Scottish Sanitary Survey Report

Sanitary Survey Report
Vementry North and South
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The hydrographic assessment and the shoreline survey and its associated report were undertaken by Shetland Seafood Quality Control, Scalloway.

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I. Executive Summary

Under (EC) Regulation 854/2004, which sets forth specific rules for the organisation of official controls on products of animal origin intended for human consumption, sanitary surveys of production areas and their associated hydrological catchments and coastal waters are required in order to establish the appropriate representative monitoring points (RMPs) for the monitoring programme.

The purpose of the sanitary survey is to demonstrate compliance with the requirements stated in Annex II (Chapter II Paragraph 6) of Regulation (EC) 854/2004. The sanitary survey results in recommendations on the location of RMPs, the frequency of sampling for microbiological monitoring, and the boundaries of the production areas deemed to be represented by the RMPs. A sanitary survey was undertaken on the classified mussel fishery at Vementry on the basis recommended in the European Union Reference Laboratory publication: “Microbiological Monitoring of Bivalve Mollusc Harvesting Area Guide to Good Practice: Technical Application” (http://www.crlcefas.org/gpg.asp). The area was selected for survey at this time based on a risk-based ranking amongst those Scottish production areas that had yet to receive a survey.

The Vementry North and South production areas are located to the south and west of the uninhabited island of Vementry, on the North side of West Mainland, Shetland. The production areas cover the water bodies to the south and east of Vementry including the Voe of Clousta, the North Voe of Clousta, Cribba Sound, Suthra Voe and the outer part of Brindister Voe.

The fishery at Vementry North and South is comprised of eight common mussel (*Mytilus edulis*) farms, some of which have been classified for production since 2001.

Overall, the fishery is subject to low levels of faecal contamination. The main sources of contamination to the fishery are:

- Diffuse contamination from livestock (mainly sheep) kept on crofts at the northeast end of Cribba Sound and along the Voe of Clousta.
- Diffuse contamination from sheep grazed extensively on Vementry, particularly around Suthra Voe.
- Diffuse contamination from wildlife, predominantly seabirds.
- One leaking septic tank was seen near Noonsbrough, to the south of the mussel farm at Clousta Voe Noonsbrough.

Faecal contamination from diffuse sources is most likely to be carried in watercourses and other surface runoff to the sea around the fishery. Transport of contaminants within the waters of the two production areas is likely to be complex, but there will be a general seaward trend in surface flows. The east and west sides

of the Vementry complex are separate basins, with most of the identified sources located around the eastern basin.

Summary of recommendations

It is recommended that the production area boundaries be amended to reflect the east-west split in settlements and natural basins within the area. The new production area boundaries are identified in the Sampling Plan overleaf and shown mapped in Section 17 of this report.

Vementry North

The amended Vementry North production area extends southward to include the Longaness site. It is recommended that the RMP be retained at its current location on Suthra Voe West site.

Vementry South

The amended Vementry South production area is curtailed at the western boundary to exclude Longaness and at the southern boundary to exclude the southern part of the Voe of Clousta. It is recommended that the RMP be moved to the southern end of the Clousta Voe Noonsbrough site to reflect contamination arising within the voe to the south.

Further details on the recommendations can be found in Section 17.

II. Sampling Plan

Production Area	Vementry North	Vementry South
Site Name	Suthra Voe West	Clousta Voe Noonsbrough
SIN	SI-322-464-08	SI-321-459-08
Species	Common Mussels	Common Mussels
Type of Fishery	Longline aquaculture	Longline aquaculture
NGR of RMP	HU 2919 6023	HU 2948 5786
East	429190	429480
North	1160230	1157860
Tolerance (m)	40	40
Depth (m)	1	1
Method of Sampling	Hand	Hand
Frequency of Sampling	Monthly	Monthly
Local Authority	Shetland Islands Council	Shetland Islands Council
Authorised Sampler(s)	Sean Williamson Marion Slater Agnes Smith Alan Harpin Vicki Smith	Sean Williamson Marion Slater Agnes Smith Alan Harpin Vicki Smith
Sampling Liaison Officer	Sean Williamson	Sean Williamson
Production Area Boundary	Area bounded by lines drawn between HU 2822 6042 and HU 2742 5959 and between HU 2821 5800 and HU 2835 5800 and between HU 2902 5830 and HU 2901 5873 and extending to MHWS.	Area bounded by lines drawn between HU 2901 5873 and HU 2902 5830 and between HU 2954 5768 and HU 2976 5762 and between HU 3048 5830 and HU 3048 5835 and between HU 3048 5998 and HU 3043 5998 and extending to MHWS.

III. Report

1. General Description

The Vementry North and South production areas are located to the south and west of the island of Vementry, on the North side of West Mainland, Shetland. Three main settlements are located around the area; Noonsbrough located at the mouth of the Voe of Clousta; Clousta, the largest settlement in the area is at the head of the Voe of Clousta and Brindister, at the head of Brindister Voe. A map of the general location Vementry is presented in Figure 1.1.

The production areas cover the water bodies to the south and east of Vementry including the Voe of Clousta, the North Voe of Clousta, Cribba Sound and the outer part of Brindister Voe.

The area has a complex coastline and bathymetry data of the area is limited Vementry North has been determined to have a maximum depth of 49 m and Vementry South a maximum depth of 34.7 m.

The sanitary survey at Vementry North and Vementry South was conducted on the basis recommended in the European Union Reference Laboratory publication: “Microbiological Monitoring of Bivalve Mollusc Harvesting Area Guide to Good Practice: Technical Application” (http://www.crlcefas.org/gpg.asp). This production area was selected for survey at this time based on a risk-based ranking of the area amongst those in Scotland that have yet to receive sanitary surveys.

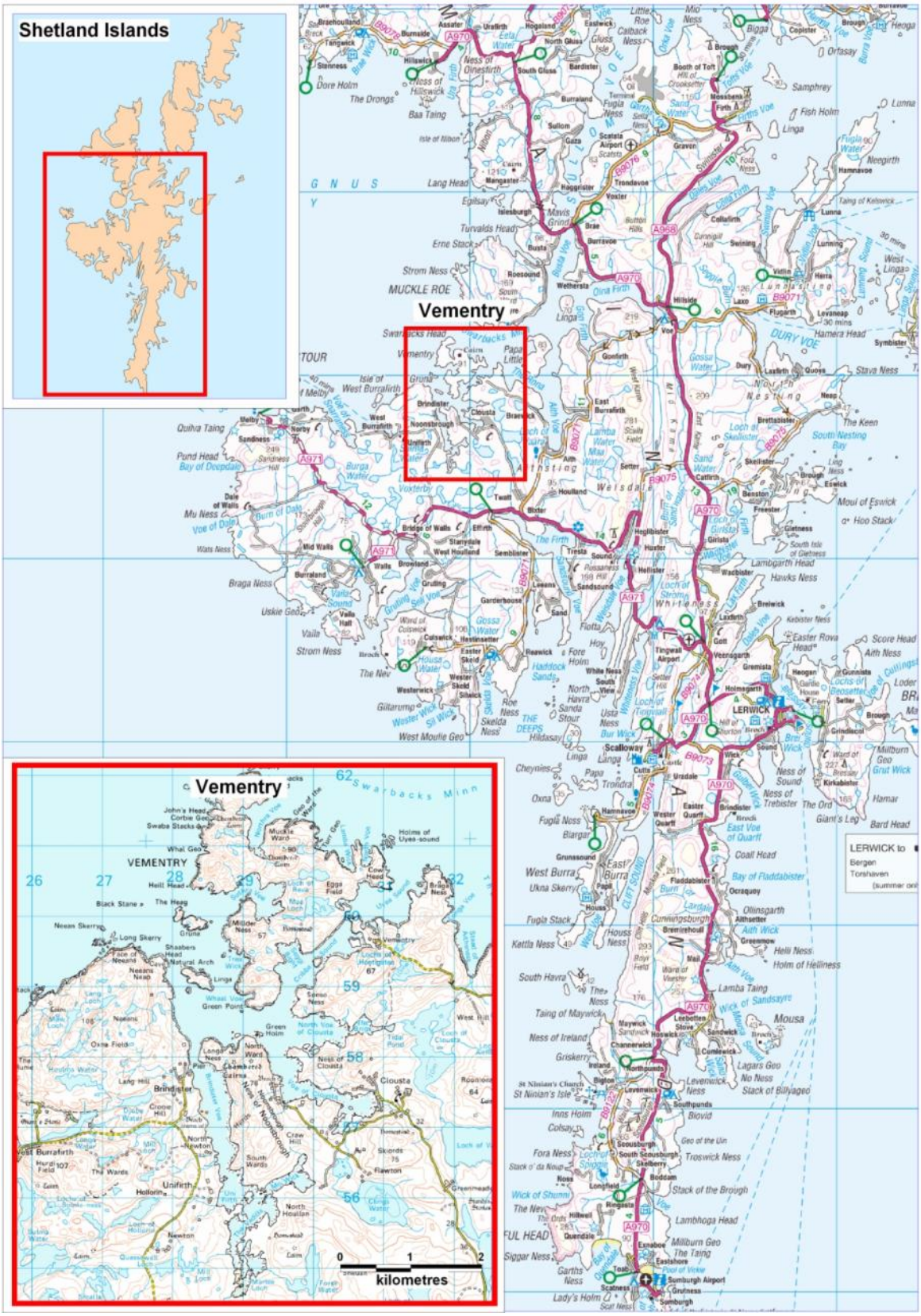


Figure 1.1 Location of Vementry North And South

2. Fishery

The fishery at Vementry North and South is comprised of eight common mussel (*Mytilus edulis*) farms, some of which have been classified for production since 2001. Details of the sites are presented in Table 2.1.

Table 2.1 Area shellfish farms

Production area	Site	SIN	Species	RMP
Vementry North	Suthra Voe West	SI-322-464-08	Common mussels	HU 2919 6023
	Suthra Voe	SI-322-463-08	Common mussels	
	Treawick	SI-322-465-08	Common mussels	
Vementry South	Clousta Voe – Noonsbrough	SI-321-459-08	Common mussels	
	Cribba Sound	SI-321-460-08	Common mussels	
	Longaness	SI-321-855-08	Common mussels	
	North Voe of Clousta	SI-321-461-08	Common mussels	
	Seggi Bight	SI-321-462-08	Common mussels	HU 2965 5918

The locations of all active mussel sites were recorded during the shoreline survey. Information on the licence conditions for each site was provided by SSQC in the shoreline survey report.

Vementry North

The production area boundary is defined by the lines drawn between HU 2822 6042 and HU 2742 5959 and between HU 2900 5873 and HU 2796 5873, extending to mean high water springs (MHWS).

At the time of the shoreline survey only two of the three farms within the production area were active. Suthra Voe had only one mussel raft, with no mussels present at the time of the shoreline survey.

The Suthra Voe West mussel farm consisted of five double-headed long lines with 8 m droppers. The site is licensed for six 220 m double headed longlines.

The Treawick mussel farm consisted of five double-headed longlines with 10 m droppers. The site is licensed for five 75 m double headed longlines.

Vementry South

The production area boundary is defined by the lines drawn between HU 2900 5873 and HU 2796 5873 and between HU 2842 5714 and HU 2880 5714 and between HU 3043 5998 and HU 3048 5998, extending to MHWS.

At the time of shoreline survey, there were six active mussel farm sites located within the production area.

The Clousta Voe-Noonsbrough mussel farm consisted of three double-headed longlines with 8 m droppers. The site is licensed for four 440 m double-headed longlines

The Cribba Sound mussel farm consisted of two groups of mussel lines. A northern group (Cribba Sound North), located northeast of the island of Grink Holm, consisted of five double-headed longlines and three shorter plastic pipes with 8 m droppers. The site is licensed for five 410 m and eleven 156 m double-headed longlines. A southern group (Cribba Sound South), found south west of Grink Holm, consisted of five double-headed long lines with 10 m droppers. The site is licensed for five 200 m double-headed longlines.

The Longaness mussel farm consisted of four double-headed long lines with 5 metre droppers. The site is licensed for five 130 m double-headed longlines.

North Voe of Clousta mussel farm consisted of seven double-headed long lines with 8 m droppers. Three of the lines were of shorter length than the other four. The site is licensed for eight 100 m doubled-headed longlines.

Seggi Bight mussel farm consisted of seven double headed long lines with 10 metre droppers. Two longlines were shorter than the remaining five lines. The site is licensed for five 200 m and two 100 m double-headed longlines.

No information was obtained on seasonality of harvest during the shoreline survey and it is assumed that this will be year-round subject to external factors (e.g. biotoxin closures).

The locations of the farms identified above are presented in the map in Figure 2.1, together with the seabed lease areas, current production area boundaries and RMP locations.

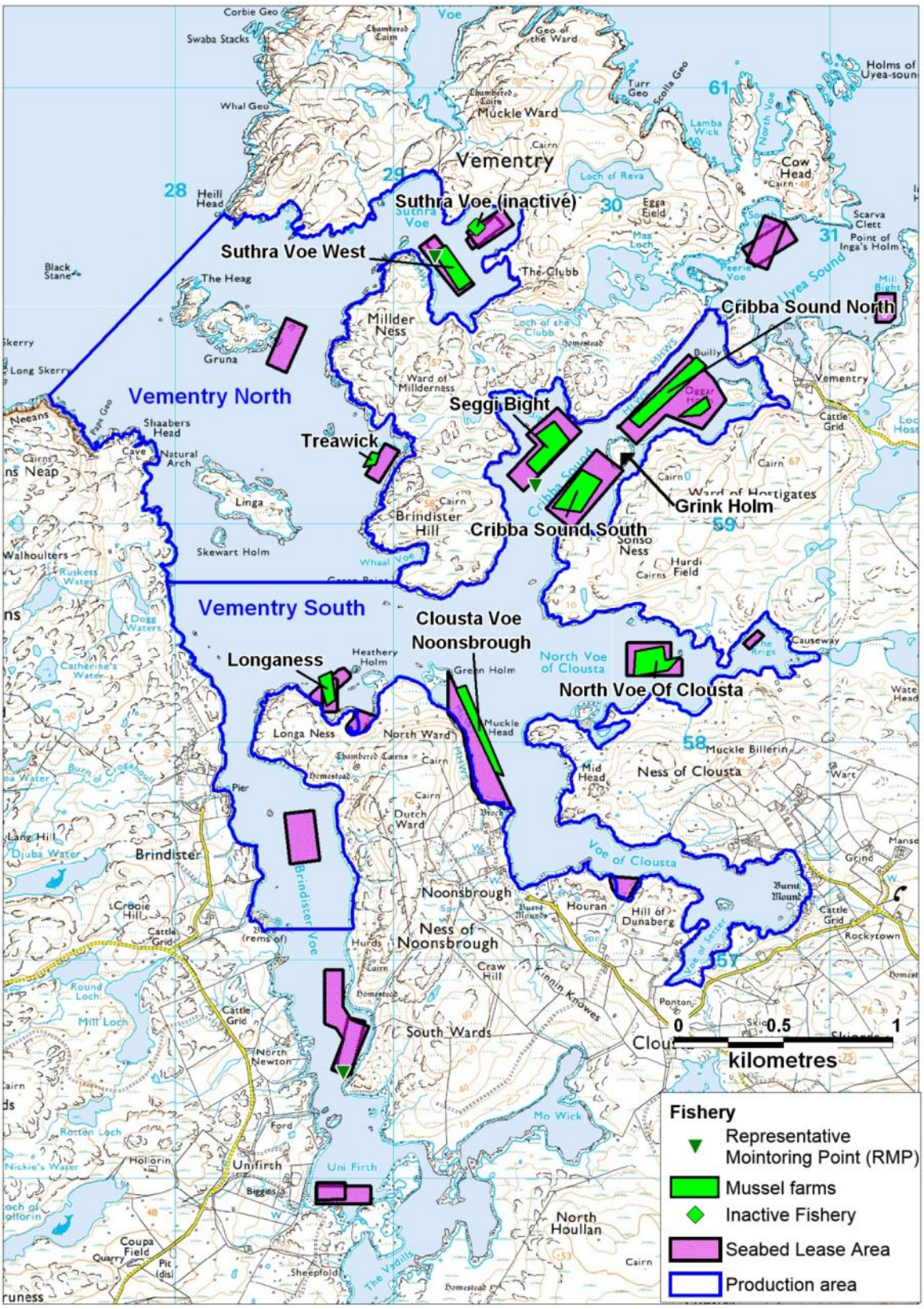


Figure 2.1 Vementry North And South Fishery

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 Vementry North and South production areas. The last census was undertaken in 2011. The population by census output area is given in Table 3.1.

Table 3.1 Human population for census output areas - Vementry

Census Output Area	Population (2011)	Population Density (People per km^2)
S00059412	81	1.91
S00059464	85	5.85
S00059538	115	5.81
Total	281	

The census output areas surrounding Vementry North and South are shown thematically mapped by the 2011 population densities in Figure 3.1. The figure shows that population density is low (fewer than 6 people per km^2) on the coastline surrounding the fisheries.

The island of Vementry is uninhabited, as is the shoreline around North Voe of Clousta. The majority of inhabited dwellings were observed around the Voe of Clousta, particularly near the head of the voe. A small cluster of houses was also seen east of the Cribba Sound North mussel farm. One of these was noted as being holiday accomodation.

There were 4 small jetties/piers in the area with a corresponding small number of fishing and work boats, some of which were used to service the shellfish farm.

Two anchorages were noted for the area: one northeast of Cribba Sound, in Uyea Sound (United Kingdom Hydrographic Office, 2002) and the other adjacent to the inactive mussel raft in Suthra Voe (Clyde Cruising Club, 2005).

Overall, impacts from human sources to the water quality in the production areas is likely to be low, with any effects predominating in the Voe of Clousta in the south and Cribba Sound in the north, where there was human habitation. Any yachts using the anchorage in Suthra Voe would be expected to have an impact in the near vicinity, and could potentially affect the mussel farms located there.

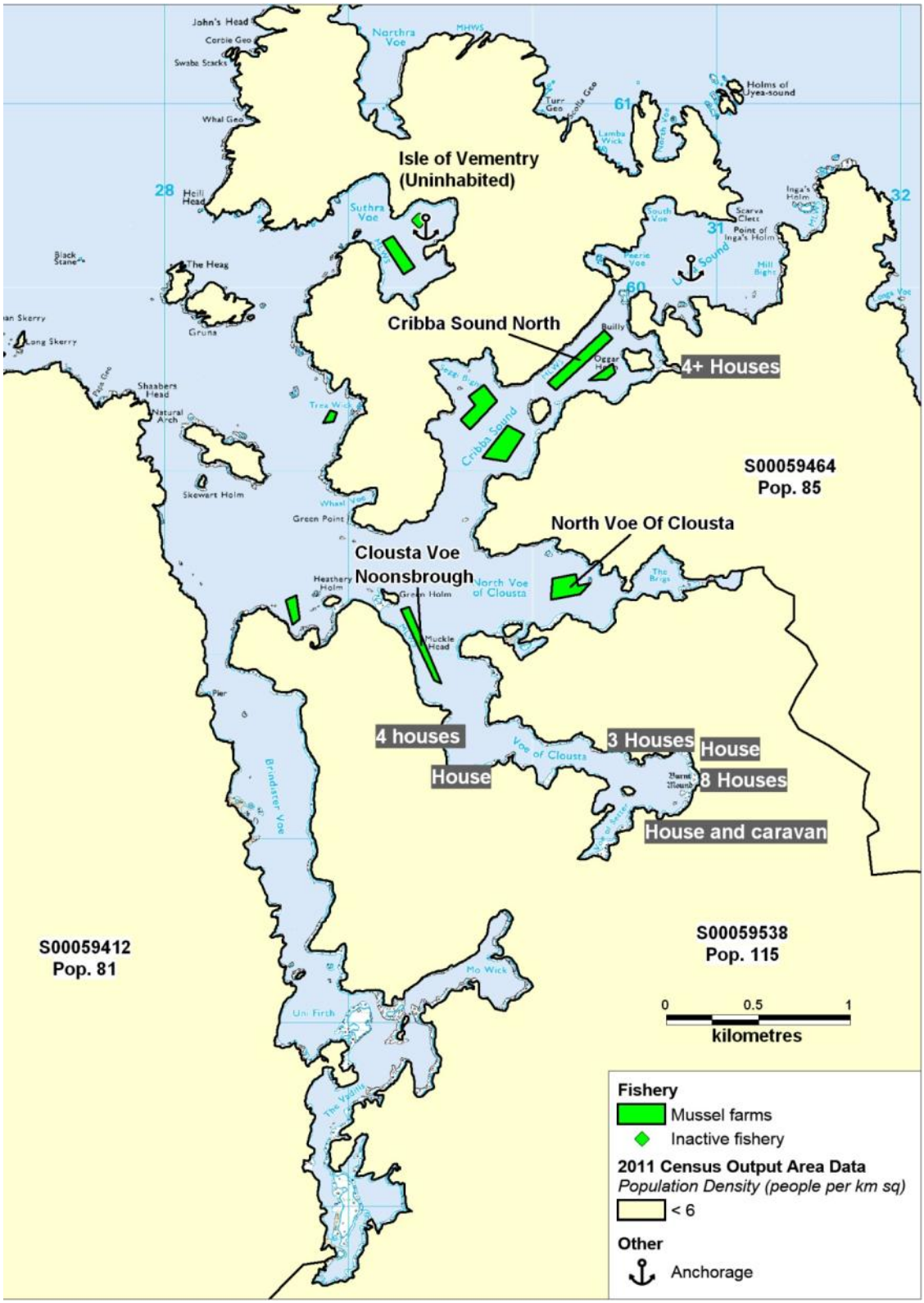


Figure 3.1 Population map for the area in the vicinity of Vementry North And South

4. Sewage Discharges

Information on sewage discharges within 5 km of point HU 2939 1597 was sought from Scottish Water and the Scottish Environment Protection Agency (SEPA). Data requested included the name, location, type, size (in either flow or population equivalent), level of treatment, sanitary or bacteriological data, spill frequency, discharge destination (to land, to waterbody or to sea), any available dispersion or dilution modelling studies, and whether improvements were in work or planned.

4.1 Scottish Water Discharges

Scottish Water advised they had no assets in the vicinity.

4.2 Consented Discharges (SEPA)

SEPA provided information on a number of consented discharges within the request area. The full list is given in Appendix 6.

Details for those consents for discharges to the production areas, to watercourses or to land that adjacent to the production areas have been extracted from the data in Appendix 6 and are given in Table 4.1. Any Marine Cage Fish Farm consents within the production areas are also included.

Public Sewage Discharges

No public sewage discharges were reported by SEPA in the vicinity of the Vementry production areas.

Private Discharge Consents

Of the data provided by SEPA, information was given on 11 private discharge consents, discharging to the areas around Vementry North and South. This included four marine cage fish farms (MCFF). Two MCFFs are located in the Vementry North and South production areas and one is located in Brindister Voe. Any overboard sewage discharges from service barges associated with these farms would contribute faecal contamination to the waters in their vicinity

SEPA provided information on seven sewage discharge consents. All of the the discharges are listed as being subjected to primary treatment by septic tank.

Of the seven sewage discharges only one discharge to the sea, CAR/R/1038759 which discharges to the Voe of Clousta. The three remaining discharges are all recorded as discharging to land.

Historically, there has been no requirement to register septic tanks in Scotland and currently these must only be registered on installation or change of ownership.

Therefore, only the houses which have registered their sewage discharges with SEPA have been listed.

SEPA have noted that, particularly in remote areas, there are likely to be registered soakaways that actually discharge to watercourses, either because they have been rerouted due to failure of the soakaway field or to misreporting in the first instance.

Table 4.1 Consented discharges potentially impacting Vementry North and South

Licence No.	NGR*	Discharge Type	Site Name	Receiving Body	PE
CAR/R/1038759	HU 3087 5735	Sewage (Private) Primary	Solhavn, Clousta, Bixter	Voe of Clousta	6
CAR/R/1014204	HU 2804 5784	Sewage (Private) Primary	Upper House, Brindister, Shetland	Soakaway	5
CAR/R/1015774	HU 3187 5618	Sewage (Private) Primary	Greenmeadow, Clousta, Shetland	Soakaway	5
CAR/R/1027431	HU 3117 5752	Sewage (Private) Primary	Grind, Clousta, Shetland	Soakaway	5
CAR/R/1031131	HU 3063 5665	Sewage (Private) Primary	Fernlea, Clousta, Shetland	Soakaway	5
CAR/R/1038804	HU 2848 5593	Sewage (Private) Primary	Midhouse, Unifirth, West Burra Firth, Shetland	Soakaway	6
CAR/R/1027431	HU 3119 5753	Sewage (Private) Primary	Grind, Clousta, Shetland	Soakaway	5
CAR/L/1003878	HU 2950 5850	Fish Farm Marine Cage	Brindister Crossroads MCFF, Clousta	North Voe of Clousta	-
CAR/L/1008811	HU 2838 5881	Fish Farm Marine Cage	Skewart Holm MCFF, Vementry Sound	Vementry Sound	-
CAR/L/1021839	HU 2920 6120	Fish Farm Marine Cage	Northra Voe MCFF, Swarbacks Minn	Swarbacks Minn	-
CAR/L/1002354	HU 2860 5760	Fish Farm Marine Cage	Brindister MCFF, Brindister Voe	Brindister Voe	-

- No data provided; PE= Population Equivalent; DWF=Dry Weather Flow;
MCFF=Marine Cage Fish Farm * All NGRs have been restated to 10 m accuracy

Shoreline Survey Discharge Observations

Septic tanks were observed during the shoreline survey. These are listed in Table 4.2.

Table 4.2 Discharge-associated observations made during the Vementry shoreline survey

No.	Date	Associated Photograph (Appendix 5)	Description
1	24/09/2013		Large concrete septic tank servicing two houses in the area, slight leakage from the side of the tank where a crack is visible
2	24/09/2013	Figure 13	Septic tank for house present at the top of the hill. Soak away very prominent leading to the shore
3	24/09/2013	Figure 16	Occupied caravan with plastic septic tank in the field below. House with old concrete septic tank below
4	24/09/2013		Concrete septic tank in the garden of a house
5	24/09/2013	Figure 14	Concrete septic tank next to a house above the shore. Plastic pipe leading to the water. End of the pipe not visible, under rocks
6	24/09/2013		Concrete septic tank servicing a house above the shore
7	24/09/2013		Plastic septic tank in a field above road
8	24/09/2013		Concrete septic tank in the field below a house
9	24/09/2013	Figure 15	Concrete septic tank associated with two houses at the top of the hill

Observations 1-7 were all recorded in the Voe of Clousta, mainly at the head of the voe. Observations 8 and 9 were recorded on the northeast shore of Cribba Sound, approximately 400 m east of the easternmost extent of the Cribba Sound North site. All appeared to relate to small private septic tanks and/or associated discharges.

Only one of the observed tanks (observation 5) appeared to correspond with consent details supplied by SEPA. The remaining observations are presumed to relate to unregistered tanks.

A shoreline survey was conducted in November of 2012 to support the sanitary survey for the neighbouring production of Brindister Voe (Cefas, 2013). Sewage observations and descriptions from that shoreline survey are included in Table 4.3 and the proceeding paragraphs.

Table 4.3 Discharge-associated observations made during the Brindister Voe shoreline survey

No.	Date	Description
1	06/11/2012	Concrete septic tank in poor condition, located adjacent to a stream. Slurry leaks on side and along grass beneath, as well as slurry pooling in boggy grass further down (within 2-3m of stream)
2	06/11/2012	Septic tank with a soak away, presumed inactive
3	06/11/2012	Septic tank at house beside road
4	06/11/2012	Suspected septic tank
5	06/11/2012	Septic tank at property here, soakaway

These discharges were approximately 700 m southwest of the Longaness site.

Summary

The area surrounding the production area is sparsely populated with few reported sewage discharges. The majority of reported septic tanks were located around the head of Voe of Clousta, however the closest septic tank to the mussel farms in Clousta Voe was a leaking septic tank observed at Noonsbrough, which was approximately 350 m southwest of the Noonsbrough mussel farm.

Two septic tanks were observed at Vementry, on the northeast shore of Cribba Sound. However, neither of these appeared to discharge to shore and are presumed to discharge to soakaways in the near vicinity. If the soakaways are functioning properly, these should not have an impact on the nearby mussel farms. However, any overland flow arising from the soakaway fields would be expected to have some impact at the Cribba Sound North mussel farm.

Three septic tanks were observed at the north end of Brindister Voe during the survey of that production area, and these are the closest discharges to the Longaness mussel farm, lying approximately 750 m to the southwest.

The Suthra Voe West , Trea Wick and North Voe of Clousta mussel farms all lie more than 1 km from the nearest recorded discharge. However, there is an anchorage adjacent to the Suthra Voe West mussel farm and therefore this farm may be subject to occasional contamination from any boats using the anchorage.

List of Acronyms

MDF	Mean daily flow
DPE	Population Equivalent
WWTW	Wastewater Treatment Work
DWF	Dry weather flow
ST	Septic Tank
CSO	Combined Sewer Overflow

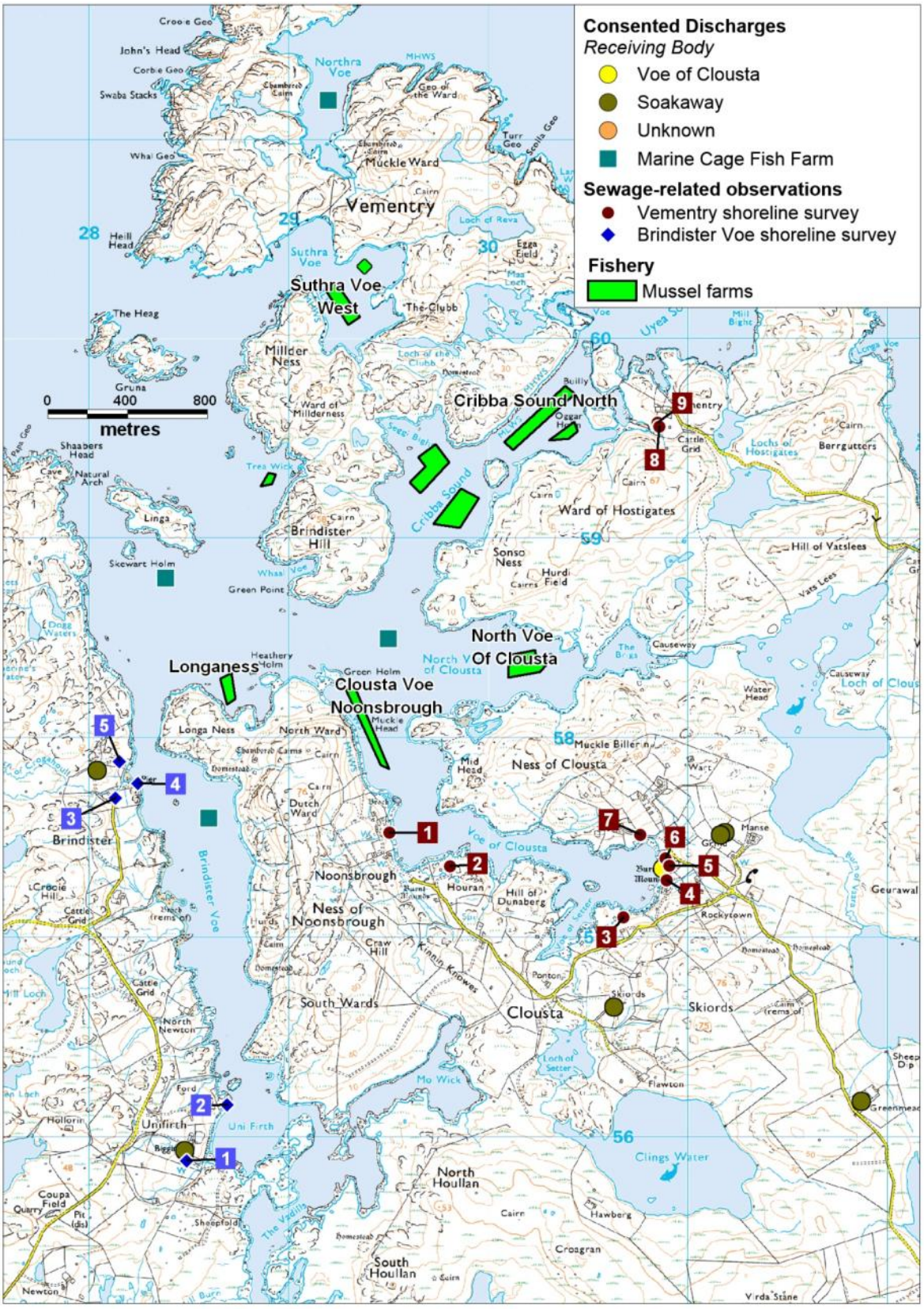


Figure 4.1 Map of discharges for Vementry North and South

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 Aithsting parish. Reported livestock populations for the parish in 2012 are listed in Table 5.1.

Table 5.1 Livestock numbers in the Aithsting agricultural parish 2012

	Aithsting 94 km^2	
	Holdings	Numbers
Poultry	14	171
Cattle	12	312
Sheep	71	18799
Other horses and ponies	7	20

Although the Aithsting agricultural parish is small in size, it also covers neighbouring islands including Vementry and therefore it is not possible to determine the spatial distribution of these livestock within the parish area. The livestock numbers indicate that sheep are very numerous within the parish area , with an average of 200 sheep per square km if an even distribution is assumed. Cattle, poultry and horses and ponies were reported in vastly lower numbers. No farms reported keeping pigs.

An additional significant source of spatially relevant information on livestock population in the area was the shoreline survey (see Appendix 5) which only relates to the time of the site visit on the 24th and 25th September 2013 (see Table 5.1). Observations made during the survey are dependent upon the viewpoint of the observer some animals may have been obscured by the terrain. Further, not all the shoreline was walked and therefore the observations relate only to the areas of shoreline viewed during the visit. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 5.1.

