and in particular the portacabin toilet on the pier at Greentaing

- Diffuse agricultural pollution arising from crofted/farmed areas along the Muckle Roe shoreline, adjacent to the west side of the production area

- Wildlife sources of diffuse faecal contamination, principally geese and seals along the western side of the production area and seabirds and seals along the eastern side.

Contaminants entering the west side of the production area are predicted to move roughly NE-SW along the shore, with the strength of flow depending on prevailing wind conditions. Contaminants arising from the east of the production area will be subject to different flow conditions than in the west, and under certain conditions may form a counter-clockwise gyre carrying contaminants toward the north and east sides of the Linga mussel farm.

Seasonal variation was seen in monitoring results, with highest results occurring from July to November. Highest results overall were found to occur at the Greentaing site, with a greater number of shellfish results >230 *E. coli* MPN/100 g occurring there than at Linga. Monitoring was not undertaken at Buddascord, however samples taken during the shoreline survey showed lower levels of contamination there than at Greentaing. The current production area boundaries overlap those of Busta Voe Lee North, and

therefore minor amendments to the boundaries have been recommended to bring them in line with adjacent boundaries and natural land features while essentially retaining the same area. It is recommended that the RMP be maintained at the Greentaing site, with the location adjusted to place it on the recorded farm location. Further details on the sampling plan and recommended boundaries can be found in tabular form overleaf and on page 63.

II. Sampling Plan

Production Area	Busta Voe Lee South
Site Name	Greentaing
SIN	SI-328-767-08
Species	common mussels
Type of Fishery	Aquaculture, longline
NGR of RMP	HU 3438 6425
East	434380
North	1164250
Tolerance (m)	40
Depth (m)	1
Method of Sampling	Hand
Frequency of Sampling	Monthly
Local Authority	Shetland Islands Council
Authorised Sampler(s)	Sean Williamson Marion Slater Agnes Smith Alan Harpin Vicki Smith

III. Report

1. General Description

Busta Voe is part of a complex inlet of St. Magnus Bay, on the west coast of Mainland Shetland. The Busta Voe Lee South production area sits at the confluence of four of the water bodies that make up the northern end of the inlet: Busta Voe to the north, Olna Firth to the east, and Cole Deep and Gon Firth to the south. The production area itself is up to 3 km at its widest point and has a maximum depth of 62m. It is bounded to the west by the island of Muckle Roe and to the east by Mainland (Figure 1.1). The uninhabited island of Linga lies in the middle of the production area.

The village of Brae lies 3 km to the north of the area. The remainder of the area is relatively sparsely inhabited, with crofts and homes lining the roads that run along the shore of Muckle Roe, to the northeast of Hevden Ness and along the head of Gon Firth.

The sanitary survey at Busta Voe Lee South is being undertaken due to the risk-based ranking for the area amongst sites that have not yet been surveyed.

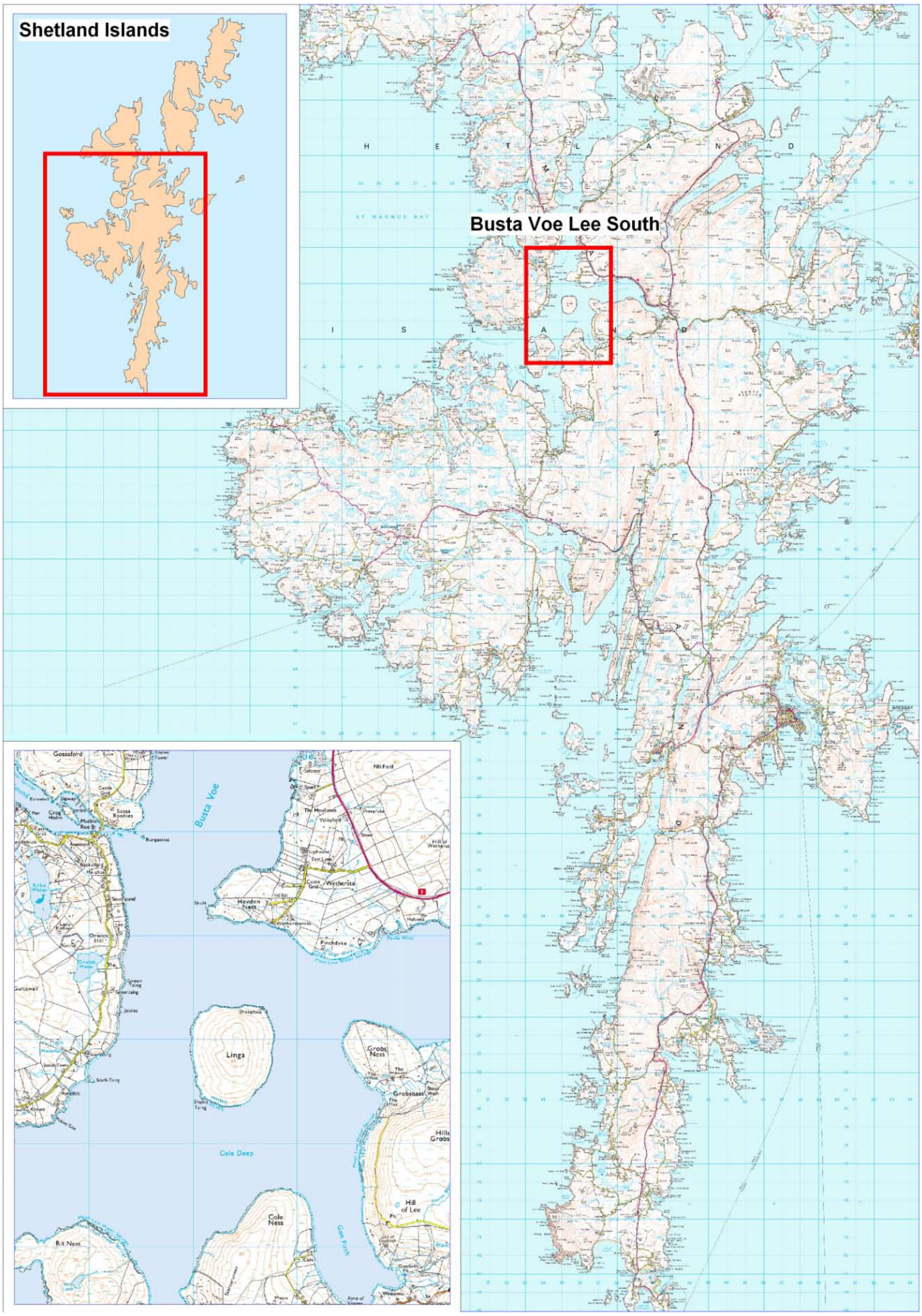

Figure 1.1 Location of survey area

2. Fishery

The fishery at Busta Voe Lee South is comprised of three common mussel (*Mytilus edulis*) farms as listed below:

Table 2.1 Area shellfish farms

Site	SIN	Species
Buddascord	SI-328-936-08	Common mussel
Greentaing	SI-328-767-08	Common mussel
Linga	SI-328-411-08	Common mussel

The mussel production area (RC-329-254-08) boundaries are described in the most recent FSA Scotland classification report as follows:"Area bounded by line drawn between HU 3657 6419, HU 3568 6428, HU 3520 6432, HU 3433 6460, HU 3364 6320, HU 3675 6320 extending to MHWS". Although current the representative monitoring point (RMP) is located at HU3440 6430, within the confines of the Greentaing site, samples have historically alternated between the vicinity of this RMP and an alternate locations off Linga (principally at HU 358 639).

The shoreline survey identified the boundaries and composition of the farms. These are detailed in Figure 1.2 below. All three sites were confirmed as having stocked mussel lines.

The site at Greentaing (SI 328 767 08) consisted of seven mussel lines running parallel to the western shoreline. All lines were double headed long lines with 10-15 metre droppers.

The Buddascord site (SI 328 936 08) consisted of seven mussel lines running parallel to the western shoreline. All lines were double headed long lines with 10 metre droppers.

The Linga site (SI 328 411 08) consisted of six mussel lines running parellel to the eastern shoreline of the island of Linga (Figure 6). All lines were double headed tubular lines with 15 metre droppers.

The maximum number of lines permitted at each fishery is fifteen at Greentaing, twelve at Buddascord and nine at Linga.

Harvest may be undertaken at any time of year, in accordance with product availability and market demand.

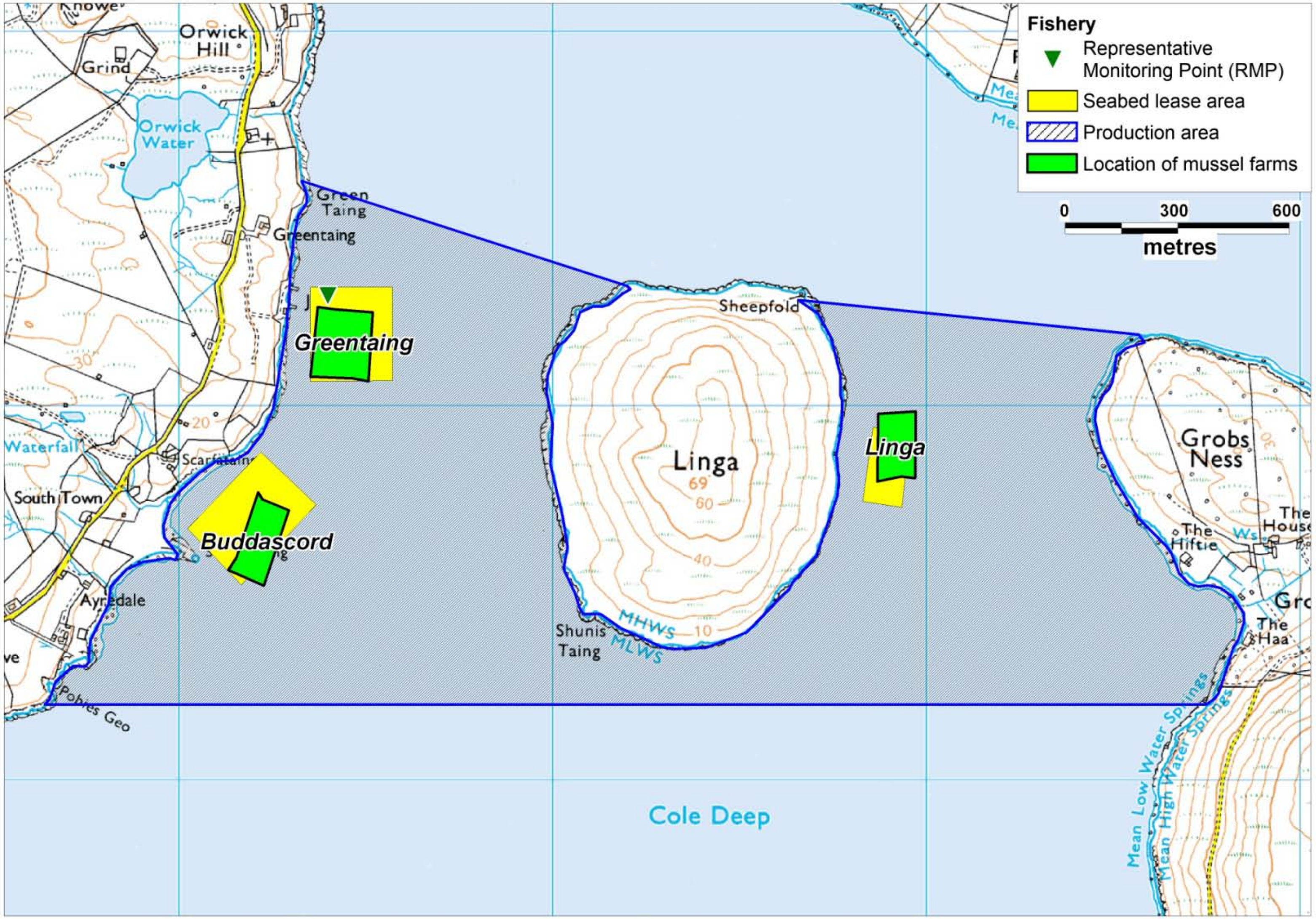

Figure 2.1 Busta Voe Lee South Fishery

3. Human Population

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

Figure 3.1 shows that population density is low on the coastlines adjacent to the fishery and slightly higher on the northern coastline where the settlements of Hevden Ness and Wethersta are located. The immediate population surrounding the Busta Voe Lee South area is spread across three census output areas, as listed in Table 3.1.

Table 3.1 Census output areas Busta Voe Lee South

No.	Output area	Population	Population Density (People per km^2)	Area (km^2)
1	60RD000037	104	6.1	17
2	60RD000047	105	2.2	48
3	60RD000137	50	16.7	3
Total		259		

There are several small settlements (Roesound, Southpund, Hevden Ness and Wethersta) located north of the production area and another (Grobsness) located east of the fishery. Each settlement accommodates less than a dozen dwellings. The nearest centre of population is the town of Brae, located 3 km north of the production area which has a population of over 1200 (Brae High School 2005). The town has a high school, with approximately 345 nursery, primary & secondary school pupils in attendance. The town has local amenities including a leisure centre and various tourist accommodations.

There is an anchorage approximately 2.7 km north of the production area in Busta Voe. Most of the boat traffic in the area is associated with aquaculture. There is a jetty adjacent to the Greentaing site which is owned by Northmavine Marine and is used as a shore base for their small work boats. A large workboat was present at the Buddascord site, harvesting mussels, on the day of the shoreline survey.

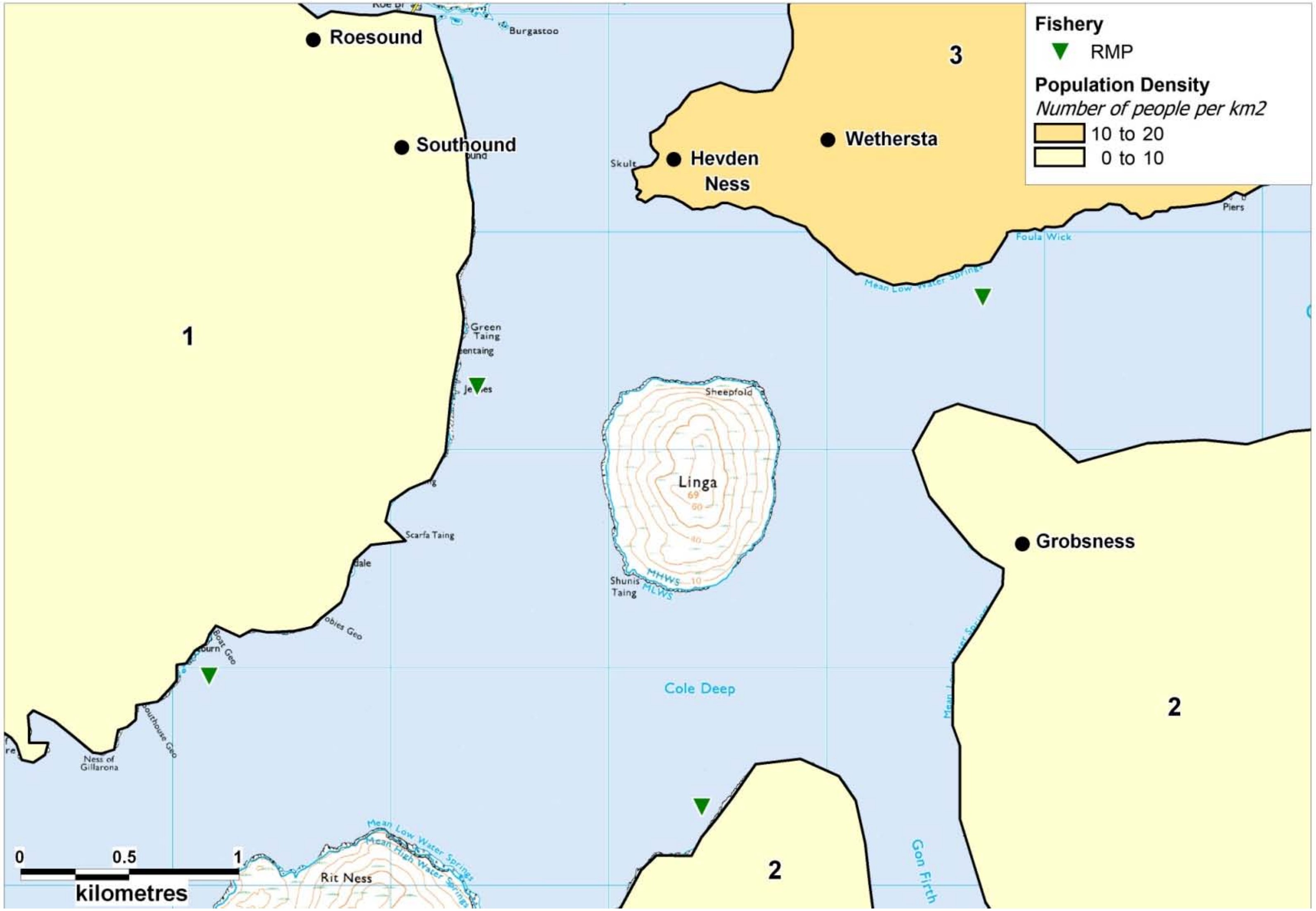

Figure 3.1 Population map of Busta Voe Lee South

4. Sewage Discharges

Information on sewage discharges to the area was sought from Scottish Water and the Scottish Environment Protection Agency (SEPA). Scottish Water identified one community septic tank for the area surrounding Busta Voe which is detailed in Table 4.1.

Table 4.1 Sewage discharges identified by Scottish Water

Consent No.	NGR	Discharge Name	Discharge Type	Level of Treatment	Flow (m^3/d)	PE
CAR/L/1001837	HU 357 675	Brae Playing Field ST	Continuous	Septic Tank	242	1000

\- No data provided

Information on microbiological and/or effluent quality data were requested from Scottish Water. However, no sanitary or microbiological data were provided for this discharge.

Brae Playing Field ST lies approximately 4.5 km northeast of the Greentaing site and approximately 5 km north of the site at Linga. This community septic tank currently has a connected population of 877. The design PE of 1000 therefore allows for future development and provision of additional housing to the area.

As part of an upgrade to the Brae ST in 2008, new tanks were installed and the outfall was extended 70 metres further offshore.

Discharges from Voe ST and an associated pumping station at the head of Olna Firth were identified by Scottish Water but due to their distance from the Busta Voe Lee South production area (6 km SE) and predicted movement of contaminants (Section 13) these discharges were not considered to pose a significant contamination risk to the mussel farms there.

SEPA identified a large number of discharge consents for the Busta Voe area. However, only those discharging to the aquatic environment or located adjacent to the shores of the production area are listed in Table 4.2. All consents provided are shown in Figure 4.1, but only those listed in Table 4.1 are numbered.

Table 4.2 Sewage discharge consents identified by SEPA

No.	Consent No.	NGR	Discharge Type	Level of Treatment	PE	Flow (m^3/d)	Discharges to
1	CAR/R/1086299	HU 3242 6307	Continuous	Septic Tank	5	-	Soakaway
2	CAR/R/1059046	HU 3308 6314	Continuous	Septic Tank	5	-	Land
3	CAR/R/1076620	HU 3300 6315	Continuous	Septic Tank	5	-	Soakaway
4	CAR/R/1076570	HU 3308 6325	Continuous	Septic Tank	5	-	Soakaway
5	CAR/R/1019472	HU 3423 6446	Continuous	Septic Tank	5	-	Land
6	CAR/R/1045105	HU 3412 6447	Continuous	Septic Tank	5	-	Soakaway
7	CAR/R/1028195	HU 3419 6474	Continuous	Septic Tank	5	-	Soakaway
8	CAR/R/1018415	HU 3435 6512	Continuous	Secondary	5	-	Busta Voe
9	CAR/R/1032546	HU 3428 6523	Continuous	Septic Tank	8	-	Soakaway
10	CAR/R/1036919	HU 3374 6599	Continuous	Septic Tank	6	-	Roe Sound
11	CAR/R/1054748	HU 3355 6603	Continuous	Septic Tank	5	-	Roe Sound
12	CAR/R/1019797	HU 3472 6695	Continuous	Septic Tank	6	-	Busta Voe
13	CAR/R/1036850	HU 3483 6702	Continuous	Septic Tank	5	-	Busta Voe
14	CAR/L/1001837	HU 3570 6750	Continuous	Septic Tank	-	-	Busta Voe
15	CAR/R/1037426	HU 3679 6498	Continuous	Septic Tank	5	-	Olna Firth
16	CAR/R/1025589	HU 3701 6362	Continuous	Septic Tank	6	-	Soakaway
17	CAR/R/1048603	HU 3731 6177	Continuous	Septic Tank	5	-	Soakaway

\- No data provided

No consented volume (either flow or PE) was provided for the Brae septic tank (No. 14, Table 4.2) by SEPA, however this information was provided by Scottish Water. The majority of consented discharges are located along the east shore of Muckle Roe and along the shores of Busta Voe to the north.

Discharges identified by SEPA to land or soakaway were from private septic tanks or small treatment works serving private dwellings with population equivalents of between 5 and 12. Six privately owned septic tanks discharged directly to sea. Of these, only one was located within 1 km of the Busta Voe Lee South mussel farms (No.8, Table 4.2). This discharge receives secondary treatment from a package treatment plant serving a single household and lies 850 m north of the Greentaing mussel farm, therefore it is not anticipated to have a material effect on water quality there. Small discharges further than 1 km away from the shellfish farms are not expected to significantly impact the water quality there. The total combined population equivalent of all the identified private discharges was 210, approximately 30% of the public sewerage system.

The island of Linga is uninhabited and only one discharge was identified for the shoreline at Grobs Ness, east of the fishery.

The nine discharges identified along the western shoreline close to the Greentaing site are likely to pose the greatest risk of contamination to the fishery.

Sewage infrastructure recorded during the shoreline survey is listed in Table 4.3. No attempt was made to ascertain the functional status of the septic tanks identified in the area of the fishery, as this was outside the scope of this survey.

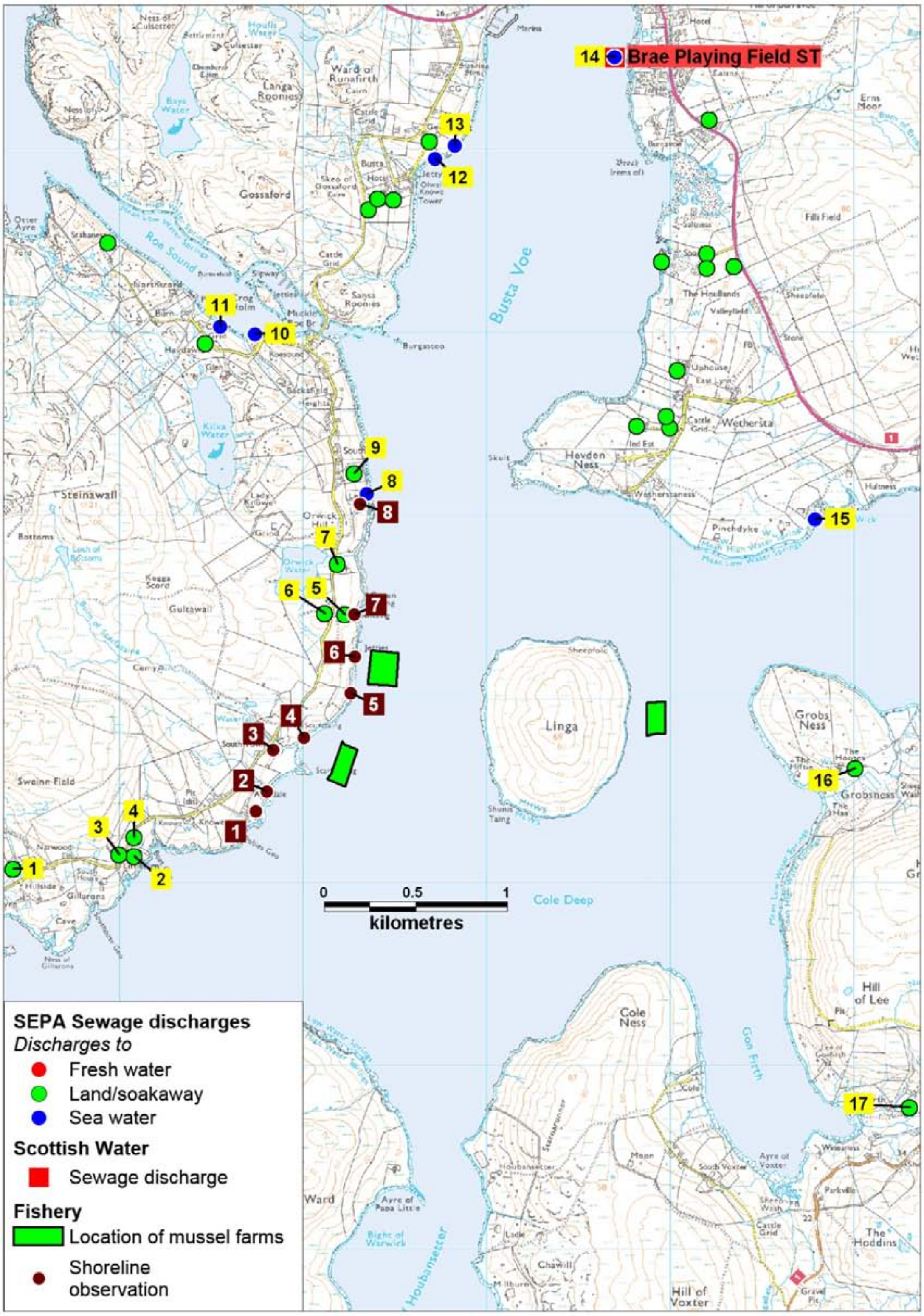

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Figure 4.1 Sewage Discharges around Busta Voe Lee South production area

Table 4.3 Discharges and septic tanks observed during shoreline surveys

No	Date	NGR	Sewage discharge observation
1	08/11/2012	HU 3371 6332	Two drains observed, one coming down from field and one from agricultural buildings, joined together further down to make one drain.
2	08/11/2012	HU 3374 6339	Occupied property above shoreline but unable to locate septic tank.
3	08/11/2012	HU 3380 6349	Occupied property above shoreline but unable to locate septic tank. No smell coming from watercourse.
4	08/11/2012	HU 3384 6372	Septic tank of an occupied property on hill above shoreline. Soakaway was to the field below.
5	08/11/2012	HU 3400 6379	Pipe observed draining to cliff, very small flow of water and water was clear. Occupied property above shoreline, no septic tank identified.
6	08/11/2012	HU 3426 6403	Pipe running into sea from field above shoreline, newer plastic pipe at top and old metal pipe at the bottom. Small pipe in vertical position mid way along, very little water flowing through the pipe, fairly clear water. Leak from pipe near the land. Field above was very wet. End of the pipe not visible so sea water sample taken in the vicinity where the pipe entered the water.
7	08/11/2012	HU 3428 6423	Discharge pipe from the portacabin/shed at the jetty most likely human waste.
8	08/11/2012	HU 3428 6446	Occupied property above the shore, no septic tank seen but registered as consented discharge.
9	08/11/2012	HU 3431 6506	Occupied house and church, [discharge registered at this location but no discharge pipe seen]

A number of potential discharges were observed that had not been identified by SEPA. As there has not historically been a requirement to register septic tanks in Scotland, except on sale or transfer of a property, this is not unexpected. The majority of observations related to houses with no apparent septic tank or tanks discharging to soakaway: however, given the lack of public sewerage provision in the immediate area, it is assumed that these must have been present. A toilet associated with a portacabin on the jetty had a discharge directly to sea adjacent to the jetty. As this is located a short distance west of the Greentaing mussel farm, any discharges from this location would be expected to have a greater impact there.

Overall the risk of contamination from sewage is likely to be highest along the west side of the production area. Registered discharges to water lie north of the production area, and therefore the Greentaing site may be affected more than the Buddascord site.

5. Agriculture

Information on the spatial distribution of animals on land adjacent to or near the fishery can provide an indication of the potential amount of organic pollution from livestock entering the shellfish production area. Agricultural census data to parish level was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for the Delting parish. Reported livestock populations for the parish in 2012 are listed in Table 5.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data. Any entries which relate to less than five holdings, or where two or fewer holdings account for 85% or more of the information, are replaced with an asterisk.

Table 5.1 Livestock numbers in the Delting parish 2012

	Delting	
	150 km^2	
	2012	
	Holdings	Numbers
Pigs	*	*
Poultry	14	229
Cattle	11	341
Sheep	62	24173
Other horses and ponies	*	*

The Busta Voe Lee South production area is covered by the agricultural parish Delting, which occupies part of the mainland, the islands of Linga and Muckle Roe and has an area of 150 km^2 (shown in the inset of Figure 5.1). Because the livestock numbers relate to a large area, it is not possible to determine the spatial distribution of the livestock in relation to the Busta Voe Lee South fishery. Therefore the figures are of little use in assessing the potential impact of livestock contamination to the fishery; however they do give an idea of the total numbers of livestock over the broader area. Sheep are the predominant type of livestock kept in the area, with a rough average of 390 per holding. Cattle are also present, with each holding having on average 31 animals. Poultry are also kept in the area.

The only significant source of spatially relevant information on livestock population in the area was the shoreline survey (see Appendix 2), which only relates to the time of the site visit on 8th November 2012. Observations made during the survey are dependent upon the viewpoint of the observer some animals may have been obscured by the terrain. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 5.1.

The shoreline survey identified that the land on the western shoreline was a mixture of rough grazing, silage fields and improved grazing land and the eastern shoreline is all rough grazing. A total of approximately 96 sheep were observed on the western shoreline, with little or no access to the shoreline. Although no cattle were observed at the time of the shoreline survey bovine faecal matter was present in fields adjacent to the Buddascord and Greentaing sites. On the eastern shoreline approximately 50 sheep were observed with access to the shoreline. No livestock were observed on the island of Linga at the time of the survey however it is known to be used for grazing sheep.

The spread of livestock observations, and the known use of the isle of Linga for sheep grazing, means that none of the mussel sites can be predicted to be impacted to a greater extent by farm animal contamination than any other.

