Scottish Sanitary Survey Project

Sanitary Survey Report

Mid Yell Voe

SI 216

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Cefas

FOOD STANDARDS AGENCY SCOTLAND

Buidheann Inbhe-Bìdhe an Alba

Report Distribution – Mid Yell Voe

Date	Name	Agency*
	Francis Brewis	Scottish Government
	Judith White	Scottish Government
	Ewan Gillespie	SEPA
	Douglas Sinclair	SEPA
	Stephan Walker	Scottish Water
	Alex Adrian	Crown Estate
	Dawn Manson	Shetland Islands Council
	Sean Williamson	NAFC
	Gilbert Clark	Harvester **
	Erland Smith	Harvester **

* Distribution of both draft and final reports to relevant agency personnel is undertaken by FSAS.

** Distribution of draft and final reports to harvesters in undertaken by the relevant local authority.

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Dr. Alan Lilly, Macaulay Land Research Institute

1. General description

Mid Yell Voe is located on the island of Yell, to the north of mainland Shetland (Figure 1.1). The voe is 3.3 km in length and maximum water depth is 20 m. There is moderate inflow of freshwater to the voe as indicated by a reported salinity reduction of 10 (SEPA). The burn of Houll empties into the voe adjacent to the pier at Camb on the north shore. Laxa Burn and the Burn of Reafirth enter the voe along the shouth shore. There are no basins within the voe and it has a fairly open easterly aspect.

The town of Mid Yell is the main population centre for the island, with population around the voe estimated at 477.

Figure 1.1 Location map of Mid Yell Voe

2. Fishery

The fishery at Mid Yell Voe consists of two long line mussel (*Mytilus* sp.) farms as listed below:

Table 2.1 Mussel farms at Mid Yell Voe

Site	SIN	Species
Seafield	SI 216 432 08	Common mussels
Camb	SI 216 430 08	Common mussels

Current production area boundaries are gives as the area bounded by lines drawn between HU 5060 9193 to HU 5060 9175 and HU 5180 9195 to HU 5190 9098 extending to mean high water springs (MHWS). The production area coincides with a designated shellfish growing water.

No lease was identified against the Seafield site in data received from the Crown Estate, however Shetland Island Council identified two areas for which it has granted permission for shellfish aquaculture both of which roughly correspond with the locations of the mussel lines observed during the shoreline survey.

The RMP for the production area is currently given as HU 514 918 which plots as lying 46 m to the south southwest of the recorded Seafield mussel farm.

At both sites, mussels are grown on double-headed longlines to a depth of 6 metres. Long lines attached to floats are laid out in parallel lines anchored at either end within the approved lease area. Vertical lines containing plastic pegs (droppers) are attached to the long lines. New lines are placed before or during spawning between May and early June and spat settle onto the droppers from the surrounding water. The spat are then left to grow for up to three years before reaching marketable size.

At the time of the shoreline survey, Seafield had 6 longlines on site one of which was due to be moved to a site at Basta Ness according to the harvester. The site at Camb also had 6 longlines.

Mature mussels are stripped either by hand or by passing them through a system of brushes mounted to a funnel.

Harvesting is done in rotation with different lines set out in different years to allow harvest of some stock each year.

Figure 2.1 shows the relative boundaries of the mussel farms, FSAS designated production area, shellfish growing water area and the seabed lease area provided by the Crown Estate.

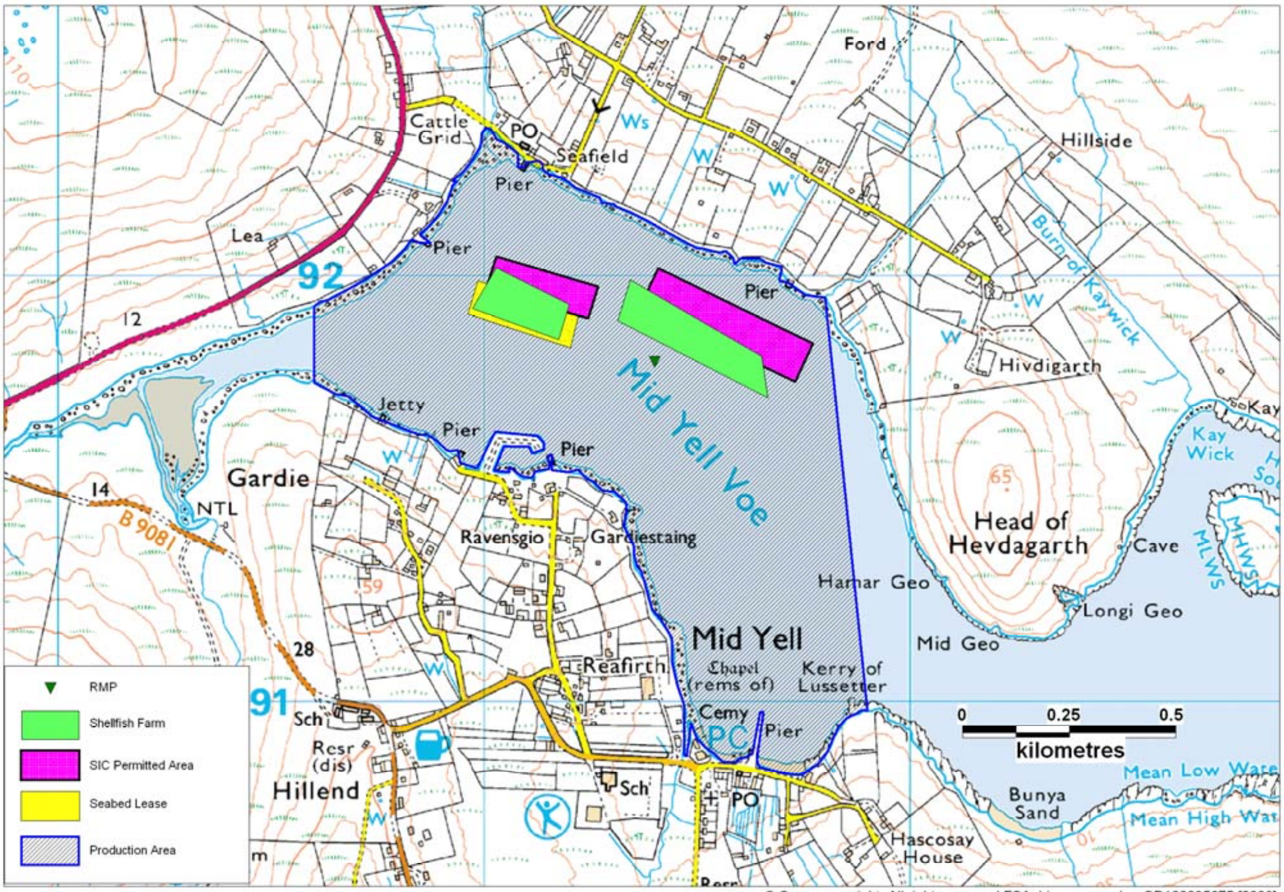


Figure 2.1 Map of Mid Yell Voe Fishery

3. Human population

The figure below shows information obtained from the General Register Office for Scotland on the population within the census output in the vicinity of Mid Yell Voe.

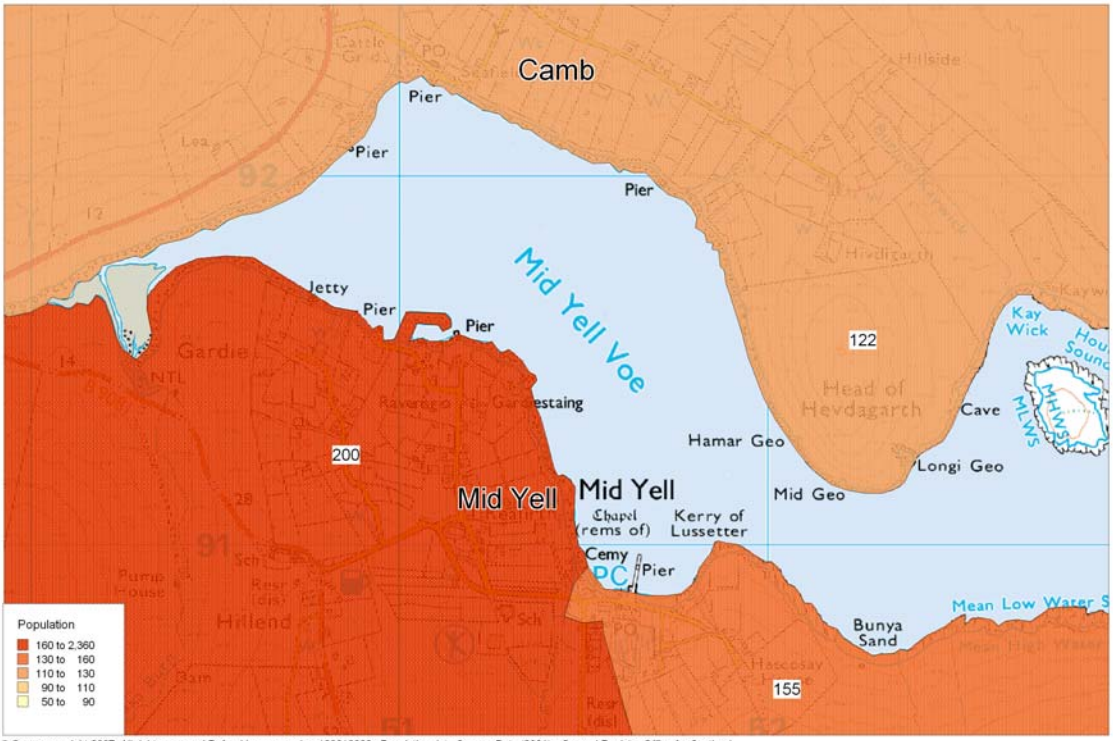


Figure 3.1 Map to show population in adjacent census output areas

The population for the three census output areas bordering immediately on Mid Yell Voe are:

60RD000057	122
60RD000055	155
60RD000056	200

There are two settlements immediately bordering Mid Yell Voe. The first is the settlement of Camb on the northern shore. The second is the town of Mid Yell, which runs along the southern coastline of the voe. Most of the population is concentrated towards the southern shore of the voe and any associated faecal pollution from human sources will be concentrated in these areas.

For Shetland as a whole, the total number of holiday travellers in 2006 was estimated as 24,744 (compared to the 2001 census population of 21, 988) with the majority of tourists (66%) visiting during the peak summer season of June to September (Shetland Enterprise, Shetland Visitor Survey 2005/2006). There is no explicit information on the number of visitors to this specific area. There are no known holiday parks or caravan sites in the immediate area of the voe. There could therefore be an increase in faecal contamination from human sources during the summer months but there is not sufficient information on which to base an estimate for this area.

4. Sewage Discharges

Community septic tanks and sewage discharges were identified by Scottish Water for the area around Mid Yell Voe. They are detailed in Table 4.1.

Table 4.1 Discharges identified by Scottish Water

NGR	Discharge name	Discharge Type	Level of Treatment	Consented design PE
HU 51449 90917	Cemetery Mid Yell	Continuous	Septic Tank	250
HU 51598 90863	Linkshouse Mid Yell	Continuous	Septic Tank	250
HU 51818 91975	North a Voe Mid Yell	Continuous	Septic Tank	250
HU 51115 91511	Ravensgeo Mid Yell	Continuous	Septic Tank	250
HU 51053 92313	Seafield Mid Yell	Continuous	Septic Tank	250

No sanitary or microbiological data were available for these discharges.

A number of discharge consents are held by SEPA and are listed in Table 4.2. At the time of writing, information on CAR/L/1012466 had not yet been received from SEPA

Table 4.2 Discharge consents held by SEPA

Ref No.	NGR of discharge	Discharge Name	Discharge Type	Level of Treatment	Consented flow (DWF) m3/d	Consented/ design PE	Notes
CAR/L/1002253	HU 5128592163 and HU5111491557	Ravensgeo Mid Yell	Continuous	Septic Tank		250	2 Grid Ref given Original consent for Gardiestaing (HU513915)
CAR/L/1002251	HU5111992244	North-a-Voe Mid Yell	Continuous	Septic Tank		250	North-a-Voe (No1)
CAR/L/1002250	HU 5151390942	Cemetery Mid Yell	Continuous	Septic Tank		250	Original consent for Reafirth (HU512915)
CAR/L/1002252	HU5096891572	Linkshouse	Continuous	Septic Tank		250	Original consent gives location of HU 515909
CAR/L/1002318	HU5125790737	Yell Leisure Centre	Swimming pool filter backwash		none specified	na	Discharge for Mid Yell Swimming Pool
CAR/L/1002284	HU5128592163	Seafield	Continuous	Septic Tank		250	Original consent for North-a-Voe 2
CAR/L/1012466	HU5074690154						

There is some discrepancy regarding the location of the discharges for septic tanks in Mid Yell Voe. SEPA discharge records contain conflicting grid references for the same discharge and the grid references given by SEPA and Scottish Water for the Cemetery, Linkshouse, North-a-Voe and Ravensgeo septic tanks do not match. The SEPA grid references appear to relate to the outfalls and the Scottish Water references to the septic tanks themselves, but this is not clear. An outfall was observed at the North-a-Voe septic tank, though its recorded outfall according to SEPA lies nearly half a kilometer to the west.

A number of septic tanks and/or outfalls were recorded during the shoreline survey. Their locations have been included in the mapped discharges in

Figure 4.1. Observed septic tanks, covers and/or discharge pipes, including results from any associated samples, are listed in Table 4.3.

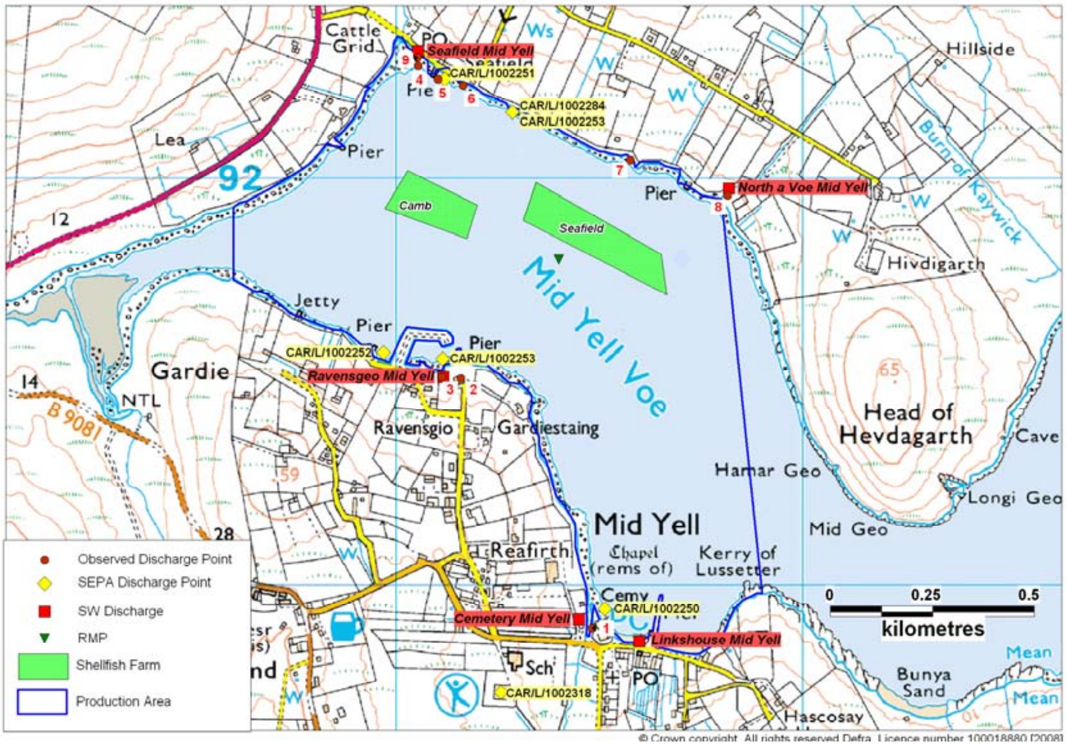


Figure 4.1 Map of discharges at Mid Yell Voe

Table 4.3 Discharges and septic tanks observed during shoreline survey

No	NGR	Description	Sample No.	Type	E.coli (cfu/100ml)
1	HU51481 90896	Septic tank at care home	none	-	-
2	HU51158 91508	Septic tank cover adjacent to stone pier	MY 8	Seawater	1900
3	HU51111 91511	Septic tank outfall	MY 9	Seawater	800
4	HU51053 92276	Sewage pipe	MY 13	Seawater	800
5	HU51102 92243	Corroded iron pipe below tide line, not discharging	MY 15	Seawater	36
6	HU51164 92228	Buried pipe and inspection cover	MY 16	Seawater	200
7	HU51575 92045	Broken pipe discharging on shore	MY 19	Freshwater	2100
8	HU51815 91958	Concrete tank with discharge into hole	MY 22	Fresh/foul	>2100
9	HU 51052 92297	Septic tank outfall	none	-	-

A substantial number of sewage discharges enter the voe within 1km of the fishery. The total consented discharge permitted to enter the voe is for a population equivalent of 1250, while according to the latest census figures the total population of the area is 477. It is likely that significantly less than the full PE discharge is entering the voe. However, given the limited area the discharges present are likely to have a significant impact on the shellfish farms. In particular, discharges from the North-a-Voe septic tank fall within

250 meters of the Seafield mussel site and would have a significant impact there.

The Seafield septic tank discharges approximately 0.5 kilometer North of the Camb mussel farm. Six septic discharge pipes were observed along the north shore of the voe during the shoreline survey though it was not possible to say whether all were in active use.

On the southern shore of the voe, a further three community septic tanks and discharges were reported. Seawater samples taken from the vicinity of these tanks showed higher levels of contamination than found along the northern shore. All but one of the reported discharge locations is again within 0.5 km of the farms.

Human sewage impact on the waters at Mid Yell Voe is significant and expected to have a negative impact on the microbiological quality of shellfish grown there.

5. Geology and soils

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

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

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

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

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

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

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

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

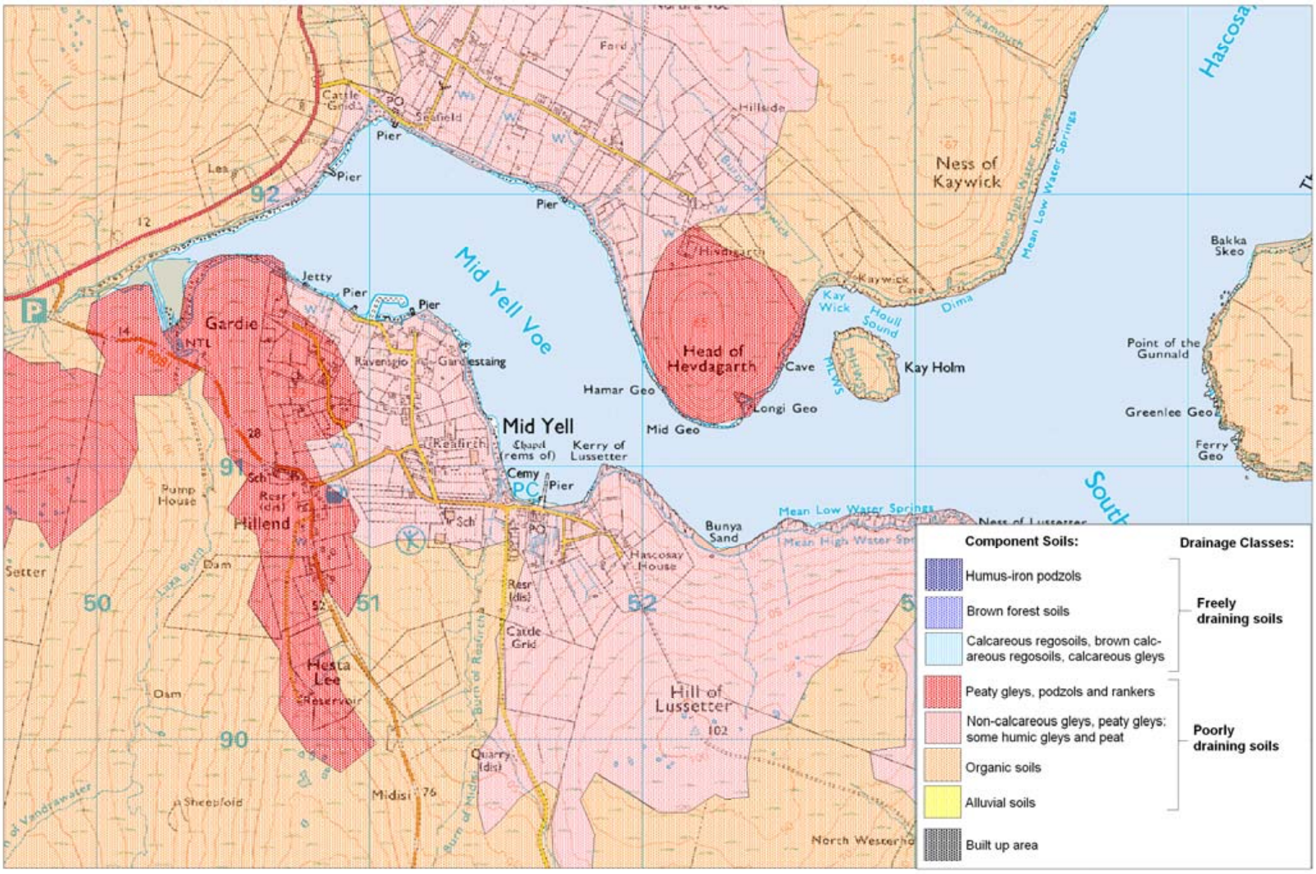


Figure 5.1 Map of component soils and drainage classes for Mid Yell Voe

Figure 5.1 shows a map of component soils and their associated drainage classes for the area of Mid Yell Voe.

There are three main types of component soils visible in this area. The most dominant is composed primarily of organic soils. This soil type only contacts with a small length of the shoreline to the north and also dominates much of the area further inland on both sides of the voe.

The second dominant component soil is composed of non-calcareous gleys, peaty gleys, some humic gleys and peat. This soil type covers much of the northern and southern coastline of Mid Yell Voe, apart from where it meets the third component soils; peaty gleys, podzols and rankers at the Head of Hevdagarth in the North and a small area, called Gardie in the west corner of the voe.

All three of the component soil types (the organic soils, peaty gleys, podzols, rankers and the non-calcareous gleys, peaty gleys: some humic gleys and peat) in this area are classed as poorly draining soils.

Understanding whether the land surrounding Mid Yell Voe is either freely or poorly draining help to indicate how much surface runoff and soil leaching could occur. In poorly draining soils (such as those surrounding Mid Yell Voe) surface run off is likely to be high, as peaty gleys, podzols, rankers, organic soils and the non-calcareous gleys are often waterlogged. This provides an indication as to the potential for contamination due to diffuse pollution from livestock and whether it is higher in certain areas.

In the case of Mid Yell Voe, the potential for runoff contaminated with *E. coli* from animal waste is high for all areas of the voe.

Glossary of Soil Terminology

Calcareous: Containing free calcium carbonate.

