Scottish Sanitary Survey Report

Sanitary Survey Report
Olna Firth
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Report Distribution – Olna Firth

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Partner Organisations

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

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Appendices

I. Executive Summary

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

Olna Firth is an inlet off St. Magnus Bay on the western side of Shetland Mainland . It is orientated roughly east to west, opening to Cole Deep at its mouth on the west side and ending at its head on the east side, where the settlement of Voe is located.

The fishery at Olna Firth was comprised of seven separate longline mussel farms, two of which were separate areas of longlines situated at either end of a single seabed lease area.

The main sources of contamination are:

- Public sewage discharge from the settlement of Voe at the head of the firth.
- Private septic tank discharges arising from individual homes around the firth.
- Diffuse contamination from livestock with access to watercourses and the shoreline around the majority of the firth

Contamination is either discharged directly or carried via watercourses to the firth. Contaminating sources, primarily human, were considered to be different for the farms at the head of the firth and those located in the outer firth. Movement of contaminants is likely to be largely wind driven, with the direction and distance of travel dependent upon the direction, strength and duration of winds prevailing at the time.

Seasonal variation was observed in sampling results, with higher results occurring in autumn. A statistically significant correlation was also found between *E. coli* results and rainfall in the days preceding sampling, suggesting rainfall dependent sources may predominate at the RMP.

All monitoring results were obtained from the outermost site in the production area and are not considered likely to be representative of contamination levels found nearer the eastern end of the production area.

Sampling undertaken during the shoreline survey appeared to confirm this, with higher results found nearer the head of the firth. Therefore it has been recommended that the production area be split into two, with an inner production area containing the five sites located nearer the head of the firth and an outer production area containing the two in the outer firth.

Further details on the sampling plan and recommended boundaries can be found in tabular form overleaf and in Section 14.

II. Sampling Plan

Production Area	Olna Firth Inner	Olna Firth Outer
Site Name	Inner	Foula Wick
SIN	To be allocated	To be allocated
Species	Common mussel	Common mussel
Type of Fishery	Longline aquaculture	Longline aquaculture
NGR of RMP	HU 3968 6363	HU 3662 6468
East	439680	436620
North	1163630	1164680
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
Production Area Boundaries	The area bounded by lines drawn between HU 4000 6372 and HU 4000 6341 and between HU 3800 6523 and HU 3800 6402 and extending to MHWS	The area bounded by lines drawn between HU 3800 6523 and HU 3800 6402 and between HU 3656 6417 and HU 3615 6482 and extending to MHWS

III. Report

1. General Description

Olna Firth is an inlet on the western side of Shetland Mainland which is orientated roughly east to west and is part of a much larger inlet on the southern coastline of St Magnus Bay.

Olna Firth is a sheltered waterbody measuring 4.6 km long with a maximum depth of 42 m. It is markedly narrower and shallower at its head, where its aspect turns toward the south. It has a relatively small watershed area of 27 km^2.

Figure 1.1 Location of Olna Firth

2. Fishery

The fishery at Olna Firth is comprised of six separate common mussel farms. Details of the farms are contained in Table 2.1

Table 2.1 Olna Firth shellfish sites

Production area	Site	SIN	Species
Olna Firth	Clubb of Mulla	SI-232-731-08	Common Mussels
Olna Firth	Foula Wick	SI-232-434-08	Common Mussels
Olna Firth	Inner	SI-232-435-08	Common Mussels
Olna Firth	Outer	SI-232-437-08	Common Mussels
Olna Firth	Parkgate	SI-232-438-08	Common Mussels
Olna Firth	Pinchdyke	SI-232-439-08	Common Mussels

All sites apart from the Parkgate site had mussels present during the shoreline survey. The farms were all made up of double headed long lines with droppers between 10 and 15 meters in length, varying between farms. The locations of the mussel farms are shown together with Crown Estate lease areas, RMP and production area boundaries in Figure 2.1.

The production area is bounded by lines drawn between HU 3614 6483 to HU 3657 6419 the line between HU 4030 6376 to HU 4030 6305 extending to Mean High Water Springs (MHWS). The RMP is located at HU 2672 6471 on the Pinchdyke site. The Pinchdyke site itself was recorded to the southwest of the lease area. Although the nominal RMP was located on the seabed lease identified for this site, it lies approximately 80 m east of the nearest point on the recorded farm area.

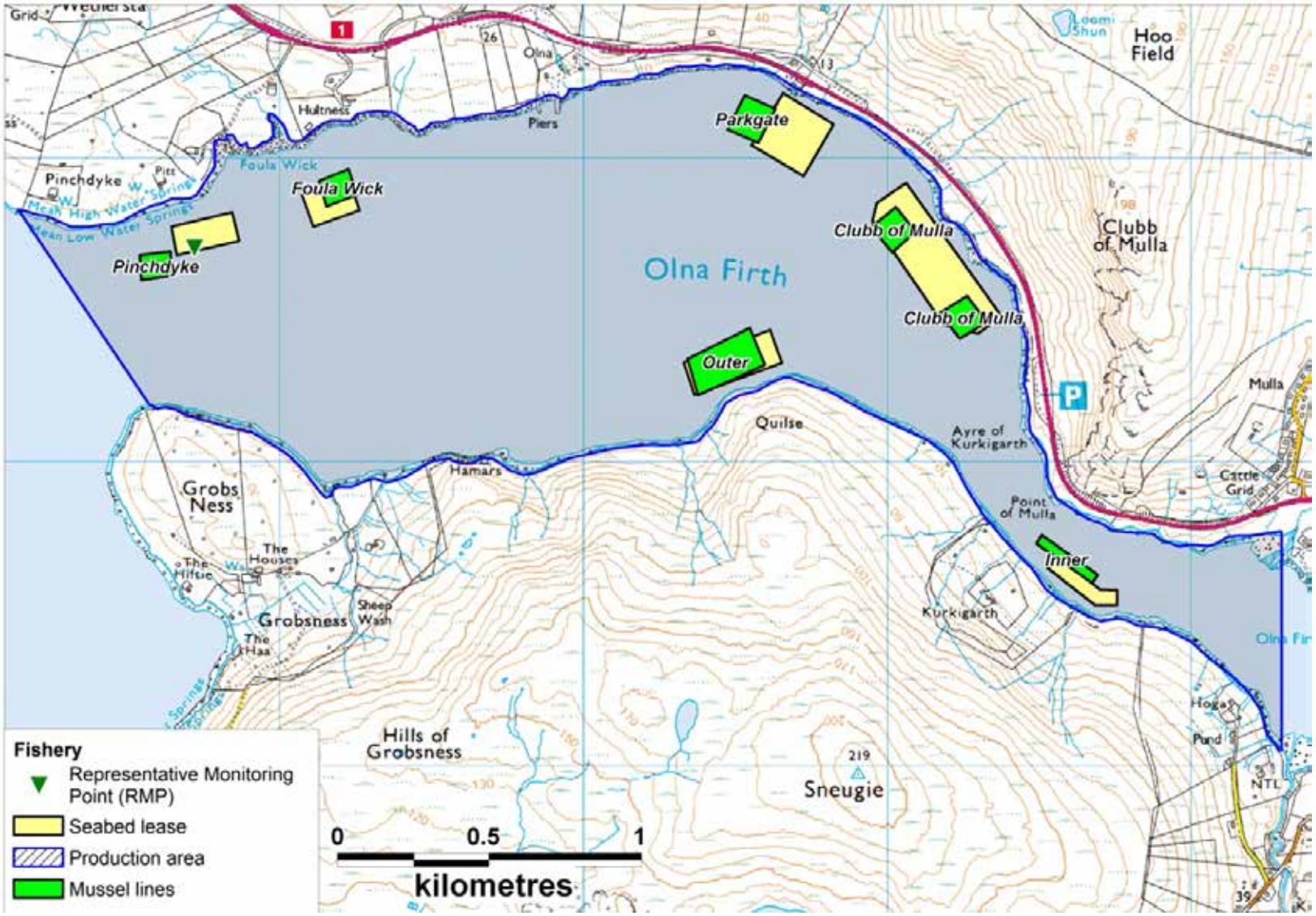

Figure 2.1 Olna Firth fishery

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 Olna Firth. The last census was undertaken in 2011. However, detailed data from the 2011 census were unavailable at the time of writing this report. Data presented below are from the 2001 census.

The five census output areas found around Olna Firth are listed in Table 3.1. The population density is low for most of the area and slightly higher nearer the head of the firth where the settlements of Hillside and Voe are located.

Table 3.1 Census output areas Olna Firth

Area No.	Output area	Population	Population Density (People per km^2)	Land Area (km^2)
1	60RD000137	50	17	2.9
2	60RD000066	65	1.3	50.7
3	60RD000045	203	9.4	21.6
4	60RD000047	105	2.2	47.9
5	60RD000046	82	681	0.1
Total		505		

Hillside has a primary school and public hall. The settlement also has parking, public toilets, a restaurant and self catering accommodation for up to 16. Wethersta, located at the north western end of Olna Firth, has dwellings and a small industrial estate. The locations of the census output areas, shellfish farms, anchorage and shoreline survey observations are shown in Figure 3.1.

Although no anchorage was noted on the Admiralty chart for the area, sailing directions for Shetland identify the area southeast of the narrows near the head of the firth as a suitable anchorage for yachts (Clyde Cruising Club, 2005). There is a pier and marina with boat yard at Voe, as well as an aquaculture operations base and floating moorings accommodating approximately 26 vessels. During the shoreline survey a number of small boats and one large workboat were observed moored at Voe Pier and Marina and five boats were observed on land in the boatyard. The designated growing waters report for the area identified boating as a source of diffuse pollution in the area.

Figure 3.1 shows information obtained from the General Register Office for Scotland on the population within the census output in the vicinity of Olna Firth.

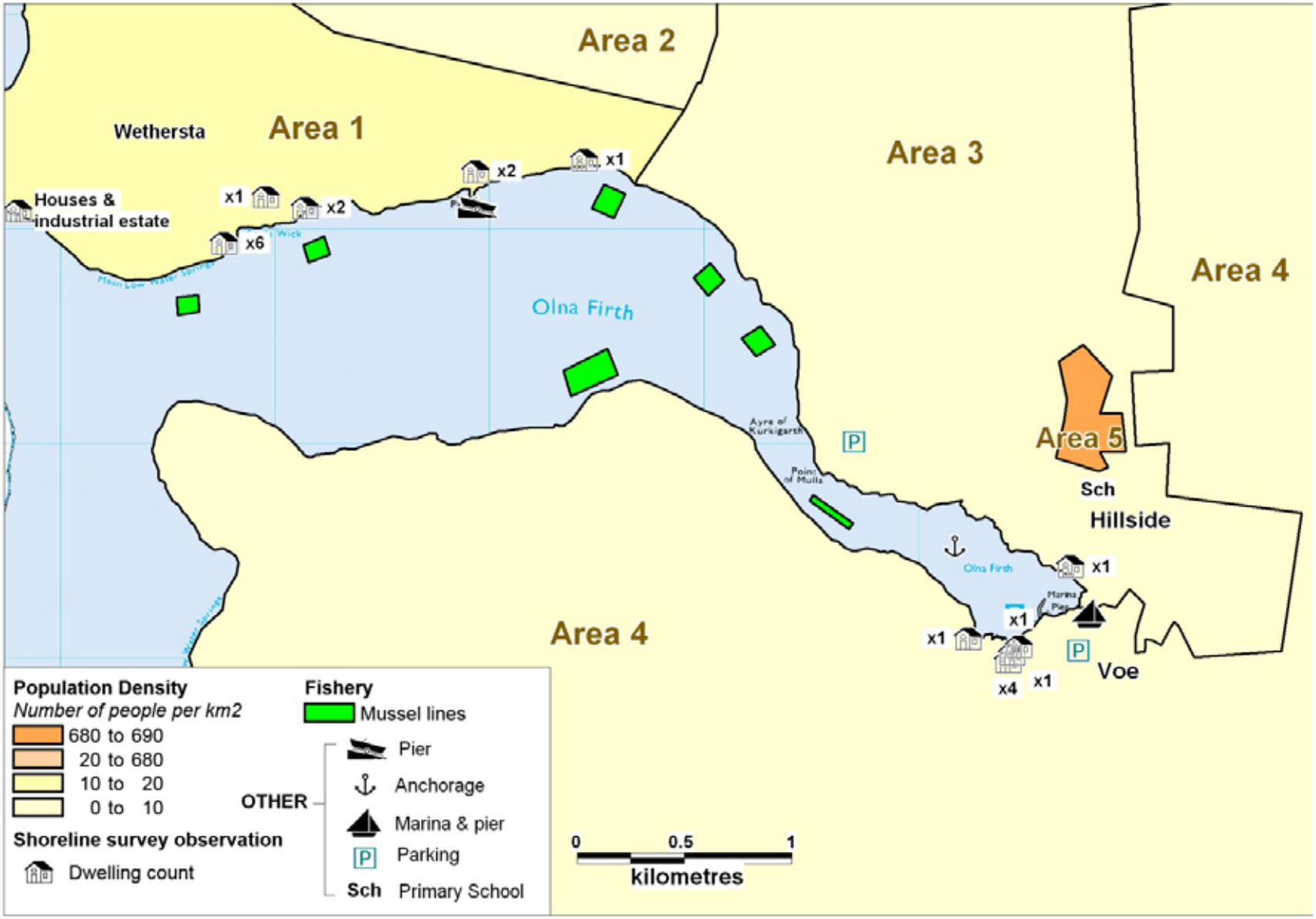

Figure 3.1 Population map of Olna Firth survey area

4. Sewage Discharges

Information on sewage discharges to the area within a 5 km radius of Olna Firth 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 or to waterbody), any available dispersion or dilution modelling studies, and whether improvements were in work or planned. All reported grid references have been restated to the nearest 10 m for the purposes of presentation in the tables below.

These datasets were cross-validated and then also compared with the shellfish growing water report for East of Burki Taing, Muckle Roe. When data did not match, further details were sought from one or both of the data providers to ensure accuracy.

Information on these discharges was then compared to ensure the data, when present on both sets, corroborated. Scottish Water identified four continuous and intermittent discharges for the area, detailed below in Table 4.1. However, all of the data in the tables below, and the associated text, relate only to the area shown in Figure 4.1.

Table 4.1 Sewage discharges identified by Scottish Water

CAR licence	NGR	Discharge Name	Discharge Type	Level of Treatment	DWF (m^3/d)	PE
CAR/L/1002247	HU 4030 6359	Voe ST FE	Continuous	Septic tank	80	1076*
		Voe WWPS EO	Intermittent	6mm screen	-	1076*

- Not given *Design PE given, connected PE is 276 See glossary of acronyms at the end of the section

Scottish Water do not collect sanitary or microbiological data for these discharges. Only Voe septic tank and its associated emergency overflow discharge directly to Olna Firth. These are shown mapped in Figure 4.1. Brae septic tank and associated emergency overflow discharge to the northern end of Busta Voe, over 3.5 km from the western production area boundary and are considered unlikely to significantly impact water quality within Olna Firth.

Although Voe septic tank has a relatively large design PE of 1076, Scottish Water have identified that the PE for the properties connected to the tank is currently only 276.

SEPA provided information on 60 consented discharges for the request area (5km radius of Olna Firth. A subset of 19 were located within the mapping area used in Figure 4.1. Table 4.2 presents SEPA discharge consents for public and private sewage assets within the mapped area.

Table 4.2 Sewage discharge consents identified by SEPA

No	Consent Ref.	NGR	Name	Discharge Type	Level of Treatment	PE or (DWF)*	Discharge to
1	CAR/R/1037426	HU 3679 6498	Foulawick, Brae,	ST	Primary	5	Olna Firth
2	CAR/R/1043378	HU 3792 6530	Olna, Brae, Shetland	ST	Primary	7	Mill Burn
3	CAR/R/1037801	HU 3801 6529	Olna Cottage, Brae,	ST	Primary	5	Soakaway
4	CAR/R/1076576	HU 3870 6530	Parkgate, Brae,	ST	Primary	7	Soakaway
5	CAR/R/1042453	HU 4080 6494	Braeside, Voe,	ST	Primary	5	Soakaway
6	CAR/R/1039081	HU 4082 6464	Old Schoolhouse, Voe	ST	Primary	5	Land
7	CAR/R/1018655	HU 4091 6463	Fograbrek, Voe,	ST	Primary	6	Land
8	CAR/L/1002247	HU 4030 6360	Bakka Voe, to Olna Firth Outfall	WWTW	Primary	80	Olna Firth
9	CAR/R/1068748	HU 4036 6264	Burgins, Yoe	ST	Primary	5	Soakaway
10	CAR/R/1039960	HU 4028 6268	Olnagarth, Voe, Shetland	ST	Primary	5	Burn of Kirkhouse
11	CAR/R/1068826	HU 4004 6233	Flett, Voe, Shetland	ST	Primary	5	Soakaway
12	CAR/R/1031700	HU 3984 6219	Rocklea, Setter, Voe, Shetland	ST	Primary	5	Soakaway
13	CAR/R/1041406	HU 3977 6208	Setter, Voe, Shetland	ST	Primary	6	Soakaway
14	CAR/R/1025589	HU 3701 6362	East House, Grobsness, Voe, Shetland	ST	Primary	6	Soakaway

Of the 19 consents, 14 related to sewage discharges and the remainder to discharges from marine cage fish farms (MCFF). One of the MCFFs appears to have been converted to a mussel farm as the consent location corresponds with the Clubb of Mulla site. One of the consents (No. 8, Table 4.2) related to the Voe Septic tank. The given location and dry weather flow agree with data supplied by Scottish Water. SEPA did not provide data, however, on the emergency overflow associated with this WWTW.

Of the remaining 13 private discharges, only Foulawick (1), with a PE of 5, discharges directly to the production area. Two discharges (2 and 10) flow into freshwater bodies which in turn feed into Olna Firth and those have a PE of 7 and 5 respectively.

The remaining consented septic tanks all discharge to land. Some of these lie close to watercourses or the shore of the firth and, in periods of high rainfall or flooding, could result in effluent entering into the waters of the production area.

Observations relating to sewerage infrastructure and discharges made during the shoreline survey are listed in Table 4.3. Observations were mainly clustered around the town of Voe. Although some pipes were observed in other locations along the shoreline, only those clearly associated with discharges of human sewage are presented here.

Table 4.3 Discharges and septic tanks observed during shoreline surveys

No.	Date	NGR	Description
1	03/04/2013	HU 40134 63244	Plastic septic tank for new house built above the shore.
2	03/04/2013	HU 40143 63257	Soakaway, brown material present on the grass. Three closed inspection pipes above soakaway.
3	03/04/2013	HU 40204 63140	Concrete septic tank in field next to the agricultural shed, most likely associated with the house above the road.
4	03/04/2013	HU 40202 63145	Drain coming down from the agricultural shed. Pipe at the top of the drain discharging small water flow and another pipe joins into the drain further down, possibly from the septic tank no water discharging from this pipe.
5	03/04/2013	HU 40253 62949	Concrete septic tank next to a house above the shore.
6	03/04/2013	HU 40435 63017	Concrete structure and pipe leading into the sea just above the shore, may be from the house above the shore, possibly an old septic tank does not look to be in use.
7	03/04/2013	HU 40469 63052	Possible septic tank for the house above the shore.
8	03/04/2013	HU 40872 63254	Voe pumping station (Voe SPS).
9	03/04/2013	HU 40731 63404	An old pipe with no water discharging and a new grey pipe with a small water discharge.
10	03/04/2013	HU 40708 63421	Old concrete septic tank next to house - doesn't look to be in use.
11	03/04/2013	HU 40338 63692	Voe community septic tank, slight smell present.
12	03/04/2013	HU 40352 63790	Joining of three large pipes at the top of the hill into one watercourse.
13	04/04/2013	HU 36226 64817	Two pipes coming out of the ground near a building but no discharge.
14	04/04/2013	HU 36778 64968	Septic tank in the garden next to the house, black pipe discharging to the shore, may be the over flow pipe. Brown discharge.
15	04/04/2013	HU 36784 64990	Second black pipe coming down from the same house, no discharge from this pipe.
16	04/04/2013	HU 37246 65151	Old concrete septic tank down from a house above the shore doesn't look to be in use..
17	04/04/2013	HU 37933 65243	Large watercourse, pipe discharging to the sea below the houses. Large flow of water.
18	04/04/2013	HU 38035 65275	Concrete septic tank in use by the house above the shore.

The majority of observations related to pipes and flows observed around the town of Voe although several observations were located along the north shore of the Voe.

Two discharges were observed with indications of faulty septic tank systems. Observation 2 mentions brown material, assumed to be faecal matter, on the surface of the soakaway. This location plotted <10 m from MHWS. Observation 14, which relates to a septic tank detailed in Table 4.2 (No. 1), states a brown discharge observed from a pipe (see Figure 13 of the shoreline survey report). This is assumed again to be faecal matter.

A sea water sample (OF-SW03) taken next to Voe septic tank (observations 14 & 15) returned a moderately high value of 140 *E. coli* cfu/100 ml. The Inner site is within 1 km of the sample location.

It was not clear in some cases whether an observed flow related to an outfall, an overflow or a flow to a watercourse. If there was any doubt, the observation was included above. Therefore, not all of the observations in Table 4.3 may relate to sewage discharges.

Summary

Sewage inputs are primarily concentrated around the head of the firth. These will mainly impact the the Inner mussel site but area also likely to affect the Club of Mulla and Outer sites. Additional sewage inputs are located on the northwestern shore of the firth. These may affecte the microbiological quality at the Pinchdyke, Foula Wick and Parkgate sites.

Glossary of Sewage-Related Acronyms

WWTW/STW	Wastewater (Sewage) treatment works	EO	Emergency overflow
CSO	Combined sewer overflow	SPS/PS	Sewage pumping station
FE	Final effluent	ST	Septic tank
PE	Population equivalent	DWF	Dry weather flow

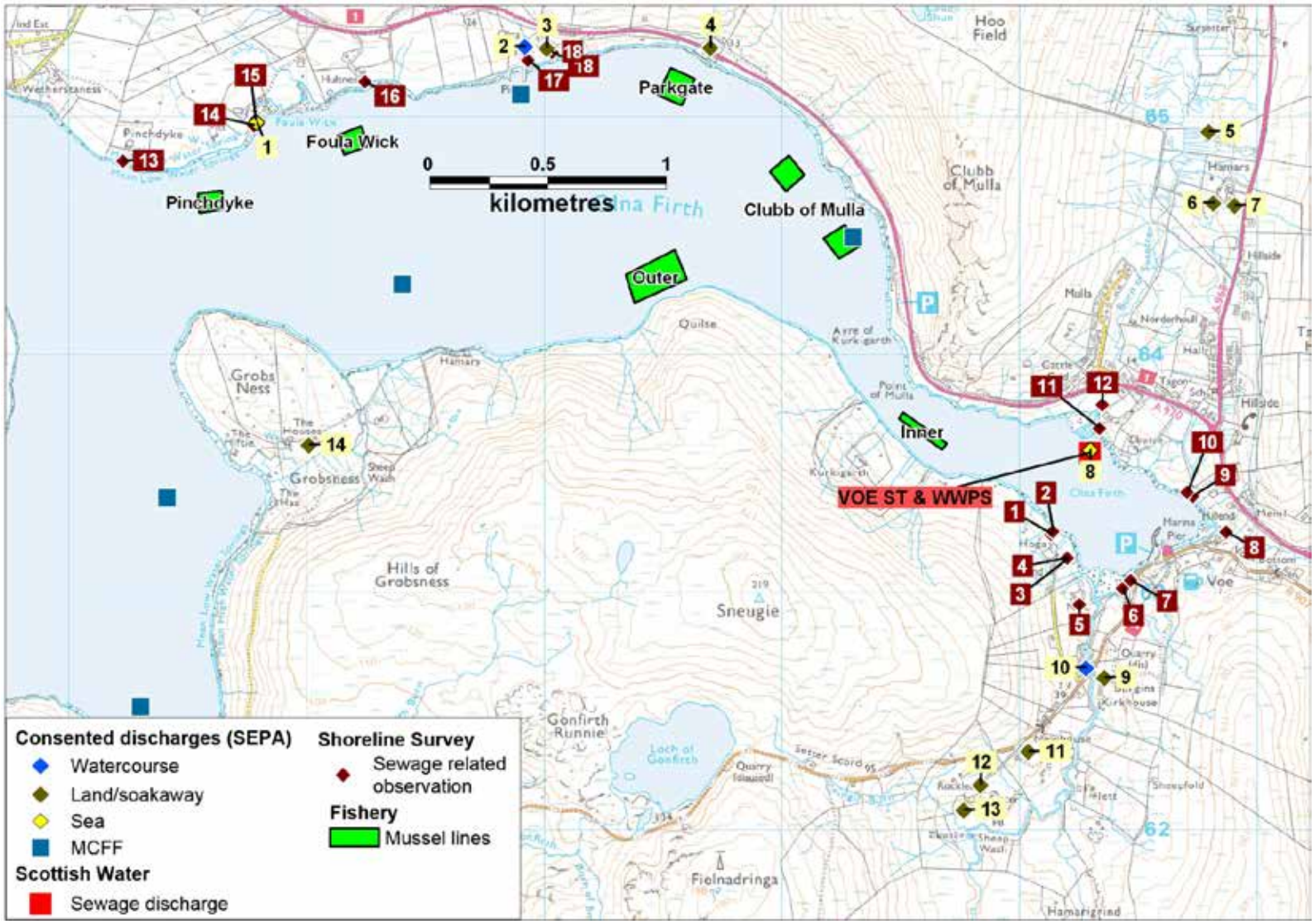

Figure 4.1 Map of discharges for Olna Firth

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. The land surrounding Olna Firth lies within the Delting Parish, which occupies part of the mainland, the islands of Linga and Muckle Roe and has a land area of approximately 150 km^2 (shown in the inset of Figure 5.1). Agricultural census data to parish level was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for that parish. Reported livestock populations for the parish in 2012 are listed in Table 5.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data. Any entries which relate to less than five holdings, or where two or fewer holdings account for 85% or more of the information, are replaced with an asterisk.

Table 5.1 Livestock numbers in the Delting parish 2012

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

Due to the large land area of the parish, it is not possible to assess the spatial distribution of the livestock with regard to the fishery within Olna Firth. However, the figures do give an idea of the total numbers of livestock over the broader area. Sheep are the predominant type of livestock kept in the area, with a rough average of 390 per holding. Cattle are also present, with an average of 31 animals per holding. Poultry are also kept in relatively small numbers. The designated shellfish growing water report for this area identified that diffuse pollution is primarily from agricultural source run-off.

The only significant source of spatially relevant information on agricultural activity population along the shores of Olna Firth was the shoreline survey (see Appendix 2), which only relates to the time of the site visit on the 3rd and 4th April 2013. Observations made during the survey are dependent upon the viewpoint of the observer some animals may have been obscured by the terrain. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 5.1.

The shoreline survey identified that the land surrounding the survey area was largely used for rough grazing with some improved pasture present around crofts lining the shore of the firth. A total of 298 sheep were observed during the shoreline survey, the majority of which (180) were seen along the southern shore. Most animals had access to the shoreline, except along the far southwest of the firth.

An agricultural shed northwest of the Pinchdyke site had a drain discharging to sea, however this drain also appeared to receive effluent from an adjacent septic tank. On the northern shoreline 117 were observed, with no access to the shoreline. Although no cattle were observed, evidence of these was recorded at the far southwestern shoreline of Olna Firth (hoof prints) and Wethersta on the northern shoreline (hoof prints and faecal matter). These animals would have access to the shore. There was also a small agricultural building close to Wethersta, thought to hold animals although not in use at the time of the shoreline survey. A feeding area for sheep with troughs and animals grazing nearby was also present on the northern coastline.