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

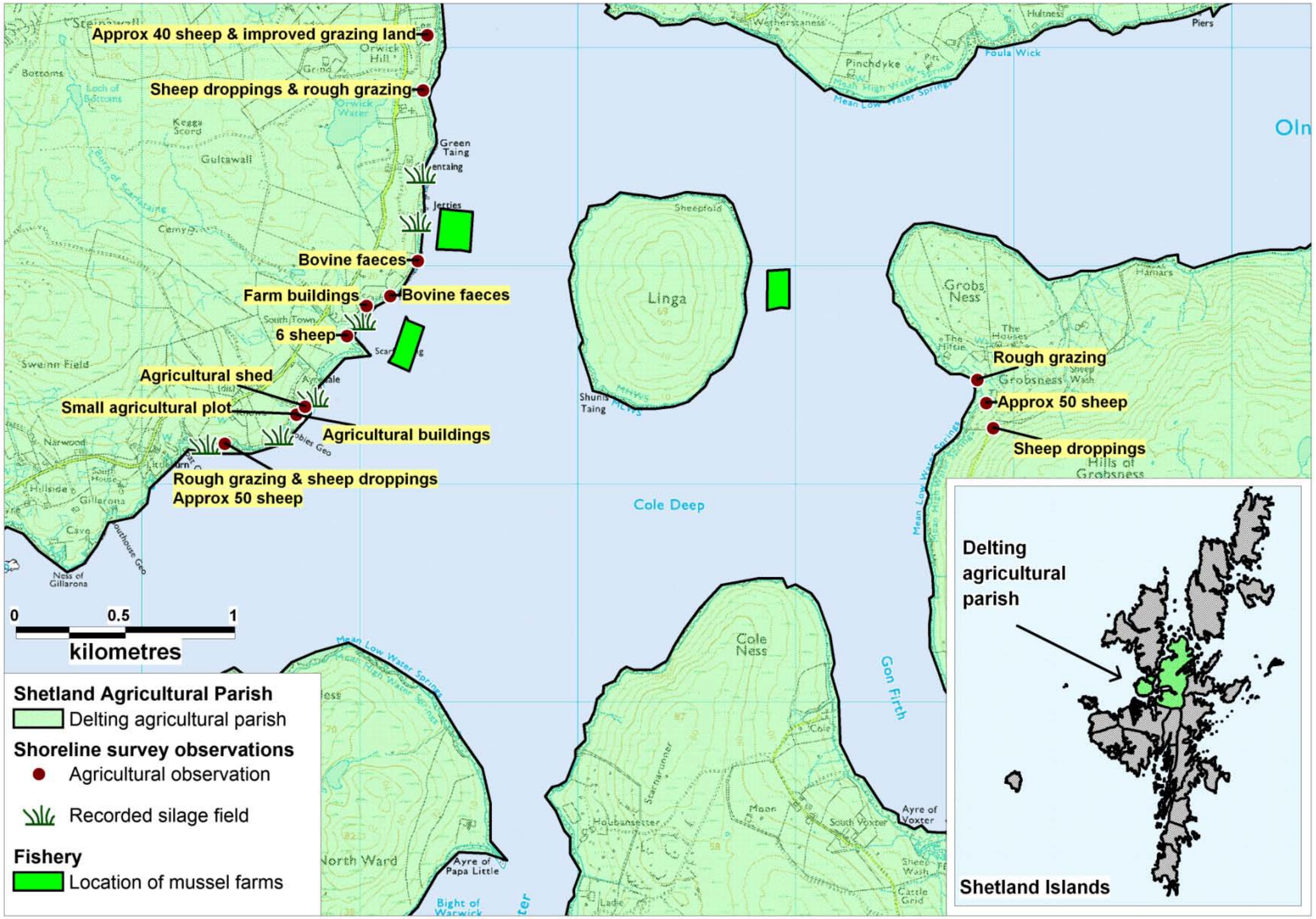

Figure 5.1 Agricultural parish boundary and livestock observations at Busta Voe Lee South

6. Wildlife

Pinnipeds

Information obtained through the Marine Spatial Plan for the Shetland Islands (2012), suggests that there is habitat present that is suitable for both the grey seal (*Halichoerus grypus*) to the west of Muckle Roe and the common/harbour seal (*Phoca vitulina*) to the southwest of the production area at Busta Voe Lee South. No quantitative or anecdotal population data was available on seal species in the area. A grey seal breeding colony is located on the western side of Muckle Roe, where they might be expected to spend more time hauled out from September to April when they are either breeding (September to December) or moulting (December to April). No harbour seal breeding colonies were identified in the area. (National Environment Research Council Special Committee on Seals, 2009). Harbour seals are also likely to be present in the area.

Seals were observed during the shoreline survey along both the east and west extents of the production area. No haul out areas are located in the near vicinity of the mussel farms, however seals are likely to be present in the waters around the mussel farms on a regular basis and therefore may contribute to background levels of faecal contamination in the area.

Cetaceans

The shallow nature of Busta Voe lagoon only allows for the small European/harbour porpoise to enter into its waters (NAFC Marine Centre 2012). There are no official population counts of harbour porpoise in Busta Voe, but anecdotal reports do exist and it is likely that the harbour porpoise seen in the area are transient. No cetaceans were seen during the shoreline survey.

Birds

There are no RSPB Reserves in the close vicinity to Busta Voe Lee South. Visually identified population counts were available from the Shetland Bird Report 2010 and are displayed in Table 6.1.

Table 6.1 Waterfowl data from Shetland Bird Report 2010

Common Name	Species	Count*	Method	Date
Great Scaup	*Aythya marila*	1	Visual ID*	11/06/2010
Common Scoter	*Melanitta nigra*	4	Visual ID	09/03/2010
Velvet Scoter	*Melanitta fusca*	2	Visual ID	30/09/2010
Red-Breasted Merganser	*Mergus serrator*	34	Visual ID	11/02/2010
Black Throated Diver	*Gavia arctica*	1	Visual ID	06/06/2010
Great Crested Grebe	*Podiceps cristatus*	1	Visual ID	11/03/2010

*ID = Identification

Few waterfowl have been counted in Busta Voe Lee South except for the Red-Breasted Merganser (*Mergus serrator*). This is likely to be resultant of the migratory nature of the birds listed in Table 6.1 and the restricted scope of the reporters. All species are categorised as 'scarce' or 'very scarce' according to Eaton *et al*. (2009) total population study, which reinforces their small contamination impacts.

Common seabird species were noted as present around Busta Voe Lee South in Seabird 2000 Census data (Mitchell et al., 2004). Data from within a 5 km radius of the Busta Voe Lee South production area is summarised in Table 6.2. This census, undertaken between 1998 and 2002 covered the 25 species of seabird that breed regularly in the UK.

Table 6.2 Seabird data within 5 km of Busta Voe Lee South, take from the Seabird Census 2000

Common Name	Species	Method	Count*
Arctic Tern	*Sterna paradisaea*	Individuals on land	1798
Great Black Backed Gull	*Larus marinus*	Occupied territory	8364
Common Gull	*Larus canus*	Occupied nests	1671
Northern Fulmar	*Fulmarus glacialis*	Occupied sites	5952
Black Guillemot	*Cepphus grylle*	Individuals on land	9049
Arctic Skua	*Stercorarius parasiticus*	Occupied territory	533
Great Cormorant	*Phalacrocorax carbo*	Occupied nests	112
Atlantic Puffin	*Fratercula arctica*	Individuals on land	1957
European Shag	*Phalacrocorax aristotelis*	Occupied sites	7983
Great Skua	*Stercorarius skua*	Occupied territory	580
Black legged Kittiwake	*Rissa tridactyla*	Occupied nests	6009
Black headed Gull	*Larus ridibundus*	Individuals on land	50
European Herring Gull	*Larus argentatus*	Occupied nests	7079
Common Tern	*Sterna hirundo*	Individuals on land	222
Lesser Black Backed Gull	*Larus fuscus*	Individuals on land	529

A large number of seabirds are found nearby to the Busta Voe Lee South production area. The black guillemot (*Cepphus grille*) was the most common, with the great black-backed gull, European shag, black legged kittiwake and northern fulmar also common. The majority of the seabirds were recorded along the west coast of Muckle Roe, although some were also found on the east side of Linga, at Grobs Ness and at Hevden Ness. The area is recognised as a key habitat area for seabirds, as noted in the Marine Spatial Plan for the Shetland Islands.

During the shoreline survey a relatively small number of birds were observed including; gulls, cormorants, a heron, and geese. There was also quite a lot of evidence of geese by way of goose droppings around the shoreline survey route.

Otters

The Eurasian otter (*Lutra lutra*) has been reported on both the east and west shorelines around Busta Voe (http://www.shetland-heritage.co.uk/downloads/resources/geographicleaflets/Nest_Lunn_Delt.pdf). These are only anecdotal reports and there was no population data available for the area at the time of this report. During a shoreline survey one adult otter was seen on the shoreline. This would have been a marine otter, and it was observed amongst dense vegetation around a burn that fed into the voe.

Overall

Gulls, cormorants and other shore birds were observed in relatively low numbers. Large numbers of seabirds, including gulls, breed around Muckle Roe and Linga in summer. The nearest recorded nesting area is on Linga, near the mussel farm east of the island. Large concentrations of breeding birds on nests may cause localised faecal contamination to the waters around the nests as rainfall washes accumulated guano into watercourses and the sea. The two mussel farms near Muckle Roe lie adjacent to farmland that is not used by breeding seabirds and therefore are less likely to be impacted by faecal contamination from this source than the mussel farm at Linga. However, geese and their droppings were seen on the farmland west of the production area and therefore are likely to contribute to diffuse faecal contamination at Greentaing and Buddascord. Direct deposition by birds passing over or resting on the mussel farms is likely at all three sites and there is no evidence to suggest one might be more affected than the others from this source.

Seals were observed during the shoreline survey along both the east and west extents of the production area. A grey seal breeding colony is located on the western side of Muckle Roe, where they might be expected to spend more time hauled out from September to April when they are either breeding (September to December) or moulting (December to April). Harbour seals are also likely to be present in the area. No haul out areas are located in the near vicinity of the mussel farms, however seals are likely to be present in the waters around the mussel farms on a regular basis and therefore may contribute to background levels of faecal contamination in the area.

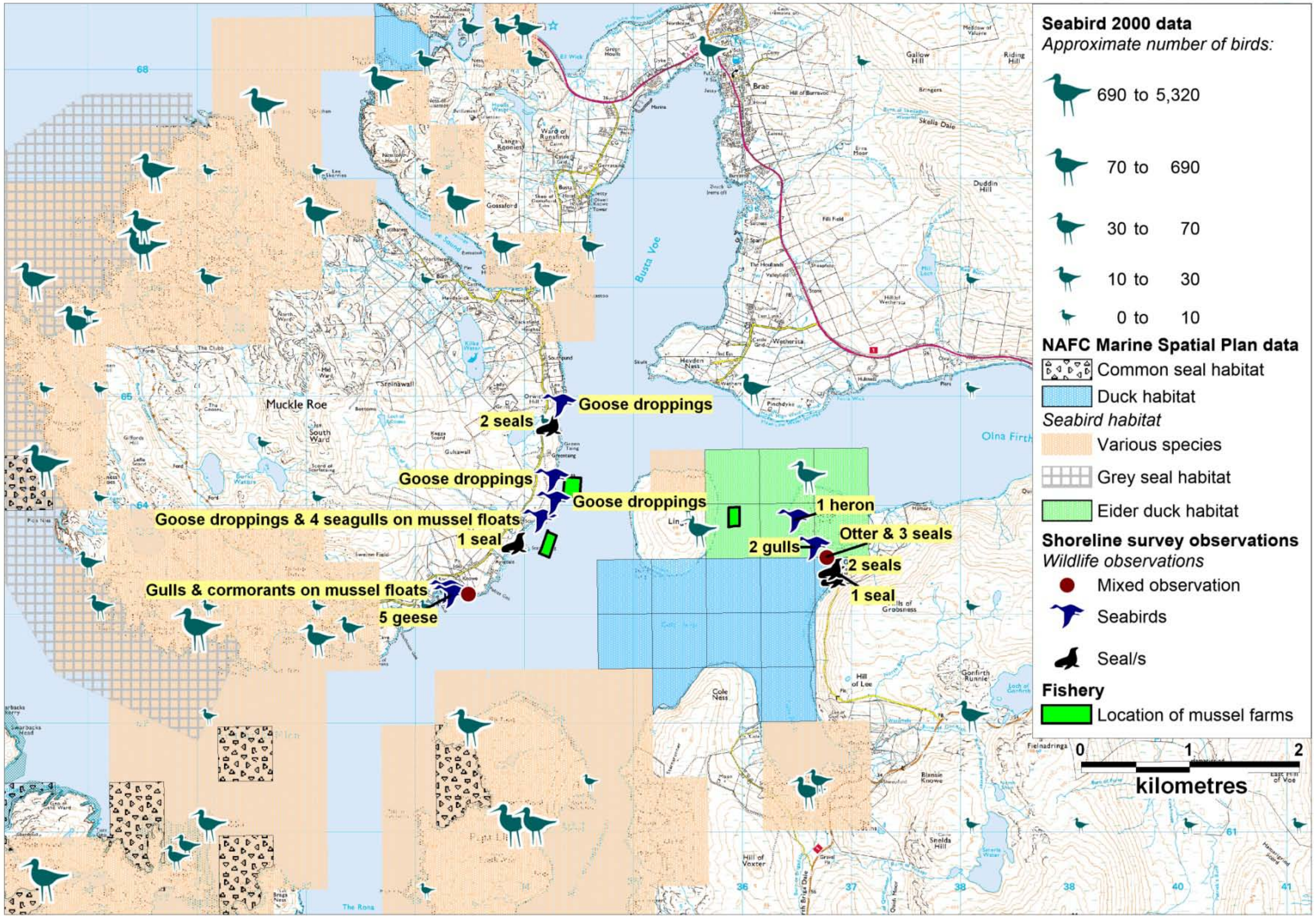

Figure 6.1Wildlife observations at Busta Voe Lee South

7. Land Cover

Rough grassland, improved grassland, dwarf shrub heath and bog are the predominant land cover types on the shorelines surrounding the Busta Voe Lee South shellfish farms. The isle of Linga in the centre of the production area is composed of dwarf shrub heath, rough grassland and bog. The shoreline to the east of the production area is primarily rough and improved grassland with areas of dwarf shrub heath and fen marsh and swamp inland. The western shoreline is lined with rough and improved grassland and areas of dwarf shrub heath and bog inland. To the south and north of the production area there the same land cover types are present. The small settlements of Hevden Ness and Roesound are represented as built up areas and gardens. During the shoreline survey land cover observations were recorded and these verified the Land Cover 2007 data.

Faecal indicator organism export coefficients for faecal coliform bacteria have been found to be approximately 1.2 – $2.8\times10^{9\ \mathrm{cfu}}$ km^{-2} hr^{-1} for urban catchment areas, approximately 8.3×10^{8} cfu km^{-2} hr^{-1} for areas of improved grassland and approximately 2.5×10^{8} cfu km^{-2} hr^{-1} for rough grazing (Kay, Crowther, et al., Faecal indicator organism concentrations and catchment export coefficients in the UK 2008a). 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, Crowther, et al., Faecal indicator organism concentrations and catchment export coefficients in the UK 2008a).

The highest potential contribution of contaminated runoff to the Busta Voe Lee South shellfish farms is from the area of improved grassland on the shoreline of Muckle Roe west of the Greentaing and Buddascord fisheries. The improved grassland on the shoreline of the mainland east of Linga may also contribute to contaminated runoff but to less effect due to the greater distance between the shoreline and the shellfish farm. Areas utilised for rough grazing on all shorelines would be expected to contribute significantly to faecal contaminant loading carried in watercourses and overland flow draining the area during rainfall. The Land Cover Map 2007 data for the area is shown in Figure 7.1.

Figure 7.1 LCM2007 land cover data for Busta Voe Lee South

8. Watercourses

There are no river gauging stations on watercourses along the Busta Voe Lee South shoreline.

The watercourses listed in Table 8.1 were recorded during the shoreline survey. These represent the largest freshwater inputs into the survey area. Rain consistently fell in the 48 hrs prior to the survey as well as throughout the first day of surveying with heavy downpours at times. The second day of surveying was dry, with sunny intervals.

Table 8.1 Watercourse loadings for Busta Voe Lee South

No	NGR	Description	Width (m)	Depth (m)	Flow (m^3/d)	*E. coli* (cfu/100 ml)	Loading (*E. coli*/day)
1	HU 3370 6333	Watercourse	0.18	0.05	143	800	1.1×10^9
2	HU 3380 6349	Watercourse	0.17	0.12	294	80	2.4×10^8
3	HU 3391 6372	Large watercourse	0.70	0.18	4757	38	1.8×10^9
4	HU 3428 6427	Land drainage to jetty	-	7L*	145	90	1.3×10^8
5	HU 3426 6477	Large watercourse	0.70	0.12	2156	330	7.1×10^9
6	HU 3685 6345	Burn	0.45	0.13	965	16	1.5×10^8
7	HU 3665 6361	Burn	0.20	0.12	299	4	1.2×10^7
8	HU 3657 6371	Stream	0.40	0.04	not measured	23	Not determined

- Not applicable *Outflow volume recorded

Due to the rain that fell in the two days prior and first day of surveying, there was a large amount of land surface runoff, particularly on the eastern shoreline by Grobs Ness. These were unable to be measured or sampled. Surface water runoff from the eastern shore is unlikely to have created a contamination risk to the mussel fishery at Linga. However, it is expected that land runoff would also occur on the island of Linga, with rainwater draining directly to the mussel lines close to the shoreline.

Four freshwater discharges from pipes were observed on the western shoreline close to South Town, adjacent to the Buddascord site. These freshwater inputs were unable to be measured due to access difficulties and/or insufficient flow at the time of the shoreline survey. One large black pipe seen on the western shoreline was measured and the daily flow was calculated at 82 m^3/d. No sample was possible.

In total seven major watercourses were measured and sampled during the shoreline survey, with the majority located on the western shoreline adjacent to the Buddascord site. The watercourses sampled were found only to be lightly - moderately contaminated, with loadings varying between 1.2×10^7 and 7.1×10^9 *E. coli*/day. Samples contained *E. coli* levels between 16 and 800 *E. coli cfu*/100 ml, with flow varying significantly between 143 and 4757 m^3/d.

Overall contamination entering the Greentaing site appears to be low, with only watercourse 4 close to the fishery with a loading of 1.3×10^9 *E. coli*/ day. The watercourse that had the largest estimated *E. coli* loading occurs north of Greentaing and may pose as a contamination risk to the north end of that fishery. The contamination sources in the vicinity of South Town will most directly impact at the Buddascord site. No watercourses were directly observed close to the Linga Site, and due to the low estimated loadings on the eastern shore at Grobs Ness, the only freshwater that would impact at this site would be direct runoff from the island.

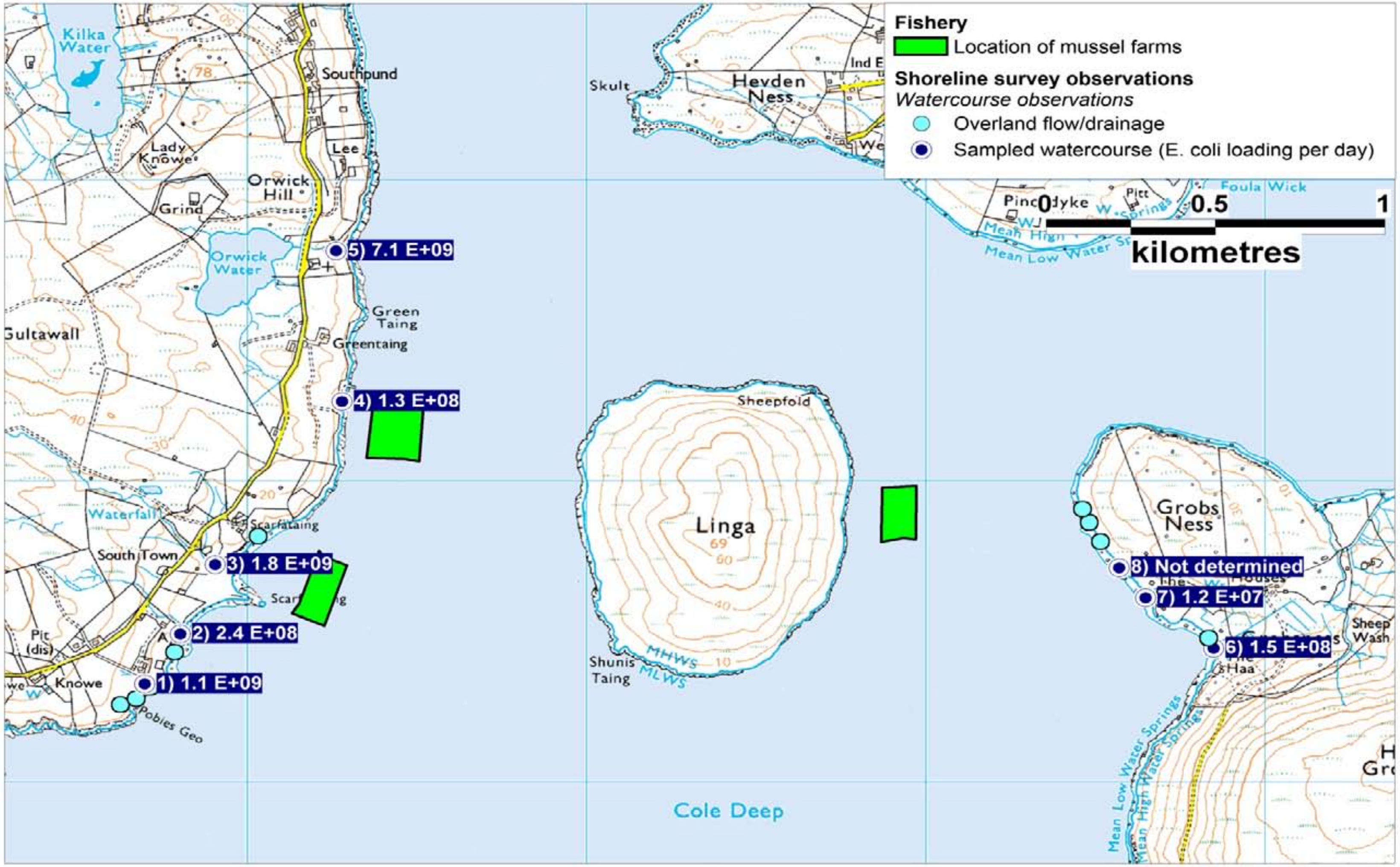

Figure 8.1 Map of watercourse loadings at Busta Voe Lee South

9. Meteorological data

The nearest weather station for which rainfall data was available is located at Lerwick, situated approximately 26 km to the south east of the production area. Rainfall data was available for January 2007 – August 2012. At the time of writing this report rainfall data for August 2012 onwards, had not been provided to Cefas. The nearest wind station is also situated in Lerwick, located 26 km south east of the production area. Conditions may differ between this station and the fisheries due to the distances between them. However, this data is still shown as it can be useful in identifying seasonal variation in wind patterns.

Data for these stations was purchased from the Meteorological Office. Unless otherwise identified, the content of this section (e.g. graphs) is based on further analysis of this data undertaken by Cefas. This section aims to describe the local rain and wind patterns in the context of the bacterial quality of shellfish at Busta Voe Lee South.

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 (Mallin, et al. 2001, Lee and Morgan 2003). The box and whisker plots in Figures 9.1 and 9.2, present a summary of the distribution of individual daily rainfall values by year and by month. The grey box represents the middle 50% of the observations, with the median 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 *. Daily rainfall values were higher during the autumn and winter. Rainfall increased from August onward and was highest in January and February. Weather was drier from March to July. An extreme rainfall event was seen in August 2012.

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

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

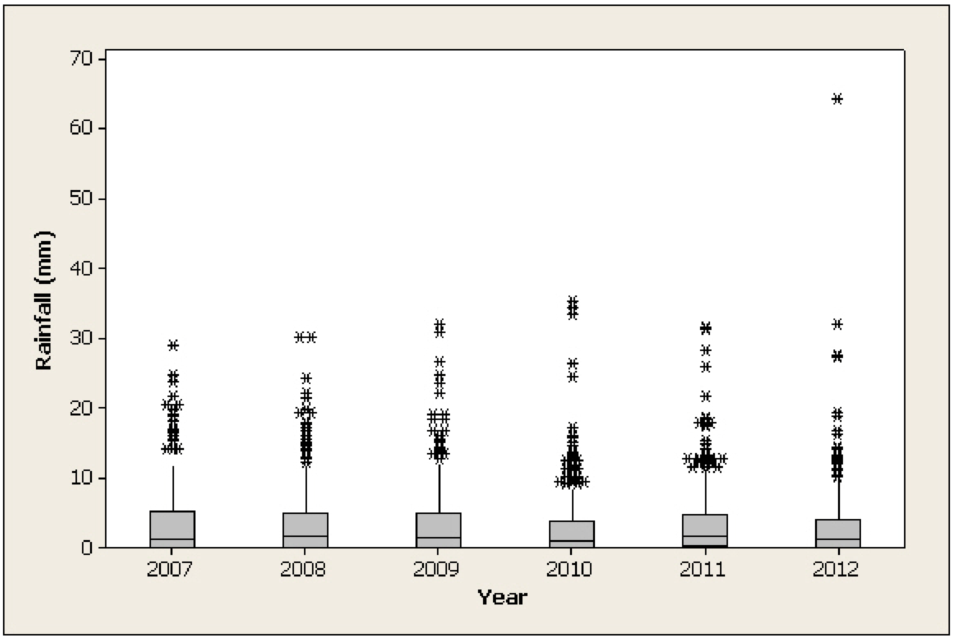

Figure 9.1 Box plot of daily rainfall values by year at Lerwick (2007 – 2011)

Daily rainfall values varied from year to year, with 2010 being the driest year. The wettest year was 2009. Outlier rainfall values, up to approximately 35 mm were similar across the years except for one extreme event in 2012.

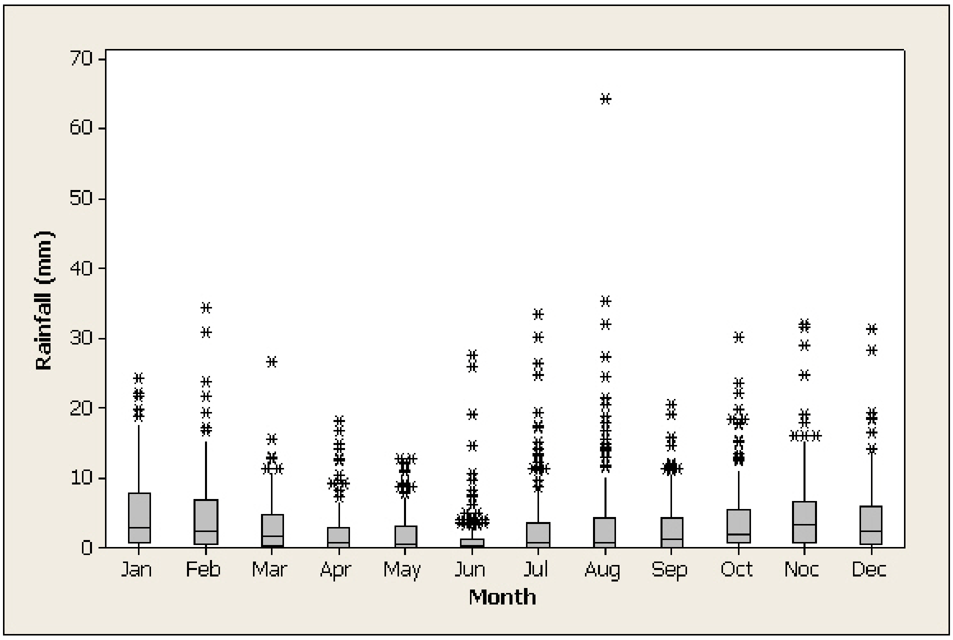

Figure 9.2 Box plot of daily rainfall values by month at Lerwick (2007 – 2012)

Daily rainfall values were higher during the autumn and winter. Rainfall increased from August onward and was highest in January and February. Weather was drier from March to September, though one extreme rainfall even was recorded in August 2012.

For the period considered here (2007-2012) 44% of days received daily rainfall of less than 1 mm and 9% of days received rainfall of over 10 mm. It is therefore expected than 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 land when greater numbers of livestock are present.

9.2 Wind

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

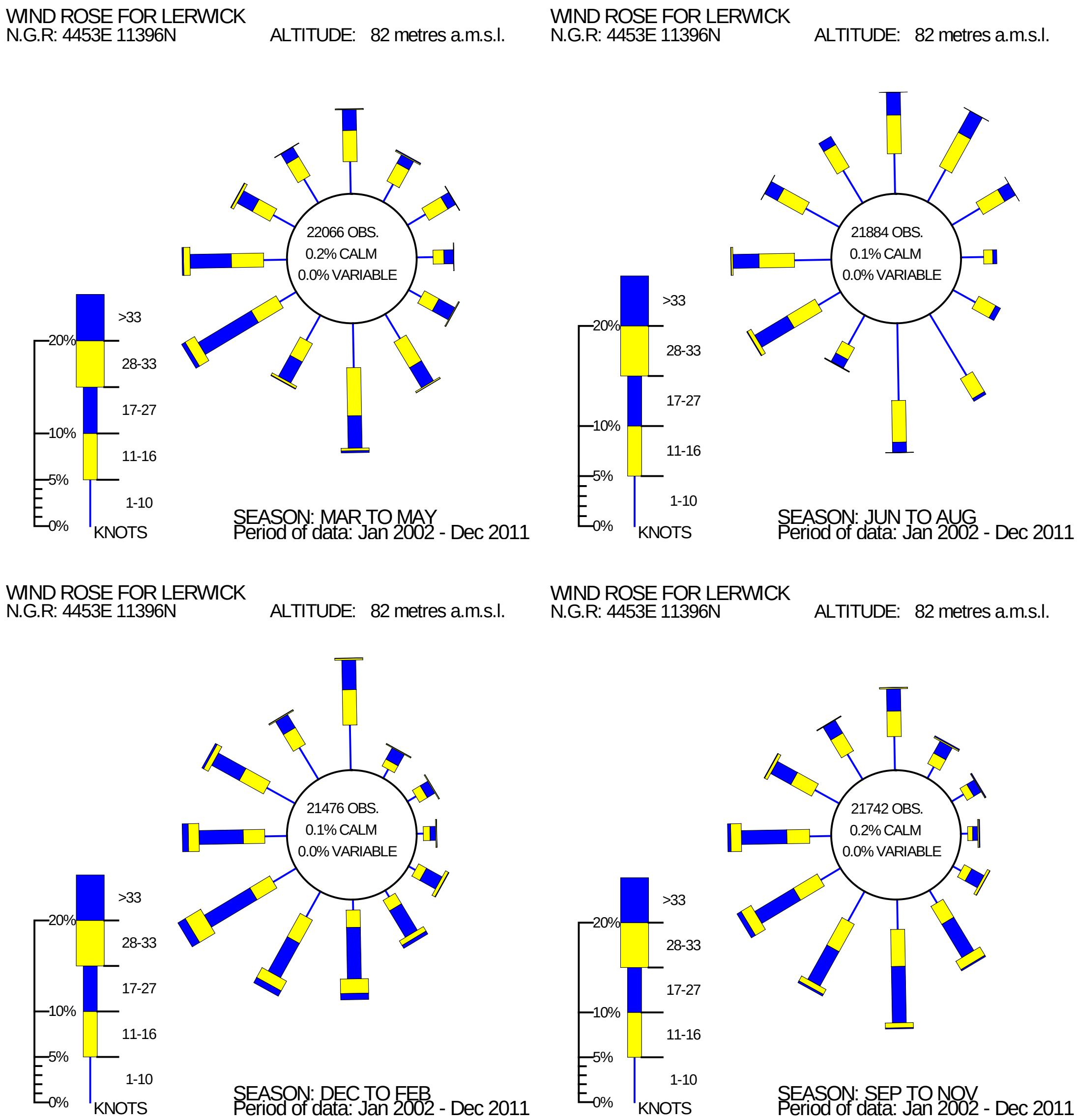

Figure 9.3 Seasonal wind roses for Lerwick

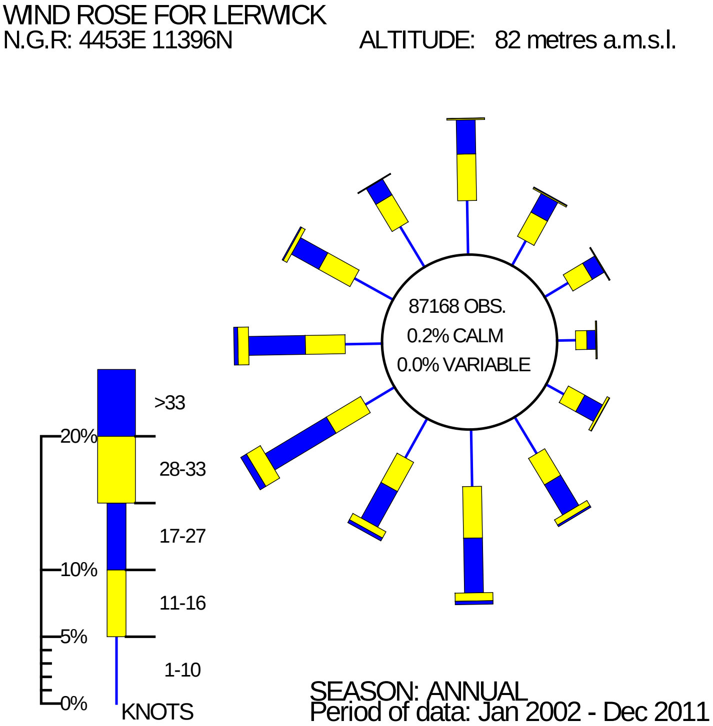

Figure 9.4 Annual wind rose for Lerwick

Overall the annual wind direction showed that wind was stronger when coming from the west than the east, and winds from the southerly direction were stronger than those from the north. Predominant winds were from the SW. Winds changed from NNE in the summer months to SW in the winter months and winds were much stronger in the winter months than in the summer months.