Approximately 75 sheep were observed on the hills of Vementry west of the Suthra Voe fishery. Forty-five sheep were observed grazing on the shoreline east of the Cribba Sound fisheries: large amounts of sheep faeces were also observed on or near the shoreline. A total of 256 sheep were observed grazing at the southern end of the production area around the shoreline of the Voe of Clousta : there was also a large amount of sheep and cattle faeces and several agricultural sheds. The majority of the sheep observed during the shoreline survey had access to the shoreline and sheep and cattle faeces were noted on a number of occasions in areas where livestock were not present. One cow was observed in a fenced area inland on the southern shoreline of the Voe of Clousta and cattle faeces and tracks were observed

on four occasions on the northern shoreline of the same voe. A large pile of manure was observed inland on the northern shoreline of Cribba Sound.

Numbers of sheep are expected to be approximately double during late spring following the birth of lambs, and decrease again in the autumn when they are sent to market.

Any contributions of faecal contamination from livestock would be most likely to affect the Suthra Voe, Cribba Sound and Voe of Clousta mussel farms, specifically the longlines of the farms closest to the shoreline where livestock or evidence of livestock has been observed. This would include the entire Suthra Voe West fishery, the northern end of Cribba Sound North fisheries and the southern end of the Clousta Voe Noonsbrough fishery.

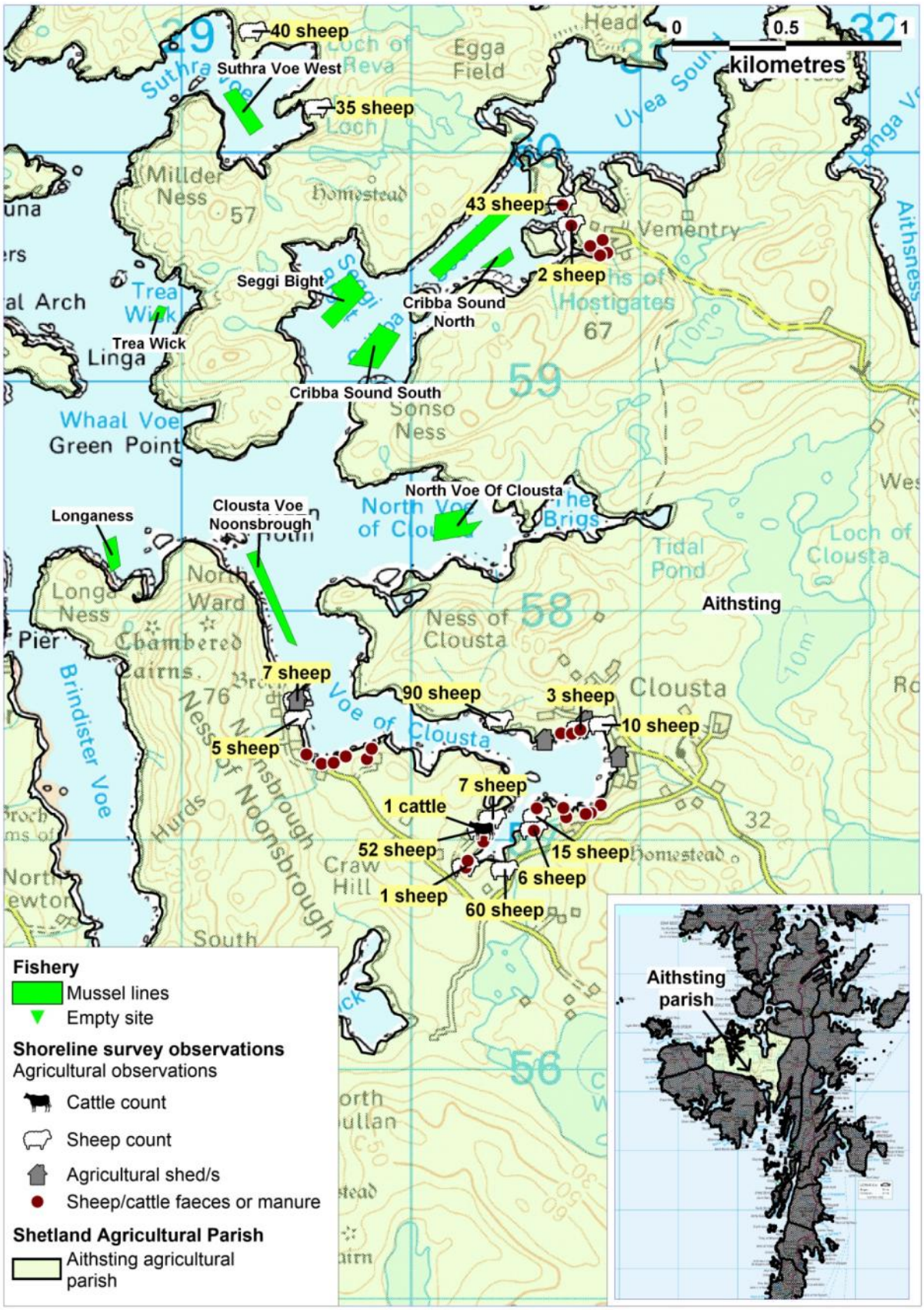


Figure 5.1 Agricultural parish boundary and shoreline survey livestock observations

6. Wildlife

Wildlife species present in and around the production area will contribute to background levels of faecal contamination at the fishery, and large concentrations of animals may constitute significant sources when they are present. Seals, cetaceans and some seabirds may deposit faeces directly into the sea, while birds and mammals present on land will contribute a proportion of any faecal indicator loading carried in diffuse run-off or watercourses.

The species most likely to contribute to faecal indicator levels at the Vementry North and South common mussel fisheries are considered below.

Pinnipeds

The Special Committee for Seals (SCOS, 2012) reported that the Vementry area supports between 50-100 grey seals and harbour seals. The Shetland Islands are recognised as supporting an increasing population of grey seals. The Shetland harbour seal population was reported to be stable.

Data from the Marine Spatial Plan for Shetland (2012) indicates that the majority of coastline around Vementry is important for common seals, whilst an important area for grey seals also exists directly to the north of the site. The website for the holiday cottage at the north end of Cribba Sound stated that two groups of seals are regularly seen on nearby beaches, though exact locations and numbers of animals are not specified (http://www.vementry.co.uk/ [Accessed 04 12 2013]).

No seals were observed during the shoreline survey.

Cetaceans

The waters outside of Vementry are known to support a diverse number of cetacean species. These include large whales such as the pilot whale, to small species such as the harbour porpoise. No information was found regarding the presence of these animals within the waters of either production area.

Birds

Seabird 2000 census data (Mitchell, et al., 2004) for the area within a 5 km radius of Vementry North and South was obtained and is summarised in Table 6.1. This census, undertaken between 1998 and 2002 covered twenty five species of seabird that breed regularly in Britain and Ireland.

Table 6.1 Seabird counts within 5 km of the Vementry North and South

Common name	Species	Count*	Method
Arctic skua	*Stercorarius parasiticus*	12	Occupied territory
Great skua	*Stercorarius skua*	12	Occupied territory
European herring gull	*Larus argentatus*	521	Individuals on land, Occupied territory, Occupied nests
Common gull	*Larus canus*	369	Individuals on land, Occupied territory, Occupied nests
Lesser black-backed gull	*Larus fuscus*	22	Individuals on land, Occupied territory
Great black-backed gull	*Larus marinus*	245	Individuals on land, Occupied territory, Occupied nests
Blacked-headed gull	*Larus ridibundus*	11	Individuals on land
Black guillemot	*Cepphus grylle*	311	Individuals on land
Arctic tern	*Sterna paradisaea*	843	Individuals on land, Occupied nests
Common tern	*Sterna hirundo*	20	Individuals on land
Northern fulmar	*Fulmarus glacialis*	3252	Occupied sites
Atlantic puffin	*Fratercula arctica*	45	Individuals on land
European shag	*Phalacrocorax aristotelis*	70	Occupied nests, occupied sites
Black-legged kittiwake	*Rissa tridactyla*	246	Occupied nests

*The counts have been adjusted where the method used was occupied nests/sites/territory to reflect the probable number of individual birds (i.e. counts of nests were doubled).

A large number of seabirds were identified in the Seabird 2000 data. The most dense populations are located on the uninhabited islands of Vementry and Papa Little and the coastline north of Suthra Voe. These dense populations of seabirds pose a potential significant source of contamination to the Vementry North production area fisheries as these birds may feed and rest in the area.

In the Marine Spatial Plan for Shetland (2012), the areas around Vementry are shown to be important areas for a wide range of seabirds. However, the area is less popular with wading and waterfowl species, with Eider ducks not shown to be present.

The areas around Vementry are anecdotally recognised as being a great area to watch a number of bird species including; gannets, puffins and eider ducks (Shetland Marine Charters, 2013).

Birds were the only wildlife observed during the shoreline survey. Evidence of seabirds feeding (empty mussel shells and crab carcasses) was observed on four occasions along the Voe of Clousta shoreline. Bird faeces were observed on mussel floats at all but four of the fisheries. Birds noted included gulls, shags, plovers, lapwings, curlews, doves, eider ducks and one crow. No large flocks were observed, although birds were observed on the mussel floats at most fisheries. As the majority of the Vementry North production area shoreline was not accessible by foot and only parts were observed from a boat, it must be noted that there could have been more birds located out of sight.

The locations of the Seabird2000 records, together with the shoreline survey observations of wildlife, are shown in Figure 6.1.

Otters

In the Marine Spatial Plan for Shetland (2012), Vementry was identified as being an important area for otters. The Eurasian otter (*Lutra lutra*) is common amongst much of Shetland. Around Vementry it is noted that otters are prevalent, largely owing to the lack of human presence. Large areas of kelp forest are also located to the west of Vementry, which will support large numbers of prey species for otters. Anecdotal accounts of otters around Vementry are also reported (Vementry, 2013)

Overall

Species potentially impacting on Vementry North and Vementry South include seals, otters and birds, including seabirds. It is likely that of these, contamination from seabirds will predominate at Suthra Voe and the northern end of Cribba Sound. Outside these areas, the deposition of faeces from these sources is likely to be intermittent and sporadic across the mussel farms. Significant seasonal variation is expected, with the highest number of birds present during summer.

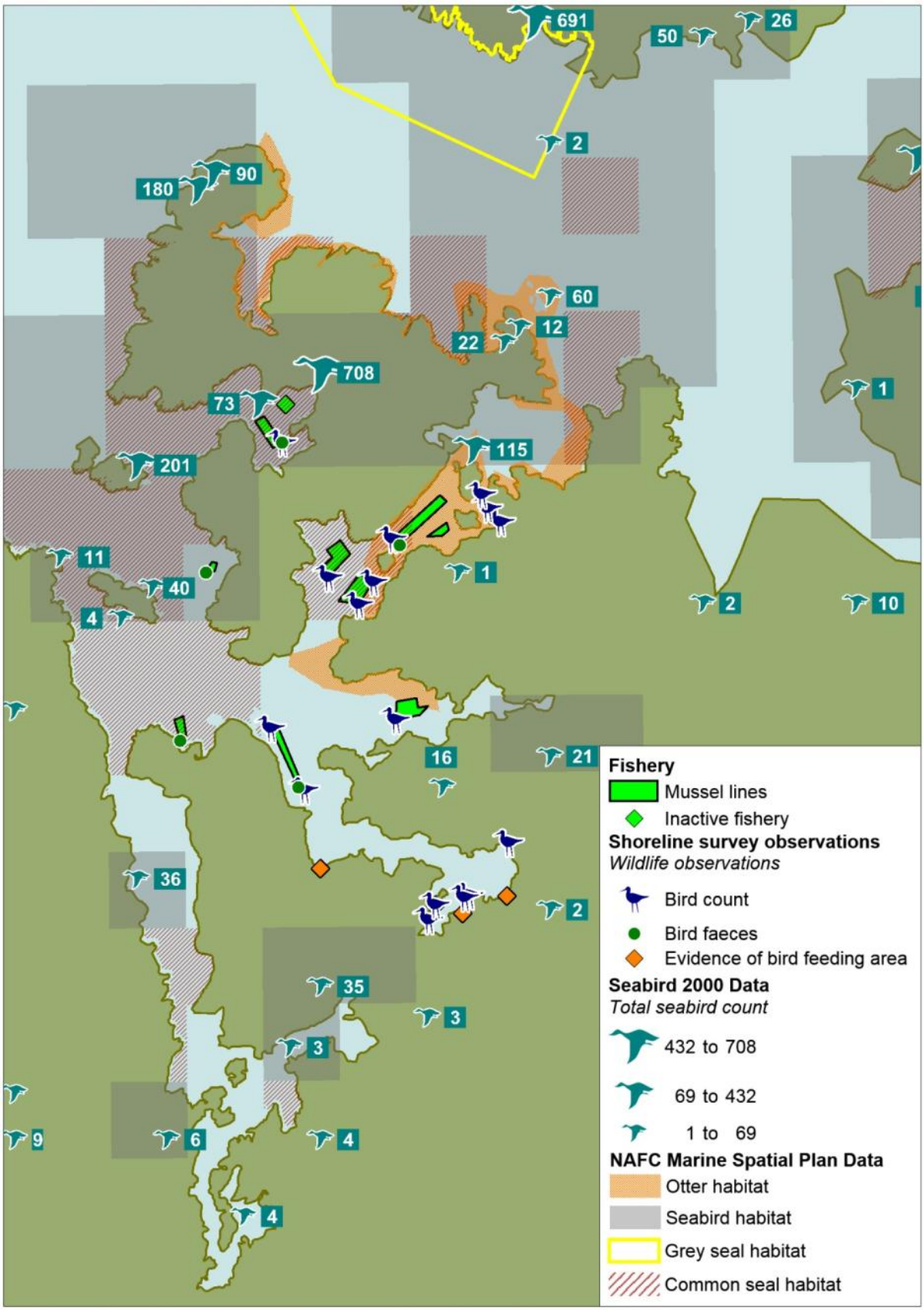


Figure 6.1 Map of wildlife Vementry North and South

7. Land Cover

The Land Cover Map 2007 data for the area is shown in Figure 7.1.

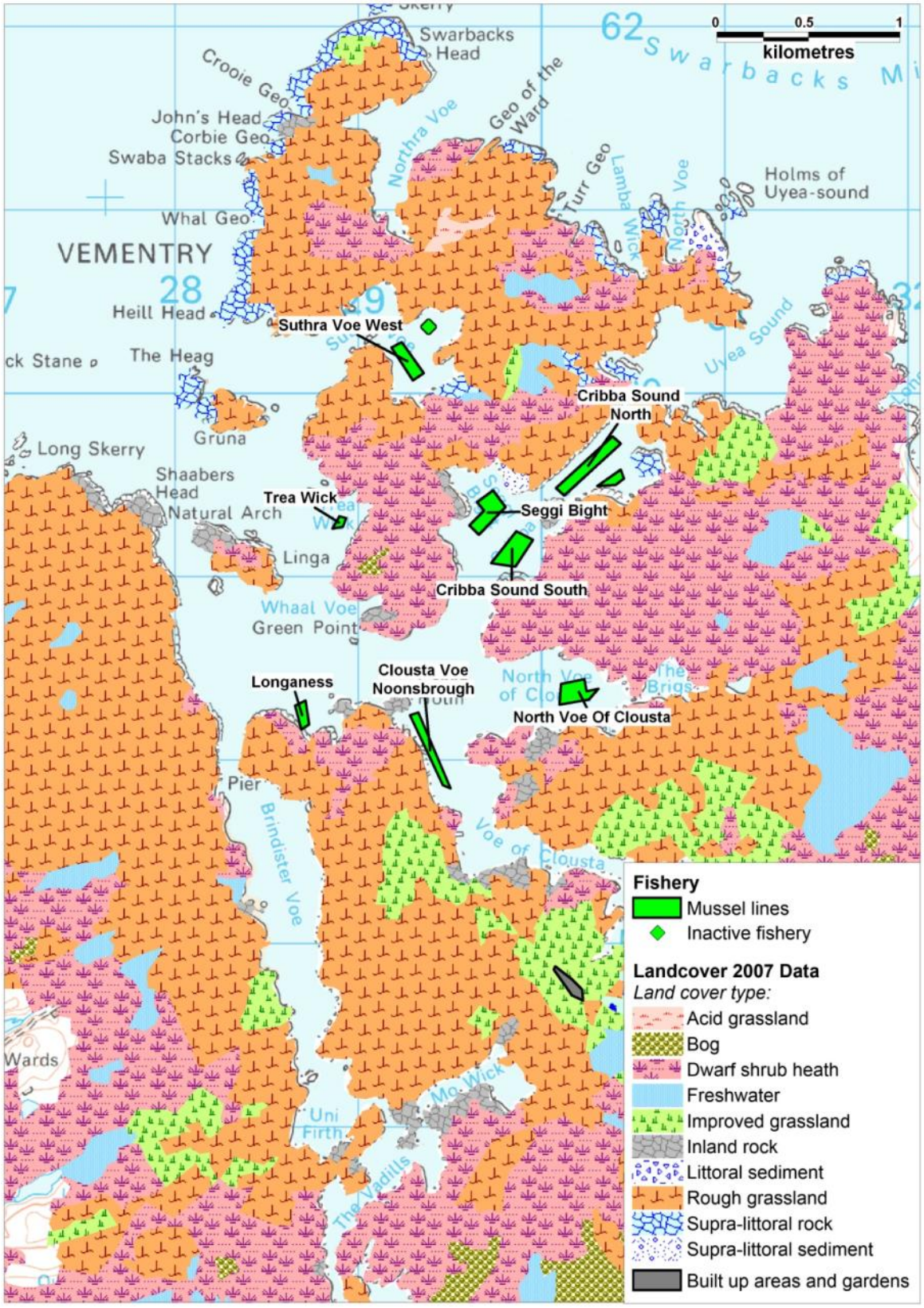


Figure 7.1 LCM2007 land cover for the area around Vementry North and South

Rough grassland and dwarf shrub heath dominates land surrounding the Vementry shellfish farms. Improved grassland is present near to the shoreline of the Voe of Clousta and this is closest to the Clousta Voe Noonsbrough fishery. An area of built up areas and gardens is noted inland south of the Voe of Clousta. The location does not coincide with any identified settlements, therefore it is thought to be incorrect.

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

The highest potential contribution of contaminated run-off to the Vementry fisheries, specifically the Clousta Voe Noonsbrough fishery is from the areas of improved grassland located near to the shorelines of the Voe of Clousta. The potential contribution of contaminated run-off to the mussel farm would be highest in this area. This impact would be expected to increase after rainfall. Any effect would be greatest at the southern end of the Clousta Voe Noonsbrough mussel farm.

8. Watercourses

There are no gauging stations on watercourses entering into Vementry North or South production areas. The only available data came from the measurements and samples taken during the shoreline survey. The weather on the first day of the shoreline survey started with light showers becoming less frequent as the day progressed with the second day of the survey being dry. Wet weather had occurred on the two days prior to them shoreline survey .

During the survey, eleven watercourses were noted, the details of which are listed in Table 8.1. All are relatively small unnamed watercourses. There were also two areas of dry land drainage at the head of the Voe of Clousta, three areas of boggy ground on the shore of the Voe of Setter and one on the north shore of the Voe of Clousta

Table 8.1 Watercourse loadings to Vementry North And South

No.	NGR	Description	Width (m)	Depth (m)	Flow (m^3/d)	Loading (*E. coli* per day)
1	HU 2959 6048	Unnamed watercourse	0.30	0.10	1800	$7.7x10^9$
2	HU 2951 5752	Unnamed watercourse	0.30	0.05	400	$1.5x10^{10}$
3	HU 2955 5737	Unnamed watercourse	0.15	0.04	140	Not Determined
4	HU 2956 5732	Unnamed watercourse	0.45	0.20	1100	$5.7x10^8$
5	HU 3084 5750	Unnamed watercourse	0.40	0.08	1200	$9.2x10^8$
6	HU 3091 5728	Unnamed watercourse	0.50	0.15	770	$2.4x10^9$
7	HU 3079 5712	Unnamed watercourse	0.30	0.10	260	$2.1x10^8$
8	HU 3068 5710	Unnamed watercourse	0.30	0.03	105	$7.3x10^8$
9	HU 3041 5687	Unnamed watercourse	0.40	0.20	4200	$1.5x10^9$
10	HU 3024 5688	Unnamed watercourse	0.10	0.05	64	Not Determined
11	HU 3082 5954	Unnamed watercourse	0.25	0.07	830	$4.2x10^9$

E. coli loadings to the Vementry production areas were estimated to be low to moderate. The highest estimated loading came from watercourse 2 ($1.5x10^{10}$ *E. coli/day*) which flows into the Voe of Clousta approximately 400 m south of the Clousta Voe Noonsbrough mussel farm. This watercourse passes through an area of pasture and settlement and therefore may carry diffuse contamination from livestock, human and wildlife sources.

Watercourse numbers 3 – 10 all flow into the Voe of Clousta, with loadings ranging from $2.1x10^8$ - $2.4x10^9$. Two watercourses were not sampled and loadings could not be calculated for these. These watercourses will likely have the greatest impact on the Clousta Voe: Noonsbrough mussel farm.

Due to the wet weather recorded prior to and during the shoreline survey, flows recorded are considered to be representative of wet weather conditions and therefore should be at the high end of their range.

Watercourse 1 flows from the island of Vementry into the head of Suthra Voe, approximately 250 m and 400 m respectively from the inactive Suthra Voe and the active Suthra Voe West fishery. It had an estimated loading of $7.7x10^9$. This watercourse is the outlet for the freshwater Loch of Reva.

Watercourse 11 flows into Cribba Sound, near the strait separating Cribba and Uyea Sounds, and is roughly 400 m from the Cribba Sound North fishery group. The estimated loading was $4.2x10^9$.

The majority of recorded watercourses flow into the Voe of Clousta and would be most likely to impact the southern end of the Clousta Voe Noonsbrough mussel farm.

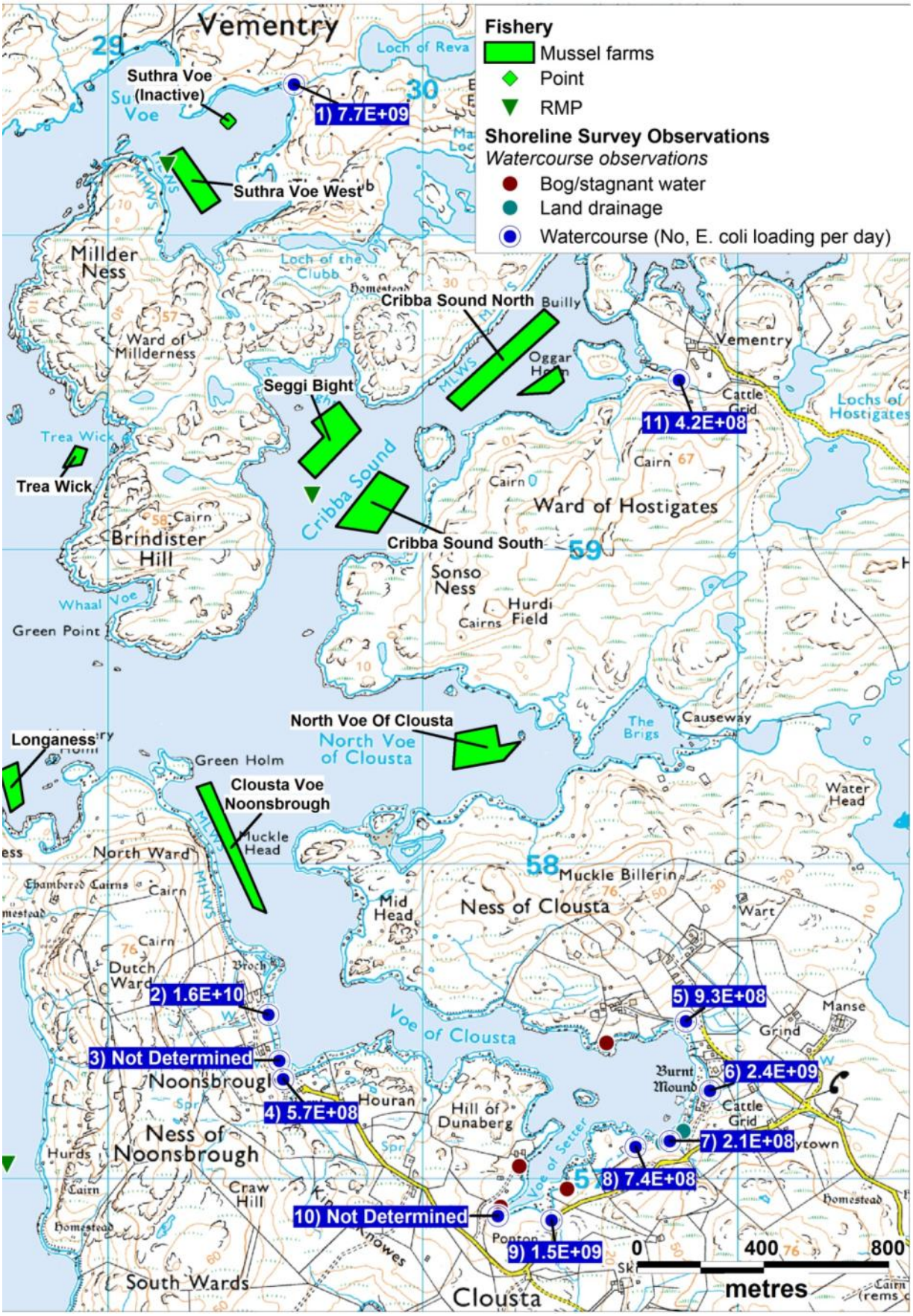


Figure 8.1 Watercourse shoreline survey observations at Vementry North And South

9. Meteorological Data

The nearest weather station for which rainfall data was available is located at Lerwick, situated approximately 23 km to the south east of the production area. Rainfall data was available for January 2007 – December 2012. The nearest wind station is also situated in Lerwick. 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 Vementry North and South mussel farms.

9.1 Rainfall

High rainfall and storm events are commonly associated with increased faecal contamination of coastal waters through surface water run-off from land where livestock or other animals are present, and through sewer and waste water treatment plant overflows (e.g. Mallin, et al., 2001; Lee & Morgan, 2003). The box and whisker plots in Figures 9.1 and 9.2, present a summary of the distribution of individual daily rainfall values by year and by month. The grey box represents the middle 50% of the observations, with the median at the midline. The whiskers extend to the largest or smallest observations up to 1.5 times the box height above or below the box. Individual observations falling outside the box and whiskers are represented by the symbol *.

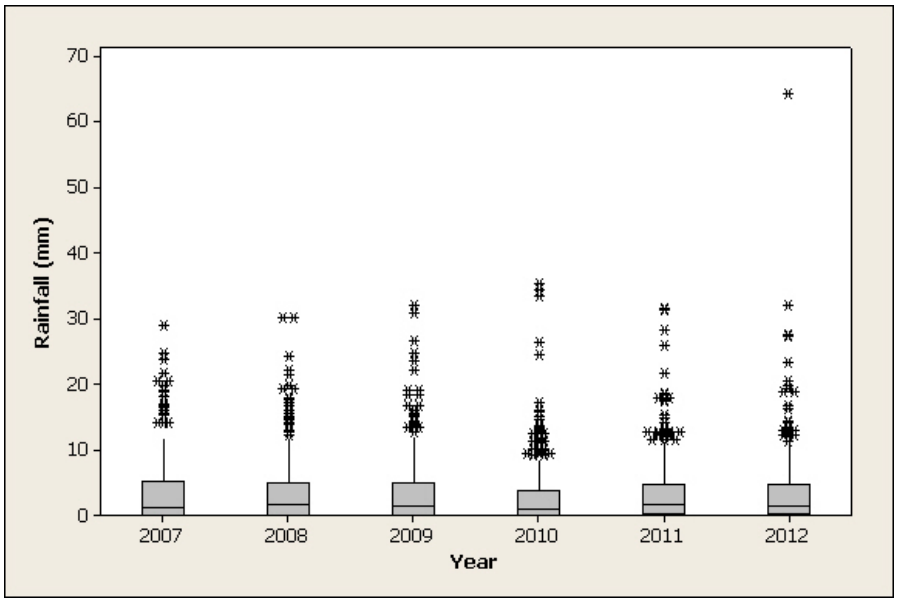


Figure 9.1 Box plot of daily rainfall values by year at Lerwick (2007 – 2012)

Total rainfall values varied somewhat from year to year, with 2010 being the driest year (a total of 1085 mm) and 2009 the wettest (1284 mm). High daily rainfall values of greater than 30 mm/d occurred in all years but an extreme rainfall event of nearly 70 mm/d was seen in 2012.

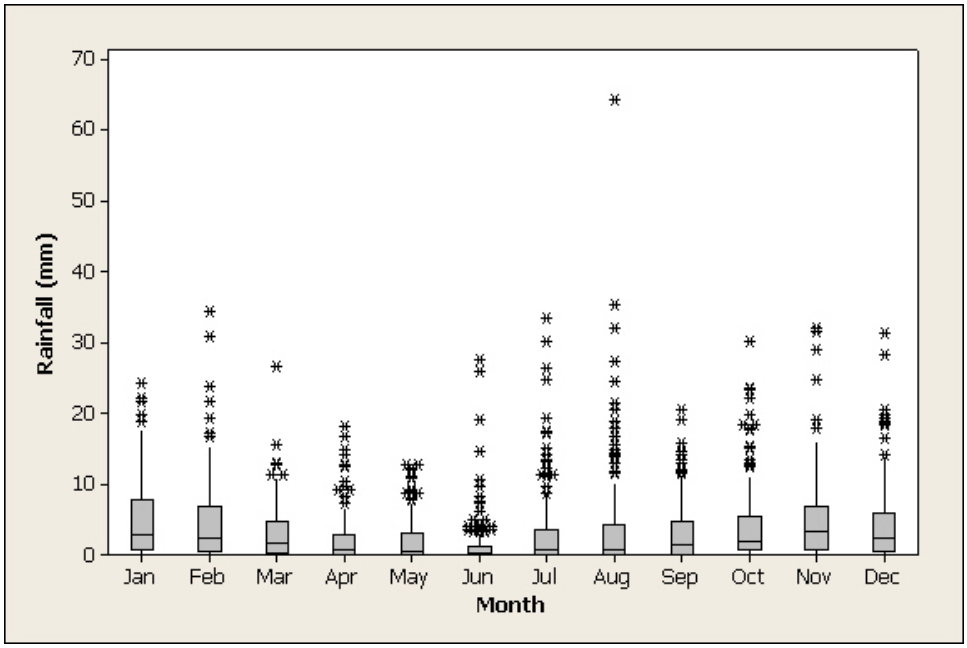


Figure 9.2 Box plot of daily rainfall values by month at Lerwick (2007 – 2012)

Rainfall was lowest between April and July and highest from November to February. Rainfall values exceeding 30 mm/d were seen in February, July, August, October, November and December. The 2012 extreme event occurred in August.

For the period considered here (2007-2012) 43 % of days received daily rainfall of less than 1 mm and 9 % of days received rainfall of over 10 mm. It is expected that, in general, 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 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.