The shoreline survey observations imply that all of the mussel sites may be expected to receive faecal contamination from farm animals.

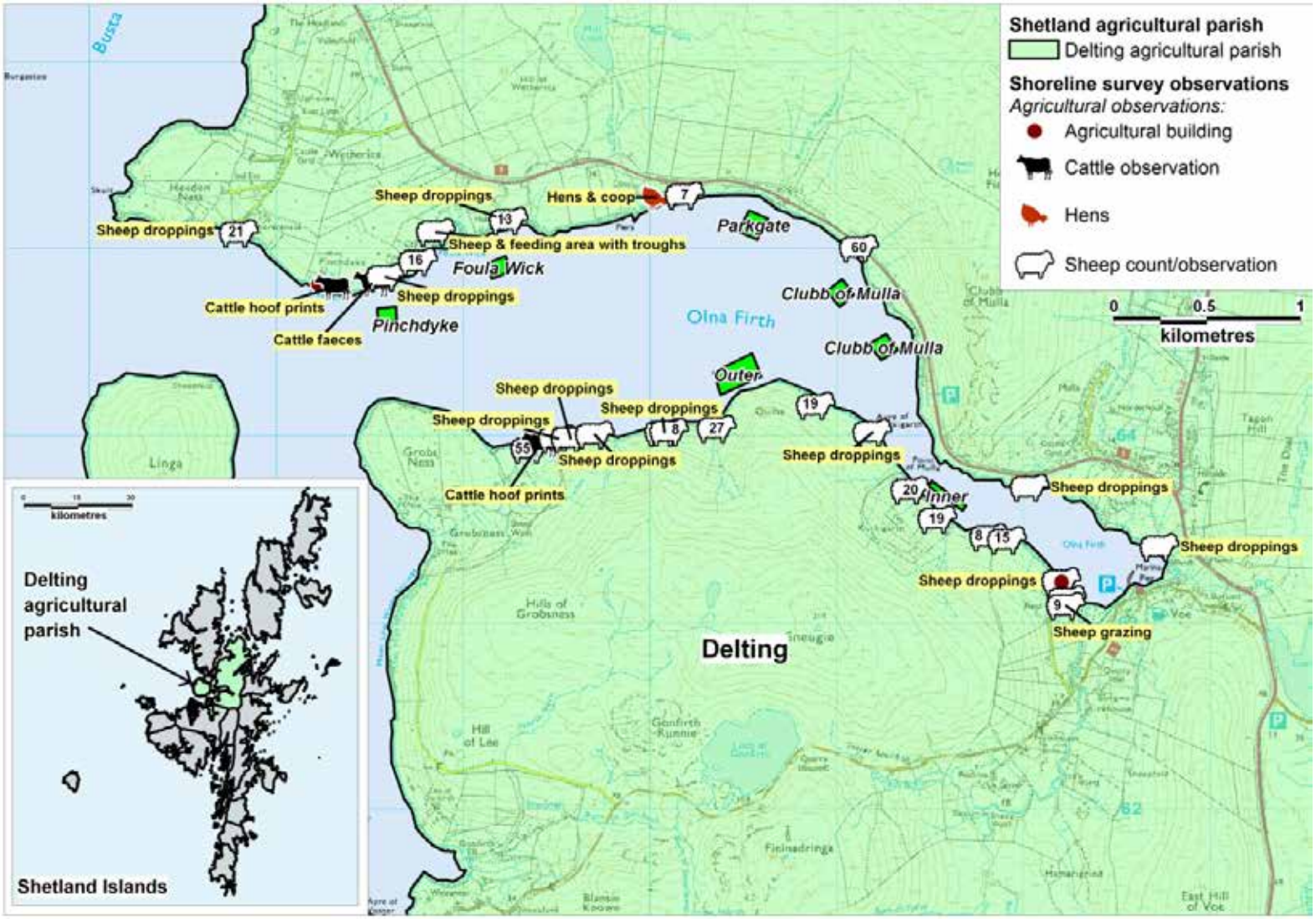

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Figure 5.1 Livestock observations at Olna Firth

6. Wildlife

Pinnipeds

Two species of seal are commonly found in Olna Firth; the grey seal (*Halichoerus grypus*) and the common/harbour seal (*Phoca vitulina vitulina*).

Declines of up to 50% have now been documented in harbour seal populations around Shetland (Special Committee on Seals, 2011). In an aerial survey conducted in 2009, 3003 harbour seals were observed in Shetland, compared to 4883 seals seen in 2001 (Special Committee on Seals, 2011). Comparatively grey seal populations are shown to be booming, with an estimated 3300 grey seal pups alone born in 2010 (Shetland and mainland Scotland) taken from aerial surveys (SCOS, 2011). Grey seal colonies are mostly found along uninhabited, rocky shorelines but are shown to have very wide foraging ranges.

During the shoreline survey, six seal sightings were made, with five of these made on the southern shoreline. Of greatest interest were the seals seen close to the mussel sites at Foula Wick and Outer Olna Firth. On the northern shore (observation 28) a dead seal carcass was also observed on the shoreline. It is unclear whether the seals observed during the survey were several individuals, or the same individual seal seen multiple times. Due to their inquisitive nature it is likely that seals would have followed the surveyors. Seals are highly transient and it is likely that this seal/ these seals were foraging in Olna Firth.

Cetaceans

There are anecdotal reports of bottle-nose dolphins spotted from Olna Firth (Shetland Sea Mammal Group, 2004). Olna Firth has a maximum depth of 42 m, so it is possible that small cetaceans such as dolphins and harbour porpoise swim in from the west coast of Shetland into Olna Firth from time to time. No cetaceans were seen at the time of the shoreline survey.

Birds

Seabird 2000 census data (Mitchell, et al., 2004) was queried for the area within a 5 km radius of the Olna Firth production area and is summarised in Table 6.1 below. This census undertaken between 1998 and 2002 covered the 25 species of seabird that breed regularly in Britain and Ireland.

Table 6.1 Seabird counts within 5 km of the site.

Common name	Species name	Count*	Method
Common gull	*Larus canus*	90	Occupied nests and individuals on land
Black headed gull	*Larus ridibundus*	50	Occupied territory
European Herring gull	*Larus argentatus*	8	Individuals on land
Great black-backed gull	*Larus marinus*	44	Occupied territory
Great Skua	*Stercorarius skua*	4	Occupied territory
Northern fulmar	*Fulmarus glacialis*	106	Occupied sites

* Counts refer to pairs

There are a number of seabird species that can be found in relatively high numbers around Olna Firth. These include breeding colonies, which are likely to experience seasonal variations in *E. coli* levels, peaking during the summer breeding season once chicks have hatched.

In the Marine Spatial Plan for Shetland (2011), an area southeast of Olna Firth is recognised as being important for ducks and divers. And just outside of Olna Firth lies an important area for eider duck moulting between the months of August and September (NAFC Marine Centre, 2012). Birds that are commonly seen around Olna Firth include: gannet, guillemot, kittiwake, fulmar and puffin can be seen along the coastline - while migrant birds such as pied wagtails, waxwings, redwings and various geese alight here. (Shetland Amenity Trust, 2007).

During the shoreline survey the following birds listed in Table 6.2 were observed.

Table 6.2 Seabirds observed during the shoreline survey.

Common name	Species	Count
Gulls	Unspecified	35
Oystercatcher	*Haematopus ostralegus*	29
Plover	*Pluvialis apricaria*	20
Geese	Unspecified	4
Cormorant	*Phalacrocorax carbo*	10
Common Eider duck	*Somateria mollissima*	32
Black-backed gull	*Larus sp.*	5

Birds were seen along all sides of the Olna Firth shoreline. The most numerous was of the oystercatcher, with 15 separate counts noted, though never more than three seen at any one time. The largest flock of birds were Eider Ducks, with 30 seen in one instance and gulls (unspecified species) with 18 seen at one location.

Shetland is estimated to have between 1000 and 2000 breeding pairs of Eider Ducks (*Somateria mollissima*), with adults known to mainly feeding on mussels (*Mytilus* sp.). Eiders are known to be sociable and often aggregate in large groups, sometimes up to hundreds. The breeding season is in May, when female ducks come in from foraging at sea to lay and incubate their egg. Chicks are born in June and after this time males leave the breeding colony and form flocks of moulting and

sub-adult ducks (Okill, 2004). It is unclear whether the flock of 30 ducks seen during the survey represented a breeding colony.

Bird droppings were observed on the mussel floats, which suggests a direct source of faecal loading to the mussel lines. Furthermore, there was evidence of birds feeding with urchin tests and mussel shells found in several areas along the shoreline at Olna Firth (Waypoints 5, 6, 15, 17 and 29). These areas suggest birds are using the surrounding areas to rest and feed, which may also suggest a concentration of faecal contamination.

Otters

Anecdotal accounts exist of the Eurasian otter (*Lutra lutra*) around Olna Firth and surrounding freshwater streams and burns. Otters are also said to use the soft peat banks to rest, shelter and breed on (Shetland Amenity Trust, 2007). No otters were seen during the shoreline survey, though this is unsurprising given that they tend to be shy animals.

Rabbits

There were six different sightings of wild rabbits (*Oryctolagus cuniculus*) made during the survey. Rabbits are recognised to be vectors for *E. coli* transmission between farm animals such as cows, though it is not clear whether their rabbit faeces pose as a contamination risk when not near to an initial source (Scaife, et al., 2006). However it has been identified that when rabbits are not suffering from pathogenic *E. coli*, their faeces contain low or undetectable levels of this organism. (Cox *et al*., 2005).

Overall

Species potentially impacting on Olna Firth include seabirds, waders in particular Eider ducks, seals and otters, with that from birds being predominant. The summary map in Figure 6.1 shows that the impact from birds is widespread around the area.

Figure 6.1 Map of wildlife around Olna Firth

7. Land Cover

The Land Cover 2007 data was only available for the land west of the Parkgate and Outer fisheries at the time of writing this report so this has been used in conjunction with the LCM2000 data to give complete coverage of the area. The Land Cover 2000 and 2007 data for the area is shown in Figure 7.1.

Rough grassland, improved grassland, dwarf shrub heath and bog are the predominant land cover types on the shorelines surrounding the Olna Firth shellfish farms. The northern shoreline of the firth is dominated by rough grassland on the west and dwarf shrub heath on the east. The southern shoreline is lined by patches of rough grassland, dwarf shrub heath and acid grassland. Improved grassland in present in small patches on the coastline closest to the Pinchdyke, Foula Wick, Parkgate and Inner sites and also dominates the shoreline surrounding the head of the firth. The small settlements of Voe and Hillside are represented as built up areas and gardens.

Faecal indicator organism export coefficients for faecal coliform bacteria have been found to be approximately 1.2 – 2.8×10^9 cfu/km^2/hr for urban catchment areas, approximately 8.3×10^8 cfu/km^2/hr for areas of improved grassland and approximately 2.5×10^8 cfu/km^2/hr for rough grazing (Kay, et al., 2008a). The contributions from all land cover types would be expected to increase significantly after rainfall events, however this effect would be particularly marked from improved grassland areas (roughly 1000-fold) (Kay, et al., 2008a).

The highest potential contribution of contaminated runoff to the Olna Firth shellfish farms is from the areas of improved grassland on the shorelines closest to the Pinchdyke, Foula Wick, Parkgate and Inner fisheries. Areas utilised for rough grazing on all shorelines would be expected to contribute significantly to faecal contaminant loading carried in watercourses and overland flow draining the area during rainfall.

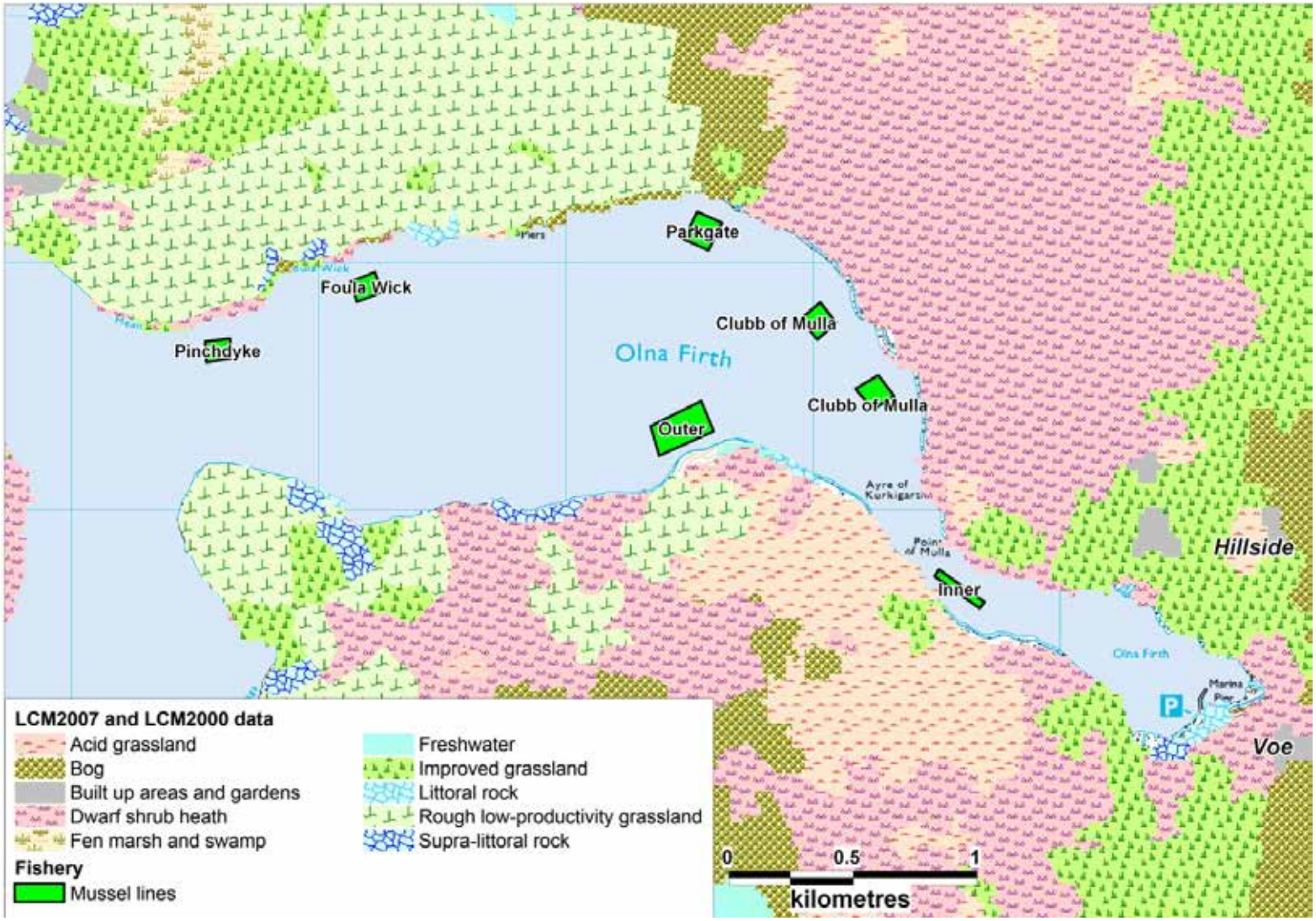

Figure 7.1 LCM2000 and LCM2007 land cover data for Olna Firth

8. Watercourses

There are no public river gauging stations on watercourses discharging to Olna Firth. The Shellfish Growing Waters Report for Busta Voe, Linga Voe and Olna Firth states that there is a moderate to high freshwater input to the area, with salinity reduction stated at 0.3 ppt. SEPA has stated freshwater inputs to be of good quality, but water quality has not been monitored. Overall SEPA believe diffuse contamination from agricultural runoff and boating activities pose the greatest impact to Olna Firth.

The following 16 watercourses listed in Table 8.1 were measured and sampled during the shoreline survey. These represent the largest freshwater inputs into the Olna Firth production area. The measurements of four other watercourses observed during the shoreline survey are also listed in Table 8.1, but were not sampled at the time of the survey. The prevailing weather conditions were mainly dry.

Table 8.1 Watercourse loadings for Olna Firth

No.	Description	NGR	Width (m)	Depth (m)	Flow (m^3/day)	*E. coli* (cfu/100ml)	Loading (*E. coli* per day)
1	Small burn	HU 3736 6392	0.40	0.10	320	3	$9.5x10^6$
2	Hamars Burn	HU 3783 6394	0.30	0.10	78.0	<1	$<7.8x10^5$*
3	Burn of Hoodale	HU 3833 6402	0.30	0.10	52.0	<1	$<5.2x10^5$*
4	Small burn	HU 3911 6405	0.20	0.10	18.0	Not sampled	Not Determined
5	Small burn	HU 3930 6382	0.40	0.10	85.0	3	$2.6x10^6$
6	Small burn	HU 3933 6379	0.30	0.10	40.0	<1	$<4.0x10^5$*
7	Burn	HU 3961 6348	0.30	0.10	40.0	1	$4.0x10^5$
8	Burn of Kirkhouse	HU 4032 6292	1.00	0.20	1200	22	$2.6x10^8$
9	Water drainage	HU 4065 6317	0.30	0.10	26.0	<1	$<2.6x10^5$*
10	Manse Burn	HU 4086 6325	0.40	0.40	1600	26	$4.2x10^6$
11	Small stream	HU 4071 6343	0.40	0.10	6.00	Not sampled	Not determined
12	Burn of Susetter	HU 4035 6379	0.40	0.40	1500	7	$1.0x10^8$
13	Burn of Foulawick	HU 3696 6515	1.00	0.20	1100	170	$1.9x10^9$
14	Small burn	HU 3739 6518	0.20	0.10	110	10	$1.1x10^7$
15	Mill Burn	HU 3793 6524	0.60	0.10	480	380	$1.8x10^9$
16	Burn	HU 3864 6529	0.20	0.00	150	2	$3.0x10^6$
17	Burn of Mangaster	HU 3869 6526	0.20	0.00	260	30	$7.7x10^7$
18	Drain under road	HU 3919 6490	0.10	0.10	5.00	<1	$<5.2x10^4$*
19	Drain under road	HU 3926 6479	0.30	0.20	27.0	Not sampled	Not determined
20	Small drain	HU 3946 6450	0.20	0.10	49.0	Not sampled	Not determined

*A nominal assumed value of 1 *E. coli CFU*/100 ml was used to calculate a 'less than' potential loading. NGRs rounded to 10 m, full NGRs found in Appendix 1.

A large number of watercourses were observed around the entire geographical extent of Olna Firth. In addition a further 52 areas of land drainage were also noted during the survey, with the majority of these areas on the south and southeastern shorelines (Figure 8.1).

Overall the majority of watercourse loadings were low, with 12 out of the 16 sampled watercourses carrying less than 10^8 *E. coli* per day. Loadings were generally lower on the southern shoreline compared to the northern shoreline.

Loadings were highest at the Burn of Foulawick ($1.9x10^9$ *E. coli* per day) located on the northwestern shoreline and Mill Burn ($1.8x10^9$ *E. coli* per day) approximately 1 km to the east of Burn of Foulawick. These loadings are still considered moderate compared to those determined for watercourses in other areas.

Loadings from watercourses 8 and 12: Burn of Kirkhouse and Burn of Susetter were moderate at $2.6x10^8$ and $1.0x10^8$ *E. coli* per day respectively. These watercourses are located at the head of Olna Firth.

Freshwater contamination input to Parkgate and the two Clubb of Mulla sites are likely to be relatively low, due to few areas of land drainage and low levels of contamination calculated from the sampled watercourses.

The shoreline survey took place after a period of dry weather and higher loadings would expected after moderate to heavy rainfall.

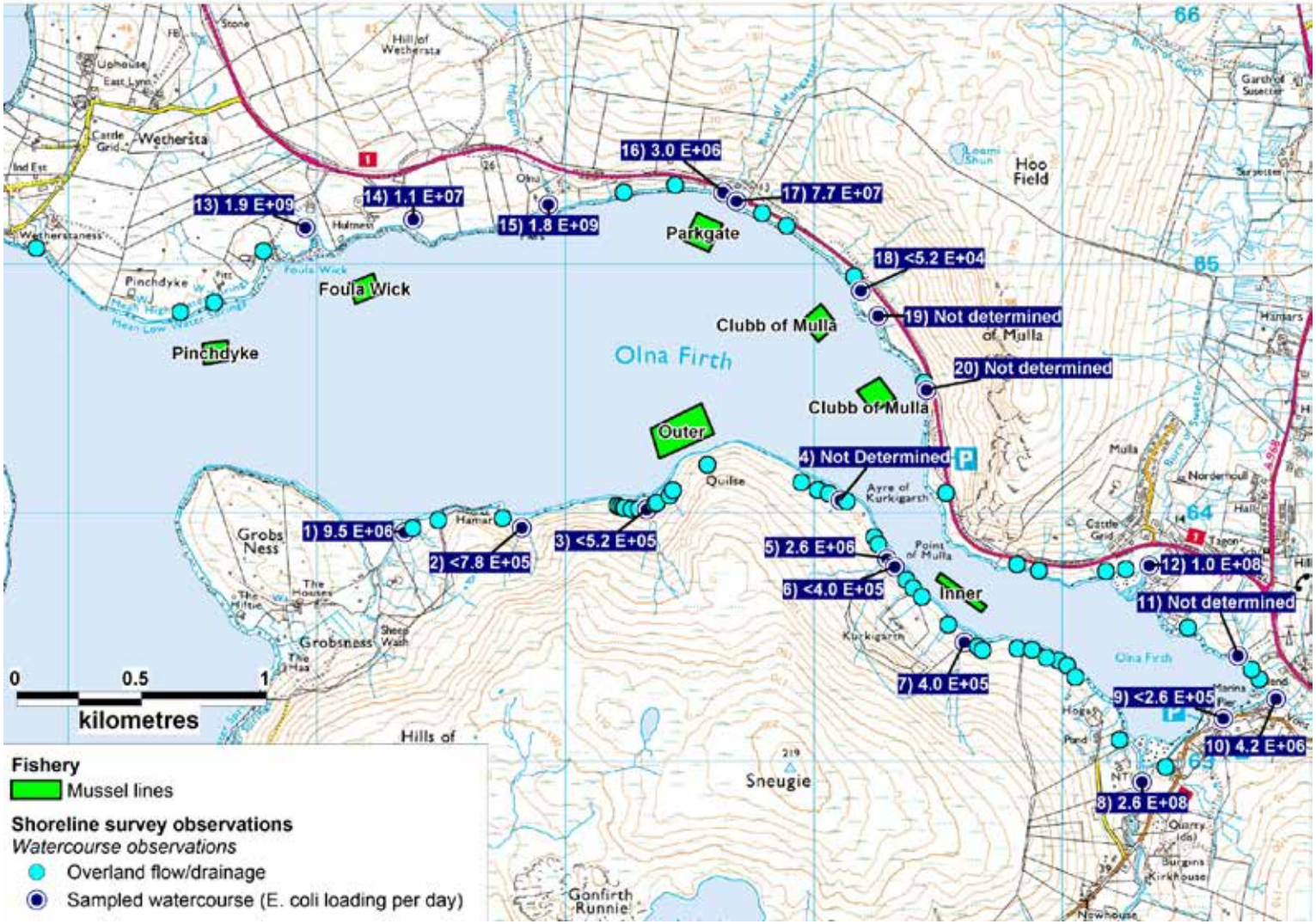

Figure 8.1 Map of river/stream loadings at Olna Firth

Where the bacterial loadings is labelled on the map, the scientific notation is written in digital format, as this is the only format recognised by the mapping software. So where normal scientific notation for 1000 is $1x10^3$, in digital format it is written as 1E+03.

9. Meteorological Data

The nearest weather station for which rainfall data was available is located at Lerwick, situated approximately 24 km to the south east of the production area. Rainfall data was available for January 2007 – December 2012. At the time of writing this report, rainfall data for December 2012 onwards had not yet been obtained. The nearest wind station is also situated in Lerwick. Conditions may differ between this station and the fisheries due to the distances between them. However, this data is still shown as it can be useful in identifying seasonal variation in wind patterns.

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

9.1 Rainfall

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

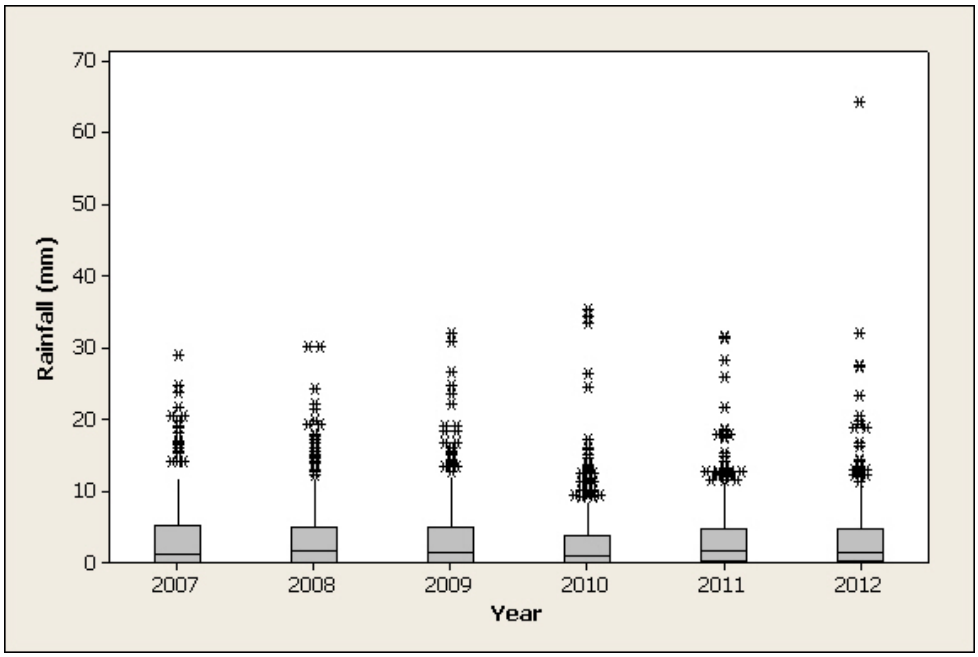

Figure 9.1 Box plot of daily rainfall values by year at Lerwick (2007 – 2012)

Daily rainfall values varied from year to year, with 2010 being the driest year. The wettest year was 2009. High rainfall values of more than 30 mm/d occurred in all years but an extreme rainfall event of nearly 70 mm/d was seen in 2012.