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

10. Classification Information

The area has been classified for mussel production since 2007. Currently the area is classified as A year round. Historically the classification has progressed from A/B to full A classification. The site was unclassified from April 2007 to March 2008 due to a lack of submitted samples.

The classification history since 2007 is presented in Table 10.1.

Table 10.1 Busta Voe Lee; South (common mussel)

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

The site has been classified as A year-round since 2010.

11. Historical *E. coli* Data

11.1 Validation of historical data

Results for all samples assigned against the Busta Voe Lee South production area for the period 01/01/2007 to 03/01/2013 were extracted from the FSAS database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. The data was extracted from the database on 03/01/2013. All *E. coli* results were reported as most probable number (MPN) per 100 g of shellfish flesh and intravalvular fluid. No results were recorded from the Buddascord site.

Three samples from Greentaing were recorded in the database as 'rejected' and were deleted. One result entry was a replicate and therefore also deleted. Fifty samples were collected and delivered to the laboratory within the 48 hr limit, and all samples had box temperatures < 8^{o}C. Twenty-two samples had an *E. coli* level of < 20, so were assigned nominal values of 10 *E. coli MPN*/100 g for the purposes of graphical representation and statistical analysis. All samples recorded within the production area.

One sample (CEFAS_2610) from Linga was recorded in the database as 'rejected' and was deleted. The remaining 39 samples were collected and delivered to the laboratory within the 48 hr limit, and all samples had a box temperature < 8^{o}C. Nineteen samples had an *E. coli* level of < 20, so were assigned nominal values of 10 *E. coli MPN*/100 g for the purposes of graphical representation and statistical analysis. All samples recorded within the production area.

11.2 Summary of microbiological results

Table 11.1 Summary of historical sampling and results

Sampling Summary			
Production area	Busta Voe Lee South		
Site	Buddascord	Greentaing	Linga
Species	common mussels		
SIN	SI-328-936-08	SI-328-767-08	SI-328-411-08
Location	-	Various	Various
Total no of samples	0	50	39
No. 2007	-	6	6
No. 2008	-	9	9
No. 2009	-	9	10
No. 2010	-	10	8
No. 2011	-	7	4
No. 2012	-	9	2
Results Summary			
Minimum	-	< 20	< 20
Maximum	-	2200	500
Median	-	20	19
Geometric mean	-	32	25
90 percentile	-	320	170
95 percentile	-	490	230
No. exceeding 230/100g	-	5 (10%)	1 (3%)
No. exceeding 1000/100g	-	1 (2%)	0
No. exceeding 4600/100g	-	0	0
No. exceeding 18000/100g	-	0	0

A greater percentage of samples exceeded 230 *E. coli* MPN/100 g at Greentaing than at Linga, and no samples exceeded 1000 *E. coli MPN*/100 g at Linga. Until 2010, sampling was evenly divided between areas.

11.3 Overall geographical pattern of results

Samples from both sites plotted close to one another, with samples from Greentaing plotting just offshore at Greentaing and samples from Linga plotting to the eastern side of the island. Reported sampling locations are presented in Figure 11.1.

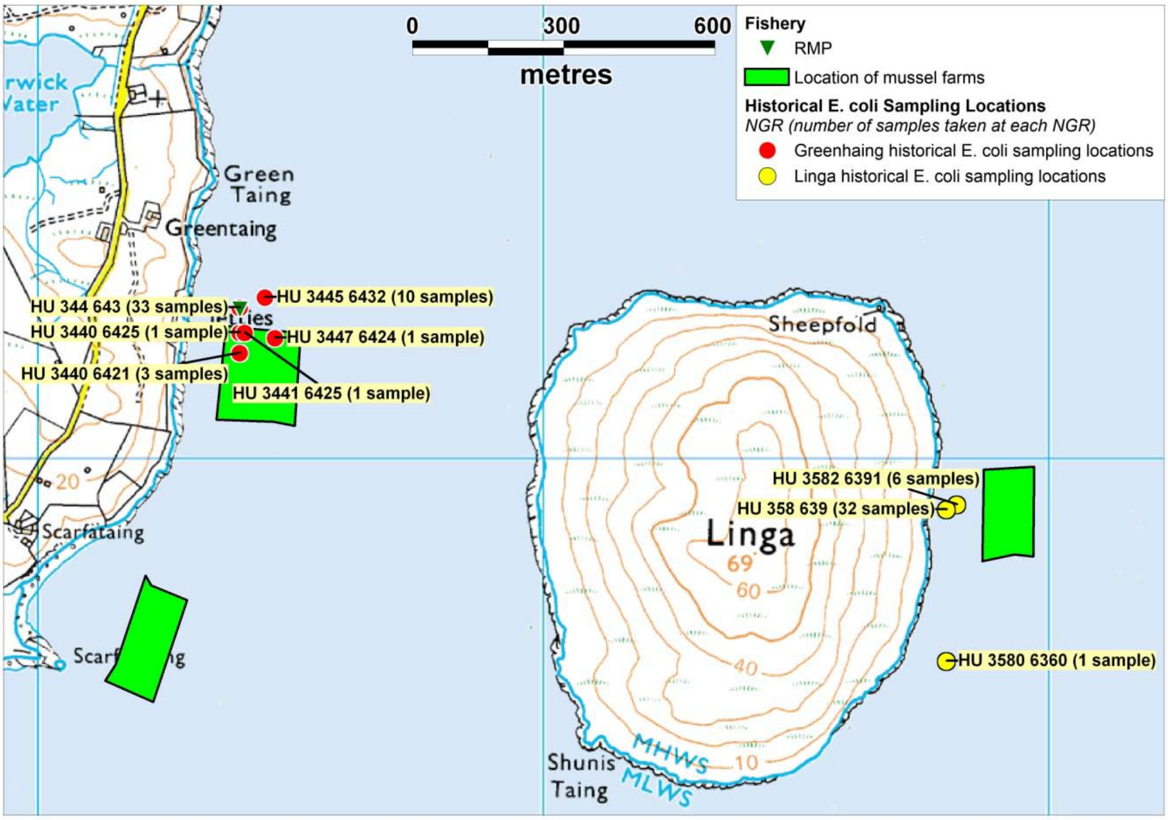

Figure 11.1 Map of reported sampling locations for Greentaing and Linga at Busta Voe Lee South

Reported sampling locations for Greentaing were within a 1 km tolerance of the nominal RMP. There were six sampling locations reported for the sampling period 01/01/2007 – 31/12/2012, with 10 samples taken at HU 3445 6432. Sampling at Linga corresponds to three locations, with the sample at HU 3580 6360 approximately 1 km south of the other two samples at Linga. A nominal RMP at [HU 340 6430] covers the whole Busta Voe Lee South production area, and is located just north of Greentaing.

For geographical evaluation, sampling results were split by location into three areas; Greentaing 1, Greentaing 2 and Linga 1. Geometric mean was calculated for results in each of the three locations, with results listed in Table 11.2 and mapped in Figure 11.2.

Table 11.2 *E. coli* results and geometric means by sampling location

Location	NGR	Easting	Northing	n	Geometric mean *E. coli*/100 g
Linga 1	HU 358 639	435800	1163900	38	25
Greentaing 1	HU 3445 6432	434450	1164320	10	21
Greentaing 2	HU 344 643	434400	1164300	34	36

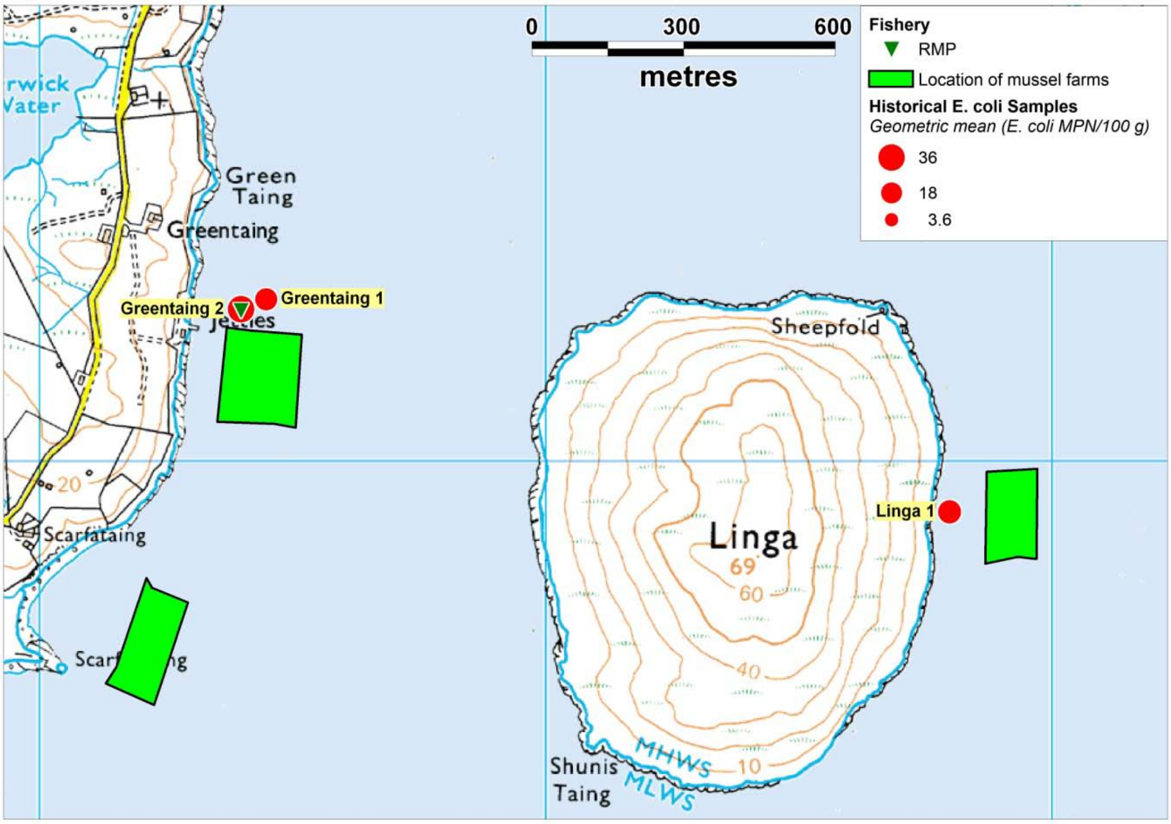

Figure 11.2 Map of geometric means of sampling locations for Greentaing and Linga at Busta Voe Lee South

The highest geometric mean *E. coli* was seen at the Greentaing 2 site.

For statistical evaluation a one-way ANOVA was conducted on *E. coli* results by sampling location, with results presented as a boxplot in Figure 11.3.

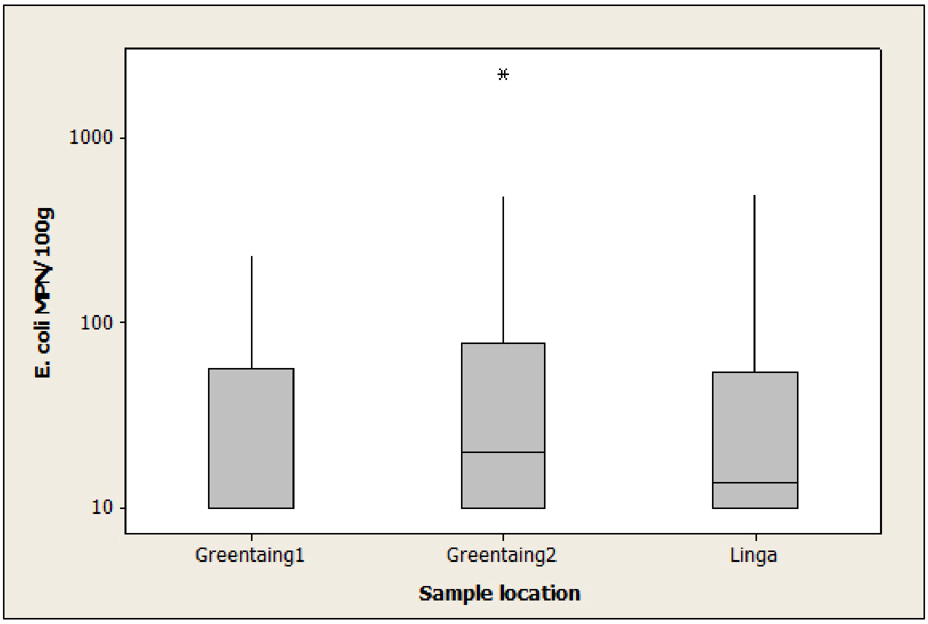

Figure 11.3 Boxplot of *E. coli* results by sample location

No significant difference was found between results by sampling location (one-way ANOVA, F 1.03, p = 0.363, Appendix 4).

11.4 Overall temporal pattern of results

Scatterplots of the common mussel *E. coli* results against dates for the individual sites are presented in Figures 11.4 and 11.5. The dataset is fitted with a lowess trend line. Lowess trendlines allow for locally weighted regression scatter plot smoothing. At each point in the dataset an estimated value is fitted to a subset of the data, using weighted least squares. The approach gives more weight to points near to the x-value where the estimate is being made and less weight to points further away. In terms of the monitoring data, this means that any point on the lowess line is influenced more by the data close to it (in time) and less by the data further away. The trend line helps to highlight any apparent underlying trends or cycles.

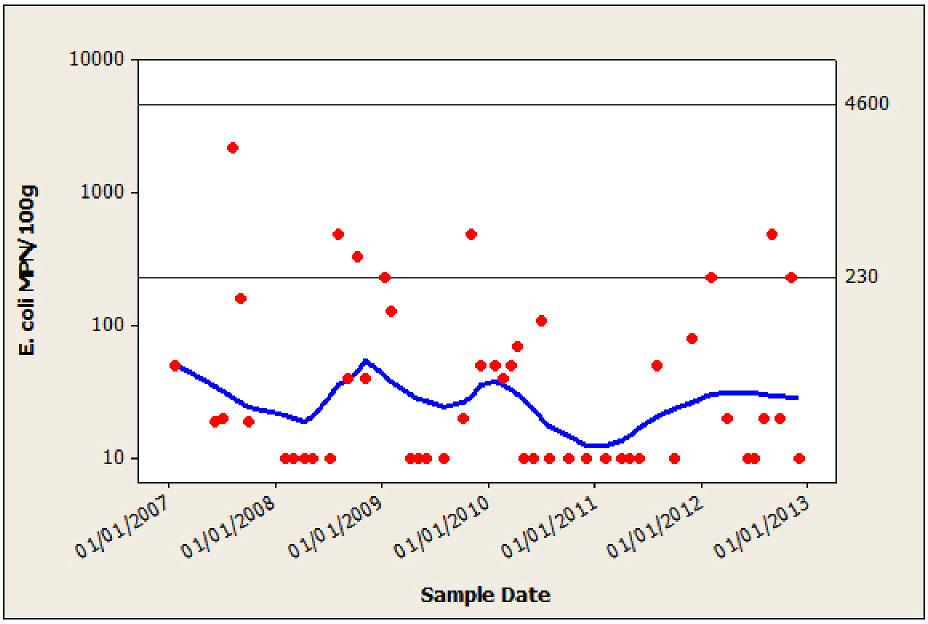

Figure 11.4 Greentaing *E. coli* results by date with a lowess line

Overall the level of contamination at Greentaing has not changed over the sampling period, illustrated by the lowess line in Figure 11.4. Within years there are times of higher and lower levels of contamination that do not coincide with annual or seasonal cycles. The majority of results are < 100 *E. coli MPN*/100 g, with many recorded at 10 *E. coli MPN*/100 g across the sampling period. There were several periods when results exceed 230 *E. coli MPN*/100 g in 2007, 2008 and 2012.

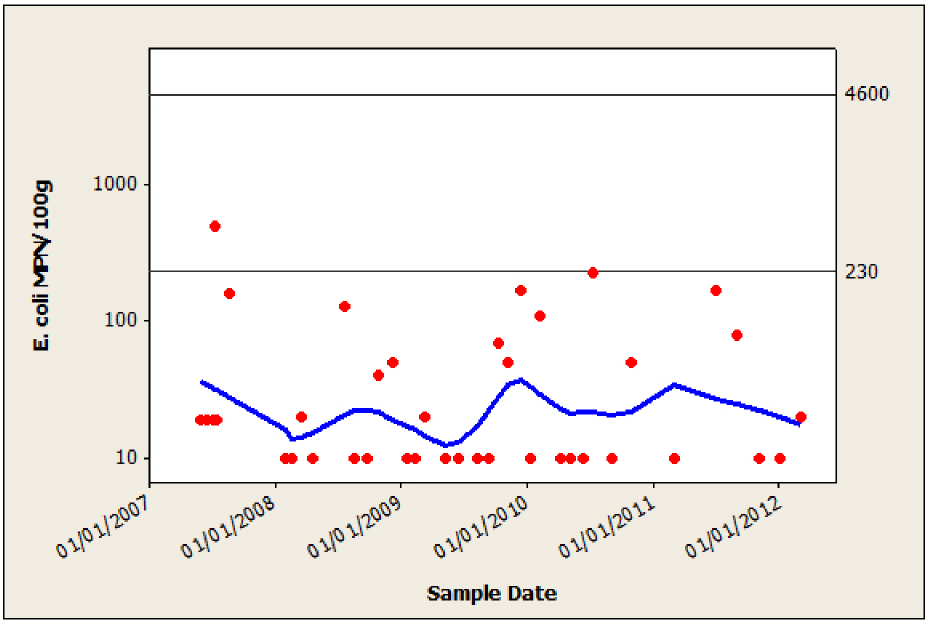

Figure 11.5 Linga *E. coli* results by date with a lowess line

Overall contamination levels at Linga have not changed over the sampling period, with times of higher and lower levels of contamination. These peaks in results do not coincide with annual or season cycles. The majority of results are < 100 *E. coli*

MPN/100 g, with many plotting at 10 *E. coli MPN*/100 g. One sample in 2010 was recorded at 230 *E. coli MPN*/100 g and one sample in 2007 > 230 *E. coli MPN*/100 g.

11.5 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns in human distribution. All of these can affect levels of microbial contamination, causing seasonal patterns in results. Figures 11.6 and 11.7 presents *E. coli* results by month for Greentaing and Linga respectively, overlaid with a lowess line to highlight trends. Points in these graphs have been 'jittered', or moved a small amount, so that as many of the points as possible are visible in the graph (jitter factors: x=0.1, y=0.001). However, some points may still represent more than one result.

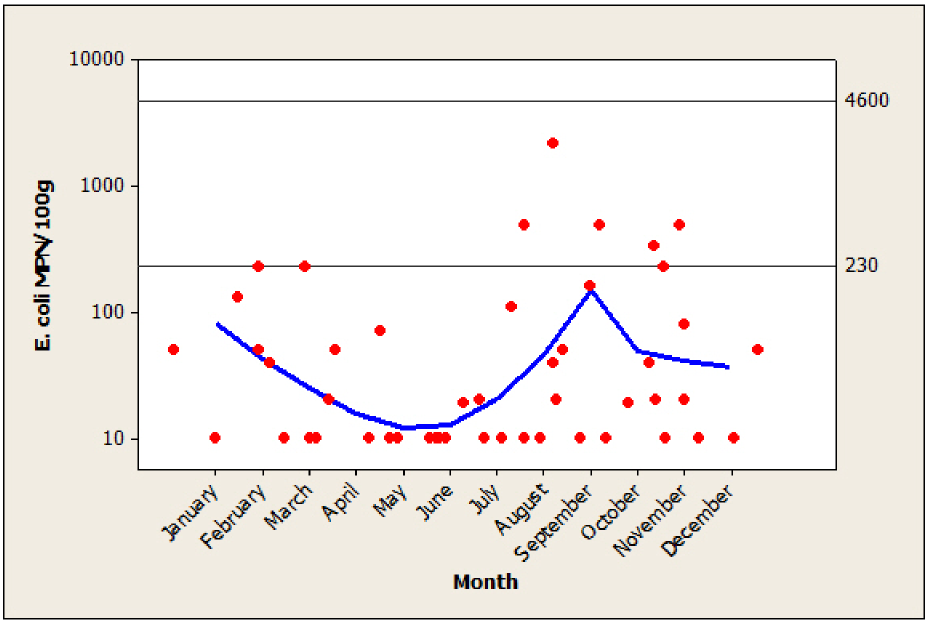

Figure 11.6 Scatterplot of Greentaing *E. coli* results by month, fitted with a lowess line

The trend line on the Greentaing scatterplot shows a sharp peak in September and then shows a slow reduction towards May, despite the highest result occurring in August. The trend shown by the lowess line can partly be described by the differences seen in sampling across months, with one sample taken in May (the trough of the trendline) and the most at five taken in August. The lowess line peak is not seen in August due to the majority of its sample results returned < 100 *E. coli MPN*/100 g.

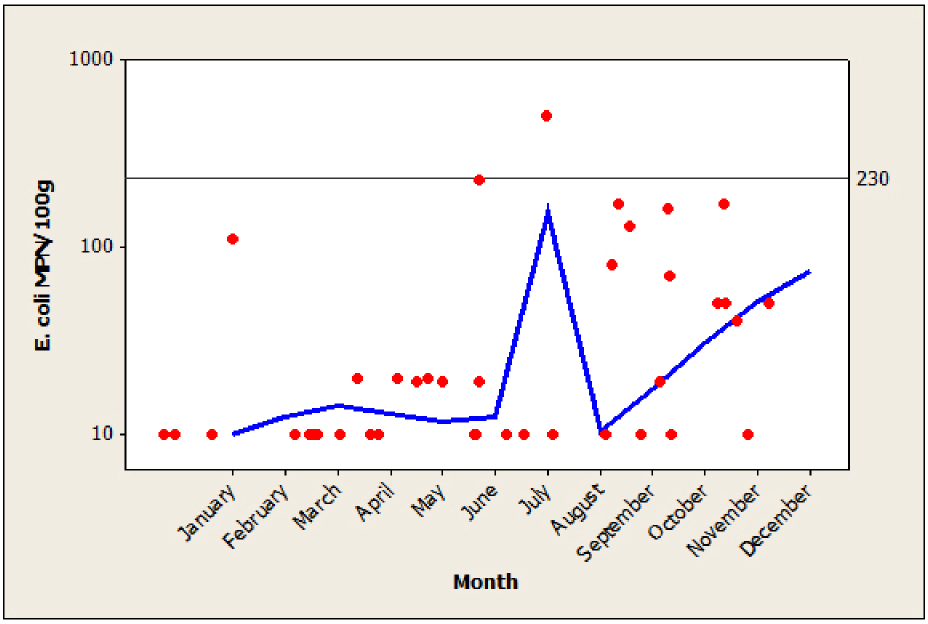

Figure 11.7 Scatterplot of Linga *E. coli* results by month, fitted with a lowess line

A sharp peak in sampling results from Linga in July in illustrated by the lowess line in Figure 11.7. This trend is resultant of differences in sampling across months, with five samples taken in July, compare to only one or two in all other months. This trend was also caused by the majority of results in July exceeding 100 *E. coli MPN*/100 g, compared to the majority of results between January – June being < 100 *E. coli MPN*/100 g. Sampling results between August and December showed an increase in higher results.

For statistical evaluation, seasons were split into spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). Figure 11.8 and 11.9 present boxplots of *E. coli* results by season for Greentaing and Linga sites respectively.

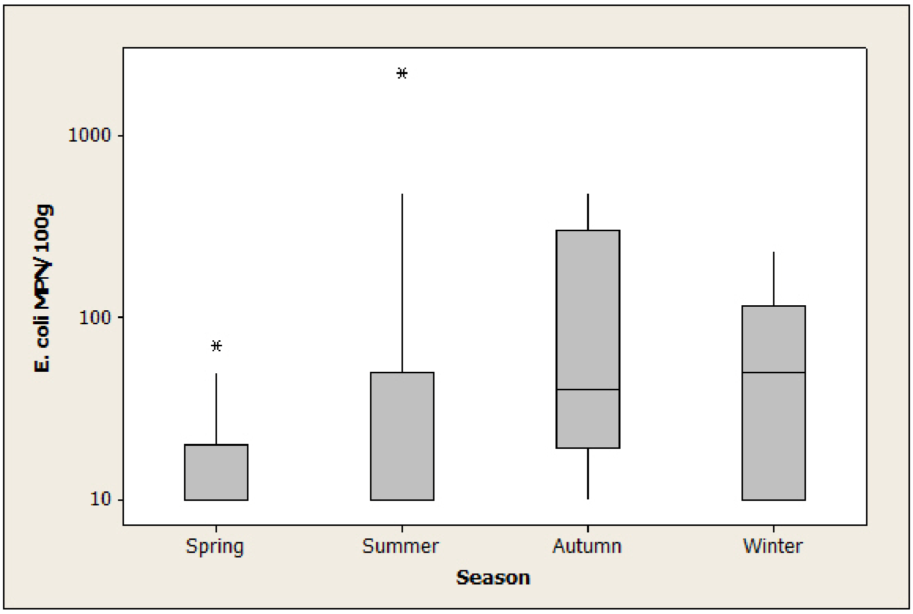

Figure 11.8 Boxplot of Greentaing *E. coli* results by season

No significant difference was found between Greentaing results by season (one-way ANOVA, F 2.39, p = 0.081).

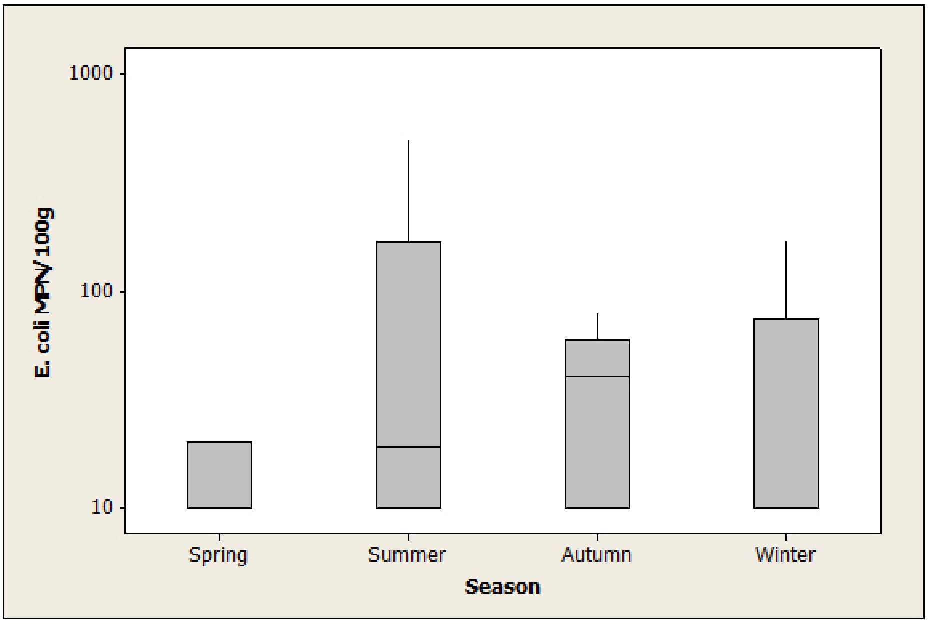

Figure 11.9 Boxplot of Linga *E. coli* results by season

No significant difference was found between Linga results by season (one-way ANOVA, F 1.82, p = 0.161).

11.6 Analysis of results against environmental factors

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

11.6.1 Analysis of results by recent rainfall

The nearest weather station with available rainfall data was at Lerwick, approximately 26 km SE of the Busta Voe Lee South production area. Rainfall data was purchased from the Meteorological Office for the period of 01/01/2007-30/11/2012 (total daily rainfall in mm) for both Greentaing and Linga. Data was extracted from this for common mussel samples from both sites. Rainfall data was unavailable for the last four samples in 2012 from Greentaing

Two-day rainfall

Figures 11.10 and 11.11 present scatterplots of individual *E. coli* results against total rainfall recorded on the two days prior to sampling for sites Greentaing and Linga respectively.

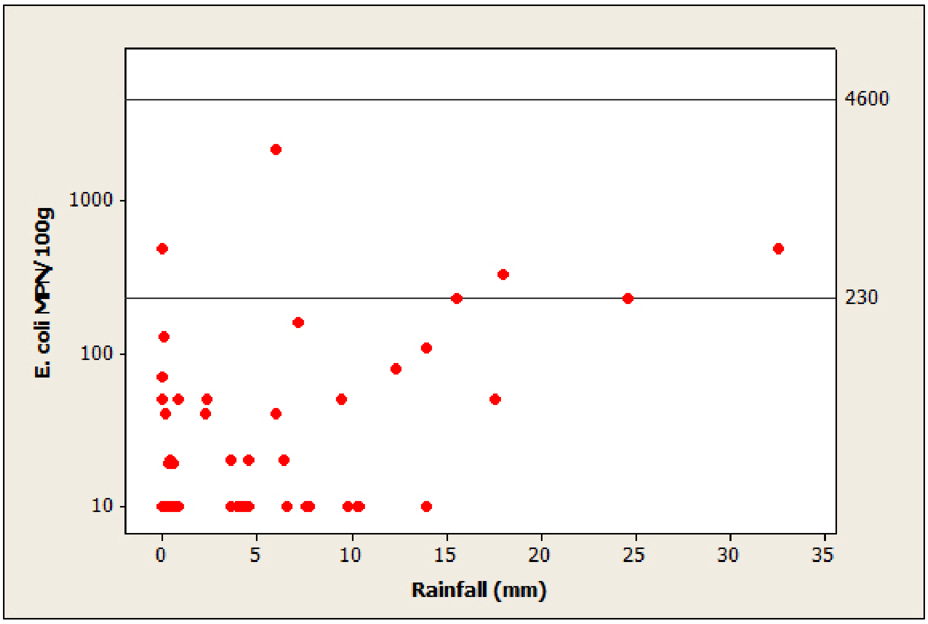

Figure 11.10 Scatterplot of Greentaing *E. coli* results against rainfall in the previous two days

No significant correlation was found between the Greentaing common mussel results and the previous two day rainfall (Spearman's rank correlation r = 0.185, p = 0.218).

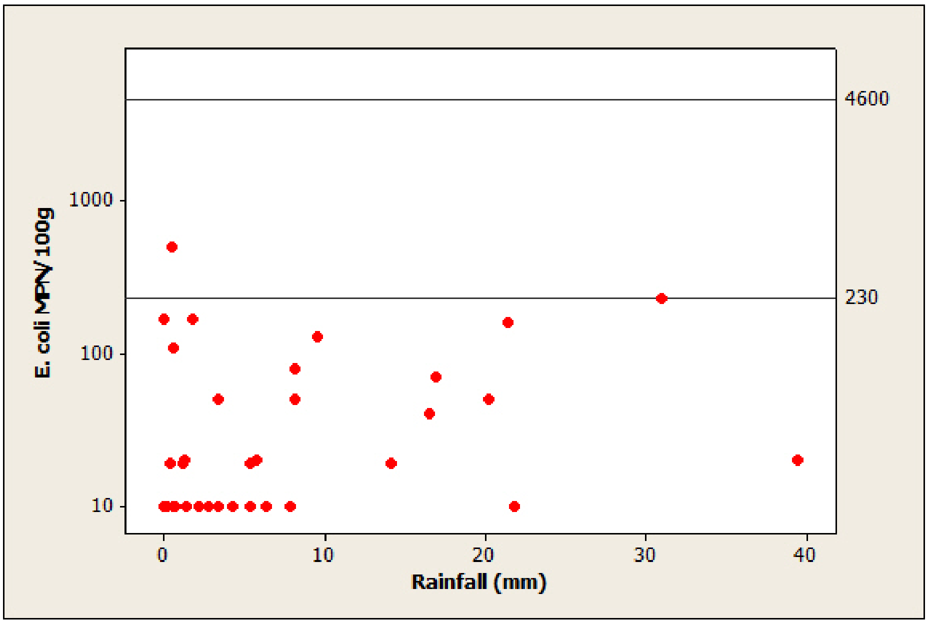

Figure 11.11 Scatterplot of Linga *E. coli* results against rainfall in the previous two days

A significant correlation was found between the Linga common mussel results and the previous two day rainfall (Spearman's rank correlation r = 0.390, p = 0.014). The majority of very low *E. coli* results correlated with very low rainfall levels of < 10 mm.