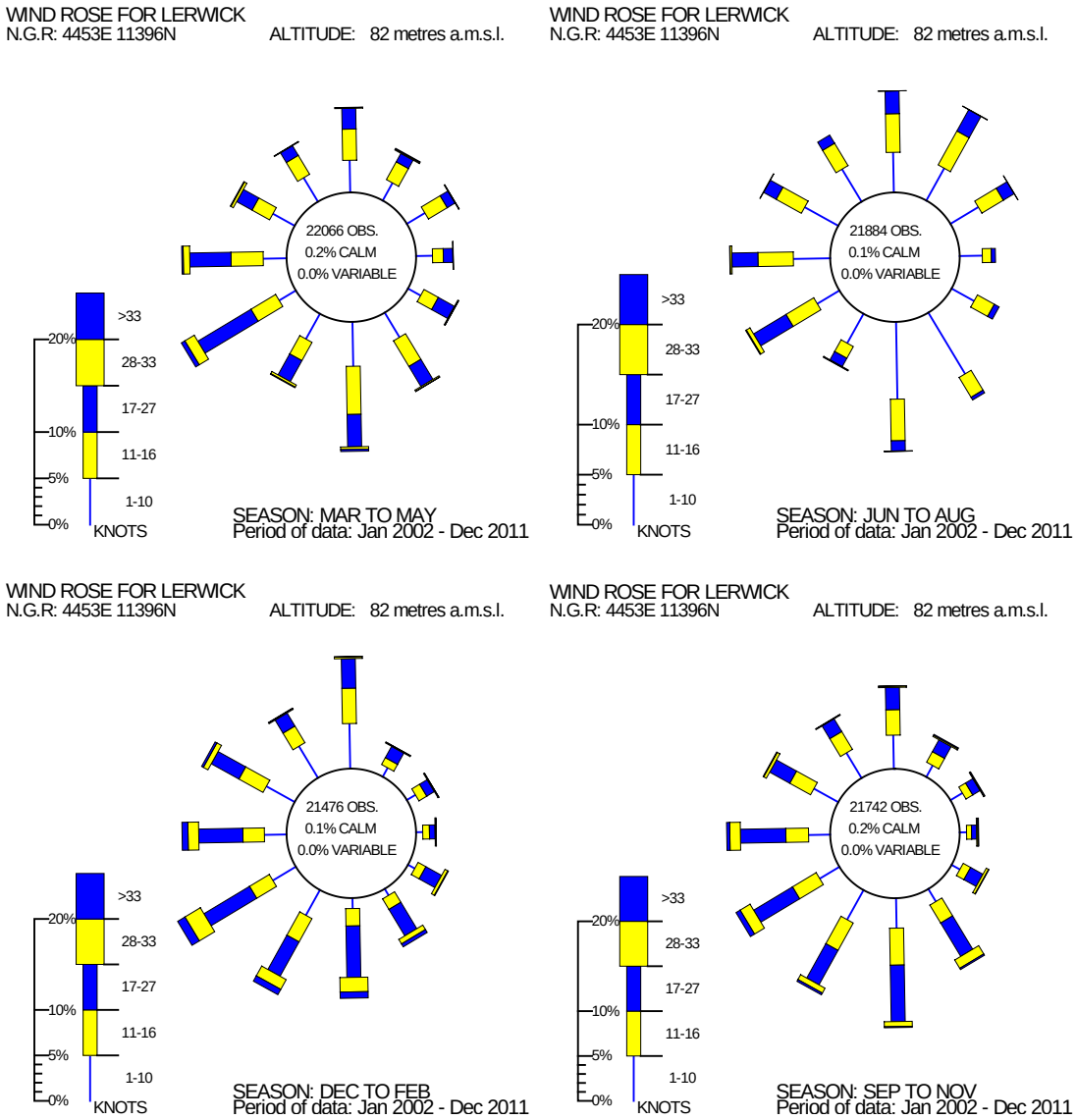


Figure 9.3 Seasonal wind roses for Lerwick

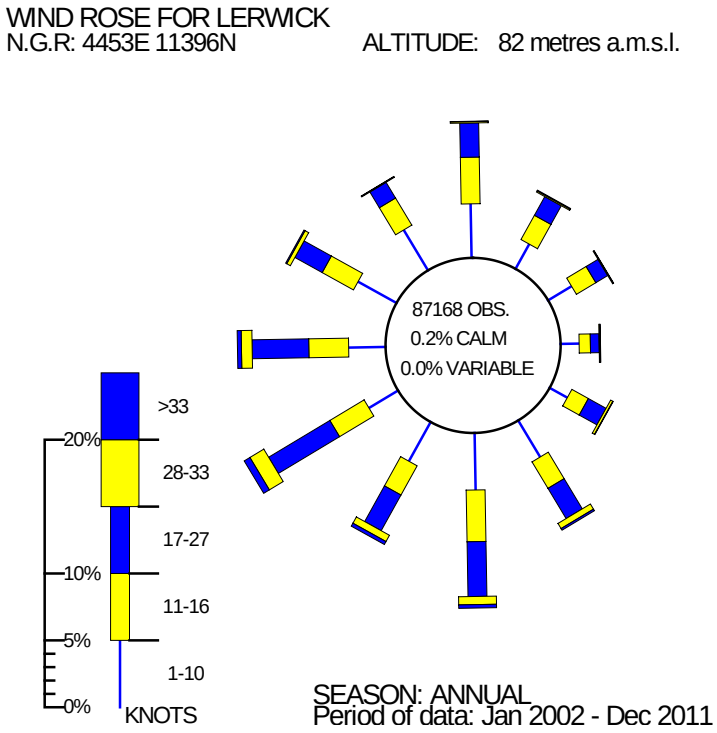


Figure 9.4 Annual wind rose for Lerwick

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

Vementry North and South have been classified for production of common mussels (*Mytilus edulis*) since 2005 although different production areas covering the same area have been active since 2001. The classification histories since 2008 are listed in Tables 10.1 and 10.2. FSAS classify production areas annually based on an assessment of previous sampling history, with the classification year running from 1 April to 31 March.

Table 10.1 Vementry North classification history

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2008	A	A	A	A	A	A	A	A	A	A	A	A
2009	A	A	A	A	A	A	A	A	A	A	A	A
2010	A	A	A	A	A	A	A	A	A	A	A	A
2011	A	A	A	A	A	A	A	A	A	A	A	A
2012	A	A	A	A	A	A	A	A	A	A	A	A
2013	A	A	A	A	A	A	A	A	A	A	A	A
2014	A	A	A									

Table 10.2 Vementry South classification history

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2008	A	A	A	A	A	A	A	A	A	A	A	A
2009	A	A	A	A	A	A	A	A	A	A	A	A
2010	A	A	A	A	A	A	A	A	A	A	A	A
2011	A	A	A	A	A	A	A	A	A	A	A	A
2012	A	A	A	A	A	A	A	A	A	A	A	A
2013	A	A	A	A	A	A	A	A	A	A	A	A
2014	A	A	A									

Both production areas have held a year-round A classification over the period.

11. Historical *E. coli* Data

11.1 Validation of historical data

Results for all samples assigned to Vementry North and South production areas were extracted from the FSAS database for the period 01/01/2008 to 10/10/2013 and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. The data were extracted from the database on 10/10/2013. All *E. coli* results were reported as most probable number (MPN) per 100 g of shellfish flesh and intravalvular fluid.

All sample results reported as <20 *E. coli* MPN / 100 g were reassigned a value of 10 *E. coli* MPN / 100 g for the purposes of statistical evaluation and graphical representation.

Samples from all three sites were all recorded as valid in the database and were received within the permitted 48 hr time window. All samples were taken within 100 m of their respective production area boundaries.

11.2 Summary of microbiological results

Historical monitoring results are summarised by sampling location in Table 11.1 below.

Table 11.1 Summary of historical sampling and results

Sampling Summary			
Production area	Vementry North	Vementry South	
Site	Suthra Voe West	Seggi Bight	Longaness
Species	Mussels	Mussels	Mussels
SIN	SI-322-464-08	SI-321-462-08	SI-321-885-08
Location	Various	Various	Various
Total no of samples	59	44	23
No. 2008	9	0	0
No. 2009	8	9	10
No. 2010	11	10	7
No. 2011	9	5	5
No. 2012	12	10	1
No. 2013	10	10	0
Results Summary			
Minimum	<20	<20	<20
Maximum	490	2200	230
Median	20	<20	20
Geometric mean	32	20	18
90 percentile	330	80	98
95 percentile	330	648	206
No. exceeding 230/100g	7 (12%)	2 (5%)	0
No. exceeding 1000/100g	0	1 (3%)	0
No. exceeding 4600/100g	0	0	0
No. exceeding 18000/100g	0	0	0

All samples for the Vementry North production area are reported to have come from the Suthra Voe West site. Sampling for the Vementry South production area has been reported to have been undertaken at two separate sites: Seggi Bight and Longaness. Only Seggi Bight has been regularly sampled in recent years. *E. coli.* The highest result was seen at the Seggi Bight site.

11.3 Overall geographical pattern of results

The geographical locations of all samples assigned to Vementry North and Vementry South are showed in Figure 11.1, with the symbol size proportional to the *E. coli* result.

A one-way ANOVA was carried out on results taken at the three different sampling locations: Suthra Voe West (site 1), Seggi Bight (site 2) and Longaness (site 3). No statistically significant difference was found in results between locations (one-way Anova, p = 0.060, Appendix 4). Geometric means, as well as minimum and

maximum results for each site is given in Table 11.2. Boxplots of the data at the three sites are presented in Figure 11.2.

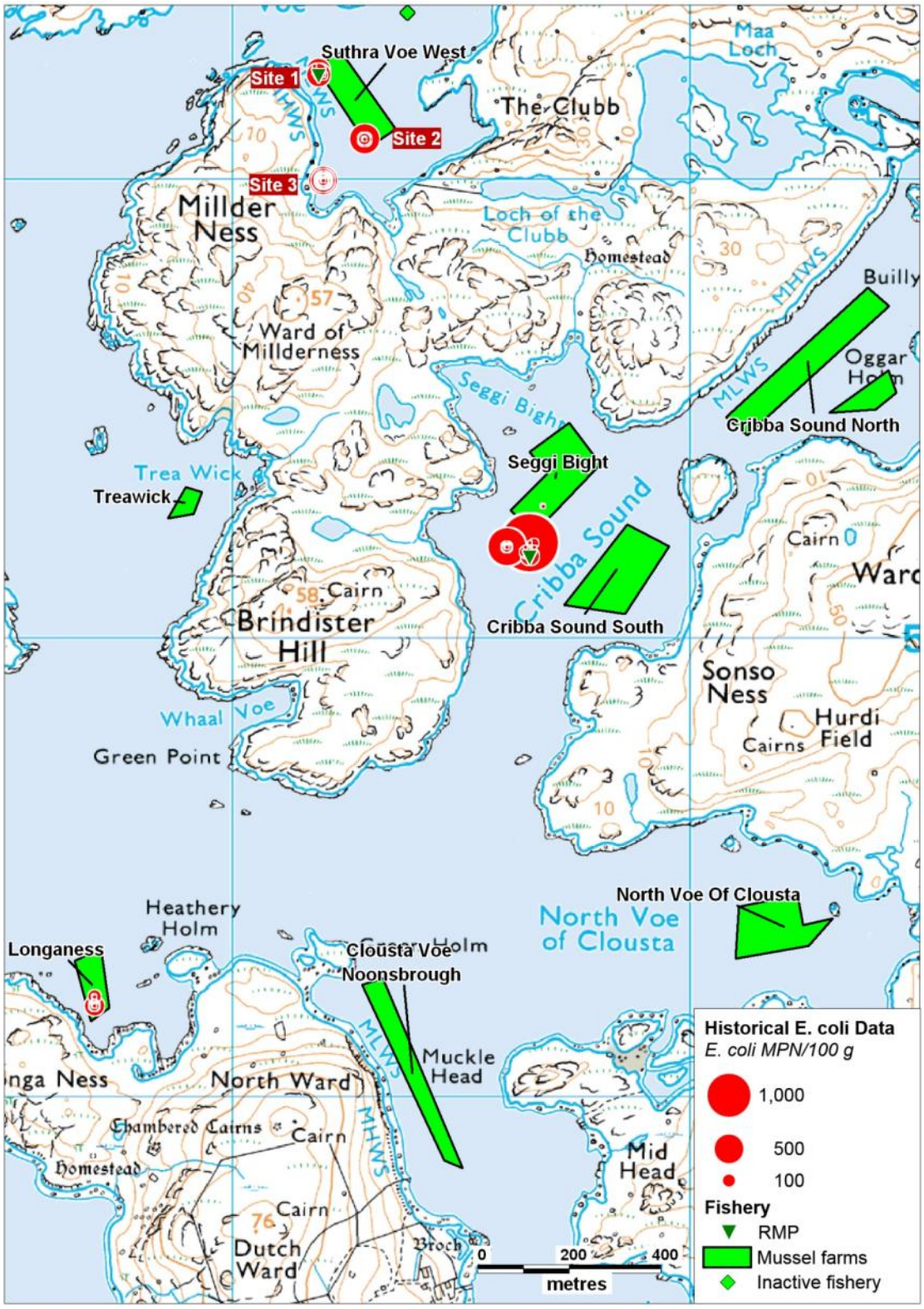


Figure 11.1 Map of reported sampling locations for common mussels at Vementry North and South

Table 11.2 Summary of results from the three sampling locations at the three sites at Vementry

Site	Site name	No. of samples	Geometric mean	Minimum	Maximum
1	Suthra Voe West	59	32	<20	490
2	Seggi Bight	44	20	<20	2200
3	Longaness	23	18	<20	230

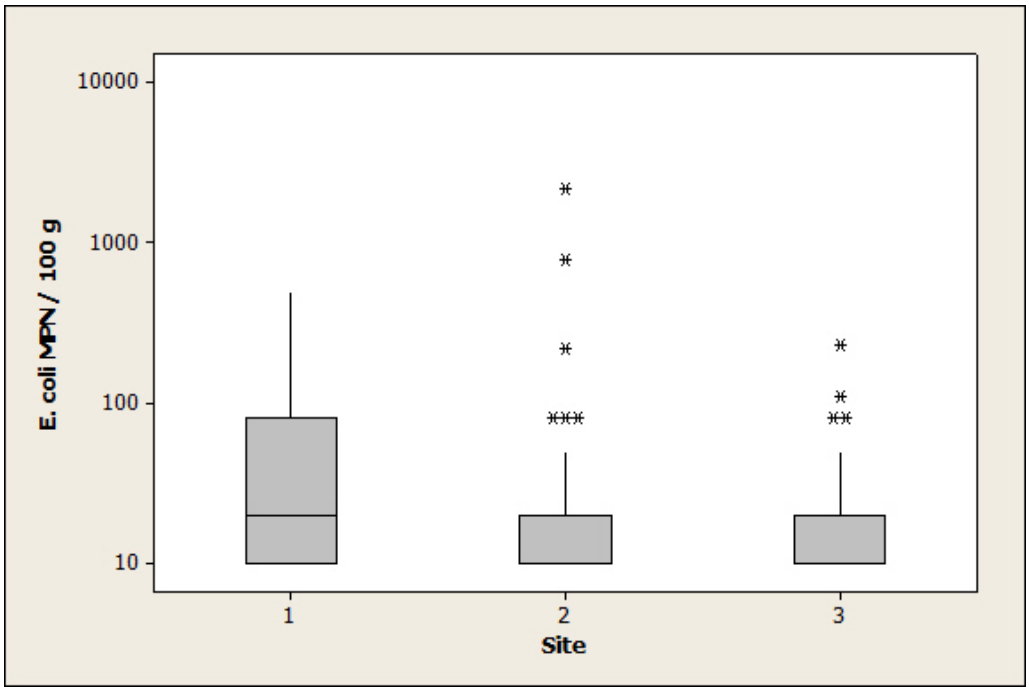


Figure 11.2 Boxplot of sampling results at the three sites at Vementry

Three distinct areas have been sampled at Suthra Voe West in the Vementry North production area; 18 samples from 2012 and 2013 were reported within 20 m of the current RMP (HU 2919 6023) (site 1), 14 samples mainly from 2011 were taken approximately 170 m southeast of the RMP at the southwest extent of the farm (site 2), and finally 27 samples from 2008 to 2010 were taken approximately 230 m south of the RMP (site 3).

A one-way Analysis of Variance (ANOVA) was carried out on results taken at the three sampling locations at Suthra Voe West. No statistically significant difference was found in results between locations (one-way ANOVA, p = 0.209). The geometric means, minimum and maximum results for each site are given in Table 11.2. The highest result was found to the southwest extent of the farm (site 2).

Table 11.3 Summary of results from the three sampling locations at Suthra Voe West

Site	No. of samples	Geometric mean	Minimum	Maximum
1	18	23	<20	330
2	14	27	<20	490
3	27	45	<20	460

Sampling was conducted at Longaness (Vementry South production area) prior to sampling being unified for all farms in Vementry South production area at Seggi Bight in 2012. Twenty-three samples were taken at Longaness in total, which lies approximately 1.3 km southwest of Seggi Bight.

Most samples taken at Seggi Bight were reported within 50 m of the RMP (HU 2965 5918), though all samples were reported within 115 m of the RMP.

The highest result recorded at Seggi Bight (2200 *E. coli* MPN / 100 g) was taken 20 m north of the RMP, though the four other results taken at the same location all returned results of <20 *E. coli* MPN / 100 g.

11.4 Overall temporal pattern of results

Scatterplots of *E. coli* results against date for sites Suthra Voe West, Seggi Bight and Longaness are presented in Figures 11.3, 11.4 and 11.5 respectively. The datasets are fitted with a lowess trend line. Lowess trend lines 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. A trend line helps to highlight any apparent underlying trends or cycles.

Suthra Voe West

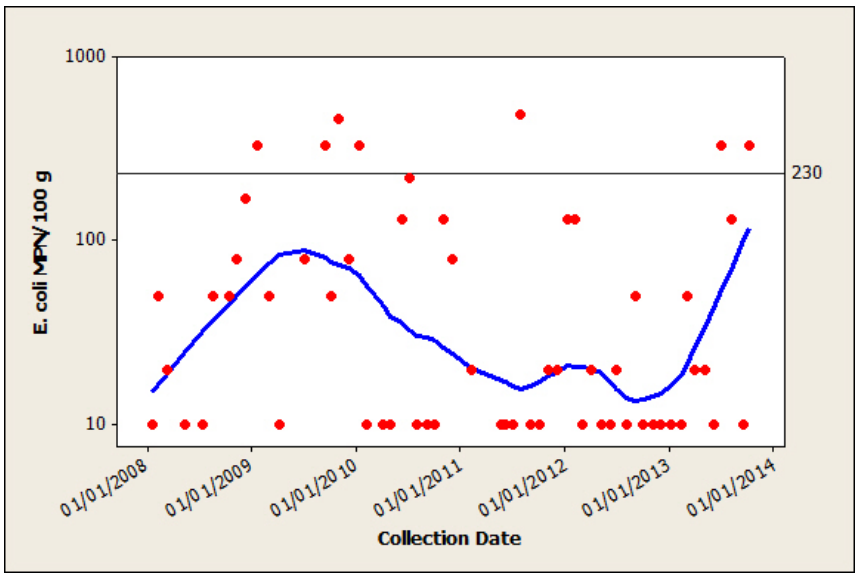


Figure 11.3 Scatterplot of *E. coli* results by collection date at Suthra Voe West

Contamination levels at this site show strong variation, with a peak in 2009-10 related to a series of results > 230 and corresponding lack of results below the limit of detection of the test. There has been a recent upward trend *E. coli*coinciding with a small number of high (for the area) results.

Seggi Bight

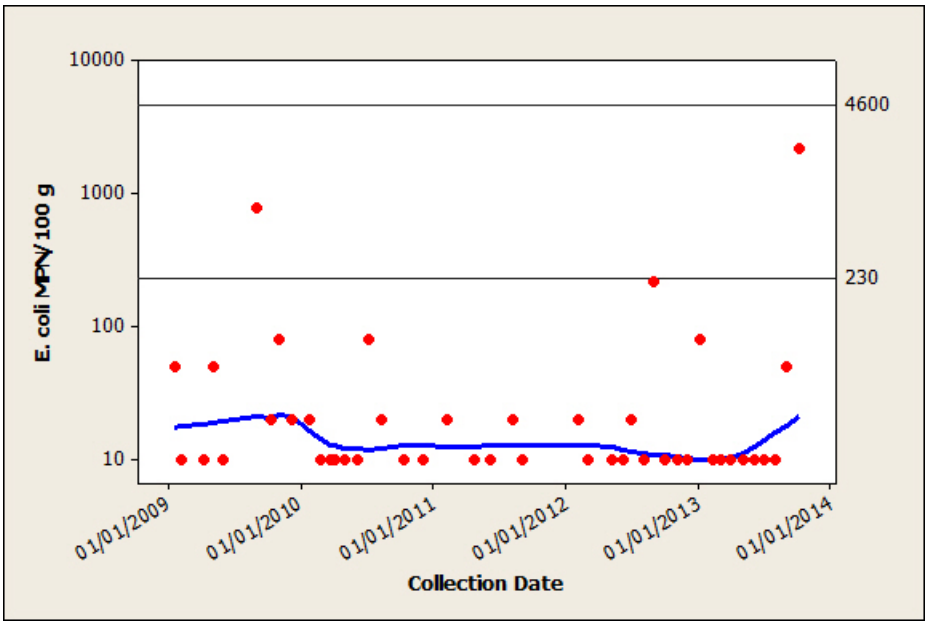


Figure 11.4 Scatterplot of *E. coli* results by collection date at Seggi Bight

The general level of contamination has been largely low and unchanging over the years with only two results above 230 *E. coli* MPN/100g.

Longaness

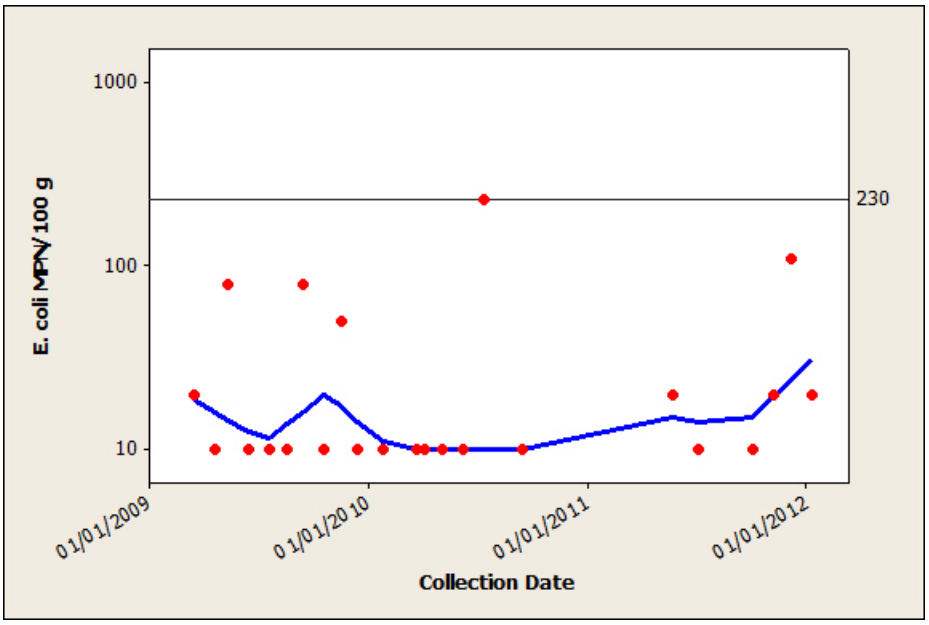


Figure 11.5 Scatterplot of *E. coli* results by collection date at Longaness

Gaps in sampling complicate assessment of trend but the available data shows no marked change over the assessment period.

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. Scatterplots of *E. coli* results by month, overlaid by a lowess line to highlight trends for sites Suthra Voe, Seggi Bight and Longaness are displayed in Figures 11.6, 11.8 and 11.10. Jittering was applied to all figures at 0.02 (x-axis) and 0.001 (y-axis) respectively.

For statistical evaluation, seasons were split into spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). Boxplots of *E. coli* results by season for Suthra Voe, Seggi Bight and Longaness are presented in Figures 11.7, 11.9 and 11.11 respectively.

Suthra Voe West

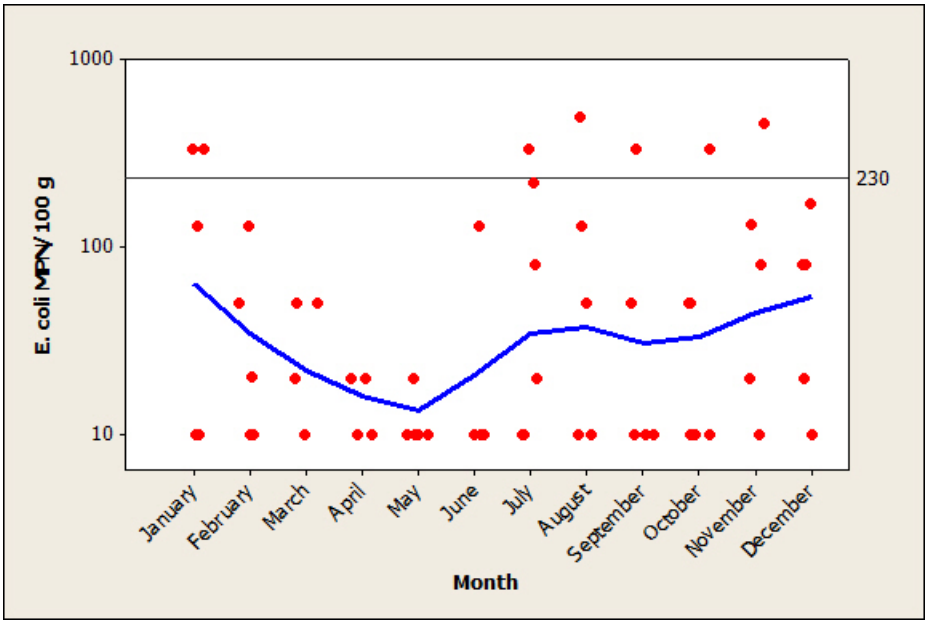


Figure 11.6 Scatterplot of *E. coli* results by month at Suthra Voe West, fitted with a lowess line

Highest results (>230 *E. coli* MPN/100 g) were recorded between July and January with results tending to be lowest in April and May.

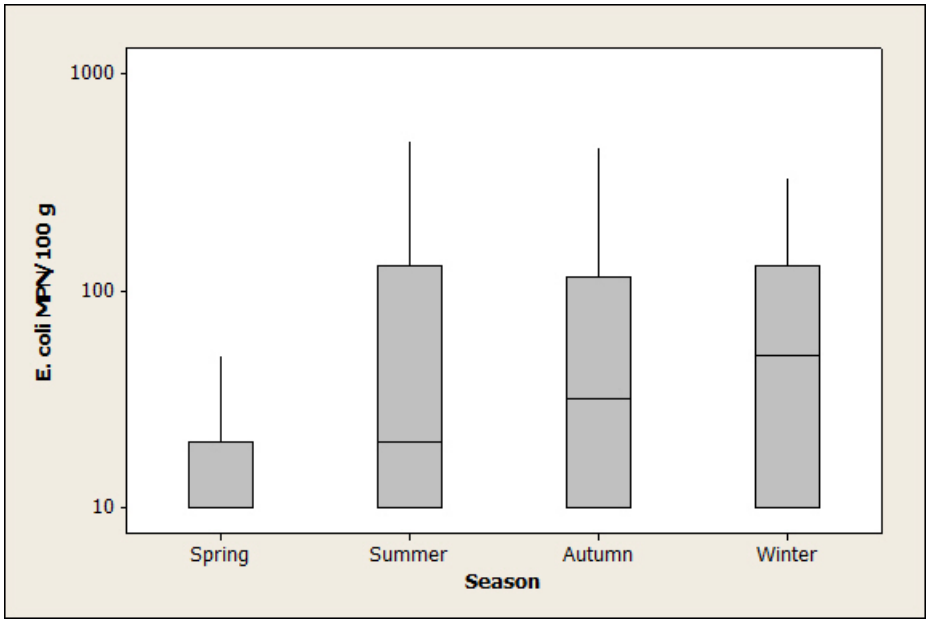


Figure 11.7 Boxplot of *E. coli* results by season at Suthra Voe West

No significant difference was found in *E. coli* results by season (one-way ANOVA, p = 0.170, Appendix 4).

Seggi Bight

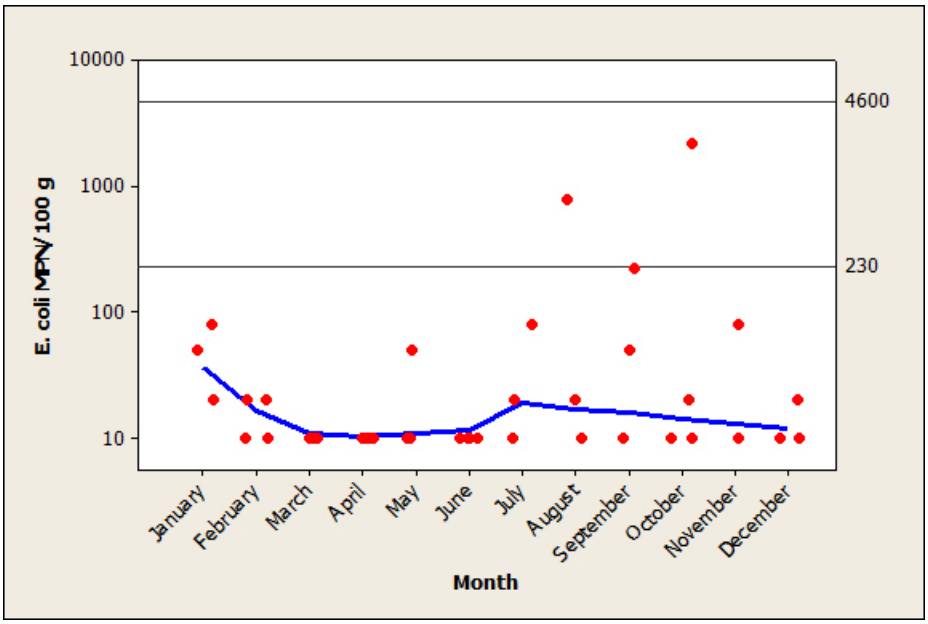


Figure 11.8 Scatterplot of *E. coli* results by month at Seggi Bight, fitted with a lowess line

Highest contamination levels were seen between August and October*E. coli* with the results tending to be lowest in March and April.

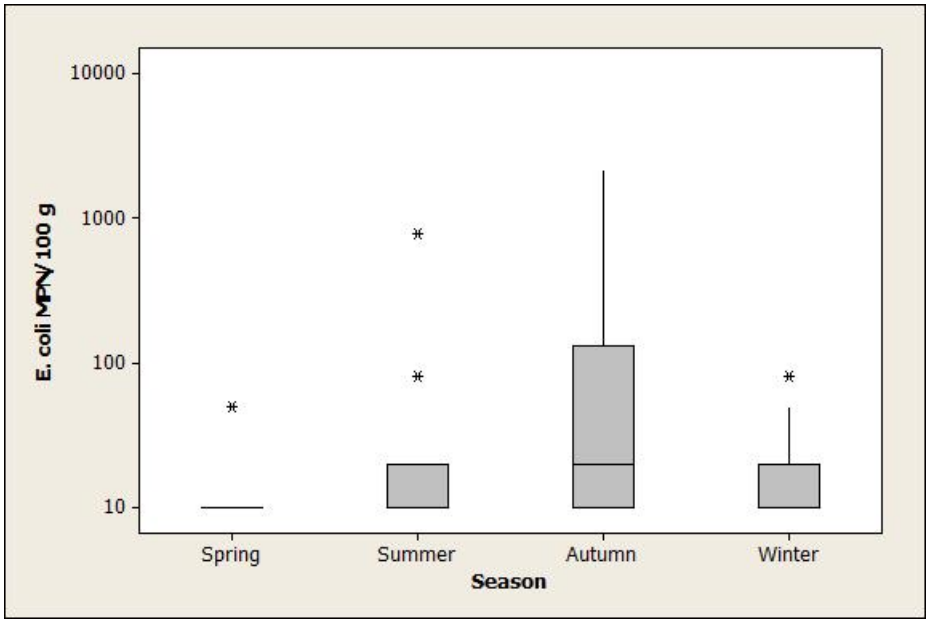


Figure 11.9 Boxplot of *E. coli* results by season at Seggi Bight

No significant difference was found in *E. coli* results by season (one-way ANOVA, p 0.124, Appendix 4.

Longaness

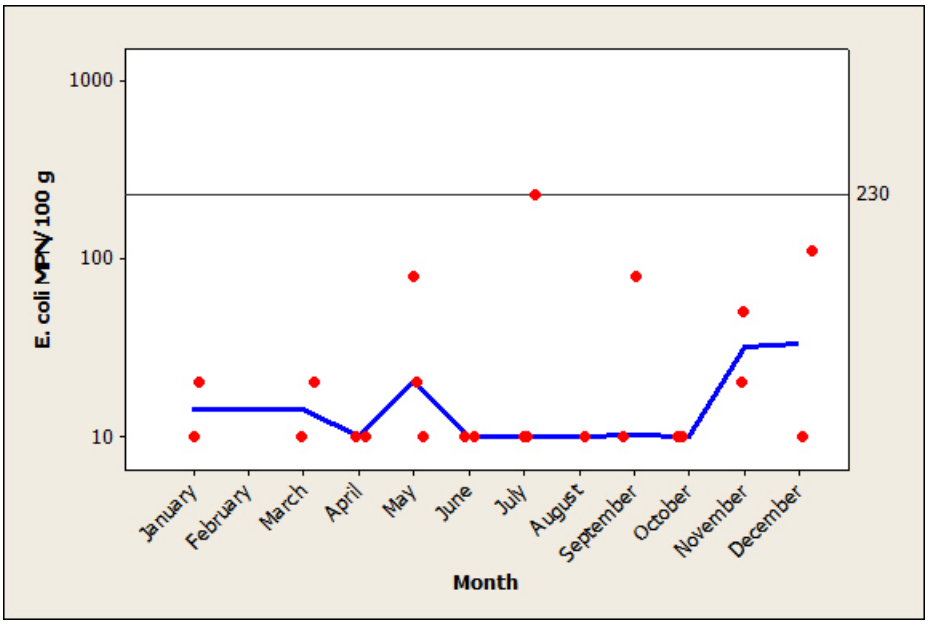


Figure 11.10 Scatterplot of *E. coli* results by month at Longaness, fitted with a lowess line

There is a scatter of results higher than the general trend (but still not markedly high) between May and December. No samples were taken in February.

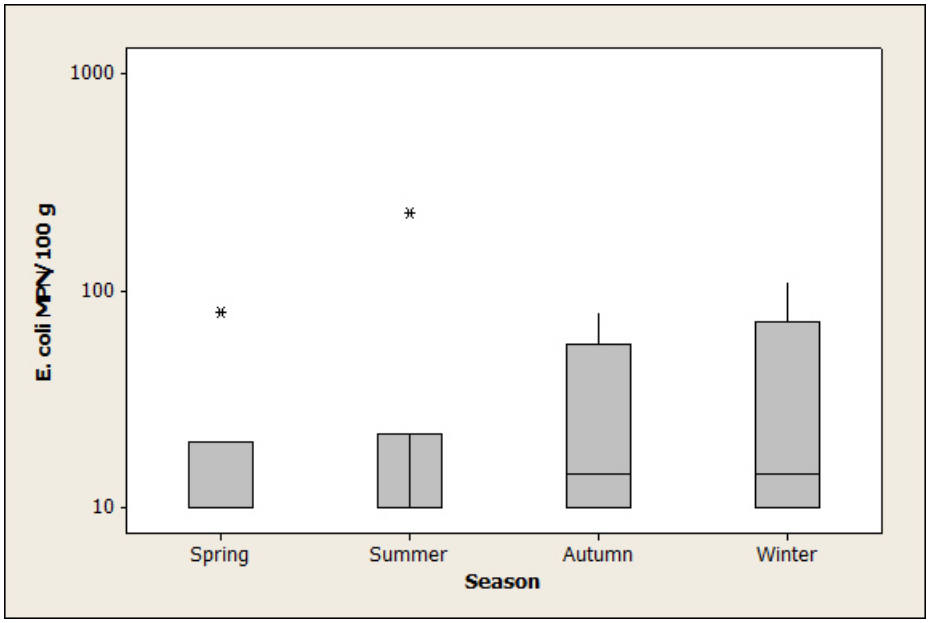


Figure 11.11 Boxplot of *E. coli* results by season at Longaness

No significant difference was found in *E. coli* results by season*E. coli* (one-way ANOVA, p=0.956, Appendix 4).