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

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

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

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

6. Land cover

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

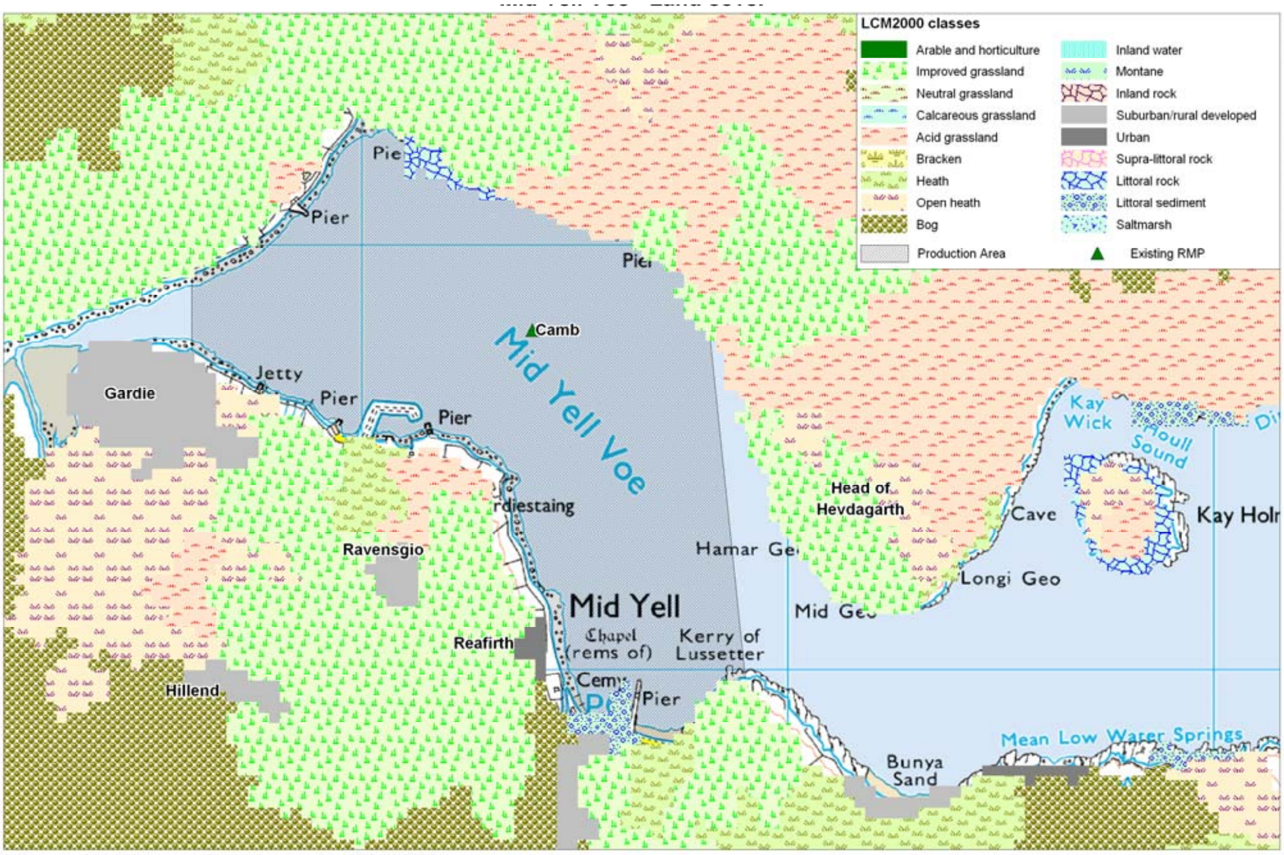


Figure 6.1 LCM2000 class data map for Mid Yell Voe

On the north side of Mid Yell Voe the land cover is predominantly improved grassland and acid grassland. On the Head of Hevdagarth there are also several patches of open heath. The land cover on the south side of the voe is more mixed with suburban/rural developed areas and patches of heath, open heath, acid grassland, improved grassland and bog. On the northern coastline there is an area of littoral rock and on the southern coastline there is an area of littoral sediment.

The faecal coliform contribution would be expected to be highest from developed areas, such as Gardie (approx 1.2 – 2.8×10^9 cfu km^{-2} hr^{-1}), with intermediate contributions from the improved grassland (approximately 8.3×10^8 cfu km^{-2} hr^{-1}) and lowest from the other land cover types (approximately 2.5×10^8 cfu km^{-2} hr^{-1}) (Kay *et al*. 2008). The contributions from all land cover types would be expected to increase significantly after marked rainfall events, this being expected to be highest, at more than 100-fold, for the improved grassland.

7. Farm Animals

Regulation (EC) No. 854/2004 requires the competent authority to:

(a) make an inventory of the sources of pollution of human or animal origin likely to be a source of contamination for the production area;
(b) examine the quantities of organic pollutants which are released during the different periods of the year, according to the seasonal variations of both human and animal populations in the catchment area, rainfall readings, waste-water treatment, etc.

With regard to potential sources of pollution of animal origin, agricultural census data to parish level was requested from the Scottish Government. The request was declined on the grounds of confidentiality because the parishes in most cases contained only a small number of farms making it possible to determine specific data for individual farms. The only significant source of information was therefore the shoreline survey (see Appendix) which only relates to the time of the site visit on 4-5 September, 2007.

The shoreline survey identified that sheep were grazed widely around the voe and that there were no significant concentrations in one or more areas over others. The geographical spread of contamination at the shores of the voe is therefore considered to be even (although random with regard to specific time and place) and therefore needs to be assumed that this factor does not have to be taken into account when identifying the location of a routine monitoring point (RMP).

Local information (Shetland Agricultural Centre, personal communication) idicated that numbers of sheep in the period May to September was approximately double that in other periods. Any contamination due to this source is therefore likely to be increased during the period.

The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1.

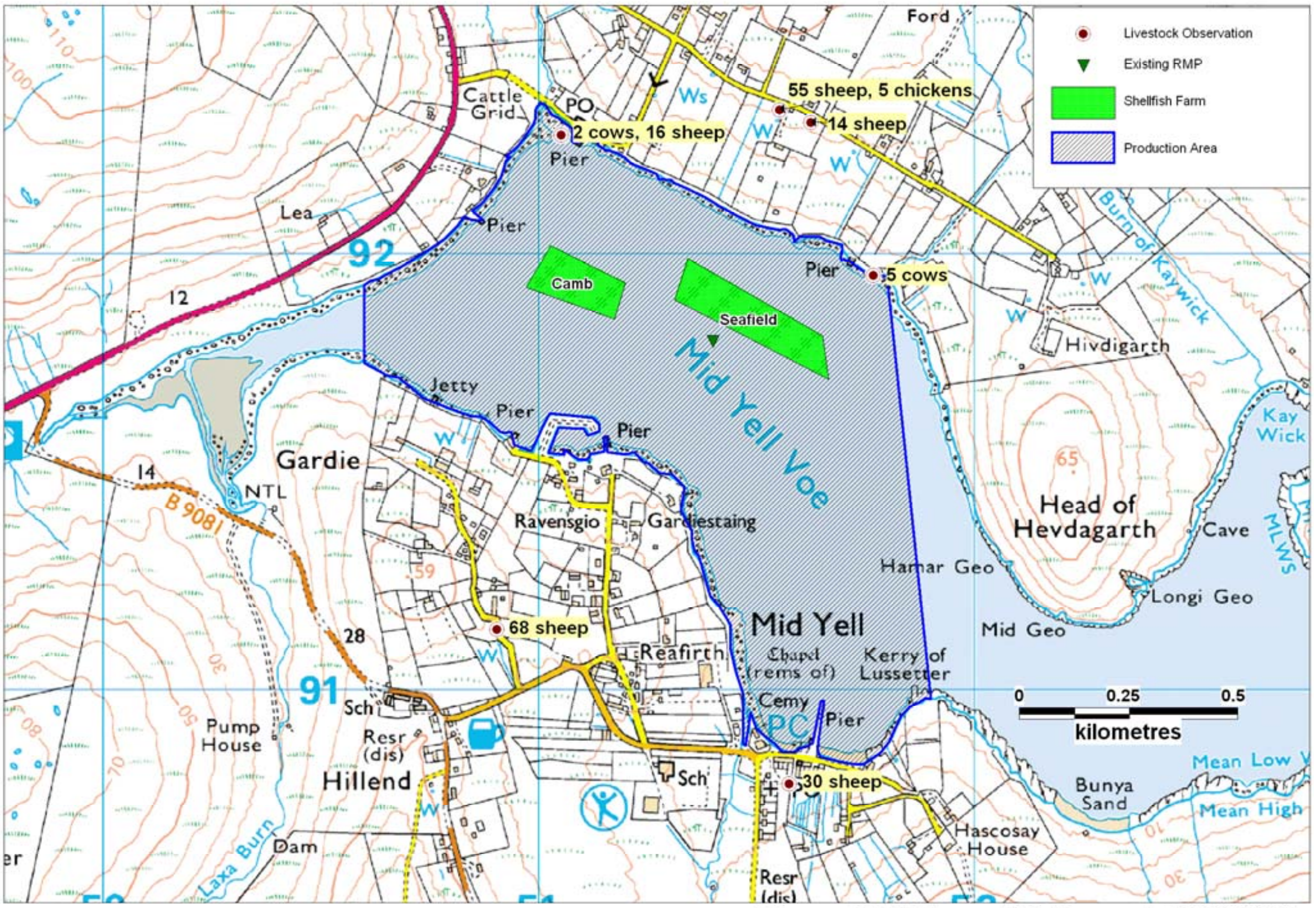


Figure 7.1 Map of livestock observed at Mid Yell Voe

8. Wildlife

8.1 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*). Shetland hosts significant populations of both species.

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

Common seals surveys are conducted every 5 years and an estimate of minimum numbers is available through Scottish Natural Heritage. The Shetland-wide count in 2001 was 4883 harbour seals, though this was anticipated to be an underestimation of the total population (Sea Mammal Research Unit 2002). A further survey was to have been conducted in 2006, however the populations observed in Shetland had declined by approximately 40% on the 2001 survey and so detailed figures have been withheld pending further survey. A final report is expected in late 2007.

While there are no haulout sites recorded within Mid Yell Voe itself, seals are likely to use the voe for foraging and may be present at any time.

According to the Scottish Executive, in 2001 there were approximately 119,00 grey seals in Scottish waters, the majority of which were found in breeding colonies in Orkney and the Outer Hebrides. While no mention was made of populations in Shetland in 2001, in 1996, the Shetland grey seal population was estimated to be around 3,500 (Brown & Duck 1996).

Seals have been observed lying between mussel floats in Shetland (R. Anderson, personal communication) so it is anticipated that there could be some impact to the fisheries though this may be spatially and temporally limited.

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 110 kg, that would equate to 6.6 kg consumed per day and probably very nearly that defecated.

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).

Seals will forage widely for food and it is likely that seals will feed near the mussel farms at some point in time. The population is relatively small in relation to the size of the area concerned and is highly mobile therefore it is likely that any impact will be limited in time and area and unpredictable.

8.2 Cetaceans

A variety of cetacean species are routinely observed near Shetland. During 2001-2002, there were confirmed sightings of the following species (Shetland Sea Mammal Group 2003):

Table 8.1 Cetacean sightings near Shetland by species.

Common name	**Scientific name**	**No. sighted***
Minke whale	*Balaenoptera acutorostrata*	28
Humpback whale	*Megaptera novaeangliae*	1
Sperm whale	*Physeter macrocephalus*	3
Killer whale	*Orcinus orca*	183
Long finned pilot whale	*Globicephala melas*	14
White-beaked dolphin	*Lagenorhynchus albirostris*	399
Atlantic white-sided dolphin	*Lagenorhynchus acutus*	136
Striped dolphin	*Stenella coeruleoalba*	1
Risso’s dolphin	*Grampus griseus*	145
Common dolphin	*Delphinus delphis*	6
Harbour porpoise	*Phocoena phocoena*	>500

*Numbers sighted are based on rough estimates based on reports received from various observers and whale watch groups.

Little is known about the volume or bacterial composition of cetacean faeces. As mammals, it can be safely assumed that their guts will contain an unknown concentration of normal commensal bacteria, including *Escherichia coli*. There have been some sightings in and around Weisdale Voe, however these accounts are sparse. It is highly likely that cetaceans will be found from time to time in the sound and the impact of their presence is, as with pinnipeds, likely to be fleeting and unpredictable.

8.3 Seabirds

A number of seabird species breed in Shetland. These were the subject of a detailed census in 2000. Of the 25 seabird species identified as regularly breeding in Britain, 19 have substantial presence in Shetland (Mitchell, *et. al.* 2004).

Table 8.2 Breeding seabirds of Shetland

Common name	Species	Population	Common name	Species	Population
Northern Fulmar	*Fulmarus glacialis*	188,544*	Northern Gannet	*Morus bassanus*	26,249
European Storm Petrel	*Hydrobates pelagicus*	7,503*	Great Cormorant	*Phalacrocorax carbo*	192*
European Shag	*Phalacrocorax aristotelis*	6,147	Arctic skua	*Stercorarius parasiticus*	1,120
Great Skua	*Stercorarius skua*	6,846*	Black-headed Gull	*Larus ridibundus*	586
Common Gull	*Larus canus*	2,424	Lesser Black-backed Gull	*Larus fuscus*	341
Herring Gull	*Larus argentatus*	4,027	Great Black-backed Gull	*Larus marinus*	2,875
Black-legged Kittiwake	*Rissa tridactyla*	16,732	Common Tern	*Sterna hirundo*	104
Arctic Tern	*Sterna paradisaea*	24,716	Common Guillemot	*Uria aalge*	172,681
Razorbill	*Alca torda*	9,492	Black Guillemot	*Cepphus grille*	15,739
Atlantic Puffin	*Fratercula arctica*	107,676*			

*Population number based on Apparently Occupied Sites, Territories, Nests or Burrows. These may equate to more than one adult.

Of these, some are pelagic except during the breeding season and so would not impact the fisheries except during the summer months.

The area around Mid Yell Voe is not particularly well suited to the cliff nesting bird species. Nothern Fulmars and various gulls have all been recorded as breeding in the area. Northern Fullmars and the common gull species breed ubiquitously around the island. Their specific distribution around Mid Yell Voe was not available. It is therefore assumed that their distribution will be roughly even and not relevant to assessing the location of an RMP for the Mid Yell Voe production area.

8.4 Other

There is a significant population of European Otters (*Lutra lutra*) present in Shetland with parts of Yell Sound nominated as candidate Special Areas of Conservation (cSAC) for otters. Within Yell Sound, an otter survey was conducted in 2002 and an estimated 277 otters were recorded (Shetland Sea Mammal Group 2003). Mid Yell Voe is not host to a significant otter population, though otters may be present in parts of the voe.

Coastal otters, such as those found in Shetland, tend to be more active during the day, feeding on bottom-dwelling fish and crustaceans among the seaweed found on rocky inshore areas. An otter will occupy a home range extending along 4-5km of coastline, though these ranges may sometimes overlap (Scottish Natural Heritage website). Otters primarily forage within the 10m depth contour and feed on a variety of fish, crustaceans and shellfish (Paul Harvey, Shetland Sea Mammal Group, personal communication).

Otters leave faeces (also known as spraint) along the shoreline or along streams which is subject to run into the water either due to rainfall or on the incoming tide. No information was found at the time of this report on the bacteriological content of otter feaces. However, given the total numbers present in Yell Sound and the foraging habits described above it is highly unlikely that otter feaces will be a significant source of contamination to the fishery.

Waterfowl (ducks and geese) are present in Shetland at various times of the year. Eider ducks feed on the mussel lines and are present, sometimes groups of 100 or more, throughout the year. Geese tend to pass through during migrations but do not linger in very large numbers as they do further south. Waterfowl impact on the fisheries in Mid Yell Voe is likely to be mostly that of Eider ducks feeding on the mussel lines and gulls or other seabirds resting on the floats.

Wildlife impact generally to the fisheries is likely to be minimal compared to the impact of diffuse pollution due to livestock. While some species can harbour bacteria and viruses that can cause illness in humans, their faeces are considered to pose a lower risk to human health than either human or livestock faecal contamination. Whilst large cetaceans and other marine mammals have been observed in and near Yell Sound, their presence is not likely to impact the fisheries within Mid Yell Voe in a manner that would impact the sampling plan.

9. Meteorological Data

The nearest weather station is located at Baltasound, approximately 19 km to the north east of the production area. Uninterrupted rainfall data is available for Baltasound from 1/1/2003 to 31/10/2006 inclusive. It is likely that rainfall patterns at Baltasound are similar but not identical to those on Mid Yell Voe and surrounding land due to their proximity, but may differ slightly on any given day. The nearest weather station for which wind data is available is located at Lerwick, approximately 50 km to the south of the production area. It is expected that wind patterns in Mid Yell Voe are broadly similar to those experienced at Lerwick, but it is possible the differences in local topography affect wind patterns and that the distance between the weather station and the production area may result in differences on any given day. This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish within Mid Yell Voe.

9.1 Rainfall

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

Figures 9.1 to 9.4 summarise the pattern of rainfall recorded at Baltasound. The box and whisker plots summarize the distribution of individual daily rainfall values (observations) by year (Figure 9.2) or by month (Figure 9.4). 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 *. No data was given for Nobember and December 2006 in the data set supplied by the Meteorological Office.

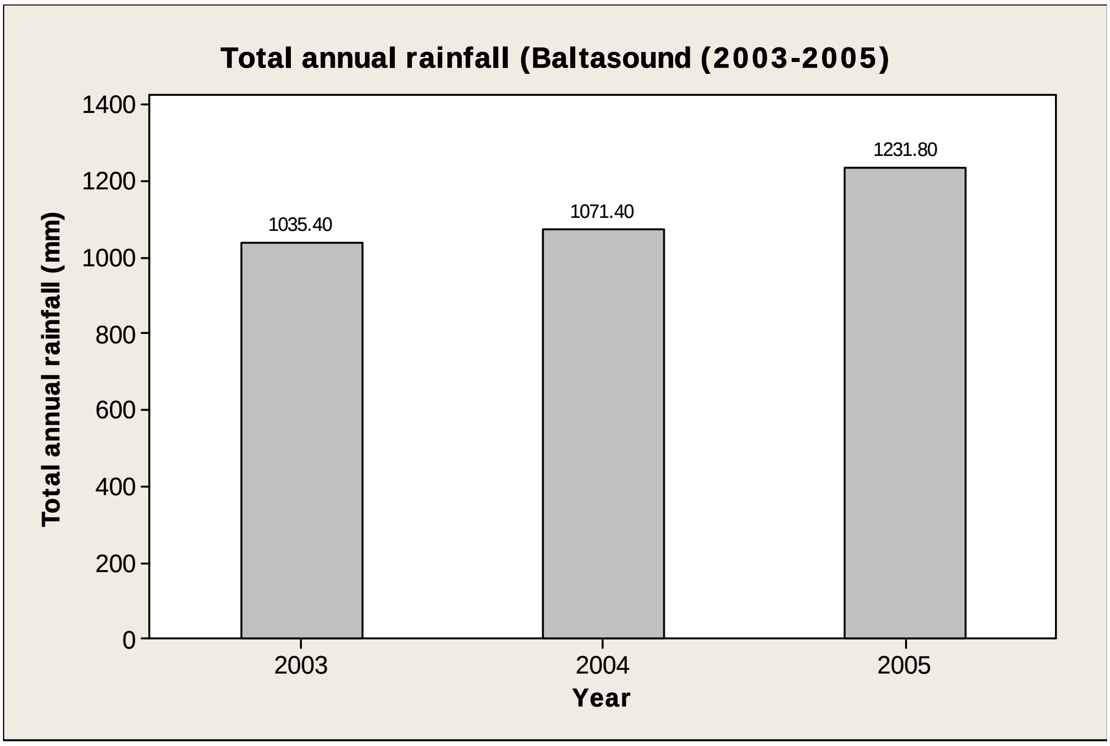


Figure 9.1 Bar chart of total annual rainfall at Baltasound 2003-2005

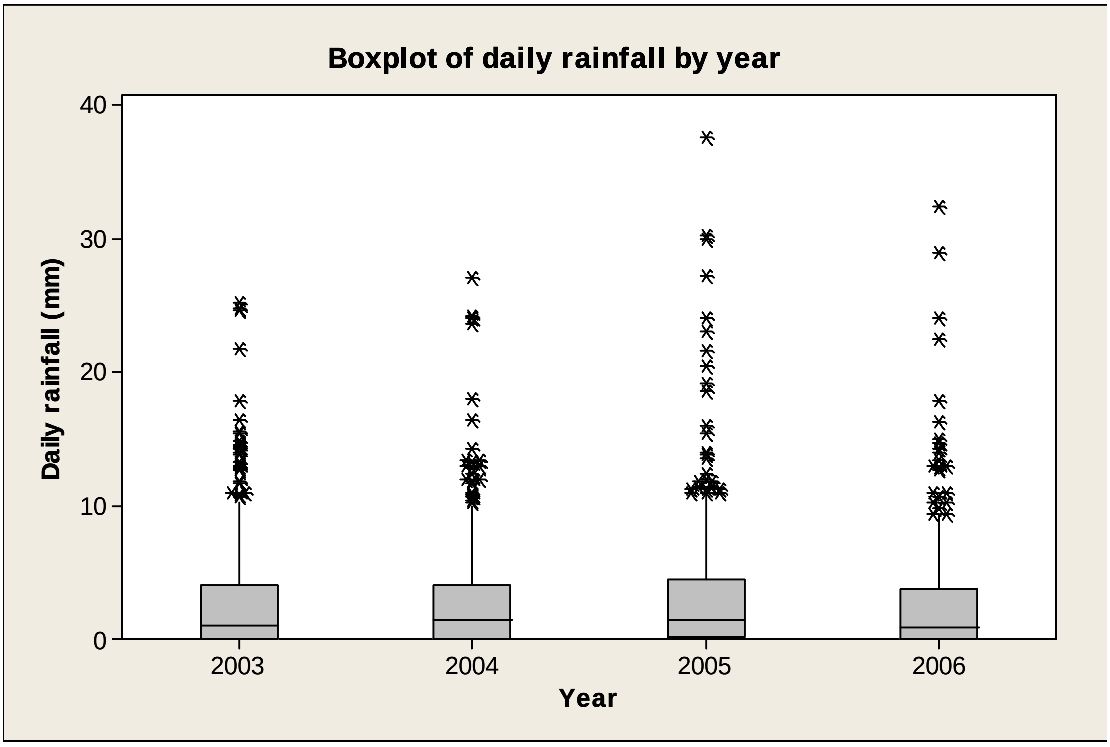


Figure 9.2 Boxplot of daily rainfall by year at Baltasound (no data for November and December 2006)

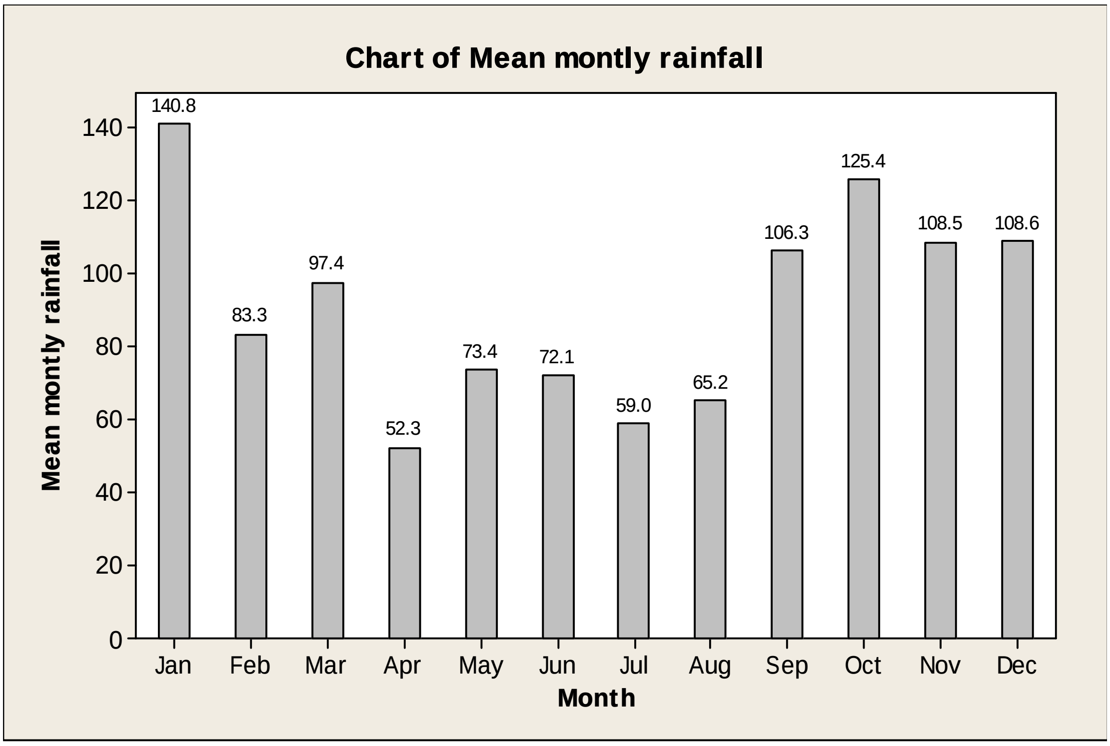


Figure 9.3 Chart of mean monthly rainfall at Baltasound 2003-2006 (no data for November and December 2006)