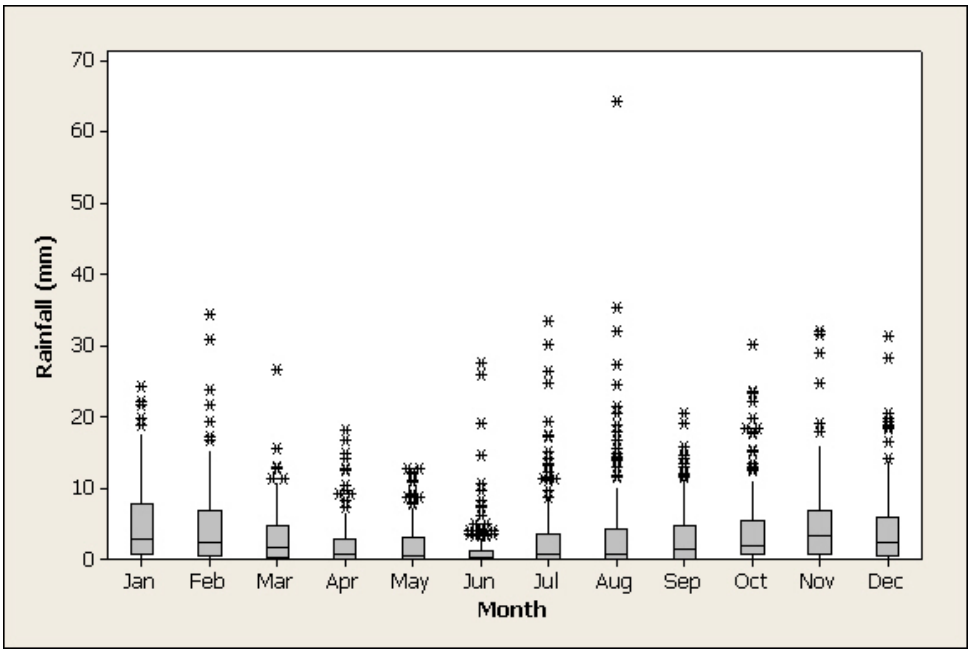

Figure 9.2 Box plot of daily rainfall values by month at Lerwick (2007 – 2012)

Daily rainfall values were higher during the autumn and winter. Rainfall increased from August onward and was highest in January and February. Weather was wettest from October to March. An extreme rainfall event of nearly 70 mm/d 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 therefore expected than run-off due to rainfall will be higher during the autumn and winter months. However, extreme rainfall events leading to episodes of high runoff can occur in most months and when these occur during generally drier periods in summer and early autumn, they are likely to carry higher loadings of faecal material that has accumulated on land when greater numbers of livestock are present.

9.2 Wind

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

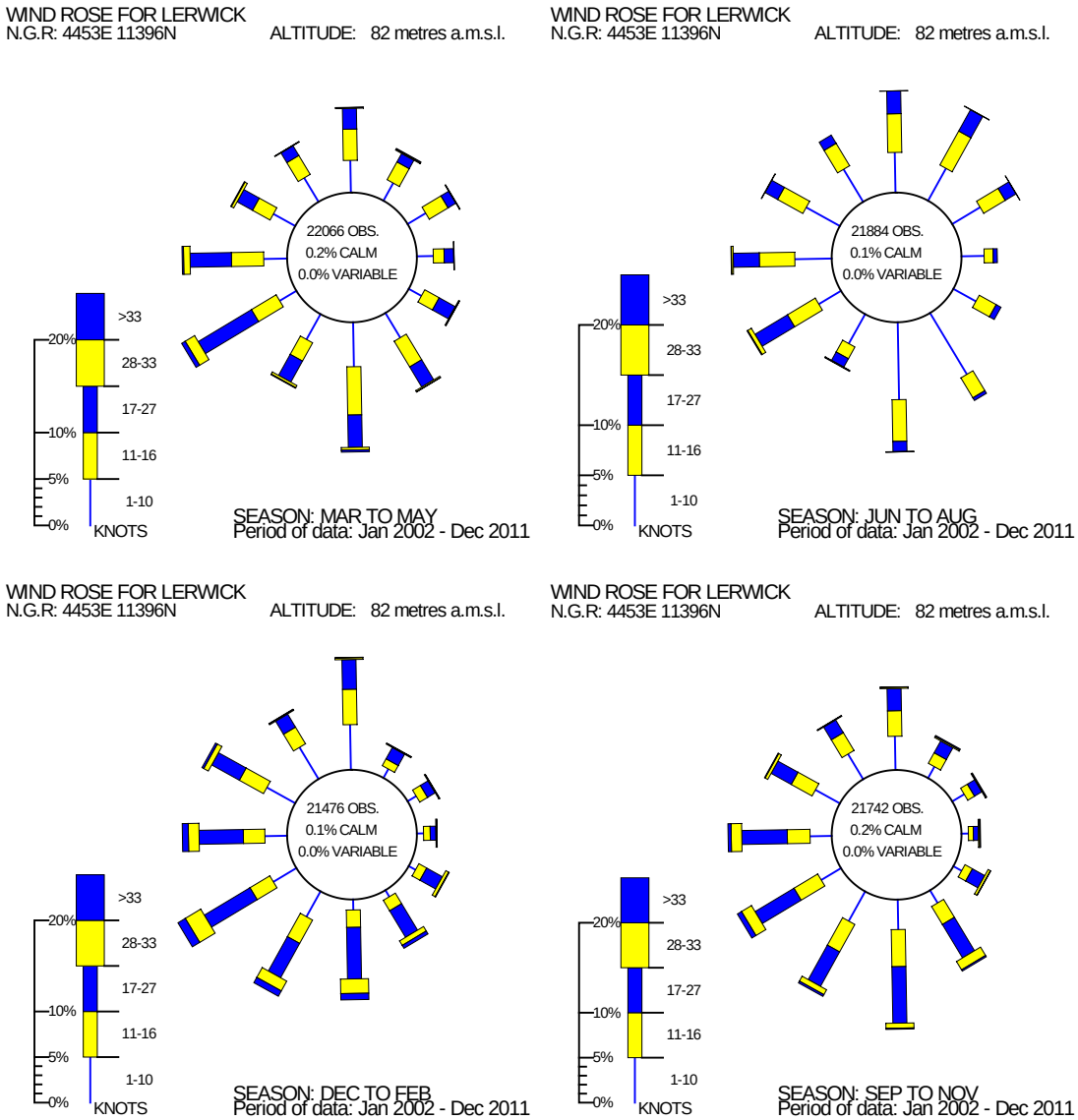

Figure 9.3 Seasonal wind roses for Lerwick

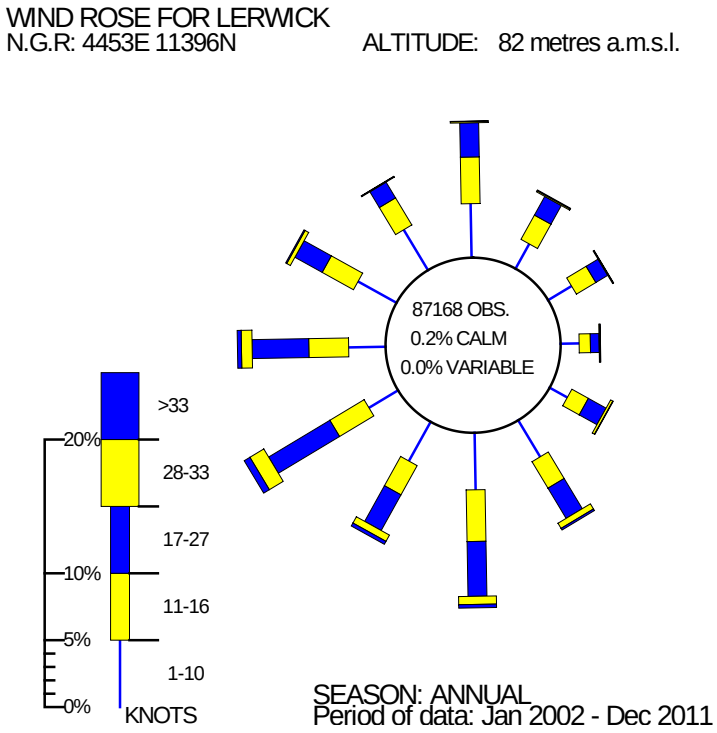

Figure 9.4 Annual wind rose for Lerwick

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

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

10. Classification Information

The area has been classified for Common Mussel production since 1999. The classifications, by month, since April 2006 are shown in Table 10.1.

Historically the area had been a seasonal A/B classification with A classification during the summer months. However it has held year round A classification since 2009

Table 10.1 Olna Firth (Common Mussel) classification history

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
2006				B	A	A	A	A	B	B	B	B
2007	B	B	B	B	A	A	A	A	B	B	B	B
2008	B	B	B	A	A	A	A	A	B	B	B	B
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									

11. Historical *E. coli* Data

11.1 Validation of historical data

Results for all samples assigned against the Olna Firth production area for the period 01/01/2007 to the 07/05/2013 were extracted from the FSAS database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. The data was extracted from the database on 07/05/2013. All *E. coli* results were reported as most probable number (MPN) per 100 g of shellfish flesh and intravalvular fluid.

One sample was reported as rejected and was deleted from the dataset. Sample SSQC 2008_461 was deleted as the stated sampling location plotted 28 km outside of the Olna Firth production area. The first 41 samples reported in the database plotted 2km south of the production area. When the first two digits of the eastings were reversed, the samples plotted within 100 m of the other samples. Therefore it is presumed that these were erroneously recorded and the eastings were adjusted accordingly. All 57 samples were collected and delivered to the laboratory within the permitted 48 hr window. All samples had a box temperature of $<8^{o}$C. Twenty-seven samples had *E. coli* levels of <20 and were reassigned nominal values of 10 *E. coli* MPN/100g.

11.2 Summary of microbiological results

Table 11.1 Summary of historical E. coli sampling and results at Olna Firth.

Sampling Summary	
Production area	Olna Firth
Site	Pinchdyke
Species	Common mussels
SIN	SI-232-438-08
Location	Various
Total no of samples	57
No. 2008	9
No. 2009	9
No. 2010	12
No. 2011	11
No. 2012	12
No. 2013	4
Results Summary	
Minimum	<20
Maximum	790
Median	20
Geometric mean	27
90 percentile	130
95 percentile	460
No. exceeding 230/100g	4 (7%)
No. exceeding 1000/100g	0 (0%)
No. exceeding 4600/100g	0 (0%)
No. exceeding 18000/100g	0 (0%)

Sampling appeared to be lowest in 2008 and 2009 when only nine samples were taken during both years. Only four samples had results >230 *E. coli* MPN/ 100 g, and none were >1000 *E. coli* MPN/ 100 g.

11.3 Overall geographical pattern of results

The sampling locations of historical *E. coli* results have been mapped and are shown in Figure 11.1.

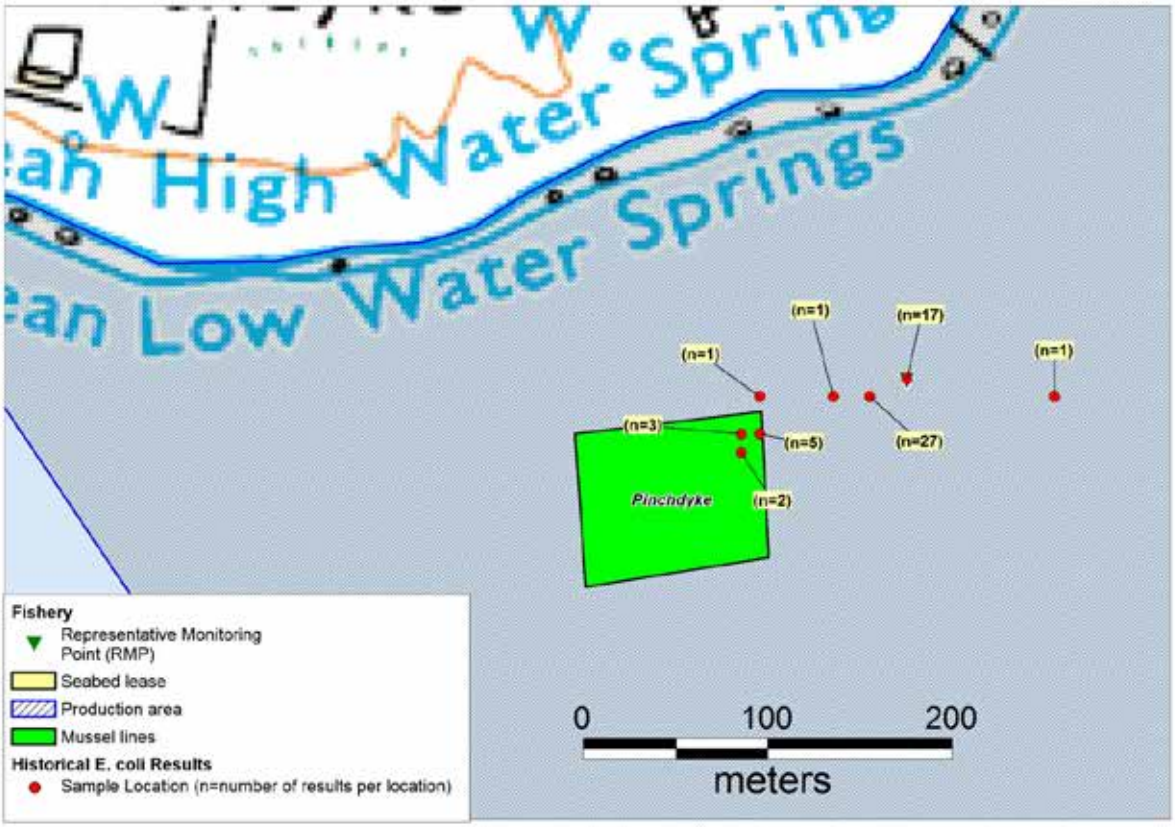

Figure 11.1 Map of reported sampling locations for common mussels at Olna Firth

All sampling locations of common mussels at Olna Firth were recorded within 100 m of the RMP at Pinchdyke. Figure 11.1 illustrates that the majority of samples were taken <50 m away from the RMP. Section 11.6 covers all high results in more detail, and notes that two out of these four results were taken at the RMP.

11.4 Overall temporal pattern of results

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

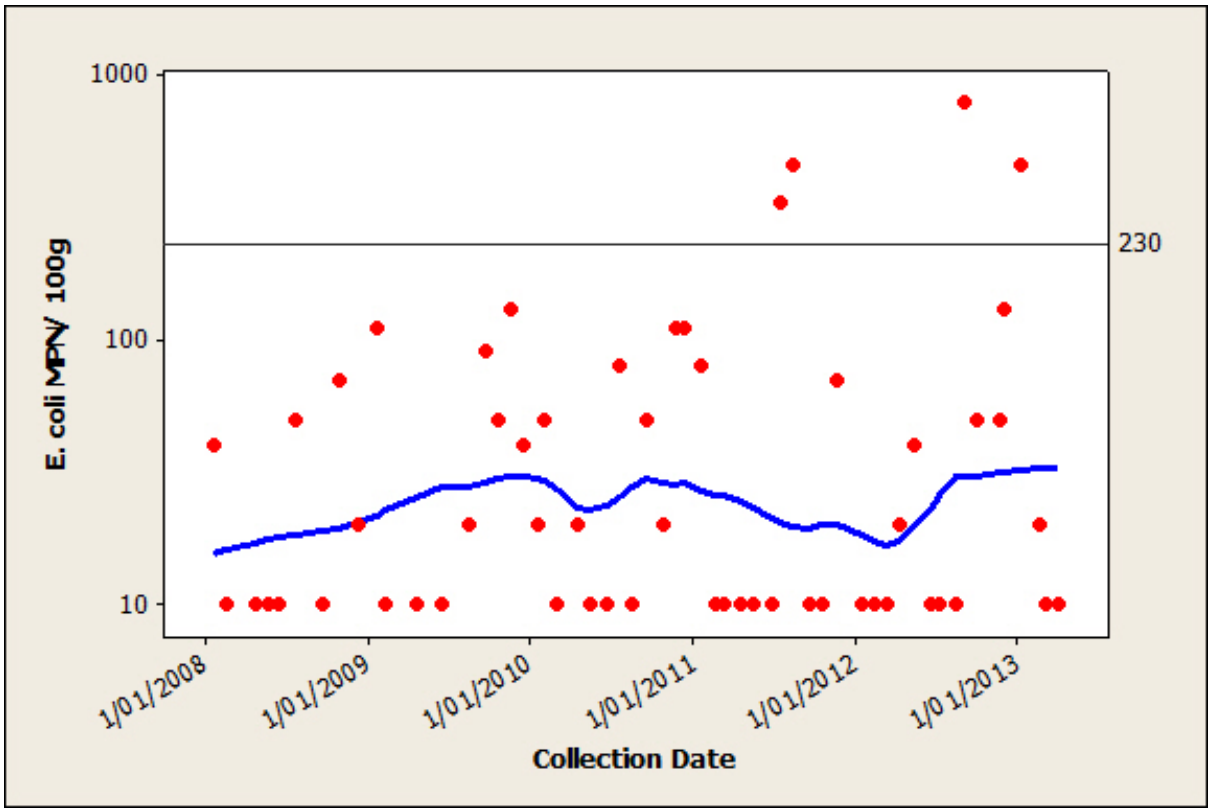

Figure 11.1 Scatterplot of common mussel *E. coli* results by collection date, fitted with a lowess line

Contamination levels appear low throughout the sampling years, with many of the results <20 *E. coli* MPN/ 100 g. The four results >230 *E. coli* MPN/ 100 g all occurred from 2011 onwards.

11.5 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns in human distribution. All of these can affect levels of microbial contamination, causing seasonal patterns in results. Figure 11.3 below displays a scatterplot of common mussel *E. coli* results by month, overlaid with a lowess line to highlight trends.

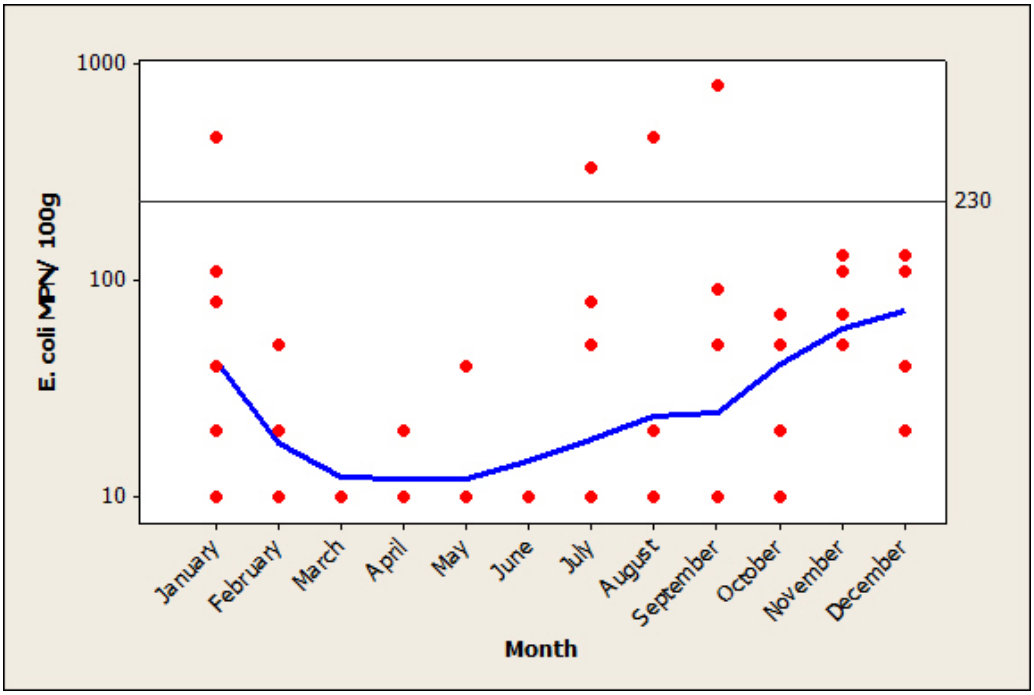

Figure 11.2 Scatterplot of common mussel *E. coli* results by month, fitted with a lowess line

Higher contamination levels (>230 *E. coli* MPN/ 100 g) occurred in January, and between July and September, with the highest in September. For statistical evaluation, seasons were split into spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). Boxplots of common mussel *E. coli* results by season are presented in Figure 11.4.

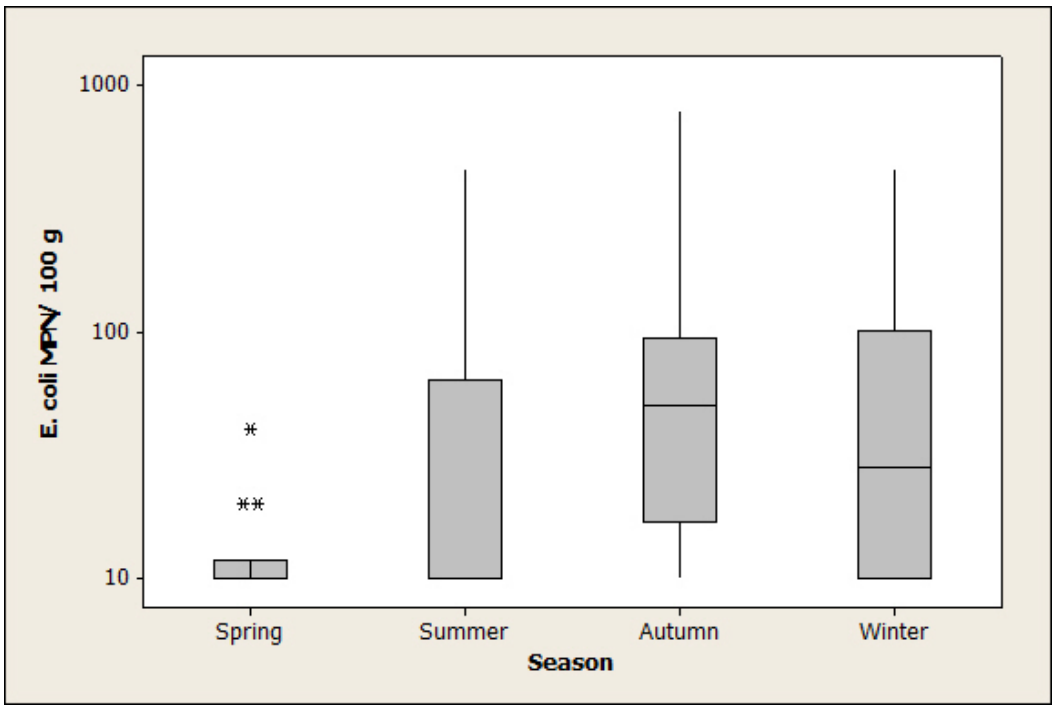

Figure 11.3 Boxplot of common mussel *E. coli* results by season

A significant difference was found between common mussel results by season (one-way ANOVA, p = 0.010, Appendix 4). Results showed that autumn results were statistically higher than those in spring, but no difference was found between results in other seasons.

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 23.8 km south-east of the production area. Rainfall data was purchased from the Meteorological Office for the period of 01/01/07 - 31/12/2012 (total daily rainfall in mm). Data was extracted from this for 53 out of the 57 common mussel results between 01/01/2008 – 31/12/2012. Data was not available for the last four samples recorded at Olna Firth, taken in 2013.

Two-day rainfall

Figure 11.5 below presents a scatterplot of common mussel E. coli results against total rainfall recorded on the two days prior to sampling. Jittering of points was applied at 0.01 and 0.001 on the X and Y axis respectively.

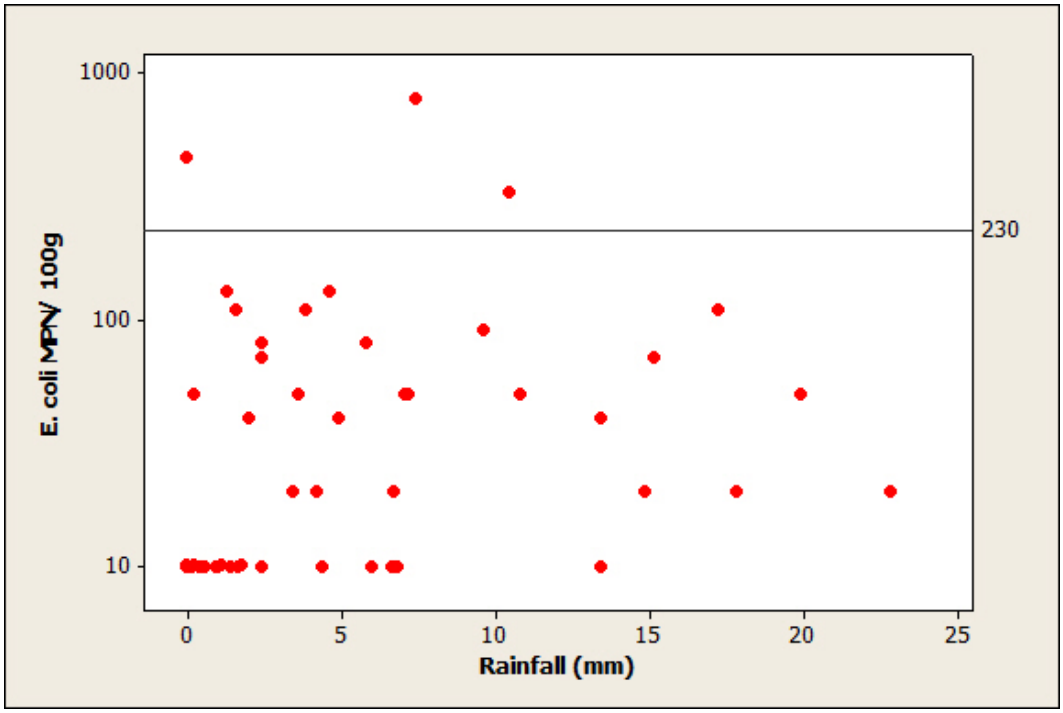

Figure 11.4 Scatterplot of common mussel *E. coli* results against rainfall in the previous two days

A significant correlation was found between the common mussel results and the previous two day rainfall (Spearman's rank correlation r = 0.470, p = <0.001). The majority of samples <20 *E. coli* MPN/ 100 g were taken when rainfall levels were low at <5 mm. However, results exceeding 230 MPN/100 g occurred under dry to moderate rainfall conditions.

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. Figure 11.6 presents a scatterplot of common mussel *E. coli* results against total rainfall recorded for the seven days prior to sampling. Jittering of points was applied at 0.01 and 0.001 on the X and Y axis respectively.

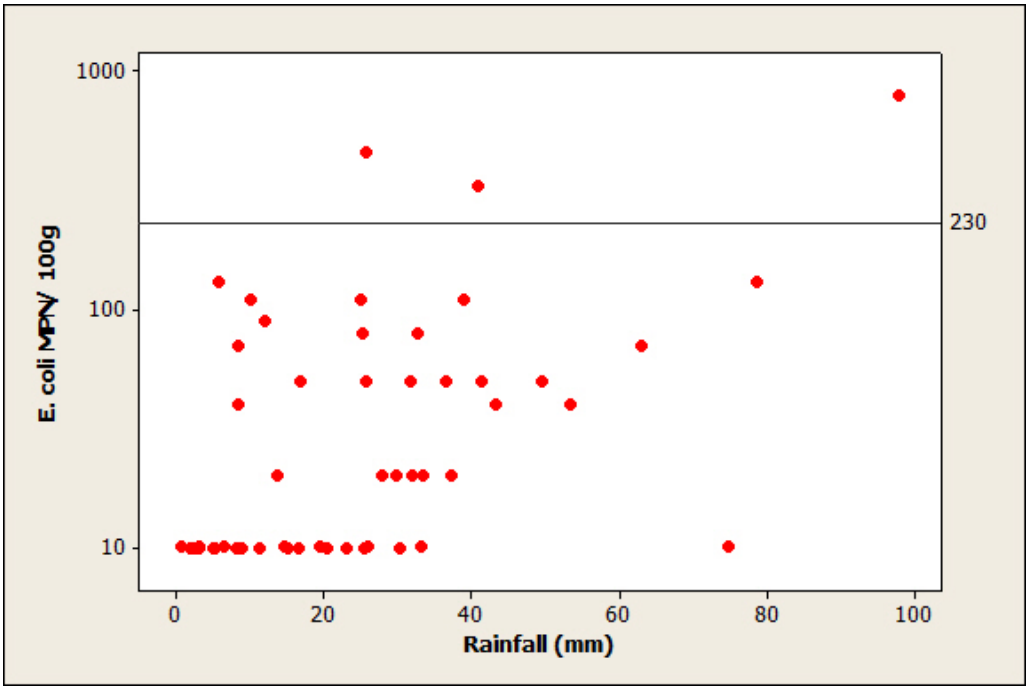

Figure 11.5 Scatterplot of common mussel *E. coli* results against rainfall in the previous seven days

A significant correlation was found between the common mussel results and the previous seven day rainfall (Spearman's rank correlation r = 0.510, p = <0.001). Low *E. coli* results (<20 *E. coli* MPN/ 100 g) mostly occurred during periods of low rainfall (<20 mm).