11.5.1 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 & 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.

11.5.2 Analysis of results by recent rainfall

The nearest weather station with available rainfall data was at Lerwick approximately 23 km southeast of Vementry. Rainfall data was purchased from the Meteorological Office for the period of 01/01/08 - 31/12/2012 (total daily rainfall in mm). Data was extracted from this for all sample results at Vementry between 01/01/2008 – 31/12/2012.

Two-day rainfall

Scatterplots of *E. coli* results against total rainfall recorded on the two days prior to sampling for Suthra Voe West, Seggi Bight and Longaness are displayed in Figure 11.12, 11.13 and 11.14 respectively. Jittering was applied to results in all figures at 0.02 (x-axis) and 0.001 (y-axis) respectively.

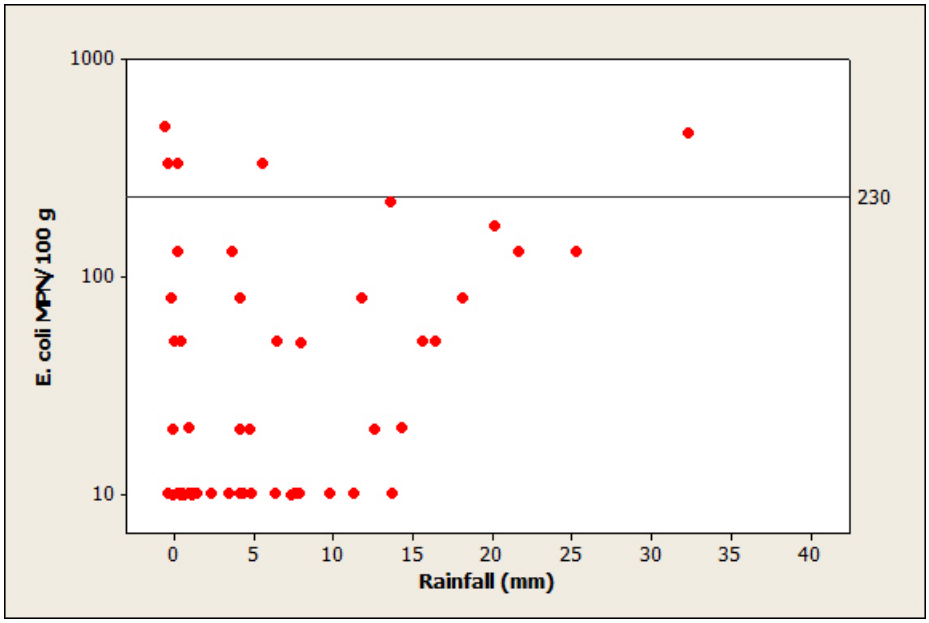


Figure 11.12 Scatterplot of *E. coli* results against rainfall in the previous two days at Suthra Voe West

No significant correlation was found between *E. coli* results and the previous two day rainfall (Spearman's rank correlation r = 0.209, p = 0.150). However, no very low results were seen after rainfall exceeding 15 mm/2 d.

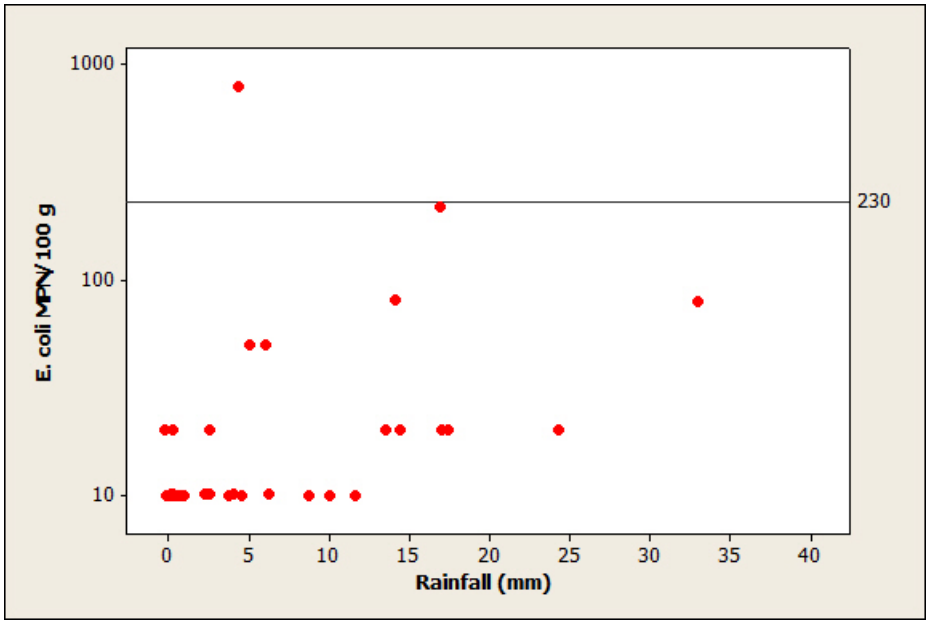


Figure 11.13 Scatterplot of *E. coli* results against rainfall in the previous two days at Seggi Bight

A strongly significant correlation was found between *E. coli* results and the previous two day rainfall (Spearman's rank correlation r = 0.605, p = 0.000). Despite the highest result recorded at <5 mm rainfall, there appears to be a general upward trend in sample results with increasing rainfall over the previous two days.

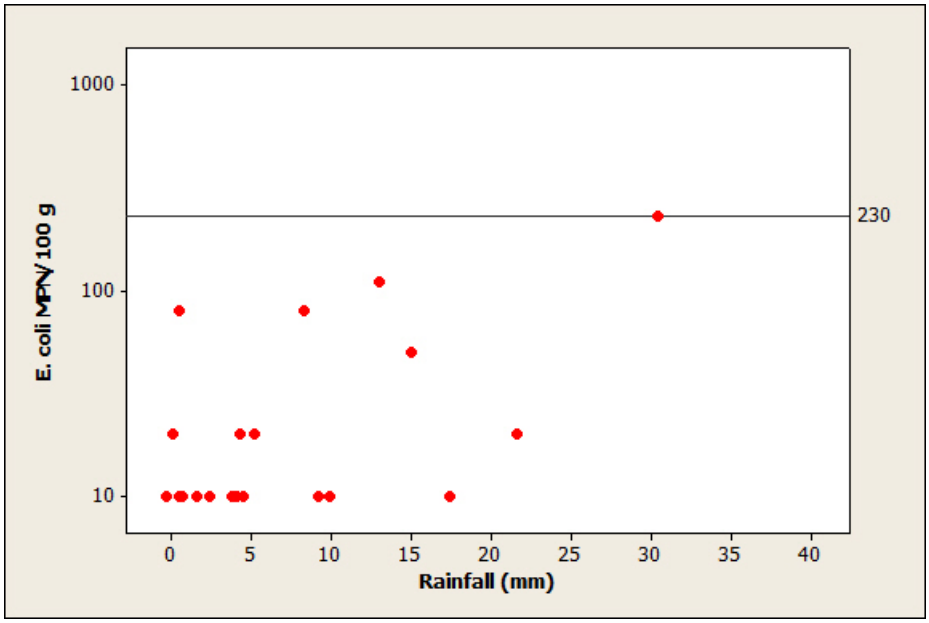


Figure 11.14 Scatterplot of *E. coli* results against rainfall in the previous two days at Longaness

A significant correlation was found between *E. coli* results and the previous two day rainfall (Spearman's rank correlation r = 0.439, p = 0.036), with the highest result recorded taken at the highest rainfall level over the previous two days.

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. Scatterplots of *E. coli* results against total rainfall recorded for the seven days prior to sampling at Suthra Voe, Seggi Bight and Longaness are shown in Figures 11.15, 11.16 and 11.17 respectively. Jittering was applied to results in all figures at 0.02 (x-axis) and 0.001 (y-axis) respectively.

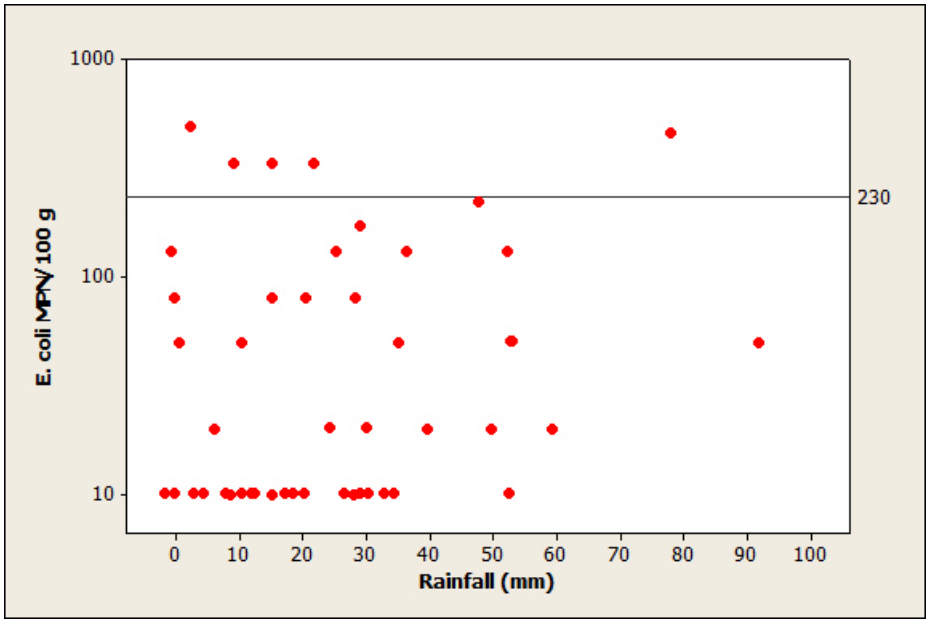


Figure 11.15 Scatterplot of *E. coli* results against rainfall in the previous seven days at Suthra Voe West

No significant correlation was found between *E. coli* results and the previous seven day rainfall (Spearman's rank correlation r = 0.182, p = 0.210), with the majority of high results taken at low rainfall levels. However, only one very low result was seen after rainfall exceeding 35 mm/ 7 d.

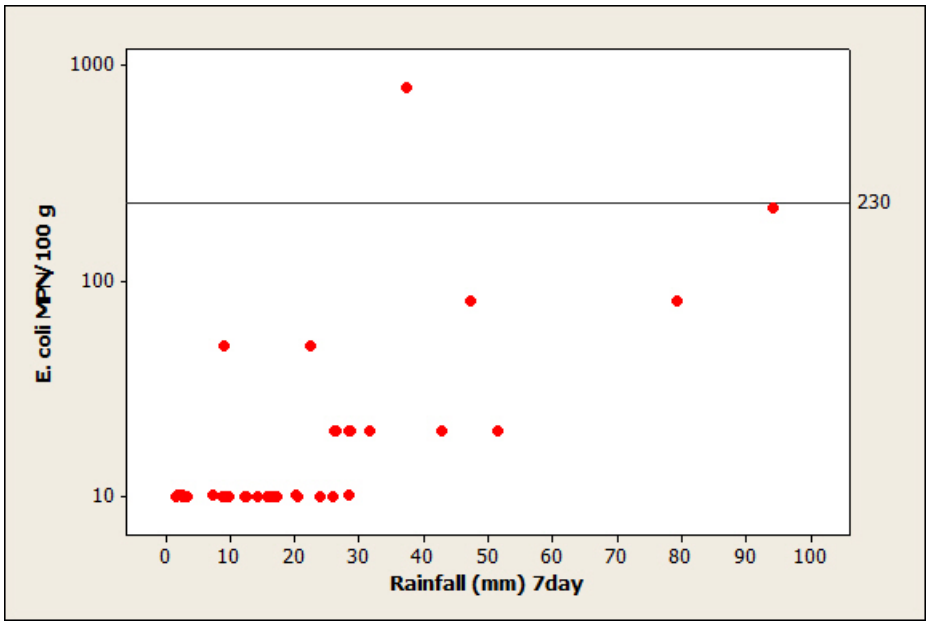


Figure 11.16 Scatterplot of *E. coli* results against rainfall in the previous seven days at Seggi Bight

A strongly significant correlation was found between *E. coli* results and the previous seven day rainfall (Spearman's rank correlation r = 0.717, p = 0.000), with all of the low results taken at low rainfall levels of <30 mm.

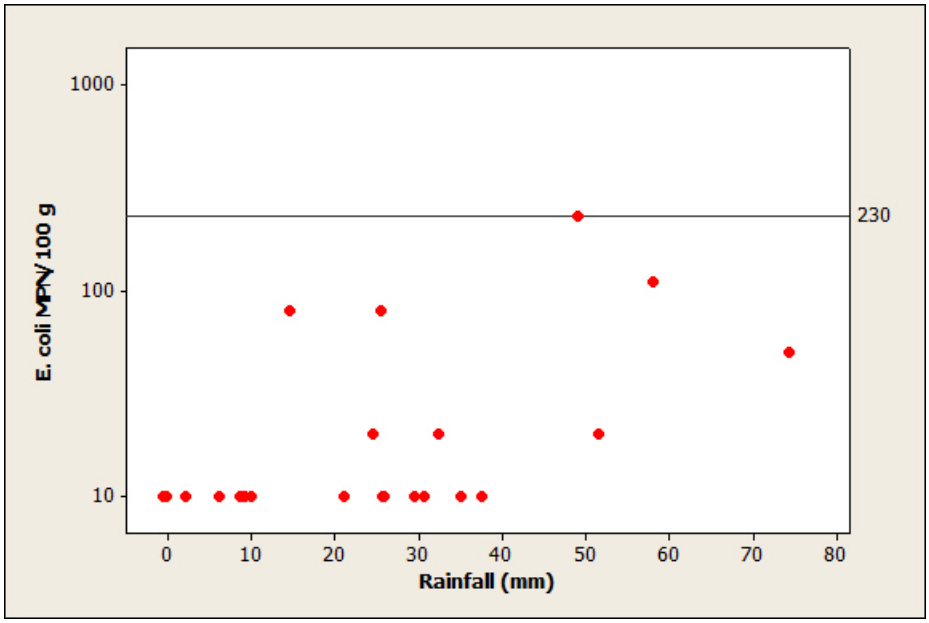


Figure 11.17 Scatterplot of *E. coli* results against rainfall in the previous seven days at Longaness

A significant correlation was found between *E. coli* results and the previous seven day rainfall (Spearman's rank correlation r = 0.498, p = 0.016), with higher results generally taken at rainfall levels of >10 mm/ 7 d and no very low results being seen at rainfall levels >40 mm/7 d.

11.5.3 Analysis of results by tidal height

Spring/neap tidal cycle

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/new moon, at about 45^{o} on a polar plot. The tides then decrease to the smallest (neap) tides, at about 225^{o}, before increasing back to spring tides. Polar plots of *E. coli* results against the lunar cycle are shown for Suthra Voe West, Seggi Bight and Longaness in Figures 11.18, 11.19 and 11.20 respectively**.** 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.

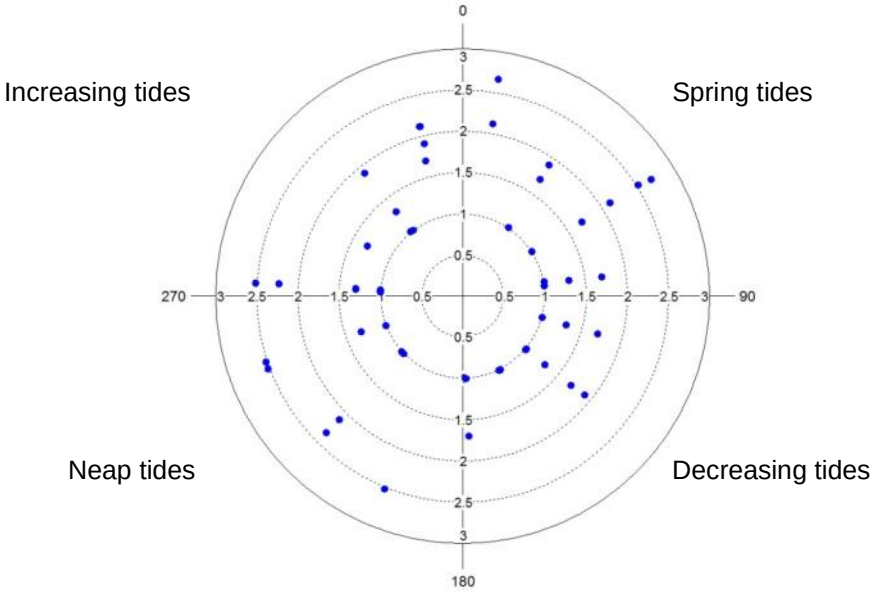


Figure 11.18 Polar plots of log_{10} *E. coli* results on the spring/neap tidal cycle at Suthra Voe West

No statistically significant correlation was found between log_{10} *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r = 0.229, p = 0.053).

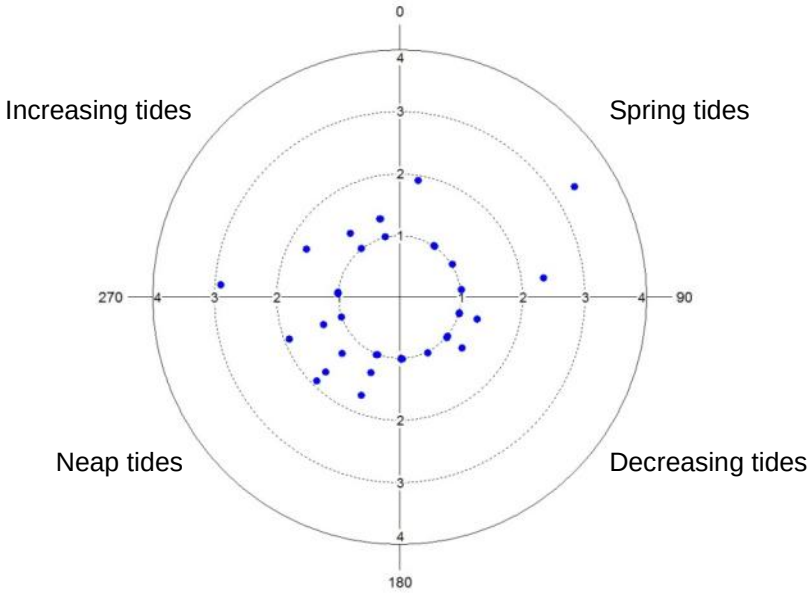


Figure 11.19 Polar plots of log10 *E. coli* results on the spring/neap tidal cycle at Seggi Bight

No statistically significant correlation was found between log_{10} *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r = 0.228, p = 0.119).

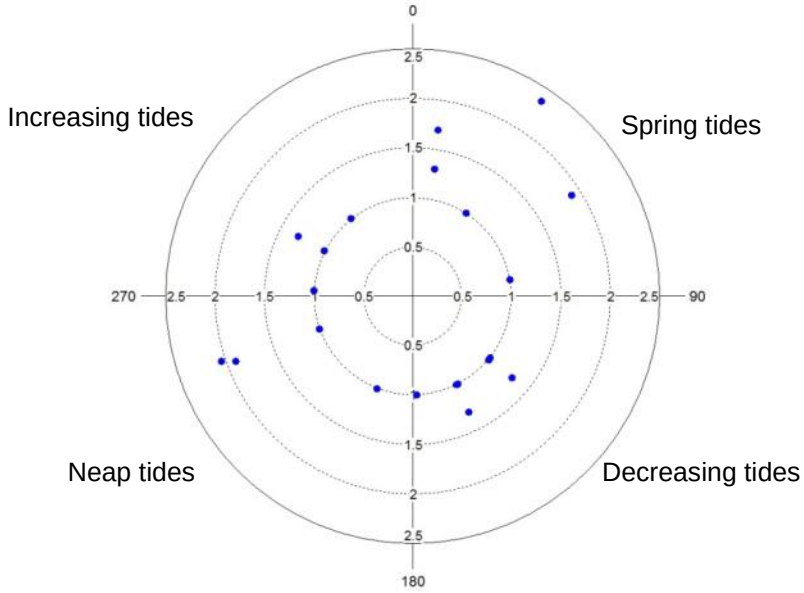


Figure 11.20 Polar plots of log10 *E. coli* results on the spring/neap tidal cycle at Longaness

No statistically significant correlation was found between $\log_{10}$ *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r = 0.327 p = 0.117).

High/low tidal cycle

Tidal state (high/low tide) changes the direction and strength of water flow around production areas. Depending on the location of contamination sources, tidal state may cause marked changes in water quality near the vicinity of the farms. Shellfish species response time to *E. coli* levels can vary from within an hour to a few hours. Polar plots of *E. coli* results against the high/low tidal cycle for Suthra Voe West, Seggi Bight and Longaness are shown in Figures 11.21, 11.22 and 11.23 respectively. High water is located at 0^o on the polar plot and low water at 180^o.

High and low water data from Hillswick was extracted from POLTIPS-3 in November 2013. This site was the closest to the production area (approximately 18 km to the northeast) and it is assumed that tidal state will be similar between sites.

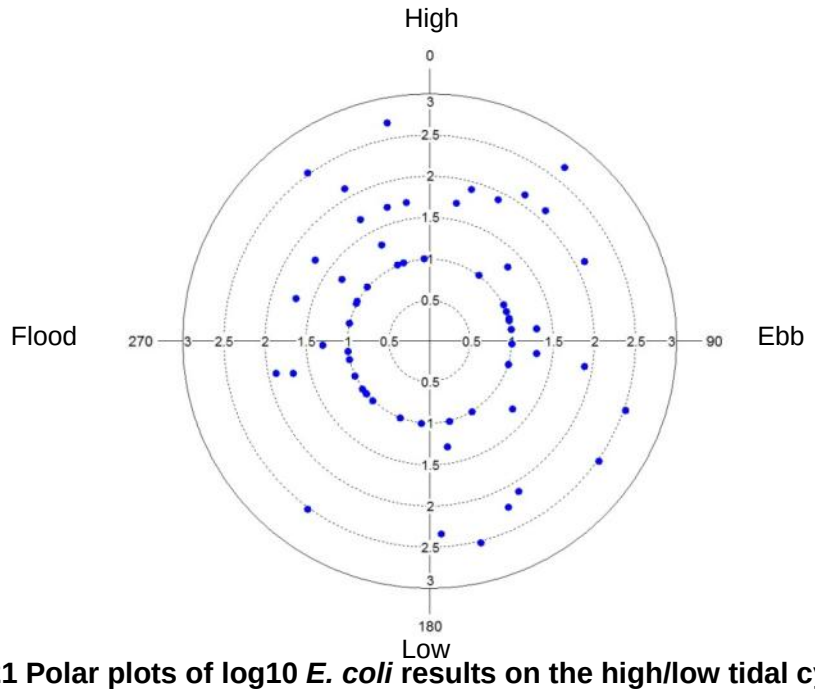


Figure 11.21 Polar plots of log10 *E. coli* results on the high/low tidal cycle at Suthra Voe West

No statistically significant correlation was found between $\log_{10}$ *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.165, p = 0.219), high results were taken on all tidal states.

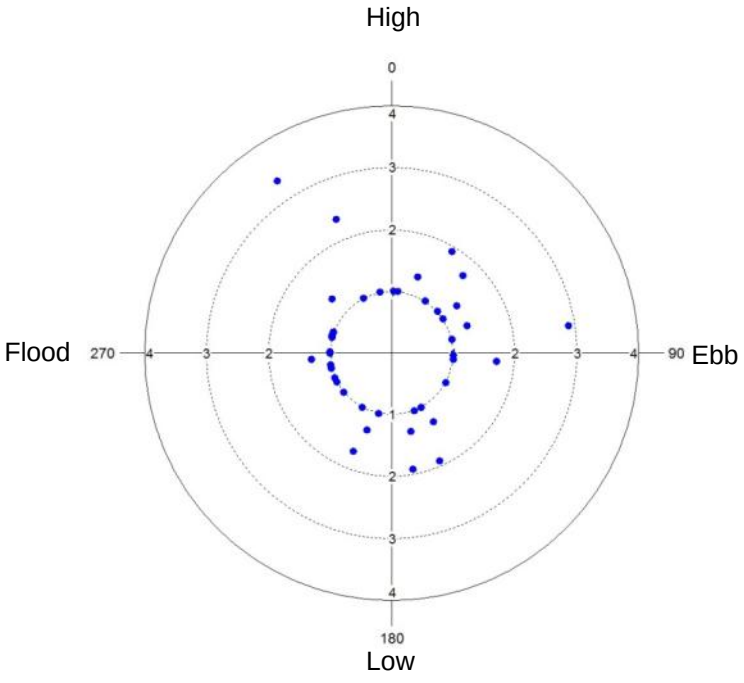


Figure 11.22 Polar plots of log10 *E. coli* results on the high/low tidal cycle at Seggi Bight

No statistically significant correlation was found between $\log_{10}$ *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.203, p = 0.184).

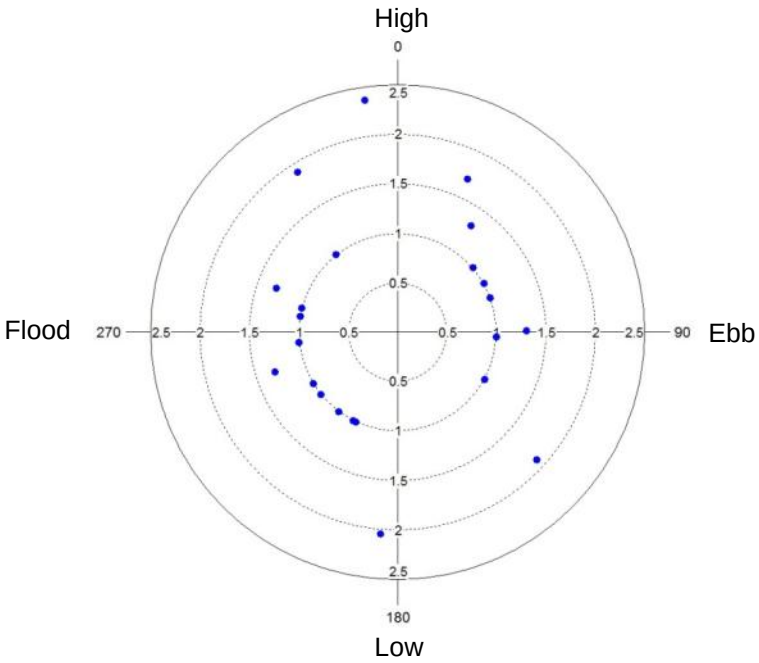


Figure 11.23 Polar plots of log10 *E. coli* results on the high/low tidal cycle at Longaness

No statistically significant correlation was found between $\log_{10}$ *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.223, p = 0.37).

11.5.4 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. Scatterplots of *E. coli* results against water temperature for Suthra Voe West, Seggi Bight and Longaness are shown in Figures 11.24, 11.25 and 11.26 respectively. Water temperature was recorded for 58/59 Suthra Voe West samples, and all 44 and 23 samples from Seggi Bight and Longaness. Jittering of results was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

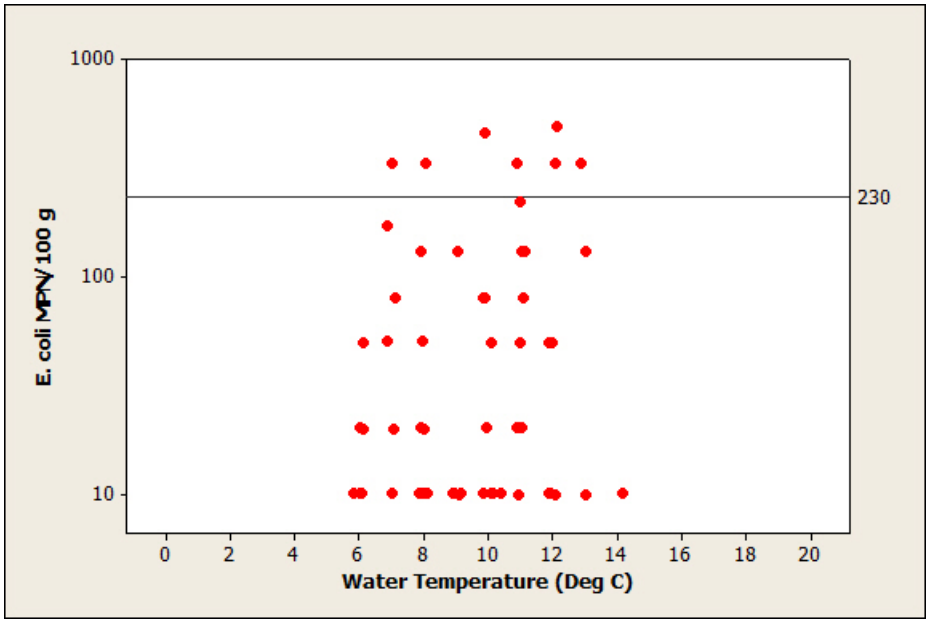


Figure 11.24 Scatterplot of *E. coli* results against water temperature at Suthra Voe West

No statistically significant correlation was found between *E. coli* results and water temperature (Spearman's rank correlation r = 0.135, p = 0.314).

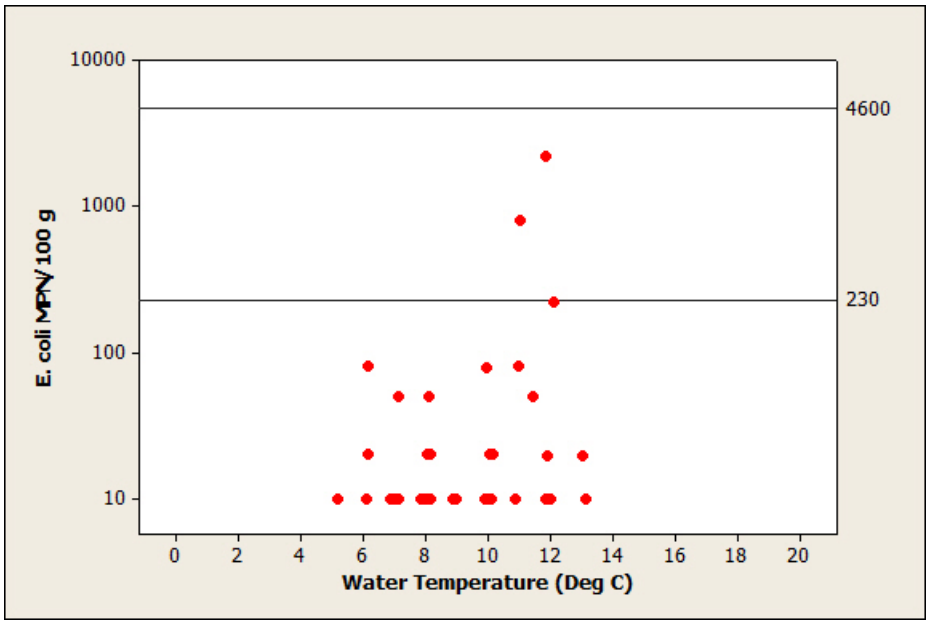


Figure 11.25 Scatterplot of *E. coli* results against water temperature at Seggi Bight

No statistically significant correlation was found between *E. coli* results and water temperature (Spearman's rank correlation r = 0.263, p = 0.085).

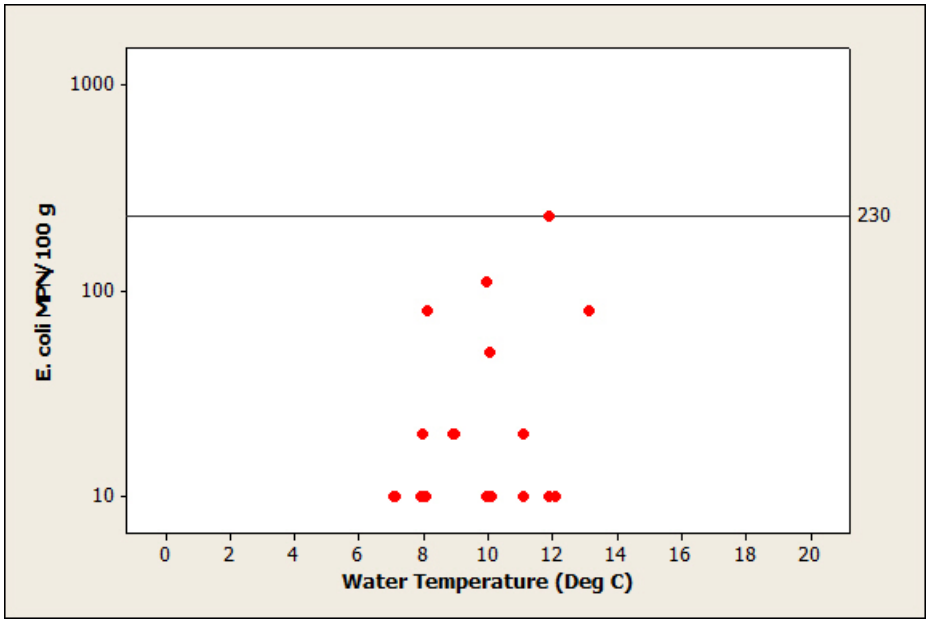


Figure 11.26 Scatterplot of *E. coli* results against water temperature at Longaness

No statistically significant correlation was found between *E. coli* results and water temperature (Spearman's rank correlation r = 0.202, p = 0.356).

11.5.5 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence and hence freshwater borne contamination at a site. Scatterplots of *E. coli* results against salinity for Suthra Voe West, Seggi Bight and Longaness are shown in Figures 11.27, 11.28 and 11.29 respectively. Salinity was recorded for 40/59 of the Suthra Voe West samples, 26/44 Seggi Bight samples and all 23 of the Longaness samples. Jittering of results was applied at 0.02 and 0.001 on the X and Y axis respectively.