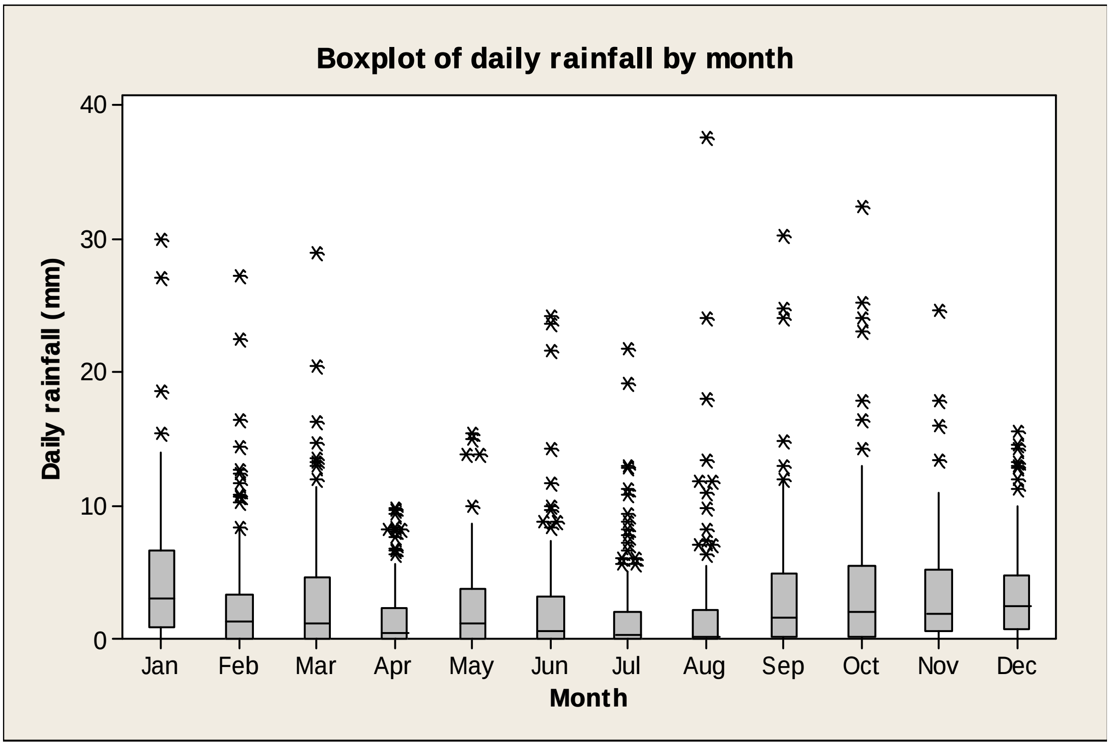


Figure 9.4 Boxplot of daily rainfall values at Baltasound by month (no data for November and December 2006)

The wettest months were September through to January. For the period considered here (1/1/2003-31/10/2006), only 27.0% of days experienced no rainfall. 45.6% of days experienced rainfall of 1mm or less.

It was not possible to draw a meaningful comparison between rainfall at Baltasound and that of Scotland as a whole with the data available. A comparison of Lerwick rainfall data with Scotland average rainfall data for the period of 1970-2000 is presented in Table 9.3 (Data from Met office website © Crown copyright). This indicates that rainfall in Lerwick was lower than the average for the whole of Scotland for every month of the year, but there were fewer dry days in Lerwick during the autumn, winter and spring.

Table 9.2 - Comparison of Lerwick mean monthly rainfall with Scottish average 1970-2000.

Month	Scotland rainfall (mm)	Lerwick rainfall (mm)	Scotland - days of rainfall >= 1mm	Lerwick - days of rainfall >= 1mm
Jan	170.5	135.4	18.6	21.3
Feb	123.4	107.8	14.8	17.8
Mar	138.5	122.3	17.3	19
Apr	86.2	74.2	13	14.4
May	79	53.6	12.2	10.1
Jun	85.1	58.6	12.7	11.3
Jul	92.1	58.5	13.3	11
Aug	107.4	78.3	14.1	12.5
Sep	139.7	115.3	15.9	17.4
Oct	162.6	131.9	17.7	19.4
Nov	165.9	152.4	17.9	21.5
Dec	169.6	150	18.2	22.2
Whole year	1520.1	1238.1	185.8	197.9

It can therefore be expected that levels of rainfall dependant faecal contamination entering the production area from these sources will be higher during the autumn and winter months. As there are few dry days, it is likely that some contaminated runoff from pastures is to be expected throughout the wetter months. It is possible that faecal matter can build up on pastures during the drier summer months when stock levels are at their highest, leading to more significant faecal contamination of runoff at the onset of the wetter in the autumn.

9.2 Wind

Wind data collected at the Lerwick weather station is summarised by season and presented in figures 9.5 to 9.8.

WIND ROSE FOR LERWICK
N.G.R: 4453E 11396N ALTITUDE: 82 metres a.m.s.l.

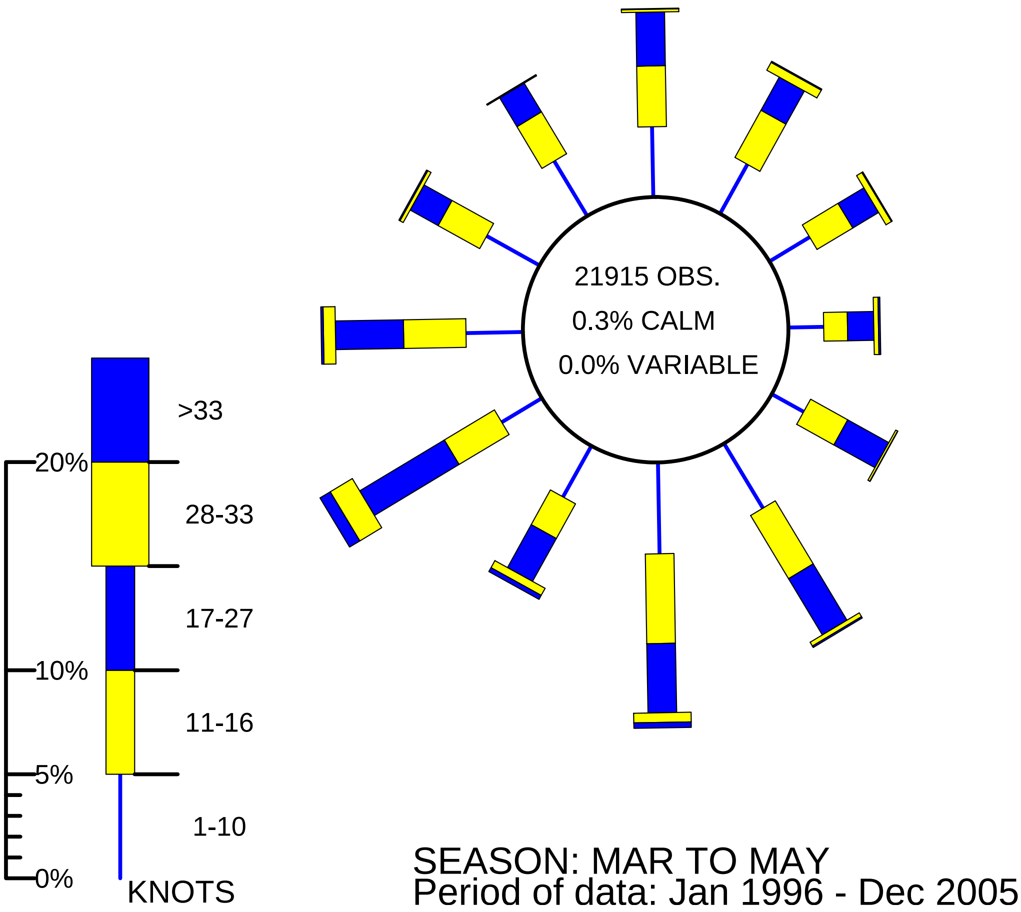


Figure 9.5 Wind rose for Lerwick (March to May)

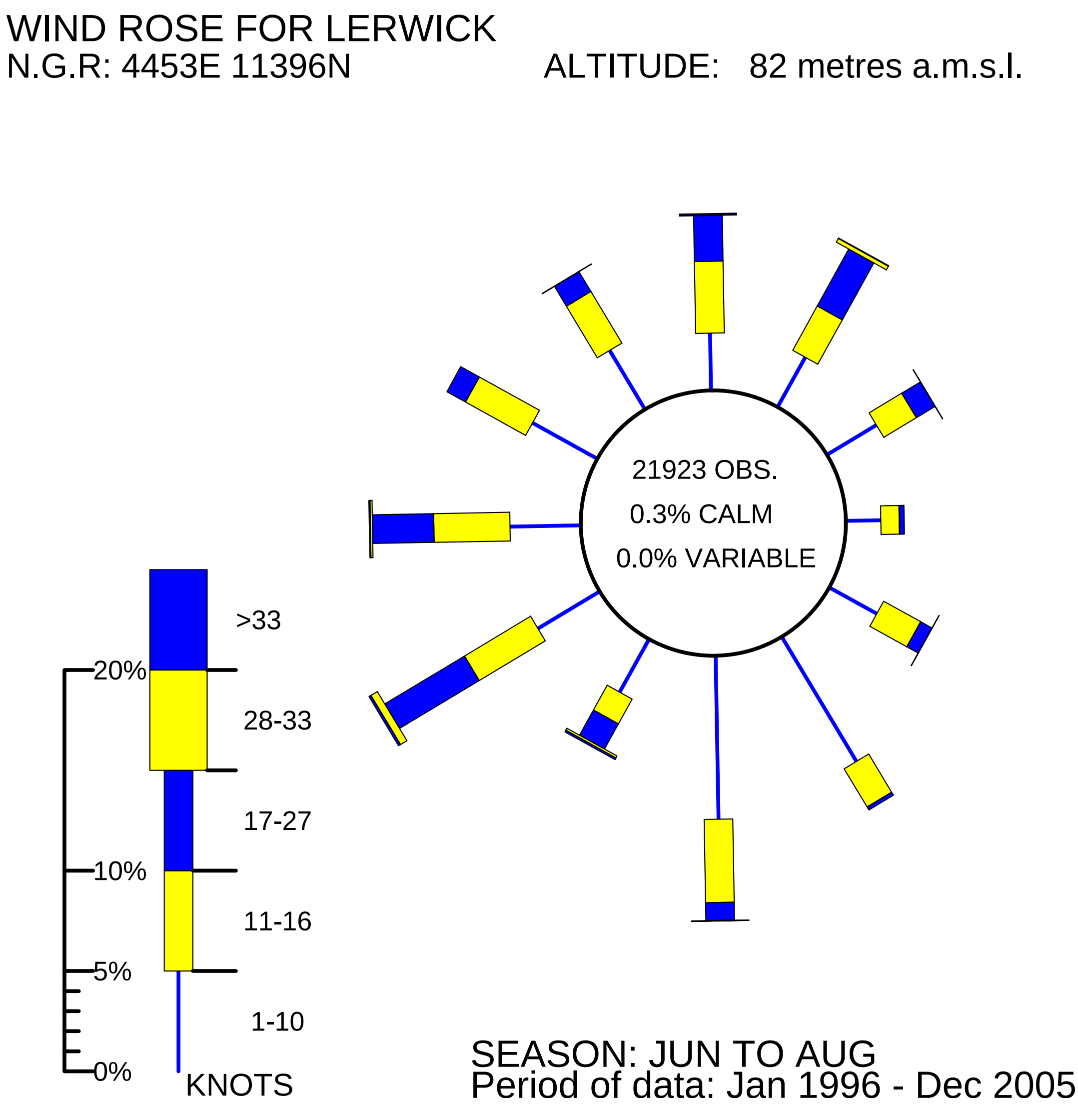


Figure 9.6 Wind rose for Lerwick (June to August)

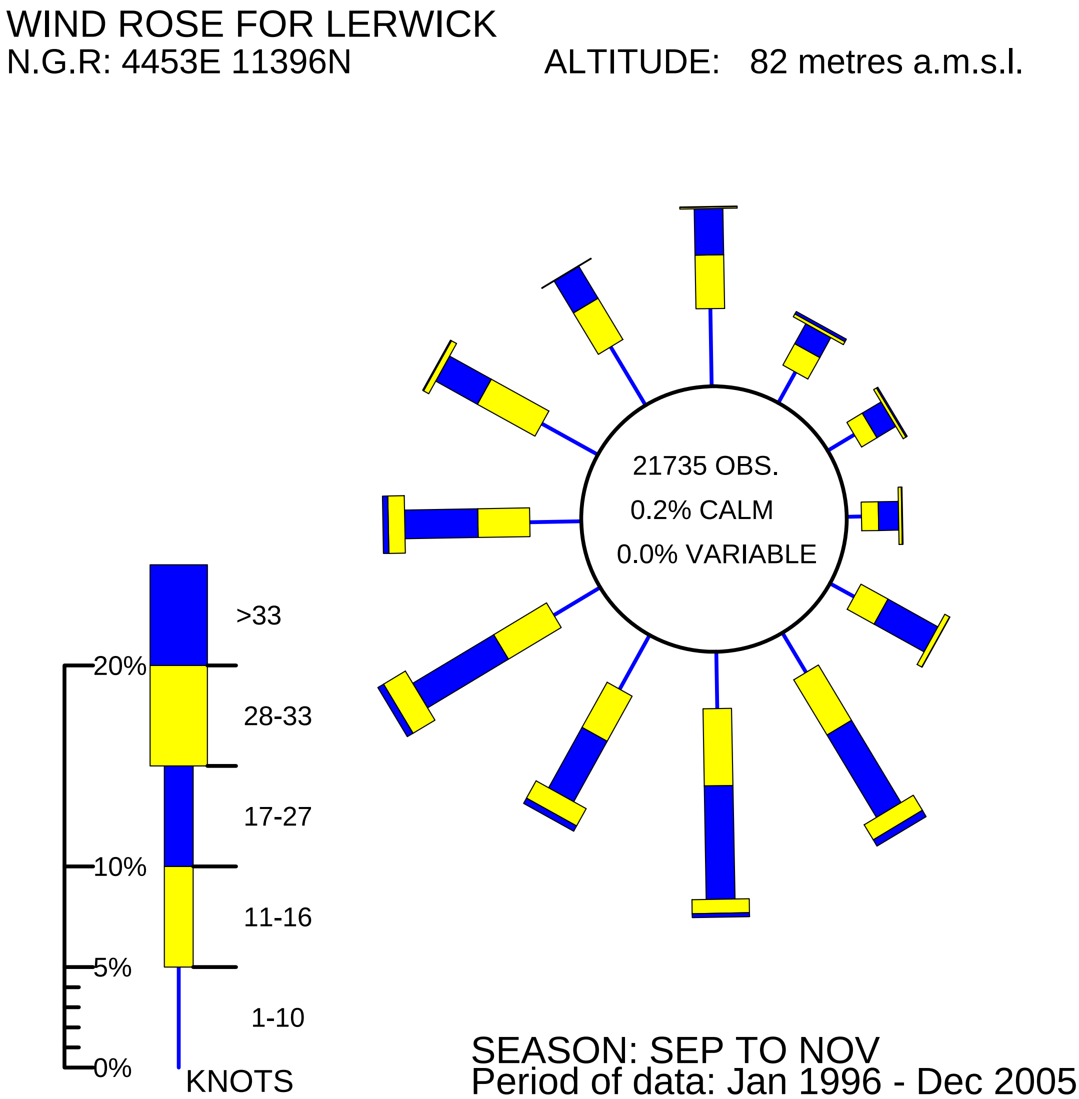


Figure 9.7 Wind rose for Lerwick (September to November)

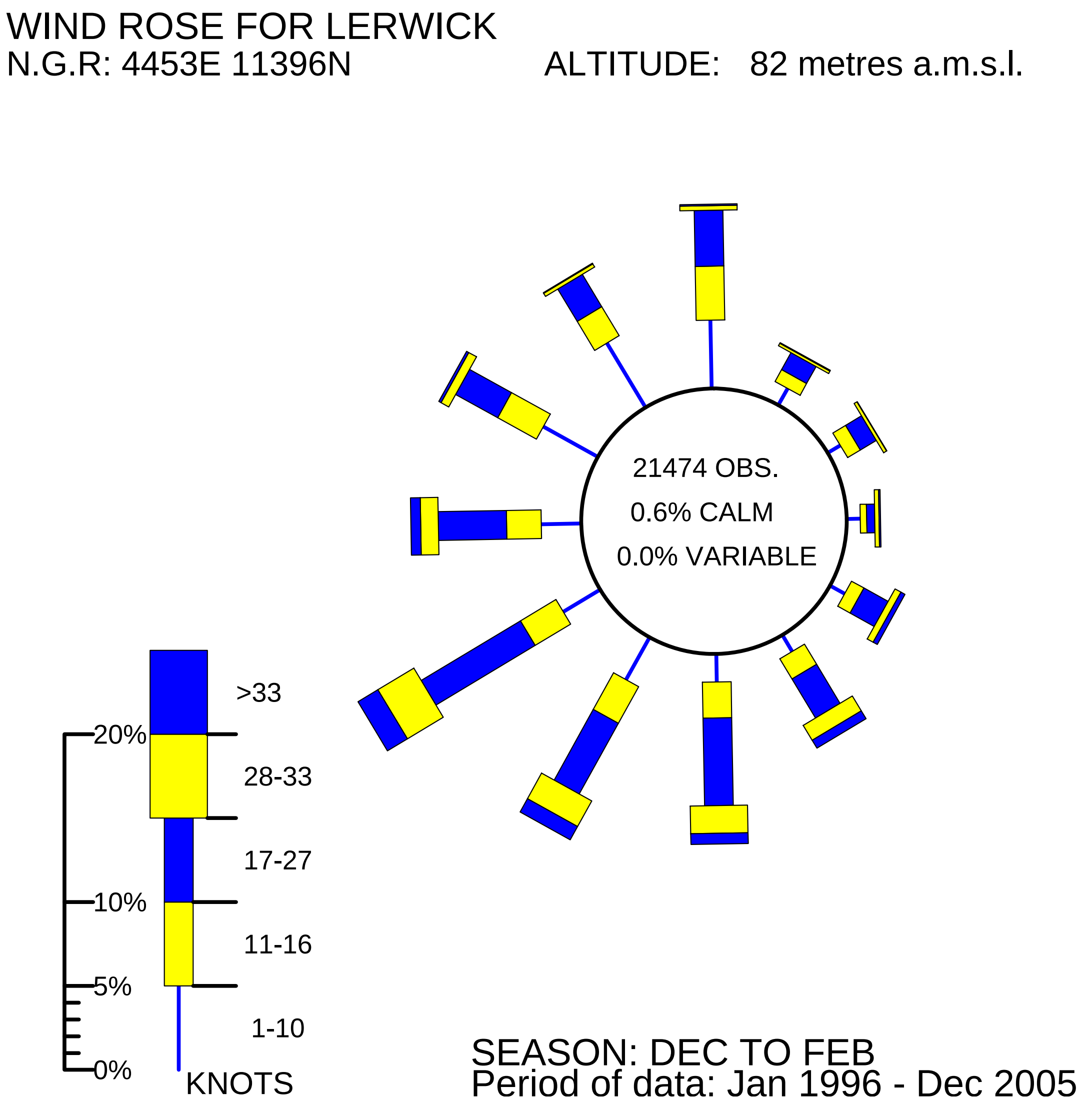


Figure 9.8 Wind rose for Lerwick (December to February)

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

A strong easterly wind combined with a spring tide may result in higher than usual tides which will carry accumulated faecal matter from livestock, in and above the normal high water mark, into the voe.

Wind effects are likely to cause significant changes in water circulation within the voe as tidally influenced movements of water are relatively weak (see section 13). Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s. These surface water currents create return currents, the path of which will depend on wind direction and local bathymetry. Strong winter winds will increase the circulation of water and hence dilution of contamination from point sources within the voe. Northerly or southerly winds may facilitate movement of contamination from the sewage discharges on the north and south shores to the mussel lines.

10. Current and Historical Classification Status

The area has been classified for production since 2001. The classification history is presented in Table 10.1. Currently, the area is classified as seasonal A/B. The area contains two active farms both growing rope mussels. A map of the current production area is presented in Figure 10.1.

Table 10.1 - Classification history

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001*	B	B	B	B	A	A	A	B	B	B	B	B
2002	A	A	A	A	A	A	A	A	B	B	A	A
2003	A	B	B	B	B	B	B	B	B	B	B	A
2004	A	A	A	A	A	A	A	B	B	B	A	A
2005	A	A	A	A	A	A	A	A	A	A	A	A
2006	B	B	B	A	A	B	B	B	B	B	B	B
2007	B	B	B	A	A	B	B	B	B	B	B	B

*Provisional classification

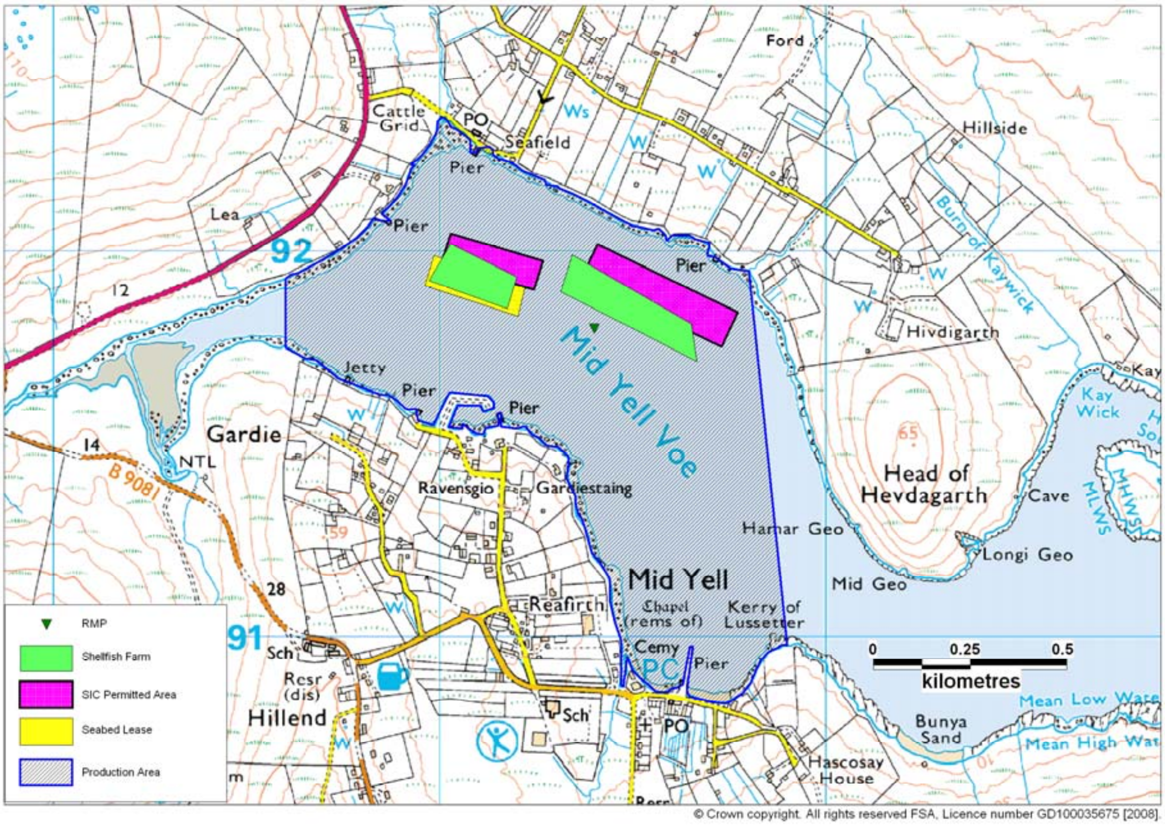


Figure 10.1 - Map of current Mid Yell Voe production area

11. Historical *E. coli* Data

11.1 Validation of historical data

All mussel samples taken from Mid Yell Voe up to the end of 2006 were extracted from the database and validated according to the criteria described in the standard operating procedure for validation of historical *E. coli* data. No samples were rejected on the basis of major geographical discrepancies. In the 10 instances where the result was reported as <20, it was assigned a nominal value of 10 for the purposes of graphical presentation and analysis. All *E. coli* results are reported in most probable number per 100g of shellfish flesh and intervalvular fluid.