Seven-day rainfall

The effects of heavy rainfall may take differing amounts of time to be reflected in shellfish sample results in different system, the relationship between rainfall in the previous seven days and sample results was investigated in an identical manner to the above. Figures 11.12 and 11.13 present scatterplots of common mussel *E. coli* results against total rainfall recorded for the seven days prior to sampling for sites Greentaing and Linga respectively.

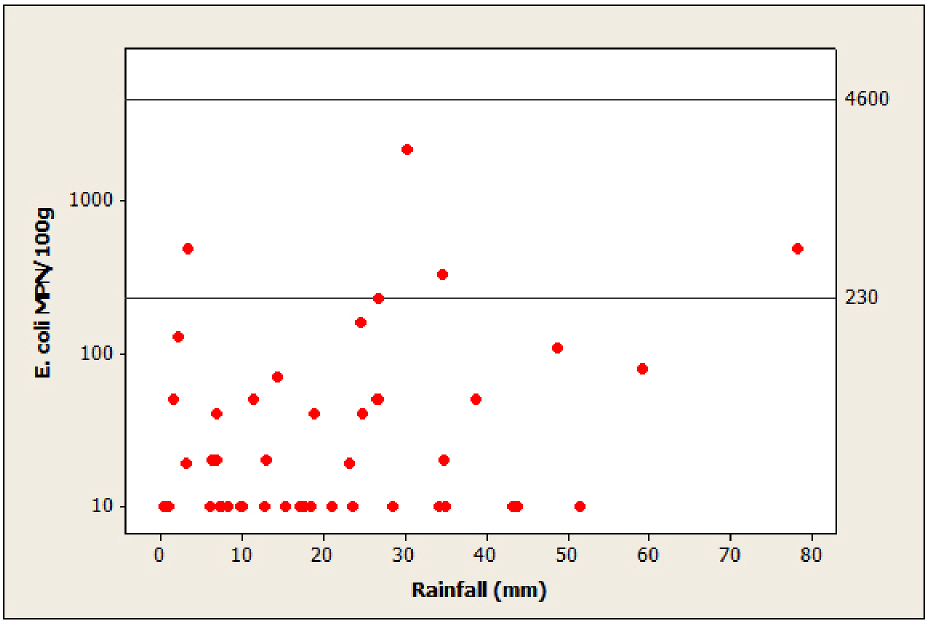

Figure 11.12 Scatterplot of Greentaing *E. coli* results against rainfall in the previous seven days

No significant correlation was found between the Greentaing common mussel results and the previous seven day rainfall (Spearman's rank correlation r = 0.198, p = 0.186).

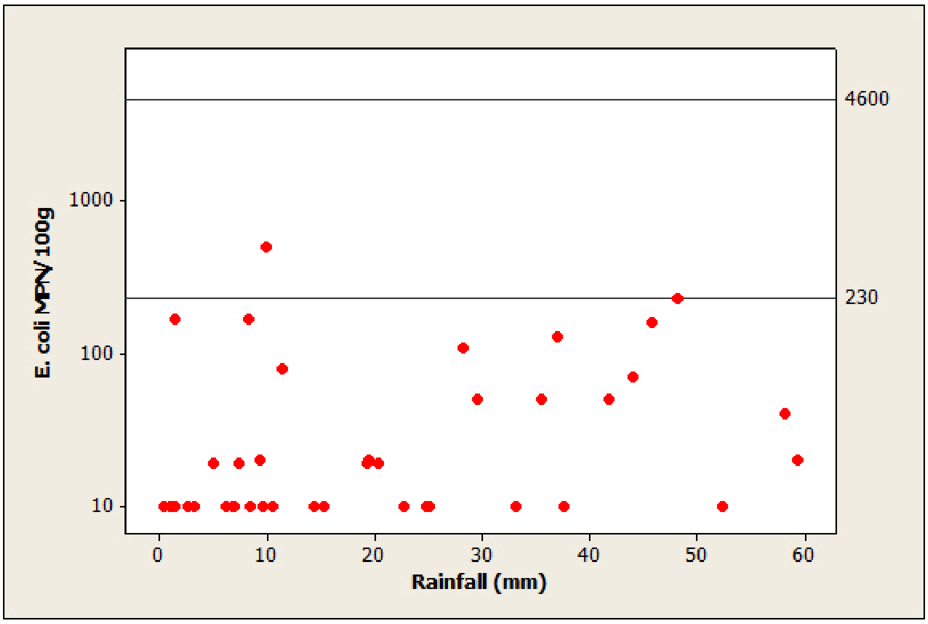

Figure 11.13 Scatterplot of Linga *E. coli* results against rainfall in the previous seven days

A significant correlation was found between the Linga common mussel results and the previous seven day rainfall (Spearman's rank correlation r = 0.352, p = 0.028). The majority of very low *E. coli* results correlated with low rainfall levels < 11 mm.

11.6.2 Analysis of results by tidal height

11.6.2.1 Tidal state spring/neap

Spring tides are large tides that occur fortnightly and are influenced by the state of the lunar cycle. They reach above the mean high water mark and therefore increase circulation and particle transport distances from potential contamination sources on the shoreline. The largest Spring tides occur approximately two days after the full moon about 45^o, then decreases to the smallest neap tides at about 225^o, before increasing back to spring tides. Polar plots are presented in Figures 11.14 and 11.15 showing *E. coli* results against the lunar cycle**.** It should be noted local meteorological conditions (e.g. wind strength and direction) can also influence tide height, but is not taken into account in this section.

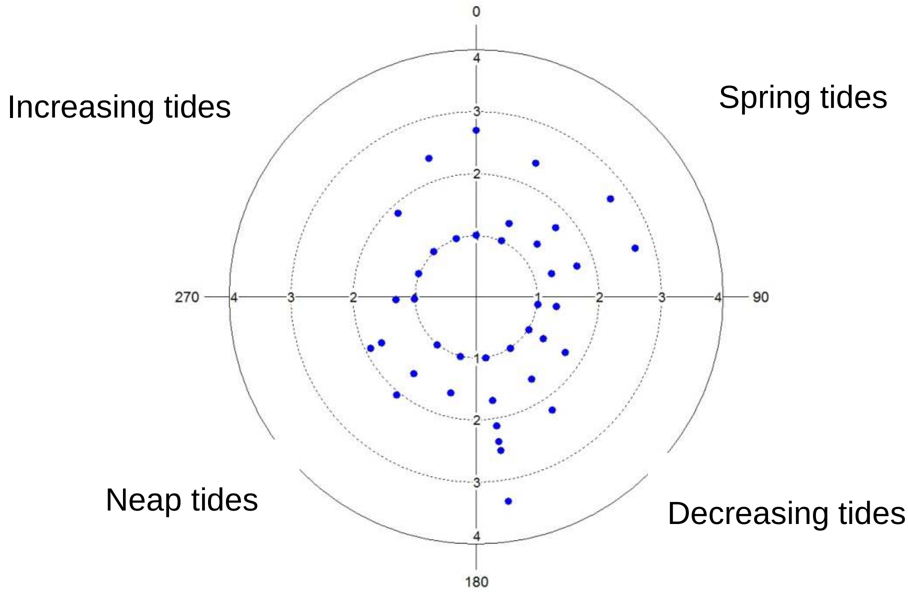

Figure 11.14 Polar plots of Greentaing Log_{10} *E. coli* results on the spring/neap tidal cycle

No significant correlation was found between Greentaing common mussel log_{10} *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r = 0.178, p = 0.224).

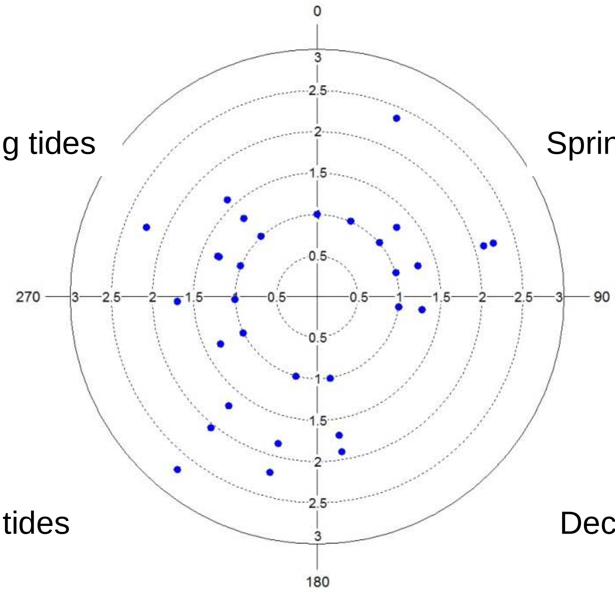

Figure 11.15 Polar plots of Linga Log_{10} *E. coli* results on the spring/neap tidal cycle

No significant correlation was found between Linga common mussel log_{10} *E. coli* results and the spring/neap tidal cycle (circular-linear correlation $r = 0.251$, $p = 0.103$).

11.6.2.2 Tidal state by high/low water

Tidal state (high/low tide) changes the direction and strength of water flow around production areas. Depending on the location of contamination sources, tidal state may cause marked changes in water quality near the vicinity of the farms. Shellfish species response time to *E. coli* levels can vary from within an hour to a few hours. High and low water data from Lerwick was extracted from POLTIPS-3 on 03/01/2013. This site was the closest to the production area and it is assumed that tidal flow will be very similar between sites. Polar plots in Figures 11.16 and 11.17 present *E. coli* results against lunar tidal cycle, where high water is at 0^o and low water at 180^o.

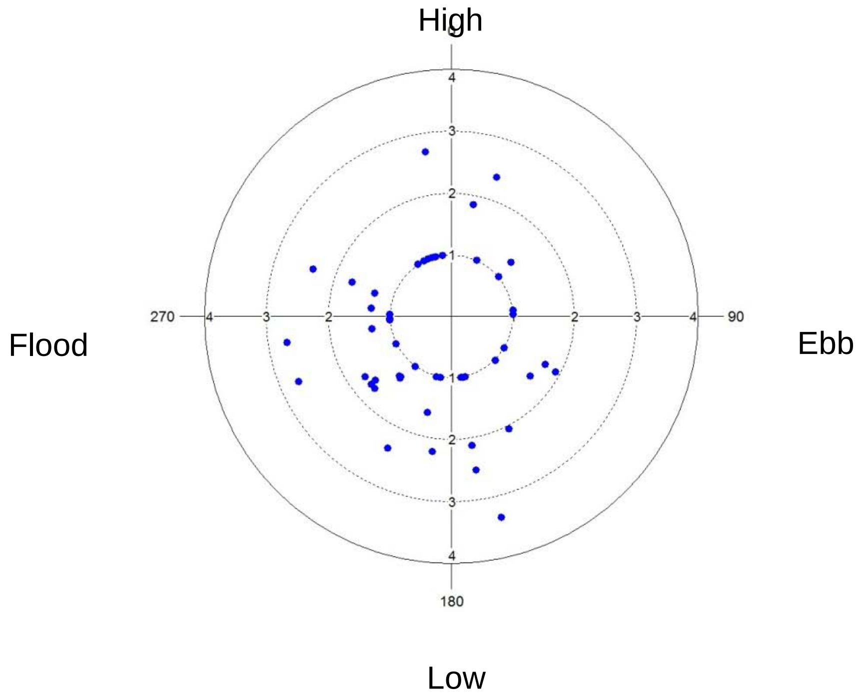

Figure 11.16 Polar plots of Greentaing $\log_{10}$ *E. coli* results on the high/low tidal cycle

No significant correlation was found between Greentaing common mussel $\log_{10}$ *E. coli* results and the high/low tidal cycle (circular-linear correlation $r = 0.153$, $p = 0.333$).

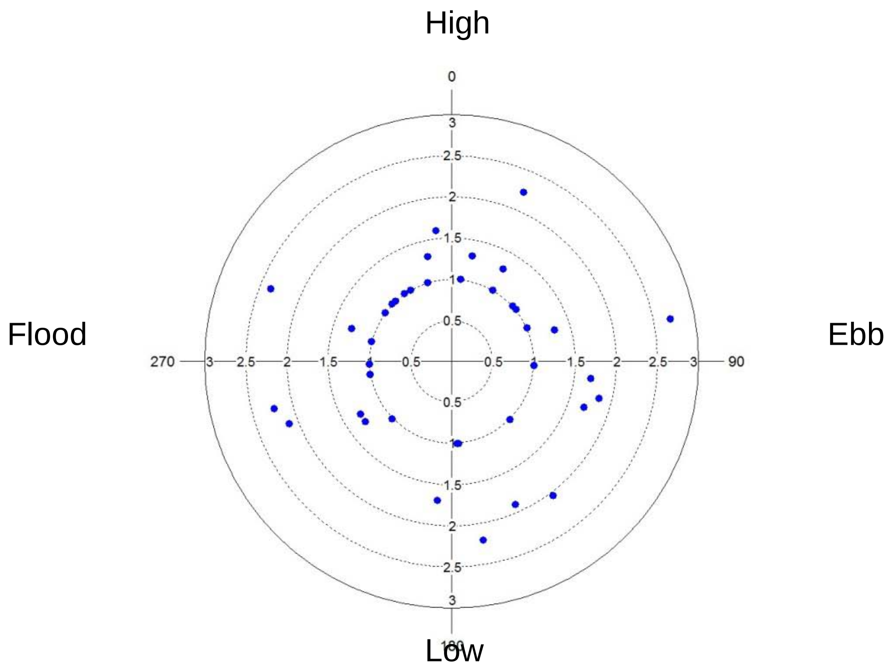

Figure 11.17 Polar plots of Linga $\log_{10}$ *E. coli* results on the high/low tidal cycle

A significant correlation was found between Linga common mussel $\log_{10}$ *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.29, p = 0.048). The majority of lower results were taken during a flood tide.

11.6.3 Analysis of results by water temperature

Water temperature can affect survival time of bacteria in seawater (Burkhardt et al, 2000). It can also affect the feeding and elimination rates in shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. Water temperature is obviously closely related to season. Any correlation between temperatures and *E. coli* levels in shellfish flesh may therefore not be directly attributable to temperature, but to the other factors e.g. seasonal differences in livestock grazing patterns. Figures11.18 and 11.19 show scatterplots of *E. coli* results against water temperature for Greentaing and Linga respectively. Water temperature was recorded for 44 out of 50 samples from Greentaing and 33 out of 39 samples from Linga. Points in these graphs have been 'jittered', or moved a small amount, so that as many of the points as possible are visible in the graph (jitter factors: x=0.02, y=0.001). However, some points may still represent more than one result.

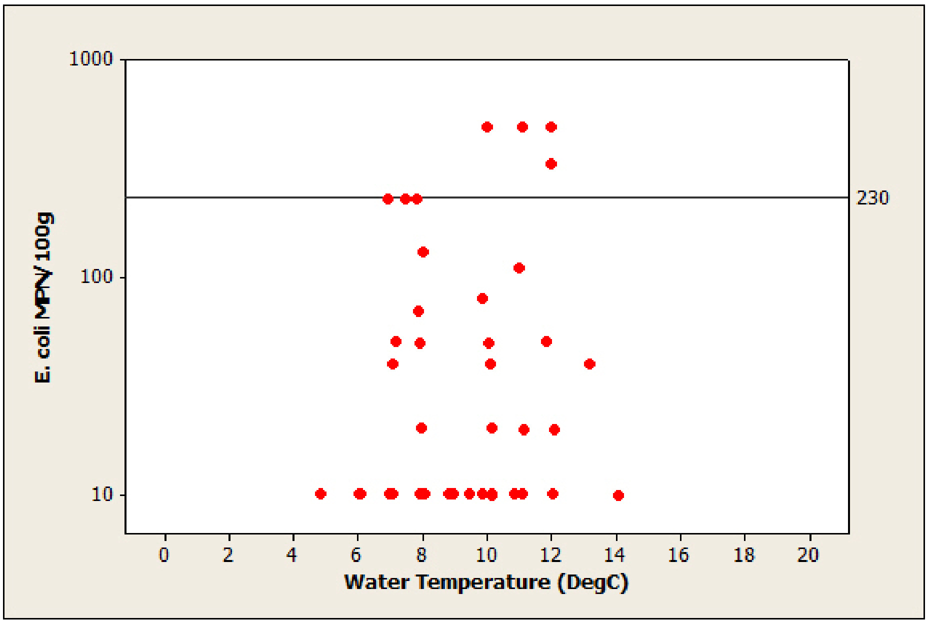

Figure 11.18 Scatterplot of Greentaing *E. coli* results against water temperature

No significant correlation was found between Greentaing common mussel *E. coli* results and water temperature (Spearman's rank correlation r = 0.193, p = 0.210).

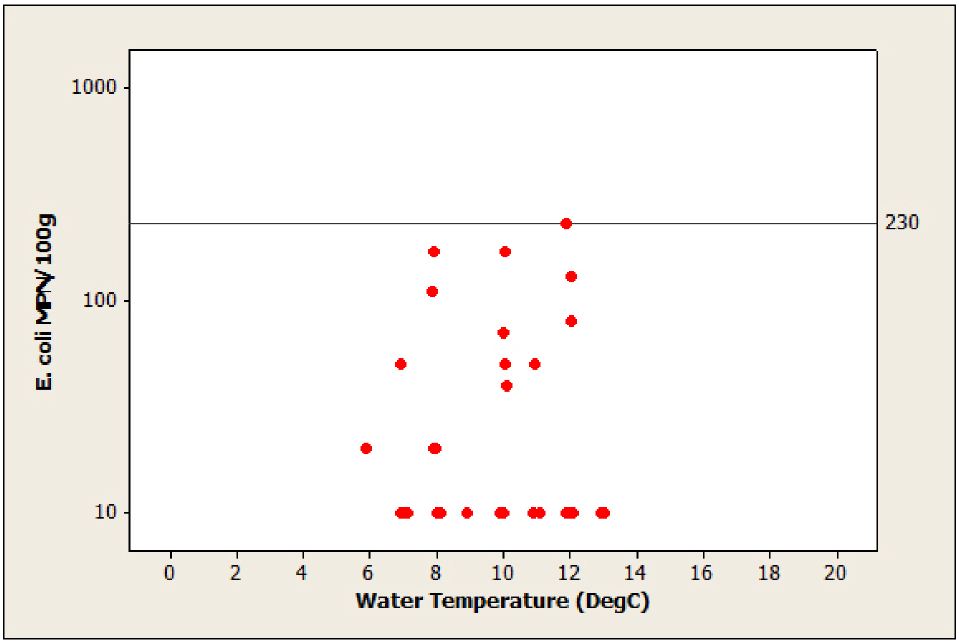

Figure 11.19 Scatterplot of Linga *E. coli* results against water temperature.

No significant correlation was found between Linga common mussel *E. coli* results and water temperature (Spearman's rank correlation r = 0.100, p = 0.578).

11.6.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence and hence freshwater borne contamination at a site. Figures 11.20 and 11.21 present scatterplots of *E. coli* results against salinity for Greentaing and Linga respectively. Salinity was recorded for 42 of the 50 samples from Greentaing and for all 39 samples taken at Linga. Points in these graphs have been 'jittered', or moved a small amount, so that as many of the points as possible are visible in the graph (jitter factors: x=0.1, y=0.001). However, some points may still represent more than one result.

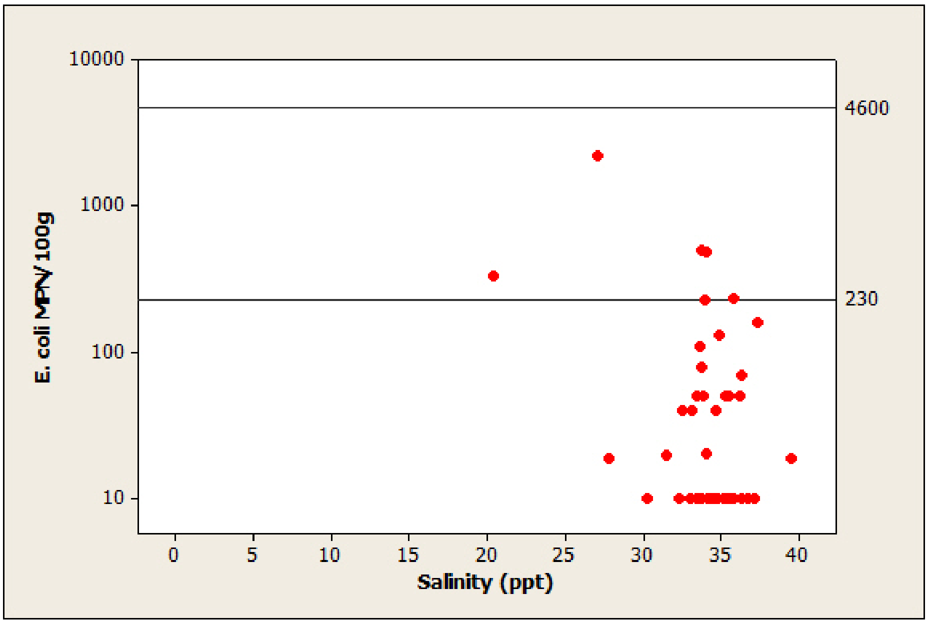

Figure 11.20 Scatterplot of Greentaing *E. coli* results against salinity

A significant negative correlation was found between Greentaing common mussel *E. coli* results and salinity (Spearman's rank correlation r = -0.282, p = 0.070). The majority of *E. coli* results were attained from samples taken between 32 and 36 ppt, with highest *E. coli* results taken at salinities < 35 ppt.

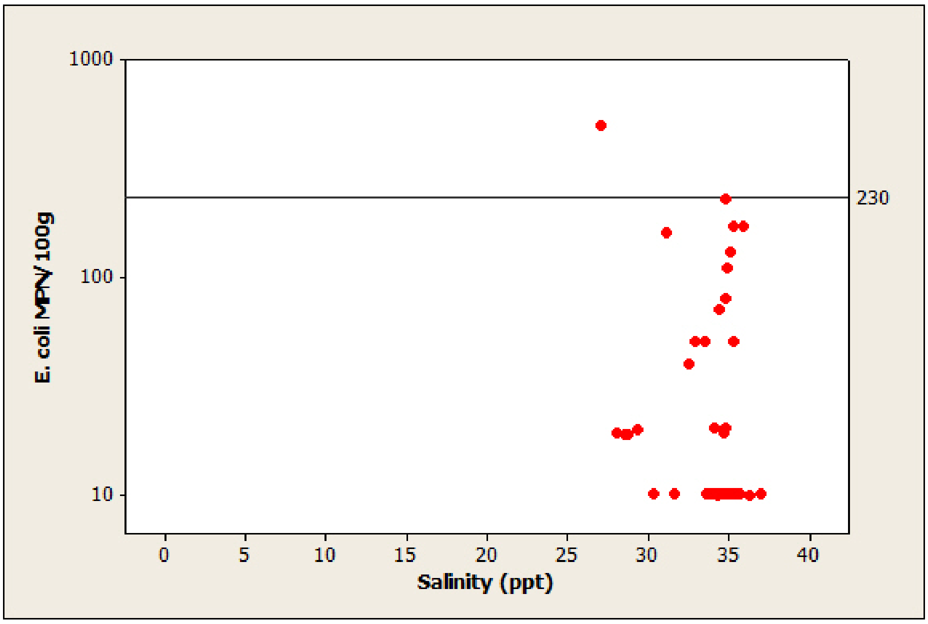

Figure 11.21 Scatterplot of Linga *E. coli* results against salinity

No significant correlation was found between Linga common mussel *E. coli* results and salinity (Spearman's rank correlation r = -0.079, p = 0.631).

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

In samples taken at Greentaing, five had results > 230 *E. coli MPN*/100 g. These are presented in Table 11.3.

Table 11.3 Historic Greentaing *E. coli* sampling results over 230 *E. coli MPN*/100 g

Collection Date	*E. coli* (MPN/100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (^oC)	Salinity (ppt)	Tidal state (spring/neap)	Tidal State (high/low)
06/08/2007	2200	HU 344 643	6.0	30.4	-	28.6	Decreasing	Ebb
04/08/2008	490	HU 344 643	0.0	3.3	12	34.6	Spring	Low
06/10/2008	330	HU 344 643	18.0	34.7	12	20.2	Decreasing	Ebb
02/11/2009	490	HU 344 643	32.6	78.3	10	33.7	Spring	Flood
03/09/2012	490	HU 3440 6425	-	-	11	-	Spring	Low

(-) Data not available.

Elevated *E. coli* sample results reported for the Greentaing site varied between 330-2200 *E. coli MPN*/100 g. Samples were recorded as being taken from approximately the same location, close to the nominal RMP for years 2007, 2008, 2009 and 2012 (although four of the locations were only recorded to 100 m accuracy). Two were taken in August, with one each in September, October and November (autumn). The sample with the largest *E. coli* result was taken in August 2007 (2200 *E. coli MPN*/100 g) and was considerably higher than the other results. Rainfall was recorded for four out of the five samples. For the two and seven days prior to sampling varying amounts of rainfall were recorded suggesting that rainfall did not have a significant influence on the elevated *E. coli* results. Water temperature was recorded for four out of the five samples, and varied slightly between 10-12^oC. Salinity was recorded for four out of the five results, and varied between 20.2-34.6 ppt. All samples were either taken on a spring or decreasing tidal cycle, with tidal state varying between ebb, low and flood.

In samples taken at Linga, only one had a result > 230 *E. coli MPN*/100 g. This is presented in Table 11.4.

Table 11.4 Historic Linga *E. coli* sampling results over 230 *E. coli MPN*/100 g

Collection Date	*E. coli* (MPN/100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (^oC)	Salinity (ppt)	Tidal state (spring/neap)	Tidal State (high/low)
09/07/2007	500	HU 358 639	0.5	9.9	-	27.6	Neap	High

(-) Data not available.

Only one sample, taken in July (2007) had a result > 230 *E. coli MPN*/100 g and therefore comparisons are not possible. For this sample, rainfall over the previous two and seven days prior to sampling was low at 0.5 mm and 9.9 mm respectively. Salinity, at 27.6 ppt, was slightly lower than full strength seawater,. This sample was taken on a neap tide, at a time of high water.

11.8 Summary and conclusions

Greentaing

All samples plot within less than a 1 km radius of the nominal RMP. Only 10% of samples taken during the sampling period had results > 230 *E. coli MPN*/100 g, with the greatest result at 2200 *E. coli MPN*/100 g. Results > 230 *E. coli MPN*/100 g were taken in 2007, 2008, 2009 and 2012 in the months from August to November. No samples were taken in January or December. No significant seasonal effect was found.

No statistically significant correlation was found between *E. coli* results and rainfall during two and seven days prior to sampling. No statistically significant correlation was found between water temperature and *E. coli* results. A statistically significant correlation was found between salinity and *E. coli* results with low salinities correlating with higher *E. coli* results. No statistically significant correlation was found between *E. coli* results and a spring/neap or high/low water tidal cycle.

Linga

The three sampling locations of sampling results at Linga, plotted within 1 km of one another. Only one sample taken during the sampling period had a result > 230 *E. coli MPN*/100 g, with this being 500 *E. coli MPN*/100 g. This sample was taken in 2007 during the month of July. Sampling took place throughout the year and no significant seasonal effect was found

A statistically significant correlation was found between *E. coli* results and both two and seven day rainfall levels prior to sampling, with very low *E. coli* results of < 20 *E. coli MPN*/100 g occurring predominately at rainfall levels of < 10 mm. No statistically significant correlation was found between *E. coli* results and water temperature or salinity. No statistically significant correlation was found between *E. coli* results and the spring/neap tidal cycle. A statistically significant correlation was found between *E. coli* results and the high/low tidal cycle, with the majority of low *E. coli* results taken during a flood tide.

12. Designated Shellfish Growing Waters Data

The Busta Voe Lee South production area falls within the designated Shellfish Waters Growing Water (SGW) of East of Burki Taing and Aith Voe (shown in Figure 12.1).

SEPA is responsible for ensuring that monitoring is undertaken on a regular basis (quarterly for faecal coliforms in mussels and less frequently for metals and organohalogens in mussels). Since 2007, SEPA have used FSAS shellfish *E. coli* results (≤230 *E. coli* /100 g) to infer compliance with Guideline Standards for faecal coliforms (≤300 FC/100 ml). Two sampling points are identified in the SGW site report: HU 35967 66400 (Busta and Linga Voe) and HU 39455 64210 (Olna Firth Mussel Site). These are presumed to be used for monitoring of metals and organohalogens as they do not correspond with current shellfish hygiene RMPs.

The area was previously designated as two, separate, much smaller SGWs: Olna Firth (Site 25) and Busta Voe and Linga Voe SGW (Site 37). In 2005, the two areas were combined.

Historical compliance for faecal coliforms for the Olna Firth and Busta Voe and Linga Voe SGWs was poor, with Olna Firth passing only in two years between 2000 and 2005, and Busta and Linga Voe not passing in any years between 2003 and 2006.

The combined area passed from 2007 until 2010 (the last year reported in the most recent available SGW site report). During this time, FSAS monitoring results would have been used. However, it is not clear which of the FSAS monitoring points was used to assess the area for SGW compliance. It should be noted that SEPA collected mussel samples from the shore, whereas the FSAS samples came from the mussel farms and away from any shore-based sources of faecal contamination.

The site was extended again in 2009 to include Cole Deep and Gon Firth, and renamed East of Burki Taing, Muckle Roe (Site 119). A further extension in 2012 to include the Sound of Houbansetter and Aith Voe produced the area shown in Figure 12.1.

The most recent available SGW site report is for East of Burki Taing, Muckle Roe and cites a small number of point source discharges, diffuse pollution from agricultural runoff and boats as the primary sources of faecal contamination to the area.

The current FSAS monitoring results for the Busta Voe Lee South production area are considered in Section 13 of this report, and therefore no further assessment of the data is considered here.