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 moon about 45^{o}, then decreases to the smallest neap tides at about 225^{o}, before increasing back to spring tides 0^{o}. Figure 11.7 presents a polar plot of common mussel *E. coli* results against the lunar cycle**.** It should be noted local meteorological conditions (e.g. wind strength and direction) can also influence tide height, but is not taken into account in this section.

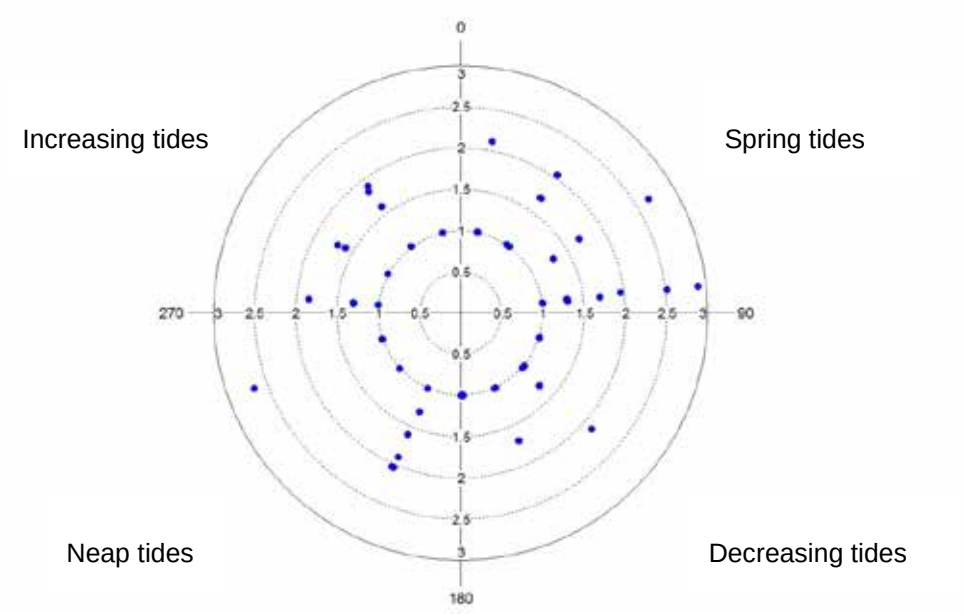

Figure 11.6 Polar plots of common mussel Log_{10} *E. coli* results on the spring/neap tidal cycle

No significant correlation was found between common mussel log_{10} *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r = 0.136, p = 0.368). Both high and low results were found during all states of the tide.

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. Figure 11.8 presents a polar plot of common mussel *E. coli* results against high/low tidal cycle, where high water is at 0^o and low water at 180^o.

High and low water data from Lerwick was extracted from POLTIPS-3 in May 2013. This site was the closest to the production area and it is assumed that tidal flow will be very similar between sites.

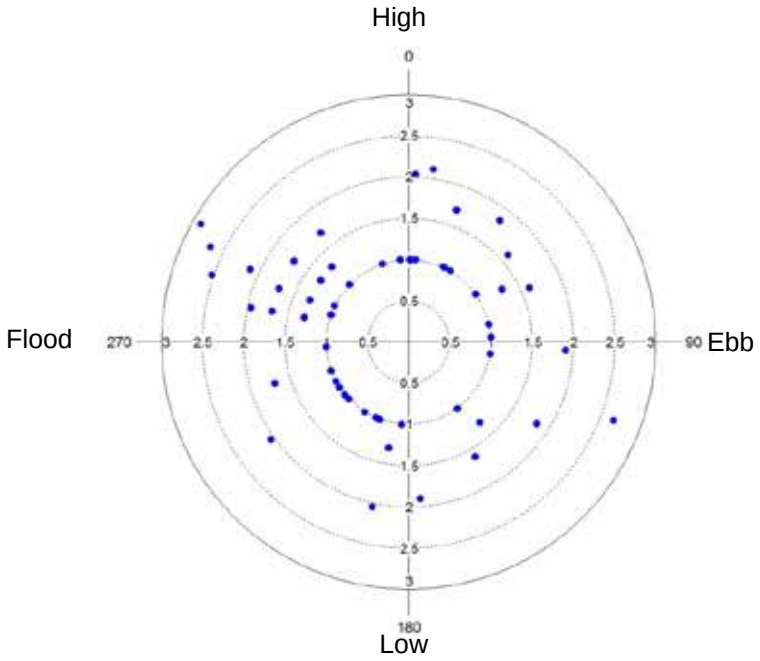

Figure 11.7 Polar plots of Common mussel log_{10} *E. coli* results on the high/low tidal cycle

No significant correlation was found between common mussel log_{10} *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.104, p = 0.559). Despite a large number of high results (>230 *E. coli* MPN/ 100 g) taken during flood tides, high results also occur during high and ebb tidal cycles.

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. Figure 11.9 presents common mussel *E. coli* results against water temperature, with water temperature recorded for 56 out of the 57 samples. Jittering of points was applied at 0.01 and 0.001 on the X and Y axis respectively.

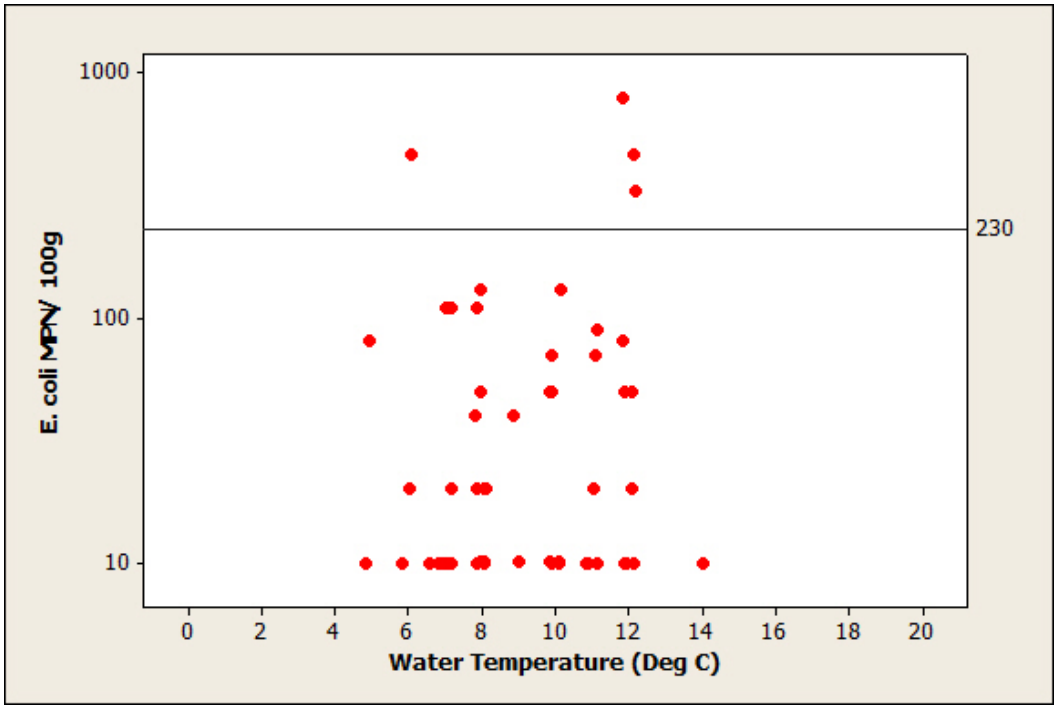

Figure 11.8 Scatterplot of common mussel *E. coli* results against water temperature

No significant correlation was found between common mussel *E. coli* results and water temperature (Spearman's rank correlation r = 0.116, p = 0.396). The majority of results were from samples taken at water temperatures between 7 and 12^{o}C.

11.5.5 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence and potentially freshwater borne contamination at a site. Salinity was recorded for 44 out of the 57 samples, and a scatterplot of common mussel *E. coli* results against salinity is shown in Figure 11.10. Jittering of points was applied at 0.01 and 0.001 on the X and Y axis respectively.

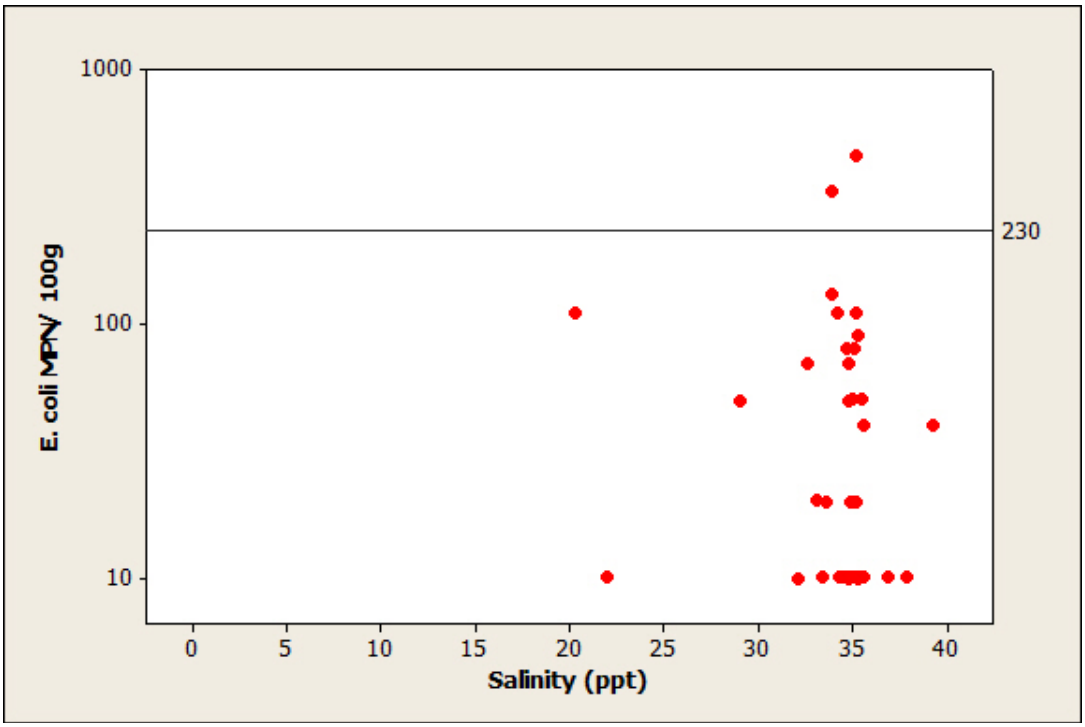

Figure 11.9 Scatterplot of common mussel E. coli results against salinity

No significant correlation was found between common mussel *E. coli* results and salinity (Spearman's rank correlation r = -0.215, p = 0.162). The majority of samples were taken when salinity was close to full strength seawater at 34 - 35 ppt.

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

In the results from Olna Firth Pinchdyke, four common mussel samples had results >230 *E. coli* MPN/100g. These are presented in Table 11.2.

Table 11.2 Historic Olna Firth common mussel 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 (high/low)	Tidal state (spring/ neap)
18/07/2011	330	HU 3672 6471	10.4	40.4	12	33.93	Flood	Spring
15/08/2011	460	HU 3672 6471	0.0	25.2	12	35.08	Flood	Spring
03/09/2012	790	HU 3663 6468	7.4	97.0	12	-	Flood	Spring
07/01/2013	460	HU 3664 6470	-	-	6	-	Ebb	Neap

(-) No data available

No results ≥ 230 *E. coli* MPN/100 g occurred prior to July 2011. Sampling months were January, July, August and September, with the highest result recorded from the September sample. Samples were taken from three different locations; two corresponded to the RMP at HU 3672 6471, one was taken 80 m west at HU3664 6470 and the other result plotted 95 m to the southwest at HU 3663 6468.

Rainfall in the two days prior to sampling ranged from 0 to just over 10 mm, and in the seven days prior to sampling ranged from 25 to 97 mm. For two of the samples, two day rainfall was moderate, but the seven day rainfall was high. Water temperatures were 12 for the warm months (July-September) and 6 for the winter sample. Only two samples had salinities recorded for them, at 33.93 and 35.08 ppt respectively. Three out of the four samples were taken on a flooding spring tide.

11.7 Summary and conclusions

Historical *E. coli* data for Olna Firth indicates that sampling has been taking place regularly across the sampling period 2008-2013. Fewer samples have historically been taken in the months of March, April and June, and the most samples have been taken in January. Seasonal results were found to be statistically lower in the spring compared to the autumn, though this may reflect fewer samples taken in the spring. The location of the samples varies, though they were all within <100 m of the RMP at Pinchdyke (HU 3672 6471).

A statistically significant correlation was found between results and rainfall two days prior to sampling and between rainfall seven days prior to sampling; low rainfall levels correlated with lower contamination levels in results. No statistically significant correlation was found between results and sea water temperature or salinity. No statistically significant correlation was found between results and tidal state of spring/neap or high/low tidal cycles.

12. Designated Waters Data

The Olna Firth production area and fishery is covered by the designated Shellfish Growing Waters (SGW) East of Burki Taing, Muckle Roe (shown in Figure 12.1). Previously named East of Burki Taing, Muckle Roe, on 1st June 2012 the designated waters was extended to include Sound of Houbansetter and Aith Voe and renamed to East of Burki Taing and Aith Voe. The SGW was originally designated in 2002 and under the current shellfish growing waters legislation must be monitored quarterly for faecal coliforms in the shellfish flesh and intervalvular fluid. SEPA is responsible for ensuring that this monitoring is undertaken, and have common mussels were used for this purpose.

There are two designated monitoring points within the SGW. The Busta and Linga Voe monitoring point is located on the eastern coastline of Busta Voe and the Olna Firth monitoring point is located on the northern coastline of Olna Firth. Faecal coliform results were provided for a single occasion at each monitoring point and these results are given in Table 12.1. The relative positions of the SGW boundary, the Olna Firth production area, RMPs and the SGW monitoring points are shown in Figure 12.1. Since 2007, SEPA have based the SGW assessment on FSAS *E. coli* results. The *E. coli* results have been reviewed in Section 11 of this report.

Table 12.1 Shellfish Growing Waters data

Monitoring point	NGR	Date of sample	Faecal coliforms MPN/100 ml
Busta and Linga Voe	HU 35967 66400	19/02/2007	1300
Olna Firth	HU 39455 64210	19/03/2007	90

The Busta and Linga Voe February 2007 result indicates that mussels in the wider area can be contaminated to a relatively high level. However due to the distance from the Busta and Linga Voe monitoring point to the Olna Firth fishery conditions and pollution sources are likely to be different.

Shellfish growing waters are currently under review by SEPA and Scottish Government, and the boundaries of the Loch Melfort SGW may be amended as part of that process. SEPA aim to have a Parliamentary Order in force by December 2013, outlining the new designation, in time for the repeal of the Shellfish Waters Directive.

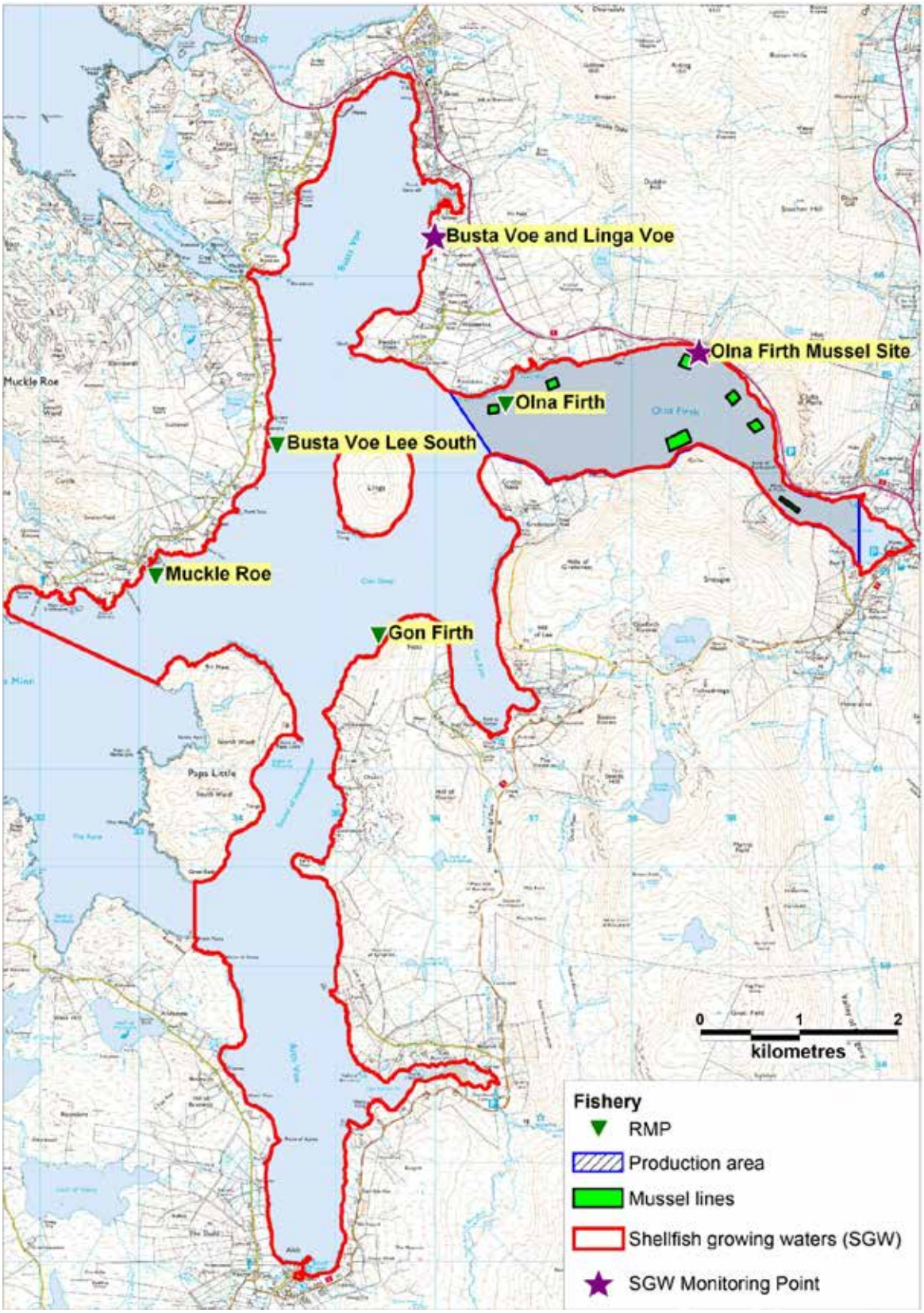

Figure 12.1 Designated shellfish growing water – East of Burki Taing, Muckle Roe

13. Bathymetry and Hydrodynamics

13.1 Introduction

The study area comprises all waters east of a line drawn between HU 3614 6483 (near Pinchdyke on Hevden Ness) and HU 3645 6402 (Grobs Ness), namely Olna Firth. The firth is located on the west Shetland mainland and is a branch of a larger inlet on the convoluted southern coastline of St. Magnus Bay. The firth is orientated roughly east – west and is characterised by a broad expanse of water for two thirds of the length. This becomes constricted in a dogleg leading to a small basin at the head of the firth and the settlement of Voe.

13.2 Bathymetry

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

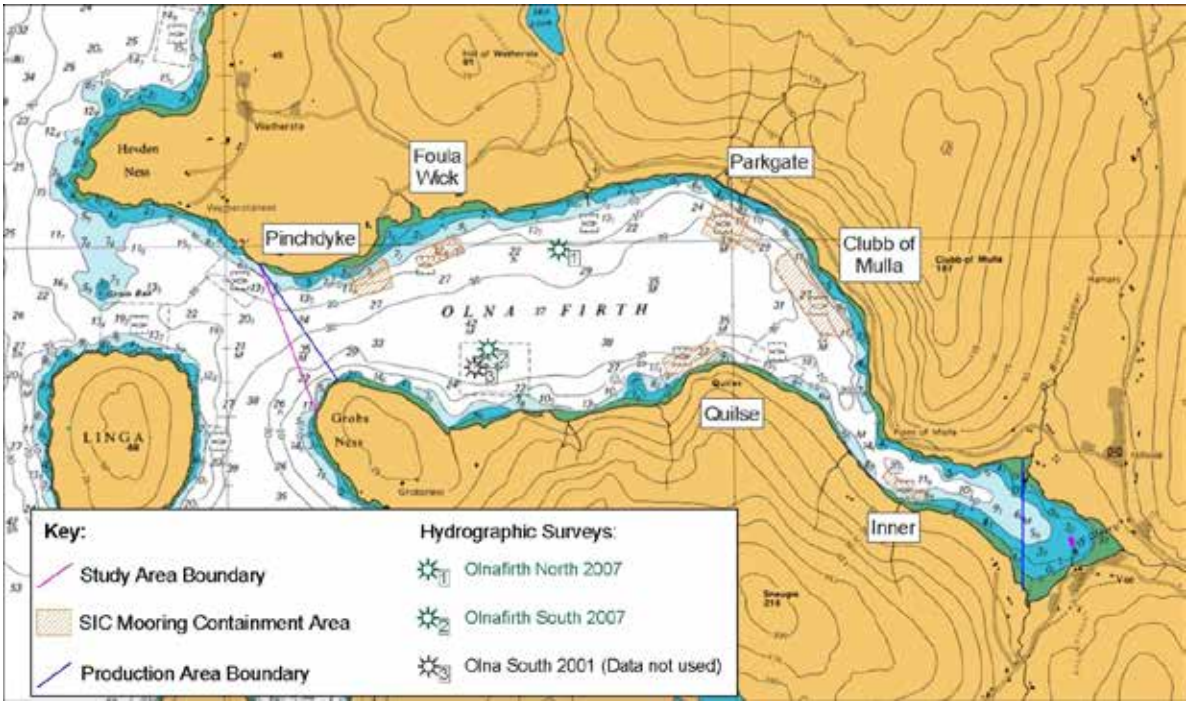

Figure 13.1 Admiralty chart extract

Vector data from an electronic version of this chart was extracted and contoured using Golden Software Surfer 8 (Figure 13.2).

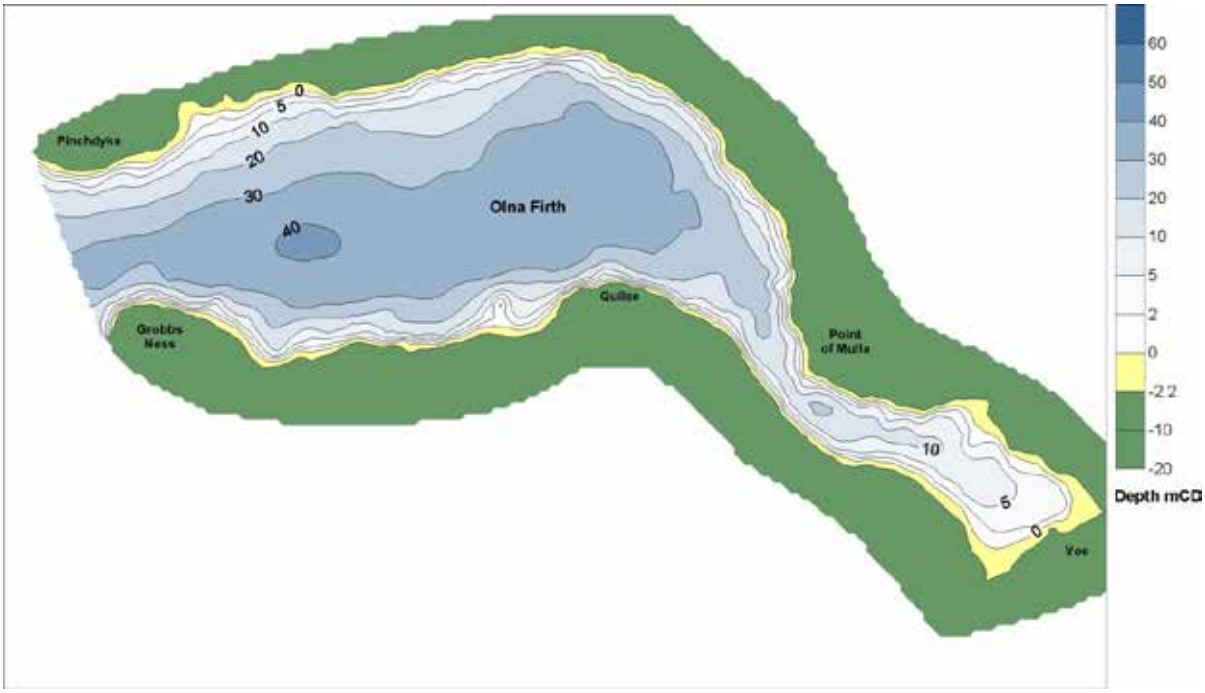

Figure 13.2 Bathymetry of Olna Firth. Depths given as metres chart datum.

The contour map illustrates:

a large area of the broad part of the firth exceeds 30 metres depth which extends beyond the entrance towards Cole Deep.

The northern shoreline of this area is characterised by a gradually sloping seabed, in contrast to the steeper gradient found at the southern shore.

Water depth decreases at the Point of Mulla to form a minor sill at 14.6m, although beyond this the gentle slope of the seabed towards Voe is not characteristic of a true basin.

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 chart datum by defining the surface “z” as zero.

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

Parameter*	Study area
Area (km^2)	3.43
Volume (Mm^3)	74.8
Mean depth (m)	21.8
Maximum depth (m)	42.0

* All values at chart datum

The area is comparable to that presented in the Scottish Sea Lochs catalogue (Edwards & Sharples, 1986) derived through manual measurement with a planimeter at chart datum (3.4 km^2). The estimate of volume in the Sea Lochs catalogue is greater than the Surfer figure (75.5 Mm^3)

13.3 Field Data

Historically there have been three field studies in the firth which give an insight into the current flow patterns within the study area. Summary information of the deployments is given in Appendix 1 while their locations are included at Figure 13.1. Data from these hydrographic studies were provided to Cefas by SEPA which archive information concerning fish farm licencing on their Public Register. For this report two of these surveys were evaluated and re-processed to the requirements outlined by SEPA in the *Regulation and Monitoring of Marine Cage Fish Farming (Scotland) Attachment VIII* (v2.7 2008) to standardise analysis, discussed in detail in Section 5. The data is considered to be of high quality in terms of accuracy and therefore can be said to be representative of the locations studied. Of the two surveys at Olnafirth South the earlier deployment at the site is disregarded from further study in favour of the higher precision survey conducted in 2007.

13.4 Tidal Information

Information pertaining to predicted tide height is derived from the UKHO TotalTide prediction for West Burra Firth, the nearest secondary port some 16 km west of the study area boundary. Figures 13.3 and 13.4 show tidal curves for a fifteen day period starting on the 1 April 2013 and therefore includes the date of the shoreline survey (3/4 & 9 April 2013).