11.2 Summary of microbiological results by sites

Common mussels were sampled from two sites within the production area as shown on Figure 11.1 and in Table 11.1. Where more than one location has been sampled for a particular site, the locations have been within a few hundred meters of each other, and have all been within or close to the appropriate Crown Estates lease boundaries. The charts summarising historical results presented on Figure 11.1 have combined all results from different locations for each site.

Table 11.1 - Summary of results from Mid Yell Voe

Sampling summary			
Production area	Mid Yell Voe	Mid Yell Voe	Mid Yell Voe
Site	Both sites combined	Camb	Seafield
Species	Common mussels	Common mussels	Common mussels
SIN	SI 216	SI 216 430 08	SI 216 432 08
Location	All sites (2) and locations (4)	HU508917, HU513920, HU514918	HU516919
Total no of samples	87	66	21
No. 2000	8	8	0
No. 2001	9	9	0
No. 2002	10	10	0
No. 2003	12	11	1
No. 2004	12	9	3
No. 2005	18	9	9
No. 2006	18	10	8
Results Summary			
Minimum	<20	<20	<20
Maximum	9100	9100	2200
Median	160	135	220
Geometric mean	128.3	127.0	132.7
90 percentile	1180	750	1300
95 percentile	1300	1300	1700
No. exceeding 230/100g	29 (33%)	20 (30%)	9 (43%)
No. exceeding 1000/100g	10 (11%)	6 (9%)	4 (19%)
No. exceeding 4600/100g	1 (1%)	1 (2%)	0 (0%)
No. exceeding 18000/100g	0 (0%)	0 (0%)	0 (0%)

A number of minor geographical discrepancies were noted. None of the sampling locations or the RMP plot within their respective actual farm or Crown Estates lease boundaries, but all sampling locations did plot within 300m of these. Reported sample locations are mapped in Figure 11.1.

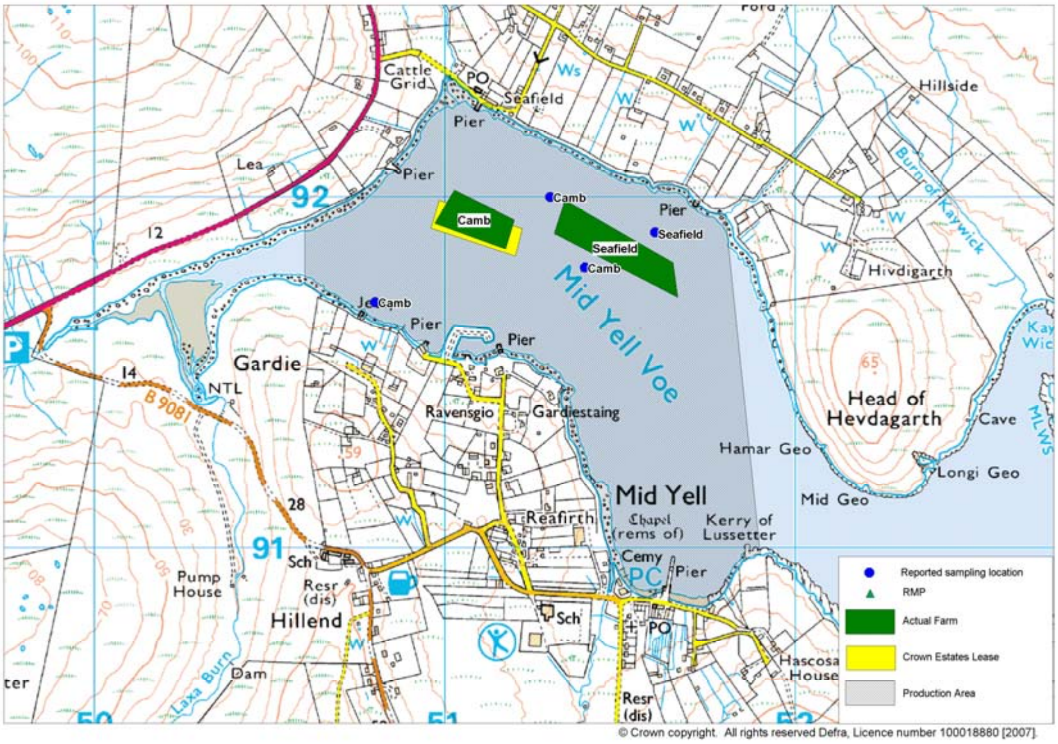


Figure 11.1 Map of reported sampling locations

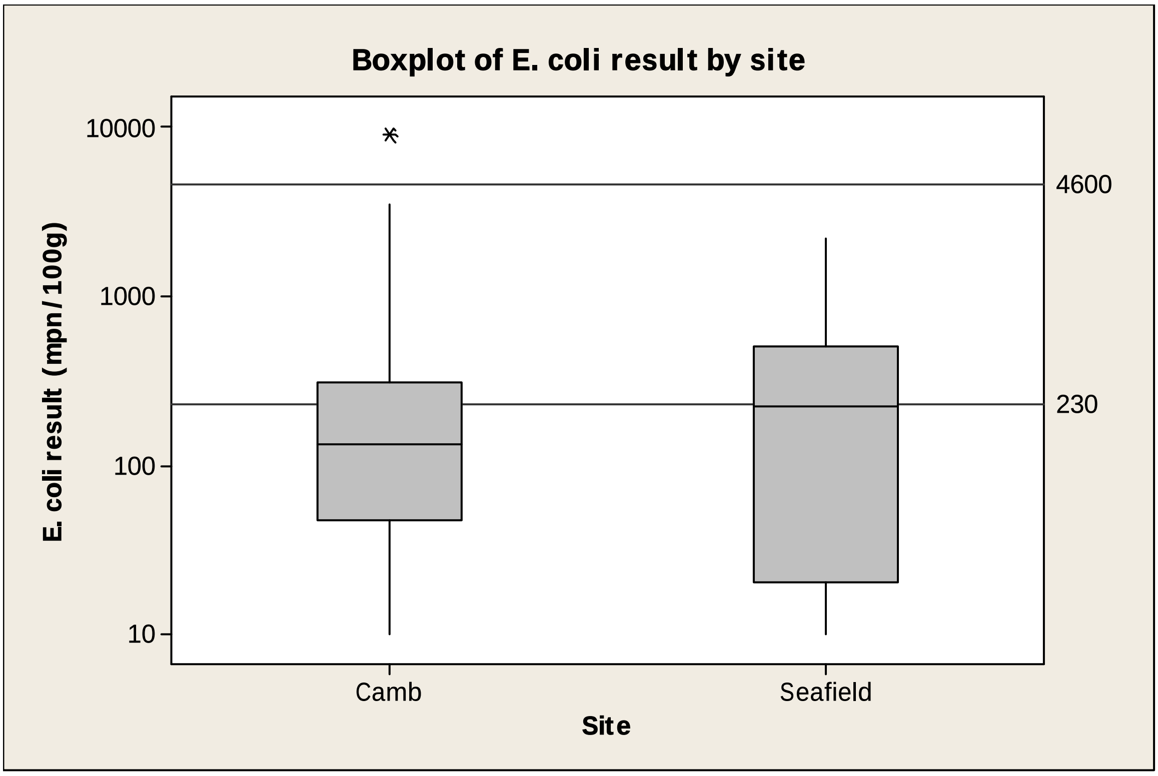


Figure 11.2 Boxplot of shellfish *E. coli* result by site

A comparison of results reveals no difference between the two sites (T-test, T=-0.10, p=0.922, Appendix 11). Due to the proximity of the sites, the uncertainty of exact sampling location, and the similar results reported for each site, all further analyses will consider all sites and sampling locations together.

11.3 Temporal pattern of results

Figures 11.3 and 11.4 present scatter plots of individual results against date for all samples taken from Busta Voe Lee North. Both are fitted with trend lines to help highlight any apparent underlying trends or cycles. Figure 11.3 is fitted with a line indicating the geometric mean of the previous 5 samples, the current sample and the following 6 samples. Figure 11.4 is fitted with a loess smoother, a regression based smoother line calculated by the Minitab statistical software. Figure 11.5 presents the geometric mean of results by month (+ 2 times the standard error).

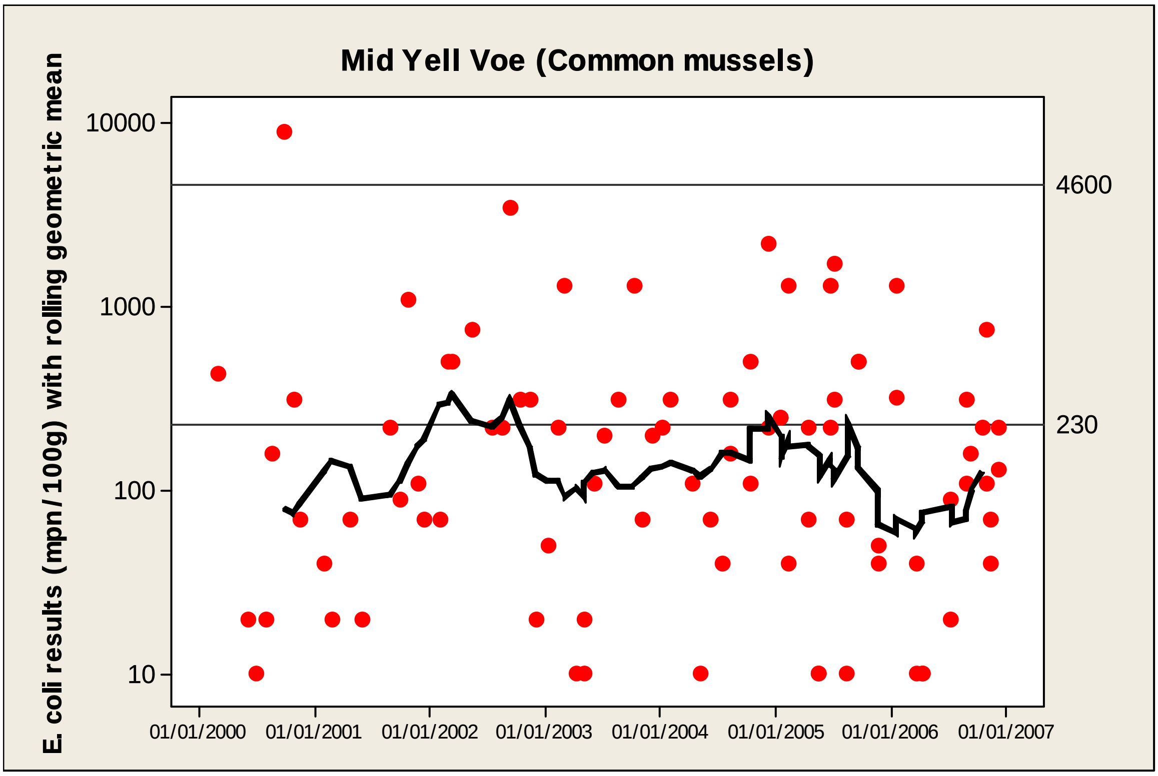


Figure 11.3 - Scatterplot of results by date with rolling geometric mean

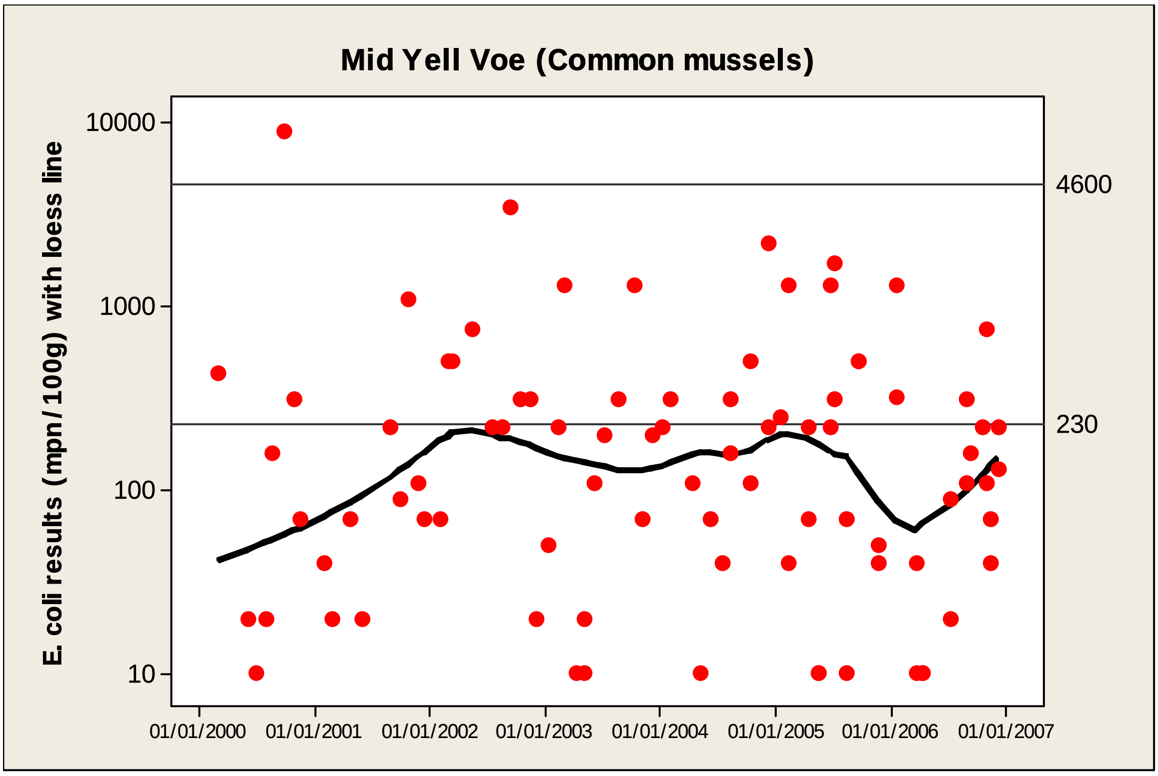


Figure 11.4 - Scatterplot of results by date with loess smoother

No trends or cycles are apparent from Figures 11.3 and 11.4.

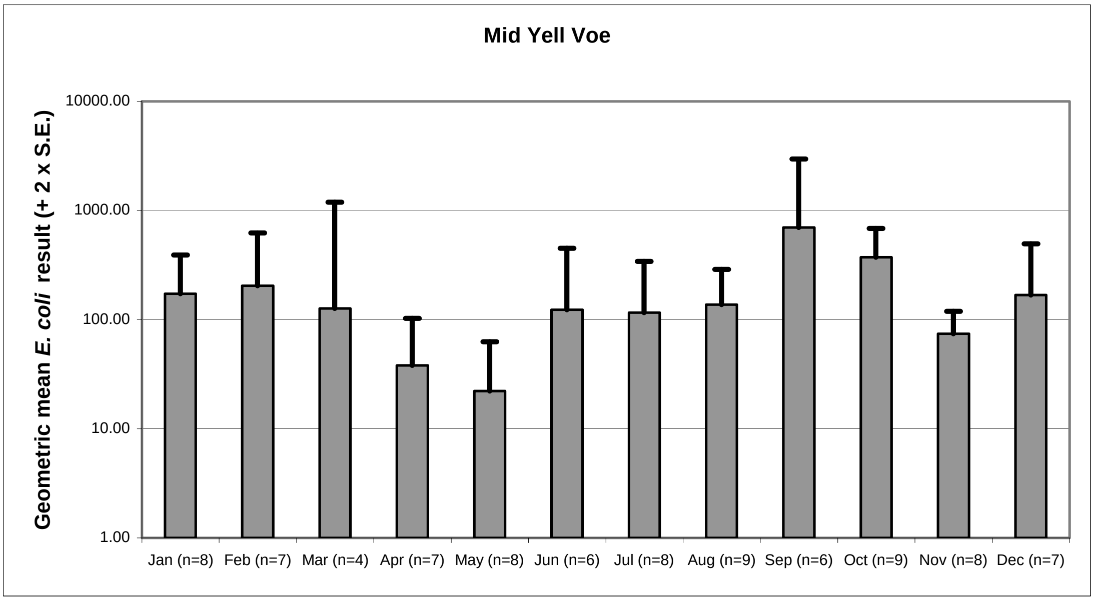


Figure 11.5 – Chart to show geometric mean result by month

Highest mean results were in September and October, and lowest mean results occurred in April and May.

11.4 Analysis of results against environmental factors

Environmental factors such as rainfall, tides, winds, sunshine and temperatures can all influence the flux of faecal contamination into growing waters (e.g. Mallin *et. al.*, 2001; Lee & Morgan, 2003). The effects of these influences can be complex and difficult to interpret. This section aims to investigate and describe the influence of these factors individually (where appropriate environmental data is available) on the sample results using basic statistical techniques. This analysis considers the 87 samples taken from Mid Yell Voe from the start of sampling in 2000 to the end of 2006.

11.4.1 Analysis of results by season

Although not strictly an environmental variable in the same way as rainfall for example, season dictates not only weather patterns, but livestock numbers and movements, presence of wild animals and patterns of human occupation. Seasons were split into spring (March - May), summer (June - August), autumn (September - November) and winter (December - February).

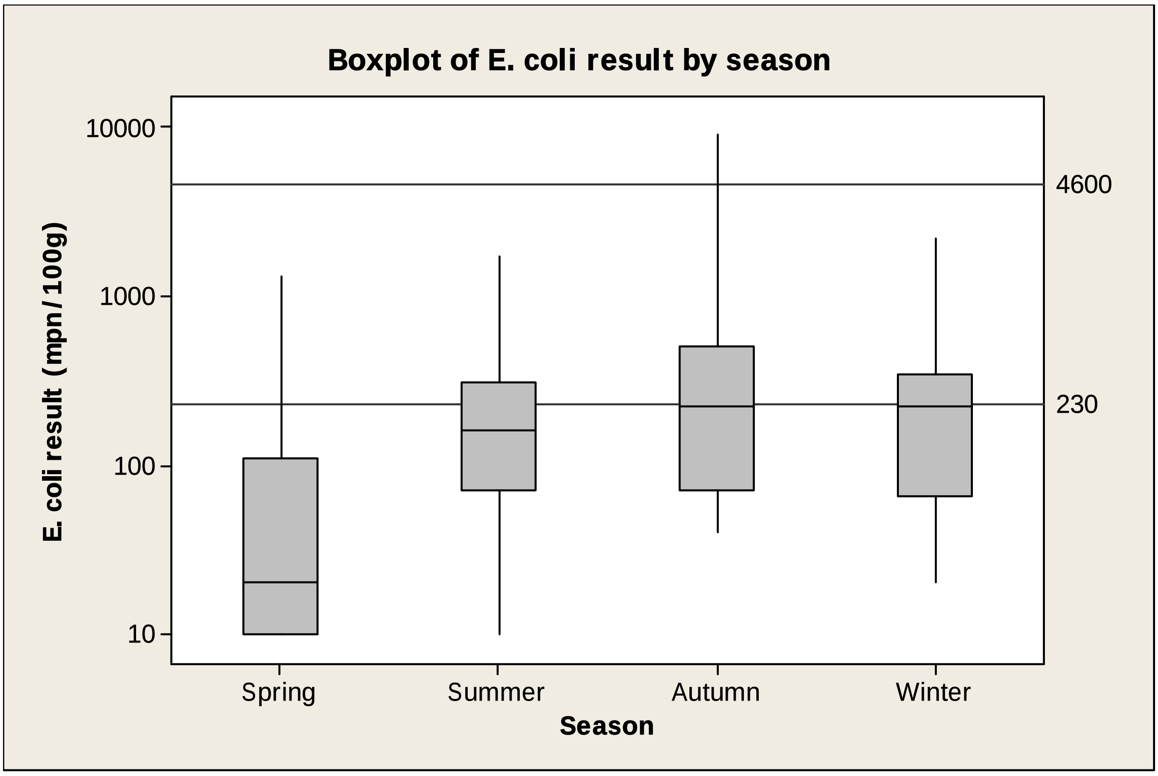


Figure 11.6 Boxplot of shellfish *E. coli* result by season

A seasonal effect was observed, with lowest results in the spring compared to all other seasons. The seasonal effect is statistically significant (One-way ANOVA, p=0.000, Appendix 11). This is in accordance with the seasonal A classification which applied in April and May 2006 and 2007.

11.4.2 Analysis of results by recent rainfall

The nearest weather station is Baltasound, approximately 19 km to the north east of the production area for which uninterrupted rainfall data is available for 1/1/2003 to 31/10/2006 inclusive.

The coefficient of determination was calculated for *E. coli* results and rainfall in the previous 2 days at Baltasound. Figure 11.7 presents a scatterplot of *E. coli* result and rainfall, with a best fit line derived by regression. Figure 11.8 presents a boxplot of results by rainfall quartile (quartile 1 = 0 to 0.80 mm, quartile 2 = 0.80 to 3.60 mm, quartile 3 = 3.60 to 8.525 mm, quartile 4 = more than 8.525 mm).

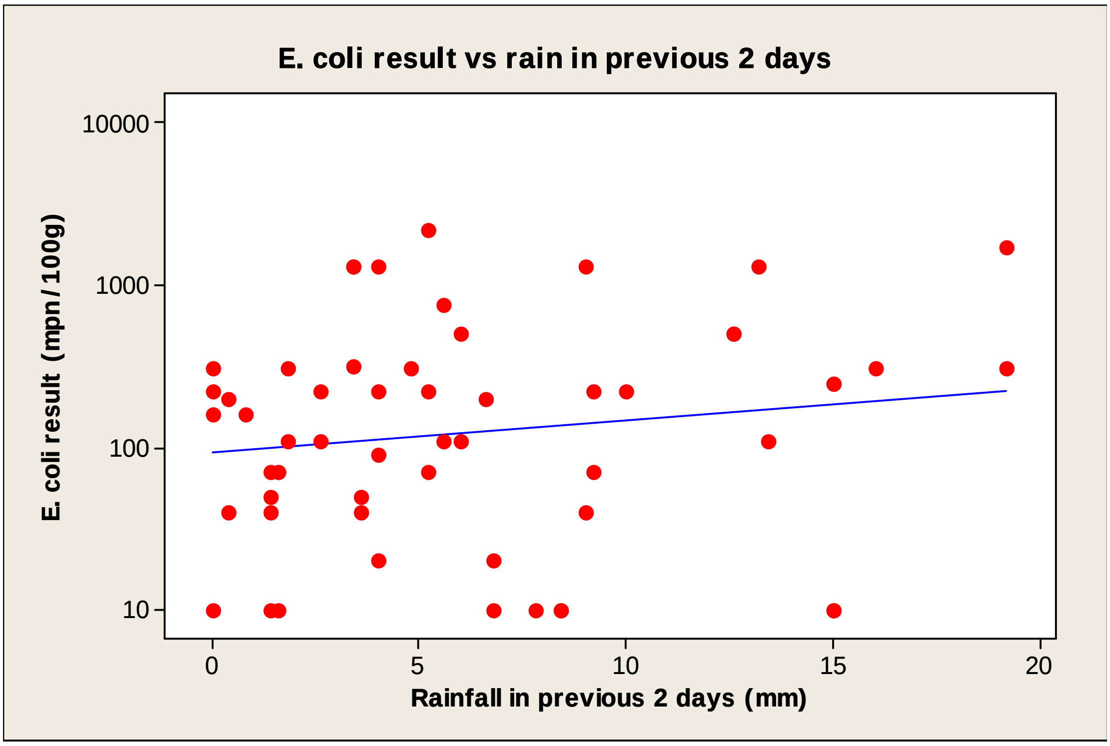


Figure 11.7 Scatterplot of shellfish *E. coli* result against rainfall in previous 2 days

The coefficient of determination indicates that there is no relationship between the *E. coli* result and the rainfall in the previous two days (Adjusted R-sq=0.5%, p=0.263, Appendix 11).