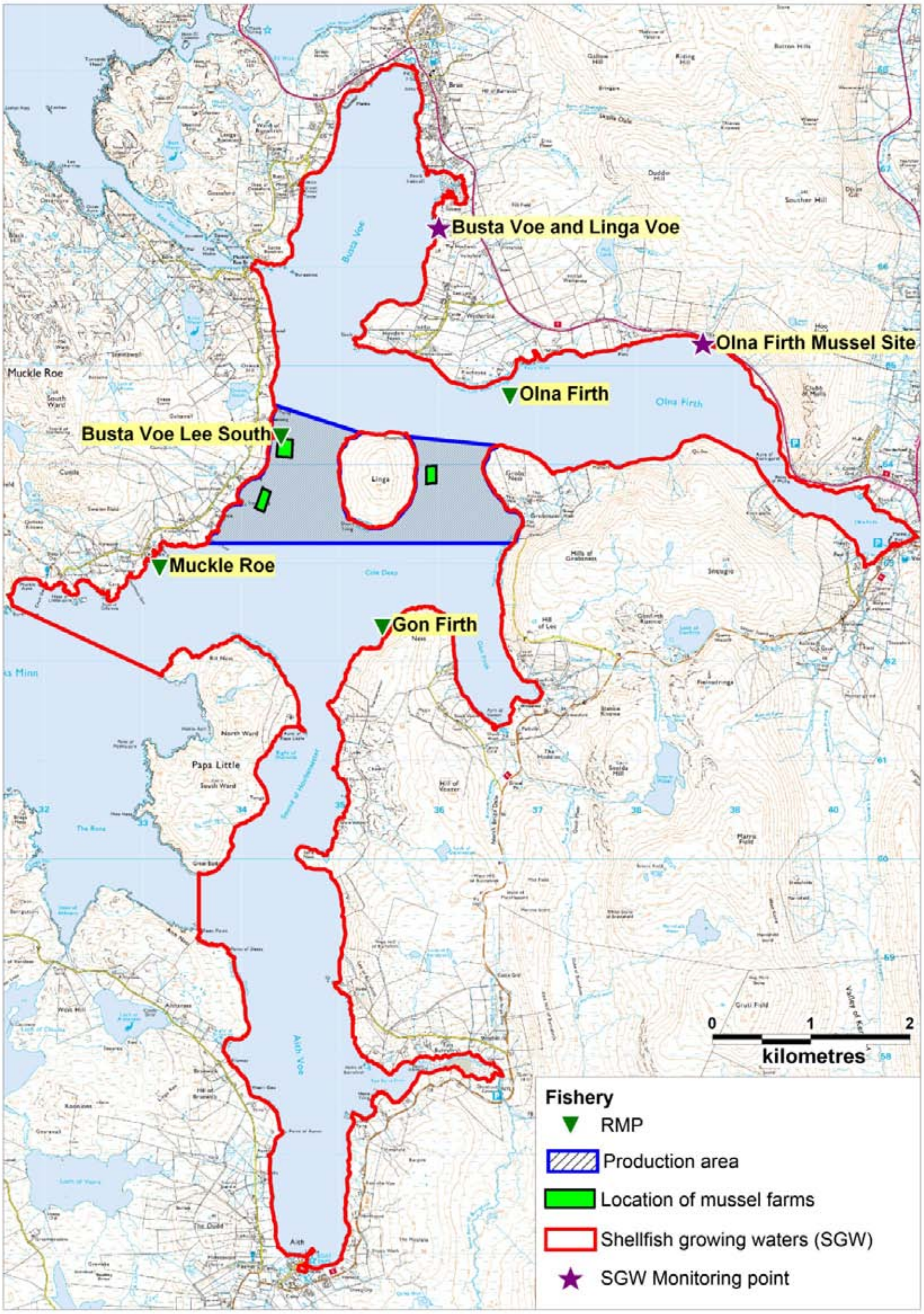

Figure 12.1 Designated shellfish growing water – East of Burki Taing and Aith Voe

13. Bathymetry and Hydrodynamics

Bathymetry and Hydrodynamic Assessment: Busta Voe Lee South

13.1 Introduction

The study area is located on the west Shetland mainland and is an inlet on the convoluted southern coastline of St. Magnus Bay. The study area comprises all waters east of a line drawn between HU 3318 6319 (Boat Geo on Muckle Roe) and HU 3392 6224 (Rit Ness on Papa Little island) and therefore includes the large inlet Cole Deep which itself branches into three large voes; Busta Voe to the north, Olna Firth to the east and Gon Firth to the south. The Sound of Houbansetter is excluded through a southern boundary defined by a line drawn between HU 3457 6162 and HU 3485 6158. The total area of the study area is 13.5 km^2.

This report pertains to the Busta Voe Lee South production area which is centrally located within the study area to the east and west of the island of Linga. With an area of 2.2 km^2 the boundaries of this body of water area not defined by shoreline topography such as the neighbouring lochs. With open boundaries to the north and south the hydrographic properties of the entire region are therefore relevant to this study.

13.2 Bathymetry

An extract from Admiralty chart BA3295-5 (1:25,000) annotated with the limits of the study area, production area and the locations of the mussel fisheries is given in Figure 2.1 below.

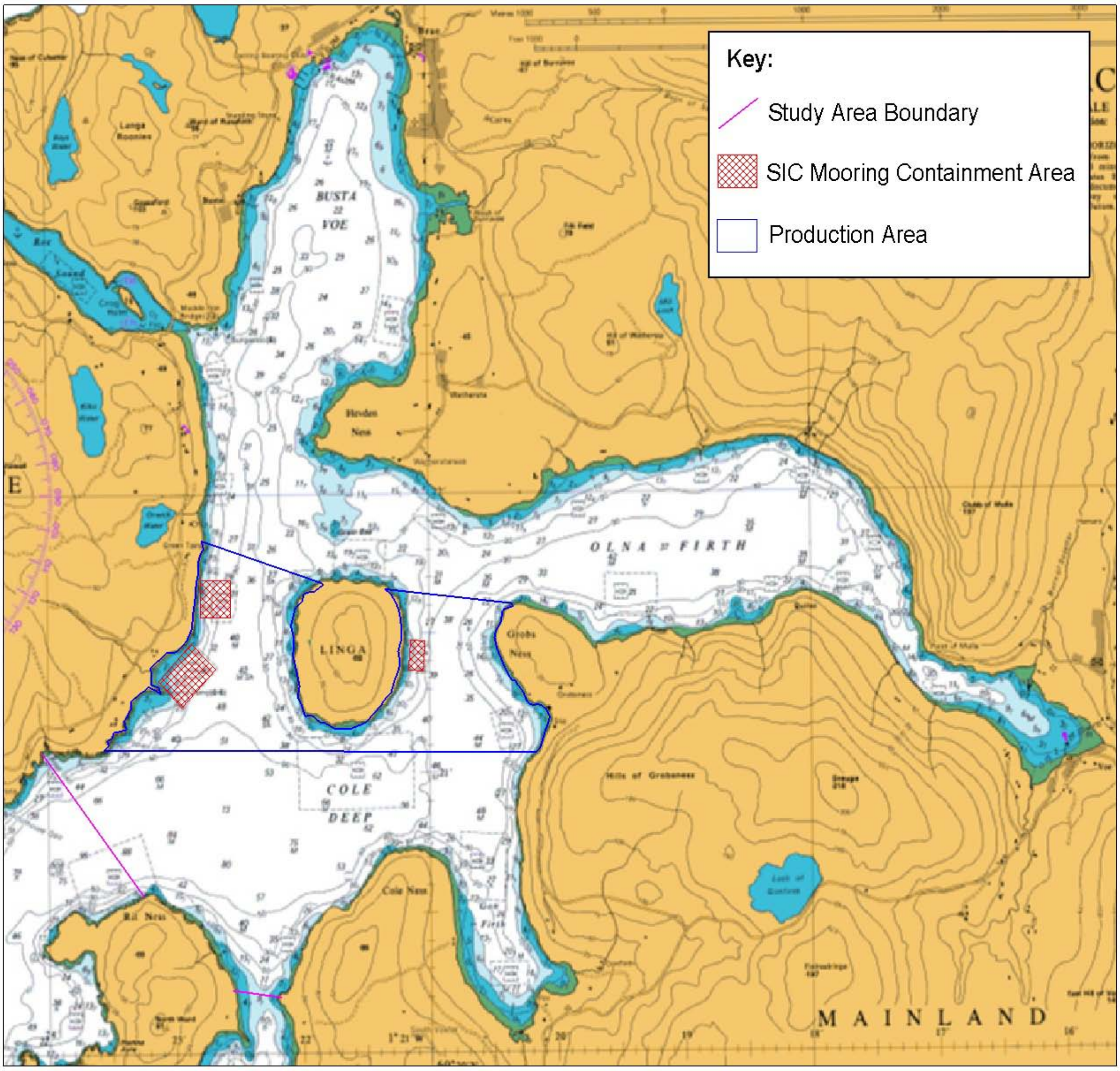

Figure 13.1 Admiralty chart extract

Vector data from an electronic version of this chart was extracted and contoured using Golden Software Surfer 8 (Figure 2.2).

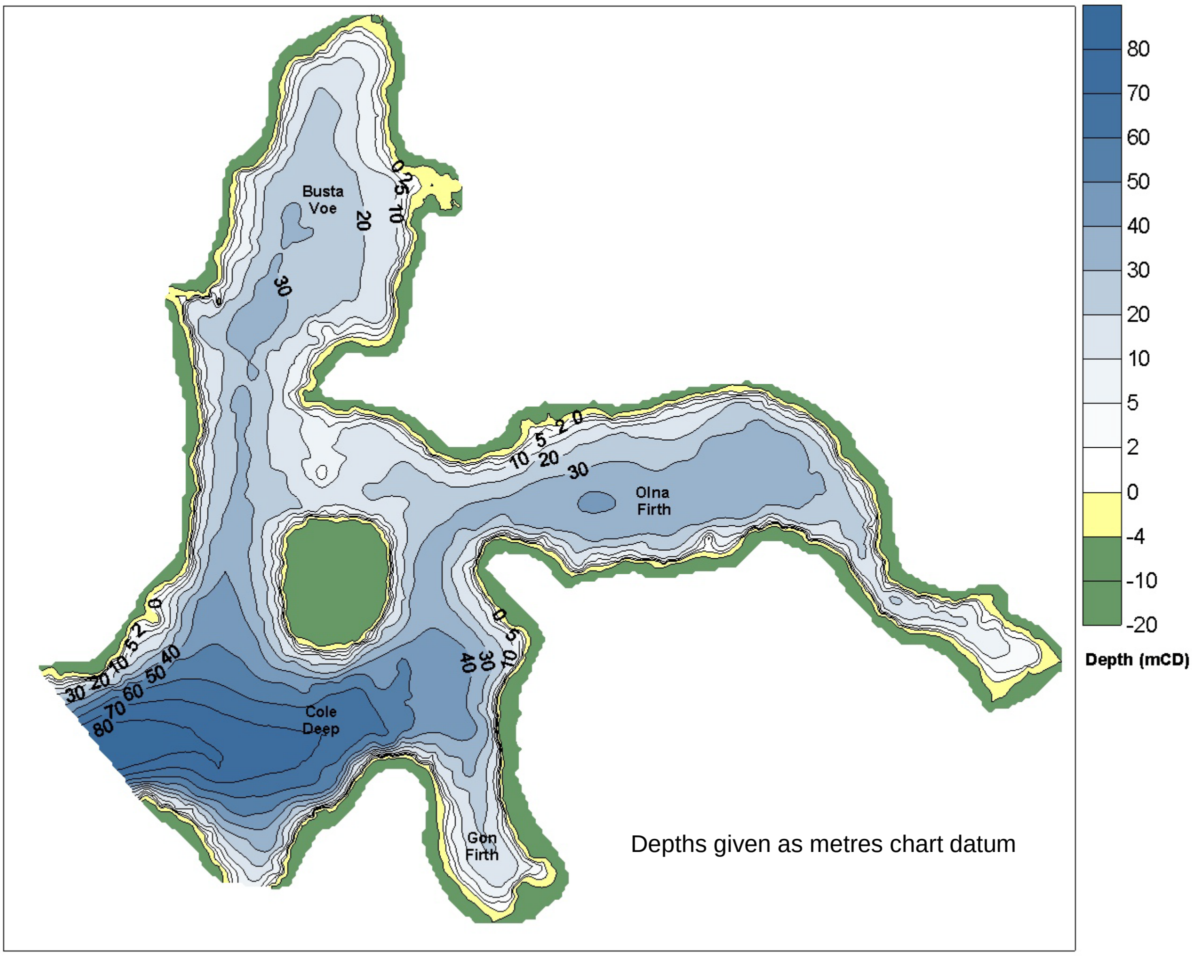

Figure 13.2 Bathymetry of Cole Deep, Busta Voe, Olna Firth and Gon Firth

The contour map illustrates that the bathymetry either side of the island of Linga is very similar with deeper water expected at the two fisheries in the western channel. Deeper water in the east and west channels appear to extend into both Olna Firth and Busta Voe. To the north of Linga water depth shallows to form a sill approximately 7 to 13 m deep for the majority of its length. Rocks marked on the chart at Groin Baa imply that this sill breaks the surface at this location.

Grid volume computations in Surfer allow for the estimation of the surface area and volume. Positional information is related to the British National Grid to give Eastings as the "x" coordinate and Northings as the "y" coordinate in a three dimensional grid. The values presented in Table 2.1 represent the area and volume at chart datum by defining the surface "z" as zero. Despite being an area with multiple open boundaries values derived for the production area are given for comparative purposes.

Table 13.1 Area and volume estimations of the study area using Surfer

Parameter*	Study area	Production Area
Area (km^2)	13.54	2.2
Volume (Mm^3)	377.9	60.0
Mean depth (m)	27.9	27.8
Maximum depth (m)	88.0	51.0

* All values at chart datum

13.3 Field Data

Historically there have been a total of fourteen field studies in the region which give an insight into the current flow patterns within the study area. Summary information of the deployments is given in Appendix 1 while their locations are illustrated in Figure 3.1. Four of these surveys have been within the production area. Data from these hydrographic studies were provided to Cefas by SEPA which archive information concerning fish farm licensing on their Public Register. For this report a selection of these surveys were evaluated and re-processed to the requirements outlined by SEPA in the *Regulation and Monitoring of Marine Cage Fish Farming (Scotland) Attachment VIII* (v2.7 2008) to standardise analysis, discussed in detail in Section 5. Regarding data quality while in most cases the instrument set up parameters of these historical surveys are not compliant with present deployment standards, the resultant data is considered to be of high quality in terms of accuracy and therefore can be said to be representative of the locations studied.

Both studies conducted at Heights were rejected over concerns with the data quality. The 2001 study was collected with instrument set up parameters that were not suited to the conditions encountered, resulting in poor accuracy which affects the reliability of both the vector and velocity data returned and leads to a potentially unrepresentative “spiky” data set. In 2007 the data describe current patterns which vary considerably throughout the water column, that do not relate to the tidal cycle, and are not consistent with topographic features. This could be indicative of interference with the signal emitted by the instrument by a physical presence. No analysis was reported from either study due to the risk of misinterpretation, with the exception of the pressure record.

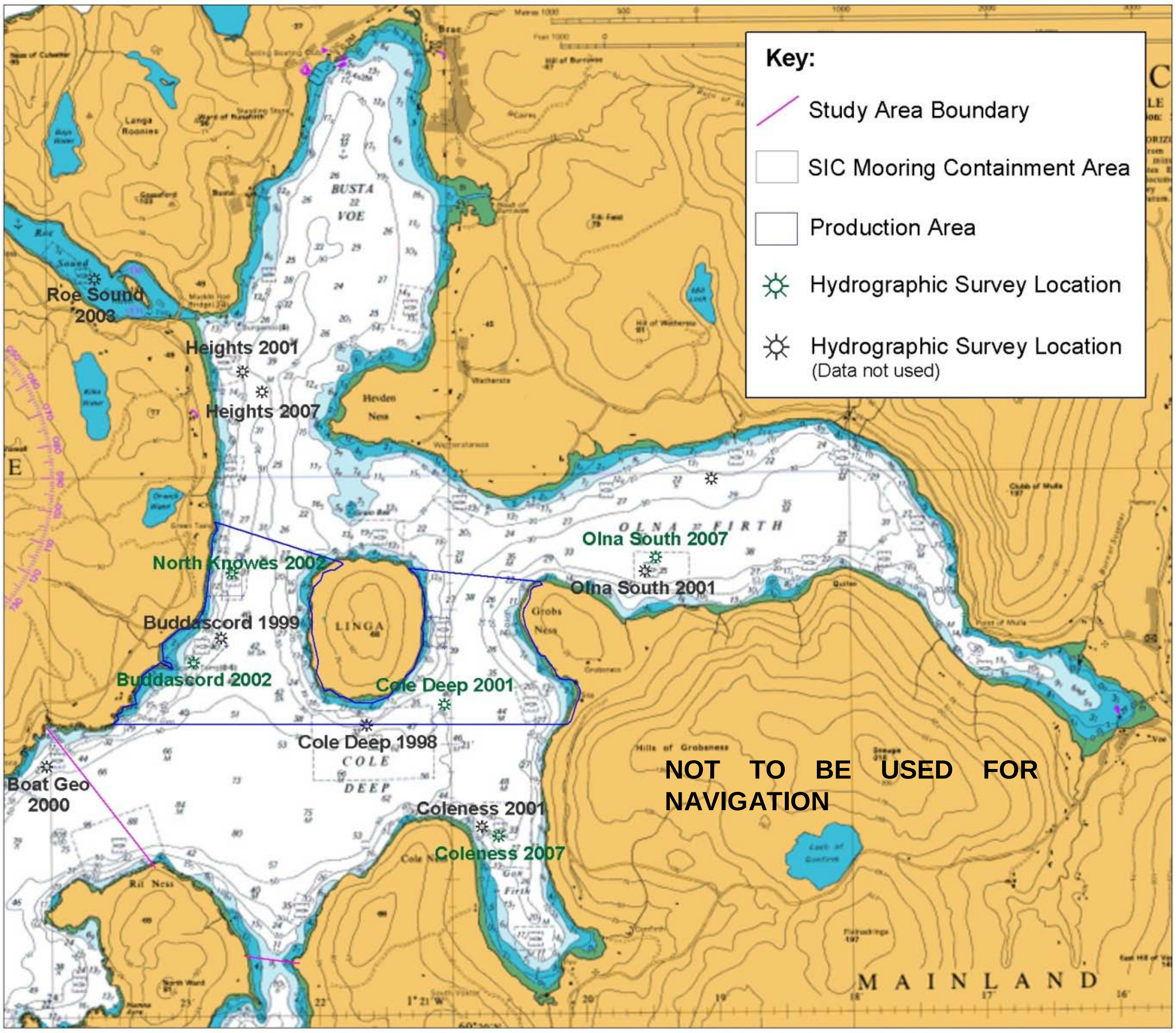

Figure 13.3 Surveys in the Cole Deep, Busta Voe, Olna Firth and Gon Firth region

13.4 Tidal Information

Information pertaining to predicted tide height is derived from the UKHO TotalTide prediction for West Burra Firth, the nearest secondary port some 12.5 km west of the study area boundary. Figures 4.1 and 4.2 show tidal curves for a fifteen day period starting on the 31 October 2012 and therefore includes the date of the shoreline survey (7/8 November 2012).

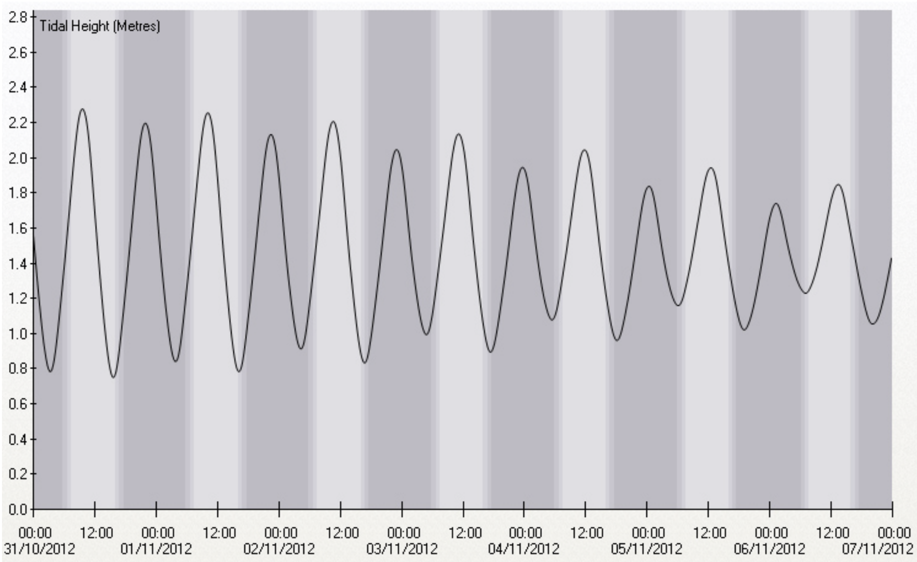

Figure 13.4 Tidal Curve West Burra Firth; 31 October to 7 November 2012

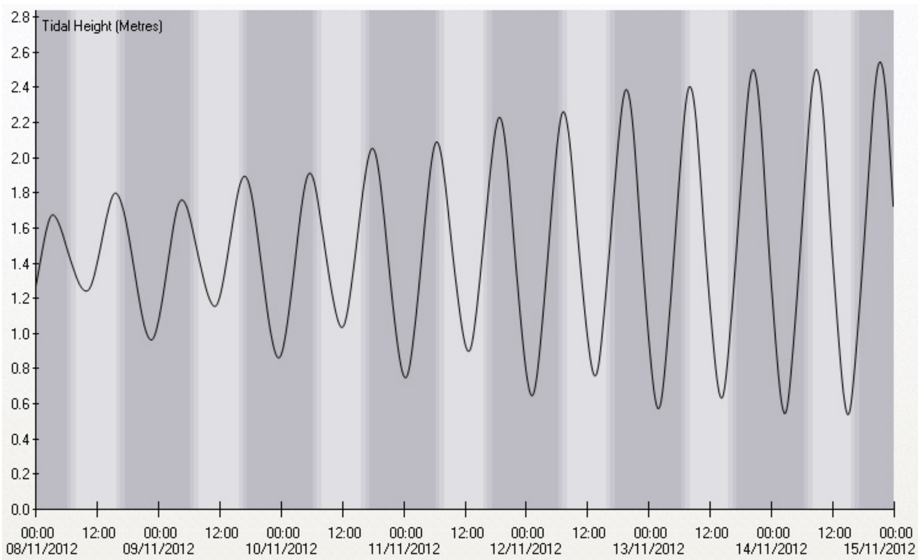

Figure 13.5 Tidal Curve West Burra Firth; 8 to 15 November 2012

Tide level information from TotalTide is summarised below. Predicted heights are in metres above chart datum.

0294A West Burra Firth is a Secondary Non-Harmonic port.

The tide type is Semi-Diurnal.

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

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

13.5 Timing

Figure 4.3 shows a plot of the first six days of the pressure record for each of the current meter survey deployments at Buddascord (2002), North Knowes (Greentaing)and Cole Deep (2001). The times of high and low water for the West Burra Firth TotalTide prediction for the same periods are also shown and it is apparent that the timing of the tidal state at the three sites within the production area is consistent with the prediction. Data was also assessed for the surveys at Heights, Cole Ness and Olna Firth South for comparison. Again consistency with the prediction is observed, with the exception with the data from Cole Ness where is appears that high or low water may be slightly earlier (within 0.5 hour) than the prediction for West Burra Firth. In summary the UKHO prediction for the secondary port West Burra Firth is considered representative of the study area.

13.6 Range

The average range of the three largest tides around springs for each of the surveys within the production area was between 1.7 and 1.9 m. The observed range is on the whole lower than that predicted for the corresponding tides at (1.6 to 2.3 m). The entire data set could not be used due to errors in each of the pressure sensor data which illustrated gradually increasing values during the survey. A similar range was observed during the Cole Ness survey while records for Heights and Olna Firth South showed a greater range at 2.1 to 2.2 m respectively. These values are closer to the highest and lowest astronomical tide predictions for the UKHO secondary port. Atmospheric pressure is not accounted for in the survey data.

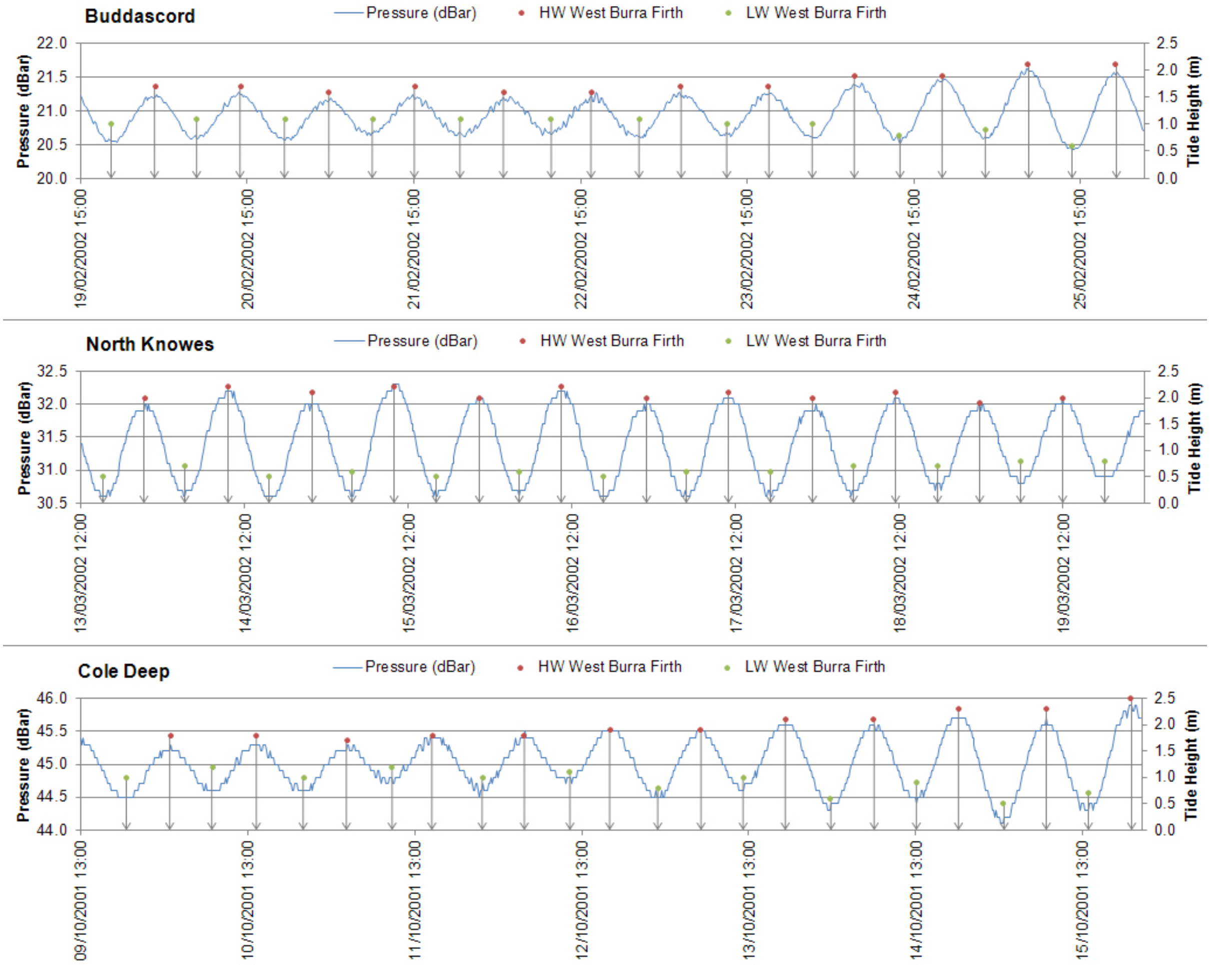

Figure 13.6 Pressure record for Buddascord, North Knowes (Greentaing) and Cole Deep compared to the TotalTide prediction for West Burra Firth

13.7 Tidal Volume

The volume of water entering and leaving the study area on each tide is estimated by two methods. The first is a simple box model based on a "tidal prism" method (Edwards and Sharples 1986):

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

where V is the volume of the loch basin (m^3), A is the surface area of the loch (m^2) and R is the spring tidal range (m). The factor 0.52 is the number of days per tidal cycle, and the factor 0.7 approximates the mean tidal range from the spring tidal range, R. As the spring tidal range is used, inputs for volume and area pertain to those calculated for MLWS. Based on this method estimates of flushing time (T_f) and flushing rate (Q) are given below in Table 4.1.

Table 13.2 Estimate of flushing rate and tidal volume for the study area using the tidal prism method

Input:		
Volume (V)	Mm^3	385.8
Area (A)	km^2	13.82
Tidal range (R)	m	1.6
Output:		
Flushing Time (T_f)	days	13.0
Flushing Rate (Q)	Mm^3/year	10,868.7
Flushing Rate (Q)	Mm^3/day	29.8
Flushing Rate (Q)	Mm^3/tidal cycle	15.5

Calculated for MLWS. Note values are slightly greater than those presented in Table 2 which relate to parameters derived for Chart Datum.

The tidal prism method indicates that 4 % of the low water volume of the study area is exchanged during each tidal cycle and that total exchange would take thirteen days.

The second method again utilises Surfer grid computations to estimate the volume of the region at different tidal states by defining the "z" surface according to the tidal level and subtracting low water from high water (Table 4.2).

Table 13.3 Estimate of flushing rate and tidal volume of the study and production areas using Surfer grid volume calculation

Tide	Z (m)	Study Area Volume (Mm^3)	Production Area Volume (Mm^3)
MLWS	0.6	385.8	61.4
MHWS	2.2	408.4	65.0
Difference (spring tide)		22.7	3.7
MLWN	1.0	391.3	62.3
MHWN	1.7	401.2	63.8
Difference (Neap tide)		9.9	1.6
Average Difference		16.2	2.6

The estimate of the flushing rate is comparable to the average tidal volume. However both estimations of the exchange rate given should be interpreted cautiously as both employ a gross simplification of hydrodynamic properties in topographically complex area. Sill and basin features will restrict exchange at depth and lead to longer residency times while wind forcing may serve to enhance or compound exchange depending on the direction. There is greater potential for exchange through Roe Sound between the island of Muckle Roe and the mainland which is not accounted for in the calculations.

13.8 Currents

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

Full hydrodynamic modelling was undertaken as part of the sanitary surveys conducted for the neighbouring Busta Voe Lee North and Papa Little Voe production areas (CEFAS; Scottish Sanitary Survey Project 2007, CEFAS; Scottish Sanitary Survey Project 2009). The Hydrotrack model was used with a domain defined that included the entire study area. The scope and extent of this modelling means that this is therefore relevant to the Busta Voe Lee South production area. The availability of data derived through various hydrographic studies conducted in the same area (Figure 3) potentially allow for validation of these simulations.

Tidal flows are simulated using a spring tidal range of 1.7 m as quoted in the Scottish Sea Lochs Catalogue (Edwards and Sharples 1986). Note that this exceeds the springs range derived from UKHO TotalTide prediction (1.6 m). The effect of wind forcing is simulated by a constant airflow from the four main cardinal directions over a 48-hour period to attain a steady state current pattern. Tidal and wind forcing scenarios were combined to simulate particle release and transport over two days from what were considered to be the two main sources of contaminants for each study; the settlement of Brae in Busta Voe to the north, a group of streams located on the eastern shore of the Sound of Houbansetter and streams and a septic discharge around to the east in the waters of Gon Firth.

In summary the results showed:

Particle transport solely attributed to tides was very small in the order of 250-500 m at all three sources leading to particles staying in the vicinity of the release point.

When the combined effects of tide and wind are considered particles released from Brae appear to be contained within Busta Voe for all four airstream scenarios with no transport to the Busta Voe Lee South production area sites.

Particles released from the sources within the Sound of Houbansetter are transported into the production area by combined wind and tidal transport during southerly and south-westerly winds. Transport would be to the western side of the production area between the islands of Linga and Muckle Roe. (Figure 5.1).

Particles released from the sources within Gon Firth are also carried into the production area, this time to the east of Linga as a result of combined wind and tide transport resulting from easterly winds (Figure 5.1).

No particle releases from Olna Firth were simulated, the potential impact from sources in this voe to the production area are unknown.

Particle movement predictions were found to be largely consistent with underlying water circulation patterns for each tide and wind scenario mapped for the entire region (Figures 5.1 & 5.2). Directly pertaining to the production area these show:

Northerly winds: A 3-4 cm/s southerly flow is generated north of the production area along the shore at Muckle Roe and the western shore of Busta Voe, giving rise to the potential for contaminants originating from here being transported to the Greentaing site, however Buddascord would be unaffected.

Easterly winds: A counter-clockwise flow around Linga is established with a south westerly flow greater than 5 cm/s at Buddascord, and to a lesser extent Greentaing, and a 3-4 cm/s northerly flow at the Linga site. In addition to the contaminant transport from sources at Gon Firth, there would appear to be a low risk of contaminants from other sources being carried to sites within the production area. Potential contaminant sources at Hevden Ness would join currents flowing into Busta Voe in these conditions.