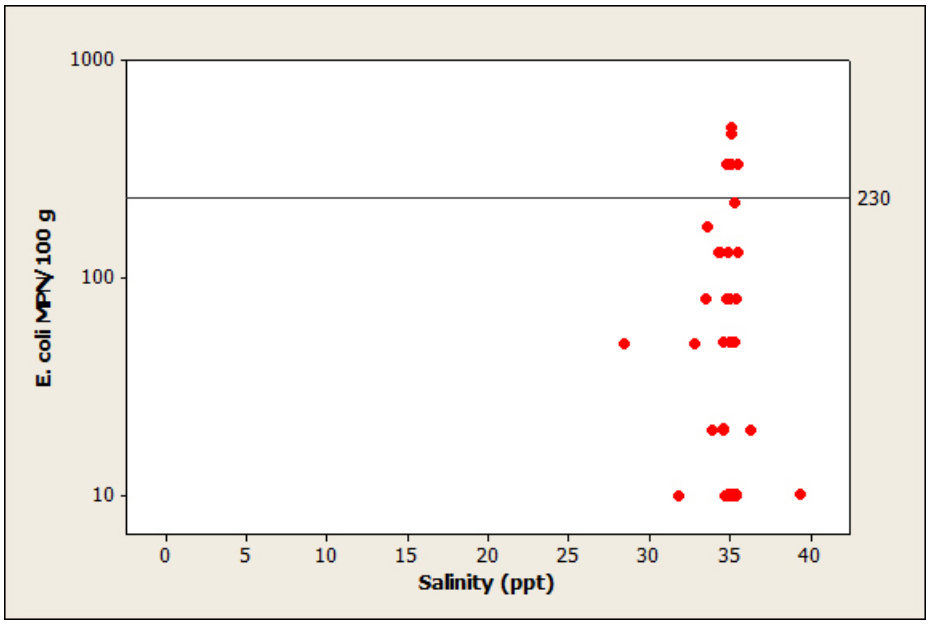


Figure 11.27 Scatterplot of *E. coli* results against salinity at Suthra Voe West

No statistically significant correlation was found between common mussel *E. coli* results and salinity (Spearman's rank correlation r = -0.155, p = 0.340).

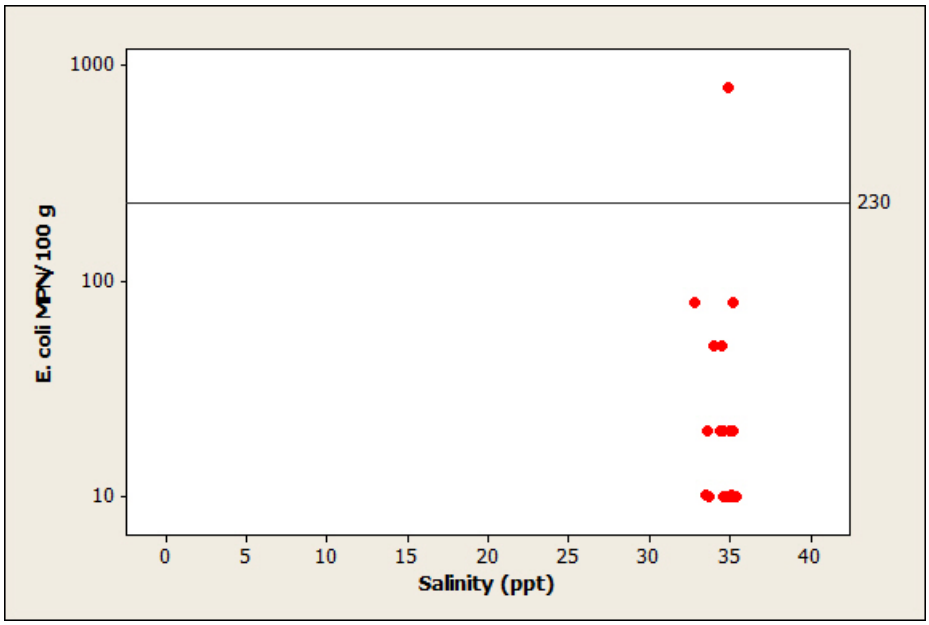


Figure 11.28 Scatterplot of *E. coli* results against salinity at Seggi Bight

No statistically significant correlation was found between common mussel *E. coli* results and salinity (Spearman's rank correlation r = -0.250, p = 0.219).

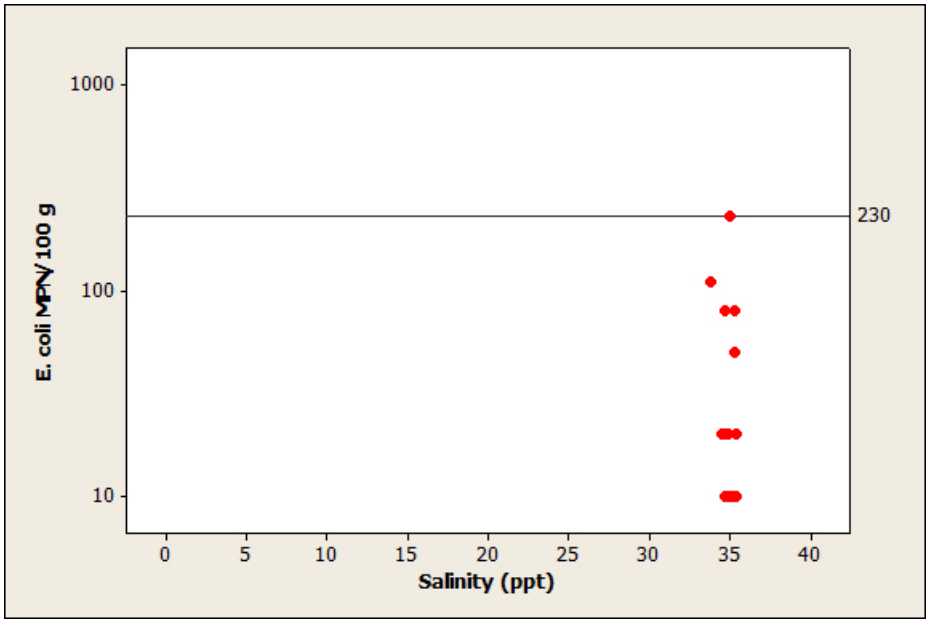


Figure 11.29 Scatterplot of *E. coli* results against salinity at Longaness

No statistically significant correlation was found between common mussel *E. coli* results and salinity (Spearman's rank correlation r = -0.386, p = 0.069). The majority of samples were taken at salinities of 34-35 ppt.

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

Suthra Voe West

In the results from Suthra Voe West, seven common mussel samples had results >230 *E. coli* MPN / 100 g. These are listed below in Table 11.4.

Table 11.4 Suthra Voe West historic *E. coli* sampling results over 230 *E. coli* MPN / 100g

Collection Date	*E. coli* (MPN/100 g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (°C)	Salinity (ppt)	Tidal state (spring/neap)	Tidal State (high/low)
19/01/2009	330	HU 292 600	5.4	22.8	7	34.52	Neap	Low
14/09/2009	330	HU 292 600	0.6	15.2	13	35.01	Neap	Ebb
02/11/2009	460	HU 292 600	32.6	78.2	10	35.15	Spring	High
11/01/2010	330	HU 292 600	0.0	10.6	8	35.28	Increasing	Ebb
01/08/2011	490	HU 2929 6009	0.0	1.6	12	35.24	Spring	Flood
03/07/2013	330	HU 2919 6024	-	-	11	-	Neap	Ebb
07/10/2013	330	HU 2919 6023	-	-	12	-	Spring	Flood

-No data available

The seven elevated sample results ranged from 330 to 490 *E. coli* MPN/100 g. The majority were taken in 2009 and 2013 and there were none in 2012. Five of the seven samples were taken in summer and autumn months, with the other two taken in January. Four of the seven samples were taken at Site 3 (see Figure 11.1) approximately 230 m SW of the present RMP. The highest result came from Site 2 (170 m SE of the RMP), and the remaining two samples were taken within 100 m of the RMP.

No clear trends were apparent in any of the other recorded environmental parameters.

Seggi Bight

Two samples taken at Seggi Bight had results >230 *E. coli* MPN/100 g and are listed below in Table 11.2.

Table 11.5 Seggi Bight historic *E. coli* sampling results over 230 *E. coli* MPN/100g

Collection Date	*E. coli* (MPN/ 100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (°C)	Salinity (ppt)	Tidal state (spring/neap)	Tidal State (high/low)
31/08/2009	790	HU 296 592	4.6	35.6	11	34.81	Spring	Flood
07/10/2013	2200	HU 2965 5921	-	-	12	-	Increasing	High

-No data available

Both results were higher than any of those recorded at Suthra Voe West. Samples were taken in 2009 and 2013, in August and October respectively. The highest result

was from a sample taken approximately 20 m to the north of the RMP, with the other sample taken approximately 40 m to the west. Due to the small number of high results, and the absence of some data for one of these, it was not possible to draw any conclusions as to the influence of environmental factors.

11.7 Summary and conclusions

Vementry North

Contamination levels have varied over the sampling period at Suthra Voe West, with a general dip in results between 2011 and the start of 2013. Lowest results were taken in April and May, though a statistical assessment did not show a significant difference between seasons. Samples had been taken from three separate locations around the mussel farm (Sites 1, 2 and 3), though no statistically significant difference was found between sites and sample results.

No statistically significant correlations were found between rainfall during either the two- or seven-day period prior to sampling and results, or between water temperature or salinity and results. Similarly, no significant correlation was found between high/low or spring/neap tidal states.

Vementry South

Seggi Bight

Contamination levels have been predominantly low at Seggi Bight, with the exception of the two results >230 *E. coli* MPN/100 g taken in August and October. No significant difference was found in results between seasons. The two highest results were taken approximately 20 m north and 40 m west of the RMP.

Significant correlations were found between results and rainfall during both the two- and seven-day periods prior to sampling, with highest results generally taken at rainfall levels >10 mm. No statistically significant correlations were found between water temperature or salinity and results. No statistically significant correlation was found between high/low or spring/neap tidal states and results.

Longaness

Sampling at Longaness has been inconsistent over the sampling period, prior to sampling being unified at Seggi Bight. No results were >230 *E. coli* MPN/ 100g, with many of the sample results <20 *E. coli* MPN/ 100g. The highest result was taken in July. No seasonal difference was found. Sampling location was to the south of the farm, close to shore, with all samples taken within 100 m of one another.

Statistically significant differences were found between rainfall during both the two- and seven-day periods prior to sampling and results. Lower results were generally found at lower rainfall levels in both the two and seven days. No statistically

significant correlation was found between results and water temperature or salinity. No statistically significant correlation was found between results and high/low of spring/neap tidal states.

12. Designated Waters Data

The eastern section of the Vementry South production area is currently designated as the Voe of Clousta shellfish growing water (SGW), as shown in Figure 12.1. The designation covers the area bounded by lines drawn between HU 30441 59992 and HU 30473 59992 and between HU 29016 58753 (Green Point) and HU 29016 58290, and extending to MHWS. The SGW monitoring point is located at HU 29600 57600 south of the Clousta Voe Noonsbrough fishery. The SGW was designated in 2002 and the waters have complied with the guideline standard for faecal coliforms since 2006. Since 2007, SEPA has used the FSAS *E. coli* data for assessing compliance with the microbiological guideline standard of the Directive. As this data has been analysed in Section 11, no separate assessment will be undertaken with respect to SGW compliance. The Scottish Government proposes to extend the current designation of the Voe of Clousta SGW to merge with the East of Burki Taing, Muckle Roe SGW, located north east of Vementry and also encompass three new areas as shown in Figure 12.1.This would expand the size of the SGW from 2 km^2 (the current size of Voe of Clousta SGW) to approximately 36 km^2. At the time of writing this report no information was available regarding the location of SGW monitoring points within this new combined SGW. This will be implemented following the repeal of the Shellfish Waters Directive (2006/113/EC) in December 2013.

The relative positions of the current SGW boundaries, proposed SGW extensions, SGW monitoring points, RMPs and current mussel farm locations are shown in Figure 12.1.

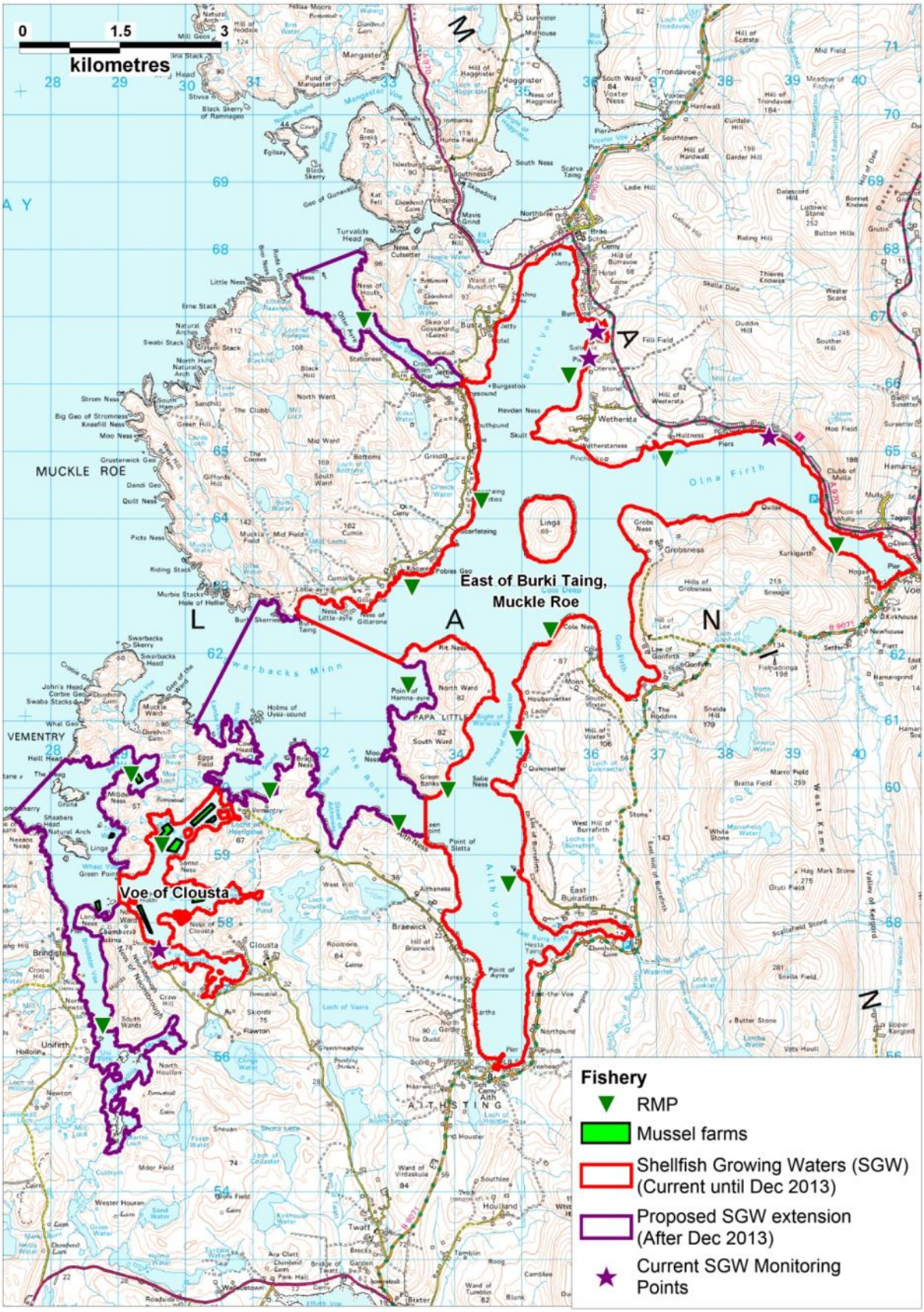


Figure 12.1 Designated shellfish growing water – Vementry North and South

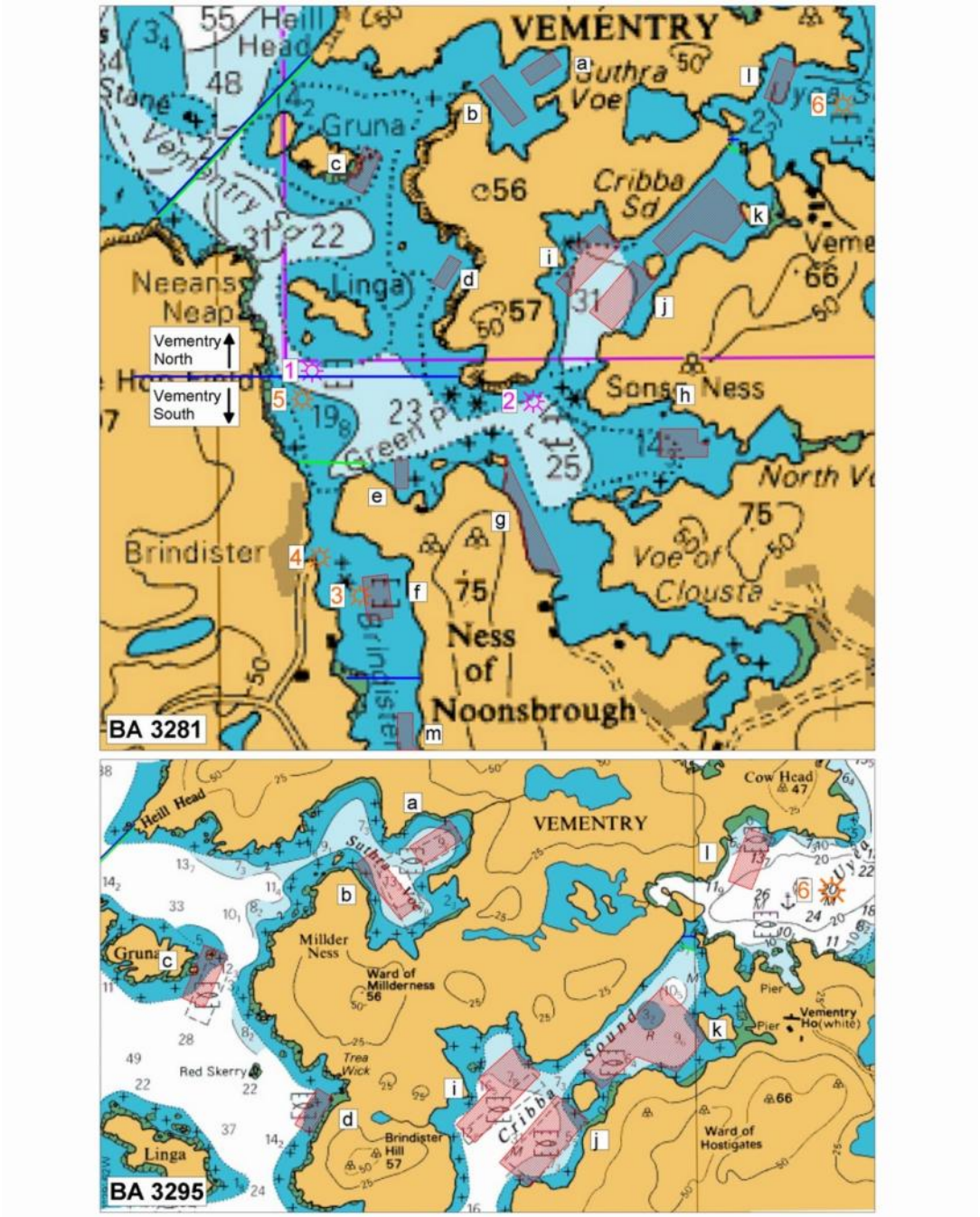
13. Bathymetry

13.1 Introduction

The study area comprises all waters to the south east of a line drawn between and HU 274 596 (Face of Neeans) and HU 282 604 (Heill Head), excluding Brindister Voe and Uyea Sound. The study area is located on the west Shetland mainland and is an inlet on the convoluted southern coastline of St. Magnus Bay. It is not one defined body of water, rather a collection of voes and sounds; namely Suthra Voe, Cribba Sound, the (South) Voe of Clousta, the North Voe of Clousta, and the approaches to these inlets. These are presently divided between two production areas with a boundary defined west from Green Point on Vementry (HU 290 587) and the shoreline south of the islet of Skewart Holm (HU 280 587).

13.2 Bathymetry

Extracts from Admiralty charts BA3281 (1:75,000) and BA3295 (1:25,000) annotated with the limits of the study area, production area and the locations of mussel farm mooring containment areas is given in Figure 13.1.



Key:

Study Area Boundary

Production Area

SIC Mooring Containment Area

Hydrographic Surveys:

1 Linga (Skewart Holm) 2007

2 Brindister Crossroads 1998

Data not used:

3 Brindister Voe 2000

4 CTD 5884 (2012)

5 Linga 2001

6 Uyeasound 2001

Shellfish Sites:

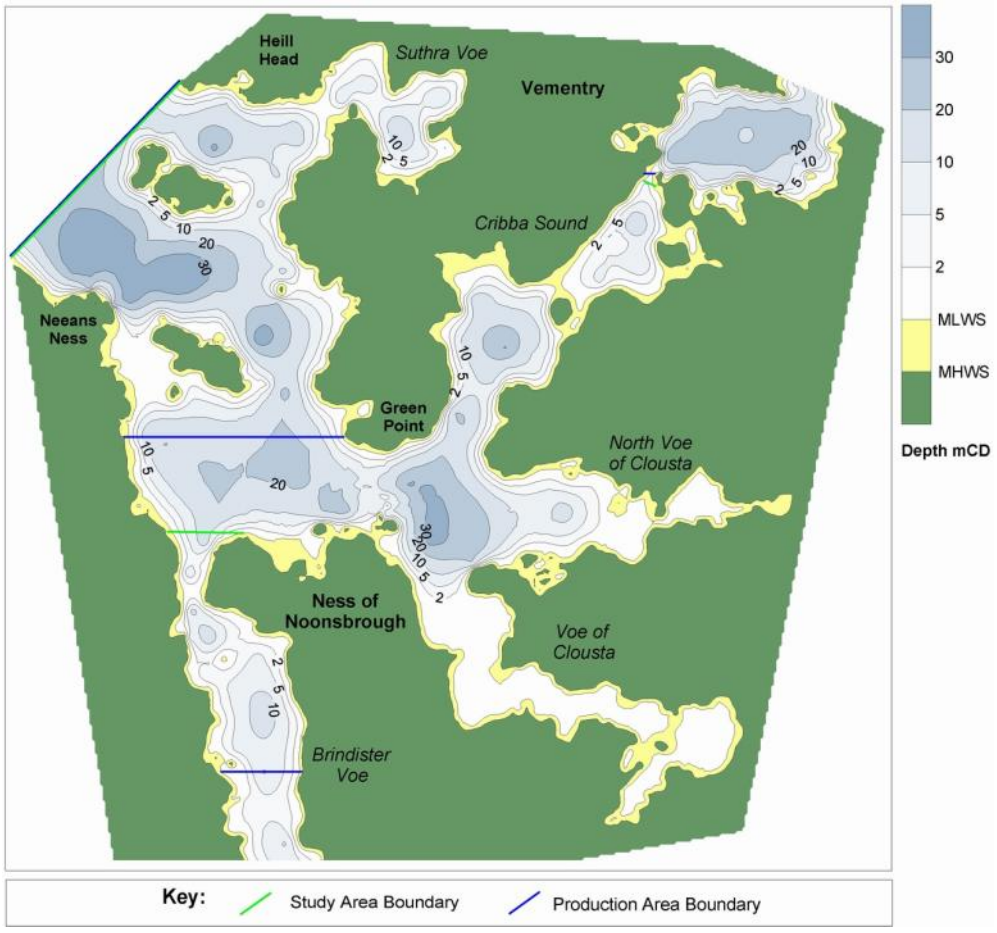
a. Suthra Voe
b. West Suthravoe
c. Gruna
d. Treawick
e. Longa Ness
f. (unnamed)
g. Noonsbrough
h. North Voe of Clousta
i. Seggie Bight
j. Cribba Sound SW of Grink Holm
k. Cribba Sound
l. Uyeasound
m. Brindister Voe

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 13.2). Due to poor chart coverage of the area these data have been supplemented with points extracted from Ordnance Survey Explorer sheet 467 derived by manually digitising the MHWS and MLWS boundaries for parts of the study area not covered by chart BA3295. Additional survey data is included where available to improve the accuracy of the contour plot:

- In November 2012 spot depth soundings were collected in Brindister Voe to support the sanitary survey process undertaken for that area (Cefas, 2013)

- In April 2008 Hjlatland Seafarms Ltd., which operate the fish farm located at the confluence of the Voe of Clousta, the North Voe of Clousta and Cribba Sound (also known as Brindister Crossroads), undertook a survey in the region of the site to characterise the reefs marked on charts to the south of Green Point using a vessel-mounted transponder. In both cases soundings were corrected to chart datum (CD) by subtracting the local tide height extracted from the Admiralty prediction for West Burra Firth, the closest port to the area.



MLWS and MHWS data extracted from Ordnance Survey Explorer Sheet 467

Figure 13.2 Bathymetry of Vementry North and South.

Depths given as metres chart datum.

The contour plot illustrates:

- Poor resolution charts in the region lead to an overestimate of the intertidal zone by the contouring algorithm in some areas. This will lead to conservative estimates of area and volume for each water body.

- This is most evident at the Voe of Clousta and Cribba Sound which in reality do not have sills which dry out at low tide.

- There is no bathymetric information for the Voe of Clousta which is illustrated as having a depth below 2 m. There is likely to be deeper water and therefore a greater volume here, as was demonstrated for Brindister Voe. Similarly the headwaters of the North Voe of Clousta are poorly represented.

- A sill is present between Green Point on Vementry and the North Ward on the Ness of Noonsbrough isolating a deeper basin (> 30 m) at Brindister Crossroads. Minimum depth at the sill is reported as approximately 4 m according to the survey undertaken by Hjaltland Seafarms Ltd. This corresponds to a description of the reef given in the sailing directions for the region (Clyde Cruising Club Publications, 2009).

- There is a constriction in the strait between Vementry and the Mainland which defines Cribba Sound to the southwest and Uyea Sound to the northeast. Depth here shoals to between 2.3 m and 3.7 m and will limit exchange with deeper water present in Uyea Sound.

- The contour plot illustrates deeper water to the east of the island of Linga than to the west, indicating that exchange may be limited in the latter. However this may be the result of the fact that the eastern side is represented in the higher resolution (1:25,000) chart of the area as the 1:75,000 chart of the whole region would indicate that the western channel is deeper

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 13.1 represent the area and volume at Mean Low Water Springs (MLWS) by defining the surface “z” as -0.6 m (refer to section 4).

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

	Parameter*			
	Area (km2)	**Volume (Mm3)**	**Mean depth (m)**	**Maximum depth (m)**
Study area	3.69	39.99	10.83	49.0
Vementry North Production area	1.70	21.87	12.90	49.0
Suthra Voe	0.22	0.99	4.60	13.3
Vementry South Production area	2.35	20.03	8.54	34.7
Cribba Sound	0.49	3.93	7.95	31.0
North Voe of Clousta	0.28	1.10	3.92	14.3
Voe of Clousta	0.38	no data	no data	no data

All values at MLWS

No part of the study area is included in the *Scottish Sea Lochs catalogue* (Edwards & Sharples, 1986) however all are described with varying detail in the *Catalogue of Voes, Firths and Sounds in Shetland* (Dixon, 1987). The only comparison to the figures given in Table 13.1 that can be made is for the low water area of the Voe of Clousta which was derived through manual measurement with a planimeter (0.6 km^2). The greater value reported by Dixon may be attributed to the use of the higher resolution Ordnance Survey map as opposed to the 1:75,000 chart and the discrepancy in the contouring algorithm which produces a sill near the head of the voe which will reduce the overall area in the calculation.

Tidal Information

Information pertaining to predicted tide height is derived from the UKHO TotalTide prediction for West Burra Firth, the nearest secondary port some 6.8 km west of the study area boundary. Figures 13.3 and 13.4 show tidal curves for a fifteen day period starting on the 16 September and therefore include the date of the shoreline survey (23 & 24 September 2013).

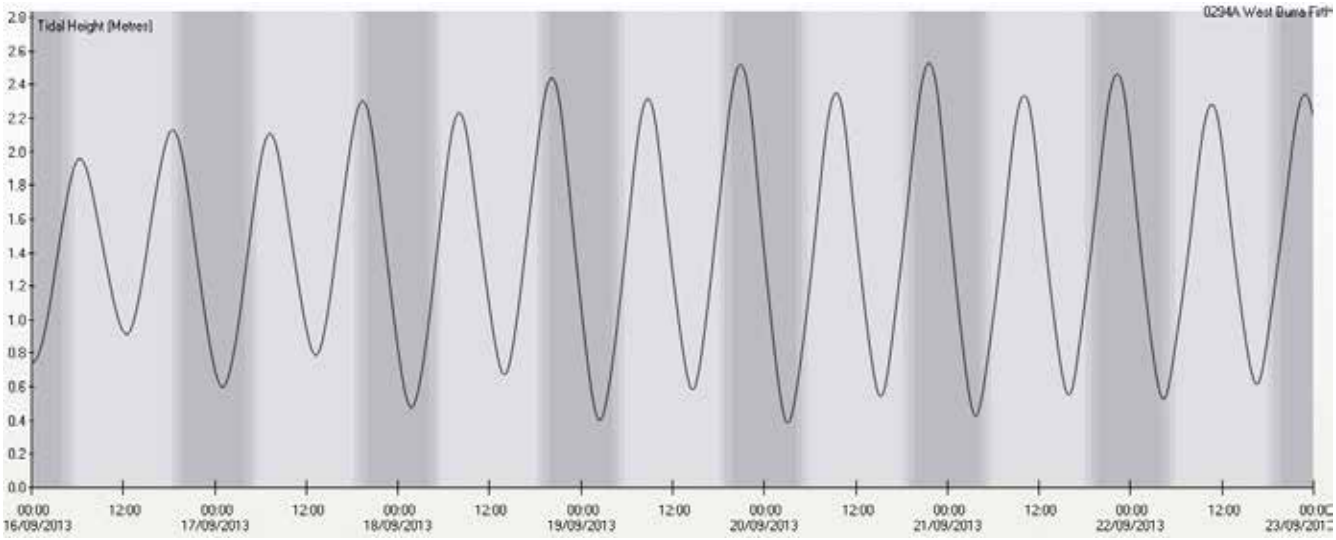


Figure 13.3 Tidal Curve West Burra Firth; 16 to 23 September 2013

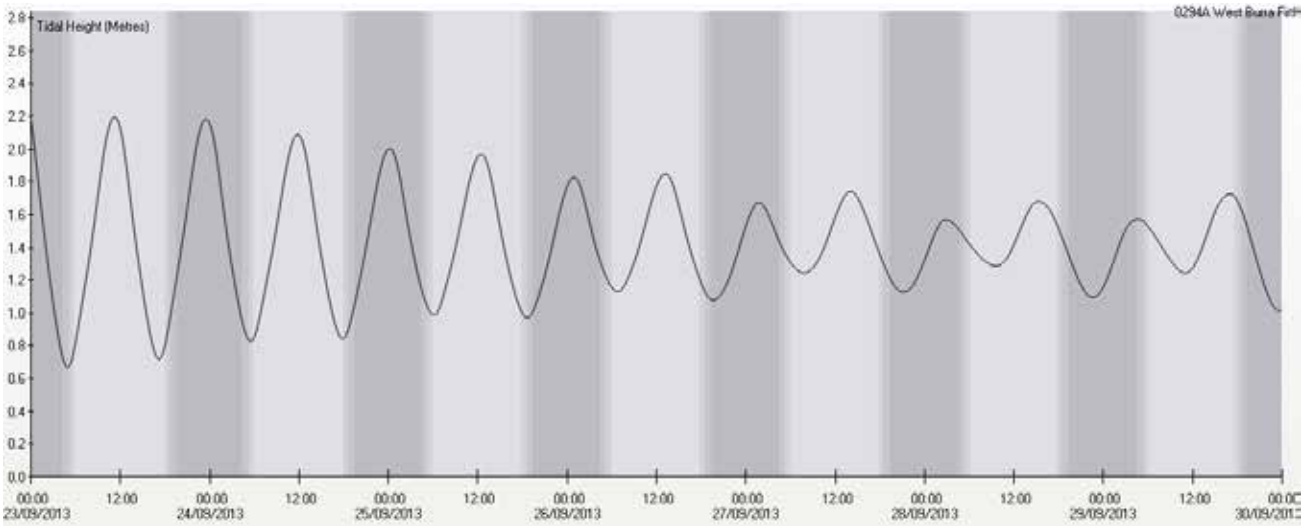


Figure 13.4 Tidal Curve West Burra Firth; 23 to 30 September 2013

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 Section 3.

Timing

The pressure record for the current meter and Star ODDI CTD deployments in Brindister Voe were compared to the West Burra Firth TotalTide prediction for the equivalent periods as part of the bathymetry and hydrodynamic component of the Brindister Voe Sanitary Survey (FSAS/Cefas, 2013). There was no discernible difference found between the timing of high and low water within the voe, therefore there is unlikely to be significant departure from the prediction throughout the study area. This is confirmed through assessment of data collected at Uyea Sound during 2001.

Range

The range of the three largest tides around springs and the three smallest tides around neaps for the deployment at Linga in 2007 were compared to that predicted for the corresponding tides at West Burra Firth. The observed tidal range during spring tides is comparable to the prediction (observed range 1.7 dBar, predicted range 1.8 m). Neap tidal range was also comparable (observed range 0.8 dBar, predicted range 0.7 m. A similar pattern was determined at Uyea Sound from the 2001 survey data. Atmospheric pressure is not accounted for in the survey data.