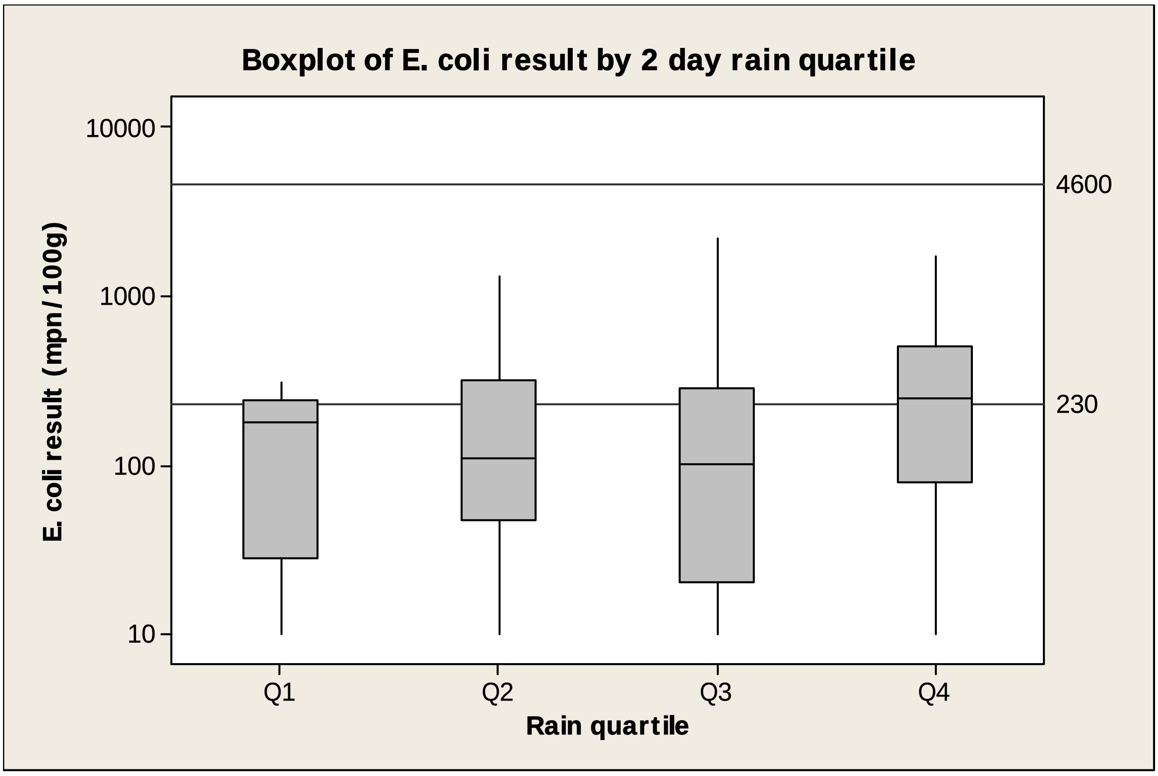


Figure 11.8 Boxplot of shellfish *E. coli* result by rainfall in previous 2 days quartile

No difference between the results for each rain quartile was found (One way ANOVA, p=0.502, Appendix 11).

As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationship between rainfall in the previous 7 days and sample results for Mid Yell Voe was investigated in an identical manner to the above. Interquartile ranges for 7 days rainfall were as follows; quartile 1 = 0 to 9.1 mm; quartile 2 = 9.1 to 17.8 mm; quartile 3 = 17.8 to 28.3 mm; quartile 4 = more than 28.3 mm.

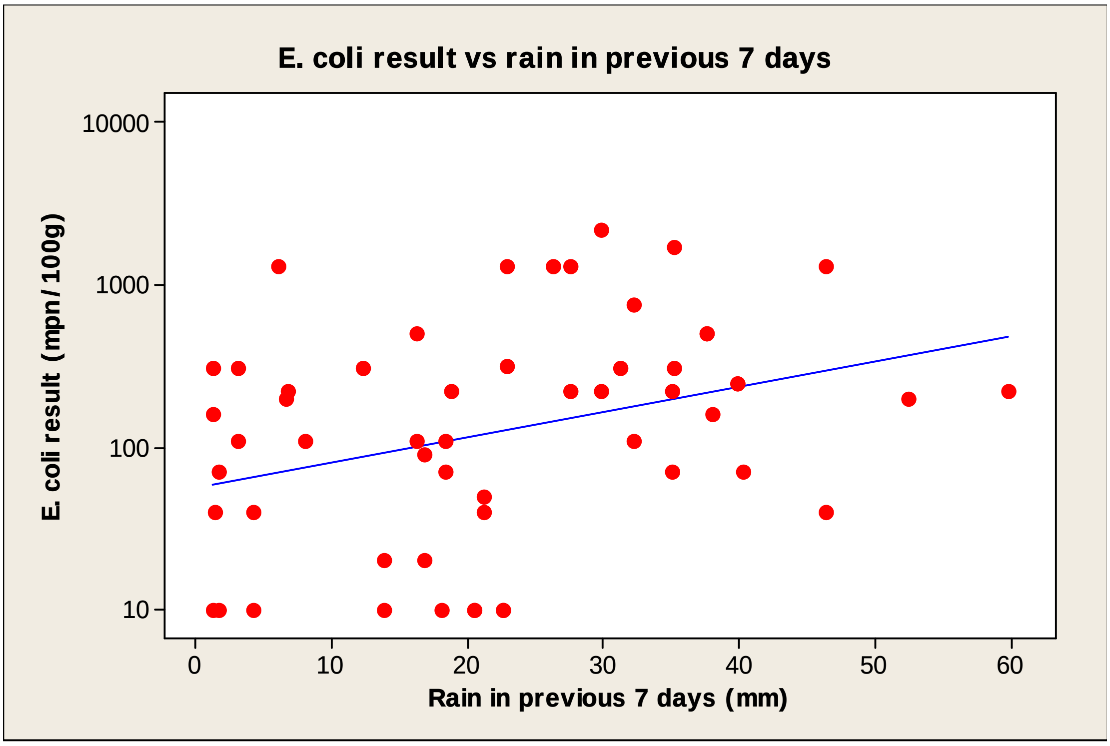


Figure 11.9 Scatterplot of shellfish *E. coli* result against rainfall in previous 7 days

The coefficient of determination indicates that there is a weak positive relationship between the *E. coli* result and the rainfall in the previous seven days (Adjusted R-sq=9.6%, p=0.012, Appendix 11).

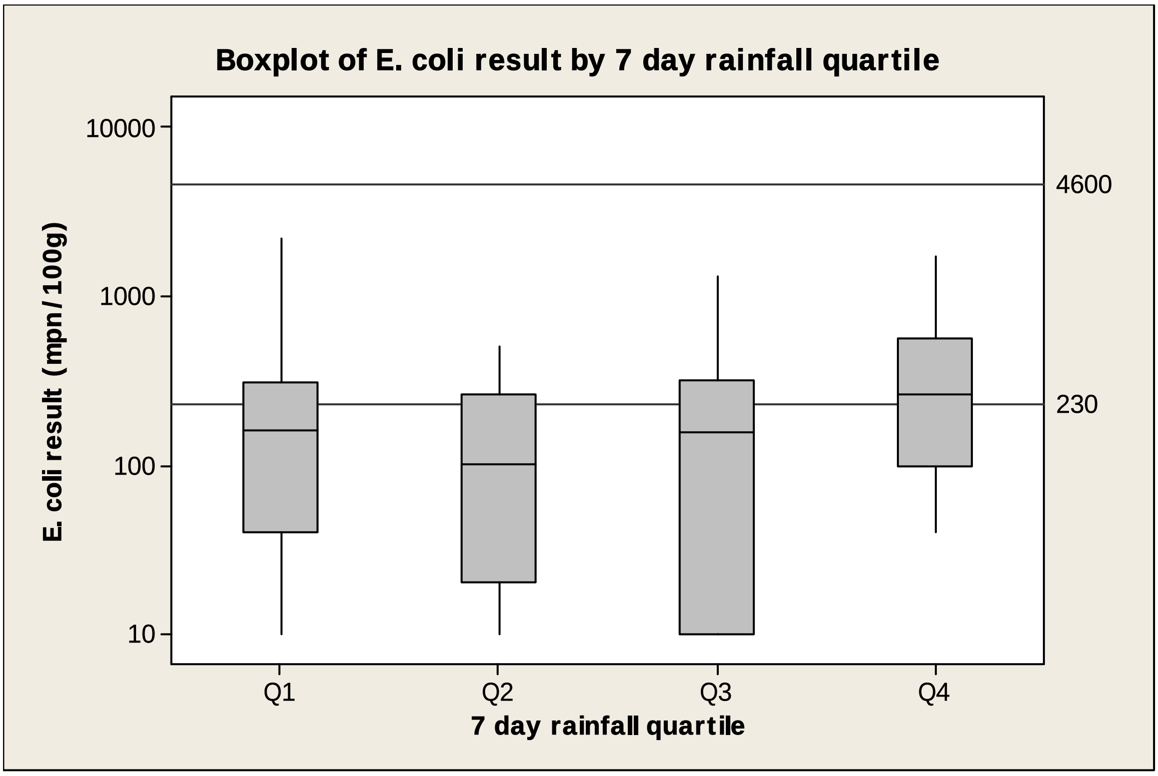


Figure 11.10 Boxplot of shellfish *E. coli* result by rainfall in previous 7 days quartile

There was no significant difference between results for each quartile (One way ANOVA, p=0.403, Appendix 11).

Overall, higher recent rainfall in the previous 7 days is weakly associated with higher contamination of shellfish in the Voe, but no effects are observed when 2 days rainfall are considered. Any rainfall related effects might be expected to be at their greatest in the autumn and winter months when rainfall is at its' highest (see section 9). The influence of rainfall on microbiological quality will depend on factors such as local geology, topography and land use.

11.4.3 Analysis of results against lunar state

Lunar state dictates tide size, with the largest tides occurring 2 days after either a full or new moon. With the larger tides, circulation of water in the voe will increase, and more of the shoreline will be covered, potentially washing more faecal contamination from livestock into the voe. Tidal ranges in the voe (as described in section 12) are small, ranging from 0.7 to 1.1m. Figure 11.11 presents a boxplot of *E. coli* results by size of tide categorised by lunar state at the time of sampling. It should be noted however that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account in Figure 11.11.

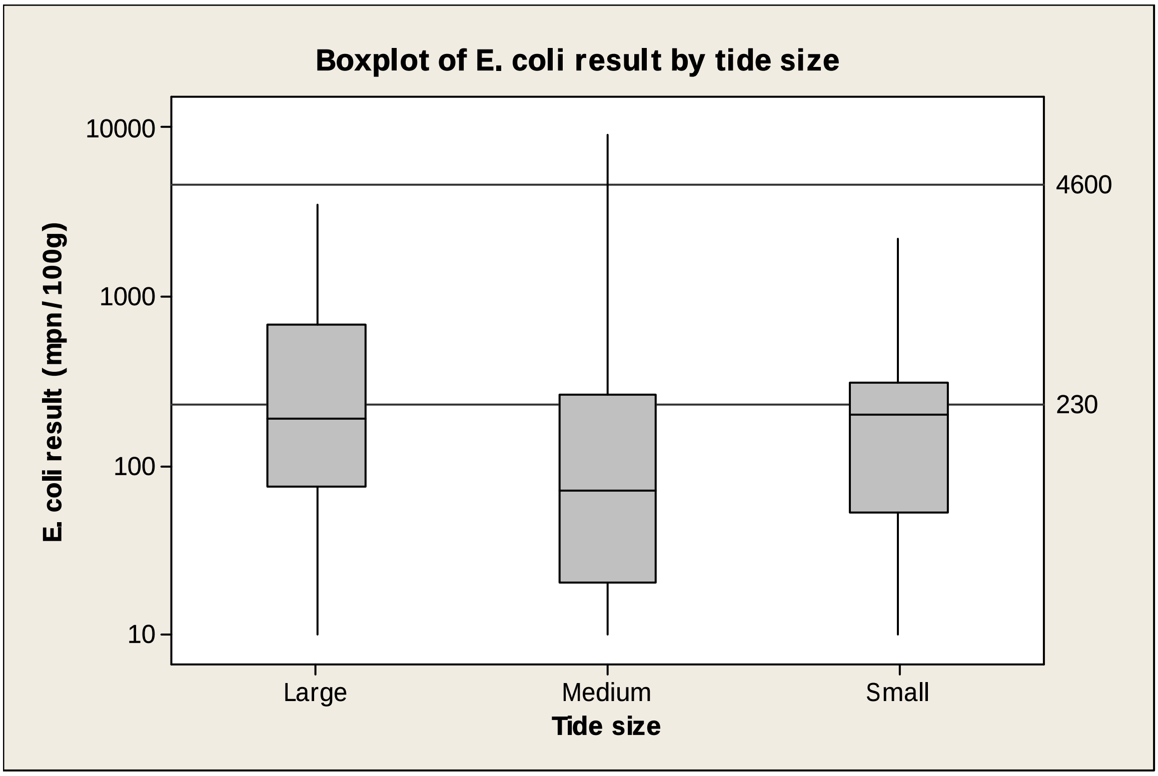


Figure 11.11 Boxplot of shellfish *E. coli* result by tide size

There was no statistically significant influence of tide size detected by this analysis (One way ANOVA, p=0.104, Appendix 11). This may be expected, as the tidal range is small.

11.4.4 Water temperature

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

Water temperature at the time of sample collection was not recorded, so no analysis was possible.

11.4.5 Wind direction

Wind speed and direction is likely to significantly change water circulation patterns in Busta Voe. Mean wind direction for the 7 days prior to each sample being collected was calculated from wind data recorded at the Lerwick weather station (where data was available), and mean result by mean wind direction in the previous 7 days is plotted in Figure 11.12.

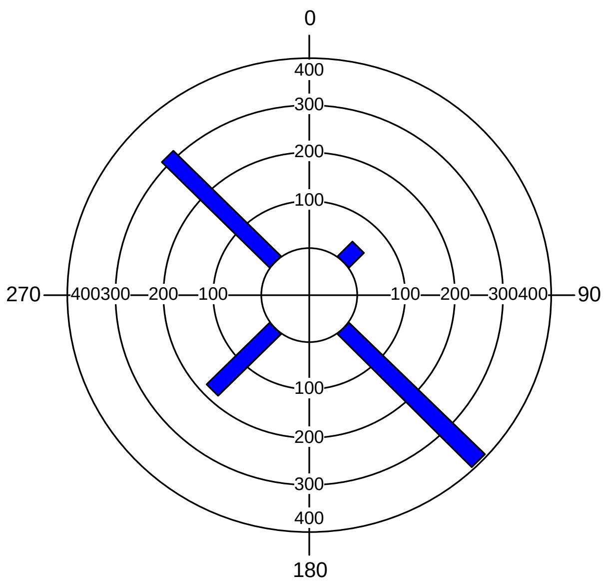


Figure 11.12 Circular histogram of mean *E. coli* result by wind direction

A significant correlation between wind direction and *E. coli* result was found (circular-linear correlation, r=0.278, p=0.025, Appendix 11). Results were highest when the wind was blowing from the northwest and the southeast, suggesting that these winds may result in increased transport of faecal contamination into the production sites. It must be noted however that there were few samples taken following a period of easterly wind.

11.4.6 Discussion of environmental effects

A seasonal effect was found, with results in the spring being significantly lower than in other seasons. A very weak positive relationship was found between rainfall in the previous 7 days and result, but there was no relationship between results and rainfall in the previous 2 days. There was no significant effect of tide size on monitoring results. North westerly winds were associated with increased contamination.

11.5 Sampling frequency

When a production area has had the same (non-seasonal) classification for 3 years, and the geometric mean of the results falls within a certain range it is recommended that the sampling frequency may be decreased from monthly to bimonthly. This is not appropriate for Mid Yell Voe, as the area had seasonal classifications in 2004 and 2006.

12. Designated Shellfish Growing Waters Data

The production area considered in this report is part of a SEPA shellfish growing water with identical boundaries which was designated in 2005. The extent of the area and the SEPA designated monitoring point are shown on figure 12.1.

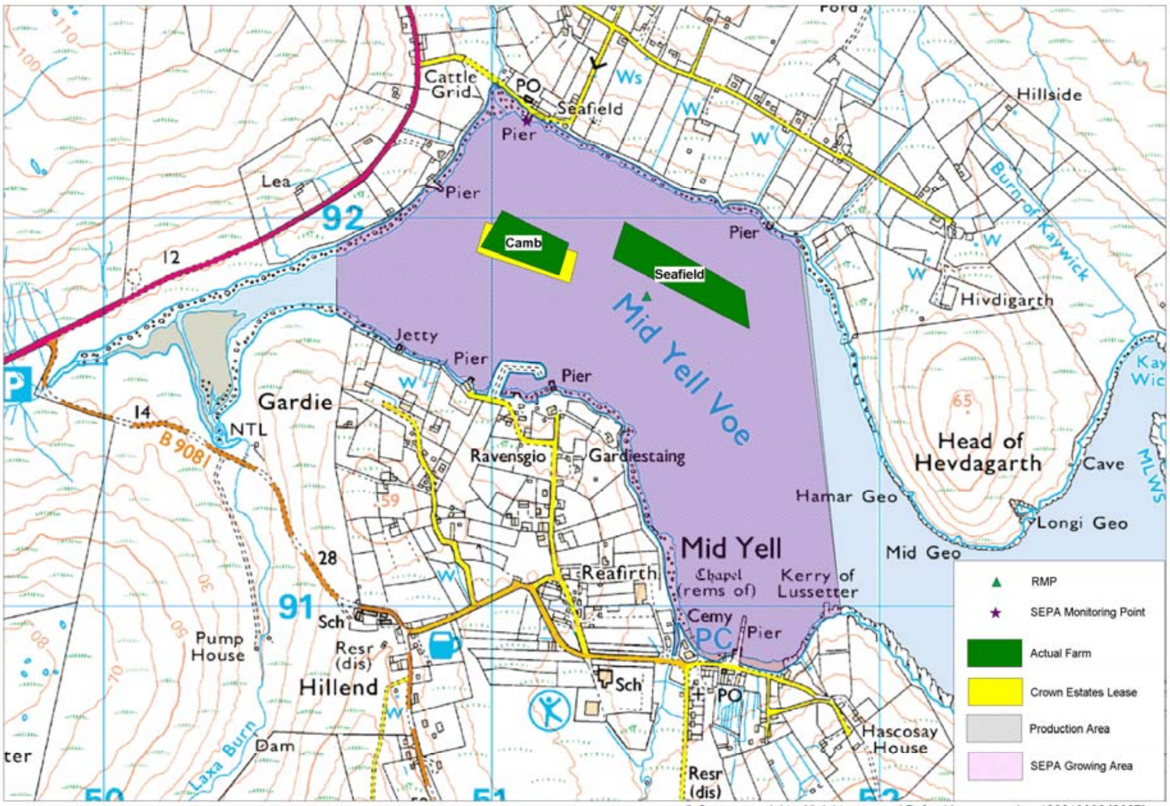


Figure 12.1 Map showing SEPA designated growing water and monitoring points

The monitoring regime requires the following testing:

- Monthly for Salinity, Dissolved Oxygen, pH and temperature.
- Biannually for metals, mercury, arsenic, suspended solids, colour and organohalogens in water.
- Annually for metals and organohalogens in mussels.
- Quarterly for faecal coliforms in mussels.

Monitoring started in 2005, and results to the end of 2006 have been provided by SEPA. Monitoring results for faecal coliforms in mussels are presented in Table 12.1.

Table 12.1. SEPA Faecal coliform results (F. coli / 100g) for shore mussels gathered from Busta Voe and Linga Voe.

	Site	Mid Yell Voe at Seafield pier
	NGR	HU 5109 9225
2005	Q1	-
	Q2	-
	Q3	2800
	Q4	320
2006	Q1	-
	Q2	10
	Q3	30
	Q4	170

All samples were gathered from the pier at Seafield. No detailed analysis of these results was carried out due to the small number of samples taken. The geometric mean result is 135.5 faecal coliforms / 100g. Levels of Faecal coliforms are usually closely correlated to levels of *E. coli* often at a ratio of approximately 1:1. The ratio depends on a number of factors, such as environmental conditions and the source of contamination. Assuming rough equivalence, the level of contamination in shore mussels taken from the current SEPA monitoring point is very similar to that observed in rope mussels in the voe.

13. Bathymetry and Hydrodynamics

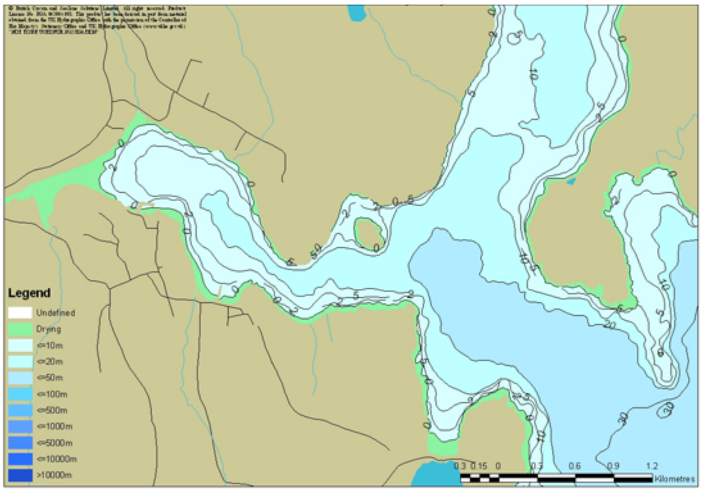


Figure 13.1 Map of Mid Yell Voe bathymetry

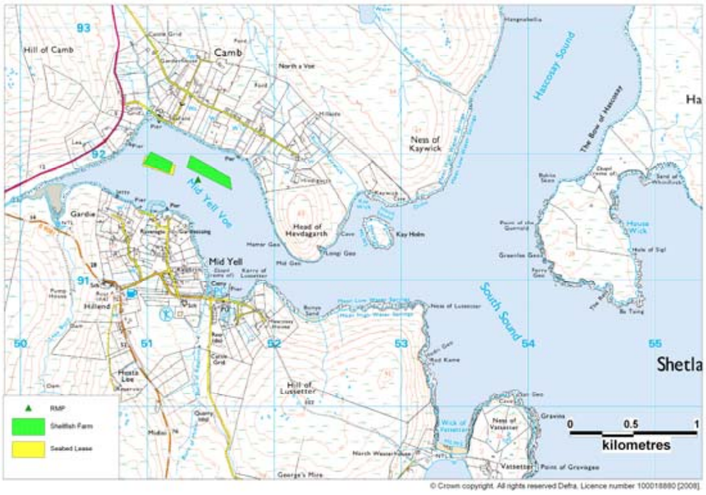


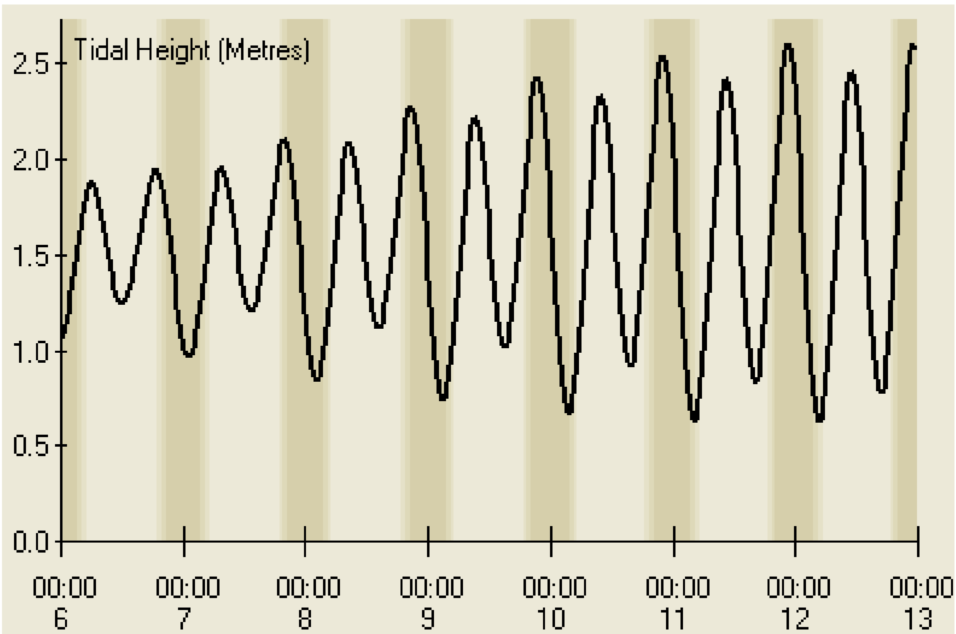
Figure 13.2 OS Map of Mid Yell Voe

Depths range from less than 5 metres, with intertidal areas at the head of the voe and along the shoreline, to under 30 metres in South Sound. Depths in the vicinity of the production area are less than 20 metres, with the two mussel farms located in 10 metres depth or less.