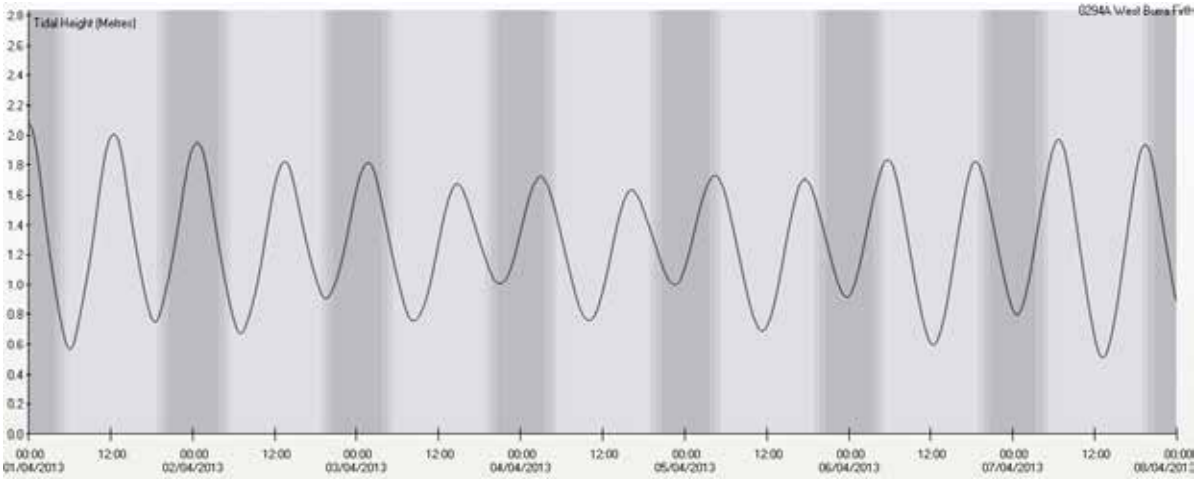

Figure 13.3 Tidal Curve West Burra Firth; 1 to 8 April 2013

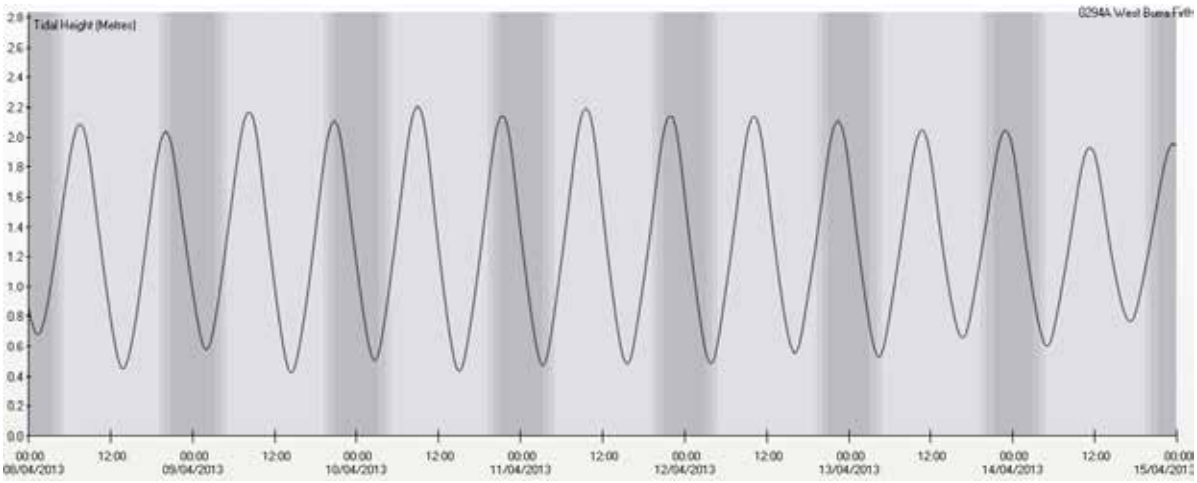

Figure 13.4 Tidal Curve West Burra Firth; 8 to 15 April 2013

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 detail in Section 3.

Timing

The first six days of the pressure record for the current meter deployments at Olnafirth North and Olnafirth South were plotted against the West Burra Firth TotalTide UKHO prediction for the same periods and it is apparent that the timing of the tidal state within Olna Firth is consistent with the prediction.

Range

The range of the three largest tides around springs and the three smallest tides around neaps for both deployments was compared to that predicted for the corresponding tides at West Burra Firth. The observed tides within the firth are typically 0.2 m greater than the prediction during both spring and neap tides. Atmospheric pressure is not accounted for in the survey data.

Tidal Volume

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

T_f (days) = 0.52V/0.7A.R

Where V is the volume of the loch basin (m^3), A is the surface area of the loch (m^2) and R is the spring tidal range (m). The factor 0.52 is the number of days per tidal cycle, and the factor 0.7 approximates the mean tidal range from the spring tidal range, R. As the spring tidal range is used, inputs for volume and area pertain to those calculated for MLWS. Based on this method estimates of flushing time (T_f) and flushing rate (Q) are given below in Table 13.2.

Table 13.2 Estimate of flushing rate and tidal volume for Olna Firth using the tidal prism method.

Input:		
Volume* (V)	Mm^3	76.9
Area (A)	km^2	3.49
Tidal range (R)	m	1.6
Output:		
Flushing Time (T_f)	days	10.2
Flushing Rate (Q)	Mm^3/year	2,745
Flushing Rate (Q)	Mm^3/day	7.5
Flushing Rate (Q)	Mm^3/tidal cycle	3.9

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

The tidal prism method indicates that 5.1 % of the low water volume of the firth is exchanged during each tidal cycle and that total exchange would take ten 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 Olna Firth using Surfer grid volume calculation.

Tide	Z (m)	Study Area Volume (Mm^3)
MLWS	0.6	76.9
MHWS	2.2	82.7
Difference (spring tide)		5.8
MLWN	1.0	78.3
MHWN	1.7	80.8
Difference (Neap tide)		2.5
Average Difference		4.1

The estimate of the flushing rate is comparable to the average tidal volume. However both estimations of the exchange rate given should be interpreted cautiously as both employ a gross simplification of hydrodynamic properties in topographically complex area. Sill and basin features will restrict exchange at depth and lead to longer residency times while wind forcing may serve to enhance or compound exchange depending on the direction.

13.5 Currents

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

Modelling

Full hydrodynamic modelling was undertaken as part of the sanitary survey conducted for the neighbouring Papa Little Voe production area (CEFAS, 2009). The Hydrotrack model was used with a domain defined that covers part of Olna Firth near the mouth, including the Pinchdyke and Foula Wick fisheries. The availability of data from the hydrographic studies at the Olnafirth North and South fish farms (Figure 13.1) potentially allow for validation of these simulations.

Tidal flows are simulated using a spring tidal range of 1.7 m as quoted in the Scottish Sea Lochs Catalogue (Edwards & Sharples, 1986). Note that this exceeds the springs range derived from UKHO TotalTide prediction (1.6 m). The effect of wind forcing is simulated by a constant airflow from the four main cardinal directions over a 48-hour period to attain a steady state current pattern.

In summary the results showed (refer to Figure 13.5):

Tidal currents are very low with the greatest predicted speeds at the constriction at the mouth of the firth, up to 4 cm/s. These are stronger along the northern shore than the southern shore and decrease with distance from the entrance.

Clockwise flow within the broader part of the firth would appear to be generated with winds originating from the south through west with the strongest currents predicted during the latter (up to 2.5 cm/s). There is the potential for contaminants from sources on the southern shore to be carried towards Pinchdyke and on to Foula Wick. There could be some minor influence from waters beyond the firth with a weak (<1 cm/s) flow along the northern shore from Hevden Ness.

Counter-clockwise flow is predicted for northerly and easterly wind conditions again with the strongest flows associated with winds along the topographical axis (up to 2.5 cm/s). There is the potential for contaminants from sources on the northern shore to be carried west towards Foula Wick and on to Pinchdyke. There is also potential for some westerly currents to form along the northern shore beyond the firth towards Hevden Ness.

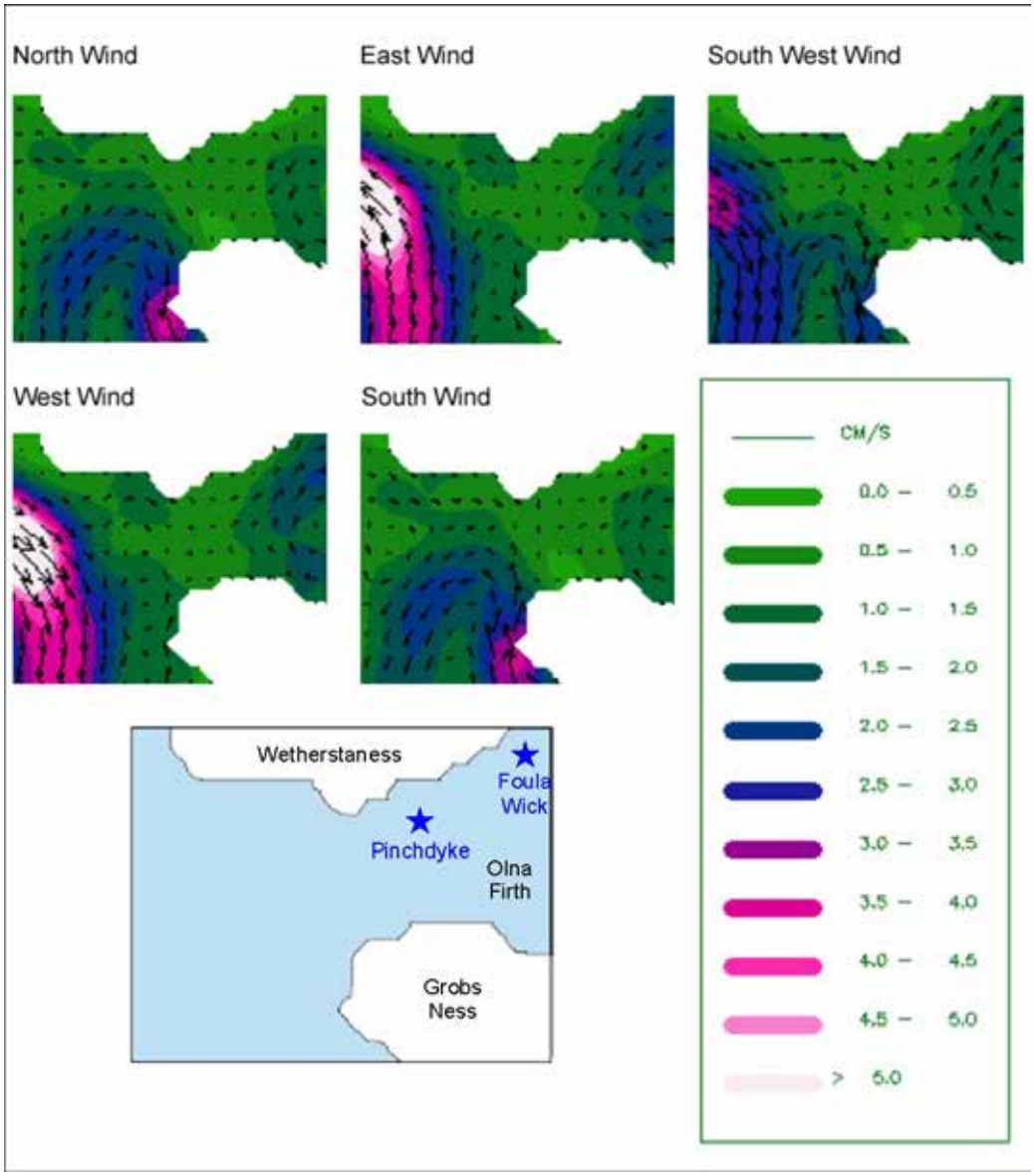

Figure 13.5 Hydrotrack model output for the approaches to Olna Firth.

The hydrotrack model provides baseline information as to how the water body may respond to various wind conditions however the results must be considered within the limitations of the simulation, namely the inability of the model to describe vertical structure within the water column and the impact this will have on the modelling of wind driven flow, the lack of any simulation of density driven flows, and the fact that in this instance the entire area of the firth is not included in the model domain.

An assessment of the hydrographic data collected at the Olnafirth North and South fish farms was undertaken with detailed summary statistics for both survey tabulated in Appendix 4.2. Figure 13.6 illustrates the frequency of currents by vector and the pertinent summary statistics for near-surface waters for each survey in the context of the surrounding area.

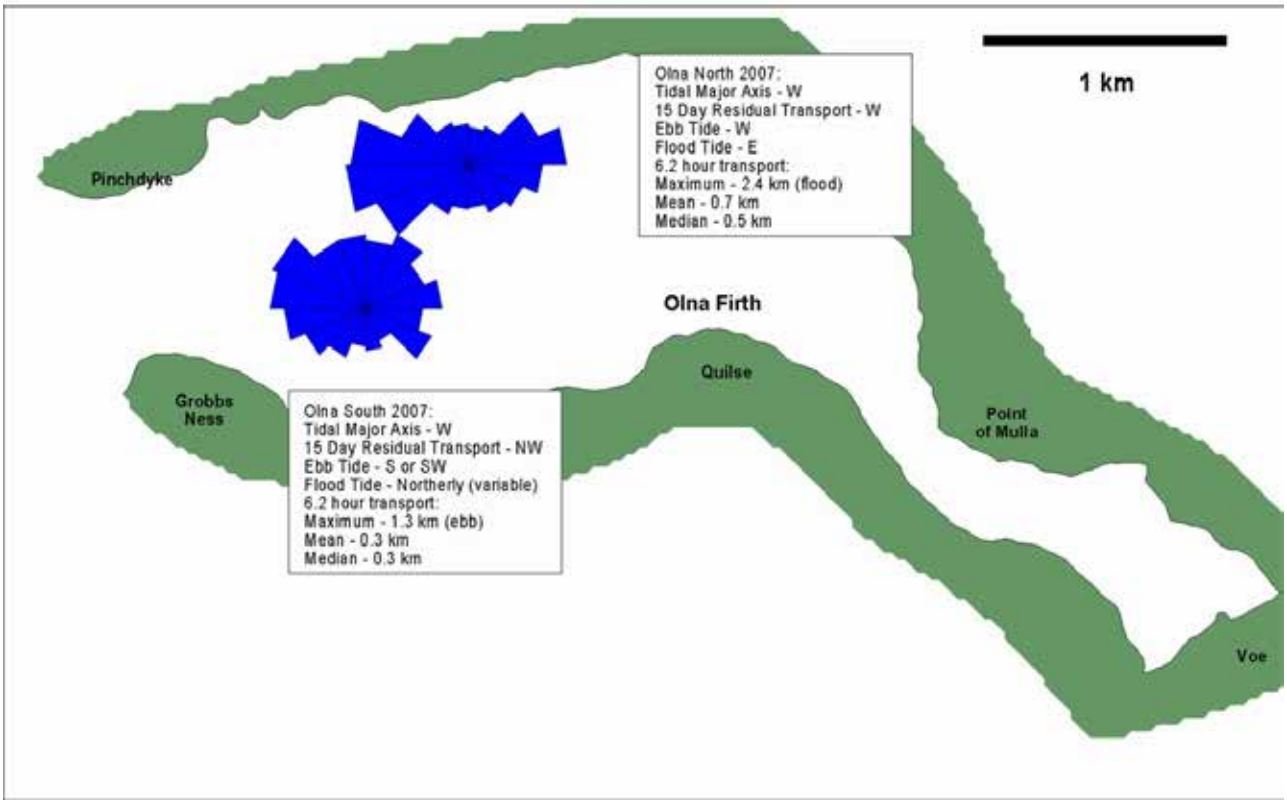

Figure 13.6 Near-surface current direction frequency (bin size 22.5°) for the two surveys assessed at Olna Firth including a summary of residual and tidal transport at each location.

Tides

As predicted by the hydrotrack model tidal currents appear to be relatively weak in this part of the firth. Currents on the northern shore of the firth exhibit greater bi-directionality than those on the southern shore however with evidence of unidirectional flow over multiple tidal cycles present in time series plots for both sites it is more likely that this pattern is related to wind driven currents than to tidal currents.

At Olnafirth North the tidal signature is more clearly defined near to the seabed. The ebb tide generally flows west towards the mouth of the voe and the flood tide to the east and therefore conforms to the topography. There is some periodicity in the time series of current direction which correlates to the tidal cycle although direction on each tide is not along a consistently defined vector for sequential tides.

At Olnafirth South throughout the water column peak velocity is generally encountered during the ebb tide, near low water. Again there is some evidence of periodicity in the current direction related to the timing of tidal cycle although it is difficult to describe bi-directional currents here, for example easterly flow can be present on both flood and ebb tides. However the tidal signature is marginally more

pronounced near to the seabed where the influence of wind forcing is lower. A variably northerly flow is present during the flood tide while a variable flow between south and southwest occurs during the ebb.

Maximum transport at both locations during a 6.2 hour period was coincidental with strong wind forcing implying that currents at this location are subject to greater influence from the wind.

Wind Forcing

At Olnafirth North periods of strong wind forcing generate velocity peaks in the near-surface that are present down through the water column to the seabed, albeit diminished in strength. The greatest transport in a 6.2 hour period occurred at this location, nearly double the value derived at Olnafirth South, and was coincidental with a short period of near hurricane force winds.

Unidirectional flow over multiple tidal cycles occurs and this movement conform to the patterns predicted by the Hydrotrack simulation for clockwise and counter clockwise flow in the outer part of the firth. There is limited evidence for currents flowing in a direction counter to those present at the surface during periods of strong wind forcing.

The Olnafirth South survey data is characterised by a dominance of strong winds (up to F10) originating from the west and south west. In near surface waters the residual current is to the northwest and thus conforms to the prediction for water movement resulting from wind forcing from these directions.

It is clear that water movement in the outer part of the firth is substantially influenced by wind forcing as predicted by the Hydrotrack model where wind driven transport exceeded relatively weak tidal currents. It is highly likely therefore that the values for 15-day residual transport determined through analysis of date from both locations is particular to the weather conditions encountered during the surveys. Sites in the production zone are exposed to moderately large fetches ranging from a minimum of 2 km at Inner (NW) to a maximum of 5 km (W) at Clubb of Mulla. For sites in the outer part of the firth the greatest currents are generated along the greatest fetch to the west.

13.6 Stratification

Salinity and temperature profiles were collected at each of the three sites within the production area during the shoreline survey in April 2013. Readings showed uniform salinity over a depth of 10 metres at all locations profiled, with the exception of the profile collected at the north eastern corner of the Pinchdyke site where lower salinity was detected at 10 metres depth. However the difference between minimum and maximum salinity readings was very low (0.44 ppt) compared to the reported accuracy of the instrument used (0.35 ppt). Salinity readings from the laboratory of

samples collected from the shoreline near head of the firth were slightly below normal seawater with the lowest reading at 30.09 on the Practical Salinity Scale compared to a mean value of 35.47 for the water samples collected at the fisheries. Temperature measurements showed little variation with depth, with readings from the inner most sites showing fractionally lower readings near the surface compared to those collected at 10 metres (up to 0.5°C). Complete salinity and temperature profile data and water sample analysis are available in the shoreline survey report.

While these observations are not indicative of stratification at the time of the survey the potential for these conditions was noted in both sanitary survey reports undertaken by Cefas for the neighbouring Busta Voe Lee North (2007) and Papa Little Voe (2009) areas. 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.

Various parameters pertaining to freshwater input are described by Edwards and Sharples, 1986 and later by Dixon, 1987 in which the values for the sea water inlets of Shetland were refined. These figures have been updated using digital mapping techniques and recent rainfall totals in Table 13.6 below.

Table 13.4 Comparing freshwater runoff parameters

Parameter	Units	Edwards & Sharples 1986	Dixon 1987	SSQC 2013
Watershed	km^2	27.0	27.6	26.7
Annual Rainfall	(mm)	1,150	1,200	1,223*
Runoff	(Mm^3/yr)	24.2	26.2	25.9
Fresh/tide, per thousand	-	8.3	8.9	9.6
Salinity reduction	ppt	0.28	0.30	0.33
Runoff/width	m^2/d	87	103	107

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

It can be seen that reported values are comparable to the values derived for the purpose of this report. Notably, there is a higher proportion of freshwater runoff relative to the tidal inflow based on a lower figure for the latter resulting from smaller estimates of high water area and a reduced tidal range used in the calculation. This leads to a greater reduction in salinity prediction on average over a year. It is acknowledged that variation from this figure is expected due to seasonal fluctuations in freshwater runoff. Increased runoff leads to a greater value for the runoff/width ratio which indicates greater importance of the freshwater supply than previously reported.

13.7 Summary

The tidal prediction for West Burra Firth is applicable to the study area in terms of timing and range, although the latter was marginally greater during the period surveyed.

Comparable figures for tidal exchange are derived from the two methods used to calculate this, namely 5.1% of the LW volume of the study area exchanged during the tidal cycle and a flushing time of 10.2 days. Weather conditions and bathymetric features may affect this, although to what extent is unknown.

Currents generated by wind transport are predicted to be greater than those attributed to the tide alone.

Modelling covered the area near to the mouth of the firth only, although the Hydrotrack simulation shows similarities to the field observations for various wind conditions. The movement of contaminants from settled shorelines can be inferred from flow patterns predicted;

Prolonged northerly and easterly winds generate a counter-clockwise flow in the firth therefore an alongshore current from west to east along the northern shore.

Prolonged southerly and westerly winds generate a clockwise flow and therefore an east to west flow along the northern shore.

Field observations confirm the Hydrotrack prediction that tidal currents are very weak in the area. Flood and ebb tides conform to the expected pattern of water moving into and out of the firth defined by the topography, although the tidal signature is often hard to discern.

The greatest transport during a single tidal period occurs at Olnafirth North where excursion of up to 2.4 km may be expected. Evidence suggests that strong winds contribute to this figure. Excursion decreases to the south.

A relationship between strong wind forcing and unidirectional flow in the near-surface waters is evident throughout the area. This is often transferred throughout the water column.

Salinity profiles collected during the November shoreline survey showed uniform salinity with depth. In the sanitary survey reports for the neighbouring areas Cefas note that as a result of weak tidal stirring the possibility exists for thermal stratification during the summer months. In these conditions warmer water above cold dense water leads to the formation of density driven currents. The timing of the fieldwork precluded any study of the potential of this phenomenon.

Estimates of freshwater influence and corresponding salinity reduction are calculated to be greater than those published in the literature.

14. Shoreline Survey Overview

The shoreline survey was conducted between the 3rd and 4th April 2013, with shellfish samples taken on the 9th April 2013. Prevailing weather conditions were mainly dry.

The Olna Firth production area was found to have six active longline mussel farms. All fisheries had the maximum permissible number of lines licensed on site, except at the Inner site which had three out of a possible five lines on site at the time of the survey. All sites except for Parkgate had stocked mussels. The fisheries consisted of the following:

Pinchdyke Eight mussel lines running parallel to the shoreline. All lines were double headed long lines with 10-15 metre droppers. This site contained the RMP sampling basket in the northeast corner of the site, at 8 m depth.

Clubb of Mulla Two sites; each with eight mussel lines running parallel to the shoreline. All lines were double headed long lines with 10-15 metre droppers.

Foula Wick Five mussel lines running parallel to the shoreline. All lines were double headed long lines with 15 metre droppers.

Inner Three mussel lines running parellel to the shoreline. All lines were double headed long lines with 12 metre droppers.

Outer Seven mussel lines running parellel to the shoreline. All lines were double headed long lines with 12-15 metre droppers.

Parkgate Twelve mussel lines running parellel to the shoreline. All lines were double headed long lines with 10-15 metre droppers. No droppers were on site at the time of the survey.

The majority of houses in Upper and Lower Voe were reported to be connected to the Voe public sewerage system. No houses were located northern shoreline between the Point of Mulla and Wethersta. Houses outside the main settlement at Voe are unlikely to be connected to the main public sewerage system, and will instead have their own private septic tanks. Two self-catering properties are located near Voe pier at the head of Olna Firth that are only available to rent from April to October. There is also a restaurant/public house in Lower Voe.

A large number of pipes observed on the northern and southern shorelines during the survey were found to be associated with land drainage. Several pipes were observed coming from agricultural buildings on the northern and southern shorelines, with discharge onto the shore. A pipe associated with a house possibly used as an overflow pipe for the septic tank was also found to be discharging brown material to the shore.

A number of small leisure boats and sailing boats were seen at Voe. One large workboat was presumed to be associated with the shellfish/finfish aquaculture nearby. Five boats were ashore at the pier.

Rough grassland dominated both southern and northern shorelines of the production area. Areas of improved grazing land were associated with crofts at Hoga, Hultness and Olna. The northern shoreline was mostly backed by lowland areas used for grazing, whereas the southern shoreline was characterised by undulating landscape alternating between steep cliffs and escarpments to lowland areas. A number of boggy areas on the southern shore were also noted, where the land was wet but had no active water flow.

A total of 181 sheep were seen grazing on hills above the southern shoreline, the majority of which had access to the shore. Only two fenced areas prevented animals from accessing the shore; an area near Grobsness and an area next to houses at Hoga. On the northern shoreline, 117 sheep were seen and most were fenced away from the shore. Sheep droppings were observed close to the shore on a few occasions where animals were not present. Six sheep carcasses were also noted on the southern shoreline. Cow/horse hoof prints were observed twice; near Grobsness and Wethersta. Several agricultural sheds were observed along the shoreline: on the northern shoreline near Wethersta, east of Hultness and on the southern shore at Hoga, which had a drain discharging to the sea.

Gulls, oystercatchers and plovers were regularly observed taking flight from the shore, feeding on the shore or resting on floats at the mussel sites. Cormorants were also seen on floats at the majority of the sites. Eider ducks were noted on two occasions, with 30 observed feeding on lines at the Clubb of Mulla site. A small number of geese were also seen taking flight from fields on the northern shoreline and goose droppings were observed on the banks of the watercourse sampled near Hultness. Seals were noted in the water at six locations, mainly around the Outer fishery. One seal carcass was present on the shore near the Foula Wick site.

Sixteen watercourses were sampled during the survey, with a further four measured but not sampled. *E. coli* levels in freshwater samples were mostly low (between <1 and 380 *E. coli* cfu/ 100 ml). The highest results were found to the northwest, at Burn of Foulawick (380 *E. coli* cfu/ 100 ml) and Mill Burn (170 *E. coli* cfu/ 100 ml). A further 52 areas of land drainage were also noted during the survey.

Contamination levels found in seawater were mostly very low. The only elevated seawater result came from adjacent to Voe community septic tank, which returned a high result of 140 *E. coli* cfu/ 100 ml.

Salinity profiles were collected at each of the six fisheries, with all profiles obtained showing a change in salinity from the bottom (10 m depth) to the surface that was within the design tolerance of the salinity metre used (+/- 1 ppt).

Temperature profiles showed a small change with depth, with four out of the six profiles showing a slight decrease between 0.1 and 0.5°C from depth to surface. This excludes the profile taken from the Outer site, which showed a 0.1°C increase in temperature from 10 m to the surface.

Shellfish samples from the six sites varied with site, and between depths. Overall shellfish *E. coli* levels were highest at Clubb of Mulla and the Inner sites, and were greater in the surface samples compared to the bottom samples. Shellfish samples at Pinchdyke contained the lowest contamination levels of all the sites. Shellfish samples at each site are as follows:

Pinchdyke Four samples were taken from the northeast corner of the site; two at the surface and two at the bottom (8 m). All samples returned results of <20 *E. coli* MPN/ 100 g.

Foula Wick One sample was taken from the northwest corner of the fishery, from the top of the mussel line. The sample returned a result of 20 *E. coli* MPN/ 100 g.

Parkgate One sample was taken from the northeast corner of the fishery, from the top of an anchor rope. The sample returned a result of 20 *E. coli* MPN/ 100 g.

Clubb of Mulla Two samples were taken from the southwest corner of the southern lines; one from the surface and one at the bottom (10 m). Samples returned results of 490 *E. coli* MPN/ 100 g and 50 *E. coli* MPN/ 100 g respectively.

Inner Two samples were taken from the south end of the fishery; one from the top and one from the bottom (12 m) of a mussel line. Samples returned results of 490 *E. coli* MPN/ 100 g and <20 *E. coli* MPN/ 100 g respectively.

Outer One sample was taken from the southwest corner of the site, from the top of the mussel line. The sample returned a result of 50 *E. coli* MPN/ 100 g.