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 for the study area. Based on this method estimates of flushing time (T_f) and flushing rate (Q) are given below in Table 13.2.

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

Input:		
Volume* (V)	Mm^3	39.99
Area* (A)	km^2	3.69
Tidal range (R)	m	1.6
Output:		
Flushing Time (T_f)	days	5.03
Flushing Rate (Q)	Mm^3/year	2,903
Flushing Rate (Q)	Mm^3/day	7.95
Flushing Rate (Q)	Mm^3/tidal cycle	4.13

*Calculated for MLWS.

The tidal prism method indicates that 10.3 % of the low water volume of the study area is exchanged during each tidal cycle and that total exchange would take five 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 13.3).

Table 13.3 Estimate of flushing rate and tidal volume of the study area using Surfer grid volume calculation.

Tide	Z (m)	Study Area Volume (Mm^3)
MLWS	0.6	39.99
MHWS	2.2	46.48
Difference (spring tide)		6.49
MLWN	1.0	41.51
MHWN	1.7	44.33
Difference (Neap tide)		2.82
Average Difference		4.65

The estimate of the flushing rate is below the average tidal volume. Both estimations of the exchange rate given should be interpreted cautiously as both employ a gross simplification of hydrodynamic properties in topographically complex area. In addition poor bathymetry for the region leads to conservative estimates of area and volume which could account for the difference between the estimated flushing rate and the average tidal volume. The latter is considered to be more reliable as this is based on the difference in volume for each tidal level, and the two extremes for this are defined by the MHWS and MLWS contours, extracted from the Ordnance Survey map which has a higher resolution than the available charts. 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. The study area is not typical of a semi-enclosed loch system for which the tidal prism

calculation is suited with exchange occurring through two boundaries. Such interactions are beyond the scope of simple box modelling techniques.

Currents

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

Field Data

Historically there have been six field studies which give an insight into the current flow patterns in the region, although half of these are beyond the study area. Summary information of the deployments is given in Appendix 1 while their locations are included at Figure 13.1. Data from these hydrographic studies were provided to Cefas by SEPA which archive information concerning fish farm licensing on their Public Register. Both 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. The quality of the data collect is assessed against Attachment VIII to determine if each survey suitably represents the hydrographic conditions at each site. The Brindister Crossroads survey in 1998 was conducted with an array of three instruments which have a measuring threshold of 0.014 m/s, above which the measuring rotor will begin to rotate reliably. With 74% of the observations within a range of 0 to 0.03 m/s and a mean speed of 0.028 m/s the effectiveness of this type of instrument to suitably represent the low current speeds recorded at the site must be questioned.

Of the two surveys at Linga the earlier deployment at the site is disregarded from further study in favour of the higher precision survey conducted in 2007. This survey produced data that is considered acceptable to the standards defined in Attachment VII. However, while velocity precision predicted to be 0.017 m/s, below the 0.020 m/s threshold required by these standards, this still represents a predicted standard deviation which is greater than half of the observed mean speed. Once again, reliability of the data will be affected to a certain extent, although overall these data are considered to be reliable.

Survey Data Assessment

An assessment of the hydrographic data collected at the Linga (Skewart Holm) and Brindister Crossroads fish farms was undertaken with detailed summary statistics tabulated in Appendix 2. Figure 13.5 illustrates the frequency of currents by vector and the pertinent summary statistics for near-surface waters in the context of the surrounding area.

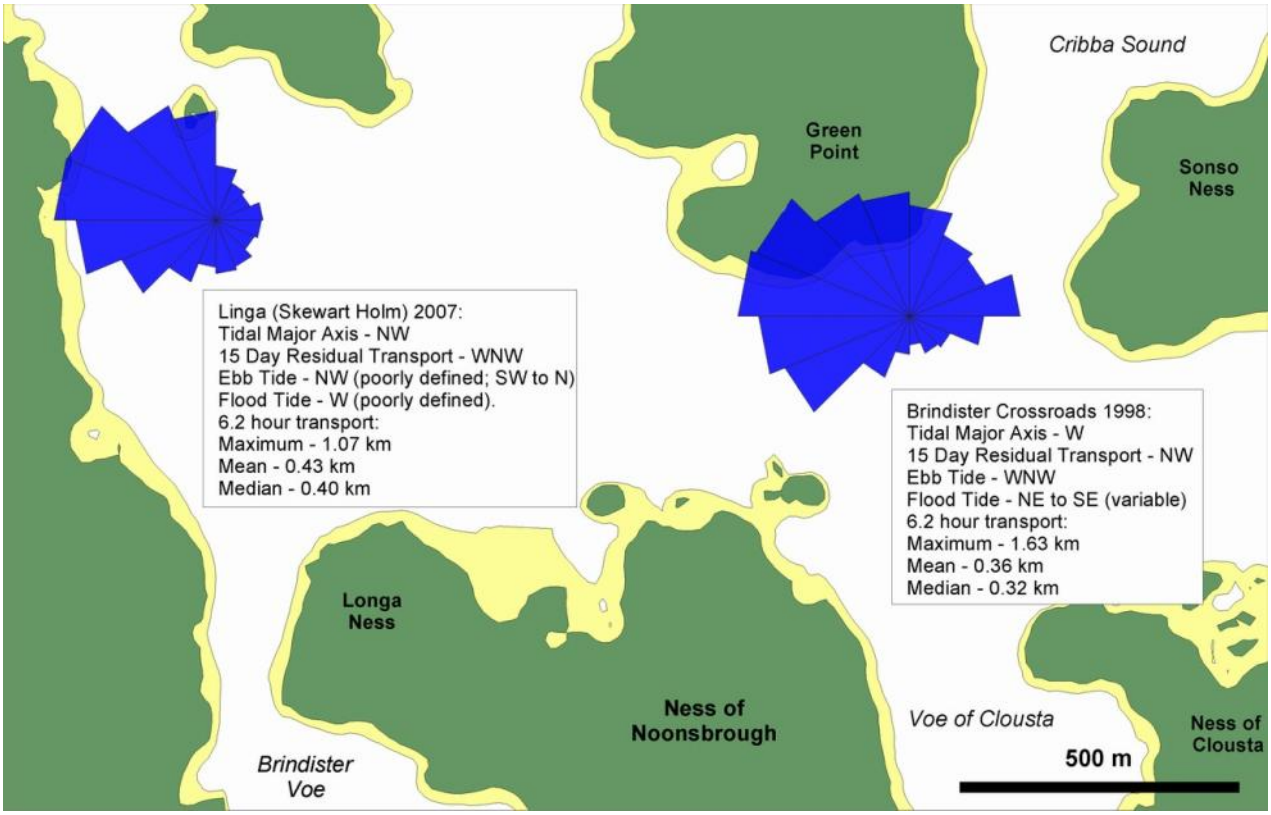


Figure 13.5 Near-surface current direction frequency (bin size 22.5°) for the surveys at Linga and Brindister Crossroads, including a summary of residual and tidal transport at each location.

Chart based on data extracted from Admiralty Charts BA3281 & BA3295, as well as MLWS and MHWS data extracted from Ordnance Survey Explorer Sheet 467.

The hydrographic data collected at Linga (Skewart Holm) in 2007 indicates that the influence from tidal currents is relatively low. Current velocities are low with a weak tidal axis aligned NW/SE corresponding to shoreline topography. Residual transport shows a net movement away from the survey location to the west towards the channel between the islands of Linga and Skewart Holm and the shoreline at Neeans. This could be indicative of either the stronger influence of the tide flowing along the NW axis or the influence of the longest fetch to the SE (~2.3 km), or a combination of both factors.

With respect to patterns of tidal movement there appears to considerable variation with depth observed in a three day period examined around a spring tide. In general terms movement to the NW is associated with the ebb tide, although in near-surface and mid-depth layers this can be from SW to N on successive tides. In near-seabed currents there is little directionality to the tidal currents; what might be a pattern on one tide is not necessarily repeated on subsequent tides, possibly as a result of the seabed topography associated with the proximity to the islands to the north of the survey location.

Regarding current velocity there is little evidence that currents on the flood tide differ to those on the ebb close to the seabed. Higher in the water column a pattern is

present, with the highest speeds expected during or near the end of the ebb tide in near-surface waters while at mid-depth a stronger pulse is present at the start of the flood tide. Data collected during a spring tide compared to that collected during a neap tide indicates very little difference in current patterns during the lunar cycle. The exception to this are currents in the near-surface layer where the effect of wind forcing cannot be ruled out as a contributing factor to small variations between spring and neap tides.

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

Periods of greatest transport during a 6.2 hour period (up to 1.07 km) are consistently coincidental with the ebb tide and also correspond to the periods of stronger wind forcing present during a relatively benign survey period.

At Brindister Crossroads current velocities are again low with limited tidal influence indicated in the summary statistics. Evidence of a strong tidal signature in the near-seabed layer is considered to be a misrepresentation; “flat-line” data present between periods of greater activity is indicative of a problem with the rotor on the instruments used not turning freely at lower velocities leading to an over-representation of tidal currents. There is no clearly defined tidal axis common to all layers, although there is more evidence of bi-directional currents here than at Linga. Overall residual transport is to the SE.

The tidal cycle is discernible in the time series of the current data for each layer, although data would imply that there is little consistency throughout the water column. In near surface waters the ebb tide demonstrates a general flow to the west with peak velocities in this layer often, but not always, present from the middle of the ebb to low water. The flood tide shows a more variable pattern of movement that can be between NE and SE with the strongest currents observed in the early part of this tide. In the middle and near seabed layers the peak in velocity occurs during the flood tide, and in the case of the deeper layer this appears to persist beyond high water into the ebb. In terms of direction the pattern is generally easterly for the flood and westerly for the ebb, although there is considerable variation in flow at any given stage in the cycle.

Winds during the survey period varied with frequent peaks in Beaufort Force 6 interspersed with lows of F2/3. The majority of the stronger periods of wind forcing originated from a northerly direction, however with a net movement to the north in near-surface current record there is little evidence of wind driven transport. In

addition there are no instances of unidirectional flow persisting over multiple tidal cycles.

Periods of greatest transport during a 6.2 hour period (up to 1.63 km) occur in a cluster associated with a single ebb tide. There is limited evidence of some periodicity in the excursion that corresponds to the tidal state.

In summary tidal currents are not very well represented in the data from the current meter surveys assessed. There is limited evidence for the classic tidal signature along a single linear axis typical of a location where the tide has a significant influence. In cases where one tide may be well represented in the data record, the evidence for the counter tidal flow is weak, potentially as a result of local influences (i.e. wind forcing, topography). In addition the poor quality of the data is likely to contribute to uncertainty in this interpretation. In general the flood tide appears to show a general movement from west to east with the ebb tide flowing counter to this. This follows the topography of the overall area and it appears that the flood tide transports seawater from St. Magnus Bay via Uyea Sound to the study area.

Both surveys were undertaken in, or close to the boundary of the Vementry South production area which is characterised by being relatively sheltered. The study area is composed of a topographically varied area and it would be unreasonable to expect the available data to fully represent the whole region. In particular the Vementry North production area will experience more wave exposure from St. Magnus Bay and there is the potential for localised increases in current velocity associated with the albeit limited tide flowing between the islands present to the west of Vementry. Suthra Voe is unique in the study area as it is a relatively enclosed body of water with moderate wave exposure at the approaches. Low tidal influence is expected here, and a limited fetch means the potential for the formation of wind driven currents is also low.

Stratification

Salinity and temperature profiles were collected at eight locations throughout the study area during the shoreline survey in September 2013. All locations showed a decrease from levels typical of normal seawater at depth to reduced salinity at the surface, with the exception of the northern group of lines of the Cribba Sound fishery where the observed change was within the accuracy for the instrument used (± 0.35 ppt). The greatest degree of change was seen at the North Voe of Clousta fishery (1.77 ppt change over the profile) where the profile was collected near to the head of the system and at the Noonsbrough fishery close to the mouth of Clousta Voe (1.32 ppt change). However it should be noted that the degree of change observed is comparatively low with respect to that measured on the Scottish Mainland, where a difference in the order of 20 ppt may be seen between bottom and surface waters. The lowest degree of change along the profile was observed at the Suthra Voe fishery. The remaining locations returned intermediate values, between 0.61 ppt and 0.84 ppt change over the profile. A comparable pattern was also observed in the

surface seawater samples collected at each site with the lowest results at the locations with the lowest surface observed from the profiles.

Temperature measurements showed minor variation with depth, on average by 0.2 °C decrease from the bottom of the profile to the surface with the greatest change at the southern group of lines of the Cribba Sound Fishery and at Suthra Voe West. Complete salinity and temperature profile data and water sample analysis are available in the shoreline survey report.

As part of the Brindister Voe Sanitary Survey salinity profiles were collected from within the voe. In addition two Star-Oddi DST CDT loggers (accuracy 1 psu) were deployed as seabed moored installations; one at the northern end of the voe near the Shetland Mussels shore base and the second to the south near the entrance to The Vadills. Salinity profiles show that near the head of the voe values are depressed when compared to normal strength seawater (33.4 ppt profile average) but are uniform with depth while near the mouth there is a decrease from surface to 10 m of around 0.7 or 0.8 ppt, comparable to that observed in the majority of the sites in study area. Data from the CTDs showed a greater range in salinity at the head of the voe (1.28 psu) compared to that recorded near to the mouth (0.91 psu). When the accuracy of the instrument is considered the values must be reported to zero decimal places which means that a range of 34 to 35 psu is observed at both locations. While the actual salinity may be within 1 psu of the value recorded by the instruments, as both were calibrated prior to the initiation of data collection it remains possible to have confidence that the spatial and temporal patterns evident in the raw data correspond to actual patterns in the voe. The data indicates that there is lower salinity water within The Vadills system with reduced values encountered as the tide ebbs. This influence extends to the mouth of the voe to a lesser extent and is more pronounced at either end of the voe during the springs phase of the tidal cycle.

Based on these observations similar conditions are expected in the neighbouring voes. Salinity profiles and water samples collected from the water bodies in question indicated reduced near-surface salinity.

While no direct correlation between precipitation data from the nearest source and the variation in salinity was made during the Brindister Voe CTD study with evident freshwater influence it can be expected therefore that annual rainfall patterns will have a corresponding effect. Figure 13.6 illustrates the monthly total rainfall and the 24 hour average rainfall from the Lerwick Meteorological Office from 2007 to 2012.

During winter months reduced salinity in near surface waters may be common with higher fresh water input, particularly in the more sheltered regions of the study area. 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.

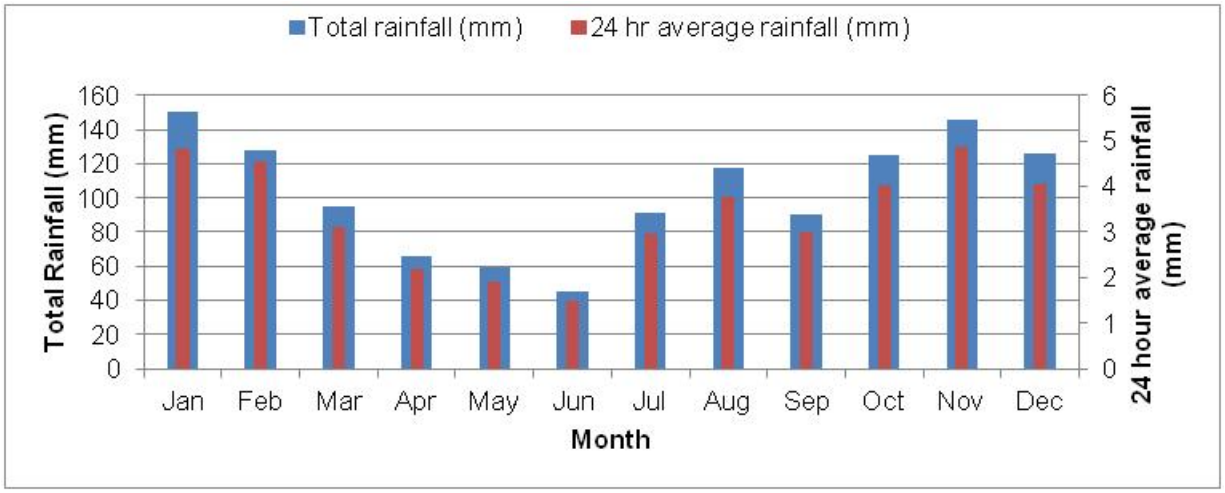


Figure 13.6 Total monthly and mean 24 hour rainfall for the period 2007 to 2012

Various parameters pertaining to freshwater input are given in Dixon, 1987. Here only the Voe of Clousta has a complete set of parameters described. These figures have been updated using digital mapping techniques and modern rainfall totals in Table 13.4 below, and the calculations have been completed for each water body in the study area.

Table 13.4 Comparing freshwater runoff parameters

		Parameter					
Water Body	**Source**	**Watershed km^2**	**Annual rainfall (mm)**	**Runoff (Million Mm^3/yr)**	**Fresh tide per thousand**	**Salinity reduction (ppt)**	**Runoff/ Width m^3/d**
Suthra Voe	Dixon 1987	1.2	1100	1.1	(no data)		
Cribba Sound		3.4		(no data)			
North Voe of Clousta		6.9		5.90	(no data)		
Voe of Clousta		2.7		2.30	4.10	0.14	18.00
Brindister Voe & the Vadills		17.9		15.20	(no data)		
Suthra Voe	SSQC 2013	0.9	1223*	0.86	4.54	0.15	6.63
Cribba Sound		1.7		1.63	3.66	0.12	13.31
North Voe of Clousta		7.7		7.48	28.29	0.96	45.04
Voe of Clousta		4.8		4.65	13.00	0.44	54.21
Brindister Voe & the Vadills		18.1		17.62	17.61	0.60	161.11

*Annual average 2007-2011. Source Met Office, rainfall data for Lerwick.

Brindister Voe and the Vadills have been included in Table 13.4 on account of the fact that this system opens onto the study area. The estimate of the watershed is comparable to the value presented by Dixon, and with the modern annual rainfall figure it is evident that runoff may be greater here than originally estimated.

The watershed is estimated to be smaller for Suthra Voe and Cribba Sound than that presented by Dixon, while for the both the North Voe of Clousta and the Voe of Clousta the watershed is calculated to be greater. For the latter voes this means that freshwater runoff is predicted to have a greater effect. A greater difference between the high and low water areas of the Voe of Clousta contributes to the prediction that there is more tidal renewal in this voe. Overall the predicted salinity reduction corresponds to the observed pattern, namely Cribba Sound had salinity readings closest to normal seawater while the greatest reduction was seen in the North Voe of Clousta.

Summary

The tidal prediction for West Burra Firth is applicable to the study area in terms of timing and range.

Figures for tidal exchange derived from the two methods indicate that 10 to 12% of the low water volume of the study area is exchanged during the tidal cycle leading to a flushing time of approximately 5 days. It is acknowledged that the area is topographically complex with numerous sill and basin features, constrictions and two exchange boundaries which may affect this, although to what extent is unknown.

Field observations from the centre of the study area, at the confluence of the main tributary voes and sounds that constitutes the production areas, indicate that tidal currents are relatively weak. In general the flood tide appears to show a general movement from west to east with the ebb tide flowing counter to this. This follows the topography of the overall area and it appears that the flood tide transports fresh seawater from St. Magnus Bay via Uyea Sound to the study area.

In the west the greatest transport events during a 6.2 hour (tidal) period of up to 1.07 km are coincidental with the ebb and are associated with elevated wind forcing. To the east the maximum excursion observed was greater at 1.63 km although this was a one-time event during the survey period associated with a single ebb tide. In a time series of excursion there is a periodicity that corresponds to the tidal cycle indicating that tidal currents may have a greater influence at this location.

With weak tidal currents present wind forcing is likely to have a large influence on surface water movement in the study area.

Salinity profiles collected during the September 2013 shoreline survey indicate freshwater influence in the near surface layer is present throughout the study area with the greatest reduction in salinity measured in the North Voe of Clousta and the Voe of Clousta. This accords well with the predicted salinity reduction estimated for each of the inlets in the production area. However the degree of change observed is comparatively low with respect to sea lochs on the Scottish Mainland, where a difference in the order of 20 ppt may be seen between bottom and surface waters.

14. Shoreline Survey Overview

The Vementry North and Vementry South shoreline survey was conducted on Monday 23rd and Tuesday 24th September 2013. The prevailing weather in the 48 hrs prior to the survey was mostly wet, with some dry spells. On the first day of the survey the weather was mainly dry with some light drizzle, with a light to moderate breeze. On the second day of the survey the weather was dry, with a light to moderate breeze

Due to access problems aoround much of the area, only short segments of shoreline were walked (shown in Figure 14.1). The rest of the area was surveyed by boat with relevant shorleien observatiosn being made from this platform.

There are eight mussel farms within the two production areas, seven of which had stock on at the time of the shoreline survey.

Houses were present at Noonsbrough and Clousta on the western, southern and eastern shoreline of the Voe of Clousta. An unspecified number of houses and a self catering cottage were also present on the north eastern shoreline of Cribba Sound. The island of Vementry and the shoreline east of Cribba Sound and surrounding the North Voe of Clousta are uninhabited. Two septic tanks servicing three houses were observed at Noonsbrough, one of which had a crack down the side and was leaking. At Clousta, five septic tanks were observed, one of which had an outfall pipe leading down to the shoreline. Two septic tanks servicing three houses were identified on the north eastern shoreline of Cribba Sound.

There is a shellfish farm company shore base and pier at Brindister Voe, southwest of the Longaness site. A workboat was berthed at the pontoon in the Voe of Setter and two further work boats were observed on site at the Seggi Bight and Clousta Voe Noonsbrough mussel farms. Small numbers of small pleasure and working boats were seen.

Land was predominantly rough open grazing. In total approximately 75 sheep were observed on the hills surrounding the Suthra Voe fisheries. Approximately 256 sheep were observed grazing around the Voe of Clousta. The majority of sheep observed during the shoreline survey had access to the shoreline and sheep faeces were noted on a number of occasions when animals were not present. One cow was observed fenced inland at the southern end of the Voe of Clousta and cattle faeces and tracks were observed on the northern shoreline of the voe.

Shellfish samples returned results ranging from <20 to 330 *E. coli* MPN/ 100g, with the three highest results being seen at Cribba Sound North, Seggi Bight and Clousta Voe Noonbrough. In general, higher shellfish results were seen near the surface than at depth.

Seawater samples returned results ranging from 2 to 10 *E. coli* cfu/100 ml, with the highest result being obtained from a sample taken at the southern end of the Cloust Voe Noonsbrough site

Eleven watercourses were observed, flow rate was recorded at all of them and nine were sampled. Eight of the samples returned results of < 700 *E. coli* cfu/100 ml. A sample taken from a small watercourse on the western shoreline of the Voe of Clousta had a result of 3900 *E. coli* cfu/100 ml.

Small numbers of birds, including seabirds and wading birds, were observed around the survey area. The majority were seen in flight and some were observed on buoys at five of the eight fisheries. Bird droppings were noted on the mussel floats and evidence of birds feeding (shellfish shells and crab carcasses) was observed near the shoreline on four occasions.

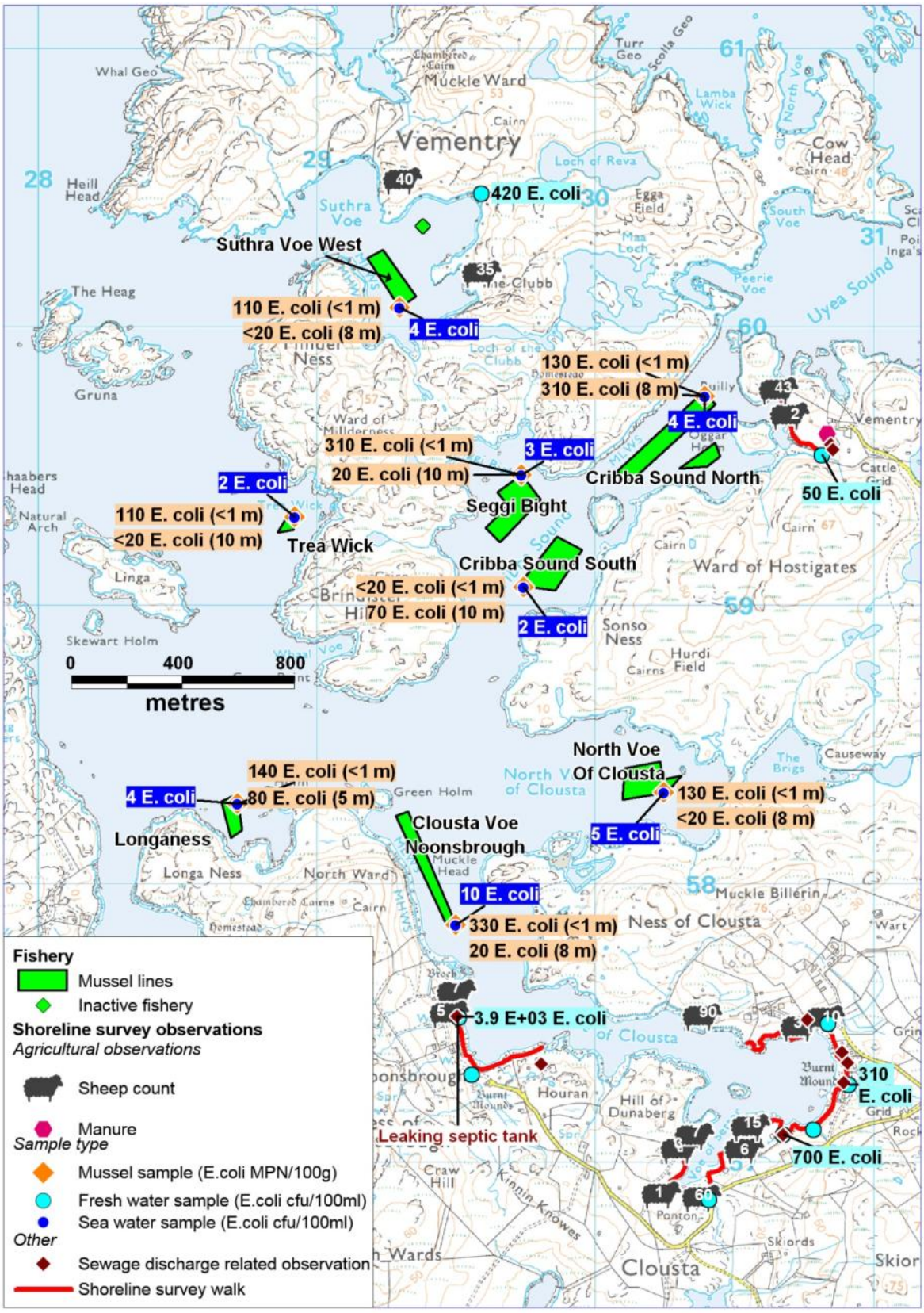


Figure 14.1 Map of shoreline survey observations at Vementry North and South

15. Bacteriological Survey

The area was not identified as requiring a bacteriological survey as historical monitoring data was available from widely separate locations and this could be supplemented with additional sampling at the time of the shoreline survey.

16. Overall Assessment

Human sewage impacts

Much of the surrounding area is uninhabited and thus overall impacts from human sewage are expected to be relatively minor. Human habitation, and therefore septic systems, are concentrated in three areas: around the head of the Voe of Clousta, at Noonsbrough along the west side of the Voe of Clousta, and at Vementry on the northeast shore of Cribba Sound. The first two areas are located in the far south of the Vementry South production area, and impacts from these would be most likely to affect the southern end of the Noonsbrough mussel farm. The closest septic tank (350 m southwest of the farm at Noonsbrough) was observed to be malfunctioning during the shoreline survey.

Two septic tanks were observed at the settlement of Vementry, on the northeast shore of Cribba Sound. These are not expected to have a significant impact on water quality at the fishery, provided the soakaways are functioning properly. However, any overland flow arising from the soakaway fields would be expected to have some impact at the Cribba Sound North mussel farm.

Three septic tanks at the north end of Brindister Voe, lying approximately 750 m to the southwest of the Longaness mussel farm, are the closest sewage discharges to this mussel farm. Contamination arising from the north end of Brindister Voe would be expected to be carried northward on the ebb tide and contribute to background levels of faecal contamination at Longaness.

The Suthra Voe West , Trea Wick and North Voe of Clousta mussel farms all lie more than 1 km from the nearest recorded discharge and are therefore unlikey to be affected by sewage contamination arising from land-based sources. However, there is an anchorage adjacent to the Suthra Voe West mussel farm and therefore this site may be subject to occasional contamination from any boats using the anchorage.

Agricultural impacts

The largest source of any faecal contamination reaching the production area waters is expected to be from agricultural sources, particularly sheep. These animals are grazed widely throughout the area, though the majority of animals seen during the shoreline survey were observed in the vicinity of crofts around Clousta, Noonsbrough, and Vementry. A large pile of manure was observed inland on the east side of Cribba Sound at Vementry. Sheep are also grazed on the island of Vementry, where two flocks were seen around Suthra Voe during the shoreline survey.

Impacts from this contamination source would be expected to be highest around the entire Suthra Voe West site, at the northern end of the Cribba Sound North site and at the southern end of the Clousta Voe Noonsbrough site.

Wildlife impacts

Species potentially impacting on Vementry North and Vementry South include seals, otters and birds, including seabirds. It is likely that of these, contamination from seabirds will predominate particularly at Suthra Voe and potentially in the northern end of Cribba Sound. Outside these areas, the deposition of faeces from these sources is likely to be intermittent and sporadic across the mussel farms.

Seasonal variation

Seasonal variation in livestock impacts is expected, with numbers of sheep present being much higher during the late spring and summer. Similarly, impacts from seabirds are also expected to be higher during this period, when a larger number of birds is present and nesting.

Rainfall patterns have also shown a seasonal trend, with overall daily rainfall values being lowest from April to July and highest from November to February. However, it should be noted that high rainfall (>30 mm/day) events occurred in all months.

No statistically significant seasonal variation was seen in shellfish hygiene monitoring results from either production area. However, at two of the monitoring points (Seggi Bight and Suthra Voe West) the trend in results by month did appear to be lowest around April and May, with much greater variability during the autumn and winter.

Rivers and streams

The large majority of recorded watercourses flowed into the Voe of Clousta. Estimated *E. coli* loadings from these were low to moderate. The highest estimated loading ($1.5x10^{10}$ *E. coli/day*) was related to a watercourse that flows into the Voe of Clousta approximately 400 m south of the Clousta Voe Noonsbrough mussel farm. This watercourse passes through a crofted area and therefore is likely to carry diffuse contamination from livestock, wildlife and potentially human sources.

Contamination contributed by these watercourses would be most likely to impact the southern end of the Clousta Voe Noonsbrough mussel farm, but may also to contribute to background levels of contamination throughout the southern part of the production area.

One watercourse was recorded at each of Suthra Voe and at the north end of Cribba Sound. Both had low estimated *E. coli* loadings, and would have received diffuse contamination predominantly from livestock and wildlife sources.

Statistically significant correlations were found between rainfall in the 2- and 7-day periods preceding sampling at both Seggi Bight and Longaness, suggesting that rainfall-associated diffuse contamination was an important mechanism at these sites. No statistically significant association between these factors and results was found at

Suthra Voe West, however, despite the lower results seen in spring in the monthly temporal trend.

Movement of contaminants

The production areas are made up of a complex of interlinked voes and sounds with a convoluted coastline and each of these is expected to behave slightly differently with regard to the mechanisms and movement of contaminants.

Suthra Voe is west facing and relatively enclosed, with a low fetch and therefore tidal movement is expected to predominate within this water body. Tidal currents at the confluence of Clousta Voe, Brindister Voe and Cribba Sound (near the boundary between the Vementry North and South production areas) were observed to be weak with a general tendency for the flood tide to flow toward the east and the ebb tide toward the west. The flood tide also transports seawater from St. Magnus Bay via Uyea Sound into Cribba Sound.

The maximum expected tidal excursion was approximately 1 km, and the greatest transport events coincided with an ebb tide and elevated wind-driven currents. Tidal excursion may be slightly long on the east side of the area than the west.

Wind forcing is likely to have a large influence on surface water movement in the study area.

Salinity profiles collected during the September 2013 shoreline survey indicate freshwater influence in the near surface layer is present throughout the study area with the greatest reduction in salinity measured in the North Voe of Clousta and the Voe of Clousta. This accords well with the predicted salinity reduction estimated for each of the inlets in the production area. However the degree of change observed is comparatively low with respect to sea lochs on the Scottish Mainland, where a difference in the order of 20 ppt may be seen between bottom and surface waters. No statistically significant associations were found between salinity and results at any of the monitored sites. Results from mussel samples taken during the shoreline survey showed a general tendency towards higher *E. coli* levels near to the surface, implying a freshwater influence.

No statistically significant associations were found between shellfish hygiene monitoring results and the high/low or spring/neap tidal cycles.

Geographical patterns of sampling results

Three sites have been monitored historically for shellfish hygiene purposes: Seggi Bight, Suthra Voe West and Longaness. Longaness has not been sampled since 2012, and there had been a lapse in monitoring during 2010/11 and this confounded an assessment of trend.

Results were low overall for all three sampled locations. The geometric mean and maximum result were both higher for Seggi Bight than the other two locations but the difference was not statistically significant. Three separate locations within the Suthra Voe West site have been sampled over time and there was no statistically significant difference between them.

Samples taken during the shoreline survey showed highest results at Clousta Voe Noonsbrough, Seggi Bight and Cribba Sound North. The Noonsbrough and Cribba Sound North mussel farms both lie nearer identified concentrations of potential sources, however this is not the case for Seggi Bight and it is not clear whether there are sources not identified here within the Seggi Bight area, or whether this is due to concentration of contaminants arising from elsewhere in the bight due to surface currents.