Southerly winds: No clear patterns established with velocities generally less than 3 cm/s. Aside from the transport of contaminants originating from the Sound of Houbansetter described above, an anti-clockwise flow forms to the east of Linga which has the potential to carry contaminants from Grobs Ness to the Linga Site.

Westerly winds: Generate clockwise flow around Linga with the reverse pattern of transport to that described for easterly winds. with a north easterly flow greater than 5 cm/s at Buddascord, and to a lesser extent Greentaing, and a 3-4 cm/s southerly flow at the Linga site. There would appear to be potential for transport to the Buddascord Site along the Muckle Roe shoreline to the south of the production area.

Southwesterly winds: Produce a similar pattern of transport described for westerly winds with a weaker clockwise flow around the island of Linga, and a counter-clockwise flow present in the east of the production area.

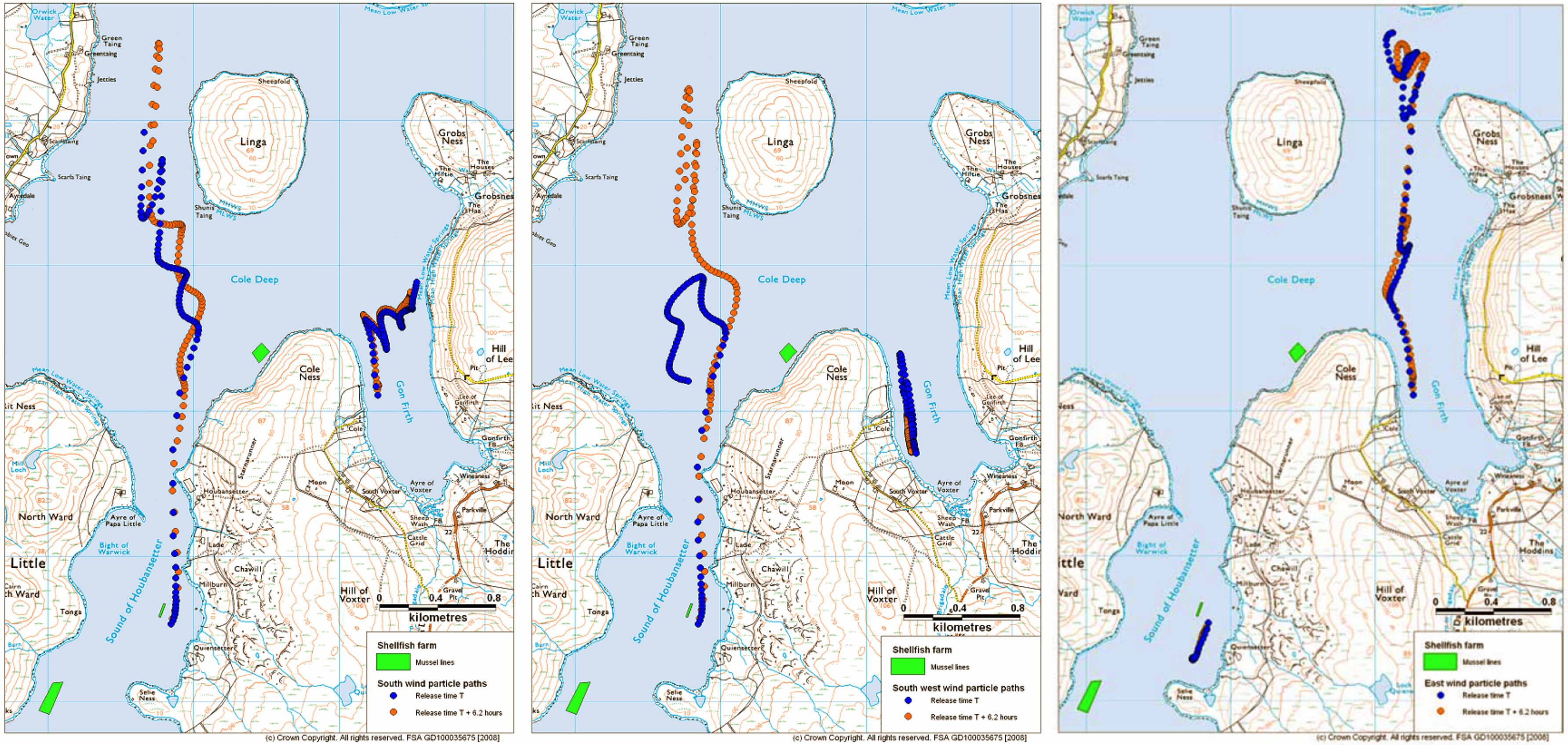

Figure 13.7 Hydrotrack output for wind and tide generated residual particle paths for west, south west and east winds
Reproduced from Papa Little Voe Sanitary Survey Report, Cefas 2009**.**

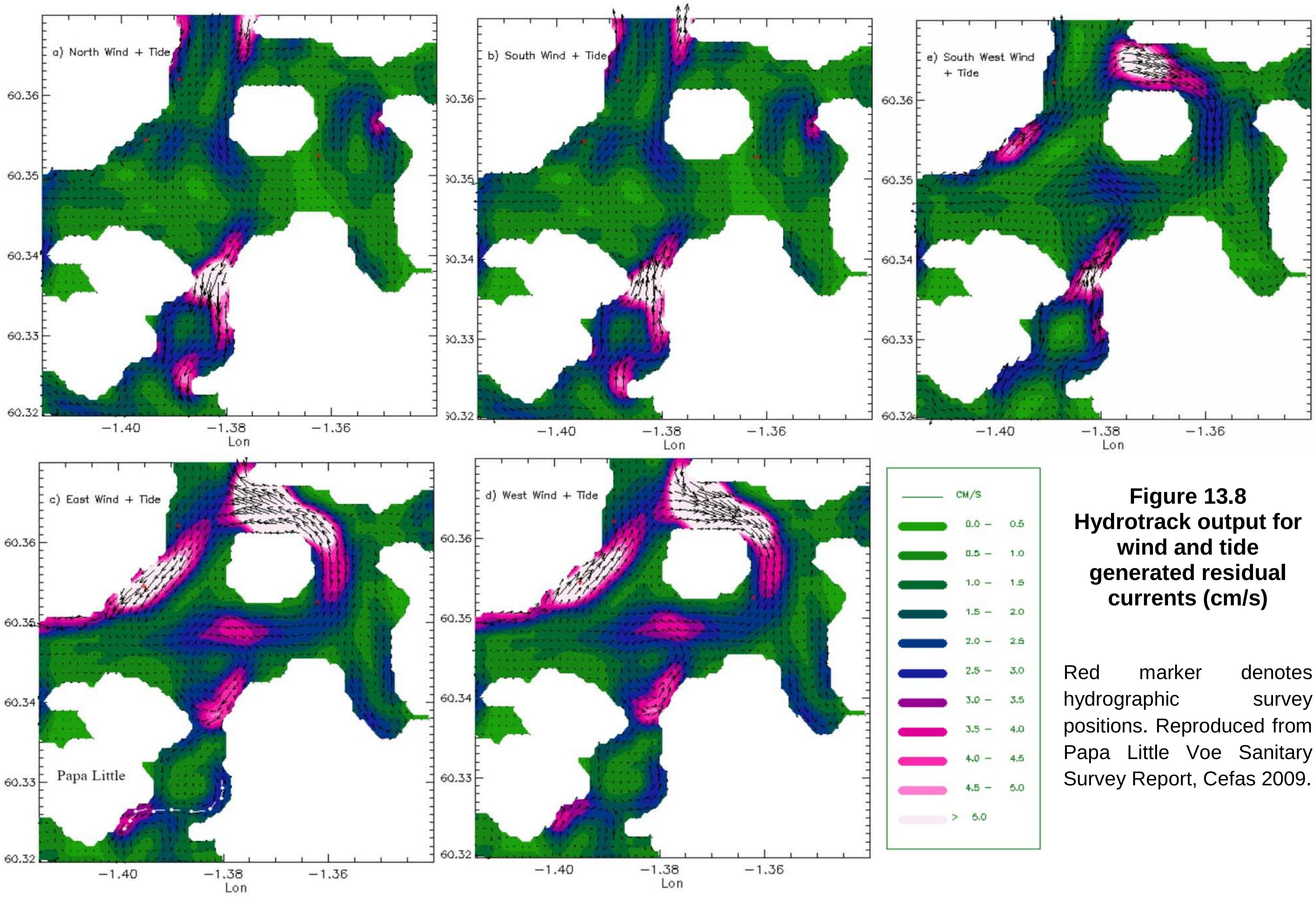

Figure 13.8 Hydrotrack output for wind and tide generated residual currents (cm/s)

Red marker denotes hydrographic survey positions. Reproduced from Papa Little Voe Sanitary Survey Report, Cefas 2009.

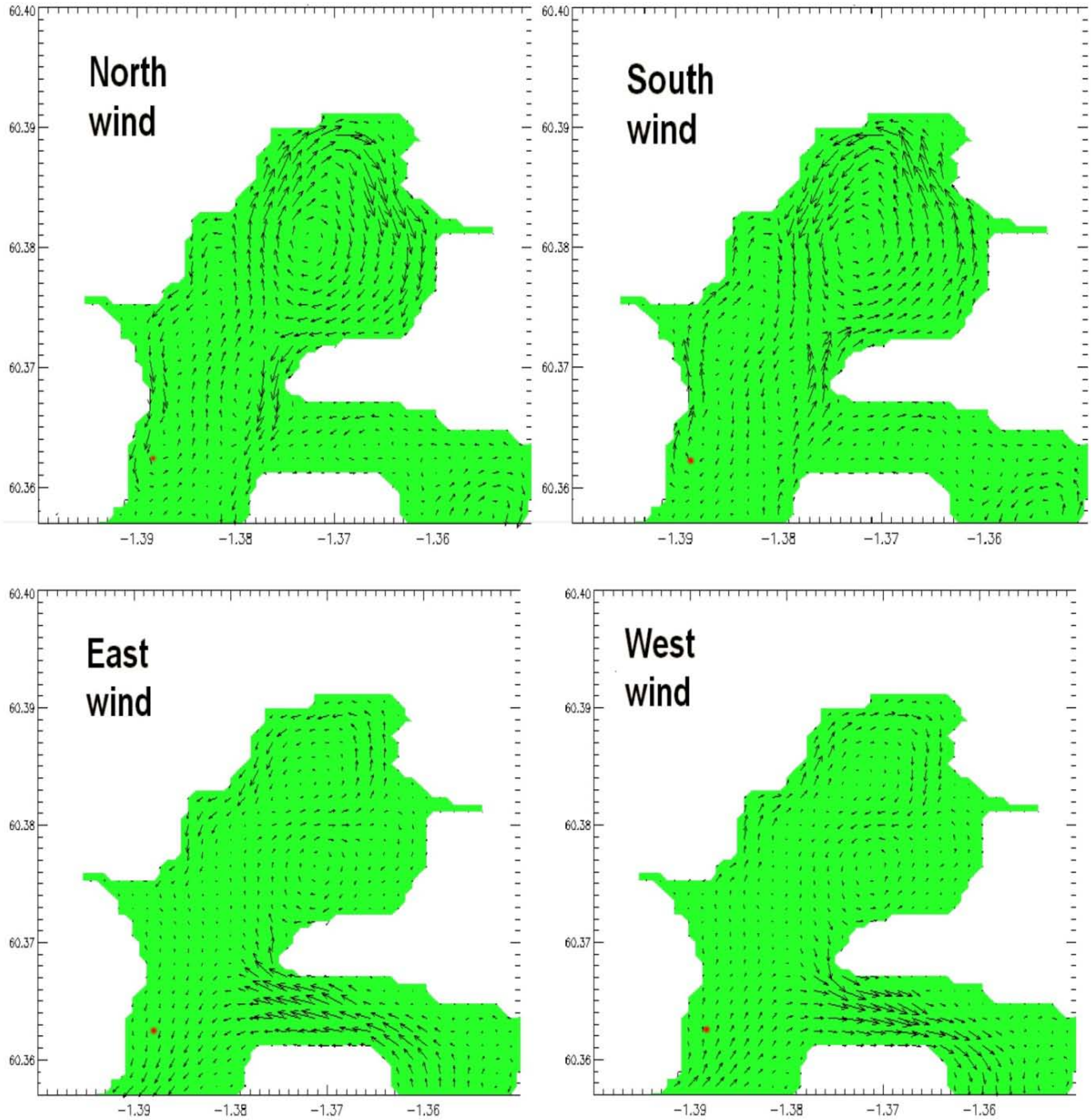

Figure 13.9 Hydrotrack output for wind driven residual currents (cm/s) in Busta Voe and the northern extent of the production area

Red marker denotes position of the 2002 hydrographic survey at North Knowes (Greentaing). Reproduced from Busta Voe Lee North Sanitary Survey Report, Cefas 2007.

The hydrotrack model provides baseline information as to how the water body may respond to various wind conditions however the results must be considered within the limitations of the simulation, namely the inability of the model to describe vertical structure within the water column and the impact this will have on the modelling of wind driven flow, the fact that flow through Roe Sound at Busta Voe is disregarded, and the lack of any simulation of density driven flows.

An assessment of the hydrographic data collected at each site was undertaken with detailed summary statistics for each survey tabulated in Appendix 2. Figure 5.4 illustrates the frequency of currents by vector and the pertinent summary statistics for near-surface waters for each of the three surveys in the context of the surrounding area.

As predicted by the hydrotrack model tidal currents appear to be relatively weak in the area. The most defined tidal signature is present between the islands of Linga and Muckle Roe in the west of the production area, as demonstrated by observations at the Greentaing (North Knowes) and Buddascord shellfish farms. Here as expected the flood tide is shown to enter the system from the south with a counter flow during the ebb tide. Particles in near surface waters appear to have the potential to be carried a greater distance during a 6.2 hour period at Buddascord, decreasing further north at Greentaing with lower maximum and mean transport observed here. Net movement over the 15 day period is to the south-southeast, not aligned with the tidal major axis likely due to the ebb tide dominating the cycle.

At Cole Deep tidal patterns are less clearly defined although the limited evidence conforms to the expected movement of water into the system with the flood tide flowing to the north between Linga and Grobs Ness. Maximum transport during a 6.2 hour period was coincidental with strong wind forcing implying that currents at this location are subject to influence from the wind.

In the two studies outwith the production area regular tidal patterns are less discernible than those already described. Movement at Coleness again conforms to that expected as a result of the landforms, with the flood tide entering Gon Firth from the NW and the ebb tide flowing in the opposite direction. At Olna South tidal currents are the weakest and as such more variable but generally show flow in and out of the voe with the flood and ebb tides respectively. Overall observed residual movement over the 15-day period at each survey location shows similarities with the Hydrotrack prediction of residual currents solely attributed to the tides, particularly at Buddascord or Cole Ness (Cefas, 2009) reinforcing the prediction.

It is evident from the analysis of tidal currents that currents in the region are influenced by wind forcing, as predicted by the Hydrotrack model where wind driven transport exceeded relatively weak tidal currents. All sites in the production zone are moderately exposed with fetches ranging of 2.5 km at Linga (SSE), 4.0 km at Greentaing (NNE) and 4.5 km at Buddascord (NNE, SW). However the straight-line distance of open water would appear not to be the only consideration in this topographically complex region as demonstrated by the modelling where the formation of clockwise and counter-clockwise currents around the island of Linga are predicted. This implies that the strongest currents generated may not be associated with the greatest fetch, and that currents established may flow in the opposite direction to driving wind influence. An attempt to validate the Hydrotrack model predictions is achieved by searching the time series plots of current flow and direction for instances of prolonged unidirectional flow over multiple tidal cycles and referring to the wind conditions recorded at the time. In most cases the depths of the mussel lines are represented by the near-surface record.

To the west of Linga at Buddascord and Greentaing the hydrographic data collected shows dominance of wind generated currents over tidal streams with periods of unidirectional flow over sequential tidal cycles, with this influence decreasing with increasing depth. Where wind conditions are coincidental to those simulated in Hydrotrack the observed flow largely corresponds to the prediction especially in shallower water. In deeper water there is evidence of currents flowing in the opposite direction to the near-surface layer during periods of strong wind forcing. The data collected at Cole Deep representing in the east of the production area shows less evidence for wind influence in the near-surface layer, with greater influence in the middle of the water column. In addition the wind direction recorded was rarely coincidental with the cardinal directions simulated with Hydrotrack making any comparison to the prediction difficult.

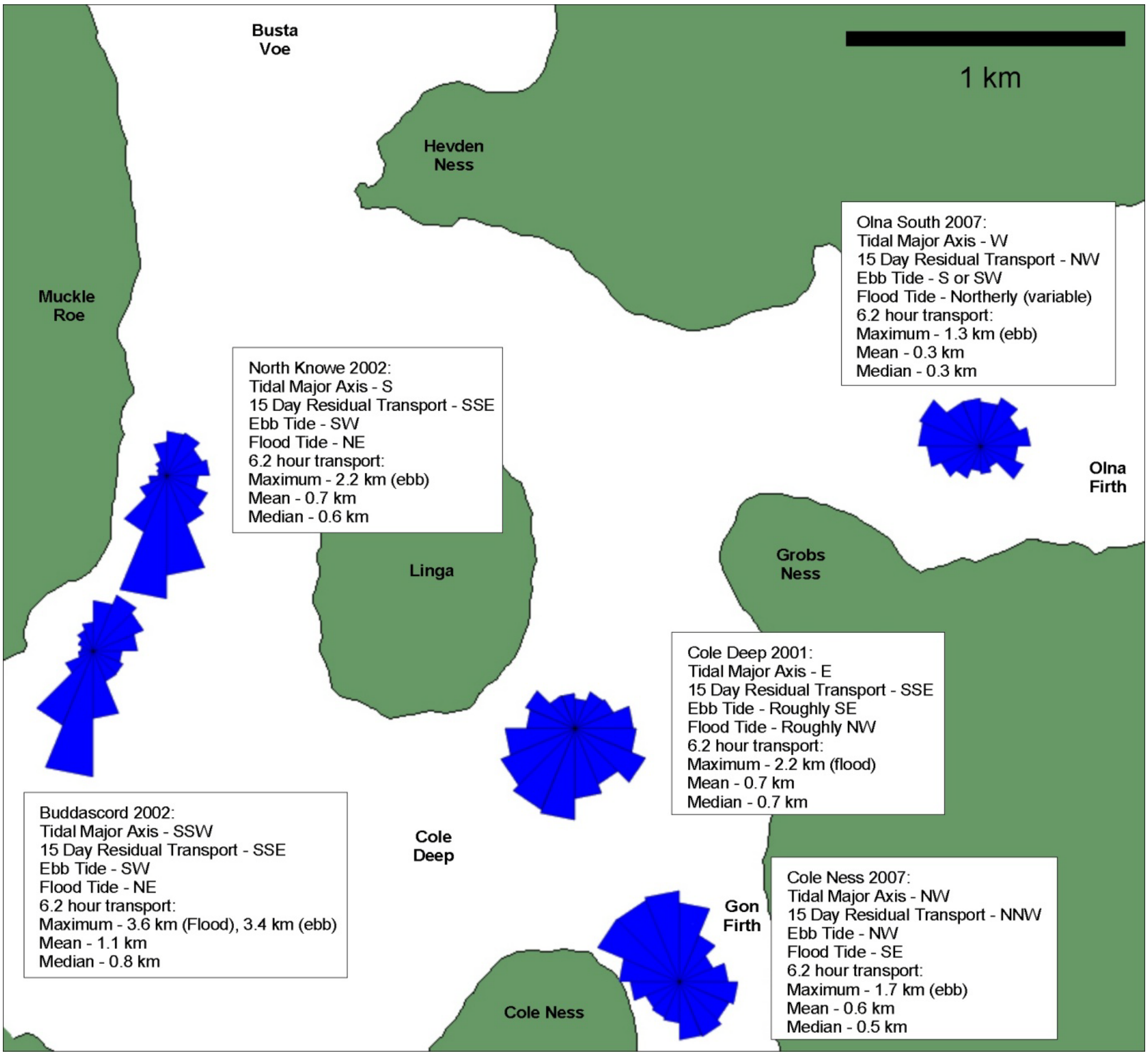

Figure 13.10 Near-surface current direction frequency (bin size 22.5°) for the three surveys assessed at Busta Voe Lee South, including a summary of residual and tidal transport at each location

13.9 Stratification

Salinity and temperature profiles were collected at each of the three sites within the production area during the shoreline survey in November 2012. Readings showed uniform salinity over a depth of 10 metres, with the exception of the profile collected at the northern end of the Buddascord site where lower salinity was detected at the surface in both the profile and the sample analysed in the laboratory. However the difference between salinity readings at the surface and at 10 metres was very low (0.37 ppt) compared to the reported accuracy of the instrument used (0.35 ppt). Temperature measurements showed no variation with depth. Complete salinity and temperature profile data and water sample analysis are available in the shoreline survey report.

While these observations are not indicative of stratification at the time of the survey the potential for these conditions was noted in both sanitary survey reports undertaken by Cefas for Busta Voe Lee North (2007) and Papa Little Voe (2009). With weak tidal influence resulting in poor mixing of the water column, thermal stratification may occur during the summer months. With a layer of warmer water above cold dense water the potential also exists for the formation of density driven currents. However the timing of the fieldwork precluded any further study of this phenomenon.

13.10 Summary

- The tidal prediction for West Burra Firth is applicable to the study area in terms of timing although a greater range was observed in the field data. This means more water may be exchanged by the tide than the various modelling techniques employed predict.
- Comparable figures for tidal exchange are derived from the two methods used to calculate this, namely 4% of the LW volume of the study area exchanged during the tidal cycle and a flushing time of 13 days. Weather conditions, bathymetric features and the exchange through Roe Sound may affect this, although to what extent is unknown.
- Particle transport is predicted to be greater for wind generated currents combined with residual tidal flow than that attributed to tide alone.
- Contaminants are predicted to be carried into the production area from sources within the Sound of Houbansetter as a result of southerly and south westerly winds, and from Gon Firth as a result of easterly winds. Contaminants from sources at Brae are unlikely to be carried into the production area under any wind conditions.
- Regarding other potential sources of contaminants from settled shorelines not modelled by particle tracking their movement can be inferred from flow patterns predicted for various wind conditions:
    - Prolonged northerly winds generate an alongshore current along the western shore of Busta Voe potentially carrying contaminants into the production area at Greentaing.
    - Prolonged southerly winds generate a counter-clockwise flow between Grobs Ness and Linga.
- Field observations confirm the Hydrotrack prediction that tidal currents are relatively weak in the area. Observed residual movement over the survey period generally shows similarities to the modelled prediction of tidal residual currents alone. Flood and ebb tides conform to the expected pattern of water moving into and out of the system defined by the topography.
- The greatest transport during a single tide occurs at Buddascord where excursion of up to 3.6 km may be expected. Excursion decreases elsewhere in the production area, and furthermore in the tributary voes.
- A relationship between strong wind forcing and unidirectional flow in the near-surface waters is evident throughout the area. Similarities are present between the Hydrotrack simulation and field observations.
- Salinity profiles collected during the November shoreline survey showed uniform salinity with depth. In the sanitary survey reports for the neighbouring areas Cefas note that as a result of weak tidal stirring the possibility exists for thermal stratification during the summer months. In these conditions warmer water above cold dense water leads to the formation of density driven

currents. The timing of the fieldwork precluded any study of the potential of this phenomenon.

13.11 References

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14. Shoreline Survey Overview

The shoreline survey was conducted on the 7th and 8th November 2012. Light to heavy rain fell throughout the morning of the first day, turning to showers in the afternoon. Wind built to a strong westerly breeze (F6) in the morning. This strong breeze persisted until early afternoon before easing. The second day was overcast, with sunny spells in the afternoon and an ESE breeze. Rain showers fell over the 48 hrs prior to this survey. Figure 14.1 shows a summary map of the significant findings from the shoreline survey at Busta Voe Lee South.

Three sites were assessed during this survey. Greentaing (SI 328 767 08) consisted of seven mussel lines running parallel to the shoreline. All lines were double headed long lines with 10-15 metre droppers.

Buddascord (SI 328 936 08) consisted of seven mussel lines running parallel to the shoreline. All lines were double headed long lines with 10 metre droppers. Harvesting at the site was taking place during the fieldwork on the furthest west line closest to the shoreline.

Linga (SI 328 411 08) consisted of six mussel lines running parellel to the eastern shoreline of the island of Linga. All lines were double headed tubular lines with 15 metre droppers.

The area was sparsely populated, with only scattered dwellings present on the western shore, and only two buildings on the eastern shoreline at Grobsness. The island of Linga that lies in Busta Voe Lee South production area was uninhabited. Of the properties on the western shoreline, two were farm buildings. Septic tanks could only be identified for one of the houses. A portacabin was present directly opposite the Greentaing fishery: this portacabin had a pipe extending into the sea.

Boat traffic in the Busta Voe Lee South area was associated with aquaculture farms in the area. The jetty adjacent to the Greentaing site was used by Northmavine Marine as a shore base, with small workboats moored here used for servicing their sites (Greentaing and Buddascord). A large workboat was harvesting mussels at the Buddascord site on the day of the shoreline survey.

The land on the western shoreline was a mix of rough grazing, crop fields, silage fields and improved grazing land. Several farms and out buildings were also noted. Sheep were observed on the western shorelines though fences and steep escarpments prevented access to the shoreline. Cow pats were present in the fields above Buddascord and Greentaing sites. No cows were observed and shore access would have been prevented by fences. Land on the eastern shoreline was predominantly rough grazing land. Sheep grazing on the eastern shoreline appeared to have access to the foreshore, though no evidence on the shoreline was observed.

No sheep were observed on Linga at the time of the survey but the island of Linga is known to be used for grazing of sheep.

Due to the precipitation on the first day of survey and in the 48 hrs prior, a number of temporary streams and land runoff areas were noted on both the eastern and western shorelines. Freshwater samples were obtained from eight watercourses. Contamination levels varied between 4 and 800 cfu/100 ml. Higher contamination levels were found on the western shoreline; in a watercourse connected to Orwick Waters (330 cfu/100 ml) and a drain adjacent to agricultural buildings near Ayredale (800 cfu/100 ml). Seawater samples had low levels of contamination and, despite the precipitation, there was not a significant reduction in salinity in the seawater samples, except for one sample that had a salinity of 32 ppt.

Shellfish samples were taken at all three sites. Four mussel samples were obtained from the north and south end of the Greentaing site. From the northern end, samples were taken at the top and bottom (depth 8 m) of the mussel line and returned results of 2400 *E. coli MPN*/100 g and 110 *E. coli MPN*/100 g respectively, with the bottom sample taken from the RMP sampling bag. Samples taken at the southern end, with the bottom sample taken at 10 m depth returned results of 330 *E. coli MPN*/100 g and 50 *E. coli MPN*/100 g respectively.

Two mussel samples were obtained from the south end of the Buddascord site, one from the top and bottom (depth 10 m) of a mussel line. Results were 20 *E. coli MPN*/100g and 50 *E. coli MPN*/100 g respectively.

Two mussel samples were obtained from the north end of the Linga site, one from the top and bottom (depth 15 m) of a mussel line. Results were < 20 *E. coli MPN*/100 g and 130 *E. coli MPN*/100 g respectively.

Birds were observed on both the eastern and western shorelines. They included: a heron, gulls and geese. Goose droppings were also noted in fields above the shore at Buddascord and Greentaing sites, and to the northwest close to Ornick Hill. Evidence of a bird feeding area was noted by broken mussel shell fragments and sea urchin tests on a patch of grass above the shoreline at the Buddascord site. Seals were present for the majority of the shoreline survey, with a total of five seen whilst surveying the eastern shoreline. An otter was also seen running into the sea on the eastern shoreline.

Figure 14.1 Summary of shoreline survey findings for Busta Voe Lee South

15. Overall Assessment

Human sewage impacts

There are no public sewerage discharges to the Busta Voe Lee South production area. The nearest public discharge is from Brae ST, which lies 3.5 km north of the Greentaing mussel farm. Contaminants from this source are not expected to significantly impact water quality at the Busta Voe Lee South production area. Only one home with septic tank discharging to soakaway was identified on the eastern side of the production area at Grobs Ness. The majority of consented discharges near the fishery were along the western side of the production area, on the east shore of Muckle Roe. These were all associated with single dwellings and the majority discharged to soakaway. A number of dwellings were noted during the shoreline survey for which consents had not been received but that were presumed to have septic tanks discharging either to land or soakaway. One outfall was noted from a portacabin near the pier at Greentaing. This appeared to be linked to a toilet facility, however it was not in use at the time of survey.

A seawater sample taken from adjacent to a discharge pipe near the south end of the Greentaing site returned a result of 37 *E. coli* cfu/100 ml, which suggests a moderate level of faecal contamination. This was the highest seawater result for the area, suggesting significant faecal input in the vicinity.

The mussel farm at Linga lies adjacent to an uninhabited island, and only one dwelling was observed on the mainland at Grobs Ness to the east. Therefore, this site is not significantly impacted by sources of human sewage.

Agricultural impacts

The east shore of Muckle Roe, adjacent to the western boundary of the production area, has numerous fields used for silage and grazing of livestock. Although only sheep were seen during the shoreline survey, both sheep and cattle droppings were seen along the shoreline there. As the western mussel farms lie in close proximity to this shoreline, agricultural sources are expected to contribute significantly to any faecal contamination at the westernmost mussel farms.

The Island of Linga is likely to be used seasonally for grazing sheep and there was a farm at Grobs Ness, east of the mussel farm. However, fewer animals and no evidence of arable agriculture were seen at this location. The mussel farm at Linga lies closer to the island, and it is therefore expected that it would be less affected by faecal contamination from agricultural sources than the other two mussel farms in the production area.

Wildlife impacts

Geese and their droppings were observed along the shore west of Greentaing and Buddascord, where they are likely to be attracted to the arable fields to graze. Impacts from geese are likely to be higher at these two sites.

Gulls, cormorants and other shore birds were observed in relatively low numbers. Large numbers of seabirds, including gulls, breed around Muckle Roe and Linga in summer. The nearest recorded nesting area is on Linga, near the mussel farm east of the island. Large concentrations of breeding birds on nests may cause localised faecal contamination to the waters around the nests as rainfall washes accumulated guano into watercourses and the sea. The two mussel farms near Muckle Roe lie adjacent to farmland that is not used by breeding seabirds and therefore are less likely to be impacted by faecal contamination from this source than the mussel farm at Linga. Direct deposition by birds passing over or through the mussel farms is likely at all three sites and there is no evidence to suggest one might be more affected than the others from this source.

Seals were observed during the shoreline survey along both the east and west extents of the production area. A grey seal breeding colony is located on the western side of Muckle Roe, where they might be expected to spend more time hauled out from September to April when they are either breeding (September to December) or moulting (December to April). Harbour seals are also likely to be present in the area. No haul out areas are located in the near vicinity of the mussel farms, however seals are likely to be present in the waters around the mussel farms on a regular basis and therefore may contribute to background levels of faecal contamination in the area.

Seasonal variation

The area may be subject to some seasonal variation in human population, however there are no significant concentrations of tourist accommodation or attractions in there area. Therefore any variation would be most likely from higher occupation rates of homes already in the area. Agricultural practices vary by season, with sheep kept nearer to crofts, and therefore closer to the shoreline, in winter. Application of fertilisers, including manure and slurry, to arable land would tend to take place in spring and possibly in summer. Numbers of sheep would be higher in summer when lambs are present, however the animals would be more likely to be grazing extensively on the hills during this time and therefore impacts may be spread over a wider area.

Seasonal variation was seen in the sampling results from both sites. At Greentaing, a distinct peak was seen in September in the trend line of results by month. Results > 230 *E. coli* MPN/100 g occurred from August to November. Ten percent of samples from this site exceeded >230 *E. coli* MPN/100 g during the period considered. At Linga, a similar trend was apparent, however results peaked in July. One sample (2%) exceeded 230 *E. coli* MPN/100 g.