The most significant shoreline survey observations are shown on the map in Figure 14.1.

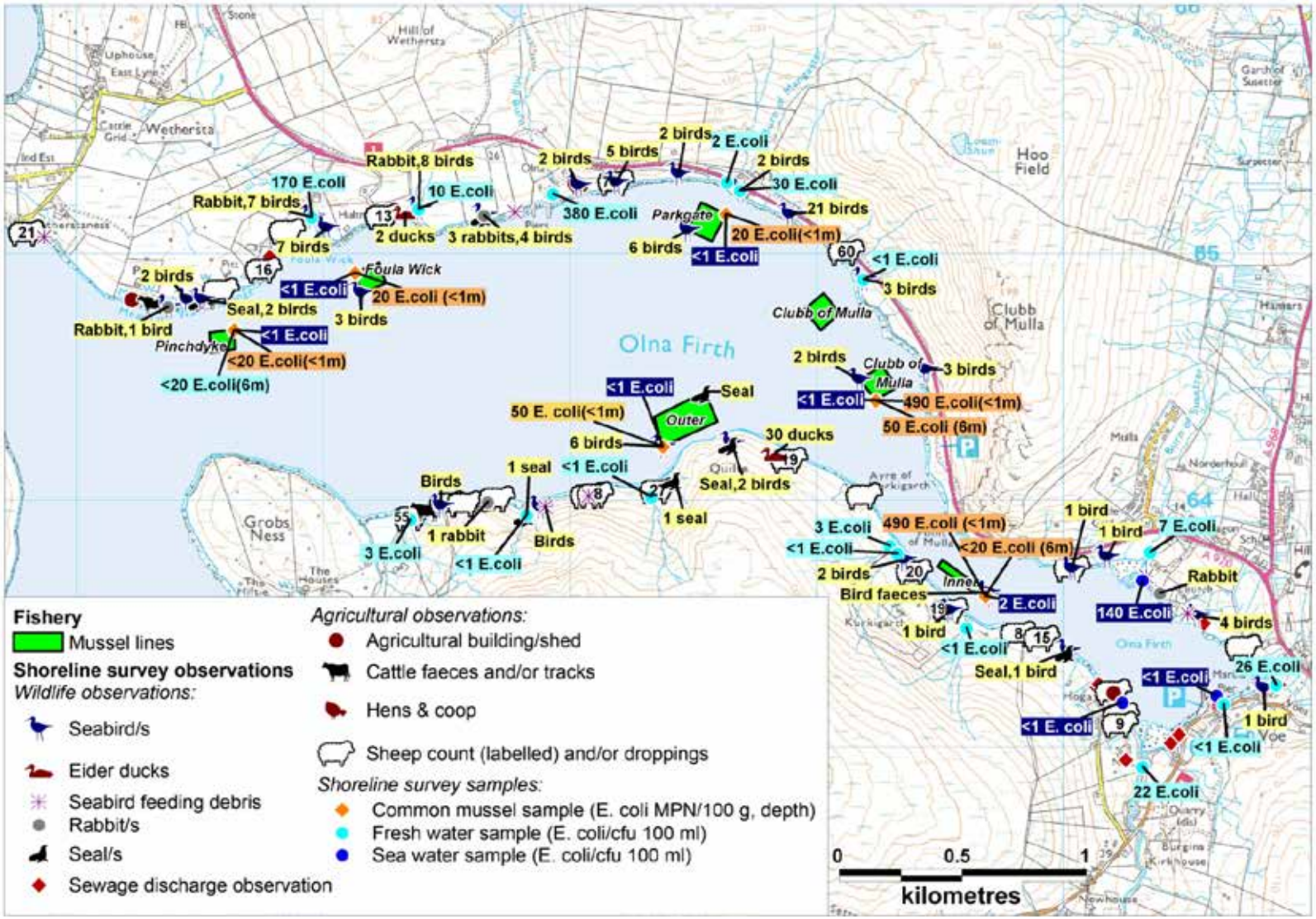

Figure 14.1 Summary of shoreline survey findings for Loch na Cille

15. Overall Assessment

Human sewage impacts

Sewage inputs are primarily concentrated around the head of the firth. The largest of these is from the Voe septic tank, which discharges approximately 600 m east of the Inner site. Inputs from this and other septic discharges to the head of the firth will mainly impact the the Inner mussel site but area also likely to affect the Club of Mulla and Outer sites.

Additional sewage inputs are located on the northwestern shore of the firth. These are more likely to impact the Pinchdyke, Foula Wick and Parkgate sites.

Agricultural impacts

Livestock were observed grazing rough land around much of the firth during the shoreline survey. In many areas, sheep and cattle had access to the shoreline and to watercourses. Crofts were concentrated around the head of the firth, along the northwest shore and along the south east shore at Grobs Ness. Therefore, much of the area is considered likely to be impacted by diffuse faecal contamination from farm animal sources.

Wildlife impacts

Seals and birds were both observed around Olna Firth, though birds were most numerous and found along much of the shoreline. Amongst wildlife sources, avian source faecal contamination is likely to be predominant, with impact widespread around the area. There is little evidence to suggest that any one part of the fishery would be more heavily affected than another.

Seasonal variation

Some seasonal variation is anticipated in human impact due to the presence of the marina and anchorage at the head of the firth and the visitor accommodation present in the area. This is likely to be higher during the summer months when tourism and boating activity are both higher. Given the predominance of sheep production within the local area, it is likely that impacts from this source may also be higher in summer, when lambs are present and the sheep population will be considerably higher. Rainfall was higher from October to March in the dataset considered for this report, however rainfall events exceeding 20 mm/day occurred in all months except April and May.

Sampling results showed a strong upward trend from May to December, with a relatively high level of contamination also seen in January. Analysis by season showed a statistically significant difference with autumn results higher than those in spring. No difference was found between results in other seasons.

Watercourses

Watercourses discharging to Olna Firth were found to have moderate levels of faecal contamination during the shoreline survey. Conditions prior to the survey were relatively dry, however, and loadings observed during the survey would be expected to be higher after moderate to heavy rainfall. Loadings were found to be highest to the Northwest shoreline nearer to the Pinchdyke and Foula Wick mussel farms. Analysis of historical results found a statistically significant correlation between rainfall and *E. coli* results at Pinchdyke, suggesting that this location may be affected by rainfall-associated diffuse contamination.

Movement of contamination

Tidal currents are predicted to be weak in the outer firth and therefore water movement is likely to be largely affected by wind driven flow, with currents moving east to west or west to east depending on wind direction. Excursions of up to 2.4 km may occur in the northern part of the outer firth, near the Foula Wick and Pinchdyke mussel farms. The Pinchdyke mussel could potentially be affected by contaminants arising from the southern shore or from sources to the west around Hevden Ness, depending upon wind conditions.

Predicting movement within the inner part of the firth is more difficult due to the lack of data pertaining to flows within that area.

Temporal and geographical patterns of sampling results

There appeared to be no significant change in contamination levels at the Pinchdyke site over time. It should be noted that sampling has only been undertaken at Pinchdyke and that due to the distance between this site and contaminating sources at the head of the firth, sampling results from this location are not expected to be indicative of contamination levels within the inner parts of the production area.

Conclusions

Sources of contamination to the sites near the head of the voe are a mix of diffuse agricultural and sewage discharges. Due to the relatively low predicted movement of contaminants, it is expected that these are most likely to impact the Inner mussel site first, and may also affect the Clubb of Mulla and Outer sites.

The sites in the outer part of the firth, Pinchdyke and Foula Wick, are more likely to be affected by diffuse agricultural and smaller human sources arising from the adjacent shoreline and potentially those along the southwest shoreline and at Hevden Ness. As these sources are expected to be relatively smaller, levels of contamination seen in this part of the firth might be expected to be lower than those occurring toward the head of the firth.

Overall Risk Table

Factor	Outer (Pinchdyke and Foula Wick)	Inner (Inner, Clubb of Mulla, Outer and Parkgate)
Sewage discharges	Low	Medium
Rainfall dependent diffuse sources – agriculture	Medium	Medium
Wildlife sources	Low	Low
Seasonal variability	Medium	Medium

16. Recommendations

It is recommended that the production area be split in to two separate areas based differences in the principal contaminating sources to the inner and outer parts of the production area.

Olna Firth Inner

Production area

The inner part of the firth should be split into a separate production area due to its proximity to sources of faecal contamination present toward the head of the firth. This will include the Inner, Clubb of Mulla, Outer and Parkgate sites. The boundaries are recommended to be the area bounded by lines drawn between HU 4000 6372 and HU 4000 6341 and between HU 3800 6523 and HU 3800 6402 and extending to MHWS.

RMP

It is recommended that the RMP for this area be established at the eastern end of the Inner mussel farm at HU 3968 6363, nearest the sources at Voe.

Tolerance

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

Depth of sampling

As higher results were seen in samples taken from near the surface, it is recommended that samples be taken from within the top 1 metre of the lines.

Frequency

Monthly monitoring is recommended for this RMP due to the lack of monitoring history within this area.

Olna Firth Outer

Production area

It is recommended that the Pinchdyke and Foula Wick sites be contained within a separate production area with the boundaries given as the area bounded by lines drawn between HU 3800 6523 and HU 3800 6402 and between HU 3656 6417 and HU 3615 6482 and extending to MHWS.

RMP

It is recommended that the RMP be moved to HU 3714 6492, which lies on the NW corner of the Foula Wick mussel farm. This location lies nearer to contaminating sources along the north shore.

Tolerance

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

Depth of sampling

As contamination at the location is likely to be carried in sources near the surface, it is recommended that samples be taken from within the top 1 metre of the lines.

Frequency

Due to the seasonal variation seen in historical sampling results, it is recommended that monthly sampling be retained.

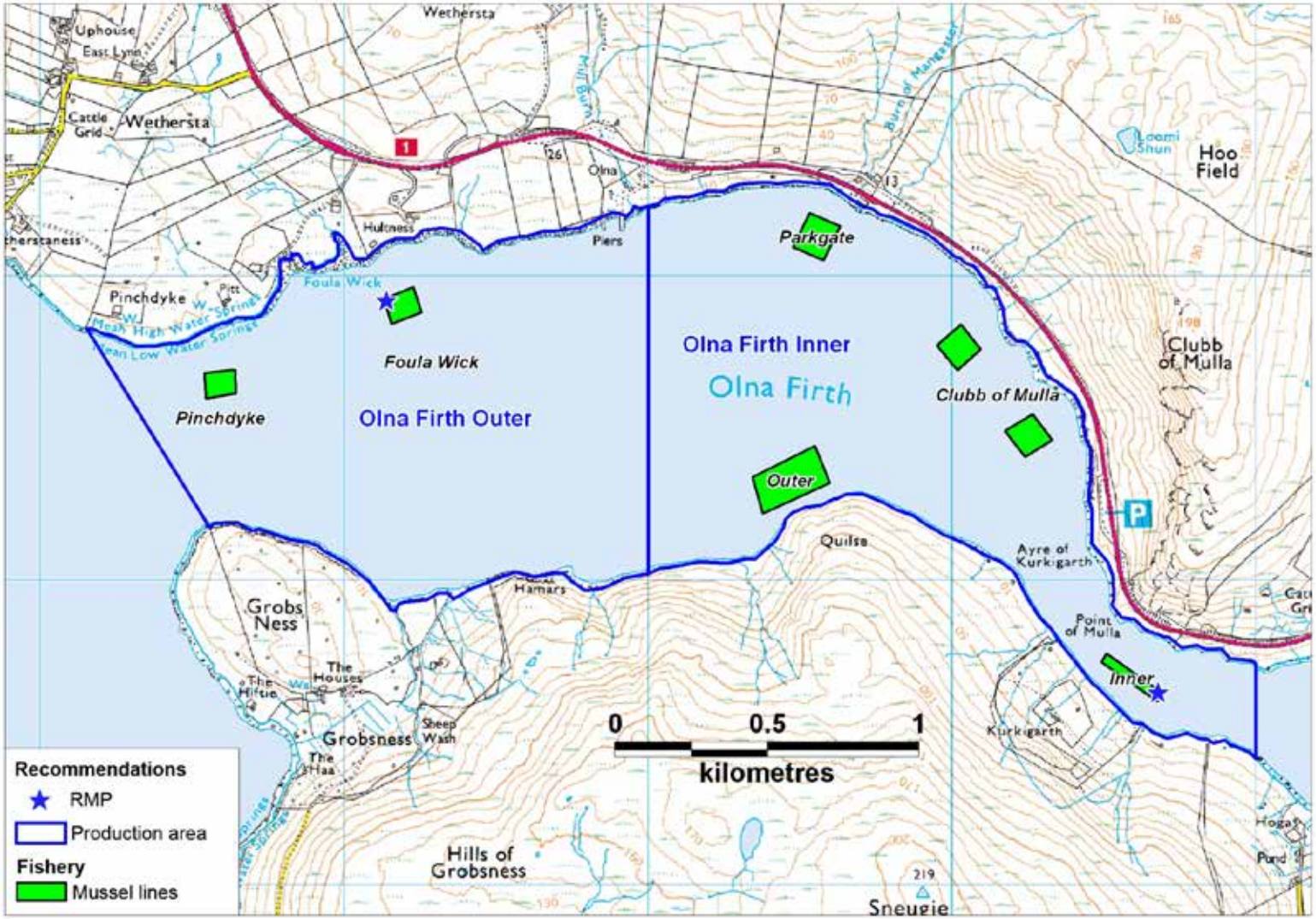

Figure 16.1 Map of recommendations for Olna Firth

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18. List of Figures and Tables

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

Appendix 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 x 104 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 x 105 faecal coliforms (FC) per faecal deposit and ring-billed gulls (Larus delawarensis) approximately 1.77 x 108 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 treams, which may be washed into the water during periods of rain.

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Appendix 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., 2008)

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

Animal	Faecal coliforms (FC) number	Excretion (g/day)	FC Load (numbers/ day)
Chicken	1,300,000	182	2.3 x 108
Cow	230,000	23,600	5.4 x 109
Duck	33,000,000	336	1.1 x 1010
Horse	12,600	20,000	2.5 x 108
Pig	3,300,000	2,700	8.9 x 108
Sheep	16,000,000	1,130	1.8 x 1010
Turkey	290,000	448	1.3 x 108
Human	13,000,000	150	1.9 x 109

Source: (Gauthier & Bedard, 1986)

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

FIO	*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)

Appendix 3. Statistical Data

One-way ANOVA: log10EC versus Season

Source DF SS MS F P
Season 3 1.788 0.596 2.18 0.103
Error 45 12.275 0.273
Total 48 14.063

S = 0.5223 R-Sq = 12.71% R-Sq(adj) = 6.89%

Individual 95% CIs For Mean Based on Pooled StDev

Level	N	Mean	StDev	---+---------+---------+---------+------
1	11	2.8357	0.5546	(----------*---------)
2	13	2.3016	0.4860	(---------*--------)
3	13	2.4594	0.4667	(---------*---------)
4	12	2.5679	0.5839	(----------*---------)

---+---------+---------+---------+------
2.10 2.40 2.70 3.00

Pooled StDev = 0.5223

Grouping Information Using Tukey Method

Season	N	Mean	Grouping
1	11	2.8357	A
4	12	2.5679	A
3	13	2.4594	A
2	13	2.3016	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	-1.1044	-0.5340	0.0363	(----------*----------)
3	-0.9466	-0.3763	0.1941	(----------*----------)
4	-0.8490	-0.2678	0.3134	(----------*----------)

--+---------+---------+---------+-------
-1.00 -0.50 0.00 0.50

Season = 2 subtracted from:

Season	Lower	Center	Upper	--+---------+---------+---------+-------
3	-0.3883	0.1578	0.7039	(----------*----------)
4	-0.2911	0.2662	0.8236	(----------*----------)

--+---------+---------+---------+-------
-1.00 -0.50 0.00 0.50

Season = 3 subtracted from:

```
Season   Lower  Center  Upper  --+---------+---------+---------+-------
4       -0.4489  0.1084  0.6658              (----------*----------)
                          --+---------+---------+---------+-------
                         -1.00     -0.50      0.00      0.50
```

Variables (& observations)	r	p
Degrees since prev moon & log10EC (49)	0.181	0.223
Variables (& observations)	r	p
time since HW & log10EC (49)	0.269	0.036

Pearson correlation of ranked temp and ranked EC = -0.245
P-Value = 0.494

Correlations: ranked 2d, ranked EC

Pearson correlation of ranked 2d and ranked EC = -0.003
P-Value = 0.985

Correlations: ranked 7d, ranked EC

Pearson correlation of ranked 7d and ranked EC = 0.096
P-Value = 0.547

Appendix 4. Hydrographic Assessment Appendices and Glossary

Appendix Table 1: Hydrographic survey details

Sitename	NGR	Survey Period	Equipment
Olnafirth North	HU 37775 64901	24/04/07-16/05/07	Aquadopp 600 kHz ADP
Olnafirth South	HU 37390 64359	04/04/07-24/04/07	Aquadopp 600 kHz ADP
Olna South	HU 37317 64262	20/12/01 - 07/01/02	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 Table 2: Hydrographic survey summary statistics

Parameter	Units	Near-surface / Mid-depth / Near-bottom	Olnafirth South 2007	Olnafirth North 2007
Mean speed	m/s	Near-surface	0.045	0.047
		Mid-depth	0.041	0.043
		Near-bottom	0.047	0.035
Tidal major axis	°Grid	Near-surface	280	265
		Mid-depth	145	265
		Near-bottom	100	290
Amplitude anisotropy	-	Near-surface	1.08	1.17
		Mid-depth	1.04	1.76
		Near-bottom	1.17	1.29
Residual speed	m/s	Near-surface	0.007	0.004
		Mid-depth	0.006	0.010
		Near-bottom	0.011	0.004
Residual direction	°Grid	Near-surface	329.8	262.1
		Mid-depth	93.1	238.5
		Near-bottom	85.5	206.3
Vector averaged residual	-		0.005 m/s at 64 °Grid	0.006 m/s at 236 °Grid
Tidal excursion	km	Near-surface	0.80	0.98
		Mid-depth	0.71	0.85
		Near-bottom	0.86	0.65

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.

The following technical terms may appear in the hydrographic assessment:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Neep tides occur during the first or last quarter of the moon when the tide-generating forces of the sun and moon oppose each other. The tidal range is smallest and tidal currents are weakest during neep tides.

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

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

Return flow. A surface flow at the surface may be accompanied by a compensating flow in the opposite direction at the bed.

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

Shoreline Survey Report

Production Area:	Olna Firth	
Site Names:	Clubb of Mulla	
	Foula Wick	
	Inner	
	Outer	
	Parkgate	
	Pinchdyke	
SIN:	Clubb of Mulla:	SI-232-731-08
	Foula Wick:	SI-232-434-08
	Inner:	SI-232-435-08
	Outer:	SI-232-437-08
	Parkgate:	SI-232-438-08
	Pinchdyke:	SI-232-439-08
Species:	Common Mussel	
Harvesters:	Blueshell Mussels Ltd. – Michael Laurenson	
Local Authority:	Shetland Islands Council	
Status:	Existing area	
Dates surveyed:	3rd, 4th and 9th April 2013	
Surveyed By:	Sean Williamson (Hall Mark Meat Hygiene Ltd.)	
	Vicki Smith (SSQC Ltd.)	
	We are grateful to Blueshell Mussels for providing a boat and employee for assistance during the marine survey work.	
Existing RMP:	Clubb of Mulla:	No sampling
	Foula Wick:	No sampling
	Inner:	No sampling
	Outer:	No sampling
	Parkgate:	HU 3870 6520 (Biotoxin)
	Pinchdyke:	HU 3672 6471 (*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 fisheries marked on Figures 2 and 3. Bacteriology results are given in Tables 2 and 3. Salinity profiles are presented in Table 4. Photographs are presented in Figures 4-22.

Weather

Wednesday 3 April 2013

Calm day to start, with little wind, which built to a F3 westerly breeze towards the end of the shoreline walk. Cloud cover present throughout the survey with occasional breaks of sunshine.

Thursday 4 April 2013

Initial overcast conditions rapidly cleared, with sunshine and scattered clouds present for the majority of the shoreline walk. Moderate breeze (F4), north easterly persisted throughout the walk.

Tuesday 9 April 2013

Clear bright conditions to start the survey with cloud cover moving in as the survey progressed. Three light snow showers occurred during the survey, with a light northerly breeze (F2) present throughout.

Preceding the shoreline walk, Monday 1st April was a calm day to start, with wind building to a F3 northerly breeze throughout the day, cloudy but no rain showers present. Tuesday 2nd April again another cloudy day with wind building to a F2/F3 easterly late morning and persisting for the remainder of the day.

Preceding the mussel sampling, Sunday 7th April was a cold day with light snow showers and rain showers present through the afternoon. Wind speed was very changeable throughout the day increasing from calm conditions to a F5 northerly in the afternoon. Monday 8th April saw a few light snow and rain showers with wind increasing to a F3 easterly in the afternoon before dying away into the evening.

Fishery

The location of the mussel lines at the six fisheries assessed in the Olna Firth production area are mapped in Figure 1. Parkgate was the only fishery which did not have mussels on site at the time of the survey the other five sites had stocked mussel lines.

Clubb of Mulla (SI-232-731-08):
The fishery consisted of two groups of eight mussel lines running parallel to the shoreline (Figure 4). All lines were double headed long lines with 10-15 metre droppers. Two mussel samples were collected from the most southerly group of mussel lines (nearest the village of Voe) at the south west corner of the site on the line furthest from the shore. One sample was taken from the top of a mussel line and one from the bottom of a mussel line at a depth of 10 metres.

Foula Wick (SI-232-434-08):
The fishery consisted of five mussel lines running parallel to the shoreline (Figure 5). All lines were double headed long lines with 15 metre droppers. One mussel sample was collected from the north west corner of the site from the line nearest the shore, taken from the top of a mussel line.

Inner (SI-232-435-08):
The fishery consisted of three mussel lines running parellel to the shoreline (Figure 6). All lines were double headed long lines with 12 metre droppers. Two mussel samples were collected from the south end of site from the central mussel line, taken from the top and bottom of a mussel line at a depth of 12 metres.

Outer (SI-232-437-08):
The fishery consisted of seven mussel lines running parellel to the shoreline (Figure 7). All lines were double headed long lines with 12-15 metre droppers. One mussel sample was collected from the south west corner of the site from the line nearest the shore, taken from the top of a mussel line.

Parkgate (SI-232-438-08):
The fishery consisted of twelve mussel lines running parellel to the shoreline (Figure 8). All lines were double headed long lines with 10-15 metre droppers. One mussel sample was collected from the north east corner of the site from the line nearest the shore, taken from the top of an anchor line as there was no mussel droppers on site at the time of the survey.

Pinchdyke (SI-232-439-08):
The fishery consisted of eight mussel lines running parellel to the shoreline (Figure 9). All lines were double headed long lines with 10-15 metre droppers. Two mussel samples were collected from the north east corner of the site from the line nearest the shore. The surface sample was taken from the top of a mussel line and the bottom sample taken from the RMP sampling basket present on site at a depth of 8 metres.

All fisheries had the maximum permissible number of lines licenced on site with the exception of the Inner site which is licenced for five lines although there were only three on site at the time of the survey.

Sewage/Faecal Sources

Human – On the southern shoreline of Olna Firth between Grobsness and the village of Voe there are very few occupied dwellings. Five houses were noted south of the Inner fishery at Hoga and Pund just west of Voe. Three of these houses had associated septic tanks however these were not highlighted on the survey plan as consented discharges (Figure 10). The other two houses septic tanks could not be identified although these dwellings were located above the road further from the shore. At the head of Olna Firth in the area known as Lower Voe there are approximately twenty occupied properties with ten of these being below the road closer to the shore. Directly above the pier/marina there are two self-catering accommodation properties, a bakery, a restaurant/public house and the Olna Firth Seafarms shorebase. The Voe pumping station is located at the head of Olna Firth to the east of the pier (Figure 11). On the first part of the northern shoreline walk travelling from Lower Voe towards the Clubb of Mulla fishery the majority of the dwelling houses are located away from the shore above the road, in the area known as Upper Voe. Only three houses and a church were noted close to the shore along with the Voe community septic tank which serves all the houses in Upper and Lower Voe. Once past the Point of Mulla directly opposite the Inner fishery the shoreline becomes very sparsely populated. Three houses were noted some distance from the shore above the road near the Parkgate fishery, one of which had been noted on the survey plan as a consented discharge although no septic tank was identified. Two properties at Olna between the Foula Wick and Parkgate sites were on the survey plan as consented discharges, a septic tank for one of the properties was identified (Figure 12). Another seven occupied dwellings were noted along the remaining part of the northern shoreline to Wethersta. One property had a septic tank in use which had been identified on the survey plan. A disused septic tank was also identified near one of the houses which had an agricultural shed adjacent to the building. The area of Wethersta at the western end of the north shoreline walk again has a number of dwelling properties and a small industrial estate although these were located some distance from the shore.

A number of pipes were identified along the northern shoreline with the majority of these being associated with land drainage. Three pipes were found to be disused and two were coming down from an agricultural building, potentially used to hold animals which would be discharging to the field above the shore, however this was not in use at the time of the survey. Also a pipe associated with a house possibly used as an overflow pipe for the septic tank was discharging brown material to the shore (Figure 13). On the southern shoreline near the village of Voe five disused pipes were noted and two were found to be associated with land drainage. A pipe was also identified coming down from an agricultural building discharging to a drain leading to the shore (Figure 14). Another pipe was observed joining the drain further down which may have been from the septic tank found in the field. A seawater sample was taken from where the drain was discharging to the shore as there was not sufficient water in the drain to sample. Five of the larger freshwater discharges from pipes were sampled on the northern shoreline, all of which were assumed to be land drainage.

A seawater sample was also taken in the vicinity of where the Voe community septic tank was discharging into the sea. As it was unknown where the end of the pipe was the sample was taken in the water at the shore directly in front of the septic tank location. The tidal state was high water at the time the sample was taken.

Sample analysis

Sixteen freshwater samples were obtained from watercourses on the shoreline survey, ten of which were outlined on the sampling plan and six were from additional locations not outlined in the plan; three from watercourses on the Grobsness to Voe walk, one west of the Outer fishery and two north of the Inner fishery. Another sample was from a small watercourse discharging beside the Voe marina and the final two were from watercourses discharging close to the Foula Wick and Parkgate fisheries. Of the sixteen watercourses sampled, fourteen were found to have *E-coli* levels of 30 cfu/100ml or below. The two locations with elevated *E.coli* counts were from a sample obtained from a large watercourse (Figure 15) below houses discharging to the shore to the west of the Foula Wick fishery (170 cfu/100ml). The other was taken from a large watercourse (Figure 16) discharging to the shore beside a pier and below the houses at Olna (380 cfu/100ml).

Three seawater samples were obtained on the shoreline walk, two of which were outlined on the survey plan at the Voe pier and Voe community septic tank and one at an additional location at Hoga where a drain coming down from an agricultural shed was discharging to the shore. The samples near the agricultural shed and at the Voe pier were found to have *E.coli* counts of <1cfu/100ml, with the sample taken near the community septic tank returning a *E-coli* result of 140 cfu/100ml.

E.coli levels in the seawater samples taken from the six fisheries in the Olna Firth production area were all <1 cfu/100ml with the exception of the sample taken from the Inner site which had a slightly higher *Ecoli* count of 2 cfu/100ml.

Two mussel samples were obtained from the Pinchdyke fishery from the north east corner of the site. The two samples were obtained from the top of a mussel line and from the RMP

sampling basket *(E-coli)* located at a depth of 8 metres. Both samples returned counts of <20 *E.coli* MPN/100g.