According to the Scottish Sea Loch Catalogue, the Mid Yell Voe is 3.3 miles long, with a maximum depth of 20 metres. Salinity reduction due to freshwater inflow is 0.3 ppt, with a watershed of 21 km2 and a flushing time of two days.

13.1 Tidal Curve and Description

The two tidal curves below are for Mid Yell – they have been output from UKHO TotalTide. The first is for seven days beginning 00:00 GMT on 06/09/07 and the second is for seven days beginning 0000 GMT on 13/09/07. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.



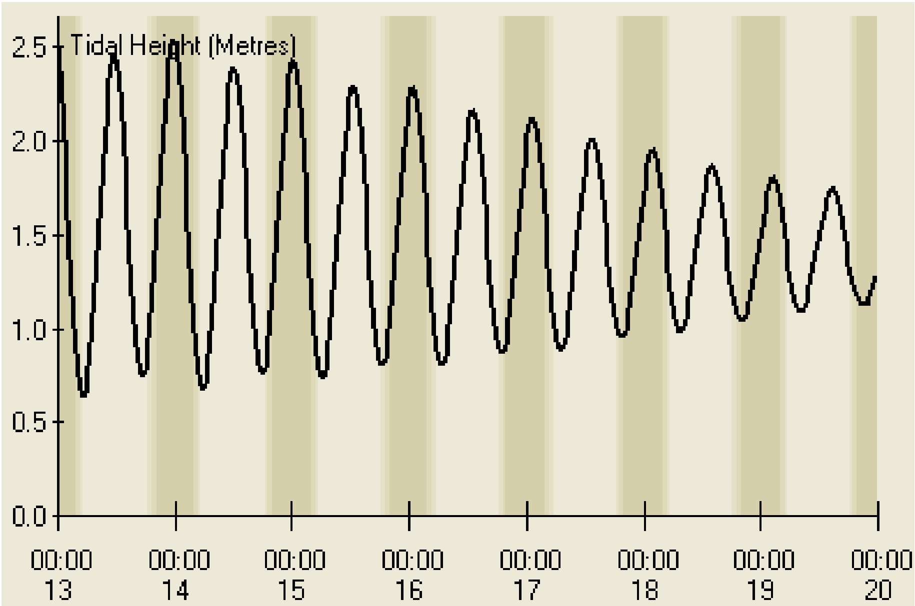


Figure 13.3 Tidal curves for Mid Yell

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

The tide type is Semi-Diurnal.

MHWS	2.4 m
MHWN	1.9 m
MLWN	1.1 m
MLWS	0.6 m

Predicted heights are in metres above chart datum. The tidal range at spring tide is therefore approximately 1.8m and at neap tide 0.8m.

13.2 Currents – Tidal Stream Software Output and Description

No tidal stream information is available for Mid Yell Voe.

Conclusions

Mid Yell Voe is shallow throughout its area, providing less potential for dilution of pollutants.

Tidal effects are expected to be limited with respect to the dispersion of pollutants and dispersion will therefore be wind and density dependent.

14. River Flow

There are no gauged rivers flowing into Mid Yell Voe. The following watercourses were measured and sampled during the shoreline survey:

Table 14.1 River flows at Mid Yell Voe

No.	NGR	Descrip-tion	Width (m)	Depth (m)	Meas. Flow (m/s)	Flow m3/day	*E. coli* (cfu/ 100ml)	Loading (*E.coli*/ day)
1	HU 51735 90822	Field drain	0.2	0.01	1 L/s	86	200	2×10^{8}
2	HU 50354 91349	Laxa Burn	5.0	0.05	0.7	15120	140	2×10^{10}
3	HU 51013 92344	Burn of Houll	2.0	0.3	0.4	20736	320	7×10^{10}
4	HU 51812 91950	Unnamed burn	1.0	0.3	0.6	15522	2100	3×10^{11}

All the above watercourses present significant sources of contaminants to the voe. The unnamed burn labelled number 4 is of the greatest concern as it discharges close to the Seafield mussel site and had the highest loading of all the burns and streams sampled. It is likely that faecal contamination from livestock is a significant contributor to bacterial levels seen in this burn.

Stream samples are illustrated in Figure 14.1. Streams are labelled with the number assigned in Table 14.1. Loadings are displayed in digital scientific format on the map, where 1E+10 is equal to 1×10^{10}.

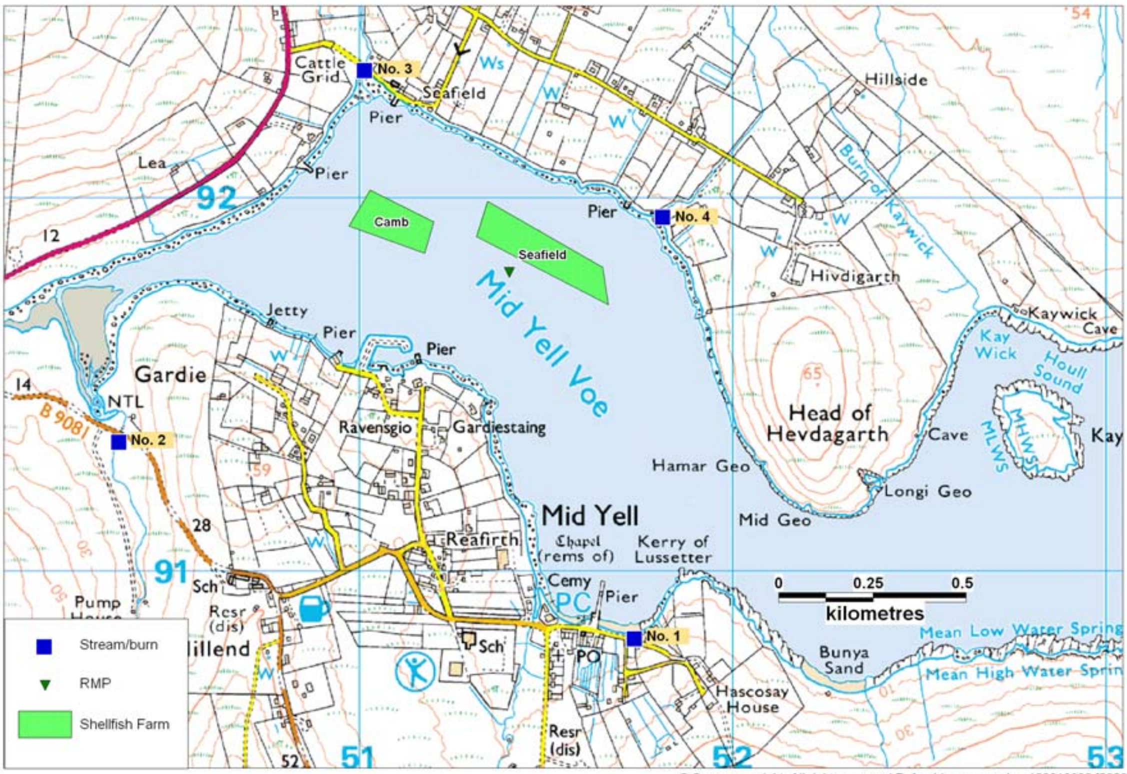


Figure 14.1 Map of burns sampled

15. Shoreline Survey Overview

The survey at Mid Yell Voe was initially triggered by the score it received in the risk matrix applied to prioritise existing fisheries for sanitary surveys. It received a high score based on changes in its classification status and monitoring results outwith its classification.

There were a relatively large number of community septic tanks located around the voe, as well as other discharge pipes seen mostly along the southern shore. None of the Scottish Water owned tanks was labelled or identified in any way, so it was not possible to positively identify them.

There were a number of public services in Mid Yell, including public toilets, a care home for the elderly, a health centre and a fitness centre. One of the septic tanks observed during the survey was located in the grounds of the care home.

A kitchen midden was found on the shoreline adjacent to the pier at Mid Yell, which contained a large number of scallop shells, peelings and other vegetable waste.

Most of the human population was concentrated on the southern shore of the voe while the northern shore was lined with crofts. Sheep, cattle and chickens were observed as well as numerous sheep droppings.

There are two piers with large fishing vessels in Mid Yell Voe as well as a marina for small boats. All are located along the southern shoreline. There were 10 fishing boats and 27 day boats present on the day.

No significant populations of seabirds or other wildlife were observed during the shoreline survey.

Both water and shellfish samples were taken during the survey. The highest levels of contamination in shellfish were found on the Seafield site, where mussels taken from the near the surface and from mid depth of the line had *E. coli* concentrations of 9100 MPN/100 g and >18000 MPN/100 g respectively.

However, samples taken from the adjacent site, Camb, had much lower concentrations, ranging from 110 MPN/100 g at the surface to 220 MPN/100 g at 6 metres depth. The Camb site is further up the voe and more distant to the septic discharges at Mid Yell, as well as more slightly further away from the northern shoreline where most of the grazing livestock is found.

Water samples were taken from freshwater sources as well as from seawater around the voe. The highest concentrations were found along the northern shoreline, where five samples contained at least 1,200 cfu *E. coli* /100 ml. The highest concentration recorded on the southern shoreline was 1,900 cfu/100 ml adjacent to the stone pier and near a septic tank.

In general, significant levels of contamination were found both in the water samples and in the mussel samples collected during the survey and this was consistent with the large number of septic discharges in the area.

The most significant shoreline survey observations are found mapped in Figure 15.1. Further details can be found in the Shoreline Survey Report in the Appendix.

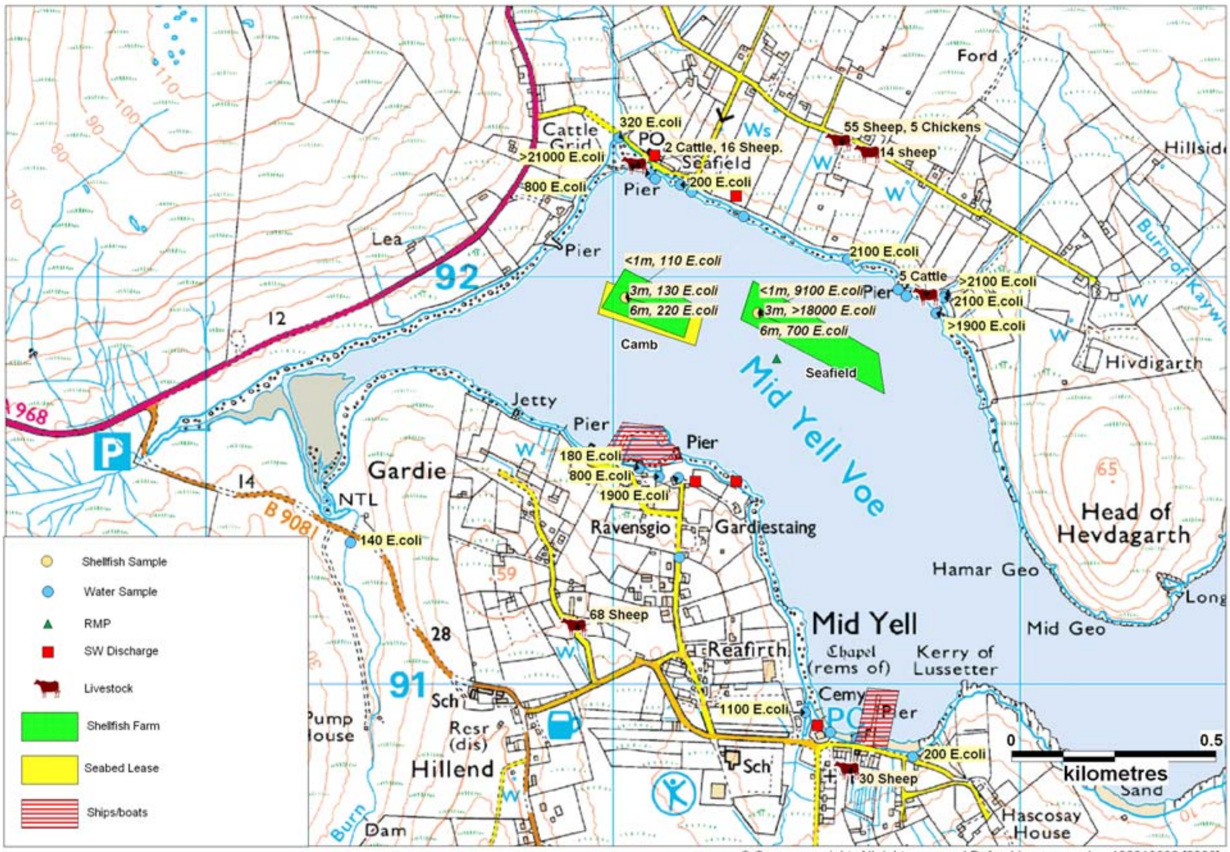


Figure 15.1 Map of significant shoreline survey observations

16. Overall Assessment

Human Sewage Impacts
Mid Yell Voe is relatively highly developed area (in the context of Shetland) with significant impacts from human sources of faecal contamination. The area population at the last census was just under 500, with the bulk living along the southern shore of the voe.

Scottish Water identified five community septic tanks for the area, each with consented design PE of 250. In addition, SEPA held consents for a further three discharges though at the time of writing this report the details had not yet been made available.

A total of nine tanks and/or outfalls were observed during the shoreline survey and water samples were taken either of the discharge or of seawater near the discharge point. As described in section 4, the concentrations of *E. coli* found in the shoreline seawater samples ranged from a low of 36 cfu/100 ml taken from next to a pipe not actively discharging to 1900 cfu/100 ml near a septic tank outfall adjacent a stone pier.

An EU working group examined the comparability of *E. coli* results from water and different shellfish species in relation to classification standards (EU Scientific Veterinary Committee Working Group on Faecal Coliforms in Shellfish, 1996). *E. coli* concentrations in seawater that related to the class B limit of 90% compliance with 4600 *E. coli* per 100g mussels were a geometric mean of 50.0 E.coli/100 ml water where the geometric mean is an estimate of the average concentration across a number of samples.

The comparable concentrations for class A were 0.9 geometric mean E.coli/100 ml water.

However, the number of class A areas used in the study was limited and thus there is more uncertainty about the comparison at these lower levels of contamination.

The range of seawater results obtained indicated that sufficient contamination is present at the shoreline to cause *E. coli* concentrations in mussels to exceed A classification levels and in many cases B levels. This was confirmed by shellfish sampling results which showed concentrations as high as >18000 *E. coli*/100 g.

It is clear from the historical monitoring results that the production area is adversely impacted by faecal contamination of some source. The concentrations of *E. coli* found in seawater adjacent to outfalls indicate that human sewage is a significant source of contamination to the area.

This is likely to impact both shellfish farms. Historical monitoring results showed no significant difference in results between the farms and so it is likely that both sites will be impacted to a broadly similar degree.

Agricultural Impacts
Livestock husbandry and farming activities are an important factor in the use of land around Mid Yell Voe. Land cover adjacent to the voe, as discussed in Section 6, is predominantly improved and acid grassland much of which is used for grazing livestock. Sheep were prevalent in the area, with some cattle observed as well. The sheep would be widely distributed around the grazing and not prevalent in one area more than others. Due to the amount of developed land on the southern shore of the voe, the majority of livestock grazing land is located along the northern shore.

Agricultural practices can have a dramatic impact locally on water quality. Sheep grazed in the area can access the shoreline, leading to a more direct input of faecal bacteria to the voe. The Scottish Government has published a set of guidelines for management of farm waste and are working with farmers and crofters to encourage implementation of the guidelines. Further changes in the way agricultural subsidies are applied and paid are anticipated to lead to a decline in sheep population and hence the amount of sheep droppings in the area.

Soils in the area are classed as poorly draining. This indicates that a higher proportion of rainfall would result in runoff into the voe, carrying with it faecal material deposited by livestock as well as other animals.

Agricultural runoff is likely to be a significant contributor to contamination levels seen in the fisheries as the predominant sources lie along the northern shore near the mussel farms. Results from water samples taken along this shoreline showed higher concentrations of *E. coli* than those taken elsewhere. However, it is not possible to discern the relative contributions of livestock vs. human sources.

Rivers and Streams
Of the four stream inputs observed at Mid Yell Voe, the two located closest to the shellfish farms also had the highest loadings (7×10^{10} and 3×10^{11} *E.coli*/day). It is not known whether the loadings observed on the day of survey were representative of those that might be found throughout the year.

Impact to the shellfish farms would be highest from the two streams discharging on the northern shore of the voe, bracketing either end of the mussel farms while impact would be somewhat lower from the burn at the head of the voe and even lower from the field drain to the east of the pier at Mid Yell. Impact would be expected to vary based on rainfall and associated stream flow rates, animal stocking rates and whether a period of dry weather preceded rainfall.

Seasonal Variation
Statistical analysis of historical monitoring results showed that *E. coli* concentrations were significantly lower in the spring in comparison to other seasons.

Seasonal changes in population due to an influx of tourists would not be likely to have a large impact in this area. There is little in the way of tourist accommodation and no campsites or caravan parks were observed during the shoreline survey.

Seasonal variation in livestock population may coincide with higher results seen in summer and autumn as sheep have lambs in May and June that are then sent off to the mainland in October. During the period of May to October, the total population of sheep on grazing land around the island is roughly double what it is during the remainder of the year.

Meteorology and Movement of Contaminants
Analysis of wind and rainfall patterns indicated a weak positive correlation between rainfall recorded in the previous 7 days and *E. coli* results (see section 9). Winds recorded at Lerwick from the Southeast and Northwest also correlated positively with *E. coli* results.

The voe is open to the southeast and winds from that direction may push water levels higher in the voe and move contaminants further from their sources, impacting the fisheries. However, local wind effects may differ somewhat as Lerwick is located a significant distance to the south of the production area.

The bathymetric and hydrodynamic analysis provided in section 12 indicates that due to the shallow nature of the voe, wind driven water movement would have a more significant impact than tides on the movement of contaminants.

No significant difference was observed in historical *E. coli* results between the two sites. However, significantly higher levels of contamination were found at the Seafield site in mussel samples taken during the shoreline survey. Contamination levels are likely to vary considerably across the site on any given day based on wind direction, state of tide and amount of rainfall.

Analysis of Results
Historical monitoring results show a significant improvement in *E.coli* concentrations observed during the spring (March to May) than for the rest of the year. While results seen in other seasons are do not differ significantly from each other, peak results have been observed during autumn (September to November). Geometric mean results were similar between samples taken from Camb and Seafield. The highest result was obtained at Camb (9100 MPN *E.coli*/100 g). However, overall results from Seafield were higher with 62% exceeding 230 *E.coli*/100 g as compared to 41% for Camb. This indicates consistently higher levels of contamination are present at the Seafield site.

Results obtained by SEPA under the shellfish growing waters monitoring program show faecal coliform results that fall broadly in line with those observed under the shellfish hygiene monitoring program. As the SEPA monitoring was only conducted on a quarterly basis, there were few samples on which to base a comparison. Additionally, samples were collected from Seafield pier rather than from on the fishery itself.

Shellfish collected on the day of the shoreline survey from Seafield showed high levels of contamination. Samples were collected from different depths to gauge whether results varied with sampling depth. Samples collected from 3 metres and less than 1 metre both showed high levels of contamination (>18000 and 9100 MPN *E.coli*/100 g, respectively). These were both well above the 4600 *E.coli*/100 g threshold for class B shellfish. The sample taken from the bottom of the line at 6 metre depth was far less contaminated (700 MPN *E.coli*/100 g).

Shellfish collected from Camb on the same day showed markedly lower levels of contamination, with all results falling under 230 *E.coli*/100 g and slightly increasing levels of contamination with increasing depth. This may be due to natural variability within the water column or it may be due resuspension of *E.coli* from the sediments below the lines, which are located in shallow water (<10 metres depth). While both sites fall within the 10 m depth curve, it is possible that the water becomes slightly shallower closer to the head of the voe and Camb is closer to the head of the voe.

Water samples collected during the shoreline survey showed high levels of contamination in seawater along the northern shoreline of the voe, close to the fisheries. The highest result (>21000 *E.coli*/100 ml) came from what was thought to be a surface water drain with a very small flow located northeast of the Camb site. The source of this level of contamination in the water was not apparent on the survey day. However, the majority of the highest concentrations observed.were from samples collected further to the east, closer to the Seafield site.

The shoreline survey was conducted at a time when higher level results would be expected based on analysis of the historical monitoring results as described in Section 11 and analysis of meteorological data as described in Section 9. Results observed appeared to consistent with the historical observations. It is also consistent with the expectation that higher results might occur as the onset of higher rainfall in the autumn washes contaminants off the fields and streets into the voe.

It is also consistent with historically higher levels observed at Seafield as compared with Camb.

17. Recommendations

This production area is not recommended for reduced sampling frequency due to instability of classification. It held a year round A classification in 2005 and then was downgraded to a seasonal A/B for 2006 and 2007. It is therefore recommended that monthly sampling be continued.

The current production area is described as the area bounded by lines drawn between HU 5060 9193 to HU 5060 9175 and from HU 5180 9195 to HU 5190 9098 extending to MHWS. It is recommended that the boundaries be maintained as described as the area covered is restricted and the current fisheries appear to be in the more contaminated sector of the production area.

The existing monitoring point is recorded at HU 514 918, which plots 45 m southwest of the recorded boundary of the shellfish farm. It is recommended the RMP be adjusted to HU 5136 9195 which places it well within the boundaries of the mussel farm and allows for a recommended 20 m tolerance to also fall within the recorded farm. This location lies nearest the principal sources of contamination and within the site that has shown the highest results and is therefore considered most protective of public health. Both the production area boundaries and the recommended and existing RMPs are mapped in Figure 17.1. The tolerance of 20m is suggested as it allows for samples to be taken from lines with mature stock.

The recommended sampling depth is between 1 and 3 metres depth as the highest levels of contamination found during the survey were at 1 and 3 metre depths at this location.