Rainfall showed seasonal variation, with the driest weather occurring in June and rainfall increasing steadily from July onward toward the wetter winter months.

Rivers and streams

Relatively few permanent watercourses discharge to the production area. During the shoreline survey, a large number of areas of overland surface flow were seen that would be unlikely to run in drier weather. Of the watercourses sampled, two returned relatively high results and consequently had two of the highest loadings. The watercourse with the highest *E. coli* concentration (800 *E. coli* cfu/100 ml) discharged to sea approximately 500 metres SW of the Buddascord mussel farm. However, it was a relatively small stream with a calculated loading of 1.1 x 10^9 *E. coli*/day. The second watercourse was located approximately 500 metres NW of the Greentaing mussel farm, and though the spot sample taken from it had a lower result (330 *E. coli* cfu/100 ml) due to it's larger size the overall loading was slightly higher than for the other watercourse. Watercourses recorded discharging to shore at Grobs Ness had low calculated loadings based on spot samples taken during the shoreline survey and therefore were not considered to pose a significant risk of contamination to the mussel farm at Linga, which lies over 1km to the west. Overall, the mussel farms along the west side are more likely to be impacted by diffuse contamination carried in watercourses. Of the two western areas, the majority of recorded watercourses were located near the Buddascord site.

Currents

Based on hydrographic assessment, tidal currents in the vicinity of the fisheries are relatively weak but wind driven surface flows can be considerably stronger. Wind direction was found to be a significant driver in both predicted and recorded near surface flows around the production area. However, behaviour of surface flows was considerably different on the east vs. the west side of the island of Linga. Prolonged northerly winds are likely to generate an alongshore current along the western shore of Busta Voe potentially carrying contaminants into the production area at Greentaing. Prolonged southerly winds are likely to generate a counter-clockwise flow between Grobs Ness and Linga, which could bring contaminants arising from the shore along the eastern side of the production area into the Linga mussel farm from the north rather than the south.

Temporal and geographical patterns of sampling results

Results appeared to be slightly higher at Greentaing than at Linga. Greentaing lies adjacent to a more inhabited shoreline, with septic discharges as well as both agricultural and wildlife sources of diffuse contamination. Results >230 *E. coli*

MPN/100 g occurred more often at Greentaing than at Linga. No historical monitoring results were reported from Buddascord, however samples taken during the shoreline survey showed much lower levels of contamination in mussels at this site than at Greentaing. The Greentaing shoreline survey samples showed much higher levels of contamination at the surface than at depth. While this might have suggested that contamination at this site arose at or near the surface, or was carried in more buoyant, lower salinity water at or near the surface. Salinity profiles taken at the same time indicated no significant reduction in surface salinity values at most locations. The only exception was at the north end of the Buddascord mussel lines, where salinity was only slightly reduced. A spot seawater sample taken from this location, however, returned a result of <1 *E. coli* cfu/100 ml. Therefore, surface contamination at this fishery does not appear to be directly related to a reduction in surface salinity.

Overall, the trend of results at both sites over the period assessed was relatively stable and did not appear to be getting better or worse.

Environmental Factors

A significant correlation was found between the Linga common mussel results and both 2- and 7-day preceding rainfall, however the highest results coincided with very rainfall totals. There are no significant watercourses near the mussel farm, and during the shoreline survey when the weather was very wet no salinity reduction was seen in salinity profiles at the mussel farm. A significant correlation was found between Linga common mussel $\log_{10}$ *E. coli* results and the high/low tidal cycle, however no clear patterns were discernible from the data when presented graphically.

No significant correlation was found between Greentaing common mussel *E. coli* results and water temperature, however no results > 230 *E. coli* MPN/100 g occurred at temperatures below 10°C. A significant correlation was found between Greentaing common mussel *E. coli* results and salinity, however no significant correlation was found with rainfall in either the 2- or 7-day period prior to sampling

Conclusions

The mussel farms at Busta Voe Lee South appear to be affected by different potential sources and different movement of sources, based on whether they are located on the east or west side of Linga Island. Overall, contamination levels are low, though monitoring results appeared to be slightly higher on the west side of the production area and, based on shoreline survey samples, slightly higher at Greentaing than at Buddascord. The seasonal pattern in historical monitoring results was broadly similar between the Greentaing and Linga, with highest results in summer. The most important sources of contamination to the fishery appear to be :

- Human contamination sources arising from inhabited areas of shoreline adjacent to the fishery, particularly along the western side of the production area.

- Diffuse agricultural pollution arising from crofted/farmed areas along the shoreline adjacent to the fishery.

- Wildlife sources of diffuse faecal contamination, particularly from nesting seabird, ducks and seals at Linga and from geese at Greentaing and Buddascord.

Overall Risk Table

Factor	Greentaing and Buddascord	Linga
Sewage discharges from private STs	Medium	Low
Rainfall dependent diffuse sources – agriculture	Medium	Low
Wildlife sources	Medium	Low
Seasonal variability	Medium	Medium

16. Recommendations

Production area

Although there are differences in sources and movement of contaminants between the east and west side of the fishery, overall contamination levels are low. However, the northwestern boundary of the Busta Voe Lee South production area overlaps that of the Busta Voe Lee North production area. The recommended production area boundaries are recommended to be the area bounded by lines drawn between HU 3568 3428 and HU 3658 6419 and between HU 3431 6450 and HU 3519 6432 and between HU 3367 6322 and HU 3677 6322 and extending to MHWS. This eliminates the overlap between the two production areas.

RMP

It is recommended that the RMP for be shifted approximately 50 metres southward to place it on the recorded mussel farm site at Greentaing. The recommended RMP is at HU 3438 6425.

Depth of sampling

During shoreline survey sampling, contamination levels appeared to be higher at the surface at Greentaing, therefore it is recommended that samples at this RMP be taken from within the top 1 metre of the lines.

Tolerance

It is recommended that a 40 metre tolerance be allowed for sampling at both RMPs to allow for some movement of the lines.

Frequency

Due to observed seasonal variation in sampling results, monthly sampling is recommended at both RMPs.

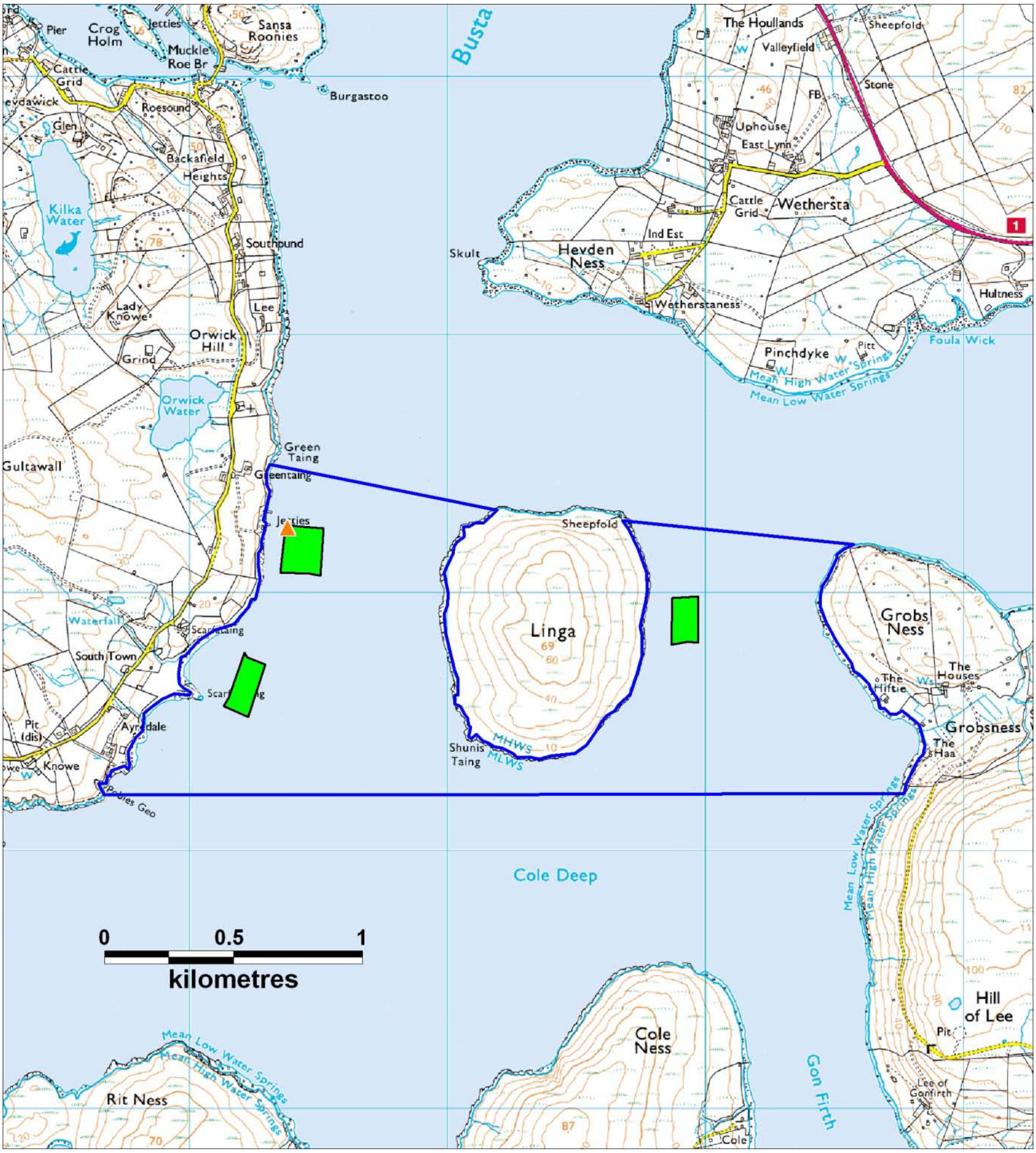

Figure 16.1 Map of recommendations at Busta Voe Lee South

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18. List of Figures and Tables

Figures

Tables

Appendices

1. **General Information on Wildlife Impacts**
2. **Tables of Typical Faecal Bacteria Concentrations**
3. **Statistical Data**
4. **Hydrographic Section Appendices and Glossary**
5. **Shoreline Survey Report**

1. General Information on Wildlife Impacts

Pinnipeds

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

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

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

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

The concentration of *E. coli* and other faecal indicator bacteria contained in seal faeces has been reported as being similar to that found in raw sewage, with counts showing up to 1.21×10^4 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 & 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 (Gauthier & Bedard, 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 National Heritage, n.d.). 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.

Alderisio, K. A. & DeLuca, N., 1999. Seasonal enumeration of fecal coliform bacretia from the feces of ring-billed gulls (Larus delawerensis) and Canada geese (Branta canadensis). *Applied and Environmental Microbiology,* 65(12), pp. 5628-5630.

Gauthier, G. & Bedard, J., 1986. Assessment of faecal output in geese. *Journal of Applied Ecology,* 23(1), pp. 77-90.

Poppe, C. et al., 1998. Salmonella typhimurium DT104: a virulent and drug-resistant pathogen. *The Canadian Veterinary Journal,* 39(9), pp. 559-565.

Scottish National Heritage, n.d. *Otters and Development.* [Online] Available at: http://www.snh.org.uk/publications/on-line/wildlife/otters/biology.asp [Accessed 10 10 2012].

Stoddard, R. A. et al., 2005. Salmonella and Campylobacter spp. in Northern Elephant Seals, California. *Emerging Infections Diseases,* 11(12), pp. 1967-1969.

2. 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, Crowther, et al., Faecal indicator organism in concentration sewage and treated effluents 2008)

Table 3 – Geometric mean (GM) and 95% confidence intervals (CIs) of the GM faecal indicator organism (FIO) concentrations (cfu 100ml$_{-1}$) under base- and high-flow conditions at the 205 sampling points and for various subsets, and results of paired t-tests to establish whether there are significant elevations at high flow compared with base flow

FIO / Subcatchment land use	*n*	**Base Flow** Geometric mean	Lower 95% CI	Upper 95% CI	**High Flow** Geometric mean[a]	Lower 95% CI	Upper 95% CI
Total coliforms							
All subcatchments	205	5.8×10^3	4.5×10^3	7.4×10^3	7.3×10^4**	5.9×10^4	9.1×10^4
Degree of urbanisation							
Urban	20	3.0×10^4	1.4×10^4	6.4×10^4	3.2×10^5**	1.7×10^5	5.9×10^5
Semi-urban	60	1.6×10^4	1.1×10^4	2.2×10^4	1.4×10^5**	1.0×10^5	2.0×10^5
Rural	125	2.8×10^3	2.1×10^3	3.7×10^3	4.2×10^4**	3.2×10^4	5.4×10^4
Rural subcatchments with different dominant land uses							
≥75% Imp pasture	15	6.6×10^3	3.7×10^3	1.2×10^4	1.3×10^5**	1.0×10^5	1.7×10^5
≥75% Rough Grazing	13	1.0×10^3	4.8×10^2	2.1×10^3	1.8×10^4**	1.1×10^4	3.1×10^4
≥75% Woodland	6	5.8×10^2	2.2×10^2	1.5×10^3	6.3×10^3*	4.0×10^3	9.9×10^3
Faecal coliform							
All subcatchments	205	1.8×10^3	1.4×10^3	2.3×10^3	2.8×10^4**	2.2×10^4	3.4×10^4
Degree of urbanisation							
Urban	20	9.7×10^3	4.6×10^3	2.0×10^4	1.0×10^5**	5.3×10^4	2.0×10^5
Semi-urban	60	4.4×10^3	3.2×10^3	6.1×10^3	4.5×10^4**	3.2×10^4	6.3×10^4
Rural	125	8.7×10^2	6.3×10^2	1.2×10^3	1.8×10^4**	1.3×10^4	2.3×10^4
Rural subcatchments with different dominant land uses							
≥75% Imp pasture	15	1.9×10^3	1.1×10^3	3.2×10^3	5.7×10^4**	4.1×10^4	7.9×10^4
≥75% Rough Grazing	13	3.6×10^2	1.6×10^2	7.8×10^2	8.6×10^3**	5.0×10^3	1.5×10^4
≥75% Woodland	6	3.7×10	1.2×10	1.2×10^2	1.5×10^3**	6.3×10^2	3.4×10^3
Enterococci							
All subcatchments	205	2.7×10^2	2.2×10^2	3.3×10^2	5.5×10^3**	4.4×10^3	6.8×10^3
Degree of urbanisation							
Urban	20	1.4×10^3	9.1×10^2	2.1×10^3	2.1×10^4**	1.3×10^4	3.3×10^4
Semi-urban	60	5.5×10^2	4.1×10^2	7.3×10^2	1.0×10^4**	7.6×10^3	1.4×10^4
Rural	125	1.5×10^2	1.1×10^2	1.9×10^2	3.3×10^3**	2.4×10^3	4.3×10^3
Rural subcatchments with different dominant land uses							
≥75% Imp. pasture	15	2.2×10^2	1.4×10^2	3.5×10^2	1.0×10^4**	7.9×10^3	1.4×10^4
≥75% Rough Grazing	13	4.7×10	1.7×10	1.3×10^2	1.2×10^3**	5.8×10^2	2.7×10^3
≥75% Woodland	6	1.6×10	7.4	3.5×10	1.7×10^2**	5.5×10	5.2×10^2

[a] Significant elevations in concentrations at high flow are indicated: **po0.001, *po0.05.

[b] Degree of urbanisation categorised according to percentage built-up land: 'Urban' (X10.0%), 'Semi-urban' (2.5–9.9%) and 'Rural' (o2.5%).

Source: (Kay, Crowther, et al., Faecal indicator organism concentrations and catchment export coefficients in the UK 2008a)

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 x 108
Cow	230,000	23,600	5.4 x 109
Duck	33,000,000	336	1.1 x 1010
Horse	12,600	20,000	2.5 x 108
Pig	3,300,000	2,700	8.9 x 108
Sheep	16,000,000	1,130	1.8 x 1010
Turkey	290,000	448	1.3 x 108
Human	13,000,000	150	1.9 x 109

Source: (Gauthier and Bedard 1986)

3. Statistical Data

One-way ANOVA: LogEC versus Season

Source DF SS MS F P

Season 3 1.278 0.426 1.82 0.161

Error 35 8.168 0.233

Total 38 9.446

S = 0.4831 R-Sq = 13.53% R-Sq(adj) = 6.11%

Individual 95% CIs For Mean Based on

Pooled StDev

Level N Mean StDev ---+---------+---------+---------+------

1 9 1.1313 0.1559 (----------*----------)

2 12 1.6205 0.6438 (--------*--------)

3 9 1.4165 0.4044 (----------*----------)

4 9 1.3301 0.5131 (----------*----------)

---+---------+---------+---------+------

0.90 1.20 1.50 1.80

Pooled StDev = 0.4831

Tukey 95% Simultaneous Confidence Intervals

All Pairwise Comparisons among Levels of Season

Individual confidence level = 98.92%

Season = 1 subtracted from:

Season Lower Center Upper -------+---------+---------+---------+--

2 -0.0848 0.4891 1.0630 (-----------*----------)

3 -0.3284 0.2851 0.8987 (------------*-----------)

4 -0.4148 0.1988 0.8123 (-----------*-----------)

-------+---------+---------+---------+--

-0.50 0.00 0.50 1.00

Season = 2 subtracted from:

Season Lower Center Upper -------+---------+---------+---------+--

3 -0.7779 -0.2040 0.3699 (-----------*----------)

4 -0.8643 -0.2904 0.2835 (----------*-----------)

-------+---------+---------+---------+--

-0.50 0.00 0.50 1.00

Season = 3 subtracted from:

Season Lower Center Upper -------+---------+---------+---------+--

4 -0.6999 -0.0864 0.5272 (-----------*------------)

-------+---------+---------+---------+--

-0.50 0.00 0.50 1.00

One-way ANOVA: logEC versus location_1

Source DF SS MS F P

```
location_1   2   0.635  0.318  1.03  0.363
Error       79  24.462  0.310
Total       81  25.097

S = 0.5565   R-Sq = 2.53%   R-Sq(adj) = 0.06%

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev   -+---------+---------+---------+--------
1      10  1.3265  0.4925   (----------------*-----------------)
2      34  1.5550  0.6239                   (---------*--------)
3      38  1.3965  0.5049             (--------*--------)
                            -+---------+---------+---------+--------
                           1.00      1.20      1.40      1.60

Pooled StDev = 0.5565

Grouping Information Using Tukey Method

location_1   N    Mean  Grouping
2           34  1.5550  A
3           38  1.3965  A
1           10  1.3265  A

Means that do not share a letter are significantly different.
```

Tukey 95% Simultaneous Confidence Intervals

All Pairwise Comparisons among Levels of location_1

Individual confidence level = 98.08%

location_1 = 1 subtracted from:

```
location_1    Lower  Center   Upper  ------+---------+---------+---------+---
2          -0.2499  0.2285  0.7070        (---------------*---------------)
3          -0.4026  0.0700  0.5427    (--------------*---------------)
                                     ------+---------+---------+---------+---
                                         -0.30      0.00      0.30      0.60
```

location_1 = 2 subtracted from:

```
location_1    Lower   Center   Upper  ------+---------+---------+---------+---
3          -0.4724  -0.1585  0.1555  (----------*---------)
                                      ------+---------+---------+---------+---
                                          -0.30      0.00      0.30      0.60
```

4. Hydrographic Assessment 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.

MHW. Mean High Water, The highest level that tides reach on average.

MHWN. Mean High Water Neep, The highest level that tides reach on average during neep tides.

MHWS. Mean High Water Spring, The highest level that tides reach on average during spring tides

MLW. Mean Low Water, The lowest level that tides reach on average.

MLWN. Mean Low Water Neep, The lowest level that tides reach on average during neep tides.

MLWS. Mean Low Water Spring, The lowest level that tides reach on average during spring tides.

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. Spring tides occur during or just after new moon and full moon when the tide-generating force of the sun acts in the same direction as that of the moon, reinforcing it. The tidal range is greatest and tidal currents strongest during spring tides.

Neep tides occur during the first or last quarter of the moon when the tide-generating forces of the sun and moon oppose each other. The tidal range is smallest and tidal currents are weakest during neep 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. A surface flow at the surface may be accompanied by a compensating flow in the opposite direction at the bed.

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.

5. Shoreline Survey Report

Shoreline Survey Report

Production Area:	Busta Voe Lee South
Site Names:	Linga Greentaing Buddascord
SIN:	Linga – SI 328 411 08 Greentaing – SI 328 767 08 Buddascord – SI 328 936 08
Species:	Common Mussel
Harvesters:	Blueshell Mussels Ltd. – Michael Laurenson (Linga) Northmaven Marine Ltd. – Addie Doull (Greentaing & Buddascord)
Local Authority:	Shetland Islands Council
Status:	Existing area
Dates surveyed:	7 & 8 November 2012
Surveyed By:	Michelle Price-Hayward (Cefas) Liefy Hendrikz (Cefas, observer) Sean Williamson (Hall Mark Meat Hygiene Ltd.) Vicki Smith (SSQC Ltd.) Alan Harpin (SSQC Ltd.) We are grateful to Blueshell Mussels for providing a boat and employee for assistance during the marine survey work.
Existing RMP:	Linga – HU 3580 6390 Greentaing – HU 3440 6430 Buddascord – No sampling
Area Surveyed:	See Figure 1

Specific observations made on site are mapped in Figure 1 and listed in Table 1. Water and shellfish samples were collected at fisheries 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 4-19.

Weather

Wednesday 7 November 2012

Rain present throughout the day ranging from a period of light rain in the morning intermittent with heavy rain for brief spells. Afternoon through to evening saw persistent rain showers. Wind built to a strong (F6) westerly breeze in the morning which persisted until early afternoon before easing into the evening.

Thursday 8 November 2012

Overcast conditions were present throughout the morning with conditions improving into the afternoon with intermittent sunny spells. A gentle F3 east south-easterly breeze dominated the day.

Preceding the survey, Monday saw rain showers continue throughout the daylight hours easing at night with north-west to northerly winds increasing from F2 to F4 over the course of the day. Tuesday saw the rain persist in the early hours before a dryer period during the day with the rain starting again in the evening. A west to north-westerly wind eased throughout the day from F6 to F2.

Fishery

The location of the mussel lines at the three fisheries assessed in the Busta Voe Lee South production area are mapped in Figure 1. All three fisheries had stocked mussel lines on site at the time of the fieldwork.

Greentaing (SI 328 767 08): The fishery consisted of seven mussel lines running parallel to the shoreline (Figure 4). All lines were double headed long lines with 10-15 metre droppers. Two mussel samples were collected from the north end of site one from the top of a mussel line and a one from a sampling basket present on site at a depth of 8 metres. Two mussel samples were collected from the south end of site taken from the top and bottom of a mussel line at a depth of 10 metres.

Buddascord (SI 328 936 08): The fishery consisted of seven mussel lines running parallel to the shoreline (Figure 5). All lines were double headed long lines with 10 metre droppers. Harvesting at the site was taking place during the fieldwork on the furthest west line closest to the shoreline. Two mussel samples were collected from the south end of site taken from the top and bottom of a mussel line at a depth of 10 metres.

Linga (SI 328 411 08): The fishery consisted of six mussel lines running parellel to the eastern shoreline of the island of Linga (Figure 6). All lines were double headed tubular lines with 15 metre droppers. Two mussel samples were collected from the north end of site (north east corner buoy) taken from the top and bottom of a mussel line at a depth of 15 metres.

Maximum permissible number of lines at each fishery are fifteen at Greentaing, twelve at Buddascord and nine at Linga.

Sewage/Faecal Sources

Human - Six occupied dwellings were identified on the western shoreline on the island of Muckle Roe, individual properties were quite evenly spaced along the shoreline with no clustering of houses. Of the six dwellings two were associated with farm buildings. Only two dwellings had been highlighted in the survey plan as being consented discharges. A septic tank was identified for one of the dwelling houses (Figure 10) but the others could not be identified. A portacabin was present at a shorebase directly opposite the Greentaing fishery which had a visible discharge pipe into the sea (Figure 13). The eastern shoreline at Grobsness had only one dwelling house which was some distance from the shoreline and had been highlighted in the survey plan as being a consented discharge. The island of Linga which is located centrally in the Busta Voe Lee South production area is uninhabited and is only used for grazing of sheep.

Eight pipes were identified along the western shoreline during the survey. Seven of the pipes were thought to be associated with land drainage and one was connected to the portacabin at the Greentaing shorebase most likely discharging sanitary waste. Water samples were only taken from two pipes as the other pipes had little or no water discharge or the end of the pipe was not accessible.

A seawater sample was taken in the vicinity of where a pipe was discharging directly into the sea between the Greentaing and Buddascord fisheries (Figure 12). As the end of the pipe was not visible the sample was taken in the water surrounding the pipe. Again this was considered to be land drainage.

A large black pipe which was discharging onto rock armouring at the jetty next to the Greentaing fishery was sampled for flow rate and *E-coli* (Figure 14). The pipe came down a steep escarpment from a field above where the fast flowing water was held before being transported out through another pipe into the jetty.

Sample analysis

Freshwater samples from three watercourses were obtained on the western shoreline (Figure 8, 11 & 15) along with two additional locations not outlined in the plan; at agricultural buildings near Ayredale (Figure 7) and from the discharge pipe at the shore adjacent to the Greentaing fishery. Three of the samples had low *E.coli* levels of between 38 to 90 cfu/100ml. The two locations with elevated *E.coli* counts were from a sample obtained from a large watercourse connected to Orwick Waters (330 cfu/100ml) and the other was taken from a drain adjacent to agricultural buildings near Ayredale (800 cfu/100ml). On the eastern shoreline freshwater samples were obtained from three small watercourses for which *E.coli* levels ranged from 4 to 23 cfu/100ml.

One seawater sample was taken from near where a discharge pipe entered the sea between the Buddascord and Greentaing fisheries, this returned a result of 37 *E.coli* cfu/100ml.

E.coli levels in the six seawater samples taken from the north and south ends of the three mussel sites ranged from < 1 to 4 cfu/100ml.

Four mussel samples were obtained from the Greentaing fishery, two from the north end and two from the south end of the site. The samples from the north end of the site were taken from the RMP position, the surface sample taken from the top of a mussel line returned a high count of 2.4×10^3 *E.coli* MPN/100g with the second sample taken from the RMP sampling basket located at a depth of 8 metres giving a lower count of 110 *E.coli* MPN/100g. At the south end of the site both samples were obtained from a mussel line with the surface sample giving a result of 330 *E.coli* MPN/100g and 50 *E.coli MPN*/100g for the bottom sample at a depth of approximately 10m.

Two mussel samples were obtained from the south end of the Buddascord fishery. Samples were taken from the top and bottom (depth 10m) of a mussel line returning levels of 20 *E.coli* MPN/100g and 50 *E.coli* MPN/100g respectively.

Two mussel samples were obtained from the north end of the Linga fishery. Samples were taken from the top and bottom (depth 15m) of a mussel line returning levels of < 20 *E.coli* MPN/100g and 130 *E.coli* MPN/100g respectively.

E.coli levels were highest at the Greentaing fishery with a decrease in *E.coli* found in the mussel tissue in the surface sample compared with the sample taken at a depth of 8 metres. *E.coli* levels were found to be lower at the southern end of the Greentaing site compared with the northern end of the site. At the Linga and Buddascord fisheries the surface mussel sample had lower *E.coli* counts than those taken from depth. Linga had a lower surface sample *E.coli* count than Buddascord however Buddascord had a lower bottom sample *E.coli* count than Linga.

Six salinity profiles were collected at the three fisheries, with 5 of the 6 profiles obtained showing < 0.1 ppt change in salinity from 10 metres to the surface which is within the accuracy of the probe used (± 0.35 ppt). The salinity profile taken from the north of the Buddascord site showed the greatest difference in salinity with a difference of 0.37 ppt from 10 metres to surface. Most profiles showed a trend of a slight increase in salinity with decreasing depth although the range of these readings were within the accuracy level reported by the probe.

Salinities of the seawater samples analysed at the laboratory showed salinities ranging from 34.99-35.27 ppt. A slightly lower salinity was recorded at the surface of the profile taken from the north end of the Buddascord site which corresponded with the laboratory result for the salinity of the seawater sample collected from the same area. Temperature profiles showed little change from 10m depth to the surface with 3 of the 6 profiles showing no change and the other 3 profiles showing a slight increase in temperature (0.1-0.2°C) from 10m to the surface.

The salinity of the seawater sample taken in the vicinity of the end of a discharge pipe entering the sea between the Buddascord and Greentaing fisheries was below full strength seawater (32.14 ppt). This would indicate the influence of freshwater input most likely from the water discharging from the pipe.

Seasonal population

There are two known guest houses on the island of Muckle Roe but neither are in the area where the shoreline survey for the Busta Voe Lee South area was conducted. All houses identified on the shoreline survey route were assumed to be dwelling houses.

Boats/Shipping

Most boat traffic in the Busta Voe Lee South area is associated with aquaculture, either salmon farming or mussel farming. There a number of mussel and salmon farms in the surrounding area both north and south of the production area with the main shorebase for Blueshell Mussels Ltd., the largest mussel farming company in Shetland, located north of the area where they moor a number of large and small workboats. There was a jetty adjacent to the Greentaing fishery which is owned by Northmaven Marine. The jetty is used by the company as a shorebase with small workboats moored here used for servicing their sites (Greentaing and Buddascord). A large workboat was present at the Buddascord fishery, harvesting mussels on the day of the shoreline survey.

Farming and Livestock

The land on the western shoreline was a mix of rough grazing, silage fields and improved grazing land. Approximately 40 sheep and sheep droppings were present at the start of the survey with another 6 sheep noted in a field at the south end of the Buddascord fishery. Towards the end of the shoreline survey sheep droppings were observed before 40 sheep were found grazing on improved grazing land. None of these animals had access to the foreshore as they were either fenced in or steep escarpments prevented access to the shore. Cow faecal matter was present in fields above the Buddascord and Greentaing fisheries but no animals were observed, fences again would have prevented these animals from accessing the shore.

On the eastern shoreline all the land was rough grassland with sheep droppings and sheep present at the start of the survey route. Approximately 50 sheep were observed on the hill above the shoreline with animals having access to the foreshore. No sheep were observed on Linga at the time of the survey but the island of Linga is known to be used for grazing of sheep.

Farm buildings were present next to a dwelling house near Ayredale. A drain coming from the buildings was tested for *E.coli* and flow rate, with an agricultural plot used to grow crops present adjacent to the drain, however no crops were being grown there at the time of the survey. Farm out buildings next to an occupied property were observed near Scarfataing.

Land Use and Land Cover

Rough grassland dominated both eastern and western shorelines of the production area and on the island of Linga. On the western shoreline silage fields were noted four times from the start of the route to the Buddascord fishery. Two silage fields were also observed further north near the Greentaing fishery. Improved grazing land was observed once at the end of the western shoreline route.

The western shoreline route was characterised by undulating landscape alternating between steep cliffs and escarpments with no access to the foreshore, to lowland areas where access to the foreshore was possible. Grazing varied between open grazing to areas where the animals had been fenced in.

The eastern shore was similar with the route starting at the bottom of a steep hill on the foreshore before the intertidal zone narrowed and the escarpments heightened limiting access to the foreshore. Open grazing was present on this shoreline with no evidence of fencing.

Due to the persistent rainfall in days preceding the shoreline survey there was a number of wet marsh like areas above the shoreline which sometimes caused temporary streams to form. The land on the eastern shoreline was sometimes more sphagnum moss due to the water runoff from the land.

Watercourses

Due to the heavy rain encountered in previous days all the watercourses and streams were in full flow with a number of temporary streams or marshy areas formed as a result. Three watercourses originating from above the road were sampled along the western shoreline with the largest coming from Orwick Water a large loch at the end of the survey route (Figure 15).

There was one major watercourse on the eastern shoreline leading to the beach with an occupied property present upstream (Figure 16). The other two watercourses tested were much smaller, draining through the vegetation (Figure 17, 18 & 19). There were a number of temporary streams and areas with land run off which were noted.