One mussel sample was obtained from the north west corner of the Foula Wick fishery and the north east corner of the Parkgate fishery. The Foula Wick sample was obtained from the top of mussel line and the Parkgate sample was taken from the top of an anchor rope, both returning levels of 20 *E.coli* MPN/100g

Two mussel samples were obtained from the south west corner of the southern group of mussel lines at the Clubb of Mulla fishery. Samples were taken from the top and bottom (depth 10m) of a mussel line returning levels of 490 *E.coli* MPN/100g and 50 *E.coli* MPN/100g respectively.

Two mussel samples were obtained from the south end of the Inner fishery. Samples were taken from the top and bottom (depth 12m) of a mussel line returning levels of 490 *E.coli* MPN/100g and <20 *E.coli* MPN/100g respectively.

One mussel sample was obtained from the south west corner of the Outer fishery. The sample was obtained from the top of mussel line and returned a level of 50 *E.coli* MPN/100g.

E.coli levels in the mussel tissue were highest at the Clubb of Mulla and Inner fisheries with the E-coli levels being found to be greater in the surface samples compared with the bottom samples. *E.coli* was found at lower levels at the other four fisheries with Pinchdyke recording the lowest levels.

Salinity profiles were collected at each of the six fisheries, with 5 of the 6 profiles obtained showing <0.25 ppt change in salinity from 10 metres to the surface which is within the accuracy of the probe used (± 0.35 ppt). The salinity profile taken from the north east corner of the Pinchdyke fishery showed the greatest difference in salinity with a difference of 0.37 ppt from 10 metres to surface. Most profiles showed a trend of a slight increase in salinity with decreasing depth although the range of these readings were within the accuracy level reported by the probe.

Temperature profiles showed little change from 10m depth to the surface with one profile showing no change, 4 of the 6 profiles showing a slight decrease in temperature (0.1-0.5°C) from 10m to the surface and the profile taken from the Outer site showing a slight increase in temperature from 10m to the surface (0.1°C).

Salinities of the seawater samples analysed at the laboratory showed salinities ranging from 35.39-35.59 PSU.

The seawater samples collected on the shoreline walk showed slightly lower salinities at Hoga and the Voe pier (34.2 and 34.56 PSU respectively). The most notable influence of freshwater was present at the Voe community septic tank as the salinity was below full strength seawater (30.09 PSU).

Seasonal population

There are two known self-catering properties at the head of Olna Firth near the Voe pier. These are seasonal as they are only available to rent from April to October. There is also a restaurant/public house in Lower Voe, up from the marina which will also be affected by seasonality as they are more likely to see higher number of customers and tourists in the summer months. All other houses identified on the shoreline survey route were assumed to be dwelling houses.

Boats/Shipping

Most boat traffic in the Olna Firth area is associated with aquaculture, either salmon farming or mussel farming. Blueshell Mussels Ltd. own the Outer, Inner and Foula Wick fisheries with Olna Firth Seafarms Ltd. owning the Parkgate, Pinchdyke and Clubb of Mulla fisheries however these three fisheries are currently being managed by Blueshell Mussels Ltd. Blueshell Mussels main shorebase is located in the neighbouring Busta Voe Lee North production area just north of Olna Firth. Moored at the Voe pier and marina was a number of small boats and sailing boats, the majority being used for leisure purposes and one large workboat (Figure 17). Ashore at the pier there were five boats currently not being used. The two salmon farms in the area are owned by Hjaltland Seafarms Ltd. who service their sites from a shorebase in Gon Firth just south of the Olna Firth production area.

Farming and Livestock

The land on the shoreline survey was largely rough grazing with some improved grazing land present near dwellings. Sheep were frequently observed grazing on the hill some distance from the shore on the southern coastline (ten occasions, 181 animals in total) with the majority having access to the shoreline (Figure 18). Only two fenced areas which prevented animals from accessing the shore were noted on the southern shoreline one being at the start of the survey near Grobsness where fencing was present at the edge of a steep escarpment and the other being next to houses at Hoga. Six sheep carcasses were noted on the south shore. Sitings of sheep were less frequent on the north shoreline (5 occasions, 117 animals total) with most of the groups of animals observed having no access to the shore, in fenced areas next to houses or above the road (Figure 19). Sheep droppings were observed close to the shore on a few occasions where animals were not present.

Cow or horse hoof prints were observed twice on the shoreline survey, near Grobsness and Wethersta although no animals were present. Faecal matter was also noted at the Wethersta location. These animals would have access to the shore if grazing in these areas.

On the north shore near Wethersta a small agricultural building which looked as if it was used to hold animals was observed however it was not in use at the time of the survey. An active feeding area for sheep was observed on the north shoreline near Hultness and an agricultural shed was also present next to a house on the north shore east of Hultness which had grazing animals in the field above. An agricultural shed at Hoga on the south shore had a drain discharging to the sea which was sampled for *E.coli* analysis.

Land Use and Land Cover

Rough grassland dominated both southern and northern shorelines of the production area. Some improved grazing land was observed close to dwellings at Hoga, Hultness and Olna.

The southern shoreline route was characterised by undulating landscape alternating between steep cliffs and escarpments with no access to the foreshore, to lowland areas where access to the foreshore was possible. Grazing was dominated by open grazing.

The northern shore was more characterised with lowland areas with easy access to the shore. Steeper escarpments were present adjacent to the Parkgate and Clubb of Mulla sites which made access to the shore difficult. Grazing varied between open and confined with animals in fenced areas near dwellings.

There was little rainfall in the days preceding the survey however there was a number of areas on the southern shore where the land was wet with no active water flow. A boggy area was present on the shore just east of the Outer fishery. On the north shore boggy areas of land were present near the Foula Wick and north of the Clubb of Mulla fisheries, with heather mixed in with rough grazing present at the south of the Clubb of Mulla site.

Watercourses

Nine watercourses were sampled on the southern shoreline, five of which were on the sample plan. The four additional samples were taken from a medium watercourse north of the Outer site with a sheep carcass at the bottom of the watercourse (Figure 20), two smaller watercourses north of the Inner site and a small watercourse at the head of Olna Firth in the village of Voe coming under the road next to the marina.

Seven watercourses were sampled on the northern shoreline, five of which were on the sample plan. The two additional samples were from a small watercourse east of the Foula Wick site and a small watercourse originating from the hill, coming under the road discharging to the shore south of the Parkgate site.

Flow rate was recorded at another five small watercourses however water samples were not obtained as these discharges were not considered to be major pollution sources. A number of other small watercourses and wet land drainage areas were noted on the shoreline survey.

Wildlife/Birds

On the southern and northern shoreline gulls, oystercatchers and plovers were observed regularly often taking flight from the shore, feeding on the shore or seen on floats at the mussel sites. Cormorants were also seen on floats at the majority of the sites with bird faecal matter also present of mussel floats at the Inner and Outer fisheries (Figure 21). Eider ducks were noted on two occasions most notably when a group of approximately 30 were observed feeding on lines at the Clubb of Mulla fishery. Four geese were seen taking flight from the field above the shore adjacent to the Voe church on the northern shoreline. Goose droppings were also observed on the banks of the watercourse sampled near Hultness on

the north shore. Mussel shells and sea urchin tests were observed on grassy verges up from the shore on a number of occasions with a large quantity present on top of the Voe community septic tank (Figure 22). Seals were noted in the water on six occasions, four of these being around the Outer fishery with the others observed near the Inner and Pinchdyke sites. A seal carcass was present on the shore near the Foula Wick site. Rabbits were observed on a six occasions in the fields above the shore mainly on the northern shoreline.

General observations

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

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

Figure 1 Map of shoreline observations

Table 1 Shoreline observations

No.	Date/Time (UT)	NGR	Easting	Northing	Associated Photograph	Associated Sample	Description
1	03/04/2013 08:45	HU 37362 63930	437362	1163930			Start of the survey at Grobsness, rough open grazing. Weather: cloudy, breaks of sunshine, light breeze. 55 sheep observed on the hill just above the shoreline, no fences, animals have access to the shore. Lowland area close to the shore. Overlooking salmon farm.
2	03/04/2013 08:51	HU 37355 63924	437355	1163924	Figure 18	OF-FW01	Small water course running down the hill to the shore over rocks. Freshwater sample taken (on survey plan) and flow rate measured; width 40 cm, depth 5 cm, flow 0.183 m/s, st. dev. 0.005 m/s. Photo taken looking upstream.
3	03/04/2013 08:53	HU 37386 63942	437386	1163942			Land drainage to the shore, little water flowing.
4	03/04/2013 08:54	HU 37411 63954	437411	1163954			Cow hoof prints observed in the field above the shore but no faecal matter or animals present. No fences so grazing animals would have access to the shore.
5	03/04/2013 08:56	HU 37479 63977	437479	1163977			Gulls inflight around the salmon farm. Shoreline, stony beach with seaweed, low water. Above the shore, rough grassland.
6	03/04/2013 08:57	HU 37489 63974	437489	1163974			Land drainage to the shore. Wood debris present in the water, little water flowing.
7	03/04/2013 08:58	HU 37508 63985	437508	1163985			Sheep droppings present. Droppings observed frequently throughout the shoreline walk with animals able to access the shore.
8	03/04/2013 09:01	HU 37576 63986	437576	1163986			Landscape changes to steep escarpments access to the shore difficult. Sheep droppings present, fenced area with no access to the shore.
9	03/04/2013 09:05	HU 37668 63994	437668	1163994			Returned to shoreline, lowland area near the shore but still steep hills a small distance from the shore. Rabbit observed running up from the shore to the grassland area.

10	03/04/2013 09:06	HU 37706 64005	437706	1164005			Sheep droppings present. No fenced areas.
11	03/04/2013 09:08	HU 37724 63999	437724	1163999			Sheep carcass on the foreshore.
12	03/04/2013 09:10	HU 37747 63982	437747	1163982			Land drainage to the shore, very little water flowing through vegetation.
13	03/04/2013 09:17	HU 37826 63942	437826	1163942	Figure 20	OF-FW02	Watercourse originating at the top of the hill running down the side of the hill. Freshwater sample taken (not on survey plan) and flow rate measured; width 25 cm, depth 5 cm, flow 0.072 m/s, st. dev. 0.016 m/s. Sheep carcass at the bottom of the watercourse on the shore. One seal observed in the water. Algae growth on the rocks at the bottom of the watercourse.
14	03/04/2013 09:20	HU 37856 63957	437856	1163957			Sheep carcass on the shore.
15	03/04/2013 09:20	HU 37880 63971	437880	1163971			Two oystercatchers on the rocks at the waterfront and one black backed gull in flight.
16	03/04/2013 09:22	HU 37903 63975	437903	1163975			Land changing again to steep escarpments. Mussel shells observed on the grassy verge above the shore where birds may have been feeding. Mussel shells frequently observed throughout the shoreline walk.
17	03/04/2013 09:25	HU 38020 63996	438020	1163996			Sheep carcass on the shore, relatively new.
18	03/04/2013 09:28	HU 38078 64019	438078	1164019			Sheep droppings present and sea urchin carcass on grassy area above the shore.
19	03/04/2013 09:29	HU 38105 64021	438105	1164021			Two sheep observed on the top of the hill some distance from the shore, six sheep observed near the shore, all have access to the shore.
20	03/04/2013 09:32	HU 38209 64031	438209	1164031			Land drainage on grassy area up from the shore, ground wet but no water flowing.
21	03/04/2013 09:32	HU 38221 64026	438221	1164026			Land drainage on grassy area up from the shore, ground wet but no water flowing.
22	03/04/2013 09:33	HU 38234 64022	438234	1164022			Land drainage, ground wet but no water flowing.
23	03/04/2013 09:34	HU 38237 64023	438237	1164023			Land drainage, ground wet but no water flowing.
24	03/04/2013 09:35	HU 38265 64018	438265	1164018			Land drainage, small water flow.

25	03/04/2013 09:35	HU 38295 64020	438295	1164020			Land drainage, small water flow.
26	03/04/2013 09:41	HU 38330 64015	438330	1164015		OF-FW03	Large watercourse down the side of the hill, fast flowing, western end of the Outer site. Freshwater sample taken (on survey plan) and flow rate measured; width 25 cm, depth 10 cm, flow 0.024 m/s, st. dev. 0.02 m/s.
27	03/04/2013 09:44	HU 38359 64038	438359	1164038			Small watercourse leading to the shore, little flow of water over rocks. 27 sheep observed on the hill.
28	03/04/2013 09:45	HU 38367 64044	438367	1164044			Land drainage, ground wet but little water flowing. Beach below stony with seaweed present.
29	03/04/2013 09:47	HU 38419 64073	438419	1164073			Land drainage, ground wet but no water flowing.
30	03/04/2013 09:47	HU 38425 64089	438425	1164089			One seal observed in the water.
31	03/04/2013 09:47	HU 38432 64095	438432	1164095			Land drainage, ground wet but no water flowing. Steep escarpment.
32	03/04/2013 09:52	HU 38535 64203	438535	1164203			One sheep observed on the hill.
33	03/04/2013 09:53	HU 38553 64202	438553	1164202	Figure 7		Photo of Outer site, 7 lines present on site.
34	03/04/2013 09:54	HU 38572 64197	438572	1164197			Land drainage down from the hill leading to the shore, ground wet but no water flowing.
35	03/04/2013 09:56	HU 38656 64232	438656	1164232			Two oystercatchers taking flight from the shore, one seal observed in the water.
36	03/04/2013 09:59	HU 38805 64198	438805	1164198			Underfoot conditions changing slightly to more boggy sphagnum moss. Sheep carcass observed on the hill.
37	03/04/2013 10:01	HU 38830 64188	438830	1164188			Weather: sunshine trying to break through cloud cover, light breeze. Large group of eider ducks (approximately 30) observed near the Clubb of Mulla site, a few breaking off from the group to feed on the mussel lines.
38	03/04/2013 10:02	HU 38890 64162	438890	1164162			19 sheep observed on the hill with access to the shore.
39	03/04/2013 10:05	HU 38950 64127	438950	1164127			Land drainage leading to the shore, ground wet but no water flowing, algae growth.

40	03/04/2013 10:07	HU 39015 64096	439015	1164096			Land drainage, large area of ground wet but little water flowing. Landscape flattened out, shore easily accessed.
41	03/04/2013 10:08	HU 39060 64081	439060	1164081			Land drainage, ground wet but no water flowing.
42	03/04/2013 10:12	HU 39109 64053	439109	1164053			Small watercourse flowing down from the hill to the shore. Flow rate measured; width 15 cm, depth 10 cm, flow 0.014 m/s, st. dev. 0.004 m/s.
43	03/04/2013 10:13	HU 39132 64050	439132	1164050			Land drainage, ground wet but no water flowing.
44	03/04/2013 10:15	HU 39193 64018	439193	1164018			Stony shelly beach, sheep droppings present.
45	03/04/2013 10:17	HU 39224 63937	439224	1163937			Sheep carcass on the hill.
46	03/04/2013 10:17	HU 39243 63906	439243	1163906			Land drainage, ground wet but no water flowing.
47	03/04/2013 10:18	HU 39259 63876	439259	1163876			Land drainage, ground wet but no water flowing.
48	03/04/2013 10:28	HU 39297 63817	439297	1163817		OF-FW04	Small water course north of the Inner site. Freshwater sample taken (not on sample plan) and flow rate measured; width 40 cm, depth 6 cm, flow 0.041 m/s, st. dev. 0.006 m/s.
49	03/04/2013 10:36	HU 39328 63785	439328	1163785		OF-FW05	Small fast flowing watercourse, north of the Inner site. Derelict mill upstream beside the watercourse. Freshwater sample taken (not on survey plan) and flow rate measured; width 30 cm, depth 13 cm, flow 0.012 m/s, st. dev. 0.023 m/s.
50	03/04/2013 10:39	HU 39354 63758	439354	1163758	Figure 6		Photo of the Inner site looking south to the village of Voe. Two cormorants observed on mussel floats at the site.
51	03/04/2013 10:40	HU 39372 63734	439372	1163734			Land drainage, little water flow.
52	03/04/2013 10:42	HU 39397 63709	439397	1163709			20 sheep observed on the hill with access to the shore.
53	03/04/2013 10:42	HU 39400 63701	439400	1163701			Land drainage with small water flow through vegetation.
54	03/04/2013 10:44	HU 39434 63665	439434	1163665			Land drainage with small water flow through vegetation.

55	03/04/2013 10:45	HU 39462 63630	439462	1163630			Weather: sunshine appearing through clouds. Sheep carcass present on the hill.
56	03/04/2013 10:47	HU 39541 63554	439541	1163554			Small watercourse with little water flow. One oystercatcher taking flight from the shore. 19 sheep observed on the hill with access to the shore.
57	03/04/2013 10:57	HU 39608 63482	439608	1163482		OF-FW06	Fast flowing watercourse over rocks near the Inner site. Freshwater sample taken (on the survey plan) and flow rate measured;width 30 cm, depth 13 cm, flow 0.012 m/s, st. dev. 0.023 m/s.
58	03/04/2013 11:01	HU 39658 63465	439658	1163465			Land drainage, ground wet but no water flowing.
59	03/04/2013 11:01	HU 39679 63451	439679	1163451			Land drainage, ground wet but no water flowing.
60	03/04/2013 11:04	HU 39819 63457	439819	1163457			Land drainage, ground wet but no water flowing. 8 sheep observed on the hill.
61	03/04/2013 11:07	HU 39878 63452	439878	1163452			Land drainage, small water flow over rocks, green/brown algae present.
62	03/04/2013 11:09	HU 39913 63440	439913	1163440			15 sheep observed on the hill with access to the shore.
63	03/04/2013 11:10	HU 39937 63420	439937	1163420			Large area of wet ground, land drainage no water flowing.
64	03/04/2013 11:11	HU 39985 63409	439985	1163409			Large area of wet ground, land drainage no water flowing. Algae present, brown/oily sheen.
65	03/04/2013 11:13	HU 40019 63389	440019	1163389			Land drainage, algae present brown with oily sheen. One plover seen taking flight from the shore. One seal observed in the water.
66	03/04/2013 11:15	HU 40052 63343	440052	1163343			Land drainage through vegetation.
67	03/04/2013 11:20	HU 40134 63244	440134	1163244	Figure 10		Plastic septic tank for new house built above the shore.
68	03/04/2013 11:23	HU 40143 63257	440143	1163257			Soakaway, brown material present on the grass. Three closed inspection pipes above soakaway.
69	03/04/2013 11:25	HU 40204 63222	440204	1163222			Agricultural shed above the shore. Sheep droppings observed.
70	03/04/2013 11:28	HU 40204 63140	440204	1163140			Concrete septic tank in field next to the agricultural shed, most likely associated with the house above the road.

71	03/04/2013 11:29	HU 40202 63145	440202	1163145	Figure 14		Drain coming down from the agricultural shed. Pipe at the top of the drain discharging small water flow and another pipe joins into the drain further down, possibly from the septic tank no water discharging from this pipe. Strong smell of manure, not much water flowing in the drain, very brown in colouration. Not enough water to sample the drain.
72	03/04/2013 11:38	HU 40240 63182	440240	1163182		OF-SW01	Seawater sample taken from where the drain discharges to the shore. Low water at the time of sampling. Green algae observed on the rocks on the shore.
73	03/04/2013 11:41	HU 40235 63125	440235	1163125			9 sheep observed in a fenced area up from the shore, no access to the shore.
74	03/04/2013 11:42	HU 40230 63090	440230	1163090			Small field drain through vegetation starting next to a house above the road coming down through a field with sheep grazing, to the shore.
75	03/04/2013 11:47	HU 40253 62949	440253	1162949			Concrete septic tank next to a house above the shore.
76	03/04/2013 11:53	HU 40322 62919	440322	1162919		OF-FW07	Large watercourse at the head of the voe. Freshwater sample taken (on survey plan) and flow rate measured; width 100 cm, depth 18 cm, flow 0.076 m/s, st. dev. 0.011 m/s.
77	03/04/2013 11:58	HU 40416 62981	440416	1162981			Small stream leading to the shore, little water flow, tall grass present in the stream. Four houses above the shore.
78	03/04/2013 12:00	HU 40435 63017	440435	1163017			Concrete structure and pipe leading into the sea just above the shore, may be from the house above the shore, possibly an old septic tank does not look to be in use.
79	03/04/2013 12:03	HU 40469 63052	440469	1163052			Possible septic tank for the house above the shore.

80	03/04/2013 12:06	HU 40518 63098	440518	1163098			Old pipe originating from the hill above the road, coming under the road leading to the sea. May not be in use, no discharge.
81	03/04/2013 12:09	HU 40548 63141	440548	1163141			Large black perforated pipe discharging to the sea, green algae on the rocks, small clear water discharge.
82	03/04/2013 12:12	HU 40584 63192	440584	1163192	Figure 17		Photo of Voe pier and marina.
83	03/04/2013 12:15	HU 40621 63210	440621	1163210		OF-SW02	Seawater sample taken from end of marina pier (on sample plan). Restaurant/public house, Sail Loft and Picking Shed: self-catering accommodation, bakery, Olna Firth Seafarms business and houses above the pier and marina.
84	03/04/2013 13:08	HU 40650 63174	440650	1163174		OF-FW08	Water drainage under the road fast flowing, next to the marina. Old pipes present but not joined. Freshwater sample taken (not on survey plan) and flow rate measured; width 30 cm, depth 5 cm, flow 0.02 m/s, st. dev. 0.004 m/s.
85	03/04/2013 13:14	HU 40681 63186	440681	1163186			Red pipe from under the road no water discharging to the rocks on the shore. May not be in use.
86	03/04/2013 13:16	HU 40701 63196	440701	1163196			Black perforated pipe under the road, no water discharging to shore.
87	03/04/2013 13:16	HU 40719 63200	440719	1163200			Old red pipe coming down from the house above the road. May not be in use.
88	03/04/2013 13:19	HU 40812 63238	440812	1163238			One plover feeding on the shore.
89	03/04/2013 13:22	HU 40862 63253	440862	1163253		OF-FW09	Large watercourse fast flowing at the head of the voe next to the pumping station. House to the west of the stream. Trees, vegetation and rocks present around and in the watercourse. Freshwater sample taken (on survey plan) and flow rate measured; width 40 cm, depth 35 cm, flow 0.132 m/s, st. dev. 0.056 m/s.
90	03/04/2013 13:28	HU 40872 63254	440872	1163254	Figure 11		Voe pumping station (Voe SPS).
91	03/04/2013 13:31	HU 40793 63334	440793	1163334			Field drainage through grey pipe to the shore, little discharge.

92	03/04/2013 13:32	HU 40762 63373	440762	1163373			Field drainage through grey pipe to the shore, small clear water discharge.
93	03/04/2013 13:33	HU 40731 63404	440731	1163404			Two field drains, two pipes an old pipe with no water discharging and a new grey pipe with a small water discharge. Sheep droppings observed.
94	03/04/2013 13:36	HU 40708 63426	440708	1163426			Small stream flowing downhill next to a house, flow rate measured; width 40 cm, depth 6 cm, flow 0.003 m/s, st. dev. 0.002 m/s.
95	03/04/2013 13:37	HU 40708 63421	440708	1163421			Old concrete septic tank next to the house mentioned above, doesn't look to be in use.
96	03/04/2013 13:41	HU 40569 63502	440569	1163502			Disused concrete septic tank and pipe leading to the sea. No water flowing.
97	03/04/2013 13:41	HU 40540 63531	440540	1163531			Four geese taking flight from a field above the shore.
98	03/04/2013 13:43	HU 40505 63541	440505	1163541			Field drainage through vegetation, long grass, water present but little flow coming down from side of a derelict church. Mussel shells on the shore where birds may have been feeding.
99	03/04/2013 13:47	HU 40392 63624	440392	1163624			One rabbit observed in the field above the shore.
100	03/04/2013 13:50	HU 40338 63692	440338	1163692	Figure 22		Voe community septic tank, slight smell present. Shell debris on tank roof where birds have been feeding. Fenced area.
101	03/04/2013 13:58	HU 40322 63677	440322	1163677		OF-SW03	Seawater sample taken from the shore next to the community septic tank.
102	03/04/2013 14:00	HU 40345 63750	440345	1163750			Two old pipes not discharging from the field above the shore. A lot of litter present of the beach.
103	03/04/2013 14:05	HU 40352 63790	440352	1163790		OF-FW10	Large watercourse flowing to the shore. Joining of three large pipes at the top of the hill into one watercourse. Freshwater sample taken (on survey plan) and flow rate measured; width 40 cm, depth 40 cm, flow 0.106 m/s, st. dev. 0.027 m/s.

104	03/04/2013 14:11	HU 40256 63777	440256	1163777			Land drainage, little water flowing through vegetation, a lot of litter present.
105	03/04/2013 14:13	HU 40176 63769	440176	1163769			One oystercatcher in flight. Small watercourse coming down from the hill under the road. Steep escarpment.
106	03/04/2013 14:16	HU 40035 63722	440035	1163722			Sheep droppings observed and seagull observed on the grass above the shore.
107	03/04/2013 14:20	HU 39906 63771	439906	1163771			Land drainage under the road from a pipe, small flow forks into two separate drainage paths.
108	03/04/2013 14:22	HU 39818 63796	439818	1163796			Land drainage under the road from a small pipe.
109	03/04/2013 14:32	HU 39532 64084	439532	1164084			Land drainage under the road from a pipe, small discharge.
110	04/04/2013 08:26	HU 35801 65084	435801	1165084			Weather: overcast, cloudy, light breeze. Start of the survey at Wethersta. One house to the west, one house to the north. A number of houses and industrial estate further inland. 21 sheep observed in the field above the shore, able to access the shore. Sheep droppings present, droppings observed frequently along the shoreline walk. Rough grassland.
111	04/04/2013 08:37	HU 35871 65069	435871	1165069			Field drainage leads to the rocky shore. Mussel shells on the shore where birds may have been feeding, mussel shells seen frequently along the shoreline walk. Sunshine breaking through the cloud cover. Ground becoming more boggy. Rocky shoreline with seaweed.
112	04/04/2013 08:46	HU 36226 64817	436226	1164817			Small agricultural shed potentially used for holding and treating animals up from the shore. Two pipes coming out of the ground near the building but no discharge.
113	04/04/2013 08:50	HU 36306 64795	436306	1164795			Cow or horse hoofs observed in the field above the shore but no animals present. Not fenced, grazing animals would have access to the shore.
114	04/04/2013 08:52	HU 36373 64785	436373	1164785			One oystercatcher seen taking flight from the shore. One rabbit observed in the field above the shore.

115	04/04/2013 08:54	HU 36450 64793	436450	1164793			Pinchdyke site, 8 mussel lines on site.
116	04/04/2013 08:56	HU 36451 64812	436451	1164812			Field drainage, small water flow. Two oystercatchers observed on the shore.
117	04/04/2013 08:58	HU 36510 64814	436510	1164814			Cow or horse faeces present in field above the shore, not fresh, no animals present. Animals would have access to shore. One seal observed in the water near the Pinchdyke site. Two oystercatchers observed on the shore.
118	04/04/2013 09:00	HU 36587 64850	436587	1164850			Field drain, small flow to the shore over rocks, near the Pinchdyke site. Flow rate measured; width 12 cm, depth 2 cm, flow 0.093 m/s, st. dev. 0.009 m/s. Landscape relatively flat, easy access to the shore. Sheep droppings present just above the shore.
119	04/04/2013 09:08	HU 36760 64933	436760	1164933	Figure 19		13 sheep observed in a fenced area next to a house. Another three sheep in the field behind the house. Six houses present in this area.
120	04/04/2013 09:10	HU 36778 64968	436778	1164968	Figure 13		Septic tank in the garden next to the house, black pipe discharging to the shore, may be the over flow pipe. Brown discharge. Two photos, one of the house and septic tank and one of the pipe discharge at the shore.
121	04/04/2013 09:12	HU 36784 64990	436784	1164990			Second black pipe coming down from the same house, no discharge from this pipe.
122	04/04/2013 09:14	HU 36784 65057	436784	1165057			Small watercourse filled with seaweed very stagnant may just be created by the sea at high water.
123	04/04/2013 09:18	HU 36856 65090	436856	1165090			Feeding area for sheep in the field above the shore. Three orange feed buckets and two troughs present with small quantities of feed present in the buckets.