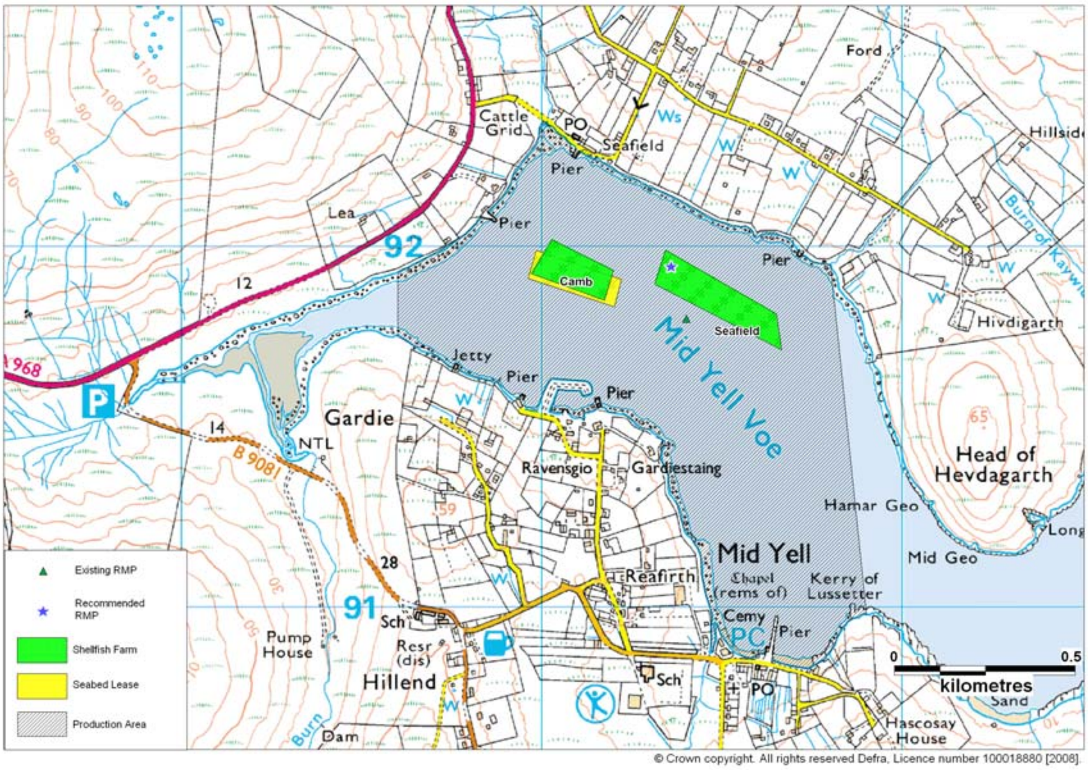


Figure 17.1 Map of Mid Yell Voe recommendations

18. References

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

Brown, E. & C. Duck. 1996. The status of seals around Shetland. *Shetland Sea Mammal Report 1996*, pp 7-15.

Brown J. (1991). The final voyage of the Rapaiti. A measure of surface drift velocity in relation to the surface wind. *Marine Pollution Bulletin*, 22, 37-40.

Burkhardt, W., Calci, K.R., Watkins, W.D., Rippey, S.R., Chirtel, S.J. (2000). Inactivation of indicator microorganisms in estuarine waters. *Water Research*, Volume 34(8), 2207-2214.

Cliver, Dean. Faculty, Food Safety Unit, University of California Davis, Posting dated 18 Sep 2001 at http://www.madsci.org/posts/archives/sep2001/1000867411.Zo.r.html Accessed 14/01/08.

Edwards, A. and F. Sharples. (1986) Scottish sea lochs: a catalogue. Scottish Marine Biological Association, Oban. 250pp.

Harrop, H. (2003). The grey seals Halichoerus grypus of Lerwick Harbour – friends or foes? A personal view. *Shetland Sea Mammal Report*, 2001 & 2002. pp 29-30.

Kay, D, Crowther, J., Stapleton, C.M., Wyer, M.D., Fewtrell, L., Anthony, S.G., Bradford, M., Edwards, A., Francis, C.A., Hopkins, M. Kay, C., McDonald, A.T., Watkins, J., Wilkinson, J. (2008). Faecal indicator organism concentrations in sewage and treated effluents. *Water Research* 42, 442-454.

Kay, D, Crowther, J., Stapleton, C.M., Wyer, M.D., Fewtrell, L., Anthony, S.G., Bradford, M., Edwards, A., Francis, C.A., Hopkins, M. Kay, C., McDonald, A.T., Watkins, J., Wilkinson, J. (2008). Faecal indicator organism concentrations and catchment export coefficients in the UK. *Water Research* 42, 2649-2661.

Lee, R.J., Morgan, O.C. (2003). Environmental factors influencing the microbial contamination of commercially harvested shellfish. *Water Science and Technology* 47, 65-70.

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

Macaulay Institute. http://www.macaulay.ac.uk/explorescotland. Accessed September 2007.

Mallin, M.A., Ensign, S.H., McIver, M.R., Shank, G.C., Fowler, P.K. (2001). Demographic, landscape, and meteorological factors controlling the microbial pollution of coastal waters. *Hydrobiologia* 460, 185-193.

Mitchell, P. Ian, S. F. Newton, N. Ratcliffe & T. E. Dunn. 2004. Seabird Populations of Britain and Ireland, Results of the Seabird 2000 Census (1998-2002). T&AD Poyser, London.

Poppe, C., Smart, N., Khakhria, R., Johnson, W., Spika, J., and Prescott, J. (1998). Salmonella typhimurium DT104: A virulent drug-resistant pathogen. *Canadian Veterinary Journal*, 39:559-565.

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

Sea Mammal Research Unit. 2002. Surveys of harbour (common) seals in Shetland and Orkney, August 2001, Scottish Natural Heritage Commissioned Report F01AA417.

Shetland Sea Mammal Group (2003) Shetland Sea Mammal Report 2001 & 2002.

Stoddard, R. A., Gulland, F.M.D., Atwill, E.R., Lawrence, J., Jang, S. and Conrad, P.A. (2005). Salmonella and Campylobacter spp. in Northern elephant seals, California. *Emerging Infectious Diseases* www.cdc.gov/eid 12:1967-1969.

19. List of Figures and Tables

Appendices

1. Shoreline Survey Report
2. Sampling Plan
3. Tables of Typical Faecal Bacteria Concentrations
4. Statistical Data
5. Hydrographic Methods

Shoreline Survey Report

Mid Yell Voe

SI 216

Scottish Sanitary Survey Project

Cefas

Shoreline Survey Report

Prod. area: Mid Yell Voe

Site name: Seafield (432) and Camb (430)
Species: Common mussels
Harvester: Gilbert Clark and Erland Smith
Local Authority: Shetland Islands Council
Status: Existing production area

Date Surveyed: 4-5 September 2007
Surveyed by: Michelle Price-Hayward, Sean Williamson
Existing RMP: HU 514 918
Area Surveyed: See Map in Figure 1

Weather observations

Rain over 48 hours prior to 3 September:
Winds force 5-6. Partly cloudy with spells of sunshine. Scattered showers.
Max air temp 12C. Water temp 12C.

Fishery

Harvester Erland Smith provided boat and assistance in conducting sampling from the mussel lines for this survey. Both the Seafield and Camb sites are in active production. Seafield had 6 longlines on site one of which was due to be moved to a site at Basta Ness according to the harvester. Droppers were set to 6m depth. The site at Camb had 6 lines at 6 meters depth.

The lines have stock at different maturities for rotational harvest.

Sewage/Faecal Sources

Table 1. Scottish Water Discharges

Discharge name	Type	Treatment	Consented design PE	NGR
Aywick	Continuous	Septic Tank	100	HU 537 868
Cemetery Mid Yell	Continuous	Septic Tank	250	HU 512 915
Linkshouse Mid Yell	Continuous	Septic Tank	250	HU 515 909
North a Voe Mid Yell	Continuous	Septic Tank	250	HU 511 923
Ravensgeo Mid Yell	Continuous	Septic Tank	250	HU 513 915
Seafield Mid Yell	Continuous	Septic Tank	250	HU 513 922

These discharges are plotted on the map in Figure 1.

None of these were labelled so positive identification was not possible. Based on the locations of the tanks observed on site, the only tank not directly observed during the survey was that at Ravensgeo.

A septic tank was observed in the grounds of a care home for the elderly. This was probably the Linkshouse septic tank, though as it was not labelled it is not possible to say for certain.

Boats/Shipping

There are two piers with large fishing vessels in Mid Yell Voe. Boats were observed on the day of survey at both piers with 5 docked at the main pier off the town of Mid Yell and 5 at the pier near Gardiestaing. In addition, there was a small boat marina located west of Gardiestaing with berths for about 40 boats of less than 10m in length. There were 27 boats present in the marina on the day of survey.

A workboat was observed working on one of the salmon farms, and this was counted at the pier later in the day.

Land Use

Land use around the voe is primarily crofting and grazing of sheep. The majority of human habitation is on the southern shore of the voe around the settlement of Mid Yell. There are some crofts located along the northern shore. Over 150 sheep were observed on the day of survey in addition to a handful of cattle.

Mid Yell is the largest centre of population on the island of Yell and provides a number of services for the area including a health centre, care home, cemetery, grocery store, petrol station, post office and general store and a fitness centre.

Wildlife/Birds

No significant populations of birds, seals, otters or other wildlife were observed during the survey.

General Observations

Specific observations taken on site are mapped in Figure 1 and listed in Table 2. Recorded observations apply to the date of survey only. Animal numbers were recorded on the day from the observer's point of view. This does not necessarily equate to total numbers present as natural features may obscure individuals and small groups of animals from view.

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

Figure 1. Survey Points at Mid Yell Voe

Nov 2007

Sampling

Water and shellfish samples were collected at sites as illustrated in Figures 2 and 3. Samples were transferred to cool boxes after collection and transported to Shetland Seafood Quality Control where they were analysed for *E. coli* content.

Seawater samples were also tested for salinity by the laboratory using a salinity meter under more controlled conditions. These results were anomalous and investigation by the laboratory revealed operator errors in measurement. Therefore, laboratory salinity results are not reported here.

Bacteriology results follow in Tables 3 and 4.

Table 2. Shoreline Observations

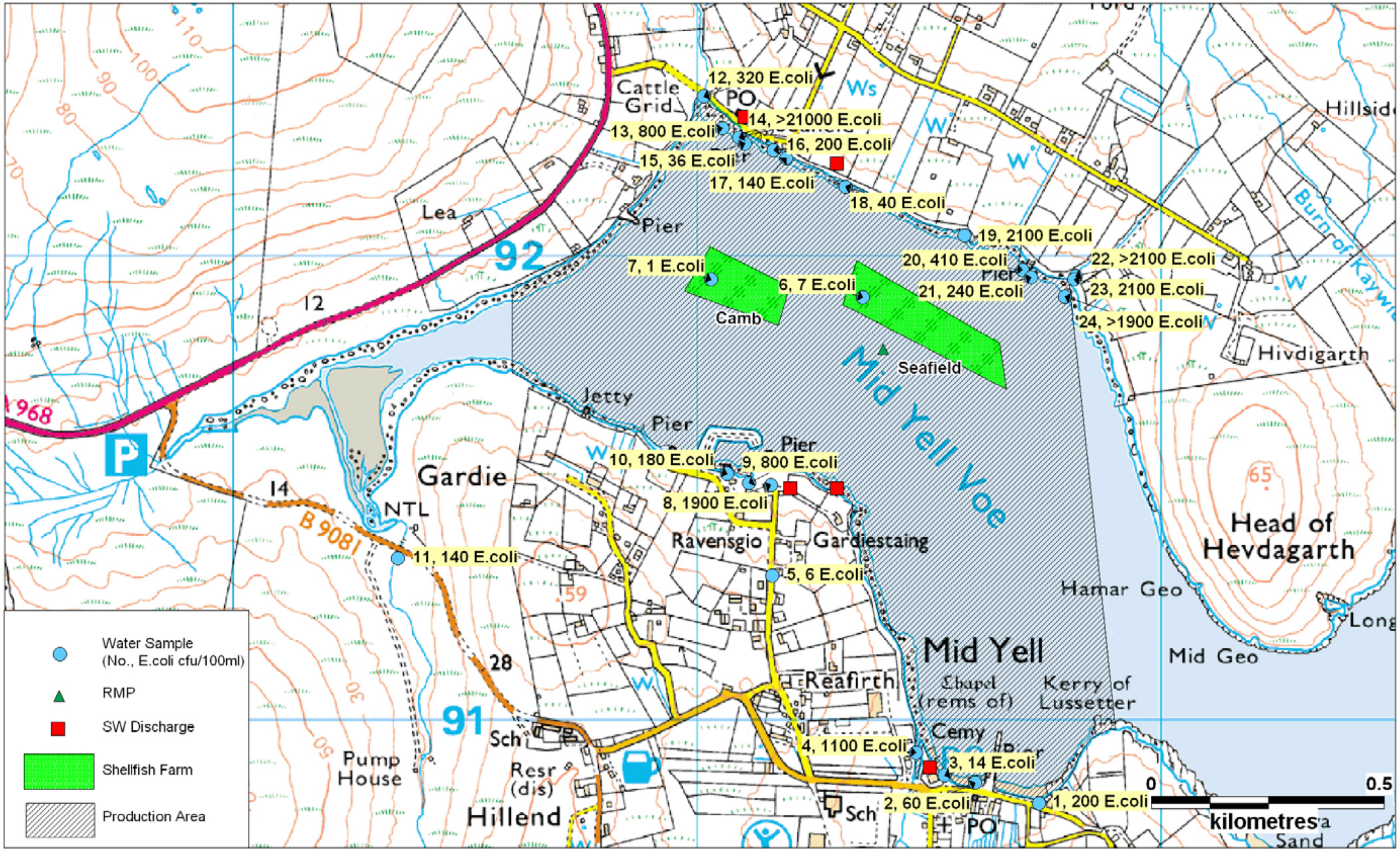
No.	Date/Time	NGR	Associated photograph	Description
1	04/09/2007 09:58	HU 51735 90822	Figure 4	Mid Yell sample 1 - Flow = 1 litre per second. 20cm wide x 1/cm deep. Photograph. Stream cascading through rock culvent, across beach. No sign of sanitary debris.
2	04/09/2007 10:12	HU 51752 90833	Figure 5	Broken discharge pipe, no apparent flow.
3	04/09/2007 10:19	HU 51788 90848		Runoff from land dripping through grass.
4	04/09/2007 10:26	HU 51829 90930	Figure 6	Photograph looking towards Yell.
5	04/09/2007 10:39	HU 51735 90821		Stream
6	04/09/2007 10:41	HU 51706 90818		End of pipe, sticking out of the sand.
7	04/09/2007 10:44	HU 51639 90832		End of under-road. Culvert dry.
8	04/09/2007 10:45	HU 51632 90843	Figure 7,8	Culvert with wet sand under. Road end of pier. Water trickling into sand, too little to sample. Photograph looking NE from pier, pier has petrol svcs, 5 fishing/workboats and public toilets at pier.
9	04/09/2007 10:54	HU 51595 90855	Figure 9	Discharge pipe.
10	04/09/2007 10:56	HU 51592 90840		Inspection hatch
11	04/09/2007 10:57	HU 51579 90815		Further inspection hatch.
12	04/09/2007 10:59	HU 51575 90789		More inspection covers. 2 fields with 30 sheep - drain towards hatch.
13	04/09/2007 11:06	HU 51598 90867		Mid Yell water sample 2. Unable to tell if actively discharging, end of pipe underwater.
14	04/09/2007 11:10	HU 51583 90855	Figure 10	Kitchen waste - eggshells, potato peelings, scallop shells. No sanitary debris.
15	04/09/2007 11:12	HU 51529 90872	Figure 11	Discharge pipe through seawall not flowing.
16	04/09/2007 11:14	HU 51532 90882		Mid Yell water sample 3.
17	04/09/2007 11:18	HU 51478 90932	Figure 12	Cemetery. stream runs below - channelised and fast flowing – return on 5/9 to measure.
18	04/09/2007 11:21	HU 51470 90931		Mid Yell water sample 4.
19	04/09/2007 11:26	HU 51500 90894		Grass clippings.
20	04/09/2007 11:27	HU 51512 90885		Grass clippings.
21	04/09/2007 11:29	HU 51533 90860		Grass clippings.
22	04/09/2007 11:32	HU 51550 90844		Workboat on salmon farm on voe viewed from this point
23	04/09/2007 11:40	HU 51161 91313	Figure 13	Mid Yell water sample 5. Pipe discharge from pier, unknown. 5cm diameter. Flow 32sec - 10m, 1.5m wide, 7.5cm depth.
24	04/09/2007 12:48	HU 51481 90896	Figure 14	Septic tank at care home.

No.	Date/Time	NGR	Associated photograph	Description
25	04/09/2007 14:44	HU 51919 91416		Salmon farm adding nets, I work boat.
26	04/09/2007 14:52	HU 51355 91912	Figure 15	Mid Yell water sample 6, Seafield 1(top), 2(mid) and 3(bottom)6 m lines, 3 have small stock only, Salinity 34.6, T. 11.5C
27	04/09/2007 15:04	HU 51343 91991		Corner of mussel lines at Seafield, 5 longlines on site plus 1 to be moved to Basta Ness.
28	04/09/2007 15:07	HU 51651 91813		NE corner of mussel lines at Seafield
29	04/09/2007 15:08	HU 51665 91714		SE corner of mussel lines at Seafield.
30	04/09/2007 15:10	HU 51312 91896		Corner of mussel lines
31	04/09/2007 15:14	HU 51029 91950		Camb sample site. Mid Yell water sample 7, mussel samples Camb 1 (top), 2 (mid line), and 3 (bottom). salinity 34.8, temp 11.5C.
32	04/09/2007 15:39	HU 50971 91925		Corner of mussel lines at Camb
33	04/09/2007 15:39	HU 51027 92020		Corner of mussel lines at Camb
34	04/09/2007 16:05	HU 51151 91131		NHS Yell Health Centre
35	04/09/2007 16:13	HU 51158 91508	Figure 16	Septic tank cover adjacent to stone pier. Mid Yell water sample 8.
36	04/09/2007 16:15	HU 51154 91540		Pier
37	04/09/2007 16:16	HU 51152 91538		Marina - 40 slips for mostly day boats.
38	04/09/2007 16:20	HU 51111 91511		Septic tank outfall, Mid Yell water sample 9. Oyster shells on beach.
39	04/09/2007 16:32	HU 51063 91532		Mid Yell water sample 10 from near end of the marina. Sheep droppings scattered about, no sheep observed.
40	04/09/2007 16:37	HU 51017 91572	Figure 17	End of marina ramp, 4 fishing boats and 1 small workboat at salmon farm pier.
41	04/09/2007 16:38	HU 50981 91521		Salmon sheds entrance.
42	04/09/2007 16:48	HU 50718 91505		End of road
43	04/09/2007 16:54	HU 50904 91142		25 sheep on left facing main road, 35 on right.
44	04/09/2007 17:01	HU 50354 91349		River emptying into head of Voe. 8 sheep. River 5m wide, 5cm deep, 0.7m/s. Water sample 11
45	05/09/2007 10:27	HU 51013 92344	Figure 18	River. Sample 12, freshwater. Flow 7 seconds - 3 metres. 30cm wide and 2cm deep at centre.
46	05/09/2007 10:41	HU 51053 92276	Figure 19,20	Sewage pipe, sample 13, seawater. Looking SE from pipe. Farm - silage bales, 2 cows, 16 sheep.
47	05/09/2007 10:49	HU 51089 92256	Figure 21	Surface drain, small flow, 30cm diameter pipe. 6cm wide flow, 3.4mm depth. Sample 14, universal, fresh.
48	05/09/2007 10:55	HU 51102 92243	Figure 22	Corroded iron pipe jutting out onto shore below high tide line. Not currently discharging.

No.	Date/Time	NGR	Associated photograph	Description
				Sample 15, seawater.
49	05/09/2007 11:02	HU 51164 92228		Buried pipe and inspection cover. Sample 16, seawater.
50	05/09/2007 11:07	HU 51191 92211	Figure 23	Surface runoff draining through field of flag iris, inspection cover on slope down from road. Too diffused to measure flow. Sample 17, freshwater.
51	05/09/2007 11:16	HU 51319 92150		Stream flowing down across rocks, no good place to measure flow. Sample 18.
52	05/09/2007 11:31	HU 51575 92045	Figure 24,25	Groundwater seepage down bank. Vertical pipe broken and discharging onto shore. Sample 19, freshwater. Flow 200ml in 2 seconds. 10cm diameter, 1mm depth, 7cm width.
53	05/09/2007 11:44	HU 51708 91971		Dry pipe, nothing flowing, made of plastic, crushed where it enters the earth. 10cm diameter.
54	05/09/2007 11:47	HU 51699 91970		Sample 20, seawater.
55	05/09/2007 11:49	HU 51727 91976		Field drain running under grass, through flag iris, then spread out across rocks.
56	05/09/2007 11:53	HU 51719 91954		Sample 21 taken of seawater just off drain. Dead sheep on ground, 20ft from drain, no other livestock in these 2 fields. 21 houses.
57	05/09/2007 11:56	HU 51769 91953		5 cows in field.
58	05/09/2007 11:59	HU 51815 91958	Figure 26,27	Water sample Mid Yell 22, foul. Concrete tank discharging out. Pipe 16cm diameter, 8cm width and 2mm depth. Discharging into deep hole above stream - not able to measure flow rate.
59	05/09/2007 12:17	HU 51625 92305		14 sheep, 1 house.
60	05/09/2007 12:18	HU 51554 92333		55 sheep, 5 chickens outside a house
61	05/09/2007 12:28	HU 51116 92255	Figure 28	Inspection cover on road.
62	05/09/2007 12:29	HU 51107 92262	Figure 29	Photograph of outfall
63	05/09/2007 12:30	HU 51052 92297		Septic tank outfall
64	05/09/2007 12:42	HU 51812 91950	Figure 30, 31	Mid Yell water sample 23, Stream, 0.6 m/s, 30cm deep, 1m wide.
65	05/09/2007 12:49	HU 51792 91913		Mid Yell seawater sample 24, water very brown.

Photographs referenced in the table can be found attached as Figures 4-31.

Figure 2. Mid Yell Voe Water Samples



Nov 2007

Figure 3. Mid Yell Voe Shellfish Samples

Nov 2007

Table 3. Water Sample Results

No.	Date	Sample	Type	NGR	*E. coli* (cfu/ 100ml)
1	04/09/2007	Mid Yell 1	freshwater	HU 51735 90822	200
2	04/09/2007	Mid Yell 2	seawater	HU 51598 90867	60
3	04/09/2007	Mid Yell 3	seawater	HU 51532 90882	14
4	04/09/2007	Mid Yell 4	freshwater	HU 51470 90931	1100
5	04/09/2007	Mid Yell 5	seawater	HU 51161 91313	6
6	04/09/2007	Mid Yell 6	seawater	HU 51355 91912	7
7	04/09/2007	Camb Mid Yell 7	seawater	HU 51029 91950	1
8	04/09/2007	Mid Yell 8	seawater	HU 51158 91508	1900
9	04/09/2007	Mid Yell 9	seawater	HU 51111 91511	800
10	04/09/2007	Mid Yell 10	seawater	HU 51063 91532	180
11	04/09/2007	Mid Yell 11	freshwater	HU 50354 91349	140
12	05/09/2007	Mid Yell 12	freshwater	HU 51013 92344	320
13	05/09/2007	Mid Yell 13	seawater	HU 51053 92276	800
14	05/09/2007	Mid Yell 14	freshwater	HU 51089 92256	>21000
15	05/09/2007	Mid Yell 15	seawater	HU 51102 92243	36
16	05/09/2007	Mid Yell 16	seawater	HU 51164 92228	200
17	05/09/2007	Mid Yell 17	freshwater	HU 51191 92211	140
18	05/09/2007	Mid Yell 18	freshwater	HU 51319 92150	40
19	05/09/2007	Mid Yell 19	freshwater	HU 51575 92045	2100
20	05/09/2007	Mid Yell 20	seawater	HU 51699 91970	410
21	05/09/2007	Mid Yell 21	seawater	HU 51719 91954	240
22	05/09/2007	Mid Yell 22	foul	HU 51815 91958	>2100
23	05/09/2007	Mid Yell 23	freshwater	HU 51812 91950	2100
24	05/09/2007	Mid Yell 24	seawater	HU 51792 91913	>1900

Table 4. Shellfish Sample Results

No.	Date	Sample	Type	NGR	*E. coli* (mpn/ 100g)	Depth (m)
1	05/09/2007	Camb 1	mussel	HU 51029 91950	110	<1
2	05/09/2007	Camb 2	mussel	HU 51029 91950	130	3
3	05/09/2007	Camb 3	mussel	HU 51029 91950	220	6
4	05/09/2007	Mid Yell 1	mussel	HU 51355 91912	9100	<1
5	05/09/2007	Mid Yell 2	mussel	HU 51355 91912	>18000	3
6	05/09/2007	Mid Yell 3	mussel	HU 51355 91912	700	6

Photographs

Figure 4. Culvert at shoreline

Figure 5. Broken pipe

Figure 6. Mid Yell.