Conclusions

Overall, the risk of faecal contamination to the fisheries within the two production areas is low but differs somewhat between the eastern and western sides of the larger water body area. There is a concentration of human habitation and agricultural use along Cribba Sound and Voe of Clousta and results from shoreline survey samples taken across all the sites showed higher levels of contamination in water and mussels from these areas. To the west, most of the adjacent land is uninhabited or used for extensive sheep grazing and correspondingly contamination levels appeared to be lower in these areas.

Within the western part of the area covered by this assessment, there is no evidence of a significant difference in contamination sources or effects between Suthra Voe and Longaness, although there may be some intermittent additional pressures at the latter (a watercourse and an anchorage). Within the eastern part of the area, The southern end of the Clousta Voe Noonsbrough site is potentially exposed to more sources of contamination than the others in the area.

The main mechanism of transport of faecal contaminants arising on land is likely to be via rainfall-associated runoff, and positive correlations between rainfall and *E. coli* results appears to confirm this effect at two of the monitored sites. Although no statistically significant correlation was found for the third site, there did appear to be some evidence of lower results corresponding with months that have seen lower rainfall.

17. Recommendations

Although the conclusions are that there is an east/west difference in risk of contamination between the water bodies making up the two existing production areas, the existing production area names have been kept to assist continuity. The east/west difference has been accommodated in the recommendations given below by re-allocating the Longaness site from Vementry South to Vementry North.

Vementry North

Production area

The recommended boundaries are:

The area bounded by lines drawn between HU 2822 6042 and HU 2742 5959 and between HU 2821 5800 and HU 2835 5800 and between HU 2902 5830 and HU 2901 5873 and extending to MHWS.

This area includes the Suthra Voe, Treawick and Longaness mussel farms.

RMP

Although two potential sources of contamination were identified to the east of the mussel farm (an anchorage and a watercourse), it is likely that the most immediate source will be from sheep grazing on the shore immediately adjacent to the farm. It is therefore recommended that the RMP be retained at HU 2919 6023, on the Suthra Voe West mussel farm.

Tolerance

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

Depth of sampling

The recommended sampling depth is 1 m. This will reflect any potential contamination arising from the surface, such as that from seabirds or nearby land runoff.

Frequency

Due to the seasonal variation in both sources and mechanisms of transport (ie. rainfall), it is recommended that monthly monitoring be maintained.

Vementry South

Production area

It is recommended that the production area boundaries be amended to reflect the east-west split in settlements and natural basins within the area. The recommended boundaries are:

The area bounded by lines drawn between HU 2901 5873 and HU 2902 5830 and between HU 2954 5768 and HU 2976 5762 and between HU 3048 5830 and HU 3048 5835 and between HU 3048 5998 and HU 3043 5998 and extending to MHWS.

This excludes the southern part of the Voe of Clousta, where the majority of potential contaminating sources were located, as well as The Brigs at the head of the North Voe of Clousta, which is likely to be more heavily impacted by runoff.

This area includes the Cribba Sound North, Cribba Sound South, Seggi Bight, North Voe of Clousta and Clousta Voe Noonsbrough mussel farms.

RMP

It is recommended that the RMP be relocated to HU 2948 5786, at the southern end of the Clousta Voe Noonbrough mussel farm. This lies nearer the identified concentration of potential faecal sources around the Voe of Clousta, south of the mussel farm.

Tolerance

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

Depth of sampling

The recommended sampling depth is 1 m. This will reflect any potential contamination arising from the surface, such as that from nearby land runoff, as well as any contamination arising from further south that may be carried in slightly less saline surface waters.

Frequency

Due to the seasonal variation in both sources and mechanisms of transport (ie. rainfall), it is recommended that monthly monitoring be maintained.

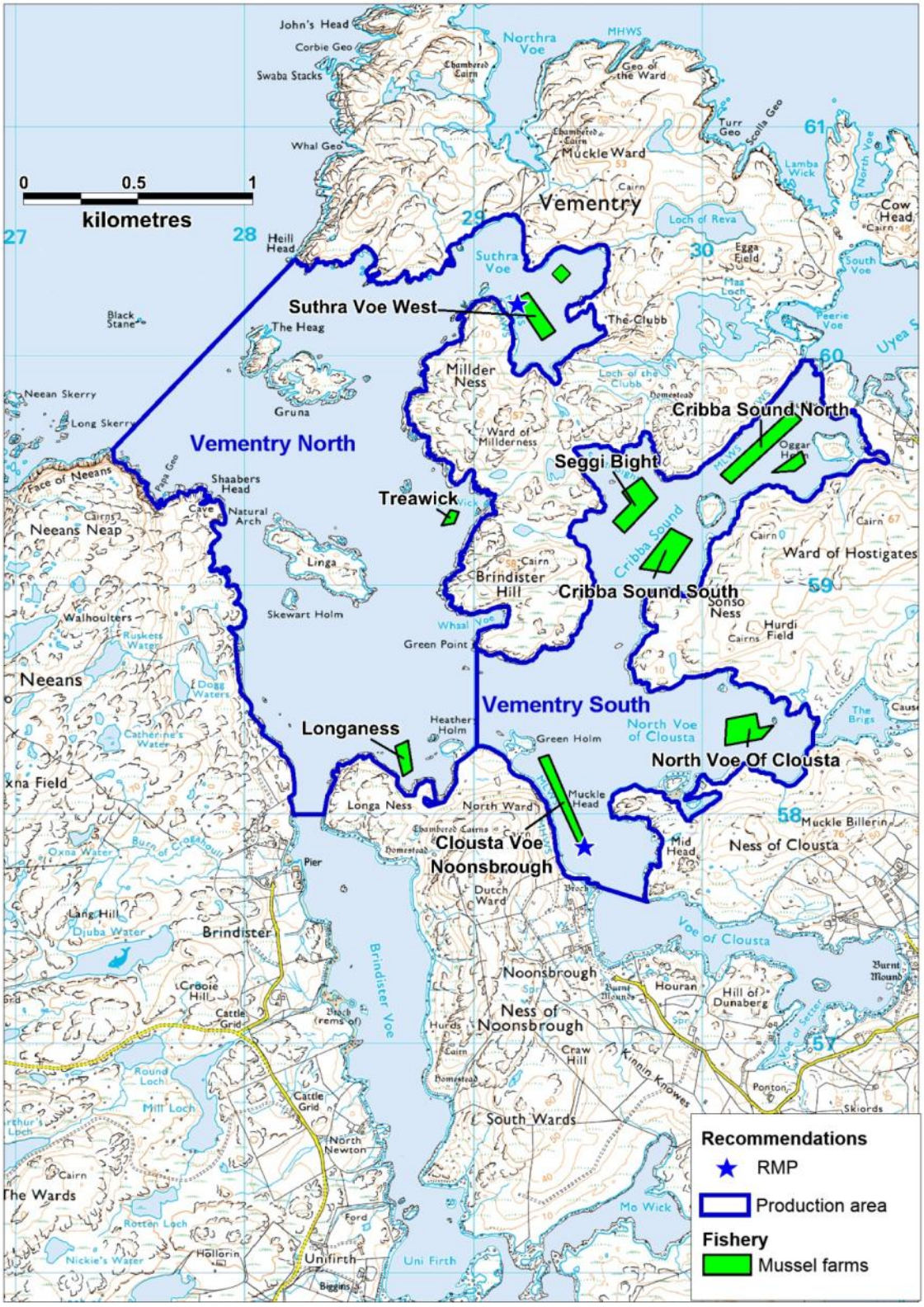


Figure 17.1 Map of recommendations at Vementry North And South

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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.

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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, *et al.*, 2008b)

Table 3 – Geometric mean (GM) and 95% confidence intervals (CIs) of the GM faecal indicator organism (FIO) concentrations (cfu/100ml) 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	*n*	**Base Flow**			**High Flow**		
Subcatchment land use		Geometric mean	Lower 95% CI	Upper 95% CI	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, *et al.*, 2008a)

Table 4 - Comparison of faecal indicator concentrations (average numbers/g wet weight) excreted in the faeces of warm-blooded animals

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

Source: (Gauthier & Bedard, 1986)

References

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

Kay, D. *et al.*, 2008a. Faecal indicator organism concentrations and catchment export coefficients in the UK. *Water Research,* 42(10/11), pp. 2649-2661.

Kay, D. *et al.*, 2008b. Faecal indicator organism in concentration sewage and treated effluents. *Water Research,* 42(1/2), pp. 442-454.

3. Statistical Data

One-way ANOVA: logec versus Season (south_seggi bight)

```
Source DF SS MS F P
Season 3 1.563 0.521 2.03 0.124
Error 40 10.242 0.256
Total 43 11.806
S = 0.5060 R-Sq = 13.24% R-Sq(adj) = 6.73%

    Individual 95% CIs For Mean Based on
    Pooled StDev
Level N Mean StDev --------+---------+---------+---------+-
1 11 1.0635 0.2107 (-------*--------)
2 13 1.2849 0.5502  (-------*-------)
3 9 1.6209 0.8073   (--------*---------)
4 11 1.2551 0.3083 (--------*--------)
    --------+---------+---------+---------+-
     1.05 1.40 1.75 2.10

Pooled StDev = 0.5060
Grouping Information Using Tukey Method

Season N Mean Grouping
3 9 1.6209 A
2 13 1.2849 A
4 11 1.2551 A
1 11 1.0635 A

Means that do not share a letter are significantly different.

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

Individual confidence level = 98.94%

Season = 1 subtracted from:

Season Lower Center Upper ------+---------+---------+---------+---
2 -0.3342 0.2214 0.7769  (---------*--------)
3 -0.0522 0.5573 1.1669   (---------*---------)
4 -0.3867 0.1916 0.7698  (--------*---------)
     ------+---------+---------+---------+---
     -0.60 0.00 0.60 1.20

Season = 2 subtracted from:

Season Lower Center Upper ------+---------+---------+---------+---
3 -0.2521 0.3360 0.9240  (---------*--------)
4 -0.5854 -0.0298 0.5258 (---------*--------)
     ------+---------+---------+---------+---
     -0.60 0.00 0.60 1.20

Season = 3 subtracted from:

Season Lower Center Upper ------+---------+---------+---------+---
4 -0.9753 -0.3658 0.2438 (---------*---------)
     ------+---------+---------+---------+---
     -0.60 0.00 0.60 1.20
```

One-way ANOVA: logec versus Season (south_longaness)

```
Source DF SS MS F P
```

```
Season 3 0.062 0.021 0.11 0.956
Error 19 3.734 0.197
Total 22 3.797

S = 0.4433 R-Sq = 1.64% R-Sq(adj) = 0.00%

    Individual 95% CIs For Mean Based on
    Pooled StDev
Level N Mean StDev ------+---------+---------+---------+---
1 7 1.2150 0.3350 (-------------*-------------)
2 6 1.2270 0.5559 (--------------*--------------)
3 6 1.3172 0.3978 (--------------*--------------)
4 4 1.3356 0.4915 (------------------*------------------)
    ------+---------+---------+---------+---
    1.00 1.25 1.50 1.75

Pooled StDev = 0.4433

Grouping Information Using Tukey Method

Season N Mean Grouping
4 4 1.3356 A
3 6 1.3172 A
2 6 1.2270 A
1 7 1.2150 A

Means that do not share a letter are significantly different.

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

Individual confidence level = 98.89%

Season = 1 subtracted from:

Season Lower Center Upper --------+---------+---------+---------+-
2 -0.6822 0.0119 0.7061 (-------------*-------------)
3 -0.5920 0.1022 0.7963 (-------------*-------------)
4 -0.6614 0.1206 0.9026 (--------------*---------------)
     --------+---------+---------+---------+-
     -0.50 0.00 0.50 1.00

Season = 2 subtracted from:

Season Lower Center Upper --------+---------+---------+---------+-
3 -0.6301 0.0902 0.8105 (--------------*-------------)
4 -0.6967 0.1087 0.9140 (---------------*---------------)
     --------+---------+---------+---------+-
     -0.50 0.00 0.50 1.00

Season = 3 subtracted from:

Season Lower Center Upper --------+---------+---------+---------+-
4 -0.7869 0.0184 0.8238 (---------------*---------------)
     --------+---------+---------+---------+-
     -0.50 0.00 0.50 1.00
```

One-way ANOVA: LogEC versus Site

```
Source  DF   SS   MS   F   P
Site   2  1.616 0.808 2.89 0.060
Error  123 34.425 0.280
Total  125 36.041

S = 0.5290  R-Sq = 4.48%  R-Sq(adj) = 2.93%


              Individual 95% CIs For Mean Based on Pooled StDev
Level  N  Mean  StDev  +---------+---------+---------+---------
1   59 1.5085 0.5697             (---------*--------)
2   44 1.2908 0.5240     (---------*----------)
3   23 1.2658 0.4154  (-------------*--------------)
               +---------+---------+---------+---------
              1.05   1.20   1.35   1.50

Pooled StDev = 0.5290


Grouping Information Using Tukey Method

Site  N  Mean Grouping
1   59 1.5085 A
2   44 1.2908 A
3   23 1.2658 A

Means that do not share a letter are significantly different.


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

Individual confidence level = 98.09%


Site = 1 subtracted from:

Site  Lower  Center  Upper  --+---------+---------+---------+-------
2   -0.4680 -0.2177 0.0327   (---------*---------)
3   -0.5517 -0.2427 0.0662  (-----------*------------)
                --+---------+---------+---------+-------
               -0.50   -0.25   0.00   0.25


Site = 2 subtracted from:

Site  Lower  Center  Upper  --+---------+---------+---------+-------
3   -0.3485 -0.0251 0.2983      (------------*------------)
                --+---------+---------+---------+-------
               -0.50   -0.25   0.00   0.25
```

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 Neap, The highest level that tides reach on average during neap 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 Neap, The lowest level that tides reach on average during neap 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.

Neap 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 neap 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

Production Areas:	Vementry North and Vementry South	
Site Names:	Vementry North:	Suthra Voe West
		Suthra Voe
		Treawick
	Vementry South:	Clousta Voe Noonsbrough
		Cribba Sound
		Longaness
		North Voe of Clousta
		Seggi Bight
SIN:	Suthra Voe West:	SI-322-464-08
	Suthra Voe:	SI-322-463-08
	Treawick:	SI-322-465-08
	Clousta Voe Noonsbrough:	SI-321-459-08
	Cribba Sound:	SI-321-460-08
	Longaness:	SI-321-885-08
	North Voe of Clousta:	SI-321-461-08
	Seggi Bight:	SI-321-462-08
Harvesters:	**Shetland Mussels Ltd.**: Michael Tait	
	-Suthra Voe West, Clousta Voe Noonsbrough, Longaness, North Voe of Clousta & Seggi Bight	
	Suthravoe Shellfish: Jim Georgeson	
	-Suthra Voe & Treawick	
	Cribba Sound Ltd.: Lindsay Angus	
	-Cribba Sound	
Local Authority:	Shetland Islands Council	
Status:	Existing area	
Date surveyed:	23 & 24 September 2013	
Surveyed by:	Sean Williamson (Hall Mark Meat Hygiene Ltd.)	
	Vicki Smith (SSQC Ltd.)	
	We are grateful to Shetland Mussels and Angus Walterson for providing assistance during the marine survey work.	
Existing RMPs:	Suthra Voe West:	HU 2919 6023 *(E. coli)*
	Seggi Bight:	HU 2965 5918 (Biotoxin & *E. coli*)
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 the locations marked on Figures 2 and 3. Bacteriology results are given in Tables 2 and 3. Salinity profiles are presented in Table 4 with profile locations marked on Figure 2. Photographs are presented in Figures 4-21.

Weather

Monday 23 September 2013

Cloudy conditions with some light drizzle at times, with a F2-F3 easterly breeze persisting throughout the day, moving north easterly into the evening. Rain showers becoming less frequent with conditions improving overnight.

Tuesday 24 September 2013

Cloudy conditions with a gentle to moderate north easterly breeze (F3-F4) persisting through the day easing into the evening to a F2 moving easterly.

Preceding the shoreline survey, Saturday 21 September was a cloudy day with rain becoming more frequent into the evening and overnight. A F4-F5 south westerly wind remained throughout the day and night moving south easterly overnight. On Sunday 22 September rain showers were present in the early hours before a brief dry period during the morning and early afternoon after which rain persisted for the remainder of the day. The wind decreased from a F3-F4 north easterly in the morning to a light F2 breeze in the afternoon before increasing again late evening to a F4 easterly.

Fishery

The location of the mussel lines for seven of the eight fisheries outlined are mapped in Figure 1. The Suthra Voe fishery just had one mussel raft on site with no mussels present at the time of the survey. The other seven fisheries had stocked mussel lines on site with no harvesting occurring at any of the fisheries at this time.

The Suthra Voe West fishery consisted of five mussel lines running parallel to the western shoreline (Figure 4). All lines were double headed longlines with 8 metre droppers. Two mussel samples were collected from the south west corner of the site. The site is licensed for six 220 metre twin-headline longlines.

The Treawick fishery consisted of five mussel lines running parallel to the eastern shoreline (Figure 5). All lines were double headed longlines with 10 metre droppers. Two mussel samples were collected at the north end of the site. The site is licensed for five 75 metre twin-headline longlines.

The Clousta Voe Noonsbrough fishery consisted of three mussel lines running parallel to the western shoreline (Figure 6). All lines were double headed longlines with 8 metre droppers. Two mussel samples were collected just north of the south east corner of the site. The site is licensed for four 440 metre twin-headline longlines.

The Cribba Sound fishery consists of two groups of mussel lines. The northern group which is found north east of the island of Grink Holm consisted of five double headed longlines to the west and three shorter plastic pipes to the east (Figure 7). The depth of droppers at the site was 8 metres. Two mussel samples were collected from the north end of the site. The site is licensed for five 410 metre and eleven 156 metre twin-headline longlines. The southern group which is found south west of the island of Grink Holm consisted of five double headed longlines with 10 metre droppers (Figure 8). Two mussel samples were

collected from the south end of the site. The site is licensed for five 200 metre twin-headline longlines.

The Longaness fishery consisted of four mussel lines running perpendicular to the southern shoreline (Figure 9). All lines were double headed longlines with 5 metre droppers. Two mussel samples were collected a small distance south of the north east corner of the site. The site is licensed for five 130 metre twin-headline longlines.

The North Voe of Clousta fishery consisted of seven mussel lines running parallel to the shoreline, the northern three lines were shorter in length compared to the southern four lines (Figure 10). All lines were double headed longlines with 8 metre droppers. Two mussel samples were collected just west of the south east corner of the site. The site is licensed for eight 100 metre twin-headline longlines.

The Seggi Bight fishery consisted of seven mussel lines running parallel to the shoreline, the western two lines were shorter in length compared to the eastern five lines (Figure 11). All lines were double headed longlines with 10 metre droppers. Two mussel samples were collected from the north west corner of the site. The site is licensed for five 200 metre and two 100m twin-headline longlines.

Sewage/Faecal Sources

The shoreline around the Vementry North production area was uninhabited. In the Vementry South production area there were three main dwelling areas. Noonsbrough is located at the mouth of the Voe of Clousta, south of the Clousta Voe Noonsbrough fishery. Four houses were noted in this area with two septic tanks identified. The first septic tank was noted at the north end of Noonsbrough servicing two houses, with one of the houses having associated agricultural sheds. The concrete septic tank was located next to a small watercourse (Figure 12). The tank had a crack down the side and there was some leakage coming from the tank. The second septic tank was located near the end of the Noonsbrough walk servicing one house (Figure 13). The soakaway for this tank was very prominent with a large area of wet boggy ground and wild iris growing below the tank. The second and largest dwelling area in the Vementry South production area is Clousta, which is situated at the head of the Voe of Clousta. Thirteen houses were observed on the shoreline walk with five septic tanks being identified. It is known there are more houses situated further east in the Clousta area but the properties could not been seen from the shore. One house near the shore, at the head of the voe had a pipe coming from the septic tank under the road leading to the water (Figure 14). The end of the pipe was not visible but it is known that the owner of the house has recently extended the pipe so the discharge was further from the shore. Five of the houses in the area had associated agricultural buildings with their properties. A small cluster of houses was present at the north end of the production area, north of the Cribba Sound (north) fishery. Three houses were present in this area with one of the properties being a self-catering holiday cottage which is available to rent all year round. Two septic tanks were

identified for the houses one servicing two of the houses (Figure 15) and the other servicing one dwelling.

Sample analysis

Nine freshwater samples were obtained from watercourses on the shoreline survey, eight of which were outlined on the sampling plan and one was an additional sample not outlined in the plan. The additional sample was taken from a small watercourse located on the southern shoreline of the Voe of Clousta (Figure 16). Of the nine watercourses sampled, five were found to have *E. coli* levels between 35-80 cfu/100ml, three had levels between 310-700 cfu/100ml and one had an *E. coli* count of 3900 cfu/100ml. The sample with the highest *E. coli* count was from the Noonsbrough area south of the Clousta Voe Noonsbrough fishery. The sample was obtained from a small watercourse discharging to the shore which was located adjacent to a septic tank that serviced two houses in the area (Figure 12).

Eight seawater samples were obtained from the seven fisheries (two samples from the Cribba Sound fishery, one from each group of mussel lines), all of which were outlined on the survey plan. All the seawater samples obtained had *E. coli* levels between 2-10 cfu/100ml.

Two mussel samples were obtained from six fisheries, with four samples obtained from the Cribba Sound fishery, two from each group of lines. Samples were obtained from the south end of the Suthra Voe West fishery, from the south west corner of the site. Mussels were obtained from sample bags located at depths of 1 metre and 8 metres from the surface. The sample obtained from the surface was found to have a count of 110 *E. coli* MPN/100g with the bottom sample returning levels of <20 *E. coli* MPN/100g. The samples from the Treawick fishery were taken from the top and bottom of a mussel dropper at the north end of the site two lines in from the east. The sample obtained from the top recorded a count of 110 *E. coli* MPN/100g with the bottom sample returning levels of <20 *E. coli* MPN/100g. The samples from the Clousta Voe Noonsbrough fishery were obtained from sample bags located at depths of 1 metre and 8 metres from the surface. The sample bags were located at the south end of the site near the south east corner. The sample from the surface recorded a count of 330 *E. coli* MPN/100g with the bottom sample returning levels of 20 *E. coli* MPN/100g. Mussel samples were collected from the Cribba Sound fishery (northern group) from sample bags located at depths of 1 metre and 8 metres from the surface from the north of the site, second line in from the west. The sample obtained from the surface recorded a count of 130 *E. coli* MPN/100g with the bottom sample returning levels of 310 *E. coli* MPN/100g. The samples obtained from the Cribba Sound fishery (southern group) were from sample bags located at depths of 1 metre and 10 metres from the surface. The bags were located at the south end of the site on the second line in from the west. The sample obtained from the surface recorded a count of <20 *E. coli* MPN/100g with the bottom sample returning levels of 70 *E. coli* MPN/100g. Samples from the Longaness fishery were obtained from sample bags located at depths of 1 metre and 5 metres from the surface, located south of the north east corner of the site. The sample obtained from the surface was found to have

a count of 140 *E. coli* MPN/100g with the bottom sample returning levels of 80 *E. coli* MPN/100g. Samples were obtained from the south end of the North Voe of Clousta fishery, near the south east corner of the site. Mussels were obtained from the top and bottom of a mussel dropper. The sample obtained from the top of the dropper was found to have a count of 130 *E. coli* MPN/100g with the bottom sample returning levels of <20 *E. coli* MPN/100g. Samples from the Seggi Bight fishery were obtained from a mussel dropper at the north west corner of the site. The sample obtained from the top of the mussel dropper was found to have a count of 310 *E. coli* MPN/100g with the bottom sample returning levels of 20 *E. coli* MPN/100g.

Eight salinity profiles were obtained from seven fisheries (two profiles obtained from the Cribba Sound fishery, one from each group). Profiles were collected from the north ends of the Treawick, Cribba Sound (north), Longaness and Seggi Bight fisheries and the south ends of the Suthra Voe West, Clousta Voe Noonsbrough, Cribba Sound (south) and North Voe of Clousta fisheries. All profiles showed decreases in salinity from 10 metres to the surface. Only one profile however showed <0.35 ppt decrease in salinity, which is within the accuracy of the probe used (± 0.35 ppt) which was the profile obtained from the Cribba Sound (north) fishery. The other seven profiles were out with the accuracy of the probe, ranging from a 0.42 ppt decrease at the Suthra Voe West fishery to a 1.77 ppt decrease in salinity at the North Voe of Clousta fishery. Salinity ranged from 33.57 ppt at the North Voe of Clousta fishery to 35.39 ppt at the Treawick fishery.

Eight temperature profiles were obtained from seven fisheries (two profiles obtained from the Cribba Sound fishery, one from each group). All profiles showed a decrease in temperature from 10 metres to the surface (0.1-0.4°C difference). Temperature ranged from 11.5°C to 11.9°C.

Salinities of the seawater samples analysed at the laboratory showed salinities ranging from 33.00 PSU present at the North Voe of Clousta fishery to 34.46 PSU present at the Treawick fishery, slightly below full strength sea water.

Seasonal population

There is one known self-catering property in the Vementry South area. Lower Cottage which overlooks the Cribba Sound north fishery is available to rent all year round and can accommodate up to three people.

Boats/Shipping

Boat traffic in the Vementry North and South production areas are largely associated with mussel farming and also leisure boats. Suthravoe Shellfish who own the Treawick and Suthra Voe fisheries have a small workboat berthed at a pontoon in the Voe of Setter within the Voe of Clousta which is used to service these sites and other fisheries found further north out with the Vementry production area (Figure 17). This boat is also used to collect samples for biotoxin and *E. coli* testing from sites out with this production area. There is a

shorebase and pier in Brindister Voe which is used by Shetland Mussels to berth large and small workboats to service their sites in the area and collect samples for biotoxin and *E. coli* testing. The shorebase is owned by Westside Salmon Ltd., a partnership between Shetland Mussels Ltd. and Hjaltland Seafarms Ltd. who own a salmon fishery in the Vementry North production area. Shetland Mussels had a large workboat on site at the Seggi Bight and Clousta Voe Noonsbrough fisheries during the boat survey. In the Noonsbrough area a small pier and pontoon was present below a house at the north end of the walk. The pier is owned by a creel fisherman who normally berths his workboat there but the boat was not present at the time of the survey (Figure 18). Equipment associated with creel fishing such as creels, buoys and boxes was being stored in a shed just above the pontoon. All the other boats observed on the survey were associated with leisure use. In the Noonsbrough area a yacht was observed at a pontoon and a rowing boat observed on the beach. In the Voe of Clousta three small motor boats and three rowing boats were observed, two of the motor boats being found on moorings in the voe and the other boats noted on the shore (Figure 19). A small pier was also noted on the southern shore of the Voe of Clousta.

Farming and Livestock

The majority of the land observed during the Vementry shoreline survey was rough grazing. In the Vementry North production area, approximately 75 sheep were observed, during the boat work, on the hills surrounding Suthra Voe. In the Vementry South production area, 301 sheep were observed during the shoreline walks (Figure 20) around the Noonsbrough (12 sheep), Voe of Clousta (244 sheep) and north of Cribba Sound areas (45 sheep). The majority of the sheep observed during the survey had access to the shore (291 animals). Animals which did not have access to the shore were observed during the Voe of Clousta walk predominately above the road in fenced areas some distance from the shore. Sheep faeces were noted near the shore on a large number of occasions where animals were not present.

One cow was observed on the southern shore of the Voe of Clousta in a fenced area above the road some distance from the shore. Cow faeces were also noted on the northern shore of the Voe of Clousta on two occasions in an area where animals would have been able to access the shore. Cow faeces and hoof prints were also observed on four occasions during the walk at the north end of Cribba Sound again in an area where animals would have been able to access the shore.

A large pile of manure was noted next to a house at the top of a hill during the walk of the shoreline at the north end of Cribba Sound (Figure 21).

Land Use and Land Cover

Rough grassland dominated the shorelines around the Vementry production areas. The Noonsbrough and Voe of Clousta areas were characterised by undulating landscape alternating between steep escarpments and lowland areas with small stony beaches. The area surveyed at the north of the Vementry South production area overlooking the Cribba

Sound fishery was more typically a lowland area where access to the shore was possible. Wet boggy areas were present in all three areas surveyed with wild iris often present around watercourses or areas of wet land. Observations made during the boat work in the Suthra Voe area characterised the landscape as rough grassland with heather and rocky outcrops with steep escarpments surrounding the voe.

A small fenced area of land on the west shore of the Voe of Setter was being used to grow vegetables.

In most areas the land was mainly used for grazing of sheep, with most of the animals having access to the shore and sheep faeces noted near the shore on a number of occasions.

There was rainfall in the days preceding the shoreline survey and on the day of the boat work with wet boggy areas noted on eight occasions on the shoreline walk.

Watercourses

Nine watercourses were sampled during the shoreline survey, eight of which were outlined on the sample plan. The additional sample not outlined in the plan was obtained from a relatively stagnant watercourse located on the southern shoreline of the Voe of Clousta. On the Noonsbrough shoreline walk the sampling plan detailed three freshwater sampling locations however only two samples were obtained. Wet boggy ground was noted at the third freshwater sample location outlined in the plan on the Noonsbrough walk however no flowing water was present. Flow rate was recorded at all of the nine watercourses sampled. Flow rate was also recorded at two additional locations, a small watercourse at the head of the Voe of Setter and a small watercourse beside an old slipway in the Noonsbrough area.

Wildlife/Birds

A number of bird species were observed during the Vementry boat work and shoreline walks. Most commonly observed were gulls (19 in total) which were seen at five of the seven fisheries visited and during the Voe of Clousta walk; the gulls were observed on buoys at the fisheries or in the water, in flight or observed near the shore. Shags, eider ducks and a crow were also observed during the boat work around the fisheries on buoys, in the water or in flight. Bird faeces was observed on buoys at most of the fisheries visited. Four curlews and four collared doves were observed in flight during the Voe of Clousta walk, with four plovers and five lapwings observed in flight during the shoreline walk at the north end of the Vementry South production area. Mussel shells and crab carcasses were observed near the shore on four occasions during the shoreline walks at Noonsbrough and the Voe of Clousta which could indicate areas where birds may have been feeding.

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 sound.

Figure 1.1 Map of shoreline observations Vementry North and South

Table 1 Shoreline Observations

0	Date/Time (UT)	NGR	Easting	Northing	Associated Photograph	Associated Sample	Description
1	23/09/2013 08:44	HU 29592 60481	429592	1160481		VEM-FW01	Start of boat work Vementry North. Large watercourse flowing down the hillside into Suthra Voe at the NW of the voe. Fast flowing over rocks. Freshwater sample obtained and flow rate measured; width 30 cm, depth 10 cm, flow 0.706 m/s, st. dev. 0.008 m/s. Broken mussel rafts at the bottom of the watercourse on the stony beach. Rough grassland, heather present. Steep escarpments surrounding the voe.
2	23/09/2013 08:50	HU 29383 60365	429383	1160365			Suthra Voe fishery - one mussel raft present. No mussels on site.
3	23/09/2013 08:51	HU 29238 60278	429238	1160278			NE corner of the Suthra Voe West fishery. 5x double headed longlines, 8m droppers.
4	23/09/2013 08:52	HU 29181 60248	429181	1160248			NW corner of the Suthra Voe West fishery.
5	23/09/2013 08:55	HU 29298 60070	429298	1160070	Figure 4	VEM-MUSS01 (Top), VEM-MUSS02 (Bottom) & VEM-SW01	SW corner of the Suthra Voe West fishery. Salinity Profile 1 collected (ppt/°C): 10m 35.32/11.8, 5m 35.22/11.7, 3m 35.14/11.7, surface 34.90/11.5. Mussels collected from furthest west line at the SW corner buoy. Surface sample collected from a sample bag at 1m depth, bottom sample collected from a sample bag at a depth of 8m. Seawater sample collected.
6	23/09/2013 09:06	HU 29357 60110	429357	1160110			SE corner of the Suthra Voe West fishery. 35 sheep noted on the southern shore and 40 sheep noted on the northern shore of Suthra Voe. Rough grassland with heather and rocks. Two eider ducks present in the water and one gull on a buoy at the site. Bird faeces present on buoys at the site.
7	23/09/2013 09:16	HU 28898 59329	428898	1159329			NW corner of the Treawick fishery. 5x double headed longlines, 10m droppers.

8	23/09/2013 09:22	HU 28922 59319	428922	1159319		VEM-MUSS03 (Top), VEM-MUSS04 (Bottom) & VEM-SW02	Treawick fishery - Salinity Profile 2 collected (ppt/°C): 10m 35.39/11.9, 5m 35.37/11.9, 3m 35.31/11.9, surface 34.78/11.8. Mussels collected from the second line in from the eastern shore at the north end of the line. Surface sample collected from the top of a mussel dropper, bottom sample collected from the bottom of a mussel dropper. Seawater sample collected.
9	23/09/2013 09:32	HU 28934 59319	428934	1159319			NE corner of the Treawick fishery.
10	23/09/2013 09:32	HU 28916 59271	428916	1159271			SE corner of the Treawick fishery.
11	23/09/2013 09:33	HU 28859 59261	428859	1159261	Figure 5		SW corner of the Treawick fishery. Some bird faeces present on the buoys at the site.
12	23/09/2013 09:38	HU 29659 59228	429659	1159228			SE corner of the Seggi Bight fishery. RMP location. One gull present on a buoy.7x double headed longlines, 5 long (east)/2 short (west), 10m droppers.
13	23/09/2013 09:47	HU 29607 59279	429607	1159279			SW corner of 5 east lines of the Seggi Bight fishery.
14	23/09/2013 09:48	HU 29649 59406	429649	1159406			SW corner of 2 west lines of the Seggi Bight fishery.
15	23/09/2013 09:50	HU 29736 59470	429736	1159470	Figure 11	VEM-MUSS05 (Top), VEM-MUSS06 (Bottom) & VEM-SW03	NW corner of the Seggi Bight fishery. Salinity Profile 3 collected (ppt/°C): 10m 35.33/11.8, 5m 35.22/11.7, 3m 34.94/11.7, surface 34.49/11.6. Mussels collected from the furthest west line at the NW corner buoy. Samples collected from the top and bottom of a mussel dropper. Seawater sample collected. Large workboat on site.
16	23/09/2013 10:03	HU 29804 59380	429804	1159380			NE corner of the Seggi Bight fishery.
17	23/09/2013 10:05	HU 30078 59482	430078	1159482			Two groups of lines associated with the Cribba Sound fishery. SW corner of the longlines at the Cribba Sound fishery (northern group). Five gulls and one shag on buoys and three gulls and one shag in flight. 5x double headed longlines to the west and 3x black plastic pipes to the east, 8m droppers.
18	23/09/2013 10:07	HU 30387 59765	430387	1159765			NW corner of the longlines at the Cribba Sound fishery (northern group).