124	04/04/2013 09:26	HU 36955 65150	436955	1165150	Figure 15	OF-FW11	Large watercourse leading to the sea. Small drainage ditches joining in to the main watercourse, one coming down from a house. Freshwater sample taken (on survey plan) and flow rate measured; width 100 cm, depth 15 cm, flow 0.088 m/s, st. dev. 0.011 m/s. Three plovers observed in the ebb, three oystercatchers in flight. Two gulls present on the rocks and one rabbit observed in the field above the shore.
125	04/04/2013 09:31	HU 37014 65104	437014	1165104			Goose faeces in the grassy area next to the watercourse. Six plovers observed on the shore and one cormorant observed on a mussel float at the Foula Wick site.
126	04/04/2013 09:37	HU 37139 65098	437139	1165098			Black pipe leading to the shore, no water discharge and barnacles growing on the inside of the pipe, so most likely old pipe not in use. Inspection pipe in field above shore. Two houses above the shore. Foula Wick site, 5 mussel lines on site.
127	04/04/2013 09:41	HU 37246 65151	437246	1165151			Old concrete septic tank down from a house above the shore doesn't look to be in use. Agricultural shed next to the house. 13 sheep observed in a fenced area next to the house. Sheep droppings present on the shore.
128	04/04/2013 09:46	HU 37334 65167	437334	1165167			Two eider ducks taking flight from the shore.
129	04/04/2013 09:51	HU 37389 65183	437389	1165183		OF-FW12	Small watercourse east of the Foula Wick site discharging to the shore, fast flowing. Freshwater sample taken (on survey plan) and flow rate measured; width 20 cm, depth 5 cm, flow 0.122 m/s, st. dev. 0.027 m/s. Ground becoming more boggy. 8 plovers in flight. One black rabbit in the field above the shore.
130	04/04/2013 10:01	HU 37653 65156	437653	1165156			Seal carcass on the shore. Three rabbits and four gulls observed.
131	04/04/2013 10:04	HU 37779 65171	437779	1165171			Salmon fish farm. Large number of mussel shells on the shore where birds have been feeding.

132	04/04/2013 10:10	HU 37934 65269	437934	1165269			Scrap yard where old boats are broken up. Pier with two houses and large shed above the shore.
133	04/04/2013 10:13	HU 37933 65243	437933	1165243	Figure 16	OF-FW13	Large watercourse, pipe discharging to the sea below the houses. Large flow of water. Freshwater sample taken (on survey plan) and flow rate measured; width 55 cm, depth 12 cm, flow 0.085 m/s, st. dev. 0.021 m/s.
134	04/04/2013 10:18	HU 38035 65275	438035	1165275	Figure 12		Concrete septic tank in use by the house above the shore. Very green grassy area below the septic tank. Hens in a coup beside the house. Two oystercatchers taking flight from the shore.
135	04/04/2013 10:24	HU 38189 65288	438189	1165288			Seven sheep observed on the hill above the shore next to the road. One oystercatcher and four gulls observed in flight.
136	04/04/2013 10:25	HU 38235 65293	438235	1165293			Field drainage coming from above the road, small discharge, little water flow, green algal growth present.
137	04/04/2013 10:30	HU 38442 65323	438442	1165323			Landscape beginning to steepen to escarpments. House above the road, drainage ditch leading to the shore, pipe under the road. No water discharging. Two oystercatchers observed in flight.
138	04/04/2013 10:37	HU 38637 65291	438637	1165291	Figure 8	OF-FW14	Watercourse fast flowing through a large pipe under the road. Flowing down the rock armour to the shore next to the Parkgate site. Freshwater sample taken (on survey plan) and flow rate measured; width 20 cm, depth 2 cm, flow 0.438 m/s, st. dev. 0.01 m/s. Parkgate site, 12 mussel lines on site.
139	04/04/2013 10:45	HU 38691 65256	438691	1165256		OF-FW15	Drain under the road, large discharge south of the Parkgate site. Freshwater sample taken (not on survey plan) and flow rate measured; width 20 cm, depth 2 cm, flow 0.742 m/s, st. dev. 0.065 m/s. Two oystercatchers observed.

140	04/04/2013 10:53	HU 38792 65210	438792	1165210			Drainage from pipe under the road, small discharge coming down rock armour to the shore between the Parkgate site and the northern lines of the Clubb of Mulla site. Flow rate measured; width 12 cm, depth 10 cm, flow 0.044 m/s, st. dev. 0.006 m/s.
141	04/04/2013 10:57	HU 38891 65159	438891	1165159			Small drainage pipe coming under the road with a small discharge through vegetation. Three oystercatchers and 18 gulls observed taking flight from the shore.
142	04/04/2013 11:03	HU 39121 65006	439121	1165006			60 sheep observed in a fenced area above the road.
143	04/04/2013 11:08	HU 39162 64956	439162	1164956			Small drainage pipe coming under the road with a small discharge. Fast flowing down rock armour to the shore at the north end of the Clubb of Mulla site. Heather present mixed in with rough grazing land.
144	04/04/2013 11:12	HU 39191 64896	439191	1164896		OF-FW16	Drain under the road, fast flowing coming down rock armour to the shore next to the most northern lines at the Clubb of Mulla site. Freshwater sample taken (on survey plan) and flow rate measured; width 12cm, depth 5 cm, flow 0.01 m/s, st. dev. 0.009 m/s. Three oystercatchers observed on the shore.
145	04/04/2013 11:21	HU 39260 64794	439260	1164794			Small drainage pipe coming under the road, fast flowing down rock armour to the shore between the two sets of mussel lines at the Clubb of Mulla site. Red/brown algae present on the rocks. Flow rate measured; width 25cm, depth 18 cm, flow 0.007 m/s, st. dev. 0.003 m/s.
146	04/04/2013 11:29	HU 39443 64529	439443	1164529			Small drain with little water discharge. Land boggy. One plover and two oystercatchers observed.

147	04/04/2013 11:30	HU 39456 64496	439456	1164496			Small drain, small water discharge near the southern lines at the Club of Mulla site, south end. Flow rate measured; width 15cm, depth 5 cm, flow 0.075 m/s, st. dev. 0.009 m/s.
148	04/04/2013 11:35	HU 39481 64341	439481	1164341	Figure 4		Clubb of Mulla site, two groups of 8 mussel lines.
149	09/04/2013 08:31	HU 36540 64680	436540	1164680			Weather: partially cloudy, fresh breeze with breaks of sunshine. NW corner of Pinchdyke site.
150	09/04/2013 08:32	HU 36546 64597	436546	1164597			SW corner of Pinchdyke site.
151	09/04/2013 08:34	HU 36645 64613	436645	1164613			SE corner of Pinchdyke site.
152	09/04/2013 08:34	HU 36641 64692	436641	1164692	Figure 9	OF-MUSS01 (Bottom) OF-MUSS02 (Top) OF-SW04	NE corner of Pinchdyke site. 8x double header long lines. Droppers 10-15m. Salinity Profile 1 collected (ppt/°C): 10m 34.53/5.6, 5m 34.94/5.6, 3m 34.97/5.6, surface 34.90/5.5. Mussels collected from most northerly line nearest the shore at the NE corner buoy. Surface sample collected from the top of a mussel line, bottom sample collected from the RMP sampling basket at a depth of 8m. Seawater sample collected.
153	09/04/2013 08:51	HU 37155 64841	437155	1164841			SW corner of Foula Wick site. Three cormorants perched on mussel buoys at the site. Light snow shower.
154	09/04/2013 08:52	HU 37255 64879	437255	1164879			SE corner of Foula Wick site.
155	09/04/2013 08:53	HU 37228 64963	437228	1164963			NE corner of Foula Wick site.
156	09/04/2013 08:54	HU 37130 64924	437130	1164924	Figure 5	OF-MUSS03 (Top) OF-SW05	NW corner of Foula Wick site. 5x double header long lines. Droppers 15m. Salinity Profile 2 collected (ppt/°C): 10m 35.10/5.5, 5m 35.06/5.5, 3m 35.07/5.5, surface 35.06/5.5. Mussels collected from most northerly line nearest the shore at the NW corner buoy. Surface sample collected from the top of a mussel line. Seawater sample collected.
157	09/04/2013 09:06	HU 38532 65207	438532	1165207			NW corner of Parkgate site.

158	09/04/2013 09:07	HU 38476 65094	438476	1165094			SW corner of Parkgate site. Four black backed gulls and two cormorants on mussel buoys at the site.
159	09/04/2013 09:09	HU 38577 65050	438577	1165050			SE corner of Parkgate site.
160	09/04/2013 09:11	HU 38633 65162	438633	1165162		OF-MUSS04 (Top) OF-SW06	NE corner of Parkgate site. 12x double header long lines. Droppers 10-15m. Salinity Profile 3 collected (ppt/°C): 10m 35.15/5.7, 5m 35.12/5.5, 3m 35.09/5.4, surface 35.06/5.4. Mussels collected from most northerly line nearest the shore at the NE corner buoy. Surface sample collected from the top of a anchor rope as no mussel droppers were on site. Seawater sample collected.
161	09/04/2013 09:21	HU 38949 64772	438949	1164772			Clubb of Mulla site has two groups of mussel lines within its lease area. Group 1 has 8x double header long lines. Droppers 10-15m and is located further north and Group 2 has 8x double header long lines. Droppers 10-15m and is located further south nearer the village of Voe. NW corner of Clubb of Mulla site Group 1.
162	09/04/2013 09:21	HU 39029 64839	439029	1164839			NE corner of Clubb of Mulla site Group 1.
163	09/04/2013 09:23	HU 39094 64757	439094	1164757			SE corner of Clubb of Mulla site Group 1.
164	09/04/2013 09:24	HU 39017 64689	439017	1164689			SW corner of Clubb of Mulla site Group 1.
165	09/04/2013 09:25	HU 39173 64489	439173	1164489			NW corner of Clubb of Mulla site Group 2. One cormorant and one gull observed on mussel buoys at the site, Group 2.
166	09/04/2013 09:26	HU 39264 64545	439264	1164545			NE corner of Clubb of Mulla site Group 2.
167	09/04/2013 09:27	HU 39329 64459	439329	1164459			SE corner of Clubb of Mulla site Group 2.
168	09/04/2013 09:28	HU 39240 64405	439240	1164405		OF-MUSS05 (Top) OF-MUSS06 (Bottom) OF-SW07	SW corner of Clubb of Mulla site Group 2. Salinity Profile 4 collected (ppt/°C): 10m 35.23/5.7, 5m 35.18/5.5, 3m 35.13/5.5, surface 34.98/5.2. Mussels collected from most westerly line on Group 2 at the SW corner buoy. Surface sample collected from the top of a mussel line and bottom sample collected from the bottom of a mussel line. Seawater sample collected.

169	09/04/2013 09:44	HU 39509 63758	439509	1163758			NE corner of Inner site.
170	09/04/2013 09:45	HU 39492 63730	439492	1163730			NW corner of Inner site.
171	09/04/2013 09:46	HU 39675 63600	439675	1163600			SW corner of Inner site.
172	09/04/2013 09:47	HU 39684 63612	439684	1163612	Figure 21	OF-MUSS07 (Top) OF-MUSS08 (Bottom) OF-SW08	Middle line buoy at south end of the Inner site. 3x double header long lines. Droppers 12m. Salinity Profile 5 collected (ppt/°C): 10m 35.24/5.7, 5m 35.22/5.7, 3m 35.19/5.8, surface 35.04/5.5. Mussels collected from most southerly buoy on the middle line of the site. Surface sample collected from the top of a mussel line, bottom sample collected from the bottom of a mussel line. Seawater sample collected. Bird faeces possibly cormorant observed on the buoy next to the sampling location.
173	09/04/2013 09:59	HU 39694 63626	439694	1163626			SE corner of Inner site. Bird faeces on the corner buoy.
174	09/04/2013 10:04	HU 38598 64318	438598	1164318			SE corner of Outer site.
175	09/04/2013 10:05	HU 38548 64440	438548	1164440			NE corner of Outer site. One seal observed in the water near most northerly line.
176	09/04/2013 10:06	HU 38343 64338	438343	1164338			NW corner of Outer site.
177	09/04/2013 10:08	HU 38378 64218	438378	1164218		OF-MUSS09 (Top) OF-SW09	SW corner of Outer site. 7x double header long lines. Droppers 12-15m. Salinity Profile 6 collected (ppt/°C): 10m 35.11/5.6, 5m 35.22/5.6, 3m 35.20/5.6, surface 35.18/5.7. Mussels collected from most southerly line closest to the shore at the SW corner buoy. Surface sample collected from the top of a mussel line. Seawater sample collected. Bird faeces (seagull) present on the corner buoy. Five gulls and one cormorant observed on mussel buoys at the site. Light snow shower.

Sampling

Water and shellfish samples were collected at the locations indicated in Figures 2 and 3. As well as those defined in the survey plan one additional seawater sample was collected from a drain discharging to the shore associated with an agricultural building at Hoga. Six additional freshwater samples were collected, four from the south shoreline; one north of the Outer fishery, two north of the Inner fishery and one from a drain discharging to the sea beside the marina. The two additional samples from the north shoreline were from small watercourses east of the Foula Wick fishery and south of the Parkgate fishery. All samples were transported initially by a cool backpack and then in a cool box to SSQC Ltd. for analysis on the same day.

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

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

Table 2 Water sample *E. coli* results

No.	Sample Ref.	Date/Time	Position	Type	*E.coli* (cfu/100ml)	Salinity*
1	OF-FW01	03/04/2013 08:51	HU 37355 63924	Fresh Water	3	-
2	OF-FW02	03/04/2013 09:17	HU 37826 63942	Fresh Water	<1	-
3	OF-FW03	03/04/2013 09:41	HU 38330 64015	Fresh Water	<1	-
4	OF-FW04	03/04/2013 10:28	HU 39297 63817	Fresh Water	3	-
5	OF-FW05	03/04/2013 10:36	HU 39328 63785	Fresh Water	<1	-
6	OF-FW06	03/04/2013 10:57	HU 39608 63482	Fresh Water	<1	-
7	OF-SW01	03/04/2013 11:38	HU 40240 63182	Sea Water	<1	34.20
8	OF-FW07	03/04/2013 11:53	HU 40322 62919	Fresh Water	22	-
9	OF-SW02	03/04/2013 12:15	HU 40621 63210	Sea Water	<1	34.56
10	OF-FW08	03/04/2013 13:08	HU 40650 63174	Fresh Water	<1	-
11	OF-FW09	03/04/2013 13:22	HU 40862 63253	Fresh Water	26	-
12	OF-SW03	03/04/2013 13:58	HU 40322 63677	Sea Water	140	30.09
13	OF-FW10	03/04/2013 14:05	HU 40352 63790	Fresh Water	7	-
14	OF-FW11	04/04/2013 09:26	HU 36955 65150	Fresh Water	170	-
15	OF-FW12	04/04/2013 09:51	HU 37389 65183	Fresh Water	10	-

16	OF-FW13	04/04/2013 10:13	HU 37933 65243	Fresh Water	380	-
17	OF-FW14	04/04/2013 10:37	HU 38637 65291	Fresh Water	2	-
18	OF-FW15	04/04/2013 10:45	HU 38691 65256	Fresh Water	30	-
19	OF-FW16	04/04/2013 11:12	HU 39191 64896	Fresh Water	<1	-
20	OF-SW04	09/04/2013 08:34	HU 36641 64692	Sea Water	<1	35.45
21	OF-SW05	09/04/2013 08:54	HU 37130 64924	Sea Water	<1	35.50
22	OF-SW06	09/04/2013 09:11	HU 38633 65162	Sea Water	<1	35.49
23	OF-SW07	09/04/2013 09:28	HU 39240 64405	Sea Water	<1	35.39
24	OF-SW08	09/04/2013 09:47	HU 39684 63612	Sea Water	2	35.42
25	OF-SW09	09/04/2013 10:08	HU 38378 64218	Sea Water	<1	35.59

*Practical Salinity Scale 1978 (PSS-78)

Table 3 Shellfish sample *E. coli* results

No.	Sample Ref.	Date/Time	Position	Type	Depth	*E.coli* (MPN/100g)
1	OF-MUSS01	09/04/2013 08:34	HU 36641 64692	Common Mussel	Bottom	<20
2	OF-MUSS02	09/04/2013 08:34	HU 36641 64692	Common Mussel	Top	<20
3	OF-MUSS03	09/04/2013 08:54	HU 37130 64924	Common Mussel	Top	20
4	OF-MUSS04	09/04/2013 09:11	HU 38633 65162	Common Mussel	Top	20
5	OF-MUSS05	09/04/2013 09:28	HU 39240 64405	Common Mussel	Top	490
6	OF-MUSS06	09/04/2013 09:28	HU 39240 64405	Common Mussel	Bottom	50
7	OF-MUSS07	09/04/2013 09:47	HU 39684 63612	Common Mussel	Top	490
8	OF-MUSS08	09/04/2013 09:47	HU 39684 63612	Common Mussel	Bottom	<20
9	OF-MUSS09	09/04/2013 10:08	HU 38378 64218	Common Mussel	Top	50

Table 4 Salinity profiles

Profile	Date/Time	Position	Depth (m)	Salinity (ppt) (± 0.35 ppt)	Temperature (°C)
1	09/04/2013 08:34	HU 36641 64692	surface	34.53	5.6
			3	34.94	5.6
			5	34.97	5.6
			10	34.9	5.5
2	09/04/2013 08:54	HU 37130 64924	surface	35.1	5.5
			3	35.06	5.5
			5	35.07	5.5
			10	35.06	5.5
3	09/04/2013 09:11	HU 38633 65162	surface	35.15	5.7
			3	35.12	5.5
			5	35.09	5.4
			10	35.06	5.4
4	09/04/2013 09:28	HU 39240 64405	surface	35.23	5.7
			3	35.18	5.5
			5	35.13	5.5
			10	34.98	5.2
5	09/04/2013 09:47	HU 39684 63612	surface	35.24	5.7
			3	35.22	5.7
			5	35.19	5.8
			10	35.04	5.5
6	09/04/2013 10:08	HU 38378 64218	surface	35.11	5.6
			3	35.22	5.6
			5	35.2	5.6
			10	35.18	5.7

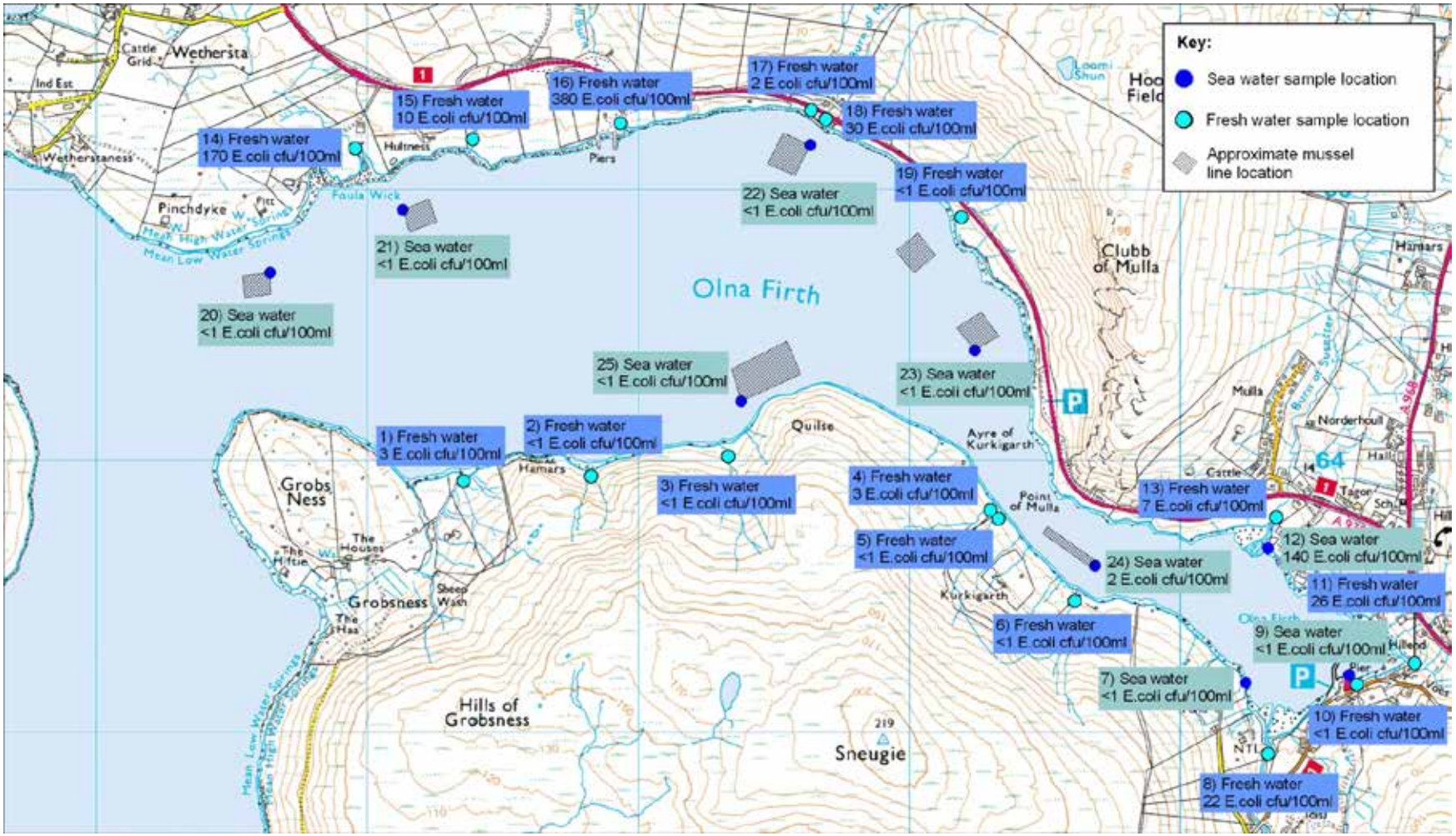

Figure 2 Map of water sample results

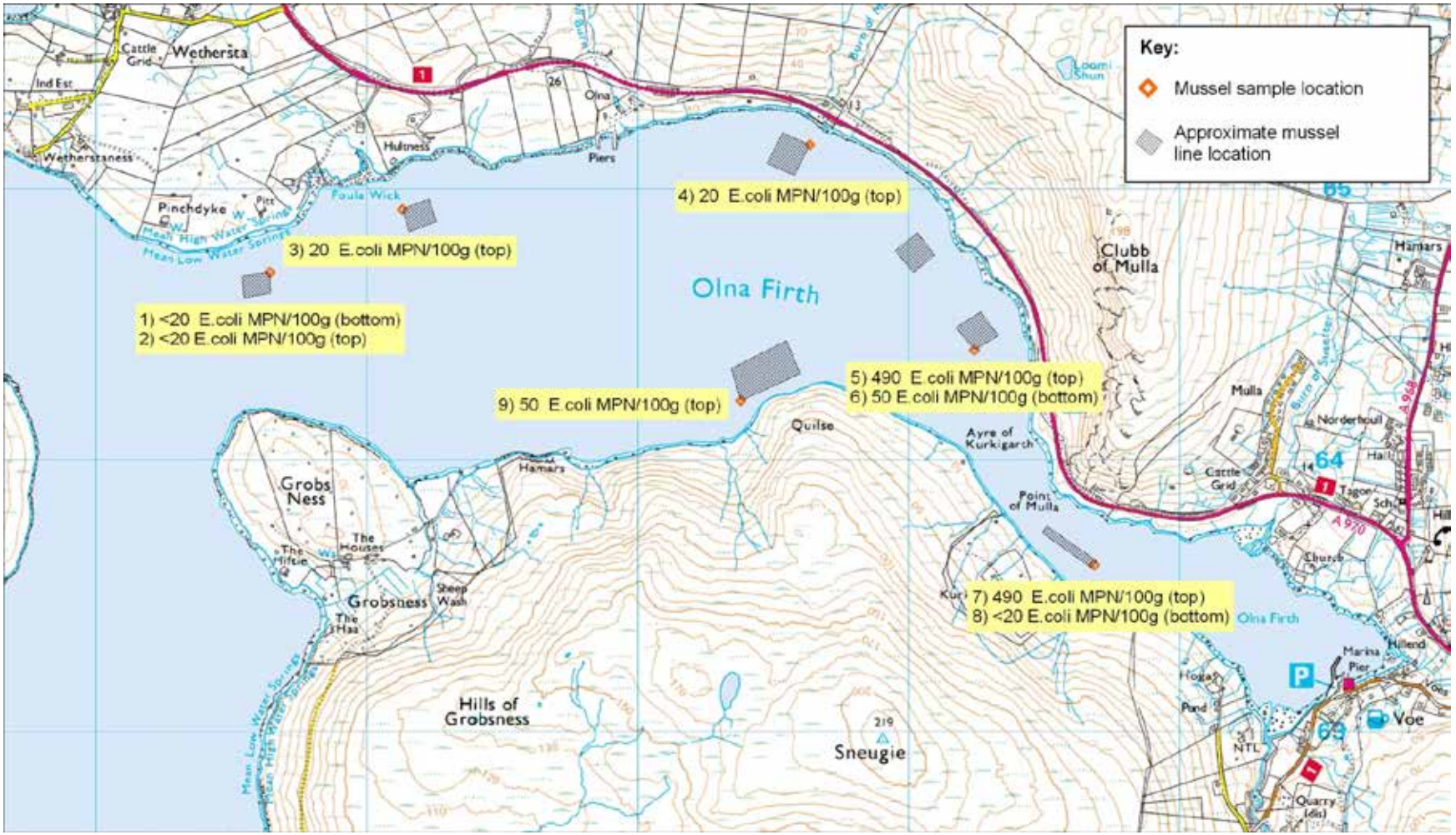

Figure 3 Map of shellfish sample results

Photographs

Figure 4 – Mussel lines at the Clubb of Mulla fishery (2 groups of 8 lines) looking north.

Figure 5 – Mussel lines at the Foula Wick fishery looking south.

Figure 6 – Mussel lines at the Inner fishery looking south to Voe.

Figure 7 – Mussel lines at the Outer fishery looking north.

Figure 8 – Mussel lines at the Parkgate fishery looking west.

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

Figure 10 – Septic tank of an occupied property at Hoga, west of Voe.

Figure 11 – Voe pumping station.

Figure 12 – Septic tank below an occupied property at Olna.

Figure 13 – Overflow pipe of a septic tank discharging to the shore associated with a property east of the Pinchdyke fishery.

Figure 14 – Drain leading to the shore from an agricultural building at Hoga.

Figure 15 – Freshwater sample and flow rate obtained from a large watercourse below occupied dwellings adjacent to the Foula Wick fishery.

Figure 16 – Freshwater sample and flow rate obtained from a watercourse below occupied dwellings at Olna.

Figure 17 – Boats berthed at Voe marina.

Figure 18 – Sheep grazing on the hill above a small watercourse near Grobsness.

Figure 19 – Sheep grazing in a fenced area next to a dwelling west of Hultness.

Figure 20 – Small watercourse sampled west of the Outer fishery with a sheep carcass present.

Figure 21 – Bird faecal matter on a mussel float at the Inner fishery.

Figure 22 – Voe community septic tank with shell debris, potentially used as a feeding area for birds.

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