Figure 7. Seepage on shore

Figure 8. Pier and public toilets

Figure 9. Discharge pipe.

Figure 10.
Kitchen waste at shoreline.

Figure 11.
Drain pipe through seawall.

Figure 12. Stream running past care centre and cemetery.

Figure 13. Discharge at pier.

Figure 14. Septic tank at care home.

Figure 15.
Sampling from mussel lines.

Figure 16. Tank cover. discharge pipe, and marina.

Figure 17

Figure 18. River.

Figure 19. Discharge pipe

Figure 20. Field with silage bales.

Figure 21. Surface drain.

Figure 22.
Corroded discharge pipe.

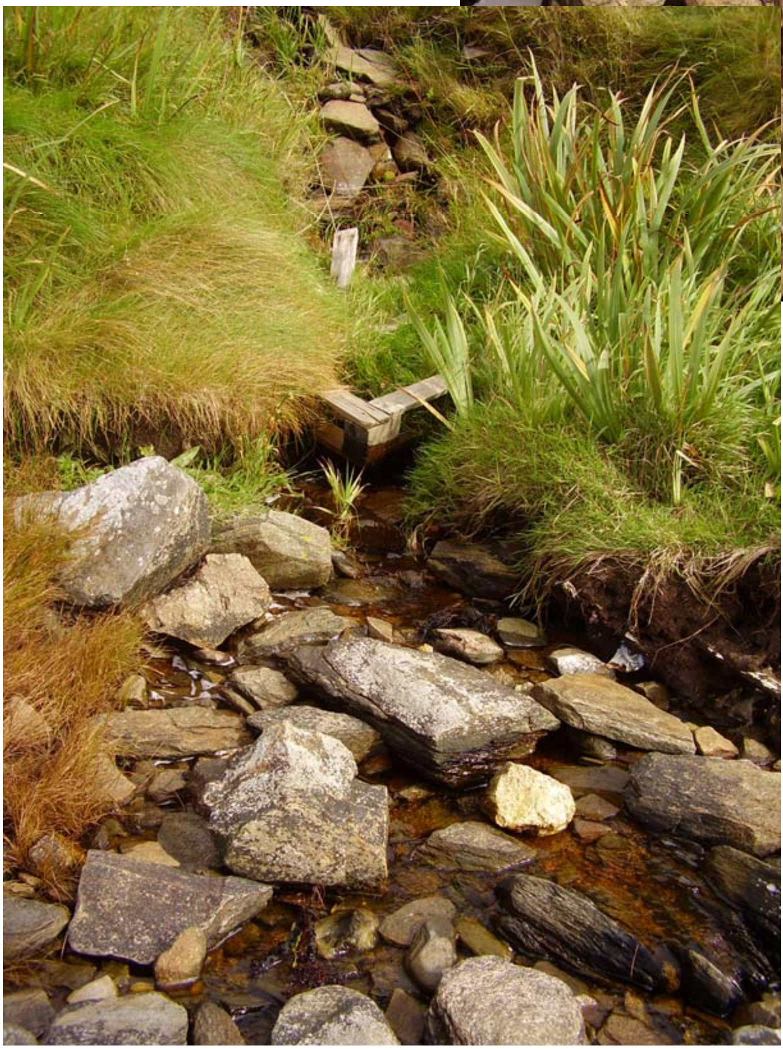


Figure 23 Stream through iris.

Figure 24.
Vertical section of pipe
discharging onto shoreline

Figure 25 Discharge end of pipe

Figure 26. Septic tank cover

Figure 27. Discharge from tank drains into this hole

Figure 28. Cover on road

Figure 29.
Septic tank outfall.

Figure 30 Stream flowing into voe

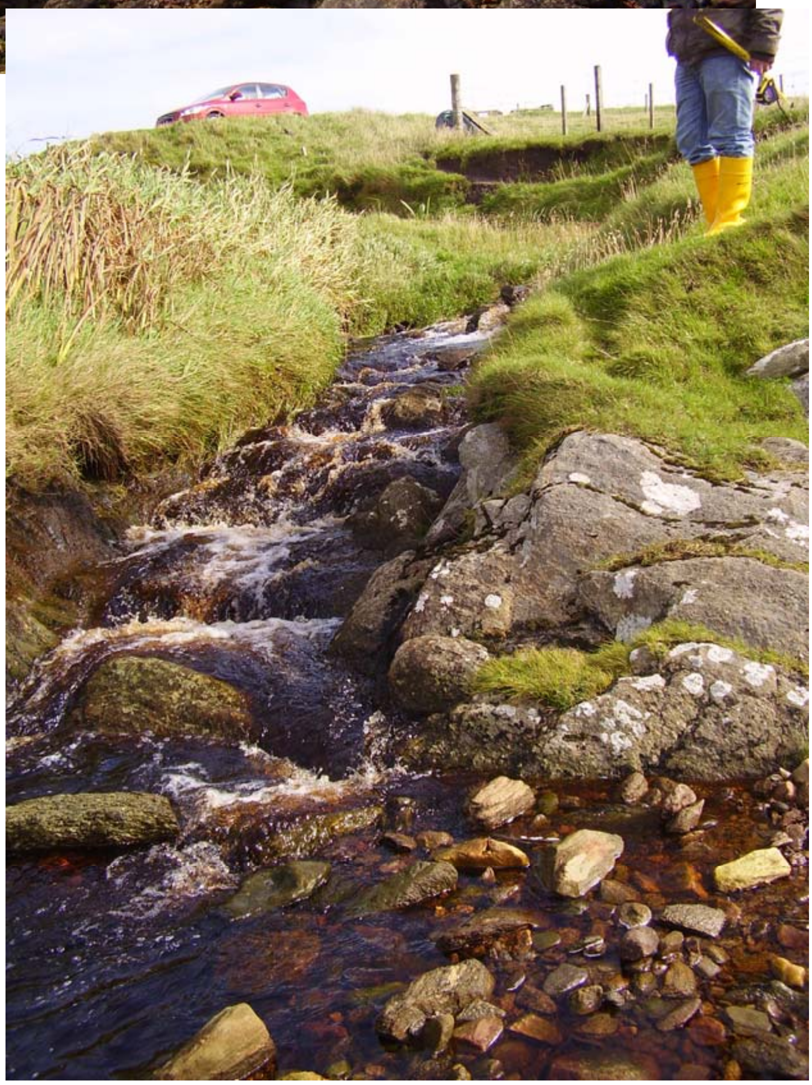


Figure 31.
Looking upstream from photograph in Figure 29

Sampling Plan for Mid Yell Voe

PRODUC-TION AREA	SITE NAME	SIN	SPECIES	TYPE OF FISH-ERY	NGR OF RMP	EAST	NORTH	TOLER-ANCE (M)	DEPTH (M)	METHOD OF SAMPLING	FREQ OF SAMPLING	LOCAL AUTHORITY	AUTHORISED SAMPLER(S)	LOCAL AUTHORITY LIAISON OFFICER
Mid Yell Voe	Seafield	SI 216 432 08	Common mussels	Long line	HU 5136 9195	45136	119195	20	1-3	Hand	Monthly	Shetland Islands Council	Sean Williamson George Williamson Kathryn Winter Marion Slater	Dawn Manson

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}		
Reedbed/grass plot	71	1.3×10^{4}	5.4×10^{3}	3.4×10^{4}	2	1.5×10^{4}		
Ultraviolet disinfection	108	2.8×10^{2}	1.7×10^{2}	4.4×10^{2}	6	3.6×10^{2}		

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

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

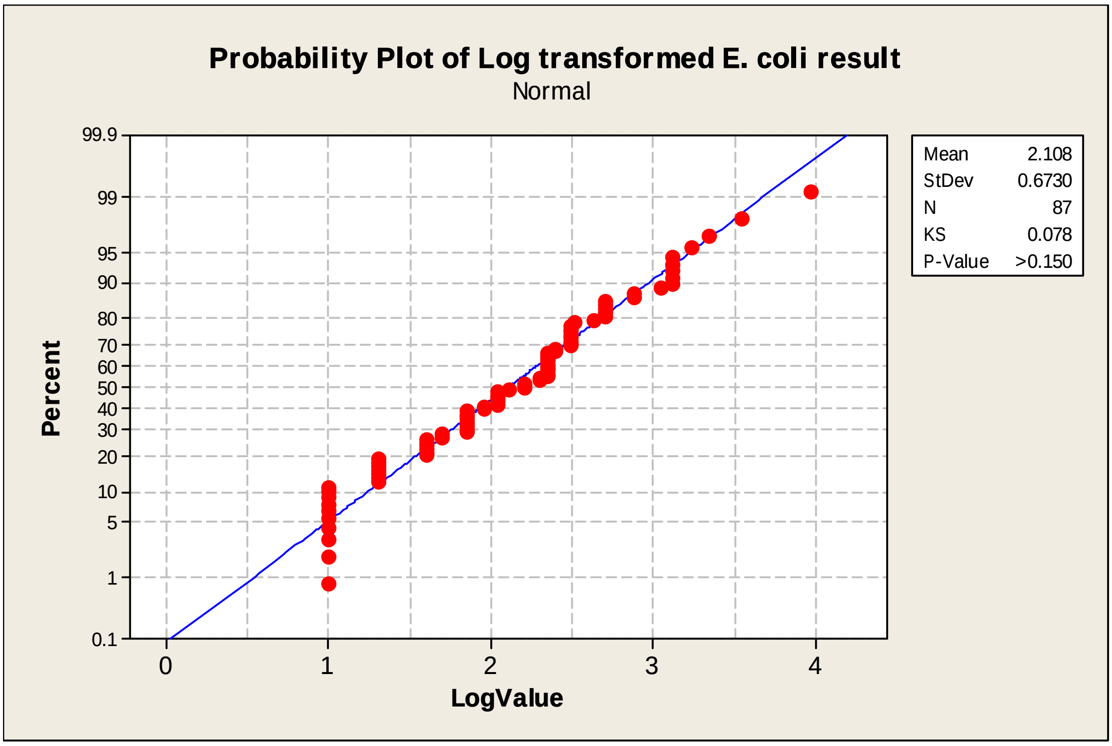
Animal	Faecal coliforms (FC) number	Excretion (g/day)	FC Load (numbers /day)
Chicken	1,300,000	182	2.3×10^{8}
Cow	230,000	23,600	5.4×10^{9}
Duck	33,000,000	336	1.1×10^{10}
Horse	12,600	20,000	2.5×10^{8}
Pig	3,300,000	2,700	8.9×10^{8}
Sheep	16,000,000	1,130	1.8×10^{10}
Turkey	290,000	448	1.3×10^{8}
Human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

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

Statistical Data

All analyses were undertaken using log transformed results (aside from the circular linear correlation) as this gives a more normal distribution.

Distribution on log scale (with Kolmogorov-Smirnov normality test results)



Section 11.2 T-Test comparison of results by site

```
Two-sample T for Log result

Site       N   Mean  StDev  SE Mean
Camb      66  2.104  0.636    0.078
Seafield  21  2.123  0.796     0.17


Difference = mu (Camb) - mu (Seafield)
Estimate for difference:  -0.019
95% CI for difference:  (-0.409, 0.371)
T-Test of difference = 0 (vs not =): T-Value = -0.10  P-Value = 0.922  DF = 28
```

Section 11.4.1 ANOVA comparison of results by season

```
Source  DF      SS     MS     F      P
Season   3   7.477  2.492  6.57  0.000
Error   83  31.480  0.379
Total   86  38.957

S = 0.6159   R-Sq = 19.19%   R-Sq(adj) = 16.27%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N   Mean   StDev   ---+---------+---------+---------+------
```

```
1      19  1.5930  0.7125  (--------*-------)
2      23  2.1009  0.5768                (------*------)
3      23  2.3986  0.6214                        (-------*------)
4      22  2.2580  0.5575                    (-------*------)
                           ---+---------+---------+---------+------
                            1.40      1.75      2.10      2.45

Pooled StDev = 0.6159


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

Individual confidence level = 98.96%


Season = 1 subtracted from:

Season   Lower  Center   Upper  ---+---------+---------+---------+------
2       0.0070  0.5079  1.0087              (-------*--------)
3       0.3047  0.8056  1.3065                   (-------*--------)
4       0.1590  0.6650  1.1709                 (-------*--------)
                                ---+---------+---------+---------+------
                                -0.60      0.00      0.60      1.20


Season = 2 subtracted from:

Season    Lower  Center   Upper  ---+---------+---------+---------+------
3       -0.1787  0.2977  0.7741           (-------*-------)
4       -0.3247  0.1571  0.6389         (-------*-------)
                                 ---+---------+---------+---------+------
                                 -0.60      0.00      0.60      1.20


Season = 3 subtracted from:

Season    Lower   Center   Upper  ---+---------+---------+---------+------
4       -0.6224  -0.1406  0.3412     (-------*-------)
                                  ---+---------+---------+---------+------
                                  -0.60      0.00      0.60
```

Section 11.4.2 Regression analysis (log Result versus rain in previous 2 days)

```
The regression equation is
LogRes R2D = 1.96 + 0.0197 R2D


Predictor     Coef  SE Coef      T      P
Constant    1.9632   0.1417  13.85  0.000
R2D        0.01965  0.01736   1.13  0.263


S = 0.672092   R-Sq = 2.3%   R-Sq(adj) = 0.5%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   0.5787  0.5787  1.28  0.263
Residual Error  54  24.3922  0.4517
Total           55  24.9709


Unusual Observations
```

```
Obs   R2D  LogRes R2D     Fit  SE Fit  Residual  St Resid
 35  19.2      2.4914  2.3405  0.2411    0.1509      0.24 X
 36  19.2      3.2304  2.3405  0.2411    0.8899      1.42 X

X denotes an observation whose X value gives it large leverage.
```

Section 11.4.2 ANOVA comparison of log Result versus rainfall quartile (previous 2 days)

```
Source  DF      SS     MS     F      P
RQ2D     3   1.095  0.365  0.79  0.502
Error   52  23.876  0.459
Total   55  24.971

S = 0.6776   R-Sq = 4.39%   R-Sq(adj) = 0.00%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  ---------+---------+---------+---------+
Q1      6  1.9902  0.5742  (---------------*---------------)
Q2     14  2.0604  0.6437         (----------*---------)
Q3     20  1.9646  0.7289        (--------*--------)
Q4     16  2.3005  0.6706                 (---------*--------)
                           ---------+---------+---------+---------+
                                 1.75      2.10      2.45      2.80

Pooled StDev = 0.6776
```

Section 11.4.2 Regression analysis (log Result versus rain in previous 7 days)

```
The regression equation is
LogRes R7D = 1.75 + 0.0155 R7D


Predictor      Coef   SE Coef      T      P
Constant     1.7515    0.1582  11.07  0.000
R7D        0.015472  0.005964   2.59  0.012


S = 0.644586   R-Sq = 11.3%   R-Sq(adj) = 9.6%


Analysis of Variance

Source          DF       SS      MS     F      P
Regression       1   2.7964  2.7964  6.73  0.012
Residual Error  53  22.0210  0.4155
Total           54  24.8174


Unusual Observations

Obs   R7D  LogRes R7D     Fit  SE Fit  Residual  St Resid
  2   6.0      3.1139  1.8444  0.1298    1.2696      2.01R
 12  59.8      2.3424  2.6768  0.2407   -0.3343     -0.56 X

R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large leverage.
```

Section 11.4.2 ANOVA comparison of log Result versus rainfall quartile (previous 7 days)

```
Source  DF      SS     MS     F      P
RQ7D     3   1.372  0.457  0.99  0.403
Error   51  23.446  0.460
Total   54  24.817

S = 0.6780   R-Sq = 5.53%   R-Sq(adj) = 0.00%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  -------+---------+---------+---------+--
Q1     17  2.1079  0.7182          (--------*---------)
Q2     10  1.9373  0.5746  (-----------*------------)
Q3     18  1.9973  0.7671       (--------*--------)
Q4     10  2.4030  0.4963               (------------*-----------)
                           -------+---------+---------+---------+--
                               1.75      2.10      2.45      2.80

Pooled StDev = 0.6780
```

Section 11.4.3 ANOVA comparison of results by tide size

```
Source         DF      SS     MS     F      P
Est tide size   2   2.043  1.021  2.32  0.104
Error          84  36.914  0.439
Total          86  38.957

S = 0.6629   R-Sq = 5.24%   R-Sq(adj) = 2.99%


                            Individual 95% CIs For Mean Based on
                            Pooled StDev
Level    N    Mean   StDev   -+---------+---------+---------+--------
Large   24  2.3400  0.6295                (----------*---------)
Medium  34  1.9602  0.6822   (--------*--------)
Small   29  2.0904  0.6665        (---------*--------)
                             -+---------+---------+---------+--------
                            1.75      2.00      2.25      2.50

Pooled StDev = 0.6629
```

Section 11.4.5 Circular-linear correlation of wind direction and result

CIRCULAR-LINEAR CORRELATION
Mid-Yell Voe
Analysis begun: 28 December 2007 14:47:44

Variables (& observations)	r	p
Angles & Linear (51)	0.278	0.025

Hydrographic Methods

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

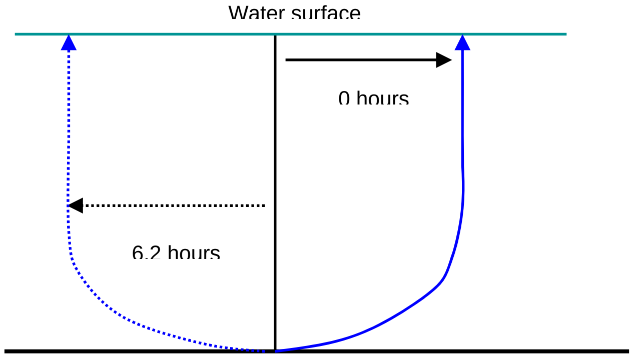
The hydrography at most sites will be assessed on the basis of bathymetry and tidal flow software only and is not discussed in any detail in this document. Selected sites will be assessed in more detail using either: 1) a hydrodynamic model, or 2) an extended consideration of sources, available field studies and expert assessment. This document will focus on this more detailed hydrographic assessment and describes the common methodology applied to all sites.

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

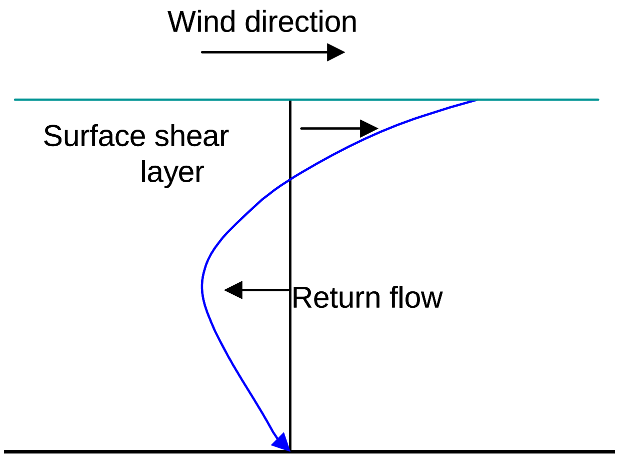
Tidal flows often dominate water movement over the short term (approximately 12 hours) and move material over the length of the *tidal excursion*. Tides move water back and forth over the tidal period often leading to only a small net movement over the 12 hours tidal cycle. This small net movement is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

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

a)



b)



c)

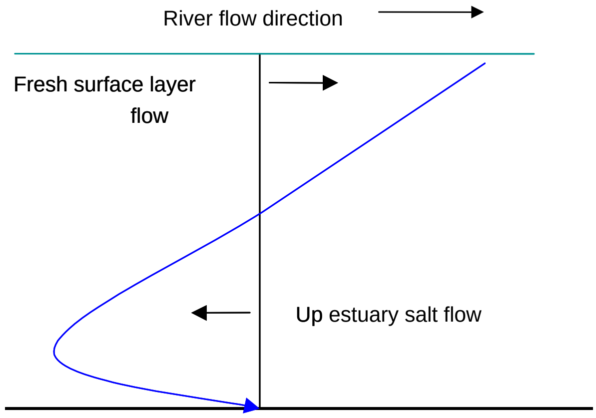


Figure 1. Typical vertical profiles for currents generated by different mechanisms. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main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

In sea lochs, currents associated with *windrows* can transport contaminated water near the shore to production areas further offshore. Windrows are often generated by winds directed along the main length of the loch. Figure 2 illustrates the water movements associated with this. As can be seen the water circulates in a series of cells that draw material across the loch at right angles to the wind direction. This is a particularly common situation for lochs with high land on either side as these tend to act as a steering mechanism to align winds along the water body.

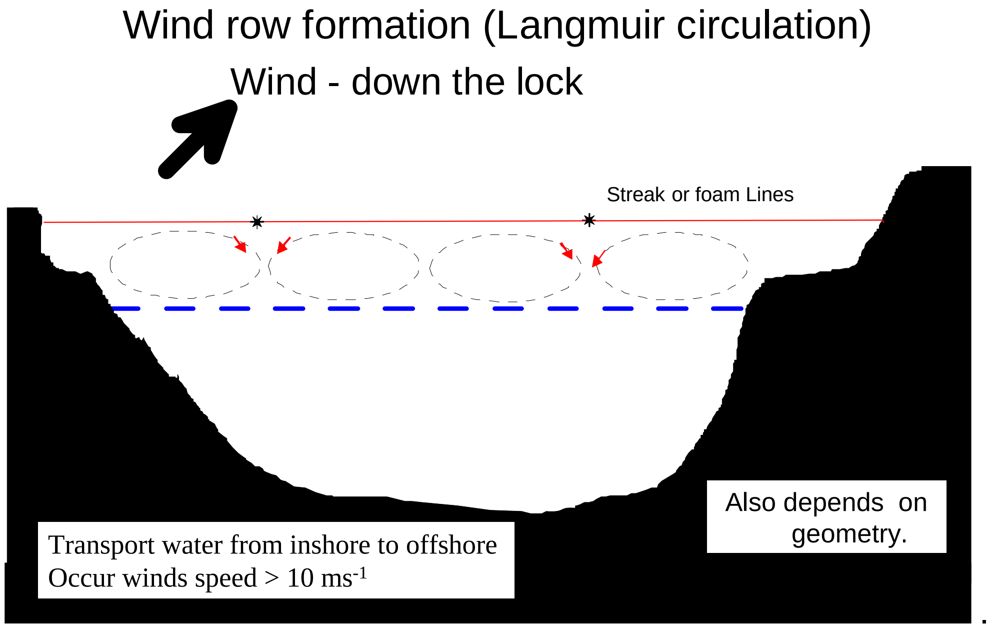


Figure 2: Schematic of wind driven 'wind row' currents. View is down the loch.The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.