19	23/09/2013 10:08	HU 30396 59751	430396	1159751	Figure 7	VEM-MUSS07 (Top), VEM-MUSS08 (Bottom) & VEM-SW04	Cribba Sound fishery (northern group) - Salinity Profile 4 collected (ppt/°C): 10m 35.23/11.8, 5m 35.18/11.7, 3m 34.98/11.7, surface 34.91/11.6. Mussels collected from the second longline in from the west at the north end of the line. Surface sample collected from a sampling bag at 1m depth, bottom sample collected from a sampling bag at a depth of 8m. Seawater sample collected.
20	23/09/2013 10:20	HU 30433 59724	430433	1159724			NE corner of the longlines at the Cribba Sound fishery (northern group).
21	23/09/2013 10:22	HU 30449 59535	430449	1159535			NE corner of the pipes at the Cribba Sound fishery (northern group).
22	23/09/2013 10:23	HU 30404 59499	430404	1159499			SE corner of the pipes at the Cribba Sound fishery (northern group).
23	23/09/2013 10:25	HU 30303 59492	430303	1159492			SW corner of the pipes at the Cribba Sound fishery (northern group).
24	23/09/2013 10:27	HU 30432 59584	430432	1159584			NW corner of the pipes at the Cribba Sound fishery (northern group).
25	23/09/2013 10:29	HU 30124 59443	430124	1159443			SE corner of the longlines at the Cribba Sound fishery (northern group). Some bird faeces on the buoys.
26	23/09/2013 10:31	HU 29862 59248	429862	1159248			NW corner of the Cribba Sound fishery (southern group). 5x double headed longlines, 10m droppers.
27	23/09/2013 10:32	HU 29954 59200	429954	1159200			NE corner of the Cribba Sound fishery (southern group). One crow on a buoy at the fishery.
28	23/09/2013 10:33	HU 29857 59053	429857	1159053			SW corner of the Cribba Sound fishery (southern group). One gull observed on a buoy and one gull in flight.
29	23/09/2013 10:35	HU 29744 59067	429744	1159067	Figure 8	VEM-MUSS09 (Top), VEM-MUSS10 (Bottom) & VEM-SW05	Cribba Sound fishery (southern group) - Salinity Profile 5 collected (ppt/°C): 10m 35.34/11.9, 5m 35.27/11.8, 3m 35.03/11.7, surface 34.61/11.5. Mussels collected from the second line in from the west at the south end of the line. Surface sample collected from a sampling bag at 1m depth, bottom sample collected from a sampling bag at a depth of 10m. Seawater sample collected.

30	23/09/2013 10:48	HU 29725 59073	429725	1159073			SE corner of the Cribba Sound fishery (southern group).
31	23/09/2013 10:51	HU 30106 58415	430106	1158415			NW corner of the North Voe of Clousta fishery. 7x double headed longlines, 4 long (south)/3 short (north), 8m droppers.
32	23/09/2013 10:52	HU 30234 58440	430234	1158440			NE corner of the 3 northern lines of the North Voe of Clousta fishery.
33	23/09/2013 10:54	HU 30311 58389	430311	1158389			NE corner of the 4 southern lines of the North Voe of Clousta fishery.
34	23/09/2013 10:55	HU 30258 58329	430258	1158329			SE corner of the North Voe of Clousta fishery.
35	23/09/2013 10:57	HU 30248 58328	430248	1158328	Figure 10	VEM-MUSS11 (Top), VEM-MUSS12 (Bottom) & VEM-SW06	North Voe of Clousta fishery - Salinity Profile 6 collected (ppt/°C): 10m 35.34/11.8, 5m 35.30/11.8, 3m 35.23/11.8, surface 33.57/11.7. Mussels collected just west of the SE corner buoy, from the southernmost line. Surface sample collected from the top of a mussel dropper, bottom sample collected from the bottom of a mussel dropper. Seawater sample collected.
36	23/09/2013 11:10	HU 30098 58301	430098	1158301			SW corner of the North Voe of Clousta fishery. One gull observed in the water.
37	23/09/2013 11:14	HU 29503 57844	429503	1157844			SE corner of the Clousta Voe Noonsbrough fishery. One gull observed in the water. 3x double headed longlines, 8m droppers.
38	23/09/2013 11:14	HU 29500 57853	429500	1157853	Figure 6	VEM-MUSS13 (Top), VEM-MUSS14 (Bottom) & VEM-SW07	Clousta Voe Noonsbrough fishery - Salinity Profile 7 collected (ppt/°C): 10m 35.36/11.9, 5m 35.23/11.8, 3m 35.16/11.8, surface 34.04/11.7. Mussels collected just north of the SE corner buoy, from the eastern most line. Surface sample collected from a sampling bag at 1m depth, bottom sample collected from a sampling bag at a depth of 8m. Seawater sample collected.
39	23/09/2013 11:26	HU 29462 57862	429462	1157862			SW corner of the Clousta Voe Noonsbrough fishery. Large workboat on site. Some bird faeces present on the buoys at the site.

40	23/09/2013 11:28	HU 29283 58244	429283	1158244			NW corner of the Clousta Voe Noonsbrough fishery. One shag observed in the water.
41	23/09/2013 11:29	HU 29328 58259	429328	1158259			NE corner of the Clousta Voe Noonsbrough fishery.
42	23/09/2013 11:31	HU 28713 58323	428713	1158323			NE corner of the Longaness fishery. 4x double headed longlines, 5m droppers.
43	23/09/2013 11:31	HU 28716 58287	428716	1158287	Figure 9	VEM-MUSS15 (Top), VEM-MUSS16 (Bottom) & VEM-SW08	Longaness fishery - Salinity Profile 8 collected (ppt/°C): 10m 35.38/11.9, 5m 35.37/11.9, 3m 35.33/11.9, surface 34.58/11.8. Mussels collected a few buoys south of the NE corner buoy, from the eastern most line. Surface sample collected from a sampling bag at 1m depth, bottom sample collected from a sampling bag at a depth of 5m. Seawater sample collected.
44	23/09/2013 11:40	HU 28732 58194	428732	1158194			SE corner of the Longaness fishery.
45	23/09/2013 11:41	HU 28691 58165	428691	1158165			SW corner of the Longaness fishery. Some bird faeces present on the buoys at the site.
46	23/09/2013 11:42	HU 28656 58296	428656	1158296			NW corner of the Longaness fishery.
47	24/09/2013 09:02	HU 29504 57607	429504	1157607			Start of shoreline walk - Noonsbrough. Weather: Overcast with a light breeze. Rough grassland, lowland area with small stony beach at the shore. Seven sheep observed with access to the shore. One house and four agricultural sheds present above the shore. Old disused boat and trailer on the beach. Noonsbrough fishery located north can be seen in the distance.
48	24/09/2013 09:05	HU 29516 57570	429516	1157570	Figure 18		Pier and pontoon below the house mentioned above. Yacht berthed at the pontoon. Car and trailer parked at the end of the pier. Small shed and large numbers of creels, buoys and boxes associated with creel fishing present above the pontoon. Creel boat usually berthed at the pier but not present at the time of the survey.

49	24/09/2013 09:10	HU 29506 57525	429506	1157525			Escarpments steepening with a stony beach below, large stones on the beach not pebbles. Seaweed present on the beach. Large concrete septic tank servicing two houses in the area, slight leakage from the side of the tank where a crack is visible. House observed further up the hill. Five sheep present in the field above the shore, not fenced.
50	24/09/2013 09:15	HU 29511 57521	429511	1157521	Figure 12	VEM-FW02	Small watercourse flowing through vegetation next to the septic tank mentioned above. Freshwater sample obtained and flow rate measured; width 30 cm, depth 5 cm, flow 0.306 m/s, st. dev. 0.012 m/s.
51	24/09/2013 09:25	HU 29541 57373	429541	1157373			House observed further up the hill unable to locate the septic tank. Derelict house near the shore. Small rowing boat present on the beach, shed present just above the shore.
52	24/09/2013 09:26	HU 29545 57374	429545	1157374			Small watercourse flowing through vegetation to the shore. Flow rate measured; width 15 cm, depth 4 cm, flow 0.27 m/s, st. dev. 0.003 m/s. Old slipway noted. Sheep faeces present on the beach.
53	24/09/2013 09:32	HU 29558 57316	429558	1157316		VEM-FW03	Lowland area. Large watercourse at the head of the inlet. Flowing under the road to the shore. Wild iris present on the verges of the watercourse. Freshwater sample obtained and flow rate measured; width 45 cm, depth 20 cm, flow 0.146 m/s, st. dev. 0.013 m/s.
54	24/09/2013 09:36	HU 29611 57333	429611	1157333			Rough grassland, undulating landscape from lowland areas with small stony beaches to steeper escarpments. Sheep faeces noted and mussel shells on the verge, a possible feeding area for birds.
55	24/09/2013 09:38	HU 29663 57338	429663	1157338			Wet boggy area leading to the shore. Sheep faeces present.
56	24/09/2013 09:40	HU 29716 57366	429716	1157366			Wet boggy area leading to the shore. Wild iris present. Sheep faeces and thistles noted.

57	24/09/2013 09:43	HU 29808 57355	429808	1157355	Figure 13		Septic tank for house present at the top of the hill. Soak away very prominent leading to the shore. Wild iris present. Sheep faeces present.
58	24/09/2013 09:45	HU 29829 57399	429829	1157399			End of shoreline walk. Lowland area with a small stony beach. Rough grassland up from the shore. Sheep faeces noted.
59	24/09/2013 10:06	HU 30585 57433	430585	1157433			Start of shoreline walk - Voe of Clousta. Four agricultural sheds and one house observed up the hill from the shore. Wet boggy area near the shore with cow faeces present.
60	24/09/2013 10:08	HU 30656 57466	430656	1157466			Broken, disused sewage pipe leading to the water. Lowland area small stony beach, rough grassland. Sheep faeces noted.
61	24/09/2013 10:10	HU 30703 57464	430703	1157464			Small motor boat on a mooring in the voe, fishing rods on-board. Sheep and cow faeces present.
62	24/09/2013 10:11	HU 30740 57481	430740	1157481			Three sheep in a fenced area above the road next to a house. Small motor boat on the shore. Sheep faeces present at the shore.
63	24/09/2013 10:13	HU 30774 57489	430774	1157489			Black plastic pipe leading to the shore. Small clear discharge most likely field drainage.
64	24/09/2013 10:15	HU 30764 57513	430764	1157513			Plastic septic tank in a field above the road, house present further up the hill. Two agricultural sheds noted a short distance to the east of the house.

65	24/09/2013 10:18	HU 30838 57500	430838	1157500		VEM-FW04	Large watercourse at the head of the voe. Flowing under the road through a large pipe leading to a small stony beach. Freshwater sample obtained and flow rate measured; width 40 cm, depth 8 cm, flow 0.418 m/s, st. dev. 0.013 m/s. Wild iris present either side of the watercourse above the road. Seaweed and sheep faeces present on the beach. One house present some distance up the hill. Ten sheep in a fenced area up the hill. Small grey plastic pipe present above the watercourse, above the road. One gull in flight and two gulls present on the shore.
66	24/09/2013 10:27	HU 30889 57396	430889	1157396			Concrete septic tank servicing a house above the shore.
67	24/09/2013 10:36	HU 30909 57358	430909	1157358	Figure 14		Concrete septic tank next to a house above the shore. Plastic pipe leading to the water. End of the pipe not visible, under rocks. Agricultural shed next to the house.
68	24/09/2013 10:43	HU 30914 57279	430914	1157279		VEM-FW05	Watercourse with a small water flow leading to the shore next to a house. Pipe present above the watercourse. Freshwater sample obtained and flow rate measured; width 50 cm, depth 15 cm, flow 0.119 m/s, st. dev. 0.014 m/s. Small shed present further up the hill beside the watercourse. Five houses observed some distance from the shore.
69	24/09/2013 10:47	HU 30896 57287	430896	1157287			Concrete septic tank in the garden of the house mentioned above. Three sheds next to the house. Lowland area with small stony beach below the house. Seaweed present on the beach.
70	24/09/2013 10:49	HU 30886 57267	430886	1157267			Small plastic grey pipe leading to the shore in front of the house. No discharge may be associated with the drain pipes.

71	24/09/2013 10:53	HU 30829 57153	430829	1157153			Escarpments steepening. Wet boggy ground, small water flow through vegetation and rocks. Sheep faeces present. Mussel shells noted near the shore where birds may have been feeding.
72	24/09/2013 10:55	HU 30786 57119	430786	1157119		VEM-FW06	Small watercourse flowing down the hill to the shore through vegetation. Freshwater sample obtained and flow rate measured; width 30 cm, depth 10 cm, flow 0.102 m/s, st. dev. 0.009 m/s. Sheep faeces noted.
73	24/09/2013 11:01	HU 30763 57114	430763	1157114			Small flow of water through vegetation to the shore. Sheep faeces present.
74	24/09/2013 11:02	HU 30724 57126	430724	1157126			Rowing boat on the shore.
75	24/09/2013 11:04	HU 30678 57100	430678	1157100	Figure 16	VEM-FW07	Small watercourse leading to the shore. Very stagnant not much water flowing. Freshwater sample obtained and flow rate measured; width 30 cm, depth 3 cm, flow 0.135 m/s, st. dev. 0.019 m/s. Wild iris growing beside the watercourse further up the hill. Disused salmon cage present near the shore. Sheep faeces present. House observed at the top of the hill, not occupied. Caravan beside the house is occupied and plastic septic tank in the field below the caravan. Old concrete septic tank below the house.
76	24/09/2013 11:10	HU 30666 57141	430666	1157141			Lowland area with a small stony beach. Small pier present. Sheep faeces noted.
77	24/09/2013 11:13	HU 30578 57155	430578	1157155			Four collared doves observed in flight.
78	24/09/2013 11:14	HU 30550 57139	430550	1157139	Figure 19		Small rowing boat on the shore and a motor boat in the water on a mooring. Sheep faeces present. Two curlews and a black backed gull observed in flight.
79	24/09/2013 11:17	HU 30550 57098	430550	1157098			Fifteen sheep on the hill, some distance from the shore, the animals would be able to access the shore.
80	24/09/2013 11:18	HU 30538 57041	430538	1157041	Figure 20		Six sheep observed with access to the shore. Sheep faeces noted and mussel shells present near the shore where birds may have been feeding.

81	24/09/2013 11:21	HU 30460 56968	430460	1156968			Wet boggy area.
82	24/09/2013 11:26	HU 30411 56867	430411	1156867		VEM-FW08	Large watercourse, coming under the road, large discharge and strong water flow. Wild iris present on the banks of the watercourse. Watercourse splits in two half way down into a smaller and larger watercourse. Freshwater sample obtained and flow rate measured; width 40 cm, depth 20 cm, flow 0.613 m/s, st. dev. 0.021 m/s. Twenty five sheep in a fenced area beside the watercourse with no access to the shore. House above the road with an agricultural shed. Thirty five sheep next to the house in a fenced area. Ninety sheep observed on the north shore on the opposite side of the voe (west of where the walk started).
83	24/09/2013 11:41	HU 30240 56881	430240	1156881			Small watercourse flowing through vegetation at the head of the Voe of Setter. Flow rate measured; width 10 cm, depth 5 cm, flow 0.149 m/s, st. dev. 0.016 m/s. Sheep faeces present on the shore, one sheep outside the fenced area on the shore.
84	24/09/2013 11:43	HU 30249 56911	430249	1156911			Wet boggy area. Pipe further up the field discharging a small volume of clear water. Sheep faeces present.
85	24/09/2013 11:45	HU 30317 56994	430317	1156994			Fenced area up from the shore where vegetables were being grown. Sheep faeces out with the fenced area near the shore. Escarpments steepening slightly. One gull observed in flight.
86	24/09/2013 11:46	HU 30308 57041	430308	1157041			Small clear water discharge from a pipe coming under a small road within the field. Wet boggy ground near the shore. Wild iris present. Forty sheep in the field with access to the shore. Twelve sheep and one cow in a fenced area above the road at the top of the hill.

87	24/09/2013 11:47	HU 30327 57062	430327	1157062	Figure 17		Pier with a small workboat owned by Suthravoe Shellfish used for collecting samples and servicing fisheries in the Vementry North production area and others out with the Vementry area. Old rowing boat on the shore and two derelict houses present just above the shore.
88	24/09/2013 11:49	HU 30358 57091	430358	1157091			Possible feeding area for birds with mussel shells and crab carcasses present on the shore. Two curlews observed in flight. Seven sheep grazing on the hill with access to the shore. Sheep faeces present. End of shoreline walk.
89	24/09/2013 12:27	HU 30849 59581	430849	1159581	Figure 15		Start of shoreline walk – North of Cribba Sound. Concrete septic tank associated with two houses at the top of the hill, one of which was a self-catering holiday cottage.
90	24/09/2013 12:28	HU 30857 59562	430857	1159562			Concrete septic tank in the field below a house. Sheep faeces present in a fenced area.
91	24/09/2013 12:30	HU 30827 59551	430827	1159551			Cow faeces and hoof prints present in the field up from the shore, animals would have had access to the shore.
92	24/09/2013 12:33	HU 30816 59541	430816	1159541		VEM-FW09	Very wet boggy and muddy ground, small watercourse flowing through vegetation at the bottom of the field near the shore. Wild iris present. Freshwater sample obtained from a small waterfall and flow rate measured; width 25 cm, depth 7 cm, flow 0.551 m/s, st. dev. 0.006 m/s.
93	24/09/2013 12:39	HU 30783 59591	430783	1159591			Rough grassland. Cow faeces and hoof prints present, animals would have had access to the shore. Two plovers observed in flight.
94	24/09/2013 12:42	HU 30701 59680	430701	1159680			Two sheep grazing in a field with access to the shore, cow faeces present. Two plovers observed in flight.
95	24/09/2013 12:44	HU 30662 59770	430662	1159770			Forty three sheep grazing with access to the shore. Cow faeces noted. Five lapwings observed in flight.
96	24/09/2013 12:50	HU 30837 59618	430837	1159618	Figure 21		Large pile of manure next to the houses at the top of the hill. End of shoreline walk.

Sampling

Water and shellfish samples were collected at the locations indicated in Figures 2 and 3. Eight of the nine freshwater samples detailed in the survey plan were obtained from watercourses, as well an additional freshwater sample which was collected from a small watercourse on the southern shore of the Voe of Clousta. All samples were transported initially by a cool backpack and then in a cool box to SSQC Ltd. for analysis within 24 hours of sample collection.

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 and locations of the profiles are mapped in Figure 2.

Table 2 Water sample *E. coli* results

No.	Sample Ref.	Date/Time (UT)	Position	Type	*E. coli* (cfu/100ml)	Salinity*
1	VEM-FW01	23/09/2013 08:44	HU 29592 60481	Fresh Water	420	-
2	VEM-SW01	23/09/2013 08:55	HU 29298 60070	Sea Water	4	34.42
3	VEM-SW02	23/09/2013 09:22	HU 28922 59319	Sea Water	2	34.46
4	VEM-SW03	23/09/2013 09:50	HU 29736 59470	Sea Water	3	34.10
5	VEM-SW04	23/09/2013 10:08	HU 30396 59751	Sea Water	4	34.40
6	VEM-SW05	23/09/2013 10:35	HU 29744 59067	Sea Water	2	33.96
7	VEM-SW06	23/09/2013 10:57	HU 30248 58328	Sea Water	5	33.00
8	VEM-SW07	23/09/2013 11:14	HU 29500 57853	Sea Water	10	33.61
9	VEM-SW08	23/09/2013 11:31	HU 28716 58287	Sea Water	4	34.32
10	VEM-FW02	24/09/2013 09:15	HU 29511 57521	Fresh Water	$3.9x10^3$	-
11	VEM-FW03	24/09/2013 09:32	HU 29558 57316	Fresh Water	50	-
12	VEM-FW04	24/09/2013 10:18	HU 30838 57500	Fresh Water	80	-
13	VEM-FW05	24/09/2013 10:43	HU 30914 57279	Fresh Water	310	-
14	VEM-FW06	24/09/2013 10:55	HU 30786 57119	Fresh Water	80	-
15	VEM-FW07	24/09/2013 11:04	HU 30678 57100	Fresh Water	700	-
16	VEM-FW08	24/09/2013 11:26	HU 30411 56867	Fresh Water	35	-
17	VEM-FW09	24/09/2013 12:33	HU 30816 59541	Fresh Water	50	-

*Practical Salinity Scale 1978 (PSS-78)

Table 3 Shellfish sample *E. coli* results

No.	Sample Ref.	Date/Time (UT)	Position	Type	Depth	*E. coli* (MPN/100g)
1	VEM-MUSS01	23/09/2013 08:55	HU 29298 60070	Common Mussel	Top	110
2	VEM-MUSS02	23/09/2013 08:55	HU 29298 60070	Common Mussel	Bottom	<20
3	VEM-MUSS03	23/09/2013 09:22	HU 28922 59319	Common Mussel	Top	110
4	VEM-MUSS04	23/09/2013 09:22	HU 28922 59319	Common Mussel	Bottom	<20
5	VEM-MUSS05	23/09/2013 09:50	HU 29736 59470	Common Mussel	Top	310
6	VEM-MUSS06	23/09/2013 09:50	HU 29736 59470	Common Mussel	Bottom	20
7	VEM-MUSS07	23/09/2013 10:08	HU 30396 59751	Common Mussel	Top	130
8	VEM-MUSS08	23/09/2013 10:08	HU 30396 59751	Common Mussel	Bottom	310
9	VEM-MUSS09	23/09/2013 10:35	HU 29744 59067	Common Mussel	Top	<20
10	VEM-MUSS10	23/09/2013 10:35	HU 29744 59067	Common Mussel	Bottom	70
11	VEM-MUSS11	23/09/2013 10:57	HU 30248 58328	Common Mussel	Top	130
12	VEM-MUSS12	23/09/2013 10:57	HU 30248 58328	Common Mussel	Bottom	<20
13	VEM-MUSS13	23/09/2013 11:14	HU 29500 57853	Common Mussel	Top	330
14	VEM-MUSS14	23/09/2013 11:14	HU 29500 57853	Common Mussel	Bottom	20
15	VEM-MUSS15	23/09/2013 11:31	HU 28716 58287	Common Mussel	Top	140
16	VEM-MUSS16	23/09/2013 11:31	HU 28716 58287	Common Mussel	Bottom	80

Table 4 Salinity profiles

Profile	Date/Time (UT)	Position	Depth (m)	Salinity (ppt) (± 0.35 ppt)	Temperature (°C)
1	23/09/2013 08:55	HU 29298 60070	surface	34.90	11.5
			3	35.14	11.7
			5	35.22	11.7
			10	35.32	11.8
2	23/09/2013 09:22	HU 28922 59319	surface	34.78	11.8
			3	35.31	11.9
			5	35.37	11.9
			10	35.39	11.9
3	23/09/2013 09:50	HU 29736 59470	surface	34.49	11.6
			3	34.94	11.7
			5	35.22	11.7
			10	35.33	11.8
4	23/09/2013 10:08	HU 30396 59751	surface	34.91	11.6
			3	34.98	11.7
			5	35.18	11.7
			10	35.23	11.8
5	23/09/2013 10:35	HU 29744 59067	surface	34.61	11.5
			3	35.03	11.7
			5	35.27	11.8
			10	35.34	11.9
6	23/09/2013 10:57	HU 30248 58328	surface	33.57	11.7
			3	35.23	11.8
			5	35.30	11.8
			10	35.34	11.8
7	23/09/2013 11:14	HU 29500 57853	surface	34.04	11.7
			3	35.16	11.8
			5	35.23	11.8
			10	35.36	11.9
8	23/09/2013 11:31	HU 28716 58287	surface	34.58	11.8
			3	35.33	11.9
			5	35.37	11.9
			10	35.38	11.9

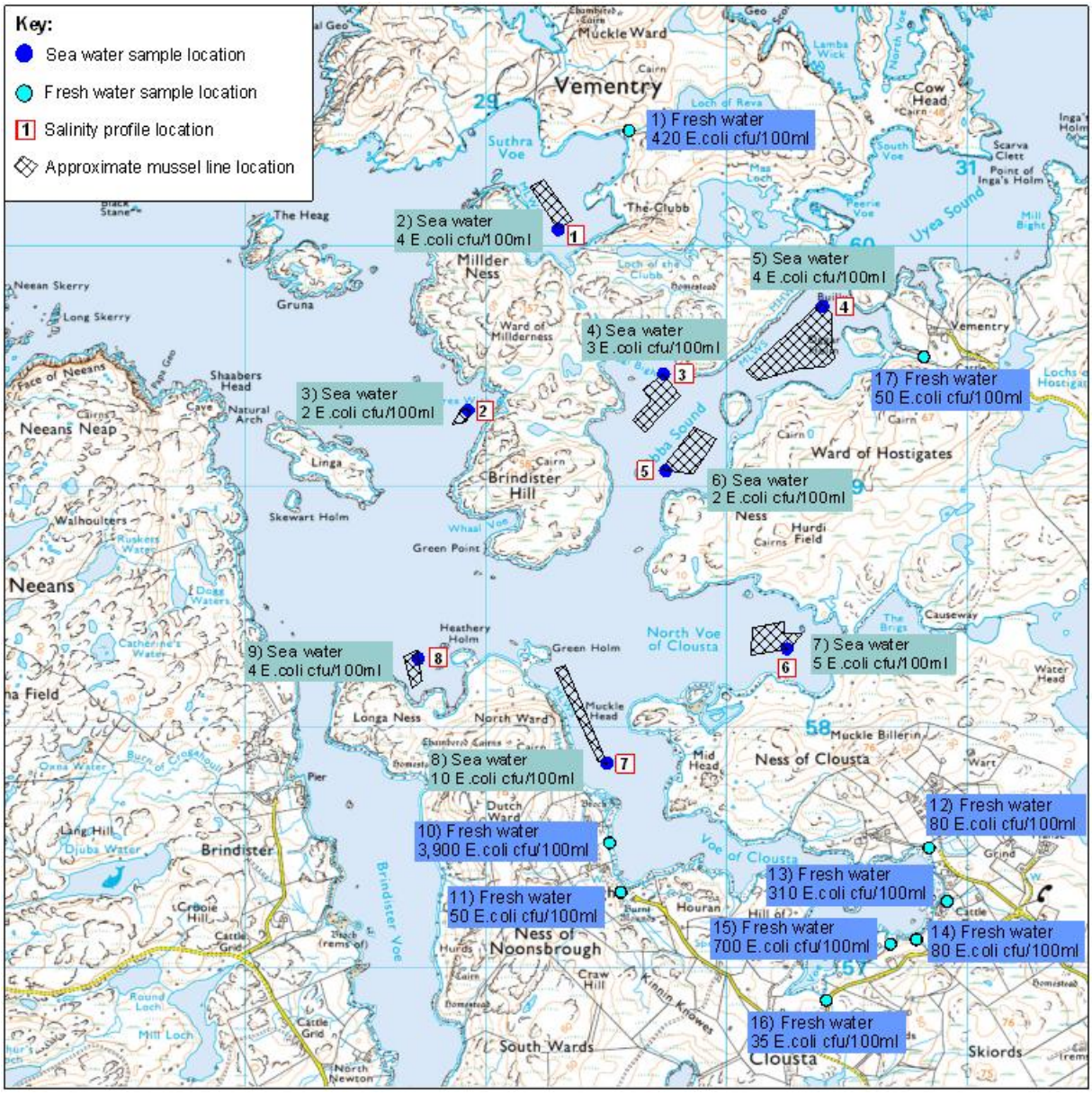

Figure 2 Map of water sample results and salinity profile locations Vementry North and South

Figure 3 Map of shellfish sample results Vementry North and South

Photographs

Figure 4 – Mussel lines at the Suthra Voe West fishery looking north.

Figure 5 – Mussel lines at the Treawick fishery looking north.

Figure 6 – Mussel lines at the Clousta Voe Noonsbrough fishery looking north with a workboat present on site.

Figure 7 – Mussel lines at the Cribba Sound (north) fishery looking south west.

Figure 8 – Mussel lines at the Cribba Sound (south) fishery looking north east.

Figure 9 – Mussel lines at the Longaness fishery looking south.

Figure 10 – Mussel lines at the North Voe of Clousta fishery looking north west.

Figure 11 – Mussel lines at the Seggi Bight fishery looking south with a workboat present on site.

Figure 12 – Septic tank servicing two houses in the Noonsbrough area next to a small watercourse.

Figure 13 – Septic tank associated with a house in the Noonsbrough area.

Figure 14 – Pipe leading to the water associated with a septic tank servicing a house at the head of the Voe of Clousta.

Figure 15 – Septic tank servicing two houses at the north end of Cribba Sound one of which being a self-catering cottage.

Figure 16 – Small watercourse on the southern shore of the Voe of Clousta where an additional freshwater sample was obtained from.

Figure 17 – Suthravoe Shellfish workboat berthed at a small pontoon in the Voe of Setter.

Figure 18 – Pier at Noonsbrough where a creel boat is usually berthed, equipment associated with creel fishing present at the pier.

Figure 19 – A rowing boat on the shore and a motor boat moored in the Voe of Clousta.

Figure 20 – Sheep grazing near the shore in the Voe of Clousta.

Figure 21 – Large pile of manure next to a house at the north of Cribba Sound.

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6. Consented Discharges (SEPA)

Licence No.	NGR	Consent Type	Site Description	PE
CAR/L/1002354	HU 28600 57600	MCFF	Brindister MCFF, Brindister Voe, Bridge of Walls, Shetland	
CAR/L/1002354	HU 32400 61400	MCFF	West of Papa Little MCFF, Swarbacks Minn, NE of Braga Ness, Shetland	
CAR/L/1002354	HU 29500 58500	Fish Farm Marine Cage	North Voe of Clousta MCFF, NE of Green Holm, Shetland	
CAR/L/1002354	HU 28383 58806	Fish Farm Marine Cage	Skewart Holm MCFF, Linga, Brindister Voe, Shetland	
CAR/L/1002354	HU 29200 61200	Fish Farm Marine Cage	Northra Voe MCFF, Vementry, Shetland	
CAR/L/1002354	HU 28040 57840	Sewage (Private) Primary	STE to land	5
CAR/L/1002354	HU 31870 56180	Sewage (Private) Primary	STE to land	5
CAR/L/1002354	HU 31166 57517	Sewage (Private) Primary	STE to soakaway	5
CAR/L/1002354	HU 31188 57527			
CAR/L/1002354	HU 30631 56654			5
CAR/L/1002354	HU 25440 56790			5
CAR/L/1002354	HU 30874 57349	Sewage (Private) Primary	STE to Voe of Clousta	6
CAR/L/1002354	HU 28480 55933			6
CAR/L/1002354	HU 25700 57490			
CAR/L/1002354	HU 25680 57480	Sewage (Private) Primary	STE to soakaway	15
CAR/L/1002354	HU 26503 57099			7
CAR/L/1002354	HU 26810 57050	Sewage (Private) Primary	STE to soakaway	5
CAR/L/1002354	HU 33842 57801	Sewage (Private) Primary	STE to soakaway	5
CAR/L/1002354	HU 33000 63150	Sewage (Private) Primary	STE to soakaway	5
CAR/L/1002354	HU 33675 58294			5
CAR/L/1002354	HU 32448 63102			5
CAR/L/1002354	HU 32670 58840	Sewage (Private) Primary	STE to soakaway	5

7. Hydrographic Appendices

Appendix 1: Hydrographic survey details

Sitename	NGR	Survey Period	Equipment
Linga (Skewart Holm)	HU 28234 58761	05/06/07 – 03/07/07	Aquadopp 600 kHz ADP
Brindister Crossroads	HU 29400 58600	16/10/98 – 03/11/98	Sensordata SD6000
Brindister Voe	HU 28486 57574	09/05/00 – 25/05/00	Nortek 500 kHz ADCP
Shetland Mussels shore base	HU 28273 57775	12/11/12 – 26/11/12	Star-Oddi DST CDT no. 5884
Linga (Skewart Holm)	HU 28182 58611	13/07/01 – 01/08/01	Nortek 500 kHz ADCP
Uyeasound	HU 31034 60164	21/08/01 – 05/09/01	Nortek 500 kHz ADCP

In the table above green shading denotes the surveys that are considered of particular interest to this study. Where two sets of data are present for a given site the deployment with the greatest precision is used.

Appendix 2: Hydrographic survey summary statistics

Parameter	Units	Near-surface / Mid-depth / Near-bottom	Linga (Skewart Holm)	Brindister Crossroads
Mean speed	m/s		0.033	0.024
			0.033	0.025
			0.031	0.035
Tidal major axis	Grid		315	260
			135	110
			285	125
Amplitude anisotropy			1.20	1.55
			1.38	1.91
			1.22	3.17
Residual speed	m/s		0.015	0.007
			0.010	0.003
			0.011	0.024
Residual direction	Grid		287	313
			189	098
			272	129
Vector averaged residual	-		0.009 m/s at 263 °Grid	0.006 m/s at 123 °Grid
Tidal excursion	km		0.55	0.47
			0.61	0.54
			0.53	0.91

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