Wildlife/Birds

On the western shoreline gulls and cormorants were seen on the floats of the Pobies Geo and Buddascord fisheries. Geese were seen flying north at the beginning of the survey in the Knowe area near the Pobie Geo site. Goose droppings were also observed on four separate occasions in fields above the shorelines near the Buddascord and Greentaing fisheries and in a field further north down from Orwick

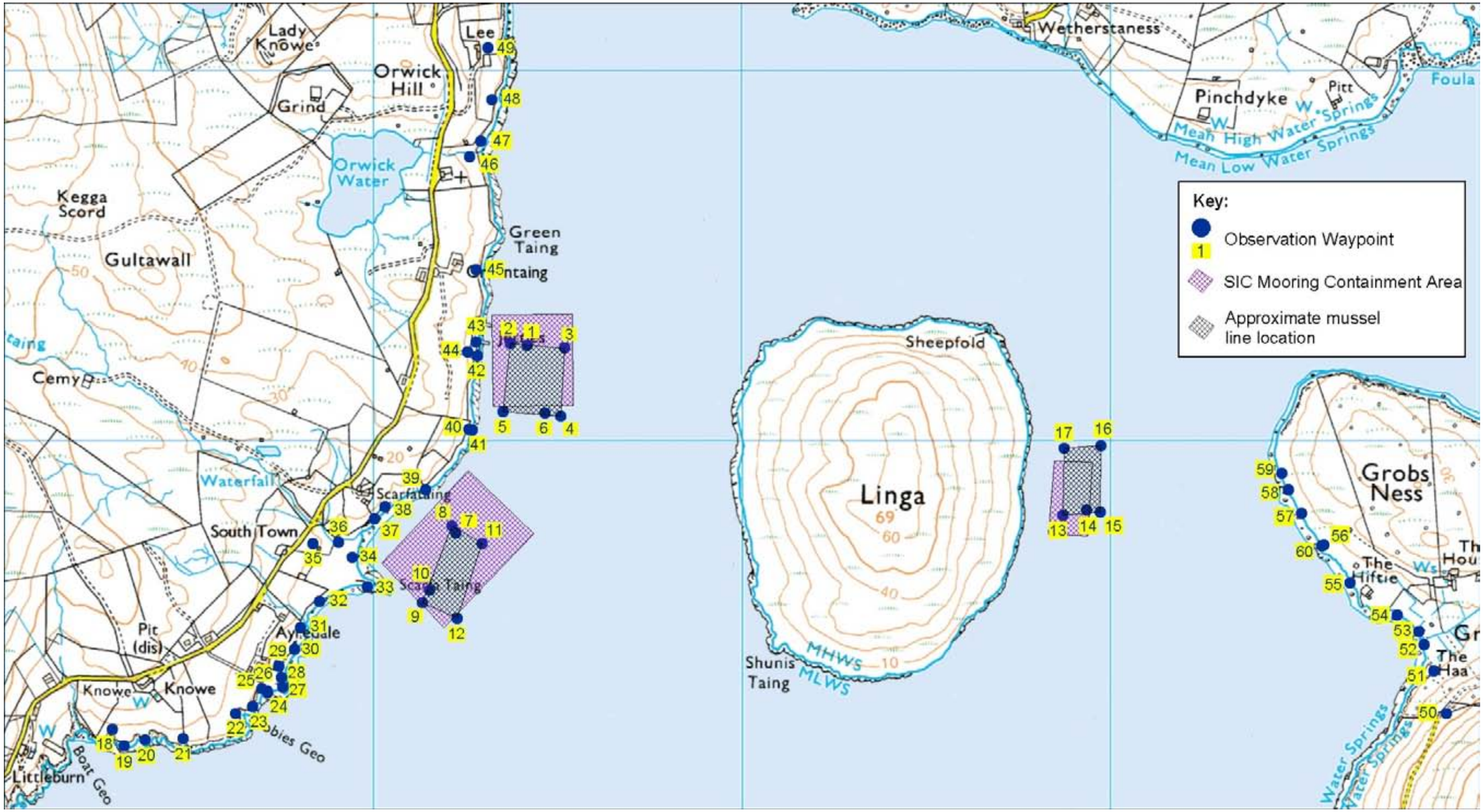
Hill. Scarfataing point looked to be a feeding ground for birds as mussel shells and fragments of sea urchin tests were present in high numbers (Figure 9). A seal was noted close to the shore at the Buddascord fishery and another two seals were observed in the water near the large watercourse coming down from Orwick Waters.

On the eastern shoreline seals were present in the waters for the majority of the shoreline survey with numbers increasing up to five in total towards the end of the route. An otter was seen running down the beach to the water. Two gulls were seen in the water and a heron was seen taking flight from the foreshore near the end of the survey route.

General observations

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

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



Produced by SSQC Ltd.

Figure 1 Map of shoreline observations

Table 1 Shoreline observations

No.	Date/Time (UT)	NGR	Easting	Northing	Associated Photograph	Associated Sample	Description
1	07/11/2012 09:41	HU 34418 64257	434418	1164257	Figure 4	BVLSMUSS01 (top), BVLSMUSS02 (bottom), BVLS-SW01	At northern end of the Busta Voe Lee South area. North end of the Greentaing site, 7x double header long lines. Droppers 10-15m. Salinity Profile 1 collected (ppt/°C): 10m 35.12/9.0, 5m 35.04/8.8, 3m 35.03/8.8, surface 35.03/8.9. Mussels collected from end of 3rd line in from the west, surface sample collected from the top of a mussel line, bottom sample collected from RMP sampling basket at a depth of 8m. Seawater sample collected.
2	07/11/2012 09:53	HU 34372 64263	434372	1164263			NW corner of Greentaing site
3	07/11/2012 09:55	HU 34520 64249	434520	1164249			NE corner of Greentaing site
4	07/11/2012 09:56	HU 34508 64065	434508	1164065			SE corner of Greentaing site
5	07/11/2012 09:57	HU 34353 64077	434353	1164077			SW corner of Greentaing site
6	07/11/2012 10:01	HU 34466 64073	434466	1164073		BVLSMUSS03 (top), BVLSMUSS04 (bottom), BVLS-SW02	South end of Greentaing site. Salinity Profile 2 collected (ppt/°C): 10m 35.06/8.9, 5m 35.04/8.9, 3m 35.02/8.9, surface 35.01/8.9. Mussels collected from end of 5th line in from the west, surface sample collected from the top of a mussel line, bottom sample collected from bottom of mussel line. Seawater sample collected.
7	07/11/2012 10:12	HU 34224 63749	434224	1163749	Figure 5	BVLS-SW03	North end of Buddascord site, 7x double header long lines. Droppers 10m. Seawater sample collected from end of 2nd line in from the west. Salinity profile 3 collected (ppt/°C): 10m 35.14/9.1, 5m 35.10/9.0, 3m 34.94/8.9,

No.	Date/Time (UT)	NGR	Easting	Northing	Associated Photograph	Associated Sample	Description
							surface 34.77/8.9.
8	07/11/2012 10:19	HU 34213 63768	434213	1163768			NW corner of Buddascord site
9	07/11/2012 10:20	HU 34133 63560	434133	1163560			SW corner of Buddascord site
10	07/11/2012 10:22	HU 34154 63593	434154	1163593		BVLSMUSS05 (top), BVLSMUSS06 (bottom), BVLS-SW04	South end of Buddascord site. Samples collected from 16th buoy in from end line nearest the Muckle Roe shoreline to the west, boat was harvesting at site at the same time. Mussel samples collected from surface and bottom of line (10m). Seawater sample collected. Salinity profile 4 collected (ppt/°C): 10m 35.10/9.0, 5m 35.06/9.0, 3m 35.04/8.9, surface 35.06/8.9.
11	07/11/2012 10:32	HU 34295 63720	434295	1163720			NE corner of Buddascord site
12	07/11/2012 10:33	HU 34228 63518	434228	1163518			SE corner of Buddascord site
13	07/11/2012 10:38	HU 35870 63797	435870	1163797			SW corner of Linga site
14	07/11/2012 10:39	HU 35934 63810	435934	1163810	Figure 6	BVLS-SW05	South end of Linga site, 6x double header long lines. Tubular lines, droppers 15m. Seawater sample collected from end of 4th line in from the west. Salinity profile 5 collected (ppt/°C): 10m 35.02/9.0, 5m 35.05/9.0, 3m 35.06/9.0, surface 35.06/9.0.
15	07/11/2012 10:43	HU 35971 63806	435971	1163806			SE corner of Linga site
16	07/11/2012 10:45	HU 35973 63984	435973	1163984		BVLSMUSS07 (top), BVLSMUSS08	NE corner of Linga site. Samples collected from NE corner buoy. Mussel samples collected from surface and bottom of line

No.	Date/Time (UT)	NGR	Easting	Northing	Associated Photograph	Associated Sample	Description
						(bottom), BVLS-SW06	(15m). Seawater sample collected. Salinity profile 6 collected (ppt/°C): 10m 35.10/9.0, 5m 35.06/9.0, 3m 35.06/9.0, surface 35.06/9.0.
17	07/11/2012 10:57	HU 35873 63978	435873	1163978			NW corner of Linga site
18	08/11/2012 09:50	HU 33293 63217	433293	1163217			Silage field, gulls and cormorants present on floats at Pobies Geo site.
19	08/11/2012 09:52	HU 33325 63172	433325	1163172			Overlooking Pobies Geo site, 5 geese observed in flight. (Locational accuracy of GPS +/-4m)
20	08/11/2012 09:55	HU 33382 63188	433382	1163188			Rough grazing, sheep droppings present. 23 sheep observed above shoreline track in fenced area not accessible to shore. 17 sheep observed in field directly above shoreline however access to the shoreline would be prohibited due to the steep cliffs.
21	08/11/2012 09:59	HU 33486 63192	433486	1163192			10 geese observed in flight, 1 seal observed in the water.
22	08/11/2012 10:08	HU 33627 63260	433627	1163260			White perforated pipe with small water discharge to cliff edge. Most likely land drainage as no houses in close proximity. Field above pipe used for silage. Water clear, white foam and brown microbial mat present but no algal scum present. Not enough water flowing to sample.
23	08/11/2012 10:15	HU 33673 63279	433673	1163279			Black perforated pipe underground can see water discharging down cliff edge but can't see end of pipe. Water looks clear and fast flowing. Suspected land drainage, unable to sample as could not access end of pipe.

No.	Date/Time (UT)	NGR	Easting	Northing	Associated Photograph	Associated Sample	Description
24	08/11/2012 10:20	HU 33714 63317	433714	1163317			Two drains observed, one coming down from field and one from agricultural buildings, join together further down to make one drain. A lot of vegetation around drainage area, waypoint taken from where watercourse meets shoreline.
25	08/11/2012 10:25	HU 33698 63327	433698	1163327	Figure 7	BVLSFW01	Waypoint from where freshwater sample was taken from above mentioned watercourse; width 18 cm, depth 5 cm, Flow 0.184 m/s st. dev. 0.049 m/s. Flow rate recorded downstream. Watercourse to south of agricultural buildings.
26	08/11/2012 10:29	HU 33712 63322	433712	1163322			Small agricultural plot next to watercourse where crops have been grown previously.
27	08/11/2012 10:30	HU 33755 63330	433755	1163330			Overlooking Buddascord fishery with harvesting boat on site.
28	08/11/2012 10:32	HU 33751 63358	433751	1163358			Ditch leading to shore, ground wet but no visible water running, coming down from north end of an agricultural shed.
29	08/11/2012 10:36	HU 33744 63388	433744	1163388			Occupied property above shoreline but unable to locate septic tank.
30	08/11/2012 10:38	HU 33787 63434	433787	1163434			Water discharging to shore through large black pipe, most likely to be land drainage. Silage field above shoreline. Water has slight brown colouration but no smell. Water flow quite fast, white foam present and red bacterial film present at end of pipe. Flow measured using 7 litre bucket. Time to fill bucket 7.5/7.5/7.0 seconds.
31	08/11/2012 10:50	HU 33803 63493	433803	1163493	Figure 8	BVLSFW02	Watercourse running through field vegetation to the shoreline as waterfall down cliff edge.

No.	Date/Time (UT)	NGR	Easting	Northing	Associated Photograph	Associated Sample	Description
							Occupied property above shoreline but unable to locate septic tank. No smell coming from watercourse. Freshwater sample taken and flow rate measured; width 17 cm, depth 12 cm, Flow 0.167 m/s st. dev. 0.027 m/s.
32	08/11/2012 10:57	HU 33854 63564	433854	1163564			Marsh area above shore draining to stony beach.
33	08/11/2012 11:01	HU 33985 63603	433985	1163603	Figure 9		Scarfataing point, mussel shells and sea urchin carcasses present in large numbers most likely brought ashore by birds to feed on. Photo of Buddascord mussel site, boat on site harvesting.
34	08/11/2012 11:06	HU 33944 63682	433944	1163682			Six sheep observed in a fenced area not accessible to the shore. One seal also observed in the water close to the shore.
35	08/11/2012 11:09	HU 33837 63720	433837	1163720	Figure 10		Septic tank of an occupied property on hill above shoreline. Soak away was to the field below.
36	08/11/2012 11:12	HU 33906 63724	433906	1163724	Figure 11	BVLSFW03	Large watercourse running downhill by the occupied property. Freshwater sample and flow rate measured; width 70 cm, depth 18 cm, Flow 0.437 m/s st. dev. 0.031 m/s.
37	08/11/2012 11:18	HU 34004 63788	434004	1163788			Pipe observed draining to cliff, very small water flow and water was clear. Occupied property above shoreline, no septic tank identified. Field above shoreline used for silage.
38	08/11/2012 11:22	HU 34033 63820	434033	1163820			Drainage through field, very small flow through vegetation, found below occupied property farm out buildings.

No.	Date/Time (UT)	NGR	Easting	Northing	Associated Photograph	Associated Sample	Description
39	08/11/2012 11:25	HU 34142 63866	434142	1163866			Bovine faeces present in field. Four seagulls observed on floats of mussel lines of Buddascord site. Goose droppings present in field.
40	08/11/2012 11:31	HU 34260 64030	434260	1164030	Figure 12	BVLS-SW07	Pipe running into sea from field above shoreline, newer plastic pipe at top and old metal pipe at the bottom. Small pipe in vertical position mid-way along, very little water flowing through the pipe, fairly clear water. Leak from pipe near the land. Field above was very wet. End of the pipe not visible so sea water sample taken in the vicinity where the pipe entered the water.
41	08/11/2012 11:36	HU 34268 64027	434268	1164027			Bovine faeces and goose droppings in the field around the water pipe.
42	08/11/2012 11:48	HU 34283 64228	434283	1164228	Figure 13		Discharge pipe from the portacabin/shed at the jetty most likely human waste. Photo from the breakwater.
43	08/11/2012 11:52	HU 34280 64266	434280	1164266	Figure 14	BVLSFW04	Land drainage to jetty, large black pipe coming down steep escarpment to holding area before being transported along another pipe out onto the rocks surrounding the jetty. Fast flowing water, brown in colour, white foam present in holding area. Freshwater sample taken. Flow rate of water recorded using 7 litre bucket. Time to fill bucket 4.0/4.5/4.0 seconds.
44	08/11/2012 12:05	HU 34257 64239	434257	1164239			Silage field above pipe with goose droppings present.
45	08/11/2012 12:09	HU 34279 64461	434279	1164461			Occupied property above the shore, unidentified septic tank but registered as consented discharge. Silage field below the

No.	Date/Time (UT)	NGR	Easting	Northing	Associated Photograph	Associated Sample	Description
							house, no discharge observed from a pipe seen at the cliff edge.
46	08/11/2012 12:22	HU 34262 64767	434262	1164767	Figure 15	BVLSFW05	Large watercourse running downhill. Freshwater sample and flow rate measured; width 70 cm, depth 12 cm, Flow 0.297 m/s st. dev. 0.008 m/s. Photos taken up and down stream. Two seals observed in the water.
47	08/11/2012 12:26	HU 34292 64810	434292	1164810			Sheep droppings present. Rough grazing.
48	08/11/2012 12:31	HU 34322 64922	434322	1164922			Goose droppings.
49	08/11/2012 12:34	HU 34312 65062	434312	1165062			Occupied house and church, registered discharges. Approximately 40 sheep in field above shoreline. Improved grazing land.
50	08/11/2012 13:53	HU 36909 63259	436909	1163259			Overlooking Grobsness area, sheep droppings in the field above the shoreline. (Accuracy of GPS +/-3m).
51	08/11/2012 13:59	HU 36876 63375	436876	1163375			Approximately 50 sheep observed on the hill with access to the shore. One seal observed in the water. Sheep droppings present. Stony beach at the bottom of the hill.
52	08/11/2012 14:03	HU 36849 63446	436849	1163446	Figure 16	BVLSFW06	Burn leading to beach. Occupied property upstream, some distance from shore. Freshwater sample taken and flow rate measured; width 45 cm, depth 13 cm, Flow 0.191 m/s st. dev. 0.027 m/s. Two seals in the water.
53	08/11/2012 14:09	HU 36835 63481	436835	1163481			Drainage ditch, boggy area. Rough grazing.
54	08/11/2012 14:11	HU 36776 63527	436776	1163527			Otter observed running down the beach to the water. Three seals in the water.

No.	Date/Time (UT)	NGR	Easting	Northing	Associated Photograph	Associated Sample	Description
55	08/11/2012 14:19	HU 36649 63614	436649	1163614	Figure 17	BVLSFW07	Burn drainage to beach through vegetation. Freshwater sample obtained and flow rate measured; width 20 cm, depth 12 cm, Flow 0.144 m/s st. dev. 0.005 m/s. Two gulls observed in the water.
56	08/11/2012 14:28	HU 36577 63717	436577	1163717	Figure 18		Water draining over the land from the hill, through vegetation. Temporary stream. Land more sphagnum moss, boggy.
57	08/11/2012 14:31	HU 36516 63802	436516	1163802			Water runoff from land, temporary stream.
58	08/11/2012 14:33	HU 36482 63865	436482	1163865			Water runoff from land, temporary burn. Heron seen taking flight from the shore.
59	08/11/2012 14:34	HU 36463 63910	436463	1163910			Water runoff from the land.
60	08/11/2012 14:44	HU 36571 63714	436571	1163714	Figure 19	BVLSFW08	Returned to stream (Obsv 56) to take freshwater sample. Not possible to estimate the flow rate as no suitable area to test. Lots of vegetation and rocks. Took depth and width of watercourse seen in the associated photo; width 40 cm, depth 4 cm.

Sampling

Water and shellfish samples were collected at the locations indicated in Figures 2 and 3. As well as those defined in the survey plan one additional seawater sample was collected from the seawater surrounding a pipe discharging directly into the sea, as the end of the pipe was not visible. Two additional freshwater samples were collected during the western shoreline walk, one sampled from a drain coming down from agricultural buildings near Ayredale and the other from a pipe discharging a large volume of water into the jetty adjacent to the Greentaing fishery. All samples were transported initially by a cool backpack and then in a cool box to SSQC Ltd. for analysis on the same day.

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

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

Table 2 Water sample *E. coli* results

No.	Sample Ref.	Date/Time	Position	Type	*E.coli* (cfu/100ml)	Salinity*
1	BVLS-SW01	07/11/2012 09:42	HU 34418 64257	Sea Water	4	35.08
2	BVLS-SW02	07/11/2012 10:02	HU 34466 64073	Sea Water	2	35.12
3	BVLS-SW03	07/11/2012 10:12	HU 34224 63749	Sea Water	< 1	34.99
4	BVLS-SW04	07/11/2012 10:22	HU 34154 63593	Sea Water	< 1	35.17
5	BVLS-SW05	07/11/2012 10:39	HU 35934 63810	Sea Water	1	35.07
6	BVLS-SW06	07/11/2012 10:46	HU 35973 63984	Sea Water	1	35.27
7	BVLSFW01	08/11/2012 10:25	HU 33698 63327	Fresh Water	800	-
8	BVLSFW02	08/11/2012 10:50	HU 33803 63493	Fresh Water	80	-
9	BVLSFW03	08/11/2012 11:12	HU 33906 63724	Fresh Water	38	-
10	BVLS-SW07	08/11/2012 11:36	HU 34268 64027	Sea Water	37	32.14
11	BVLSFW04	08/11/2012 11:52	HU 34280 64266	Fresh Water	90	-
12	BVLSFW05	08/11/2012 12:22	HU 34262 64767	Fresh Water	330	-
13	BVLSFW06	08/11/2012 14:03	HU 36849 63446	Fresh Water	16	-
14	BVLSFW07	08/11/2012 14:19	HU 36649 63614	Fresh Water	4	-
15	BVLSFW08	08/11/2012 14:44	HU 36571 63714	Fresh Water	23	-

*Practical Salinity Scale 1978 (PSS-78)

Table 3 Shellfish sample *E. coli* results

No.	Sample Ref.	Date/Time	Position	Type	Depth	*E.coli* (MPN/100g)
1	BVLSMUSS01	07/11/2012 09:41	HU 34418 64257	Common Mussel	Top	$2.4x10^3$
2	BVLSMUSS02	07/11/2012 09:41	HU 34418 64257	Common Mussel	Bottom	110
3	BVLSMUSS03	07/11/2012 10:01	HU 34466 64073	Common Mussel	Top	330
4	BVLSMUSS04	07/11/2012 10:01	HU 34466 64073	Common Mussel	Bottom	50
5	BVLSMUSS05	07/11/2012 10:22	HU 34154 63593	Common Mussel	Top	20
6	BVLSMUSS06	07/11/2012 10:22	HU 34154 63593	Common Mussel	Bottom	50
7	BVLSMUSS07	07/11/2012 10:45	HU 35973 63984	Common Mussel	Top	< 20
8	BVLSMUSS08	07/11/2012 10:45	HU 35973 63984	Common Mussel	Bottom	130

Table 4 Salinity profiles

Profile	Date/Time	Position	Depth (m)	Salinity (ppt) (± 0.35 ppt)	Temperature (°C)
1	07/11/2012 09:42	HU 34418 64257	surface	35.03	8.9
			3	35.03	8.8
			5	35.04	8.8
			10	35.12	9.0
2	07/11/2012 10:02	HU 34466 64073	surface	35.01	8.9
			3	35.02	8.9
			5	35.04	8.9
			10	35.06	8.9
3	07/11/2012 10:12	HU 34224 63749	surface	34.77	8.9
			3	34.94	8.9
			5	35.10	9.0
			10	35.14	9.1
4	07/11/2012 10:22	HU 34154 63593	surface	35.06	8.9
			3	35.04	8.9
			5	35.06	9.0
			10	35.10	9.0
5	07/11/2012 10:39	HU 35934 63810	surface	35.06	9.0
			3	35.06	9.0
			5	35.05	9.0
			10	35.02	9.0
6	07/11/2012 10:46	HU 35973 63984	surface	35.06	9.0
			3	35.06	9.0
			5	35.06	9.0
			10	35.10	9.0

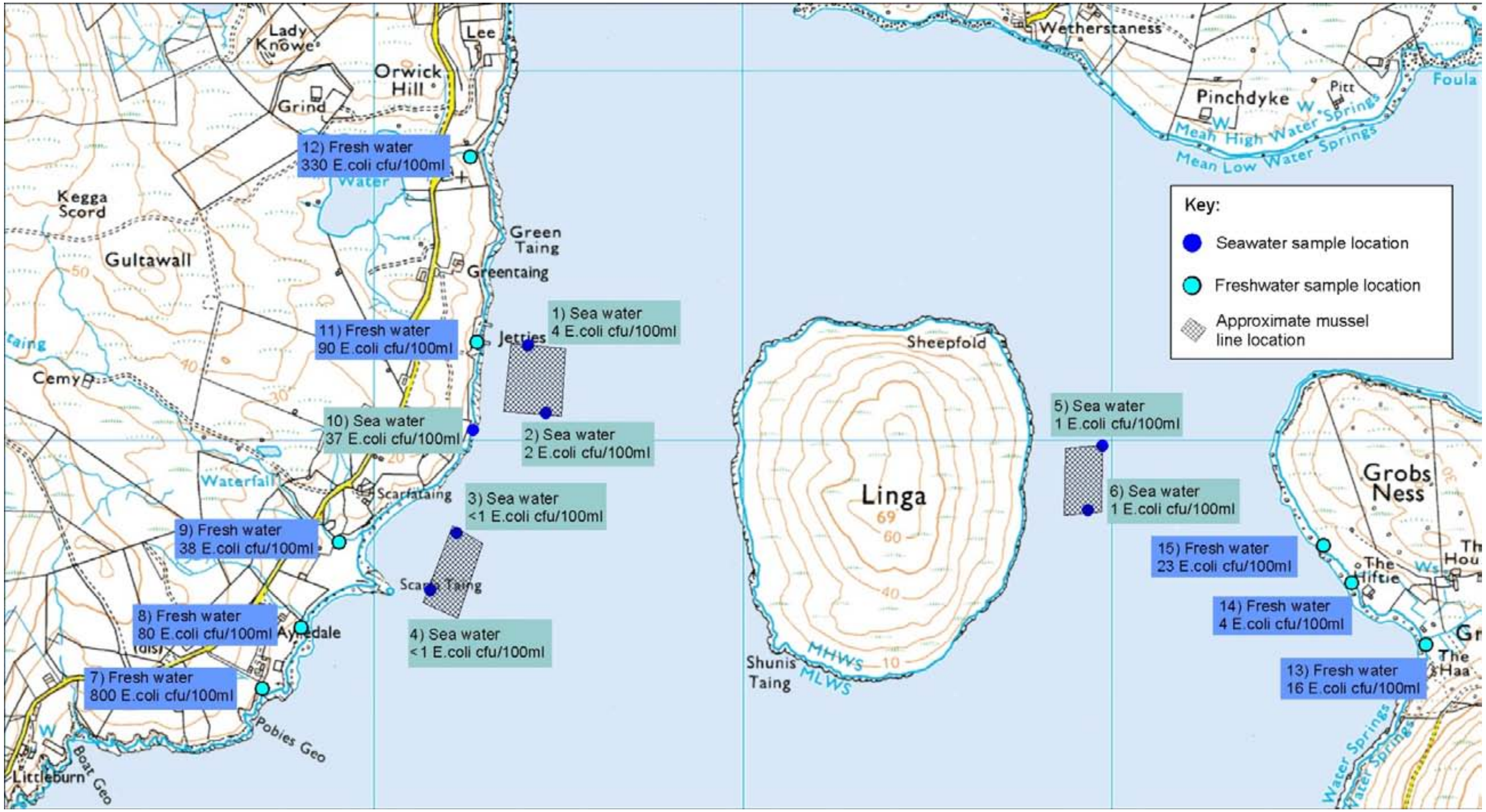


Figure 2 Map of water sample results

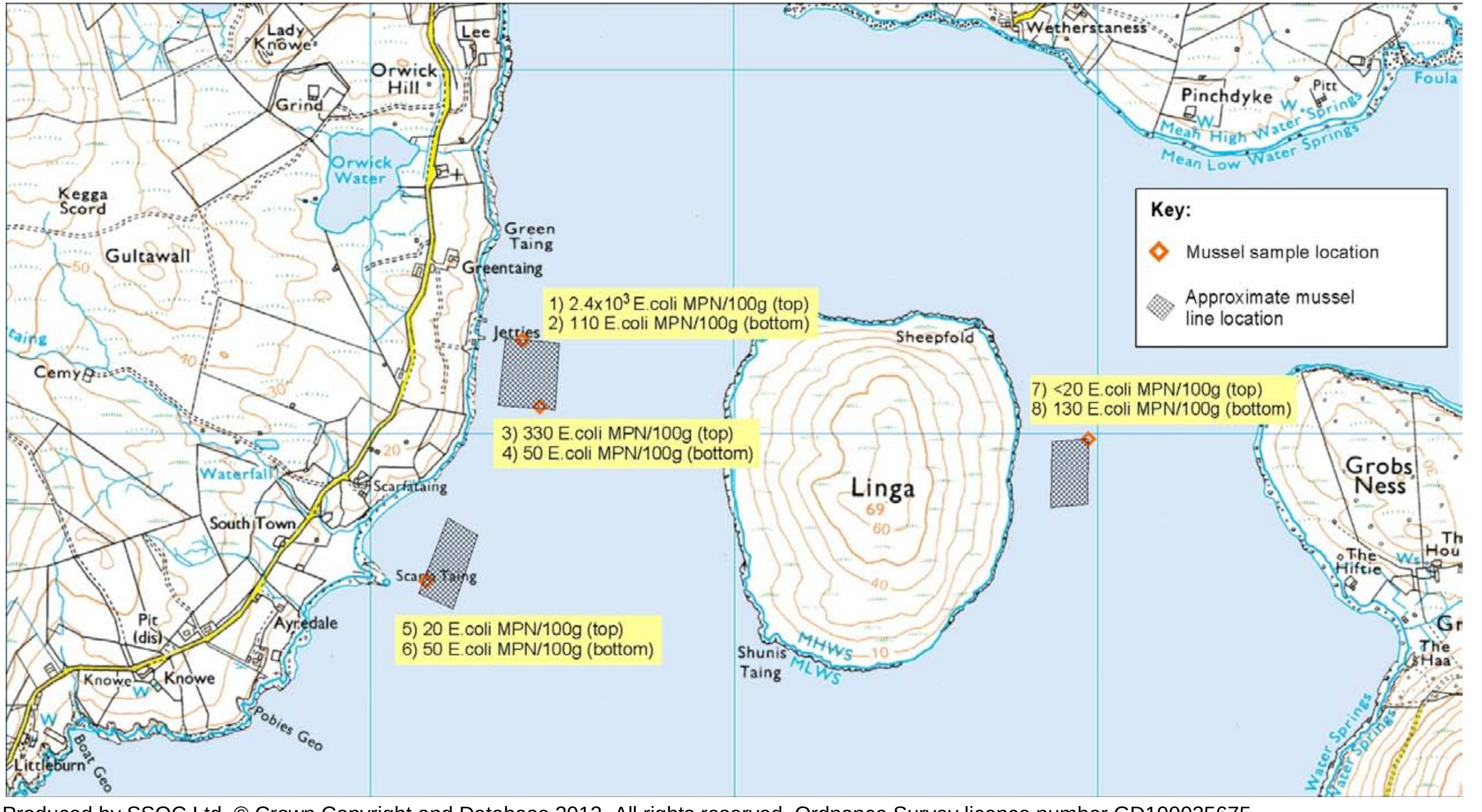


Figure 3 Map of shellfish sample results

Photographs

Figure 4 – Mussel lines at the Greentaing fishery looking south.

Figure 5 – Mussel lines at the Buddascord fishery looking south with harvesting boat on site.

Figure 6 – Mussel lines at the Linga fishery looking north.

Figure 7 – Drainage ditch coming down from agricultural buildings sampled near Ayredale (western shoreline).

Figure 8 – Watercourse sampled at Ayredale draining to the shoreline.

Figure 9 – Scarfataing point overlooking the Buddascord fishery.

Figure 10 – Septic tank below an occupied property adjacent to the Buddascord fishery.

Figure 11 – Freshwater sample and flow rate being obtained from a large watercourse adjacent to the Buddascord fishery.

Figure 12 – Assessing water flow in a pipe discharging to the sea between the Greentaing and Buddascord fisheries.

Figure 13 – Discharge pipe from portacabin at the jetty near the Greentaing fishery.

Figure 14 – Land drainage pipe discharging to jetty adjacent to the Greentaing fishery.

Figure 15 – Measuring flow rate of a large watercourse below Orwick Water.

Figure 16 – Burn sampled near The Haa downstream of an occupied property (eastern shoreline).

Figure 17 – Burn draining to the beach sampled near The Hiftie.

Figure 18 – Stream sampled draining through vegetation to the shoreline.

Figure 19 – Location where flow rate was to be recorded in the stream mentioned above (Figure 18) but due to limited depth and vegetation present only the depth and width of stream could be measured.

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